Lower Arkansas River Basin Wetland Mapping and Reference Network

NATURAL HERITAGE PROGRAM
COLORADO

December 2015

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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Recommended Citation:
Lemly, J., L. Gilligan, G. Smith, and C. Wiechmann. 2015. Lower Arkansas River Basin Wetland Mapping and Reference Network. Colorado Natural Heritage Program, Colorado State University, Fort Collins, Colorado.

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EXECUTIVE SUMMARY

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, Region 8. The overarching goal of the basin assessments 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. The lower Arkansas River Basin Assessment is being conducted in two phases. This report covers phase one of the project.

The first major component of this project was the creation of ***a digital map of wetlands and aquatic resources*** in the basin, a dataset that did not exist previously. This project created a map of wetlands for the Arkansas River Basin to documents their spatial distribution by type, hydrologic regime, land owner and protection status. The map was primarily based on converting 1970s era National Wetlands Inventory (NWI) data from paper maps to digital data. While converting existing NWI maps to digital data represents a huge leap forward for the Arkansas River basin, certain regions of the basin, particularly the urban corridor from Colorado Springs and Pueblo, have experienced significant land use changes since the original maps were produced. In addition, mapping methods have changed since the original NWI mapping was created. Given these concerns, the accuracy of the entire dataset was analyzed and selected quads were remapped using the most recent aerial photography available. Differences between the old and new mapping provide a context for interpreting the mapping data.

Once converted to digital data, original NWI mapping of the Lower Arkansas basin contained 205,587 acres of aquatic resources, including both wetlands and waterbodies. This represents only 1.5% of the total land area. The accuracy assessment, however, showed clear trends that should be taken into account whenever these data are used. Overall accuracy of the original map was only 47.6% (90% CI = 44.8–50.5%). The most significant source of discrepancy was within the forested wetland class. While the original mapping contained >30,000 acres of forested wetlands, the revised estimate showed less than 1,300 acres, indicating 96% fewer acres of forested wetlands than the original mapping showed. Many of the acres mapped as forested wetlands should actually be considered non-wetland riparian areas, while others should be classified as shrub wetlands. Herbaceous wetlands were also significantly over-mapped in the original NWI mapping by roughly 45%.

Though it would be ideal to update NWI mapping throughout the basin, this project included funding to update the mapping within 18 USGS quads, twelve quads around John Martin Reservoir and six quads around and upstream of Pueblo Reservoir. Within the John Martin priority area, original 1970s NWI mapping contained ~19,500 acres of mapped wetlands and ~4,800 acres of mapped waterbodies. The updated mapping contained ~8,600 acres of wetlands, ~8,400 acres of waterbodies, and ~10,400 acres of riparian areas. Many acres mapped as forested and shrub wetlands in the original mapping were classified as riparian in the new mapping. Similar to the

accuracy assessment, this represents a 56% decrease in wetland acreage, but a 74% increase in waterbody acres. Results from around Pueblo Reservoir show very similar patterns to the John Martin mapping.

The clearest result to emerge from the analysis of wetland mapping is how few acres of wetlands there are in the Lower Arkansas River basin. Original NWI mapping placed the estimate at just over 200,000 acres of wetlands and waterbodies, with ~143,000 acres of wetlands and ~63,000 acres of waterbodies. The accuracy assessment and new mapping showed that wetland acreage was grossly overrepresented. In actuality, the basin likely contains only ~80,000 acres of true wetlands, which represents <0.5% of the landscape. The second clear conclusion is the importance of working with private land owners in the management and conservation of wetland resources. Over 80% of the mapped wetland resources are on private lands or public lands managed by private leases. This represents an important opportunity for collaborative conservation efforts between private landowners who own and manage most wetland acres and federal and state agencies with resources and technical assistance.

The second major component of the project was identifying and collecting data within a set of ***reference standard wetlands and riparian areas*** throughout the basin. A set of 48 high quality, reference condition wetlands and riparian areas were hand selected across the basin to represent the most common wetland and riparian types. In-depth surveys were conducted in all reference sites, including fully detailed vegetation plots, soil profiles, basic water chemistry parameters, and characteristics of site hydrology. The ecological condition of references sites was assessed using the Ecological Integrity Assessment (EIA) Framework. Sites were spread across the basin and divided among seven main types: marshes, wet meadows, playas, plains floodplain, plains riparian area, foothills riparian areas, and canyon springs. All reference sites considered natural in origin, though 42% were altered or augmented by some degree of human action.

A total of 426 unique plant species were identified in the 59 site visits, with an average of 30 species per site. The most diverse site supported 75 different plant species. The least botanically diverse sites were typically playas, which frequently had <10 plant species. Of the twenty most common plant species observed in reference wetland and riparian sites, two-thirds were native and seven were nonnative, including two species listed as noxious weeds: Canada thistle (*Breea arvensis,* syn = *Cirsium arvense*) and tamarisk (*Tamarix ramosissima*). In all, 24 noxious weeds were observed in reference wetland and riparian sites. In addition to listed noxious weeds, two highly aggressive non-native species, kochia (*Bassia sieversiana*) and Russian thistle (*Salsola australis* or *S. collina*), were also frequently found in reference sites.

Nearly thirty percent of sites were ranked A for overall ecological integrity and an additional 52% were ranked B, indicating that the site selection process was generally successful at picking wetlands in excellent or good condition. Canyon springs had the highest average EIA score of 3.61. All but one canyon springs sampled were ranked A. Wet meadows had the second highest average EIA score of 3.49. Four out of five wet meadow sites were ranked A. Playas had the third highest average EIA score of 3.42 and were more evenly split between A and B ranks. Plains riparian sites had an average EIA score of 3.26 and included two sites ranked A and 14 sites ranked B. The one foothills riparian site was ranked B, with an EIA score of 3.03. Marsh sites had an average EIA score of 2.96 and included one A-ranked site, three B-ranked sites, and two C-ranked sites. Plains floodplain sites scored the lowest, with an average EIA score of 2.24 and were evenly split between B and C ranks.

All sites sampled were ranked A or B for landscape context, as a relatively intact landscape was one of the most important filters for selecting reference sites. Biotic condition showed the most variability among sites, with the full range of ranks from A to D. Lower scores for biotic condition were generally driven by the presence of invasive species, particularly for plains floodplain and plains riparian sites. Many of the sampled sites had intact hydrology, as shown by a high number of sites with A ranks for hydrologic condition, but the exception to this were reference sites along the Arkansas River floodplain, specifically floodplain marshes and plains floodplain sites.

The most common stressor observed in the landscapes surrounding reference sites was the presence of roads. In addition to roads, both grazing and low impact recreation were common in the landscapes surrounding surveyed sites. All three landscape stressors, however, most frequently occurred with low to moderate impact. The most common vegetation stressor observed within the sites was grazing, which was generally considered light in most sites. The second most common vegetation stressor was invasive species, which ranged from low to high impact. The most common hydrologic stressor was canals, diversion, and ditches, which affected a third of all sites and all of the plains floodplain sites. This common hydrologic stressor had a medium average impact, but ranged from low to high within individual sites. When all impacts were aggregated into an overall Human Stressor Index (HSI) for each site, it was clear that the plains floodplain sites faced the most cumulative stress, while other types generally experienced low cumulative stress.

While the Lower Arkansas River basin has been heavily modified over many years, it is remarkable that this study included 17 A-ranked wetlands. There are some truly special wetlands in this basin. The best sites were also located in smaller watersheds, often on private land or state land leased by private ranches, and had with fewer cumulative impacts from hydrologic alterations. These sites provide an encouraging outlook for wetlands in the basin and should serve as a model land managers. Most of the true wetlands reference sites (as opposed to non-wetland riparian areas) were located in a localized depression and/or had a seep water source. Therefore, wetland health in the Lower Arkansas Basin is dependent on and sensitive to both the maintenance of existing groundwater sources and levels, and a contiguous landscape with intact soils that do not intercept surface water runoff and groundwater recharge. In contrast, the paucity of good condition wetlands and riparian areas identified along the floodplain highlights both the need for improvement of the health of the wetland and riparian resources along the floodplain ecosystems, and the challenges managers face when attempting restoration projects along a landscape with large scale altered hydrology and invasion of undesirable plants.

ACKNOWLEDGMENTS

The authors at Colorado Natural Heritage Program (CNHP) would like to acknowledge the U.S. Environmental Protection Agency (EPA) Region 8 and Colorado Parks and Wildlife (CPW)'s Wetlands Program for their financial support and encouragement of this project. Special thanks to Brent Truskowski, EPA Project Officer, for his 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 project could not have happened without the support and assistance of local partners in the Lower Arkansas River 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.

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, a tow through flooded roads, and an invite to a live music show on their ranch!

We extend much gratitude to CNHP field technicians Spencer Rubin for his hard work and good humor collecting data and Sarah Marshall for her detailed data collection and willingness to survey in high-spider season. Thanks to botanists extraordinaire Pam Smith of CNHP and Jennifer Ackerfield of the CSU Herbarium for help with plant identification. CNHP work studies Lindsey Powers, Cora Marrama, and Claire Tortorelli were invaluable for entering and QC'ing pages and pages of field data.

For the mapping portion of the project, Rusty Griffin from U.S. Fish and Wildlife Services (USFWS)'s National Wetland Inventory (NWI) Program provided valuable assistance streamlining our NWI map conversion process. Thanks also to CPW pilot Denise Corcoran for taking Joanna Lemly and Brian Sullivan on a low-elevation flight of the basin, which helped clarify questions raised through the mapping analysis.

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, Bernadette Kuhn, Renee Rondeau, and Jeremy Sueltenfuss. Finally, we would like to thank Mary Olivas and Carmen Morales with Colorado State University for logistical support and grant administration.

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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, 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 project addresses the same major themes of extent, ecological condition, and habitat quality, methods for each study have been tailored for the basin. The Lower Arkansas project has been divided into two phases. This report documents work carried out under phase one of the project. The emphasis of phase one was on mapping wetland and riparian resources in the basin and sampling a network of hand-picked reference sites to establish a standard for ecological condition and habitat quality. The first phase of the project also included researching the habitat needs of wetland dependent wildlife species in the basin. The second phase of the project, which is being carried out under a separate EPA grant, will produce overall, basin-wide estimates of ecological condition and habitat quality for all wetlands and riparian areas in the basin by sampling a randomly selected set of sites.

1.2 Project Background

The Arkansas River Basin is that largest basin in the state of Colorado and drains a quarter of the state's land area. The floodplain of the Arkansas River, its tributaries, and numerous playa lake complexes are important migratory and wintering bird habitat (USFWS 1955). These areas are utilized by several priority wildlife species, including the federally listed Piping Plover, Least Tern, and Preble's meadow jumping mouse; state listed Arkansas darter; and scores of other bird and reptile species (RMBO & PWFAC 2004; Crockett 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 and tributaries (Gates et al. 2012). Highly managed water flows have contributed to an invasion of tamarisk (or salt cedar), a non-native riparian shrub that has choked ~67,000 acres of floodplain and riparian areas in the basin. The Lower Arkansas contains 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), and this pressure is exacerbated by several recent years of drought (U.S. Drought Monitor 2015). 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, Rocky Mountain Bird Observatory, Ducks Unlimited, Playa Lakes Joint Venture, and many other conservation organizations. However, to date, there has been no systematic, scientifically grounded accounting of the acreage, types, and distribution of the basin's wetlands because the information and tools necessary to carry out such an assessment have been.

A major component of this project was the creation of a digital map of wetlands and aquatic habitats in the basin, a dataset that did not exist previously. Thought all of Colorado's wetlands were mapped by USFWS's National Wetlands Inventory (NWI) Program in the late 1970s and early 1980s, they were created as paper maps and most were unavailable as digital data. In today's electronic era where geographic information systems (GIS) are the norm, paper maps are not as useful as digital data. Acreages cannot be calculated and analyses cannot be conducted based on paper maps. This project created a map of wetlands for the Arkansas River Basin to documents their spatial distribution by type, landowner and protection status.

While converting existing NWI maps to digital data represents a huge leap forward for the Arkansas River basin, certain regions of the basin, particularly the urban corridor from Colorado Springs and Pueblo, have experienced significant land use changes since the original maps were produced. In addition, technological advances since the 1970s have allowed the NWI program to increase the resolution of its mapping standards and new maps are far more accurate. Though delineating new maps is too time consuming and expensive for the entire basin, two additional analyses were undertaken. The accuracy of the entire dataset was analyzed and selected quads were remapped using the most recent aerial photography available. Differences between the old and new mapping provide a context for interpreting the mapping data.

The second major component of the project was identifying and collecting data within a set of reference standard wetlands and riparian areas throughout the basin. Reference sites are essential for establishing benchmarks for future condition assessments. Quantitative data on the best available sites helps identify departures from good ecological condition that may be caused by human impacts (Stoddard et al. 2006). Conditions observed within reference sites are called "reference condition", a term that refers to the "naturalness" of a system's biota and physical processes in the absence of human-induced stressors. For the Lower Arkansas basin, which has a long history of human land uses, this project focused on identifying the "least disturbed condition," a term that implies the best available physical, chemical, and biological habitat given conditions on the landscape today.

The third major component of the project was to take the first step in developing tools to monitor the extent of suitable wildlife habitat and the condition of wetlands in the basin. Extensive research was carried out on the habitat needs of wetland-dependent species. This research will feed into developing Habitat Quality Indices for the basin in the second phase of the project. All three components contribute information necessary to prioritize on-the-ground efforts for efficient and effective conservation action.

1.3 Project Objectives

The project objectives were to (1) create a digital map of wetlands in the Lower Arkansas River 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. The objectives of this project were carried out through the following tasks:

1) **Create a digital map of wetlands in the Arkansas River Basin and determine its accuracy.**
   - 350 7.5" USGS quadrangles (quads) of NWI mapping within the Lower Arkansas River Basin that were previously only available on paper were converted to digital spatial data in ArcGIS 10.2.
   - To determine accuracy of the wetland map, 1200 randomly distributed points were selected across the basin and evaluated using the most recent aerial photography. An error matrix was developed to document how well the original NWI mapping represents the current landscape.
   - To supplement the original NWI mapping, 18 quads were selected across the basin for new, updated NWI mapping using the most recent aerial photography. Areas of critical importance to wildlife habitat were targeted for this new mapping.
2) **Identify and assess a set of reference condition wetlands within the Arkansas River Basin.**
   - A set of 48 high quality, reference condition wetlands and riparian areas were hand selected across the basin to represent the most common wetland and riparian types.
   - In-depth surveys were conducted in all reference sites, including fully detailed vegetation plots, soil profiles, basic water chemistry parameters, and characteristics of site hydrology. The ecological condition of references sites was assessed using the Ecological Integrity Assessment (EIA) Framework.
   - Data from the field surveys will be used to establish thresholds for future condition assessments in the basin.
3) **Research habitat requirements of priority wetland-dependent wildlife species within the Arkansas River Basin.**
   - Literature on the specific wetland habitat needs of priority wetland-dependent wildlife species was reviewed to determine key habitat features that can be easily and repeatedly measured in the field (i.e., hydrological regime, water depth, plant associations, open water interspersion, proximity of upland types, food sources, etc.).
   - Where literature was not sufficient, experts on the priority species were interviewed to add additional information.
   - The information obtained through literature review and interviews will be used to develop Habitat Quality Indices for use in future studies.

1.4 Report Organization

Results from this project address three major aspects of the wetland resource: extent, ecological condition, and habitat 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 ***wetland mapping*** and its accuracy.
- **Section 4** focuses on the assessment of ***reference wetlands and riparian areas.***

Research on habitat requirements was carried out through a contract with independent Wildlife Biologist Dr. Catherine Ortega. The information presented in that research is extensive enough that it is a separate, standalone report.

2.0 STUDY AREA

2.1 Geography

The Arkansas River basin in Colorado (including both HUC6 110200: Upper Arkansas and HUC6 110300: Middle Arkansas) is located in southeast Colorado. It drains the Arkansas River from its headwaters near the town of Leadville, passes through Colorado's eastern plains, and extends to the state boarder with Kansas. The study area for this project includes only the lower portion of the Arkansas basin (hereafter called the Lower Arkansas River basin or 'basin'), and also incorporates the Colorado section of the Upper Cimarron basin (HUC6 110400) in the far southeast corner of the state. 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, which are not included (Figure 1).

The basin is situated in the southern half of Colorado's eastern plains and is dominated by the floodplain of the Arkansas River. The larger tributary rivers to the north include Fountain, Chico, Horse, Rush, and Big Sandy Creeks; and to the south include Hardscrabble Creek, St Charles River, Huerfano River, Cucharas Creek, Apishapa River, Purgatoire River, and Two Butte Creek. North Carrizo Creek and the Cimmaron River are also located in the far southeast corner (Figure 2). Elevation in the basin ranges from a high of 7,750 ft. (2,360 m) in both the southern mesas near Trinidad and the northern foothills near Colorado Springs to a low of 3,350 ft. (1,020 m) where the Arkansas River drains into Kansas. The mean elevation in the basin is 4,875 ft. (1485 m).

The basin encompasses sixteen counties: all of Otero, Crowley, Kiowa, Bent, Prowers, and Baca counties; and portions of Pueblo, Huerfano, Las Animas, Fremont, El Paso, Elbert, Lincoln, Cheyenne, Kit Carson, and Custer counties. Colorado Springs and Pueblo are the largest cities in the basin. Colorado Springs has a population of ~446,000 people and Pueblo of ~108,000 people (US Census Bureau 2014). Outside of those cities, the remainder of the basin's population is < 200,000, and is most populated along the I-25 corridor at the western edge and within small towns along the Arkansas River.

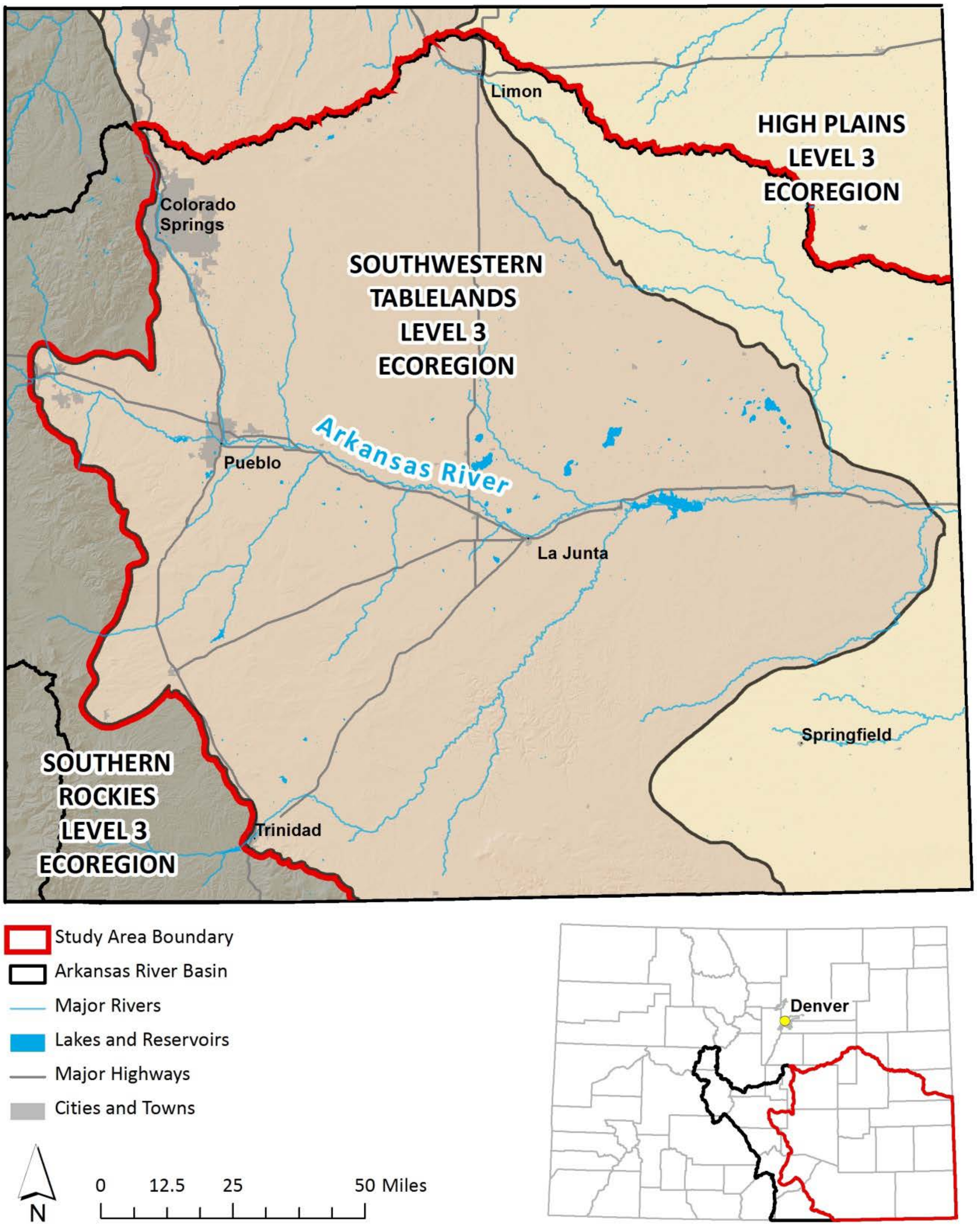


Figure 1. Location of the Lower Arkansas River basin study area within the state of Colorado.

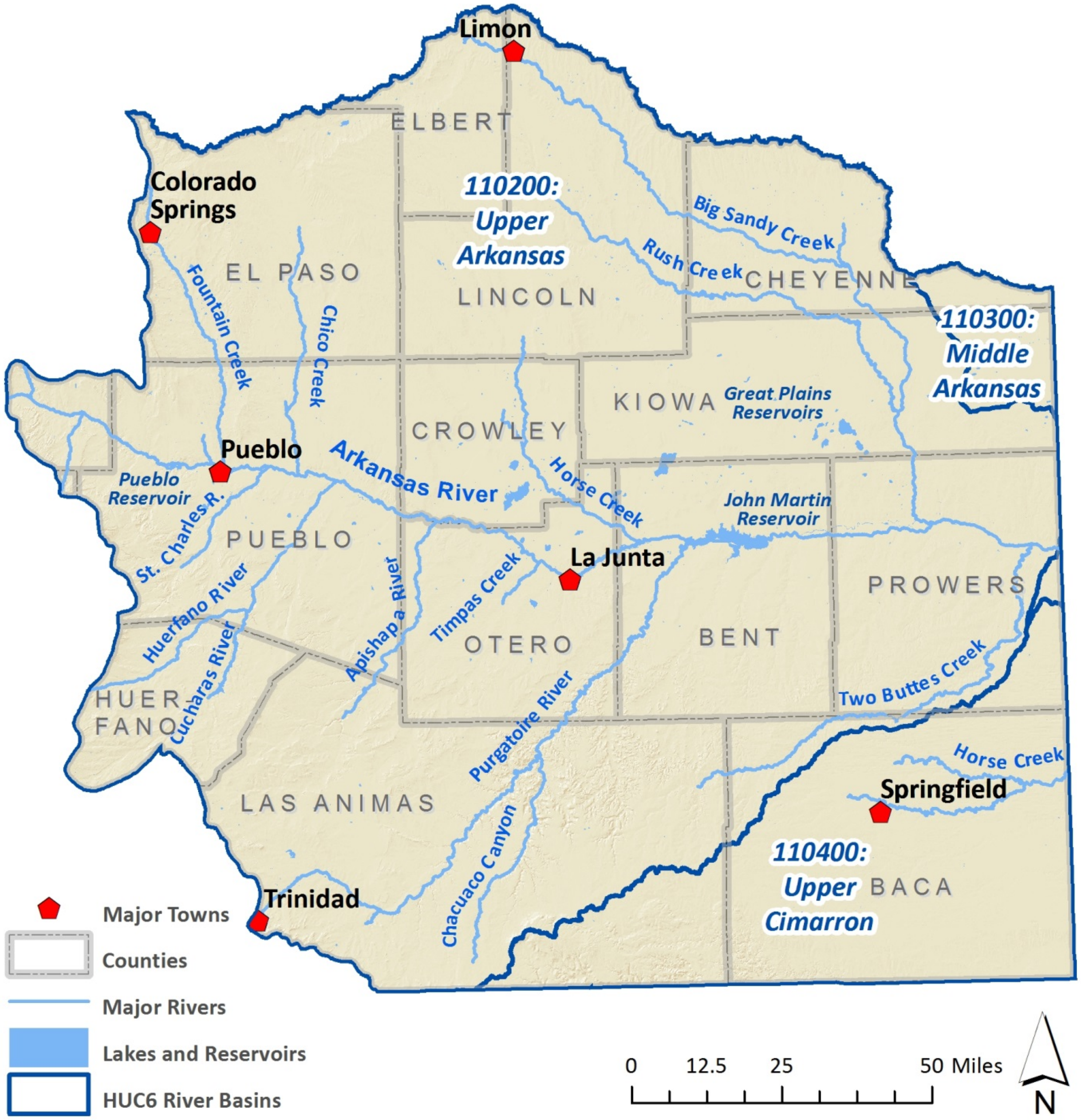


Figure 2. HUC6 river basis, major waterways, and counties in the Lower Arkansas River basin.

2.3 Geology and Soils

The topography across much of the basin is nearly flat to gentle rolling hills. More dissected topography of canyonlands and tablelands, such as the Purgatoire River Canyon and Mesa de Maya, lie embedded in the shortgrass prairie south of the Arkansas River.

Shales, limestone, sandstone, basalt, and gypsum deposits make up the old Jurassic and Cretaceous bedrock geology throughout much of the basin (Figure 3). The sedimentary geology was formed from a historic shallow sea that used to cover the plains of Colorado. The larger bedrock formations in the lower Arkansas basin include the Jurassic-formed Entrada Sandstone and the Morrison and Ralston Creek Formations. Major Cretaceous age formations in the basin include the Purgatoire Formation, Dakota Sandstone, Graneros Shale, Greenhorn Limestone, Carlile Shale, Pierre Shale, and the Niobrara Formations. Tall buttes and canyons have more complex surface geology and bedrock layers exposed.

Newer unconsolidated alluvial deposits cover riparian and floodplain lowlands of the larger tributaries and rivers, often of sand-gravel. In addition to coarse alluvium, the Arkansas River floodplain includes patches of poorly drained clay and clay-loam soil associations that support narrow swale and large marsh wetlands. Sandy tributary creeks such as Big Sandy and Rush Creek are underlain by deep alluvial soils. These deep sandy soils transport water above and below ground along the riparian areas of the plains, with only subsurface flow across some plains riparian reaches. Outcrops immediately outside the Arkansas floodplain are often loamy soils upon sandstone breaks or limestone and shale escarpments. Just south of the Arkansas River and surrounding some of the larger tributaries are rolling sandhills on hummocky uplands and historic stabilized dunes. Spreading playa complexes are common throughout loessial uplands, occurring upon historic sand dune lowlands that lack drainage, eroded eolian soils, and saline subirrigated lowlands.

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, such as Adobe Creek, have naturally saline soils. Shale derived soil can be naturally high in selenium. Irrigation return flows can further concentrate levels of selenium and salts, so there has been study and debate on how much irrigation contributes to water quality issues in the basin.

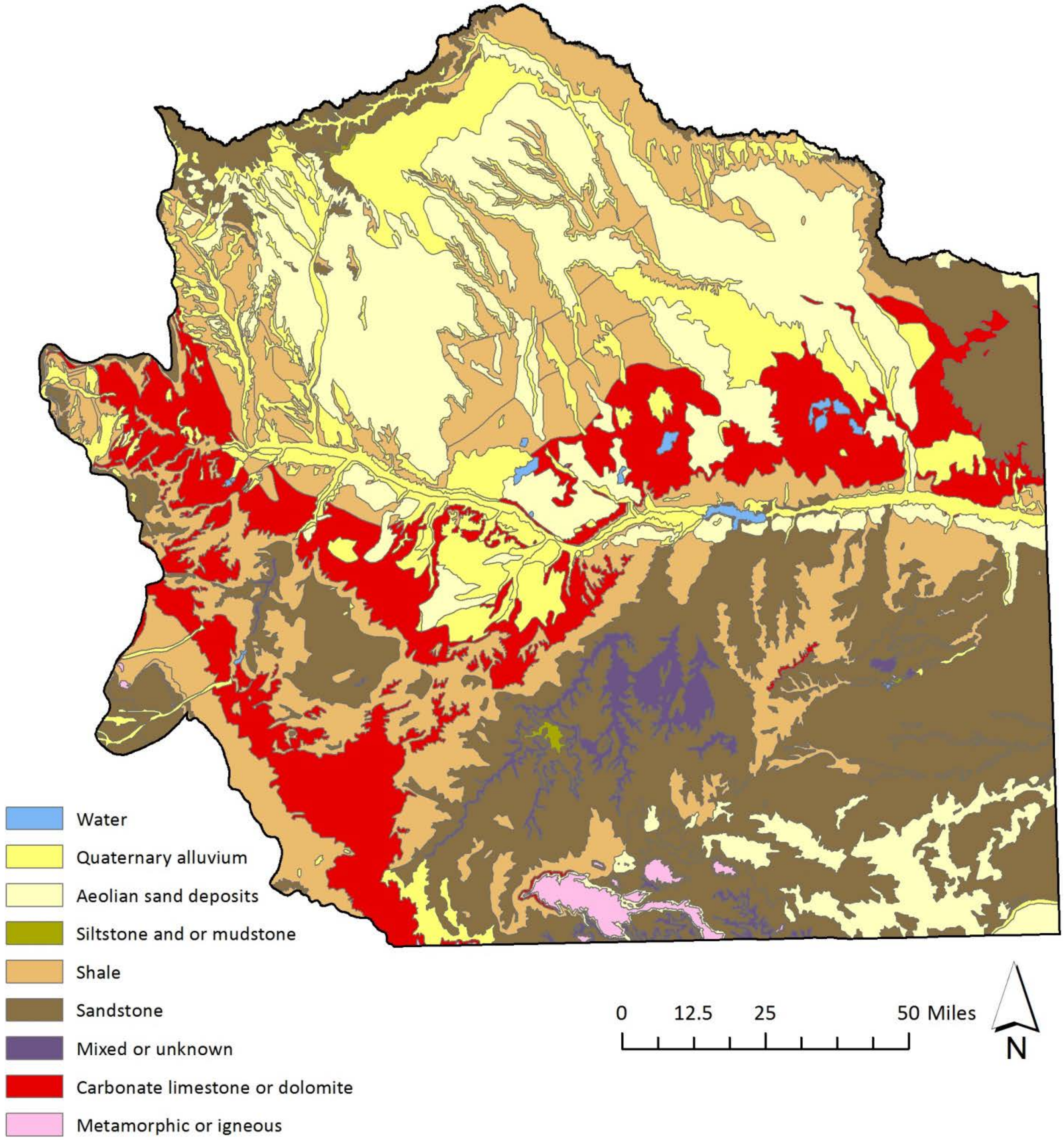


Figure 3. Dominant geology of the Lower Arkansas River basin.

2.4 Ecoregions and Vegetation

The basin falls within two Omernik Level 3 ecoregions: the High Plains and the Southwest Tablelands (Omernik 1987[1]). Level 4 Ecoregions further divide the landscape into finer units based on vegetation, topography and geology (Figure 4; Table 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 (*Buchloe dactyloides*), blue grama (*Chondrosum gracile*), 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, in part due to the basin's large size and the predominately rural land use (Rondeau et al. 2010).

The dominant landscape of semi-arid shortgrass prairie uplands can sharply contrast with the basin's seep wetlands, riparian areas, and inundated playas and reservoirs. The Lower Arkansas floodplain is a mosaic of vegetation zones, with woody bands of native cottonwood (*Populus deltoides*) and non-native tamarisk (*Tamarix spp.*), open herbaceous areas dominated by mesic grasses (*Panicum virgatum* and *Distichlis stricta*), sandy shrub terraces dominated by willows (*Salix exigua*, *S. eriocephala*, *S. amygdaloides*, and *S. fragilis*), and interspersed agriculture fields. Small to large swaths of cattail (*Typha* spp.) marshes are located along the river between Pueblo and John Martin Reservoirs. Perennial reaches of the larger tributary streams to the Arkansas support similar overstory species, with understory more influenced by shortgrass prairie species. Non-native species kochia (*Bassia sieversiana*) and Russian thistle (*Salsola* spp.) are prevalent in the basin's riparian understory composition, and similar to tamarisk, they can often dominate their strata. Russian thistle was identified as a problem 'noxious weed' in the basin over a century ago (Lapham 1902).

Other lowlands support playas and riparian areas with plant communities adapted to fluctuating and often intermittent flows. Narrower riparian areas range from open sandy-wash cottonwood galleries with upland or mesic understory grasses, to patchy seep-groundwater fed wetlands along slow-flow 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 wetland resource; vegetation species that fringe the large reservoirs are similar to the riparian species of the Arkansas floodplain. These reservoirs were not targeted for sampling for this reference wetland study, as most are linked to a canal system and have managed hydrology.

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

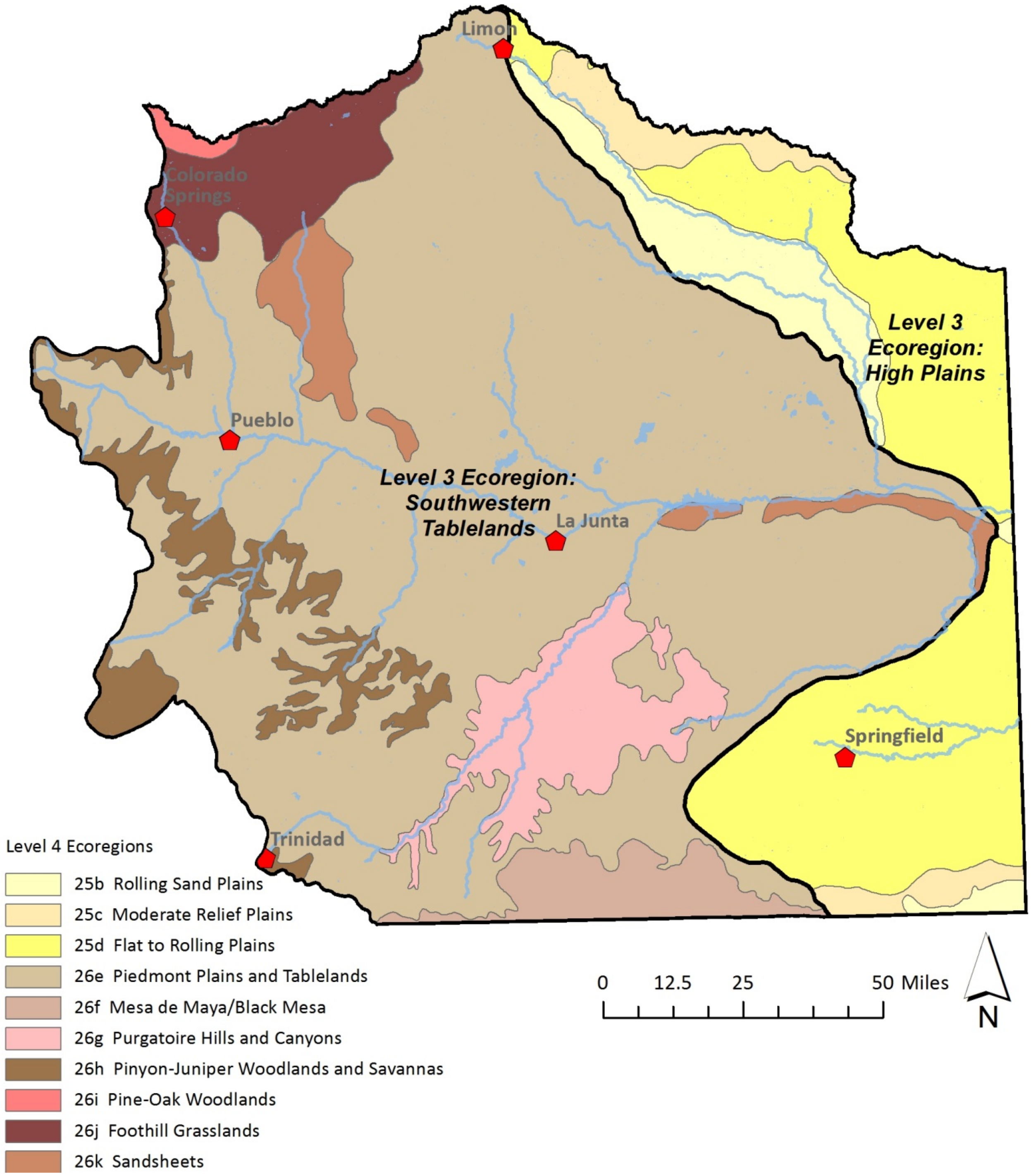


Figure 4. Level 3 and 4 Ecoregions of the Lower Arkansas River basin.

