Targeted Inventory and Assessment of Plains Groundwater-Dependent Wetlands in Eastern Colorado

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Front Cover: Top photo - *Eleocharis rostellata* peat-accumulating wetland at Brett Gray Ranch, Bottom outer photos - GDE species *Sparganium eurycarpum* with seep forbs (left) and *Scutellaria galericulata* with bulrushes (right) in a flooded and saturated wet prairie at Lowry Ranch. Central photos – *Lithobates blairi* (top), and saline depression (bottom).

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EXECUTIVE SUMMARY

Wetlands in Colorado cover a small percent of the landscape that is estimated between 2-3% of the landcover, but support most of Colorado's wildlife, and provide essential ecosystem services for biodiversity and humans. In the eastern plains of Colorado, wetlands that are dependent primarily on groundwater inputs are a type of groundwater-dependent ecosystem (GDE) that offer especially important biodiversity habitat, but remain among the least understood and managed for wetland types in the state. Groundwater-dependent wetlands in the Colorado lower foothills and plains are sensitive ecosystems due to their reliance on predictably high groundwater tables in a semi-arid climatic region and their reliance on seep and spring-fed saturated conditions.

Prior to this study, and the concurrent Boulder County wet meadow research, documentation of eastern Colorado GDE wetland sensitive species and the wetland attributes of plains GDEs has been primarily from general wetland or targeted wildlife studies and from case studies. The goals of this study were to collect multi-scale GDE datasets to improve the baseline understanding of groundwater-dependent wetlands in Colorado's plains and Front Range, and to create GDE resources that will help the guide the successful conservation of plains GDEs.

This study collected wetland data on the location, distribution, types, condition, and conservation significance of GDE wetlands located in Colorado's Front Range shortgrass prairie and eastern plains regions. These wetlands included peat-accumulating wet meadows and fens, and groundwater-dependent swales, floodplain meadows, riparian areas, and saline depressions. This study surveyed 51 wetlands across the Colorado plains and shortgrass prairie region of the Front Range to provide data on the distribution, types, and condition of GDE wetlands across the region. Data from these surveys – along with Boulder County wet meadow plots and previously collected GDE data from the Colorado Natural Heritage Program (CNHP) studies – together have provided an improved understanding of the distribution, ecological characteristics, and the biodiversity value of groundwater-dependent wetlands in Colorado's eastern plains.

In much of eastern Colorado, the National Wetland Inventory (NWI) mapping does not map GDE wetlands accurately, along with most plains wetlands. This study developed a mapping method for plains GDEs similar to higher elevation fen mapping to distinguish highly groundwater-dependent wetlands and guide GDE conservation priorities in eastern Colorado.

Most of the GDE wetlands surveyed in this study received an Ecological Integrity Assessment (EIA) rank of good/B condition or higher (72%), and many supported rare species and high biodiversity. These scores were higher on average than other wetland types from CNHP EIA plains studies with randomized sites and from Front Range targeted wetland surveys.

Most of these sites meet the Ecological Occurrence criteria in the Natural Heritage Program tracking system based on their relatively higher condition than many other CO plains wetlands, presence of imperiled plants and communities, leopard frogs, rare wildlife, or moderate to fen depths of peat in the semi-arid Colorado plains. Synthesis of current and past amphibian surveys showed that leopard frogs were found in most surveyed freshwater GDEs regardless of their condition, indicating plains GDE wetlands are important amphibian habitat. Invertebrate surveys

revealed rare and unique species in plains GDE wetlands, including species typically found at higher elevations.

This study publishes the mapping and plot data on Colorado Plains groundwater-dependent wetland locations, types, and their assessment, available on the Colorado Wetland Information Center (CWIC) Wetland Plots Database and Wetland Mapper. These data can be used for strategic management and conservation, from avoiding development projects that may impact the Colorado plains' most critical wetlands, to guiding conservation planning and data-informed management for high quality and irreplaceable groundwater-dependent wetlands.

Recommended management for GDE plains wetlands begins with inventory and assessment: to identify the wetland locations, water sources and types, organic soil layer depth and soil types, and biodiversity including detection of any rare species. Comparing this information with land uses and potential ecological stressors and threats to degradation or loss of GDE wetlands helps determine management priorities, ranging from preservation, to active management and monitoring, to restoration. Key best management practices include protecting organic soils and minimizing substrate disturbance, maintaining groundwater and site hydrology and wide natural buffers, avoiding further disruption to site groundwater, conserving native and rare species, and limiting water quality degradation. Human activities such as berm construction, overgrazing, or land use that causes vegetation simplification can significantly impact wetland quality and biodiversity. Land uses that support or mimic natural processes can benefit GDE health when carefully managed, some of which may be compatible with other land uses such as recreation and strategic grazing in some GDE areas. Education about rare species and presence of GDEs in an array of plains landscapes can promote better stewardship. Pairing current site surveys with historical imagery can inform context-aware and resilient management strategies. More research is needed to understand and manage natural disturbance regimes in plains GDEs, and continued inventory and monitoring will be critical to track biodiversity trends, groundwater loss, and changes in saturated, seep/spring, and riparian pool habitats. A cautious, adaptive approach is recommended: protecting intact wetlands while carefully adjusting practices to restore ecological processes in areas showing signs of degradation.

More research is needed on managing for natural disturbance regimes in plains GDEs. Both passive strategies that protect ecological integrity, especially in the wettest GDEs, and active strategies that mimic natural disturbance conditions can be needed depending on the wetland. A precautionary approach is recommended, avoiding rapid changes in GDEs already in good condition, while incorporating adaptive management and monitoring to guide restoration where needed.

KEY FINDINGS

- **GDEs Need Mapping**: Plains GDE wetlands are significantly undermapped in the National Wetlands Inventory. A pilot desktop mapping effort developed a plains-specific method to identify confidence of peat-accumulating and saturated GDEs, similar to montane and fen mapping. This tool prioritizes wetlands likely to contain rare biodiversity and supports regional conservation planning.

- **Condition Assessments**: Ecological Integrity Assessments (EIA) and surveys for critical biological resources were conducted at 51 targeted assessment areas in Colorado eastern plains groundwater-dependent wetlands. Sites ranged from excellent to fair condition; and most were in good condition or better. One wetland rated an A EIA rank; 71% rated as B, 25% rated as C, and one rated as D. These GDEs scored higher on average than other regional wetlands, suggesting that many plains GDE wetlands have high conservation value.

- **Peatlands and Rare Wetlands:** Eleven fens with deep organic soil >40 cm were found across three major plains watershed basins; from the seven organic soil fens surveyed from this GDE study plus another 4 from the plots analysis. These organic soil fens plus many other peat-accumulating plains wetlands support regionally unique, uncommon, and rare biodiversity. Plains calcareous fens, marl wetlands, saline playas, and plains peatlands are regionally and globally imperiled wetland plant community types, needing further inventory and protection in eastern Colorado.

- **Saline Playas at Risk:** Unique saline depressional wetlands support rare halophyte communities and shorebird habitat. Historical aerial imagery shows both drying and increased inundation trends, indicating hydrologic instability in this wetland type. These wetlands need further study and watershed-scale protection.

- **Land Use Impacts:** Land uses such as ditch seepage and grazing are associated with variable stress levels to GDEs. Light or well-managed grazing had limited impacts on wetland health and in some sites can support wetland health, but excessive or heavy grazing degraded sensitive substrates and hydrology. Irrigation seepage can degrade or sustain GDEs. Human alterations like berms, overgrazing, soil excavation, and drainage modifications can cause GDE loss. Wide buffers and watersheds with minimal fragmentation were positively linked to wetland condition.

- **Sensitive Substrates:** Protection of seeps, springs, and fragile saturated organic soils can be needed to maintain fen and peat-accumulating wetland hydrology in some sites.

- **Protect GDE Water Sources:** Minimizing development and groundwater consumption, and retiring unnecessary groundwater usage, supports sustainability of groundwater-dependent wetlands.

- **Rare Wildlife Habitat:** Rare, at-risk, and uncommon wildlife species were observed in a variety of GDE habitats, such as black rail in peatland marshes, leopard frogs in saturated wet meadows and peatlands, fritillary butterflies in fens and seeps, and native fish in pools.

- **Changes in Disturbance Regime:** Plains wetlands are in a shortgrass prairie ecoregion that historically experienced more frequent and widespread natural disturbance, such as bison grazing, flooding and dynamic hydrology, wildfire, beaver use, and widespread prairie dogs. This landscape also has a history of cumulative anthropogenic disturbance. Managing for plains GDE wetland health can benefit from research and lessons learned from similar prairie and fen systems management.

- **Hydrology and Vegetation Shifts:** Plains GDE wetland surveys show trends in drying, cattail dominance, and both weedy and woody species invasion; suggesting vegetation responses to altered hydrology and nutrients. Occasional native woody cover is natural, but species like tamarisk and invading shrubs can threaten wet meadow and peatlands, affecting peat-accumulating vegetation cover and groundwater-driven site conditions. Some woody native floodplain and riparian GDEs have high quality unique floristics, and more eastern Colorado research is needed to determine where woody GDEs are natural, versus response to loss of streamflow.

- **Urban GDEs:** A single wetland from this study received a D (poor) EIA condition rank and received urban stormwater inputs and had hydrology impacted by surrounding development. This is a common at-risk GDE type in the Front Range, and without GDE mapping, GDE function loss from groundwater to surface water systems is difficult to track. This transitional wetland type still provides important biodiversity habitat in urban areas.

- **Recognize GDEs as Biodiversity Hotspots:** Prioritize conservation of regionally and globally rare GDE types such as fens, saline playas, and canyon seeps. More research and inventory are needed across eastern Colorado, and research-informed adaptive management approaches can help maintain GDEs and minimize loss of biodiversity.

- **Data and Mapping Resource:** Spatial and tabular data for this study's EIA plots and mapping are viewable in CNHP's wetland plots database and mapper, and mapped quadrangle data are available for download upon request.

ACKNOWLEDGEMENTS

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This project's success was due in large part to the CNHP field team of skilled and hard working staff committed to telling the stories of prairie wetlands through data including: Becca Hiller, herpetologist; Angelina Pietroniro and Matthew Klimock, wetland botany technicians; Daniel Vidal-Dominguez and Tara Flood, Siegele wetland interns; Nancy Bartholomew and Emma Kelly, wetland volunteers; Georgia Doyle, botanist, Janet Miller aquatic ecologist, and Mason Mizener, botanist.

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Finally, extra thanks to all who care about plains groundwater-fed wetlands. Despite the odds, they are still here, and many are healthy and highly functioning, thanks in no small part to the commitment of public and private and conservation and research, and to those willing to support plains GDE management for ecological health.

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1.0 Introduction

The purpose of this study was to improve the regional understanding of the types, distribution, and characteristics of freshwater and saline groundwater-dependent ecosystems in eastern Colorado's central shortgrass prairie ecoregion and to synthesize findings from this study's inventory and assessment to inform their best-management. This study included multi-level baseline data on Colorado's plains groundwater-fed wetlands, including mapping, rapid condition assessment, and in-depth surveys of biota indicative of ecosystem condition and ecological importance. Field data on vegetation, soil, and wetland condition were collected in 51 sites and data on amphibians, invertebrates, and water chemistry were collected in a subset of those sites.

Groundwater-dependent ecosystems (GDEs) are surface wetlands or subsurface ecosystems that depend on early growing season and often continuous groundwater discharge. In describing GDE wetlands, the U.S. Forest Service (USFS) states "where groundwater meets the surface, a unique community of plants and animals flourish" (USFS 2025). The USFS produced protocols for Level 1 and Level 2 GDE Assessments (USFS 2012; USFS 2022) that can be used in non-riparian and non-lacustrine surface water GDE wetlands across many regions. These are useful tools for both inventory and education about groundwater ecosystems, and they serve as a reference for groundwater indicators. This study included several GDE wetland types within the USFS guides, including springs, fens and other peatlands, marshes and swamps, as well as baseflow GDE riparian ecosystems that are not included in the USFS guides. This study does not include groundwater-fed lake fringes, except a specialized type of depressional wetland called saline closed depressions or saline playas. Lake fringes are often in ditched and irrigated landscapes, so parsing surface from groundwater indicators can be difficult. This study prioritized obligate GDEs for mapping and field sites but also included facultative GDE areas adjacent to the targeted GDEs. Obligate GDEs are entirely dependent on groundwater, and facultative GDEs have partial dependence on groundwater (Herron et al. 2018). This study does not focus on subsurface GDEs.

Many GDE wetlands on Colorado's eastern plains are threatened by habitat loss and degradation. Wetlands positioned in the Front Range prairie landscape are often impacted by urban growth. Rural wetlands have a long history of cumulative land uses that affect groundwater. Wet meadow and fen GDEs can be small and semi-isolated, without perennial surface outflow, and often overlooked in regional mapping products including the U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (NWI). GDE wetlands are at risk of drying due to their reliance on sustained microclimate moisture levels (Harvey et al. 2007a), groundwater depletion from wells and hydrologic alteration, and compounded regional risk of lowered groundwater tables with warmer temperatures from climate change (CNHP 2015), and they also undergo conversion to surface water-fed marsh with anthropogenic flow additions. Mapping and assessment data for plains GDEs is needed to track their condition and loss.

While plains GDE wetlands are inherently sensitive, they also provide unique and important wildlife habitat refugia and watershed functions within the prairie landscape. In Colorado, plains GDEs such as peat-accumulating wetlands and wet meadow drainages with marsh pools provide important habitat for sensitive at-risk wildlife species, such as leopard frogs and red-belly dace, which are priority species for habitat management and protection efforts (CPW 2016). Some GDEs have unique features such as fens with deep pockets of peat soil thousands of years old (Gilmore and Sullivan 2010; Gage and Cooper 2013), or hypersaline depressional wetlands shown to support endangered biodiversity in other states (Harvey et al. 2007a). In Colorado, saline playas are not well researched across the plains and Front Range, but they are present in many watersheds (Harvey et al 2007a; Lemly et al. 2015). Other groundwater-dependent slope wetlands can support a multitude of rare and uncommon plant species. Documentation of sensitive plains species and wetland attributes in Colorado plains GDEs are often from case studies and individually known occurrences (e.g. Gilmore and Sullivan 2010; Kelso et al 2014). The mapping, surveys, and management guidance from this study informs the regional baseline understanding of the importance of GDE wetlands within eastern Colorado prairie and can inform their effective conservation.

The groundwater-fed wetland types prioritized in this study are less studied than other Colorado wetlands and only cover a small percentage of the Front Range and plains landscape. Wetlands on Colorado's eastern plains were mapped by the NWI program in the 1970s at coarse resolution (USFWS 2025). Without good mapping, systematic study of these sensitive wetland types is limited. CNHP has mapped fens in higher elevation forests in Colorado and elsewhere (e.g. Smith et al. 2017, Laughlin et al. 2025). The GDE mapping in this study develops a comparable approach to identify saturated and peat-accumulating ecosystems, tailored to the Colorado plains GDEs. This targeted study improves the understanding of the spatial distribution, location, types, condition, and ecological significance of plains GDEs. These data provide key information for the next steps to conservation efforts.

1.1 Project Objectives

The four primary objectives of this targeted inventory and assessment of Colorado plains groundwater-dependent wetlands study were:

1. Map Colorado plains and Front Range GDEs in several focus areas to understand their spatial distribution and to pilot a GDE mapping approach for the Colorado plains.
2. Conduct field assessment to fill data gaps on the vegetation and wildlife species composition of plains GDEs.
3. Analyze condition assessment data from new and previous GDE plots to characterize the condition and characteristics of lesser studied plains GDE wetland types.
4. Summarize findings into management recommendations and refine methods to assess their condition using Ecological Integrity Assessment (EIA).

2.0 STUDY AREA

2.1 Geography

The plains of eastern Colorado occupy approximately one third of the state, with elevations of ~3300 to 7000 feet. They begin along the Front Range at the base of the foothills and include municipalities, suburbs, farmland, rangeland, and open prairie as they extend east to the state line. The shortgrass prairie ecoregion in Colorado includes the floodplains and watersheds of three major rivers: the South Platte to the north, the Arkansas to the south, and the Republican to the east. There are several large reservoirs along the major rivers and scattered across the Front Range that offer recreation and habitat, along with many smaller state wildlife areas. For this study, the project area was defined as the Colorado portion of the Central Shortgrass Prairie ecoregion (TNC 2009, modified from Bailey 1998) (Figure 1). There are 29 counties within the study area, which spans 275 miles from north to south state line and 175 miles from the base of the foothills to the eastern state line. The Colorado plains counties fully included in the study area are: Adams, Arapahoe, Baca, Bent, Broomfield, Cheyenne, Denver, Douglas, Elbert, Kiowa, Kit Carson, Lincoln, Logan, Morgan, Otero, Phillips, Prowers, Sedgwick, Washington, Weld, and Yuma. Additional Front Range counties that span mountains and prairies are partially included in the study area: Boulder, El Paso, Fremont, Huerfano, Jefferson, Pueblo, Larimer, and Las Animas. The study includes cities of the Denver metropolitan area, plus the Front Range municipalities of Fort Collins, Boulder, Colorado Springs, and Pueblo.

Major threats to Colorado plains habitats include habitat loss, agriculture, energy exploration, wind and solar development, property development and subdivisions, roads, water extraction, and flow modification. Soil carbon and productivity loss from long-term continual grazing without adequate recovery periods create cumulative stress. Fire regimes on the plains have been altered by direct and indirect fire suppression resulting in longer fire return intervals, and more invasion by woody plants and weeds. Invasive and exotic plant encroachment threatens native habitats, as can herbicide application. Prairie dog habitat is reduced and constrained in many areas, causing decreased natural disturbance to soils and vegetation. Climate change and non-renewable groundwater use also presents rising concerns about lower soil moisture, and reduced stream flows. Yet despite continual development, cultivation, water use, ranching, and other modifications across much of the Colorado plains, numerous areas of high biological significance and ecological integrity remain. Plains groundwater dependent wetlands are ecosystems with high potential for such biodiversity.

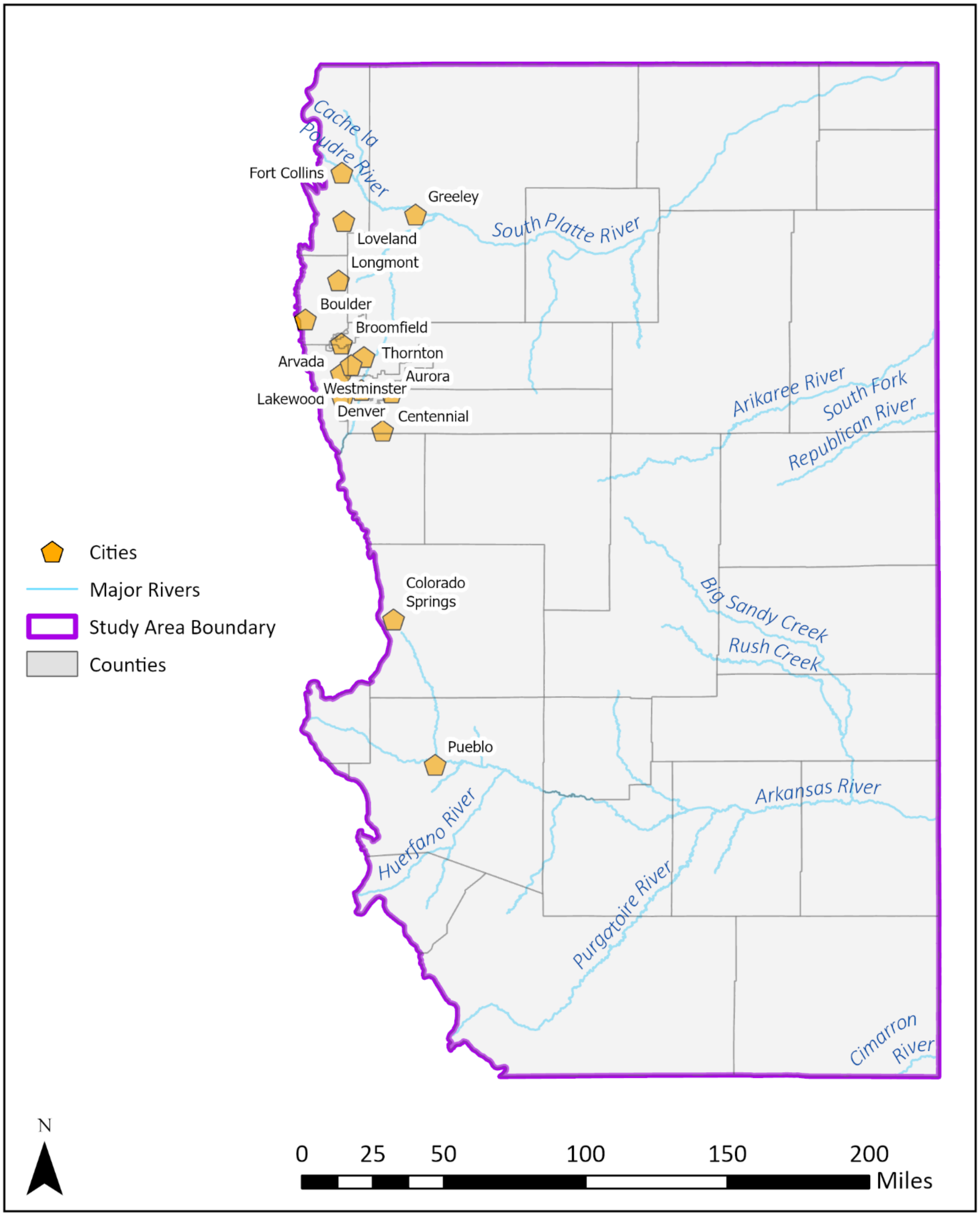

Figure 1. Study area of TNC Shortgrass Prairie Ecoregion in Colorado, displayed with Level III EPA Ecoregions

2.2 Ecoregions and Vegetation

Level 3 & Level 4 Ecoregions

The basin falls primarily within two EPA Level 3 Ecoregions: Southwest Tablelands and High Plains (Omernik 2014) (Figure 2). The western study area also includes a relatively small area in the Southern Rocky Mountain EPA Level 3 Ecoregion, where the western edges of the EPA plains ecoregions and the TNC Shortgrass Prairie ecoregion differ. EPA Level 4 Ecoregions further divide the landscape into finer units based on vegetation, topography and geology (Table 1). Colorado's great plains are higher in elevation compared to other plains states. The Piedmont Plains and Tablelands (26e) is the most common Level 4 Ecoregion, representing over 8.5 million acres or 30% in the center of the study area. Underlain by shale and sandstone, the dominant natural cover of the Piedmont Plains is rolling shortgrass prairie grasses with grama (*Buchloe* spp.) and buffalograsses (*Bouteloua* spp.), western wheatgrass (*Pascopyrum smithii*), sacatons (*Sporobolus* spp.) and yucca (*Yucca glauca*). Land uses are primarily rangeland, irrigated agriculture, and dryland farming. The Flat to Rolling Plains (25d) is the next most common Level 4 Ecoregion, with just under 8.5 million acres representing another 30% of the study area, occurring in areas of now-stabilized wind-blown eolian silty sediments.

