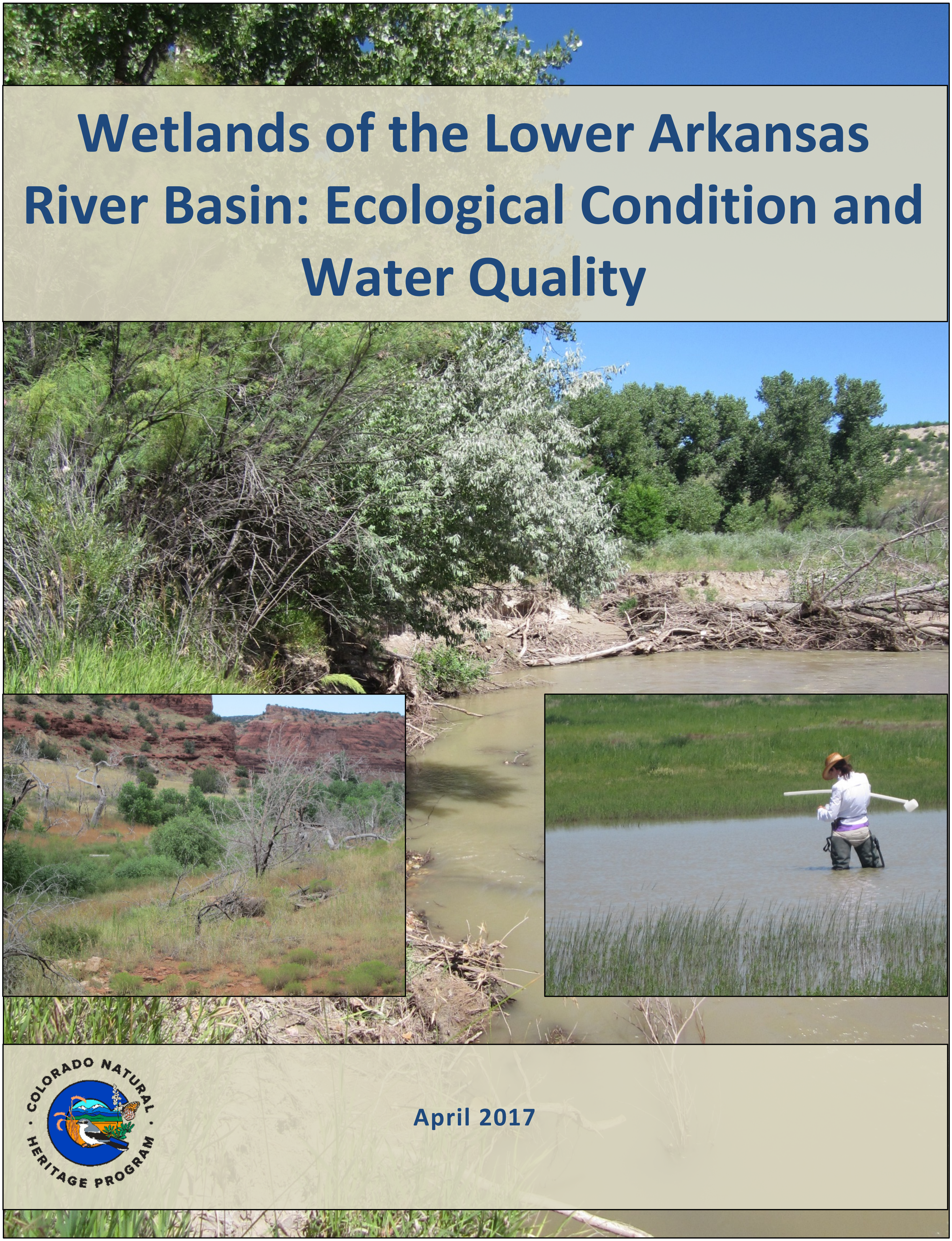
Wetlands of the Lower Arkansas River Basin: Ecological Condition and Water Quality



April 2017

CNHP's mission is to preserve the natural diversity of life by contributing the essential scientific foundation that leads to lasting conservation of Colorado's biological wealth.

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Wetlands of the Lower Arkansas River Basin: Ecological Condition and Water Quality

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EXECUTIVE SUMMARY

With funding from the U.S. Environmental Protection Agency (EPA), Region 8, Colorado Natural Heritage Program (CNHP) and Colorado Parks and Wildlife (CPW) are assessing the condition of wetlands in each major river basin within the state. The overarching goal of each project is to assess the extent, ecological condition, and habitat quality of wetlands within the basin. The Lower Arkansas Basin wetland assessment project is the fourth in this series and has been divided into two phases. Completed in 2015, the objectives of Phase 1 were to 1) create a digital map of wetlands in the Lower Arkansas Basin; 2) identify and assess a network of reference standard wetlands and riparian areas; and 3) research habitat requirements of target wetland-dependent wildlife species within the basin. This report documents work carried out under the second phase of the project. The objectives of Phase 2 were to 1) produce overall basin-wide estimates of ecological condition for wetlands and riparian areas in the basin by sampling a spatially balanced, randomly selected set of sites and 2) pilot the collection of water quality data in wetlands.

The Arkansas River basin is the largest in the state of Colorado and drains a quarter of the state's land area. In the lower portion of the basin, the floodplain of the Arkansas River, its tributaries, and numerous playa lake complexes are important habitat for migratory and wintering bird. However, aquatic resources in the basin face several major threats, including high concentrations of salts and minerals in the river and extensive invasion of non-native species. This report provides a baseline assessment of ecological condition of wetlands and riparian areas in the Lower Arkansas Basin that can inform on-the-ground restoration and conservation action. In addition, this project also piloted the collection and analysis of water quality parameters to determine the range of potential values.

For the **condition assessment,** 62 random wetland and riparian sites were selected for sampling based on a spatially balanced probabilistic sample design. Sites were selected from digital National Wetlands Inventory (NWI) mapping created through Phase 1 of this project, and site selection was stratified to ensure spatial distribution across the basin. Field methods followed the rapid Ecological Integrity Assessment method. Results from the random sites were used to estimate the extent of wetland types and the range of ecological condition throughout the basin.

Based on the sampled sites and those rejected as non-target, wetlands and riparian areas across the basin were estimated to cover 118,642 (±16,517) acres, which represents less than one percent of the entire land area in the basin. Half of these acres fell within the central irrigated valley along the Arkansas River floodplain and surrounding zone of concentrated agricultural production. Major wetland types in the irrigated valley included plains floodplains, reservoir fringes, and marshes. Major wetland types on the northern and southern plains included smaller riparian areas, playas, and seep-fed wet meadows in the north.

On a four-tiered scale of excellent, good, fair, and poor, 35% of wetland and riparian acres across the basin were rated in good condition, 60% in fair condition, and 5% in poor condition. No areas sampled were rated in excellent condition. The wetland types in the highest condition were playas and plains riparian areas. These areas should continue to be managed to preserve their condition and protect their full suite of beneficial functions. Those wetland types in the lowest condition were

plains floodplain, marshes, and reservoir fringes, which are concentrated in the central irrigated valley. The most significant stressors observed in the basin were hydrologic modifications and invasive species, particularly tamarisk, kochia, and Russian thistle. Lower condition sites within the central irrigated valley pose challenges for land managers. The extent of hydrologic modification and increased salinity has exacerbated the spread of non-native species. These conditions plus possible nutrient loading has likely contributes to densely vegetated marshes, which are less valuable for waterfowl habitat. Large scale efforts to treat tamarisk have often replaced overstory weeds with dense herbaceous weeds rather than native species. Restoration in these areas should be done at a local scale, where active revegetation and long term monitoring can support successful reestablishment of native species.

For the **pilot water quality study,** water samples were collected in 15 reference sites that were hand-picked to represent three common wetland types in the basin (marshes, plains riparian areas, and playas). Reference sites were visited up to three times during the field season to detect seasonal change. Water quality samples were also collected in 14 randomly selected wetlands sampled through the condition assessment described above. Samples were collected in the first five random sites of each targeted wetlands type (marshes, plains riparian areas, and playas) encountered in the condition assessment. Random sites were only visited one during the field season. From both reference and random sites, two sets of water samples were collected per site at each visit to detect spatial variation within the same site on the same day.

Water sampling protocols were based on methods for monitoring water quality in rivers and streams developed by the volunteer stream monitoring program, River Watch, combined with methods from the EPA National Wetland Condition Assessment. Twenty-four water quality parameters were measured at each sampling event. Temperature, pH, and electrical conductivity (EC) were recorded onsite using a hand-held probe. Alkalinity and hardness were titrated out of the field. Nutrients, major ions, and metals were analyzed in the River Watch water chemistry lab from collected water samples. Water quality data were analyzed to determine: 1) within-site variability in water quality data and 2) the range of values observed in each of the three wetland types.

The most notable result from the water quality study was the contrast between values measured in marshes and plains riparian areas, which were generally similar to the Arkansas River mainstem, and playas, which were strikingly different. In addition, there were clear patterns related to location within the basin and by proximity to intensive land uses. Marshes sampled in the basin, particularly those on the floodplain and influenced by irrigation return flows, had high EC, high hardness, and high concentrations of dissolved cations and sulfates. Water quality values in plains riparian areas were variable depending on location within the basin, surrounding geology, and proximity to the Arkansas floodplain. In contrast, playas had lower EC, alkalinity, hardens, dissolved cations, and sulfate than other wetland types. Metals were generally not a concern for marshes or riparian areas, though selenium was detected in three riparian sites. Metals were far more common in playas, but selenium was absent. Nutrients were only elevated in a handful of sites.

The findings from both the condition assessment and pilot water quality study should be used by land and water managers to better incorporate wetland and riparian areas within management plans.

ACKNOWLEDGMENTS

The authors at Colorado Natural Heritage Program (CNHP) would like to acknowledge the U.S. Environmental Protection Agency (EPA) Region 8, Colorado Parks and Wildlife (CPW)'s Wetlands Program, and the River Water Program for their financial support and encouragement of this project. Special thanks to Penney Trujillo, EPA Project Officer, for her support of the project. Brian Sullivan, CPW Wetlands Program Coordinator, has been a major driver of this project and has helped facilitate the steering committee that made this study possible. The water quality section would not have been possible without the help of Barb Horn and Michaela Taylor from River Watch.

The project could not have happened without the support and assistance of local partners in the Lower Arkansas Basin. Special thanks to members of our steering committee (current and former members): Travis Black, Cory Chick, Brian Dreher, April Estep, Paul Foutz, Frank McGee, Ed Schmal, Mike Smith, and Trent Verquer, all with CPW; Shelly Simmons with the Colorado State Forest Service; Patty Knupp with National Resource Conservation Service; Katy Fitzgerald with U.S. Fish and Wildlife Service; Fran Pannebaker the National Park Service; Steve Olson with the U.S. Forest Service; Matt Moorhead with The Nature Conservancy; and Josh Carpenter of the U.S. Army Corps of Engineers.

We extend much gratitude to CNHP field technicians Rachel Crownhart, Kate Drake, and Jake Muller for their long days in the field and long night keying plants. Thanks to botanists extraordinaire Pam Smith of CNHP and Jennifer Ackerfield of the CSU Herbarium for help with plant identification. CNHP work study Cora Marrama was invaluable for entering and QC'ing pages and pages of field data. Thanks also go to agency biologists and land managers who facilitated our surveys on their lands. And a very special thanks to the private landowners who allowed us onto their lands, many of who gave above-and-beyond hospitality—kindly offering camping and lodging, out-of-the way field visits just to open gates, driving escorts to sites, and information on their management.

Technical assistance in setting up and analyzing the spatially balanced random sample design goes to Dr. Tony Olson and Dr. Tom Kincaid with EPA's National Health and Environmental Effects Research Laboratory, Western Ecology Division in Corvallis, Oregon. Thanks also to colleagues in other states who carry out similar large-scale wetland assessment projects, especially Diane Menuz of the Utah Geologic Survey and Michael Bourdaghs of the Minnesota Pollution Control Agency. Conversations with Diane over the statistical analysis of these projects have help broaden our understanding of the techniques used. Mike's very nice charts and graphs in the 2015 *Status and Trends of Wetlands in Minnesota* served as the template for graphs in this report.

During the course of this project, we gained tremendous technical assistance, ideas and overall guidance from our colleagues at CNHP, especially Dave Anderson, Denise Culver, Karin Decker, Sarah Marshall, Gabrielle Smith, and Pam Smith. Sarah's help was particularly valuable with the water quality analysis. Pam was especially helpful in understanding the complex role of tamarisk in this landscape. Finally, we would like to thank Mary Olivas, Joe Fattor, and Carmen Morales with Colorado State University for accounting support and grant administration.

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TABLE OF CONTENTS

TABLE OF TABLES

Section 2.0

Section 3.0

Section 4.0

TABLE OF FIGURES

Section 2.0

Section 3.0

Section 4.0

1.0 INTRODUCTION

1.1 Colorado's Strategy for River Basin Wetland Assessments

This project is the fourth in a series of river basin-scale wetland assessment projects carried out by Colorado Natural Heritage Program (CNHP) and Colorado Parks and Wildlife (CPW) with funding from the U.S. Environmental Protection Agency (EPA), Region 8. The overarching goal is to assess the extent, ecological condition, and habitat quality of wetlands in each major river basin within the state. Information gained from these studies is being used by the CPW Wetlands Program and other conservation partners to develop measurable strategic goals for each basin and prioritize project funding (CWP 2011).

While each basin assessment addresses the same major themes of extent, ecological condition, and habitat quality, methods for each study have been tailored to the basin. The Lower Arkansas Basin project has been divided into two phases. The objectives of Phase 1, the *Lower Arkansas Wetland Mapping and Reference Network* project were to 1) create a digital map of wetlands in the Lower Arkansas Basin, 2) identify and assess a network of reference standard wetlands and riparian areas, and 3) research habitat requirements of target wetland-dependent wildlife species within the basin (Lemly et al. 2015). This report documents work carried out under the second phase of the project. The objectives of Phase 2 were to 1) produce overall basin-wide estimates of ecological condition for wetlands and riparian areas in the basin by sampling a spatially balanced, randomly selected set of sites and 2) pilot the collection of water quality data in wetlands. A companion report will be produced in the future that specifically details the habitat value of wetland and riparian sites in the basin, based on habitat quality indices developed in Phase 1 (Ortega 2014).

1.2 Project Background

The Arkansas River basin is the largest basin in the state of Colorado and drains a quarter of the state's land area. On the plains of eastern Colorado, the floodplain of the Arkansas River, its tributaries, and numerous playa lake complexes are important migratory and wintering bird habitat (USFWS 1955; RMBO & PWFAC 2004). Wetlands and riparian areas in the basin are utilized by several priority wildlife species, including the Federally Endangered piping plover (*Charadrius melodus*) and least tern (*Sternula albifrons,* syn = *Sterna antillarum*), the Federally Threatened Preble's meadow jumping mouse (*Zapus hudsonius preblei*), the State Threatened Arkansas darter (*Etheostoma cragini*), and scores of other bird, mammal and reptile species (Schorr 2003; Crockett 2010; Rondeau et al. 2010). However, aquatic resources in the basin face several major threats. There are serious issues with soil salinity and high concentrations of salts and minerals in the river, including selenium and uranium, which have been exacerbated by a century of irrigation (Miles 1977; Gates et al. 2009; Miller et al. 2010). Highly managed water flows have contributed to an invasion of the non-native shrub tamarisk (*Tamarix ramosissima,* syn = *T. chinensis*), which has choked ~67,000 acres of floodplain and riparian areas in the basin. The Arkansas basin represents over 70% of the tamarisk infestation in Colorado (Tamarisk Coalition 2008). Projected population growth of 55% in the next 20 years will place even more pressure on the already over allocated water supply (Brown and Caldwell 2011). This pressure has been exacerbated by several recent years of drought (Gunter et al. 2012; U.S. Drought Monitor 2015) and drought may worsen under future climate scenarios (Azadani 2012; Decker & Fink 2014). As population growth and development result in more intensive land use, with potentially negative effects on natural water resources like wetlands, these changes pose a cumulative threat to the basin's water quality, water supply and wildlife habitat.

The lower portion of the Arkansas River basin, from the base of the Rocky Mountains east to the state line, has been a primary focus area of CPW, U.S. Fish and Wildlife Service (USFWS)'s Partners for Fish and Wildlife Program, National Resource Conservation Service's Wetland Reserve Program, Bird Conservancy of the Rockies[1], Ducks Unlimited, Playa Lakes Joint Venture, and many other conservation organizations. However, to date, there has been no systematic assessment of condition of wetlands or riparian areas in this portion of the basin. Through the Phase 1 *Reference Network* project (Lemly et al. 2015), CNHP and CPW set the stage for such an assessment by creating a digital map of wetlands in the basin, identifying a network of reference wetlands, and researching habitat needs of wetland-dependent wildlife species. This project took the next step by carrying out a probabilistic field-based assessment of ecological condition in wetlands and riparian areas within basin. This information is necessary to prioritize on-the-ground efforts for efficient and effective conservation action.

In addition, this project also piloted the collection and analysis of water quality parameters in wetlands. Systematic sampling of water quality in vegetated wetlands is a challenge because the natural range of variability is poorly understood and variability is not always related to wetland condition (Wigham & Jordan 2003). Colorado's water quality agency does not currently conduct water quality monitoring in wetlands. However, because they are located at the interface between terrestrial lands and water bodies, wetlands absorb numerous pollutants and are an important buffer for protecting water quality downstream (Johnston 1991; USEPA 2015). By piloting the collection of water chemistry parameters, this project shed light on the complexities involved in wetland water quality sampling and the range of values observed in the basin.

1.3 Project Objectives

The project objectives were to: 1) conduct a statistically valid, field-based probabilistic assessment of wetland condition and habitat value in the Lower Arkansas Basin; and 2) pilot water quality sampling in the basin's wetlands. The objectives of this project were carried out through the following tasks:

1) **Conduct a statistically valid, field-based probabilistic assessment of wetland condition and habitat value in the basin.**
    - Sixty-two random wetland and riparian sites were selected for sampling based on a spatially balanced probabilistic sample design (Stevens and Olsen 2004).
    - Sites were selected from digital National Wetlands Inventory (NWI) mapping created through the *Lower Arkansas Wetland Profile and Reference Network* project (Lemly et al.

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[1] Formerly Rocky Mountain Bird Observatory or RMBO.

2015). Site selection was stratified to ensure spatial distribution across the basin and include the range of wetland types.

- Field methods followed the rapid Ecological Integrity Assessment methods developed by CNHP (Lemly et al. 2016).
- Results from the random sites were used to estimate wetland types and ecological condition throughout the basin and were compared with data from reference wetlands sampled in the *Reference Network* project to inform practical restoration goals.

2) **Pilot water quality sampling in the basin's wetlands to enhance Level 3 sampling methods.**
   - Water quality samples were collected in 15 reference condition wetlands sampled through the *Reference Network* project. Sites were selected to represent three common wetland types with surface water (marshes, plains riparian areas, and playas). Reference sites were visited up to three times during the field season to detect seasonal change.
   - Water quality samples were collected in 14 randomly selected wetlands sampled through Objective 1 of this project. Samples were collected in the first five random sites of each targeted wetlands type (marshes, plains riparian areas, and playas) encountered. Random sites were only visited one during the field season.
   - From both reference and random sites, two sets of water samples were collected per site at each visit to detect spatial variation within the same site on the same day.
   - Water sampling protocols were based on methods for monitoring water quality in rivers and streams developed by the volunteer stream monitoring program, River Watch,[2] combined with methods from the EPA National Wetland Condition Assessment (USEPA 2011).
   - Twenty-four water quality parameters were measured at each sampling event. Temperature, pH, and electrical conductivity (EC) were recorded onsite using a hand-held probe. Alkalinity and hardness were titrated out of the field. Nutrients, major ions, and metals were analyzed in the River Watch water chemistry lab from collected water samples.
   - Water quality data were analyzed to determine: 1) within-site variability in water quality data and 2) the range of values observed in each of the three wetland types.

1.4 Report Organization

Results from this project address two major aspects of the wetland resource: ecological condition and water quality. For ease of reading, the report is organized into several discrete sections.

- **Section 1** is this introduction to the overall project.
- **Section 2** is a description of the project study area.
- **Section 3** details the ***ecological condition*** assessment and estimates for the basin.
- **Section 4** focuses on the pilot study of ***wetland water quality.***

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[2] For more information, please see the River Watch webpage http://coloradoriverwatch.org/.

2.0 STUDY AREA

2.1 Geography

The Arkansas River basin is located in southeast Colorado. It drains the Arkansas River from its headwaters near the Town of Leadville, passes through a picturesque high mountain valley known for past mining and present-day recreation, and flows out through Colorado's eastern plains to the state border with Kansas. The study area for this project includes only the lower elevation portion of the Arkansas basin (hereafter called the Lower Arkansas Basin or 'basin'), which starts at Cañon City, on the dividing line between the Southern Rocky Mountains Ecoregion to the west and the Southwestern Tablelands Ecoregion to the east (Figure 2.1).[3] The Southern Rockies portion of the Arkansas basin is excluded from this study due to its distinct geography and wetland types. The study area is bound to the east and south by the state line, north by the boundary between the Arkansas and South Platte basins, and the west by the Southern Rocky Mountains Ecoregion.

The Lower Arkansas Basin encompasses 21,800 square miles (13.9 million acres or 56,450 km^2) of shortgrass prairie, floodplain, and canyons. Topography across much of the basin is nearly flat to gentle rolling hills as the land slopes gradually to the east. However, dissected topography of canyonlands and tablelands, such as the Purgatoire Canyon and Mesa de Maya, lie embedded in the shortgrass prairie south of the river. Elevation in the basin generally ranges from 5,500–3,500 ft. (1,675–1,0605 m.), though elevation can be as high as 7,750 ft. (2,360 m) in both the southern mesas near Trinidad and the northwestern foothills near Colorado Springs. The mean elevation in the basin is 4,875 ft. (1,485 m).

The most prevalent feature in the basin is the floodplain of the Arkansas River, which cuts a two- to five-mile wide swath across the center of the basin from west to east (Figure 2.2). Prominent bluffs and minor terraces border the floodplain along the river, evidence of shifts in the course of the riverbed over millennia. From Cañon City to the Kansas state line, the river drops just under 2,000 ft., with an average fall of 9 ft. per mile. Larger tributary rivers to the north of the Arkansas River include Fountain Creek, Chico Creek, Horse Creek, Rush Creek, and Big Sandy Creek and to the south include St Charles River, Huerfano River, Cucharas River, Apishapa River, Purgatoire River, and Two Butte Creek. In the far southeast corner, North Carrizo Creek, Bear Creek, and the Cimarron River are included in the study area, but join the Arkansas River farther east in Oklahoma.

The basin includes part or all of sixteen counties: Baca, Bent, Cheyenne, Custer, Fremont, El Paso, Elbert, Huerfano, Kit Carson, Las Animas, Lincoln, Otero, Crowley, Kiowa, Prowers, and Pueblo (Figure 2.2). Colorado Springs and Pueblo are the largest cities in the basin. Colorado Springs is located on the northwestern edge of the basin along Fountain Creek and has a population of ~446,000 people. Pueblo is located further south at the confluence of Fountain Creek with the Arkansas River and has a population of ~108,000 people (US Census Bureau 2014). These two

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[3] For the purpose of this report, the Arkansas River Basin includes the Colorado portions of HUC6 110200: Upper Arkansas; HUC6 110300: Middle Arkansas; and HUC6 110400: Upper Cimarron basins, as defined by the U.S. Geological Survey (http://water.usgs.gov/GIS/huc.html).

cities combined account for ~75% of the basin's population. Outside of those cities, the remainder of the basin's population is <200,000, and is concentrated in suburbs along the I-25 corridor or in small towns along the Arkansas River, including Cañon City, Rocky Ford, La Junta, Las Animas, and Lamar.

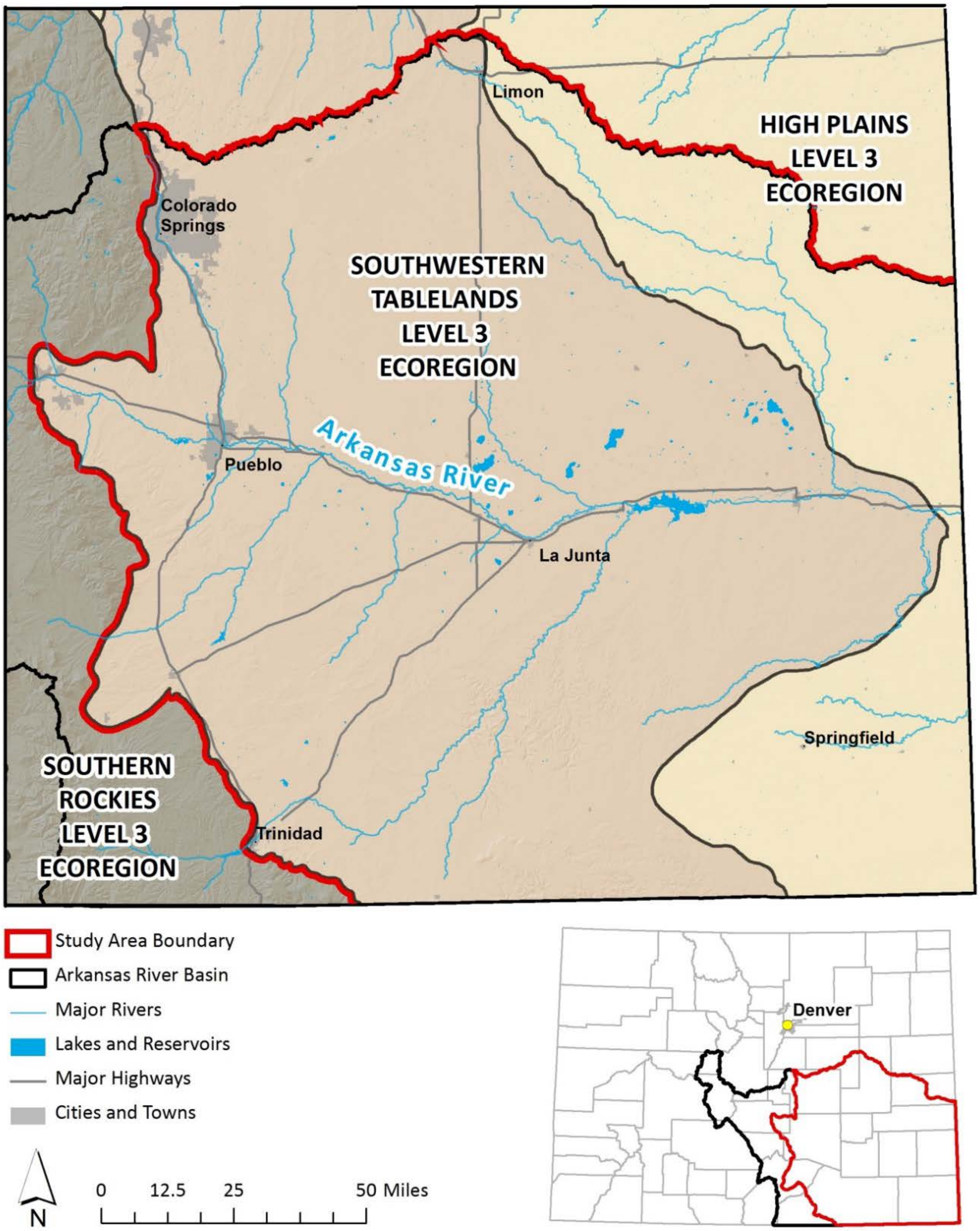

Figure 2.1. Location of the Lower Arkansas Basin study area within the state of Colorado. The Southern Rockies Level 3 Ecoregion is excluded from the study area.

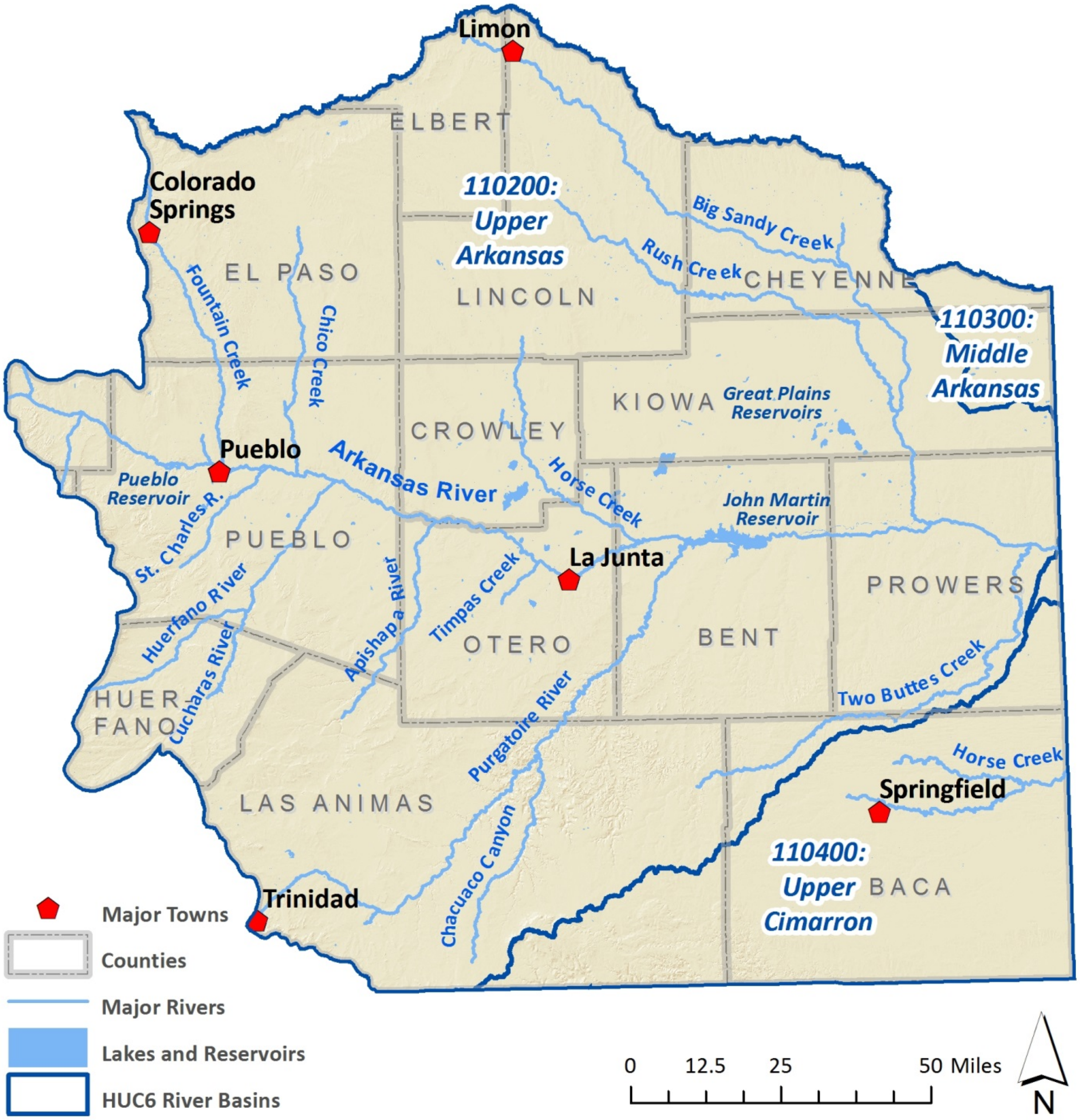

Figure 2.2. HUC6 river basis, major waterways, and counties in the Lower Arkansas Basin.

2.2 Climate

The basin is located in the semi-arid southeastern Colorado plains, where evaporation exceeds precipitation by as much as three to four fold (Topper et al. 2003). Annual precipitation ranges from 10–17 inches (25–43 cm) throughout the basin, with the highest precipitation falling during the summer months of July and August when summer thunder storms bring drenching rains (WRCC 2015). Temperatures fluctuate widely, with low winter temperatures often less than 0˚F and summer highs frequently exceeding 100˚F. Average daily highs are 45˚F in January and 95˚F in July.

Field data collection for this study took place in 2015, following several years of extreme drought. The Lower Arkansas Basin is part of the country impacted by the worst drought since the 1950s. Drought in the study area began in the summer of 2011, with nearly all of Colorado's Arkansas basin in 'severe to exceptional' drought in the summers of 2012 and 2013, and abated to 'moderate to severe' drought by the end of summer 2014 (U. S. Drought Monitor 2015). Regional climate change modeling shows that more frequent and severe drought years can be expected in the future for the basin, further stressing the water resources (Azadani 2012). High winds are common in the plains throughout the year, which compound the impacts of drought on the basin's plant communities and soil.

Average annual rainfall for the drought years (2011–2013) was 9.8 inches, which is 69% of normal annual precipitation for the Lower Arkansas Basin.[4] The worst drought year was 2012, during which the basin received only 43% of its normal precipitation. In 2015, the year this study was conducted, the basin received 20. 8 inches, roughly 147% of its normal rainfall (WRCC 2017). March 2015 precipitation in the basin was only slightly greater than during the severe drought years (Figure 2.3). In contrast, May 2015 was one of the wettest on record in the region. June and July thunderstorm activity produced typical year precipitation values, while above average precipitation was evident again in late summer.

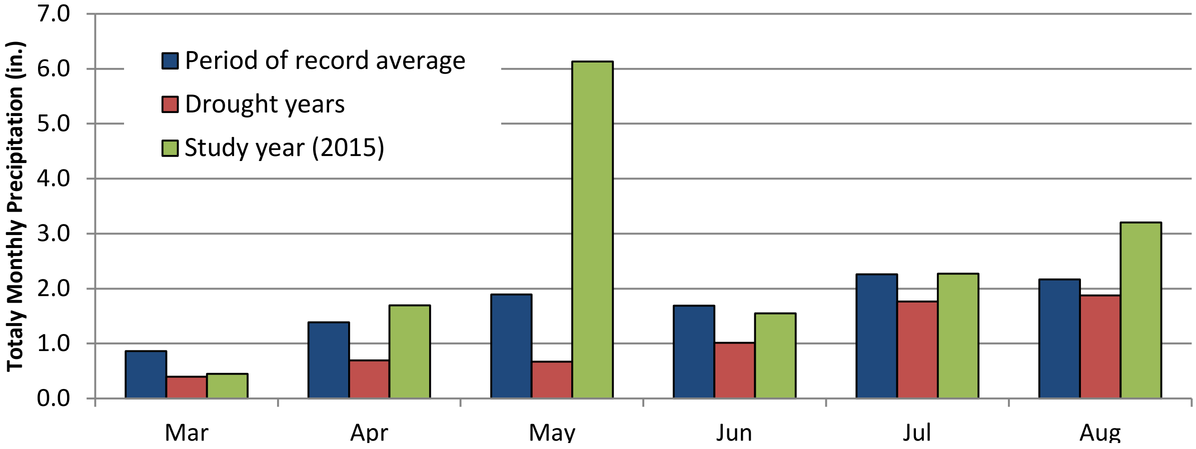

Figure 2.3. Total monthly precipitation for the Lower Arkansas Basin for the study year (2015), compared with the drought years of 2011-2013 and with the historical average.

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[4] Precipitation values calculated from the annual precipitation for three major cities in the basin (Pueblo, Lamar, Trinidad), which are representative of basin's geographic spread and climatic conditions.

2.3 Geology and Soils

Sedimentary rock dominates the basin's bedrock geology, including sandstone, shale, limestone, basalt, and gypsum deposits formed beneath a historic shallow sea that covered the plains of Colorado millions of years ago (Figure 2.4). Larger bedrock formations from the Jurassic period include Entrada Sandstone, Morrison Formation, and Ralston Creek Formation (Tweto 1979). Major formations from the Cretaceous period include the Purgatoire Formation, Dakota Sandstone, Graneros Shale, Greenhorn Limestone, Carlile Shale, Pierre Shale, and the Niobrara Formations. Aeolian (wind-blown) sand deposits cover much of the basin north of the Arkansas River as well as the southeast corner within the Cimarron drainage. Tall buttes and canyons in the south have more complex surface geology with igneous or metamorphic bedrock layers exposed.

There are four main soil order found in the basin: Entisols (recently developed soils), Aridisols (soils formed in dry climates, often with high salts and carbonates), Alfisols (productive soils with clay stored in subsurface layers), and Mollisols (soils with high organic content within the surface layer, often formed under grasslands). Young Entisols formed by newer unconsolidated alluvial or aeolian deposits cover riparian and floodplain lowlands of the Arkansas floodplain, and are often comprised of sand and gravel (Sweet and Inman 1926). In addition to coarse alluvium, the Arkansas floodplain includes patches of poorly drained clay and clay-loam soil associations that support narrow swale and large marsh wetlands. Outcrops immediately outside the Arkansas floodplain are often loamy soils upon sandstone breaks or limestone and shale escarpments.

The Arkansas River floodplain generally breaks the basin in half, with distinctive soil characteristics north and south. To the north, tributary creeks such as Big Sandy and Rush Creeks are underlain by young soils formed from deep aeolian sand deposits. These deep sandy soils transport water above and below ground along the riparian corridors, often flowing subsurface through some reaches. South of the Arkansas River and surrounding some of the larger tributaries, soils are predominantly formed on rolling sandstone, sandhills, hummocky uplands and historic stabilized dunes. Tributary streams have cut deeper canyons through these soils. Spreading playa complexes are common throughout uplands both north and south, occurring upon eroded loess soils, saline subirrigated lowlands, and historic sand dune lowlands that lack drainage.

Overall, many soils in the basin are saline, calcareous, or both, ranging from the lowland alluvium rising up to the upland grass prairies and shale outcrops. Some watersheds with shale soils near or at the surface have naturally saline soils. Shale derived soil can be naturally high in selenium. Irrigation return flows can further concentrate levels of selenium and salts and there has been extensive study on irrigation's contribution to water quality issues in the basin (Miles 1977; Ortiz et al. 1998; Gates et al. 2009; Miller et al. 2010).

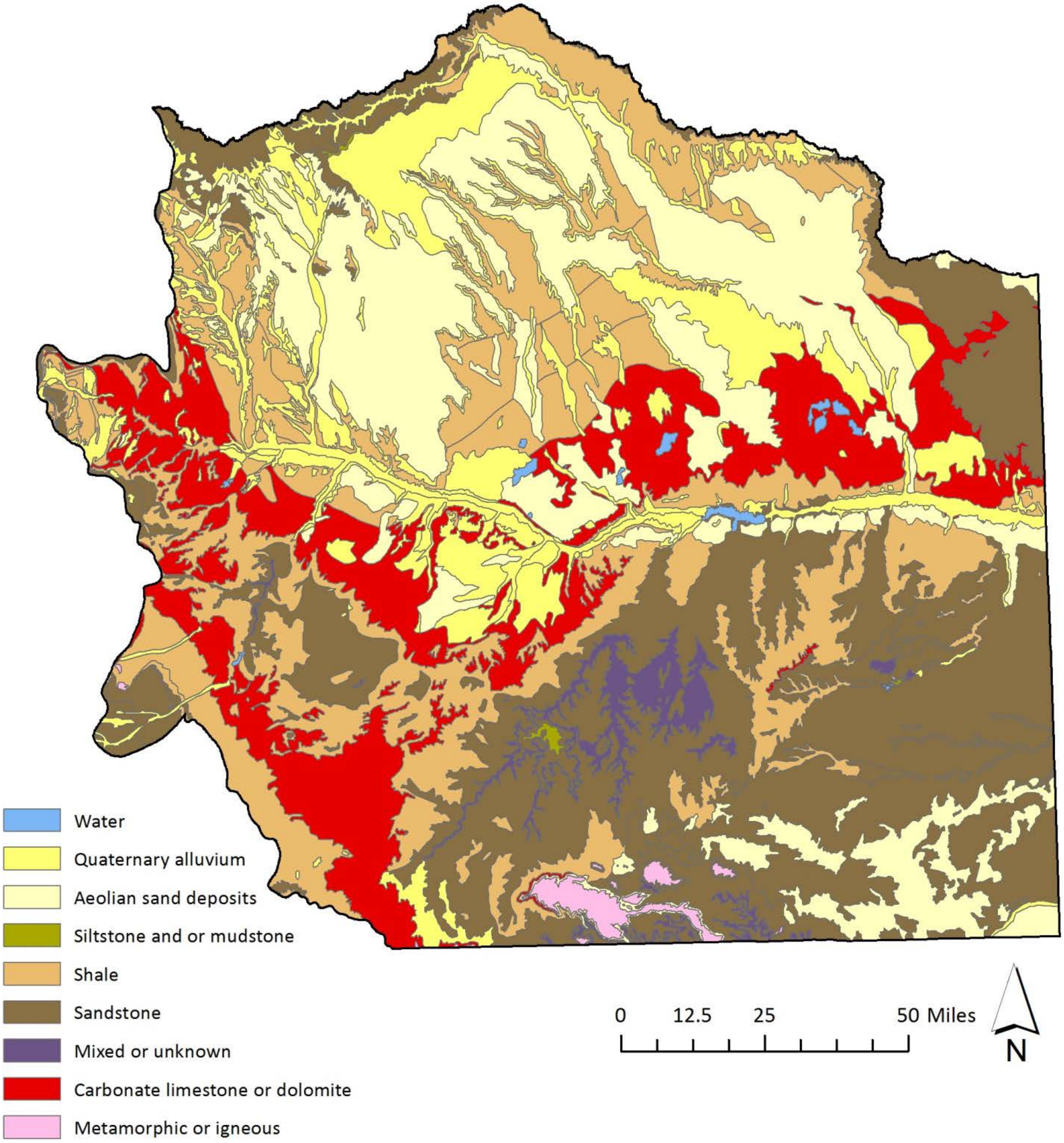

Figure 2.4. Dominant surface geology of the Lower Arkansas Basin.

2.4 Ecoregions and Vegetation

The basin falls within two Omernik Level 3 ecoregions: the Southwest Tablelands and the High Plains (Omernik 1987[5]). Level 4 Ecoregions further divide the landscape into finer units based on vegetation, topography and geology (Figure 2.5; Table 2.1).

The basin's upland vegetation is dominated by shortgrass prairie, with patches of mixed-grass and sand sage (*Artemisia filifolia)* shrublands*.* Common dominant grasses include buffalograss (*Buchloë dactyloides,* syn = *Bouteloua dactyloides*), blue grama (*Chondrosum gracile,* syn = *Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), switchgrass (*Panicum virgatum*), and sacaton species (*Sporobolus* spp.). County soil surveys note that the potential native grass communities would include more tall grass and less sand sage if overgrazing was controlled. Juniper woodlands, and shale hills and barrens are other characteristic upland ecosystems of the basin. Greasewood (*Sarcobatus vermiculatus*) flats, four-wing saltbush (*Atriplex canescens*) gullies, canyon uplands and seeps, and stands of tree-cholla (*Cylindropuntia imbricata*) contribute to the unique vegetation associations of the Lower Arkansas Basin. Besides dominant species and communities, the basin supports many unique and rare species and communities, including wetlands (Rondeau et al. 2010; Culver & Smith 2017).

The dominant landscape of semi-arid shortgrass prairie uplands can sharply contrast with the basin's wetlands, riparian areas, playas, and reservoirs. The Lower Arkansas floodplain is a mosaic of vegetation zones interspersed between agriculture fields. Dense woody bands of non-native tamarisk (*Tamarix ramosissima,* syn = *T. chinensis*) and native cottonwood (*Populus deltoides*) alternate with open meadows dominated by mesic grasses (*Panicum virgatum* and *Distichlis stricta*) and sandy shrub terraces dominated by willows (*Salix exigua*, *S. eriocephala*, *S. amygdaloides*, and *S. fragilis*). Small to large swaths of cattail (*Typha* spp.) marsh are located along the river between Pueblo and John Martin Reservoirs. Perennial reaches of the larger tributary streams support similar overstory species, and have more diverse understories influenced by shortgrass prairie species. Non-native species kochia (*Bassia sieversiana,* syn = *Bassia* or *Kochia scoparia*) and Russian thistle (*Salsola* spp.) are prevalent in the basin's floodplains and riparian understory composition, and similar to tamarisk, they are functionally invasive and often dominate their strata. Russian thistle was identified as a problem 'noxious weed' in the basin over a century ago (Lapham 1902). Tamarisk was observed in the basin in 1913 and spread considerably in the following decades. By 1979, tamarisk essentially dominated the floodplain (Lindauer 1983). Control efforts carried out in the past two decades have killed hundreds of acres of tamarisk, though much remains as standing dead with weedy understory composition.

Away from the floodplain, the open plains support numerous playas complexes and small riparian areas with plant communities adapted to fluctuating and often intermittent flows. Playa vegetation changes dramatically during wet and dry phases, from upland grasses, such as western wheatgrass and buffalograss when dry to spikerushes (*Eleocharis* spp.) and other wetland plants when wet. Narrower riparian areas range from open sandy washes with cottonwood galleries and upland or

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[5] For more information on Omernik/EPA Ecoregions and to download GIS shapefiles, visit the following website: http://www.epa.gov/wed/pages/ecoregions.htm.

mesic understory grasses, to patchy groundwater-fed wetlands along slow flowing channels with mixed wetland graminoids (*Carex, Schoenoplectus,* and *Eleocharis* spp.), forbs, and aquatics. Many of the large reservoirs north of the Arkansas River are also important components of the aquatic resource base; vegetation species that fringe the large reservoirs are similar to the riparian species of the Arkansas floodplain, but are generally very disturbed.

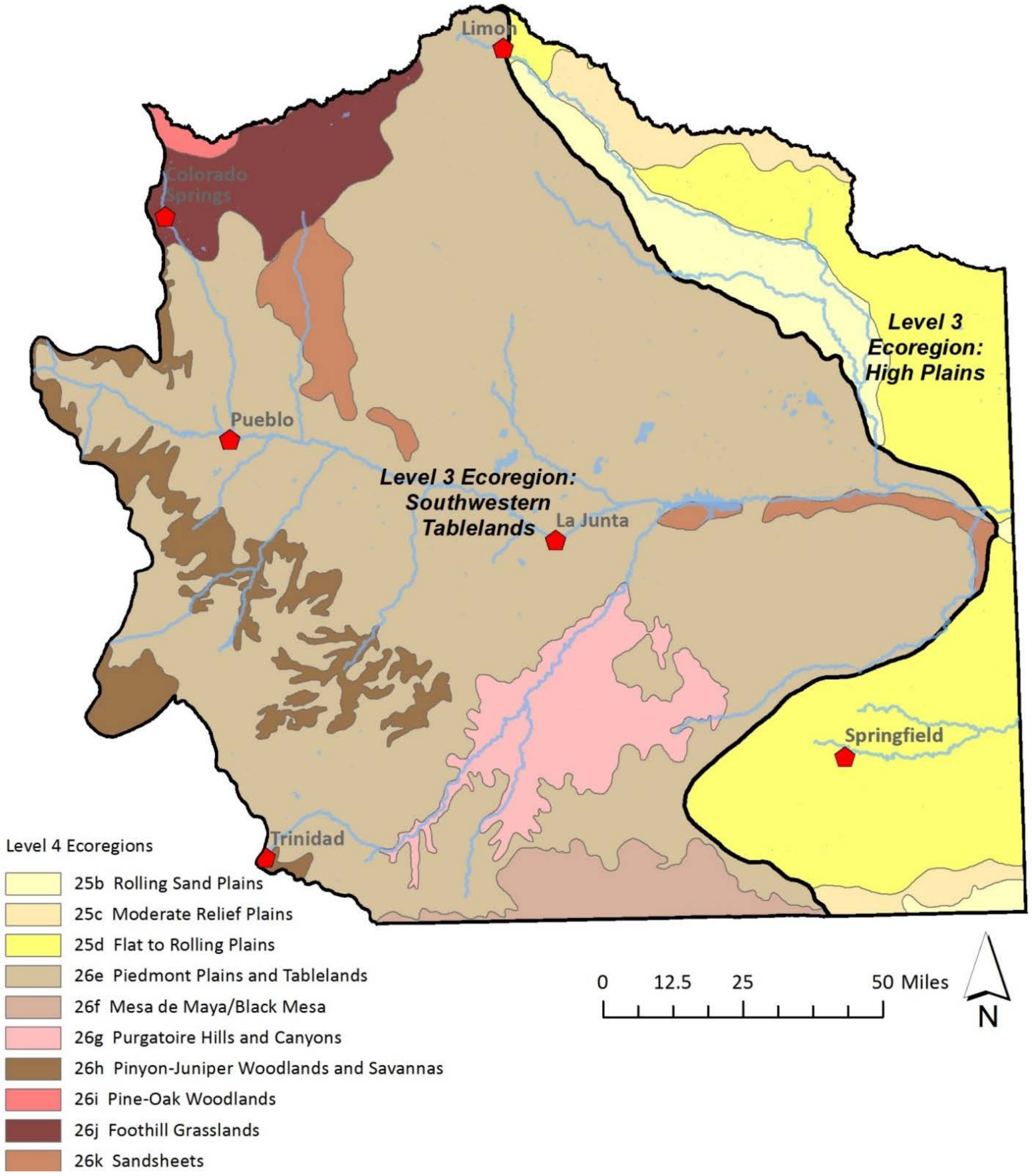

Figure 2.5. Level 3 and 4 Ecoregions of the Lower Arkansas Basin.

Table 2.1. Descriptions of Level 4 Ecoregions within the Lower Arkansas Basin.

NAME	***DESCRIPTION***
25b: Rolling Sand Plains	The grass-stabilized sand plains, sand dunes and sand sheets of the **Rolling Sand Plains** ecoregion are a divergence from the mostly loess-covered plains of adjacent ecoregions. Sandy soils, formed from eolian deposits, supported a sandsage prairie natural vegetation type, different from the shortgrass and midgrass prairie of other neighboring level IV ecoregions in the High Plains (25). Sand sagebrush, rabbitbrush, sand bluestem, prairie sandreed, and Indian ricegrass were typical plants. Land use is primarily rangeland, although a few scattered areas have been developed for irrigated cropland using deep wells.
25c: Moderate Relief Plains	The **Moderate Relief Plains** ecoregion is typified by irregular plains with slopes greater than the surrounding at and rolling plains of Ecoregion 25d. Land use is predominantly rangeland, in contrast to the cropland or mosaic of cropland and rangeland of surrounding ecoregions. Soils are silty and clayey loams, formed from eolian sediments, shallower than the thicker loess-capped uplands of 25d. Blue grama-buffalograss was the natural prairie type.
25d: Flat to Rolling Plains	The **Flat to Rolling Plains** ecoregion is more level and less dissected than the adjacent Moderate Relief Plains (25c). Soils are generally silty with a veneer of loess. Dryland farming is extensive, with areas of irrigated cropland scattered throughout the ecoregion. Winter wheat is the main cash crop, with a smaller acreage in forage crops.
26e: Piedmont Plains and Tablelands	The **Piedmont Plains and Tablelands** ecoregion is a vast area of irregular and dissected plains underlain by shale and sandstone. Precipitation varies from 10 to 16 inches, with the lowest amounts found along the Arkansas River between Pueblo and Las Animas. The shortgrass prairie contains buffalograss, blue grama, western wheatgrass, galleta, alkali sacaton, sand dropseed, sideoats grama, and yucca. Land use is mostly rangeland. Irrigated agriculture occurs along the Arkansas River, and dryland farming is found primarily in the north half of the region.
26f: Mesa de Maya / Black Mesa	The **Mesa de Maya/Black Mesa** ecoregion contains a broad basaltic mesa and dissected plateaus with steep canyons. Juniper and pinyon-juniper woodlands grow along canyons and mesa sides, while grasslands occur on the basalt cap of the mesa. This is the only region in Colorado where small areas of mesquite are found. Soils are formed in materials weathered from basalt, limestone, sandstone, and shale. Rock outcrops are common. Low precipitation, low available water capacity, and erodibility limit agricultural use.
26g: Purgatoire Hills and Canyons	The **Purgatoire Hills and Canyons** ecoregion includes dissected hills, canyons, and rock outcrops. Woodland vegetation is dominated by juniper with less grassland vegetation than found in 26f. Unlike Ecoregion 26f, the Purgatoire Hills and Canyons ecoregion is generally more dissected and does not contain the basaltic mesa or soils derived from basalt. Soils are well drained and formed in calcareous eolian sediments and material weathered from sandstone; rock outcrops are common. The Purgatoire River supports a diverse fish assemblage.
26h: Pinyon-Juniper Woodlands and Savannas	Scattered, dissected areas with pinyon and juniper on the uplands characterize the **Pinyon-Juniper Woodlands and Savannas** ecoregion. The region is a continuation or an outlier of the pinyon-juniper woodlands found in Ecoregion 21d in the Southern Rocky Mountains to the west. Soils tend to be thin and are formed in materials weathered from limestone, sandstone, and shale. Rock outcrops are common. Annual precipitation varies from 12 to 20 inches, with the highest amounts found in areas closest to the mountains. Land use is mainly wildlife habitat and rangeland.

Table continued on next page.