Table 1. Descriptions of Level 4 Ecoregions within the Lower Arkansas River 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: Pinon-Oak 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.

Table 1. Descriptions of Level 4 Ecoregions within the Lower Arkansas River basin *continued.*

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.

2.2 Climate

The basin is located in semi-arid southeastern Colorado plains, where evaporation exceeds precipitation. Annual precipitation ranges from ~11–17 inches throughout the basin (WRCC 2015). Temperatures fluctuate widely, with low winter temperatures < 0˚F and daily summer highs frequently exceeding 100˚F. Field data collection for this study took place in 2014, following several years of extreme drought. The Lower Arkansas River basin is part of the country impacted by what is said to be the worst drought since 1956 (National Public Radio 2012). The 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 for the future of 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 9.2 inches, which is 65% of normal annual precipitation for the Lower Arkansas River basin.[2] The worst drought year was 2012, during which the basin received only 45% of its normal precipitation. In 2014, the year this study was conducted, the basin received roughly 83% of its normal rainfall (12.0 inches) (U.S. Climate Data 2015). Although considered to be in the drought, precipitation in the basin during the spring of 2014 was more than during the severe drought years (Figure 5). Compared to historical annual precipitation, however, March through June were still notably dry. July and August brought multiple storms and heavy rainfall throughout the basin, and even surpassed typical year precipitation values. The wet late summer marked a turning point for the basin's drought.

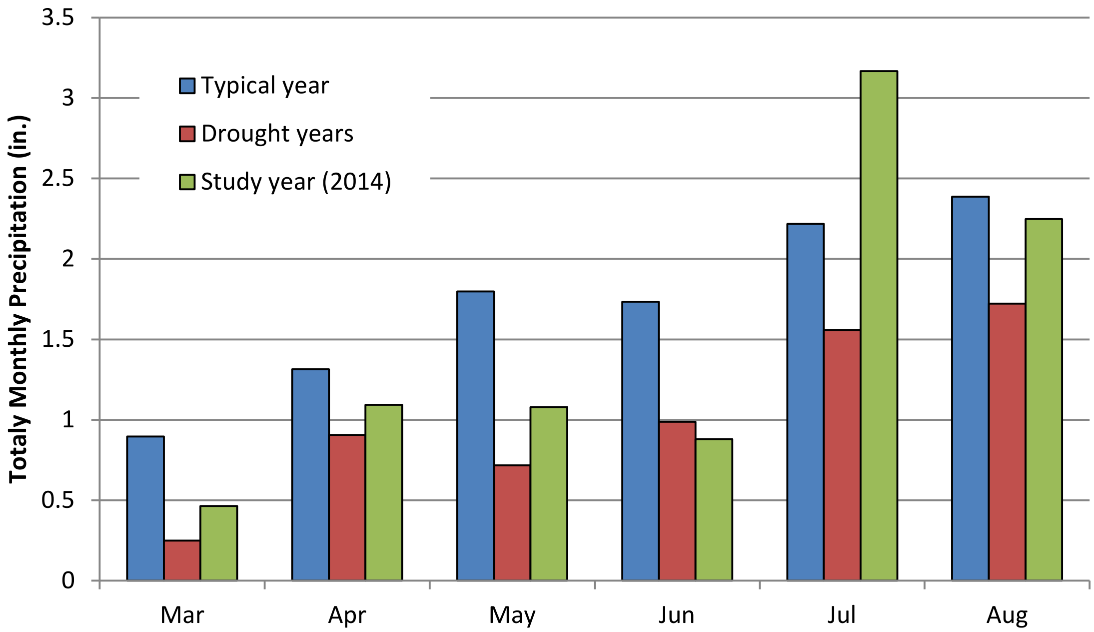


Figure 5. Total monthly precipitation for the Lower Arkansas River Basin for the study year (2014), compared with the preceding drought years and with the historical average.

2.5 Hydrology

Hydrology of the basin's wetlands and riparian areas vary depending on location. Wetlands and riparian areas along the Arkansas River's floodplain are heavily influenced by seasonal precipitation and snowmelt from the Upper Arkansas Basin, and are extensively managed in the lower basin. John Martin and Pueblo Reservoirs are 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. In contrast, most of the basin's tributary streams originate in the plains,

[2] 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.

and are more influenced by local precipitation patterns. The basin's tributaries range from perennial to intermittent flow. Most 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 also numerous precipitation and runoff-fed depressional playas throughout the basin. These range from large complexes of small, naturally 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 were historically large natural playa lakes that are now linked up to a canal system and function as reservoirs (Kettler et al. 1999). Some large historic playas were once filled as reservoirs, but have since lost their water rights. Common hydrologic alterations to smaller playas are pits for livestock, or conversion to cropland.

2.5.1 Irrigation Practices

Irrigation has shaped the hydrology across much of the basin. The basin's first evidence of irrigated agricultural crops dates to 1854 (Lapham 1902). Large canal systems were built in the late 19th century, and irrigated farming was well-established by 1890. Over time, irrigation raised water tables around the floodplain of the basin's larger rivers (Gates et al. 2012). 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 fully and 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 tributary or surface-connected groundwater wells decreed after 1948 are responsible for replacing pumped water with augmentation water back to the river.

A total of 48,731 acres of irrigated lands were mapped in the basin as of 2003 (CDSS 2012). Of those acres, 61% are categorized as "flood" irrigation lands, meaning that fields are irrigated using the surface irrigation method, which is a low-technology and less efficient irrigation method. This flood and furrow irrigation type can also create many incidental wetlands as water is indiscriminately put onto the landscape. The other majority of irrigated lands (38%) are categorized as "dry", meaning they were historically irrigated, but the management has since been changed. Less than one percent is either sprinkler or drip irrigated. Of the actively irrigated lands, nearly three quarters (73%) are planted as alfalfa crops for hay and another 16% are irrigated for livestock pasture. Other crops on irrigated lands include grain and silage corn, dry beans, small grains, vegetables, wheat and fall wheat, but each account for less than 3% of irrigated croplands.

While irrigated agriculture accounts for the majority of the basin's water use (87% of the entire Arkansas Basin), urban municipal and industrial water needs are increasing (Arkansas Basin Rountable 2015). 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. In an already water-stressed basin, this transfer of water may result in irreversible changes to the wetland resource.

Water diversions range from small diversions from the closest stream for crop irrigation, to larger storage and irrigation canals such as the Fort Lyon Storage Canal and Fort Lyon Canals, to trans-basin diversions transporting water from outside of the basin. The Fryingpan-Arkansas Project is the basin's largest trans-basin project. It 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 upstream to the City of Aurora.

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 groundwater quality where agricultural uses are concentrated (Topper et al. 2003). However, both surface and subsurface irrigation return flow and the basin's natural shale geology contribute to salt loads in the basin's waters (Cooper et al. 2006).

The majority of the Lower Arkansas River Basin is underlain by the Dakota-Cheyenne aquifer, more or less corresponding with the Southwestern Tablelands Level 3 ecoregion. North and east of Colorado Springs in El Paso and Elbert counties is the Denver Basin, and west of Walsenburg and Trinidad is the Raton Basin. The eastern portion of the basin, within the High Plains Level 3 ecoregion, is underlain by the High Plains (Ogallala) Aquifer. Irrigation and domestic water above the Ogallala is pumped from wells, as surface water irrigation is not available. Deeper alluvial aquifers are also pumped for irrigation water along the Arkansas River Valley, the Upper Black Squirrel and Upper Big Sandy watersheds. The Denver Basin and Dakota-Cheyenne aquifers are also pumped for groundwater. These bedrock aquifers are non-renewable and have a total projected life of ~100 years (CDWR 2014). 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 (Brown and Caldwell 2011). 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.

2.5.2 Comparison of 2014 to Historic Flows for the Basin's Three Largest Rivers

Annual discharge in the basin's major waterways during the 2014 water year (October 2013–September 2014) ranged from just below to moderately above average historical flows (Table 2).[3] The Arkansas River at Pueblo, CO had annual discharge of 103% 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 slightly below historical levels at 81% and 93% of the historical average, respectively. The Purgatoire River, one of the largest tributaries to the Arkansas River, was slightly under historical flow at Madrid, CO (91% of historical), but closer to the confluence with the Arkansas River in Timpas, CO, annual discharge was slightly above historical levels (117%). Fountain Creek, another large tributary to the Arkansas River near the foothills, had annual discharge of 134% of historical flow, with a much higher and earlier spring peak than the average year. Natural flows in all parts of the basin, especially major waterways, are affected by storage

[3] Annual discharge for the 2014 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.

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.

Table 2. Annual discharge for the 2014 water year compared to historical annual discharge at six gauging stations along the Arkansas River, Purgatoire River, and Fountain Creek.

		Annual Discharge (ft.^{3}/s)		*2014 Discharge as a Percent of Historical*
Water body	***Station Location***	***2014***	***Historical***	
Arkansas River	Moffat St., Pueblo, CO	575.7	555.9	103%
Arkansas River	Las Animas, CO	206.2	253.2	81%
Arkansas River	Below John Martin Reservoir, CO	256.3	275.1	93%
Purgatoire River	Madrid, CO	61.9	67.9	91%
Purgatoire River	Timpas, CO	80.3	68.6	117%
Fountain Creek	Pueblo, CO	135.1	101	134%

Along the Arkansas River, peak flow in 2014 occurred in June at Pueblo (2711 ft.^{3}/s), and in July at Las Animas and John Martin Reservoir (699 ft.^{3}/s and 792 ft.^{3}/s respectively).[4] Monthly discharge values for 2014 and for historical data for the three aforementioned gauging stations were averaged to create a coarse hydrograph for the Lower Arkansas River (Figure 6). Flows in the Arkansas were slightly to moderately below historical mean flows from October 2013 to May 2014, matching the low precipitation in these months. River flows were high and surpassed historical means in June and 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 181 ft^3/s, but the Purgatoire further downstream at Timpas, CO peaked in July at 172 ft.^{3}/s. Fountain Creek peaked in April (342 ft.^{3}/s), and experienced a unique secondary peak again in July (175 ft.^{3}/s).

Outside of the riverine setting are depressional lakes called playas. These range from large complexes of small, intermittently-filled playas, to large reservoirs near the Arkansas floodplain. For example, the Great Plains Reservoirs of Queens State Wildlife Area were historically large natural playa lakes that were linked up to a canal system and now function as reservoirs (Kettler et al. 1999). Other large historic playas have also been filled as reservoirs, and some have since lost their water rights. Some playas still have intact hydrology, while others have been modified by pits or farming.

[4] Arkansas River discharge values were assessed for the 2014 water year from gauging stations located in Pueblo, Las Animas, and below John Martin Reservoir near Hasty, CO.

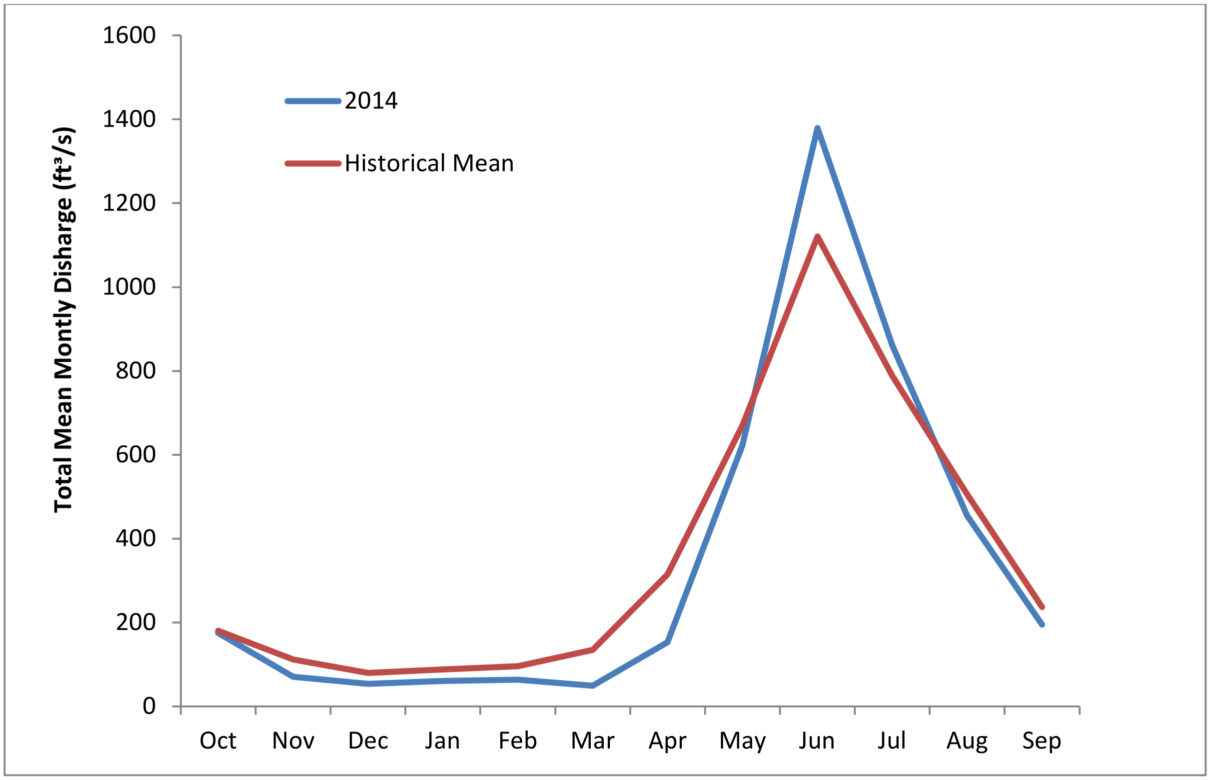


Figure 6. Hydrograph displaying total mean monthly discharge (ft.^{3}/s) for 2014 water year (October 2013–September 2014) and historical mean monthly discharge calculated from discharge data from 1975–2014 and averaged for three gauge stations along the Arkansas River (Pueblo, Las Animas, and below 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. 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.

Once a 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. 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 greatly reduce intermittent streamflow in runoff-fed riparian ecosystems.

Today, the vast majority of the basin is privately owned (84.1%). 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 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 tracks owned by the Bureau of Land Management, and the Military Lands of Pinon Canyon Maneuver Site, Fort Carson, Pueblo Chemical Depot, and the Air Force Academy.

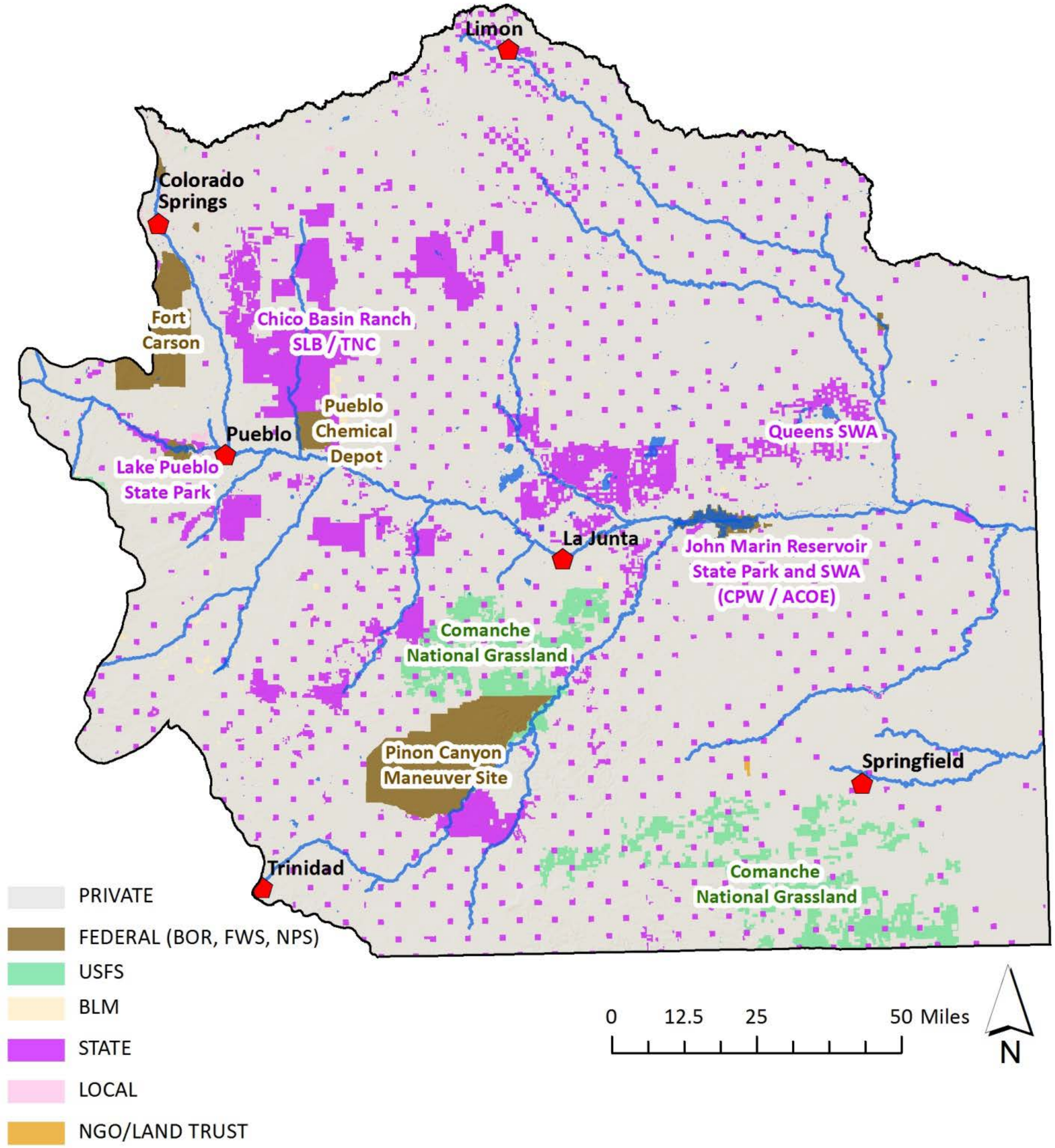


Figure 7. Landownership within the Lower Arkansas River basin.

3.0 Wetland Mapping

3.1 Introduction to Wetland Mapping

Management decisions about wetlands should be based on a solid understanding of the extent and distribution of wetland resources. The U.S. Fish and Wildlife Service's National Wetland Inventory (NWI) program began mapping wetlands across the U.S. in the 1970s in an effort to provide that very information. NWI is the most ambitious and comprehensive attempt to map wetlands in the country. All of Colorado was mapped on paper in the early years of the NWI program, but the majority of this mapping was unavailable in a digital format. With today's regular use of geographic information systems (GIS) to inform management decisions, digital data are necessary for any landscape-scale analyses.

Wetlands across Colorado's eastern plains, including the Lower Arkansas basin, were mapped by NWI in the late 1970s using the best aerial imagery at the time, which was black and white photography at a scale of 1:80,000. Both the scale and type of imagery available limited the level of detail that could be photo-interpreted reliably. In addition, mapping within the study area was carried out in the early years of the NWI program, when the classification system used to attribute polygons was still in development. Several changes have been made to the mapping and classification standards since the 1970s that increase the accuracy of more recent NWI maps. While the original 1970s maps were made on paper and were only available digitally as scanned images, a few specific areas covering 15% of the basin were updated in the 1980s and 1990s and these were available as digital polygons (Figure 8).

Through this project, CNHP digitized original 1970s NWI maps for the 85% of the basin lacking digital data and merged the 1970s data with existing 1980s and 1990s digital data to produce a comprehensive map of wetlands in the basin. However, based on previous work with NWI maps from the same era, we knew these early maps were not a precise representation of wetlands on the landscape today, both due to changes in mapping methodology and changes on the landscape. To address the limitations in the mapping and to quantify how well it reflects the wetland resources in the basin today, we assessed the accuracy of original NWI data through a systematic accuracy assessment. We also created new, updated NWI maps for 18 USGS quads located in two specific areas of the basin. The updated mapping was then combined with the original mapping to create the best representation of wetland extent and distribution currently available for the basin.

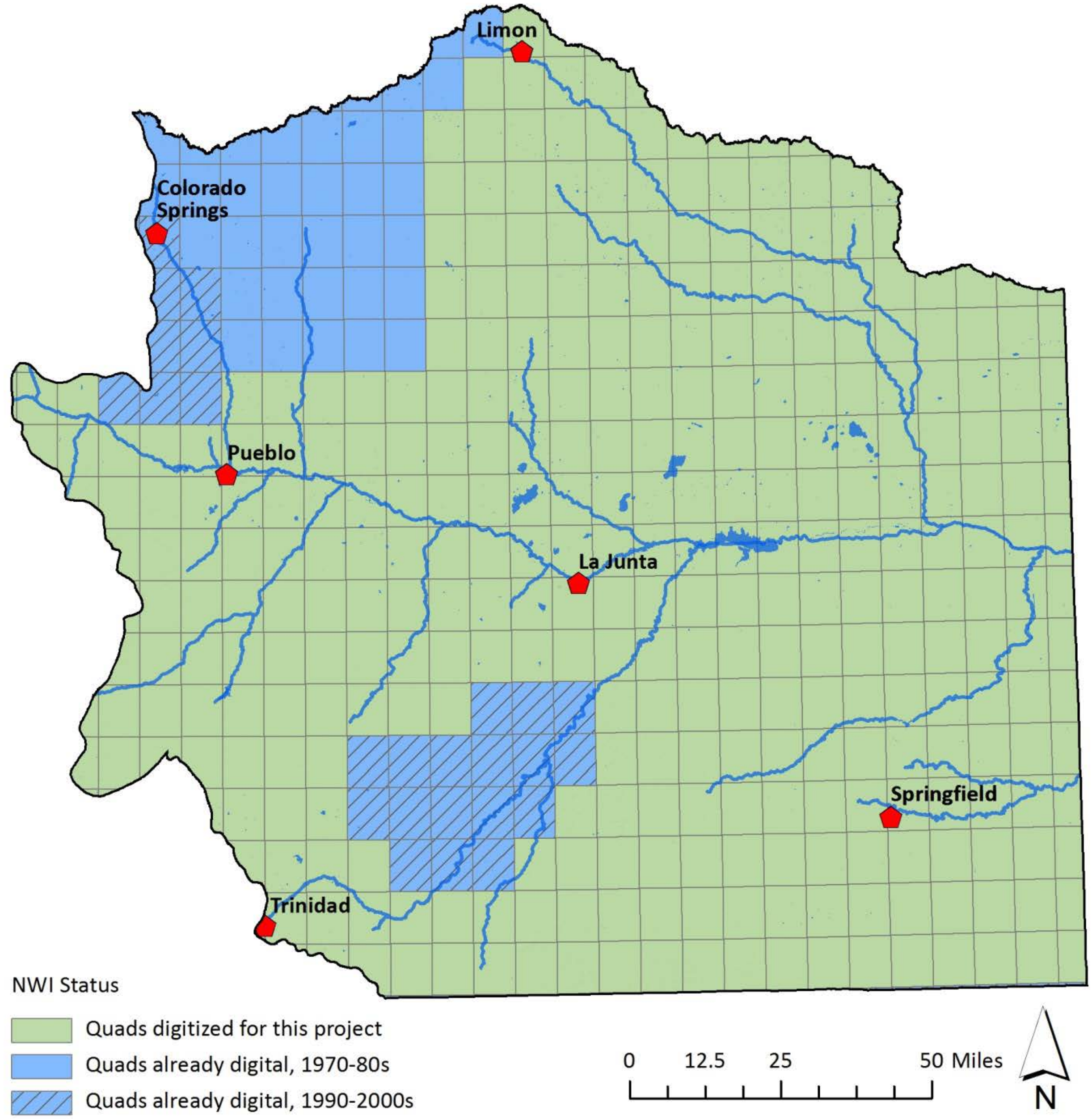


Figure 8. Quads lacking digital NWI data in the Lower Arkansas Basin study area.

3.2 Wetland Mapping Methods

The methods for digital conversion, accuracy assessment, and new mapping are explained below, preceded by an explanation of the NWI classification system.

3.2.1 National Wetland Inventory (NWI) Classification System

The NWI classification system was first described by Cowardin et al. in 1979 and has been updated periodically over time. The current NWI classification system, shown in brief in Appendix A, is now the federal standard for wetland mapping (FGDC 2013).[5] The basic structure of the classification system is the same for all mapping presented in this report. Codes used in the early 1970s mapping that are now obsolete (e.g., POW for Palustrine Open Water) have been replaced by their current equivalents (e.g., POW = PUB for Palustrine Unconsolidated Bottom). However, code interpretation and application in the 1970s was somewhat different than it is today. Issues with code interpretation are described in the results sections.

The NWI or Cowardin classification system is based on the following definition of wetlands:

> *"Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following attributes: (1) at least periodically, the land supports predominantly hydrophytes; (2) the substrate is predominantly undrained hydric soil; and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year"* (Cowardin et al. 1979).

NWI mapping includes both wetlands and deep waterbodies. Each mapped polygon is attributed by system, subsystem, class, hydrology, and optional special modifiers. The result is a 4–6 character alpha-numeric code. System divides mapped features into a handful of aquatic resource types and is followed (when appropriate) by a numeric subsystem code (Table 3). The three systems used for Colorado NWI mapping are Riverine (rivers / streams / canals), Lacustrine (lakes and lake shores), and Palustrine (vegetated wetlands). After system and subsystem, class identifies the dominate substrate or vegetation structure present and is represented by a two letter code (Table 4).

Hydrologic regimes describe the duration and timing of flooding and is represented by a single letter character (Table 5). Duration increases from A–H, though B (saturated) sites are rarely flooded, but have water at or very near the surface consistently. The J hydrologic regime of intermittently flooded refers to areas where the hydroperiod is driven by stochastic rainfall events and where surface water is present for variable periods without detectably seasonality.

The final component of the code is an optional special modifier, represented by a lowercase letter. Many modifiers are possible, though only a handful of codes were applied in the study area in either the original 1970s mapping or any updates (Table 6). Though irrigation is known to influence Rocky Mountain wetlands (Peck & Lovvorn 2001; Sueltenfuss et al. 2013), it is not included in the

[5] For more information on the current NWI classification system, please visit: http://www.fws.gov/wetlands/data/wetland-codes.html.

list of modifiers because the type and extent of modification is impossible to identify from aerial images. The hydrologic regime code of 'K' or 'Artificially flooded' is occasionally used in NWI mapping for irrigated wetland, though its use has changed over time within the NWI mapping standards. In the Arkansas basin, it was not consistently applied to all irrigated acres, and is not a reliable indication of irrigation. In the current NWI classification standards, the K hydrologic regime is now reserved for sites where the hydrology is controlled by pipes or siphons, such as a water treatment facility.

For summary purposes, NWI codes were lumped to create several reporting groups, called wetland and waterbody types throughout most of the results section (Table 7).

Table 3: NWI system and subsystem codes and interpretation.

System	*Subsystem*	*Code*	*Interpretation*
Riverine		**R**	**Rivers and streams**
	Lower Perennial	2	low gradient, slow moving channels
	Upper Perennial	3	steep, fast moving channels
	Intermittent	4	channels that do not flow year round, including manmade canals and ditches
Lacustrine		**L**	**Lakes (water bodies > 20 acres and/or > 2.5 m deep)**
	Limnetic	1	lake water > 2.5 m deep
	Littoral	2	lake water < 2.5 m deep along lake shores and margins
Palustrine		**P**	**Vegetated wetlands (marshes, swamps, bogs, etc.) even if associated with rivers or lakes**

Table 4: NWI class codes and interpretation.

Class	*Code*	*Interpretation*
Aquatic Bed	AB	aquatic rooted or floating vegetation
Emergent	EM	herbaceous, non-woody vegetation
Scrub-shrub	SS	low woody vegetation
Forested	FO	trees
Unconsolidated Bottom	UB	habitats with at least 25% cover of particles smaller than stones and less than 30% areal cover of vegetation
Unconsolidated Shore	US	unconsolidated substrates with less than 75% areal cover of stones, boulders or bedrock and less than 30% areal cover of vegetation
Stream Bed	SB	unvegetated surfaces with variable substrate sizes within stream channels

Table 5: NWI hydrologic regime codes and interpretation.

Code	*Interpretation*
A	temporarily flooded
B	saturated
C	seasonally flooded
F	semi-permanently flooded
G	intermittently exposed
H	permanently flooded
J	Intermittently flooded
K	artificially flooded

Table 6: NWI special modifier codes and interpretation.

Code	*Interpretation*
b	Beaver
d	Drained
h	impounded
x	Excavated

Table 7: NWI attribute groups for summary tables.

NWI Group	*Codes*	*Interpretation*
Herbaceous Wetlands	PEM*	all herbaceous wetlands (e.g., marshes, wet meadows, playas, etc.)
Shrub Wetlands	PSS*	shrub dominated wetlands (e.g. willow stands)
Forested Wetlands	PFO*	tree dominated wetlands (e.g., wet cottonwood stands)
Ponds and Impoundments	PAB*/PUB*/ PUS*	ponds of all kinds, either vegetated or not, but with open water < 2 m (e.g. beaver ponds, stock ponds, golf ponds, etc.)
Farmed Wetlands	Pf	misc. other classes, primarily unvegetated surface (i.e. sparsely vegetated salt flats) and some farmed wetlands (used only rarely)
Lakes and Shores	L*	all lakes and unvegetated lake shores, including reservoirs
Rivers	R2/R3*(not x)	river channels and their associated unvegetated shores (i.e., unvegetated sandbars)
Streams	R4*(not x)	smaller stream channels
Canals	R*(x)	excavated channels, specifically manmade ditches

In the years since the original NWI classification was introduced, USFWS realized the need to map riparian areas that may not meet the criteria used for mapping wetlands. This need is particularly great in the western U.S. where numerous wildlife species depend on riparian habitats in an otherwise arid landscape. These habitats are moist, can be flooded for short periods of time, and are commonly associated with flowing water. Riparian areas are "wetter" than uplands, but do not always meet the flooding, biological composition or soil criteria to be classified as a wetland. To identify, map, and classify a broad spectrum of non-wetland riparian areas, USFWS issued guidance in a document titled *A System for Mapping Riparian Areas in the Western United States* (USFWS 2009).

The definition of riparian used in the mapping guidance is:

> *"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."*

This USFWS riparian mapping classification system is fully integrated into the NWI classification scheme and also includes system, subsystem and class. The system is a single unit category of Rp (riparian vegetation) and subsystem defines the water source (lotic for flowing and lentic for standing water). Class denotes the dominant life form of riparian vegetation, similar to class within the primary NWI classification. No water regime or modifiers are applied.

It is important to note that most general definitions of riparian areas do include wetland habitats within the riparian zone. The wettest areas within riparian corridors can meet the wetland criteria, especially at higher elevations. However, riparian areas can include drier areas that are not wetland. The two concepts of wetland and riparian are best conceptualized as two overlapping spheres. There are wetlands within riparian areas, but not all wetlands are within riparian areas *and* not all riparian areas are wetlands. It is the drier, non-wetland riparian areas that are targeted with the supplemental USFWS riparian mapping standards.

The riparian mapping standard was not developed when the Lower Arkansas basin was mapped. Because of this, many areas dominated by cottonwood and tamarisk that would be mapped as riparian today were included in the original NWI mapping, but with the driest water regimes of A or J. This is a major cause of error in the mapping, as explained in the results below.

It is also important to note that the NWI or Cowardin definition of wetland is different than the definition used by the Army Corps of Engineers (ACOE) and the Environmental Protection Agency (EPA) for regulatory purposes under Section 404 of the Federal Clean Water Act:

> *"[Wetlands are] those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.* (ACOE 1987)*"*

The primary difference between the two definitions is that the Clean Water Act definition requires positive identification of all three wetland parameters (hydrology, vegetation, and soils) while the NWI definition requires only one to be present. Because it would be impossible to verify all three parameters through aerial photos interpretation, not all wetlands mapped by NWI would be considered jurisdictional wetlands under the Clean Water Act and NWI mapped boundaries should not be interpreted as wetland delineations.

3.2.2 Conversion of Original NWI Paper Maps to Digital Data

At the outset of this project, 350 topographic quadrangles within the study area lacked digital wetland mapping (Figure 8). Quads surrounding Colorado Springs and the Pinon Canyon Maneuver Site had previously been updated as digital data in the 1980s or 1990s by other entities. To complete the digital map of wetlands, scans of original NWI paper maps were converted to digital data following CNHP's wetland mapping procedures (CNHP 2013) and adhering to the federal wetland mapping standard (FGDC 2009), to the extent possible.

Wetland mapping data were not updated or corrected in this process, except in cases where the original code was no longer accepted by NWI. The purpose of the digital conversion was not to create an up-to-date map of wetlands, but to convert a large quantity of hard copy data into digital polygons in an efficient and cost effective manner. All newly converted digital data were submitted to the NWI program for incorporation into the national dataset.

To create a seamless data layer of wetlands throughout the study area, the newly converted original 1970s mapping was merged with more recent 1980s and 1990s mapping already in a digital format. Mapping in quads along the edge of the study area were clipped to the study area boundary. This clipped dataset was used for all other tasks within the project and was the basis of determining the extent of wetlands in the basin based on original NWI mapping. Though the 1980s and 1990s mapping was newer than the 1970s paper maps, this seamless dataset is referred to as the original mapping throughout this report.