Table 1: Level 3 & 4 Ecoregion acreage in the study area.

Level 3 & 4 Ecoregion	Study Area Acres	Percent of Study Area
21. Southern Rocky Mountains		
21b. Crystalline Subalpine Forests	152	0%
21c. Crystalline Mid-Elevation Forests	55,979	0%
21d. Foothill Shrublands	321,644	1%
21f. Sedimentary Mid-Elevation Forests	24,098	0%
21j. Grassland Parks	593	0%
25. High Plains		
25b. Rolling Sand Plains	2,949,146	10%
25c. Moderate Relief Plains	3,974,187	14%
25d. Flat to Rolling Plains	8,466,369	30%
25i. Front Range Fans	500,198	2%
26. Southwestern Tablelands		
26e. Piedmont Plains and Tablelands	8,532,610	30%
26f. Mesa de Maya/Black Mesa	367,686	1%
26g. Purgatoire Hills and Canyons	666,268	2%
26h. Pinyon-Juniper Woodlands and Savannas	529,237	2%
26i. Pine-Oak Woodlands	371,521	1%
26j. Foothill Grasslands	1,155,165	4%
26k Sandsheets	362,322	1%
Total	**28,264,289**	

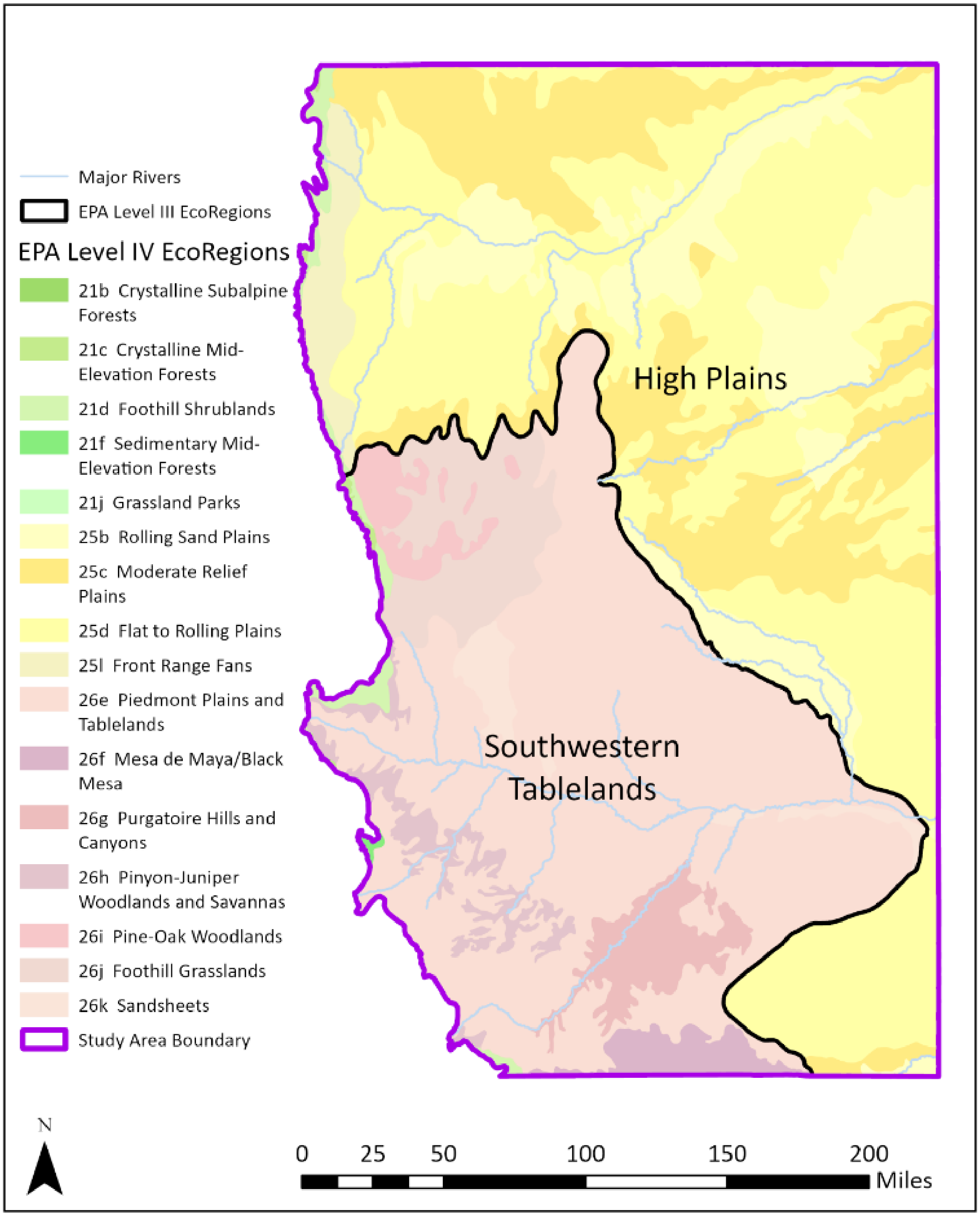

Figure 2. Level 4 Ecoregions in the shortgrass prairie of Colorado.

Certain ecoregions in the study area support high wetland biodiversity. The Rolling Sand Plains (25b) ecoregion in the northeast along the South Platte River floodplain and in portions of the Republican Basin contains unique wetlands with deep organic layers upon sandy soil. The uplands of this region have mixed and tall grasslands that grow in sand. Occasional groundwater-fed depressional wetlands are visible in the aerial imagery in sandy landscapes, but far fewer today than in historical aerials. The Foothill Grasslands (26j) and Front Range Fans (25l) ecoregions, both on the far western edge of the study area, have outwash gravel and floodplain features from terraces to alluvial fans, and have diverse soil types over relatively smaller areas, including alluvium, shales, arkosic sedimentary rock, and sandstone. At the base of the foothills these regions support many small slope wet meadows, some of which have accumulated peat.

The Colorado plains have a variety of upland landforms and vegetation including shortgrass, mixed-grass, tallgrass, and sand-sage prairies; mesas and canyons; rocky outcrops and bluffs; and open woodlands. These all support a diversity of smaller patch wetlands and riparian areas such as mesic to wet meadow, marsh, fen, refuge pools, rocky pools, springs, playas, lakes, wooded and shrubland wetlands, vegetated sandbars, sloughs, and ponds. In larger floodplains of the Front Range and plains, areas with wetlands can be spotted as a line of trees stretching through valleys. Colorado plains wetlands also can lie tucked away in most types of landforms in lowlands and at slope breaks within smaller drainage networks and depressional landscapes. Prairie wetland landscapes vary from low hills and gently undulating prairie to nearly flat and broad grassy expanses, which nevertheless somehow hide the greenest wetlands from seep pockets to linear reedy swales to a wide sea of lush and verdant saturated ground, so much that if a person is lucky enough to stumble upon an unannounced prairie wetland, wonder and sheer joy may follow. The canyon, mesa, and bluff landscapes offer more topography but sparser occurrences of true wetlands. Shortgrass prairie vegetation is also common in these dissected grasslands, along with less dense sand and scrub vegetation, and small wetlands can be tucked into washy or rocky edges with the scrub. These wetlands scale up in size into deeper or higher order drainages where larger pools, springs, and canyon riparian areas are a part of the landscape, but most wetlands in plains canyon topography are narrow.

Plains Wetland Vegetation

Much of the wetland vegetation on Colorado eastern plains is comprised of marshes, ponds and reservoir fringes, or relatively small patch herbaceous wetlands interspersed within non-wetland riparian areas and floodplains. The stream corridors and wetlands of the plains support a mix of native and non-native vegetation, with many patches of non-native invasives that indicate changing hydrology or drying conditions.

Common riparian woody species include natives such as coyote willow (*Salix exigua*), plains cottonwood (*Populus deltoides*), and peachleaf willow (*Salix amygdaloides*). Common non-native species are crack willow (*Salix fragilis*), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia virgata*) and smooth brome (*Bromus inermis*). Native herbaceous understory of woody wetlands is uncommon. Russian olive (*Eleagnus angustifolia)* and tamarisk (*Tamarix)* species also invade riparian wetlands. Snowberry (*Symphoricarpus*) species occur in mesic floodplain areas in the lower foothills and in eastern Colorado along major rivers. Front Range riparian shrublands have more diverse shrub layers than open woody wetlands farther east, with mixed native shrubs, such as species of cherry and plum (*Prunus)*, rose (*Rosa),* currant *(Ribes),* and hawthorn (*Craetagus).* Some reservoir fringe wetlands also have woody riparian vegetation.

Herbaceous emergent marshes are the most recognized wetland type in the semi-arid Colorado plains, typically dominated by cattails (*Typha* spp.) and bulrushes (*Schoenoplectus* spp.), often located in excavated or impounded ponds. Marshes also can follow streams and the wettest floodplain, often have shallow water or surface saturation, and can be natural in lowland wetlands with groundwater and without local hydrological impediments. Warm water slough floodplain vegetation varies depending on pace of moving water, from lush marsh species and more cattail to more diverse and riparian species in faster moving sloughs.

Wet meadows occur as marsh fringes, surface or subirrigated wet meadows in floodplains, and as narrow drainage vegetation in a variety of landscape settings. Common species are arctic rush (*Juncus arcticus* var. *balticus),* three-square *(Schoenoplectus pungens),* horsetails *(Equisetum spp),* and non-native pasture grasses *(Lolium* spp., *Alopecurus* spp.*)*. In the most saturated areas in wet meadows and marshes, spikerushes (*Eleocharis* spp) are common. Smartweed (*Persicaria)* species can establish in early successional areas of drainages and floodplains, and pondweeds (*Potamogeton* spp.) populate slow-moving to ponded and herbaceous drainages, many with groundwater inputs.

Most of the natural depressional wetlands in the eastern plains are freshwater playas, with an outer zone of western wheatgrass (*Pascopyrum smithii*) and an inner zone of spikerushes (*Eleocharis* spp.) ephemerally growing during the wet phase. Saltgrass (*Distichlis stricta*) is another common native herbaceous species in wooded understories, marsh fringes, and small riparian areas, and playas with more saline soils. Outer floodplain wet meadows with good hydrologic function (natural near-flats and depressions, or seasonally irrigated hydrology with hydroperiods like natural systems) can have a variety of native sedges, rushes and bulrushes (*Carex, Juncus, Scirpus, Schoenoplectus* spp.), and some also have significant forb diversity.

2.3 Climate

Climate in eastern Colorado is shaped by the Front Range rain shadow and semi-arid conditions of the plains. Local weather dynamics exert a greater influence on the plains than the snowmelt-driven hydrologic cycles common in the mountains. In the plains, local and regional precipitation events such as summer thunderstorms and spring rains produce much of the annual precipitation, and about 70% of annual precipitation falls during the peak growing season of May through September (Figure 3). Severe storm events can cause major flooding along the major rivers and their tributaries. In headwater wetlands, periods of heavy precipitation can pond shallow water in seepage wetlands. In intermittent drainages, precipitation events drain surface water into intermittent creeks and streams and transform hydrology usually driven by slope and depressional hydrogeomorphic dynamics into through-flow riparian conditions. Flooding is less frequent than annually or biannually in the small headwater creeks and low order streams. Winters are typically cold and dry but are often less harsh than in higher elevation areas of Colorado. During the hot summer months, the average daily high temperature is 88°F (Colorado Climate Center 2025), and there are many ninety and hundred-degree days.

The 2021 growing season was closer to average than 2022, which was a drought year on the Colorado eastern plains. During much of 2021, the study area Drought Monitor[1] was nearly normal, except in August when the northeast region of the state moved into abnormally dry to moderate drought. In contrast, by early 2022, the plains region was in severe/extreme drought and remained in drought through the summer ranging from abnormally dry to extreme. Regions within the study area had variation in timing of exceptional drought. The Front Range started to come out of the 2022 drought conditions in mid-August. In early summer, the southeast study area was in exceptional drought, which lessened over the summer to abnormally dry while the northeast most study area moved into exceptional drought. Precipitation at a weather station from the central study area in Limon, CO (Colorado Climate Center 2025) in 2021 was 94% of a normal water year. In 2022, Limon was 69% of a normal water year, and on average the area east of Limon had more intense drought, and west of Limon was less dry. Precipitation and temperatures varied across weather stations in the study area, and there were 57 and 61 days 90 degrees F or higher during 2021 and 2022 growing season, respectively, with several days 100+ degrees F each year. In 2021 the Limon weather station had 13 inches of annual precipitation and in 2022 it had 11 inches.

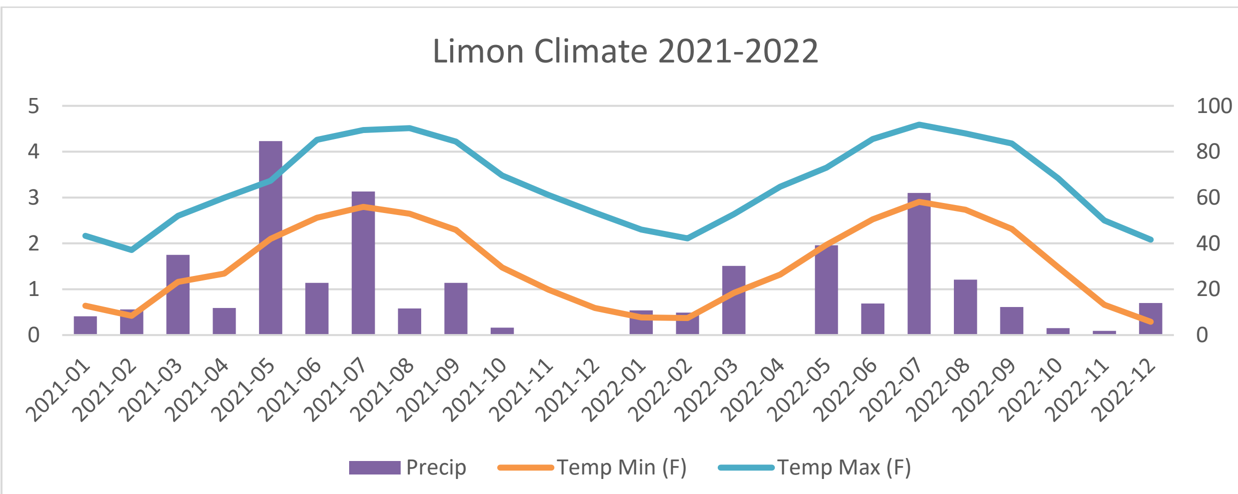

Figure 3. Average monthly precipitation data and average monthly temperature in 2021 and 2022 for Limon weather station: in the central GDE wetland study area (Colorado Climate Center 2025).

2.4 Hydrology

Hydrology in eastern Colorado varies across the region. The study area includes three major river basins, as defined by the six-digit USGS hydrologic unit code (HUC6): the South Platte River basin, the Arkansas River basin, and the Republican River basin (Figure 4). The Cimmaron River HUC6 basin occurs in the far southeast study area, with most of its watershed in neighboring states. For simplicity, we merged the Cimmaron basin with the Arkansas basin in this study. Although the South Platte and Arkansas Rivers originate in the mountains, many of their tributaries originate within or just west of the plains. That, combined with the drier semi-arid lower foothills and plains

[1] Drought monitor: https://droughtmonitor.unl.edu/Maps/ComparisonSlider.aspx

climate, creates conditions for plains streamflow driven by warm season precipitation. In addition, groundwater from basin and alluvial aquifers interacts with geologic variation and soil texture, creating localized variability in surface groundwater expression across a variety of landscape positions and regions in eastern Colorado. Many wetlands on the plains are associated with river systems or their alluvial footprint. In addition to natural riparian and floodplain wetlands, these include irrigated wetlands, marshes above impounded large reservoirs and drainages, ponded wetlands from former gravel pits, and smaller bermed or dugout plains creeks and streams. After large rain events or wet periods, ephemeral depressional wetlands nested in the shortgrass prairie also fill with water. North of the Arkansas River, historical small to large natural lakes are now modified into the Great Plains Reservoirs, and the largest of these are interconnected for irrigation. These reservoirs were once natural depressions, formed from when groundwater reached and dissolved the deep Flowerpot Formation Salts and caused sinking (Johnson 2021). There are also smaller natural saline or alkaline depressional wetlands where minerals from parent geology and soils are dissolved and mobilized by groundwater contact and lack of flushing or a regular outlet. Saline flats, drainages, and depressional wetlands can also be created where wetting and drying from irrigation onto mineral-rich fine soils increases salts and wetness.

The Arkansas River basin and South Platte River basin are large eastern Colorado watersheds with broad alluvial valleys and numerous tributaries that carry surface water and contribute groundwater to the larger now-perennial rivers. Their alluvial aquifers contribute to groundwater recharge in losing, often unconfined areas of the drainage network. Recharge ponds and irrigation return flow can also recharge these aquifers. Most of Colorado's population is concentrated along the Front Range urban corridor, and the water in these aquifers is used many times over by residents. Water availability is limited and insufficient for the growing urban population, and so it is supplemented by several transbasin diversions that bring water from Colorado's west slope to the Front Range urban corridor, primarily into the South Platte River basin, and into the Arkansas River basin. Water use also affects the water availability in the Lower South Platte and Arkansas alluvial valleys.

Aquifers in eastern Colorado include two major deep aquifers: the Ogallala aquifer and the Denver Basin aquifer system, plus alluvial aquifers close to the rivers (Figure 5). The Republican Basin is situated over the unconsolidated Ogallala aquifer, which is drying over time (Haacker et al. 2015). Groundwater from the Ogallala aquifer is pumped excessively for agriculture. When combined with prolonged drought, pumping lowers water levels across more area over time, affecting surface water duration and groundwater levels in streams and wetlands. The major rivers in this basin, the South Fork Republican, North Fork Republican, and Arikaree all have groundwater-rich alluvium that has lost water over time. The deepest pools in the Arikaree River are lowering, and portions of many rivers over the Ogallala now run dry (Perkin et al. 2017). The Denver Basin is a series of layered shallow-to-deep confined aquifers in the South Platte and Lower Arkansas basins, which also are experiencing groundwater depletion (Ruybal et al. 2019). These layered basins have low recharge rates, with concentrations of recharge in areas of permeable soil and rock, which are often outcrops, especially at the foothill edge of the eastern Colorado plains. Both the Ogallala and Denver Basin aquifers are considered non-renewable aquifers because of their slow recharge rates in comparison to human use needs and rates of loss.

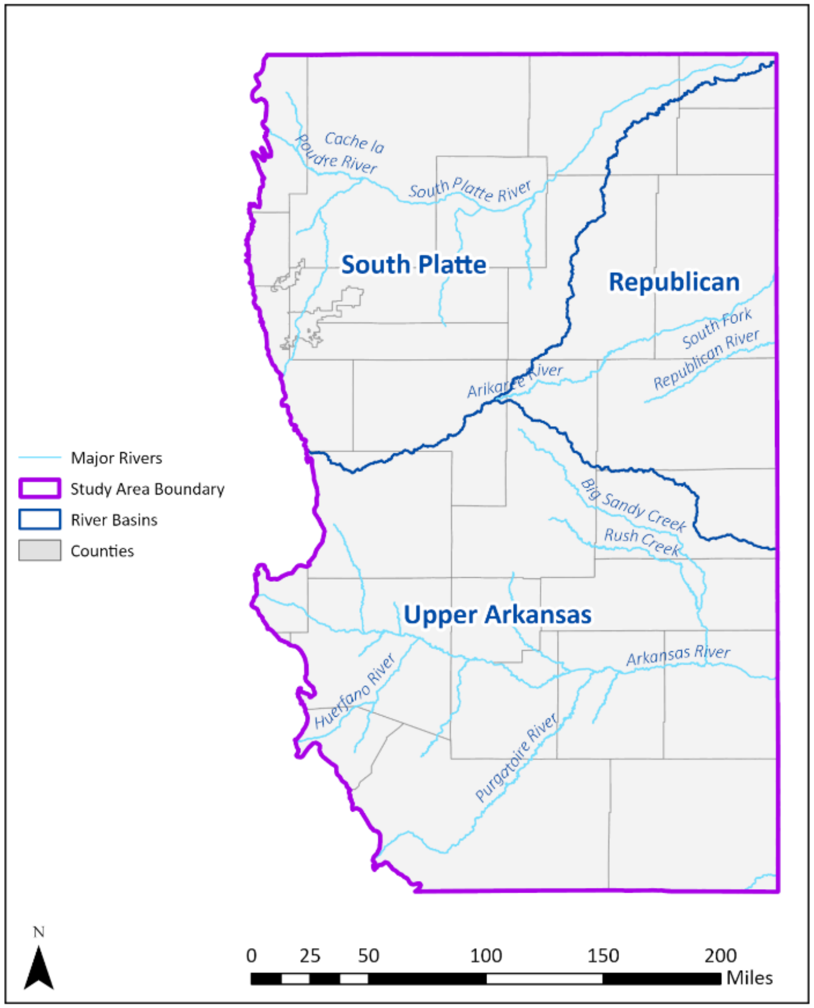

Figure 4. Streams and Hydrologic Unit Code (HUC) 6 generalized boundaries in the TNC Central Shortgrass Prairie Ecoregion of Colorado.

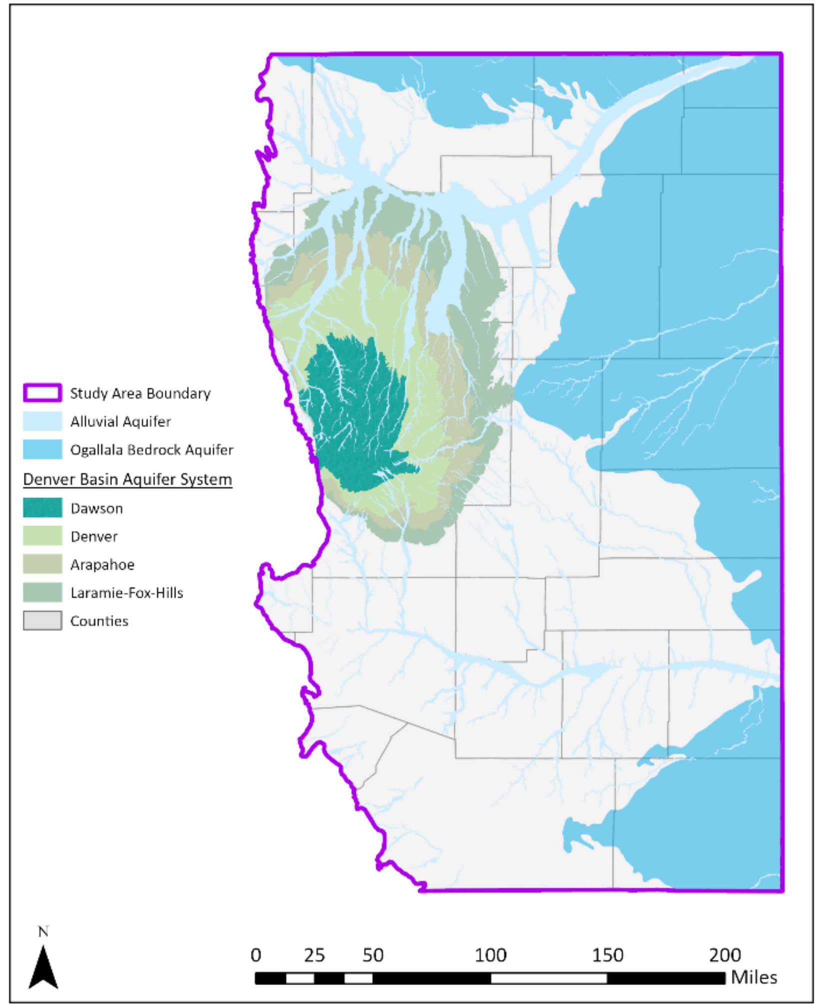

Figure 5. Eastern Colorado drainage networks and major alluvial and bedrock aquifers, including the Denver Basin aquifer system (DWR 2017).