NAME	*DESCRIPTION*
26i: Pine-Oak Woodlands	The **Pine-Oak Woodlands** ecoregion is a dissected plain with dense oakbrush and deciduous oak woodlands combined with ponderosa pine woodlands. The southern portion is known locally as the Black Forest. Although woodlands dominate, the region is a mosaic of woodlands and grasslands. It is somewhat more dissected than the surrounding Foothill Grasslands (26j) ecoregion. The Pine-Oak Woodlands may be an outlier of the ponderosa pine woodlands found in the mid-elevation forests of the Southern Rockies (21) to the west. Soils are formed from weathered sandstone and shale with some outwash on uplands. Land use is woodland, wildlife habitat, and some rangeland. Areas of the region are rapidly urbanizing.
26j: Foothills Grasslands	The **Foothill Grasslands** ecoregion contains a mix of grassland types, with some small areas of isolated tallgrass prairie species that are more common much further east. The proximity to runoff and moisture from the Front Range and the more loamy, gravelly, and deeper soils are able to support more tallgrass and midgrass species than neighboring ecoregions. Big and little bluestem, yellow Indiangrass, and switchgrass occur, along with foothill grassland communities similar to those of Ecoregion 21d. Although grasslands dominate, scattered pine woodlands similar to those found in 26i also occur. The annual precipitation of 14 to 20 inches tends to be greater than in regions farther east. Soils are loamy, gravelly, moderately deep, and mesic. They are formed from weathered arkosic sedimentary rock, gravelly alluvium, and materials weathered from sandstone and shales. Rangeland and pasture are common, with small areas of cropland. Urban and suburban development has increased in recent years, expanding out from Colorado Springs and the greater Denver area.
26k. Sand Sheets	The **Sand Sheets** ecoregion has rolling plains with stabilized sand sheets and areas of low sand dunes. Soils are formed from wind-deposited and alluvial sands. Natural vegetation is primarily sandsage prairie with sand reed grass, blue grama, sand dropseed, needlegrass, and sand sagebrush, and is similar to the Rolling Sand Plains (25b) ecoregion found in the neighboring High Plains (25). Annual precipitation ranges from 10 to 16 inches, less than the Foothill Grasslands to the northwest. Land use in this region is mainly rangeland.

2.5 Hydrology and Water Use

Hydrology of the Arkansas River is heavily influenced by seasonal precipitation and snowmelt from the upper Arkansas basin, as well as major summer thunderstorms, and the flow is extensively managed in the lower basin. John Martin Reservoir (built in 1943) and Pueblo Reservoir (built in 1975) are both positioned across the Arkansas River, damming the river for flood protection, water storage, and recreation. Despite managed flows, the perennially-flowing Arkansas River and its largest tributary, Fountain Creek, can have dynamic floodplains at high water. Mean annual discharge for the Arkansas River at Pueblo is only 550 cubic feet per second (cfs), however mean peak flows for the same location is 7,715 cfs and the recorded max peak flow reached over 100,000 cfs in June 1921 (Javier et al. 2007). In contrast, many of the basin's tributary streams originate in the plains and are more influenced by local precipitation patterns. The basin's tributaries range from perennial (e.g., Huerfano River, St. Charles River, Purgatoire River) to intermittent (e.g., Big Sandy Creek, Rush Creek) and ephemeral (many smaller tributaries). Many lack surface flow across some reaches during part or all of the year, while other reaches receive groundwater input and support patches of perennial wetlands and springs.

There are numerous precipitation and runoff-fed depressional playas throughout the basin. These range from large complexes of small, intermittently filled playas, to large reservoirs near the Arkansas floodplain that receive supplemental irrigation water. For example, the Great Plains Reservoirs of Queens State Wildlife Area are natural broad, shallow playa lakes that have been used as storage reservoirs, though they are now primarily managed for wildlife and their water levels fluctuate widely. There is some evidence that the largest playas are connected to the groundwater table, but the hydrology is not well studied. Common hydrologic alterations for larger playas include water additions and invasive species and for smaller playas include conversion to cropland and pits dug to concentrate water for livestock (Cariveau & Pavlacky 2008).

Groundwater in the basin occurs in two types of aquifers, *alluvial aquifers* associated with the Arkansas River and major tributaries and larger *bedrock aquifer systems* (Topper et al. 2003). Alluvial aquifers provide readily available groundwater within unconfined coarse sediments and are extensive pumped for irrigation water along the Arkansas River Valley, Fountain Creek, Upper Black Squirrel Creek, and Upper Big Sandy Creek. The largest bedrock aquifer in the Lower Arkansas Basin is the Dakota-Cheyenne aquifer, which generally corresponds with the Southwestern Tablelands Level 3 Ecoregion. In portions of the basin, farther from the Arkansas floodplain, water levels within the Dakota-Cheyenne aquifer are close to the surface and springs are common. Despite the Dakota-Cheyenne's large coverage over the basin, its wells only contribute to a small proportion of the water used in the basin due to the high reliance on surface and groundwater from the Arkansas River (Brown and Caldwell 2011). Other bedrock aquifers include the Denver Basin north and east of Colorado Springs in El Paso and Elbert counties, the Raton Basin west of Walsenburg and Trinidad, and the High Plains (Ogallala) Aquifer, which underlies the eastern portion of the basin within the High Plains Level 3 ecoregion. Irrigation and domestic water above the Ogallala is pumped from groundwater wells, as surface water irrigation is not available. Water levels within the High Plains Aquifer have been falling since the 1960s, due to excessive pumping. While some recharge occurs within the bedrock aquifers, they are considered non-renewable and have a total projected life of ~100 years (McGuire 2004; CDWR 2014).

Annual water use in the entire Arkansas River basin is over 2.0 million acre-feet, of which 87% is for agricultural use (Arkansas Basin Rountable 2015). The percentage of urban use is expected to rise considerably over the coming decades, however, as urban populations grow, farming declines, and agricultural water is transferred to urban uses (Brown and Caldwell 2011). Current municipal water use varies by city/town, ranging from diverted flows and canals from the Arkansas River and its tributaries, to groundwater pumping coupled with augmentation return flow requirements.

2.5.1 Irrigation Practices

Irrigation has shaped hydrology across much of the basin. The basin's first evidence of irrigated agricultural dates to 1839 in temporary settlements, with the first permanent ditches constructed in the 1850s (Lapham 1902; Van Hook 1933). Large canal systems were built in the late 19th century, and irrigated farming was well-established by 1890. At the advent of irrigated agriculture, in the late nineteenth century, the Arkansas Valley was known as the 'Valley of Content' because the fertile soil of the floodplain combined with the intense summer sunshine created a highly productive farming region perfect for sugar beets, cantaloupe, and other cash crops (Sherow 1990).

Within just a few decades, however, return flows from irrigation raised water tables beneath the floodplain and the arid climate wicked salts out of the naturally saline soils (Latham 1902; Gates et al. 2012). Extreme fluctuations in annual precipitation, from destructive floods to years of punishing drought also made farming difficult. Groundwater wells were introduced to the basin in the 1930s, tapping into the extensive alluvial aquifer. Disputes over water allocation lead to the 1948 Arkansas River Compact, which now controls the over-appropriated flow of the Arkansas River and its supporting perennial tributaries, splitting the river's appropriation between Colorado and Kansas with 60%/40%, respectively (Arkansas Basin Roundtable 2015). The Compact's 1996 amendment requires that users of tributary or surface-connected groundwater wells decreed after 1948 be responsible for replacing pumped water with augmentation water back to the river.

While irrigated agriculture still accounts for the majority of the basin's water use, farming is on the decline and urban municipal and industrial water needs are increasing. As a result, irrigated land area is decreasing and water uses are being transferred from local diversions to municipal and industrial uses (Salcone 2013). This ongoing process is shifting and concentrating the location of water to larger reservoirs, and in some cases, is drying formerly irrigated landscapes and associated wetlands. The most dramatic example is Crowley County, where nearly 90% of irrigated acres were taken out of production in the 1980s when the City of Aurora purchased nearly all water rights held by the Colorado Canal. The resulting drying of farmland in Crowley County, and the associated collapse of the County's economy, has come to symbolize the worst effects of this "buy and dry" approach to agriculture-to-urban water transfers (Howe et al 1990; Howe & Goemans 2003; Goodland 2015). In an already water-stressed basin, transfers of water from agriculture along the floodplain to urban areas may result in irreversible changes to the wetland resource.

There are 8,660 decreed points of diversion and 16,550 decreed wells mapped in the basin (CDSS 2012). Water diversions range from small diversions for local crop irrigation to larger storage and irrigation canals such as the Fort Lyon, Rocky Ford, and Amity Canals. In addition, the basin also imports water through the Fryingpan-Arkansas Trans-basin Project, which pipes water from the Colorado basin's Fryingpan River to Turquoise Lake in the Arkansas headwaters. Trans-basin waters from this project are used to meet flow and augmentation requirements. The Lower Arkansas Basin also exports water out of the basin to the City of Aurora, in the South Platte drainage. Several large reservoirs (John Martin, Pueblo, and the Great Plains Reservoirs) are involved in the storage and transfer of water between users.

A total of 316,978 acres of irrigated lands were mapped in the basin as of 2003 (CDSS 2012, most recent data available), primarily concentrated along the floodplains of the Arkansas River and Fountain Creek. Of all acres mapped, 120,513 (38%) were categorized as "dry" or "N/A", meaning they were not actively irrigated in 2003. A large majority of these acres were reported to have no crops and have likely been retired from production. The remaining 196,465 acres were actively irrigated land.[6] Nearly all actively irrigated land (98%) was flood irrigated, meaning that fields were flooded from small lateral ditches extending through the fields. Flood and furrow irrigation is a low-technology and relatively inefficient method that can create many incidental wetlands as

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[6] This number differs from the 249,450 acres of irrigated lands reported on the Colorado Decision Support System website for the Arkansas Basin (http://cdss.state.co.us/basins/Pages/Arkansas.aspx, accessed Oct 2016), though the raw data source is the same. The discrepancy may be with how the CDSS calculation treated acres that are temporarily fallowed vs. permanently fallowed.

excess water and return flows raise the water table or is caught in depressions on the margins of fields (Peck & Lovvern 2001; Sueltenfuss et al. 2013; Berkowitz & Evans 2014). Only two percent of actively irrigated land was either sprinkler or drip irrigated. Of the actively irrigated land, nearly three quarters (73%) were planted as alfalfa crops for hay and another 16% were irrigated for livestock pasture. Other crops on irrigated land included corn for grain and silage, dry beans, grains, fruits and vegetables, and wheat, but each accounted for less than 3% of actively irrigated land. These smaller acreage crops, however, are far more lucrative for producers.

Irrigation is associated with high salinity levels in the basin's alluvial aquifer, particularly in the downstream reaches of the basin, and agricultural runoff has influenced surface and groundwater quality where agricultural uses are concentrated. Both surface and subsurface irrigation return flow passing through the basin's natural shale geology contribute to salt loads in the basin's waters (Miles 1977; Gates et al. 2002). The elevated salt loads have reduced crop yields in many areas of the valleys, rendering once fertile land less productive (Burkhalter & Gates 2005). In certain locations along the river, return flows can dissolve mineral constituents (uranium and selenium) (Gates et al. 2009; Miller et al. 2010) that are dangerous to human health and wildlife (Lemly 1993; Lemly et al. 1993).

2.5.2 Comparison of 2015 to Historic Flows for the Basin's Three Largest Rivers

During the summer of 2015, when this study was conducted, the basin had emerged from an extended drought, and experienced a wetter than normal year. Mean discharge levels in the basin's major waterways during the 2015 water year (October 2014–September 2015) were all above average period-of-record flows (Table 2.2).[7] The Arkansas River at Pueblo, CO had annual discharge of 171% of historical mean flows, with the majority of excess water flowing in June. Downstream at both Las Animas and below John Martin Reservoir, flows were also well above historical levels at 280% and 134% of the period-of-record average, respectively. The Purgatoire River, one of the largest tributaries to the Arkansas River, was above average historical mean flow at both Madrid, CO (135% of historical), as well as closer to the confluence with the Arkansas River in Timpas, CO (151%). Fountain Creek, another large tributary to the Arkansas River near the foothills, had annual discharge of 360% of historical flow, with record mean flow levels in May and June. Natural flows in all parts of the basin, especially major waterways, are affected by storage reservoirs, diversions for irrigation and municipal use, groundwater withdrawals, return flows from irrigated areas, and flows from sewage treatment plants, which temper the natural hydroperiod.

Along the Arkansas River, peak flow in 2015 occurred in June at Pueblo and Las Animas (4579 cfs and 3605 cfs respectively), and in July at and John Martin Reservoir (1424 cfs).[8] Monthly discharge values for 2015 and for historical data for the three aforementioned gauging stations were averaged to create a coarse hydrograph for the Lower Arkansas River (Figure 2.6). Flows in the Arkansas were close to historical mean flows from October 2014 to April 2015, matching the low precipitation in these months. River flows were unusually high and significantly exceeded historical

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[7] Mean discharge for the 2015 water year was assessed at six USGS gauging stations along the Arkansas River, Purgatoire River, and Fountain Creek and compared to historical flows. Time periods for each gauge vary, but most date back to 1975.

[8] Arkansas River discharge values were assessed for the 2015 water year from gauging stations located in Pueblo, Las Animas, and below John Martin Reservoir near Hasty, CO.

means in May through July, then approximated historical flows again in August and September. The Purgatoire River by Madrid, CO also experienced peak flow in June with a discharge of 339 ft³/s, and the Purgatoire further downstream at Timpas, CO also peaked in June at 191 ft.³/s. Fountain Creek peaked in May (1770 ft.³/s).

Table 2.2. Annual discharge in cubic feet per second (cfs) for the 2015 water year compared to historical annual discharge at six gauging stations along the Arkansas River, Purgatoire River, and Fountain Creek.

		Annual Discharge (cfs)		***2014 Discharge as a Percent of Historical***
Water body	***Station Location***	***2014***	***Historical***	
Arkansas River	Moffat St., Pueblo, CO	979	572	171%
Arkansas River	Las Animas, CO	742	265	280%
Arkansas River	Below John Martin Reservoir, CO	370	277	134%
Purgatoire River	Madrid, CO	93	69	135%
Purgatoire River	Timpas, CO	95	63	151%
Fountain Creek	Pueblo, CO	378	105	360%

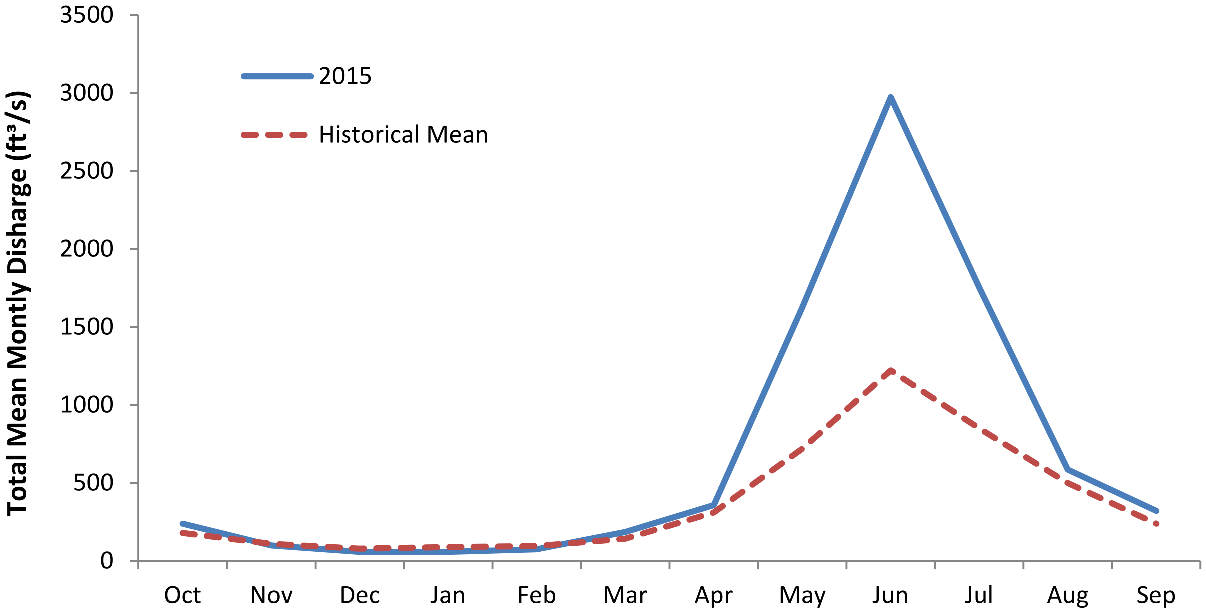

Figure 2.6. Hydrograph displaying total mean monthly discharge (cfs) for 2015 water year (October 2014–September 2015) and historical mean monthly discharge calculated from discharge data from 1975–2015 and averaged for three gauge stations along the Arkansas River (Pueblo, Las Animas, and below John Martin Reservoir).

2.6 Land Ownership and Land Use

When Euro-American settlers first arrived in the 1830s, Native American tribes of the plains utilized territory throughout the entire basin, and held semi-permanent settlements in some regions. Bent's Fort, established along the Arkansas River in 1833, served as an important stopover and trading point along the Santa Fe Trail, where Native Americans, Mexicans of Spanish descent, and west-bound Anglo-Americans traded freely (Lavender 1954). Over the next few decades, conflicts between settlers and the plains tribes occurred. The infamous Sand Creek Massacre, one of the most brutal battles of the Plains Indian Wars, took place on Big Sandy Creek in 1864. Meanwhile, settlers aggressively hunted bison with the backing of the U.S. Government to eradicate the primary food source of the local tribes. By the 1870s, survivors of Native American tribes were displaced to reservations outside of Colorado. Plains bison populations, formerly in the millions, were decimated by the end of the century (Boyd & Gates 2006).

Once the railroad was built, settlements boomed and agriculture and ranching were a way of life. Success of homesteaders often corresponded with the basin's seasonal precipitation, with wet years and decades of productive, tillable land alternating with drought years. As landowners attempted to use the land at its maximum during the range of wet to dry climatic trends, long-term degradation and erosion occurred. Along with a growing irrigated agriculture sector on the Arkansas floodplain, from the early 20th century, much of the basin's native shortgrass prairie was plowed into farmland. Economic busts were punctuated by major droughts, including the Dust Bowl of the 1930's that caused major soil loss from the large plowed land area. Many settlers abandoned their land after the Dust Bowl, and prairie was converted back to grassland and rangeland. Comanche National Grassland was established (formerly managed by the Soil Conservation Service) to revegetate previously cultivated degraded lands back to grassland, and to create a more sustainable ranching economy for those that wanted to stay on the land (Larsen et al. 1972). One water and soil management technique was to terrace farmland, to reduce surface runoff to crops. As water tables lower and drought years rendered lands non-arable, many terraced landscapes became historic. The imprint the terraces left behind on the landscape still intercepts runoff today and can reduce intermittent streamflow in runoff-fed riparian ecosystems.

Today, the vast majority of the basin is privately owned (84%). Common rural land uses in the basin include livestock grazing on rangeland; irrigated and dryland farming; extractive industries such as concrete quarries, ore mining, and oil/gas; and recreation such as dude ranches, hunting/fishing, and use of natural areas. A wide band of irrigated crops are located east of Pueblo Reservoir, between the Arkansas River's active floodplain and large irrigation canals. Other major tributary rivers support locally irrigated fields, especially on the western edge of basin, and groundwater wells also support limited center-pivot irrigated crops throughout the basin. Dryland farming, mostly wheat and some sorghum and millet, is fairly widespread but is most concentrated in the east basin. In the growing cities and suburbs of Colorado Springs and Pueblo, land uses are urban. Smaller cities and towns include a mix of urban and more rural land uses.

Aside from private land ownership, 9.4% of the basin is state owned, administered by either the State Land Board or Colorado Parks and Wildlife. State Land Board lands include a number of large ranches, some of which are managed for conservation interests. Colorado Parks and Wildlife lands include small to large State Wildlife Areas and State Parks, managed for wildlife habitat and recreation opportunities. The remainder 6.4% of the basin is owned by federal or local public entities. Large federal tracts in the basin include Comanche National Grassland, various small tracts owned by the Bureau of Land Management, and the Military Lands of Piñon Canyon Maneuver Site, Fort Carson, Pueblo Chemical Depot, and the Air Force Academy.

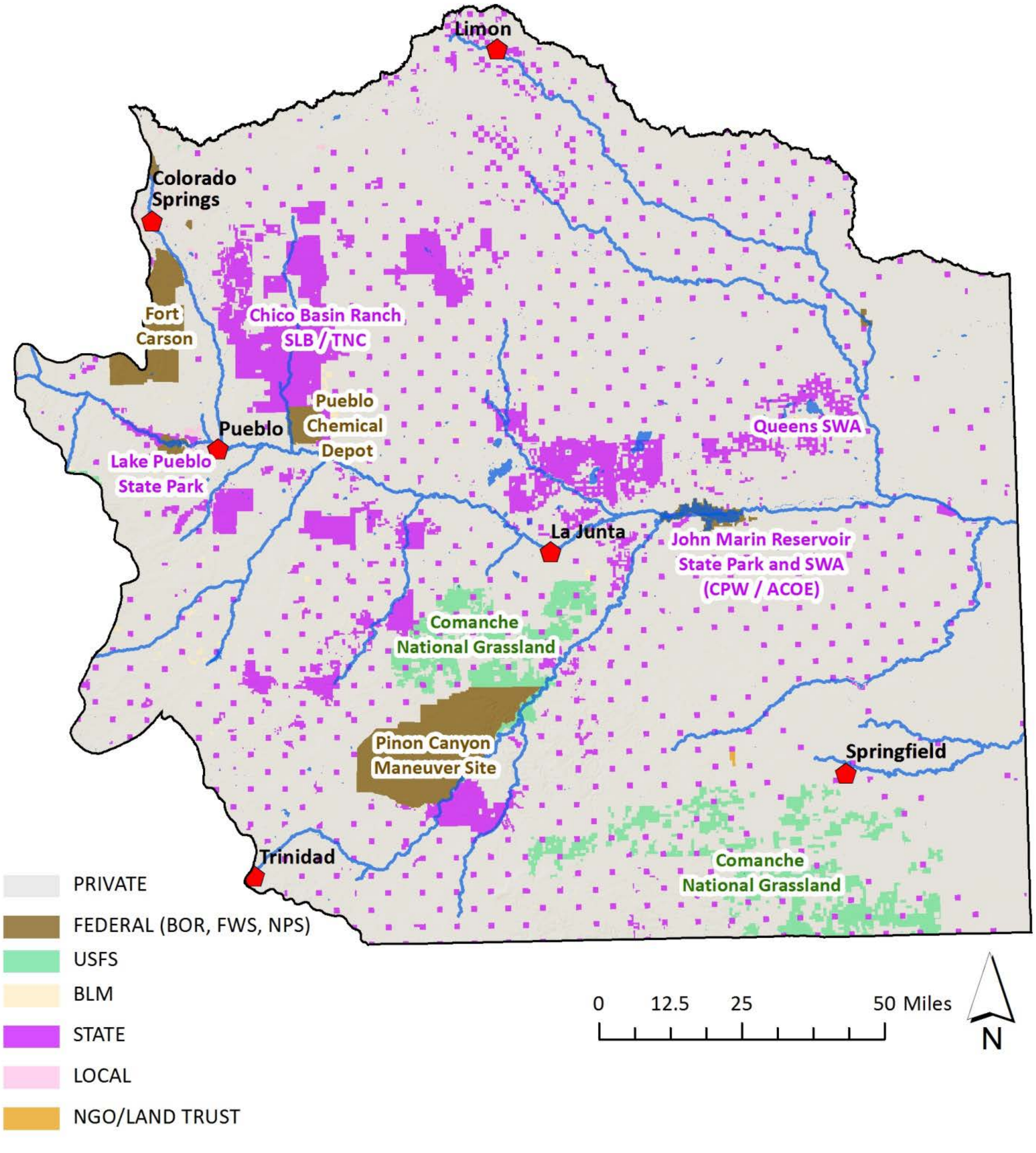

Figure 2.7. Landownership within the Lower Arkansas Basin.

3.0 ECOLOGICAL CONDITION OF WETLANDS AND RIPARIAN AREAS IN THE LOWER ARKANSAS BASIN

3.1 Introduction to Ecological Condition Assessment

Wetland and riparian environments are complex combinations of plants, animals, soils, and other abiotic factors that provide critical ecological benefits, such as water quality improvement, flood control, carbon storage, climate regulation, aesthetic enjoyment, and biodiversity support (Millennium Ecosystem Assessment 2005; USEPA 2015). But their complexity also makes it challenging to characterize their ecological condition. Assessing that condition has become important, as broad scale stressors such as land use, invasive species, and climate change alter the processes and benefits that ecosystems provide. For that reason, ecologists have pursued a variety of methods to track and respond to declines in ecosystem condition, including integrated ecological condition or ecological integrity assessment. Ecological integrity can be defined as "the structure, composition and function of an ecosystem operating within the bounds of natural or historic disturbance regimes" (adapted from Lindenmayer and Franklin 2002; Young and Sanzone 2002; Parrish et al. 2003) or the ability of an ecosystem to support and maintain a full suite of organisms with species composition, diversity, and function comparable to similar systems in an undisturbed state (Karr and Dudley 1981). High ecological integrity is generally regarded as an ecosystem property where expected structural components are complete and all ecological processes are functioning optimally (Campbell 2000). Ecological integrity assessments, therefore, can be defined as a means of assessing the degree to which, under current conditions, a system matches reference characteristics of similar systems with high ecological integrity.

3.1.1 Ecological Integrity Assessment (EIA) Framework

This project used the Ecological Integrity Assessment (EIA) Framework to evaluate the condition and integrity of randomly selected wetlands and riparian areas in the Lower Arkansas Basin. The EIA Framework was developed by NatureServe[9] and ecologists from Natural Heritage Programs across the country (Faber-Langendoen et al. 2008; Faber-Langendoen et al. 2016). The EIA Framework evaluates wetland condition based on a multi-metric index. Biotic and abiotic metrics are selected to measure the integrity of key wetland attributes within four major categories:

1. Landscape context (buffer and supporting landscape)
2. Biotic condition (vegetation composition and structure)
3. Hydrologic condition (water quantity)
4. Physiochemical condition (soils and water chemistry)

Using field and GIS data, each metric is rated according to deviation from its natural range of variability, which is defined based on the current understanding of how wetlands function under

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[9] NatureServe is a non-profit conservation organization whose mission is to provide the scientific basis for effective conservation action. For more information about NatureServe, see their website: www.natureserve.org.

reference conditions absent human disturbance. The farther a metric deviates from its natural range of variability, the lower the rating it receives. Numeric and narrative criteria define rating thresholds for each metric. Once metrics are rated, scores are rolled up into the four major categories. Ratings for these four categories are then rolled up into an overall EIA score. For ease of communication, category scores and the overall EIA score are converted to ranks following the ranges shown in Table 3.1. The scores and ranks can be used to track change and progress toward meeting management goals and objectives.

With past funding from EPA Region 8 and CPW, CNHP has developed EIA protocols specific for application in Colorado. Further details on the EIA method can be found in the Ecological Integrity Assessment for Colorado Wetlands Field Manual, Version 2.1 (Lemly et al. 2016).

Table 3.1. Overall EIA scores and ranks and associated definitions.

Rank	*Condition Category*	*Interpretation*
A	**Excellent / Reference Condition** **(No or Minimal Human Impact)**	Wetland functions within the bounds of natural disturbance regimes. The surrounding landscape contains natural habitats that are essentially unfragmented with little to no stressors; vegetation structure and composition are within the natural range of variation, nonnative species are essentially absent, and a comprehensive set of key species are present; soil properties and hydrological functions are intact. ***Management should focus on preservation and protection.***
B	**Good / Slight Deviation from Reference**	Wetland predominantly functions within the bounds of natural disturbance regimes. The surrounding landscape contains largely natural habitats that are minimally fragmented with few stressors; vegetation structure and composition deviate slightly from the natural range of variation, nonnative species and noxious weeds are present in minor amounts, and most key species are present; soils properties and hydrology are only slightly altered. ***Management should focus on the prevention of further alteration.***
C	**Fair / Moderate Deviation from Reference**	Wetland has a number of unfavorable characteristics. The surrounding landscape is moderately fragmented with several stressors; the vegetation structure and composition is somewhat outside the natural range of variation, nonnative species and noxious weeds may have a sizeable presence or moderately negative impacts, and many key species are absent; soil properties and hydrology are altered. ***Management would be needed to maintain or restore certain ecological attributes.***
D	**Poor / Significant Deviation from Reference**	Wetland has severely altered characteristics. The surrounding landscape contains little natural habitat and is very fragmented; the vegetation structure and composition are well beyond their natural range of variation, nonnative species and noxious weeds exert a strong negative impact, and most key species are absent; soil properties and hydrology are severely altered. ***Management should focus on restoration and protection, with the understanding that restoration efforts may be challenging and that ecological value may be limited.***

3.1.2 Floristic Quality Assessment

At the same time that the Colorado EIA protocols were being developed, CNHP also developed a Floristic Quality Assessment (FQA) tool for use in Colorado (Rocchio 2007). The FQA approach to assessing ecological communities is based on the concept of species conservatism. The core of the FQA method is the use of “coefficients of conservatism” (C-values), which are assigned to all native species in a flora following the methods described by Swink and Wilhelm (1979, 1994) and Taft et al. (1997). C-values range from 0 to 10 and represent an estimated probability that a plant is likely to occur in a landscape relatively unaltered from pre-European settlement conditions (Table 3.2). High C-values are assigned to species which are obligate to high-quality natural areas and cannot tolerate habitat degradation, while low C-values are assigned to species with a wide tolerance to human disturbance. Generally, C-values of 0 are reserved for nonnative species.

The proportion of conservative plants in a community provides a powerful and relatively easy assessment of the integrity of both biotic and abiotic processes and is indicative of the ecological integrity of a site (Wilhelm and Ladd 1988). The most basic FQA index is a simple average of C-values for a given site, generally called the Mean C. However, more complex indices can be calculated. For instance, Mean C can be calculated with all species present or with only the native species. A cover- or frequency-weighted Mean C can also be calculated by weighting the C-value of each species proportional to its cover or frequency, giving more weight to the most abundant species. Additional indices take species richness into account by multiplying Mean C by the square root of species richness. For this project, FQA indices informed the native plant species composition metric within the EIA scorecard and were also calculated as a stand-alone measure of biotic condition.

Table 3.2. C-value ranges and associated interpretation.

C-Values	*Interpretation*
0	Nonnative species. Very prevalent in new ground or non-natural areas.
1-3	Commonly found in non-natural areas.
4-6	Equally found in natural and non-natural areas.
7-9	Obligate to natural areas but can sustain some habitat degradation.
10	Obligate to high quality natural areas (relatively unaltered from pre-European settlement).

3.2 Ecological Condition Assessment Methods

3.2.1 Site Selection

The goal of the field-based assessment was to estimate the range of ecological condition of both wetlands and riparian areas across the Lower Arkansas Basin. The following paragraphs detail elements of the survey design for selecting random sites to inform those estimates. Elements include the target population, sample frame, sample size, and selection criteria. The survey design follows principles outlined by the EPA's National Aquatic Resource Survey program (Stevens & Olsen 2004; Detenbeck et al. 2005).

Wetland and Riparian Definitions for Target Population

For this project, both wetlands and mesic riparian areas that lack full wetland characteristics were included in the target population. This was done for two reasons: 1) both provide essential habitat for wildlife in an otherwise arid region, and 2) in the mapping work conducted under Phase 1 of this project (Lemly et al. 2015), we found that the NWI mapping originally drawn in the 1970s, which was used to select random sites, often included mesic areas and there was no way to systematically remove these areas from the sample frame.

To define wetlands, we relied on the federal definition, as spelled out in the Army Corps of Engineers Wetland Delineation Manual (ACOE 1987):

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

In order to determine when an area met the wetland definition, standard wetland identification and delineation techniques were used, based on materials produced by the ACOE and NRCS, including the *Interim Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region* (ACOE 2008) and the *Indicators of Hydric Soils in the United States* (NRCS 2010). Though we used delineation techniques for wetland determinations, the area of assessment was often smaller than the entire wetland and our survey ***would not serve as an official delineation for regulatory purposes.*** The ACOE definition does differ from the one used by the USFWS's NWI Program (Cowardin et al. 1979), but was used in this study because no field guidance is provided by NWI on meeting the Cowardin definition.

Many riparian areas within the Lower Arkansas Basin do not meet the federal definition of wetlands, but still provide essential functions, such as wildlife habitat and flood protection. The project steering committee agreed that mesic riparian areas should be included in the target population to fully capture the wetland and riparian resources. To define riparian areas, we relied on the U.S. Fish and Wildlife Service's definition for mapping riparian areas (USFWS 2009):

> *"Riparian areas are plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermitted lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one of both of the following characteristics: 1) distinctively different vegetation species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland*."

Sampled sites could be entirely wetland, entirely mesic riparian, or a mix of both. We did not use the wetland / mesic riparian boundary to delineate our assessment areas, as both were considered part of the target population, but we did use the boundary between either wetlands or mesic riparian areas and fully upland areas to restrict assessment areas.

Classification of Sampled Sites

Sampled sites were classified in the field by a number of classification systems. Two of those systems are most important for this report. The first is the Ecological Systems classification (Comer et al. 2003), which uses biotic and abiotic factors to classify repeated patterns on the landscape. From that classification, we defined six main ***wetland and riparian types*** based on one or more Ecological Systems found in the basin (Table 3.3). A key to Ecological Systems in the Lower Arkansas Basin is included in Appendix A and a fuller description of these types can be found in the *Reference Network* report (Lemly et al. 2015). In addition to accepted Ecological System types, we defined one additional wetland type called "reservoir fringe" for highly altered wetland and riparian areas around reservoir fringes that did not meet definitions of the other classes.

The second important classification system is the hydrogeomorphic (HGM) classification, which groups wetlands according to hydrologic characteristics and geomorphic position (Brinson 1993). Hydrologic and geomorphic "controls" are responsible for maintaining many of the functional aspects of wetland ecosystems. These hydrogeomorphic controls include geomorphic setting, water source, and hydrodynamics. There are four main HGM classes in the Lower Arkansas Basin (Table 3.4). A key to HGM classes are included as Appendix B. Though the HGM classification is typically applied only to wetlands, we also assigned the riverine HGM class to all mesic riparian areas because they are also driven by riverine processes.

Table 3.3. Wetland and riparian types of the Lower Arkansas Basin, based on Ecological Systems.

Wetland / Riparian Type	***Ecological System(s)***
Emergent Marsh	Western North American Emergent Marsh
Wet meadow	Western Great Plains Wet Meadow-Marsh Complex (modified from Western Great Plains Open Freshwater Depression)
Playa	Western Great Plains Closed Depression Wetland Western Great Plains Saline Depression Wetland
Plains floodplain	Western Great Plains Floodplain
Plains riparian	Western Great Plains Riparian
Foothills riparian	Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland
Reservoir fringe	Highly disturbed vegetation around reservoir fringes

Table 3.4. HGM classes found in the Lower Arkansas Basin.

HGM Class	***Interpretation***
Riverine	Wetlands occurring in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank or backwater flow from the channel and connection to the alluvial aquifer. Water can also be from seeps and spring feeding the channel. Flow is horizontal and unidirectional.
Lacustrine Fringe	Wetlands adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. Flow is bidirectional, meaning water levels rise and fall with lake levels and with wave action.
Depressional	Wetlands formed in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water by ponding or saturation to the surface. Potential water sources are precipitation, overland flow from adjacent uplands, or groundwater. Flow into the wetland is from higher elevations toward the center of the depression. Outflow is generally restricted, except in times of high water.
Slope	Wetlands found in association with the discharge of groundwater to the land surface or saturated overland flow and no channel formation. Dominant source of water is groundwater or interflow discharging at the land surface. Flow is downslope and unidirectional.

Sample Frame

In a probabilistic sample design, sample sites are randomly selected from a digital representation of the target population, also known as a sample frame. For this project, the sample frame was based on the digital GIS-based version of National Wetland Inventory (NWI) polygons converted from paper maps in the *Lower Arkansas Basin Wetland Mapping and Reference Network* project (Lemly et al. 2015). From the NWI dataset, we will eliminate all polygons that represented deep water lakes and river/stream channels (NWI codes that begin with L or R, except R2US*, which represented sandbars). Because of extreme variation in the size of individual polygons, target sample points were selected from within any area of wetland mapping and not from polygon centroids. All estimates made during analysis are for wetland area, not percent or number of individual wetlands.

Sample Size and Selection Criteria

The target sample size was 60–75 wetland and riparian sites. A sample size of 50 is recommended by EPA statisticians for use in large-scale assessments of aquatic resources, as it provides ~10% precision with 90-95% confidence. Target sample points were selected through a spatially balanced Generalized Random Tessellation Stratified (GRTS) survey design using the 'spsurvey' package in R version 2.14.0 (R Foundation for Statistical Computing 2011). The survey design selected 75 base sample points and a 500% oversample (375 points) using a one-stage, stratified, unequal probability survey design.

Stratifying the target sample points enforced a wider geographic distribution, which in turn targeted a more diverse array of wetland types. For the strata, we divided the basin into three regions: 1) the irrigated valley surrounding the Arkansas floodplain, 2) the northern plains, and 3) the southern plains (Figure 3.1). We selected 25 sites in each of the three strata. Nearly half of the NWI mapped acres fall within the zone we defined as the irrigated valley, which was delineated based on predominant riparian vegetation and the major irrigation canals associated with the river. Without stratification, half the sample points would have fallen in this zone. By stratifying, we were able to visit more wetland sites outside of the floodplain.

An unequal design allowed us to concentrate sampling effort on wetter areas in the NWI mapping. As mentioned above, we found that the original NWI contained many dry areas that would not be considered true wetlands by the ACOE definition. We used NWI hydrologic regimes to form two multi-density categories for unequal probability selection, one category called "dry" and one called "wet". All polygons with a temporarily flooded or intermittently flooded hydrologic regime were classified in the dry category (except PEMJ, which represents playas, an important type on the plains). All remaining polygons were classified within the wet category. Out of the 25 sites in each stratum, we targeted 10 from the dry and 15 from the wet. This had a particularly strong effect in the floodplain strata, where ~90% of the polygons fall within the dry category because they are generally mesic riparian areas (Table 3.5).

Though this survey design allowed us to spread more time in wetter areas and in wetlands farther from the floodplain, the analysis weighted "dry" points in the irrigated valley more heavily than points in other areas, since they represent the largest portion of the mapped resource.

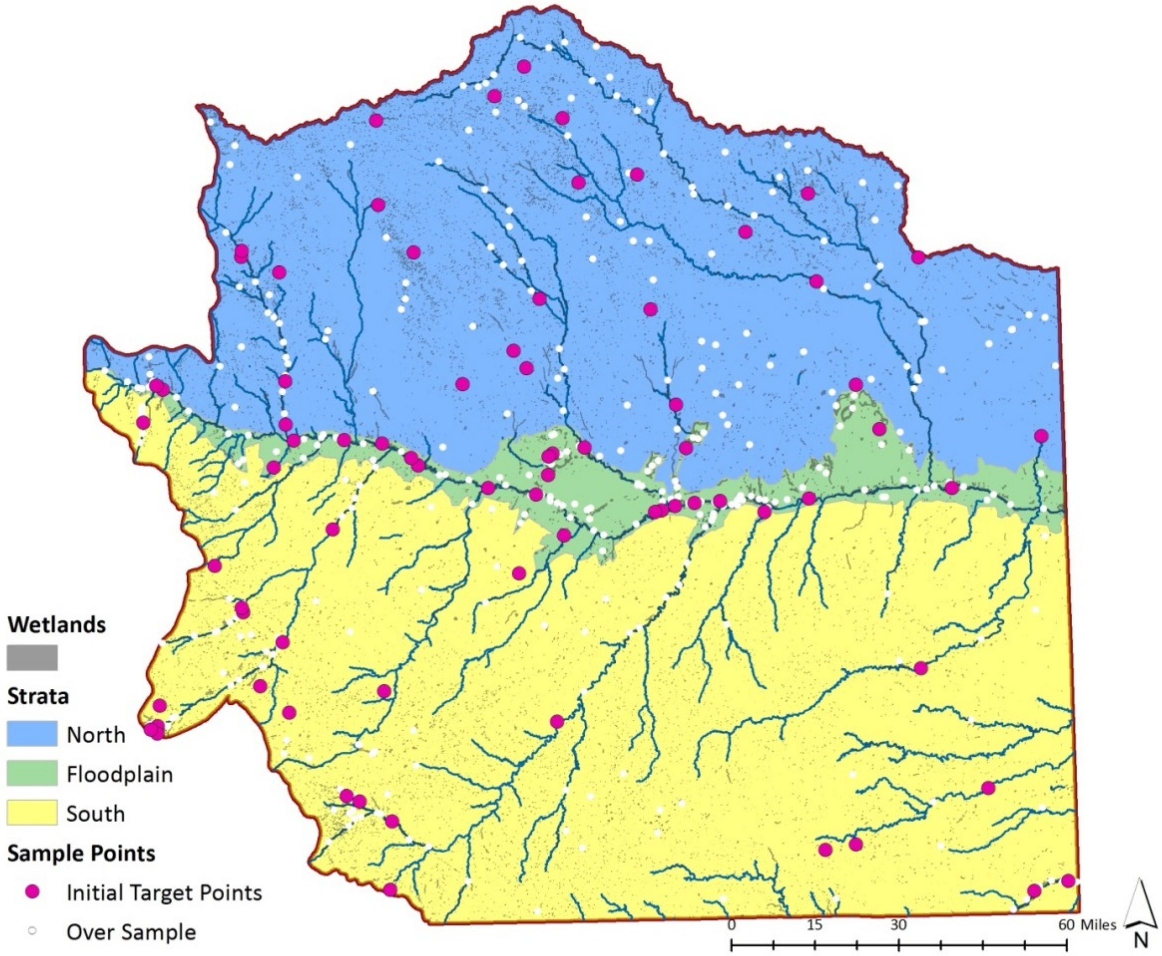

Figure 3.1. Initial survey design for the Lower Arkansas probabilistic wetland assessment. Map does not represent actual points surveyed.

Table 3.5. Distribution of NWI mapped acres vs. target sample points by strata and category.

Category	*Strata*			
	Irrigated Valley	*Northern Plains*	*Southern Plains*	*Total*
Share of NWI mapped acres				
Dry	42%	15%	16%	74%
Wet	5%	11%	10%	26%
Total	**47%**	**27%**	**26%**	**100%**
Share of target sample points				
Dry	13%	13%	13%	40%
Wet	20%	20%	20%	60%
Total	**33%**	**33%**	**33%**	**100%**

3.2.2 Field Methods

The field methods used for this project have been developed at CNHP with previous EPA Region 8 funding and have been further refined through basinwide wetland condition assessments in the Rio Grande Headwaters (Lemly et al. 2011), North Platte River Basins (Lemly & Gilligan 2012), and the Lower South Platte River Basin (Lemly et al. 2014). Condition assessment metrics followed the Ecological Integrity Assessment (EIA) framework for assessing wetland condition (Faber-Langendoen et al. 2016), modified for application in Colorado (Lemly et al. 2016). Data analysis also relied on the Floristic Quality Assessment (FQA) for Colorado wetlands (Rocchio 2007). An example field form is included as Appendix C. A detailed explanation of the field methods are included in the project's field manual (CNHP 2015). An overview of the most relevant methods are described here.

Site Evaluation

Field data collection relies on the identification and establishment of an assessment area (AA) within the target population. In order to establish an AA, field crews first verified that each sample point met the target population and size and water depth criteria. In order to meet the target population, the area must be a wetland or riparian area (definitions provided above) that was at least 0.1 ha in size with minimal water > 1 m deep. As described above, sample points were randomly selected throughout the study area using a spatially balanced survey design. Crew members navigated to randomly selected sample points using a GPS and verified that they could establish an AA in the target population within 60 m of the provided sample point before carrying out any data collection. If an AA could be established, the crew can begin sampling. If not, the crew rejected the point.

Defining the Assessment Area

At all wetland and riparian reference sites, a 0.5-ha (5,000-m^2) assessment area was defined and all data collection took place inside the AA. Where possible, the AA was delineated as a 40-m radius circle. However, the size and shape of the AA varied depending on site conditions. While 0.5 ha was the target size, AAs could be as small as 0.1 ha (1,000 m^2). For large playas, the AA could be up to 200 m diameter to capture the zonation of vegetation that occurs in playa. To best interpret the data, the AA was confined to one wetland or riparian type and one HGM class, but could include both wetland areas and mesic riparian areas, if both occurred within the same type.

In general, protocols for establishing the AA in this project closely match those developed for the EPA's National Wetland Condition Assessment (NWCA). Extensive details on AA establishment can be found in the *2011 National Wetland Condition Assessment Field Operations Manual* (USEPA 2011). The most significant difference between protocols from the NWCA and the Lower Arkansas project is that the target population for this project included mesic riparian areas. Secondarily, AAs for large playas could be much larger than standard NWCA protocols.

Once the AA was established, standard site variables were collected from each sample location. This included:

- UTM coordinates at four locations around the AA
- Elevation, slope, and aspect
- Place name, county, and land ownership
- Ecological System classification (Comer et al. 2003)

- Cowardin classification (Cowardin et al. 1979)
- HGM classification (Brinson 1993)
- Vegetation zones within the AA
- Wildlife habitats within the AA
- Description of onsite and adjacent ecological processes and land use
- Description of general site characteristics and a site drawing
- Several photographs of the AA boundary, vegetation plots, soil pits, and any notable features.

Vegetation Data Collection

All sites for this project were sampled with rapid Level 2[10] vegetation sampling protocols. Once the AA was established, all species present within the AA were identified and listed on the field form. The search for species was limited to no more than one hour to minimize the amount of time spent at the site. When all species were identified, or one hour of time was spent searching for species, the overall cover of each species within the AA was visually estimated using the following cover classes (Peet et al. 1998):

1 = trace (one or two individuals)
2 = 0–1%
3 = >1–2%
4 = >2–5%
5 = >5–10%
6 = >10–25%
7 = >25–50%
8 = >50–75%
9 = >75–95%
10 = >95%

Nomenclature for all plant species followed Weber and Wittmann (2012a, 2012b) and all species were recorded on the field form using the fully spelled out scientific name. Any unknown species were entered on the field form with a unique descriptive name and given a collection number for later identification.

Soil Profile Descriptions and Water Chemistry

At least two soil pits were dug within each AA to document variation in the soil. Soil pits were not dug in sites on the Comanche National Grassland, where any soil disturbance requires archeological review. If there was high variability within the vegetation and soil, up to four soil pits were dug to assess the dominant site soil type and capture the range of variation within the site. Among the pits dug, crews will note which should be considered the most representative of the larger AA. Soil pits were dug with a 40-cm sharp shooter shovel to one shovel length depth (35 to 40 cm), when

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[10] USEPA´s National Wetlands Monitoring Workgroup has endorsed the concept of a Level 1, 2, 3 approach to monitoring. Level 1 (landscape assessment) relies on coarse, landscape scale inventory information, typically gathered through remote sensing and preferably stored in, or convertible to, a geographic information system (GIS) format. Level 2 (rapid assessment) is at the specific wetland site scale, using relatively simple, rapid protocols. Level 2 assessment protocols are to be validated by and calibrated to Level 3 assessments. Level 3 (intensive site assessment) uses intensive research-derived, multi-metric indices of biological integrity.

possible. A bucket auger was used to examine the soil deeper in the profile, if needed, to find hydric soil indicators. Because it is difficult to dig soil pits in areas with deep standing water, crews concentrated on areas near the water's edge if standing water is a significant part of the AA.

Following guidance in the *ACOE Regional Supplement* and the *NRCS Field Indicators of Hydric Soils in the United States* (NRCS 2010), crews identified and described each distinct layer in the soil pit. Crews measured and recorded the depth of each distinct layer. For each layer, the following information was recorded: 1) color (based on a Munsell Soil Color Chart) of the matrix and any redoximorphic concentrations (mottles and oxidized root channels) and depletions; 2) the soil texture; and 3) any specifics about the concentration of roots, the presence of gravel or cobble, or any usual features to the soil. Based on the characteristics, crew identified which, if any, hydric soil indicators occurred at the pit.

Water table measurements were recorded for each soil pit. Prior to taking measurements, the crew allowed the pit to sit at least 15 minutes and up to one hour to allow the water table to equilibrate. Once the pit equilibrated as much as possible, the crew measured the distance to saturated soil and to free water. Basic water chemistry parameters were measured at up to four locations in the AA, where water was accessible. At each location, the crew measured pH, conductivity, and temperature using a using a Hanna Instruments hand-held meter (Model # HI98129).

Ecological Integrity Assessment Metrics and Stressors

For every sampled wetland, an EIA field form was filled out according to HGM Class and Ecological System. EIA metrics used in the Lower Arkansas Basin are shown in Table 3.6. Metric narrative ratings and scoring formulas are included in the field manual (CNHP 2015) or the *Ecological Integrity Assessment for Colorado Wetlands: Field Manual, Version 2.1* (Lemly et al. 2016).

In addition to the condition metrics, a stressor checklist was filled out at each site to document the most common stressors in the basin and to examine relationships between stressors and condition. Stressors were divided into four primary categories: 1) landscape stressors that occurred within 500 m surrounding the assessment area (AA); 2) vegetation stressors that occurred within the AA; 3) hydrologic stressors that affect the AA; and 4) soil / substrate stressors that occurred within the AA. Hydrologic stressors, such as agricultural and urban / storm water runoff, can also be interpreted as water quality stressors. For each stressor, the percent of the AA or landscape affected by the stressor was noted on a scale of 1 to 4 as the scope. The severity of the stressor was also noted on a scale of 1 to 4. The scope and severity of the stressor was then combined into an impact rating of 1 to 10, based on the matrix shown on the stressor checklist data form (Appendix C). All stressor impacts were then combined into an overall Human Stressor Index for the site.

3.2.3 Data Analysis

Field-based classifications of sampled sites, EIA condition scores, and Human Stressor Index scores were used to produce estimates of both wetland type and condition for all wetland and riparian area in the basin. This was done following data analysis scripts included in the 'spsurvey' package in R version 2.14.0 (R Foundation for Statistical Computing 2011). Data are displayed as percent of the mapped wetland and riparian resource for each variable.

Table 3.6. EIA metrics used in the Lower Arkansas Basin.

Rank Factor	*Major Ecological Factor*	*Metrics*
Landscape Context	Landscape	L1. Contiguous Natural Land Cover L2. Land Use Index
	Buffer	B1. Perimeter with Natural Buffer B2. Width of Natural Buffer B3. Condition of Natural Buffer
Condition	Vegetation	V1. Native Plant Species Cover V2. Invasive Nonnative Plant Species Cover V3. Native Plant Species Composition V4. Vegetation Structure V5. Regeneration of Native Woody Species **[opt.]**[1] V6. Coarse and Fine Woody Debris **[opt.]**[1]
	Hydrology	H1. Water Source H2. Hydroperiod H3. Hydrologic Connectivity
	Physiochemistry	S1. Soil Condition S2. Surface Water Turbidity / Pollutants **[opt.]**[2] S3. Algal Growth **[opt.]**[2]

[1] Only applied to sites where woody species are naturally common.

[2] Only applied when surface water is present.

3.3 Ecological Condition Assessment Results

3.3.1 Characteristics of Sampled Sites

From June and August 2015, 62 randomly selected sites were sampled to characterize the vegetation and assess the condition of wetlands and riparian areas in the Lower Arkansas Basin (Figure 3.2). Of those sites, 22 were located in the irrigated valley stratum, 21 in the northern plains, and 19 in the southern plains (Table 3.7). Roughly two-thirds of sites (n=39) were located on private land. Another quarter of sites (n=15) were located on land owned or managed by the State of Colorado, either through Colorado Parks and Wildlife or the Colorado State Land Board. This included sites located around John Martin Reservoir, which is jointly administered by CPW and the Army Corps of Engineers as John Martin State Wildlife Area. The remaining sites were located on either federal lands (Comanche National Grassland or Bureau of Land Management), local municipal lands, or lands owned by land trusts. The wet spring of 2015 lead to unusually high water in the mainstem of the Arkansas River and in the basin's reservoirs, including John Martin, which prevented access to several target sample points. However, the wet spring also meant that many of the playas sampled in early summer contained standing water.

Each sampled site was classified by the Ecological System classification into seven main wetland / riparian types (Table 3.8). Sites were also classified into four HGM classes based on dominant water source and hydrodymanics (Table 3.9), and sites were classified by a very general estimation of origin, whether 1) natural and relatively undisturbed, 2) natural but augmented or altered, or 3) formed non-natural (Table 3.10).

Three of the wetland / riparian types surveyed in the basin (plains riparian, foothills riparian, and plains floodplains) fell within the riverine HGM class, with hydrology driven by channelized flow from rivers or streams. Plains riparian areas (n=19; Figure 3.3) were the most commonly sampled type and were found in every stratum, though more commonly in the northern and southern plains. Plains riparian areas occurred along larger, perennially flowing rivers such as the Huerfano, St. Charles, and Purgatoire Rivers, and smaller, intermittent and ephemeral creeks such as Big Sandy, Horse, and Adobe Creeks and their tributaries. Many plains riparian systems contained pockets of true wetland vegetation around small pools, even at low flow, and appeared connected to groundwater springs. Other plains riparian systems were more mesic and lacked a dominance of wetland plants; these sites were considered mesic riparian areas. Nearly all plains riparian areas were considered natural in origin, but most were altered. Only five were considered unaltered and one plains riparian site was considered non-natural because it formed along an irrigation ditch. One foothills riparian area was sampled on the far western edge of the study area in the southern plain stratum. Foothills riparian areas are located only in the foothills zone and are more influenced by seasonal snowmelt patterns in the mountains than are their plains riparian counterpart. They are far less common in the Lower Arkansas Basin and therefore, for the remainder of this report, foothills riparian areas are combined with plains riparian areas in tables and figures.

Plains floodplains (n=12; Figure 3.4) were the third most commonly sampled type. This type was predominantly found in the irrigated valley stratum along the mainstem of the Arkansas River, but was also found in the northern plains along the highly active floodplain of Fountain Creek. Plains floodplain systems are wider, more complex mosaics of plant communities than plains riparian areas and are linked by the underlying alluvial soils and highly dynamic flooding regimes of large rivers. Like plains riparian areas, plains floodplains systems were all within the riverine HGM class. All floodplain sites were considered natural but altered because current water management has disrupted natural flood pulses. While many sites near the river's edge had wetland hydrology and vegetation, older floodplain terraces often lacked true wetland vegetation.