3.2.3 Accuracy Assessment of NWI Mapped Wetlands

To assess the accuracy of the original NWI maps, 900 points were randomly selected from within the mapping and the original attribution at these points was compared to independent photo interpretation of current aerial imagery. Accuracy assessment points were selected through a Generalized Random Tessellation Stratified (GRTS) sample design executed using the 'spsurvey' package in R version 2.14.0 (R Foundation for Statistical Computing 2011) were distributed across the entire study area, spanning quads that were converted to digital data through this project (1970s mapping) and quads that were already in a digital format (1980s and 1990s mapping).

Accuracy assessment points were allocated between mapping classes (NWI System and Class combinations) using unequal probability selection criteria based on their relative abundance (Table 8). Points per class ranged from ~20 to 150, with more points allocated to mapping classes that covered more acres. In addition, 160 points were selected in areas not mapped by NWI to identify missed wetland acres.

Table 8. Allocation of accuracy assessment points among NWI mapping classes.

NWI System/Class	*NWI Acres*	*Percent of NWI Acres*	*AA Points*
Palustrine Wetlands			
PEM	64,047	31%	117
PSS	35,452	17%	127
PFO	32,224	16%	148
PAB, PUB, PUS	9,450	5%	92
Pf	1,532	1%	19
Lakes and Lakeshores			
L1	7,700	4%	76
L2	17,465	8%	100
Rivers, Streams, Canals			
R2, R3	10,993	5%	88
R4	26,724	13%	133
Grand Total	205,587	100%	900
Upland	NA	NA	160

To conduct the accuracy assessment, a photo interpreter examined each of the points using multiple data sources and assigned a NWI code to the class level based on current information. We did not assign hydrologic regimes or modifiers in the accuracy assessment, as testing the accuracy of these codes would have introduced even more sources of error. The primary data source used for the accuracy assessment evaluation was digital aerial photography flown in the summer of 2013 by the U.S. Department of Agriculture (USDA)'s National Agricultural Imagery Program (NAIP). In addition to the 2013 imagery, additional NAIP image dates (2015, 2011, 2009 and 2005) were used to inform the classification, but the final classification was based on 2013 imagery. USGS topographic maps, soil survey data, hydrography data, land use data, and other ancillary data sources were also used to aid interpretation.

The accuracy assessment evaluation and coding was first done independent of the original code, meaning the interpreter did not know what original code was assigned to the accuracy assessment point. In a thorough review of the AA points, we did look at the original code to best determine whether discrepancies were a result of land use change or changing mapping methods. Understanding how the original mappers viewed the landscape was important to tease out reasons for error.

The accuracy assessment was conducted with two levels of precision. At the highest level of precision, an NWI mapping class was assigned based on aerial imagery at the exact accuracy assessment point. At the second level of precision, the photo interpreter also identified closest NWI mapping class within a 100 m buffer, if it differed from the point itself. Because the original mapping was created at a coarse scale, this allowed for some shifting of the original polygons. Many wetlands did fall just beyond the AA point and, in those cases, it was clear that the mapping was accurately representing the wetland feature, but the polygon was not in the precise location. To take into account the instances when the mapping was both accurate and precise *and* the instances when the mapping was accurate but not precise, this less restrictive 'buffer' analysis considered a point correctly attributed if the current attribution matched either the attribution at the point or within the buffer. This approach gave the benefit of the doubt to the original mapping.

Once all accuracy assessment points were classified, the independent classification was compared with the original classification. Results from the independent photo interpretation were summarized in an error matrix that separated errors of omission, errors of commission, and overall accuracy following standard accuracy assessment methods described in Congalton & Green (1999) and Lea & Curtis (2012). This technique allows for extrapolation to the entire basin based on the allocation of points in each original mapping class and the total area that the mapping class covers in the study area.

3.2.4 Creation of Updated Mapping for Priority Areas

New, updated NWI mapping was created for 18 USGS quads in the study area. Updated wetland mapping was conducted on screen in ESRI ArcGIS 10.2 at a scale of 1:4,500 and was based on photo-interpretation of 2013 NAIP CIR imagery. Procedures and methods for new photo-interpretation are documented in CNHP (2013) and follow the Federal Geographic Data Committee standards for wetland mapping (FGDC 2009). All source imagery followed the standards outlined in the federal wetland mapping standard. In addition to the 2013 NAIP imagery, multiple ancillary data sources were used to map wetlands. Older NAIP image dates (2011, 2009 and 2005), USGS topographic maps, soil survey data, hydrography data, land use data, and other ancillary data sources were also used to aid interpretation.

The most recent coding rules of the NWI classification system were used to attribute the polygons. Special modifiers were used more effectively in the new mapping compared to the original mapping. Polygons were also created for riparian features, following the USFWS riparian mapping classification (USFWS 2009).

Two quality control procedures were carried out to ensure the most accurate updated mapping. 1) *Comparison with on-the-ground data:* The new, updated mapping was conducted concurrent with field data collection also carried out for this project. Field data and photographs taken in the areas being mapped were shared with the CNHP Mapping Specialist. This familiarized the interpreter with photo signatures of specific wetland complexes. Questions about certain areas were shared with the field team, who helped relay ground-based information to the mapper. 2) *Final automated check:* To ensure accuracy in coding, a final automated procedure checked the data layer for invalid wetland codes, size limitations and topological errors. Each error flagged was identified and carefully examined using multiple data layers and on-the-ground and in-the-air field verification to reconcile errors.[6]

[6] For information on the NWI Data Verification Procedure, please visit: http://www.fws.gov/wetlands/Data/Tools-Forms.html.

2.3.5 Final Estimate of Wetland Acres

The ultimate goal of the project was to estimate the extent of wetland acres across the basin and examine patterns of type, distribution and landownership. To produce the final acreage estimates, the updated mapping was merged with digital mapping from 1970s, 1980s, and 1990s. The basic NWI classification-based reporting groups (Table 7) were evaluated to see if information gained from the accuracy assessment and updated mapping exercises could inform a better organization of reporting groups. In some cases this meant using hydrologic regimes to pull out certain types of features, combining class codes or using geographic areas to assign groups. No actual NWI code attributes were changed, but an additional attribute class was added to the dataset for the final grouping.

3.3 Wetland Mapping Results

3.2.1 Original Mapped Wetland Acreage

Once converted to digital data, original NWI mapping of the Lower Arkansas basin contained 205,587 acres (83,198 ha) of aquatic resources, including both wetlands and waterbodies (Table 9). This represents only 1.5% of the total land area. Area mapped as wetlands (classified within the Palustrine system) accounted for roughly two-thirds of mapped aquatic resources (142,705 acres or 69.4%), while waterbodies (lakes, river, streams and canals) accounted for the remaining third (62,882 acres or 30.6%).

Within the original NWI mapping, herbaceous wetlands were the most abundant mapped type, with 64,047 acres or 31.2% of all mapped aquatic resources. With lakes and rivers removed to specifically highlight wetlands, herbaceous wetlands accounted for 44.9% of wetland acres. Areas mapped as herbaceous wetlands include marshes, seep-fed meadow, playas, and mesic herbaceous areas along floodplains and riparian corridors.

Shrub and forested wetlands also made up a large share of mapped acres, 35,452 and 32,224 acres, respectively. Shrub wetlands accounted for 17.2% of all aquatic resources and 24.8% of wetland acres. Forested wetlands accounted for 15.7% of all aquatic resources and 22.6% of wetland acres. Shrub and forested wetlands were primarily mapped along floodplains and riparian corridors throughout the basin; however, their extensive acreage is largely a result of early mapping methods. Most of the mapped acres are not true wetlands. As explained in the methods section, drier riparian areas, specifically cottonwood and tamarisk stands, were often included as wetlands in early NWI mapping, before USFWS developed a separate riparian mapping standard. See the following sections on accuracy assessment and updated mapping for more information on how these acres should be interpreted.

The final two wetland types mapped by NWI include ponds and impoundments and farmed wetlands. Ponds and impoundments were mapped throughout the basin. Most were small in size and located within either bermed drainages or artificially dug stock ponds. Some wetlands in this group are actually saline playas that have little vegetation. As a category of mapped wetlands, ponds and impoundments made up 9,450 acres, or 4.6% of all aquatic resources and 6.6% of wetland acres. Farmed wetlands also occurred as small patches throughout the plains. Most appeared to be playa wetlands that were occasionally ploughed in dry years. This category made up 1,532 acres, or 0.7% of aquatic resources and 1.1% of wetland acres.

Mapped lakes covered 25,165 acres across the basin and represented 12.2% of mapped aquatic resources. Interestingly, only 7,700 acres were mapped as the deep water (> 2 m) portion of lakes. Most of the mapped lake acres were considered shallow water lake shores. Nearly all lakes in the study area are artificially created reservoirs and are primarily used for water storage. The biggest reservoirs, John Martin and Pueblo, are located along the Arkansas River, while other smaller reservoirs take advantage of natural depressions, like historic playas. Rivers, streams and artificially dug irrigation canals together made up another 37,717 acres across the basin (18.3% of mapped aquatic resources).

Table 9. Acres of wetlands and waterbodies in the Lower Arkansas basin originally mapped by NWI.

Wetland and Waterbody Type		*Acres*	*% of Basin Area*	*% of NWI Acres*	*% of Wetland Acres*
Total Basin Area		13,949,575	100.0%	---	---
Upland Area (not mapped by NWI)		13,743,988	98.5%	---	---
Wetlands					
NWI Code	**Wetland Type**				
PEM	Herbaceous Wetlands	64,047	0.5%	31.2%	44.9%
PSS	Shrub Wetlands	35,452	0.3%	17.2%	24.8%
PFO	Forested Wetland	32,224	0.2%	15.7%	22.6%
PAB/PUB/PUS	Ponds and Impoundments	9,450	0.1%	4.6%	6.6%
Pf	Farmed Wetlands	1,532	<0.1%	0.7%	1.1%
Total Area of Wetlands		**142,705**	**1.0%**	**69.4%**	**100%**
Waterbodies					
NWI Code	**Waterbody Type**				
L	Lakes and Shores	25,165	0.2%	12.2%	---
R2 / R3	Large Rivers	10,993	0.1%	5.3%	---
R4	Smaller Streams	24,217	0.2%	11.8%	---
R*/x mod	Canals and Ditches	2,507	<0.1%	1.2%	---
Total Area of Waterbodies		**62,882**	**0.5%**	**30.6%**	**---**
Total Area of Wetlands and Waterbodies		**205,587**	**1.5%**	**100.0%**	**---**

3.2.2 Accuracy Assessment of Original Mapping

Given concerns over the original 1970s NWI mapping, a statistically rigorous accuracy assessment of the original mapping was conducted. The accuracy assessment showed clear trends that should be taken into account whenever these data are used. Even with the less restrictive 'buffer' analysis, overall accuracy of the map was only 53.0% (90% CI = 50.2–55.9%). Without the buffer analysis, the accuracy was a mere 39.9% (90% CI = 37.0–42.8%). Our close review of the original mapping, however, indicated that much of the discrepancy comes from changes in the mapping and coding methods rather than gross errors in the mapping or dramatic change on the landscape.

The most significant source of discrepancy was within the forested wetland class (Table 10; Figure 9). While the original mapping contained 32,224 acres of forested wetlands, the revised estimate shows ~1,300 acres. This represents a change of 96% ***fewer*** acres of forested wetlands. More than 60% of points originally mapped as forested wetlands were classified as non-wetland riparian areas with the accuracy assessment (Table 11). These are primarily either tall stands of tamarisk or cottonwood gallery forests with dry understories. Because the USFWS riparian mapping system was not in place when the original mapping was created, the original mapping incorporated tall tamarisk stands and cottonwood galleries into the Palustrine Forested (PFO) class because they were evident on the landscape, even though many have dry understories and do not meet the definition of wetland. Most of these acres were mapped with the A (temporarily flooded) or J (intermittently flooded) hydrologic regimes, indicating the original photo interpreters did recognize how dry these areas were. But with the current riparian standards in place, it is more accurate to classify them as non-wetland riparian, rather than forested wetland with a dry hydrologic regime.

Table 10. Estimates of wetland and waterbody acres based on the accuracy assessment analysis.

Wetland and Waterbody Type	*Estimate of Acres*			*Difference between Buffer and Original*	
	Original	*Point*	*Buffer*	*Acres*	*% Change*[1]
Herbaceous Wetlands	64,047	34,100	35,276	-28,771	-45%
Shrub Wetlands	35,452	26,142	25,756	-9,699	-27%
Forested Wetland	32,224	1,290	1,306	-30,918	-96%
Ponds and Impoundments	9,450	9,116	11,889	2,439	26%
Farmed Wetlands	1,532	3,017	3,725	2,193	143%
All Wetland Acres	**142,705**	**73,664**	**77,953**	**-64,752**	**-45%**
Lakes and Shores	25,165	26,626	28,213	3,048	12%
Large Rivers	10,993	7,088	12,102	1,109	10%
Smaller Streams, Canals	26,724	20,287	27,508	784	3%
All Waterbody Acres	**62,882**	**54,001**	**67,823**	**4,941**	**8%**
Riparian	--	41,431	34,745	34,745	--
All NWI Acres	**205,587**	**169,096**	**180,521**	**-25,066**	**-12%**
Upland Predicted	--	36,491	25,006	25,066	--

[1] The percent change represents the difference between the buffer and the original, divided by the original.

Another significant share of originally mapped forested wetlands (20%) was reclassified as shrub wetlands. These points did appear to be woody wetlands, with a dark photo signature that indicates a wet understory. Most of these woody wetland points were located in close proximity to the Arkansas River, along two particularly wet stretches of the floodplain, upstream of John Martin Reservoir and a stretch in Pueblo County. Some points were also located on Fountain Creek and the Purgatoire River, two of the basin's largest tributaries, and a handful of smaller creek. Nearly all points reclassified as shrub wetlands appeared to be dominated by tamarisk, based on visual examination of air photos and tamarisk mapping data from the Tamarisk Coalition (2009). The fact that these points were originally mapped as forested and not shrub is likely because the original mappers focused on the height of the tamarisk rather than the growth form and does not represent a conversion from cottonwood to tamarisk. Reports of vegetation along the Arkansas floodplain from the 1970s suggest that tamarisk was already well established at that point (Lindauer 1983). Our decision to re-classify them as shrub was in an effort to code tamarisk consistently as a shrub, regardless of height.

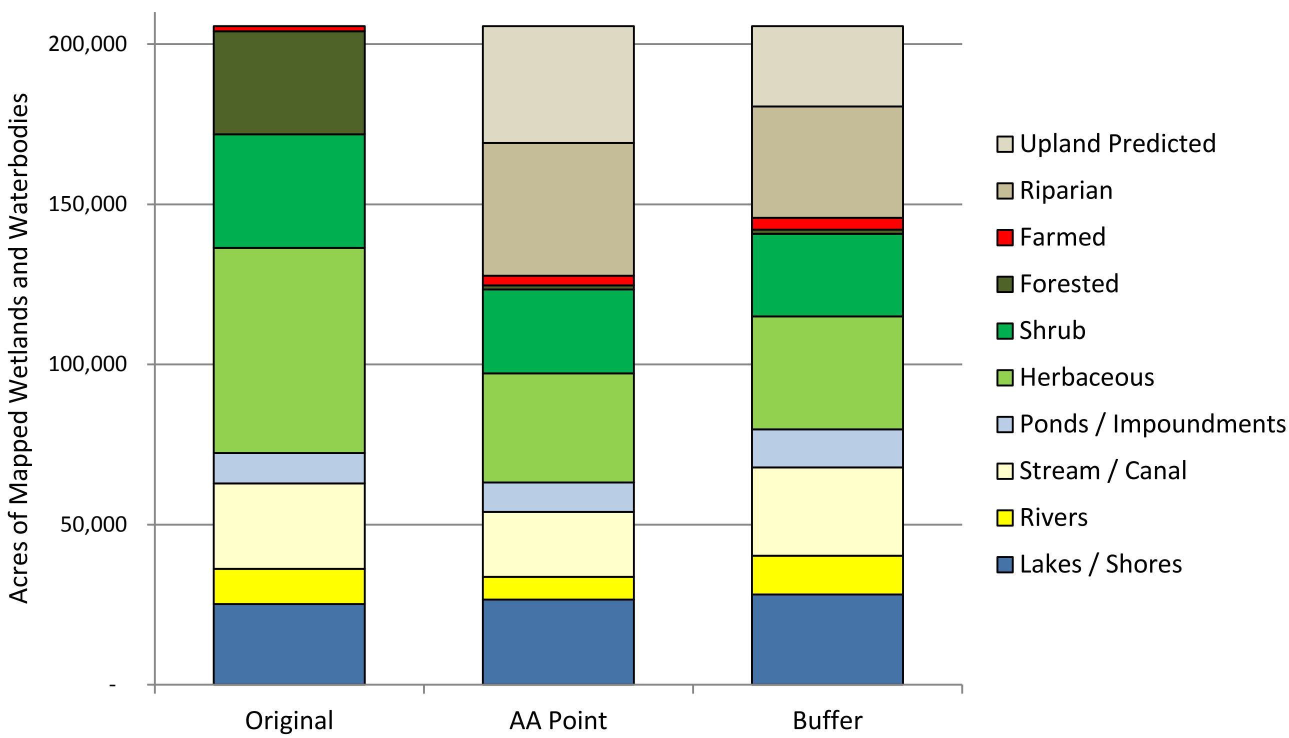


Figure 9. Estimates of wetland and waterbody acres based on the accuracy assessment analysis.

Herbaceous wetlands were also over-represented in the original NWI mapping. The final estimate of herbaceous wetland acres based on the buffer analysis was just over half the original acreage mapped. The largest share of incorrectly mapped herbaceous wetland points (26% of all original herbaceous points) were reclassified as upland in the accuracy assessment. It is difficult to say exactly how much of the inaccuracy comes from incorrect original NWI mapping or from drying in the basin since the original mapping was created. It is likely a combination of both, as there was a significant dry up of irrigated lands in the 1970s and 1980s, which would have affected some wetlands. While the analysis did not look at 1970s air photos to determine the exact cause of the discrepancy, we did pay close attention to whether points reclassified as upland were in close proximity to dry agriculture land. It appeared that half the points reclassified as upland may be linked to agricultural dry up. These included points that fell within or near reservoirs that appear to be retired (e.g., Cucharas Reservoir and Nepesta Reservoir) and points located in swales downslope from dry irrigation fields or irrigation ditches. One point that fell within a recently developed area of the town of La Veta represents herbaceous wetland acres lost to development. The remaining herbaceous points reclassified as upland appear to have been overmapped in the 1970s. Most were located within either the Arkansas floodplain or the wide, sandy riparian zones of creeks such as Big Sandy Creek, Dry Creek, Horse Creek and Wild Horse Creek. These floodplain and riparian zones have a wide zone of influence, and the path of historic flooding can still be seen on the landscape. While the historic flood paths are visible, the very farthest reaches of these zones are not wetland and are not even riparian, as the vegetation is not markedly different from the surrounding uplands.

Another smaller share of incorrectly mapped herbaceous wetland points (8% of original) was reclassified as lakes and shores. In the original mapping, some areas around reservoir edges were mapped as herbaceous wetlands, but were reclassified as lake shore in the accuracy analysis. This happened specifically around Adobe Creek Reservoir, Horse Creek Reservoir, and Lake Meredith. Many lakes in the basin were developed within the original depressions of large playas. Water levels within these lakes fluctuate widely, depending on water availability and precipitation. While the edges of these reservoirs do become vegetated when water levels draw down, we felt they were best represented as lake shores in the 2013 imagery.

Another equally small share of incorrectly mapped herbaceous points (7% of original) was reclassified as ponds or impoundments. These typically represent small, ephemeral impoundments that hold water following local precipitation events. Throughout the majority of the basin, where the original mapping dates from 1970s, these features are mapped as Palustrine Unconsolidated Shore (PUS), which we group into ponds and impoundments. The area around Pinon Canyon Maneuver Sites, however, was re-mapped in the 1990s. In the quads mapped in the 1990s, photo interpreters attributed the same small impoundments as Palustrine Emergent (PEM) wetlands, which we call herbaceous, with an excavated or impounded modifier. For the sake of consistency, in the accuracy assessment, we called all these features PUS and moved them to the ponds and impoundments group.

Shrub wetlands, like both forested and herbaceous wetlands, were also over-mapped. Less than half of the points originally mapped as shrub wetlands were classified as shrub wetlands in the accuracy assessment. However, as points from other original mapping classes were moved to the shrub class, the resulting estimate of shrub wetland acres dropped by only 31%. The largest share of incorrectly mapped shrub wetland points (27% of original shrub points) was re-classified as non-wetland riparian areas; another 9% of original points were re-classified as dry uplands. All points re-classified as riparian were dry tamarisk. Those reclassified as upland were along the margins of the Arkansas floodplain or other rivers in the basin and were simply not vegetated enough to call even riparian. Another share of incorrect shrub points (7% of original) was reclassified as herbaceous. Some of these were dense marshes along the Arkansas floodplain that were interspersed with shrubs. The original mapping largely mapped these areas as shrub, but we pulled out points located in the most herbaceous sections.

The last notable share of incorrect shrub points (6% of original) was reclassified as lakes and shores. In the original mapping, both John Martin and Pueblo Reservoirs were mapped as fairly small waterbodies, with much of the upstream portions mapped as herbaceous and shrub wetlands. For this analysis, we did not look back at aerial photography from the 1970s to determine if those boundaries were correct. We did, however, look water level readings from the reservoirs and it is clear from the data that the reservoirs were very low in the late 1970s, so these boundaries may have made sense for the time.

The discrepancies mentioned above around the mapping of John Martin and Pueblo Reservoir were also the cause for increased lake acres in the accuracy assessment analysis. The estimate of lakes and shore acres based on the accuracy assessment is 12% greater than the original acreage, adding over 3,000 acres. Additional classes that gained acreage include farmed wetland and ponds and impoundments, both of which may be caused more by reinterpretation of the classification system. Some wetlands mapped originally as herbaceous were moved to the farmed class and some points originally mapped as small lakes were moved to the pond class. There was also a small increase in stream and canal acres, which is likely due to more accurate mapping.

Based on extrapolation from the accuracy assessment analysis, the final estimate of wetland acres in the study area (not including waterbodies or riparian areas) was 77,953 acres instead of 142,705 acres. This is roughly half the original mapped acreage and represents a more accurate picture of wetlands in the basin. With lakes, rivers, and riparian included, the difference is only 12% less than the original estimate or total acres, but shows far more acres within mapping classes that are not considered true wetlands. While the original mapping is the first comprehensive accounting of wetland acres, and this accuracy assessment can help interpret how the data should be used, the magnitude of this difference underscores the need for new, updated wetland mapping on the plains in order to use the data for significant management decisions.

Table 11. Comparison of original attribution vs. accuracy assessment attribution. Results are shown as the percent of points within each original attribute class. Shaded boxes represent points where the original attribution and the accuracy assessment attribution agreed.

Original 1970s Attribution	*Accuracy Assessment Attribution, as percent of original attribute class*									
	Herb	*Shrub*	*Forest*	*Pond / Impound*	*Farmed*	*Lakes*	*Rivers*	*Stream / Canal*	*Rip*	*Upland*
Herbaceous	44%	3%	--	7%	3%	8%	1%	3%	5%	26%
Shrub	7%	48%	--	1%	--	6%	--	2%	27%	9%
Forested	3%	20%	4%	--	--	1%	4%	1%	61%	5%
Pond / Impoundment	12%	--	--	75%	1%	1%	1%	1%	--	9%
Farmed	5%	--	--	--	84%	--	--	--	--	11%
Lake	9%	2%	--	1%	1%	82%	--	--	--	6%
River	--	1%	--	--	--	--	89%	2%	7%	1%
Stream / Canal	2%	--	--	--	--	--	2%	89%	5%	2%

3.2.3 Comparison of Original Mapping to Updated Mapping

The accuracy assessment analysis highlighted issues with the original NWI mapping for the Lower Arkansas River basin, many of which were anticipated before the start of this project. Though it would be ideal to update NWI mapping throughout the basin, this project included funding to update the mapping within 18 USGS quads. The project steering committee was consulted to determine priority quads and the committee selected twelve quads around John Martin Reservoir and six quads around and upstream of Pueblo Reservoir (Figure 10). These quads represent only 5% of the landscape, but included 15% of the originally mapped acres. While results from the accuracy assessment provide estimates for the true wetland acreage across the entire basin, comparing the original mapping to updated mapping in these two priority area shows a more precise accounting of the acreage of wetland, waterbodies, and riparian areas in these areas.

Original and updated mapping were compared in two ways: 1) the total acres mapped within each wetland and waterbody type, including riparian areas, and 2) the degree of overlap between the two dataset, both in terms of overlapping polygons and similar attribution. Because the original NWI mapping was created on paper first, and digitized many years later, some shifting of polygons from their originally intended location can occur. This can result in acres that do not overlap exactly between original NWI mapping and updated NWI mapping, though the area mapped is the same.

Within the John Martin priority area, original 1970s NWI mapping contained 19,560 acres of mapped wetlands and 4,826 acres of mapped waterbodies, for a total of 24,386 mapped acres (Table 12). The updated 2015 mapping contained 8,626 acres of wetlands, 8,403 acres of waterbodies, and 10,401 acres of riparian areas, for a total of 27,429 acres. This represents a 56% decrease in wetland acreage, but a 74% increase in waterbody acres. With the increase in waterbody acres and the over 10,401 acres of mapped riparian acres, the total mapped acres actually increased by 3,043 acres or 12%.

Much of the decrease in wetland acres came from reinterpreting what was mapped as forested wetlands. While the original mapping contained 6,514 acres of forested wetlands, the updated mapping included only 10 acres that appeared to truly be forested wetland. As mentioned in previous sections, the original mapping included tall tamarisk stands and dry cottonwood galleries within forested wetlands. These areas are better classified as non-wetland riparian areas (Figure 11). By intersecting the original mapping with the updated mapping, we can compare the original attribution of specific areas on the ground to the updated attribution (Table 14). Of the 6,514 acres originally mapped as forested wetlands, 80% overlapped polygons in the updated mapping, but only 4 acres were still called forested wetlands. The largest share of originally mapped forest wetlands (4,235 acres) was classified as non-wetland riparian areas within the updated mapping. Another large share (467 acres) was classified as shrub wetlands, of which nearly all were tamarisk stands. This is likely a change in coding rather than a change in vegetation. As mentioned previously, we decided to code all tamarisk as shrub, regardless of height, while we believe earlier mappers used the forested class for many tall tamarisk stands. The last large share of originally mapped forested wetlands (1,347 acres or 20%) was not included in the updated mapping. These may represent areas where the original mapping was shifted from its intended location, meaning the exact boundaries of the original polygons may have been off by a few hundred feet. Given that there are >3,700 acres of riparian areas in the updated mapping that were not in the original mapping, these unmapped acres are probably accounted for in some of the new acres.

Along with decreases in forested wetlands, the updated mapping also included fewer acres of shrub wetland acres. For shrub acres, the biggest change was a large share of acres (2,028 acres) originally mapped as shrub wetlands within the footprint of John Martin Reservoir that were classified as actual lake or lake shore in the updated mapping. Without examining old photography from the 1970s, we do not know if these were shrub wetlands at that time, but in the 2013 imagery used for the updated mapping, these areas were either under water or strongly influenced by water levels (Figure 12). The second largest share of reclassified shrub acres (1,286 acres) was reinterpreted as non-wetland riparian areas in the updated mapping. These were also dry tamarisk stands, like the original acres mapped as forested wetlands. Another 1,096 acres were shifted from shrub to herbaceous wetlands. Some of these were within the John Martin Reservoir footprint as well. Lastly, 999 of the original shrub wetland acres were not mapped in the updated mapping, but at least some of these may have been due to shifted polygons.

For herbaceous wetlands, the total acreage mapped in the 1970s and 2015 were relatively similar, though only half of those acres overlapped exactly in both time periods. The largest share of originally mapped herbaceous wetlands (2,600 acres) was simply not mapped in the updated mapping. Some of these were likely errors due to shifting, as the updated mapping included 1,634 acres that were not mapped in the 1970s. But many other acres were likely over mapped and would be considered dry uplands today. And many of the newly added acres came from small wetlands on the floodplain that may have been overlooked in the original mapping. Another share of originally mapped herbaceous wetlands (721 acres) were classified as non-wetland riparian areas in the new mapping, as they are too dry to be considered wetlands.

The biggest increase in acres came from mapping John Martin Reservoir itself. The original mapping included only 2,584 acres of lakes and shores. The updated mapping included 6,202 acres. A large share of those new lake acres came from shrub acres, as mentioned above, but another 2,040 acres was newly mapped. Based on our review of lake level data, we believe that John Martin was simply much fuller in 2013 than it had been in the 1970s. The other major contributor to increased acres overall was the addition of riparian mapping. The updated mapping included 10,401 acres mapped as non-wetland riparian areas. Of those, 65% (6,694 acres) were included in the original mapping, but were classified differently, mainly as shrub or forested wetland. The remaining 3,707 acres were new to the mapping.

Results from around Pueblo Reservoir show very similar patterns to the John Martin mapping (Tables 13 and 15.) The original mapping included 1,102 acres of forested wetlands, while the updated mapping did not include a single acre. Shrub and herbaceous acres were 29% and 53% less in the updated mapping, respectively. The updated Pueblo mapping included 2,362 acres of non-wetland riparian areas, much of it in the same areas as originally mapped forested, shrub, and herbaceous wetlands. The Pueblo mapping also included an increase of lake acres, with only 831 acres in the original mapping and 2,180 acres in the updated mapping.

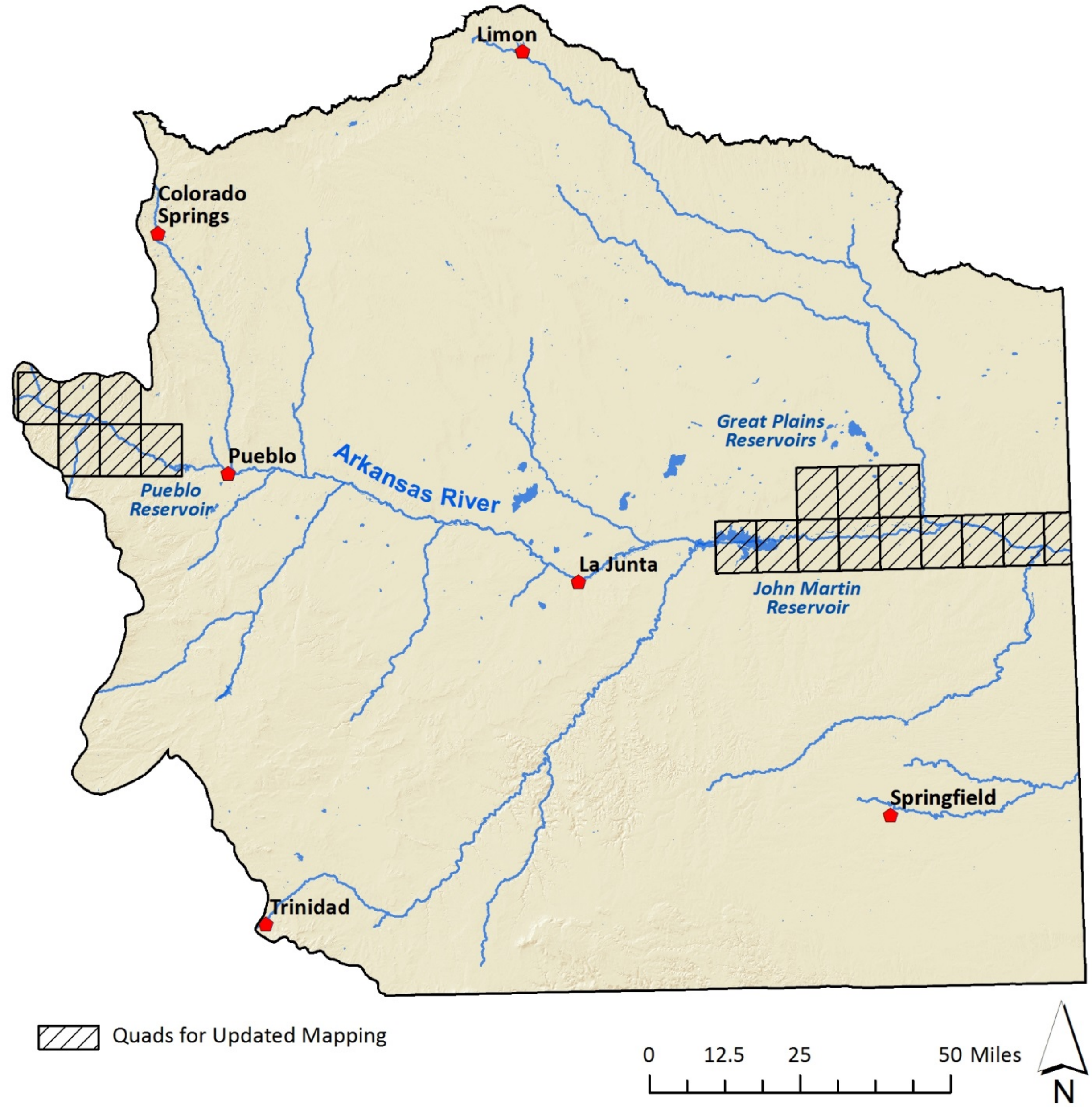


Figure 10. Priority quads selected for updated NWI mapping.

Table 12. Comparison of original 1970s NWI mapping vs. updated 2015 NWI mapping, by wetland and waterbody type, for quads around John Martin Reservoir. Results are shown as the total acres mapped in each attribute class for each time period, regardless of whether they were mapped in the same place.

Wetland and Waterbody Type	*Mapped Acres*			*% Change from Original*
	Original	*Updated*	*Difference*	
Herbaceous Wetlands	4,830	4,464	-366	-8%
Shrub Wetlands	7,979	3,625	-4,354	-55%
Forested Wetland	6,514	10	-6,504	-100%
Ponds and Impoundments	237	513	276	+116%
Farmed Wetlands	--	14	14	--
All Wetland Acres	**19,560**	**8,626**	**-10,935**	**-56%**
Lakes and Shores	2,584	6,202	3,619	+140%
Large Rivers	1,142	1,225	83	+7%
Smaller Streams, Canals	1,101	976	-125	-11%
All Waterbody Acres	**4,826**	**8,403**	**3,577**	**+74%**
Riparian	--	10,401	10,401	--
All NWI Acres	**24,386**	**27,429**	**3,043**	**+12%**

Table 13. Comparison of original 1970s NWI mapping vs. updated 2015 NWI mapping, by wetland and waterbody type, for quads around Pueblo Reservoir. Results are shown as the total acres mapped in each attribute class for each time period, regardless of whether they were mapped in the same place.