2.5 Geology

Sedimentary rock dominates the study area's bedrock geology, including sandstone, shale, limestone, basalt, and gypsum deposits formed beneath a historic shallow sea that covered the plains of Colorado millions of years ago (SWREGAP 2004, Figure 6). The most common geologic substrate in the study is sandstone which underlies 32% of the study area (Table 2). Unconsolidated Aeolian (wind-blown) sand deposits are the next most common geologic substrate (25% of the study area). These deposits cover much of the Republican basin, portions of the Lower Arkansas basin north of the Arkansas River as well as areas surrounding the South Platte River in the South Platte basin. Shale is the third most common substrate in the study area, underlying nearly 5 million acres or 18% of the study area.

Table 2. Bedrock geology in the TNC Central Shortgrass Prairie Ecoregion of Colorado.

Geologic Substrate	Acres in Study Area	Percent of Study Area
Sandstone	9,155,837	32%
Unconsolidated Aeolian sand deposits	7,129,589	25%
Shale	4,991,287	18%
Carbonate limestone or dolomite	1,934,315	7%
Quaternary age younger alluvium	1,913,725	7%
Quaternary age older alluvium	1,511,371	5%
Siltstone and/or mudstone	1,134,001	4%
Mixed or undetermined	263,037	1%
Metamorphic or igneous	*155,429*	1%
Water	75,697	<1%
Total	**28,264,289**	

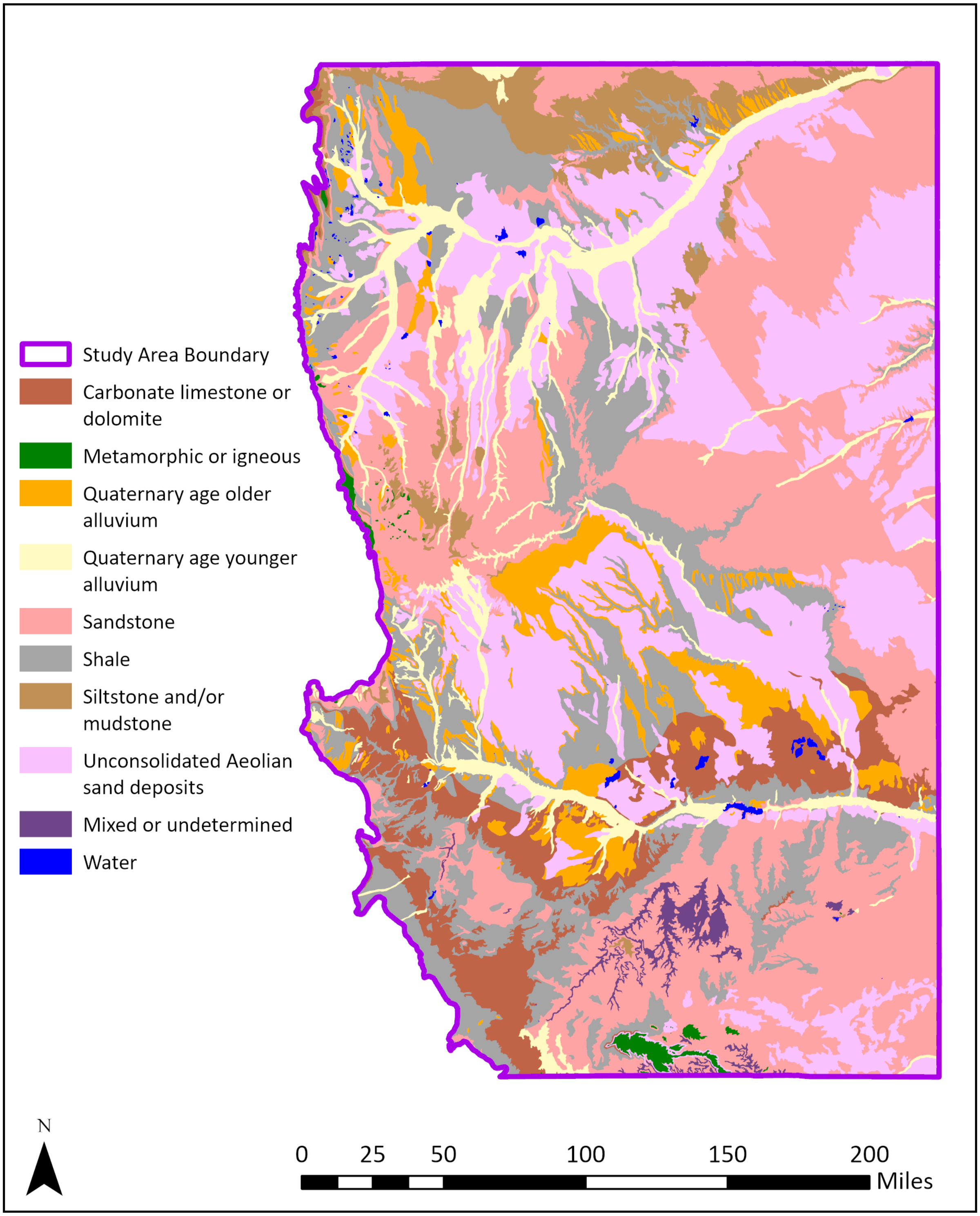

Figure 6. Colorado surface geology in the TNC Central Shortgrass Prairie Ecoregion of Colorado (SWREGAP 2004).

2.6 Land Ownership and Land Use History

Land ownership in the study area is a patchwork of mostly privately owned lands, a mix of smaller federal and state parcels, and local municipalities (Figure 7). Some public entities own larger tracts, such as the USFS Comanche and Pawnee National Grasslands, and several military areas. There are Colorado Parks and Wildlife (CPW) owned State Parks and State Wildlife Areas, ranch-leased State Land Board tracts, and conservation easements on private lands. Multiple landowners are clustered together in some locations to form larger preserved open spaces. The State Land Board also owns a checkerboard of single parcels nested in private land. Cities and counties own smaller parcels, with some owned in higher densities in the Front Range such as in Boulder County. Private lands are either privately owned and managed, or are managed by wildlife agencies, land trusts, and others.

Land use in eastern Colorado has a long history of change and cumulative impacts. Prior to Euro-American settlement in the mid-1800s, the Cheyenne and Arapaho nations and other plains tribes such as the Comanche, Kiowa, Apache, Ute, and others held territories across much of eastern Colorado or traveled to the region for hunting and trade. They hunted bison, used horses, and lived off the land with a nomadic lifestyle. With the 1858 Gold Rush, there was an influx of settlers, and brutal conflict towards Native Americans ensued. Settlement rapidly shifted land use over the next twenty years. Land management became more stationary with agriculture, and hunting and trapping caused major biodiversity loss, especially of beaver and bison. Agriculture soon became a dominant industry, first using water in the floodplains with hand dug ditches in the 1850-70s, then large ditches and canals were developed. In the early 1900s, canals and trans-basin diversions brought water from the west slope of Colorado. In the early settlement, farmers attempted to work many land types and found some areas too alkaline, swampy, or less arable than others. Settlement was encouraged with various success, while the remoteness of the plains was also selected for colonization settlement experiments and a Japanese American internment during World War II (Schemp 2011). Residents along the region's rivers learned the risk of their powerful flood events. Dams were built to protect homes and industry near the rivers and to tame their powerful floods. Agricultural products differed by region and included a major sugar beet industry on the floodplains. Over time, ditching continued to expand, and once center-pivots were used, there was steady irrigation for agriculture and groundwater withdrawal. Pumps and windmills also used water for stock ponds and other uses, lowering the groundwater table from the moderate use in the 1960s and on. The water landscape is now a very different picture than it was in the past, due to these cumulative uses for agricultural and industry.

Current industries are still largely farming and ranching, but others are common. There is Rocky Ford cantaloupe, dryland wheat in the eastern part of the state, center pivot agriculture, ranching, hay production along floodplains, and increasing urban development in the Front Range.

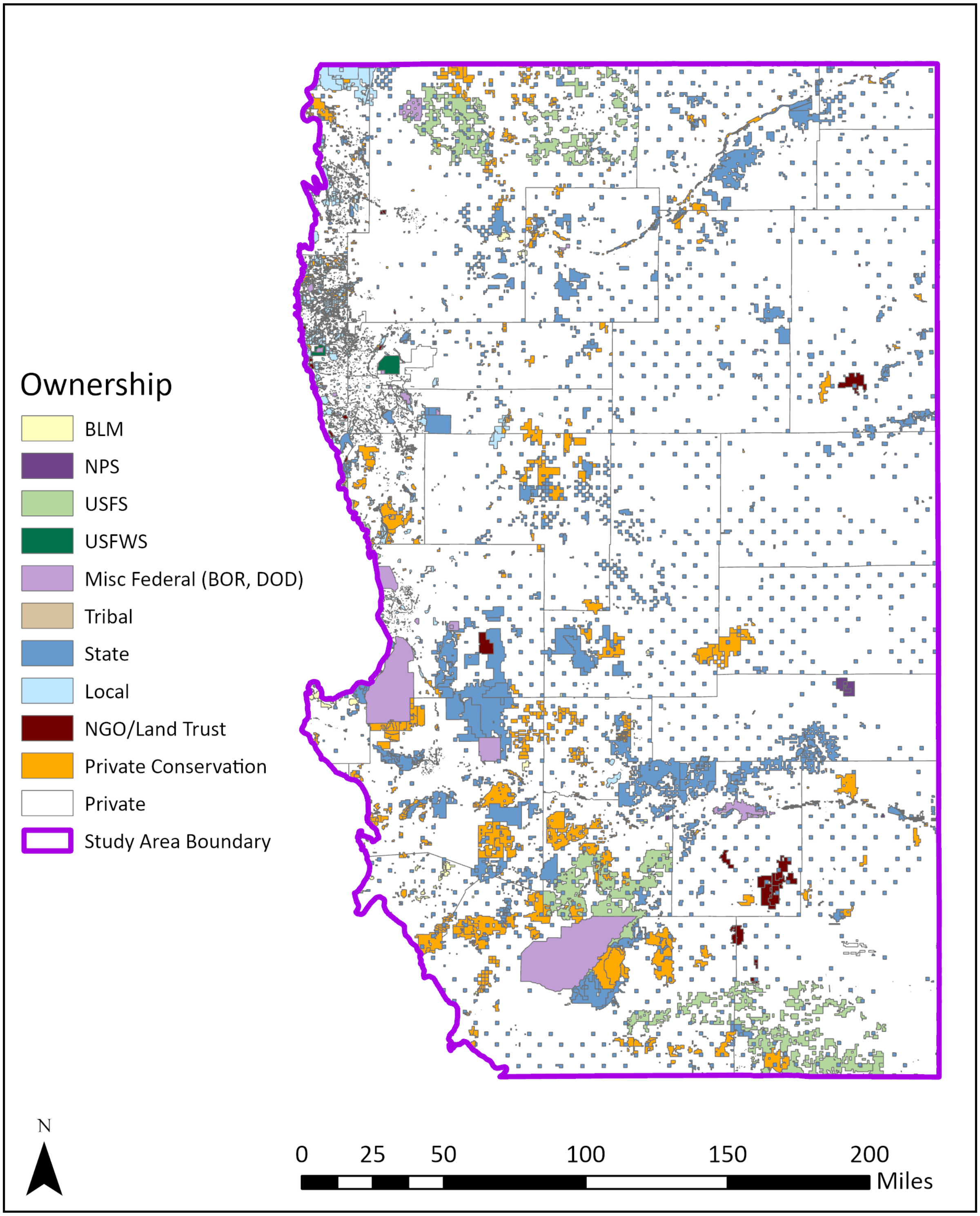

Figure 7. Land ownership in the Colorado Plains Groundwater Dependent Wetland Inventory Study Area

Water is today's gold in eastern Colorado, with agriculture, other industries, and population growth dependent on it. The water is used many times over for municipal and farmland use, oil/gas operations, and even to meet compacts to return water to the river and state line. Farming before the 2000s impounded many of the intermittent streams, and farmers have shared memories of wetter days of flowing ephemeral streams. Many of those impoundments are the only mapped wetlands from the 1970s NWI mapping. These impoundments are not representative of the wetland landscape and are now mostly dry and filled with thistle and cheatgrass as streams lack the flow to surpass the berms. Many saline depressions and playas, a focus of this study, were once described as alkali lakes, and one landowner of a surveyed saline playa site remembered when it was used as an ice-skating rink long ago. There is groundwater pumping, development from urban sprawl, and movement towards Colorado urban areas. Oil and gas extraction creates fragmentation with networks of roads and vegetation transformation, has leaked chemicals and contaminated groundwater (McLaughlin et al. 2016, ECMC 2025), and consumes high volumes of water. There is a newer pulse in solar and wind energy development concentrated in eastern Colorado that can impact surface water runoff and trajectories of groundwater flow along transmission corridors and energy production areas. Review of old aerial photography and topographic maps shows drying trends of ephemeral, intermittent, and groundwater-fed herbaceous wetlands alike throughout the plains.

The long history of dispersed yet intensive land use combined with long-term drought and the occasional intense flood has shaped and transformed the Colorado plains, but patches of native vegetation and high biodiversity remain. Old peatland wetlands can be found in surprising places, in both newly purchased and 5th generation ranches, near railroads that didn't get developed, in Front Range open spaces, in current and former military lands, and in many wildlife areas known for their biodiversity. Some GDEs may have avoided the level of development of their surrounding landscape because of their high saturation. As groundwater is depleted, there is a greater risk of GDE loss and conversion. There are saline depressions that receive crop runoff or direct freshwater irrigation, and many peatlands that have been excavated into ponds. There are stock ponds with windmill pumps dispersed throughout most of the plains, with varying levels of use. Overall, as the development continues and emerging industries continue to fragment the landscape and transfer groundwater, watershed health can be affected, and regulation can take time to catch up and negotiate least-impacts. With that, the need to identify native landscapes, especially GDEs known for their biodiversity refugia, becomes increasingly important for informed conservation stewardship. There are many opportunities for conservation with landowners who hold increasingly rare natural wetlands in their stewardship.

3.0 METHODS

Throughout this study, GDEs are defined as sites that have specific characteristics related to presence of or dependence on groundwater, known as indicators of GDEs. Identifying actual groundwater-dependence and groundwater sources is a time-consuming process that requires site knowledge and more in-depth hydrologic study than surveyed in this project. A study of groundwater-dependent wetlands in California (Klausmeyer et al. 2018) uses the term iGDEs for indicators of GDEs to clarify the difference between sites with indicators of GDEs and sites with known groundwater-dependence. This study is also GDE-indicator based but uses the term GDEs to align with the USFS GDE Protocol that includes 'likely' GDE wetlands. This study focuses on mapping, inventory, and findings from sites with GDE indicators detectable from aerial imagery and a single-day ocular survey but does not confirm if the site is certainly groundwater-dependent.

3.1 Mapping Plains Groundwater-Dependent Wetlands

One primary objective of this study was to map GDEs in targeted USGS topographic quadrangles through aerial photo interpretation. In aerial photography, GDEs can be identified by mottled brownish-green colors, rather than the bright green colors of more surface water-fed and dynamic wetland systems. GDEs may be saturated, may contain small pools of surface water, or may be located on the margin of ponds or small lakes. They are often located at the headwaters of small streams and have distinctive edges that mirror the contours of the local topography.

Preliminary GDE Hotspot Mapping

The Colorado eastern plains region was mapped by the USFWS NWI program in the 1970s at coarse resolution and many wetland features were not included in the mapping. Only a few areas around the cities of Aurora, Boulder, and Denver have updated wetland mapping (USFWS Wetlands Mapper 2025). To conduct a successful GDE field assessment, to rapidly identify areas of high-density or "hotspots" of GDEs, and to understand the variety of GDE wetland types, we conducted a rapid mapping effort across the entire study area in advance of more detailed mapping. The rapid mapping was conducted over one week and used a desktop analysis of World Imagery from Environmental Systems Research Institute (ESRI) in a wet year together with Google Earth imagery in a dry year. Imagery was reviewed by county at a 1:50,000 scale and ovals were drawn around the length and width of wetted or saturated GDE wetlands.

Factors included in determining hotspot wetlands:

- Saturated or increasingly wet gradient into open water pools or creeks in dry year.
- Landscape position that supports GDEs.
- Aerials color and tone: intermixed brown and lighter green or deep saturated forest green.
- Pattern of dark green or brown circular splotching indicating seeps.
- Light colored bluffs with dark green at the slope break.
- White mineral concentrations adjacent to darker green wetland saturation.
- Where intermittent stream daylights into creek from a dry upstream drainage.

- Where creeks lose their single channel and have a rougher riparian area margin with high open water and wetland vegetation interspersion.
- Wetland features on USGS topo maps like springs or terminal basins, NHD seep data, and place names indicating groundwater or muck such as 'spring creek' or 'black water.' These considerations were used as secondary indicators.

In the Front Range, hotspot mapping was more difficult due to extensive ditching and land-use that confounds the ability to rapidly identify groundwater-dependent wetlands with high confidence, so those polygons have more variability in our confidence. More GDEs may have been unmapped in the Front Range region as we avoided drawing hotspots in locations in areas with high density of surface water and agriculture that obscured the dominant water sources. If an area had distinct wetness and the right topographic position, but ditching or other secondary water sources like center pivot irrigation was extensive, older Google Earth aerials or historical aerial imagery (historicalaerials.com) was reviewed. Historical aerial imagery revealed that some wetlands that appeared to be driven by irrigation due to extensive ditching, likely existed as natural slope wetlands prior to water development. In other areas, groundwater-fed wetlands persisted below ditches despite drying above, or diversion of a spring-fed drainage into a pond or field had some return flow back to the GDE wetland that supported the GDE site hydrology. Ditches contributed to sustaining GDE hydrology, cut off water source to downslope wetland, and created wetlands in uplands or different wetland types. Wetland types were mapped with the hotspot mapping if the historical imagery review suggested a likely dominant groundwater source, even if other sources were present.

The rapid mapping effort identified many wetland complexes that were not mapped by NWI. Although the hotspot mapping was not initially intended as a deliverable for the project, it is included in the report and associated datasets to help other wetland stakeholders identify areas with high GDE concentrations. While the GDE hotspot mapping covers the study area, and the coarse ovals used to map the GDEs cover the general area of wetlands observed, the mapping does not comprehensively map every GDE wetland visible at 1:50k and the polygons include both upland and wetland. The size and length of the ovals varied depending on the hydrology of the area, so we do not recommend using these mapped areas to determine wetland acreage or size, rather to use the hotspot mapping as a data source for potential GDE wetlands, particularly areas with clusters of GDE wetlands.

Detailed GDE Mapping

The GDE hotspot map was used to identify USGS topographic quadrangles with the highest concentration of GDE for detailed GDE mapping. In two GDE mapping areas, only half quads were mapped. The quadrangles and half quadrangles selected for detailed GDE mapping included: Lewis Ranch, Kinney Lake, Greenland, Carr West, Battle Canyon, Falcon, Bar J H Ranch, Meredith Hill, Hygiene (W half), Round Butte, Peace Valley, Eastonville, Sanborn Reservoir, Kutch SE, Lyons (E half), and Dipper Spring.

Potential GDE in each quad and half quad were identified through interpretations of digital aerial photography and topographic maps and hand-drawn in ArcGIS 10.8 based on the best estimation of GDE wetland boundaries. True color aerial photography taken by the National Agricultural Imagery

Program (NAIP) in 2005, 2009, 2011, 2015, 2019, 2021 and 2023 was used in conjunction with color-infrared imagery from 2015, 2019, 2021 and 2023. High (but variable) resolution ESRI World Imagery was also used. To focus the initial search, where possible, all wetland polygons mapped by NWI in the 1970s with a "B" (seasonally saturated) or "D" (continuously saturated) hydrologic regime were isolated from the full NWI dataset and examined. Each potential GDE wetland polygon was attributed with a confidence value of 1 (low confidence GDE), 3 (possible GDE), or 5 (likely GDE) (Table 3). Each GDE location for the purposes of this report is a single potential GDE wetland polygon. Potential GDE wetland polygons of different confidence levels may be adjacent or nested within each other and together represent a larger groundwater dependent complex.

Table 3. Description of potential GDE confidence levels.

Confidence	Description
5	***Likely GDE.*** Strong photo signature of continuously saturated wetland vegetation, continuously saturated hydrology, and good landscape position.
3	***Possible GDE.*** Some continuously saturated hydrologic indicators present (vegetation signature, topographic position, ponding or visibly saturated substrate), but not all indicators present. Some may be weak or missing.
1	***Low confidence GDE.*** At least one continuously saturated indicator present, but weak.

In addition to existing NWI mapping, several auxiliary datasets were also used to identify potential GDE wetlands. Those included spring locations from the National Hydrography Dataset (NHD), field data from this project and previous CNHP wetland assessment survey efforts. Most of the mapping occurred after the field surveys and a preliminary rapid mapping effort to identify the field sites, so the maximum available data resources were used from this region.

3.2 Site Selection for Field Sampling

Target wetland sites were selected for field sampling using the basemap of GDE hotspots created with this study, plus additional desktop review of aerial imagery, topographical maps, NWI mapping, and NHD mapped seep/springs. Additional input was provided by a stakeholder group during the project planning phase. Pilot sites for 2021 surveys were selected from stakeholder suggestions of known groundwater-dependent wetlands by managers from the City of Fort Collins, Colorado Parks and Wildlife, the State Land Board, and Boulder County Parks and Open Space.

The 2022 target site list included revisits of the 2021 pilot sites plus the desktop-identified sites that were prioritized with the goal of improving the spatial distribution of groundwater-dependent wetlands in CNHP's plots database. This study focused on three of the least understood plains GDE wetland types: saline playas, groundwater fed wet meadow-marsh complexes, and peat-accumulating wetlands of any physiognomy. Saturated woody wetlands were also targeted with fewer sites, as they are relatively more surveyed. The sample design prioritized wetlands for survey located in denser hotspots of GDEs, in geomorphic positions more likely to have obligate GDEs, that had signs of saturation in dry years, and that could be accessed and surveyed in a single day. Rush Creek is an example of a target GDE site (Figure 8). Public ownership also became a priority through the outreach process, as establishing survey permissions for private sites was challenging.

Figure 8. Riparian wetland along Rush Creek and a wet meadow with aerial imagery indicators of groundwater expression, including white-color mineral deposits, intermixed green and brown saturated colors, slope break topographic position and bluffs, dry year wetted drainage with pools.