Playas (n=17; Figure 3.5) were the second most commonly sampled type and were found in all three strata. All playas were depressional wetlands and all were natural features, though many had been altered. Playas have very ephemeral hydrology driven by local precipitation events, and can be dry for years at time. With the wet spring of 2015, 11 of the 17 playas sampled contained water or showed evidence of recent wetting, and contained hydrophytic plant species. Because most playas contain wetland species when wet, we considered all playas to be wetlands instead of mesic riparian. However, the wetland vegetation within playas is generally restricted to a central core area that is wet more frequently and for the longest duration.

The remaining types were found less frequently and were more restricted by strata. Marshes (n=5; Figure 3.6) were found only in the irrigated valley stratum, located in either depressions in the Arkansas floodplain or along lake fringes. Many marshes were considered non-natural features formed due to elevated groundwater levels and irrigation return flows. Review of historical accounts would be needed to confirm the extent of marshes in the floodplain prior to irrigation. Wet meadows (n=5; Figure 3.7) were found primarily in the northern plains and were natural sloping features fed by springs. In the *Reference Network* report (Lemly et al. 2015), we used the marsh type for all sites with robust wetland plant species (cattail, bulrushes, etc.), whether they occurred on the floodplain or on the plains. In analyzing data from both phases of the project and reviewing the Ecological System classification, we decided to split the plains marshes from the floodplain marshes. Marsh vegetation on the plains often occurs in a mosaic of marsh and wet meadow vegetation. We decided that marsh vegetation on the plains fit better with the wet meadows than with the floodplains marshes. This is a difference from the Ecological System descriptions presented in the *Reference Network* report.

Lastly, three sites were classified as disturbed reservoir fringes (Figure 3.8). These three sites were located on the margins of reservoirs formed within historic playas. The reservoir fringe type was developed for this study because the sites did not fit well in the other traditional classes. The vegetation in these sites was similar to plains riparian areas, with a mix of invasive woody riparian species and mesic grasses, but they were located within the bounds of historic playas. We classified them as natural but altered, though there is uncertainty in this classification. We also tentatively classified them as true wetlands, because they had a mix of wetland species and mesic species.

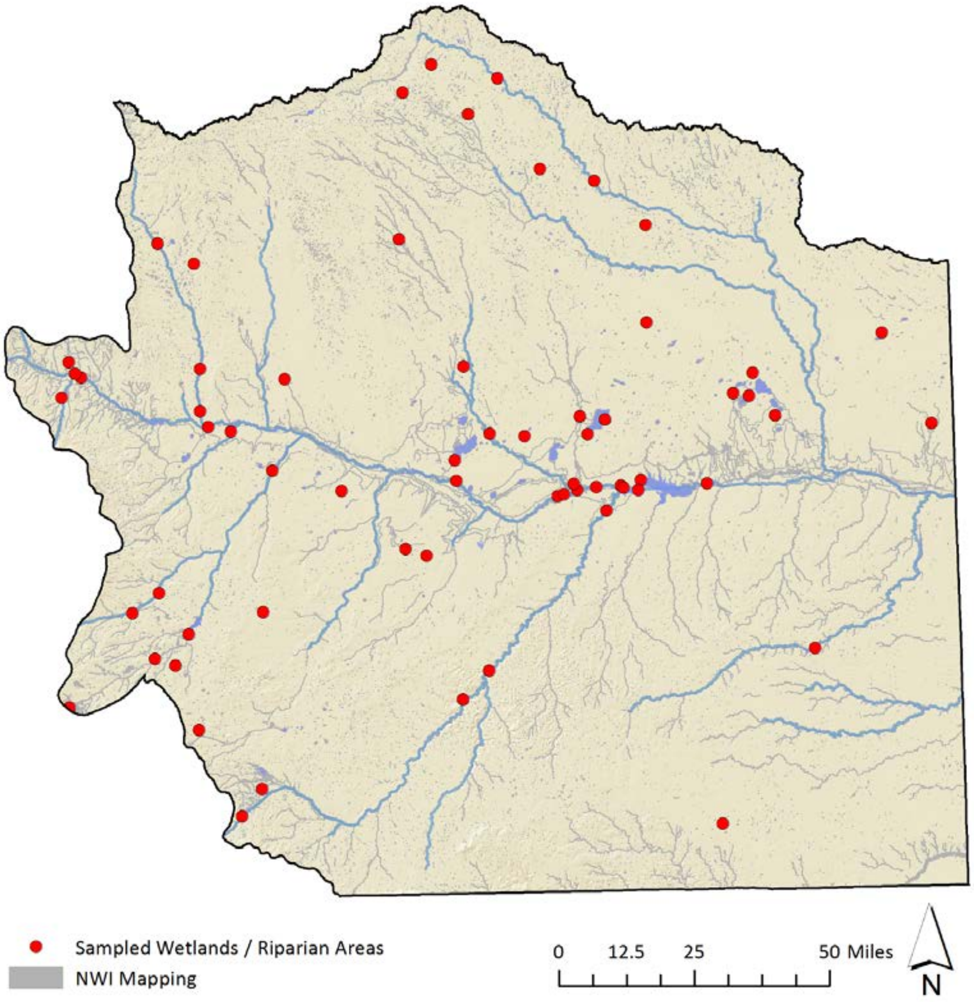

Figure 3.2. Randomly sampled wetlands and riparian areas in the Lower Arkansas Basin.

Table 3.7. Sampled wetlands and riparian areas in the Lower Arkansas Basin, by strata and landowner.

Landowner / Manager	*Strata*				
	Irrigated Valley	*Northern Plains*	*Southern Plains*	*Total*	*% of Total*
Private	13	14	12	**39**	**63%**
Colo Parks and Wildlife[1]	6	1	1	**8**	**13%**
State Land Board	2	4	1	**7**	**11%**
USFS National Grasslands	--	--	3	**3**	**5%**
Bureau of Land Management	1	1	--	**2**	**3%**
Local gov't	--	1	1	**2**	**3%**
Land Trusts	--	--	1	**1**	**2%**
Total	**22**	**21**	**19**	**62**	**100%**
% of Total	**35%**	**34%**	**31%**	**100%**	

[1] For the purpose of this table, the CPW row also includes John Martin Reservoir, which is jointly administered by the Army Corps of Engineers and CPW as the John Martin State Wildlife Area. This row also include some portions of other State Wildlife Areas that are privately owned, but managed by CPW.

Table 3.8. Sampled wetlands and riparian areas in the Lower Arkansas Basin, by strata and wetland / riparian type.

Wetland /Riparian Type	*Strata*				
	Irrigated Valley	*Northern Plains*	*Southern Plains*	*Total*	*% of Total*
Plains riparian	2	6	11	**19**	**31%**
Foothills riparian	--	--	1	**1**	**2%**
Plains floodplain	9	3	--	**12**	**19%**
Playa	2	8	7	**17**	**27%**
Emergent marsh	5	--	--	**5**	**8%**
Wet meadow	1	4	--	**5**	**8%**
Disturbed vegetation	3	--	--	**3**	**5%**
Total	**22**	**21**	**19**	**62**	**100%**
% of Total	**35%**	**34%**	**31%**	**100%**	

Table 3.9. Sampled sites by type, HGM Class, and generalized source.

HGM Class / Origin	*Wetland / Riparian Type*							*Total*	*% of Total*
	Plains Riparian	*Foothills Riparian*	*Plains Floodplain*	*Playa*	*Emergent Marsh*	*Wet Meadow*	*Reservoir Fringe*		
Riverine	**19**	**1**	**12**					**32**	**52%**
1) Natural feature with minimal alteration	5	1						**6**	**10%**
2) Natural feature, but altered or augmented	13		12					**25**	**40%**
3) Non-natural feature	1							**1**	**2%**
Depressional				**17**	**4**			**21**	**34%**
1) Natural feature with minimal alteration				12				**12**	**19%**
2) Natural feature, but altered or augmented				5	1			**6**	**10%**
3) Non-natural feature					3			**3**	**5%**
Lacustrine Fringe					**1**		**3**	**4**	**6%**
2) Natural feature, but altered or augmented							3	**3**	**5%**
3) Non-natural feature					1			**1**	**1%**
Slope						**5**		**5**	**8%**
2) Natural feature, but altered or augmented						4		**4**	**6%**
3) Non-natural feature						1		**1**	**2%**
Total	**19**	**1**	**12**	**17**	**5**	**5**	**3**	**62**	**100%**
% of Total	**31%**	**2%**	**19%**	**27%**	**8%**	**8%**	**5%**	**100%**	

Table 3.10. Generalized origin of sampled reference sites.

Origin	*Count*	*% of Total*
1) Natural feature with minimal alteration	18	29%
2) Natural feature, but altered or augmented	38	61%
3) Non-natural feature	6	10%
Total	**48**	**100%**

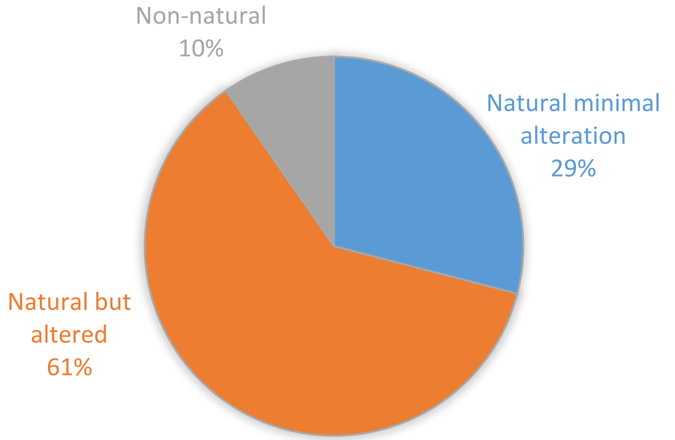

Figure 3.3. Photographs of plains riparian systems in the Lower Arkansas Basin.

Figure 3.4. Photographs of plains floodplain systems in the Lower Arkansas Basin. Photo at left shows wooded component of the system on floodplain terraces, while photo at right shows open sand bar along the channel.

Figure 3.5. Photographs of playas in the Lower Arkansas Basin.

Figure 3.6. Photographs of emergent marshes in the Lower Arkansas Basin.

Figure 3.7. Photographs of wet meadows in the Lower Arkansas Basin.

Figure 3.8. Photographs of disturbed vegetation on the fringes of reservoirs made from historic playas in the Arkansas Basin.

3.3.2 Plant Species Observed

The size of the basin and diverse array of wetland and riparian types contributed to moderately high species diversity. A total of 344 unique species were identified in the 62 sampled sites, 331 to species level. The average number of species per site was 25. The most diverse site sampled was an altered wet meadow on the northern plains that supported 61 different plant species, in part due to the invasion of upland species into the meadow. Other diverse sites were either plains floodplains, plains riparian areas, or the one foothills riparian site. The least diverse sites were either reservoir fringes, playas, or marshes. Each of these types had sites with < 10 species.

Common Plants Observed

Of the twenty-five most common plant species observed in random wetland and riparian sites (Table 3.11), fifteen were native and ten were nonnative, including three species listed as noxious weeds: tamarisk (*Tamarix ramosissima,* syn = *T. chinensis*), Russian olive (*Elaeagnus angustifolia*), and Canada thistle (*Breea arvensis,* syn = *Cirsium arvense*). The twenty-five most common species were generally considered tolerant of a wide range of conditions, as indicated by their coefficients on conservatism (C-values), which ranged from 0 to 5. The most common species observed included only three true wetland obligates (OBL): common threesquare (*Schoenoplectus pungens*), pale spikerush (*Eleocharis macrostachya*), and narrowleaf cattail (*Typha angustifolia*). Many more of the common species, including the four very most common species—common sunflower (*Helianthus annuus*), kochia (*Bassia sieversiana,* syn = *Bassia* or *Kochia scoparia*), Canadian horseweed (*Conyza canadensis*), and prickly Russian thistle (*Salsola australis*)—are often found in upland areas (FACU or UPL) and many are tolerant of disturbance (C-value < 3).

Many of the most common species observed occurred in low cover. To focus on the species that best represent the sites surveyed, a unitless 'importance value' was calculated by adding relative frequency and relative abundance of each species.[11] The resulting twenty-five most important species (Table 3.12) best characterize the Lower Arkansas Basin's wetland and riparian areas. Together, these species comprised approximately 69% of the total plant cover recorded in all site visits. Along with the ubiquitous weedy species, the most important species include several woody species: plains cottonwood (*Populus deltoides*), the dominant native canopy tree of floodplains and riparian areas; both tamarisk and Russian olive, aggressive nonnative woody species that have colonized floodplains and riparian areas in the basin; and sandbar willow (*Salix exigua*), commonly found within riparian areas and on sandbars on the floodplain. The list also includes plains grasses, such as western wheatgrass (*Pascopyrum smithii*), switchgrass (*Panicum virgatum*), saltgrass (*Distichlis stricta*), foxtail barley (*Critesion jubatum,* syn = *Hordeum jubatum*), and buffalograss (*Buchloë dactyloides,* syn = *Bouteloua dactyloides*), all of which can dominate dry playas and the understory of drier riparian areas. The three dominant marsh plants are on the list, narrowleaf cattail, common threesquare, and pale spikerush, as well as several species characteristic of playas: wedgeleaf (*Phyla cuneifolia*), bigbract verbena (*Verbena bracteata*), and povertyweed (*Iva axillaris*).

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[11] Relative frequency for each species = number of times the species was observed / total number of species observations across all sites. Relative abundance for each species = sum of cover for that species wherever it occurred / sum of cover of all species across all sites.

Table 3.11. Twenty-five most common plant species observed in Lower Arkansas random wetlands and riparian sites.

Scientific Name	*Common Name*	*# of Obs*	*Average Cover*	*Wetland Status*[1]	*C-Value*	*Native Status*
Helianthus annuus	common sunflower	40	3.8%	FACU	1	Native
Bassia sieversiana	Kochia	37	7.2%	FACU	0	Non-native
Conyza canadensis	Canadian horseweed	35	3.5%	FACU	1	Native
Salsola australis	prickly Russian thistle	31	5.2%	FACU	0	Non-native
Tamarix ramosissima	tamarisk / saltcedar	31	17.3%	FACW	0	Non-native, List B Nox Weed
Populus deltoides ssp. *monilifera*	plains cottonwood	28	22.1%	FAC	3	Native
Critesion jubatum	foxtail barley	28	2.3%	FACW	2	Native
Pascopyrum smithii	western wheatgrass	27	13.0%	FACU	5	Native
Panicum virgatum	switchgrass	25	13.6%	FAC	5	Native
Salix exigua	narrowleaf willow	22	14.3%	FACW	3	Native
Grindelia squarrosa	curlycup gumweed	21	2.2%	UPL	1	Native
Lactuca serriola	prickly lettuce	20	0.8%	FAC	0	Non-native
Schoenoplectus pungens	common threesquare	20	5.5%	OBL	4	Native
Rumex crispus	curly dock	19	1.8%	FAC	0	Non-native
Breea arvensis	Canada thistle	19	8.1%	FACU	0	Non-native, List B Nox Weed
Glycyrrhiza lepidota	American licorice	19	2.2%	FACU	3	Native
Distichlis stricta	saltgrass	18	17.6%	FACW	4	Native
Erigeron bellidiastrum	western daisy fleabane	18	0.9%	NI	4	Native
Elaeagnus angustifolia	Russian olive	18	10.0%	FACU	0	Non-native, List B Nox Weed
Ambrosia psilostachya var. *coronopifolia*	Cuman ragweed	17	3.5%	FACU	3	Native
Typha angustifolia	narrowleaf cattail	17	20.7%	OBL	2	Native / Non-native
Echinochloa crus-galli	barnyardgrass	17	1.2%	FAC	0	Non-native
Eleocharis macrostachya	pale spikerush	17	5.8%	OBL	3	Native
Chenopodium album	lambsquarters	17	1.0%	FACU	0	Non-native
Chondrosum gracile	blue grama	16	3.1%	NI	4	Native

[1] Wetland Indicator Status based on the 2013 National Wetland Plant List for the Great Plains region. OBL = obligate wetland species, found in wetlands 99% of the time; FACW = facultative wetland species, found in wetlands 67–99% of the time; FAC = facultative species, found in wetlands 34–66% of the time; FACU = facultative upland species, found in uplands 67–99% of the time; UPL = obligate upland species, found in uplands 99% of the time.

Table 3.12. Twenty-five most important plant species observed in Lower Arkansas random wetland and riparian sites.

Scientific Name	*Common Name*	*Import. Value*[1]	*# of Obs*	*Average Cover*	*Wetland Status*	*C-Value*	*Native Status*
Populus deltoides ssp. *monilifera*	plains cottonwood	10.37	28	22.1%	FAC	3	Native
Tamarix ramosissima	tamarisk / saltcedar	9.39	31	17.3%	FACW	0	Non-native, List B Nox Weed
Pascopyrum smithii	western wheatgrass	6.56	27	13.0%	FACU	5	Native
Panicum virgatum	switchgrass	6.29	25	13.6%	FAC	5	Native
Bassia sieversiana	kochia	6.02	37	7.2%	FACU	0	Non-native
Typha angustifolia	narrowleaf cattail	5.95	17	20.7%	OBL	2	Native / Non-native
Salix exigua	narrowleaf willow	5.73	22	14.3%	FACW	3	Native
Distichlis stricta	saltgrass	5.52	18	17.6%	FACW	4	Native
Helianthus annuus	common sunflower	4.58	40	3.8%	FACU	1	Native
Salsola australis	prickly Russian thistle	4.18	31	5.2%	FACU	0	Non-native
Conyza canadensis	Canadian horseweed	3.90	35	3.5%	FACU	1	Native
Elaeagnus angustifolia	Russian olive	3.62	18	10.0%	FACU	0	Non-native, List B Nox Weed
Breea arvensis	Canada thistle	3.31	19	8.1%	FACU	0	Non-native, List B Nox Weed
Schoenoplectus pungens	common threesquare	2.78	20	5.5%	OBL	4	Native
Anisantha tectorum	cheatgrass	2.74	8	20.1%	NI	0	Non-native, List C Nox Weed
Iva axillaris	povertyweed	2.67	11	13.0%	FAC	2	Native
Critesion jubatum	foxtail barley	2.65	28	2.3%	FACW	2	Native
Eleocharis macrostachya	pale spikerush	2.43	17	5.8%	OBL	3	Native
Phragmites australis	common reed	2.40	15	7.0%	FACW	3	Native / Non-native, Watch List
Phyla cuneifolia	wedgeleaf	2.04	13	6.8%	FAC	4	Native
Grindelia squarrosa	curlycup gumweed	1.93	21	2.2%	UPL	1	Native
Ambrosia psilostachya var. *coronopifolia*	Cuman ragweed	1.88	17	3.5%	FACU	3	Native
Buchloë dactyloides	buffalograss	1.80	9	9.9%	FACU	4	Native
Bromus japonicus	field brome	1.77	13	5.3%	FACU	0	Non-native
Glycyrrhiza lepidota	American licorice	1.76	19	2.2%	FACU	3	Native

[1] Importance value is a unitless number derived as the sum of relative frequency and relative cover across all species and all sites.

Noxious Weeds and Other Highly Invasive Species

Twenty-one species listed as noxious weeds by the Colorado Department of Agriculture[12] were observed in random wetland and riparian sites in the Lower Arkansas Basin (Table 3.13). In addition to listed noxious weeds, kochia and Russian thistle (*Salsola australis* or *S. collina*) were also frequently found. These two species are considered highly invasive, but are not included on the official noxious weed lists because they are so pervasive on the landscape that their eradication is not mandated by state government (Patty York, Colorado Dept. of Agriculture, Noxious Weed Specialist, *personal communication*).

Invasive species are a serious concern in the basin. At least one noxious or highly invasive species was found in nearly every random wetland and riparian site sampled. Only four out of 62 sites lacked these species entirely. The average combined cover of noxious and highly invasive species was 28% and could be as high 60–100% total cover. Sites with the highest invasive cover were typically dominated by noxious woody species tamarisk and Russian olive.

Tamarisk and the two highly invasive species (kochia and Russian thistle) were the most commonly observed invasive species. Each of these three species was observed in over half of site visits (31–37 observations) and each with maximum cover 30–60%. All three species were also included in the twenty most important species within the random sites (Table 3.12). Four additional noxious weeds were occasionally found with high cover. Canada thistle, a List B species, was found in 19 sites with cover up to 62.5%. Russian olive, a List B species, was found in 18 sites with up to 37.5% cover. Common reed (*Phragmites australis*), a Watch List species, was found in 15 site visits with up to ~62.5% cover. And cheatgrass (*Anisantha tectorum* syn = *Bromus tectorum*) was found in eight sites with cover up to 62.5%. All other noxious weeds were found in fewer sites with < 5% cover.

Table 3.13. Noxious weeds and other highly invasive species observed in Lower Arkansas random wetland and riparian sites. *Continued on next page.*

Scientific Name	*Common Name*	*Noxious Weed List*	*# of Obs*	*Average Cover*	*Max Cover*
Bassia sieversiana	kochia	Not Listed	37	7.2%	62.5%
Salsola australis OR *collina*	Russian thistle	Not Listed	34	5.2%	37.5%
Tamarix ramosissima	tamarisk / saltcedar	List B	31	17.3%	62.5%
Breea arvensis	Canada thistle	List B	19	8.1%	62.5%
Elaeagnus angustifolia	Russian olive	List B	18	10.0%	37.5%
Phragmites australis[1]	common reed	Watch List	15	7.0%	62.5%
Convolvulus arvensis	field bindweed	List C	11	0.8%	3.5%
Elytrigia repens	quackgrass	List C	10	3.2%	17.5%
Anisantha tectorum	cheatgrass	List C	8	20.1%	62.5%
Verbascum thapsus	common mullein	List C	7	0.3%	0.5%
Dipsacus fullonum	Fuller's teasel	List B	4	0.8%	1.5%

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[12] Official Noxious Weed Lists can be found online at https://www.colorado.gov/pacific/agconservation/noxiousweeds.

Cirsium vulgare	bull thistle	List B	3	0.4%	0.5%
Cardaria latifolia	broadleaved pepperweed	List B	2	2.5%	3.5%
Acosta maculosa	spotted knapweed	List B	2	0.8%	1.5%
Conium maculatum	poison hemlock	List C	2	0.5%	0.5%
Carduus acanthoides	spiny plumeless thistle	List B	1	1.5%	1.5%
Matricaria perforata	scentless false mayweed	List B	1	1.5%	1.5%
Acosta diffusa	diffuse knapweed	List B	1	0.5%	0.5%
Cardaria draba	whitetop	List B	1	0.5%	0.5%
Arctium minus	lesser burdock	List C	1	0.5%	0.5%
Acroptilon repens	hardheads	List B	1	0.5%	0.5%
Saponaria officinalis	bouncingbet	List B	1	0.5%	0.5%
Carduus nutans ssp. *macrolepis*	nodding plumeless thistle	List B	1	0.5%	0.5%

[1] Native populations of *Phragmites* are likely also present in the Lower Arkansas Basin and are not easily distinguished from the non-native genotype.

Significant Plant Species

Only two significant plant species[13] were observed in random wetland and riparian sites in the Lower Arkansas Basin (Table 3.14). The most significant plant species observed was streaked bur ragweed (*Ambrosia linearis*), a member of the sunflower family endemic to playas on Colorado's eastern plains. This species is considered vulnerable at both the global and state level (G3 S3), with fewer than 100 known populations. Streaked bur ragweed was found in two playas with low cover. The other significant plant species encountered was variegated scouringrush (*Hippochaete variegata*), found in one plains riparian area. This species is considered globally secure (G5), but or imperiled within Colorado (S1).

Table 3.14. Significant plant species observed in Lower Arkansas random wetland and riparian sites.

Scientific Name	***Common Name***	***G Rank***	***S Rank***	***# of Obs***	***Average Cover***	***Max Cover***
Ambrosia linearis	streaked bur ragweed	G3	S3	2	0.8%	1.5%
Hippochaete variegata	variegated scouringrush	G5	S1	1	0.5%	0.5%

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[13] Significance was determined based on the Colorado Natural Heritage ranking system. For more information, please see: http://www.cnhp.colostate.edu/about/heritage.asp.

3.3.3 Floristic Quality Assessment Indices

As a separate, stand-alone measure of biotic condition, two Mean C scores were calculated for all sites, one with all species included (Mean C) and one with only native species (Mean C Native). Calculating Mean C with all species incorporates the influence that non-native species, which have a C-value of 0, have on overall biotic integrity. Calculating Mean C with only native species focuses on the biotic integrity of the remaining native species. Within the vegetation condition metrics for the EIA, metric V3 focuses on the composition of native species. Calculating Mean C of only native species can help assign a rank for that metric. Because the potential range of Mean C scores varies greatly by wetland and riparian type (Rocchio 2007; Lemly & Rocchio 2009), Mean C data from the reference sites sampled in Phase 1 this project were used as expected ranges to aid in data interpretation.

Mean C scores calculated with all species ranged from 1.3 to 3.9, with nearly all sites falling between 1.5–3.0 (Figure 3.9). Mean C Native scores were higher, ranging from 2.3 to 4.2, with most sites falling between 3.0–4.0. Only two sites had a Mean C above 3.5 and just three sites had a Mean C Native over 4.0. While wetlands in the mountains can have Mean C scores between 6.0–7.0 (Lemly et al. 2011, Lemly & Gilligan 2012), Mean C score from reference sites in this basin were lower. For reference sites, Mean C scores were mostly between 2.0–4.0 and Mean C Native score were between 3.0–5.0 (Lemly et al. 2015). Wetland and riparian sites on the plains are naturally adapted to disturbance, such as flooding and drying cycles and grazing by large native ungulates. Even in good condition, they are dominated by species that can tolerate these conditions, therefor the expected Mean C scores are lower on the plains that in the mountains. However, the fact that random sites had lower Mean C values than the comparable reference sites indicates that human disturbance is impacting these randomly selected sites.

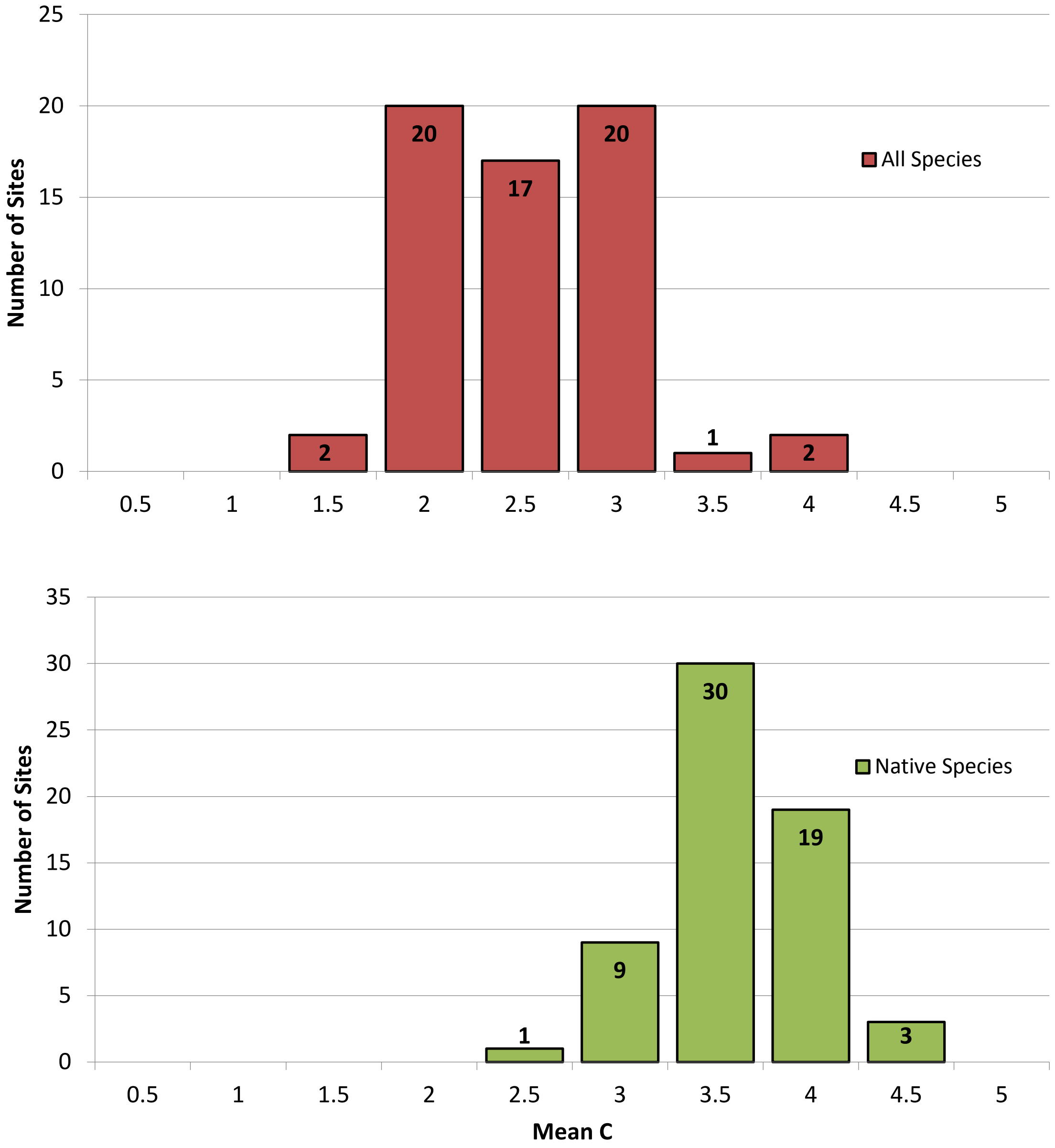


Figure 3.9. Frequency of Mean C scores for all sites sampled, showing Mean C calculated with all species in red above and Mean C calculated with only native species below in green. Number under each bar represents the upper bound of the bin.

3.3.3 Extent Estimates of Wetlands and Riparian Areas

Using the in-field classification of sampled wetlands and survey design parameters, including sites that were rejected as non-target, the total acres of wetland and riparian areas within the Lower Arkansas Basin were estimated, along with the proportion of acres within each of the classified wetland and riparian types (Figure 3.9). Estimates were made separately for the entire basin and each of the three strata. In addition to wetland types, estimates were also made for the percent of the resource classified as true wetland vs. mesic riparian area, each of the HGM classes, and the generalized classes of origin (Figure 3.10). The survey design estimates are similar to the distribution of sampled types described in Section 3.3.1, but differ in some important ways. Proportional to the NWI mapping, fewer sites were sampled in the irrigated valley stratum than in either of the plains strata. For this reason, the estimated distribution of plains floodplain and reservoir fringe areas, both found in the irrigated valley, were higher than their proportions of sampled sites, and the estimated distribution of playas, primarily found on the plains, was lower. See Appendix D for a fuller discussion of survey design parameters and implications for final estimates.

Based on the sampled sites and those rejected as non-target, wetlands and riparian areas across the basin were estimated to cover 118,642 (±16,517) acres (Figure 3.9), which represents less than one percent of the entire land area in the basin. This estimate is very similar to the acreage estimate derived in Phase 1 of this project. In Phase 1, all original NWI maps were digitize and their accuracy was assessed. Though NWI maps contain 142,705 acres mapped as wetlands, the Phase 1 accuracy assessment found that only 77,953 acres were likely true wetlands and another 34,745 acres were mesic riparian areas, totaling 112,698 acres of wetlands and riparian areas (Lemly et al. 2015). That number is well within the 95% confidence interval of the estimate derived in this field-based study.

Estimates by strata showed the central irrigated valley contains half of the wetland and riparian acreage (58,582 acres), and these acres represent over 6% of the land area in that stratum. Slightly more than a quarter of wetland and riparian acres were estimated to occur in the northern plains, and slightly less than a quarter in the southern plains. Wetlands and riparian areas represent a tiny fraction of the land areas in both the northern and southern plains (<1% in each stratum).

Estimates of wetland types were calculated as a percentage or proportion of all wetland and riparian acres in either the entire basin or in each stratum. The results show which wetland and riparian types are most common in each area of the basin. Across the whole basin, plains riparian areas comprised one-third (33%) of the wetland and riparian acres, plains floodplains 20% and playas another 19%. Fourteen percent of the acreage was estimated to be the disturbed reservoir fringes around large, historic playas, such as the Great Plains Reservoirs. Marshes were estimated to comprise 10% of the area, and wet meadows the last 4%.

Estimates by strata reveal important patterns in the distribution of wetland and riparian types. All six of the main types occurred within the central irrigated valley. In this stratum, the plains floodplain system along the mainstem of the Arkansas River made up the largest share of acres (29%). Reservoir fringes represented the second largest share at 26%. Marsh complexes along the floodplain were the third largest share at 19%. Plains riparian areas in this stratum, which occur along tributary streams as they approach and join the floodplain, represented 17% of the wetland

and riparian acres in the stratum. Playas comprised only 9%, and wet meadows less than one percent. The two plains strata, by contrast, have less diversity in wetland and riparian types. In the northern plains, 43% of the wetland and riparian acres were plains riparian areas and 28% were playas. The floodplain of Fountain Creek comprised 17% of the acreage. This stratum also contained natural seep-fed wet meadow wetlands, which comprised 12% of the estimated area. The southern plains were even less diverse. All wetland and riparian acres in the southern plains were estimated to be either plains riparian areas (64%) or playas (36%).

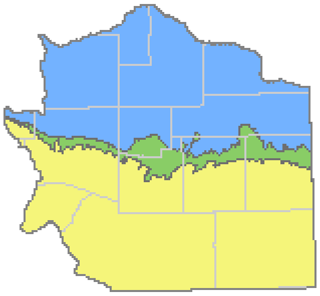
Across the entire basin, roughly two-thirds of the wetland and riparian acres were estimated to be true wetland, as opposed to riparian areas with more mesic vegetation (Figure 3.10). This number is also consistent with results from the Phase 1 analysis of NWI mapping. The estimate for percent true wetland was largest for the irrigated valley, which contained the large marsh complexes and the disturbed reservoir fringes, which we tentatively called wetland. Several of the plains floodplains floodplain sites surveyed in the irrigated valley were also considered true wetland because they included sand bar areas with coyote willow and wetland herbaceous species. Other plains floodplain areas, those located farther from the main channel, were too dry and were classified as mesic riparian. The estimate for percent true wetland area was smallest for the northern plains, where many plains riparian systems were too dry to contain a prevalence of wetland plant species.

Across the basin, more than half of the acreage was estimated to fall within the riverine HGM class, which included all the plains riparian and plains floodplain systems (Figure 3.10). A quarter of the acreage was estimated to be depressional, which included playas and many marshes in large depressions along the floodplain. Eighteen percent was estimated was lacustrine fringe, which included the vegetation along the Great Plains Reservoirs and marshes on more active reservoirs. Only four percent of acres were estimate as slope wetlands. These were the groundwater-fed wet meadows. The irrigated valley was the only stratum to contain lacustrine fringe wetlands, as this stratum was drawn specifically to encompass the major reservoirs close to the floodplain. No major reservoirs are located on the plains far from the floodplain. Both plains strata were dominated by riverine system and depressions, though the northern plains also contained 12% slope wetlands.

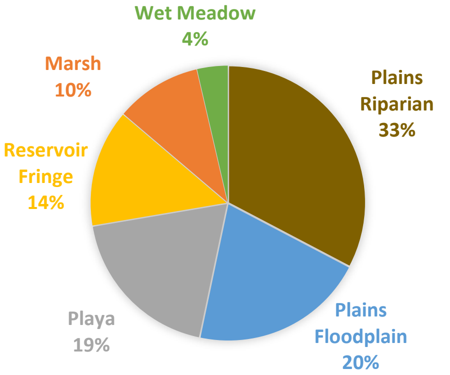
Lastly, across the basin, 17% of wetland and riparian acres were estimated to be natural with minimum alteration and 58% were natural but altered, meaning their hydrology has been effected by human modifications. Another 25% of wetlands are estimated to be non-natural, meaning they likely would not exist on the landscape if it weren’t for human water management. These acres were mainly concentrated in the irrigated valley, where stream withdrawls and irrigation return flows have dramatically changed the distribution of water on the landscape. This number should be seen as a very rough estimation, as the origin classification is based on a field interpretation. To accurately determine which wetlands are non-natural, historic photos and surveying notes from the mid-1880s would need to be reviewed.

Wetland and Riparian Extent Estimates by Strata and Ecological System

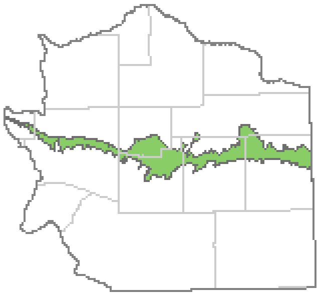
Lower Arkansas Basin



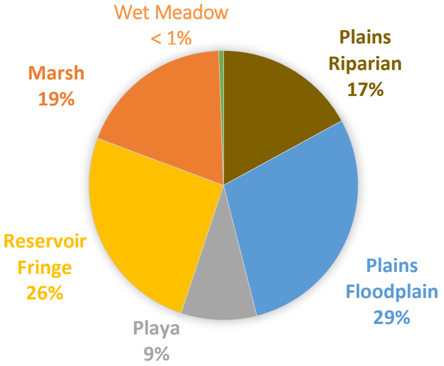
Wetland / Riparian Acres	118,642
95% CI (Acres)	(+/-) 16,517
Wetlands and riparian areas as a % of the region	0.85%
% of the basin's total wetland and riparian extent	100%



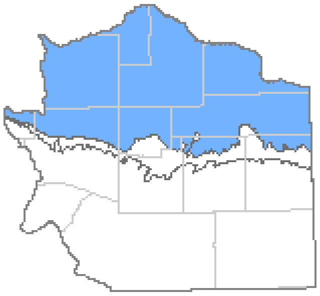
Irrigated Valley



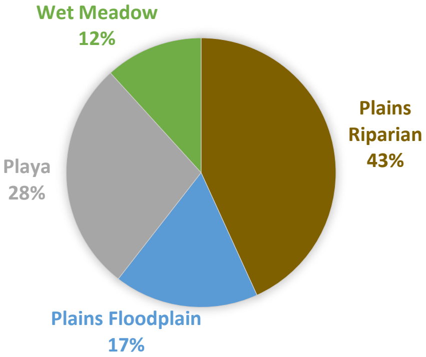
Wetland / Riparian Acres	58,582
95% CI (Acres)	(+/-) 15,548
Wetlands and riparian areas as a % of the region	6.16%
% of the basin's total wetland and riparian extent	49.4%



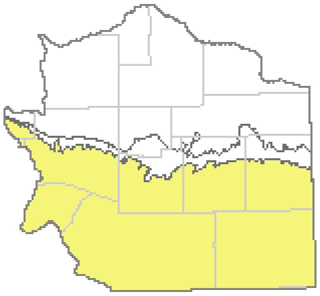
Northern Plains



Wetland / Riparian Acres	32,408
95% CI (Acres)	(+/-) 4,926
Wetlands and riparian areas as a % of the region	0.56%
% of the basin's total wetland and riparian extent	27.3%



Southern Plains



Wetland / Riparian Acres	27,651
95% CI (Acres)	(+/-) 2,993
Wetlands and riparian areas as a % of the region	0.38%
% of the basin's total wetland and riparian extent	23.3%

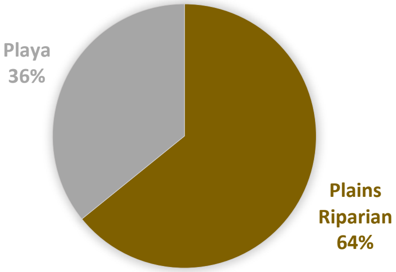


Figure 3.10 Estimates of wetland and riparian areas in acres by the full study area and study design strata. 95% CI = 95% confidence interval around the acreage estimates. Pie charts show the breakdown by Ecological System.

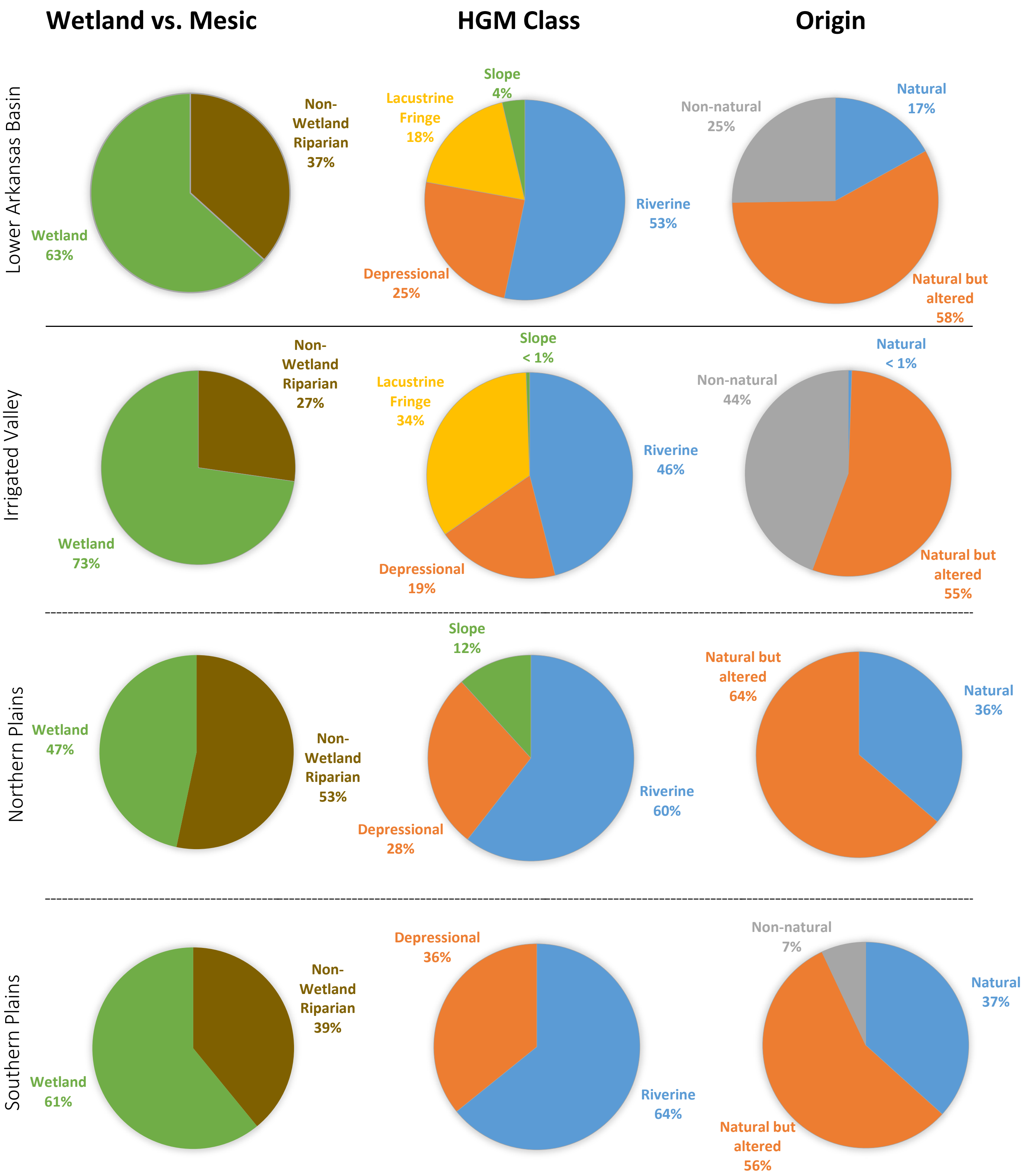


Figure 3.11. Estimates of wetland and riparian areas by three classification systems across the full study area and study design strata. Pie charts show wetland vs. mesic riparian areas, HGM Class, and origin.

3.3.4 Extent Estimate of Ecological Condition

The EIA scorecard method was used to assign overall ecological condition ranks to each wetland and riparian site surveyed in the Lower Arkansas Basin. Survey design parameters were then used to extrapolate the EIA ranks to all wetland and riparian area in the basin and for each stratum. The vast majority of acres fell within the good (B-rank) or fair (C-rank) condition classes, so these classes were further broken out show finer precision. Scores were split into very good (overall EIA score 3.0–3.5), good (2.5–3.0), fair (2.0–2.5) and fairly poor (1.5–2.0) condition classes. The excellent (3.5–4.0) and poor (1.0–1.5) condition classes remained the same.

Across the whole basin, roughly 30% of acres were estimated to fall within the good, fair, and fairly poor condition classes each (Figure 3.11). Only 5% of acres were estimated to be in very good condition and 5% of the acres in poor condition. If the classes were compressed to excellent (A), good (B), fair (C), and poor (D), 35% would be considered good, 60% would be considered fair, and 5% poor. Estimates for the irrigated valley contained no acres in the very good condition class and larger proportions in the fairly poor and poor classes. Both plains strata, in contrast, had no poor acres, fewer fairly poor acres, and more acres within the good and very good classes, including 21% of acres in the southern plains in very good condition. Ninety-five percent confidence intervals on these estimates are fairly wide, however. A larger sample size would be needed for more precise estimates. Given the confidence intervals, it is possible that there are wetlands in very good condition in the irrigated valley and poor condition wetlands on the plains, even though the estimates show none. But they likely represent a small percentage of the acreage.

Estimates were also calculated for condition class by wetland and riparian type. Ninety-five percent confidence intervals on these estimates were even greater, since the number of sites sampled in each wetland type is relatively small. However, the estimates can indicate broad patterns. Playas were the only type with acres estimated in the very good condition class (Figure 3.12). Roughly one quarter of all playa acres were estimated to be in very good condition. Estimates for plains riparian areas and wet meadows both contained many acres in good condition. Even the estimate for plains floodplains contained 22% in good condition, driven by one good condition site with high weight in the estimates. This site had few invasive species and less landscape alteration. Emergent marshes, however, were nearly all estimated to be in fair condition. Disturbed vegetation on reservoir fringes were estimated as fairly poor or poor, primarily due to modification of their hydrology.

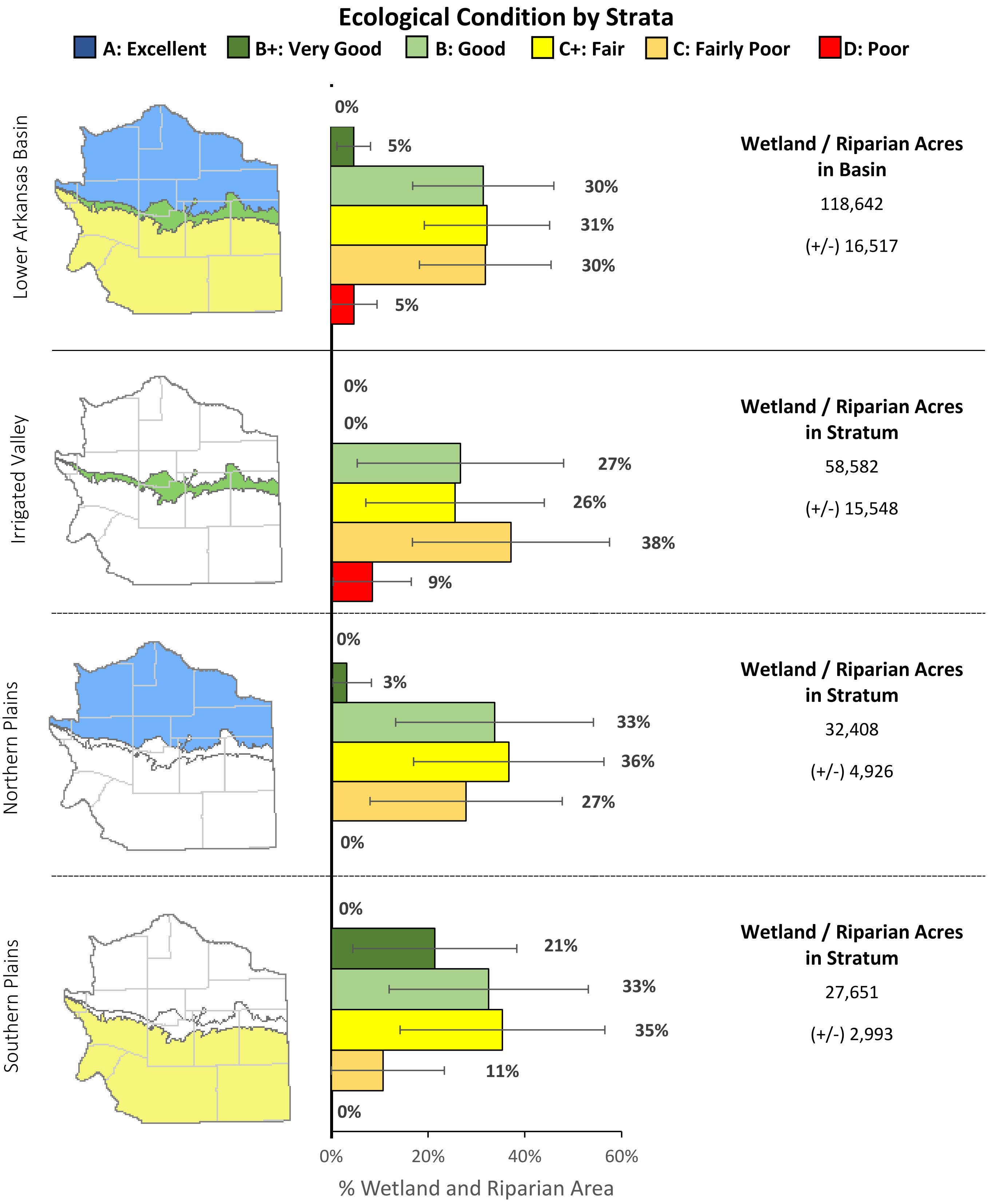


Figure 3.12. Estimates of ecological condition by the full study area and study design strata, shown as a percent of the total acreage. Error bars represent the 95% confidence interval around the proportion estimates.

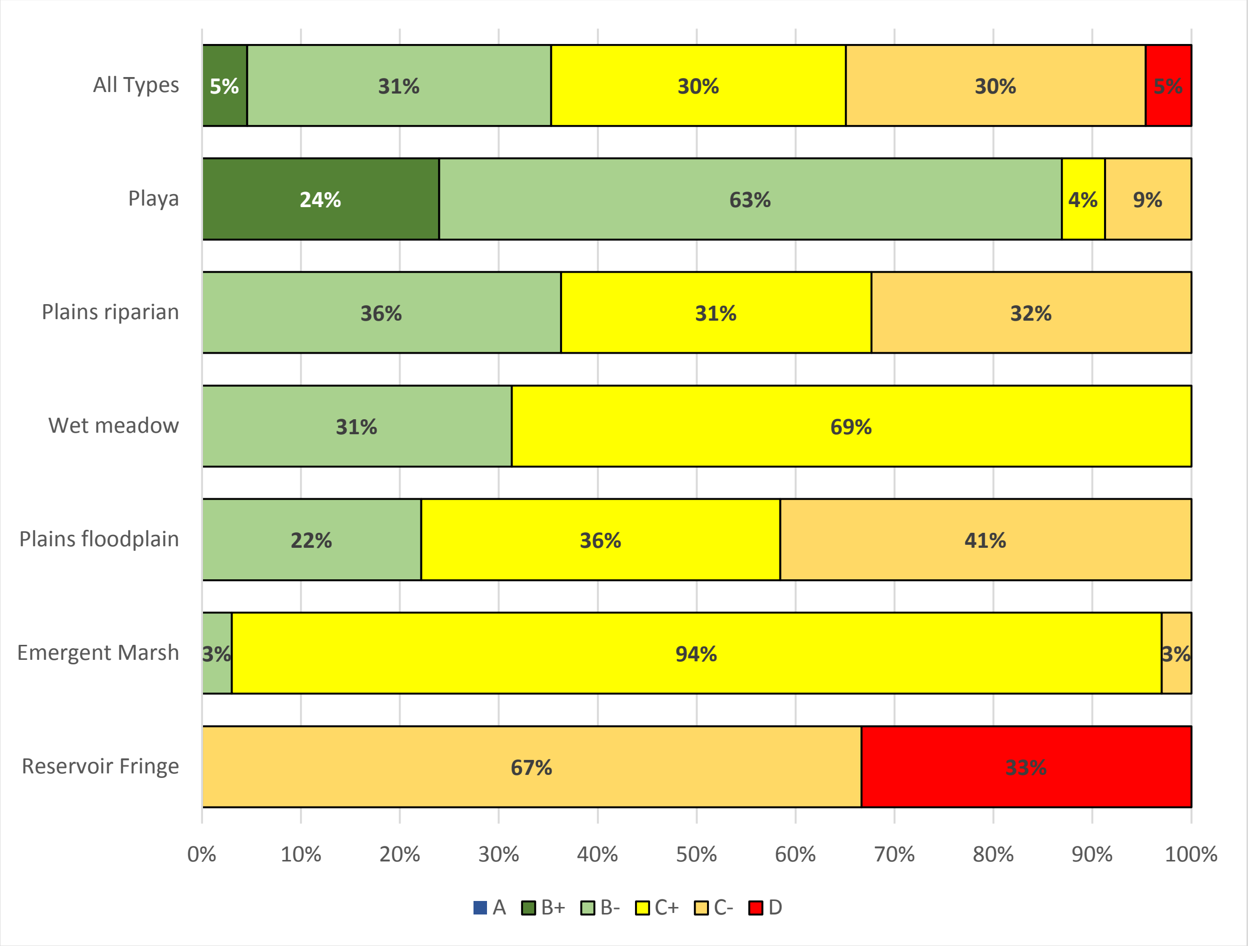


Figure 3.13. Estimates of ecological condition by wetland and riparian type, shown as a percent of the total acreage.