Wetland and Waterbody Type	*Mapped Acres*			*% Change from Original*
	Original	*Updated*	*Difference*	
Herbaceous Wetlands	1,964	1,389	-575	-29%
Shrub Wetlands	1,616	753	-863	-53%
Forested Wetland	1,102	--	-1,102	-100%
Ponds and Impoundments	163	397	233	+143%
Farmed Wetlands	--	--	--	--
All Wetland Acres	**4,845**	**2,538**	**-2,307**	**-48%**
Lakes and Shores	831	2,180	1,349	+162%
Large Rivers	789	652	-137	-17%
Smaller Streams, Canals	547	1,073	527	96%
All Waterbody Acres	**2,167**	**3,905**	**1,738**	**80%**
Riparian	--	2,362	2,362	--
All NWI Acres	**7,012**	**8,806**	**1,794**	**26%**

Table 14. Overlap between original 1970s NWI mapping vs. updated 2015 NWI mapping by wetland and waterbody type for quads around John Martin Reservoir. Results are shown as acres within each class. Shaded boxes represent acres mapped the same in both years. Acres mapped in both years, but given a different classification, are in boxes that are not shaded. Acres mapped in one time period and not the other are shown at the far right (for acres not mapped in 2015) and the bottom (for acres not mapped in 1970s).

Acres Mapped in Both Years		*Updated 2015 Mapping*[1]										*Acres Not Mapped in 2015*	*1970s Grand Total*
		Herb	*Shrub*	*Forest*	*Pond / Impound*	*Farmed*	*Lake*	*River*	*Stream / Canal*	*Riparian*	*Total*		
Original 1970s Mapping	*Herbaceous*	1,224	102	1	44	--	81	16	42	721	**2,230**	2,600	**4,830**
	Shrub	1,096	2,382	5	12	--	2,028	156	15	1,286	**6,980**	999	**7,979**
	Forested	145	467	4	21	--	26	259	9	4,235	**5,167**	1,347	**6,514**
	Pond / Impound	31	2	--	78	--	4	--	1	4	**120**	118	**237**
	Farmed	--	--	--	--	--	--	--	--	--	**--**	--	**--**
	Lake	278	1	--	10	--	2,002	--	--	75	**2,366**	217	**2,584**
	River	41	294	--	1	--	19	377	1	338	**1,069**	72	**1,142**
	Stream / Canal	16	12	--	--	--	4	81	143	34	**291**	810	**1,101**
	Total	**2,830**	**3,260**	**10**	**167**	**--**	**4,163**	**888**	**211**	**6,694**	**18,223**	**6,163**	**24,386**
Acres Not Mapped in 1970s		1,634	365	--	346	14	2,040	336	765	3,707	**9,206**		
2015 Grand Total		**4,646**	**3,625**	**10**	**513**	**14**	**6,202**	**1,225**	**976**	**10,401**	**27,429**		

[1] The updated mapping was conducted in 2015, but was based on imagery from 2013.

Table 15. Overlap between original 1970s NWI mapping vs. updated 2015 NWI mapping by wetland and waterbody type for quads around Pueblo Reservoir. Results are shown as acres within each class. Shaded boxes represent acres mapped the same in both years. Acres mapped in both years, but given a different classification, are in boxes that are not shaded. Acres mapped in one time period and not the other are shown at the far right (for acres not mapped in 2015) and the bottom (for acres not mapped in 1970s).

Acres Mapped in Both Years		Updated 2015 Mapping[1]										Acres Not Mapped in 2015	1970s Grand Total
		Herb	Shrub	Forest	Pond / Impound	Farmed	Lake	River	Stream / Canal	Riparian	Total		
Original 1970s Mapping	Herbaceous	181	54	--	49	--	182	32	33	89	**620**	1,343	**1,964**
	Shrub	113	97	--	13	--	246	91	38	327	**925**	691	**1,616**
	Forested	82	194	--	21	--	79	110	19	299	**803**	299	**1,102**
	Pond / Impound	20	2	--	47	--	1	1	1	4	**75**	89	**163**
	Farmed	--	--	--	--	--	--	--	--	--	**--**	--	**--**
	Lake	13	--	--	--	--	807	--	--	--	**820**	11	**831**
	River	52	127	--	2	--	111	282	1	113	**688**	102	**789**
	Stream / Canal	5	1	--	--	--	6	--	221	28	**250**	296	**547**
	Total	**465**	**475**	**--**	**132**	**--**	**1,431**	**515**	**303**	**860**	**4,181**	**2,831**	**7,012**
Acres Not Mapped in 1970s		924	278	--	265	--	748	137	771	1,503	**4,625**		
2015 Grand Total		**1,389**	**753**	**--**	**397**	**--**	**2,180**	**652**	**1,073**	**2,362**	**8,806**		

[1] The updated mapping was conducted in 2015, but was based on imagery from 2013.

Figure 11. Comparison of original NWI mapping to updated NWI mapping for a portion of the Lower Arkansas floodplain. For this stretch of the floodplain, the original NWI mapping contains large polygons of Palustrine Forested wetlands (PFOA). The updated NWI mapping classifies these as riparian areas (Rp1FO, Rp1SS, and Rp1EM). The new mapping also includes narrow backwater channels mapped as PEMC or PEMF that were missing from the original mapping.

Figure 12. Comparison of original NWI mapping to updated NWI mapping for the upper edge of John Martin Reservoir. This section of the reservoir was mapped as shrub wetland (PSSA) in the original mapping, but was classified as lake (L1UBHh) and lake shore (L2USCh and L2USJh) in the updated mapping.

3.2.4 Final Estimate of Wetland Acreage

To produce a final estimate of wetland acreage in the basin, the updated mapping was incorporated into the original mapping. We then integrated what we learned in the accuracy assessment of the whole basin and the updated mapping in specific areas along the floodplain to form final reporting groups for wetland acreage (Table 16). We did not examine or reclassify every polygon, but formed groups based on attribute combinations. This is not the same as updating the mapping across the basin, but the resulting summary is closer to reflecting the actual acreage than reporting based strictly on the NWI classes. To create final reporting groups, we addressed the following major limitations in the dataset:

- All Palustrine Forested (PFO) and Palustrine Shrub (PSS) wetlands with a temporarily or intermittently flooded hydrologic regime (A or J) were grouped with riparian areas. The only exception was polygons drawn in the updated mapping; these remained as forested or shrub wetlands.
- All Palustrine Emergent (PEM) wetlands with an excavated (x) or impounded (h) modifier were grouped with ponds and impoundments to address the inconsistence between 1970s era mapping and 1990s era mapping.
- All Palustrine Unconsolidated Shore (PUS) wetlands with an intermittently flooded hydrologic regime (J) were grouped with herbaceous wetlands. These polygons typically represent saline, unvegetated playas. While the coding is not incorrect, it is better to group these polygons with the vegetated playas that are mapped as Palustrine Emergent (PEM) with the same intermittently flooded hydrologic regime (J).

The final NWI map of the Lower Arkansas basin contains 209,770 acres of wetlands, water bodies, and riparian areas, still representing only 1.5% of the total land area (Figures 13; Table 16). The overall total is fairly similar to the summary of all original mapping (Section 3.2.1), with a modest increase coming from the new mapping around John Martin and Pueblo Reservoirs. Using the final reporting groups, areas mapped as wetlands now account for 38.9% of the total acres, waterbodies account for 32.4%, and non-wetland riparian areas account for 28.7% (Figure 14).

Mapped Wetland Acres by General Wetland Type

Within the final NWI mapping, herbaceous wetlands were still the most abundant mapped type, with 61,757 acres or 29.5% of all mapped aquatic resources. With lakes and rivers removed to specifically highlight wetlands, herbaceous wetlands accounted for 75.7% of wetland acres. Areas mapped as herbaceous wetlands include marshes, seep-fed meadow, playas, and mesic herbaceous areas along floodplains and riparian corridors. Based on the accuracy assessment, we can reasonably assume that the true acreage of herbaceous wetlands is less by half to one third. True herbaceous wetlands do occur throughout the basin. There are significant marshes associated with the Arkansas River floodplain, small to medium sized wet meadows fed by seeps in the northern half of the basin, and playa wetlands throughout the plains. However, the mesic areas mapped within floodplains and riparian corridors would not be considered true wetlands on the ground and some wetlands have been lost with the dry up of formerly irrigated lands. Accounting for these changes would require more in-depth reclassification on a polygon by polygon basis.

Table 16. Acres of wetlands and waterbodies in the Lower Arkansas basin mapped by NWI, including sections of both original and updated mapping, by final reporting group.

Final NWI Reporting Group		*Acres*	*% of Basin Area*	*% of NWI Acres*	*% of Wetland Acres*
Total Basin Area		13,949,575	100.0%	---	---
Upland Area (not mapped by NWI)		13,739,875	98.5%	---	---
Wetlands					
NWI Code	**Wetland Type**				
PEM (no x/h), PUSJ	Herbaceous Wetlands	61,757	0.4%	29.5%	74.7%
Pf	Farmed Wetlands	1,561	<0.1%	0.7%	1.9%
PSS (no A)	Shrub Wetlands	6,503	<0.1%	3.1%	8.0%
PFO (no A)	Forested Wetland	519	<0.1%	0.2%	0.6%
PAB, PUB, PUS (no PUSJ), PEMx/h	Ponds and Impoundments	11,211	0.1%	5.3%	13.7%
Total Area of Wetlands		**81,551**	**0.6%**	**38.9%**	**100.0%**
Waterbodies					
NWI Code	**Waterbody Type**				
L	Lakes and Shores	30,108	0.2%	14.4%	---
R2	Large Rivers	10,482	0.1%	5.0%	---
R3 / R4	Smaller Streams	24,378	0.2%	11.6%	---
R*/x mod	Canals and Ditches	3,074	<0.1%	1.5%	---
Total Area of Waterbodies		**68,042**	**0.5%**	**32.4%**	**---**
Riparian Areas					
NWI Code	**Riparian Type**				
Rp, PSSA, PFOA	All Riparian	60,107	0.4%	28.7%	---
Total Area of Riparian		**60,107**	**0.4%**	**28.7%**	**---**
Total Area Wetlands, Waterbodies, Riparian		**209,700**	**1.5%**	**100.0%**	**---**

Following herbaceous wetlands, ponds and impoundment are the second most abundant wetland type. In both the accuracy assessment and in the updated mapping, the acreage of ponds and impoundments increased. In the final dataset, ponds and impoundments made up 9,930 acres, or 5.3% of all aquatic resources and 13.7% of wetland acres. Ponds and impoundments are scattered throughout the basin, mostly away from the main floodplain. Their hydrology, and whether they should all be considered true wetlands, largely depends on what water source they are impounding. Some intercept groundwater seepage and remain wet year round in most years. Others occur on ephemeral drainages and are likely full only sporadically. The differences are difficult to tease apart with the current mapping. Regardless, they represent a significant component of the aquatic resources in the landscape.

Following ponds and impoundments, shrub wetlands are the next largest group, with 6,503 acres or 8% of wetland acres. This figure is far lower than the 35,000 originally mapped. It is also much lower than the 25,000 acres estimated in the accuracy assessment. By moving all polygons with a temporarily or intermittently flooded hydrologic regime to the riparian group, we likely moved some areas of true shrub wetlands. We can reasonably assume that the true number is higher, perhaps as high as the 25,000 estimated in the accuracy assessment. While the majority of woody riparian vegetation along the floodplain and within many riparian corridors has a dry understory, some is certainly wet enough to be considered true shrub wetland. There are wetter stands of both tamarisk and coyote willow located right along the banks of the Arkansas River itself and most tributaries. There is also a significant stretch of the Arkansas floodplain in Pueblo County that is far wetter than much of the rest of the floodplain that would be considered shrub wetland.

Farmed wetlands and forested wetlands are the smallest groups in the final dataset. Farmed wetlands are nearly all playas that have been ploughed through. The dataset contains 1,561 acres of this type. The true acreage may be somewhat higher, as this group increases in both the accuracy assessment and the updated mapping. The final estimate for forested wetlands is 516 acres. The accuracy assessment estimated 1,306. The true acreage is likely between the two. While there are many wooded acres along the floodplain and riparian corridors, few are wet enough to be considered true forested wetlands.

Mapped lakes increased in the final dataset to 30,108 acres across the basin and now represent 14.4% of mapped aquatic resources. The updated mapping did include portions of the two biggest reservoirs, Pueblo and John Martin, both of which were under-mapped in the original mapping. This number is close to the estimate from the accuracy assessment and is likely close to the truth, at least for the summer of 2013. Mapping the exact boundaries of many reservoirs in the basin is extremely channeling. The gentle topography of the landscape means that relatively small increases in volume can greatly increase the footprint of reservoirs. That paired with wide variation in river flow can mean dramatic differences in size from year to year. Rivers, streams and artificially dug irrigation canals together made up another 37,934 acres across the basin (18.1% of mapped aquatic resources). This estimate is also likely accurate.

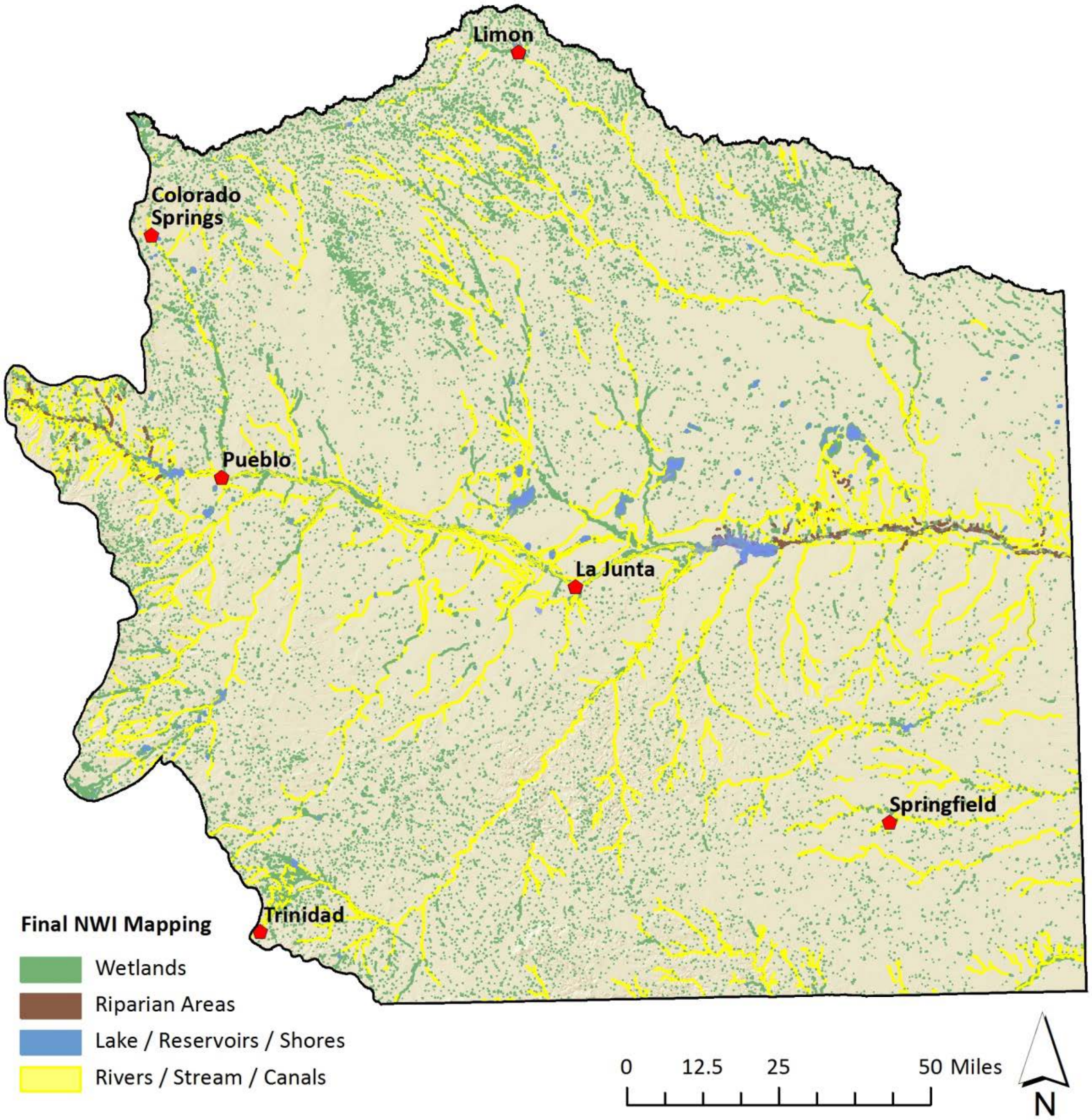


Figure 13. Final NWI mapping for the Lower Arkansas River basin.

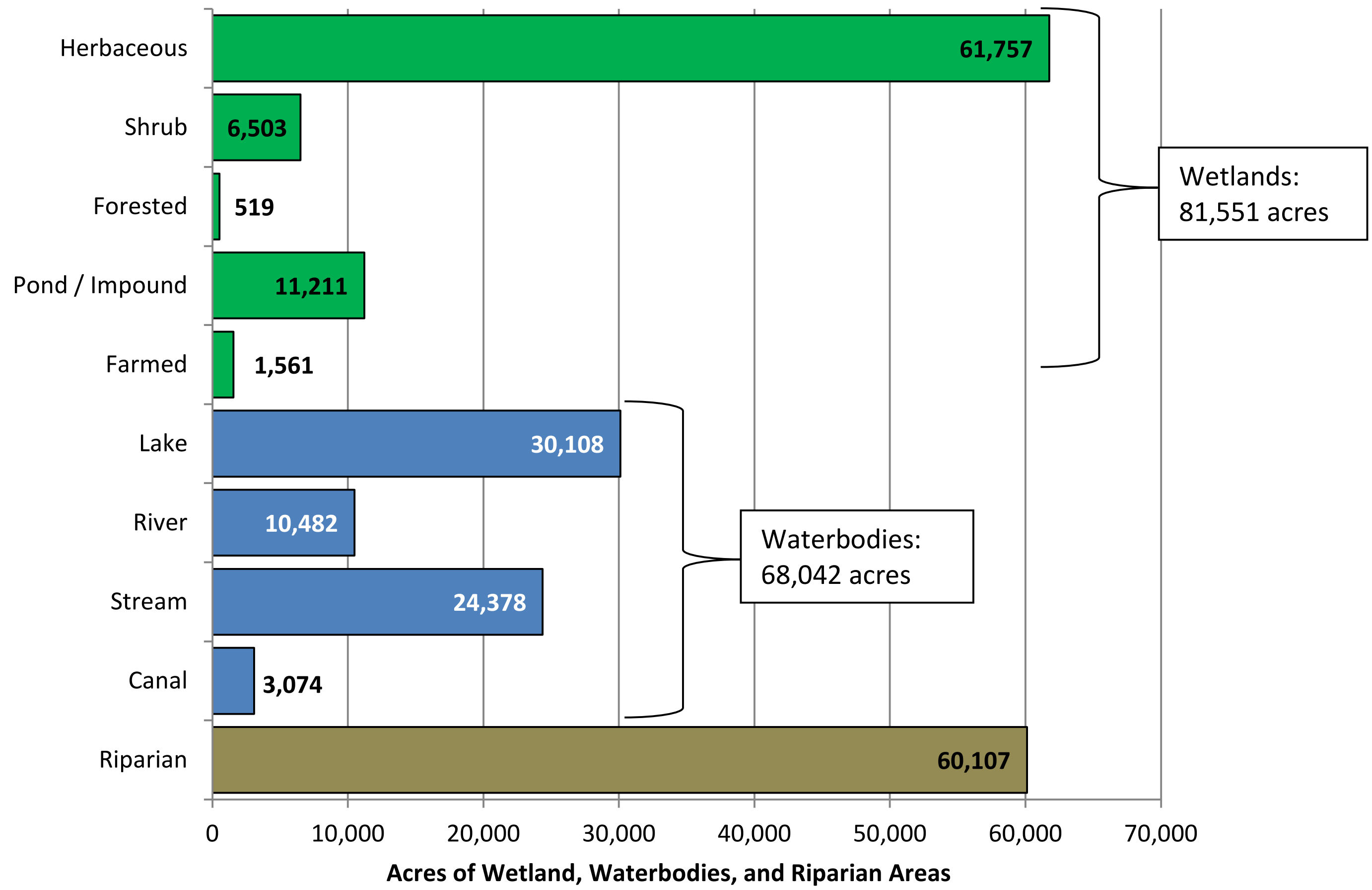


Figure 14. Acres of wetlands and waterbodies in the Lower Arkansas basin mapped by NWI, including sections of both original and updated mapping, by final reporting group detailed in Table 16.

Mapped Wetland Acres by Hydrologic Regime

The most prevalent hydrologic regime used in the study area was A: temporarily flooded (57% of all acres, 51% of wetland acres) (Table 17). This water regime was used for polygons in every wetland and waterbody type mapped in the basin, though most shrub and all forested polygons with this regime were moved to the riparian group (Table 18). The temporarily flooded regime is the driest regime included in the Cowardin classification system. It refers to sites that are wet for less than two weeks during the growing season; a hydroperiod that could arguably be considered too dry for true wetland formation. In the accuracy assessment, many of the areas that were reclassified as upland or non-wetland riparian areas were originally mapped with this hydrologic regime, hence our decision to move the woody polygons to the riparian group.

The next most common hydrologic regime was C: seasonally flooded (14% of all acres, 25% of wetland acres). Seasonally flooded wetlands rely on seasonal precipitation, overbank flooding from adjacent rivers and streams, or direct or indirect addition of irrigation water. These wetlands are wet from a few weeks to a few months a year, typically in the beginning of the growing season, and may be dry towards the end of the growing season. Seasonally flooded wetlands were more correctly mapped in the original dataset and represent many of the true wetland acres in the basin, including herbaceous marshes and meadows, true shrub wetlands along river and stream margins, and ponds. This regime is also used for many of the lake shore, stream, and canal acres.

Table 17. NWI acres by hydrologic regime code.

NWI Code	*Hydrologic Regime*	*All NWI Acres*	*% of NWI Acres*	*Wetland Acres Only*	*% of Wetland Acres*
A	Temporarily flooded	119,956	57%	41,551	51%
B	Saturated	65	< 1%	65	< 1%
C	Seasonally flooded	28,633	14%	20,385	25%
F	Semipermanently flooded	11,121	5%	2,324	3%
G	Intermittently exposed	4,445	2%	859	1%
H	Permanently flooded	12,166	6%	15	< 1%
J	Intermittently flooded	18,882	9%	14,608	18%
K	Artificially flooded	551	< 1%	183	< 1%
None	No hydrologic regime (Pf and Rp)	13,880	7%	1,561	2%
Total		**209,700**	**100%**	**81,551**	**100%**

The third most common hydrologic regime was J: intermittently flooded. This regime refers to areas where the hydroperiod is driven by stochastic rainfall events and where surface water is present for variable periods without detectably seasonality. This regime primarily applies to playas, which are scattered throughout the plains. The accuracy of polygons with this hydrologic regime was better than some others, and playas are fairly well represented in the NWI mapping. By grouping the unvegetated playas (PUSJ) with vegetated playas (PEMJ) in the final reporting groups, the acreage of herbaceous wetlands with this hydrologic regime provides a rough estimate for small, unfarmed playas in the basin (14,608 acres). This estimate is not perfect, however, as some playas are also mapped with the A: temporarily flooded regime. The other large share of acres mapped with this regime is within the lake group. Lake acres with this hydrologic regime are either large natural playa lakes that occur in a few areas of the basin or they are reservoir shorelines that wet periodically in extremely high waters. In cases where historic large playas are now being used as reservoirs, these acres may fit both the preceding descriptors.

Wetter hydrologic regimes of F: semi-permanently flooded, G intermittently exposed, and H: permanently flooded describe a gradient from typically wet to always wet. These regimes were more often associated with lakes and rivers rather than wetlands, though some herbaceous and pond acres were given the semi-permanently flooded regime.

Table 18. NWI acres by hydrologic regime code and wetland / waterbody type. See Table 17 for explanation of hydrologic regime codes.

Final NWI Reporting Group	*Hydrologic Regime, in acres*									*Total*
	A	*B*	*C*	*F*	*G*	*H*	*J*	*K*	*None*	
Herbaceous	36,531	51	10,019	551	--	--	14,608	--	--	61,757
Shrub	102	14	6,386	--	--	--	--	--	--	6,503
Forested	--	--	519	--	--	--	--	--	--	519
Pond / Impoundment	4,918	--	3,461	1,772	859	15	--	183	--	11,211
Farmed	--	--	--	--	--	--	--	--	1,561	1,561
All Wetland Acres	**41,551**	**65**	**20,385**	**2,324**	**859**	**15**	**14,608**	**183**	**1,561**	**81,551**
Lakes / Shores	6,404	--	2,895	7,585	2,221	6,756	3,969	368	--	30,108
Rivers	2,261	--	677	860	1,329	5,354	--	--	--	10,482
Streams	22,106	--	2,264	--	--	--	8	--	--	24,378
Canals	144	--	2,500	353	37	41	--	--	--	3,074
All Waterbody Acres	**30,914**	**--**	**8,247**	**8,789**	**3,586**	**12,151**	**3,978**	**368**	**--**	**68,042**
Riparian	47,491	--	--	--	--	--	297	--	12,319	60,107
All NWI Acres	**119,956**	**65**	**28,633**	**11,121**	**4,445**	**12,166**	**18,882**	**551**	**13,880**	**209,700**

Mapped Wetland Acres by Extent Modified and Irrigated

The NWI classification includes several modifiers that describe alteration from both human and natural causes. The four official NWI modifications mapped in the Lower Arkansas basin are: 1) x: excavated, 2) h: impounded, 3) d: drained, and 4) b: beaver influenced. Among those four official modifiers, a polygon can only be attributed with one of the four. While many lakes and ponds are both excavated and impounded, they are mapped with one or the other depending on which modifier is dominant. In addition to those four modifiers, we looked at two additional non-NWI modifiers: 1) the degree of overlap with previous mapping of tamarisk by the Tamarisk Coalition (2009) and 2) the degree of overlap with mapping of irrigated lands by the Colorado Water Conservation Board's Colorado Decision Support System (2015).

In total, only 16% of total acres and wetlands were mapped with an official NWI modifier (Table 19). Eighty-eight percent of lake acres were classified as either excavation or impoundment, which may be a reasonable estimate. Many lakes within the study area are reservoirs created for flood control and/or water storage and are either impounded, excavated, or both. Some lakes, including those in Queens State Wildlife Area known as the Great Plains Reservoirs, were historical playa lakes that are now filled for irrigation storage and are not extensively excavated or impounded.

Ponds were also often mapped as excavated or impounded, with 33% mapped with one or the other modifier. Many small impoundments mapped in the 1970s, however, were not mapped with a modifier, but the impoundments are clearly evident. This appears to be an oversight of the early mappers. Canals were the other significant group mapped with an NWI modifier. All canal acres were, by definition, mapped with an excavated modifier. However, while most rivers and streams were not mapped as modified, the NWI modifiers do not account for hydrologic modification, such as dams and diversions, which affects every mile of the Arkansas River itself, as well as many of the major tributaries.

To estimate the impact of tamarisk on the wetlands and riparian areas mapped in NWI, we intersected the NWI dataset with mapping of tamarisk conducted by the Tamarisk Coalition in the late 2000s (Tamarisk Coalition 2009). In total, the Tamarisk Coalition map of tamarisk includes 70,975 acres of tamarisk across basin. This includes areas with dense stands and areas of scattered growth. When intersected with the NWI mapping, 52,718 acres overlap in both datasets, meaning 75% of what was mapped by the Tamarisk Coalition is captured in the NWI mapping. Of those overlapping acres, 31,662 are within the riparian reporting group and make up half the acres in this group. The other acres affected by tamarisk are spread between herbaceous and shrub wetlands, as well as lakes, rivers, and streams. The Tamarisk Coalition mapping included areas with scattered tamarisk growth, meaning areas mapped in NWI as herbaceous or lake shore may have scatter, low density tamarisk.

The last analysis of modification of the basin's wetland was the prevalence of irrigation. Wetlands can be created or recharged from irrigation water through a number of mechanisms, including leakage from canals, overflow from adjacent irrigated fields, and through direct application of irrigation water. With the current mapping, it is not practical to identify wetlands receiving leakage from canals or overflow from adjacent fields, which is likely a significant percentage in some areas of the basin, but it is possible to estimate the area of wetlands directly receiving irrigation water by overlaying NWI mapping with mapping of irrigated parcels. This analysis provides a conservative estimate for the influence of irrigation on wetlands, but underestimates the total impact of irrigation by addressing only one of the possible wetland recharge mechanism.

Within the Lower Arkansas basin, irrigation practices have changed dramatically since the 1970s, when the original NWI mapping was created. Many acres of irrigated lands have dried as a result of water right transfers to major urban areas. In total, < 1% of mapped wetlands and waterbodies are also mapped as irrigated lands. This is a very small percent compared to other areas of Colorado, where direct irrigation plays a much more significant role in wetland hydrology (Lemly & Gilligan 2012). Data on irrigated lands in the basin separates parcels that are actively irrigated from those that are now dry. Actively irrigated parcels overlap only 0.3% of the NWI mapped acres. There greater overlap between NWI mapping and inactive irrigated parcels, suggesting that perhaps some of the conversion from what was once mapped as herbaceous wetlands to non-wetland riparian areas may be linked to irrigation dry up. However, in general, the connection between direct irrigation and wetland hydrology appear to be small. The link between irrigation return flows and wetland hydrology is not included in this analysis, but may be very high.

Table 19. NWI acres by modifiers and non-NWI modifiers, including tamarisk[1] and active and inactive irrigation.[2]

Final NWI Reporting Group	*Modifier, in acres*							*Total[3]*
	Excavated	*Impounded*	*Ditched*	*Beaver*	*Tamarisk*	*Active Irrigation*	*Inactive Irrigation*	
Herbaceous	--	--	20	7	5,326	203	344	61,757
Shrub	45	13	--	--	4,188	8	17	6,503
Forested	--	--	--	--	45	--	--	519
Pond / Impoundment	1,462	2,399	--	9	293	133	54	11,211
Farmed	--	--	--	--	--	13	19	1,561
All Wetland Acres	**1,507**	**2,413**	**20**	**16**	**9,852**	**357**	**434**	**81,551**
Lakes / Shores	17,714	8,790	--	--	5,500	23	54	30,108
Rivers	--	--	--	--	4,079	12	11	10,482
Streams	--	--	--	--	1,601	7	8	24,378
Canals	3,074	--	--	--	25	82	65	3,074
All Waterbody Acres	**20,789**	**8,790**	**--**	**--**	**11,204**	**125**	**138**	**68,042**
Riparian	--	75	--	--	31,662	210	342	60,107
All NWI Acres	**22,296**	**11,278**	**20**	**16**	**52,718**	**692**	**914**	**209,700**

[1] Tamarisk data are from the Tamarisk Coalition (2008).
[2] Irrigated lands data are from the Colorado Decision Support System (CDSS 2012) and represent irrigated lands as of 2003.
[3] Total is for reference only and is not a sum of all modifiers, as they are not mutually exclusive.

Mapped Wetland Acres by Regional Strata

To understand the distribution of wetlands across the basin, it is helpful to look at regional patterns in the mapping. To do this, we divided the basin into three zones or regional strata: 1) the Arkansas River Floodplain itself, which covered a narrow band on either side of the river that is directly influenced by flooding of the river itself or by active irrigation from river water; 2) the Northern Plains, including all lands of the basin north or the floodplain; and 3) the Southern Plains and Canyons, which included the plains south of the floodplain and the canyons of Mesa de Maya, the Purgatoire River, and other tributary streams. The floodplain stratum includes only 7% of the land areas of the basin, while the northern plains covers 41% and the southern plains and canyons covers 52%.

Table 20. NWI acres by three regional strata: Arkansas River Floodplain, Northern Plains, and Southern Plains and Canyons.

Final NWI Reporting Group	*Arkansas River Floodplain*		*Northern Plains*		*Southern Plains and Canyons*		*Total*
	Acres	*% of Class*	*Acres*	*% of Class*	*Acres*	*% of Class*	
Herbaceous	24,296	39%	23,886	39%	13,646	22%	61,757
Shrub	4,291	64%	420	6%	1,980	30%	6,503
Forested	83	16%	150	29%	285	55%	519
Pond / Impoundment	1,855	17%	4,212	38%	5,054	45%	11,211
Farmed	45	3%	1,178	75%	337	22%	1,561
All Wetland Acres	**30,571**	**37%**	**29,847**	**37%**	**21,302**	**26%**	**81,551**
Lakes / Shores	24,690	82%	2,845	9%	2,573	9%	30,108
Rivers	6,272	60%	1,660	16%	2,589	25%	10,482
Streams	762	3%	13,057	54%	10,556	43%	24,378
Canals	2,410	79%	307	10%	317	10%	3,074
All Waterbody Acres	**34,134**	**50%**	**17,870**	**26%**	**16,035**	**24%**	**68,042**
Riparian	36,602	61%	8,321	14%	14,992	25%	60,107
All NWI Acres	**101,307**	**48%**	**56,037**	**27%**	**52,329**	**25%**	**209,700**

It is immediately apparent from this analysis how concentrated the NWI mapping is within the relatively small area of the floodplain stratum (Table 20). While the floodplain only covers 7% of the land area, in includes nearly half (48%) of the NWI mapping. The narrow floodplain stratum includes 37% of all mapped wetland acres (39% of herbaceous wetlands, 64% of shrub wetlands, but only 16% of forested wetlands, 17% of impoundments and 3% of farmed wetlands). These patterns make sense. For herbaceous wetlands within the floodplain stratum, there are large swaths of emergent marsh along the floodplain upstream of John Martin Reservoir, small backwater channels and sloughs near the river, and numerous marshes and meadows just outside the floodplain fed by groundwater seepage and irrigation return flows. For shrub wetlands, there are a few very wet stretches of the floodplain where tamarisk and coyote willow occur with very wet understories. But while there are large herbaceous and shrub wetlands in the floodplain, there are far fewer small impoundments or farmed wetlands. Both of these types occur far more frequently on the plains away from the floodplain.

The floodplain stratum also includes 82% of the lake acres, including all of John Martin, Pueblo, and the Great Plains Reservoirs. The floodplain stratum was specifically drawn to encompass the major irrigation network, so it extends up to the Great Plains Reservoirs in that areas of the basin. Similarly, the floodplain stratum includes 60% of river acres and 79% of canal acres, though only 3% of stream acres, which represent the smaller tributaries on the plains. In addition to wetland and waterbody acres, the floodplain includes 61% of acres in the riparian reporting group. These are the polygons mapped as riparian in the new mapping, as well as all drier forested and shrub polygons from the original mapping.

The northern and southern plains are distinctly different from the floodplain, and they are also different from each other. The northern plains contain relatively more acres of mapped wetlands than does the southern plains (37% vs 26%), even while the southern plains stratum is larger. Within the mapped wetlands, the northern plains include far more herbaceous and farmed wetlands and far fewer shrub and forested wetlands. The density of playas is far greater in the northern plains, and these wetlands are represented in both the herbaceous and the farmed wetland group. Groundwater seeps in the northern plains also feed several large wet meadow-marsh complexes, such as those on Brett Gray and Chico Basin Ranches. Lastly, the northern tributaries, including Rush, Horse and Big Sandy Creeks, are less wooded than those to the south. In contrast, tributaries to the south—the Purgatoire, Huerfano, and Cucharas Rivers—are larger and more wooded, and these wooded systems have pockets of shrub and even forested wetlands along their corridors. The southern plains also include more riparian vegetation, which flanks most of the tributary streams. Both plains strata are peppered with small impoundments, which occur along nearly all washes and drainages.