Ditches were pervasive across the study area and overlapped with potential GDEs, so sites near ditches were included but assessed more closely for GDE indicators. Sites near large canals were generally avoided unless historical imagery suggested a natural groundwater source. Areas influenced by irrigation (e.g., center pivots, pond seepage) were lower survey priority but some were mapped as hotspots if saturation aligned with natural groundwater patterns. Ease of landowner and/or manager site access approval shaped the final sites selected for survey. Some other GDE wetland types were low priority including warm water sloughs, which CNHP targeted in the Lower South Platte basin surveys from 2012-2013 (Lemly et al. 2014); large saline reservoirs that may have historically been saline playas, such as the Great Plains Reservoirs and Terry Lake, because these receive major water inputs from ditches and canals; and moist soil units because of their surface water hydrology management (although some of these are located in areas of groundwater seepage and natural GDE floodplains). Warm water sloughs are a component of the drainage networks within saturated floodplains, so if they were a small component of a target saturated herbaceous wetland, they were not avoided. Beaver wetlands visible on aerials were also avoided due to surface water.

The target wetland sites were in various watershed positions, from outer watershed saline depressions and slope headwater wetlands, to slow draining headwater or gaining riparian wetlands and narrow to larger creek floodplains, to central watershed outer floodplain locations. Target plots were in small wetlands to large wetland complexes with drainage networks many kilometers long. We sought wetlands with the range of landscape positions, land uses, and conditions in the target wetland types that were visible on aerial imagery. While we did not avoid low condition wetlands, prioritizing GDEs with higher confidence of groundwater source dominance often oriented the sample frame to sites with fewer landscape alterations, and so had some effect on the range of potential GDE wetland conditions sampled.

3.3 Field Methods

Assessment Area (AA) Establishment

In the field, assessment areas (AAs) were established within target wetlands and represented the portion of the wetland where data collection was concentrated. The field crew used GPS points to navigate to target field locations. The target location was inventoried for GDE site characteristics using a checklist while referencing aerial imagery maps. If GDE indicators were confirmed, the AA was established or if not, moved to a nearby location with more evident GDE indicators. Crews searched for the following indicators of groundwater expression: quaking and/or visible organic soil, deep green vegetation signature in aerial imagery, organic sheen, seeps, springs, and groundwater-dependent wetland plants. AAs typically targeted the most saturated areas of larger wetland complexes. They also placed the AA in a location likely to achieve the target plot size of approximately 0.5 ha (5000 m^2) based on a standard plot 40-m radius circle used in many CNHP wetland condition assessment studies, but AAs could vary in size and shape to fit the wetland as long as the wetland was at least 0.1 ha (1000 m^2) and at least 10 m wide. AA shapes included circles (n=21), rectangles (n=9), and free-form polygons (n=21) along drainages or narrower wetlands. The AA placement optimized the balance of the least amount of plot edge with the majority of plot in the wetter section of the wetland, and aimed for diversity of the common GDE vegetation patch types and hydrology zonation. However, AAs might not always represent the most saturated part of the GDE if the wettest area was small or challenging to sample with the rest of the larger wetland. Also, an AA could include variable patch types such as a fen patch, an area with peat accumulation of <40 cm, and a seasonally saturated wetland edge to capture the vegetation zones and site variation. The AA boundary did not necessarily represent the wetland boundary, but some AAs were located at a wetland edge.

Data Collection Overview

The Ecological Integrity Assessment (EIA) method (Lemly et al. 2016) with vegetation surveys was used to assess the condition of each AA in this study. Field forms for the EIA are included in Appendix A. Vegetation data were collected with a mix of walk-through relevés (Level 2, n=38) and in-depth vegetation plots (Level 3, n=13). The two methods were used to maximize the number of sites sampled while collecting more in-depth data on the vegetation communities in some sites. In non-circle vegetation plot layout, five 10 x 10 m vegetation plots were spaced evenly across the AA. Additionally, Colorado Parks & Wildlife Leopard Frog Scorecards (CPW 2016) were used to rate leopard frog habitat in all AAs except for saline depressions. In-depth biological inventory data on herpetofauna and invertebrates were taken from a subset of AAs, including both pilot sites and additional Level 3 sites surveyed in 2022.

The following data were collected in either all AAs or as additional biotic data taken in Level 3 Plots:

- UTM coordinates and photo points taken at four locations on the perimeter of the AA
- Elevation and slope determined from GIS data layers unless slope was visible, then rated in the field
- Checklist of GDE indicators
- Ecological System classification
- HGM classification
- Cowardin classification
- Description of general site characteristics and a site drawing
- Vegetation species list in either Level 2 or Level 3:
    - Level 2: Plants observed with a site walk-through relevé with cover classes estimated at the AA-level, or
    - Level 3: Species list of every plant observed in four 10x10 m vegetation plots, new species observed in a 5th 'residual' 10x10 plot, and additional common or unique species observed while conducting the EIA
- Herpetofauna search in Level 3 sites
- Invertebrate sweeps in Level 3 sites (Appendix B)
- Incidental wildlife observations
- Description of soil profile in 1-3 soil pits
- Water quality parameters (pH, temperature, and electrical conductivity/EC)
- Land ownership notes when known in field

Amphibian and Invertebrate Surveys

Amphibian surveys consisted of visual searches for frogs and tadpoles during slow walks along the edges of ponds and other water bodies by herpetologists. The primary species of interest for the amphibian surveys were the state Tier 1 species of conservation concern (CPW 2015) northern leopard frog (*Lithobates pipiens*) and the state Tier 2 species of conservation concern plains leopard frog (*Lithobates blairi*). However, all amphibians and reptiles encountered during wetland surveys were recorded.

Due to concerns over the amphibian chytrid fungus disease, chytrid fungus testing was incorporated into the amphibian surveys. The pathogenic chytrid fungus (*Batrachochytrium dendrobatidis*) has been implicated in amphibian declines around the world (Daszak et al. 2003) and has been documented in Colorado populations of leopard frogs. Amphibians encountered during the surveys were targeted for temporary capture and wearing fresh gloves were swabbed for chytrid fungus using swab kits provided by Pisces Molecular in Boulder, Colorado, then frogs were immediately released. The samples were then sent to Pisces Molecular for analysis. Waders and equipment were sterilized between sites with a 10% bleach solution to help stop the accidental introduction or spread of disease or pathogens.

Invertebrate surveys were collected to improve baseline datasets to inform water quality research in vegetated wetlands in the Colorado eastern plains. CNHP received funds from Wild Earth Guardians for this work and is reported on separately in Appendix B. The invertebrate data collection effort took place in Level 3 wetland sites with surface water. At each site, three sweep locations were collected and combined into a single sample. Wetlands in this region are relatively under-sampled for invertebrates, and baseline data such as taxonomic lists from these sites can be used for research in the plains region on wetland invertebrates as indicators of plains GDE biological integrity (IBIs) and water quality.

Non-herpetological surveys also consisted of incidental wildlife observations made during wetland condition assessments. Incidental wildlife observations were recorded by all wetland field staff, as they were observed and included reptiles, amphibians, birds, fish, invertebrates, and beaver evidence (*Castor canadensis)* at the survey locations. When possible, photographs were taken of incidental wildlife observations to assist with identification.

Ecological Integrity Assessment (EIA)

The Ecological Integrity Assessment (EIA) framework was developed by NatureServe (Faber-Langendoen et al. 2006; Faber-Langendoen et al. 2008) and modified by the Colorado Natural Heritage Program (Lemly et al. 2016). The EIA framework evaluates wetland condition based on biotic and abiotic categories including landscape context, vegetation condition, hydrologic condition, and physiochemical condition (Table 4). Each category contains three to six metrics (see description below), which are used to evaluate how far the wetland deviates from reference condition (i.e., before human disturbance). Both qualitative and quantitative criteria are used to score each metric. The metric scores are then rolled up into a category score, and category scores are rolled up into an overall EIA score and rank. Possible scores range from 1.0 to 5.0[2], and can be given alphabetic ranks of A, B, C or D, which correspond to different levels of alteration and represent different management opportunities.

The EIA protocols were developed for Colorado wetland types CNHP with funding from EPA Region 8 and Colorado Parks and Wildlife (Lemly and Rocchio 2009; Lemly et al. 2011; Lemly and Gilligan 2013; Lemly et al. 2016). Initial testing was based on montane and higher elevation wetland types, and while 2016 updates included some Colorado plains wetland types, the protocols were not tested on groundwater-dependent plains wetlands. This study explored potential adjustments to the EIA protocol about key ecological processes in groundwater dependent wetlands. These trial protocols were sourced from other GDE assessments and state EIAs and were aimed at refining the assessment of plains groundwater dependent wetlands using the existing Colorado and National EIA framework, and are not groundwater-specific wetland assessment protocols, such as the USFS GDE Inventory protocol (USFS 2012; USFS 2022.).
The EIA method can be used at varying levels of intensity. For this study, the EIA method was used

[2] The 5 point scale scoring method described in Field Manual Version 1.0 (Lemly and Gilligan 2013) was used for this project instead of the 4 point scale described in Field Manual Version 2.1 (Lemly et al. 2016). The 5-point scale was used to provide consistency with the scoring method used in all CNHP wetland assessments except the Arkansas basin, and because the 4-point scale can result in few 'D' wetlands even in sites with multiple poor condition individual metrics.

at both the rapid (Level 2) and in-depth (Level 3) levels to evaluate the general condition of wetlands. The field portion of the EIA took approximately 2–4 hours, and additional ecology data including soil pits, amphibian surveys, and invertebrate sampling resulted in many sites taking a full day to conduct the assessment. Field crews spent about an hour to establish the AA, walking through the wetland complex to confirm GDE indicators and a suitable plot location. Many of the GDEs were in drainage networks with a variety of hydrology sources that fluctuate throughout the drainage length and width with changing topography, soil texture and aquifer access, land use, and surface flow patterns. In addition, a substantial amount of time was spent on data entry, quality checking, analysis, and interpretation of the results. A Level 3 EIA can take a full day to record all the vegetation in the plots, depending on site diversity.

Table 4. Ecological Integrity Assessment metrics used to evaluate wetland condition (Lemly et al. 2016).

Rank Factor	*Major Ecological Factor*	*Metric*
Landscape Context **Weight = 0.3**	Landscape Weight = 0.33	Contiguous natural land cover, land use index
	Buffer Weight = 0.67	Perimeter with natural buffer, width of natural buffer, condition of natural buffer
Condition **Weight = 0.7**	Vegetation Weight = 0.55	Native plant species cover, invasive non-native species cover, native plant species composition, vegetation structure, regeneration of woody species, coarse and fine woody debris
	Hydrology Weight = 0.35	Water source, hydroperiod, hydrologic connectivity
	Physiochemistry Weight = 0.10	Soil/substrate disturbance, surface water turbitidy/pollutants, algal growth

Landscape Context Metrics

The Landscape Context scores were based on qualitative and quantitative metrics that reflect the quality of the landscape that surrounds the AA, including fragmentation, buffer size and buffer condition.

Condition Metrics

Vegetation Condition

Vegetation condition scores were based on the plant species data with additional information on the community structure and regeneration. Out of the ecological categories used to generate EIA scores, the Vegetation Condition category was assigned the highest weight (Lemly et al. 2016). This was due to our high confidence in assessing plant species composition and structure.

Nested within the Vegetation Condition assessment is the Floristic Quality Assessment (FQA) which allows for the calculation of various indices that reflect the quality of the vegetation from the species list and cover data collected. The FQA method uses the proportion of conservative plant species in a plant community to assess the degree of "naturalness" of an area (Swink and Wilhelm 1994; Wilhelm and Masters 1996). In the FQA method, every plant species in a state or regional flora is assigned a Coefficient of Conservatism, or C-value. 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 5). 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. In Colorado, C-values of 0 are reserved for non-native species. C-values for Colorado plant species were assigned by a panel of botanical experts (Rocchio 2007) and updated by additional reviewer input (Smith et al. 2020).[3]

Table 5. C-value ranges and associated interpretation.

C-Value	*Interpretation*
0	Non-native 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 – no evidence species occurs outside high quality natural areas.

Several metrics can be calculated based on the C-values of all species within a site. The most basic FQA index is Mean C, a simple average of C-values for a given site. For the Aurora sites, the Mean C as well as the Mean Native C, the average C-value for just the native plant species, were calculated. This study follows the 2020 FQA (Smith et al. 2020) native status and C-values. In the 2020 FQA, narrowleaf cattail (*Typha angustifolia*), hybrid cattail (*Typha* x *glauca*), and reed canarygrass (*Phalaris arundinacea*), are considered cryptogenic species. Cryptogenic species include taxa with both native and non-native varieties and where the non-native variety is often invasive (Magee et al. 2019). Therefore, cryptogenic species were treated as non-native vegetation cover and composition in EIA vegetation metrics. This treatment differs from the methodology of Lemly et al. (2016). Plant species evaluated in the invasive non-native vegetation metric included both species from the state noxious weed list following Lemly et al. (2016), and the above listed cryptogenic species.

Hydrologic Condition

Hydrologic condition scores are based on the water source (e.g., ground water, surface water, runoff), connectivity to other wetlands, and non-natural alterations to the hydroperiod. Water sources and other aspects of hydrology are difficult to determine in densely urbanized developments. Therefore, a lower weight was used to calculate the Hydrologic Condition score (Lemly et al. 2016).

[3] C-values for Colorado plant species are available on the CNHP website https://cnhp.colostate.edu/cwic/tools/calculator/.

Physiochemical Condition

Physiochemical condition scores are calculated based on both water quality and the soil disturbances within the AA. The physiochemical condition was assigned the lowest weight of all the ecological categories. Water quality is difficult to determine solely from a single field observation and requires repeated observations and chemical sampling over time. The metric for this study was not meant to replicate that type of effort. However, there are some obvious indicators of water quality that can be observed or inferred. Other observations include hydric soil presence, soil compaction or sedimentation, excessive algal growth, and water turbidity.

Overall EIA Score

Data collected in the field and supporting evidence of condition gleaned from aerial photography imagery and wetland mapping were used to rate each EIA metric. To calculate the overall EIA scores, subscores were first calculated for the categories based on their component metrics. The formulas and weights for each metric and category are provided in Appendix C. The metric categories were then weighted and combined to generate an overall numeric EIA score and an accompanying EIA rank. The weights for each category are based on the relative importance of each category to the overall score. EIA ranks are summarized in Table 6.

Table 6. Definition of overall Ecological Integrity Assessment ranks.

Rank and score	*Description*
A: **>4.5 to 5.0**	**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, non-native 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: **>3.5 to 4.5**	**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, non-native species and noxious weeds are present in minor amounts, and most key species are present; soils properties and hydrology are only slightly altered. Management should focus on the prevention of further alteration.
C: **>2.5 to 3.5**	**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, non-native 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: **1.0 to 2.5**	**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, non-native species and noxious weeds exert a strong negative impact, and most key species are absent; soil properties and hydrology are severely altered. There may be little long term conservation value without restoration, and such restoration may be difficult or uncertain.

Stressors

Four categories of stressors (landscape, vegetation, hydrological and physiochemical) were scored corresponding to four ecological categories that comprise the EIA score (Landscape Context, Vegetation Condition, Hydrologic Condition and Physiochemical Condition, respectively). Each stressor was assigned an intensity of 1 – 4, with 1=mild, 2=moderate, 3=major, and 4=severe, based on the cover and location of the area affected and the intensity of the stressor in relation to estimated role that stressor plays in watershed or wetland health. This method is a shift from past CNHP EIA studies that rated scope as a standard cumulative rating of percent cover of the AA or buffer and stressor severity into a cumulative stress score. The purpose of the change was to better reflect the impact of the stressor on the wetland or watershed conditions. The impact of some stressors can be related to area, such as severe grazing impacts that are worse if present throughout the wetland rather than a few eroded locations. However, some stressors are not related to stressor area, such as a groundwater well nearby. Another goal of the 1-4 rank was to determine which stressors comparatively had the most impact on wetland health, and this approach was simpler to conceptualize in data collection with a 4-point scale. All stressors were evaluated within a 500m envelope zone surrounding the AA, and within the AA itself. Hydrology stressors were also evaluated further upstream, up to ~2 km, if stressors were visible that significantly affected AA's hydrology, such as a large reservoir. The landscape, soil, and hydrological stressors were estimated from satellite imagery and GIS layers and were field verified to the extent possible from within the wetland and during travel to the wetland. Physiochemical stressors were rated based on both imagery and from site visits. Vegetation composition such as weed cover was more heavily informed by vantage points within and near the field sites than aerials, but some vegetation types such as cattail were identified in aerials.

Groundwater-Dependent Wetland EIA Method Refinement

Following review of several Natural Heritage Program Wetland Assessment Methods (Rocchio et al. 2024), and the United States Forest Service Groundwater Dependent Ecosystems Protocol (USFS 2012; USFS 2022), we added several metrics to trial in the 2022 GDE EIA surveys. Keeping the EIA protocol aligned with the existing EIA structure, the goal was to capture the key drivers of ecological condition with consistency and accuracy in plains GDE wetlands. Additional guidance will be added to the updated EIA field manual to detail changes.

Metrics Added or Changed:

- GDE Indicator Checklist: Shallow surface water (secondary), surface saturation in dry period, organic sheen, organic soil layers and # cm, floating or quaking substrate, muck, baseflow woody riparian stream, diffuse groundwater discharge, seep/spring, gaining stream, groundwater discharge in stream (visible), wetland in localized headwater location, GDE phreatophytes and species listed, sphagnum and other moss and percent, marl, travertine, topography – slope break/stratigraphy change, permanent pools (secondary), refuge pools, and option to populate other indicators observed.
- Stressor List: Rate each stressor for both wetland AA and for 500m envelope, updated stressor list, separation of light grazing, grouping of moderate and heavy grazing impacts, list changed 4 point stressor rating of wetland health impact as 1-slight/2-moderate/3-major/4-severe impact by stressor.

- Management Comments Notes Field.
- Added Landscape Metric on Riparian Corridor Continuity (in riparian) or Contributing Watershed Connectivity (in non-riparian) to also evaluate contributing watershed to wetland up to 2k upstream or upslope, and average with Contiguous Landscape Metric.
- Water source questions on if wetland showed signs of drying.
- Hydrologic connectivity question on if there are differences in connectivity between AA edge and wetland edge and why.

We provided basic guidance in field training on field form edits. Changes were added to identify types and indicators of plains GDEs, to detect drying trends and their influence on plains GDE wetlands, and to add more guidance to the stressor list for a simpler approach and consistent application. Post-field season data review indicated more specific guidance was needed for indicators of hydrology drying and soil alteration metrics, and for grazing impacts. Areas that needed refinement were particularly regarding groundwater hydrology and soils, including:

- Water source: Rating includes both water additions and sources, and subtractions to the natural water source. Per Washington Natural Heritage Program's Online EIA training, 'Natural inflows are important for a wetland's ability to persist, it affects the sediment processes and the physical structure of the wetland, and it maintains 'natural' water chemistry'.
- Hydroperiod: Broader focus than drainage on pugging: moderate pugging by livestock that could consolidate, channelize, or prevent water movement through the site and substrate.
- Hydrologic connectivity: Includes signs of horizontal water movement within AA and into buffer. Drainage is not only at the exact AA boundary (except perhaps in randomized survey) but it's ability to move out. Excess hydrologic connection is also a negative factor in wet meadows and fens, and a fen variant is needed.
- Soil disturbance metric needs guidance on signs of likelihood of recovery such as degradation of side-faces of pugs by steepness and degree of vegetation, and differential in wetness from bottom to top of pug.
- Soil pit section should have checkbox on soil profile signs of alteration including soil mineral-organic mixing, depth of mixing, or other signs.

Overall, the hydroperiod and soil metrics are often interconnected, and crews can be hesitant to rate multiple metrics poorly in a category. More guidance is needed on how each metric may be correlated, and where a stressor only affects one hydrology metric versus affects each metric in different ways. For trial metrics, the added questions in the notes column were not consistently populated, so any future trial metrics should include primary assessment checkboxes, as done in the contributing watershed metric addition.

3.4 Natural Heritage Methodology Conservation Ranking

One of CNHP's core research activities is managing a statewide database that details the locations of rare and imperiled species and natural plant communities in Colorado. The data are compiled and managed in Biodiversity Information Management System (CNHP 2025), a web-enabled database platform hosted by NatureServe. The species and natural plant communities CNHP tracks are assigned global and state imperilment ranks based on rarity, threats, and trends, and mapped data from element occurrences (see Appendix D for detail on Natural Heritage Methodology). Element occurrences include spatial data as well as details on condition, size, and landscape context, and they inform the state's understanding of what biodiversity elements are imperiled.

Species data from this study were compared with a list of CNHP-tracked rare species and plant communities generated by the June 2025 CNHP tracking list and are reported on to document the relationship between GDE wetlands and imperiled biodiversity.

3.5 Analysis of Previously Sampled Plots

We reviewed 447 wetland EIA surveys from the past seven regional wetland studies with EIAs (Figure 9) (Lemly et al. 2013, Lemly et al 2014, Smith and Kuhn 2015, Lemly et al. 2015, Lemly et al. 2017, Gilligan et al. 2020, Peak Ecological Services et al. 2021, Orthner et al. 2021) to identify additional data for analysis of high confidence groundwater-dependent wetlands within this project's study area. From all 447 plots, data from 433 soil pits (0-3 pits/plot) were reviewed to identify high confidence GDEs. In addition, the Boulder County Parks and Open Space wet meadow study (Peak Ecological Services et al. 2021, Orthner et al. 2021) did not include standardized soil pit data but did include notes on soil conditions and measurements of organic soil depth in some sites with suspected organic soil. Strong GDE indicators from the plots review included histic epipedon or deeper organic soils (≥20 cm organic soil). Secondary indicators included shallower peat, surface saturation, mucky mineral, salts crusts and halophytes, and mention of organic content in mineral horizons. Seventy-one sites in this soil review had at least one soil pit with one or more indicators.

We then reviewed the vegetation within the 447 plots and searched for wet meadows, fens and saline depressions, and also high-fidelity plains GDE indicator plant species including: *Scutellaria* spp., *Lobelia* spp, *Triglochin* spp, *Calamagrostis* spp., *Viola sororia (*now *V. nephrophylla), Carex aurea, Carex hystericina, Carex utriculata,* Gentianaceae*, Muhlenbergia filiformis, Dichanthelium acuminatum, Erythranthe* spp., *Sisrynchium* spp, *Valeriana edulis,* and also *Carex nebrascensis* where it was a site dominant. Plains floodplain sites with deep peat, including several warm water sloughs and outer floodplain wet meadows were included in the review, but most potential GDE floodplain sites were excluded due to evidence of potential surface flow dominance or inclusion of large areas of non-GDE floodplain in those survey plots. Most of the Boulder County wet meadows and peat-accumulating wetlands had groundwater as a component water source, and thus those were mostly GDEs, but soil pits were only dug in sites with high probability of organic content. In addition, many Boulder County landscapes had impoundments or irrigation, and only higher confidence GDEs were retained as plots.