3.3.5 Extent Estimate of Human Disturbance

Results from the stressor checklists and Human Stressor Index were used to interpret the condition assessment data. The stressor checklist evaluated stressors that affect four attributes of the wetland or riparian area: landscape stress, vegetation stress, hydrologic stress, and soil / substrate stress. Stressors within each category can be rolled up to a stress level of absent, low, medium, high, or very high stress. Survey design parameters were used to estimate the overall stress within wetlands and riparian areas of the Lower Arkansas Basin and stress within each of the four categories. Across the basin, overall stress was estimated to be medium for half of all wetland and riparian acres. Another third of acres was estimated to be high, while smaller shares were estimated to be both low and very high. The category with the highest stress across the whole basin, and for each of the individual strata, was hydrologic stress. Half of all acres in the whole basin were estimated to face very high hydrologic stress, and this number was much higher for the irrigated valley stratum. Vegetation stress was also estimated at very high in large share of the whole basin and the irrigated valley.

Analysis of individual stressors by wetland / riparian type is best viewed as counts of stressors observed, rather than estimates based on survey design parameter because many were observed in small numbers. The most common landscape stressor observed surrounding random sites was the presence of roads (Table 3.15). Grazing or browse by livestock or native ungulates occurred within the surrounding landscape of nearly all surveyed sites (85%), but with a low average impact rating of 1.2. Three-quarters of sites were located within 500 m of roads. The average impact rating of those roads, however, was low (1.1), indicating that most were dirt road or small paved roads that occupied a small portion of the landscape. In addition to roads and grazing, five other landscape stressors were common and occurred surrounding at least one-quarter of all sites: hay fields or fallow field dominated with non-native species; recreation, either low or high impact; residential, commercial or industrial development; row-crop agriculture; and major utility corridors or water conveyance canals. Of those common stressors, development, row crop agriculture, and hay field had higher average impact scores (medium low) than recreation and utility corridors (low). All other landscape stressors occurred in less than 20% of sites. The landscape stressor with the greatest impact was high cover of invasive species, which was called out specifically occurred in the landscape of seven sites, with an average impact rating of 5.7 (medium).

The most common vegetation stressor observed within the sites was invasive species. This stressor was noted when invasive species covered more than 1% of the AA, which was the case in 79% of the sites. The impact rating of invasive species ranged from 1 (low) to 10 (very high) within individual sites, for an average rating of 5.5 (medium). The second most common vegetation stressor was grazing or browse, which was noted in 76% of sites, but still with a low impact score on average (1.8). Whenever grazing or browse was observed in the landscape surrounding an AA, it was also observed within the AA. Grazing was generally considered light in most sites, and only considered to have a moderate impact in ten sites. Recreation was the only other stressor that occurring in more than a quarter of sites, with a medium low average impact (2.0). The vegetation stressors with the greatest impact were fallow field and herbicide spraying. One playa site was a former agricultural field that had been removed from production. The impact of historic farming was rated as 7.0 (high) because of its effect on the vegetation. Known application of herbicide was noted at three sites, with an average impact of 4.0 (medium). The impact of herbicide spraying is difficult to assess in the short run, as it is used as a management tool to combat another stressor, invasive species. Spraying, however, can have unintentional and sometimes severe consequences on the native understory composition. Spraying is included in our stressor list because it can have highly variable results depending on how the vegetation is managed post-spraying.

The most common hydrologic stressor was canals, diversion, and ditches, which affected over half of all sites and nearly all of the plains floodplain sites. This common hydrologic stressor had an average impact score of 4.0 (medium), but ranged from 1 (low) to 10 (very high) within individual sites. Agriculture runoff was the next most common hydrologic stressors, affecting roughly one-third (37%) of sites. The average impact of agricultural runoff was 3.5 (medium low), with ratings of 4 (medium) or 7 (high) in most sites. Impoundments, groundwater extraction, and flow obstructions were all also fairly common. Of these three impoundments and flow obstructions had higher average impact ratings or 2.6 and 3.1, respectively, while the average impact rating of groundwater extraction was 1.3 (low). This rating is based on the density of wells observed, but does not address potential long-term impacts that wells can cause if they gradually lower the groundwater table over time. Those impacts are beyond the scope of a one-year field project. Several other hydrologic stressors occurred with high average impact rating, including large dams / reservoirs, urban / stormwater runoff, and engineered channels.

The most common soil / substrate stressor occurring within sites was compaction, most often from trampling by livestock, but also from recreation. This stressor occurred in over half of all sites (61%), with an average impact rating of 2.6 (medium low). Erosion, sedimentation, and trash or refuse dumping, excavation, excess salinity and historic plowing each occurred in a quarter or less of all sites, but each with a low average impact rating.

When all impacts were aggregated into an overall Human Stressor Index (HSI) for each site, it was clear that the disturbed reservoir fringes and plains floodplain sites faced the most cumulative stress (Table 3.16). Plains floodplain sites had, on average, 10.8 stressors per site and an average HSI of 8.56, which is considered high. The HSI of plains floodplain sites ranged from 6.20 to 10.40. Reservoir fringes had fewer stressors (average = 8.7), but their impact was considered nearly as high (average HSI = 8.53). For most other wetland and riparian types, the average HSI scores were lower, but each wetland type had at least one wetland with high to very high stress.

When HSI scores are plotted against overall EIA condition scores, there is a clear and strong relationship (Figure 3.14). The stressor checklist serves as a useful tool for identifying the specific stressors that are correlated with lower site condition. Understanding the potential causes of low condition can help land managers prioritize management actions.

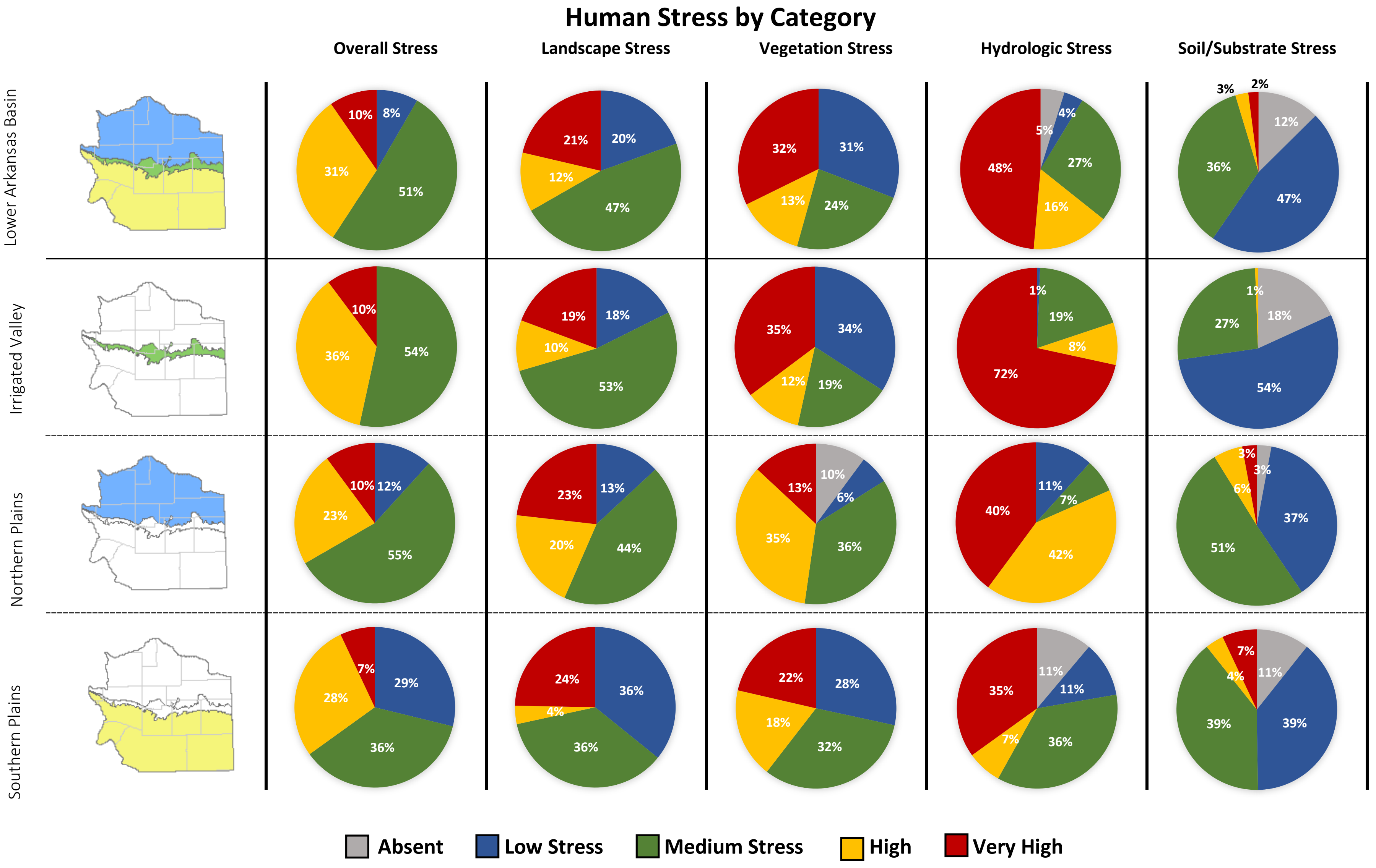


Figure 3.14. Estimates of ecological condition by the full study area and study design strata shown as a percent of the total acreage. Error bars represent the 95% confidence interval around the proportion estimates.

Table 3.15. Landscape, vegetation, hydrologic, and physiochemical stressors observed by wetland / riparian type. ***Continued on next page.***

Stressor by Category	*Marsh (n = 5)*	*Wet meadow (n = 5)*	*Playa (n = 17)*	*Plains floodplain (n = 12)*	*Plains / foothills riparian (n = 20)*	*Reservoir fringe (n = 3)*	*Total (n = 62)*	*% of Sites with Stressor*	*Average Impact Rating*[1]
Landscape stressors within 500 m surrounding the AA									
Grazing, browse	3	5	16	8	18	3	**53**	**85%**	**1.8**
Roads	3	5	11	11	14	3	**47**	**76%**	**1.5**
Hay field, fallow field	2	2	4	4	7		**19**	**31%**	**2.3**
Recreation	2	2		6	6	2	**18**	**29%**	**1.5**
Development		1		7	9		**17**	**27%**	**2.4**
Row-crop agriculture	2	1	4	3	2	1	**13**	**21%**	**2.8**
Utility corridor / major canal	3	2	1	5	6		**16**	**26%**	**1.4**
Invasive species				5	2		**7**	**11%**	**5.7**
Evidence of recent fire	1				3		**4**	**6%**	**1.0**
Gravel mining (current or historic)	1			3			**4**	**6%**	**3.8**
Oil and gas wells					1		**1**	**2%**	**4.0**
Total	**17**	**18**	**36**	**52**	**68**	**9**	**199**		
Average stressors / site	**3.4**	**3.6**	**2.1**	**4.3**	**3.4**	**3.0**	**3.2**		
Vegetation stressors within the AA									
Invasive species	4	4	8	11	19	3	**49**	**79%**	**5.5**
Grazing, browse	2	3	16	7	17	2	**47**	**76%**	**1.8**
Recreation	**1**	1		3	3	1	**9**	**15%**	**2.0**
Haying, mowing (current or historic)		2	1			1	**4**	**6%**	**1.8**
Evidence of recent fire	1				2		**3**	**5%**	**1.0**
Herbicide spraying	1				2		**3**	**5%**	**4.0**
Roads		1	1				**2**	**3%**	**1.0**
Hay field, fallow field			1				**1**	**2%**	**7.0**
Total	**9**	**11**	**27**	**21**	**43**	**7**	**118**		
Average stressors / site	**1.8**	**2.2**	**1.6**	**1.8**	**2.2**	**2.3**	**1.9**		

Stressor by Category	*Marsh (n = 5)*	*Wet meadow (n = 5)*	*Playa (n = 17)*	*Plains floodplain (n = 12)*	*Plains / foothills riparian (n = 20)*	*Reservoir fringe (n = 3)*	*Total (n = 62)*	*% of Sites with Stressor*	*Average Impact Rating*[1]
Hydrologic stressors that effect the AA (may occur within or beyond the AA)									
Canals, diversions, ditches	3	1	5	11	13	3	**36**	**58%**	**4.0**
Agricultural runoff, excess manure	4	1	4	7	7		**23**	**37%**	**3.5**
Impoundments	3	3	2	3	6		**17**	**27%**	**2.6**
Groundwater extraction		1	2	4	8		**15**	**24%**	**1.6**
Flow obstructions		2	6	1	5		**14**	**23%**	**3.1**
Excavation for water retention		1	6	2	2		**11**	**18%**	**1.8**
Large dams / reservoirs	2			3	2	3	**10**	**16%**	**5.2**
Urban / storm water runoff				3	3		**6**	**10%**	**4.5**
Flow control / engineered channel				3			**3**	**5%**	**5.0**
Misc. discharge				2			**2**	**3%**	**2.5**
Spring box		1					**1**	**2%**	**4.0**
Total	**12**	**10**	**25**	**39**	**46**	**6**	**138**		
Average stressors / site	**2.4**	**2.0**	**1.5**	**3.3**	**2.3**	**2.0**	**2.2**		
Soil / substrate stressors within the AA									
Compaction	1	3	14	3	14	3	**38**	**61%**	**2.6**
Excessive erosion		1		5	9		**15**	**24%**	**1.2**
Trash or refuse dumping				6	4	1	**11**	**18%**	**1.0**
Sedimentation	1		4	3	3		**11**	**18%**	**2.1**
Excavation			4	2	3		**9**	**15%**	**2.7**
Filling or dumping	2		4		1		**7**	**11%**	**1.9**
Excess salinity		1	2		2		**5**	**8%**	**2.2**
Plowing (current or historic)		2	2				**4**	**6%**	**2.5**
Total	**4**	**7**	**30**	**19**	**36**	**4**	**100**		
Average stressors / site	**0.8**	**1.4**	**1.8**	**1.6**	**1.8**	**1.3**	**1.6**		

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[1] Impact rating is a combination of the scope and severity of the stressor in a particular site. Impact scores range from 1–10.

Table 3.16. Average stressors per site and average Human Stressor Index (HSI) by wetland / riparian type.

Wetland / Riparian Type	***Average Stressors per Site***	***Average HSI***	***Range of HSI***
Playa	6.2	4.55	1.70 – 10.10
Wet meadow	9.2	6.06	3.90 – 8.40
Plains / foothills riparian	9.7	6.46	2.00 – 10.50
Emergent marsh	8.4	6.68	4.60 – 7.90
Reservoir fringe	8.7	8.53	6.10 – 10.00
Plains floodplain	10.8	8.56	5.30 – 12.40
All Sites	**9.0**	**6.42**	**1.70 – 12.40**

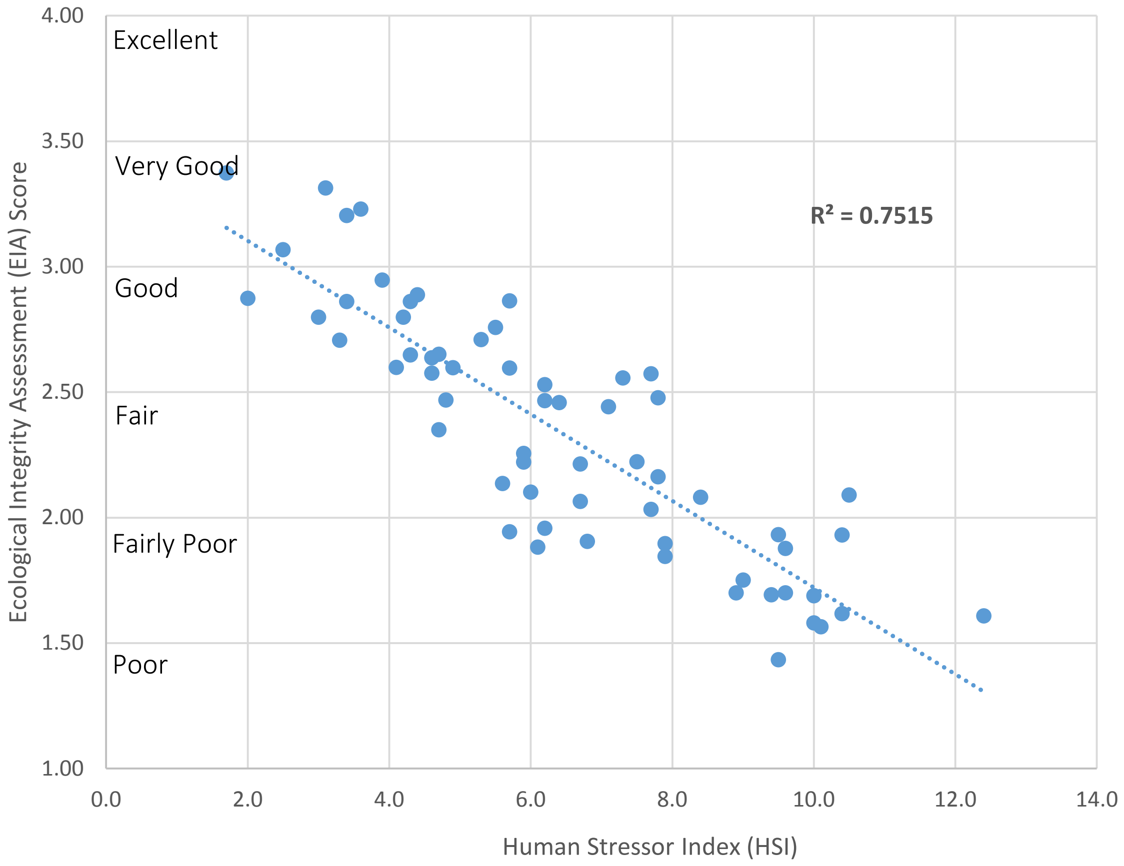

Figure 3.15. Overall Ecological Integrity Assessment (EIA) score vs. Human Stressor Index (HSI).

3.4 Discussion

The Lower Arkansas Basin is critical to the agricultural economy of Colorado. Wetlands in the basin, though rare, are also vital to many wildlife species. This report, along with finding from Phase 1 of the project, provides important baseline information on the extent and condition of wetlands and riparian areas in the basin, and should help land managers from many sectors consider wetlands and riparian areas in management decisions.

In the Lower Arkansas Basin, there is a clear connection between water and land management and the condition of wetlands and riparian areas. Ecological condition is closely tied to location within the basin and the associated land uses. On the plains, where population density is low and land uses more passive, many playas and plains riparian areas face relatively less disturbance and remain in good condition. In contrast, intensive land use and water management is concentrated in the central irrigated valley. Wetlands and riparian areas within this area face the greatest stress from human disturbances and had the lowest condition scores. The wetland and riparian types most affected were plains floodplains, emergent marshes, and reservoir fringes, all of which are concentrated in the central valley. The two largest sources of stress within the irrigated valley were water management, either surface water withdrawals or inputs from irrigation runoff, and invasive species, which were present in moderate to high cover in nearly every site within the irrigated valley. These two sources of stress are highly related. Studies have shown that alteration to natural hydrologic processes can result in the invasion of non-native species, particularly the now ubiquitous woody shrub tamarisk (Lovell et al. 2009; Merritt & Poff 2010).

Ecological Condition by Wetland / Riparian Type

Across the Lower Arkansas Basin, playas were found to be in the best condition. They were the only type with sites in very good condition (ranked B+), and very good playas were more often found in the southern plains than other locations in the basin. Playas tended to occur in relatively intact landscapes, though nearly all were located close to minor roads. Evidence of grazing was observed within and surrounding all playas, but with low intensity. Only six playas were located near agricultural fields, and even these sites were not fully surrounded by fields. The sampled playas had higher quality vegetation than other types, with fewer invasive species, and had fewer hydrologic alterations. Six of the sampled playas did have evidence of pitting, meaning ponds had been dug within the playas to hold water longer for livestock. Pitting can disrupt the natural hydrology of playas by concentrating water in a smaller area, rather than allowing it to spread across a greater area (Smith 2003). However, pits were relatively shallow and did not severely degrade the playas. The greatest area of concern for playas was compaction by livestock, which can break up the hardpan surface of playas and allow for faster infiltration.

Earlier studies of playas in Colorado have found that our playas are more ephemeral, but less disturbed than playas in the Texas panhandle and Oklahoma, where much playa research is focused (Cariveau and Pavlacky 2008). Results from this study similarly show that Colorado playas are more likely to be embedded within native grassland and have few severe hydrologic alterations. Playas are also important for native biodiversity on the plains. When wet, they are used by numerous waterfowl and shorebird species, as well as amphibians and invertebrates. In studies focused on significant biological resources on the eastern plains, playa complexes in the Lower Arkansas Basin have been identified as among the most important wetland resources (Rondeau et al. 2010; Culver & Smith 2017).

Wet meadows, which occur only in the northern plains of the Lower Arkansas Basin, were also found to be in good (B-) to fair (C+) condition. Large seeps are relatively rare on the plains and only occur where groundwater is close to the ground surface. Wet meadows in good condition contain high plant species diversity and can support rare species (Kelso et al. 2014; Lemly et al 2015). Some seep-fed wetlands in the Lower Arkansas Basin even form pockets of deep organic or peat soils (Gilmore & Sullivan 2010), which can be used to study climate and vegetation patterns of the past. Of the wet meadows sampled in the random selection, most were subject to grazing or mowing, most contained invasive species, and most were impacted by some degree of hydrologic modification. The most common hydrologic stressors were impoundments or flow obstructions, like roads or berms, that held water within the sites and flooded small areas. A spring box had been installed within one site to capture natural spring outflow and pump it into a dugout pond. This impact appeared to be drying the surrounding natural meadow. In a landscape as dry as the Lower Arkansas Basin, areas of natural seeps are often utilized as a water source. However, they represent important habitats for a diverse array or plant and possibly amphibian species and should be protected from hydrologic alternations, such as groundwater pumping that could lower water tables, impoundments that could drown existing communities, or diversions that could shunt water away from healthy wetlands. Managers should also be cautious of overgrazing that can lead to channelization and drying in seep-fed systems.

The condition of plains riparian areas across the basin varied depending on location. The highest condition riparian areas were located farther from the floodplain. The very best condition sites were located in the deep, relatively undisturbed canyons south of the floodplain. Canyons in southeast Colorado have been found to support numerous significant plants, animals and natural communities and are a true gem for biodiversity in the state (Rondeau et al. 2010). Elsewhere, plains riparian areas were impacted by invasive species, especially the non-native shrub tamarisk, which was found in two-thirds of plains riparian sites. Cattle grazing was also common in plains riparian areas and, in some location, compaction and erosion of banks were evident. Canals or diversions were observed upstream of from two-thirds of streams associated with plains riparian areas. Groundwater wells were also noted within the surrounding landscape of half of riparian areas, though in low density. Many of the streams associated with plains riparian areas were ephemeral and appeared to flow only seasonally or after periods of heavy rain. These systems are periodically subject to pulses of flow that facilitate the establishment of new cottonwood trees, if hydrologic disturbances do not impede flows. Healthy regeneration was noted in several plains riparian areas, particularly along Big Sandy Creek, but was lacking in others, such as Horse and Adobe Creeks. The National Park Service studied Big Sandy Creek within the Sand Creek Massacre National Historic Site and also found high functioning hydrology within the watershed (Wagner et al. 2014). Where flows are left unaltered, riparian areas of the basin can support healthy native vegetation. These areas are important for songbirds, amphibians, and native fish.

Marshes comprise a significant portion of the wetland acres within the central irrigated valley. The large marsh complexes of the floodplain are sizable and evident on aerial photography. We were only able to include five marsh sites within this study because high water within John Martin Reservoir during the sampling year prevented access to several additional randomly selected marsh sites, but conditions within marshes did not vary significantly and additional marsh sites likely had similar conditions, with most rated fair (C+). Marshes of the basin were generally dominated by dense stands of cattail. All marshes sampled were dominated by narrowleaf cattail (*Typha angustifolia*), with only minimal cover of broadleaf cattail (*Typha latifolia*). Considerable research has been devoted to differences in the two cattail species. Some authors suggest that narrowleaf cattail was introduced into North America (Stuckey & Salamon 1987), though the conclusion is far from certain. What is clear is that the range of narrowleaf cattail expanded rapidly in the early to mid-20th century and this expansion outpaced broadleaf cattail (Shih & Finkelstein 2008). There is evidence to suggest that narrowleaf cattail can thrive in deeper water than broadleaf cattail (Grace & Wetzel 1982). There is also evidence that nutrient enrichment has led to invasion of cattails at the expense of other species (Newman et al. 1996; Shih & Finklestein 2008).

Most of the marsh sites sampled were located in the floodplain and were supported, if not created, by elevated groundwater levels due to irrigation runoff, which likely contains elevated nutrients. The combination of high water level and potential nutrient enrichment has created dense marshes with little open water for waterfowl use. However, dense marshes do provide nesting cover for more secretive marsh birds, such as American bittern (*Botaurus lentiginosus*) and black rail (*Laterallus jamaicensis*), both of which are known or suspected to nest in the basin (COBBAII 2017). Restoration and improvement of the basin's marshes will take a combined effort of water managers and habitat managers to balance needs of various species and timing of water use and run-off. In their current state, however, these sites may play an important in improving water quality in the basin, as cattail and other robust wetland species have been shown to absorb nutrients and metals (Dhote & Dixit 2009).

Plains floodplain sites within the basin, on both the Arkansas mainstem and Fountain Creek, generally scored fair (C+) to fairly poor (C-). Conditions across most sites followed a common pattern. The hydrology was consistently rated fair to poor due to major surface water withdrawals, upstream impoundments, and irrigation return flows or stormwater runoff. Most were dominated by non-native species, including tamarisk and Russian olive in the overstory and Russian thistle, kochia, and non-native grasses in the understory. Low regeneration of native species was regularly noted. However, the optimal response to poor vegetation condition may not be aggressive treatment. Current vegetation composition within plains floodplains is indicative of anthropogenic hydrologic alteration that favors the establishment of tamarisk over native cottonwoods and willows. In many areas of the west, tamarisk has replaced native species because it is better adapted to the reduced flows caused by impoundments and surface water withdrawals and to saline conditions created by irrigation return flows (Zouhar 2003; Lovell et al. 2009; Merritt & Poff 2010). Out of concern about the rapid spread of tamarisk, its impacts on wildlife habitat, and the perception that tamarisk used significantly more water than native woody species, considerable effort has been put towards tamarisk removal across the west (Chew 2009) and in the Lower Arkansas basin specifically (Douglass 2013). However, tamarisk removal alone has not been shown to be successful because the underlying reasons for the invasion have not been addressed. Few examples exist where tamarisk was successfully removed and native vegetation re-established, especially at large scales. The most successful examples are small scale efforts with comprehensive revegetation plans (Zouhar 2003; Harms & Hiebert 2006; Shafroth et al. 2008). Recent studies have shown that tamarisk does not consume as much water as previously thought (Owens & Moore 2007); other studies have shown bird use is actually higher in tamarisk stands than where tamarisk removal results in a depauperate vegetation community (Hunter et al. 1988; van Riper et al. 2008). With the extensive distribution in the Lower Arkansas, the best recommendation may be to focus on small scale efforts for native revegetation and to work with the existing stands of tamarisk rather than attempt to eradicate them (Pearson & Ortega 2009; Chew 2009).

Lastly, the reservoir fringes posed a challenge for assessing condition. These systems have been highly altered from their original state, though it is difficult to determine the vegetation composition and hydrologic function of their original state. Many off-channel reservoirs in the basin were historically large playa lakes, but it is unknown how often then filled and whether the vegetation was similar to the smaller playas that scatter the plains. What is clear today is that their hydrology is now highly managed and the vegetation composition is dominated by non-native species, including tamarisk, Russian thistle and Canada thistle, along with native grasses. Reservoir fringes and open sand bars in the basin are known to be important habitat for federally listed bird species, the least tern (*Sternula albifrons,* syn = *Sterna antillarum*) and piping plover (*Charadrius melodus*). Only three reservoir fringe sites were sampled in this study. Others were targeted, but were inaccessible in 2015 due to high water. Because of the sample size, too few sites were sampled to serve as a comprehensive assessment of habitat for these important species.

Condition of Random Sites Compared to Reference Sites

Findings from the random sample of wetlands were very similar to results found in Phase 1, the *Reference Network* project (Lemly et al. 2015). In both studies, plains floodplains and marshes were more impacted than wet meadows, playas and many plains riparian areas. However, on the whole, the handpicked reference sites, which were selected to represent the best available condition within the basin, were in significantly better condition than the randomly sampled sites (Table 3.17; Figure 3.16). The comparison of reference to random sites confirms that the reference sites were well chosen as reference examples. It also confirms the ecological significance of many of the reference sites.

Table 3.17. Condition and stress of reference sites compared to random sites.

Wetland / Riparian Type	*Reference*			*Random*		
	Count	*Ave EIA Score*	*Ave HSI Score*	*Count*	*Ave EIA Score*	*Ave HSI Score*
Reservoir fringe	NA	NA	NA	3	1.63	8.53
Plains floodplain	8	2.24	8.15	12	2.01	8.56
Emergent marsh	6	2.96	4.57	5	2.20	6.68
Plains / foothills riparian	17	3.26	2.36	20	2.31	6.46
Wet meadow	5	3.49	1.24	5	2.51	6.06
Playas	7	3.42	1.70	17	2.72	4.55
Canyon spring	5	3.61	1.78	NA	NA	NA
Total	**48**	**3.13**	**3.35**	**62**	**2.34**	**6.42**

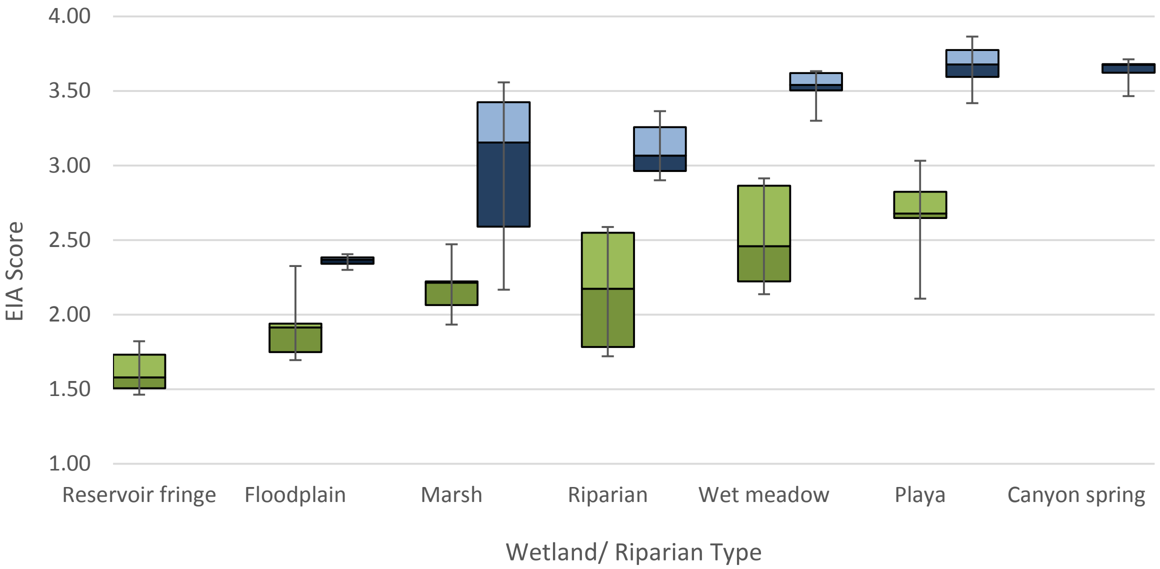

Figure 3.16. Condition and stress of reference sites compared to random sites. Random sites are in green and reference sites in blue. Boxes represent the 25th to 75th percentile, split by the median. Error bars represent the 10th to 90th percentile.

4.0 PILOT STUDY OF WATER QUALITY IN WETLANDS OF THE LOWER ARKANSAS BASIN

4.1 Introduction to Water Quality Sampling

The Lower Arkansas Valley is a critically important agricultural region for the state of Colorado and has been since the initial development of irrigated agriculture in the 1870s. When the Arkansas floodplain was first farmed, the fertile soils produced high yielding crops, including sugar beets and cash crops of melons and other vegetables. Following several decades of intensive irrigation, however, problems with excess soil salinity began to emerge (Sherow 1990). By the early 1900s, floodplain soils were already prone to waterlogging due to excess irrigation and it was recognized that irrigation return flows could mobilize and concentrate salts from surrounding marine deposits (Lantham 1902). These concerns have only magnified over time.

Salinity in the Arkansas River is largely natural in origin, but is intensified by human actions. The basin is predominantly underlain by marine deposits of gypsum, limestone, and other sedimentary layers (Tweto 1979) that readily release salt as water percolates through their porous structure. Intensive irrigation exacerbates the natural release of salts. Arkansas River water is diverted through a series of irrigation canals and some is stored in large, relatively shallow reservoirs. While a portion of diverted water is permanently removed through evapotranspiration from cropland and other irrigated areas, or evaporation in shallow surface water reservoirs, another portion of diverted water is returned to the river via overland flow or subsurface return flows and is available for downstream users. As each successive user returns water to the river, existing salts in the water are concentrated in a smaller volume of water, and additional salts are leached out of the bedrock (Miles 1977; Gates et al. 2012).

It has been estimated that over 85% of the surface water in the Arkansas River is removed from the river and used for agricultural, municipal and industrial purposes before reaching the Kansas state line (Miles 1977). Nearly all the water (95%) that enters the lower basin from upstream of Canon City is used in Colorado. Additional water within the lower basin, up to 40% of the river by volume, is from tributaries below Canon City. The extent that tributary water is fully consumed depends on its entry point relative to the major diversions. Use figures vary widely by year, depending on annual flows and demand, but these estimates indicate the magnitude of water use and consumption in the basin.

The first comprehensive study of salinity in the Arkansas Valley found that the Arkansas River was one of the most saline rivers in the United States, with total dissolved solids concentrations (TDS) in excess of 4,000 mg/L—twice the recommended level for irrigation waters (Miles 1977). Subsequent studies of the salinity problem and potential management solutions have found that high levels of salinity have reduced crop yields and impaired water quality downstream (Ortiz et al. 1998; Bukhalter & Gates 2005; Miller et al. 2010).

Along with salinity, the Arkansas Basin faces a second water quality concern originating from water passing through marine deposits: high levels of selenium and other heavy metals including iron, uranium, and zinc. Selenium contained in natural marine shale deposits can be oxidized by dissolved oxygen and nitrate when irrigation water passes through shale-derived sediments (Gates et al. 2009; Bailey et al. 2015). Rising selenium levels in surface water and sediment in the basin have raised concerns for human health and aquatic life, as selenium can cause deformation and reproductive impairment in fish and wildlife (Lemly 1993; Presser et al. 1994; Van Derveer & Canton 1997). Most sections of the mainstem Arkansas River below Pueblo Reservoir, and many of the major tributaries are currently listed as impaired for high selenium levels by the Colorado Department of Public Health and Environment (CDPHE)'s Water Quality Control Commission (Figure 4.1). Several intensive studies have been conducted to understand the source, distribution and concentration of selenium in the basin (Gates et al. 2009; Miler et al. 2010), and strategies to remediate impaired waters (Bailey et al. 2015).

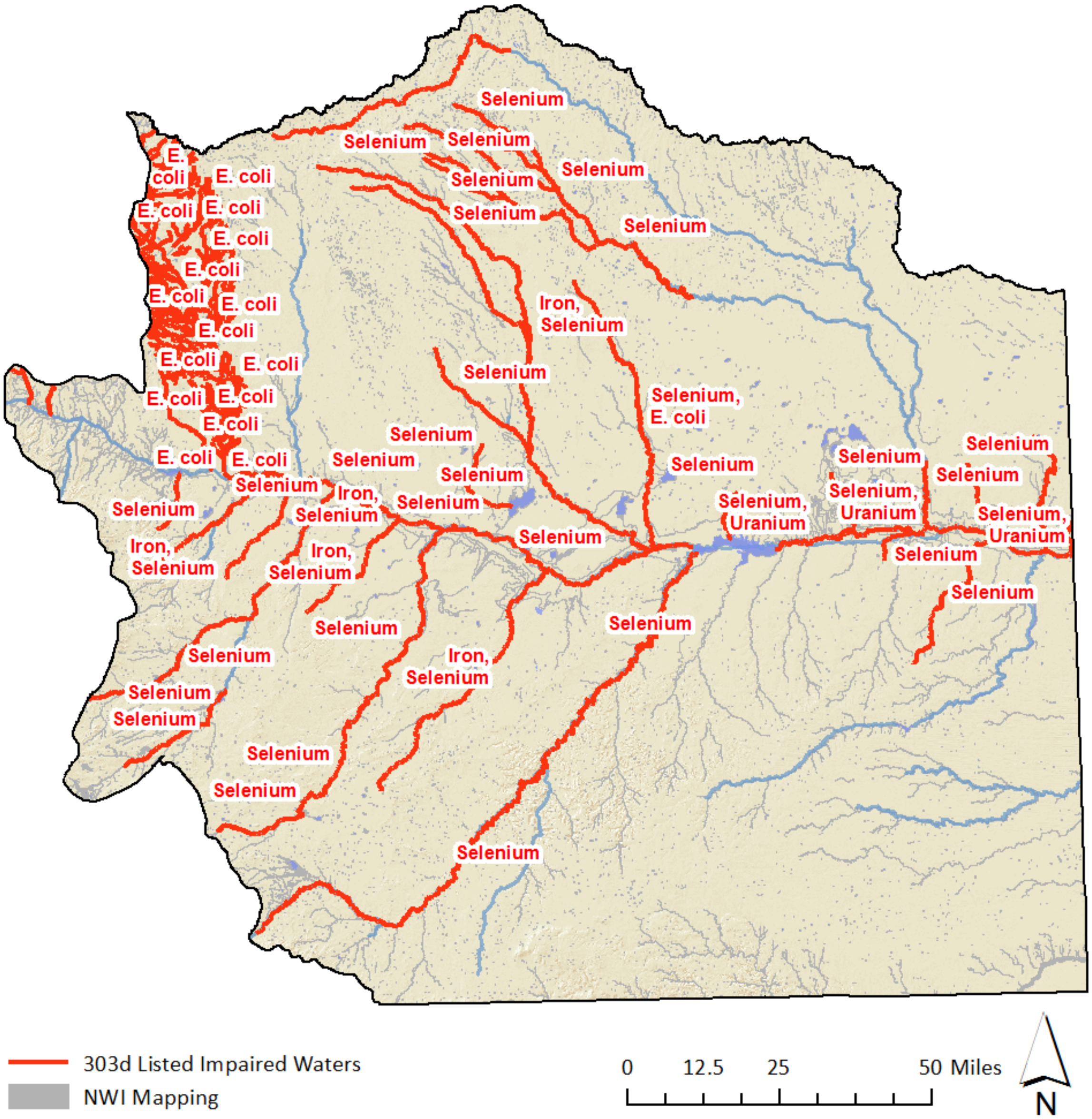

Figure 4.1. Impaired waters in the Lower Arkansas Basin.

While water quality within the Arkansas River mainstem has been studied extensively in the past three decades, there has been less emphasis on tributary streams and little to no study of wetland water quality to better understand: a) the role that wetlands play in mitigating impaired water quality, and b) the water quality conditions faced by native birds, mammals, amphibians, fish, and other wildlife using wetland habitats in the basin. Wetlands are known to mitigate some water quality issues through a variety of physical and biogeochemical pathways (Mitsch and Gosselink 2007). For example, by delaying and storing surface water runoff, wetlands become sinks for metals and nutrients adsorbed to sediment suspended in the water column (USEPA 2015). Within wetland soils and sediments, a complex set of anaerobic and aerobic biogeochemical processes remove constituents such as nitrate and metals from the water column. While wetlands may improve water quality for downstream users, concentrated salinity and metals may have detrimental impacts on wildlife species using wetland habitats (Lemly 1993).

The goal of this pilot study was to examine and document temporal and spatial variability in water quality within common wetland types of the Lower Arkansas basin to understand patterns in current water quality conditions and to identify future questions related to the role of wetlands in water quality improvement and the condition of wetland habitats across the basin. While this study involved a relatively small sample size, it provides important baseline data to compare with extensive information collected in stream reaches across the basin. Study results are not intended for use in setting water quality standards for wetlands, beyond the narrative standards that already exist (WQCC Regulation 31.27), or to identify wetlands as impaired waters. ***No regulatory action will be taken*** based on samples collected through this study.

4.2 Water Quality Sampling Methods

4.2.1 Site Selection

Water quality samples were collected in wetlands throughout the Lower Arkansas Basin. To focus our sampling, the study included three common wetland types[14] of the Western Great Plains: 1) Western North American Emergent Marsh (**marshes**), both within and outside of the Arkansas River floodplain; 2) Western Great Plains Riparian (**plains riparian areas**), located along small tributary streams, including streams connected to regional groundwater systems with standing water during low flow periods; and 3) Western Great Plains Closed Depression (**playas**), which are intermittently filled wetlands located on the plains above the Arkansas floodplain. All three wetland types are associated with standing or flowing surface water, though the duration and permanence of water is dependent on local and regional weather patterns, and they represent aquatic resources not already monitored for water quality. The Western Great Plains Floodplain system is another common wetland type along the mainstem of the Arkansas River, but was omitted from this study because mainstem surface water quality is routinely monitored.

Water quality sampling sites were selected from two different groups of wetlands. 1) **Reference sites** were targeted, non-randomly selected wetlands in good condition that were surveyed by CNHP in 2014 through the *Lower Arkansas Wetland Mapping and Reference Network* project (Lemly

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[14] Wetland types defined by the Ecological Systems classification (Comer et al. 2003). See Section 3 of this report for more on Ecological Systems. Emergent marshes sampled in this portion of the study include both floodplain marshes within the Western North American Emergent Marsh Ecological System and marsh vegetation on the pains that we would now call part of the Western Great Plains Wet Meadow-Marsh Compex.

et at. 2015). From all reference sites surveyed in 2014, we selected five of each of the three target wetland types and attempted to collect water samples in these sites up to three different times throughout the field season. Repeat samples from reference sites were collected to understand how water quality values change with time. 2) **Random sites** were part of the larger random condition assessment detailed in Section 3 of this report. We collected one-time water samples from the first five randomly selected sites from each of the three target wetland types encountered during the random wetland condition assessment. One-time samples from random sites were collected to understand water quality variability across different parts of the landscape.

For most sites, sampling was focused in a 0.5-ha Assessment Area (AA), though size could be variable depending on site conditions (see description of establishing the AA in Section 3). To understand within-site sample variability, we attempted to collect two samples from different locations in each sampled wetland during each visit. In total, we targeted 24–30 sites and 78–102 individual water samples (Table 4.1). Target ranges accounted for uncertainty in finding five of each wetland type within the random sample and our ability to sample surface water in all repeat visits to reference sites—especially playas, which are only temporarily wet.

Table 4.1. Targeted distribution of water quality sampling effort between reference and random sites.

Task	*Wetland Types*	*Sites / System*	*Total Sites*	*Visits*	*Samples / Visit*	*Total Samples*
Reference Sites	3	5	15	2 – 3	2	60 – 90
Random Sites	3	3 – 5	9 – 15	1	2	18 – 30
Total	**3**	**3 – 5**	**24 – 30**	**1 – 3**	**2**	**78 – 120**

4.2.2 Sampling and Data Acquisition Methods

To successfully carry out this pilot project, CNHP partnered with the River Watch program, a volunteer water quality monitoring program jointly administered by Colorado Parks and Wildlife and the Colorado Watershed Assembly.[15] River Watch has been monitoring streams in Colorado for over 25 years and employs methods used by the CDPHE Water Quality Control Division (WQCD). Sampling procedures, labeling, containers, and preservation follow standard methods of the American Public Health Association (APHA 2005) and/or EPA guidelines (Table II of 40 CFR 136)[16] and are detailed in Keith (1996). For this project, CNHP adapted River Watch's sampling protocols for wadeable streams for use in wetland environments. A detailed explanation of the field methods used in this project are included in the project's field manual (CNHP 2015). An overview of the most relevant methods are described here.

Parameters sampled

For every water quality sampling event, 24 parameters were measured either in the field (methods in Table 4.2) or through lab analysis (methods in Table 4.3). In-situ water quality parameters

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[15] For more information, please see the River Watch webpage http://coloradoriverwatch.org/.

[16] Please see http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title40/40cfr136_main_02.tpl for a full text of these guidelines.

included pH, electrical conductivity (EC), and temperature. Upon returning to the field house at the end of each sampling day, the field crew titrated water samples for alkalinity and hardness.

Table 4.2. Water quality parameters measured in-situ or within field holding times.

Parameter	*Frequency*	*Method*[1]	*Holding Time*	*Reporting Limit*
pH	1 at site, 1 off site w/in 24hr	Meter, probe for fresh water	24 hours, kept cold	0.1 S.U.
EC	1 at site	Meter, probe for fresh water	None	1 µS/cm
Temperature	1 at site	Meter, probe for fresh water	None	1.0 unit
Phenol/Total Alkalinity	1 off site w/in 24hr	EPA 310.1	24 hours, kept cold	2 mg/L
Total Hardness	1 off site w/in 24hr	SM 314 B	24 hours, kept cold	2 mg/L

[1] SM = Standard Method (2005). EPA = EPA guidelines in 40 CFR 136.

Electrical conductivity (EC), or specific conductance, was measured instantaneously in µS/cm at 25°C and is a measure of the ionic concentration of water. This value is strongly related to total dissolved solids (TDS) or salinity, though the exact empirical relationship must be established for individual locations based on paired measurements of both values. Given the concern over salinity in the basin, previous studies have developed empirical equations for salinity as a function of EC for several locations on the Arkansas River (e.g., Miller et al. 2010). EC measurements taken in floodplain marshes were converted to TDS using equations for the closest known location with an established empirical relationship. TDS could not be calculated for the plains marshes, plains riparian areas, or playas, as these sites lacked prior sampling to establish relationships between TDS and EC.

Alkalinity and hardness are important and often related properties of water quality. *Alkalinity* is a measure of the acid-neutralizing or buffering capacity of water, largely driven by the presence of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and hydroxyl anions (OH^-). *Hardness* is the sum of polyvalent cations dissolved in water, the most common of which are calcium (Ca^{2+}) and magnesium (Mg^{2+}). Hardness is most often associated with the effectiveness of soap. Harder water requires more soap for cleaning due to chemical reactions between cations and soap. Alkalinity and hardness are important because they can influence many different chemical reactions in water, especially the bioavailability and toxicity of metals. If water is hard (more available cations), dissolved metals bind first to the cations in the water before affecting aquatic life. For this reason, water quality standards for some metals are dependent on water hardness.

Because calcium carbonate ($CaCO_3$) is the most common compound that can contribute to both alkalinity (through the carbonates) and hardness (through the calcium), alkalinity and hardness are both measured as equivalents of $CaCO_3$ in mg/L. However, the bases that lead to higher alkalinity may include borates, phosphates, silicates and other bases beyond carbonates and the polyvalent cations that lead to harder water may include magnesium, iron or manganese. In addition, calcium and magnesium cations in hard water may be contributed by noncarbonate salts such as calcium sulfate ($CaSO_4$ or gypsum), calcium chloride ($CaCl_2$), and magnesium sulfate ($MgSO_4$), which can be found in sedimentary rocks. Therefore, hardness that exceeds alkalinity represents noncarbonate harness contributed by noncarbonate salts.

In the lab, collected samples were analyzed for major ions of calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}) and sulfate (SO_4^{2-}). In addition, bicarbonate (HCO_3^{2-}) was calculated based on known relationships between phenolphthalein alkalinity and total alkalinity.[17] Samples were also analyzed for common and trace metals in both the total and dissolved forms, and nutrients. Two measurements of nutrients were taken in wetland water samples, a combination measure of nitrate plus nitrite and a measure of total phosphorus. While ammonia and inorganic nitrogen were not measured, patterns in nitrate-nitrite levels represent general patterns for total nitrogen in wetland systems.

Table 4.3. Water quality parameters measured through lab analysis.

Parameter	*Method*[1]	*Holding Time*	*Reporting Limit*
Major ions			
Calcium	EPA 200.7 (ICP)	6 months	100 µg/l
Magnesium	EPA 200.7 (ICP)	6 months	100 µg/l
Sodium	EPA 200.7 (ICP)	6 months	100 µg/l
Potassium	EPA 200.7 (ICP)	6 months	100 µg/l
Chloride	EPA 325.1	28 days	1.0 mg/L
Sulfate	EPA 375.4	28 days	0.5 mg/L
Nutrients			
Nitrate-Nitrite	EPA 353.2	28 days	0.02 mg/L
Total Phosphorus	EPA 365.1 and .3	28 days	0.005 mg/L
Total Suspended Solids	SM 2540 D	28 days	4 mg/L
Common and trace metals			
Iron	EPA 200.7 (ICP)	6 months	10 µg/l
Manganese	EPA 200.7 (ICP)	6 months	5 µg/l
Aluminum	EPA 200.7 (ICP)	6 months	15 µg/l
Arsenic	EPA 200.7 (ICP)	6 months	15 µg/l
Cadmium	EPA 200.7 (ICP)	6 months	0.15 µg/l
Copper	EPA 200.7 (ICP)	6 months	1.0 µg/l
Lead	EPA 200.7 (ICP)	6 months	5 µg/l
Selenium	EPA 200.7 (ICP)	6 months	5 µg/l
Zinc	EPA 200.7 (ICP)	6 months	3 µg/l

[1] SM = Standard Method (APHA 2005). EPA = EPA guidelines in 40 CFR 136.

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[17] See the Alkalinity Method 10244 procedures from Hatch Company, DOC316.53.01308: https://www.hach.com/asset-get.download.jsa?id=10803910351.

Field methods

Every wetland site where water quality samples were collected was given a unique station number to identify the site in the River Watch database.[18] This station number was different from the site code used for the condition assessment project. Every time water quality samples were collected was considered a sampling event. Each sampling event was uniquely identified by station number, sample date, and sample time. Station numbers and sample events were tracked closely on a tracking sheet carried by each field team.

For each wetland targeted for water quality sampling, the crew determined the best locations for collecting water samples (carrying out a sampling event). For every site visit, two locations within the wetland were selected for sampling to understand the variability of each parameter within the same site on the same day. The site was considered one sample station, but each sampling location within the site was a separate sampling event with a separate start time. For all sites, sampling event locations were selected to represent the dominant water sources on site, following these general guidelines:

- Water samples were collected from water within the AA, if the water met the additional guidance below. If there was no water in the AA or if the only water was too small (<1 m^2) or too shallow (<15 cm), water could be sampled in a larger body of water (stream or pool) adjacent to the AA, if that water was connected to the wetland within the AA.
- The first water sample was collected from the largest and most dominant water body within or adjacent to the AA. This may have been a stream running through the AA, a pool within the AA, or standing water over the entire AA.
- If there was only one water body within the AA, the second sample was collected from the same water body, but the two locations represented two ends of a gradient, such as upstream/downstream or upslope/downslope and the two samples were collected at least 20 m apart. If the minimum distance could not be met, only one sample was collected. If there were multiple bodies of water (such as pools), samples were collected in the two largest waterbodies.
- Samples were taken near the middle for the water body and away from edges to the extent possible.
- Because collecting a water sample can stir up sediments from below the water column, samples were collected from water at least 15 cm deep, if possible.
- If there was an obvious inlet or input—such as a spring, a culvert, or a tributary stream—samples were collected at least 10 m from the inlet to dampen the influence of the point source and capture the water within the main wetland, if possible.
- Because depth within the water column can affect physical and chemical properties, water samples collected in deep water were collected from within the top 30 cm to be comparable with samples from shallower water.

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[18] To protect information collected on provide land, exact UTM coordinates of sampling locations were not given to River Watch. Instead, a standard location base on the southwest corner of the nearest section, township and range was entered into the River Water database.

- Because emergent vegetation can affect chemical processes and can make it more difficult to collect a clean sample, samples were collected in open water when possible. However, the goal of the project was to document water quality within wetlands, which are often vegetated. If the water body was fringed with vegetation, water samples were collected in relatively open water. If there was a mix of vegetated and unvegetated water, samples were collected in pockets of open water. If there were few or no areas of open water, samples were collected within emergent vegetation and this characteristic was documented.

Beyond the overall guidance provided above, additional guidance was provided by wetland type.

- **Western North American Emergent Marsh:** Marsh sites tended to have standing water with depths varying between 5–50+ cm covering most or all of the AA, and a mix of vegetated and unvegetated areas. Samples were taken at opposing ends of the AA, in depths of 15–30 cm, and in relatively open water.
- **Western Great Plains Riparian**: Plains riparian sites either contained flowing streams, were adjacent to flowing streams, or contained one or more pools. If the site contained or was adjacent to a stream, and that stream was the dominant water body for the site, at least one sample was taken in the stream. If both samples were taken in the stream, they were taken at the upstream and downstream ends of the stream within or adjacent to the AA. If the site contained multiple pools, samples were taken in the two largest pools. If the site contained only one pool, samples were taken at two locations within the pool where the water was deep enough for sampling, if the minimum distance was met.
- **Western Great Plains Closed Depression (playas):** Playa sites either contained shallow water (5–20 cm deep) at the time of sampling or were dry. If there was water onsite, samples were taken within the water at two locations spaced as far apart as possible, while still meeting the depth, distance and vegetation guidance.

All water sample bottles were filled using a long-handled dipper to allow the crew to reach beyond the point where they were standing (Figure 4.2). This procedure was similar to protocols for the EPA's National Wetland Condition Assessment (EPA 2011). The crew wore nitrile gloves when sampling and handling the sample bottles. The dipper and all sample equipment were rinsed with sample water before and deionized water after sampling. In-situ measurements of pH, EC, and temperature were taken from samples in the long-handled dipper. Multiple sample bottles were then filled with water for analysis of alkalinity, hardness, nutrients, and metals. For metals, one sample was taken directly from the water and a second sample was filtered to measure dissolved metals in the water column.