Mapped Wetland Acres by Land Ownership

Management decisions are ultimately made by those who own the land. The last analysis of mapped wetlands was the distribution of wetlands by landowner. This analysis highlights the importance of private lands for the wetland resources in the Lower Arkansas basin. Private lands make up 84.1% of the entire Lower Arkansas basin in Colorado and they own the vast majority of the basin's wetlands: 78.0% of all NWI acres and 82.2% of mapped wetlands are located on private land (Table 21).

The State of Colorado owns 9.4% of the study area, mostly lands administered under the State Land Board. These lands contain an important share of wetland acres, 7.1% of all NWI acres and 7.4% of wetland acres. These acres are a mix of playa wetlands and seep-fed wetland meadows, marshes, and drainages scattered across the plains, some managed by conservation groups, such as The Nature Conservancy, for their biodiversity significance. In addition, lands managed by Colorado Parks and Wildlife (CPW), also represent an important share of aquatic resources. CPW owns 2.3% of all NWI acres and 1.8% of mapped wetland acres, mostly on large State Wildlife Areas established for waterfowl habitat and recreational opportunities.

Very little of the Arkansas basin is federally owned (6.4% of the basin), much of it within the Comanche National Grassland (3.2% of the basin). The other significant federal land owner is the Department of Defense, which owns and administers Pinon Canyon Maneuver Site, Pueblo Chemical Depot, Peterson Air Force Base, and the Air Force Academy, representing 2.6% of the basin. The Bureau of Land Management, Army Corps of Engineers, National Park Service, and Bureau of Reclamation each own a small portion of the basin. Of all federal lands, the Army Corps of Engineers owns 6.2% of NWI mapped acres, mostly around John Martin Reservoir. The BLM also owns 3.2% of NWI acres and 1.8% of wetland acres, including many playa wetlands scattered across the basin.

Table 21. NWI acres by grouped land owner.

Grouped Owner[1]	*Total Land Area within Basin*		*All NWI Acres*		*Wetland Acres Only*	
	Acres	*% of Basin*	*Acres*	*% of NWI Acres*	*Acres*	*% of Wet Acres*
Federal Lands	**892,353**	**6.4%**	**25,192**	**12.0%**	**10,714**	**8.3%**
U.S. Forest Service	444,630	3.2%	1,144	0.5%	734	0.6%
U.S. Dept. of Defense	364,713	2.6%	1,689	0.8%	1,174	0.9%
Bureau of Land Management	45,064	0.3%	6,790	3.2%	2,290	1.8%
Army Corps of Engineers	25,412	0.2%	13,070	6.2%	5,819	4.5%
Misc. Federal (BOR, NPS)	12,533	0.1%	2,498	1.2%	697	0.5%
State Lands	**1,314,959**	**9.4%**	**19,782**	**9.4%**	**11,919**	**9.2%**
State Land Board	1,251,155	9.0%	14,918	7.1%	9,600	7.4%
Colorado Parks and Wildlife	63,769	0.5%	4,864	2.3%	2,320	1.8%
Misc. State	35	< 0.1%	--	--	--	**--**
Local Government	**16,411**	**0.1%**	**1,137**	**0.5%**	**397**	**0.3%**
Cities	12,617	0.1%	886	0.4%	345	0.3%
Counties	3,307	< 0.1%	250	0.1%	52	< 0.1%
School Districts	487	< 0.1%	--	--	--	--
Other	**11,725,852**	**84.1%**	**163,589**	**78.0%**	**106,309**	**82.2%**
Land Trusts	1,323	< 0.1%	3	< 0.1%	3	< 0.1%
Private	11,724,852	84.0%	163,587	78.0%	106,306	82.2%
Total	**13,949,575**	**100%**	**209,700**	**100.0%**	**129,339**	**100.0%**

[1] Many properties in the basin are owned by one agency but managed by another agency through inter-agency agreements or are owned by private land owners but managed by an agency through easements. Therefore, the numbers of acres owned by a given agency is different than the number of acres managed by that agency.

3.4 Discussion

The clearest result to emerge from the analysis of wetland mapping is how few acres of wetlands there are in the Lower Arkansas River basin. Original NWI mapping placed the estimate at just over 200,000 acres of wetlands and waterbodies, with ~143,000 acres of wetlands and ~63,000 acres of waterbodies. The accuracy assessment and new mapping showed these numbers to be gross overestimates, at least for wetlands. In actuality, the basin likely contains only ~80,000 acres or less of true wetlands, which represents <0.5% of the landscape. In cannot be overstated that wetlands are an exceedingly rare feature in the basin, yet they are absolutely critical for many wildlife species. Migratory birds passing through Colorado's plains depend on ponds, marshes, and playa lakes for forage and resting sites. Lake shores and playa lakes within the basin are the only known habitat for Least Tern and Piping Plover in the state of Colorado.

While the majority of the basin was mapped in the 1970s, with different standards than today, the accuracy assessment and updated mapping provide important information for interpreting mapped wetland acreage. These analyses, and the final reporting groups used in this report, allow for revealing trends in the data to emerge. But they also highlight the need for new mapping to accurately depict the basin's resources. With picture of the basin's wetland that emerges from careful study of the mapping is one of great diversity and strong regional patterns. North of the river, the wetland resources is dominated my playas, seep-fed meadow complex, and open riparian corridors. The floodplain itself is heavily wooded and infested with non-native tamarisk, which has limited the growth of native floodplain vegetation. Much of these wooded stretches of the river are too dry to be considered wetland, but should more accurately be called non-wetland riparian areas. In addition to the wooded riparian vegetation, however, there are stretches of the river that are very wet. Large marshes occur along the floodplain west of John Martin Reservoir and large shrub wetlands occur further west in Pueblo County. The southern plains have fewer meadows, marshes and playas, but included larger, more wooded tributary streams and canyons, many of which include small patch wetlands. Throughout the basin, impoundments dot the landscape, providing standing water when full, but also intercepting flow that would otherwise reach natural streams. The picture that emerges from the mapping data is reinforced and made richer through field surveys of the highest condition examples of the dominant wetland types, as detailed in Section 4.0 below.

The second clear conclusion is the importance of working with private land owners in the management and conservation of wetland resources. Over 80% of the mapped wetland resources are privately owned or public lands managed by private leases. This represents an important opportunity for collaborative conservation efforts between private landowners who own and manage most wetland acres and federal and state agencies with resources and technical assistance. CPW, NRCS, and USFWS all have active programs to work with lands owners on wetland protection and restoration efforts. These should be continued and augmented in whatever way possible.

4.0 REFERENCE WETLANDS AND RIPARIAN AREAS

4.1 Introduction to Reference Sampling

4.1.1 Importance of Reference Sites

There is a pressing need to assess the current ecological condition of natural resources, particularly aquatic and wetland resources, in order to formulate sound management goals for preservation and restoration. Assessing current condition, however, relies on understanding what optimal condition looks like and how it degrades with increasing human stress. A scientific consensus has emerged around the idea that changes in ecological condition caused by increased stress occur along a gradient, are measureable, and follow predictable patterns (Carins et al. 1993; Davies & Jackson 2006). “Reference sites” or “reference standard sties” are essential for establishing benchmarks against which current condition can be compared. Conditions observed within reference standard sites are called “reference conditions,” a term that refers to the “naturalness” of a system’s biota and physical processes in the absence of human-induced stressors (Stoddard et al. 2006). Quantitative data collected within reference standard sites helps identify the pristine or natural end of the condition gradient. Comparing reference standard sites with highly impact sites helps define the rate of change along the gradient with increasing stress.

Ideally, reference standard sites should be located in landscapes with minimal or no human impacts in order to set benchmarks that represent conditions in the absence of human disturbance. However, in many parts of the Unites States, human land use has been so extensive that there simply are no minimally disturbed reference standard sites left. For these areas, reference sites should be selected from the least disturbed examples available. Conditions measured in those sites are considered “least disturbed conditions,” a term that implies the best available physical, chemical, and biological habitat given conditions on the landscape today (Stoddard et al. 2006). While least disturbed reference sites can help establish thresholds for assessing condition, they should not be interpreted as the pristine or natural end of the condition gradient. Instead, least disturbed sites may fall within the middle of the gradient. In the Lower Arkansas basin, which has a long history of human land uses, we focused on identifying least disturbed reference sites for many wetland and riparian types that have been heavily impacted by human land use and water management. Though far from pristine, these sites still set the bar against which other sites can be measured.

In addition to their value as benchmarks for assessing the condition of surrounding wetlands, reference sites can serve a number of other purposes. Reference sites can be models for future restoration projects that aim to achieve the best condition attainable within the current landscape, which may even be better than conditions within the least disturbed reference sites. Reference sites are also important for long term studies of the impact of broad-scale trends, such as climate change, that may slowly shift species composition and hydrologic patterns over time. For this reason, it is helpful to establish reference sites that can be visited repeatedly over time to detect change.

4.1.2 Ecological Integrity Assessment (EIA) Framework

This project used the Ecological Integrity Assessment (EIA) Framework to evaluate the condition of reference wetlands and riparian areas in the Lower Arkansas River basin. The EIA Framework was developed by NatureServe[7] and ecologists from several Natural Heritage Programs across the country (Faber-Langendoen et al. 2008; Faber-Langendoen et al. *in prep*). 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)
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 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 22. 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 2.0 (Lemly & Gilligan 2015).

Table 22. 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.

[7] 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.

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.

4.2 Reference Sampling Methods

4.2.1 Site Selection

Reference sites were hand selected to represent wetlands and riparian areas across the basin in the least disturbed condition available (*sensu* Stoddard et al. 2006), where access was permitted. Most sites were selected based on recommendations by the project steering committee or other partners knowledgeable about wetlands and riparian areas in the Lower Arkansas basin. Some additional sites were selected based on air photo reconnaissance of areas within the basin with largely intact landscapes capable of supporting higher quality wetlands and riparian areas.

The primary filter used for site selection was an absence of major intensive human land uses within 500 m of the site. Though major land uses were screened out, many sites still occurred within working ranches or on State Wildlife Areas and were subject to less intensive land uses, such as grazing and recreation. In many instances, a general area was targeted in the office based on aerial imagery, but the field crew made the final call on exactly where to sample. The field call was made based on vegetation composition and lack of obvious within-site stressors.

The original target sample size was 30–40 sites, with at least three sites per major wetland and riparian type. For wetland types with high variability, greater sampling effort was allocated. Though the initial target was 30–40 sites, we were able to exceed that target and sampled 48 individual sites, with at least five sites for most types. In addition to initial visits, a number of sites were revisited to understand variability associated with seasonality and varying moisture conditions.

Wetland and Riparian Definitions

For this project, both wetlands and non-wetland riparian areas were targeted as reference sites. 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.

Many riparian areas within the Lower Arkansas River Basin do not meet the federal definition of wetlands, but still provide many essential functions, such as wildlife habitat and flood protection. The project steering committee agreed that non-wetland riparian areas should be included in the reference network 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."*

Reference sites sampled could be entirely wetland, entirely non-wetland riparian, or a mix of both. We did not use the wetland, non-wetland riparian boundary to delineate our assessment areas, but we did use the boundary between either wetlands or non-wetland riparian areas and upland areas.

Classification of Sampled Sites

Reference 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 23). In addition to the six main Ecological System groups, we added one additional type, canyon spring, to describe small wetlands fed by seeps and springs from canyon walls within the far southeast corner of the basin. Canyon springs are generally very small features that would not typically be called out as their own Ecological System, but would be captured as part of larger riparian features. The canyon springs surveyed in this study were of general interest to the steering committee and represent an important small-scale wetland type in the far southeast of the basin, therefore we did sample them separately.

A key to Ecological Systems in the Lower Arkansas River Basin is included in Appendix B. Full descriptions of the seven wetland and riparian types, including dominant vegetation, hydrologic dynamics, soil properties, and basic water chemistry is included as Appendix C. Some aspects of the

Ecological Systems classification, as used in this report, are still under development and will be further refined based on data collected in random sites in Phase 2 of the project. We are specifically still working on the relationship between the emergent marsh, wet meadow, and plans riparian types, which can share similar characteristics in certain settings.

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 24). A key to HGM classes are included as Appendix D. Though the HGM classification is typically applied only to wetlands, we also assigned the riverine HGM class to all non-wetland riparian areas because they are also driven by riverine processes.

Table 23. Wetland and riparian types of the Lower Arkansas River 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 (under development)
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
Canyon spring	Not an official Ecological System

Table 24. HGM classes found in the Lower Arkansas River Basin. ***Continued on next page.***

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.

4.2.2 Field Methods

Data collection protocols for this project were based, in part, on protocols developed for EPA's National Wetland Condition Assessment (EPA 2011) and modified for use in Colorado. Condition assessment metrics followed the Ecological Integrity Assessment (EIA) framework for assessing wetland condition (Faber-Langendoen et al. 2008; Faber-Langendoen et al. *in prep*), also modified for application in Colorado (Lemly & Gilligan 2015). Data analysis also relied on the Floristic Quality Assessment (FQA) for Colorado Wetlands (Rocchio 2007). An example field form is included as Appendix E.

Defining the Assessment Area

At all wetland and riparian reference sites, a 0.5-ha (5,000-m^2) assessment area (AA) 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 non-wetland 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* (EPA 2011). The most significant difference between protocols from the NWCA and the Lower Arkansas project is that the target population for this project included non-wetland 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 reference sites were sampled with intensive Level 3 protocols, based on EPA's NWCA vegetation plots layout. A fully documented description of the NWCA vegetation protocols can be found in the *2011 NWCA Field Operations Manual* (EPA 2011). A brief description is included here for reference. Several modifications to the protocols have been made for this project in the interest of time; those are also described here. The NWCA field protocol was developed for a crew of four people to carry out in one full field day. The crew for this project was two people, so protocols were pared down to fit the field day.

The standard arrangement for vegetation sampling was five 100 m^2 plots distributed adjacent to four plot placement lines established along the cardinal axes (Figure 15). Plots were laid out to the left of the plot placement lines when facing from the AA center to the outer edge. Plots were numbered 1 through 5, beginning with the plot closest to the center and radiating out in a clockwise direction from south to east, according to the following guidelines:

- To avoid the trampled area at the AA center, plot 1 was located approximately 2 m from the AA center along the south plot placement line.
- Plot 2 was located 10 m beyond plot 1, also along the south plot placement line.
- Plot 3 was located 15 m from the AA center along the west plot placement line.
- Plot 4 was located 15 m from the AA center along the north plot placement line.
- Plot 5 was located 20 m from the AA center along the east plot placement line.

The standard vegetation plot layout could be modified in a number of different ways to best fit the AA. The *NWCA Field Operations Manual* has extensive detail on various alternative plot layouts. We followed all of the NWCA guidance in this project. The only difference was that, in the interest of time and to be consistent with our past vegetation protocols, we intensively sampled only four of the five plots. Once all five were laid out, the field crew decided which plots to sample, prioritizing plots that included new species over plots that were similar to those already sampled. The plot that was not sampled intensively was considered the "residual" plot. GPS waypoints and photographs were taken at the southeast-most corner of all five plots.

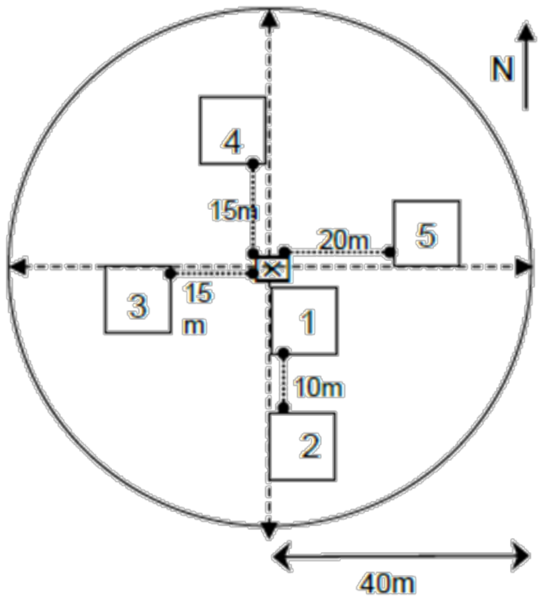


Figure 15. Schematic of the standard vegetation plot layout. Five plots are arranged along the cardinal axes.

Floristic measurements including presence/absence and abundance (i.e., cover) of all vascular plant species were made within the four selected plots. Within the NWCA protocol, presence/absence data is collected in a series of nested quadrats. For this project, presence/absence data was collected for the entire plot instead of nested quadrats, again in the interest of time. However, sampling began in one 1-m^2 corner of the plot to focus the field crew's search. Once all species in that corner were identified, the crew moved throughout the entire plot and noted all species encountered. Any unknown species were entered on the field form with a descriptive name and all unknown species were collected by the field crew to be identified later. Nomenclature for all plant species followed Weber and Wittmann (2012a, 2012b).

When all species within a plot were identified, cover was visually estimated for the plot using the following cover classes (Peet et al. 1998).

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

After sampling each of the intensive plots, the remaining (i.e. residual) plot was walked to document presence of any species not recorded in the intensive plots. Percent cover of these species was estimated over all five plots.

Soil Profile Descriptions and Water Chemistry

At least two soil pits were dug within each AA, except for sites on the Comanche National Grassland, where any soil disturbance requires archeological review. If there was 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. Soil pits were dug with a 40-cm sharp shooter shovel to one shovel length depth (35 to 40 cm), when 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

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 River basin are shown in Table 25. Metric narrative ratings and scoring formulas are included in the field manual (Lemly & Gilligan 2015).

Table 25. EIA metrics used in the Lower Arkansas River basin.

Rank Factor	***Major Ecological Factor***	***Metrics***
Landscape Context	Landscape	L1. Contiguous Natural Land Cover
	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.

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 26). 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 26. 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).

Stressor Checklist

In addition to the condition metrics, the EIA protocol involves collecting data on stressors specific to the landscape, vegetation, hydrology, and soils. Each stressor is designated with a severity and scope rating, indicating the intensity of the stressor and percent of the landscape or AA that it affects. This information allows for correlations between wetland condition and potential stressors.

4.3 Reference Sampling Results

4.3.1 Reference Sites Sampled

During the summer of 2014, 48 individual sites were visited to characterize the vegetation and assess the condition of reference wetlands and riparian areas in the Lower Arkansas River Basin (Table 27). Of those sites, 11 were revisited to detect seasonal variability. Revisits were focused on dynamic wetland and riparian types, specifically playas, plains floodplain systems, and plains riparian systems. For playa revisits, the goal was to sample sites in both wetland and dry conditions. A total of 59 successful site visits were conducted for this phase of the study. The majority of sites were located on publicly owned land, which facilitated repeat sampling, but ten sites were located on private land. Thirteen additional sites were on State Land Board parcels leased by private ranches.

Table 27. Reference wetland and riparian sites sampled in the Lower Arkansas River Basin by type.

Wetland / Riparian Type	***Initial Visits***	***Repeat Visits***
Emergent marsh	6	
Wet meadow	5	
Playas	7	6
Plains floodplain	8	3
Plains riparian	16	2
Foothills riparian	1	
Canyon spring	5	
Total Site Visits	**48**	**11**

Reference sites were well distributed across the basin (Figure 16), though certain types were, by definition, concentrated in certain areas. Plains floodplain sites were all located within the floodplain of either the Arkansas River itself or Fountain Creek, the largest tributary in the basin. Plains riparian sites, the largest group sampled with 16 individual sites, were located along smaller tributaries throughout the basin, both north and south of the Arkansas River and both east and west of La Junta. The one foothills riparian site was located in the far northwest edge of the study area along Monument Creek, one of the few places in the basin where there is a significant foothills zone. Marshes were located either within the floodplain of the Arkansas River or were associated with large seeps in the plains north of the river. Wet meadows were also associated with seep complexes north of the river. Playas were located throughout the basin, all outside the floodplain zone both north and south of the river. Lastly, canyon springs were all located south of the river associated with small seeps along canyon walls.

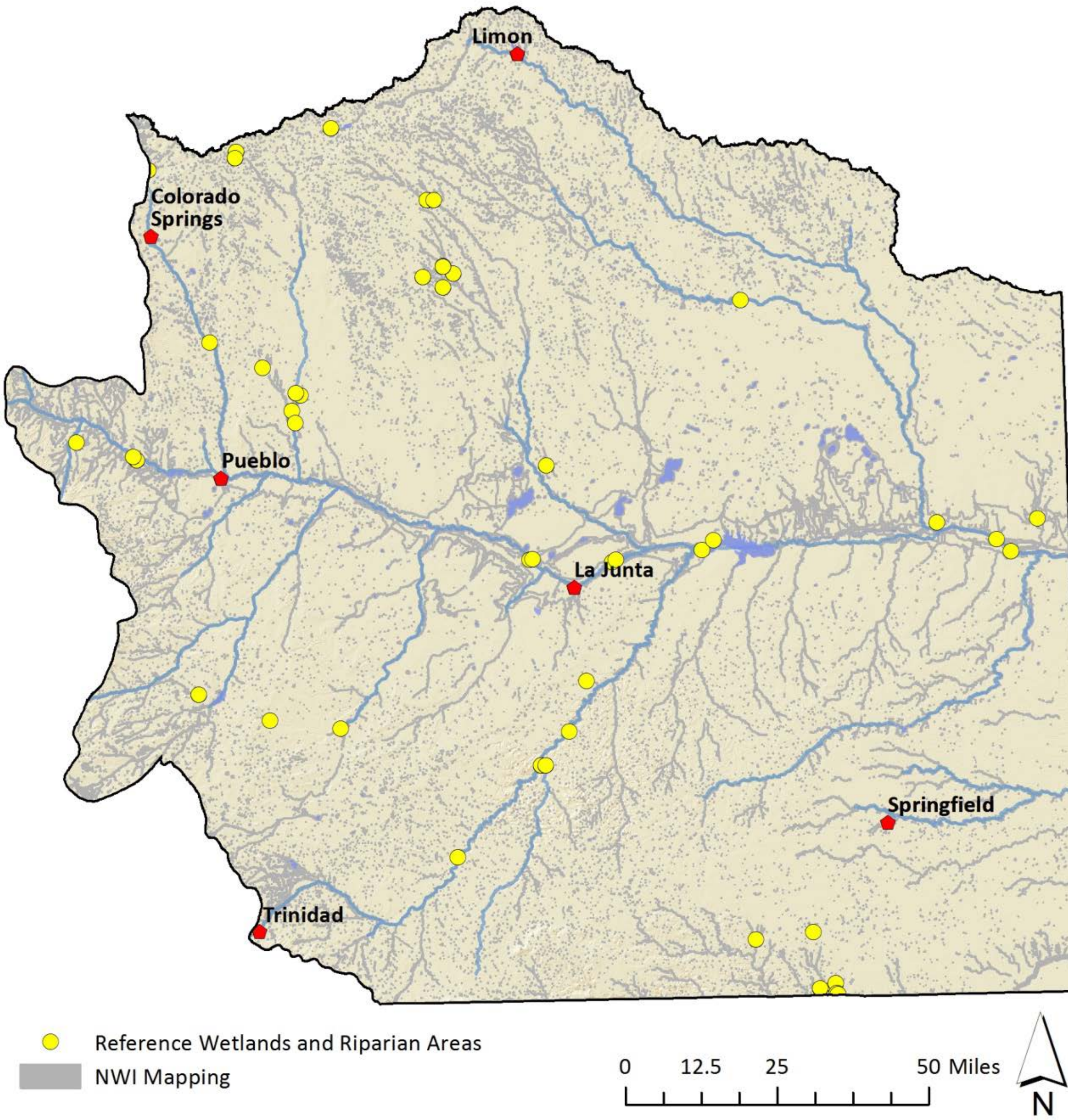


Figure 16. Map of reference wetland and riparian sites sampled in the Lower Arkansas River Basin.

All sites were classified by a general interpretation of origin and by the hydrogeomorphic (HGM) classification system. The general origin classification notes whether a site was natural with minimal alteration, natural but altered, or non-natural (intentionally or unintentionally created by human land or water management). HGM classes lump wetlands by water source and flow, landscape position, and site geomorphology. This classification is closely related to the potential functions and services provided by wetlands. For each wetland, one HGM class was selected based on the dominant landscape position and water source, though many sites in the basin share characteristics of more than one HGM class.

By the general origin classification, all sites sampled for this phase of the project were considered natural in origin, though 42% were altered or augmented (Table 29). No sites surveyed were considered non-natural in origin. This reinforces that the site selection process targeted natural wetlands and riparian areas rather than created or non-natural wetlands.

The HGM class of sampled sites varied by wetland and riparian type (Table 28). Marsh wetlands were evenly split between depressional and slope HGM classes, but many tended to have characteristics of depressional, slope, and even riverine classes. They were often depressional features with outlets that connected to a channel, but the dominant water source was seepage from either natural groundwater or irrigation returns and not overbank flooding or channel through-flow. All depressional marshes were located within the Arkansas River floodplain and all were considered natural, but altered or augmented, as the floodplain is highly altered by water management and agriculture practices. Floodplain marshes receive irrigation return flows and are much larger than they would have been naturally. The three sloping marshes were located out of the floodplain zone and were associated with large seeps north of the river. Two of these sites were considered natural with minimal alteration. One natural seep marsh was considered altered because its water source had been disrupted.

All wet meadow sites were classified as slope HGM wetlands because they were fed by groundwater seeps, and all were considered natural with minimal alteration. Playas were all classified as depressional HGM wetlands and all but one were considered natural with minimal alteration. The one altered playa contained an old pit, likely dug to increase water supply for livestock.

Plains floodplain sites, plains riparian sites, and the one foothills riparian site were all classified within the riverine HGM class. Though not all of the floodplain and riparian sites were technically wetlands, any non-wetland riparian sites were classified within the riverine HGM class because they are also driven by riverine processes. For many plains riparian sites, the riverine HGM class does not fully describe the hydrologic dynamics. Many of these sites are strongly connected to groundwater discharge and share some characteristics of the slope HGM class. They also tend to form permanent pools within the stream channel, and therefore share some characteristics with the depressional HGM class. Many would best be described as a hybrid between riverine, slope, and depressional HGM classes. For the sake of data interpretation, they are all classified as riverine for this report.

All plains floodplain sites were considered natural, but altered or augmented. Intensive regulation of flows on the Arkansas River has dramatically altered the original floodplain. Plains riparian sites were primarily considered natural with minimal alteration, but five of the 16 sites were considered altered for a variety of hydrologic modifications. The one foothills riparian site was also considered natural, but altered or augmented by development surrounding the site that contributes urban stormwater runoff.

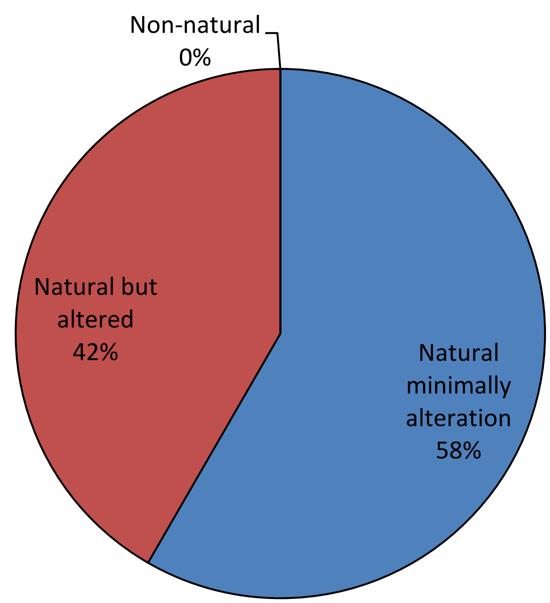
The canyon springs were mainly classified within the depressional HGM class. Most of the springs sampled were pools formed at the base of canyon walls. One site was classified within the slope HGM class because the sloping wall face itself was surveyed. All canyon springs were considered natural with minimal alteration.

Table 28. Sampled reference sites by type, HGM Class, and generalized source.

HGM Class / Origin	*Wetland / Riparian Type*							*Total*	*% of Total*
	Emergent Marsh	*Wet Meadow*	*Playa*	*Plains Floodplain*	*Plains Riparian*	*Foothills Riparian*	*Canyon Spring*		
Depressional	**3**		**7**				**4**	**14**	**29%**
1) Natural feature with minimal alteration			6				3	**9**	**19%**
2) Natural feature, but altered or augmented	3		1				1	**5**	**10%**
Slope	**3**	**5**					**1**	**9**	**19%**
1) Natural feature with minimal alteration	2	5					1	**8**	**17%**
2) Natural feature, but altered or augmented	1							**1**	**2%**
Riverine				**8**	**16**	**1**		**25**	**52%**
1) Natural feature with minimal alteration					11			**11**	**23%**
2) Natural feature, but altered or augmented				8	5	1		**14**	**29%**
Total	**6**	**5**	**7**	**8**	**16**	**1**	**5**	**48**	**100%**
% of Total	**13%**	**10%**	**15%**	**17%**	**33%**	**2%**	**10%**	**100%**	

Table 29. Generalized origin of sampled reference sites.

Origin	*Count*	*% of Total*
1) Natural feature with minimal alteration	28	58%
2) Natural feature, but altered or augmented	20	42%
3) Non-natural feature	0	0%
Total	**48**	**100%**



4.3.2 Plant Species Observed

The size of the basin and diverse array of wetland and riparian types present lent to high species diversity. A total of 458 unique species were identified in the 59 site visits; 432 to species level. The average number of species per site was 30. The most diverse site sampled was the foothills riparian site on Monument Creek, which supported 75 different plant species. The least diverse sites were typically playas, which frequently had < 10 species.

Common Plants Observed

Of the twenty most common plant species observed in reference wetland and riparian sites (Table 30), two-thirds were native and seven were nonnative, including two species listed as noxious weeds: Canada thistle (*Breea arvensis,* syn = *Cirsium arvense*) and tamarisk (*Tamarix ramosissima*). The twenty most common species are 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 true wetland obligates (OBL)—like common threesquare (*Schoenoplectus pungens*), pale spikerush (*Eleocharis macrostachya*), narrowleaf cattail (*Typha angustifolia*), and hardstem bulrush (*Schoenoplectus lacustris* ssp. *acutus*)—as well as species often found in upland areas (FACU), including three of the very most common species, American licorice (*Glycyrrhiza lepidota*), prickly Russian thistle (*Salsola australis*), and common sunflower (*Helianthus annuus*). However, none of the twenty most common species are considered obligate upland species (UPL).

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.[8] The resulting twenty most important species (Table 31) best characterize the Lower Arkansas basin's wetland and riparian areas. Together, these species comprised approximately 60% of the total plant cover recorded in all site visits. The most important species include dominant marsh plants like narrowleaf cattail, common threesquare, pale spikerush, and hardstem bulrush. The list include several woody species, such as sandbar willow (*Salix exigua*), commonly found within riparian areas and on sandbars on the floodplain; plains cottonwood (*Populus deltoides*), the dominant native canopy of floodplains and riparian areas; and tamarisk, an aggressive nonnative woody species that has colonized many of the riparian areas and floodplains in the basin. The list also includes plains grasses, such as saltgrass (*Distichlis stricta*), western wheatgrass (*Pascopyrum smithii*), and buffalograss (*Buchloe dactyloides*), which can dominate both dry playas and the understory of drier riparian areas.

More detailed descriptions of vegetation by wetland and riparian type can be found in Appendix D, which included dominant and characteristic species.

[8] 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 30. Twenty most common plant species observed in Lower Arkansas reference wetlands and riparian sites. Both initial and revisit surveys are included in observations, for a total of 59 site visits.

Scientific Name	***Common Name***	***# of Obs***	***Average Cover***	***Wetland Status[1]***	***C-Value***	***Native Status***
Glycyrrhiza lepidota	American licorice	29	1.9%	FACU	3	Native
Schoenoplectus pungens	common threesquare	27	6.2%	OBL	4	Native
Salsola australis	prickly Russian thistle	27	1.8%	FACU	0	Non-native
Helianthus annuus	common sunflower	27	0.9%	FACU	1	Native
Salix exigua	sandbar willow	26	18.7%	FACW	3	Native
Bassia sieversiana	kochia	26	7.5%	FACU	0	Non-native
Eleocharis macrostachya	pale spikerush	26	5.3%	OBL	3	Native
Pascopyrum smithii	western wheatgrass	26	2.2%	FACU	5	Native
Tamarix ramosissima	tamarisk or salt cedar	25	8.1%	FACW	0	Non-native, List B Nox Weed
Breea arvensis	Canada thistle	24	2.6%	FACU	0	Non-native, List B Nox Weed
Conyza canadensis	Canadian horseweed	24	1.5%	FACU	0	Non-native
Typha angustifolia	narrowleaf cattail	23	12.0%	OBL	2	Native
Critesion jubatum	foxtail barley	22	2.8%	FACW	2	Native
Elymus canadensis	Canada wildrye	21	3.0%	FACU	4	Native
Panicum virgatum	switchgrass	21	2.8%	FAC	5	Native
Populus deltoides ssp. *monilifera*	plains cottonwood	20	13.3%	FAC	3	Native
Distichlis stricta	saltgrass	20	7.0%	FACW	4	Native
Schoenoplectus lacustris ssp. *acutus*	hardstem bulrush	20	5.0%	OBL	3	Native
Polypogon monspeliensis	annual rabbitsfoot grass	20	0.7%	FACW	0	Non-native
Rumex crispus	curly dock	19	0.6%	FAC	0	Non-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 31. Twenty most important plant species observed in Lower Arkansas reference wetland and riparian sites.

Scientific Name	***Common Name***	***Import. Value[1]***	***# of Obs***	***Average Cover***	***Wetland Status***	***C-Value***	***Native Status***
Salix exigua	sandbar willow	11.03	26	18.7%	FACW	3	Native
Typha angustifolia	narrowleaf cattail	6.68	23	12.0%	OBL	2	Native
Populus deltoides ssp. *monilifera*	plains cottonwood	6.33	20	13.3%	FAC	3	Native
Tamarix ramosissima	saltcedar	5.35	25	8.1%	FACW	0	Non-native, List B Nox Weed
Bassia sieversiana	kochia	5.28	26	7.5%	FACU	0	Non-native
Schoenoplectus pungens	common threesquare	4.77	27	6.2%	OBL	4	Native
Eleocharis macrostachya	pale spikerush	4.12	26	5.3%	OBL	3	Native
Distichlis stricta	saltgrass	3.86	20	7.0%	FACW	4	Native
Marsilea mucronata	hairy waterclover	3.43	7	22.1%	OBL	7	Native
Schoenoplectus lacustris ssp. *acutus*	hardstem bulrush	3.08	20	5.0%	OBL	3	Native
Carex nebrascensis	Nebraska sedge	2.99	11	11.0%	OBL	5	Native
Lemna minor	common duckweed	2.79	12	9.0%	OBL	2	Native
Buchloë dactyloides	buffalograss	2.68	8	14.2%	FACU	4	Native
Glycyrrhiza lepidota	American licorice	2.66	29	1.9%	FACU	3	Native
Salix amygdaloides	peachleaf willow	2.62	10	10.5%	FACW	5	Native
Pascopyrum smithii	western wheatgrass	2.58	26	2.2%	FACU	5	Native
Bromopsis inermis	smooth brome	2.53	12	7.9%	UPL	0	Non-native
Breea arvensis	Canada thistle	2.53	24	2.6%	FACU	0	Non-native, List B Nox Weed
Juncus arcticus ssp. *ater*	mountain rush	2.45	16	5.0%	FACW	4	Native
Salsola australis	prickly Russian thistle	2.45	27	1.8%	FACU	0	Non-native

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

Noxious Weeds and Other Highly Invasive Species

Twenty-four species listed as noxious weeds by the Colorado Department of Agriculture[9] were observed in reference wetland and riparian sites in the Lower Arkansas basin (Table 32). In addition to listed noxious weeds, kochia (*Bassia sieversiana*) and Russian thistle (*Salsola australis* or *S. collina*) were also frequently found in reference sites. These species are considered highly invasive, but are not included on the official noxious weed lists because they are so pervasive on the

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

landscape that their eradication is not mandated by state government (Patty York, Colorado Dept. of Agriculture, Noxious Weed Specialist, personal communication).