A total of 58 GDE EIA and vegetation plots data from other studies were incorporated into the wetland characteristics and vegetation report sections with 16 sites included from the Boulder County plots, and additional 42 from previous CNHP studies. The quantitative data from GDE plots reported in this study, such as percents of project AAs with site attributes like soil or water chemistry characteristics, did not include the 58 additional plots due to differences in study designs across the project years. This GDE study focused on the GDE-areas of wetland complexes, whereas the other EIA studies focused on plots that included any contiguous wetland of one type, regardless of water source. Several Denver project marsh plots also had GDE indicators, such as Bluff Lake, but GDE dominance from these urban plots was unclear due to hydrology controls and impoundments, so these were not included in the analysis.

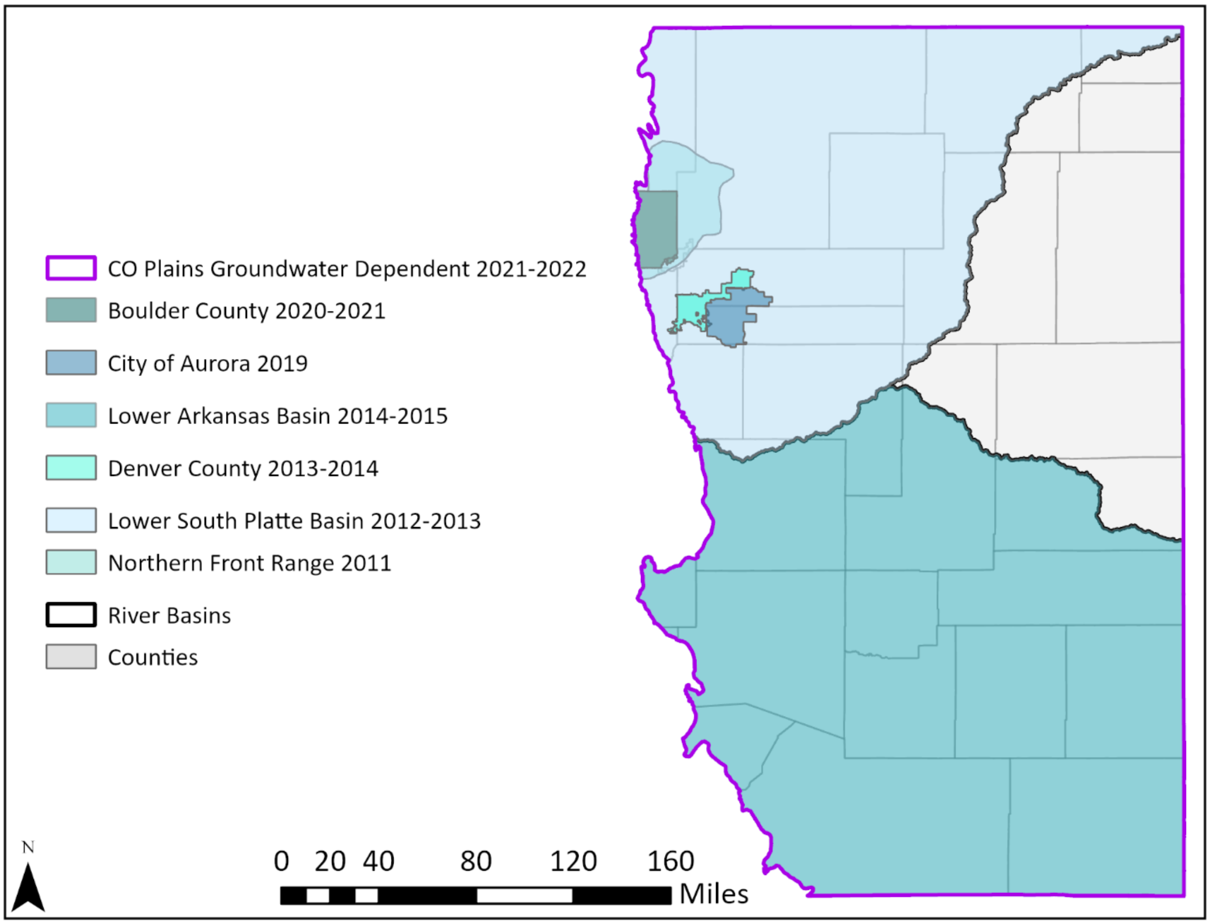

Figure 9. CNHP Regional Wetland Assessment Study Areas of the Colorado Plains 2011-2022.

3.6 Data Management

Wetland EIA and vegetation data were entered into an EIA Microsoft Access database used for CNHP EIA projects at the completion of the 2021 pilot field season. CNHP is currently transitioning the previous EIA data to a geospatial database. This created some additional work in project data management of 2022 data, and data are currently in Microsoft Excel spreadsheets stored on the CNHP network and backup locations. All plots from this GDE study's survey data, plus data from 92 wet meadow or GDE plots from Boulder County Parks and Open Space 2020-2021 surveys (some which were a product of this study's in-kind match) will be uploaded into the CNHP Wetlands Plots Database on CWIC when the geospatial formatting work is complete, expected in the fall of 2025.

The BIOTICS pre-defined species list was used for plant species entry, which follows Ackerfield 2015, except for select species related to the CNHP tracking list that are not recognized as species in

Ackerfield. A species table from the Colorado FQA was used to populate native status, wetland indicator status, and C-values. Names were cross-referenced to the nationally accepted names in the U.S. Department of Agriculture's PLANTS Database for Wetland Indicator Status assignments[4]. During data entry, unknown or ambiguous species (e.g., *Carex* spp.) were entered into the database but only included in data analysis if analysis attributes were known. Rare plant specimens collected during the project will be deposited at Colorado State University Herbarium (CSU).

Results from chytrid testing conducted as part of the amphibian surveys are presented in the results section of this report and were submitted to Colorado Parks and Wildlife as part of our permit requirements. GDE mapping will be uploaded into CWIC's wetland mapper during the next iteration of Wetland Mapper web uploads in the fall of 2025. Geospatial GDE mapping files are available in downloadable format upon request by contacting the Colorado Natural Heritage Program. Updates to the EIA Manual detailed in this study will be included in the next version of the EIA manual.

[4] PLANTS National Database can be accessed at the following website: http://plants.usda.gov.

4.0 RESULTS

4.1 Mapped Groundwater-Dependent Wetlands

GDE Wetland Hotspots

The GDE hotspot map was created because a coarse map of groundwater-dependent wetlands was needed to prioritize more detailed GDE mapping and to identify GDE survey sites. The hotspot map identified many groundwater-dependent wetlands throughout the study area (Figure 10). The highest concentrations of groundwater-dependent wetlands were detected in three areas: 1) the central study area at the boundary of the South Platte River basin and the Arkansas River basin along the Palmer Divide; 2) northern tributaries to the Arkansas River, especially in shale formations, quaternary age alluvium, and surficial deposits; and 3) along Horse Creek in the Arkansas River basin. Many of these hotspots included larger headwater wetland complexes and groundwater-rich seep areas of intermittent drainages, especially in Lincoln, Elbert, El Paso, and Crowley counties.

Other concentrations of GDE wetlands were detected in saline and carbonate-rich areas north of the Arkansas river in various mapped geologies but especially in carbonate formations of limestone or dolomites. Smaller concentrations of seepy and peat-accumulating slope wetlands were located where the central Front Range foothills meet the shortgrass prairie in Boulder County. In the northern Colorado plains, especially over siltstone and mudstone bedrock, various wetlands were clustered amid bluff landforms and spring-fed areas of narrow creeks. Additional areas of less dense GDEs included the South Republican and Arikaree Rivers in the Republican basin, tributaries of the Purgatoire River in the southwestern study area, sections of West and East Carrizo Creeks and their tributaries, and concentrations of springs in the Comanche National Grassland southern unit. Many hotspots were also mapped along intermittent streams that shift from losing to gaining reaches over alluvium and surficial deposits of various ages.

The most concentrated hotspots were categorized by number and polygon length in a HUC10 watershed heatmap (Figure 11) to identify areas for GDE mapping priority. Stakeholder input on this map guided the selection of areas for more detailed GDE mapping.

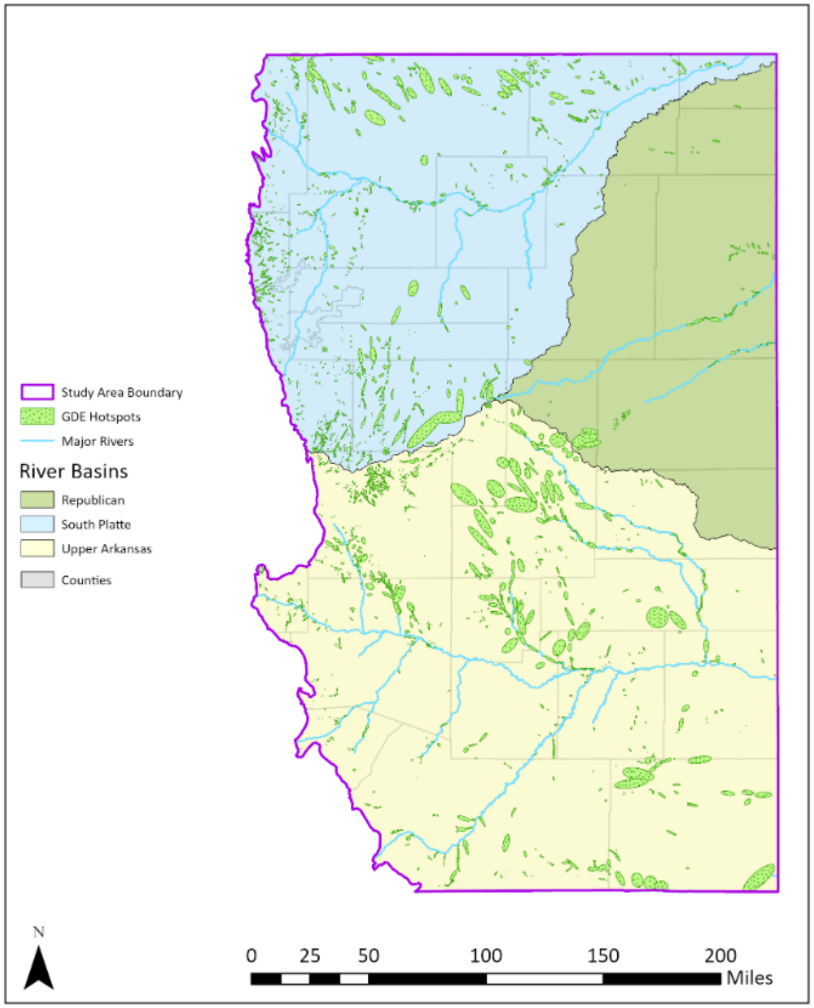

Figure 10. Mapped GDE hotspots in the project study area.

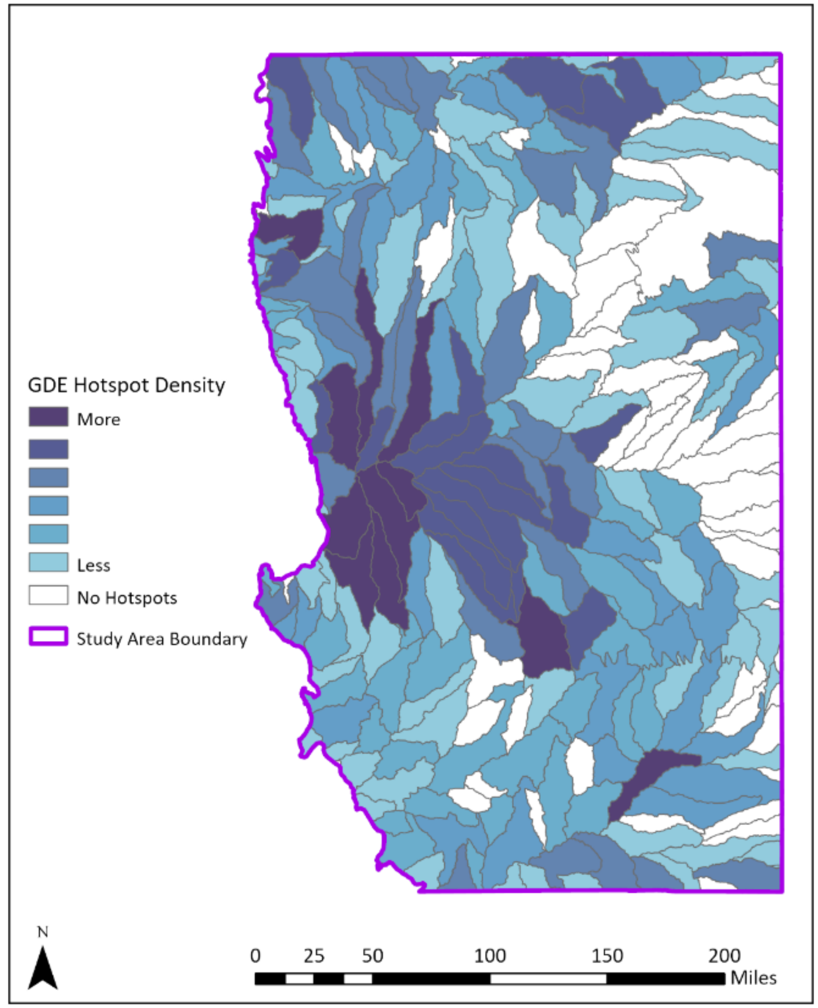

Figure 11. HUC10 watershed basins with higher density of mapped GDE hotspots in the project study area.

Detailed GDE Mapping

The final map of potential groundwater-dependent wetlands in select quads and half-quads contained 2,369 potential groundwater-dependent wetlands (all confidence levels), covering 17,522 acres (Table 7, Figures 12 & 13). This total included 350 'likely GDE' wetlands (2,665 acres), 684 'possible GDE' wetlands (5,372 acres), and 4,570 'low confidence GDE' wetlands (9,486 acres). The most common geologic substrate under 'likely GDE' wetlands was shale, which underlies 153 mapped 'likely GDE' wetlands (1,120 acres) and represents 44% of 'likely GDE' polygons and 42% of acres (Table 8). Alluvium of all ages underlies another 102 'likely GDE' wetlands (29%) and 616 'likely GDE' acres (23%).

Table 6. Mapped potential GDE wetland acreage

GDE Confidence	Count	Acres
5 - Likely GDE	350	2,665
3 - Possible GDE	684	5,372
1 - Low Confidence GDE	1,335	9,486
Total	**2,369**	**17,522**

Table 7. Likely GDE wetland acreage by geology

Geology	Count of Likely GDE Wetlands	Likely GDE Wetland Acres
Shale	153	1,120
Quaternary age older alluvium	59	323
Quaternary age younger alluvium	43	293
Siltstone and/or mudstone	41	291
Sandstone	40	286
Unconsolidated Aeolian sand deposits	10	257
Carbonate limestone or dolomite	3	85
Water	1	8
Total	**350**	**2,665**

Within the mapped quads and half-quads, the density of mapped GDEs ranged from 1-12% of the land area. The Lewis Ranch quad along Horse Creek in Otero County had the highest density of mapped GDEs, covering 12% of the quad map area. Kinney Lake in the Rush Creek drainage of Lincoln County had the next highest density at 8% of the area. Kinney Lake also had the highest percentage of 'likely GDEs.' The original NWI mapping in this quad was sparse and mostly limited to ponds and occasional springs shown on the topographic map, which appeared to be excavated and impounded saturated GDEs. The Hygiene half quad in Boulder County was the next most dense, with 7% of land area, then Greenland in Douglas County at 5%. NWI mapping in all of the mapped quads did not include any continuously saturated polygons and only included a total of 21 acres of seasonally saturated polygons, with 19 of the acres mapped in the Greenland quad. Thus, the current NWI mapping does not accurately represent the GDE wetland population in some of the densest hotspot areas for GDEs in the eastern Colorado Plains. NWI mapping of GDEs were often mapped with a flooded water regime rather than a saturated regime or as part of river or stream channels.

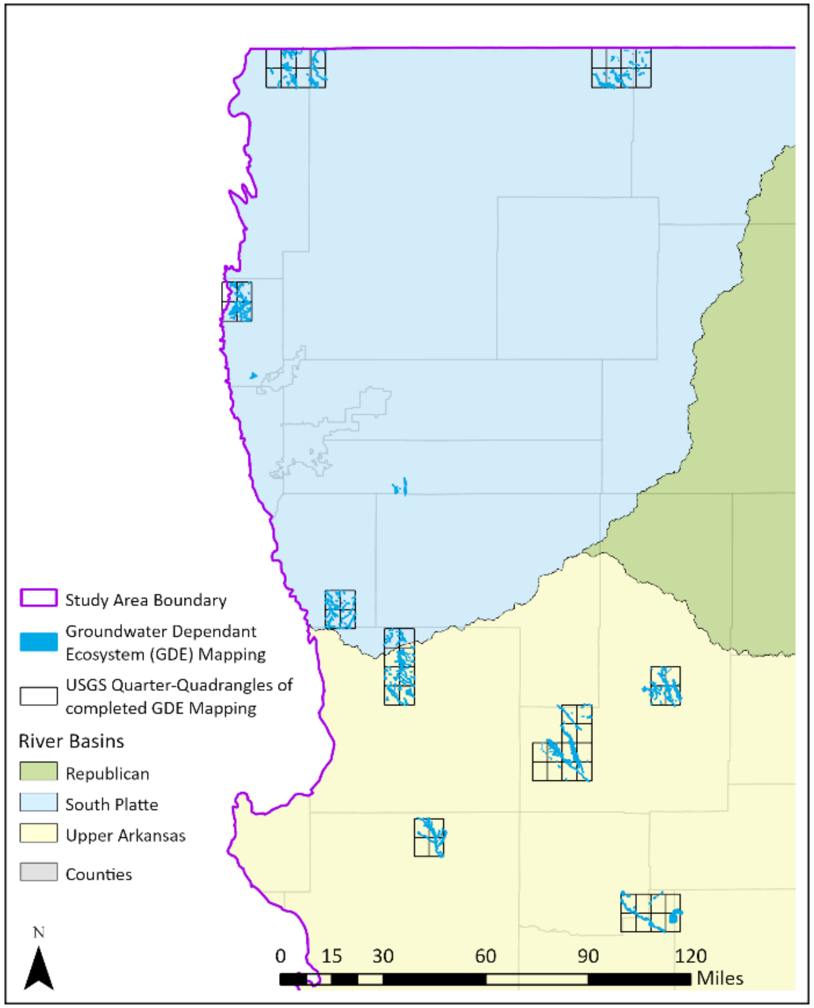

Figure 12. GDE wetland mapping of all confidence levels and completed USGS quarter-quadrangles in the Colorado eastern plains GDE study area.

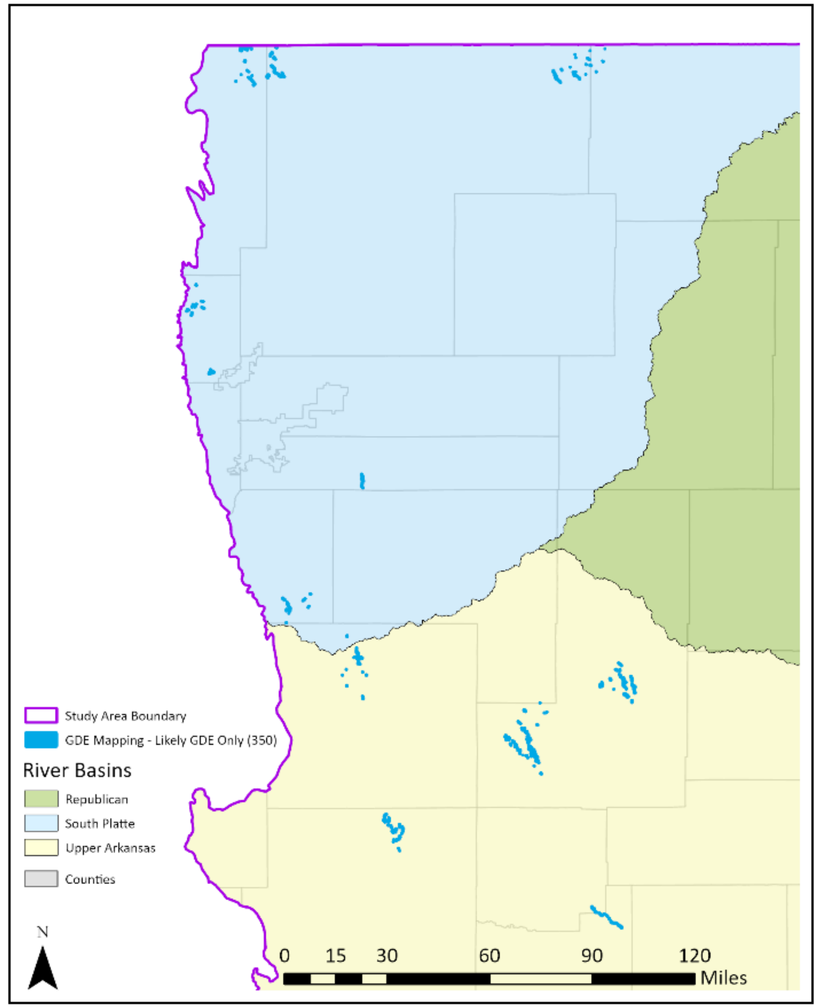

Figure 13. Likely GDE wetlands (350) mapped in the Colorado eastern plains GDE study area quads.

GDE wetlands were mapped based on data and aerial imagery signatures indicating that prolonged groundwater-fed saturated soils and groundwater-dependent hydrophytes were likely present. 'Likely GDEs' with a 5-confidence rating are more likely to be peat accumulating or to have springs, or if saline, then wetted and with visible salts, and both types have very high conservation value because they have higher potential for imperiled biota or other difficult to restore site characteristics. Some of the '3'-ranked 'possible GDE' wetlands could be the same wetland types as the high confidence 'likely GDEs,' as the numbers rate the probability of a GDE. Low confidence GDEs were a mixture of mapped wetlands with more seasonally saturated groundwater-sources, or wetlands in areas with lower confidence in the groundwater-dominance over other water sources, such as in areas in landscapes that could pond water or areas of excavated peat where the water table is still likely maintained by groundwater. The GDE mapping provides detailed locations of the most saturated lands in the map area along with potential peripheral seasonal GDE wetland areas.

Kinney Lake SWA is an example of a mapped site with multiple polygons with different confidence ratings (Figure 14). This site also included two years of field data collection. Areas with likely continuous saturation were mapped as 'likely GDE.' In the field, these areas were found to have areas of very saturated soils with organic layers and visible groundwater discharge and some quaking areas. One of these 'likely GDE' polygons was also mapped as a spring on the topographic map, and that was confirmed in the field. The next confidence level of 'possible GDE' includes areas in the wetland complex with groundwater discharge and seeps, organic soil and muck layers, groundwater-dependent vegetation, a slow drainage without any defined bank, and edge areas of more seasonal saturation. Although an impounded pond outside of a GDE wetland would not receive a GDE rating and would not be mapped, at this site Kinney Lake is an impounded groundwater-fed feature with some excavation, so it was decided to rate excavated peatlands with standing water as a possible GDE, indicating that groundwater is contributing to the pond and was likely a groundwater-dependent wetland, but is now altered. These 'possible GDE' map areas also have high conservation value, and minimal impacts are recommended to areas with saturated substrate, including GDEs with excavated areas. Some of these 'possible GDEs can also have fen or deeper organic soil potential, but with lower mapper confidence. The riparian-seep plot surveyed for this study was mapped as 'possible GDE' and it had histic epipedon in some areas with >20 cm of organic soil and other seasonally saturated wet meadow areas.