Figure 4.2. Photos demonstrating the use of the long-handled dipper for collecting sample water and filling a sample bottle. Photos taken by Eric Vance, EPA Photographer, and shared from the *NWCA Field Operations Manual* (EPA 2011).

4.2.3 Data Analysis

A series of questions were addressed through data analysis. The first question addressed within-site variability for each parameter by comparing values for the two sampling events carried out at each site visit. The absolute difference between values in each sample pair and the mean and maximum absolute difference across all pairs was calculated for each parameter. For parameters detected in nearly every sample pair, the mean percent difference between the two values was also calculated. This measure lost meaning for parameters that were detected in few samples. In addition, we counted the number of sample pairs where the absolute difference was more than two times the reporting limit and the number of times that the parameter was detected in only one of two samples.

The remaining questions addressed the range of water quality observed within each target wetland type. We summarized the means and ranges of each parameter sampled. Through the analysis, we looked for patterns related to time of sampling (early, mid, or late summer) or to location within the basin. We also compared the values observed with previous water quality studies and with existing water quality standards for each water body. Standards were defined based on CDPHE Water Control Commission Regulation No. 32, Appendix 32-1, and were specific to each water body or stream segment sampled or, for the smallest playa, for the closest comparable water body. The standard for the highest classified use was used. In many cases this was aquatic life, but some segments were classified as water supply. However, the data from this study ***will not be used for regulatory purposes*** related to those standards.

4.3 Water Quality Sampling Results

4.3.1 Characteristics of Sampled Sites

From May to September 2015, we sampled 29 individual wetland sites and collected 92 water quality samples (Figure 4.3; Table 4.4). We successfully sampled all 15 reference sites at least once, but not all reference sites were sampled in each time period. We also successfully sampled 14 random sites, including four marshes, five plains riparian areas, and five playas.

Twenty-seven water samples were taken from eight marshes across the basin (Figure 4.4; Table 4.5). Of the eight marshes sampled, four were reference sites sampled in multiple time periods, though not all samples could be collected in all time periods. Six of the eight marshes were within or very near the Arkansas River floodplain: one marsh on the margin of an off channel reservoir just north of the floodplain; two smaller marshes on the floodplain between Rocky Ford and Las Animas; and three sites within large marsh complexes upstream from John Martin Reservoir. Of the three sites upstream of John Martin, the eastern-most site was partially inundated by reservoir waters during the field season of 2015, which was a very high water year. The other two were within the potential maximum bounds of the reservoir, but are rarely, if ever, in direct contact with reservoir water. All floodplain marshes were strongly influenced by irrigation runoff, which artificially elevates groundwater levels within the floodplain. The other two marshes were located far north of the floodplain and not influenced by irrigation waters. These two plains marshes had strong natural groundwater connections and drained into small creeks. All marsh sites were dominated by robust obligate wetland species, such as cattails (*Typha* spp.) and bulrush (*Schoenoplectus* spp.). Marsh waters were generally characterized as standing, though some sample locations had low velocity flow. Two-thirds were characterized as clear, while the other third was turbid. More than half were open to sunlight, while the rest were shaded.

Forty-four water samples were taken from eleven plains riparian areas across the basin (Figure 4.5; Table 4.5). Of the eleven plains riparian sites, six were reference sites sampled multiple times during the summer. Plains riparian sites were located both north and south of the Arkansas River, on tributaries that ranged from small unnamed drainages to larger streams, including the Purgatoire, Huerfano, Two Buttes, and Big Sandy Creeks. Just over half of samples were taken in standing water, while the remaining samples were taken in flowing water. Water samples were often clear, though several sites were characterized as turbid. Most were open to sunlight, but some were shady. The areas targeted all had wetland vegetation (facultative or obligate) surrounding the channel, rather than upland riparian vegetation, though vegetation was mixed between woody and herbaceous. Most samples were taken in side channels, on very small streams, or in pools in intermittent streams. Several sites had obvious groundwater connections.

Twenty-one water samples were taken in ten playas across the basin, located both north and south of the floodplain (Figure 4.6; Table 4.5). The ten sites were evenly split between reference and random sites. Though multiple visits were made to all reference playas, only one reference playa was sampled in two time periods because the remaining sites were wet during only one sample date each. This included one reference site that was too dry during early summer, but wet in mid-summer. Three random playas were sampled in early summer and two in mid-summer, providing additional information about seasonal patterns. However, no playa was wet in late summer. Water samples were generally taken in the center of playas, where little vegetation grew. They were all characterized as having open standing water, and most were considered turbid.

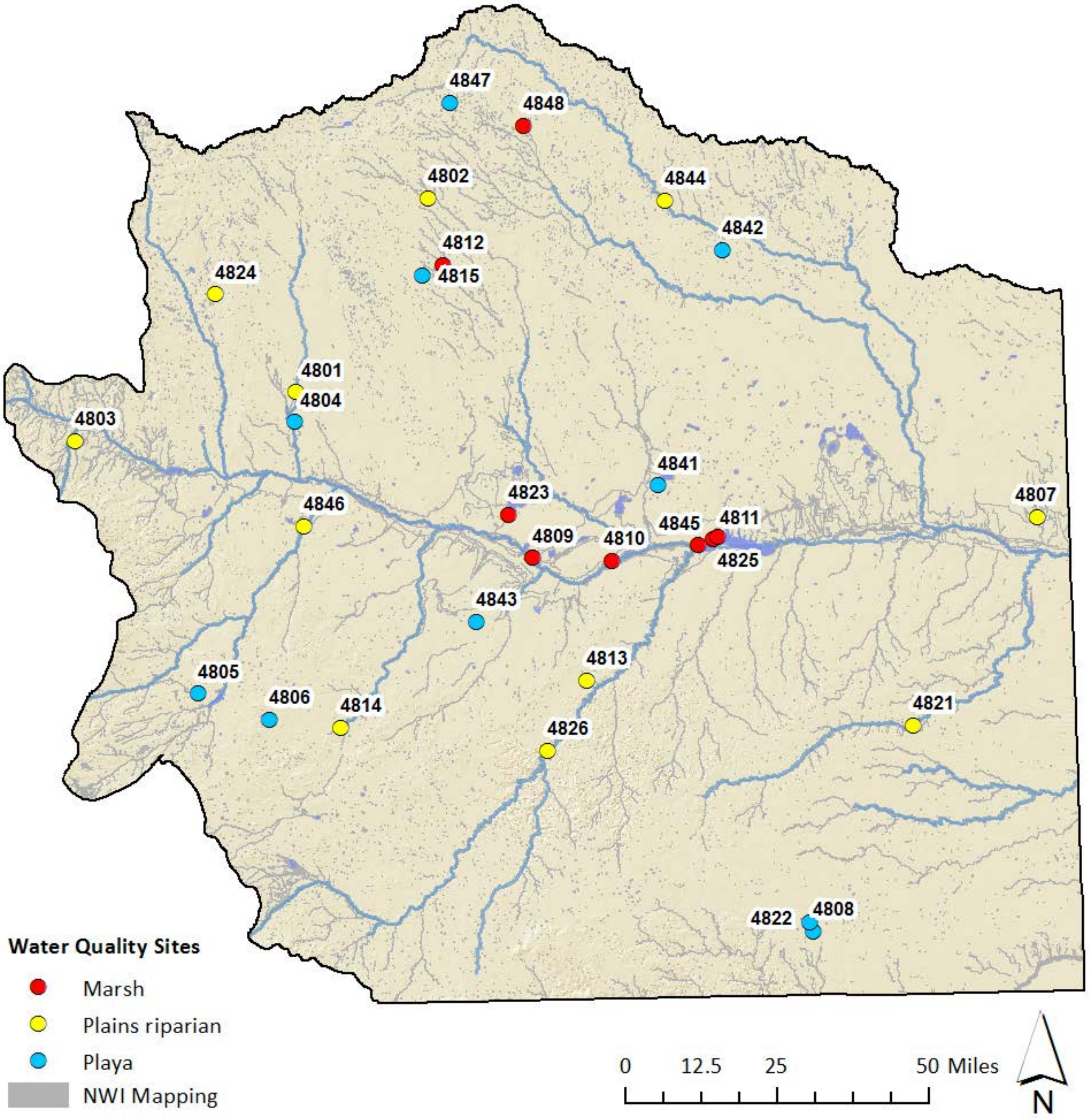

Figure 4.3. Water quality sampling locations across the Lower Arkansas basin, symbolized by wetland type and labeled by station number.

Table 4.4. Actual distribution of water quality sampling effort between reference and random sites.

Site Group/Type	*Sites*	*Visits*	*Samples / Visit*	*Total Samples*
Reference Sites Total	**15**	**1 – 3**	**1 – 2**	**64**
Marshes[1]	4	2 – 3	1 – 2	19
Plains riparian areas	6	2 – 3	2	34
Playas	5	1 – 2	1 – 2	11
Random Sites Total	**14**	**1**	**2**	**28**
Marshes	4	1	2	8
Plains riparian areas	5	1	2	10
Playas	5	1	2	10
Total	**29**	**1 – 3**	**1 – 2**	**92**

[1] One original marsh reference site was later classified as a plain riparian area. This site was a large groundwater-fed pool associated with an intermittent stream on the plains. It was intermediate between a marsh and plains riparian area.

Figure 4.4. Sampling water quality in a marsh.

Figure 4.5. Sampling water quality in a plains riparian area.

Figure 4.6. Sampling water quality in a playa.

Table 4.5. Characteristics of water quality samples.

Site Group/Type	*Total Sites*	*Total Samples*	*Season (count)*			*Ave Depth (cm)*	*Ave Temp (°C)*	*Ave %Veg*	*Velocity (count)*		*Clarity (count)*		*Exposure (count)*	
			Early (May-Jun)	*Mid (Jul-Aug)*	*Late (Sept)*				*Standing*	*Flowing*	*Clear*	*Turbid*	*Open*	*Shady*
Marshes	**8**	**27**	**8**	**11**	**8**	**36**	**24.7**	**30**	**24**	**3**	**19**	**8**	**17**	**10**
Reference	4	19	6	5	8	40	23.3	41	18	1	15	4	11	8
Random	4	8	2	6	--	25	27.9	5	6	2	4	4	6	2
Plains riparian areas	**11**	**44**	**16**	**18**	**10**	**44**	**24.0**	**11**	**23**	**21**	**28**	**16**	**34**	**10**
Reference	6	34	12	12	10	47	22.6	12	21	13	24	10	27	7
Random	5	10	4	6	--	34	28.7	9	2	8	4	6	7	3
Playas	**10**	**21**	**13**	**8**	**--**	**24**	**26.0**	**2**	**21**	**--**	**2**	**19**	**21**	**--**
Reference	5	11	7	4	--	23	23.0	2	11	--	2	9	11	--
Random	5	10	6	4	--	25	29.3	1	10	--	--	10	10	--
Total	**29**	**92**	**37**	**37**	**18**	**37**	**24.7**	**15**	**68**	**24**	**49**	**43**	**72**	**20**

4.3.2 Within-Site Variability

We successfully collected two separate sets of water samples in 44 out of 48 sampling visits. In the remaining four sampling visits, only one set of water samples was collected because the water body was two small (two playas) or impending weather limited time available. However problems collecting metal samples, including three instances where playa water was so turbid that filtering was nearly impossible, reduced the number of metal sample pairs to 41 for dissolved and 43 for total constituents.

In absolute terms, within-site variability was much higher for common constituents, like standard parameters, dissolved ions, and common metals of iron, manganese and aluminum, than it was for less common constituents. For the common constituents, which were found in nearly every sample, the majority of sample pairs differed by greater than two times the reporting limit and the maximum difference between the pairs could be quite high (Table 4.6). However, two times the reporting limit for these parameters is a fairly low bar, as the reporting limit was dramatically lower than the average value observed. For these parameters, a better measure may be the mean percent difference between the two values. For standard parameters and dissolved ions, the mean percent difference was generally 10–15%, indicating that the two samples generally conveyed the same information. Exceptions include TSS, potassium, sulfate, and nutrients, which showed high variability.

Table 4.6. Measures of variability between sample pairs for standard parameters, dissolved ions, and nutrients. Mean and max absolute difference between sample pairs, mean percent difference between sample pairs, number of sample pairs with an absolute difference more than two times the reporting limit, and number of samples pairs where the parameter was detected in only one of the two samples.

Parameter	*Reporting Limit (mg/L)*	*Abs Difference Between Sample Pairs (mg/L)*		*Mean Percent Difference Between Sample Pairs*	*Count of Sample Pairs*	
		Mean	*Max*		*Differ by 2x Reporting Limit*	*Detection in Only One Sample*
Standard Parameters *(total pairs = 44)*						
Alkalinity	2.0	25	194	12%	28	0
Hardness	2.0	44	441	10%	29	0
TSS	4.0	41	522	38%	20	9
Dissolved Ions *(total pairs = 41)*						
Calcium	0.1	14	205	12%	38	0
Magnesium	0.1	4	23	11%	32	0
Potassium	0.1	21	267	24%	37	0
Sodium	0.1	1	20	10%	26	0
Chloride	1.0	3	26	6%	13	0
Sulfate	0.5	104	965	24%	38	0
Nutrients *(total pairs = 44)*						
Nitrate-Nitrite	0.02	0.2	16.8	38%	30	1
Phosphorus	0.005	0.5	10.5	41%	22	3

For the less common trace metals, differences were less pronounced (Table 4.7). The important measure to consider with less common constituents was how often the metal was found in one of the sample pairs, but not the other, which indicates that a measurement could be missed with only one sample. Single-sample occurrence was highest for dissolved zinc, where single sample detection was more frequent than detection in both sample pairs.

Table 4.7. Measures of variability between sample pairs for dissolved and total trace metals.

Parameter	*Reporting Limit (µg/L)*	*Abs Difference Between Sample Pairs (µg/L)*		*Count of Sample Pairs*			
		Mean	*Max*	*Differ by 2x Reporting Limit*	*Detection in Both Samples*	*Detection in Only One Sample*	*Not Detected*
Dissolved Metals, Common and Trace *(total pairs = 41)*							
Iron	10	388	14,825	19	30	4	7
Manganese	5	194	5,712	22	36	2	3
Aluminum	15	7	87	1	5	7	29
Arsenic	15	1	20	0	6	2	33
Cadmium	0.15	0.07	0.46	2	29	5	7
Copper	1.0	0.2	4.3	3	3	3	35
Lead	5	1	5	0	19	4	18
Selenium	5	< 1	6	0	3	2	36
Zinc	3	3	19	7	6	12	23
Total Metals, Common and Trace *(total pairs = 43)*							
Iron	10	1,440	20,075	41	42	1	0
Manganese	5	212	5,963	28	42	1	0
Aluminum	15	1,524	20,694	35	36	7	0
Arsenic	15	1	15	0	6	2	35
Cadmium	0.15	0.13	0.36	4	35	7	1
Copper	1.0	1.1	10.6	12	12	4	27
Lead	5	2	32	2	28	5	10
Selenium	5	1	25	2	6	2	35
Zinc	3	16	452	5	19	10	14

4.3.3 Water Quality in Emergent Marsh Wetlands

Standard Parameters (pH, EC, TSS, Alkalinity and Hardness)

The pH of marsh samples was near neutral to slightly basic across all sites. Marshes had the lowest pH values among the three wetland types sampled (Table 4.8). The average pH of marsh samples was 7.51 (range 6.11–8.22). From repeat samples, pH appeared to rise slightly over the summer season. There was greater variability in early and mid-summer readings, but universally high values (7.70–8.22) taken in late summer. Location in the basin did not seem to contribute to the range of values. The lowest values and the highest values were both seen in marsh complexes near John Martin Reservoir, while the plains marshes had intermediate values. Overall water depth, which ranged from 5 cm to 100 cm, also did not correlate with pH. The values observed were within the range of normal for the basin and no obvious trend was noted.

EC in marsh samples ranged from 371 to 3598 µS/cm, with an average of 1441 µS/cm. There was no seasonal trend in EC for the three marshes sampled at multiple time periods. In general, the irrigation influenced floodplain marshes had higher EC values (most over 1200 µS/cm) than the plains marshes (400–800 µS/c) and EC in floodplain marshes generally increased from west to east along the grade of the Arkansas River, with the highest value observed at the edge of John Martin Reservoir. However, the lowest EC values observed (371 and 376 µS/cm) were also taken upstream of John Martin (Station 4845). This site was located within John Martin State Wildlife Area near a berm and a deep, open water body cleared for waterfowl use. Salts in this site may have more of a chance to settle out than in other floodplain marshes.

For the floodplain marshes where TDS could be calculated, values ranged from 110 mg/L to 2515 mg/L, with most close to or over 1000 mg/L. Aside from the two low values near John Martin, these values fall within the general ranges observed within the Arkansas River between Rocky Ford and John Martin Reservoir and can be attributed to the surrounding sedimentary bedrock and reuse of irrigation waters (Miller et al 2010).

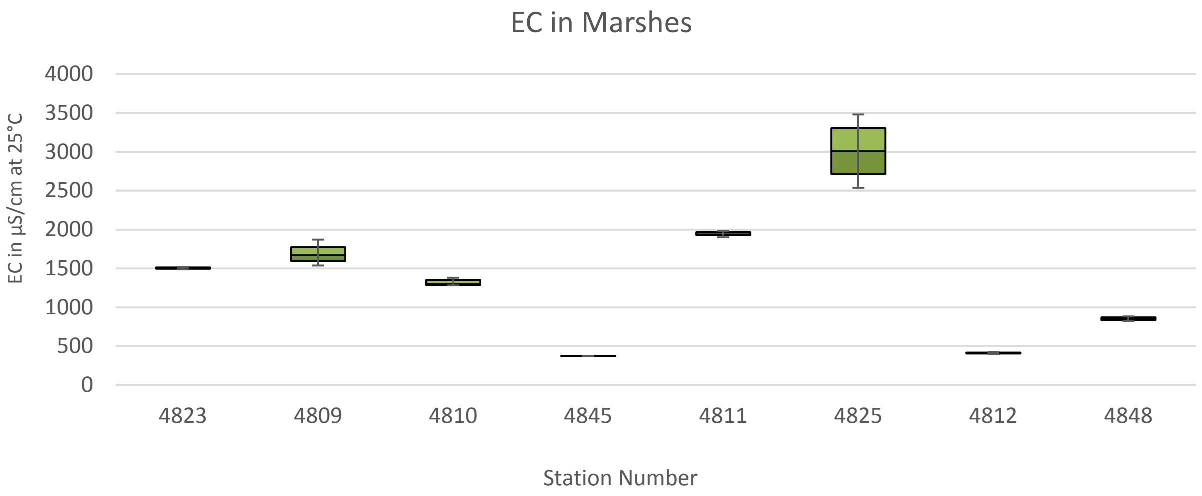

Figure 4.7. Electrical conductivity in marsh water samples. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile. For this and all marsh graphs: Floodplain marshes (Stations 4823–4825) are presented first and ordered from west to east along the floodplain. The two plains marshes are shown at the far right (4812, 4848).

Table 4.8. Mean and ranges of all parameters by wetland type, no outliers removed.

Parameter	*Marsh*		*Plains riparian*		*Playa*	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*
Standard Parameters						
pH	7.51	6.11–8.22	8.01	6.50–9.74	8.67	7.69–9.78
EC (µS)	1441	371–3598	1682	291–3999+	675	121–3999+
TSS (mg/L)	35	0–260	49	0–915	270	9–928
Alkalinity (mg/L)	252	116–600	210	50–336	251	40–1380
Hardness (mg/L)	569	64–1480	591	82–1240	149	38–278
Dissolved Ions						
Calcium (mg/L)	134	36–393	127	2–318	36	7–77
Magnesium (mg/L)	48	10–114	63	2.9–282	11	2.5–58
Sodium (mg/L)	112	18–231	143	11–501	119	0.3–1200
Potassium (mg/L)	4	0.4–11	7	0.9–13	16	4.4–50
Chloride (mg/L)	50	11–76	37	0.0–106	42	1.4–369
Sulfate (mg/L)	447	24–948	682	0.8–1930	72	4.9–529
Bicarbonate (mg/L)	245	116–600	191	10–332	88	0–212
Nutrients						
Nitrate-Nitrite (mg/L)	0.91	0.00–7.72	1.19	0.00–11.60	0.34	0.00–1.32
Phosphorus (mg/L)	0.28	0.00–2.48	0.10	0.00–1.79	5.20	0.05–14.20
Dissolved Metals, Common and Trace						
Iron (µg/L)	620	0.0–14,943	35	0.0–248	60	0.0–269
Manganese (µg/L)	475	0.0–7,813	173	0.0–678	45	0.0–258
Aluminum (µg/L)	0.7	0.0–19	5.3	0.0–58	19.2	0.0–116
Arsenic (µg/L)	1.7	0.0–16	0.5	0.0–20	16.6	0.0–41
Cadmium (µg/L)	0.3	0.0–0.7	0.3	0.0–0.7	0.3	0.0–0.6
Copper (µg/L)	0.0	0.0–0.0	0.1	0.0–2.1	2.2	0.0–11
Lead (µg/L)	4.4	0.0–9.6	2.3	0.0–6.7	2.2	0.0–11
Selenium (µg/L)	0.0	0.0–0.0	2.1	0.0–15	0.0	0.0–0.0
Zinc (µg/L)	1.1	0.0–5.2	2.8	0.0–24	1.3	0.0–17
Total Metals, Common and Trace						
Iron (µg/L)	1,413	38–18,220	1,296	38–19,004	11,242	0.0–34,800
Manganese (µg/L)	509	9.1–8,081	180	17–1,130	470	0.0–1,800
Aluminum (µg/L)	541	0.0–2,844	772	0.0–8,466	12,818	0.0–48,780
Arsenic (µg/L)	1.6	0.0–16	0.3	0.0–11	24	0.0–115
Cadmium (µg/L)	0.4	0.0–0.8	0.3	0.0–1.2	1.0	0.3–4.5
Copper (µg/L)	0.3	0.0–4.5	1.1	0.0–16.6	11	0.0–60
Lead (µg/L)	5.4	0.0–12	4.5	0.0–38	22	0.0–73
Selenium (µg/L)	0.0	0.0–0.0	3.0	0.0–15	1.2	0.0–25
Zinc (µg/L)	2.9	0.0–13	17	0.0–456	47	0.0–195

While our analysis did not include a direct measurement of TDS, the analysis did include total suspended solids (TSS), which indicates the extent of undissolved particulate matter within the water. Overall, marsh samples had low TSS measurements and two thirds of waters were reported clear (vs. turbid) by field crews. The average TSS value was 35 mg/L (range 0–260 mg/L). Only three individual samples exceeded 100 mg/L and all three were taken in the same plains marsh on multiple sample dates. This site was densely vegetated, located within a mosaic of emergent marsh and wet meadow vegetation at the headwaters of an intermittent stream network, and had shallower water than most marshes sampled. This site was also the only marsh sampled that was grazed by livestock.

Average alkalinity for marsh samples was 252 mg/L (range 116–600 mg/L). Average hardness for marsh samples was 569 mg/L (range 64–1480 mg/L). Based on standard interpretations of hardness (EPA 1986), marsh waters would be considered hard to very hard. Alkalinity and hardness in marshes were somewhat correlated ($R^2=0.65$), and both were strongly correlated with dissolved calcium and magnesium ($R^2=0.83$ to 0.95). Hardness was also strongly correlated with EC, but the relationship between alkalinity and EC was much weaker. Hardness was greater than alkalinity in all but two samples. In the samples where hardness exceeded alkalinity, the difference between the two (the noncarbonated hardness) was strongly correlated to sulfates. This indicated that the hardness in marsh waters was a mix of both carbonate hardness and noncarbonated sulfate-based hardness derived from the marine sedimentary deposits of the basin (e.g., gypsum, which is calcium sulfate or $CaSO_4$).

Both alkalinity and hardness remained relatively consistent throughout the summer for sites sampled more than once. There was no obvious pattern by location in the basin for alkalinity. However, water in floodplain marshes was generally harder than in plains marshes, which are farther from the marine deposits and not influenced by irrigation water. Reuse of irrigation water concentrates calcium and magnesium, leading to harder water. The one exception was Station 4845, the floodplain marsh with low EC values, which had hardness similar to the plains marshes.

Median alkalinity and hardness in marsh samples were similar to the medians in riparian samples (Figure 4.8), but were both higher than in playa samples. Mean alkalinity in playas, however, was similar to marshes because one playa was extremely alkaline and inflated the mean.

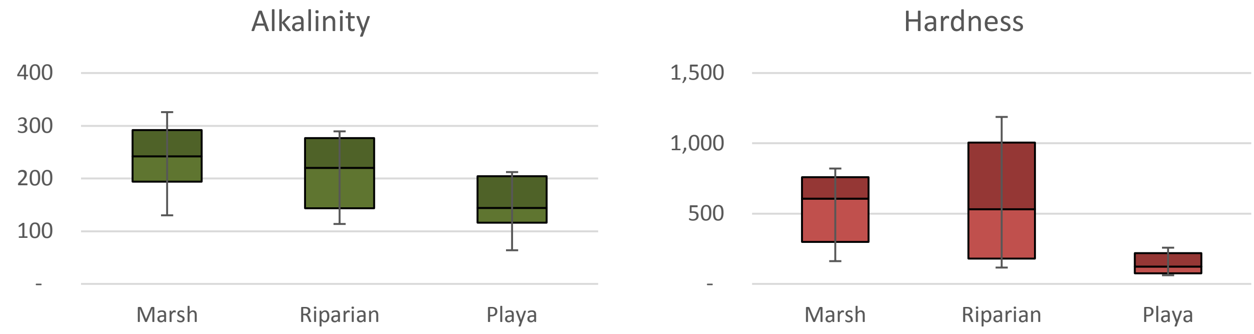

Figure 4.8. Alkalinity and hardness for all three wetland types sampled. Boxes represent the 25th to 75th percentile, split by the median. Error bars represent the 10th to 90th percentile.

Major ions (Ca, Mg, Na, K, HCO_3, SO_4, Cl)

The dominant dissolved cations in marsh samples were calcium (45% of cations on average) and sodium (38%), with lesser amounts of magnesium (16%) and trace amounts of potassium (1%) (Figure 4.9). The average concentration of dissolved calcium was 134 mg/L (range 36–393 mg/L) (Table 4.8); average dissolved sodium was 112 mg/L (range 18–231 mg/L); average dissolved magnesium was 48 mg/L (range 10–114 mg/L); and average dissolved potassium was 4 mg/L (range 0.4–11 mg/L). The two plains marshes (Stations 4812 and 4848) had lower cation concentrations than the floodplain marshes, similar to patterns of EC and hardness, with the exception of floodplain marsh Station 4845, which showed similar cation concentrations to the plains marshes. Floodplain marshes received significantly greater inputs of cations than the plains marshes from both the surrounding geology and irrigation return flows.

The dominant dissolved anions in marsh samples were sulfate (60% of anions on average) and bicarbonate (33%). Chloride represented only 7% of anions on average (Figure 4.10). As with cations, floodplain marshes had higher concentrations of anions than plains marshes, and the relative concentration of sulfate was much higher. This is likely because geology on the plains differs from the sulfate containing marine deposits that surround the floodplain. The average concentration of dissolved sulfate across all sites was 447 mg/L (range 24–948 mg/L); average dissolved bicarbonate was 248 mg/L (range 116–600 mg/L); and average concentration of chloride was 50 mg/L (range 11–76 mg/L).

There are no water quality standards for major cations in the Lower Arkansas Basin to compare these numbers against, but the cation values for floodplain marshes are consistent with data shown for the Arkansas River itself (Dash & Ortiz 1996). There are water quality standards for both sulfate and chloride in the Lower Arkansas Basin. The chronic standard for sulfate is 902 mg/L along the Arkansas River itself and 1900 mg/L on tributaries associated with the plains marshes. Two individual water samples taken on different dates from floodplain marsh Station 4811 did surpass the sulfate standard, but on average, this site was below the standard. No other sites approached the standards. The standard for chloride is 250 mg/L, if used for drinking water. No samples taken in marshes were close to this standard.

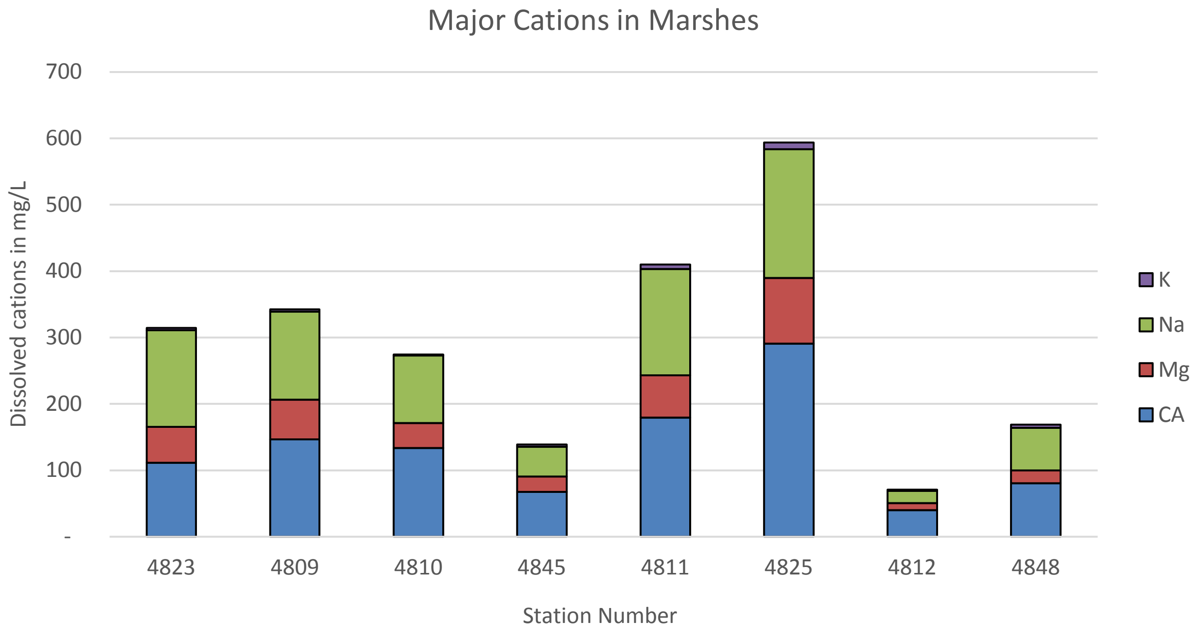

Figure 4.9. Major dissolved cations in marsh water samples. Values shown are averaged by site.

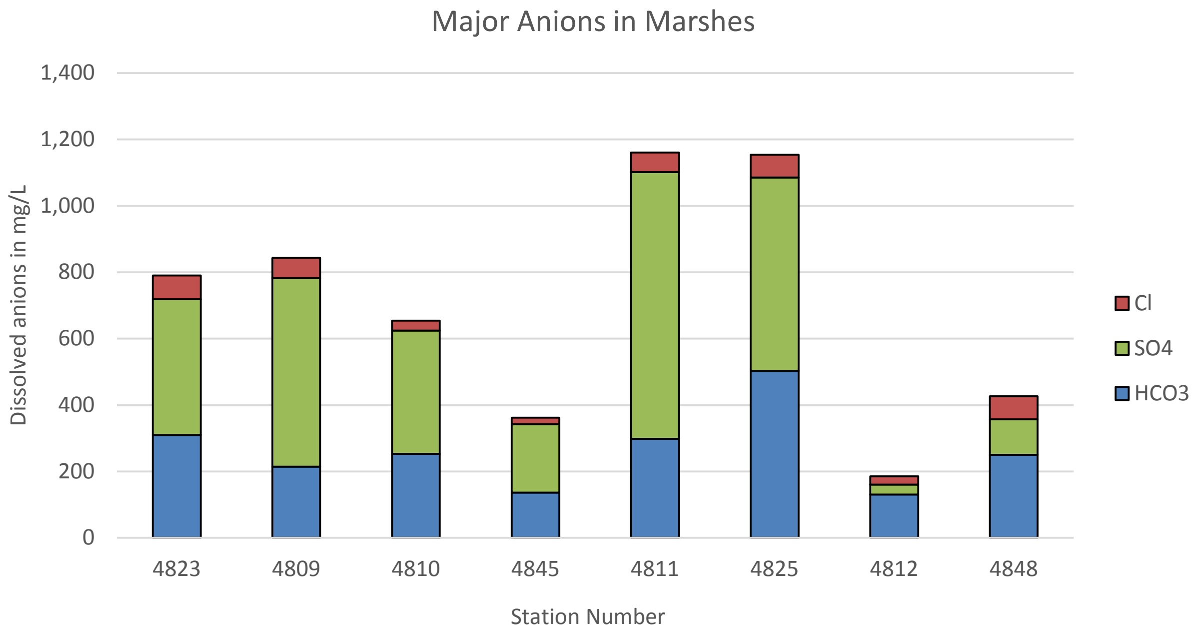

Figure 4.10. Major dissolved anions in marsh water samples. Values shown are averaged by site.

Common and Trace Metals (Fe, Mn, Al, As, Cd, Cu, Pb, Se, Zn)

Of the nine metals analyzed in marsh water samples, iron (Fe) and manganese (Mn) were by far the most prevalent in both the dissolved and total forms, and total aluminum (Al) was also very common (Table 4.8, Figures 4.14–4.16). Iron and manganese can become soluble in anoxic conditions, such as the waterlogged soils of wetlands, and it is not surprising that these two elements would be present in marsh waters. One site (Station 4825, just above John Martin Reservoir), showed highly elevated levels of both iron and manganese (Figure 4.14). This site was only sampled once in late summer, and it is unclear if these levels are typical of the site or represent an atypical spike. Figure 4.15 shows dissolved concentration of trace metals in marsh samples with Station 4825 removed to highlight patterns in the other marshes. The following paragraphs discuss each element in terms of concentrations and water quality standards, beginning with the most common metals.

Iron (Fe): As mentioned above, iron was one of the most common metals measured in marsh water samples. The average concentration of dissolved iron was 620 µg/L (range 0.0–14,949 µg/L). The average concentration of total iron was 1,419 µg/L (range 0.0–18,220 µg/L). Individual sites showed spikes, such as the one described for Station 4825 above John Martin Reservoir, but there were no consistent trends by season or location. The chronic water quality standard for total iron is either 1,000 µg/L or 1,950 µg/L, depending on location. While the spikes were higher than those standards, the mean values measured across time for most sites were lower. Given that soluble iron is common in wetlands, these standards may not be reasonable to apply to marsh wetlands, though marshes may represent a source of iron in downstream waters.

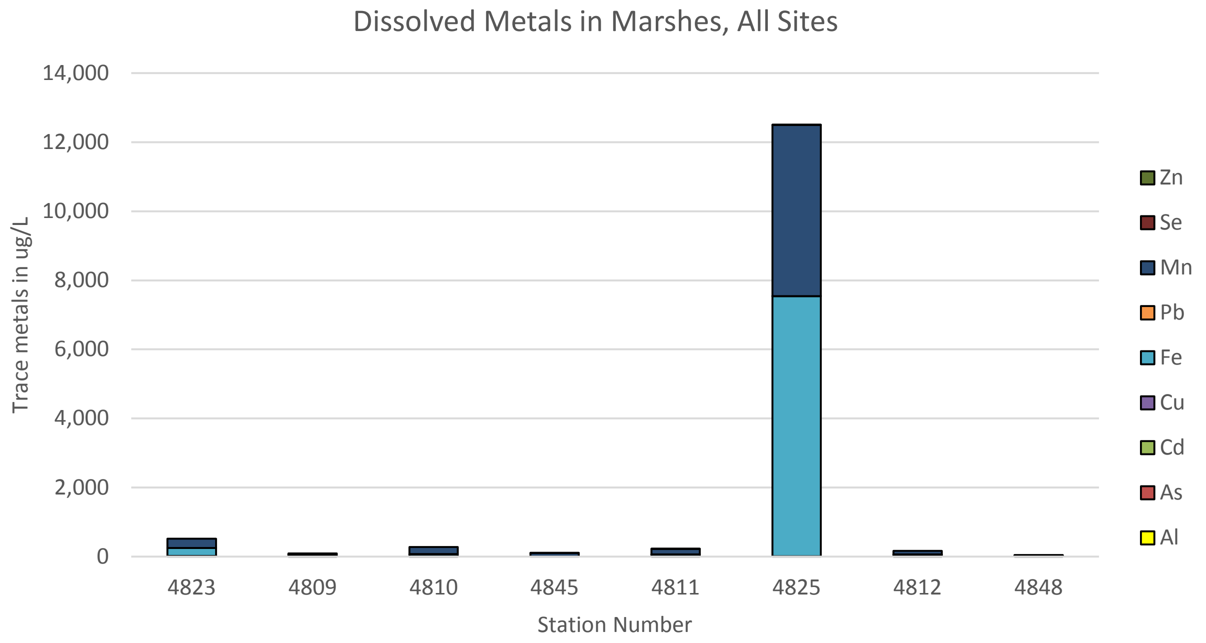

Figure 4.11. Dissolved metals in marsh water samples. Values shown are averaged by site.

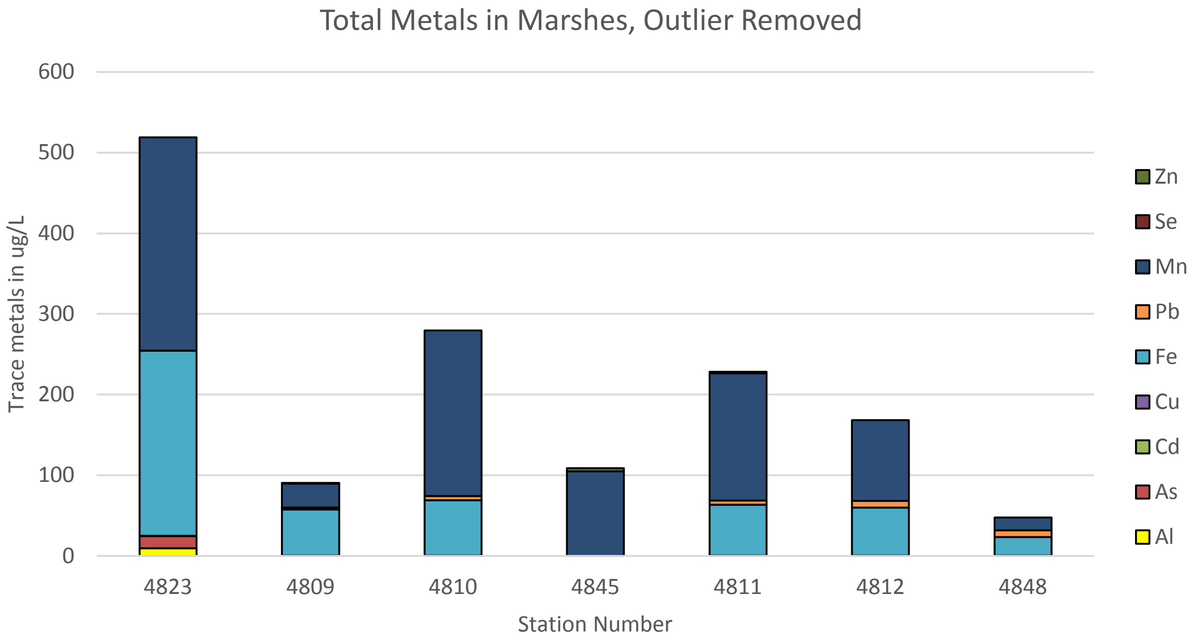

Figure 4.12. Dissolved metals in marshes with Station 4825 removed to show sites with lower concentrations.

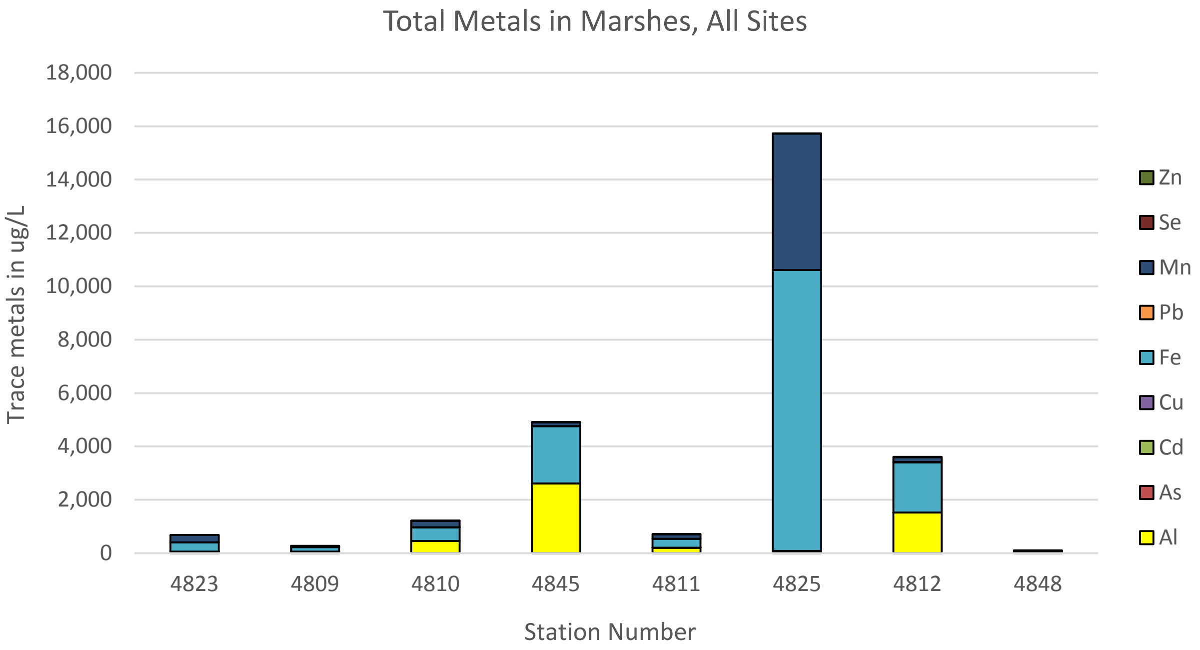

Figure 4.13. Total metals in marsh water samples. Values shown are averaged by site.

Manganese (Mn): Similar to iron, manganese was one of the most common metals measured in marsh water samples. The average concentration of dissolved manganese was 475 µg/L (range 0.0–7,813 µg/L). The average concentration of total manganese was 509 µg/L (range 9–8,081 µg/L). Like iron, individual sites showed spikes, but there were no consistent trends by season or location. Acute and chronic water quality standards for dissolved manganese are based on hardness. Only Station 4825, which showed the highest spike in both iron and manganese, exceeded the chronic standard. However, the value represents only a one-time sample and may not represent a chronic water quality concern.

Aluminum (Al): Aluminum was one of the more common metals found in marsh water samples in the total form. The average concentration of total aluminum was 541 µg/L (range 0.0–2,844 µg/L). Because aluminum is a common element in soil, high values for total aluminum were most likely derived from soil particles suspended in the water. When total aluminum values from all wetland types were compared based on a visual observation of water clarity (clear vs. turbid), sites with turbid water had significantly more total aluminum than those with clear water (Figure 4.17). While total aluminum was common in marsh samples, dissolved aluminum was virtually absent. Only one sample had any measureable dissolved aluminum (19 µg/L), and this reading was only slightly above the reporting limit (15 µg/L). There are no water quality standard for aluminum in the basin to compare these values against, however studies of aluminum toxicity suggest that acute and chronic standards for dissolved aluminum should be based on hardness and the values observed are well within recommended ranges (GEI Consultants 2011).

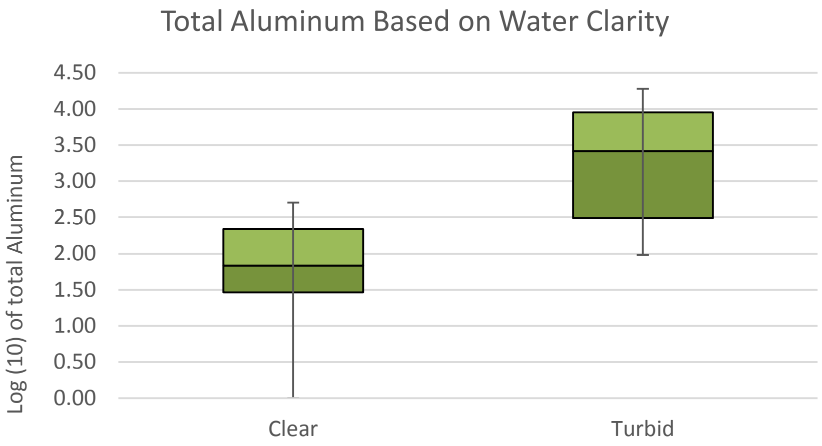

Figure 4.14. Total aluminum by water clarity. Log$_{10}$ of aluminum in µg/L is shown to highlight the differences.

Arsenic (As): Arsenic in either the dissolved or total form was found in only two marsh sites. In one site, dissolved and total arsenic were found in both samples, but the measurements were just above or below the reporting limit (15 µg/L). At the second site, arsenic was only measured in one of two samples taken and values for both dissolved and total were right at the reporting limit. The acute water quality standard for dissolved arsenic is 340 µg/L, which is far higher than the values measured. The chronic water quality standard varies by water body and use. For the site where arsenic was measured in both samples, the chronic standard for total recoverable arsenic is 7.6 µg/L, which was exceeded. However, the measurements were only taken once during the summer and do not document a long-term pattern for this site, nor a violation of the water quality standard. Repeat measurements with finer precision would be necessary to document a true water quality concern.

Cadmium (Cd): Cadmium was found above the reporting limit (0.15 µg/L) in nearly all marshes, but was never measured above 1.00 µg/L. In comparison with other metals, the concentration of cadmium was very low. The average concentration of dissolved cadmium was 0.34 µg/L (range 0.0–0.66 µg/L). The average concentration of total cadmium was 0.38 µg/L (range 0.0–0.83 µg/L). Water quality standards for cadmium are based on water hardness, with higher standards for harder water. Due to the high hardness values in marsh water samples, the water quality standards for cadmium were relatively high and no site exceeded either its acute or chronic standards. The only sites that approach the standard were those on the plains with softer water.

Copper (Cu): Copper was found in the total form at only one marsh site and was not detected at all in the dissolved form. The site where copper was detected was sampled three times throughout the summer and only samples taken mid-summer contained copper. The values measured at this site (2.7 and 4.5 µg/L in two samples) were far below either the acute or chronic water quality standards, which are calculated based on hardness.

Lead (Pb): After iron and manganese, lead was the third most common dissolved trace metal found in marsh water samples and the fourth behind aluminum in the total form. Dissolved lead was found in all but two sites and total lead was found in all but one. The average concentration of dissolved lead was 4.4 µg/L (range 0.0–9.6 µg/L). The average concentration of total lead was 5.5 µg/L (range 0.0–11.3 µg/L). There was no obvious seasonal pattern in lead concentrations, but plains marshes had consistently higher values (average values by site for both dissolved and total lead > 8.0 µg/L) than the floodplain marshes (average values by site all < 8.0 µg/L). Acute and chronic water quality standards for dissolved lead are based on hardness. No site exceeded its acute water quality standard for lead. However, given that the plains marshes had softer water and higher values of lead, these sites did exceed the chronic water quality standards (Figure 4.18).

Selenium (Se): There was no measureable selenium, in either dissolved or total form, in marsh water samples.

Zinc (Zn): Low levels of dissolved zinc were detected at least once in half of marsh sites, while total zinc was detected at least once in nearly all sites. The average concentration of dissolved zinc was 1.1 µg/L (range 0.0–5.2 µg/L). The average concentration of total iron was 2.9 µg/L (range 0.0–12.6 µg/L). There were no clear seasonal or geographic patterns in zinc concentrations and no values measured exceeded water quality standards, which are based on hardness.

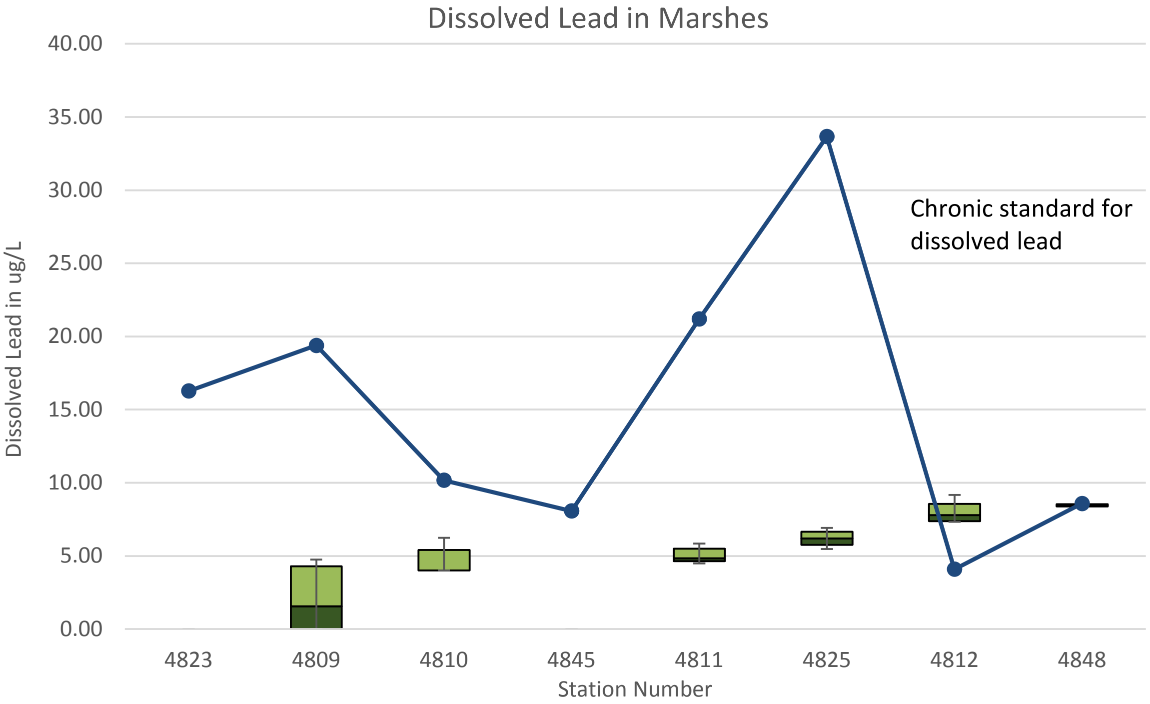

Figure 4.15. Dissolved lead in marsh water samples by site, compared to the chronic water quality standard, which depends on hardness. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

Nutrients (Nitrate-Nitrite, Phosphorus)

Nitrate-nitrite was relatively low in marsh water samples. The average across all values in marsh samples was 0.91 mg/L (range 0.00–7.72). There are separate water quality standards for nitrate (acute standard = 10 mg/L) and nitrite (chronic standard = 0.5 mg/L) in potential drinking water sources. All marsh samples were well below the acute standards for nitrate (Figure 4.11). Nearly all samples were below the chronic standard for nitrite, except for one plains marsh (Station 4812), which showed consistently higher values. This site was also the plains marsh with high TSS values with dense vegetation, shallow water, and was grazed. Because the measure taken was for nitrate and nitrite combined, additional sampling would be needed to determine which form of nitrogen is driving the values in this site. In general, however, nitrogen levels in marshes appear to be low and were much lower than values measured in the mainstem of the Arkansas River, which were generally in the range of 1.0–5.0 mg/L (Ortiz et al. 1998). There was no obvious seasonal pattern to the measurements, though the highest value was recorded in mid-summer.

Total phosphorus was more variable than nitrogen in marsh samples. The average value was 0.28 mg/L (range 0.00–2.48 mg/L). Five marshes had consistently low phosphorus concentrations, but three sites had samples with phosphorus levels above 1.00 mg/L (Figure 4.12). Of the marshes with high phosphorus, two were in the floodplain and one was a plains marsh. The highest values were all taken in mid-summer (Figure 4.13), but most high values were taken in sites sampled only in mid-summer, so it is unknown whether those sites had high phosphorus in early and late summer as well. One site sampled multiple times did show a spike in the mid-summer reading.

Phosphorus is a natural element that is essential to plant life, however, excess phosphorus can enter the water system through fertilizers and sewage effluent. There are no specific water quality standards for phosphorus for the river and stream segments associated with the marshes, but EPA recommends the following levels (EPA 1986):

1. No more than 0.100 mg/L for streams which do not empty into reservoirs,
2. No more than 0.050 mg/L for streams discharging into reservoirs, and
3. No more than 0.025 mg/L for reservoirs.

Most samples were above the 0.05 mg/L threshold for streams that discharge to reservoirs, and the majority of sampled marshes do have a surface water connection with reservoirs. Prior studies also found that many water samples along the Arkansas mainstem has phosphorus levels above the recommended levels for streams discharging into reservoirs (Ortiz et al. 1998).