At least one noxious or highly invasive species was found in nearly every reference site sampled in the Lower Arkansas basin (data not shown). Only four out of 59 site visits lacked these species entirely. However, the combined cover of noxious and highly invasive species was generally under 10% in most sites. The exception to this was plains floodplain sites, many of which supported 20–70% total cover of noxious and highly invasive species, typically the noxious woody species tamarisk and Russian olive (*Elaeagnus angustifolia*).

Two noxious weeds (Canada thistle and tamarisk) and the two highly invasive species (kochia and Russian thistle) were the most commonly observed invasives (Table 32). Each of these four species was observed in over a third of site visits (22–26 observations) and each with maximum cover of ~20–50%. All four species were also included in the twenty most important species within the reference sites (Table 31). Two additional noxious weeds were occasionally found with high cover. Common reed (*Phragmites australis*), a Watch List species, was found in nine site visits with up to ~45% cover. Russian olive, a List B species, was found in eight site visits with up to ~35% cover. All other noxious weeds were found in a handful of sites with < 5% cover.

Table 32. Noxious weeds and other highly invasive species observed in Lower Arkansas reference wetland and riparian sites. **Continued on next page.**

Scientific Name	*Common Name*	*Noxious Weed List*	*# of Obs*	*Average Cover*	*Max Cover*
Salsola australis OR *collina*	Russian thistle	Not Listed	31	1.6	18.4
Bassia sieversiana	kochia	Not Listed	26	7.5	50.0
Tamarix ramosissima	tamarisk or salt cedar	List B	25	8.1	45.0
Breea arvensis	Canada thistle	List B	24	2.6	21.5
Cirsium vulgare	bull thistle	List B	10	0.4	0.9
Phragmites australis[1]	common reed	Watch List	9	8.7	43.8
Elaeagnus angustifolia	Russian olive	List B	8	8.6	34.4
Verbascum thapsus	common mullein	List C	7	0.5	1.5
Anisantha tectorum	cheatgrass	List C	5	0.9	3.5
Cardaria latifolia	broadleaved pepperweed	List B	3	1.3	2.8
Convolvulus arvensis	field bindweed	List C	3	0.4	0.5
Sonchus arvensis	field sowthistle	List C	3	0.2	0.5
Elytrigia repens	quackgrass	List C	2	1.3	1.8
Saponaria officinalis	bouncingbet	List B	2	0.3	0.5
Artemisia absinthium	absinthium	List B	2	0.7	0.9
Arctium minus	lesser burdock	List C	2	0.9	1.6
Acosta maculosa	spotted knapweed	List B	2	0.2	0.3

Cynoglossum officinale	gypsyflower	List B	2	0.2	0.4
Erodium cicutarium	redstem stork's bill	List C	1	0.1	0.1
Linaria vulgaris	butter and eggs	List B	1	0.1	0.1
Matricaria perforata	scentless false mayweed	List B	1	0.1	0.1
Acanthoxanthium spinosum	spiny cocklebur	Watch List	1	0.1	0.1
Carduus nutans ssp. *macrolepis*	nodding plumeless thistle	List B	1	0.1	0.1
Panicum miliaceum	broomcorn millet	List C	1	0.4	0.4
Anthemis cotula	stinking chamomile	List B	1	0.1	0.1
Acroptilon repens	hardheads	List B	1	0.1	0.1

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

Significant Plant Species

Ten significant plant species were observed in reference wetland and riparian sites in the Lower Arkansas basin (Table 33).[10] 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. All other significant plant species observed are considered globally secure (G5), but rare or imperiled within Colorado (S1 or S2). The most commonly observed was variegated scouringrush (*Hippochaete variegata*), found in seven different riparian and floodplain site visits.

Table 33. Significant plant species observed in Lower Arkansas reference 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	4	4.7%	9.0%
Bothriochloa springfieldii	Springfield's beardgrass	G5	S1	1	0.8%	0.8%
Carex gravida var. lunelliana	Lunell's heavy-fruited sedge	G5T3T5 Q	S1	1	1.5%	1.5%
Dichanthelium acuminatum var. *sericeum*	Pacific panicgrass	G5TNR	S1	1	0.4%	0.4%
Heterotheca latifolia	camphorweed	G5T5	S1	4	0.6%	1.3%
Hippochaete variegata	variegated scouringrush	G5	S1	7	1.5%	5.3%
Hypoxis hirsuta	common goldstar	G5	S1	1	0.1%	0.1%
Sagittaria montevidensis ssp. *calycina*	hooded arrowhead	G5T5?	S1	1	0.1%	0.1%
Sparganium eurycarpum	broadfruit bur-reed	G5	S2?	2	1.0%	1.3%
Vernonia baldwinii ssp. interior	interior ironweed	G5T5	S1	1	0.5%	0.5%

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

4.3.3 Condition of Reference Sites

Ecological Integrity Assessment (EIA)

Ecological Integrity Assessment (EIA) scores, which range from 1.00–4.00, were calculated for all reference wetland and riparian sites visited. EIA scores were translated into a letter grade rank of A, B, C, or D based on thresholds listed in Table 34. These ranks can be interpreted as the degree to which a site differs from true reference condition (no or minimal human impact). See Table 22 in Section 4.1.2 for more information on the interpretation of EIA ranks.

Table 34. EIA rank interpretation.

Rank	*Score Range*	*Condition*
A	3.50–4.00	Excellent = Reference (no or minimal human impact)
B	2.50–3.49	Good = Slight deviation from reference
C	1.50–2.49	Fair = Moderate deviation from reference
D	1.00–1.49	Poor = Significant or severe deviation from reference

Nearly thirty percent of sites were ranked A for overall ecological integrity and an additional 52% were ranked B, indicating that the site selection process was generally successful at picking wetlands in excellent or good condition (Table 35; Figure 17). Only a small number of sites were ranked C and no sites were ranked D. The average overall EIA score across all sites was 3.13, squarely in the B or good condition range. While the scores and ranks of reference sites do not reflect the condition of sites in general across the basin—that analysis can only come from sampling randomly selected sites—the scores do indicate trends in condition. For many of the targeted wetland and riparian types, it was possible to find A-ranked reference sites. However, it was nearly impossible for others. Sites associated with flowing water, namely all riparian and floodplain sites as well as marshes in the floodplain, tended to score lower because they occurred in larger systems where impacts to hydrology can accumulate. Isolated sites, such as canyons seeps, playas, and spring-fed meadows and marshes, tended to score higher.

Canyon springs had the highest average EIA score of 3.61 (Table 35). All but one canyon spring sampled were ranked A. Wet meadows had the second highest average EIA score of 3.49. Similarly, four out of five sites were ranked A. Playas had the third highest average EIA score of 3.42 and were more evenly split between A and B ranks. Plains riparian sites had an average EIA score of 3.26 and included two sites ranked A and 14 sites ranked B. The one foothills riparian site was ranked B, with an EIA score of 3.03. Marsh sites had an average EIA score of 2.96 and included one A-ranked site, three B-ranked sites, and two C-ranked sites. Plains floodplain sites scored the lowest, with an average EIA score of 2.24, with only one B rank and seven C ranks. The low EIA scores for plains floodplain sites are indicative of how stressed the floodplain system is. The sites chosen did represent the best available conditions we had access to for this type in the basin, though they are far from minimally disturbed.

Table 35. Overall EIA ranks and average EIA score by wetland / riparian type. Only first visits are included as primary number. Revisits are included in parentheses.

Wetland / Riparian Type	*A*	*B*	*C*	*D*	*Total*	*Average EIA Score*
Emergent marsh	1	3	2	--	6	2.96
Wet meadow	4	1	--	--	5	3.49
Playas	3 (3)	4 (3)	--	--	7 (6)	3.42
Plains floodplain	--	1	7 (3)	--	8 (3)	2.24
Plains riparian	2(1)	14 (1)	--	--	16 (2)	3.26
Foothills riparian	--	1	--	--	1	3.03
Canyon spring	4	1	--	--	5	3.61
Total	**14**	**25**	**9**	**--**	**48**	**3.13**
Percent of Total	**29%**	**52%**	**19%**	**--**	**100%**	

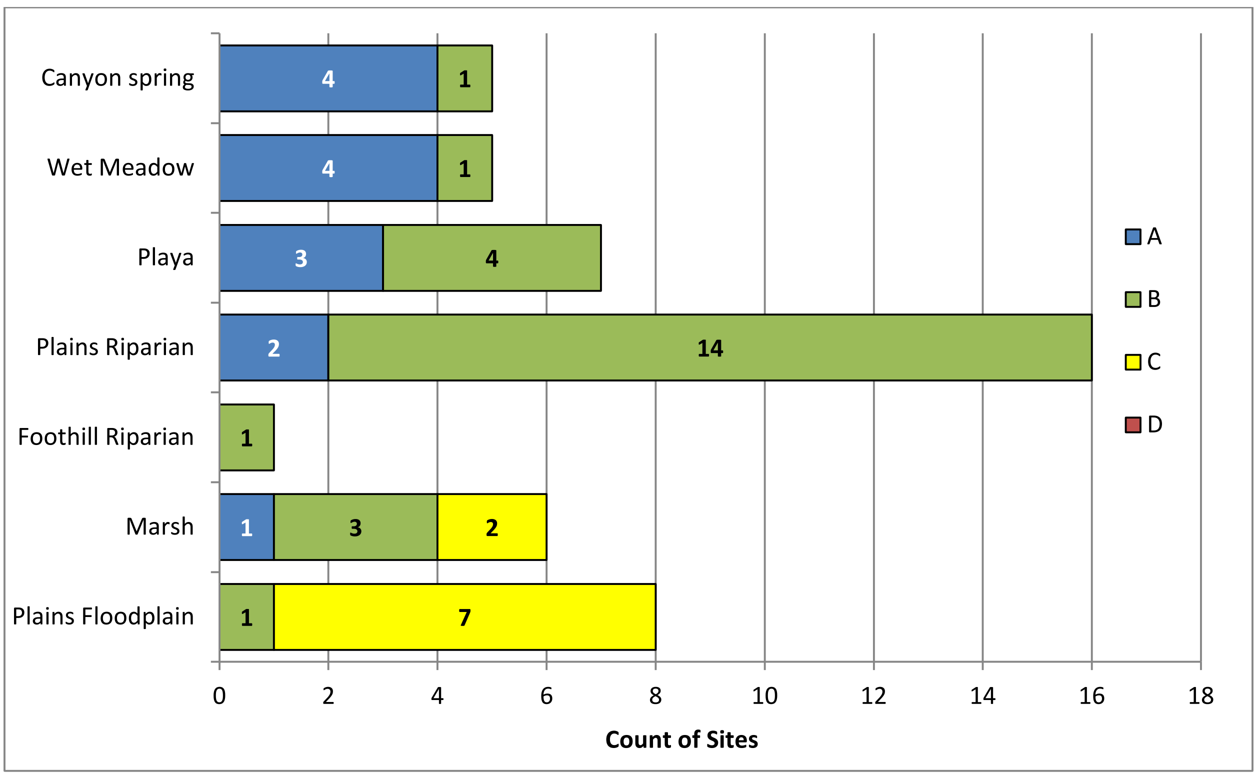


Figure 17. Overall EIA ranks by wetland / riparian type. Types are ordered by average EIA score, as shown in Table 34. Only first visits are included.

Along with overall EIA scores and ranks, the component EIA ranks of landscape context, biotic condition, hydrologic condition, and physiochemical condition help explain the drivers of the overall scores (Table 36). Nearly all sites sampled were ranked A or B for landscape context. A relatively intact landscape was one of the most important filters for selecting reference sites, so this result is not surprising. Biotic condition showed the most variability among sites, with the full range of ranks from A to D. Lower scores for biotic condition were generally driven by the presence of invasive species, particularly for plains floodplain and plains riparian sites. Marsh sites also scored lower for biotic condition, due to invasive species and dense stands of cattails, which thrive where water is influenced by agricultural runoff and lacks seasonal flood pulses.

Roughly half the sampled sites had intact hydrology, as shown by a high number of sites with A ranks for hydrologic condition. The exception to this was marshes (especially those on the floodplain) and plains floodplain sites; the hydrology of both these groups heavily hydrology by dams, diversions, and irrigation runoff. Physiochemical condition was generally good, with most sites ranked B. Some sites showed minor water quality concerns, such as turbidity or algal blooms. Others showed concerns with soil disturbance and compaction from livestock and native ungulates.

Eleven out of the 48 sites were revisited to explore seasonal variability of EIA scores and ranks (Table 37). Six playas were revisited. Of those, four were sampled during both wet and dry phases; the other two playas were sampled twice during the dry phase. Wet playas had slightly higher scores, but typically not enough to change their rank, unless the score was right on the edge of a threshold. Wet playas typically had higher species diversity, more wetland indicator species, and fewer invasive species. Wet playas also had more zonation within the vegetation and more structural diversity, all contributing to higher biotic condition and overall scores. The variability in scores from wet to dry is an important consideration when rating playas based on a one-time visit. However, variability was also seen in a playa site sampled twice when dry. For this site, the cover of invasive species, specifically Russian thistle, increased substantially between the first early season visit and the second late season visit. Some degree of variability is inevitable when sampling vegetation that changes over the course of a growing season and with dynamic hydrology.

In addition to revisiting playas, three plains floodplain sites and two plains riparian sites were revisited. The plains floodplains scores and ranks appear to be very stable. These sites all contain a high cover of invasive species and have highly modified hydrology. Seasonal variation did not seem to change these two major factors. For the two plains riparian sites, however, the change from early season to late season did have an effect on the scores. Both plains riparian sites scored lower on their second visit than on the first. This was mainly driven by higher cover of invasive species later in the season and greater evidence of cattle grazing disturbing the soils. But the change for these two sites was also not enough to change their scores.

Table 36. Component EIA ranks by wetland / riparian type. Only first visit ranks are included.

Wetland / Riparian Type	*A*	*B*	*C*	*D*	*Total*
Landscape Rank Factor					
Emergent marsh	2	3	1	--	6
Wet meadow	3	2	--	--	5
Playas	4	3	--	--	7
Plains floodplain	--	7	1	--	8
Plains riparian	11	5	--	--	16
Foothills riparian	--	1	--	--	1
Canyon spring	5	--	--	--	5
Total	**25**	**21**	**2**	**--**	**48**
Vegetation Condition Major Ecological Factor					
Emergent marsh	--	4	1	1	6
Wet meadow	1	3	1	--	5
Playas	2	4	1	--	7
Plains floodplain	--	1	4	3	8
Plains riparian	1	9	6	--	16
Foothills riparian	--	1	--	--	1
Canyon spring	2	3	--	--	5
Total	**6**	**25**	**13**	**4**	**48**
Hydrology Major Ecological Factor					
Emergent marsh	2	2	2	--	6
Wet meadow	4	1	--	--	5
Playas	6	1	--	--	7
Plains floodplain	--	--	7	1	8
Plains riparian	10	6	--	--	16
Foothills riparian	--	1	--	--	1
Canyon spring	4	--	1	--	5
Total	**26**	**11**	**10**	**1**	**48**
Physiochemistry Major Ecological Factor					
Emergent marsh	1	4	1	--	6
Wet meadow	3	2	--	--	5
Playas	1	5	1	--	7
Plains floodplain	4	4	--	--	8
Plains riparian	7	7	2	--	16
Foothills riparian	--	1	--	--	1
Canyon spring	1	4	--	--	5
Total	**17**	**27**	**4**	**--**	**48**

Table 37. Comparison of overall EIA scores and ranks between visit 1 and visit 2 for revisit sites.

Site	Conditions at Visit 1 / Visit 2	Score	Rank	Score Diff	Rank Diff
Playas					
LA-PL01	Dry	3.59	A	**+0.26**	**--**
	Wet	3.85	A		
LA-PL02	Dry	3.50	A	**-0.26**	**A to B**
	Dry	3.25	B		
LA-PL03	Dry	3.75	A	**+0.03**	**--**
	Dry	3.78	A		
LA-PL04	Dry	3.49	B	**+0.08**	**B to A**
	Wet	3.57	A		
LA-PL06	Wet	3.45	B	**-0.24**	**--**
	Dry	3.21	B		
LA-PL07	Dry	2.98	B	**+0.09**	**--**
	Wet	3.07	B		
Plains floodplain sites					
LA-PF01	Early season	2.33	C	**+0.04**	**--**
	Late season	2.37	C		
LA-PF03	Early season	2.42	C	**-0.05**	**--**
	Late season	2.37	C		
LA-PF05	Early season	1.77	C	**-0.03**	**--**
	Late season	1.74	C		
Plains riparian sites					
LA-PR06	Early season	3.32	B	**-0.09**	**--**
	Late season	3.21	B		
LA-PR10	Early season	3.73	A	**-0.23**	**--**
	Late season	3.50	A		

Floristic Quality

As a separate, stand-alone measure of biotic condition, two Mean C scores were calculated for all sites, one with all species included and one with only native species. 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 reference sites, like those sampled in this project, are essential for determining expected ranges and aiding in data interpretation.

Mean C scores calculated with all species ranged from 1.0 to 5.1, with most sites falling between 2.5 and 4.0 (Figure 18). Mean C scores calculated with only native species were noticeably higher, ranging from 2.3 to 6.4, and the data are more closely lumped, with nearly all sites fall between 3.0 and 5.0. Compared to wetlands in the mountains, where Mean C scores can be in the 6.0–7.0 range (Lemly et al. 2011, Lemly & Gilligan 2012), these Mean C scores are relatively low and are indicative of dynamic ecosystems of the plains. Only one site had a Mean C above 5.0 when calculated with all species and only two did when calculated with native species only. For individual species, a C-value of 5 or less represents species that are tolerant of or indifferent to disturbance. Wetland and riparian sites on the plains are adapted to disturbance, such as flooding and drying cycles and grazing by large native ungulates. Even in good condition, they are, therefore, dominated by species that can tolerate these conditions.

While Mean C scores are fairly clumped when all sites are analyzed together, there are differences in the scores when analyzed separately by wetland and riparian type (Figure 19) and these differences are repeated with other Floristic Quality Assessment (FQA) metrics (Table 38).The highest Mean C scores, calculated either with all species or with natives only, were found within wet meadows and canyon springs. Both wetland types were primarily seep- or spring-fed and maintained stable water levels that supported a diverse composition of species, including sedges and ferns. For these types, Mean C scores greater than 5.0 were observed. For playas and plains riparian areas, Mean C scores of native species ranged from just above 3.0 to above 4.0. Plains floodplain sites and marshes generally had the lowest Mean C scores, calculated either with all species or native species only. When calculated with all species, the scores for these sites never reached above 3.0 and was as low as 1.0. When calculated with native species only, the scores never reached above 4.0.

Mean C scores were influenced by seasonal variation, as shown in site revisits (Table 39). Mean C scores were higher in wet playas than in dry and were higher earlier in the season for plains riparian areas, though the spread was greater for Mean C calculated with all species than when calculated with natives only. It appears that native species composition, and therefore Mean C calculated with only native species, remains more stable throughout the season, while additional annual weeds can populate a site over the growing season.

The ranges observed in these reference sites, along with additional data forthcoming from randomly selected sites sampled in 2015 and data collected previously in the Arkansas River Basin, will help CNHP set thresholds for future use across the plains.

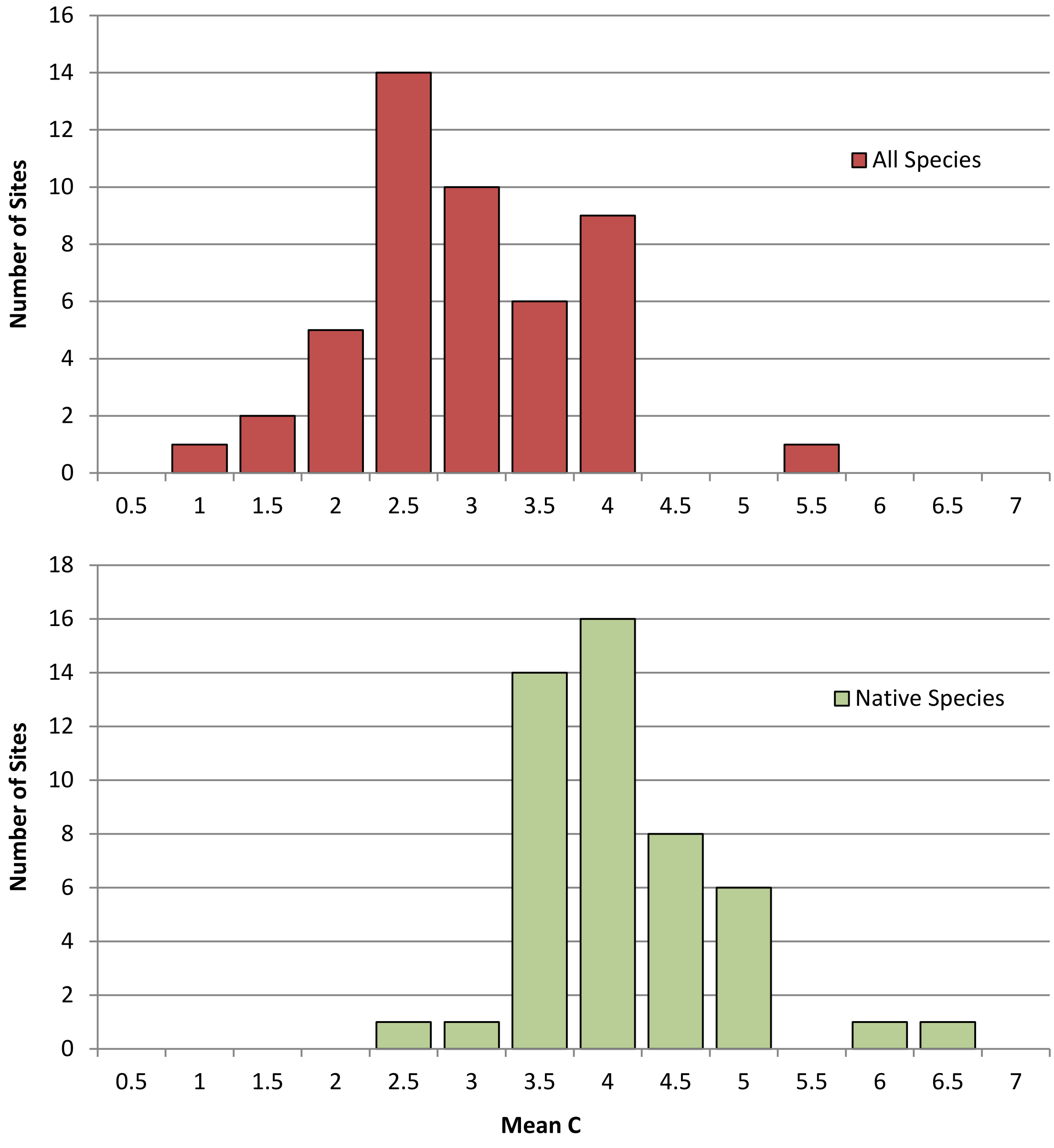


Figure 18. Frequency of Mean C scores for all sites sampled, showing Mean C calculated with all species in red above and Mean C calculated with only native species below in green. Number under each bar represents the upper bound of the bin. Only first visit scores included.

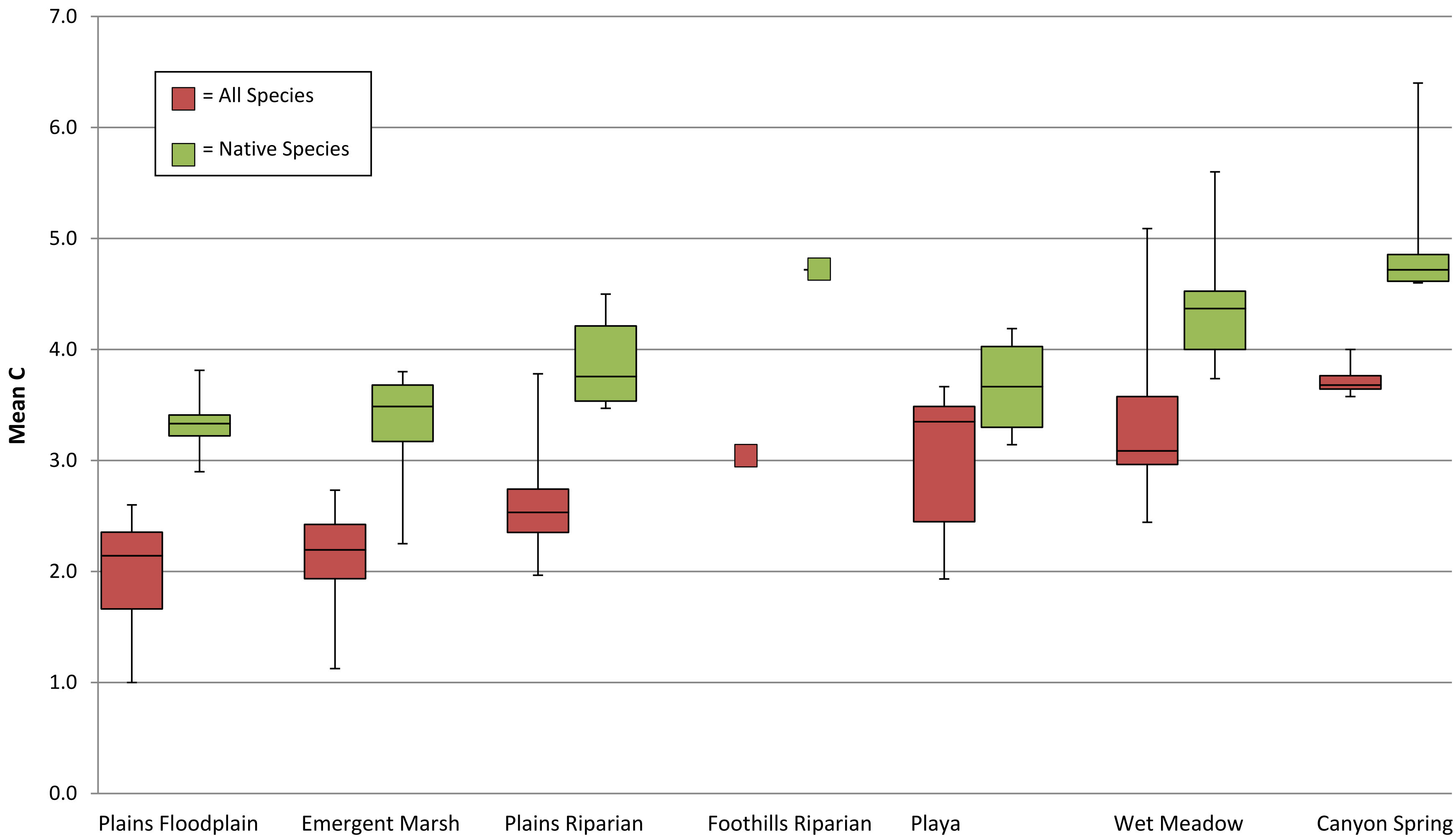


Figure 19. Range of Mean C scores by wetland / riparian type. Only first visit scores included. Red is Mean C of all species; green in Mean C of native species. Boxes represent 25th to 75th percentile. Horizontal line represents the median. Whiskers extend to highest and lowest observed scores. There is no box or whiskers for Foothills Riparian, which had only one reference site.

Table 38. Mean scores for all FQA metrics by wetland / riparian type and min, max, and mean scores for all sites. Only first visit scores included.

FQA Metric	Marsh (n = 6)	Wet meadow (n = 5)	Playa (n = 7)	Plains floodplain (n = 8)	Plains riparian (n = 16)	Foothills riparian (n = 1)	Canyon spring (n = 5)	All Sites (n = 48)		
								Min Score	Max Score	Mean Score
Total species richness	22	31	13	27	40	75	31	3	75	30
Native species richness	14	22	10	15	27	46	23	3	51	20
Non-native species richness	8	6	3	11	12	24	7	0	24	9
% Non-native species	37%	23%	19%	40%	31%	34%	24%	0	66	30
Mean C of all species	2.1	3.4	3.0	2.0	2.7	3.0	3.7	1.0	5.1	2.7
Mean C of native species	3.3	4.4	3.7	3.3	3.9	4.7	5.0	2.3	6.4	3.9
Cover-weighted Mean C of all species	2.3	3.9	3.8	1.7	2.9	3.8	3.8	0.1	5.9	3.0
Cover-weighted Mean C of native species	2.8	4.4	4.2	3.2	3.6	4.2	4.7	2.1	6.1	3.7
FQI of all species	9.7	18.2	10.0	9.6	16.3	24.8	19.4	3.2	29.2	14.2
FQI of native species	12.2	20.5	11.2	12.5	19.6	31.0	22.4	4.5	31.8	16.9
Cover-weighted FQI of all species	11.1	20.4	12.8	8.6	17.9	30.7	20.1	0.4	30.7	15.5
Cover-weighted FQI of native species	10.4	19.7	12.8	12.1	18.1	27.9	21.2	4.8	31.3	16.1
Adjusted FQI	26.3	39.0	32.9	25.5	32.0	37.8	43.3	15.9	53.4	32.4
Adjusted cover-weighted FQI	22.3	38.0	38.1	24.6	29.6	34.0	40.3	15.1	55.1	31.2

Table 39. Comparison of Mean C scores between visit 1 and visit 2 for revisit sites.

Site	Conditions at Visit 1 / Visit 2	Mean C All Species	Diff	Mean C Native Species	Diff
Playas					
LA-PL01	Dry	3.48	**+0.05**	4.06	**+0.21**
	Wet	3.52		4.26	
LA-PL02	Dry	3.35	**-0.91**	4.19	**-0.38**
	Dry	2.44		3.81	
LA-PL03	Dry	3.67	**-1.00**	3.67	**+0.33**
	Dry	2.67		4.00	
LA-PL04	Dry	2.44	**+0.70**	3.14	**+0.52**
	Wet	3.14		3.67	
LA-PL06	Wet	3.50	**-1.13**	4.00	**-0.24**
	Dry	2.37		3.76	
LA-PL07	Dry	1.93	**+0.98**	3.22	**+0.33**
	Wet	2.91		3.56	
Plains floodplain sites					
LA-PF01	Early season	2.29	**+0.43**	3.39	**+0.52**
	Late season	2.73		3.91	
LA-PF03	Early season	1.42	**+0.03**	3.14	**+0.25**
	Late season	1.45		3.39	
LA-PF05	Early season	2.60	**-0.66**	3.47	**-0.31**
	Late season	1.94		3.16	
Plains riparian sites					
LA-PR06	Early season	2.52	**-0.21**	3.48	**-0.02**
	Late season	2.30		3.45	
LA-PR10	Early season	3.29	**-0.24**	4.28	**+0.05**
	Late season	3.05		4.33	

4.3.4 Common Stressors Observed

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. All stressor impacts were then combined into an overall Human Stressor Index for the site (see Appendix E for stressor checklist within the field form).

The most common landscape stressor observed surrounding reference sites was the presence of roads (Table 40). Nearly all reference sites (85%) 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, two other landscape stressors were common. Grazing or browse by livestock or native ungulates occurred within the surrounding landscape of 77% of sites, but also with a low average impact rating of 1.2. Low impact recreation occurred in the surrounding landscape of just over half the sites, also with a low (1.0) average impact rating. All other landscape stressors occurred in less than 20% of sites. The landscape stressor with the greatest impact was development, which occurred in the landscape of two sites, with an average impact rating of 2.5 (medium low).

The most common vegetation stressor observed within the sites was grazing or browse, which was also noted in 77% of sites, but still with a low impact score on average (1.3). 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 three sites. The second most common vegetation stressor was invasive species. This stressor was noted when invasive species covered more than 1% of the AA, which was the case in two-thirds (67%) of the sites. The impact rating of invasive species ranged from 1 (low) to 7 (high) within individual sites, for an average rating of 2.7 (medium-low). Low impact recreation was the only other stressor that occurring in more than a quarter of sites, but with a low average impact (1.0). The vegetation stressors with the greatest impact were herbicide spraying, which was observed in two sites with an average impact of 7.0 (high), and high impact recreation, which occurred in one site with an impact of 7.0 (high). 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 a third of all sites and all of the plains floodplain sites. This common hydrologic stressor had an average impact score of 3.9 (medium), but ranged from 1 (low) to 7 (high) within individual sites.

Agriculture runoff and groundwater extraction were the next most common hydrologic stressors, affecting roughly a quarter (23%) of sites both, but with very different impacts. The average impact of agricultural runoff was 4.5 (medium), with ratings of 4 (medium) or 7 (high) in most sites. Groundwater extraction, in contrast, had an average impact rating of 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. The hydrologic stressor with the highest average impact rating was large dams / reservoirs, which affected three sites with an average impact rating of 5.0 (medium high). Those sites were located immediately downstream of the basin's largest dams. Three other hydrologic stressors, impoundments, excavation for water retention, and urban / stormwater runoff, had medium-low to medium impact ratings (2.5, 2.5, and 4.0, respectively), but affected only a few sites.

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 just under half of all sites (44%), with an average impact rating of 1.6 (low). Erosion, sedimentation, and trash or refuse dumping occurred in a quarter to a third of all sites, but each with a low average impact rating. Lastly, excavation was observed in one marsh site with an impact rating of 4 (medium).

When all impacts were aggregated into an overall Human Stressor Index (HSI) for each site, it was clear that the plains floodplain sites faced the most cumulative stress (Table 41). These sites had, on average, 13 stressors per site and an average HSI of 8.15, which is considered high. The HSI of plains floodplain sites ranged from 6.20 to 10.40. For most other wetland and riparian types, the highest HSI scores were well below the lowest HSI score of plains floodplain sites. Only a couple of the marsh sites had HSI scores in a similar range as the plains floodplain sites. Conversely, wet meadows, playas and canyon seeps all had very low HSI scores, with averages below 2.0 and individual sites with virtually no stressors. Plains riparian sites were more mixed, with some sites scoring very low and others with medium scores. The one foothill riparian site had an HSI of 3.20, which is medium low.

When HSI scores are plotted against overall EIA condition scores, there is a clear and strong relationship (Figure 20). 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.