The outer wetland area in the figure that is mapped as 'low confidence GDE' is low confidence due areas of more marginal wetland, but the wetland is situated in a landscape position of groundwater-influence. Low confidence areas may also have other confounding mapping factors such as land uses or drying that affect confidence in the groundwater source. These low-confidence GDE areas are not likely to currently support the most imperiled wetland types or continuous saturation, but they are a component of the GDE complex for its groundwater source and maintenance of wetland hydrology. The low confidence mapping may also include areas that are changed or changing. In Figure 14, a low confidence GDE wetland polygon mapped south of the road is drier now than it appears in 1956 historical aerial imagery. Overall, this mapped GDE site example highlights the extent of the estimated GDE wetland complex today, and areas with '5's', and some areas with '3's' include locations with the highest saturation, and the full mapping identifying areas with estimated dominant or codominant groundwater inputs. This surveyed wetland had high quality GDE and wet meadow plant species in both the seasonally saturated and seep areas of the wetland and supported wildlife species with conservation priorities. The mapping example highlights the complexities of mapping GDE wetland areas in locations with a layered land uses and history typical in the eastern plains.

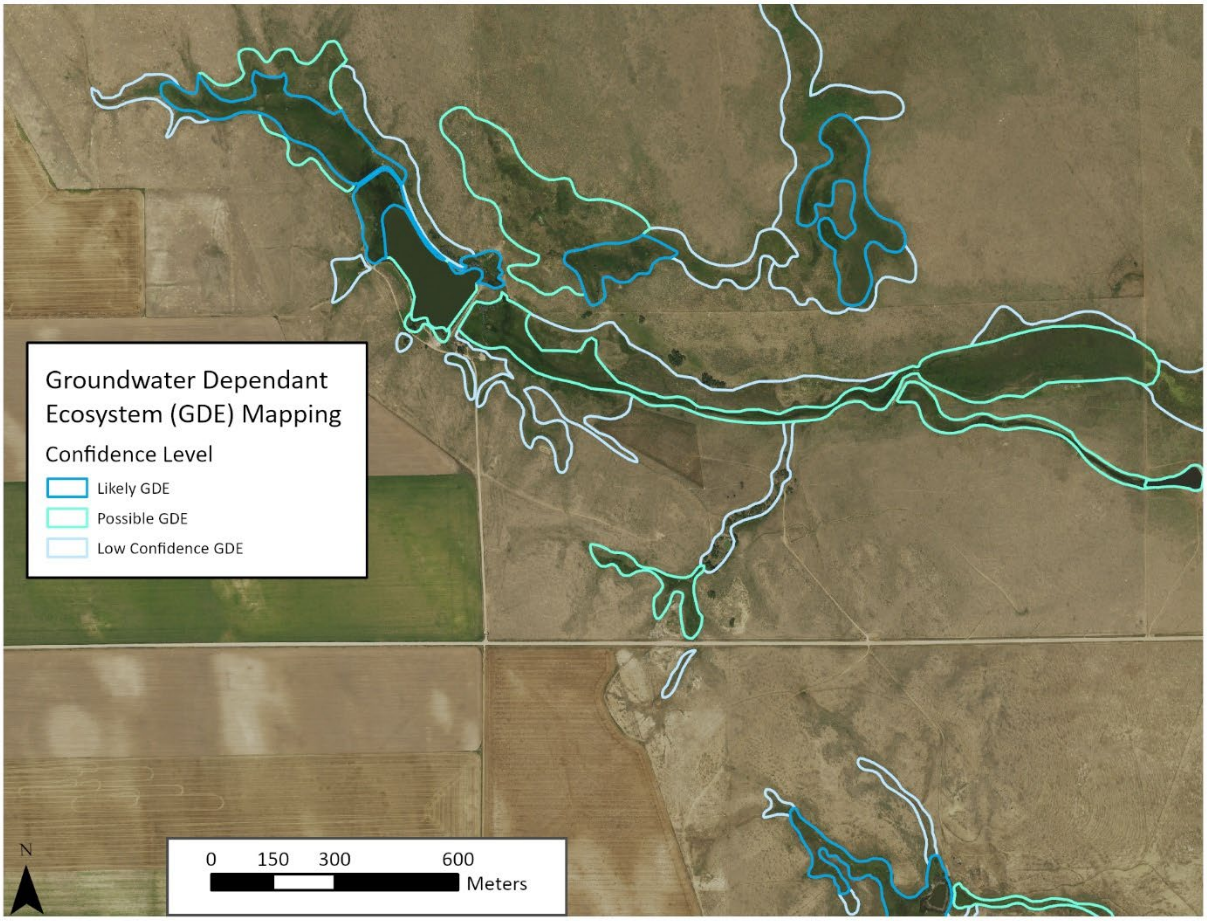

Figure 14. Groundwater-dependent wetland mapping at Kinney Lake SWA.

4.2 Wetland Condition Assessment Results

Sampled Sites

For the 2021 pilot year, six sites were selected for in-depth study. Those included two groundwater-rich woody floodplains at Box Elder Creek and the South Fork Republican River, two slope herbaceous wetlands in Boulder and Larimer County, and two seep-drainage wetland complexes at Hugo State Wildlife Area and Kinney Lake State Wildlife Area (Figure 15, top left). One of these 6 pilot sites (Hugo) was surveyed for invertebrates and amphibians, but not EIA and vegetation in 2021, due to severe weather. Another of the 6 pilot sites (Boulder Co.) was not revisited in 2022 but was surveyed both in 2020 (CNHP plot survey data) and 2021 for vegetation; and for Level 3 data in 2022.

For 2022 surveys, 173 potential groundwater-dependent wetlands were identified to create a priority list (Figure 16) and of those, 50 were surveyed (Figure 17). This included 5 of the 6 pilot sites and another 46 new site visits. Unsurveyed sites from the potential target survey layer can be used for future CNHP biodiversity surveys. Of the 2022 sites, 13 were sampled with Level 3 vegetation plots (Figure 15, top right), and the remaining 38 sites were sampled with Level 2 relevé. In addition, invertebrate sweeps were conducted in 16 sites, and amphibian and reptile surveys were conducted in 16 sites (Figure 15, bottom). In general, we refer to Level 3 sites as all sites with either intensive surveys of vegetation, amphibians, and/or invertebrates. Not all Level 3 sites had all three types of intensive biotic data collection, because invertebrate surveys required site surface water, amphibian surveys targeted freshwater (not saline playas), and the mix of both Level 2 and Level 3 vegetation collection types in pilot sites (although all pilot sites included intensive herpetology and invertebrate survey types). The goal to collect in-depth Level 3 GDE biodiversity data across the range of surveyed GDE types in approximately one-third of surveyed sites was accomplished.

Many plains GDEs are located on private lands and most of the initial target points (104 of the 173) were privately owned. Extensive effort was invested in identifying and contacting private landowners. However, the success rate was relatively low. In the end, 80% of the sites with access granted were publicly owned sites. There was hesitation by many private landowners to conduct the surveys due to concerns with CSU's access agreement and CNHP's data release waivers, and some wariness of public reporting on wetlands in general. The final 51 sites were primarily located on lands with public managers or private landowners interested in information about wetlands. This resulted in certain regions and wetland types being less represented in the sample, such as saturated wetlands at slope breaks on the outer floodplain of big rivers, canyon riparian areas, and no sampling in the far southeast study area. However, the variety of owners, especially the SLB distribution of sites across the study area, added spatial spread in surveyed area and newly documented diversity of GDE wetland vegetation and water to past surveyed plots.

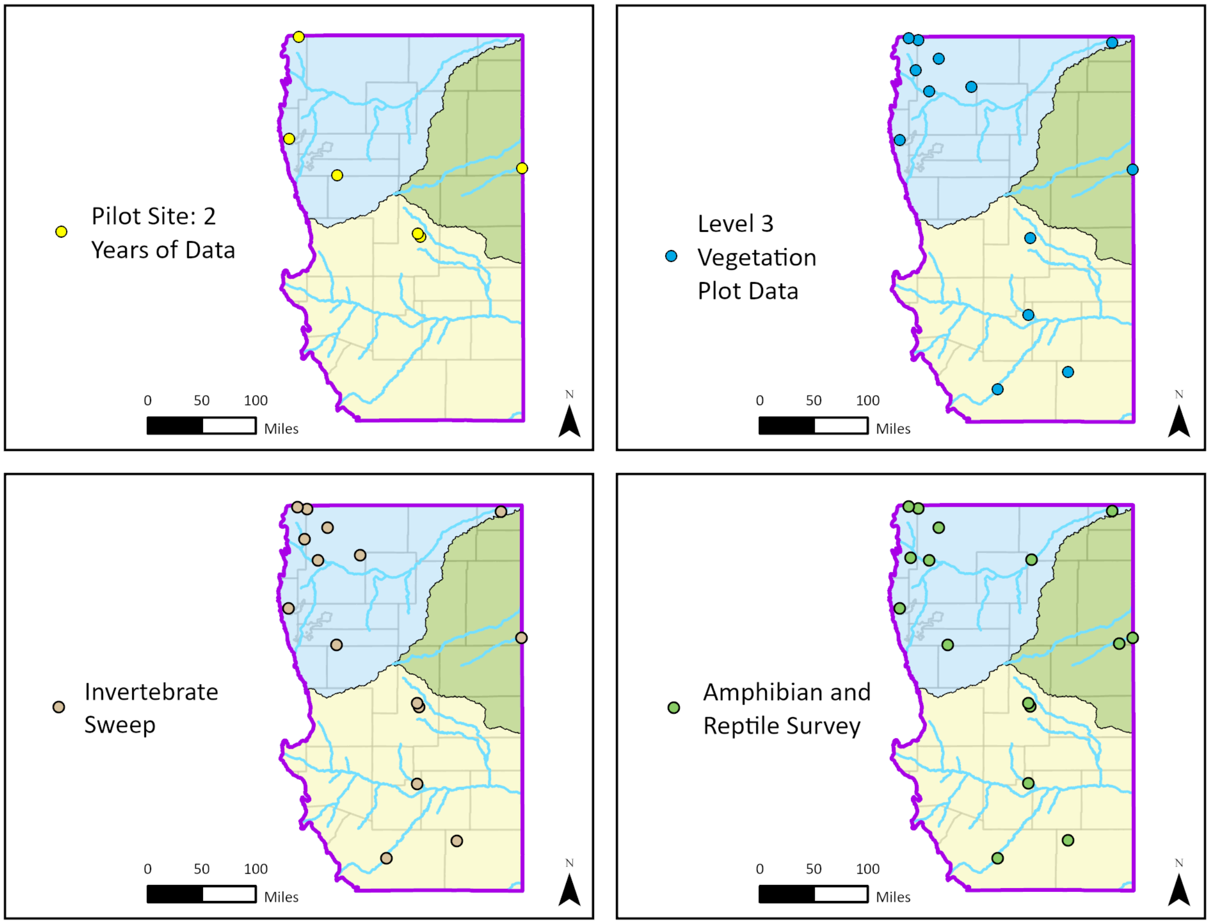

Figure 15. Pilot sites and sites surveyed with Level 3 in-depth methods.

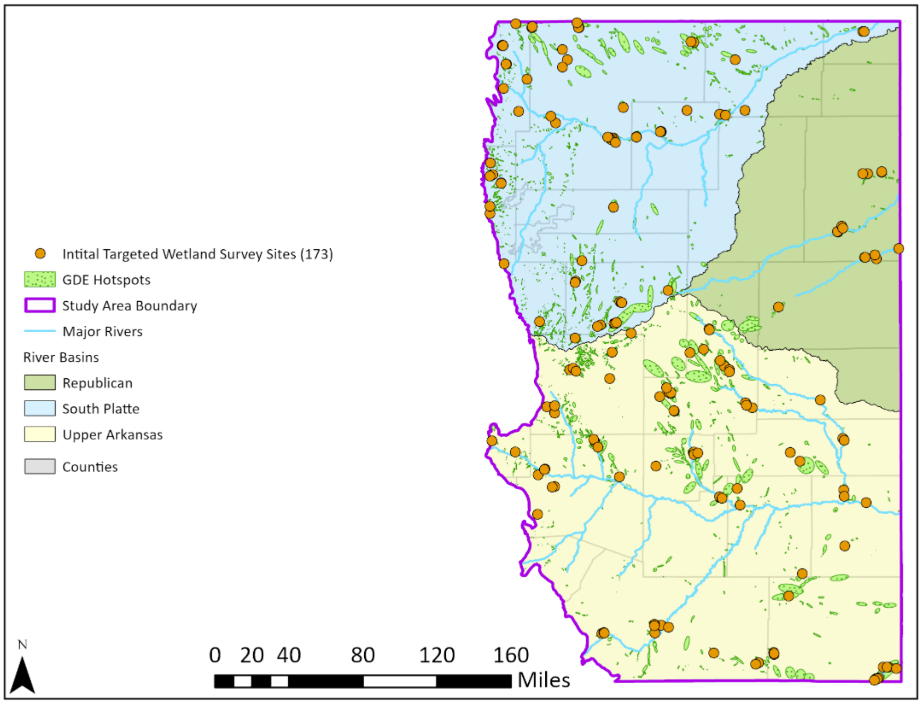

Figure 16. Initial 173 target survey points for 2021-2022 Plains GDE wetland study field work.

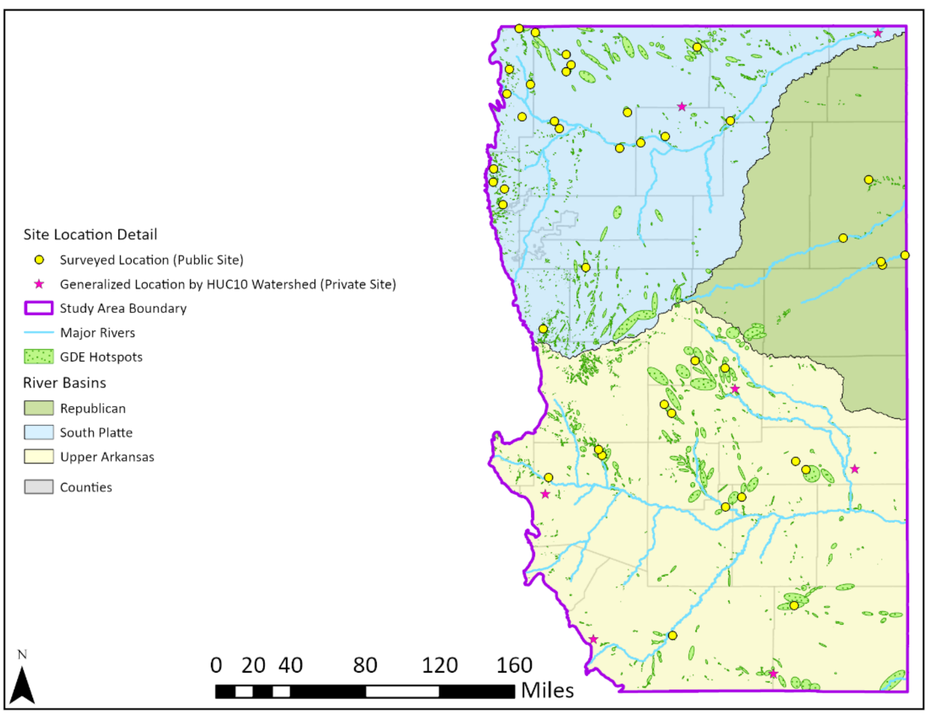

Figure 17. Surveyed Sites for the Plains GDE wetland study. Ten sites with private land ownership are displayed by a general location at the center of their HUC 10 watershed. Sites with public land ownership are displayed at the surveyed location.

Classification of Plains Groundwater-Dependent Wetlands

GDE Indicators

The GDE wetlands in this study include a diverse range of wetland types that share the common factor of local and consistent inputs of groundwater. The most common GDE indicators observed, all observed in more than half of sites, were organic soil layers, GDE phreatophytes, seep/springs, and organic sheen coating on the water surface. Some other sites had visible groundwater discharge into a stream, saturated floodplain, and a gaining drainage location.

Ecological System Classification

The study sites were classified as one of five wetland types using the Ecological System classification (Comer et al. 2003, Decker et al. 2020) (Figure 18). The Ecological System classification groups dynamic assemblages of wetland types and species within an ecoregion by their shared processes, function, and similar underlying environmental factors into readily identifiable units on the ground. Wetlands positioned in the outer floodplain of major rivers were classified as Western Great Plains Floodplain (n=4), woody wetlands of medium sized drainages and creeks were classified as Western Great Plains Riparian (n=6), saline depressions and playas were classified as Western Great Plains Saline Depression (n=7), and wet meadow-marsh complexes were classified as Western Great Plains Wet Meadow-Marsh Drainage Network (n=27). In addition, we separated plains fens with deep peat as a subtype of the wet meadow-marsh complexes (n=7).

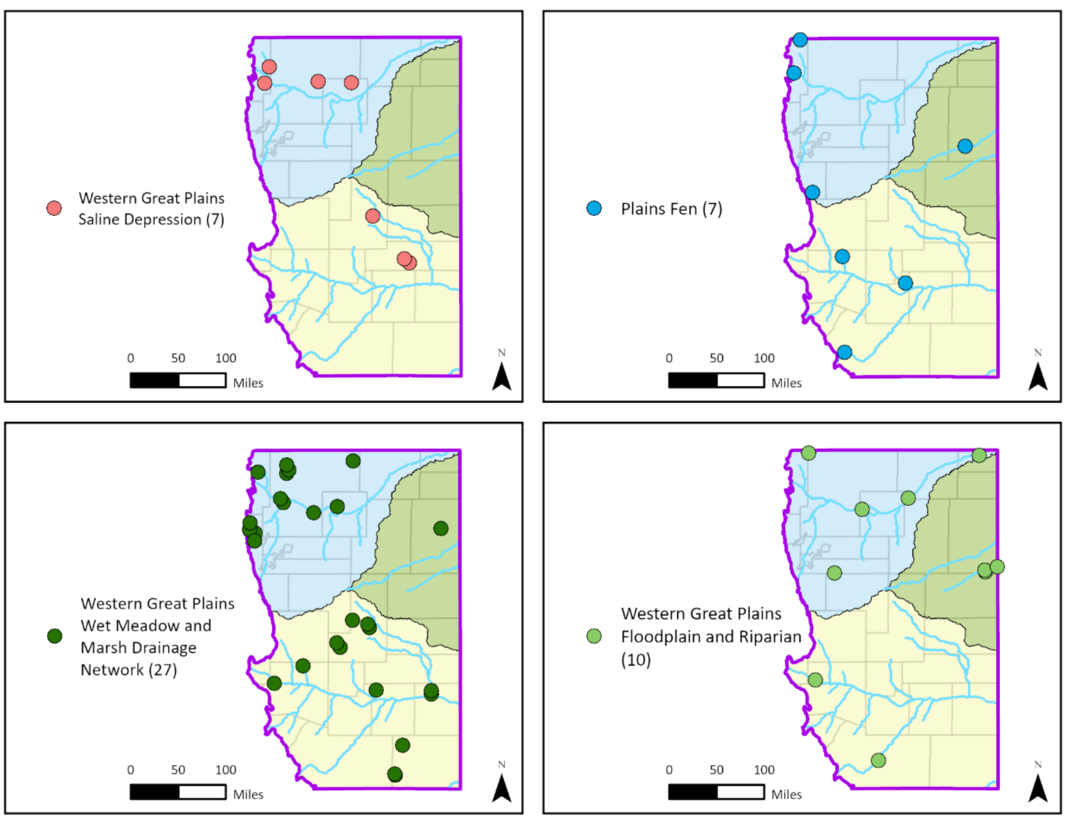

Figure 18. Ecological Systems of Surveyed Sites for the Plains GDE wetland study.

Hydrogeomorphic Classification

There were three major Hydrogeomorphic (HGM; Brinson 1993) wetland types surveyed across the study area: slope, depressional, and riverine. Most of the wetlands had features of all HGM categories, with open depressional or very flat areas in the wetland low points, active seeps onsite, slope break geomorphic position, and connection with a drainage. Because most sites lack regular flow and flooding, only a few intermittent riparian sites were classified as riverine. Many HGM classification were rated low confidence by crews, due to the multiple-geomorphic setting characteristics needed to maintain a GDE wetland in eastern Colorado. The surveyed GDEs may have more in common with each other's hydrogeomorphology than they do with other wetland types that share their HGM class, excepting wet meadows and fens with moderate to steeper slopes.

Cowardin Classification and Comparison to NWI Mapping

Each wetland AA was classified by the Cowardin classification used for NWI mapping to indicate it's the site's physiognomy, and hydroperiod (FGDC 2013). Each wetland AA was also compared with existing NWI mapping and assigned a status of not-mapped, partially mapped, or mapped at three levels: the AA center, the overall wetland AA polygon, and the larger wetland complex that includes the AA. The most common dominant Cowardin code in the surveyed wetlands was palustrine emergent permanently saturated (PEMD, n=20), and the second most common class was palustrine emergent seasonally flooded (PEMC). Other surveyed wetlands had semi-permanently flooded (F), seasonally saturated (B), or temporarily flooded (A) water regimes and herbaceous (PEM), scrub-shrub (PSS), or open wooded physiognomies (PFO).

Among the 51 surveyed AAs, all five wetland types surveyed (fens, wet meadow-marshes, saline playas, woody riparian, and plains floodplain) included a mix of NWI mapped and unmapped AAs. Eleven surveyed wetland AAs had no mapping within their AA boundary, and these were all herbaceous wetlands. Two AAs were partially mapped as buffered streamlines, 23 AAs were partially mapped with an NWI polygon (of any classification), and 15 had their AAs mapped. Woody wetlands were more consistently mapped by NWI, and of five woody wetlands, four were partially mapped, and one was fully mapped. The surveyed AA centers were checked for mapping, as a general indicator of NWI mapping coverage. Half (49%) of the AAs had mapped wetland centers and half did not. Most of the larger wetland complexes surrounding the AAs had some NWI-mapped wetlands in their broader drainage networks. However, fourteen wetlands had either no (n=4) or minimal (n=10) mapping in their surrounding drainage network. Conversely, eleven wetland AAs were in drainage networks that were largely mapped by NWI.

Twenty AAs had permanently saturated water regimes (D). Field surveys identified 19 of these as PEMD (herbaceous) and one as PSSD (scrub-shrub). More than twenty wetlands had small areas of permanently saturated wetland in the AA, but this analysis focused on the dominant water regime across the AA. Among these 20 permanently saturated sites, seven were completely unmapped in NWI, six were partially mapped, and six were fully mapped. Seven of the most saturated sites also had no NWI mapping either in their larger wetland complexes. NWI mapping for these saturated sites was misclassified using non-saturated water regime codes including PEMC (4), PEMA (5) and PEMF (1), PUSC (1), and R4SBA (2).