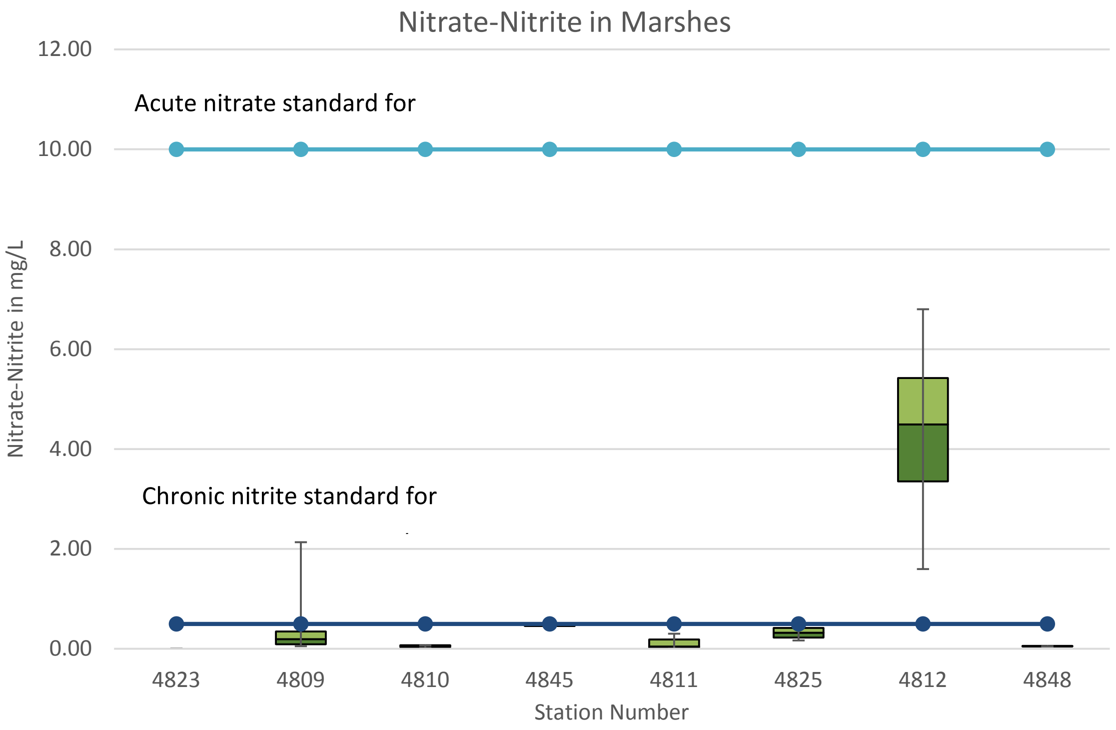

Figure 4.16. Nitrate-nitrite in marsh water samples by site, compared to drinking water standards for both nitrate (acute) and nitrite (chronic). Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

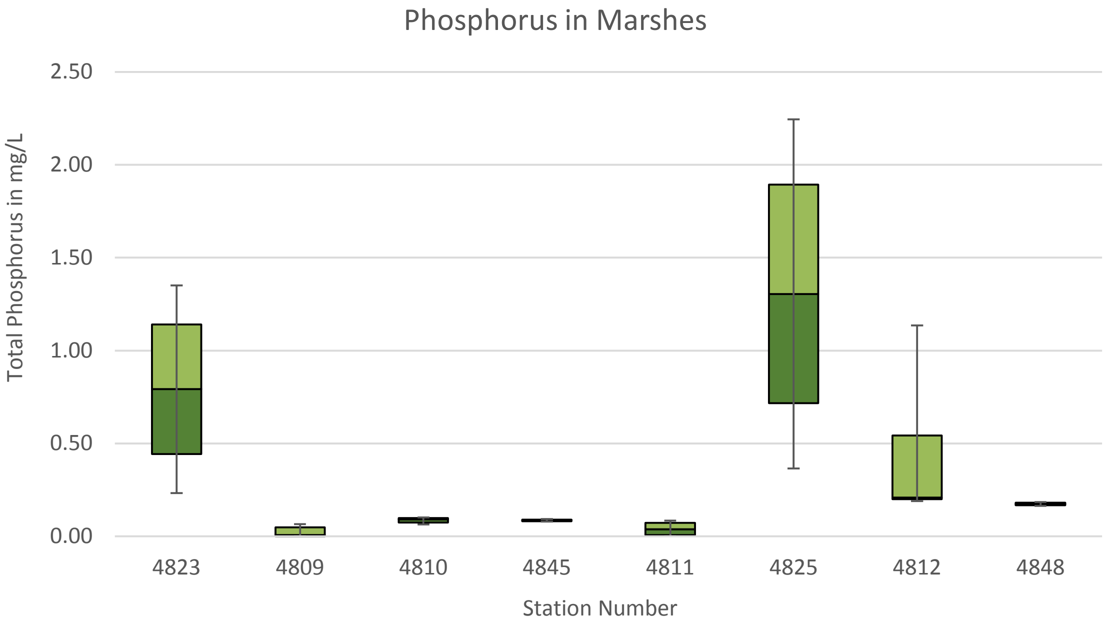

Figure 4.17. Total phosphorus in marsh water samples by site. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

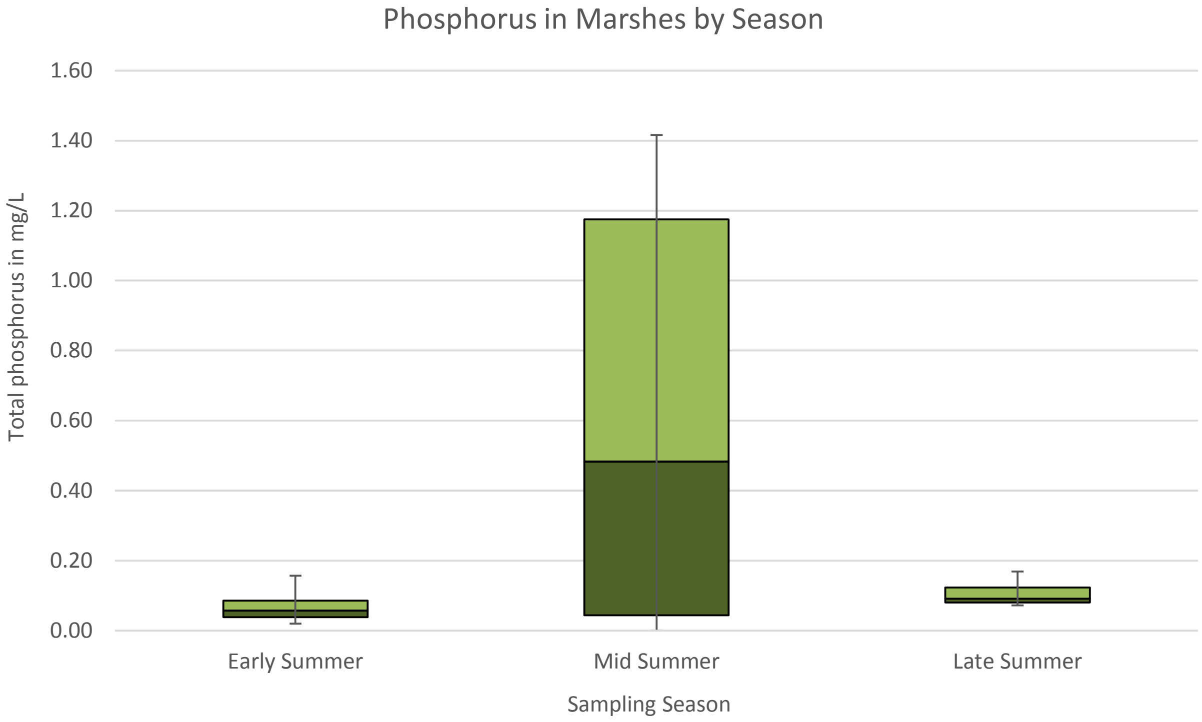

Figure 4.18. Phosphorus is marshes by season. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

4.3.4 Water Quality in Plains Riparian Areas

Standard Parameters (pH, EC, TSS, Alkalinity and Hardness)

The pH of plains riparian waters was slightly basic across all sites. Plains riparian areas had pH values intermediate between marshes and playas. The average pH of plains riparian samples was 8.01 (range 6.50–9.74) (Table 4.8). From repeat samples, pH of many plains riparian areas rose slightly over the summer season, as it did in marsh samples, however, two of the highest reading were taken during mid-summer. Location in the basin did not seem to contribute to the range of values. The highest values were seen both north and south of the floodplain. The values observed were within the range of normal for the basin and no obvious trend was noted.

EC in plains riparian samples ranged from 291 µS/cm to greater than the meter could measure (3999 µS/cm), with an average value of 1682 µS/cm. There was no obvious seasonal trend in EC for the plains riparian areas sampled at multiple time periods. There did appear to be geographic trends, however (Figure 4.19). Plains riparian areas north of the floodplain, where the dominant geology was unconsolidated Aeolian sand deposits, generally had lower EC values than those south of the floodplain, where the dominant geology was sandstone. The three plains riparian sites closest to the floodplain had the highest EC values. These sites may be influenced by geologic outcrops closer to the floodplain and they also may receive more influence from irrigation return flows. The site with the highest EC was in a residual pool along a side channel of the Huerfano River. There were no established relationships between EC and TDS, so no estimates of TDS could be made.

Overall, plains riparian samples generally had low TSS measurements. The average TSS was 49 mg/L (range 0.0–915 mg/L). TSS values were strongly related to water clarity, however. When waters were reported clear by field crews, the average TSS was 9 mg/L. When waters were reported as turbid by field crews, TSS climbed to 118 mg/L on average. The highest TSS measurements were recorded in one of the plains riparian areas with repeat samples. While that site had low TSS values in early and mid-summer, values from the late summer sampling were 393 and 915 mg/L. Crews noted that the area was being actively grazed at the time of sampling and the water was very turbid.

Average alkalinity for plains riparian samples was 210 mg/L (range 50–336 mg/L). Average hardness for plains riparian samples was 594 mg/L (range 82–1240 mg/L). Based on standard interpretations of hardness (EPA 1986), plains riparian waters would be considered hard to very hard, as were marsh waters. Alkalinity rose slightly over the summer in repeat samples, but hardness remained consistent. The same geographic trends seen in plains riparian EC values held true for alkalinity and hardness, with the lowest values seen in riparian areas north of the floodplain, intermediate values seen south, and the highest values seen close to the floodplain, likely due to the influence of marine deposits and the reuse of irrigation water.

Alkalinity and hardness in plains riparian areas were somewhat correlated, as they were in marshes, with a R^2 value of 0.60. For plains riparian areas, hardness was much more closely correlated with dissolved calcium and magnesium than was alkalinity. Hardness was greater than alkalinity in all but one site. Like marshes, the difference between hardness and alkalinity (the noncarbonated hardness) was strongly correlated to sulfates ($R^2 = 0.88$). This indicated that the hardness in marsh waters was a mix of both carbonate hardness and noncarbonated sulfate-based hardness derived from the marine sedimentary deposits of the basin.

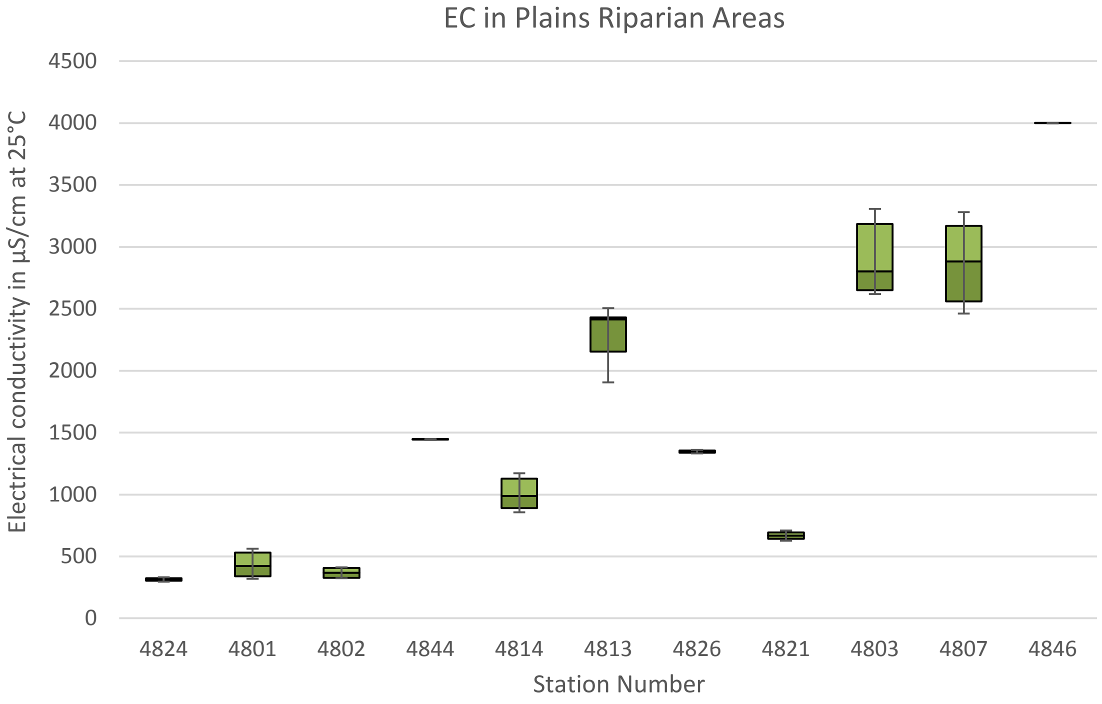

Figure 4.19. Electrical conductivity in plains riparian water samples. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

For this and all plains riparian graphs: Sites north of the floodplain (Stations 4824, 4801, 4802, 4844) are presented first, ordered west to east. Sites south of the floodplain (Stations 4814, 4813, 4826, 4821) are shown next, ordered west to east. The last three sites are located very close to the floodplain: Station 4803 on the western edge of the basin, 4807 on the eastern edge, and 4846 in the middle.

Major ions (Ca, Mg, Na, K, HCO_3, SO_4, Cl)

The dominant dissolved cations in plains riparian samples were sodium (42% of cations on average) and calcium (37%), with lesser amounts of magnesium (19%) and trace amounts of potassium (2%) (Table 4.8; Figure 4.20). The average concentration of dissolved sodium was 143 mg/L (range 11–501 mg/L); average dissolved calcium was 127 mg/L (range 2–318 mg/L); average dissolved magnesium was 63 mg/L (range 3–282 mg/L); and average dissolved potassium was 7 mg/L (range 0.9–13 mg/L). The geographic patterns of cations was similar to EC and hardness, with the highest values in sites near the floodplain. The Huerfano River site with very high EC also had very high sodium levels.

The dominant dissolved anions in plains riparian samples were sulfate (75% of anions on average) and bicarbonate (21%) (Figure 4.21). Chloride represented only 4% of anions on average. As with cations, sites near the floodplain had the highest anion concentrations, especially sulfate. The average concentration of dissolved sulfate across all sites was 682 mg/L (range 0.8–1930 mg/L); average dissolved bicarbonate was 191 mg/L (range 10–332 mg/L); and average chloride was 37 mg/L (range 0.0–106 mg/L).

There are no water quality standards for major cations in the Lower Arkansas Basin to compare these numbers against. There are water quality standards for both sulfate and chloride in the Lower Arkansas Basin. The chronic standard for sulfate is 1900 mg/L on major tributaries to the Arkansas River. Only one individual water sample surpassed the sulfate standard and a handful of other samples, all from the sites close to the floodplain, approached the standard. The standard for chloride is 250 mg/L, if used for drinking water. No samples taken in plains riparian areas were close to this standard.

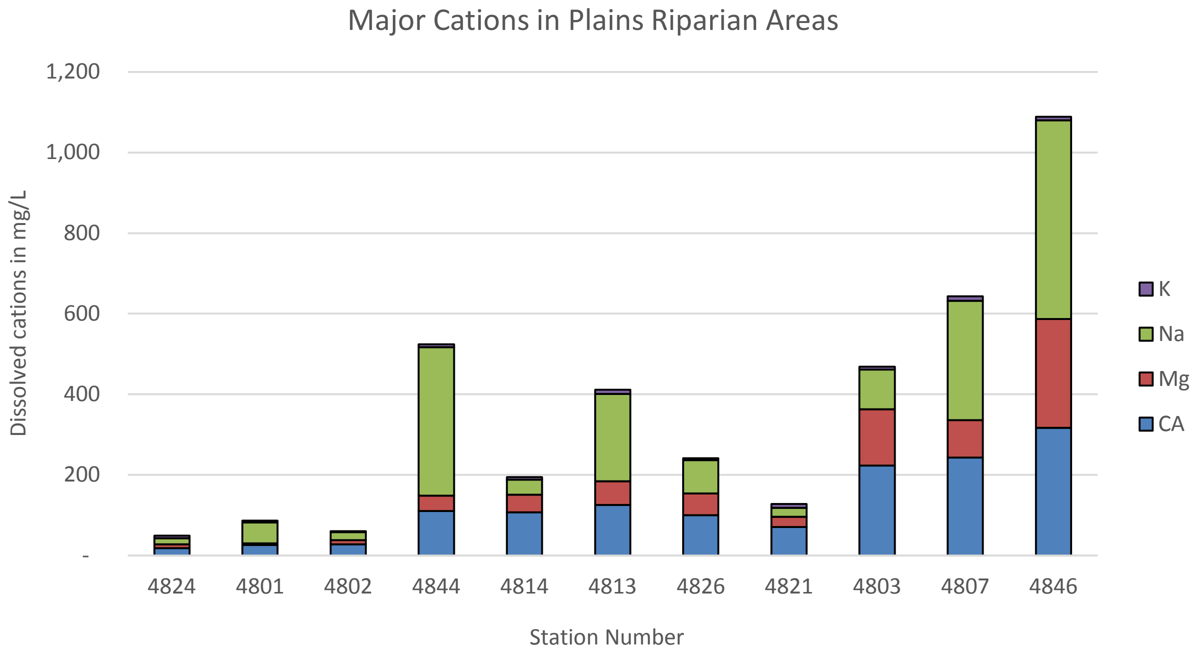

Figure 4.20. Major dissolved cations in plains riparian water samples. Values shown are averaged by site.

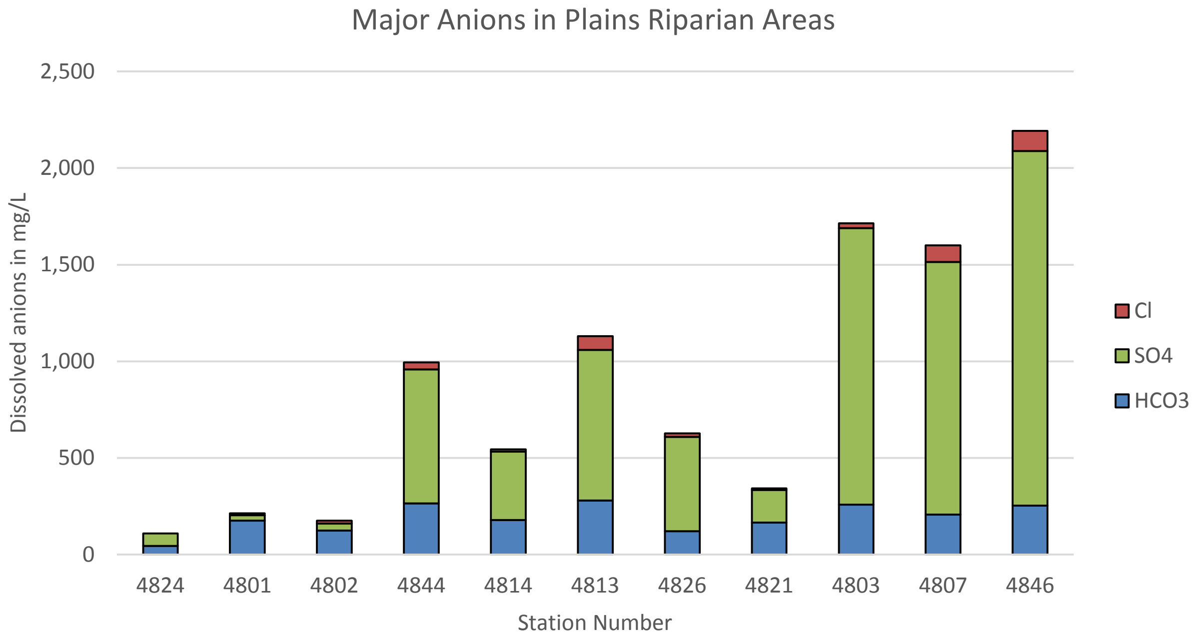

Figure 4.21. Major dissolved cations in plains riparian water samples. Values shown are averaged by site.

Common and Trace Metals (Fe, Mn, Al, As, Cd, Cu, Pb, Se, Zn)

For plains riparian areas, manganese (Mn) was the most prevalent dissolved trace metal, followed by iron (Fe) and aluminum (Al) (Table 4.8; Figure 4.24). These three metals were also the most prevalent in the total form, but in a different order. Total iron concentrations were the highest, followed by aluminum and magnesium (Figure 4.25). Iron and manganese can become soluble in anoxic conditions and it is not surprising to see these two elements in wetland waters. Aluminum is a very common element in soil and was most often found in turbid waters. The following paragraphs discuss each element in terms of concentrations and water quality standards.

Iron (Fe): As mentioned above, iron was one of the most common metals measured in plains riparian water samples, especially in the total form. The average concentration of dissolved iron was 35 µg/L (range 0.0–248 µg/L). Dissolved iron was generally low for plains riparian areas, but the highest values were seen in early summer. The average concentration of total iron was 1,295 µg/L (range 38–19,004 µg/L). Individual sites showed spikes in total iron at individual sampling dates, but there were no consistent trends by season or location. The largest spike in total iron was seen at the end of the summer in a site sampled multiple times (Station 4801). During the sample visit, the crew noted that the site was heavily grazed and the water body had been disturbed. The spike in iron occurred along with a large spike in TSS and a rise in phosphorus. The chronic water quality standard for total iron is 1,000 µg/L for all sites sampled. While the spikes were higher than those standards, the other values measured across time for most sites were lower. Iron is a concern for several tributary streams in the Lower Arkansas Basin, including Horse Creek, Timpas Creek, and Chicosa Creek. Our mid-summer samples from Horse Creek did show high total irons levels.

Manganese (Mn): Similar to iron, manganese was one of the most common metals measured in plains riparian water samples, especially in the dissolved form. The average concentration of dissolved manganese was 136 µg/L (range 0.0–678 µg/L) and far exceeded any other metal. The average concentration of total manganese was 180 µg/L (range 21–1,130 µg/L). Like iron, individual sites showed spikes. The largest spike in manganese was in Station 4801 at the end of the summer, co-occurring with the spike in TSS, iron and phosphorus. Acute and chronic water quality standards for dissolved manganese are based on hardness. Even with the spikes, no site exceeded its water quality standards.

Aluminum (Al): Aluminum was the second most prevalent metal found in plains riparian water samples in the total form. The average concentration of total aluminum was 772 µg/L (range 0.0–8,466 µg/L). As mentioned previously, total aluminum appears to be related to water clarity. The highest values for plains riparian sites all came from samples that the crew noted as turbid. While total aluminum was common in plains riparian samples, dissolved aluminum was far less common. A handful of sites had measureable dissolved aluminum during at least one time period, but no sites had dissolved aluminum in all time periods. Most measurements were below or only slightly above the reporting limit (15 µg/L). Only one sample was notably higher (58 µg/L), but several other samples from that site contained no dissolved aluminum. There are no water quality standards for aluminum in the basin to compare these values against.

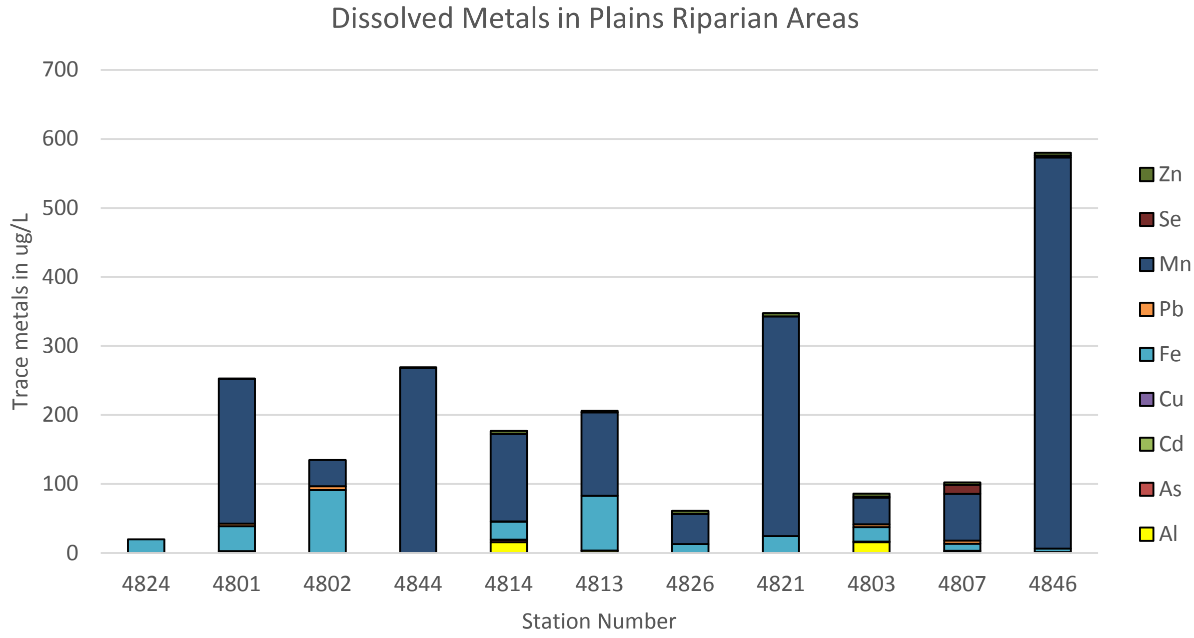

Figure 4.22. Dissolved metals in plains riparian water samples. Values shown are averaged by site.

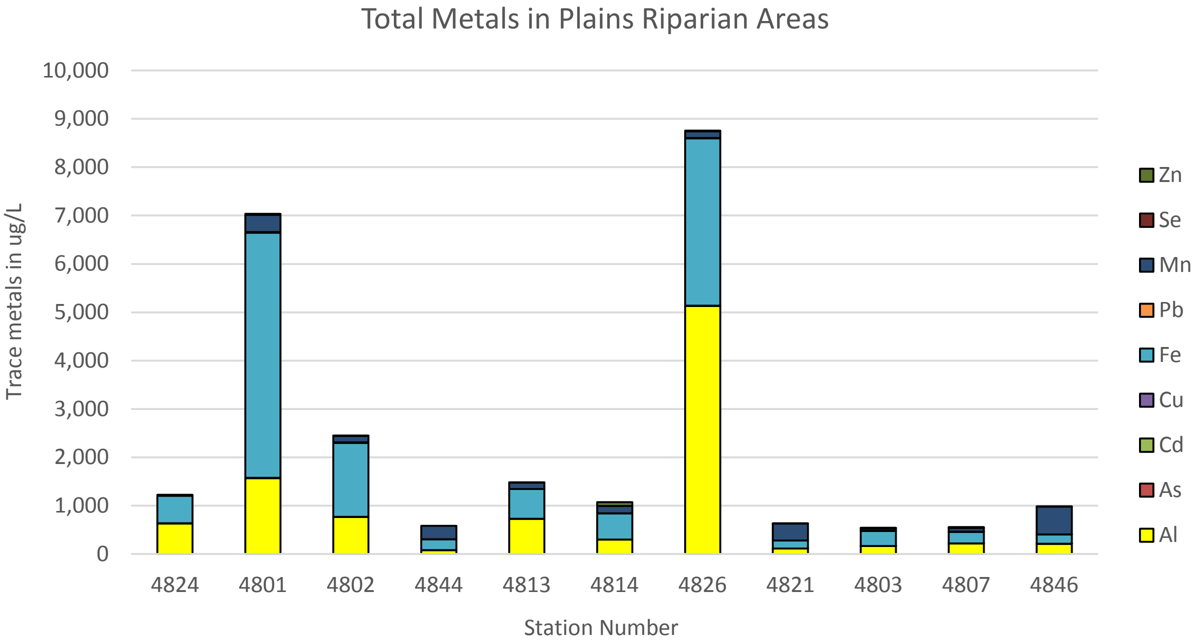

Figure 4.23. Total metals in plains riparian water samples. Values shown are averaged by site.

Arsenic (As): Arsenic in either the dissolved or total form was found in only two plains riparian sites. In both cases, arsenic was found in only one sample taken. In one sites, the measurement was below the reporting limit (15 µg/L). At the second site, the measurement of 20 µg/L was above the reporting limit, but was not found in the other five samples taken throughout the summer. The acute water quality standard for dissolved arsenic is 340 µg/L, which is far higher than the values measured. The chronic water quality standard varies by water body and use and can be as low as 0.02 µg/L. Because arsenic was only found in individual samples and not consistently within any site, these measurements do not seem to indicate a concern.

Cadmium (Cd): Cadmium was found above the reporting limit (0.15 µg/L) in nearly all plains riparian areas, but was measured above 1.0 µg/L in only one single sample in the total form. In comparison with other common metals, the concentration of cadmium was very low. The average concentration of dissolved cadmium was 0.26 µg/L (range 0.00–0.72 µg/L). The average concentration of total cadmium was 0.34 µg/L (range 0.00–1.21 µg/L). Water quality standards for cadmium are based on water hardness, with higher standards for harder water. Due to the high hardness values in plains riparian water samples, the water quality standards for cadmium were relatively high and no site exceeded either its acute or chronic standards.

Copper (Cu): Copper was found in the total form in five plains riparian sites, but in only two sites in the dissolved form. All samples where copper was detected were above the reporting limit (1.0 µg/L) and ranged from 2.0 to 16.6 µg/L. Of the five sites where total copper was detected, three were sampled multiple times throughout the summer and copper was only detected at one of the multiple sampling periods. Water quality standards for copper vary by water body. For one site where copper was detected, Station 4803 at the far western edge of the study area, the chronic standard for total copper is 200 µg/L, far beyond the values measured, and there is no standard for dissolved copper. For all other sites, there is no standard for total copper and the acute and chronic standards for dissolved cooper are based on hardness. Where detected, the values measured were far below the standards.

Lead (Pb): Lead was frequently found in plains riparian water samples, though in far lower concentrations than manganese, iron and aluminum. Dissolved lead was found in half of plains riparian sites and total lead was found in eight of 11 sites. The average concentration of dissolved lead was 2.3 µg/L (range 0.0–6.7 µg/L). The average concentration of total lead was 4.5 µg/L (range 0.0–38.4 µg/L). There were no obvious seasonal or geographic pattern in lead concentrations. Sites with high lead concentrations were found north, south and close to the floodplain. Like for copper, water quality standards for Station 4803 at the far western edge of the study area are different htan for other streams. For Station 4803, the chronic standard for total lead is 100 µg/L, far beyond the values measured, and there is no standard for dissolved lead. For all other sites, there is no standard for total lead and acute and chronic standards for dissolved lead are based on hardness. No site exceeded its acute water quality standard for lead. However, given that plains riparian areas north of the floodplain had softer water and some had higher values of lead, two of these sites did exceed the chronic water quality standards, which were fairly low and, in some case, even below the reporting limit of 5.0 µg/L (Figure 4.26).

Selenium (Se): Selenium was found in four of the eleven plains riparian sites. In three of the four, selenium was found in both total and dissolved forms. The last site contained only total selenium. In samples where dissolved selenium was found, values ranged from 5.7 to 14.6 µg/L. The acute water quality standard for dissolved selenium is 18.4 µg/L, which was never exceeded. The chronic was quality standard for dissolved selenium, however, is 4.6 µg/L, which was exceeded consistently at one site and in individual water samples from two other sites. Selenium is a major water quality concern in the Lower Arkansas Basin because it readily occurs in the basin's bedrock and is leached out both naturally and through irrigation practices. The stream reach where we consistently found selenium has been by CDPHE as an impaired water for high selenium concentrations.

Zinc (Zn): Low levels of zinc were detected in nearly all plains riparian sites. The average concentration of dissolved zinc was 2.8 µg/L (range 0.0–23.6 µg/L). The average concentration of total zinc was 16.8 µg/L (0.0–456.2 µg/L). The highest reading was an outlier that did not match other measurements form that site. There were no clear seasonal or geographic patterns in zinc concentrations and no values measured exceeded water quality standards, which are based on hardness.

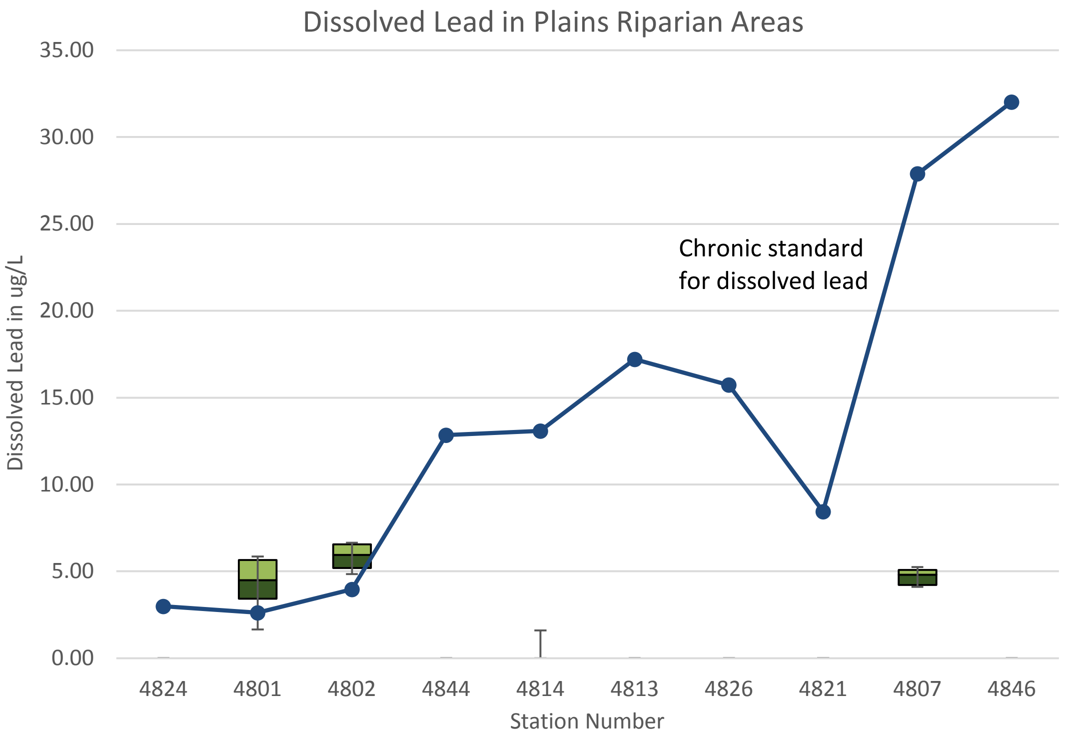

Figure 4.24. Dissolved lead in plains riparian water samples by site, compared to the chronic water quality standard, which depends on hardness. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

Nutrients (Nitrate-Nitrite, Phosphorus)

Elevated nitrate-nitrite was found slightly more often in plains riparian water samples than in marsh samples. The average value across all plains riparian samples was 1.19 mg/L (range 0.00–11.60 mg/L). Only two samples from one site (Station 4807) were above the acute standards for nitrate (Figure 4.22). Most sites also had values below the chronic standard for nitrite, but two sites (Stations 4807 and 4802) showed consistently higher values. Both sites were actively grazed by livestock and were vegetated, slowly flowing channels. The landscape surrounding Station 4807 also contained a greater percentage of cropped agriculture than other plains riparian areas. Because the measure taken was for nitrate and nitrite combined, additional sampling would be needed to determine which form of nitrogen is driving the values in these sites.

Total phosphorus was lower than nitrogen in plains riparian samples, and phosphorus was lower in plains riparian areas than it was in either marshes r playas. The average value was 0.10 mg/L (range 0.00–1.79 mg/L). All but two plains riparian areas had values less than 0.20 mg/L. The two sites with high phosphorus were north of the floodplain and both were grazed by livestock. The highest values were sampled in both mid and late summer. Water quality standards for phosphorus have been established for only one plains riparian area sampled, Station 4846 on the far eastern edge of the basin. No phosphorus was detected in that site.

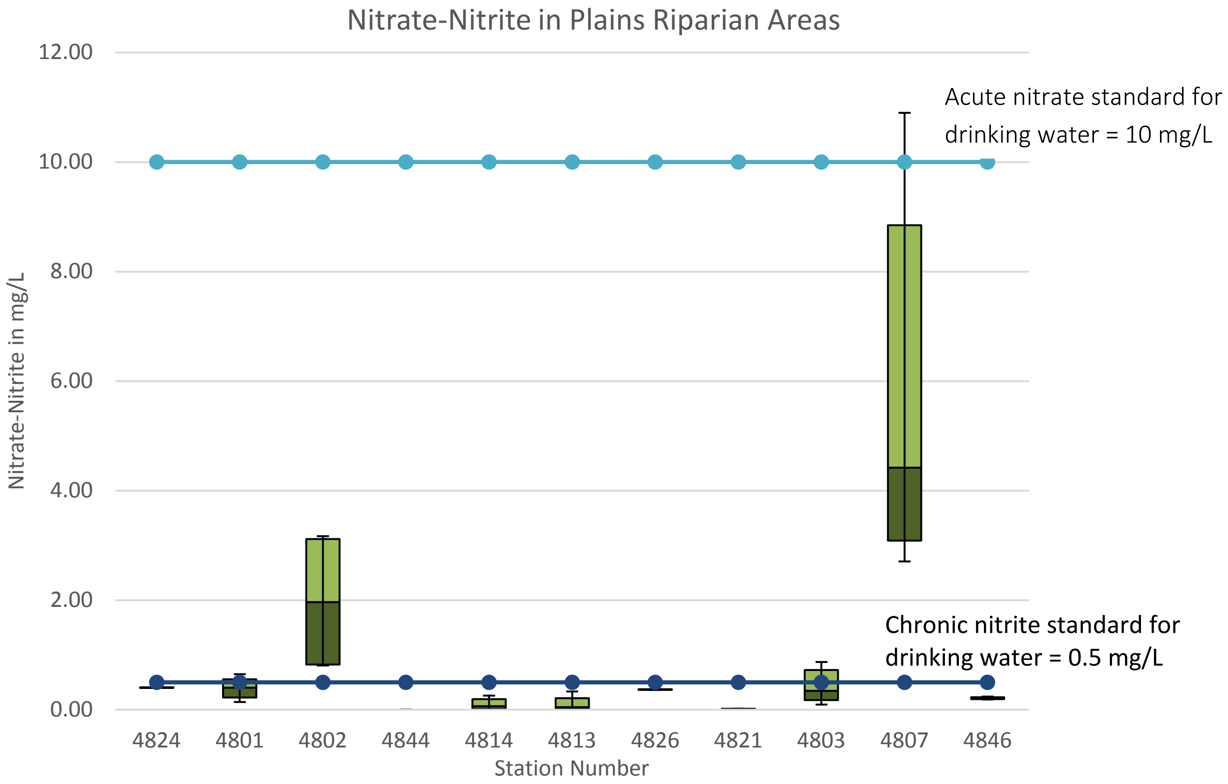

Figure 4.25. Nitrate-nitrite in plains riparian water samples by site, compared to drinking water standards for both nitrate (acute) and nitrite (chronic). Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

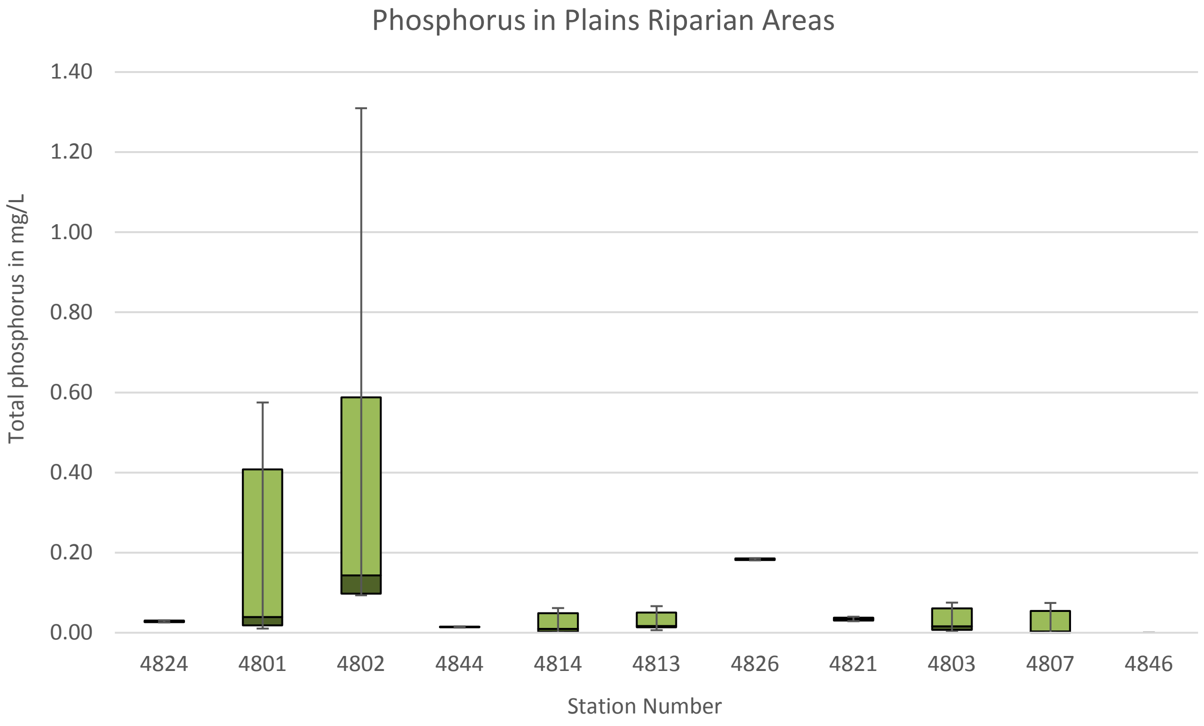

Figure 4.26. Total phosphorus in plains riparian water samples by site. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

4.3.5 Water Quality in Playas

Standard Parameters (pH, EC, TSS, Alkalinity and Hardness)

Playas had the highest pH across wetland types. The average for all playa samples was 8.67 (range 7.69–9.78) (Table 4.8). With only one site sampled in two time periods, there was not enough data to reveal trends across the season. On average, samples taken early in the summer were higher than those taken in mid-summer, but for the one site sampled twice, pH went up between early and mid-summer.

In contrast to pH, playas had the lowest EC values across wetland types. Like pH, there was not enough data to show a seasonal trend in EC in playas. The average EC for all playa samples that could be measured was 315 µS (range 121–528 µS). However, one playa (Station 4804) had an EC that was too high to be measured by our field probe, which maxed out at 3999 µS. Water samples from Station 4804 showed a number of distinct characteristics that will be mentioned throughout this section. For calculating most averages and relationships, Station 4804 was removed from the analysis and is described separately, as its water chemistry was unlike any other site sampled.

Playa water samples contained higher total suspended solids (TSS) than either marsh or riparian samples, in general, although there were high TSS measurements in all wetland types. On average, TSS in playa sample was 270 mg/L, compared to 34 mg/L in marsh samples and 49 mg/L in riparian samples. Most TSS measurements in playas ranged from 60 mg/L to nearly 850 mg/L. The highest TSS measurements were in mid-summer, but there were not enough data to conclude whether TSS rises throughout the summer. TSS and other parameters in playas may rise throughout the summer, as water within playas slowly evaporates and constituents within the water could become more concentrated.

In general, playa samples had lower alkalinity and hardness than marsh or riparian samples. However, Station 4804 was an extremely alkaline playa with the highest alkalinity measurement by far across all sites (1380 and 1230 mg/L for the two samples taken in early summer). The water samples for Station 4804 could not be titrated for hardness because they reacted to the buffer immediately. With Station 4804 removed, average alkalinity was 133 mg/L, compared to 252 mg/L for marsh samples and 210 mg/L for riparian samples. Average hardness for playa samples was 149 mg/L, compared to 569 mg/L for marsh samples and 594 mg/L for riparian samples. Hardness was closely related to alkalinity in playas, with an R^2 value of 0.81. This relationship was far stronger than for marshes or plains riparian areas. The tight relationship indicates that most hardness in playas is carbonate harness. Alkalinity and harness were both closely related to total calcium and magnesium concentrations.

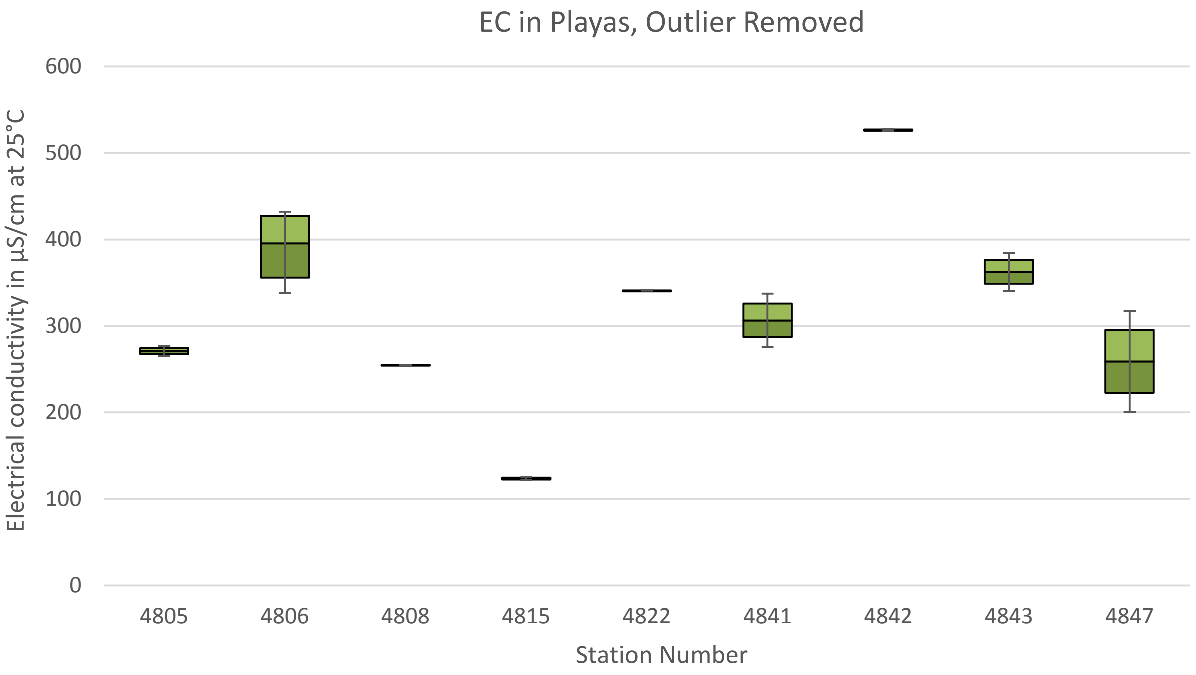

Figure 4.27. Electrical conductivity in playa water samples, outlier Station 4804 removed. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile. Sites ordered by station number, as no clear geographic pattern was found.

Major ions (Ca, Mg, Na, K, HCO_3, SO_4, Cl)

We were unable to filter a sample for dissolved cations and metals in the outlier Station 4804, as the water was so turbid. However, total measurements were taken for cations and can be used as a proxy to show the degree to which it differed from other playas because dissolved and total cations were strongly correlated across all sites. While calcium and potassium levels were similar between Station 4804 and other playas, magnesium levels were 5–10x higher and sodium levels were up to three orders of magnitude higher. The two water samples taken in Station 4804 contained 50 and 55 mg/L of magnesium and 1200 and 1130 mg/L of sodium (Figure 4.28). Similarly, Station 4804 had the highest chloride measurement across all sites (369 and 343 mg/L for the two samples) (Figure 4.29).

With Station 4804 removed, playa samples contained substantially lower levels of dissolved calcium, magnesium, and sodium than marshes or riparian areas, but higher levels of potassium. The dominant dissolved cations in playa samples were calcium (54% of cations on average) and potassium (24%), with lesser amounts of sodium (14%) and magnesium (9%) (Table 4.8; Figure 4.30). The average concentration of dissolved calcium was 34 mg/L (range 7–77 mg/L); average dissolved potassium was 15 mg/L (range 4–50 mg/L); average dissolved sodium was 9 mg/L (range 0.3–65 mg/L); and average dissolved magnesium was 6 mg/L (range 2–12) mg/L.

The dominant dissolved anions in playa samples were bicarbonate (44% of anions on average), sulfate (36%) and chloride (21%) (Figure 4.31). Playa water samples contained significantly lower levels of sulfate than marshes and plains riparian samples. Average sulfate across all playa samples was 72 mg/L, compared to 447 mg/L in marsh samples and 682 mg/L in riparian samples. The average for playas, however, was significantly affected by the outlier Station 4804, which contain 529 and 462 mg/L sulfates in its two samples. With the outlier removed, average sulfate in playa samples was even lower, only 25 mg/L. Sulfate levels were generally the same between early and mid-summer samples, though the one site sampled twice did have higher sulfate in mid-summer than in early summer. With the exception of Station 4804, chloride was far lower in playa samples than in marsh or riparian samples. With Station 4804 removed, the average chloride level in playa samples was 7 mg/L, compared to 50 mg/L in marsh samples and 37 mg/L in riparian samples. Chloride also appeared to rise during the summer, with higher measurements taken in mid-summer.

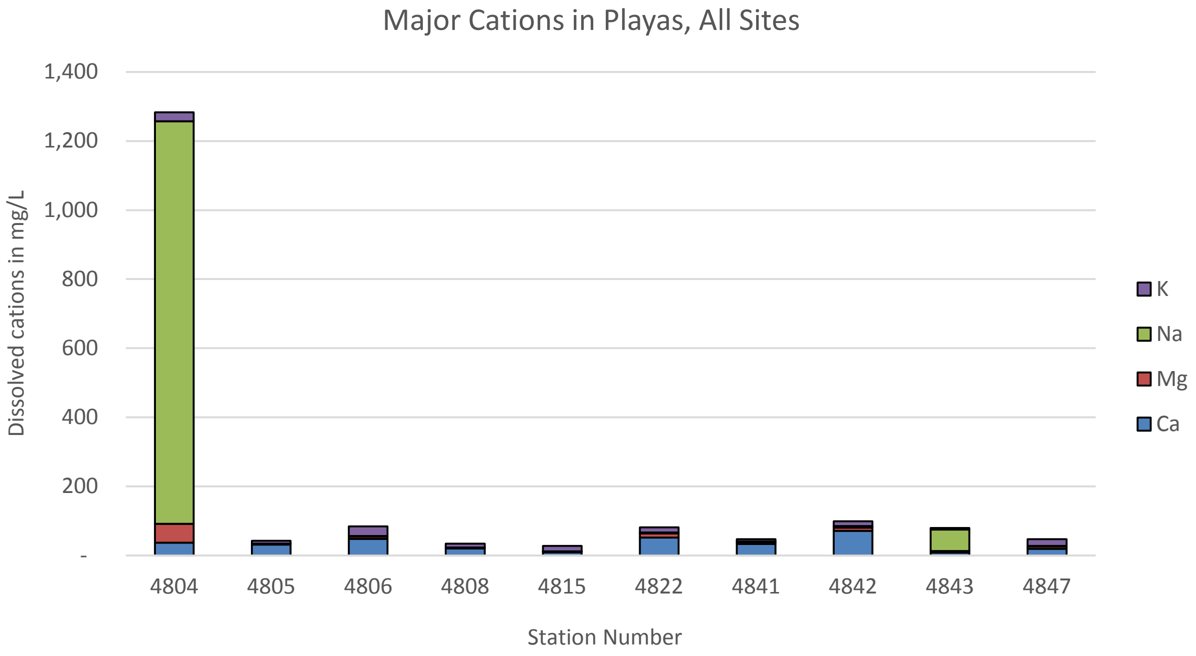

Figure 4.28. Major dissolved cations in playas water samples. Values shown are averaged by site. Values for Station 4804 are total Ca, Mg, Na, K rather than dissolved.

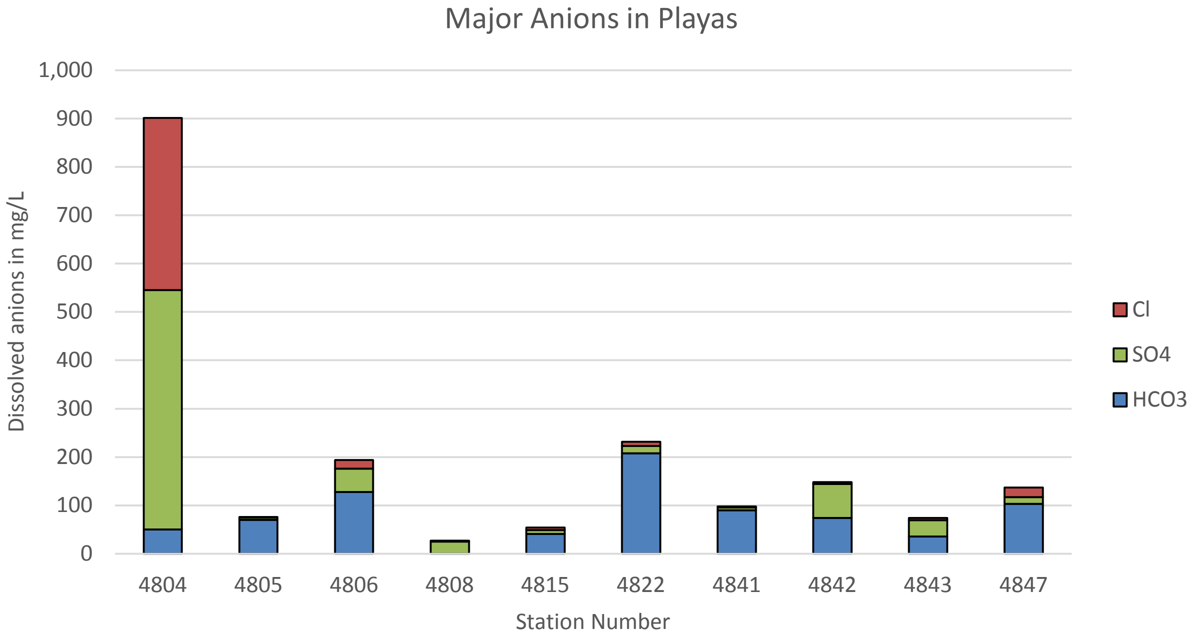

Figure 4.29. Major dissolved anions in playa water samples. Values shown are averaged by site.