Table 40. Landscape, vegetation, hydrologic, and physiochemical stressors observed by wetland / riparian type (continued on next page). Only first visits are included. *Continued on next page.*

Stressor by Category	*Marsh (n = 6)*	*Wet meadow (n = 5)*	*Playa (n = 7)*	*Plains floodplain (n = 8)*	*Plains riparian (n = 16)*	*Foothills riparian (n = 1)*	*Canyon spring (n = 5)*	*Total (n = 48)*	*% of Sites with Stressor*	*Average Impact Rating[1]*
Landscape stressors within 500 m surrounding the AA										
Roads	6	3	6	8	13	1	4	**41**	**85%**	**1.1**
Grazing, browse	5	4	7	3	14		4	**37**	**77%**	**1.2**
Low impact recreation	3	1	2	6	11		4	**27**	**56%**	**1.0**
Row-crop agriculture	3			4	1			**8**	**17%**	**2.1**
Evidence of recent fire	1			3				**4**	**8%**	**1.0**
High impact recreation	1			1		1		**3**	**6%**	**2.0**
Hay field, fallow field				3				**3**	**6%**	**2.0**
Development				1	1			**2**	**4%**	**2.5**
Utility / power line corridor				1				**1**	**2%**	**1.0**
Total	**19**	**8**	**15**	**30**	**40**	**2**	**12**	**126**		
Average stressors / site	**3.2**	**1.6**	**2.1**	**3.8**	**2.5**	**2.0**	**2.4**	**2.6**		
Vegetation stressors within the AA										
Grazing, browse	5	3	7	5	13		4	**37**	**77%**	**1.3**
Invasive species	4	3	2	8	13		2	**32**	**67%**	**2.7**
Low impact recreation	2			5	4		1	**12**	**25%**	**1.0**
Evidence of recent fire				3				**3**	**6%**	**2.0**
Herbicide spraying	1			1				**2**	**4%**	**7.0**
Hay field, fallow field				1				**1**	**2%**	**1.0**
Recent major flood				1				**1**	**2%**	**4.0**
High impact recreation				1				**1**	**2%**	**7.0**
Total	**12**	**6**	**9**	**25**	**30**		**7**	**89**		
Average stressors / site	**2.0**	**1.2**	**1.3**	**3.1**	**1.9**	**0.0**	**1.4**	**1.9**		

Stressor by Category	*Marsh (n = 6)*	*Wet meadow (n = 5)*	*Playa (n = 7)*	*Plains floodplain (n = 8)*	*Plains riparian (n = 16)*	*Foothills riparian (n = 1)*	*Canyon spring (n = 5)*	*Total (n = 48)*	*% of Sites with Stressor*	*Average Impact Rating[1]*
Hydrologic stressors that effect the AA (may occur within or beyond the AA)										
Canals, diversions, ditches	2			8	4		2	**16**	**33%**	**3.9**
Agricultural runoff	4			6	1			**11**	**23%**	**4.5**
Groundwater extraction	3	1		6	1			**11**	**23%**	**1.3**
Flow obstructions					4			**4**	**8%**	**1.0**
Impoundments	1		1		1		1	**4**	**8%**	**2.5**
Urban / storm water runoff				1	2	1		**4**	**8%**	**4.0**
Large dams / reservoirs				3				**3**	**6%**	**5.0**
Excavation for water retention			2					**2**	**4%**	**2.5**
Total	**10**	**1**	**3**	**24**	**13**	**1**	**3**	**54**		
Average stressors / site	**1.7**	**0.2**	**0.4**	**3.0**	**0.8**	**1.0**	**0.6**	**1.1**		
Soil / substrate stressors within the AA										
Compaction	2	1	7	2	6		3	**21**	**44%**	**1.6**
Excessive erosion	1	1		2	10	1	1	**16**	**33%**	**1.4**
Trash or refuse dumping		2		6	5			**13**	**27%**	**1.5**
Sedimentation		1	1		8	1	1	**12**	**25%**	**1.0**
Excavation	1							**1**	**2%**	**4.0**
Total	**4**	**5**	**8**	**10**	**29**	**2**	**5**	**63**		
Average stressors / site	**0.7**	**1.0**	**1.1**	**1.3**	**1.8**	**2.0**	**1.0**	**1.3**		

[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 41. 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*
Emergent marsh	9	4.57	1.00 – 9.30
Wet meadow	4	1.24	0.90 – 1.60
Playa	5	1.70	0.70 – 2.80
Plains floodplain	13	8.15	6.20 – 10.40
Plains riparian	7	2.36	1.10 – 6.40
Foothills riparian	5	3.20	3.20
Canyon spring	4	1.78	0.30 – 3.00
All Sites	**7**	**3.35**	**0.30 – 10.40**

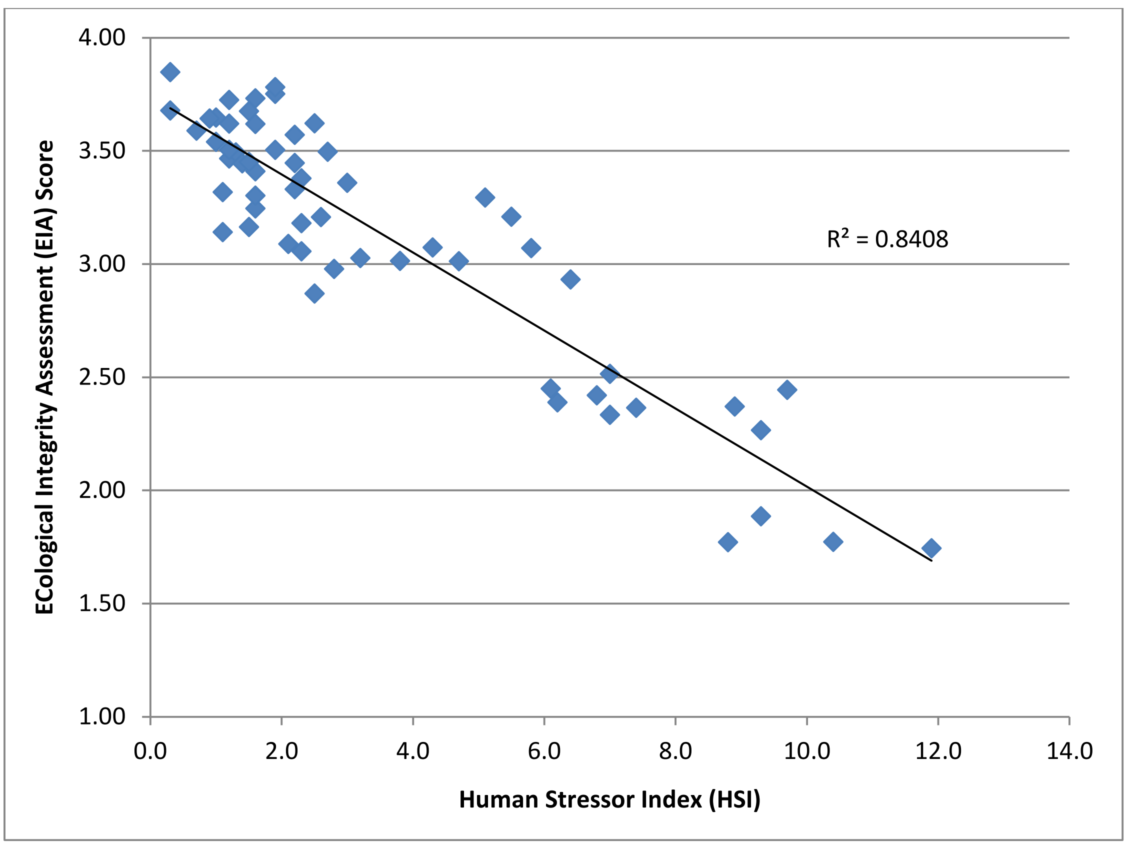


Figure 20. Overall Ecological Integrity Assessment (EIA) score vs. Human Stressor Index (HSI).

4.4 Discussion

4.4.1 Notable Wetlands of the Lower Arkansas River Basin and their Importance

The landscape of the Lower Arkansas River basin has been heavily modified over many years. From early years under cultivation to today's ranching and agricultural land uses, the landscape is markedly different than it was before European settlement. From aerial imagery, the impacts of grazing and intensive water management are evident in this dry landscape. Irrigation has turned a concentrated portion or the valley into a bright green strip along the river, while impoundments and diversions affect many tributary streams and groundwater pumping pulls water from underground stores. It is impossible to know exactly what wetlands and riparian areas looked like more than 200 years ago and how to define true "reference" condition. There may have been more groundwater seeps that fed complexes of wet meadows and marshes and there were certainly more large, intact playas. The floodplain corridors likely contained a more diverse array of wetland types, such as marshes alternating with willow sandbars and cottonwood stands of varying ages. These patches would have continually changed after intensive flood pulses rearranged the dominant pathways of the river.

With this backdrop of an active, working landscape, however, it is remarkable that this study included 14 A-ranked wetlands. It is evident that there are a number of truly special wetlands in this basin. Groundwater-fed wet meadows and marshes support notable plant communities in excellent condition. More than half of the surveyed playas were A-ranked, and it was clear from the number of bird species observed during field surveys that these sites are vital for wildlife during wet phases. The small canyon springs function as pockets of high quality wetlands embedded in a mostly upland landscape. The smaller to mid-sized plains riparian systems, many with zones of open water and mixed wetland and riparian species, represent healthy, robust habitat for wildlife. Along with horizontal zonation, many small streams they had variable water depths, light exposure, and herbaceous vegetation occupying diverse vertical strata.

Though many of these A-ranked wetlands and riparian areas did show signs of human impacts, the impacts were generally restricted in scope and severity. Many of the highest ranked sites fell on privately owned lands or on State Land Board parcels managed by private ranches. These ranches were often managed with an emphasis towards ecosystem health and typically had management plans that included alternate sources of income, such as education or recreational opportunities. The best sites were also located in smaller watersheds, away from the main floodplain, and faced fewer cumulative impacts from hydrologic alterations. These sites provide an encouraging outlook for wetlands in the basin and should serve as models for land managers. This study intentionally focused on the basin's highest condition sites, where access was granted, and it is likely that more reference condition sites exits beyond those surveyed. But those conditions are not repeated everywhere in the basin, where hydrologic alterations, heavy grazing, and invasive species have modified many other wetlands and riparian areas.

The data collected from the reference wetlands and riparian areas in this study are critical for a number of reasons. For one, they provide a benchmark against which other sites in the basin can be measured. The vegetation composition and structure, the Mean C scores calculated, and the hydrologic patterns observed in these sites all aid in the interpretation of condition in other sites to be studied in future years. Secondly, they are also important because they represent models for future restoration efforts or management plans aimed at re-establishing high quality wetland habitats on the plains. Thirdly, in and of themselves, many of the reference sites studied are biologically significant resources worthy of conservation protection, and many of them are already under conservation easements or on public land. Those that are not may represent high priorities for conservation action. Lastly, and perhaps most importantly over time, wetlands and riparian areas of the eastern plains have been shown to be highly vulnerable to the potential impacts of climate change (CNHP 2015). Potential future climate scenarios for the plains predict warmer temperatures without a commensurate increase in precipitation to offset evapotranspiration, indicating overall drying. Establishing baseline conditions within reference wetlands and riparian areas on the plains is essential for observing early signs of degradation linked to climate changes.

4.4.2 Condition and Stress Observed by Wetland and Riparian Types and Associated Management Recommendations

Patterns in condition and stress observed were closely linked to wetland and riparian type and to location within the basin. Sites facing the most stress were those along the floodplain of the Arkansas River itself, namely plains floodplain sites and marshes located within the floodplain. It was difficult to find any "minimally disturbed" sites along the floodplain. Instead, the sites selected truly fit the "best available" concept. Those that were included as reference sites scored as well as they did largely because as they were located in the least fragmented portions of the floodplain and were surrounded by the least intensive land used. In contrast, sites with the highest condition were located away from the floodplain and had localized water sources, such as seeps, spring, or local surface water runoff. For these types, we surveyed several examples of minimally disturbed conditions.

For **plains floodplain** sites, the lowest condition type on average, conditions across most sites followed a consistent pattern. Most had seriously degraded vegetation dominated by non-native, especially tamarisk and Russian olive in the overstory and Russian thistle, kochia, and non-native grasses in the understory. The structure of the vegetation in most sites has been compromised by dense patches of tamarisk and low regeneration of native woody species. Hydrology of plains floodplains sites was also consistently poor. Even though the targeted reference sites were close to the water along reaches of the river that appeared connected to the floodplain in aerial imagery, most were heavily terraced and appeared disconnected from regular flooding once on-site. Portions of some sites did experience some overbank flooding (in high water years), but it was clear that the flood zone of the Arkansas River is more limited by entrenchment and lower river flows than by basic geomorphology. Floodplain sties had both the lowest condition scores and the highest stress, driven by invasive species, on-site land uses such as grazing and light recreations, and hydrologic modification.

Though highly degraded, efforts are underway to treat tamarisk in portions of the floodplain. One floodplain site surveyed at Bent's Old Fort National Historic Site had only a trace of tamarisk, indicating that floodplain management of this woody species is possible at a local scale with long-term investment. Because floodplain reaches with native understory and native dominant shrub layers are approaching 'relict' status, those that still exist—even with some tamarisk—have conservation value and may be good candidates for restoration. This is especially the case in sites that are still hydrologically connected to the river (on low terraces or along a depressional swale or side channel) and contain wetland species. Sites with some connection to water are more restorable, while drying landscapes are more prone to degradation. However, restoration measures can only succeed provided that they protect the native understory, fit within the confines of water law to ensure access to water, and that the restoration plan is long-term and includes revegetation.

Second only to plains floodplains, **emergent marshes** were the second most stressed and lowest condition sites sampled. There were two distinct groups of marshes, however, and the differences may warrant revisiting the classification in the future. Marshes on the floodplain were tied to the alluvial aquifer of the floodplain and to influxes of agricultural run-off. These sites were far more degraded by invasive species, dense cattails, and hydrologic alterations. Marshes off the floodplain were linked to groundwater seeps and were in far less disturbed.

Most marshes on the floodplain were dense cattail stands instead of more open hemi marshes. Those that were open had been cleared by active management, such as dredging or spraying. Those efforts can pay off in some instances, including on one reference site within Rocky Ford State Wildlife Area. This site had notable interspersion of water and vegetation, and a high diversity of wetland species expected in a healthy wetland. However, it is hard to replace the intensive, vegetation-clearing flushing that the floodplain once experienced during annual floods. Intensive management actions risk other alterations to site health, particularly when funding is not available for revegetation throughout the process. Dredging and chemical application without active revegetation runs the risk of non-native understory growth. Meanwhile, unvegetated zones can erode, sometimes quickly returning sedimentation back into a restored site. The lack of open marshes on the floodplain, even within the reference sites, does reflect the value in opening up floodplain marshes to hemi-marsh conditions that can support a broader range of wildlife habitat niches through water depths, interspersion, and vegetation diversity. With strict limitations on water use, it is very difficult to manage the floodplain marshes in a way that mimics their historical hydrology. But action taken where ever possible to allow for high flows and scouring of vegetation, coupled with active post-treatment monitoring, could be very important in this landscape. It may be that smaller pet projects are more important than large scale spraying, if they create small patches of the key habitat that's extremely limited along the basin's floodplain.

In general, the reference **plains riparian** sites sampled were in overall good condition. About one third of plains riparian sites did have moderate impacts to the vegetation composition and structure, with sites in 'fair' condition. In contrast to the floodplain sites, hydrologic condition of reference sites in this ecological system ranged from A to B (excellent to good). In this basin, riparian sites with good condition hydrology represent important open water and wetland resources, especially considering that these sites have withstood the long-term land uses of a working landscape and frequent cycles of drought with resilience. However, while overall, the plains riparian reference sites were generally in 'good' condition, the reference sites that received the lowest overall site scores had substantial pugging from grazing, lowering the site's physiochemical condition to C (fair). Pugging can risk long term damage to site hydrology, causing site drying and wetland health degradation, but is challenging for managers because many livestock rely on moist riparian areas for their water source. In some cases, grazing rotation and timing methods can be directed to minimize pugging and substrate disturbance. These observations of pugging highlight a point of sensitivity to the healthiest plains riparian ecosystems in the basin.

Across the basin, reference **playas** were in relatively good condition, with all sampled sites scoring A or B (excellent or good). Playas tended to occur in relatively intact landscapes, though nearly all were located close to minor roads and all were impacted by grazing both surrounding and within them. For systems with such local hydrology, even minor stressors such as dirt roads and light grazing, can have more severe impacts if they disrupt natural surface water flows. The reference playas sampled had high quality vegetation, with few invasive species observed, and were generally free from hydrologic alterations. The greatest area of concern for reference playas was compaction by livestock.

Both **wet meadows** and **canyon spring** were the highest condition sites in the basin. Both types are fed by groundwater seeps or springs and were far less impacted by large-scale alterations experienced in other areas of the basin. Both did occur in landscapes with light to moderate grazing, and were not untouched by human land uses. But their stable, local water sources provided a more consistent environment for healthy wetland vegetation. These sites should be protected where they occur, 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.

As most of the land area supporting wetlands in the basin is also utilized for grazing and ranching, three management considerations are of utmost importance to help maintain the health of the remaining wetland resource, specifically true wetlands on the plains: 1) Sustainable grazing practices that consider the impacts of soil compaction and pugging from overgrazing; 2) Maintaining the basin's well-connected landscape of both wetlands and the surrounding shortgrass prairie by limiting development of new roads (even small dirt roads); and 3) Maintaining groundwater sources that feed the highest quality wetlands by limiting the development of new groundwater withdrawals.

In a basin that is subject to major droughts and the trying profit margin of a ranching economy, these are sensitive considerations. However, in addition to supporting valuable wildlife habitat and important wetland ecosystem services, these management considerations will keep the basin in a condition more resilient to the next drought and potential impact from climate change, will facilitate long-term land use at sustainable levels, and will maintain the wildlife habitat that supports southeast Colorado's growing recreation economy around hunting, fishing, wildlife viewing, and multiple-use of ranchlands open space.

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APPENDIX A: NWI CLASSIFICATION CHART

Appendix B: Field Key to Wetland and Riparian Ecological Systems of the Lower Arkansas River Basin

Last Updated May 29, 2015

How to Use This Key:

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 River 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 River 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 (not an official Ecological System)**

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 (not an official Ecological System)**

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 linked by underlying soils and the historic flooding regime. 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**

APPENDIX C: 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**

APPENDIX D: WETLAND AND RIPARIAN ECOLOGICAL SYSTEMS OF THE LOWER ARKANSAS BASIN: REFERENCE SITES

North American Arid West Emergent Marsh

Six marsh sites were selected for reference surveys for this study. Marshes are characterized as ecosystems with coarse herbaceous vegetation and standing water. One site was dry at the time of survey, likely due to drought in the region, so will not be described as a reference marsh here. Although the site was still saturated at the surface and had a moist organic soil component, indicating a natural groundwater influence, the site had higher dominance of kochia than cattail and bulrushes, and the peat appeared to be drying. The five sampled marsh sites were classified as true wetlands dominated by herbaceous vegetation (Palustrine emergent).

Two reference marshes were sampled north of the floodplain (plains sites; Figure 1) and three riverine marshes were sampled along the Arkansas River floodplain (floodplain sites; Figure 2). The two sites north of the river were targeted as relatively undisturbed herbaceous seeps within a broader plains riparian setting. Upon arrival, they were reclassified as North American Arid West Emergent Marshes (marsh) due to their inundated condition, dominant marsh vegetation, and lack of moving channel.

Figure 1 Photographs of plains marshes in the Lower Arkansas River Basin. Left photos: landscape scale, right photos: detail view of vegetation in the same wetlands.

The three floodplain marshes were targeted as marsh types typical of the floodplain, in best-available condition for the basin. All floodplain marshes had hydrology heavily impacted by river management and irrigation seepage, but these marshes were also located in landscape positions that historically supported wetlands of some type before the construction of the reservoirs. Two of the floodplain marsh sites had recent management to reduce cattail and increase open water, and the other was managed as a natural area by the National Park Service.

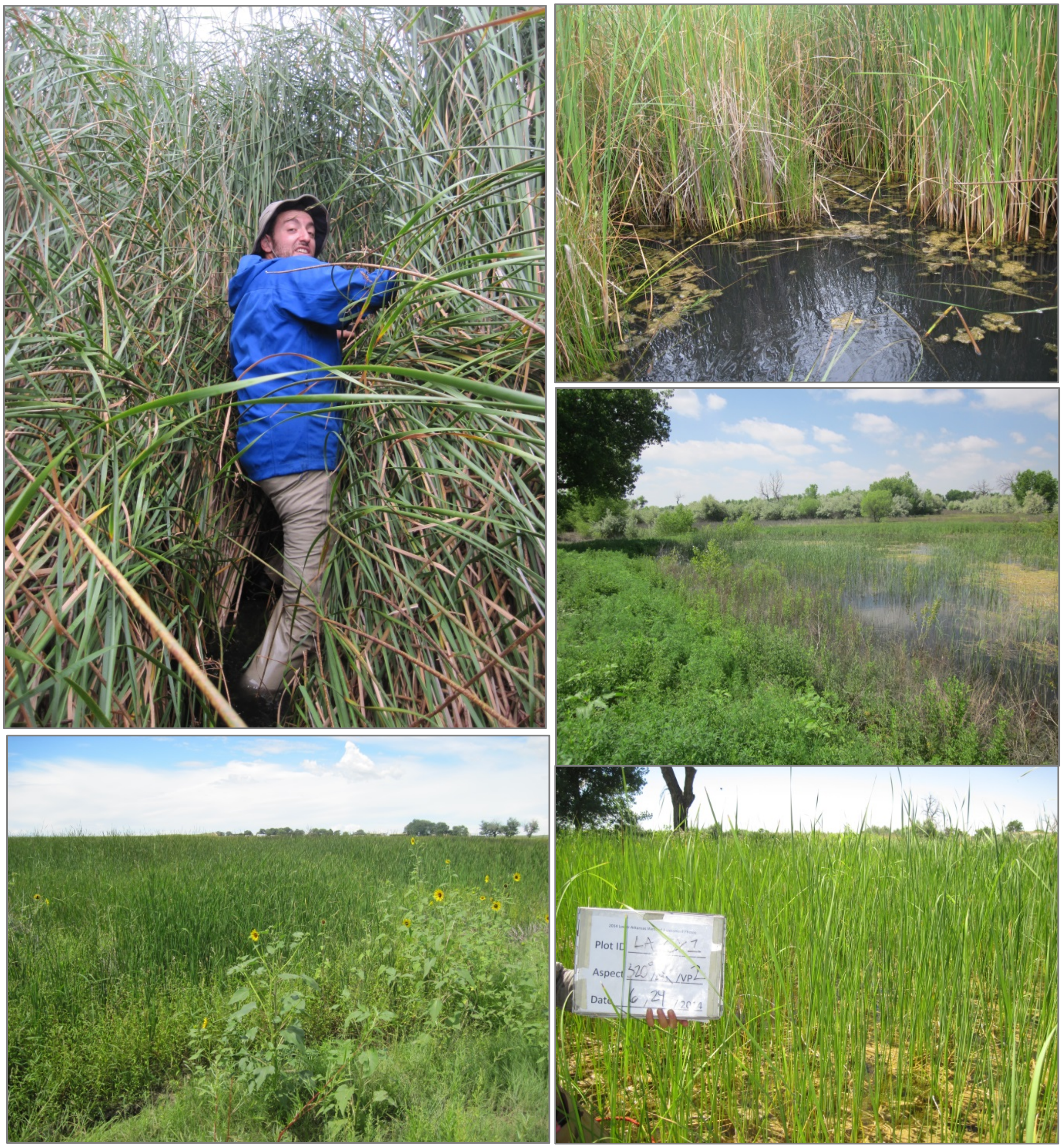

Figure 2. Photographs of reference marshes associated with the Lower Arkansas River Basin floodplain.

Vegetation: Vegetation at all reference marsh sites was dominated by relatively tall herbaceous species, specifically narrow-leaf cattail (*Typha angustifolia*) or hardstem bulrush (*Schoenoplectus lacustris* ssp. *acutus).* Four of the five sites also had low-statured wetland graminoids including mixed sedge (*Carex spp*: *C. nebraskensis, C. lanuginosa, C. praegracilis*), spikerush (*Eleocharis spp: E. macrostachya, E. erythropoda*), mountain rush (*Juncus articus* ssp. *ater*), and foxtail barley (*Critesion jubatum*). These low graminoids occupied distinct zones in the plains marshes, but were sparser and less diverse in the floodplain sites. Aquatics were present in all sites – they were codominant in standing water with the cattail/bulrushes in the plains sites and were sparser in the floodplain sites. The floodplain sites had a woody riparian vegetation component, often fringing the site in either standing water or adjacent riparian zones. These woody species included cottonwood (*Populus deltoides*), coyote willow (*Salix exigua*), peachleaf willow (*Salix amygdaloides*), and snowberry (*Symphoricarpos occidentalis*). Tamarisk (*Tamarix spp.*) and Russian olive (*Eleagnus angustifolia*) were also present at two of the floodplain marshes. Wetland forb and aquatic genera observed at more than one marsh site, from highest number of occurrences and cover to lowest, included cutleaf waterparsnip (*Berula erecta*), speedwells (*Veronica anagallis-aquatica and americana),* wild mint (*Mentha arvensis*), common duckweed (*Lemna minor*), roundleaf monkeyflower (*Mimulus glabratus),* nodding beggartick (*Bidens cernus*), swamp milkweed (*Asclepias incarnata*), rough bugleweed (*Lycopus asper*), and cursed buttercup (*Hecatonia sclerata*). Upland and riparian forbs and grass species, some of which were non-native or noxious, were also present in low cover at all marsh reference sites.

Hydrology: The plains marshes north of the floodplain were primarily fed groundwater seepage (slope HGM), were associated with open depressions, and based on their channel position, likely also received subsurface slow-moving alluvial water. They were unique features that shared characteristics with a montane headwaters setting, and one was part of perhaps the largest natural seep wetland complex in the basin. These lowlands were both positioned at the confluence of various intermittent stream paths that appeared to dry at the land surface upstream of the site, but then wetted again from active seeps farther upstream. They were situated in a larger plains riparian landscape, but were classified as marsh based on their size and dominance of marshy vegetation. Four of the five sites had standing water throughout the majority of the assessment area, and one had 40% cover of water and a dominance of marshy vegetation.

The floodplain marshes were located in lowland depressions within the larger plains floodplain riverine setting. Two were upstream of reservoirs and heavily influenced by reservoir water levels, and all were below an irrigated landscape. They were also influenced by seasonal river flow levels and upstream snowmelt. Historical photos have documented that marshes were present in their landscape prior to reservoir construction. The other marsh was also historically a wetland, but thought to have less marsh and more wet meadow area prior to the time of irrigation. All marshes were described by land managers to receive seep water, however, the seepage was heavily influenced by the irrigated landscape, so the level of natural groundwater input the marshes receive by seepage is unknown. Without historical research the extent and prevalence of natural marshes is poorly understood, however they are documented to have been a part of the natural Arkansas River Floodplain along various stretches of the river.

Marsh vegetation patches were also components of the reference sites sampled in the plains floodplain and plains riparian ecological systems. The five sites classified as marsh ecological systems had large swaths of marsh vegetation and standing water. Sites classified as plains riparian with marshy components had an obvious channel with throughflow, and the plains floodplain site with a marshy component had a mixture of riparian vegetation and marsh vegetation, and lacked any standing water.

Soils: The two plains marshes had soil pits with organic components at the surface (<20 cm deep), perched upon loams with high percent of organic matter, upon sandy clay loams. One site had lenses of loamy sand alluvium in both soil pits. Two floodplain marsh sites had sandy loams and sandy clay loams with organic fibers and decomposing roots, and the other had silty clay and clay textures but had been dredged.

Water Chemistry: Surface water was present at all of the reference marshes, and varied widely in water chemistry (Table 1). The plains marsh site that was located in the large seep complex had the lowest marsh pH values (4.85-6.32). Most sites exhibited surface and groundwater pH values within 6.3-7.0. The plains marshes had markedly lower electroconductivity(EC) measurements than the floodplain. Of the nine plains marsh water samples taken, seven had EC values below 650 µs – relatively low for water chemistry measurements in the basin. All floodplain-associated marshes had EC values > 1550 µs. The marsh sites exhibited high temperatures ranging from 18 ˚C -22˚C, due to standing water of often shallow depths.

Table 1. Water chemistry measurements for 5 surveyed emergent marsh sites.

	Surface-water (n=13)			Groundwater (n=5)		
Marsh	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
pH	5.2	6.48	7.56	4.8	6.58	6.82
EC (µs)	445	1300	2686	611	1553	1886
Temp. ˚F (˚C)	64 (18)	72 (22)	87 (30)	64 (18)	67 (19)	71 (22)

Western Great Plains Wet Meadow-Marsh Seep Complex

Five reference seep wet meadows were sampled in the basin (Figure 3). These wet meadows were characterized by low-statured herbaceous mixed graminoids and forbs on moist soils. They had occasional to numerous open water seeps, which supported inclusions of either tall marsh and/or low aquatic vegetation. All five surveyed wet meadows were classified as emergent wetlands, with four in the saturated water regime (PEMB), and one with a seasonal high water table (PEMC).

Natural (not maintained by irrigation) wet meadows are little-described in the Colorado plains, and they are delineated in this section as wet meadows when they had large enough tracts of herbaceous wet meadow vegetation to be described separately (wetland type ~0.5 ha or larger, with more than half of the site dominated by wet meadow). They do not classify well into any previously described ecological systems in the region. We describe these surveyed reference wet meadows here as a Western Great Plains Wet Meadow-Marsh Seep Complex, with a mosaic groundwater-fed wet meadow and marsh vegetation components. Despite dominant meadow vegetation at the five wet meadow sites, they intergraded into seeps and marshes of various sizes over a small area, often with various patches within the assessment area, without obvious transition in HGM or vegetation zone. This ecological system shares characteristics with Western Great Plains Open Freshwater Depressions (described in states further north), with the Eastern Great Plains Wet Meadow, Prairie, and Marsh (described in states further east), and with the Rocky Mountain Alpine-Montane Wet Meadow and Subalpine-Montane Fen (described in higher elevations in central to western Colorado) Ecological Systems (NatureServe Explorer accessed 2015).

Various other reference sites surveyed in this study included prominent seep features (Figure 4) and groundwater sources as substantial contributors to overall site hydrology. Some or all of these sites may also better fit in the wet meadow-marsh seep complex ecological system we are describing here. However, for now we limit the delineation of this new system to the wet meadow components, which do not fit in any other previously described ecological system, and we keep large marshes and plains riparian sites with seeps in their previously described ecological systems. Further study of natural wet meadow, plain riparian, and marsh wetlands in the plains are needed to help describe this groundwater-influenced wetland type.

The sampled wet meadows ranged from hillslope seeps, to linear lowland wetlands in the headwaters of plains riparian rivers, to groundwater-fed meadows that were sections of broader depressional seep complexes with multiple wetland types. To further complicate matters, their surrounding landscape varies, and can overlap with the wetter variations of the plains riparian ecological system, which can have both localized seeps and springs and hydrology strongly influenced by channelized through-flow.

Vegetation: Species were generally a mix of wetland graminoids and forbs, with varying dominance at each wet meadow site. *Carex* spp., *Eleocharis macrostachya,* and *Juncus arcticus* were present at all sites. In addition to those specifics, wetland graminoids that were present in high cover (at least 25-50%) in at least one site vegetation plot were: beaked sedge (*Carex nebraskensis)*, clustered field sedge (*Carex praegracilis)*, wooly sedge (*Carex pellita/lanuginosa)*, analogue sedge (*Carex simulata)*, alkali cordgrass (*Spartina gracilis)*, *Critesion jubatum*, and, *Schoenoplectus lacustris* ssp. *acutus*.

Figure 3. Photographs of five reference wet meadow-marsh seep complex. Each photo is from a different site, except for the bottom two photos.

Other wetland forbs observed in at least three wet meadow sites included: *Mentha arvensis*, American licorice (*Glycyrrhiza lepidota*), *Typha angustifolia, Lemna minor,* common three-square *(Schoenoplectus pungens),* water speedwell (*Veronica anagallis-aquatica),* and milkweeds (*Asclepias* spp: *A. speciosa* and *A. incarnata*). The noxious weed Canada thistle (*Breea arvensis*) was also present at four of the five sites, and had patches of high cover at one site. One site was situated on a steeper hillslope than the other four sites sampled (located adjacent to a break in slope, and had patchier physiognomy, with poison ivy (*Toxicodendron rydbergii*), *Carex nebraskensis, Typha angustifolia, Symphoricarpos occidentalis,* and American plum (*Prunus americana)* all dominant in different zones. Despite some patches of woody shrubs, the site best fit into the wet meadow classification, based on its side-slope position, stable seep water source, and overall herbaceous dominance.

Four of the five wet meadows surveyed supported open water and vegetated seeps (Figure 4). The vegetated seeps ranged from slow-moving water tracks and streamlets with floating and emergent aquatics or taller marsh vegetation; to sedge mats interspersed with open seep zones; to small seeps hidden in a more densely vegetated hillslope landscape. Small patches of quaking soils (organic soil perched above water) were present at least two sites, and hummocks were present at all sites. The site without visible seeps was in a lowland with hummock and swale topography. The swales were mossy, an uncommon feature for a wet meadow in the plains, but the moss was discolored to brown. Although the soil was moist, the water table appeared lower than typical of such topography, perhaps due to recent drought or alteration to hydrology.