Ecological Integrity Assessment Scores

Overall EIA scores of the surveyed wetlands ranged from 2.33 to 4.56 on a 1.00 to 5.00-point scale (Figures 19-20). The mean overall EIA score was 3.8. Most surveyed wetlands (71%) ranked in good condition (B), and all but two others ranked in fair condition (C). The highest EIA score and the only A-site was from a narrow canyon riparian tributary with pools. This site was more remote and in a landscape with minimal disturbance. The lowest EIA score and the only D-site in this study was a wet-meadow-marsh recommended by a land manager that was in an urban area and had both groundwater sources and additional stormwater inputs. Though there was active groundwater seepage, the wetland was an impounded urban wetland, a type not prioritized in this study. However, based on its wet meadow history and active groundwater seepage, it proved valuable for inclusion in the survey. Both the A-ranked canyon site and this D-ranked urban wetland are examples of key groundwater-fed wetland types in the region: the canyon site represents a type in need of more targeted study, and the urban site is an example of many wet meadow-marsh wetland types in the Front Range that were historically a groundwater-fed wet meadow and now have mixed hydrology and depressional marsh characteristics.

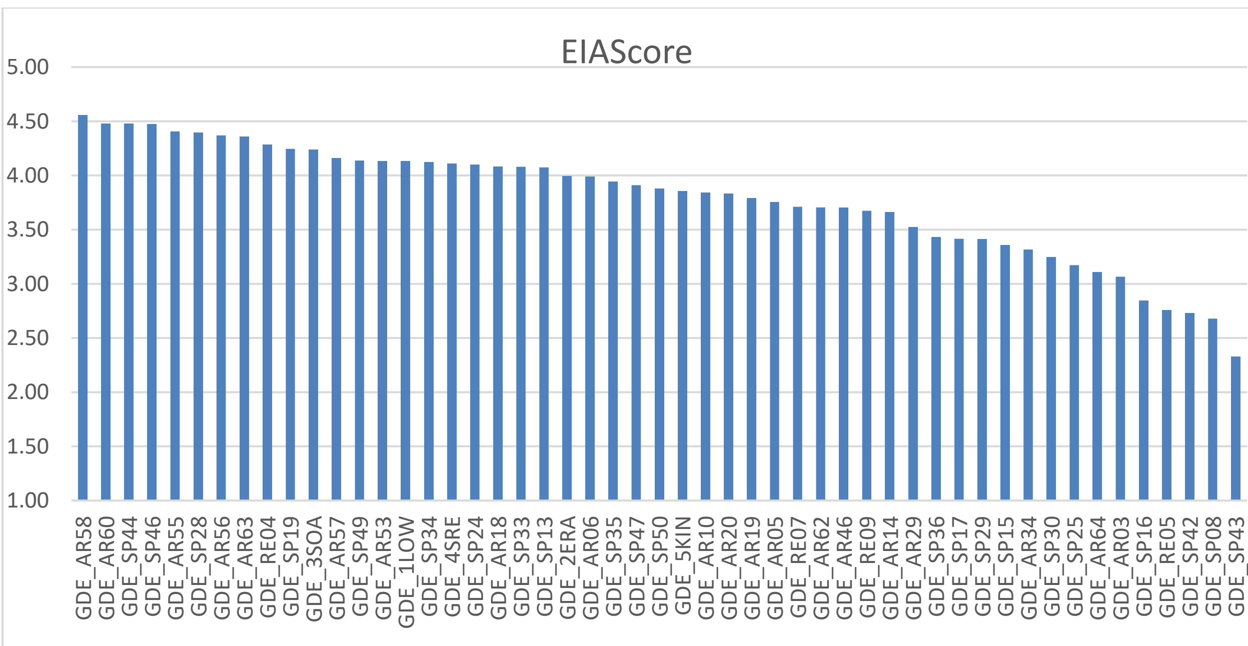

Figure 19. Overall Distribution of GDE Environmental Integrity Assessment (EIA) scores by Assessment Area (AA) and site code. Site scores with 2 visits displayed as score average. A=>4.5, B>3.5, C=>2.5, D=1-2.5.

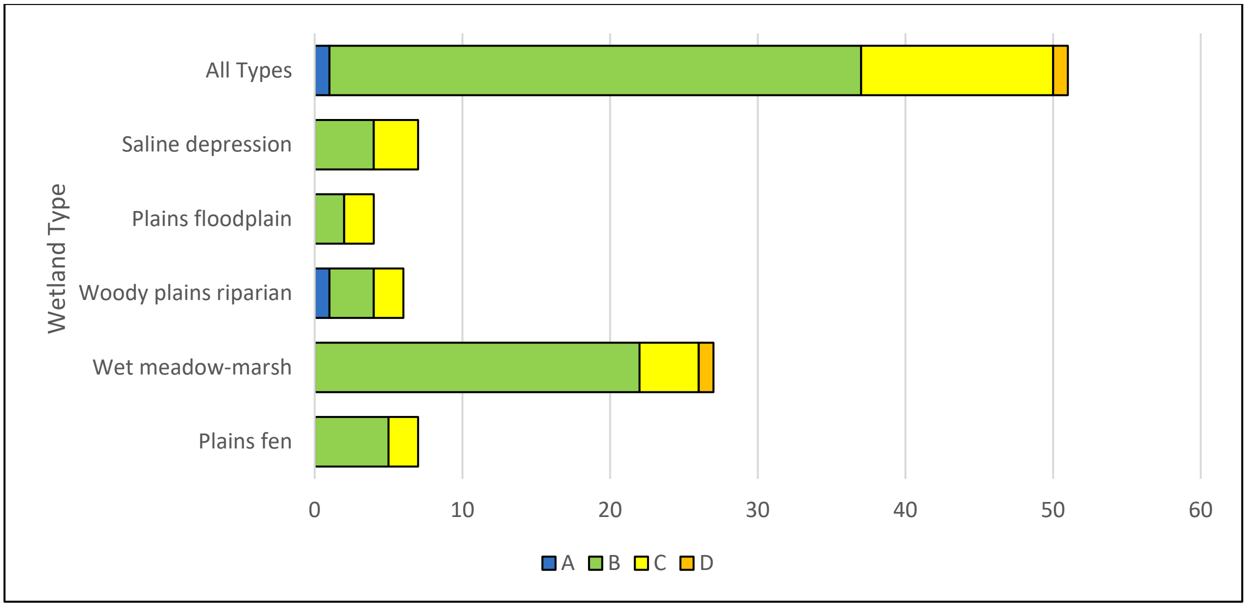

Figure 20. The Ecological Integrity Assessment (EIA) scores by wetland type of 51 surveyed groundwater-dependent wetland sites.

EIA scores for the private land sites averaged slightly higher than public land EIA scores, and all private land sites scored a B. The State Land Board and Colorado Parks and Wildlife owned sites also averaged B EIA ranks but had larger ranges of scores from C to nearly A or A. For other AAs, there was a very small sample size by owner type of <10 sites surveyed by each owner group, but each group averaged a B EIA rank across all surveyed AAs in that ownership class, including: City (8 sites), County (3 sites), Federal (1 site), Land Trust (1 site), and USFS Pawnee National Grassland (3 sites). In addition to overall EIA scores, subscores were also calculated for the four main ecological categories (Landscape Context, Vegetation Condition, Hydrologic Condition, and Physiochemical Condition) that make up the overall score. All site-level EIA scores are listed in Tables 8-17 in the following sections describing characteristics by wetland types. The calculations for the EIA metric ranking criteria are provided in Appendix C.

Landscape Context Scores

Landscape context scores are based on the degree of landscape fragmentation and the extent and condition of the buffer within a 500 m envelope surrounding an Assessment Area (AA). Lands surrounded by naturally vegetated buffers scored higher while lands dominated by intensive land uses, infrastructure and residential developments scored lower, and landscapes with grazing or recreation scored variably depending on intensity of use. The surrounding landscapes play a large part in the protection of the larger wetland complex, the diversity of plants and animals, water quality, and overall wetland health. The AA surrounding landscapes and buffers were mostly in good to excellent condition, with ten AAs within an A-ranked landscape, thirty B-ranked, nine C-ranked, and two D-ranked AAs. The A-ranked AAs were in a variety of settings with minimal development, and eight sites had grazing evidence plus the two others were on ranches with potential grazing. Roads, berms, and ditches/canals were noted to interrupt groundwater flow paths and contributing watershed surface runoff. Grazing practices varied in intensity from minimal to low visible impacts on buffer vegetation, to overgrazing that degraded surrounding landscape. The causes of the D-ranked surrounding landscapes were dense urban fragmentation, and intensive grazing. Landscape condition was correlated with overall score, and all the A and B-ranked landscape condition scores also received B+ or higher EIA scores. Sites with two visit years had variability in the landscape disturbance metrics, particularly related to grazing intensity. This can be caused by user variability in ranking subjective land use metrics in need of EIA rank specs, and also can be related to the variability in site condition resulting from grazing intensity and survey timing in relation to active grazing.

Vegetation Condition Scores

Vegetation condition scores are based on the floristic data collected during the field surveys, including the native cover assemblages and their role as invasives, type-species, or high-quality vegetation, plus non-native cover and aggressive invasives. In addition, the vegetation structure is rated for the expected wetland type biotic and associated abiotic patch diversity, structure, and density. Most of the sites were herbaceous, so in the surveyed plains GDEs, this metric reflected the uniformity of wetland vegetation, presence of microtopography and vegetation zonation, and diversity of plant structure. Sites where vegetation rated as good condition were strong indicators of overall condition, as each of the 23 site visits that ranked good (B) in the vegetation condition metrics also received an A or B in the overall EIA score.

None of the GDE wetlands had A-ranked vegetation condition overall, due to presence of non-native species and aggressive invasives, including noxious weeds or cryptogenic species (*Typha angustifolia*). Cryptogenic cattail was present at over a third of sites (35%), and Canada thistle (*Cirsium arvense*) was present in over three-quarters of sites (76%). Reed canary grass was also present at six sites, four of which were outer floodplains. However, the majority of site visits ranked excellent for native vegetation composition, and most others scored as good condition, indicating that the surveyed GDEs supported high quality plant communities and groundwater-dependent wetland species in most sites. Nine site visits had fair vegetation condition, but even those surveys contained native species or communities in every site, and some of those supported rare species or communities as well. Vegetation structure had more impacts than vegetation composition, with 43% of sites in fair or lower condition, with either overly dense or overgrazed vegetation, invasion by undesirable species, woody dieback, or a simplified structure.

Hydrologic Condition Scores

Hydrologic condition scores are based on the wetland water source, the naturalness in timing, amount, and functioning of the hydroperiod, and hydrologic connectivity. Overall, most sites had good (B) ranked hydrology. Excellent (A) hydrology condition is uncommon in the plains wetlands, except for in some playas, but both a saline playa plus 12 other wetland sites scored A for hydrology. Some remote site locations scored A, and other A sites had local hydrology dynamics in headwater locations. All sites with hydrology scores below an A for hydroperiod or connectivity had notes reporting signs of drying. Some of the mild hydrology impacts included adjacent dirt roads or trails affecting the water source or wetland connectivity, and mild or localized livestock-caused pugging that affected limited areas of the wetlands. Moderately impacted hydrology condition scores were most frequently due to livestock pugging and/or compaction changing the hydrology in areas with peat or peat-mineral mixing and substrate drying, and other livestock-related erosion decreasing connectivity at the margin of the wetland or the boundary of the wettest wetland section. Other impacts included erosion that affected hydrologic connectivity, impoundments, groundwater wells, and railroads affecting connectivity to the wetland's adjacent runoff watersheds. Impoundments and upslope excavated peat ponds create different flow regimes and can have side ditches moving water from upslope GDE around the impoundment and down into the wetlands, creating less overall wetland area, altered hydroperiod, and channelized flow paths.

The urban site scored a D due to stormwater contributions, and the perimeter of the wetland impounded by road development, but the wetland hydroperiod and water sources were also buffered by the groundwater seeps and the Ds were all on the high end of the C/D break. Three other sites had D hydroperiods: a saline depression had freshwater agricultural runoff input and cattails was expanding in response, a riparian area and a slope wetland both had signs of drying with early season dry and cracked soil in hydrophyte locations, a riparian area had drought stress indicators at a site with an upslope canal interrupting hydrologic connectivity. At that site with native saline species, there was a saline depressional pool within the drainage that crews thought increased salinity was developing, and an outer floodplain seep area had high weed cover despite obligate hydrophytes and evidence of drying and soil cracks. Overall, most of the hydrologic impacts identified in the surveys were related to drought stress and drying trajectories, excepting for at one beaver site with more water, established on a slope wet meadow below a canal. A review of aerial imagery revealed an increase in marsh cover over time in some wetlands, however, this change is not considered in the hydrology rating.

Physiochemical Condition Scores

Physiochemical condition scores include metrics for visible signs of water quality and soil disturbances within AAs. Most sites scored A or B physiochemical scores, with the most common disturbances in good condition sites light pugging and livestock compaction. Similarly, lower ranking sites had more grazing-caused pugging and heavier compaction that mixed organic soils with mineral soils, leaving high mounds of mineral soil to dry and break, and clods of organic soil sloughing off of the wetland. There may be a condition threshold break between grazing soil impacts that expose, dry, and mix the tops of the wetland substrate, versus grazing that impacts the side of the soil and creates minor pugs. These effects interact with other site conditions besides management that affect site wetness and sensitive substrates with soft organic soil and seeps, and degree of vegetated substrate. Sites with grazing impacts in the most saturated substrates appeared to have a significant effect on groundwater-dependent wetland sustainability, causing conversion to surface water wetlands. Extra attention to spring, seep, and highly saturated sites is needed in plains GDE wetland conservation, and site-specific adaptive management may be needed to determine thresholds of land use that maintain GDE wetland function and optimal vegetation disturbance.

Observed Stressors

Fifty of the wetland surveys from 2022 included a checklist of observed stressors within the assessment area and in the 500 meters surrounding the wetland, that rated each stressor's impact as slight, moderate, major, or severe. Substrate disturbance by surface compaction and pugging/soil exposure in the 500m area surrounding the wetland was present in three-quarters of sites, and this stressor had the most intense effect on health of the landscape around the AA. Moderate to heavy grazing affecting vegetation in the 500 m area was the second most intense stressor. Grazing in the area upslope and upstream of the surrounding the AA can have indirect effects on hydrology and vegetation, especially in smaller wetlands with less buffer. Within the AA, these same two grazing impact stressors were rated as most intense but they were observed in only half of the wetland AAs. Compaction and soil disturbance caused major impacts at seven sites and moderate impacts at eight. The remaining sites with substrate disturbances only had light and localized impacts. Several sites had grazing impacts surrounding the AA but no impact or lesser impacts within, sometimes due to exclosures. Of the 25 sites without observed substrate stressors, more than half of those had light to heavy rated levels of grazing. Eleven sites had no signs of grazing.

Grazing impacts vary based on season, intensity, and duration. Physical impacts like compaction are more lasting and can be more permanent than vegetation impacts. Second to grazing impacts, paved roads and unpaved roads were the next overall highest rated stressors, with paved roads in the 500m surrounding the AA rated as causing moderate or higher intensity of stress to wetland health in 12 sites, and as present in an additional 10 sites. Roads can interrupt the surface and groundwater inputs and hydrologic connectivity. Unpaved roads were the cause of moderate wetland health stress in three additional sites without paved roads and were also observed within 500m of the AA in more than half of the surveyed wetlands. Invasive non-native species in the area surrounding the AA affected the surrounding watershed health in one third of the wetlands, with a stress intensity of moderate or higher intensity in 10 sites. Urban runoff affected six wetland AAs with moderate or higher rated stress. There were other types of stressors that affected singular or a few surveyed wetlands, and some were rated severe, such as a road through a saline playa.

4.3 Characteristics of GDEs by Wetland Types

The following subsections describe characteristics of each Ecological Systems type surveyed. The information presented is based on both data collected through this project and data compiled from previous GDE surveys on the plains. Plant names are listed by scientific name. A list of vascular plant species observed in this study is included as Appendix E and can be referenced for common name and additional attributes.

Wet Meadow-Marsh Drainage Network

Herbaceous wetlands of interspersed wet meadows and marshes with <40 cm of organic soil were the most common surveyed wetland type in the study (n=27) and the most variable type (Figure 21). Eleven of these wetlands had histic epipedons (20-40 cm organic soil) and all but one site either had organic soil layers of lesser thickness or a high percent of organic content in the mineral layers. Wet meadow-marsh sites in outer parts of a local watershed, or higher in drainage positions, included springs and their associated seeps, and shoulder or toeslope slope break wetlands (Figure 22). Mid-watershed to lower valley drainages and floodplain wet meadow-marshes (Figure 23) included seep water tracks through marshy vegetation, saturated intermittent narrow tributaries with groundwater-fed refuge pools, and wider valley-bottom saturated wet meadow-marshes. Some medium-sized seep drainages changed geomorphology where hydrology dissipated, and other narrow seeps combined downslope into a larger GDE basin or drainage. Some wetlands had highly variable water chemistry pH and EC YSI measurements in close proximity, with patch variation that aligns with substrate transitions across quaking soil, peat, clay, and mineral salt crusts.

Figure 21. Photos of wet meadow-marsh GDE wetlands showing refuge pools and seep water tracks.

Wet meadows with similar species to fen vegetation (and sites with peat accumulation) included *Carex nebrascensis, Carex pellita,* or *Eleocharis rostellata*, and in lower cover, *Carex hystericina,* and seeps with *Glyceria* spp., *Leersia oryzoides*, *Erythranthe* spp. (previously *Mimulus*), *Berula erecta*, *Veronica anagallis-aquatica,* and *Eleocharis palustris.* Floodplain vegetation often had similar species to high quality woody floodplain and riparian understory such as *Carex emoryi* and *Spartina pectinata* or *Spartina gracilis* (latter from wetland plots), and with tall *Panicum virgatum* and *Schoenoplectus pungens*. These species are spread across the study area and are also common in wet prairie from other states (Slaughter and Kost 2010, MN DNR 2025).

Figure 22. Aerial imagery of variation in wetland topographic position, saturation, and shape in a wet meadow-marsh wetland complex. The GDEs are in shades of green to forest green, and cattail is in light tan.

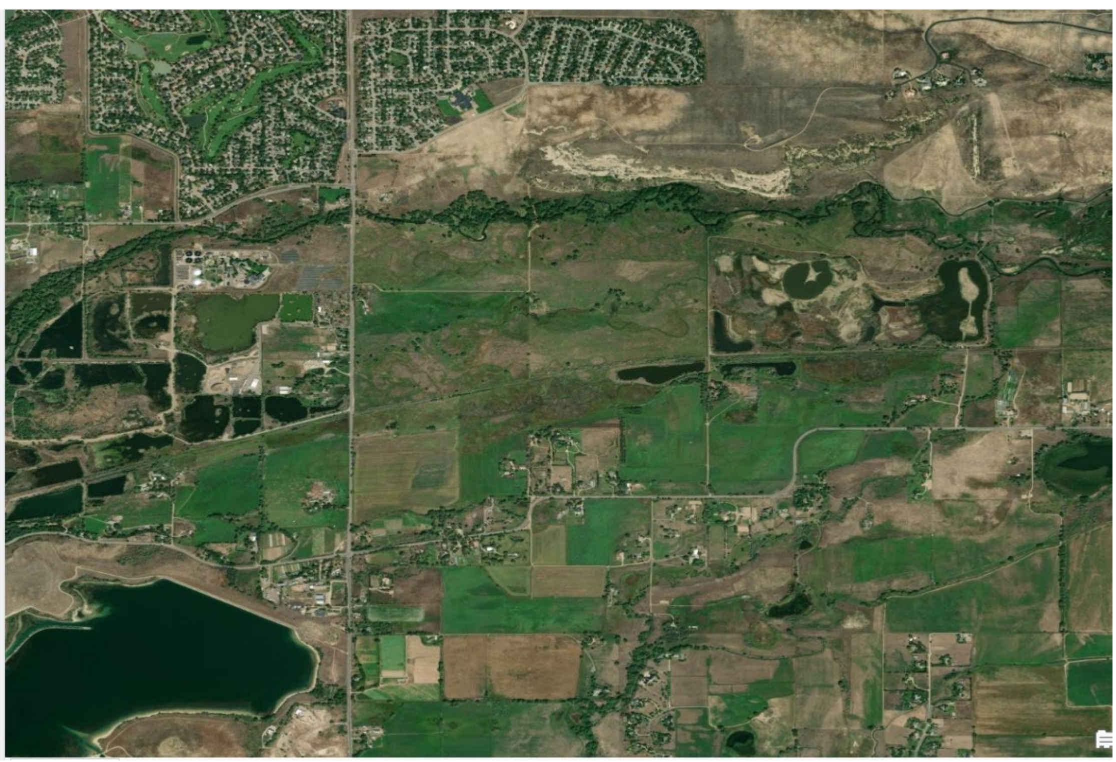

Figure 23. Front Range GDE wet meadow-marsh areas in the central floodplain, visible by bruised saturation colors and darker greens. These have altered hydrology but retention of groundwater influence and historical swale topography.

Many sites from the Front Range towards the central study area had well-known wet meadow-marsh vegetation dominants common to the foothills and lower-montane zones such as *Carex praegracilis, Schoenoplectus tabernaemontani, Schoenoplectus acutus*, *Juncus arcticus*, *Juncus* *compressus, Juncus torreyi, Schoenoplectus pungens*, and mesic forbs such as *Glycyrrhiza lepidota*, *Rumex* spp., or hay grasses (e.g.: *Agrostis*, *Alopecurus, Lolium*) and *Equisetum laevigatum.* Occasional woody species were present such as *Salix exigua* and *Amorpha fruticosa* and *Rosa* spp.

These slope and riparian herbaceous Front Range GDE sites had similar dominants to other wet meadow-marsh plains wetlands, but with higher overall richness of hydrophytic forbs or more diverse wetland graminoids. The wet meadow-marsh GDEs differ from surface water-dominated wetlands less by their dominant species, but by component diversity or indicators, with areas of diverse sedge and rushes such as *Carex bebbii, Carex brevior, Carex scoparia, Carex vulpinoidea, Juncus confusus, Juncus interior*, and *Juncus torreyi*. Common quality wet meadow forbs were *Asclepias* spp., *Verbena bracteata, Solidago* spp. and Lamiaceae species. *Distichlis stricta* and *Hordeum jubatum* are the more dominant graminoids in alkaline or saline herbaceous drainages. Smaller patches of alkaline to saline wet meadow, marshes, and riparian areas have taxa such as *Suaeda* spp., *Spergularia*, *Muhlenbergia asperifolia,* and *Puccinellia nuttalliana*, that intermix with freshwater wet meadow wetlands and taxa.