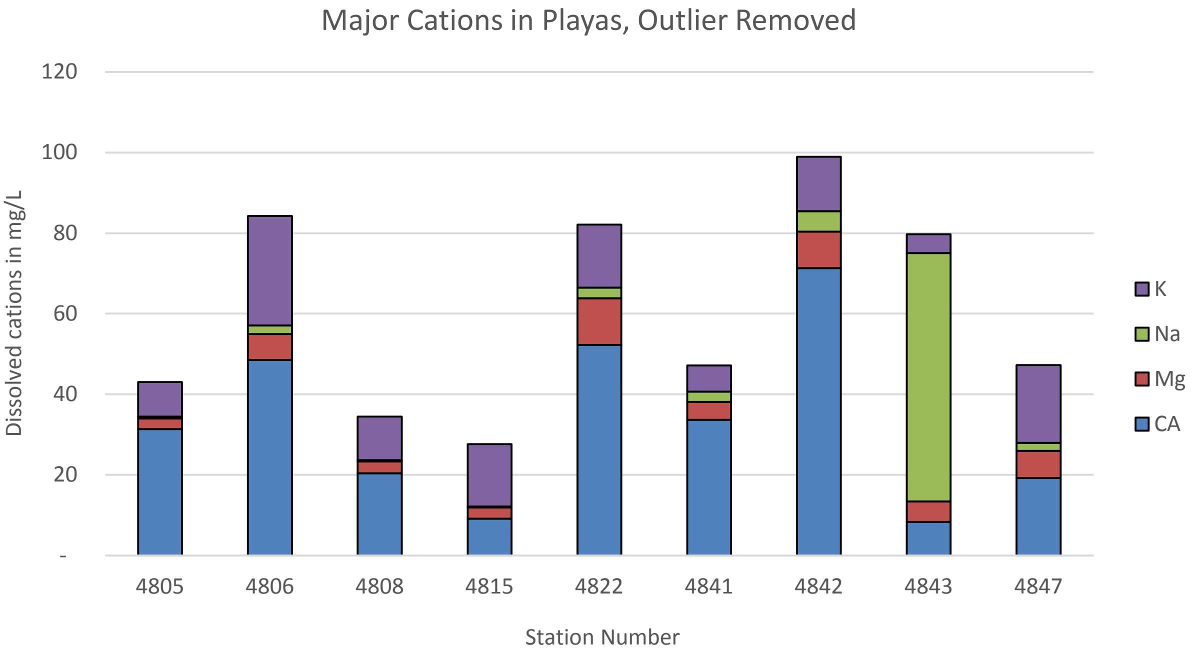

Figure 4.30. Major dissolved cations in playa water samples, outlier removed. Values shown are averaged by site.

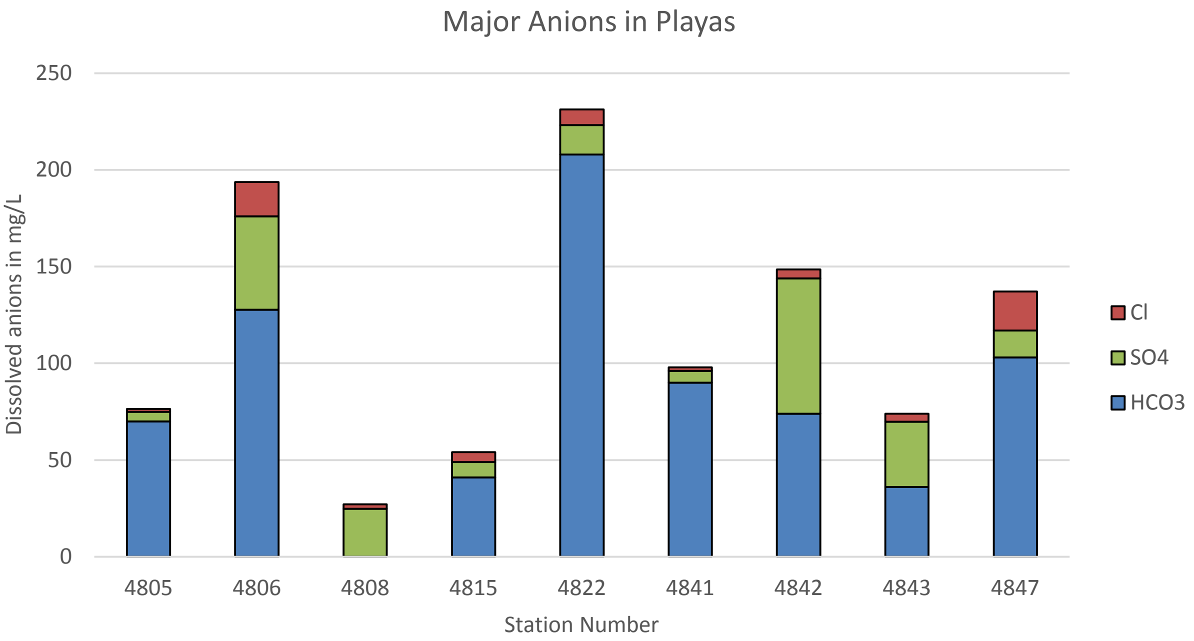

Figure 4.31. Major dissolved anions in playa water samples, outlier removed. Values shown are averaged by site.

Common and Trace Metals (Fe, Mn, Al, As, Cd, Cu, Pb, Se, Zn)

Similar to marshes and plains riparian areas, iron, manganese and aluminum were common metals in playas (Table 4.8). However, unlike marshes and plains riparian areas, other dissolved metals like arsenic, copper, and zinc were far more common in playas. For total metals, iron and aluminum were by far the most prevalent, likely derived from suspended fine soil particles in the turbid waters of playas (Figure 4.35). Total metals as a group were far higher for playas than the other wetland types, as we saw with TSS. The outlier playa, Station 4804, which had the highest alkalinity and major ions, and unmeasurable hardness and EC, also contained the highest levels of total metals. The waters of this site were so turbid that we were unable to collect a filtered sample for analyzing dissolved metals, so this site is excluded from discussions of dissolved metals. The following paragraphs discuss each element in terms of concentrations and water quality standards.

Iron (Fe): Iron was one of the most common metals measured in playa water samples, especially in the total form. The average concentration of dissolved iron was 60 µg/L (range of 0.0–269 µg/L). The average concentration of total iron was 11,242 µg/L (range 576–34,800 µg/L). Total iron was proportionally similar across all playas (i.e., sites with high total metals had high total iron and sites with lower total metals had less). But dissolved iron was high in just a couple specific sites. Total iron concentrations were higher than other wetland types, but dissolved iron was not as high as was seen in marshes. The chronic water quality standard for total iron is 1,000 µg/L for all sites sampled, which was exceeded in nearly every sample taken.

Manganese (Mn): Manganese was not nearly as common in playa water samples as it was in other wetland types, but was still one of the most prevalent dissolved metals. The average concentration of dissolved manganese was 45 µg/L (range 0.0–258 µg/L) and it was particularly high in only a few sites. The average concentration of total manganese was 469 µg/L (range 29–1,800 µg/L). Acute and chronic water quality standards for dissolved manganese are based on hardness and no site exceeded its water quality standards.

Aluminum (Al): Aluminum was the second most prevalent trace metal, behind iron, found in playa water samples in the total form. The average concentration of total aluminum was 12,818 µg/L (range 0.0–48,780 µg/L), which was far greater than the concentrations found in marshes and plains riparian areas. Levels of total aluminum were likely much higher in playas than in other wetland types due to the naturally shallow and turbid waters of playas. While high levels of total aluminum was common in playas, dissolved aluminum was less common, occurring in just over half of playa water samples. The average concentration of dissolved aluminum was 19.2 µg/L (range 0.0–116 µg/L), which is still much higher than other wetland types. There are no water quality standards for aluminum in the basin to compare these values against, however, these values are not above generally recommended standards (GEI Consultants 2011).

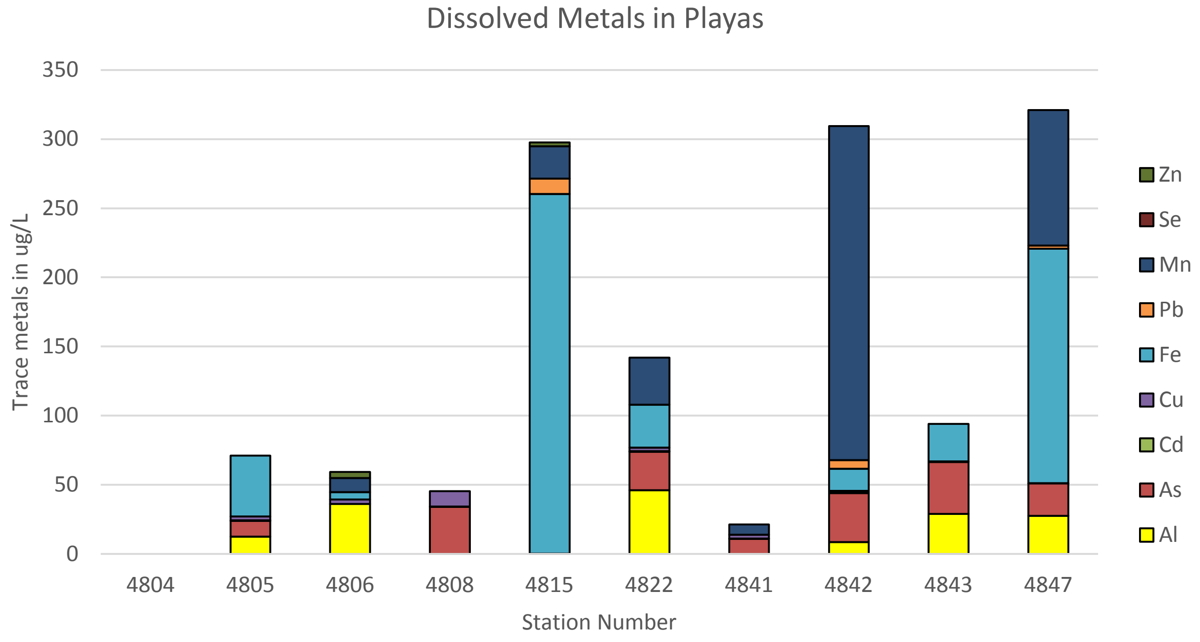

Figure 4.32. Dissolved metals in playa water samples. Values shown are averaged by site.

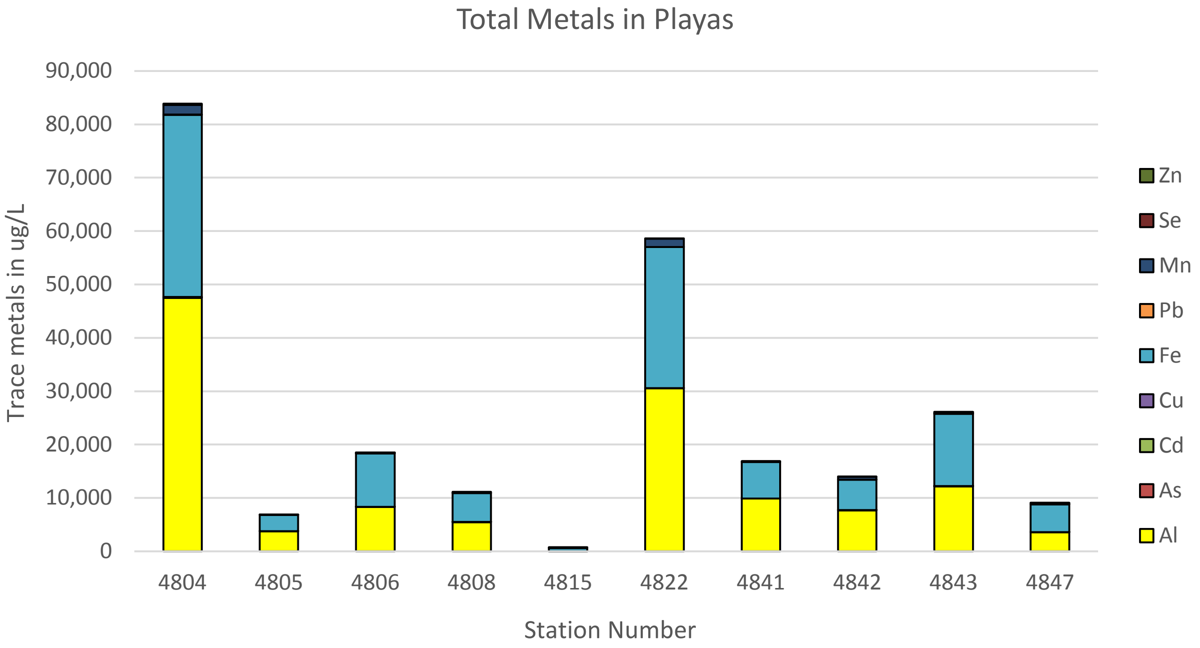

Figure 4.33. Total metals in playa water samples. Values shown are averaged by site.

Arsenic (As): Arsenic was relatively common in playa water samples and was found in all but two playas, generally above the reporting limit. The average of dissolved arsenic was 16.6 µg/L (range 0.0–41 µg/L). The average of total arsenic was 24 µg/L (range 0.0–115 µg/L). The acute water quality standard for dissolved arsenic is 340 µg/L, which is far higher than the values measured. The chronic water quality standard varies by water body and can be as low as 0.02 µg/L if used as a water supply or 7.6 µg/L if not. Many playas in the basin are used to water cattle, and some of the very large playas were historically used to hold irrigation water. None of the playas sampled in this study appear to be used for human drinking water, however, so the levels of arsenic are likely not a concern for human consumption, but might be a concern for livestock.

Cadmium (Cd): Total cadmium was found above the reporting limit (0.15 µg/L) in all playas, and did exceed 1.0 µg/L in several sites. The average concentration of total cadmium was 1.04 µg/L (range 0.27–4.50 µg/L), which was much higher than in other wetlands types. Dissolved cadmium was found in all but one playa. The average concentration of dissolved cadmium was 0.28 µg/L (range 0.0–0.56 µg/L). There are no water quality standards for total cadmium for the playas sampled, but chronic water quality standards for dissolved cadmium are based on water hardness. While the levels of dissolved cadmium were similar for many playas, some sites with softer water did exceed the chronic standards (Figure 4.37).

Copper (Cu): Total copper was found all but one playa sampled, and dissolved copper was found in six out of ten sites, though we were unable to collected a filtered sample for dissolved metals from Station 4804, which had the highest total copper by far (54 and 60 µg/L). This site may have had dissolved copper as well, but we could not measure it. The average concentration of total copper, including Station 4804, was 11 µg/L. Without Station 4804, the average was only 6 µg/L (range 0.0–14.2 µg/L). There are no water quality standards for total copper for the playas sampled, but acute and chronic standards for dissolved cooper are based on hardness. One playa exceeded the acute standard for dissolved copper and several playas exceeded the chronic standard (Figure 4.38).

Lead (Pb): Total lead was found in every playa, but dissolved lead was found in only three. The average concentration of total lead was 22.4 µg/L, with values ranging from 5.6 to 73.3 µg/L. The average concentration of dissolved lead was 2.8 µg/L, with values ranging from 0.0 to 11.1 µg/L. Acute and chronic water quality standards for dissolved lead are based on hardness. No site exceeded its acute water quality standard for lead, but one of the three sites where dissolved lead was detected did exceed its chronic standard in both samples, while another exceeded the standard in one sample (Figure 4.39).

Selenium (Se): Total selenium was found in only one playa, but dissolved selenium was never detected in any playa water sample.

Zinc (Zn): Total zinc was found in all playas, but dissolved zinc was only detected in two sites and in both cases, it was found in only one of two samples. The average concentration of total zinc was 47 µg/L (range 0.0–195 µg/L). The average concentration of dissolved zinc was 1.3 µg/L (0.0–17.5 µg/L). Water quality standards were not exceeded.

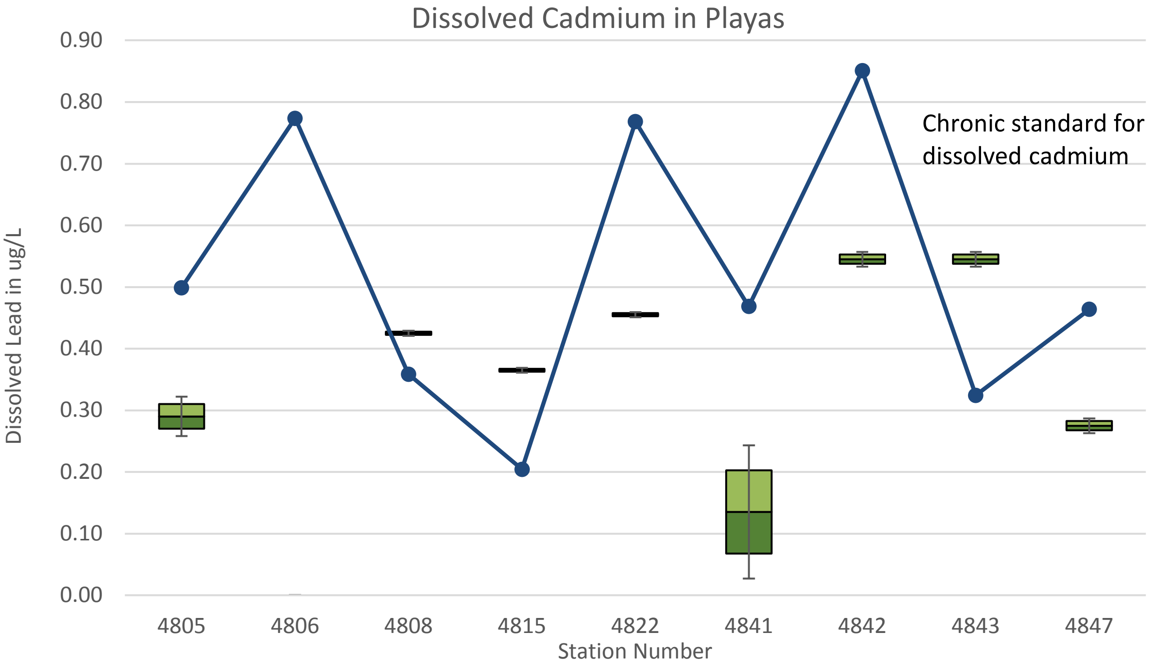

Figure 4.34. Dissolved cadmium in playa water samples by site, compared to the chronic water quality standard, which depends on hardness. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

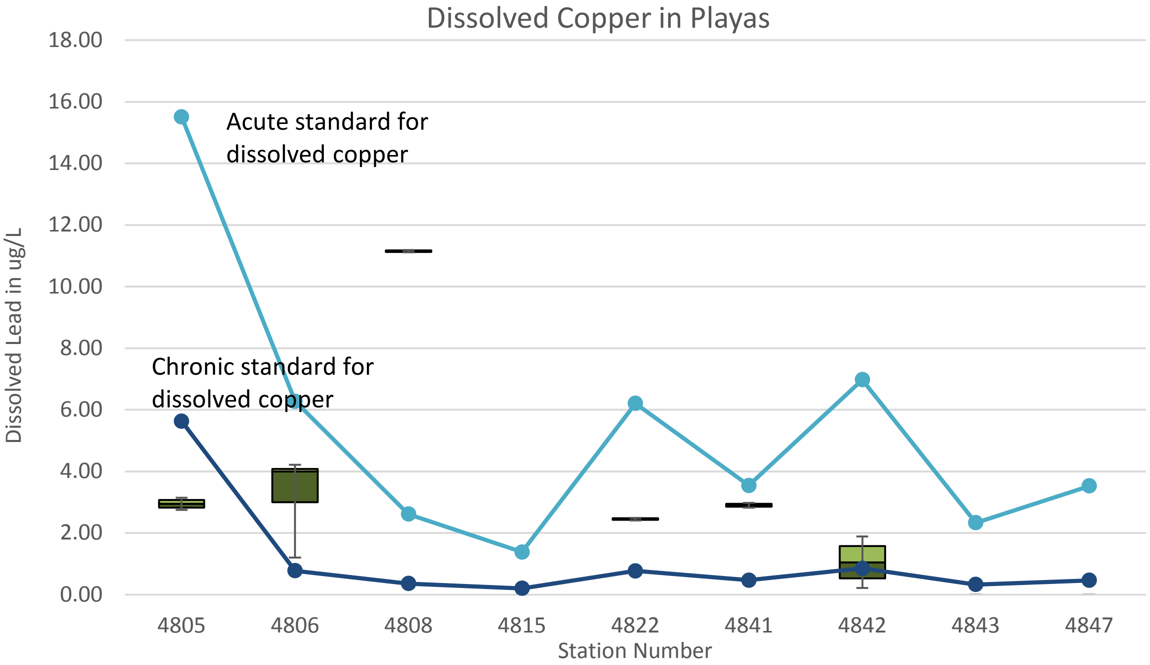

Figure 4.35. Dissolved copper in playa water samples by site, compared to the acute and chronic water quality standards, which depends on hardness. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

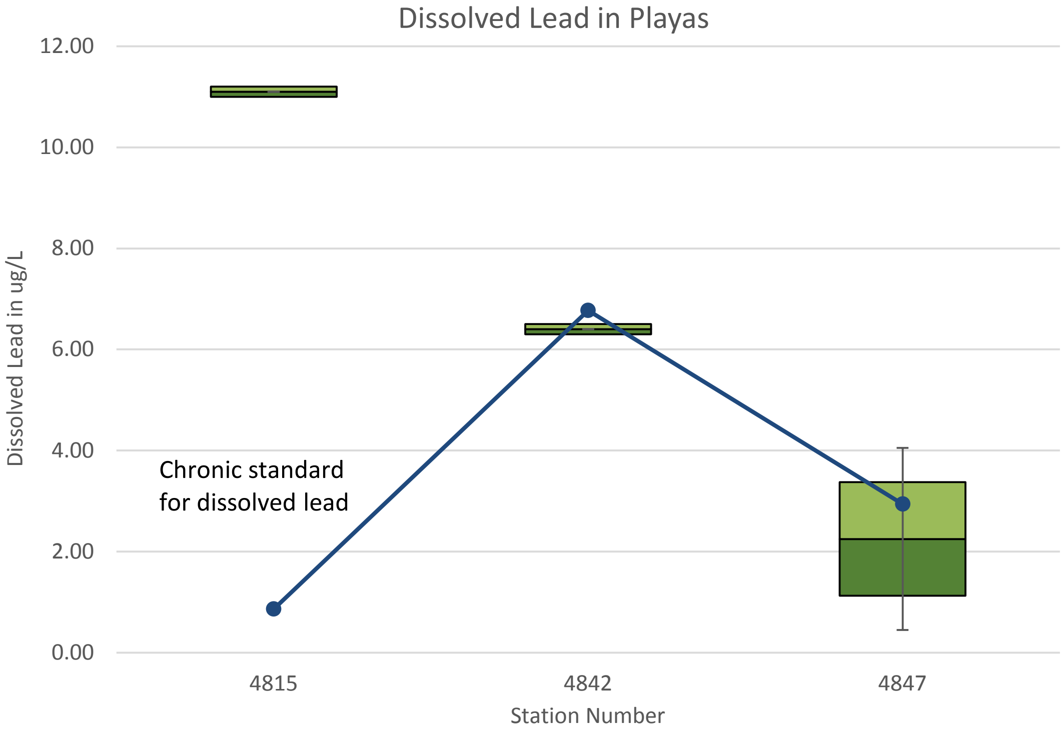

Figure 4.36. Dissolved lead in playa water samples by site, compared to the chronic water quality standard, which depends on hardness. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile. Only sites where lead was detected are shown.

Nutrients (Nitrate-Nitrite, Phosphorus)

Playa water samples contained significantly lower levels of nitrate-nitrite than marshes and plains riparian samples. Average nitrate+nitrite across all playa samples was 0.34 mg/L (range 0.00–1.32 mg/L), compared to 0.91 mg/L in marsh samples and 1.19 mg/L in riparian samples (Table 4.8). All samples were well below the acute water quality standard, though two sites did have values above the chronic nitrite standard (Figure 4.32). There was some indication that nitrate+nitrite levels increased during the summer, as mid-summer values were higher than early summer values, but there are too few data to say with confidence.

Unlike nitrate-nitrite and sulfate, phosphorus levels were much higher in playas than other wetland types and this difference was most pronounced in mid-summer (Figure 4.33). Average total phosphorus across all playa samples was 5.2 mg/L, but the average of early summer samples was 0.9 mg/L and the average of mid-summer samples was 12.2 mg/L (Figure 4.34). The average for marsh and riparian samples was 0.3 mg/L and 0.1 mg/L, respectively, and the highest value in either system was 1.5, an order of magnitude lower than the high values found in mid-summer playas.

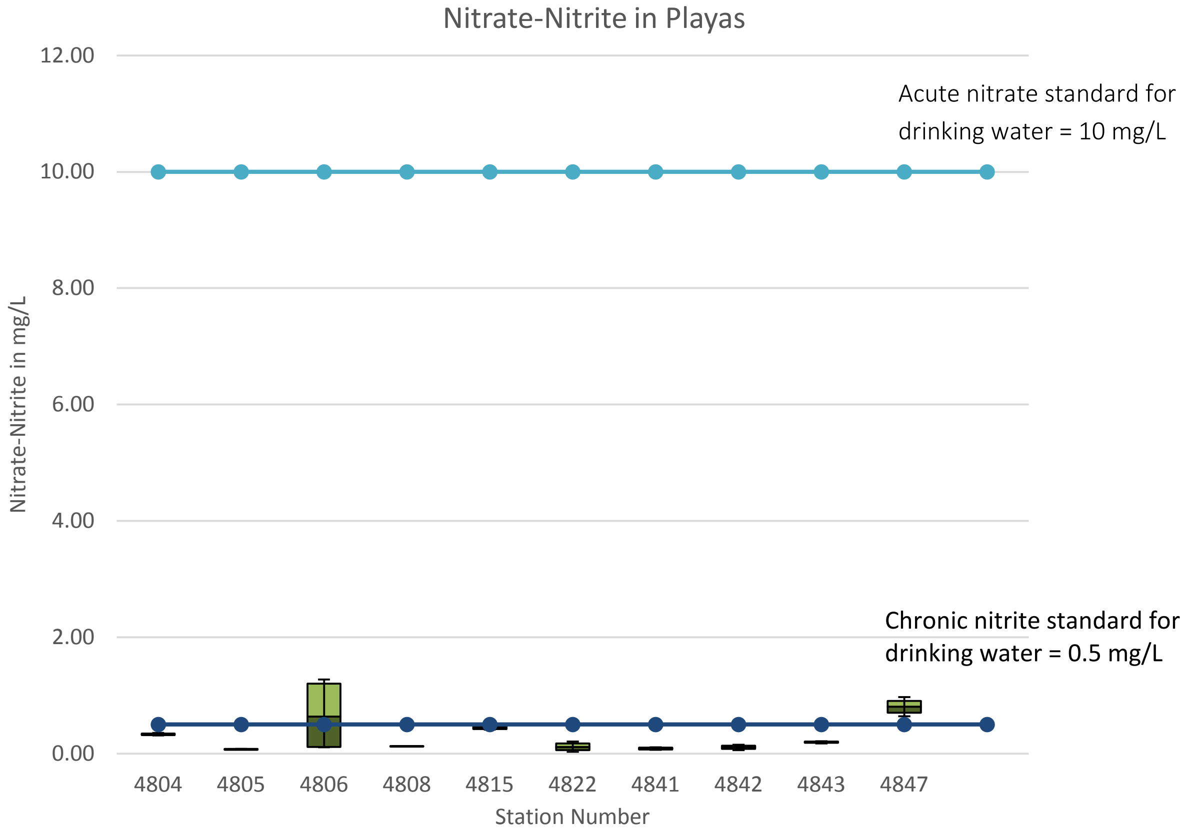

Figure 4.37. Nitrate-nitrite in playa water samples by site, compared to drinking water standards for both nitrate (acute) and nitrite (chronic). Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

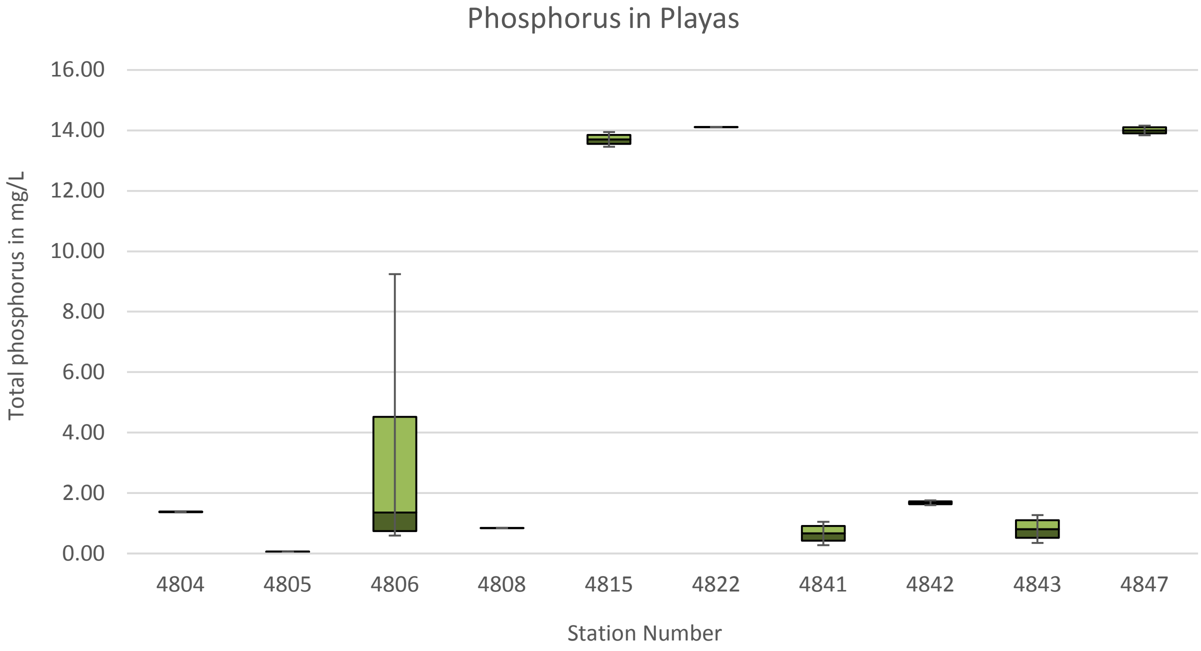

Figure 4.38. Total phosphorus in playa water samples by site. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

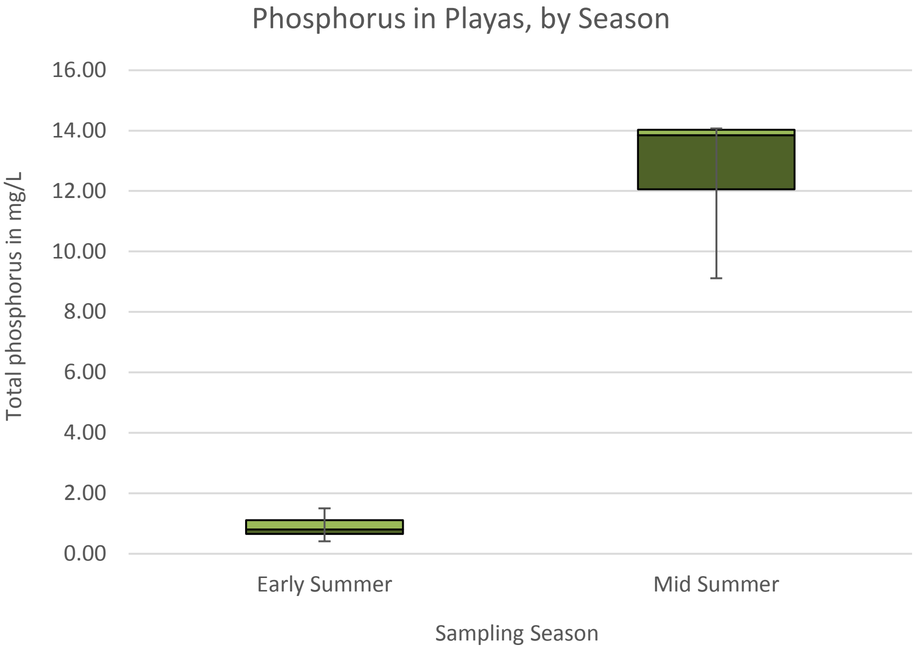

Figure 4.39. Phosphorus is playas by season. Boxes represent the 25th to 75th percentile, with dark green below the median and light green above. Error bars represent the 10th to 90th percentile.

4.4 Discussion

This study is the first to sample and analyze water quality parameters in a range of wetland types on the plains of Colorado, and specifically the Lower Arkansas Basin, to compare those values against known ranges in the well-monitored mainstem of the Arkansas River and against water quality standards. The most notable finding was the contrast between water quality values in marshes and plains riparian areas, which were generally similar to the Arkansas River mainstem, and playas, which were strikingly different.

In addition, there were clear patterns related to location within the basin and by proximity to intensive land uses. The highest levels of salts, sulfate, and chloride were found near the Arkansas floodplain within the central irrigated valley of the basin, while lower levels were found in the plains. While natural bedrock geology is a major contributor to these constituents in the Lower Arkansas, land use also plays a role. Few states monitor water quality in wetlands, but those that do have found that phosphate, sulfate, and chloride are the biggest constituents of concern (Genet 2015; Sandy Crystall, New Hampshire Department of Environmental Services, *personal communications*).

Water Quality by Wetland Type

Marshes sampled in the Lower Arkansas Basin, particularly those on the floodplain, had high EC, high hardness, and high concentrations of dissolved cations and sulfates. There was some indication that these parameters increased in a downstream gradient, with the exception of one floodplain marsh near John Martin Reservoir with lower values. In general, these values and the increasing trends down gradient are similar to values shown for the mainstem. Previous studies have found that major ion concentrations are high in the Lower Arkansas Basin and increase downstream, as a result of both the natural sedimentary geology and increased agricultural return flows that concentrate salts (Ortiz et al. 1998). Marshes on the plains, however, were distinct from their floodplain counterparts. Plains marshes were not influenced by irrigation return flows and were located in a different geologic setting. These sites had lower EC, hardness, and concentrations of dissolved cations.

Most metals were relatively absent in marsh water samples, with the exception of iron and manganese, which were present in high levels, likely due to anoxic conditions within marsh soils that can mobilize soluble iron. Total aluminum was also present in marshes, likely from soil particles suspended in marsh waters, but was generally only high in turbid water samples. Dissolved aluminum was essentially absent, as was arsenic, copper, and selenium in both total and dissolved forms. Cadmium, zinc and lead were present, but generally in low concentrations below water quality standards, especially because the high hardness of floodplain marshes buffers the impact of these metals. Where hardness was high, water quality standards for many metals were also high. However, the lower hardness of the plains marshes meant that similar concentrations of lead in these sites actually exceeded their chronic water quality standards.

Water quality values in plains riparian areas were variable depending on location within the basin, surrounding geology, and proximity to the Arkansas floodplain. Sites closest to the floodplain showed water quality signatures similar to marshes and to the mainstem Arkansas River, with high EC, hardness and cations; sites in the southern plains had intermediate values of EC, hardness, and cations; while sites on the northern plains had the lowest. Like marshes, total aluminum was present in turbid waters of plains riparian areas, but dissolved aluminum was rare. In addition, arsenic, cadmium, copper, and zinc were all either absent or found at very low levels. However, dissolved lead and dissolved selenium were found to be of concern in certain sites. Two riparian areas on the northern plains with softer water exceeded their chronic standards for dissolved lead. This was similar to the plains marshes with softer water. Dissolved selenium was detected in three plains riparian sites, and was consistently above the chronic threshold at one of these sites. Selenium was not detected, however, in one other stream that was previous known to carry selenium.

Selenium has been regularly detected in numerous rivers and stream in the basin, including the mainstem, which is close proximity to the floodplain marshes (Miller et al. 2010). Given the known occurrence of selenium, the frequency and level of detection in this study was relatively low. A potential future study could sample waters both entering and leaving wetlands along stream reaches where selenium is known to occur to test whether there is any reduction in selenium as water passes through the wetlands, as has been documented in other locations (Hansen et al. 1998; Mackowiak et al. 2004). In addition, tissue from wetland plants could also be tested for selenium concentrations. While the wetlands may be removing selenium from the water column, selenium in wetland sediments and wetland plant tissue may be a concern for wildlife using the wetlands (Pressler et al. 1994; Lemly et al. 1993).

In contrast to marshes and plains riparian areas, playas were very different in terms of EC, hardness, dissolved cations, and metals. Aside from one highly alkaline playa that was an outlier in many ways, playas generally had lower EC, alkalinity, hardens, dissolved cations, and sulfate than other wetland types. The dominant ions in playas were also different. Playas contained substantially lower levels of calcium, magnesium, and sodium cations, but higher levels of potassium. They also contained higher concentrations of bicarbonate anions, as opposed to the dominance of sulfate anions in marshes and riparian areas.

While playas had lower hardness to act as a buffer, they also had higher concentrations of most metals and they were more likely to exceed water quality standards. Playas exceeded water quality standards for total iron and dissolved arsenic, cadmium, copper, and lead. They also contained much higher concentrations of dissolved aluminum. Higher concentrations of metals in playas is likely linked to their hydrodynamics and position within the landscape. While plains riparian areas and even most marshes are flow-through systems, with water passing through wetland areas and moving downstream, playas are sinks that absorb runoff from the surrounding landscape. Any material that enters a playa will likely stay within the playa, as most have no natural outlet. Over time, metals within the surrounding soil, either naturally occurring metals or metals applied to the soil through agricultural chemicals, can accumulate in playas through conveyance by both surface water runoff and wind deposition (Smith 2003). However, though many metals occurred within playas in high levels, dissolved selenium, the metal of highest concern in the basin, was never detected. This may be because sampled playas were not located to major outcrops of selenium baring bedrock.

Nutrients in Wetland Water Samples

Across all wetland types, nutrients were not a major concern, but there were notable trends. Elevated nitrogen, in the form of nitrate and nitrite combined, occurred in a handful of sites, including one plains marsh, two plains riparian areas, and, to a lesser extent, two playas. All sites with elevated nitrogen were grazed and nitrogen may have entered the sites through livestock waste. The watershed surrounding the riparian area with the highest levels also contained a high percentage of tilled crop fields of corn, sorghum, and wheat. While wetlands are known to be particularly efficient at removing nitrogen (Johnston 1991), the elevated levels may indicate that either inputs were higher than could be processed or that residence time within the wetland was not long enough for complete denitrification.

Phosphorus showed the clearest seasonal pattern of any parameter measured. Phosphorus was highest in mid-summer for all three wetland types and was particularly high in playas. Phosphorus can enter wetlands with suspended sediments or as dissolved phosphorus. Phosphorus entering wetlands can become bound up in soil particles or in plant tissue, especially in flooded conditions. However, phosphorus is released as wetlands dry out, which happens throughout the summer as water levels recede (Reddy et al. 1999; Aldous et al. 2005).

Summary Conclusions

The findings in this study merely begin to describe water quality conditions in wetlands of the Lower Arkansas Basin. We hope future studies can use the results presented here to explore additional questions about the processes and transformation of water quality constituents in wetlands on Colorado’s plains. Given the attention paid to water quality in the basin, more should be done to explore the role that wetlands currently play in improving water quality conditions and how additional management of wetlands, whether through restoration of native vegetation or managing water levels, might increase their water quality functions.

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APPENDIX A: FIELD KEY TO WETLAND AND RIPARIAN ECOLOGICAL SYSTEMS OF THE LOWER ARKANSAS BASIN

Last Updated June 6, 2015

Ecological systems are dynamic assemblages of plant communities that 1) occur together on the landscape; 2) are tied together by similar ecological processes and underlying abiotic environmental factors (soils, hydrology, landscape position, disturbance regime, etc.); and 3) form a readily identifiable unit on the ground. Ecological systems include both native, natural vegetation and non-native, human influenced vegetation. All wetland and riparian areas encountered in the Lower Arkansas Basin should fit within the key. If a wetland or riparian area is clearly manipulated, created, or otherwise does not fit a description, attempt to fit it in one of the ecological systems and take note of how and why it differs from the description given. Within this version of the key, many comments are specific to the Lower Arkansas Basin.

The scale at which ecological systems are delineated is important. Within the context of CNHP's wetland assessment projects, an assessment area (AA) could represent the entire extent of an ecological system or just part of one. If a wetland or riparian area is larger than the AA, all aspects of the system should be considered in the key, not just those within the AA. ***Make sure to look at the larger landscape when using this key.*** A mosaic of herbaceous and shrubby vegetation patches does not necessarily mean multiple ecological systems. Changes in dominant soil type or hydrology, however, can mean multiple ecological systems. Pay close attention to the size thresholds in the key when determining the ecological system or systems present. Percent cover thresholds are guidelines for the *footprint of an entire stratum*, not the percent cover of individual species, and are determined for the overall ecological system rather than the confines of the specific AA.

1a. Wetlands that are isolated or partially isolated from floodplains and riparian zones. Often depressional or sloping, but may have an outlet. May be influenced by direct or indirect irrigation water. Vegetation is generally herbaceous. Large marshes associated with reservoirs key here, as do marshes located on the historic floodplain of the Arkansas River, but far from the active area of overbank flooding.................................... **2**

2b. Sites located within the floodplain or immediate riparian zone of a river or stream. Look at the entire landscape context to determine if the site is in a riparian zone, as some riparian sites may seem depressional in local areas. Vegetation often contains tall stature woody species, such as *Populus* spp*, Salix* spp., or non-native woody species (Salt Cedar and/or Russian Olive) OR vegetation may be entirely herbaceous and can sometimes seem marshy in character. Woody vegetation that occurs along reservoir edges can also be included here.. **5**

2a. Natural shallow depressional wetlands in the Western Great Plains with an impermeable soil layer, such as dense hardpan clay, that causes periodic ponding after heavy rains. Sites generally have closed contour topography and are surrounded by upland vegetation. Hydrology is typically tied to precipitation and runoff and lacks a groundwater connection. Ponding is often ephemeral and sites may be dry throughout the entire growing season during dry years. Species composition depends on soil salinity, may fluctuate significantly depending on seasonal moisture availability, and many persistent species may be upland species. Sites may have obvious vegetation zonation of tied to water levels, with the most hydrophytic species occurring in the wetland center where ponding lasts the longest. ……………………**Western Great Plains Playa Wetland Group**

- **i.** In less saline environments, dominant species are typically not salt-tolerant. Common native species include *Pascopyrum smithii, Buchloe dactyloides, Eleocharis* spp., *Oenothera canescens, Ratibida tagetes, Plantago* spp., *Polygonum* spp., and *Phyla cuneifolia.* Non-native species are very common in these sites, including *Salsola australis, Bassia sieversiana, Verbena bracteata,* and *Conyza canadensis.* Sites have often been disturbed by agriculture and heavy grazing. Many have been dug out or "pitted" to increase water retention and to tap shallow groundwater. ……………………**Western Great Plains Closed Depression Wetland**
- **ii.** In saline environments, salt encrustations can occur on the surface. Species are typically salt-tolerant, including *Distichlis spicata*, *Puccinellia* spp., *Salicornia* spp., *Schoenoplectus spp,. Sporobolus airoides,* and *Hordeum jubatum.* Other commonly occurring taxa include *Puccinellia nuttalliana, Suaeda calceoliformis, Spartina* spp., *Triglochin maritima,* and occasional shrubs such as *Sarcobatus vermiculatus* and *Krascheninnikovia lanata.* ……….**Western Great Plains Saline Depression Wetland**

b. Herbaceous wetlands in the Western Great Plains not associated with hardpan clay soils. Sites may or may not be depressional and may or may not be natural.……………………**3**

3a. Herbaceous wetlands with persistent, deep standing water at or above the surface at some point in the growing season, except in drought years. The hydrology may be entirely managed or artificial. Managed systems may be drawn down at any point depending on water management regimes. Water may be brackish or not. Soils are highly variable. Vegetation typically dominated by species of *Typha, Scirpus, Schoenoplectus*, with *Carex*, *Eleocharis*, and *Juncus* spp. in lesser amount around the edges and floating genera such as *Potamogeton*, *Sagittaria*, and *Ceratophyllum* in open water. If located within a matrix of vegetation communities, the portion of the wetland meeting these characteristics must be at least **0.1 hectares (0.25 acres)** to be classified here (i.e., a small puddle with a few cattails does not count). The isolated expression of this system can occur as fringes around ponds or lakes, or associated with any impoundment of water, including irrigation run-off. The floodplain expression of this system can be located on the floodplain, but may be disconnected from flooding regimes. This system includes natural oxbows, sloughs, and other natural floodplain marshes as well as a variety of managed wetlands on the floodplain ……………………**Western North American Emergent Marsh**

3b. Herbaceous wetlands with that lack persistent, deep standing water at some point in the growing season OR experience extreme fluctuation in water levels to the point that wetland vegetation is difficult to establish or has died back. May be natural or non-natural.……………………**4**

4a. Herbaceous wetlands associated with a high water table at or near the surface that typically lack prolonged standing water. Sites may be dominated by *natural* groundwater inputs with fairly stable hydrology. These wetlands generally occur on the landscape where there is a break in slope, seeps or springs, and/or stream headwaters. Sites may also be controlled by *artificial* overland flow (surface or subsurface irrigation runoff or return flow) or artificial groundwater seepage (including from leaky irrigation ditches). Site may be small or very large in size. These sites may be intentionally managed for hay production or may be the result of unintentional return flows, runoff or seepage. Vegetation is dominated by native or non-native herbaceous species; graminoids (grasses, sedges, rushes) have the highest canopy cover. Species composition may be dominated by non-native hay grasses. Patches of emergent marsh vegetation and standing water are less than 0.1 ha in size and not the predominant vegetation.……………………**Western Great Plains Wet Meadow**

4b Herbaceous (or occasionally herbaceous and woody mixed) sites within an obviously disturbed or non-natural landscape position, including reservoir fringes and/ or impounded ponds. Hydrology is often inconsistent and vegetation may not me dominated by wetland species. ....**Western Great Plains Disturbed Vegetation**

5a. Riparian woodlands and shrublands of the Rocky Mountain foothills. Woodlands are dominated by *Populus* spp. (*Populus angustifolia*, *P. deltoides,* or the hybrid *P. acuminata*). Common native shrub species include *Salix* spp., *Alnus incana*, *Betula occidentalis, Cornus sericea*, and *Crataegus* spp. Exotic shrub species include *Tamarix spp.* and *Elaeagnus angustifolia.* Sites are most often associated with a stream channel, including ephemeral, intermittent, or perennial streams (Riverine HGM Class). This system can also occur on slopes, lakeshores, or around ponds where the vegetation is associated with groundwater discharge or a subsurface connection to lake or pond water, and may experience overland flow but no channel formation (Slope, Lacustrine, or Depressional HGM Classes). It is also typically found in backwater channels and other perennially wet but less scoured sites, such as floodplain swales and irrigation ditches..**Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland**

5b. Riparian woodlands, shrublands and meadows of Colorado's Western Great Plains. Dominant native species include *Populus deltoides*, *Salix fragilis, Salix amygdaloides, Salix exigua, Acer negundo, Fraxinus* spp., and *Ulmus* spp. Dominant non-native species include *Tamarix* spp., *Elaeagnus angustifolia,* and other introduced woody species Site may lack woody vegetation and be entirely herbaceous. **6**

6a. Riparian woodlands, shrublands, and meadows along medium and small rivers and streams. Sites have less floodplain development and flashier hydrology than the next, and all streamflow may drawdown completely for some portion of the year. Water sources include snowmelt runoff (streams closer to the Rocky Mountain front), groundwater seeps (prairie streams), and summer rainfall. Some spring-fed sites can include patches of marshy vegetation with very slow moving water. Dominant species include *Populus deltoides, Salix* spp., *Fraxinus pennsylvanica, Artemisia cana, Carex* spp., *Pascopyrum smithii, Panicum virgatum, Panicum obtusum, Sporobolus cryptandrus,* and *Schizachyrium scoparium.* Non-native species including *Tamarix* spp., *Elaeagnus angustifolia,* and less desirable grasses and forbs can invade degraded examples. Groundwater depletion, lack of fire, heavy grazing, and/or agriculture have resulted in species and hydroperiod changes..**Western Great Plains Riparian**

6b. Woodlands, shrublands, and meadows along large rivers (the Arkansas River) with extensive floodplain development and periodic flooding that is more associated with snowmelt and seasonal dynamics in the mountains than with local precipitation events. Site may or may not be wetland. Dominant communities within this system range from floodplain forests to wet meadow patches, to gravel/sand flats dominated by early successional herbs and annuals; however, they are <u>linked by underlying soils and the historic flooding regime</u>. Dominant species include *Populus deltoides* and *Salix* spp., *Carex* spp., *Panicum virgatum*, and *Andropogon gerardii.* Non-native species including *Tamarix* spp., *Elaeagnus angustifolia,* and non-native grasses have invaded degraded areas within the floodplains, which are subjected to heavy grazing and/or agriculture. Groundwater depletion and lack of fire have created additional alterations in species composition and hydroperiod. In most cases, the majority of the native wet meadow and prairie communities may be extremely degraded or extirpated from examples of this system...................... **Western Great Plains Floodplain**

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APPENDIX B: FIELD KEY TO THE HYDROGEOMORPHIC (HGM) CLASSES OF WETLANDS IN COLORADO'S ROCKY MOUNTAINS AND PLAINS

1a. Entire wetland unit is flat and precipitation is the primary source (>90%) of water. Groundwater and surface water runoff are not significant sources of water to the unit. **NOTE:** *Flat wetlands are very uncommon in Colorado.* .... **Flats HGM Class**

1b. Wetland does not meet the above criteria; primary water sources include groundwater and/or surface water **2**

2a. Entire wetland unit meets ***all*** of the following criteria: a) the vegetated portion of the wetland is on the shores of a permanent open water body at least 8 ha (20 acres) in size; b) at least 30% of the open water area is deeper than 2 m (6.6 ft); c) vegetation in the wetland experiences bidirectional flow as the result of vertical fluctuations of water levels due to rising and falling lake levels. .... **Lacustrine Fringe HGM Class**

2b. Wetland does not meet the above criteria; wetland is not found on the shore of a water body, water body is either smaller or shallower, OR vegetation is not effected by lake water levels........ **3**

3a. Entire wetland unit meets ***all*** of the following criteria: a) wetland unit is in a valley, floodplain, or along a stream channel where it is inundated by overbank flooding from that stream or river; b) overbank flooding occurs at least once every five years; and c) wetland does not receive significant inputs from groundwater. **NOTE:** *Riverine wetlands can contain depressions that are filled with water when the river is not flooding such as oxbows and beaver ponds. However, depressions on the floodplain that are not strongly influenced by flooding would be classified as true depressions. These include depressions disconnected due to modified hydrology and channel entrenchment, and impounded managed wetlands.* ...... **Riverine HGM Class**

3b. Wetland does not meet the above criteria; if the wetland is located within a valley, floodplain, or along a stream channel, it is outside of the influence of overbank flooding or receives significant hydrologic inputs from groundwater or managed hydrology. **4**

4a. Entire wetland unit is located in a topographic depression in which water ponds or is saturated to the surface at some time during the year. **NOTE:** *Any outlet, if present, is higher than the interior of the wetland.* .... **Depressional HGM Class**

4b. Wetland does not meet the above criteria. There is no significant ponding except at times of very high water. **5**

5a. Wetland unit meets the following criteria: a) wetland is on a slope (slope can be very gradual or nearly flat); b) *natural* groundwater is the primary hydrologic input; c) water, if present, flows through the wetland in one direction and usually comes from seeps or springs; and d) water leaves the wetland without being impounded. **NOTE:** *Small channels can form within slope wetlands, but are not subject to overbank flooding. Surface water does not pond in these types of wetlands, except occasionally in very small and shallow depressions or behind hummocks (depressions are usually < 3ft diameter and less than 1 foot deep).* .... **Slope HGM Class**

5b. Wetland water source, when surface water flow or subsurface groundwater expression, is largely connected to irrigation water, either through direct application or seepage from fields or ditches .... **Novel Irrigation-Fed HGM Class**

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APPENDIX C: EXAMPLE FIELD FORM AND STRESSOR CHECKLIST

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QC_________

2015 LOWER ARKANSAS WETLAND ASSESSMENT – SITE INFORMATION

LOCATION AND GENERAL INFORMATION

Point Code: ______________________ Site Name: ____ LEVEL 2 ASSESSMENT

Date: ___________________________ Surveyors: ____ ☐ Team A OR ☐ Team B

General Location: ____

General Ownership: _______________________ Specific Ownership: ____

Directions to Point:

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

GPS COORDINATES OF TARGET POINT AND ASSESSMENT AREA

GPS UNIT (*if different than Team Unit)*_______

Original Point WP #: ________ Target?: ☐ Yes ☐ No Cowardin Code: _________ Relation to AA: ☐ Centered ☐ Included ☐ Outside

Dimensions of AA:

____40 m radius circle

____Large area circle *(playas only)*

____Freeform, describe and take a GPS Track

Elevation (m):

Slope (deg):

Aspect (deg):

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

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

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

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

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

AA-Track Track Name: ____ Area: ____

AA Placement and Dimensions Comments (*if playa, note if AA encompasses entire playa)*:

PHOTOS OF ASSESSMENT AREA (Taken at four points on edge of AA looking in. Record WPs of each photo in table above.)