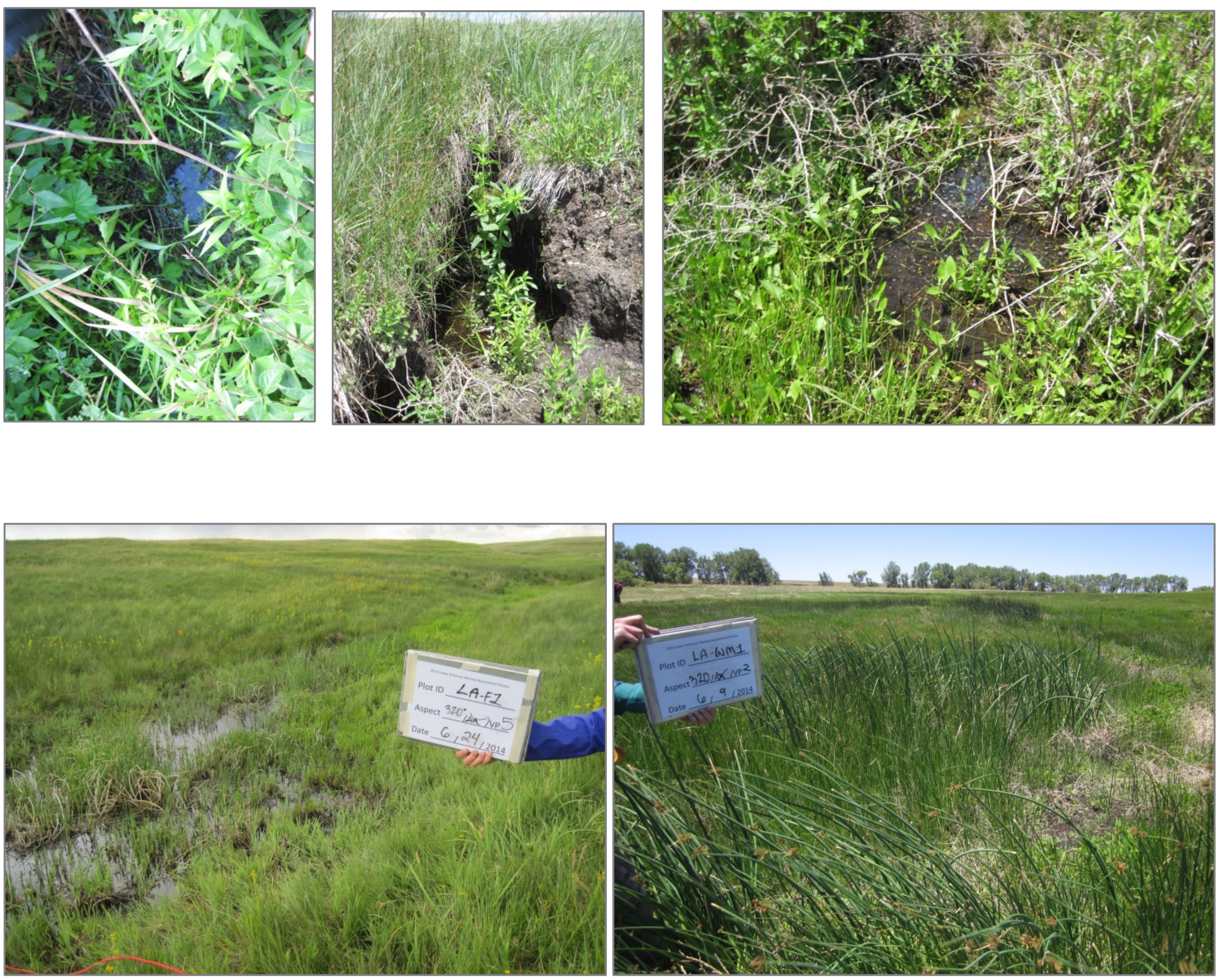

Figure 4. Examples of seeps in the Plains Wet Meadow-Marsh Seep Complex.

A floristic survey of the Black Squirrel Creek watershed (Kelso et al. 2014), where one reference wet meadow (the fen site) was located, revealed very high diversity of herbaceous wetland plant communities in this region and elevation. Surveys of groundwater-fed plains wetlands in southeastern Colorado often document rare or unexpected species to the region (Rondeau et al 2010). Given the low percent cover of natural wet meadows in the southeast Colorado landscape, plant species in these ecosystems seem especially poorly documented, with sites surveyed in good condition (such as these reference sites) contributing to many new plant county records.

Figure 5. Soil examples in wet meadow-marsh seep complex sites. Top left: organic peat alternating with coarse sandy loam alluvium, with >40cm cumulative peat; top right: mineral moist soil with moss at the surface; bottom left: fibric organic soil above dark clay mixed with fine organic, bottom right: coarse fibric organic soil mixed with roots and some mineral soil above fine-textured hemic peat.

Soil: Two to three soil pits were dug at each wet meadow site. Soil textures varied between and within site (Figure 5). Organic layers were present in four of the five sites. One site had >40 cm organic soil in all soil pits that alternated with lenses of alluvial sand, qualifying the site as a fen. Three sites had histic epipedons, and at least one soil pit of organic soil. These organic layers in the non-fen wet meadow sites were perched on soils ranging from clayey to sandy-loam. Just as fens are known for their unique vegetation composition at higher elevations, the organic soils supported unique plant communities to the plains region. One site had a large stand of a *Carex pellita* upon organic soil of variable depths, some that was quaking. Another site had a fen patch located in a headwaters region of a plains riparian creek, with floating mats of *Carex simulata,* golden sedge (*Carex aurea)*, and inland sedge (*Carex interior).* Seep inclusions often had sapric, watery muck, where vegetation could float on open water and shallow surface muck. Two meadows had exposed salt flat inclusions within or near the assessment area boundary. One site was entirely finer textured clayey soils, ranging from clay to clay loam.

Water Chemistry: Surface water was present within three of the five wet meadow assessment areas at the time of survey (Table 2). One site had surface water just outside the site boundary in a seep, and the other site had algae and moss cover in lowland swales. Soil water data was recorded at two sites, Soils were noted to be moist at all sites, saturated at three, and data was collected at two. Groundwater data collection was probably overlooked at the third saturated site.

Table 2. Water chemistry measurements for surveyed wet meadow sites.

	Surface-water (n=6)			Groundwater (n=3)		
Wet Meadow	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
pH	5.6	7.66	7.89	6	6.74	6.83
EC (µs)	274	344	412	410	550	1327
Temp. ˚F (˚C)	62 (17)	65 (18)	79 (26)	59 (15)	62 (17)	65 (18)

Wet meadows had some of the lowest pH measurements for all ecological systems, ranging from 5.6 to 7.89. The wet meadow in the northwest study area, a spring-fed fen/meadow system, had the lowest recorded wet meadow pH at 5.6 in a surface water sample. This site had a similar pH to a plains marsh in a seep-complex supporting deep organic soils. Wet meadow EC measurements were mostly on the low range when compared with other ecological systems, with only one recorded soil-pit measurement exceeding 1000 µs. The lowest recorded measurement was 274 µs in the fen surface water. Wet meadows also exhibited the lowest surface and groundwater temperature medians of all ecological system data, which may be because their hydrology is more heavily driven by groundwater than any other system, and possibly also from dense graminoids shading and cooling the water.

Western Great Plains Riparian

The Western Great Plains Riparian (plains riparian) ecological system includes woody and herbaceous wetlands and riparian areas. These are located along tributary rivers, streams, and creeks originating from the plains portion of the basin. They are positioned in a flat to rolling landscape (Plains; Figure 6), to nested within steep rocky canyons (canyon; Figure 7). Most of the surveyed tributaries flow towards the Arkansas River, though a few empty out of the southeast corner of the state into the Cimmaron River. These streams can flood and flow ephemerally, intermittently, or perennially. Soil textures and moisture levels vary widely. The plains riparian ecological system is a diverse wetland and riparian mosaic-type characterized by its tributary river setting in the plains, and stream hydrology that is strongly influenced by flood pulses (even if infrequent) and localized weather.

Figure 6. Photos of reference canyon plains riparian ecosystems in the lower Arkansas Basin. Clockwise from top left: Vogel Canyon, Purgatoire River, North Carrizo Creek, and the Apishapa River.

Of the sixteen plains riparian sites, twelve were identified as true wetland and four were classified as non-wetland riparian. All four of the sites dominated by overstory trees (forested) were classified as non-wetland riparian (RpFO). The other site was shrub-dominated, and located along the Purgatoire River. Three other shrub-dominated sites along the Purgatoire River and Carrizo Creek supported hydrophytic vegetation, but it was not known whether they supported hydric soils, so there is a possibility they would classify instead in the non-wetland riparian type. All herbaceous dominated sites classified as true wetland, but the shrub-dominated sites represented a mix of wetland and non-wetland riparian zones.

Figure7. Photographs of six reference plains riparian ecosystems in the Lower Arkansas River Basin. Photos clockwise from top left: Wild Horse Creek, Horse Creek, Chico Creek, Big Sandy Creek, Black Squirrel Creek, and Low Back Creek.

Sites from this ecological system were the most variable – supporting the highest vegetation species diversity, variability in water source and duration of flooding/moisture, and widespread site locations across the basin. To better understand this variable wetland and riparian resource, a major assessment emphasis (16 out of 48 wetlands) was placed on riparian zones for this reference wetland study.

Vegetation: All sites had several vegetation zones, with woody low shrubs such as *Salix exigua* and *Tamarix*, wetland graminoids such as *Schoenoplectus* spp. (*S. pungens* and *S. lacustris*), *Juncus arcticus, Eleocharis macrostachya, Carex nebraskensis*; and various combinations of other patch types including grasses, floating and rooted aquatics, mesic to wetland forbs, and weedy annuals. At any one site, woody species richness tends to be limited to several or fewer species, with much higher herbaceous diversity. Some plains riparian sites were completely herbaceous.

Common grasses, observed in half or more of the sites, included annual rabbitsfoot grass (*Polypogon monspeliensis),* Canada wild-rye *(Elymus canadensis),* switchgrass (*Panicum virgatum), Critesion jubatum,* western wheatgrass (*Pascopyrum smithii),*and dropseed grass (*Sporobolus* spp: *S. airoides, S. cryptandrus,* and *S, texanus).* Burningbush/kochia (*Bassia sieversiana)* and Russian thistle/tumbleweed (*Salsola* spp) were common weeds, each occurring in ten sites. Common forb species and genera observed in at least half the sites were cattails (*Typha* spp*: T. angustifolia* and *T. latifolia*), *Glycyrrhiza lepidota,* common sunflower (*Helianthus annuus),* speedwells *(Veronica* spp: *V. Americana, V. anagallis-aquatica,* and *V. catenata*), smartweeds (*Persicaria* spp: *P. lapathifolia* and *P. bicornis*), Canadian horseweed *(Conyza canadensis)*, sweet-clovers (*Melilotus* spp: *M. officinale* and *M. albus*), Canada goldenrod *(Solidago canadensis)*, and curly dock (*Rumex crispus)*.

Hydrology: Plains riparian reference sites sampled in the basin had a range of water sources including stream surface flow and overbank flooding, upland runoff after intense precipitation, subsurface alluvial flow and high water tables, side-slope groundwater seeps and lowland springs, and localized within-channel clayey depressions that collect floodwaters and precipitation until evaporation. Their hydrology is inherently dynamic and can include various combination of the above sources. These ecosystems are a mosaic of wetland and non-wetland riparian area. In some cases, the mosaic of wetland/non-wetland was small-patch within the surveyed assessment area (AA), and in other cases the mosaic was at a larger scale and the entire AA was entirely wetland or non-wetland. In this basin, many of the plains rivers and streams run perennially to intermittently across some of their reaches, then appear to dry up over other reaches except when in flood stage, but sometimes alluvial water is still transported underground through these regions, until springing to surface again downstream. Baseline surface flows tend to be fairly slow, but can increase to moderate from repeated or intense local precipitation events. Some streams or reaches only flow in very wet water years.

Soil: Two to three soil pits each were dug at eleven of the sixteen sites. Five sites were located on Comanche National Grassland, and for these, only surface texture was noted. Soil pits often had multiple layers with various textures. All sites but one had loamy soil, ranging from clay loams to sandy loams. One site had sandy soils, and was different than the other surveyed plains riparian sites, by it being much drier and washy – classified in this ecosystem due to an open cottonwood overstory along a plains tributary. This site fell on the driest spectrum of 'riparian' in the basin, however, it was mapped in NWI as Palustrine forested or scrub-shrub (PFOA or PSSA). At least half of the sites (eight) received groundwater input in additional to tributary through-flow, and these pits were generally moist or saturated. Some of these sites had redoximorphic features, depleted layers, or organic surface (one site with a histic epipedon), but others with moist soil did not meet hydric criteria. These may be problem soils due to high sand content. However, the prevalence of 'problem' soils in reference sites fed by ground water in the basin, may identify a need for more description of hydric soils in wetlands of the Colorado Plains. Many sites had both moist and dry soil pits. The moist soils were likely influenced by presence of groundwater seeps or underlying stream alluvium, whereas the dry soils likely only experienced short-term flooding and inundation. Some dry soils had redoximorphic features, and often had a clayey component and were situated in a localized depression that could hold flood waters for longer periods of time.

Water Chemistry: The plains riparian sites had the most water samples collected, and a wide-range of parameter values (Table 3). Thirteen of the sixteen sites contained surface water, with a combination of flowing and standing water, and only four groundwater samples were taken. Plains riparian sites demonstrated the highest median values for electro-conductivity for surface and ground waters. While some sites had low EC values, 56% of sites measured >1000 µs, with numerous measurements exceeding the Hanna meter's measurement capacity (>3999 µs). Plains riparian sites were split almost evenly between sites that are heavily groundwater influenced and sites that were primarily surface and rain-water influenced. When water quality parameters are compared between these groups of riparian sites, some notable differences are observed. Surface water influenced sites have a median EC value five-times higher than the groundwater influenced sites (EC=2739 µs and 509 µs respectively). This could be due to more sediment and particles, and potentially salinity, in surface and rain water. Surface water influenced sites had a median temperature 5.3 ˚C warmer than that of the groundwater influenced sites (25.0 ˚C and 19.6 ˚C respectfully). The pH median values were comparable with groundwater influenced sites with a nearly neutral median pH (7.04), and surface water influenced sites with a slightly more basic pH median value (7.41).

Table 3. Water chemistry measurements for plains riparian sites.

	Surface-water (n=32)			Groundwater (n=4)		
Riparian	**Min**	**Median**	**Max**	**Min**	**Median**	**Max**
pH	6.1	7.3	9.45	4.8	5.26	5.27
EC (µs)	288	1414	>3999	462	2027	>3999
Temp. ˚F (˚C)	60 (16)	74 (24)	83 (29)	65 (19)	69 (20)	83 (29)

Canyon Springs

Five canyon springs were surveyed for this reference study. These do not have their own wetland ecological system, but are smaller features within that would classify into various ecological systems from each site's larger surrounding canyon landscape south of the Arkansas River. Many canyon spring wetlands are so small that they would not be mapped with National Wetlands Inventory (NWI). While they are small in size, they can harbor unique biodiversity and can be natural wetland features. CNHP's basin-wide wetland assessment studies are centered around NWI mapping, and generally, wetlands the size of these canyon springs are beyond the scope of these studies. However, to highlight these springs as a wetland resource in the basin, we surveyed several that were suggested by members of the steering committee. Four sites were located on Comanche National Grassland, and the other was along the cliff slope of a ranch along the Purgatoire River. There are also canyon springs elsewhere in the basin where the topography is similar, and many of these are noted as springs features on USGS quadrangle maps.

The canyon springs were located adjacent to a canyon wall. The site was either the water directly seeping from the base of the rock and surrounding area of influence, or the lowland narrow valley adjacent to the wall supporting pools and wetland vegetation(usually <10m from wall). All but one site had open water pools in small to moderate-sized depressions present at the time of survey(Figure 8). The site lacking pools was fairly dry at the time of survey and appeared to have a shift in hydrology, and was primarily dominated by riparian vegetation. That site had *Epicactus gigantea* present when previously surveyed, but the rare wetland plant was not observed at the 2014 visit.

Vegetation: Plant species within the small canyon spring wetlands occupied a diverse range of vertical strata. All sites had woody vines, and most sites also supported shrubs, subcanopy and canopy trees, graminoids, forbs, and aquatics. The canyon spring sites on Comanche National Grassland also supported a range of obligate wetland to upland species in close proximity, but the other site had vegetation more typical of riparian areas and lacked wetland obligate species. The diverse combination of physiognomy with highly localized hydrology forms plant community combinations unique to these spring wetlands. Mapleleaf grape (*Vitis acerifolia)* was present at all sites. Common woody species observed (in more than half the sites) included *Populus deltoides*/one-seed juniper *(Sabina (Juniperus) monosperma)/Salix* spp *(S. exigua, S. amygdaloides*) associations, or combinations of those species often comprised the taller strata. Other common woody shrubs and vines were *Toxicodendron rydbergii,* pubescent skunkbush sumac *(Rhus aromatica* ssp*. pilosissima),* whitestem gooseberry *(Ribes inerme),* and netleaf hackberry *(Celtis reticulata)*. Common graminoids, ranging from wetland obligate to upland species, were river bulrush (*Bolboschoenus fluviatilis),* fox sedge *(Carex vulpinoidea),* bottlebrush sedge (*Carex hystericina), Elymus canadensis. Juncus interior,* Torreyi's rush (*Juncus torreyi) , Panicum virgatum,* field brome (*Bromus japonicus),* and *Polypogon monspeliensis.* Common blue violet *(Viola sororia),* American water horehound (*Lycopus americanus), Conyza canadensis,* and prickly lettuce (*Lactuca serriola)* were all present in three sites. Dead tumbleweeds (*Salsola australis*) collected in lowlands, and were concentrated in some sampled pools.

Hydrology: The water source was exposed at the base of the bedrock, or in depressional lowlands adjacent to canyon walls. Many pools were small in size, but were reported to remain filled year-round from groundwater input. The site with riparian vegetation was still more lush than the nearby hillslope, so appeared to be receiving some water, but the water source was not evident.

Figure 8. Photographs of the four canyon springs with water.

Soils: Due to their location on Comanche National Grassland, soil pits were not dug at four of the five canyon springs. At the surface they supported a mixture of wetland vegetation and saturated or mucky-surface soils, and non-wetland riparian vegetation with a dry mineral soil surface and rock. Mineral soil surfaces had a sandy component but seemed to be dominantly loam or clay loams. The other canyon spring site lacked observable seep or springs, lacked hydric soils, supported a higher percentage of non-wetland riparian vegetation than the other sites, and was overall in a drier phase that previously surveyed.

Water Chemistry: Surface water data was collected in pools in four of the five seep-springs sites (Table 4). Due to regulations against soil excavation in the Comanche National Grasslands, no soil water samples were collected. Seep-springs systems had the highest minimum pH value at 7.0, and a relatively high maximum value at 8.8. Electroconductivity values were among the lowest median values for surface waters along with wet meadow, floodplain, and closed depression ecological systems. Seep-springs systems also have the highest temperature median at 27 ˚C, which is the same median value as closed depression systems.

Table 4. Water chemistry measurements for surveyed seep/springs sites.

	Surface-water (n=12)		
Seep/Springs	**Min**	**Median**	**Max**
pH	7	7.92	8.8
EC (µs)	108	281	365
Temp. ˚F (˚C)	65 (19)	81 (27)	85 (29)

Western Great Plains Floodplain

The Western Great Plains Floodplain ecological system in the Lower Arkansas Basin includes wetlands and riparian areas located along the Arkansas River and Fountain Creek. Eight reference sites were sampled in this ecological system, with one site along Fountain Creek, and the remainder along the Arkansas River. The floodplain is characterized by a mosaic of vegetation, dominated by trees, shrubs, herbaceous grasses and forbs, and open sand and water (Figure 9). The various vegetation patch types are connected by their location in the historic active floodplain, and by sharing similar alluvial soil dynamics. The majority (7 of 8 sites) in this ecosystem were classified as River (R2 Cowardin system) or Riparian (Rp) rather than true wetland. One floodplain site, located farther from the river than the others, had more wetland than non-wetland riparian area and was classified as Palustrine, but was a mosaic of both systems. The dominant Cowardin classes at each floodplain site were either scrub-shrub, forested, or unconsolidated shore.

Vegetation: Vegetation in this system was patchy, and zones tended to be stratified in terraces along with distance and height from the river. Much of the floodplain zone is dominated by woody species. Open cottonwood (*Populus deltoides)* forest galleries with saltgrass (*Distichlis spicata)* or mixed prairie grass and forb understory were generally well-above the river. These were often interspersed with small depressional lowlands and swales of common reed (*Phragmites australis)*and *Typha* spp (*T. angustifolia* and *T. latifolia*), and sandy washes supporting a mix of riparian and upland prairie understory species. Lower terraces frequently observed included *Salix exigua*, narrower terraces of dense tall herbaceous vegetation (often annuals), and moderate to sparsely populated sandbars with species ranging from weedy annuals to wetland perennial herbs and graminoids.

Overall, floodplain vegetation was degraded, even though attempts were made to select reference sites connected to the river and in the best available condition. The only species observed at all eight floodplain sites was tamarisk (*Tamarix ramosissima*, occasionally *T. parviflora*). It ranged from only a trace of cover at one site where noxious weeds were actively managed against, to 45% cover, and was often the dominant shrub strata at sites. Several reference sites also had moderate cover of dead tamarisk shrubs, which were not included in percent cover estimates. *Bassia sieversiana* was often a dominant understory species, and *Helianthus annuus* was present at all but one site. *Eleagnus angustifolia* was also present at three sites. Reference wetland site selection attempted to avoid dense stands of noxious species such as tamarisk, and tamarisk elsewhere on the floodplain frequently reaches higher densities than these sampled sites. Cottonwood stands with high cover of understory weeds such as *Breea arvensis* and *Salsola* spp. were also avoided, however, *Salsola* was recorded in six sites, and *Breea* in five. Small patches of *Phragmites australis* were frequently in the understory in low cover, but were dominant in the understory of one site located further from the river, underlain by clayey soils. More intact sites had understories consisting frequently of *Distichlis spicata*/mixed grass.

The most common understory species were highly tolerant of disturbance (natural and anthropogenic), and in addition to the above species, species occurring in more than half the sites *were Glycyrrhiza lepidota, Conyza canadensis,* and mapleleaf goosefoot (*Chenopodium simplex).*

Figure 9. Photograph examples of vegetation patch types in plains floodplain reference sites of the Lower Arkansas River Basin. Clockwise from top left: open river and unvegetated sandy shore, inundated sandbar, low terrace with tall herbaceous vegetation, higher terrace with woody vegetation, live and dead tamarisk, cottonwood gallery.

Native perennial graminoids were frequently observed in low cover amongst a weedier understory, with *Panicum* spp*. (P. virgatum and P. obtusum), Critesion jubatum* (nativity varies by authority), *Elymus canadensis, Pascopyrum smithii, Schoenoplectus lacustris* ssp*. acutus*, *and Schoenoplectus pungens* occurring in at least three sites each. Other species and genera present in at least four of the surveyed sites included the non-native wetland grasses, barnyard grass (*Echinochloa crus-galli)* and *Polypogon monspeliensis*; and various riparian and wetland forbs including *Conyza canadensis,* ragweeds (*Ambrosia spp: A. psilostachya* and *A. artemisiifolia* ssp. *velatior*), goosefoots (*Chenopodium spp: C. album, C. rubrum, C. pratericola, C. atrovirens,* and *C. fremontii*), smartweeds (*Persicaria spp: P. maculata, P. lapathifolia, and P. amphibia*), and milkweeds (*Ascelepias spp: A. engelmanniana, A. incarnata, A. speciosa,* and *A. subverticillata*).

Floodplain reference sites were purposefully placed near water, so sampled sites were not representative of the mesic herbaceous floodplain zones farther from the river occurring in historic river flow-paths or swales, dominated by grasses such as *Panicum virgatum*.

Hydrology: Plains floodplain sites were fed by the surface and subsurface alluvial flow of the Arkansas River, which includes return flows and seepage from the surrounding irrigated landscape. John Martin and Pueblo Reservoirs are large reservoirs situated along the floodplain, and river flow rates are heavily managed. Historically, the rivers overbanked in the spring, flooding the entire width of the geomorphic floodplain, but today the floodplain's hydrology is separated into the active river channel and the cottonwood gallery zone. The river channel pulses in the spring with open fast flowing water, shallow water that skims woody-vegetated sandbars, and covers open sandbars. The channel then dries down to a narrow open water zone later in the growing season, exposes sandbars and supports colonization by annual vegetation and allowing growth of open perennial marshy wetland species. The lowest sandy terraces ('shores') are seasonally inundated. Higher terraces rarely flood if at all, and much of the river is entrenched. However, sections of the river do still overbank in high water years such as 2015.

Farther from the river's central stem, are small to large marshy depressions with clayey soils that can perch water. Old oxbows also share subsurface flow with the floodplain, and may also receive groundwater input when next to a break in slope on the outer floodplain. Due to being highly managed, the spring flows lack the energy they had historically. This shapes the landscape and has contributed to aggradation and sedimentation, decreasing open water in side channels. Narrow oxbow ecosystems along the floodplain corridor can be choked with thick vegetation as a result. Wider marsh oxbows and large swaths of cattail classify into marsh ecological systems, but narrow oxbow bands and marshy pockets are considered pieces of the larger Plains Floodplain mosaic.

Soil: Two soil pits were dug at each floodplain site in soils representative of the site. All sites had soil pits with coarse-textured soils, ranging from sand to loamy sand. One site that was situated farthest from the river also had a clay loam soil pit that was moist throughout. It lacked hydric indicators but supported wetland vegetation, so appeared to be a "problem" hydric soil. The floodplain site on Fountain Creek had a hydric moist soil pit with a sandy lens reduced in color with redoximorphic features. However, the pit was not overlain by hydrophytic vegetation, and the overall site classified as non-wetland riparian. Both the hydric soil and the problem hydric soil pits were situated in lowland swales that received alluvial groundwater. All other soil pits lacked hydric indicators. Some pits on sandy terraces next to the river may receive too much water fluctuation to create hydric indicators in sand. However, a large portion of the plains floodplain surveyed sites were on terraces that rarely wetted for long, so the general lack of hydric indicators supports that these plains floodplain ecosystems are often non-wetland riparian ecosystems.

Water Chemistry: Water quality data was taken from the river in seven of the eight floodplain sites (Table 5), and only one of these was a groundwater sample. Floodplain sites all fall in the non-wetland riparian category therefore there was rarely saturated soils during the summer season. River water temperatures ranged from 15 ˚C to 29˚C, with a median of 20 ˚C.

Table 5. Water chemistry measurements for surveyed floodplain sites.

	Surface-water(n=16)			Groundwater (n=1)
Floodplain	**Min**	**Median**	**Max**	**Value**
pH	6.9	7.5	8.56	6.9
EC (µs)	202	715.5	2986	1315
Temp. ˚F (˚C)	60 (15)	68 (20)	84 (29)	79 (29)

Western Great Plains Closed Depressions and Saline Depressions (Playas)

Seven reference playas were visited. Six of those playas were the Western Great Plains Closed Depression (Figure 10; closed depression) ecological system, and the other was a Western Great Plains Saline Depression (Figure 11; saline depression). All playas were classified as wetlands based on intermittently ponding hydrology (PEMJ Cowardin Class). Playas typically have "problematic soils", and vegetation composition varies from wetland obligate species during their wet phase, to a mixture of dry to wet wetland indicator species during their dry phase.

Figure 10. Photographs of two reference playas in their wet (top) and dry (bottom) stages in the Lower Arkansas River Basin.

Intact closed depressions in the southeast Colorado plains are characterized by precipitation and runoff-fed, shallow clay-lined depressional isolated (not fed by rivers) wetlands surrounded by a landscape of shortgrass prairie. Many of the basin's playas occur in complexes of undulating landscape supporting playas of various sizes. Saline depressions can occur in similar isolated depressions to the closed depressions, but are characterized by high salinity soils, an outer ring of halophytic vegetation, and a central unvegetated zone. Saline depressions, including the one sampled for this study, can be closely associated with greasewood plant associations outside of the ponding zone. In addition to the surface water source, some (or possibly all) of the saline depressions in this region, including saline wet meadows, appear to receive groundwater input secondary to their surface water source. However, more research regarding these saline features during their wet phase is needed to determine the origin of all water sources.

Figure 11. Photographs of the saline depression reference site surveyed in the Lower Arkanasas Basin in dry (2014) and wet phase (2015).

Vegetation: All reference playas had distinct concentric vegetation zones that varied with microtopography and the frequency of wetting, but surveyed assessment areas ranged from fairly uniform in structure and vegetation, to capturing all the playa vegetation zones. Assessment areas did not capture entire wetland with very large playas, that compared with the sizes of managed reservoirs. Closed depressions tend to have sparse to low cover of vegetation in the central depression zone, but the saline depressions often lack vegetation in the central zone that typically wets. Plant community composition changes substantially between their wet and dry phase (Figure 12). Vegetation densities in the central most frequently-wetted zones are generally low. Cover over the playa fringe is higher and dominated by grasses.

The saline depression had the lowest vegetation species richness of all reference sites for the study, with only three species observed at each visit. The saline depression had a large central bare zone, with only the fringe zone vegetated by a ring of *Distichlis spicata* and a small patch of *Schoenoplectus pungens*. Purse seepweed (*Suaeda calceoliformis*) was observed in low cover at the first visit, and *Lactuca serriola* in low cover at the second. Outside of the playa depression was a ring of greasewood (*Sarcobatus vermiculatus*) between the wetland and the transition to upland shortgrass prairie.

The most common vegetation species in the other surveyed playas (closed depressions), and are often high in cover in the frequently-wetted zone, include spikerushes (*Eleocharis spp: E. macrostachya* and *E. acicularis*), hairy water-clover (*Marsilea mucronata*), and wedgeleaf (*Phyla cuneata)* along with other mixed playa forbs. Buffalograss (*Buchloe dactyloides*) and western wheatgrass (*Pascopyrum smithii*) both colonized the central playa in low cover, and formed a ring around the outer playa in higher cover. Other forbs observed in half of the closed depressions (3) include green prairie coneflower (*Ratibida tagetes*), bigbract verbena (*Verbena bracteata*), spotted evening primrose (*Oenothera bracteata)*, wooly plaintain (*Plantago patagonica*), curlycup gumweed (*Grindelia squarrosa*), povertyweed (*Iva axillaris),* aridland goosefoot (*Chenopodium desiccatum), Helianthus annuus,* silky sophora (*Vexibia nuttalliana),* cuman ragweed *(Ambrosia psilostachya* var. *coronopifloia),* and hairy false goldenaster (*Heterotheca villosa).*

Hydrology: Most of the reference playas in the study area wet only ephemerally (irregular hydroperiod and years), though a few are often wetted each growing season. Playas are primarily fed by local precipitation events filling their gently sloping depressions, and by precipitation runoff from the surrounding landscape. Two reference playas appeared to have soil alterations that were historic pits, creating a deeper water zone during the inundated stage, but the pits did not appear to substantially affect the slope of the overall wetted area, or the ability of the playa to fill beyond the pit. The substrate alterations were more obvious on aerial imagery, and were hardly noticeable onsite, so overall, their effects on the playas were minor.

Soil: Two soil pits were dug in each playa site, except for the one playa on Comanche National Grassland where we were not permitted to dig soils. At that site, soil texture was recorded at the playa surface only. Soils in the saline depression were clay with up to ~8-10% visible salts*.* Salts were concentrated at the soil surface, and at depths >25cm, but were lower in concentration between ~5-25cm. All of the other playas (closed depressions) had clayey soils classifying as sandy clay loam, clay loam, or clay. One site also had a sandy loam soil that was in the grassy vegetated

Figure 12. Repeat photos of one reference playa from central (right) and edge (left) vantage points, over three field visits between June and September.

outer ring of the playa that did not frequently wet. However, all reference wetlands visited for the study had cracked soils and other signs of regular wetting in some areas of the playa. Only one of the twelve pits had enough visible redoximorphic features to classify as hydric, and the second pit at that site in the more frequently wetted playa central zone did not have visible redoximorphic features. The playa with a 'hydric soil pit' was also the only playa of the seven surveyed that did not wet during the 2014 and 2015 (Lower Arkansas Random Assessment) field surveys, or visibly from

Google Earth 2014 imagery. Playa soils are often described as ‘problematic’ for accumulating hydric characters.

Water Chemistry: Water chemistry data were collected at four of the seven closed depressions (Table 6). Playas exhibited wide ranges of water chemistry measurements especially in pH values. All wetted playas were turbid. Most playas experience moderate to intensive cattle traffic, therefore cow dung and sediment disturbance likely has an effect on water chemistry parameters and turbidity. Playas exhibited some of the most basic pH values, with 50% of the samples reaching 8.18 to 10.3 pH. Electro-conductivity measurements are among the lowest values of all the ecological systems with a range of 115µs to 336µs, and a median of 304 µs. Closed depressions systems also represent a portion of the highest water temperatures, because they are shallow and only receive new water with large or frequent rain events. The median temperature was 27 ˚C, and the highest was 34 ˚C.

Table 6. Water chemistry measurements for surveyed closed depression sites.

Closed Depression	Surface-water (n=9)		
	Min	Median	Max
pH	6.2	8.18	10.3
EC (µs)	115	304	336
Temp. ˚F (˚C)	68 (20)	81 (27)	93 (34)

Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland

The Rocky Mountain Lower Montane-Foothill Riparian Woodland and Shrubland ecological system (foothills riparian; Figure 13) supports the wetland and riparian ecosystems fed by streams originating from the foothills. One reference site was surveyed for this study in this system, as riparian areas in the basin in reference condition mostly originated in the plains. This foothills ecosystem was mostly present in the basin in urban areas that were not reference condition. This site also had urban development not far from the site, but the riparian corridor was fairly intact. The site was considered true wetland (PSSA Cowardin Class) based on dominant hydrophytic species and redoximorphic features meeting hydric soil criteria.

Figure 13. Photographs of a foothills riparian site along Monument Creek in the Lower Arkansas River Basin.

Vegetation: Vegetation density and diversity is typically higher in the foothills region than in the plains riparian counterparts, and that held true for the foothills riparian site surveyed for this study which had 75 species recorded. In particular, woody species diversity and vertical complexity tend to also be higher in foothills than plains ecosystems. The most common species onsite were *Salix exigua,* deweystem willow (*Salix irrorata),* and thinleaf alder (*Alnus incana).* Other woody species present included ponderosa pine (*Pinus ponderosa),* Gambel's oak *(Quercus gambelii), Ribes inerme,* prairie rose *(Rosa arkansana),* Raspberry *(Rubus idaeus ssp. Melanolasius),* park willow *(Salix monticola),* Western snowberry *(Symphorocarpos occidentalis),* and chokecherry (*Padus virginiana).*

There were diverse patches of vegetation at the site varying with topography and water levels, ranging from aquatics along slow-moving shallow water, to *Carex* spp. sandbars, to *Juncus arcticus*, mixed grass, and a multitude of perennial forbs and annuals with low percent cover. This site had vegetation patterns typical of wetlands with beaver activity, and coarse and fine woody debris jams sawed by beaver, but no active dams within the assessment area.

Hydrology: The reference foothills riparian hydrology was most strongly driven by the river. Water depths and flow rates were variable across the site in active and older channel pathways (some likely influenced by beaver). Flow rates of foothills riparian systems are influenced by snowmelt and spring weather conditions, in addition to seasonal weather dynamics.

Soils: Soils ranged from sand to sandy loam. Exposed soil was present along channel sandbars and dried down channels. The channel was connected to the vegetated riparian area within the site, and shallow streamlets meandered through some of the wetland vegetation, but one side of the floodplain edge was steeply eroded, creating an abrupt transition from riparian to upland.

Water Chemistry: Compared to plains riparian sites, water measurements at the foothills riparian site had comparable pH and temperature measurements for surface and ground water, but the electro-conductivity measurements were markedly lower for this site (Table 7).

Table 7. Water chemistry measurements for surveyed foothill riparian sites.

Foothill Riparian	Surface-water (n=2)			Groundwater (n=1)
	Min	Median	Max	Value
pH	6.9	6.97	7.03	7.4
EC (µs)	432	435	437	510
Temp. ˚F (˚C)	73 (23)	73 (23)	73 (23)	72 (22)

Citations

Kelso, S., L. Fugere, M. Kummel, S. Tsocanos. (2014) Vegetation and vascular flora of tallgrass prairie and wetlands, Black Squirrel Creek Drainage, south-central Colorado: perspectives from the 1940's and 2011. Journal of the Botanical Research Institute of Texas 8(1): 203-225.

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APPENDIX E: EXAMPLE FIELD FORM AND STRESSOR CHECKLIST