AA-1 Photo #: ______________ Aspect: ______________

AA-2 Photo #: ______________ Aspect: ______________

AA-3 Photo #: ______________ Aspect: ______________

AA-4 Photo #: ______________ Aspect: ______________

Photo Range:

Overview Photos:

Comments:

Point Code___________________ QC_________

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

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

Cowardin Classification Fidelity: High Med Low

(see manual and pick *one each* of System, Class, Water Regime, and optional Modifier for dominant type)

HGM Class: (pick *only one*) Fidelity: High Med Low

____Riverine* ____Lacustrine Fringe

____Depressional ____ Slope

____ Flats ____ Novel (Irrigation-Fed) Riverine / Slope

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

RIVERINE SPECIFIC CLASSIFICATION OF THE ASSESSMENT AREA

Confined vs. Unconfined Valley Setting

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

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

Stream Flow Duration

______ Perennial

______ Intermittent

______ Ephemeral

Proximity to Channel

______ AA includes the channel and both banks

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

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

Stream Depth at Time of Survey (if evaluated)

______ Wadeable

______ Non-wadeable

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

Wetland / riparian / upland inclusions: *(should = 100%)*

_________ % AA with true wetland and/or water

_________ % AA with non-wetland riparian area

_________ % AA with upland inclusions

Wetland origin: *(if known)*

____ Natural feature with minimal alteration

____ Natural feature, but altered or augmented by modification

____ Non-natural feature created by passive or active management

____ Unknown

Zone 1 Description ______________________________ Dom spp: ____________________________________ % of AA: __________

Zone 2 Description ______________________________ Dom spp: ____________________________________ % of AA: __________

Zone 3 Description ______________________________ Dom spp: ____________________________________ % of AA: __________

Zone 4 Description ______________________________ Dom spp: ____________________________________ % of AA: __________

Zone 5 Description ______________________________ Dom spp: ____________________________________ % of AA: __________

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

Classification Issues (important for sites with low fidelity to one or more classification systems):

AA REPRESENTATIVENESS

Is AA the entire wetland/riparian area? ☐ Yes ☐ No

If no, is AA representative of larger wetland/riparian area? ☐ Yes ☐ No ☐ NA (*if AA is the entire wetland*)

Comments:

Point Code___________________ QC_________

ASSESSMENT AREA DRAWING

Add north arrow and approx. scale bar. Document **habitat features** and **biotic and abiotic zones** (particularly open water), inflows and outflows, and indicate direction of drainage. Include location of **AA points, soil pits,** and **water chemistry** samples. If appropriate, add a **cross-sectional diagram** and indicate slope of side.

ASSESSMENT AREA DESCRIPTION AND COMMENTS

Overall site description and details on site hydrology, soil, and vegetation. *If playa,* what shape is the entire playa (round, kidney, etc.?

Point Code___________________ QC_________

2015 LOWER ARKANSAS WETLAND ASSESSMENT – VEGETATION, SOILS, BASIC WATER CHEMISTRY

VEGETATION PLOT SPECIES TABLE

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

Scientific Name or Pseudonym (If repeated/common pseudonym, mark with *)	Cover Class	Coll #	Press (√)	Photos	Workspace

Point Code___________________ QC_________

VEGETATION PLOT SPECIES TABLE

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

Scientific Name or Pseudonym (If repeated/common pseudonym, mark with *)	Cover Class	Coll #	Press (√)	Photos	Workspace

Point Code__________________ QC_________

SOIL PROFILE DESCRIPTION – SOIL PIT 1 ☐ Representative Pit? WP # _________ Photo #s _________________ (mark on site sketch)

Depth to saturated soil (+/-cm): ______________ Depth to free water (+/-cm): _______________ ☐ Pit dry and groundwater not observed Settling Time: ________

Horizon (optional)	Depth (cm)	Matrix	Dominant Redox Features		Secondary Redox Features		Texture	Remarks (*note % visible salts in each layer)*
		Color (moist)	Color (moist)	%	Color (moist)	%		
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____

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

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Features (S5/F6/F8/S6/F7)
____**No Hydric Indicators**

Comments: (*if playa, note depth of sedimentation in cm)*

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

SOIL PROFILE DESCRIPTION – SOIL PIT 2 ☐ Representative Pit? WP # _________ Photo #s _________________ (mark on site sketch)

Depth to saturated soil (+/-cm): ______________ Depth to free water (+/-cm): _______________ ☐ Pit dry and groundwater not observed Settling Time: ________

Horizon (optional)	Depth (cm)	Matrix	Dominant Redox Features		Secondary Redox Features		Texture	Remarks (*note % visible salts in each layer)*
		Color (moist)	Color (moist)	%	Color (moist)	%		
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____

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

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Features (S5/F6/F8/S6/F7)
____**No Hydric Indicators**

Comments: (*if playa, note depth of sedimentation in cm)*

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

SOIL PROFILE DESCRIPTION – SOIL PIT 3 ☐ **Representative Pit?** **WP # _________ Photo #s ________________ (mark on site sketch)**

Depth to saturated soil (+/-cm): ______________ Depth to free water (+/-cm): _______________ ☐ Pit dry and groundwater not observed Settling Time: ________

Horizon (optional)	Depth (cm)	Matrix Color (moist)	Dominant Redox Features Color (moist)	Dominant Redox Features %	Secondary Redox Features Color (moist)	Secondary Redox Features %	Texture	Remarks (*note % visible salts in each layer)*
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____
________	_______	______________	______________	________	_____________	________	______________	____

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

____Histosol (A1)
____Histic Epipedon (A2/A3)
____Mucky Mineral (S1/F1)
____Hydrogen Sulfide Odor (A4)
____Gleyed Matrix (S4/F2)
____Depleted Matrix (A11/A12/F3)
____Redox Features (S5/F6/F8/S6/F7)
____**No Hydric Indicators**

Comments: (*if playa, note depth of sedimentation in cm)*

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

BASIC WATER CHEMISTRY - PH, EC, AND TEMPERATE MEASUREMENTS ☐ **No water observed**

Take pH, EC, and water temperature recording at up to four locations within the AA and circle the appropriate characteristics. Take measurements within representative examples of the water within or adjacent to the AA, including channels, pools, and/or groundwater. Take GPS Waypoints at each location. Estimate water depth in cm, + for surface water, - for groundwater.

	GPS WP#	**Time of day**	**Location**	**Depth (+/-cm)**	**Surface OR Ground**	**Standing OR Flowing (NA for ground)**	**Clear OR Turbid (NA for ground)**	**Open OR Shade (NA for ground)**	**pH**	**EC**	**Temp**
Site 1					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			
Site 2					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			
Site 3					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			
Site 4					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			
Site 5					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			
Site 6					Surface / Ground	Standing / Flowing	Clear / Turbid	Open / Shade			

Water chemistry measurement comments:

Point Code__________________ QC_________

2015 LOWER ARKANSAS WETLAND ASSESSMENT – HABITAT METRICS

HABITAT TYPES WITHIN THE ASSESSMENT AREA

See manual for rules and definitions. Mark features on the site sketch.

Habitat type	% AA	Dominant Vegetation Code
1.		
2.		
3.		

DOMINANT SPECIES BY HABITAT TYPE

List 4–8 dominant species by habitat type. Estimate cover base on 1% or 5% increments (not cover classes).

Habitat Type (same order as above) →		1		2		3		
Scientific Name or Pseudonym	**Dominant / Cover →**	**D**	**C**	**D**	**C**	**D**	**C**	**Comments**

VERTICAL STRATA BY HABITAT TYPE

Estimate cover of each vertical strata by habitat type. Estimate height using classes. Estimate cover base on 1% or 5% increments (not classes).

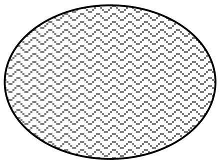
Height Classes 0: <0.2 m **1:** 0.2–0.5 m **2:** 0.5–1m **3:** 1–2 m **4:** 2–5 m **5:** 5–10 m **6:** 10–15 m **7:** 15–20 m **8:** 20–35 m **9:** 35–50 m **10:** >50 m

Vertical Vegetation Strata (live or very recently dead)	**Height / Cover →**	**H**	**C**	**H**	**C**	**H**	**C**	**Comments**
(T1) Dominant canopy trees (>5 m and >~ 30% cover)								
(T2) Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover								
(S1) Tall shrubs, tree saplings or seedling (>2 m)								
(S2) Short shrubs (<2 m)								
(HT) Herbaceous total								
(H1) Graminoids (grass and grass-like plants)								
(H2) Forbs (all non-graminoids)								
(AQ) Submergent or floating aquatics								

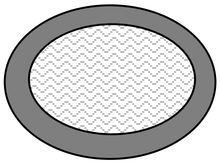
Point Code__________________ QC_________

GROUND COVER BY HABITAT TYPE				
Habitat Type →	**1**	**2**	**3**	
Estimate cover of each ground cover by habitat type. Estimate cover based on 1% or 5% increments (not cover classes).				
Cover (unless otherwise noted) →	**C**	**C**	**C**	**Comments**
Actual cover of water (any depth, vegetated or not, standing or flowing) (A+B+C below)				
Actual cover of open water zone and no vegetation (or only algae) (A)				
Actual cover of water zone with emergent vegetation (B)				
Actual cover of water zone with submergent / floating vegetation (C)				
Actual predominant depth of water (cm)				
Actual max depth of water (cm)				
Potential cover of water at ordinary high water				
Potential predominant depth at ordinary high water (cm)				
Stability of water level (*Pick one:* A: permanent and stable / B: permanent but fluctuates / C: intermittent or ephemeral)				
Cover of exposed bare ground (any substrate, can have algae cover)				
Predominant substrate texture (*Pick one:* organic / silt / clay / sand / soft mud / muddy sand / gravel / cobble / pebble / boulders / bedrock / rip-rap / concrete)				
Cover of litter (all cover, including under water or vegetation)				
Depth of litter (cm) – average of four non-trampled locations where litter occurs				
Count of standing dead trees (>25 cm diameter at breast height)				
Cover of standing dead shrubs or small trees (<25 cm diameter at breast height)				
Cover of downed coarse woody debris (fallen trees, rotting logs, >25 cm diameter)				
Cover of downed fine woody debris (<25 cm diameter)				
Cover bryophytes (all cover, including under water, vegetation or litter cover)				
Cover lichens (all cover, including under water, vegetation or litter cover)				
Cover algae (all cover, including under water, vegetation or litter cover)				
INTERSPERSION BY HABITAT TYPE				
Use graphics and descriptors below to approximate the interspersion of water and vegetation in/adjacent to the habitat.				
Actual interspersion of vegetation and water at time of sampling *(NA if dry at sampling)*				
Potential interspersion of vegetation and water at ordinary high water *(NA if always dry)*				

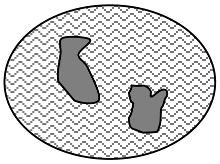
A



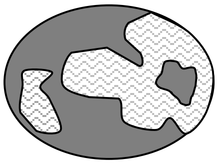
B



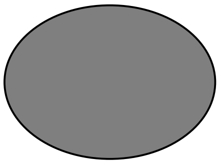
C



D



E



A: Open Water	Habitat is essentially not vegetated and covered exclusively by open water
B: Fringe	Habitat has vegetation around the perimeter of the wetland with central open water
C: Partially interspersed	Habitat contains a few vegetation patches in the central portion
D: Complex	Habitat contains vegetation interspersed in many patches
E: Closed	Habitat has few or no areas of open water

Point Code__________________ QC_________

Habitat Type →	**1**	**2**	**3**	**Comments**
SPECIES SPECIFIC QUESTIONS				
Answer the following questions as best as possible. Refer to species write-ups for more contextual information.				
Bald eagles and Lewis' woodpecker ***(assess at the AA scale)***				
How many trees are in the biggest cluster (~15-m radius circle) in or within 100 m of the AA? **(Count / NA)**				
How tall is the tallest tree in or within 100 m of AA? **(height in m / NA)**				
Are there 1 or more super canopy trees (several m taller than other canopy trees OR single tree > 10 m tall) in the AA or within 100 m of the AA? **(Y / NA)**				
Is there permanent open water capable of supporting fish < 50 m from a live or dead super canopy tree? **(Y / N / NA)**				
If there is permanent open water, what is its apparent depth? Does the open water appear to be **A:** < 6 m deep within 100 m of shore, **B:** <6 m deep within 50 m from shore but deeper beyond, or **C:** > 6 m deep within 50 m from shore? **(A / B / C / NA)**				
If the habitat contains a closed tree canopy (>50% tree cover), is the edge visible from within the AA? **(Y / N / NA)**				
Are there prairie dog towns within 500 m of AA? **(Y / N)**				
Ducks				
What percent of the herbaceous vegetation is too dense and coarse for a duck to move through? **(% of herbaceous veg)**				
Black rail				
Is the soil moist to the touch or covered with water in the majority of the habitat patch? **(Y / N)**				
Frogs				
What is the cover of shallow pools (up to 1 m deep) with potential for open sunlight? **(% cover)**				
Least tern ***(assess for sandbars or other open sandy habitats, including open reservoir or gravel pit edges)***				
Max unobstructed view **(A: < 50 m / B: 50–100 m / C: 100–250 m / D: >250 m / NA)**				
Is the habitat patch **A:** Totally surrounded by water, **B:** Partially connected and adjacent to water, or **C:** Not adjacent to water? **(A / B / C / NA)**				
Preble's meadow jumping mice ***(assess only for Foothills Riparian systems, not on the plains)***				
What is the distance to the closest water? **(distance in m / NA)**				
Fish ***(assess for stream and river channels, even if the channel is ephemeral, otherwise NA for all measures)***				
Is there a river or stream channel in or adjacent to the AA? **(Y / N)**				
Actual max depth of stream. **(cm)**				
Width of stream, up to 40 m. **(width in cm, m OR >40 m)**				
How shaded is the stream channel? **(A: full shade, B: some shade, C: no shade)**				
Is the stream spring-fed? **(Y / N)**				
Are the stream banks undercut or slumping? **(Y / N)**				
Are there permanent pools in the stream? **(Y / N)**				
Would you characterize the channel as narrow and meandering? **(Y / N)**				
Is there an active or functioning beaver dam on the stream? **(Y / N)**				
Is there woody debris in the channel? **(Y / N)**				

Point Code__________________ QC_________

Habitat Type →				
SPECIES SPECIFIC QUESTIONS CONTINUED				
Yellow mud turtle				
Is there a suitable site for aestivation (egg burrows) within 90 m of ordinary high water? Look for sandy soil at least 5 cm deep and 5 m above the ordinary high water line. **(Y / N / NA if there is no ordinary high water within 90 m)**				
Depth of sandy soil layer. Only include layers of sand, loamy sand, and sandy loam that start within the upper 10 cm. **(depth in cm / NA)**				
LAND USE / LAND COVER				
Answer the following questions as best as possible. Refer to site maps as needed.				
Land cover / land use w/in 100 m				
% cover of fallow fields **(% cover)**				
% cover of corn fields **(% cover)**				
% cover of recently burned trees **(% cover)**				
% cover of grassland **(% cover)**				
Extent of grazing **(A: light, B: moderate, C: intense, NA: none)**				
HABITAT SIZE				
Does the feature extend beyond the AA? **(Y / N)**				
Is the overall size of the feature evident form aerial images? If not, please provide comments and estimate habitat size using classes. **(Y / N)**				
COMMENTS				
Please comment by habitat (if there is more than one).				
WILDLIFE SPECIES OBSERVED				

Point Code__________________ QC_________

ECOLOGICAL INTEGRITY ASSESSMENT

1. BUFFER AND LANDSCAPE CONTEXT METRICS – Check the applicable box.

PERIMETER WITH NATURAL BUFFER

Select the statement that best describes the AA **perimeter with natural buffer**. To determine, estimate the percent of the AA surrounded by buffer land covers. Or, inversely, identify any non-buffer land covers surrounding the AA and subtract them from 100%. Buffer land covers must be ≥ 5 m wide and extend along ≥ 10 m of the AA perimeter. Buffer land covers are stricter than natural land covers used above. See list of buffer land covers in the field manual.	Natural buffer surrounds 100% of the AA perimeter.	
	Natural buffer surrounds 75–99% of the AA perimeter.	
	Natural buffer surrounds 25–75% of the AA perimeter.	
	Natural buffer surrounds <25% of the AA perimeter.	

WIDTH OF NATURAL BUFFER

Select the statement that best describes the **width of the natural buffer**. To determine, estimate the width of buffer land covers along eight lines radiating out from the AA at the cardinal and ordinal directions (N, NE, E, SE, S, SW, W, NW) and average their width. Estimate up to 100 m.

1: ____________ 5: ____________ 2: ____________ 6: ____________	Average buffer width is 100 m	
3: ____________ 7: ____________	Average buffer width is 75–99 m	
4: ____________ 8: ____________	Average buffer width is 25–75 m	
Average width: ________________________	Average buffer width is <25 m	

NATURAL BUFFER CONDITION

Select the statement that best describes the **natural buffer condition**. Select one statement per column. Only consider the actual natural buffer measured in metrics above. *Remember to look for non-native **hay grasses** when evaluating native / non-native vegetation in the buffer.*

Abundant (≥95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.		Intact soils, no water quality concerns, little or no trash, AND little or no evidence of human visitation.	
Substantial (75–95%) relative cover of native vegetation and low (5–25%) cover of non-native plants.		Intact or minor soil disruption, minor water quality concerns, moderate or lesser amounts of trash, AND/OR minor intensity of human visitation or recreation.	
Low (25–75%) relative cover of native vegetation and moderate to substantial (25–75%) cover of non-native plants.		Moderate or extensive soil disruption, moderate to strong water quality concerns, moderate or greater amounts of trash, AND/OR moderate intensity of human use.	
Very low (<25%) relative cover of native vegetation and dominant (>75% cover) of non-native plants OR no buffer exists.		Barren ground and highly compacted or otherwise disrupted soils, significant water quality concerns, substantial amounts of trash, extensive human use, OR no buffer exists.	

List dominant species in buffer:

Buffer comments:

Point Code__________________ QC_________

CONTIGUOUS NATURAL LAND COVER

Select the statement that best describes the **contiguous natural land cover** within the 500 m envelope surrounding the AA. To determine, identify the largest unfragmented block of natural land cover *that includes the AA* within the 500 m envelope and estimate its percent of the total envelope. Well-traveled dirt roads and major canals break unfragmented blocks, but vegetated two-track roads, hiking trails, hayfields, low fences and small ditches can be included. See list of natural land covers in the field manual.	Intact: AA embedded in 90–100% contiguous natural land cover.	
	Variegated: AA embedded in 60–90% contiguous natural land cover.	
	Fragmented: AA embedded in 20–60% contiguous natural land cover.	
	Relictual: AA embedded in <20% contiguous natural land cover.	

Natural land cover comments:

LANDSCAPE STRESSORS

Using the table below, estimate the scope of each **landscape stressor within the 100 and 500 m envelopes** surrounding the AA. Stressors can overlap and do not need to total 100% (e.g., light grazing and moderate recreation can both be counted in the same portion of the envelope).

Scope: 1 = 1–10%, 2 = >10–30%, 3 = >30–70%, 4 = >70%. ***Severity: 1 = slight, 2 = moderate, 3 = serious, 4 = extreme.***

Landscape stressor	*100 m Scope*	*100 m Severity*	*500 m Scope*	*500 m Severity*
Development: Paved roads, parking lots, railroad tracks				
Development: Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)				
Development: Domestic or commercially developed buildings				
Development: Industrial buildings or complexes				
Development: Intensively managed golf courses, sports fields, urban parks, expansive lawns				
Resource extraction: Active gravel pit operation, open pit mining, strip mining, abandoned mines				
Resource extraction: Oil and gas wells and surrounding footprint				
Resource extraction: Power lines and/or other utility lines				
Resource extraction: Water storage reservoirs ,reclaimed gravel ponds, major conveyance canals				
Logging: Clear-cutting with >50% of trees removed				
Logging: Selective logging with <50% of trees removed				
Agriculture: Tilled crop production				
Agriculture: Permanent crop (vineyard, orchard, tree plantation)				
Agriculture: Hay fields, haying of native or non-native grasses				
Grazing: Heavy grazing/browse by livestock or native ungulates				
Grazing: Moderate grazing/browse by livestock or native ungulates				
Grazing: Light grazing/browse by livestock or native ungulates				
Recreation: Active recreation (ATV use / camping / popular fishing spot, etc.)				
Recreation: Passive recreation (hiking trail, birding, low-use fishing)				
Fallow lands dominated by invasive non-native species				
Evidence of recent fire (<5 years old, still apparent on vegetation)				
Insect infestation (pine beetle, spruce bud worm, etc.)				
Other:				
Other:				

Landscape stressor comments:

2. VEGETATION CONDITION METRICS – Check the applicable box.

VEGETATION COMPOSITION

NATIVE PLANT SPECIES COVER (RELATIVE)

Select the statement that best describes the relative **native plant species cover** within the AA.	AA contains >99% relative cover of native plant species.	
	AA contains 95–99% relative cover of native plant species.	
	AA contains 85–95% relative cover of native plant species.	
	AA contains 60–85% relative cover of native plant species.	
	AA contains <60% relative cover of native plant species.	

NOXIOUS WEED COVER (ABSOLUTE)

Select the statement that best describes the **absolute cover of noxious weeds** within the AA. Use Colorado Noxious Weed List A, B, or C.	Noxious weeds are absent from all strata.	
	Noxious weeds present, but sporadic (<4% absolute cover).	
	Noxious weeds somewhat abundant (4–10% cover).	
	Noxious weeds abundant (10–30% cover).	
	Noxious weed very abundant (>30% cover).	

NATIVE PLANT SPECIES COMPOSITION

Select the statement that best describes the **native plant species composition** (species abundance and diversity) within the AA. Look for native species diagnostic of the system vs. native increasers that may thrive in human disturbance.

Native plant species composition with expected natural conditions: i) Typical range of native diagnostic species present, AND ii) Native species sensitive to anthropogenic degradation are present, AND iii) Native species indicative of anthropogenic disturbance (i.e., increasers, weedy or ruderal species) absent to minor.	
Native plant species composition with minor disturbed conditions: i) Some native diagnostic species absent or substantially reduced in abundance, OR ii) Native species indicative of anthropogenic disturbance are present with low cover.	
Native plant species composition with moderately disturbed conditions: i) Many native diagnostic species absent or substantially reduced in abundance, OR ii) Native species indicative of anthropogenic disturbance are present with moderate cover.	
Native plant species composition with severely disturbed conditions: i) Most or all native diagnostic species absent, a few remain in low cover, OR ii) Native species indicative of anthropogenic disturbance are present with high cover.	

Vegetation composition comments and photo #'s:

VEGETATION STRUCTURE

VEGETATION STRUCTURE (VERTICAL AND HORIZONTAL)

Select the statement below that best describes the **overall vertical and horizontal structure** within the AA. Vertical structure relates to the number of vertical vegetation strata. Horizontal structure relates to the number and complexity of biotic and abiotic patches within the wetland/riparian area. See reference card for potential structural patches. Assess each site based on the expected conditions within its Ecological System type. For woody systems, rate regeneration and woody debris individually on next page, then consider those ratings in the overall assessment of structure.

Herbaceous systems: Marsh, Meadow, Playa	***Woody systems: Riparian and Floodplain***	
Vegetation structure is at or near minimally disturbed natural conditions. Little to no structural indicators of degradation evident.		
Structural patches/zones are appropriate in number and type for the system (can be few in playas, fens, meadows). There is diversity in vertical strata within the herbaceous vegetation (some tall and some short layers and/or low cover of shrubs or trees, where appropriate). Litter and other organic inputs are typical of the system (i.e., playas should have low litter while meadows and marshes should have moderate amounts of litter).	AA is characterized by a complex array of nested or interspersed patches. Canopy (if present) contains a mosaic of different ages or sizes, including large old trees and obvious regeneration. Number of live stems is well within expected range. Shrub and herbaceous layers are complex, providing a diversity of vertical strata. Woody species are of sufficient size and density to provide future woody debris to stream or floodplain. Litter layer is neither lacking nor extensive.	
Vegetation structure shows minor alterations from natural conditions.		
Marshes: cattail and bulrush density may prevent animal movement in some areas of the wetland, but not throughout. ***Meadows:*** grazing and mowing have minor effects. ***Playas:*** natural areas of bare ground are still prevalent, though non-native or weedy species may be encroaching.	AA is characterized by a moderate array of nested or interspersed zones with no single dominant zone, though some structural patches (especially open zones) may be missing. Canopy still heterogeneous in age or size, but may be missing some age classes. Vertical strata may be somewhat less complex than natural conditions. Woody debris or litter may be somewhat lacking.	
Vegetation structure is moderately altered from natural conditions.		
Marshes: cattail and bulrush density may prevent animal movement in half or more of the wetland. ***Meadows:*** grazing and mowing have moderate effects. ***Playas:*** natural areas of bare ground are present, but non-native or weedy species have filled in many area.	AA is characterized by a simple array of nested or interspersed zones. One zone may dominate others. Vertical strata may be moderately less complex than natural conditions. Site may be denser than natural conditions (due to non-native woody species) or may be more open and decadent. Woody debris or litter may be moderately lacking.	
Vegetation structure is greatly altered from natural conditions.		
Marshes: cattail and bulrush density prevent animal movement throughout the wetland. ***Meadows:*** grazing and mowing greatly affect the structure of the vegetation and prevalence of litter. ***Playas:*** natural areas of bare ground are absent due to an abundance of non-native or weedy species.	AA is characterized by one dominant zone and several expected structural patches or vertical strata are missing. Site is either extremely dense with non-native woody species or open with predominantly decadent or dead trees. Woody debris and/or litter may be absent entirely or may be excessive due to decadent trees.	

Vegetation structure comments (including regeneration and woody debris) and photo #'s:

Point Code__________________ QC_________

REGENERATION OF NATIVE WOODY SPECIES

Select the statement that best describes the **regeneration of native woody species** within the AA.

Woody species are naturally uncommon or absent.	**NA**
All age classes of *native* woody species present. Native tree saplings /seedlings and shrubs common to the type present in expected amounts and diversity. Regeneration in obvious.	
Age classes of *native* woody species restricted to mature individuals and young sprouts. Middle age groups appear to be absent or there is some other indication that regeneration is moderately impacted.	
Native woody species comprised of mainly mature individuals OR mainly evenly aged young sprouts that choke out other vegetation. Regeneration is obviously impacted. Site may contain Russian Olive and/or Salt Cedar.	
Native woody species predominantly consist of decadent or dying individuals OR *native* woody species absent from an area that should be wooded. Site may be dominated by Russian Olive and/or Salt Cedar.	

COARSE AND FINE WOODY DEBRIS

Select the statement that best describes **coarse and fine woody debris** within the AA.

There are no obvious inputs of woody debris or if woody species are naturally uncommon.	**NA**
AA characterized by moderate amount of coarse and fine woody debris, relative to expected conditions. A wide size-class diversity of downed woody debris and standing snags is present and common. For riverine wetlands, debris is sufficient to trap sediment, but does not inhibit stream flow. Woody debris provides structural complexity, but does not overwhelm the site.	
AA characterized by small amounts of woody debris OR debris is somewhat excessive. For riverine wetlands, lack of debris may affect stream temperatures and reduce available habitat.	
AA lacks woody debris, even though inputs are available.	

VEGETATION STRESSORS WITHIN THE AA

Using the table below, estimate the scope and severity of each vegetation stressor within the AA.

Scope: 1 = 1–10%, 2 = >10–30%, 3 = >30–70%, 4 = >70%. ***Severity: 1 = slight, 2 = moderate, 3 = serious, 4 = extreme.***

Vegetation stressor categories	*Scope*	*Severity*
Development: Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)		
Logging: Clear-cutting with >50% of trees removed		
Logging: Selective logging with <50% of trees removed		
Grazing: Heavy grazing by livestock or native ungulates		
Grazing: Moderate grazing by livestock or native ungulates		
Grazing: Light grazing by livestock or native ungulates		
Browsing: Heavy browse by livestock or native ungulates		
Browsing: Moderate browse by livestock or native ungulates		
Browsing: Light browse by livestock or native ungulates		
Recreation: Active recreation (ATV use / camping / popular fishing spot, etc.)		
Recreation: Passive recreation (hiking trail, birding, low-use fishing)		
Haying or mowing		
Probably or known herbicide use		
Invasive non-native species		
Prairie dog town		
Insect infestation (pine beetle, spruce bud worm, etc.)		
Evidence of recent fire (<5 years old)		
Other:		

Vegetation stressor comments and photo #'s:

Point Code__________________ QC_________

3. HYDROLOGY METRICS – Check the applicable box.

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

Water sources are natural. Site hydrology is fed by precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body. The system may naturally lack water at times, even for several years. There is no indication of direct artificial water sources, either point sources or non-point sources. Land use in the local watershed is primarily open space or low density, passive use with little irrigation.	
Water sources are mostly natural, but also include occasional or small amounts of inflow from anthropogenic sources. Indications of anthropogenic sources include developed land or irrigated agriculture that comprises < 20% of the immediate drainage area, some road runoff, small storm drains or other minor point source discharges. No large point sources control the overall hydrology.	
Water sources are moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources. Indications of moderate contribution from anthropogenic sources include developed land or irrigated agriculture that comprises 20–60% of the immediate drainage area or moderate point source discharges into the wetland, such as many small storm drains or a few large ones or many sources of irrigation runoff. The key factors to consider are whether the wetland is located in a landscape position that supported wetlands before irrigation / development *AND* whether the wetland is still connected to its natural water source (e.g., modified ponds on a floodplain that are still connected to alluvial aquifers or natural stream channels that now receive substantial irrigation return flows).	
Water sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology). Indications of substantial artificial hydrology include developed or irrigated agricultural land that comprises > 60% of `the immediate drainage basin of the AA, or the presence of major drainage point source discharges that obviously control the hydrology of the AA. The key factors to consider are whether the wetland is located in a landscape position that likely never supported a wetland prior to human development *OR* did support a wetland, but is now disconnected from its natural water source. The reason the wetland exists is because of direct irrigation, irrigation seepage, irrigation return flows, urban storm water runoff, or direct pumping.	
Water source comments:	

HYDROPERIOD	
Select the statement below that best describes the **hydroperiod** within the AA (extent and duration of inundation and/or saturation). Search the AA and 500 m envelope for hydrologic stressors (see list on following pages). Use best professional judgment to determine the overall condition of the hydroperiod. For some wetlands, this may mean that water is being channelized or diverted away from the wetland. For others, water may be concentrated or increased. *Please add comments on next page.*	
Hydroperiod is characterized by natural patterns of inundation/saturation and drawdown and/or flood frequency, duration, level and timing. There are no major hydrologic stressors that impact the natural hydroperiod. Riparian channels are characterized by equilibrium conditions with no evidence of severe aggradation or degradation indicative of altered hydrology.	
Hydroperiod inundation and drying patterns deviate slightly from natural conditions due to presence of stressors such as: flood control/water storage dams upstream; berms or roads at/near grade; minor pugging by livestock; small ditches or diversions removing water; or minor flow additions from irrigation return flow or storm water runoff. Outlets may be slightly constricted, but not to significantly slow outflow. Riparian channels may have some sign of aggradation or degradation, but approach equilibrium conditions. Playas are not significantly impacted pitted or dissected. *If wetland is artificially controlled,* the management regime closely mimics a natural analogue (it is very unusual for a purely artificial wetland to be rated in this category).	
Hydroperiod inundation and drying patterns deviate moderately from natural conditions due to presence of stressors such as: flood control/water storage dams upstream or downstream that moderately effect hydroperiod; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; ditches or diversions 1–3 ft. deep; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible. Riparian channels may show distinct signs of aggradation or degradation. *If wetland is artificially controlled,* the management regime approaches a natural analogue. Site may be passively managed, meaning that the hydroperiod is still connected to and influenced by natural high flows timed with seasonal water levels.	
Hydroperiod inundation and drawdown patterns deviate substantially from natural conditions from high intensity alterations such as: significant flood control / water storage das upstream or downstream; a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be significantly constricted, blocking most flow. Riparian channels may be concrete or artificially hardened. *If wetland is artificially controlled,* the site is actively managed and not connected to any natural season fluctuations.	

Hydroperiod comments:

HYDROLOGIC CONNECTIVITY

Select the statement below that best describes the degree to which **hydrology within the AA is connected to the larger landscape** throughout the year, but particularly at times of high water. Consider the effect of impoundments, entrenchment, or other obstructions to connectivity that occur within the surrounding landscape, if those impoundments clearly impact the AA.

Riparian variant	***Marsh / Meadow variant***	***Playa variant***	
Completely connected to floodplain (backwater sloughs and channels). No geomorphic modifications made to contemporary floodplain. Channel is not entrenched.	No unnatural obstructions to lateral or vertical movement of surface or ground water. Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.	Surrounding land cover / vegetation does not interrupt surface flow. No artificial channels feed water to playa.	
Minimally disconnected from floodplain. Up to 25% of stream banks may be affected by dikes, rip rap, and/or elevated culverts. Channel may be somewhat entrenched, but overbank flow occurs during most floods.	Minor restrictions to the lateral or vertical movement of surface and ground water by unnatural features such as levees, road grades or excessively high banks. Up to 25% of the site may be restricted by barriers to drainage. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. Flood flows may exceed the impoundments, but drainage back into the wetland may be incomplete due to the impoundments.	Surrounding land cover / vegetation may interrupt a minor amount of surface flow. Artificial channels may feed minor amounts of excess water to playa.	
Moderately disconnected from floodplain due to multiple geomorphic modifications. Between 25-75% of stream banks may be affected by bikes, rip rap, concrete, and/or elevated culverts. Channel may be moderately entrenched and disconnected from the floodplain except in large floods.	Moderate restrictions to the lateral or vertical movement of surface and ground water by unnatural features such as levees, road grades or excessively high banks. Between 25–75% of the site may be restricted by barriers to drainage. Flood flows may exceed the impoundments, but drainage back into the wetland may be incomplete due to the impoundments.	Surrounding land cover / vegetation may interrupt a moderate amount of surface flow. Artificial channels may feed moderate amounts of excess water to playa.	
Channel is severely entrenched and entirely disconnected from the floodplain. More than 75% of stream banks may be affected by dikes, rip rap, concrete and/or elevated culverts. Overbank flow never occurs or only in severs floods.	Essentially no hydrologic connection to adjacent landscape. Most or all stages may be contained within artificial banks, levees, or comparable features. Greater than 75% of the site is restricted by barriers to drainage.	Surrounding land cover / vegetation may dramatically restrict surface flow. Artificial channels may feed significant amounts of excess water to playa.	

Hydrologic connectivity comments:

Point Code___________________ QC_________

HYDROLOGY STRESSORS WITHIN A 500 M ENVELOPE AND BEYOND

Using the table below, estimate the scope and severity of each **hydrology stressor within at least the 500 m envelope of the AA, if not beyond**. Use topo maps, gazetteers, and/or GIS to look beyond the 500 m envelope, particularly in Riverine systems.

Scope: 1 = 1–10%, 2 = >10–30%, 3 = >30–70%, 4 = >70%. ***Severity: 1 = slight, 2 = moderate, 3 = serious, 4 = extreme.***

Hydrology stressor categories	*Scope*	*Severity*
Dam / reservoir		
Impoundment / stock pond		
Gravel ponds – reclaimed or not		
Spring box diverting water from wetland		
One or few wells in the surrounding area (including cattle wells)		
Extensive groundwater wells in the surrounding area (potential to lower water table)		
Pumps, diversions, ditches that move water *out of* the wetland / source channel		
Pumps, diversions, ditches that move water *into* the wetland / source channel		
Berms, dikes, levees that hold water in the wetland		
Deeply dug pits for holding water (stock ponds)		
Weir or drop structure that impounds water and controls energy of flow		
Point source discharges (treatment water, non-storm discharge, septic)		
Observed or potential agricultural runoff		
Observed or potential urban runoff		
Flow obstructions into or out of wetland (roads without culverts)		
Dredged inlet or outlet channel		
Engineered inlet or outlet channel (e.g., riprap)		
Other:		
Other:		

Hydrology stressor comments:

Point Code__________________ QC_________

4. *PHYSIOCHEMICAL METRICS – Check the applicable box.*

WATER QUALITY - SURFACE WATER TURBIDITY / POLLUTANTS	
Select the statement that best describes the **turbidity or evidence or pollutants** in surface water within the AA.	
No open water in AA	**NA**
No visual evidence of turbidity or other pollutants.	
Some turbidity in water (such as turbidity caused by high flows or naturally occurring in playas) OR presence of other pollutants, but limited to small and localized areas within the wetland. Water may be slightly cloudy.	
Water is cloudy or has unnatural oil sheen, but the bottom is still visible. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	
Surface water turbidity / pollutants comments and photo #'s: *Turbidity may be natural depending on recent weather patterns and flow timing (i.e., higher flows are often more turbid). Please rank the system as you see it, regardless of whether the turbidity is natural. Make sure to include good notes if you down rank the system and please take photos.*	

WATER QUALITY - ALGAL GROWTH	
Select the statement that best describes **algal growth** within surface water in the AA. Exclude *Chara* (multicellular algae) in estimates of cover.	
No open water in AA or evidence of open water.	**NA**
Water is clear with minimal algal growth.	
Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	
Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen.	
Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see.	
Algal growth comments and photo #'s: *Algal growth may be natural and not necessarily indicative of poor water quality. Please rank the system as you see it, regardless of whether the algae presence appears natural. Make sure to include good notes if you down rank the system and please take photos.*	

SUBSTRATE / SOIL DISTURBANCE

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

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

Substrate / soil comments and photo #'s:

PHYSIOCHEMICAL STRESSORS WITHIN THE AA

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

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

Physiochemical stressor comments:

Site ID / Name: ____________________________ Date: __________________

2015 COLORADO ECOLOGICAL INTEGRITY ASSESSMENT (EIA) –STRESSOR CHECKLIST

Stressors: *direct threats*; “the proximate (human) activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity and natural processes” or altered disturbance regime (e.g. flooding, fire, or browse).

Some Important Points about Stressors Checklists:

1. The Stressors Checklist must be completed for the 500 m envelop surrounding the AA (Landscape) and for the 0.5 ha AA (Veg, Hydro, Soils). Rely on imagery in combination with what you can field check.
2. Assess stressors in the 500 m envelope for their effects on land surrounding the AA (*NOT how they may impact the AA*)
3. Stressors for Vegetation, Soils, and Hydrology are assessed across the full 0.5 ha assessment area (AA)
4. Severity has been pre-assigned for many stressors. If the severity differs from the pre-assigned rating, cross it out and note the true severity. If there is more than one pre-assigned value, circle the appropriate value.
5. To comment, note the stressor number before writing comments.

SCOPE of Threat (% of AA or Buffer affected by direct threat)	
1 = Small	Affects a small portion (1-10%) of the AA or landscape
2 = Restricted	Affects some (11-30%) of the AA or landscape
3 = Large	Affects much (31-70%) of the AA or landscape
4 = Pervasive	Affects all or most (71-100%) of the AA or landscape

SEVERITY of Threat within the defined Scope (degree of degradation to AA or Buffer)	
1 = Slight	Likely to only slightly degrade/reduce
2 = Moderate	Likely to moderately degrade/reduce
3 = Serious	Likely to seriously degrade/reduce
4 = Extreme	Likely to extremely degrade/destroy or eliminate

		500 m Envelope Landscape			**ASSESSMENT AREA (0.5 ha)**									
					Vegetation			**Soil / Substrate**			**Hydrology**			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT	Scope	Severity	IMPACT	Scope	Severity	IMPACT	Scope	Severity	IMPACT	**Comments**
	1. Residential, recreational buildings, associated pavement		3											
D	2. Industrial, commercial, military buildings, associated pavement		4											
E	3. Oil and gas wells and surrounding footprint		4											
V	4. Roads (gravel=2, paved=3, highway=4), railroad=3		2, 3, 4											
E	5. Sports field, golf course, urban parkland, expansive lawns		2											
L	6. Row-crop agriculture, orchard, nursery		3											
O	7. Hay field, fallow field		2, 3											
P	8. Utility / power line corridor		1, 2, 3			1, 2, 3								
	9. Other [specify]:													
R	10. Low impact recreation (hunting, fishing, camping, hiking, bird-watching, canoe/kayak)		1			1								
E	11. High impact recreation (ATV, mountain biking, motor boats)		3			3								
C	12. Other [specify]:													
	13. Tree resource extraction (clear cut=3 or 4, selective cut= 2 or 3)		2, 3, 4			2, 3, 4								
	14. Vegetation management (cutting, mowing)		2			2								
V	15. Livestock grazing, excessive herbivory by native species (ungulates, prairie dogs) (low=1, mod=2, high=3)		1, 2, 3			1, 2, 3								
E	16. Insect pest damage (low=1, mod=2, high=3)		1, 2, 3			1, 2, 3								
G	17. Invasive plant species (see noxious weed list)		3			3								
	18. Direct application of agricultural chemicals, herbicide spraying		2, 3			2, 3								
	19. Other [specify]:													
N	20a. Evidence of recent fire (low=1, mod=2, high=3)		1, 2, 3			1, 2, 3								
A	20b. Recent beaver dam blowout		1, 2			1, 2								
T	21. Other [specify]:													

Site ID / Name: ___________________________ Date: _________________

		500 m Envelope Landscape			ASSESSMENT AREA (0.5 ha)									
					Vegetation			Soil / Substrate			Hydrology			
	STRESSORS CHECKLIST	Scope	Severity	IMPACT	Scope	Severity	IMPACT	Scope	Severity	IMPACT	Scope	Severity	IMPACT	**Comments**
	22. Excessive sediment or organic debris (inputs from recently logged sites, sedimentation in playas)													
	23. Excessive erosion or loss of organic matter (gullying, decay of organic soils)													
	24. Trash or refuse dumping													
S	25. Filling or dumping of sediment (spoils from excavation)													
O	26. Substrate removal (excavation)													
I	27. Indirect soil disturbance (compaction or trampling by livestock, human use, vehicles)													
L	28. Direct soil disturbance (grading, compaction, plowing, discing, deeply dug fire lines)													
S	29. Physical resource extraction (rock, sand, gravel, minerals, etc.)													
	30. Obvious excess salinity (dead or stressed plants, salt crusts)													
	31. Other [specify]:													
	32. PS discharge (waste water treatment, factory discharge, septic)													
	33. NPS discharge (urban / storm water runoff)													
H	34. NPS discharge (agricultural runoff, excess irrigation, feedlots, excess manure)													
Y	35. NPS discharge (mine runoff, discharge from oil and gas)													
D	36. Large dams / reservoirs													
R	37. Impoundments, berms, dikes, levees that hold water in or out													
O	38. Canals, diversions, ditches, pumps that move water in or out													
L	39. Excavation for water retention (gravel ponds, pitted playas)													
O	40. Groundwater extraction (few small wells=2, extensive extraction cause a lowered water table=4)													
G	41. Flow obstructions (culverts, paved stream crossings)													
Y	42. Engineered channel (riprap, armored channel bank, bed)													
	43. Control of flow and energy (weir/drop structure, dredging)													
	44. Other [specify]:													
	Stressors Very Minimal or Not Evident (check box, if true)	☐			☐			☐			☐			
	STRESSOR RATING BY CATEGORY (Envelope, Veg, Soils, Hydro)	Score:	Rating:		Score:	Rating:		Score:	Rating:		Score:	Rating:		HIS Score: HIS Rating:
	OVERALL HUMAN STRESSOR INDEX (HSI) – use category weights	**0.3**			**0.3**			**0.1**			**0.3**			

Threat Impact Calculator		**Scope**			
		Pervasive = 4	**Large = 3**	**Restricted = 2**	**Small = 1**
Severity	**Extreme = 4**	VERY HIGH = 10	High = 7	*Medium = 4*	Low = 1
	Serious = 3	High = 7	High = 7	*Medium = 4*	Low = 1
	Moderate = 2	*Medium = 4*	*Medium = 4*	Low = 1	Low = 1
	Slight = 1	Low = 1	Low = 1	Low = 1	Low = 1

Category / HSI Roll-up Formulas	
Score	**Rating**
10+	**Very High**
7 – 9.9	**High**
4 – 6.9	**Medium**
1 – 3.9	**Low**
0 – 0.9	**Absent**

APPENDIX D: SURVEY DESIGN PARAMETERS AND IMPLICATIONS

Probabilistic survey designs allow for results collected in a few sites to be extrapolated to a larger population of interest. In a probabilistic design, target sample points are selected from a geospatial representation of the entire population and every point within that representation has a known (non-zero) chance of being included in the design, also called an inclusion probability. If the design is unstratified and contains no subpopulations, every point within population has the same chance of being included. When estimates are calculated based on the sample, each point will have the same weight in the overall estimate. However, if the design is stratified or contains unequal probability categories (subpopulations), points from certain areas within the spatial representation or certain categories of points will have a higher chance of being selected than others. Depending on their proportion in the overall population, some points will have a greater weight in the overall estimate than others. This has implications for translating sample results to final estimates.

In addition, once target points have been selected, they are evaluated through desktop reconnaissance and/or a field visit to determine if they represent the actual population of interest. In some instances, like with wetlands of the Lower Arkansas Basin, the only available spatial representation of the resource may include non-target areas. Points that are non-target are excluded from final estimates and alter the overall estimated size of the population. For sites that are determined to meet the population of interest, considerable effort is put into contacting land owners and land managers to obtain access. Often many target sites cannot be access due to lack of permission. Final estimates are therefore based only on the points that are target and can be accessed. If sites that cannot be accessed are significantly different that those that can be accessed, the overall estimates may not represent the entire population, but only the portion of the population that can be accessed.

For the Lower Arkansas Basin wetland assessment, the survey design was both stratified and contained subpopulations of wet and dry codes within the NWI mapping. Each of the resulting six survey design categories had a different weight in the overall population estimates (Table A1). Drier attributes within the central irrigated valley had significantly higher weight in the overall estimate than other categories. Unevenness of the weights can lead to large confidence intervals around the final estimates. However, the design was set up in this way in the hopes of sampling more actual wetlands than mesic riparian areas.

In total, 182 potential sample points were evaluated for inclusion in the study (Table A2.). Of those, 41 (23%) were determined to be non-target, either through desktop reconnaissance and/or a field visit. Proportionally more points were considered to be non-target in the southern plains, where large irrigated hay fields were included in the wetland mapping, but did not meet the definition of wetland. Many irrigated hay fields in Colorado do meet the definition of wetlands, especially if the hayfields are located in a landscape position that likely supported wetlands before irrigation. The hay fields of the southern plains, mostly in the far southwest corner of the study, did not meet the definition. In addition, 79 points (43%) could not be accessed due to either lack of permission, temporary high water, or safety concerns. Permission was easier to obtain for points in the central irrigated valley than it was for either plains stratum, partially because there is more public land within the central valley.

Table A1. Initial and final survey design weights for each survey design category.

Survey Design Category	*Initial Weight*	*Percent of Total Weight*	*Final Weight*	*Percent of Total Weight*
Irrigated Valley, Wet	1,984,365	4%	744,137	3%
Irrigated Valley, Dry	24,780,294	46%	11,263,769	48%
Northern Plains, Wet	4,452,080	8%	2,023,672	9%
Northern Plains, Dry	8,939,012	17%	4,966,117	21%
Southern Plains, Wet	3,890,834	7%	1,577,365	7%
Southern Plains, Dry	9,501,596	18%	2,969,248	13%

Table A2. Count of points evaluated for inclusion in the study and actual points surveyed.

Category	*Floodplain*		*North*		*South*		*Total*	
	Count	*% of Strata*	*Count*	*% of Strata*	*Count*	*% of Strata*	*Count*	*% of Total*
Non-Target	**12**	**19%**	**8**	**16%**	**21**	**30%**	**41**	**23%**
Perm deep water	1	2%	--	--	1	1%	2	**1%**
Dry	11	18%	4	8%	18	26%	33	**18%**
Farmed	--	--	3	6%	--	--	3	**2%**
Small size	--	--	1	2%	2	3%	3	**2%**
No Access	**28**	**45%**	**22**	**43%**	**29**	**42%**	**79**	**43%**
Permission	18	29%	22	43%	29	42%	69	**38%**
Safety concern	3	5%	--	--	--	--	3	**2%**
Temp high water	7	11%	--	--	--	--	7	**4%**
Target / Sampled	**22**	**35%**	**21**	**41%**	**19**	**28%**	**62**	**34%**
Total	**62**	**100%**	**51**	**100%**	**69**	**100%**	**182**	**100%**

Using the weights from each survey design category and the breakdown of points considered target, non-target, or no access, the proportion of the entire mapped resource in these categories was estimates (Figure A1). While 23% of points were considered non-target, the population level estimate was only 18% because more of the points in the irrigated valley (which had higher weight in the estimate) were considered target than in either of the plains strata.

Another statistic estimated based on the results in Table A2 and survey design weights was the percent of the mapped resource determined to be non-target within each of the six survey design categories (Figure A2). These results were surprising and counter to the original assumption of the survey design. The original survey design assumption was that drier codes within the NWI mapping were more likely to be non-target. However, for both the irrigated valley and the southern plains, wetter NWI codes were more likely to be considered non-target than drier NWI codes. To best understand these results, it is important to remember that the population of interest included both wetlands and mesic riparian areas. Many points with drier NWI codes were not necessarily true wetlands, but were considered target for this study.

Lastly, there was a shift in land ownership between the original sample design and the final target points sampled. While eight-four percent of original sample points were located on private lands, only 63% of final sample points were on private lands. It is unknown whether this slight bias towards public lands shifted the condition results of not.

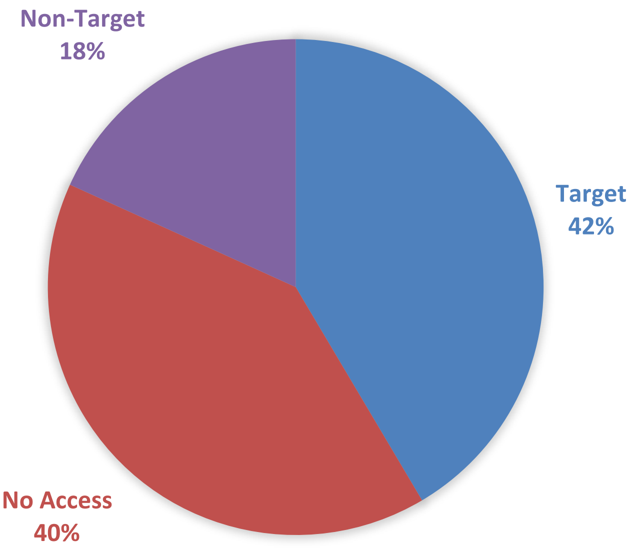


Figure A1. Survey design estimates of target, non-target, and no access for the entire mapped resource.

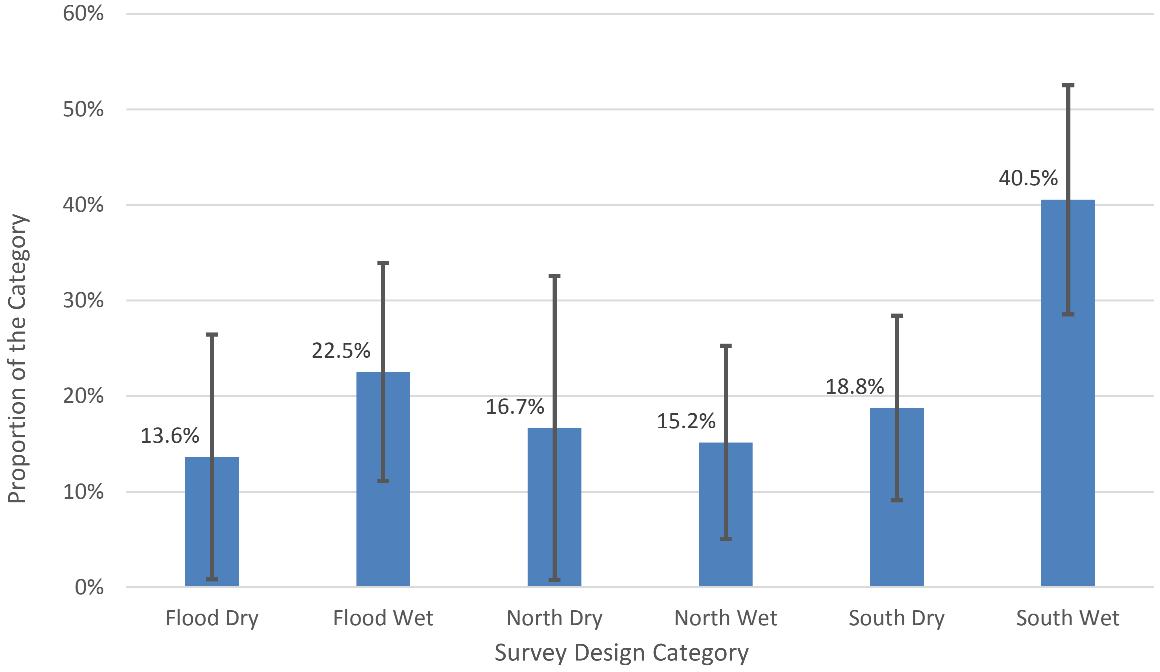


Figure A2. Survey design estimates of the percent of the mapped resource that is non-target, by survey design category.

Table A3. Distribution of original sample design points vs. actual sites sampled by major landowners/land manager.

Landowner / Manager	***Original Design***	***Sites Sampled***
Private	63	39
Colo Parks and Wildlife[1]	5	8
State Land Board	4	7
USFS National Grasslands	1	3
Bureau of Land Management	1	2
Local gov't	1	2
Land Trusts	--	1
Total	**75**	**62**

[1] For the purpose of this table, the CPW row also includes John Martin Reservoir, which is jointly administered by the Army Corps of Engineers and CPW as the John Martin State Wildlife Area. This row also include some portions of other State Wildlife Areas that are privately owned, but managed by CPW.