The uncommon species in wet meadow-marshes were also indicators of more biodiversity. For example, several sites from the plots analysis revealed uncommon native early successional seep species and a natural slough. A unique depressional wet meadow-marsh slough had *Eleocharis palustris* and *Schoenoplectus pungens* dominants, plus uncommon to Colorado plains species *Anemopsis californica, Polypogon interruptus, Triglochin maritima,* and *Puccinellia nuttaliana*. A historical voucher of *Anemopsis* revealed this site was a slough since the early 1900's, and the unique species composition may reflect an uncommon depressional GDE wetland type, despite its current condition with hydrologic modification. The GDE Boulder County sites supported uncommon mudflat seep species such as grand redstem (*Ammannia robusta)*, rufous bulrush (*Scirpus pendulus),* while other sites included quality moist soil grass diversity such as vine mesquite (*Hopia obtusa*) and prairie wedgegrass (*Sphenopholis obtusata*). Some GDE survey sites found new observations to Colorado or significant range expansions with this study, including marsh elder (*Iva annua),* two-flowered dwarf-dandelion *(Krigia biflora),* and flowering spurge *(Euphorbia corollata)*. Another recent CNHP study GDE plot also documented a new species observation for Colorado of American burnweed (*Erechtites hieraciifolius)* near the Arikaree River site (Lemly et al. 2025). Generally, sites with unique and high floristic quality had multiple notable factors, such as high-quality vegetation communities or important wildlife, and occasional species from uncommon guilds to plains wetlands such as native annuals, species associated with post-fire, or species better known to the midwest wet prairie or montane wet meadows and fens. The diagnostic GDE communities of *Eleocharis rostellata* fens, *Sparganium eurycarpum/Typha* marsh, and diverse wetland graminoid *Carex-Spartina* meadows occur together with other high C-value GDE species in scattered cover, such as *Lobelia* spp., *Triglochin* spp., *Sisrynchium* spp*., Eustoma grandiflorum* and *Carex hystericina.*

Most wet meadow marshes scored in good condition Bs, four scored Cs, and one scored a D (Table 8). The wet meadow-marsh Mean C range was from 1.71 in an actively grazed peat-accumulating site to 3.47 in a peat-accumulating drainage with high-quality plains GDE species plus alkaline species *Suaeda nigra* and *Sarcobatus vermiculata* (Table 9). The median Mean C across all wet meadow marshes surveyed was 2.8. Some plains wet meadow-marsh GDEs, along with plains fens, had risk of woody encroachment by tamarisk which risks the herbaceous GDEs integrity, though the wettest areas surveyed in this targeted study remained herbaceous. Other woody species such as willows can establish in plains wetlands when the water table drops or flow decreases, followed later by dieback. This study didn't survey enough shrubland GDEs to understand shrub functional roles in Colorado plains GDEs, but invasion is a possible trajectory to be aware of.

Table 8. Wet meadow-marsh wetlands surveyed in GDE study with wetland EIA scores for landscape context, vegetation, hydrology, physiochemistry subscores, and overall score.

Site x EIA Scores	*Site Code*	*Landscape Context*	*Vegetation*	*Hydrology*	*Physio-chemistry*	*EIA Score*
Boulder County	2ERAR21	4.29	3.5	4.33	4.25	**3.99 (B-)**
Boulder County	2ERAR22	4.29	3.5	4.33	4.25	**3.99 (B-)**
Kinney Lake SWA	5KIN21	4.12	3.5	3.67	3.75	**3.74 (B-)**
Kinney Lake SWA	5KIN22	4.12	3.5	4.33	4.5	**3.96 (B-)**
Two Butte Creek	AR05	3.91	2.75	5.00	4.25	**3.75 (B-)**
Springs Carrizo Creek	AR06	4.32	3.25	4.67	4.25	**3.98 (B-)**
May Ranch North	AR18	4.32	3.75	4.33	4.00	**4.08 (B+)**
Chico Creek	AR19	4.00	3.50	4.00	3.75	**3.78 (B-)**
Hugo SWA	AR29	3.79	2.75	4.33	3.75	**3.52 (B-)**
Adobe Creek	AR34	4.12	2.60	3.33	3.75	**3.31 (C+)**
Rush Creek	AR46	4.32	3.33	3.67	3.25	**3.70 (B-)**
Apache Creek	AR55	4.66	4.25	4.67	3.25	**4.40 (B+)**
Steels Fork Downstream	AR56	4.84	3.75	4.67	4.75	**4.37 (B+)**
Steels Fork Headwaters	AR60	4.66	4.00	5.00	4.50	**4.47 (B+)**
East Carrizo Creek	AR62	3.96	2.75	4.67	4.50	**3.70 (B-)**
May Ranch South	AR63	4.66	4.25	4.33	3.75	**4.35 (B+)**
Chief Creek Railroad	RE07	3.31	4.00	3.67	4.00	**3.71 (B-)**
Aker Draw	SP16	3.46	2.75	2.33	2.50	**2.84 (C-)**
Eastman Creek	SP24	3.77	4.50	4.33	2.50	**4.10 (B+)**
Sheep Draw	SP25	3.11	2.50	4.00	4.25	**3.17 (C+)**
Lost Creek	SP28	4.66	4.25	4.33	4.25	**4.39 (B+)**
Park Creek	SP29	3.03	3.50	4.00	2.50	**3.41 (C+)**
Eastman Creek Headwaters	SP33	4.65	3.75	4.00	3.75	**4.08 (B+)**
City of Boulder	SP34	4.34	3.75	4.33	4.50	**4.12 (B+)**
Loukenon	SP35	4.29	3.50	4.33	3.50	**3.94 (B-)**
West Greeley	SP43	2.09	2.20	2.33	4.00	**2.32 (D+)**
Little Dry Creek	SP46	4.15	4.50	4.67	5.00	**4.47 (B+)**
Two Mile Creek	SP47	4.32	3.75	4.00	2.75	**3.91 (B-)**
Little Owl Creek	SP49	4.50	3.50	4.67	4.25	**4.13 (B+)**

Table 9. Wet meadow-marsh wetlands surveyed in GDE study with Floristic Quality Indices and the land use index from the stressor checklist.

Site x EIA Scores	Native Richness	% Native Species	Mean C	Mean C Native	FQAI	Land Use Index
Boulder County	33	72%	3.15	4.09	18.11	4.00
Boulder County	33	72%	3.15	3.44	18.11	No data
Kinney Lake SWA	20	74%	3.04	3.58	13.58	5.00
Kinney Lake SWA	22	75%	3.10	4.11	14.56	8.37
Two Butte Creek	23	64%	2.25	3.33	10.79	4.38
Springs Carrizo Creek	30	76%	3.00	3.83	16.43	8.32
May Ranch North	17	84%	2.85	4.92	11.75	9.50
Chico Creek	29	90%	3.47	3.79	18.68	7.53
Hugo SWA	17	77%	2.91	3.67	11.99	7.29
Adobe Creek	16	60%	1.73	2.80	6.92	5.30
Rush Creek	30	73%	2.54	4.29	13.89	9.62
Apache Creek	28	78%	3.19	4.67	16.90	7.04
Steels Fork Downstream	25	74%	2.79	4.71	13.97	9.01
Steels Fork Headwaters	35	76%	3.26	5.37	19.29	9.00
East Carrizo Creek	25	65%	2.42	3.70	12.11	5.15
May Ranch South	19	75%	2.72	3.33	11.86	9.91
Chief Creek Railroad	22	69%	2.84	3.54	13.34	6.89
Aker Draw	9	69%	2.31	3.40	6.92	6.60
Eastman Creek	16	73%	3.00	3.82	12.00	7.00
Sheep Draw	15	93%	3.13	3.48	12.10	7.39
Lost Creek	31	71%	2.88	4.43	16.06	8.05
Park Creek	8	47%	1.71	3.85	4.82	3.00
Eastman Creek Headwaters	14	78%	3.44	4.13	12.89	6.90
City of Boulder	29	78%	3.41	4.10	18.34	9.97
Loukenon	30	57%	2.53	3.68	13.85	8.52
West Greeley Park	15	52%	1.89	4.25	7.32	1.41
Little Dry Creek	26	69%	3.08	3.47	15.71	8.55
Two Mile Creek	27	66%	2.54	4.20	13.18	7.90
Little Owl Creek	31	75%	2.85	2.81	15.89	6.07

Plains Fens

Fens are wetlands with consistent surface saturation at or near the ground surface and an anaerobic environment that allows accumulation of broken-down plant material, which over time builds peat, or soil of partially decomposed organic material from plants (Figure 24). Wetland science generally separates fens from other wetlands by having organic soil accumulation of 40 cm or more in the top 80 cm of soil. This study surveyed seven fen wetlands. There was not a clear break between the vegetation characteristics of fens with >40 cm of organic soil and wet meadow marsh sites with 20 to <40 cm of organic soil. Both contained communities of *Carex nebrascensis, C. pellita, C. simulata,* or *Eleocharis rostellata*. However, fens and all peat accumulating wetlands have high conservation need. They rely on undrained hydrology, a surrounding watershed that sustains a high groundwater table and consistent water source, and their organic soil is sensitive to disturbance and drying and takes hundreds to thousands of years to develop, so is very difficult to impossible restore once degraded. Plains fens are undermapped, and inventories are likely to uncover more diversity to the Colorado plains.

Figure 24. Photos of slope fen and valley bottom fen wetlands.

Fen wetlands in the plains of Colorado are formed in semi-arid climate with more fluctuation in wet-dry conditions than in wetter Colorado montane to alpine ecoregion fens and Midwest fens. As such, excepting fens with steeper slopes, many fens have and likely require factors of both depressional and slope hydrogeomorphology (Gilmore and Sullivan 2010). They can be positioned along multiple topographic positions with higher moisture and access to groundwater from alluvial aquifers or bedrock aquifer discharge, from outer watershed shoulder slope breaks, aprons, and toeslopes, to mid-watershed drainageways or valley bottom basins. Compared with other plains wetland types, plains fen indicator species are more typical of the mountains and/or the Midwest than other plains wetland species. However, there is usually some overlap with certain common plains wetland species, such as *Typha* spp., *Schoenoplectus pungens*, and *Juncus arcticus*. The similarities of Colorado eastern plain fen vegetation with the fen indicator plant species of the Midwest, includes many calcareous fen indicators, a wetland type many considered globally rare. Calcareous fens have carbon accumulation into peat and their calcium carbonates also can form marl and tufa. Plains fens frequently support sensitive and rare species, but many are not mapped, which puts them at high-risk of loss.

The surveyed eastern Colorado plains fen communities were usually dominated by peat forming Cyperaceae graminoids, often with these dominants in high percent cover such as *Carex nebrascensis*, *Carex utriculata*, *Eleocharis rostellata*, *Carex pellita* and *Carex simulata*, and occasionally *Carex aquatilis*. Plains fens can be dominated by one or two of those Cyperaceae species with low cover of other wetland graminoids and forbs or can have more diverse mixed wetland graminoid communities with high forb diversity. Plains fens have mostly to fully herbaceous structure but can have small patches of shrub species or scattered woody individuals. Some plains fens have organic soil marsh vegetation with bands of saturated *Typha latifolia* and *Schoenoplectus* marsh and understory seep forbs such as *Erythranthe* spp., *Berula erecta*, or *Cicuta maculata*; located next to swaths of wetland graminoids, some of which can form quaking mats such as *Eleocharis rostellata* or *Leersia oryzoides*. Fen wetland seep vegetation also can include finer graminoids *Muhlenbergia richardsonis*, *Polypogon monspeliensis*, *Muhlenbergia asperifolia*, and smaller forbs such as *Epilobium* spp.

The high and unique-to-the plains diversity in fens often occurs as small patches or scattered individual species diversity with low cover. Seep/springs in fens can have more bryophytes and grasses such as *Muhlenbergia filiformis*, and uncommon-to the region species across sites. One fen close to hot springs may be a warm spring fen, and in addition to *Eleocharis rostellata*, it had *Distichlis stricta* and *Almutaster pauciflorus*, an aster species rarely reported in the Colorado plains. Many plains fens have unique features such as springs, quaking mats, groundcover of non-*Sphagnum* mosses and violets, and occasionally liverworts. Most surveyed plains fens had uncommon or rare species to the region with flowering forbs such as Gentianaceae, *Scutellaria, Lobelia, Epilobium, Symphyotrichum, Helenium, Liatris, Rudbeckia, Packera,* and many others. Inundated areas can have *Hippuris vulgaris, Chara*, and aquatic grasses along seeping drainages and pool edges. Fen soils ranged from uniformly dense hemic to fibric peat or had diverse organic and mineral textures across their soil layers with bands of alluvium. Decomposed sapric organic soil occurred in patches visible at the surface in floating mats, seep/springs, or under quaking soil. Some fens had soil evidence of fluctuation in climate and natural disturbance conditions in their formation, with charcoal, inclusions of loam to clay loam sedimentation layers above more peat layers, and deep seemingly undisturbed layers with both mineral layers with high % organic content below peat. Some fen soils were underlain by a layer of fine textured mineral soil, others by weathered sedimentary bedrock soils or bedrock.

Calcareous fens and other peat-accumulating wetlands with marl substrates support exceptionally high diversity and rare species (Bart et al. 2020). These were observed with marl patches and calcareous indicators such as *Carex crawei, Utricularia minor, Triglochin maritima*, and *Eleocharis pauciflora* within *Carex nebrascensis* hummocks. Additional diversity included uncommon plains species such as *Dichanthelinum acuminatum*, *Sisyrinchium* spp., and *Parnassia* spp., many of which are specialists, add diversity to plains calcareous wetlands. Calcareous plains fens can be associated with landscapes with light colored bluffs visible on aerial imagery. In the Front Range region, many groundwater-fed wetlands in these landscapes show signs of human impacts.

Surveyed fens rated fair to very good EIA condition (Table 10), and had a Mean C range from 2.21 in a *Typha* and *Eleocharis rostellata* valley drainage fen to 4.47 in a slope fen with diverse and rare species (Table 11). Native species composition was often excellent but there was varying cover of non-natives and weeds. Eastern Colorado plains fen vegetation communities remain under-documented and more survey will help characterize their community ecology patterns.

Table 10. Fen wetlands surveyed in GDE study with wetland EIA scores for landscape context, vegetation, hydrology, physiochemistry subscores, and overall score.

Site x EIA Scores	*Site Code*	*Landscape Context*	*Vegetation*	*Hydrology*	*Physio-chemistry*	*EIA Score*
Soapstone Prairie	3SOAP21	4.15	4.5	4	3.75	**4.22 (B-)**
Soapstone Prairie	3SOAP22	3.99	4.5	4.33	3.75	**4.25 (B+)**
Horse Creek	AR03	3.16	2.50	4.00	2.50	**3.06 (C+)**
Carpenter Creek	SP36	3.79	3.50	3.00	3.00	**3.43 (C+)**
Reservoir Ridge	SP50	4.33	3.25	4.00	5.00	**3.87 (B-)**
Hoehne	AR14	3.83	3.25	4.00	4.00	**3.66 (B-)**
Chico Seeps	AR20	4.29	3.50	3.67	4.25	**3.82 (B-)**
Arikaree River	RE04	4.65	3.60	5.00	4.00	**4.28 (B+)**

Table 11. Fen wetlands surveyed in GDE study with Floristic Quality Indices and the land use index from the stressor checklist.

Site x FQA	# Native Species	% Native Species	Mean C	Mean C Native	FQAI	Land Use Index
Soapstone Prairie	46	79%	4.19	5.37	28.39	**5.30**
Soapstone Prairie	47	81%	4.47	5.51	30.61	**9.76**
Horse Creek	9	62%	2.21	3.44	6.64	**1.92**
Carpenter Creek	32	70%	2.96	4.25	16.72	**6.69**
Reservoir Ridge	30	83%	3.83	4.60	21.00	**8.31**
Hoehne	15	64%	2.43	3.73	9.43	**6.45**
Chico Seeps	23	81%	3.64	4.43	17.47	**8.40**
Arikaree River	30	81%	3.41	4.20	18.65	**9.80**

Plains Riparian

Plains riparian sites (n=6) were some of the most unique and biodiverse sites when compared with others surveyed in this study. The woody species component in medium to narrow floodplains separate this wetland type from others, with *Salix interior* (previously *S. exigua*), *Populus deltoides,* and *Salix amygdaloides*, and infrequent *Amorpha* and *Crataegus* patches (Figure 25). Common GDE features in these sites can be shallow to deep pools with seeping outcrops, saturated seepy shallow-water shrub drainages, lush forbs such as *Sparganium eurycarpum* and *Sagittaria* spp. – usually both alongside *Typha*, *Schoenoplectus* and *Scirpus* spp., *Scutellaria* spp., *Persicaria amphibia*, and visible groundwater bubbling into a sandy to mucky drainage along with more saturated areas with peat accumulation. Intermittent pools and slow groundwater-drainages include mudflat species, wetland graminoids, and some support *Potemogeton* spp. These sites can have varied physiognomy from herbaceous to shrub to woody patches interspersed growing in shared saturated to inundated hydrology. The GDE understory species in these sites included some cover of mixed sedges, grasses, rushes and bulrushes both common in GDE wet meadow-marshes and plains floodplains, plus moderate cover of native floodplain forbs such as *Toxicodendron radicans, Urtica dioica, Ranunculus* spp., and *Bidens* spp., and high diversity of less common forbs. These sites have seep drainages and swales with near-succulent GDE graminoids such as *Glyceria* spp., and *Poa palustris.* Examples of wetland graminoid diversity were *Carex bebbii, Carex hystericina, Eleocharis palustris, Spartina pectinata, Carex pellita, Eleocharis rostellata, Elymus* spp., and *Panicum virgatum.*

Figure 25. Photos of plains riparian GDE wetlands

The confined canyon site and a second similar site in the plots analysis had unique sedge zone codominants *Carex gravida* and *Carex vulpinoidea*, and more shrub and willow cover. *Carex vulpinoidea* is also common in the quality Front Range wet meadows in Boulder County and in other woody canyon riparian GDEs from the Plots Analysis, but the combination of those two species in plains floodplain is unusual. The surveyed canyon site also had deep pools in the channel. Another calcareous riparian site had light colored (potentially marl) substrates with sheet-flow seeps, and small patch vegetated mossy slope break seeps with diminutive forbs. This site had the highest surveyed diversity, with unique or high-quality species to the region such as *Torreyochloa pallida var. pauciflora, Carex crawei, Elodea canadensis, Eleocharis pauciflora, Triglochin spp., Deschampsia cespitosa*, and others. Woody canyon riparian areas and springs from the plots analysis often supported *Bolboschoenus fluviatilis,* plus high C-value taxa such as *Muhlenbergia alopecuroides, Cystopteris fragilis, Carex gravida, Viola nephrophylla*, and Berlandier's sundrops (*Calylophus berlandieri*)*.* Overall, GDE vegetation assemblages and hydrology in plains riparian wetlands had such high patch diversity of vegetation and water features, that there was low vegetation patch redundancy in the woody riparian sites surveyed, excepting of species that are also common in non-GDE wetlands.

Surveyed plains riparian GDEs received B+ to C- EIA Ranks (Table 12) and had a Mean C from 2.24 to 3.52 (Table 13). The FQA values didn't clearly correspond to floristic diversity, as the site with the lowest C-value supported excellent imperiled species habitat and plant communities, and also was the east-most surveyed site, and the highest C-value site also had and a mix of good quality eastern Colorado floodplain species such as sandbar willow and prairie cordgrass and wetland graminoid diversity with fewer state-imperiled species.

Table 12. Plains riparian wetlands surveyed in GDE study with wetland EIA scores for landscape context, vegetation, hydrology, physiochemistry subscores, and overall score.

Site x EIA Scores	*Site Code*	*Landscape Context*	*Vegetation*	*Hydrology*	*Physio-chemistry*	*EIA Score*
Box Elder Creek at Lowry Ranch	1LOW21	4.29	3.83	4.33	4.5	**4.13 (B+)**
Box Elder Creek at Lowry Ranch	1LOW22	4.12	3.67	4.67	4.75	**4.12 (B+)**
South Fork Republican Downst.	4SREP21	4.33	4	4.33	4.75	**4.23 (B-)**
South Fork Republican Downst.	4SREP22	4.15	4	3.67	4.25	**3.98 (B-)**
Perly Canyon	AR58	4.83	4.17	5.00	4.00	**4.55 (A)**
Turkey Creek	AR64	3.91	2.00	3.67	3.75	**3.10 (C+)**
Landsman Creek	RE05	2.49	2.6	3.33	2.75	**2.75 (C-)**
Lone Tree Creek	SP19	3.75	4.50	4.67	3.50	**4.24 (B+)**

Table 13. Plains riparian wetlands surveyed in GDE study with Floristic Quality Indices and the land use index from the stressor checklist.

Site x FQA	# Native Species	% Native Species	Mean C	Mean C Native	FQAI	Land Use Index
Box Elder Creek	38	72%	3.06	4.24	18.84	**5.10**
Box Elder Creek	39	67%	2.88	4.26	17.98	**7.79**
South Fork Republican Downst.	28	74%	2.79	3.79	14.76	**5.00**
South Fork Republican Downst.	31	64%	2.24	3.55	12.50	**9.22**
Perly Canyon	31	65%	2.85	4.39	15.89	**10.00**
Turkey Creek	13	63%	2.30	3.54	8.29	**9.79**
Landsman Creek	23	85%	3.52	4.13	16.87	**4.95**
Lone Tree Creek	49	71%	3.49	4.92	24.45	**7.82**

Plains Floodplain

Floodplain wetlands are influenced by river processes, with vegetation patch variation depending on the groundwater hydrology, surface and alluvial flow paths, and invasive species. Groundwater-dependent floodplain wetlands need more study and are a small portion of the overall floodplain, but plains floodplain with native understory or peatlands are of high conservation value. This study included four plains floodplain surveyed sites. Groundwater-influenced floodplain features include large wet meadow-marshes with flooded and groundwater-fed swales, warm-water sloughs, and peatlands; and open-wooded near flats, depressions, and ponded areas. Most Colorado plains floodplains are much drier and with high weed cover or upland species. However the wettest areas in the floodplain that connect to groundwater have occurrences of native understory wetland vegetation, and open water side channels or slough drainages. Soils in this study's surveyed wetlands were clay loam or clay with either a low chroma or brown 10 YR 2/2 that can indicate high organic content, but the pits were classified as mineral with organic or muck areas layers of 5 cm or less. However, plains floodplain soils from the plots analysis included deep organic layers up to fen depths.

Figure 26. Photos of plains floodplain with groundwater influence.

The healthiest plains floodplain GDE (Figure 26) ranked a B+ with EIA had excellent native diversity with open *Salix amygdaloides* and *Populus deltoides*, and a native understory of *Carex emoryi, Spartina pectinata, Panicum virgatum,* and *Schoenoplectus pungens*, plus many native species. Examples of less dominant native understory species included *Carex brevior, Carex praegracilis, Asclepias incarnata, Eleocharis palustris, Teucrium canadense var. occidentale, Toxicodendron rydbergii*, and *Sagittaria cuneata.* Other surveyed floodplains surveyed and wetland plots had a mix of desirable native species with similar dominants plus *Carex pellita, Bolboschoenus fluviatus, Spartina gracilis, Fraxinus pennsylvanica, Panicum* (previously *Hopia*) *obtusum, Muhlenbergia asperifolia,* and other diverse forbs and graminoids such as *Sphenopholis obtusata, Scirpus pallidus, Eustoma exaltatum* ssp*. russellianum, Mainthemum stellatum,* and *Phyla lanceolata,* but these three other sites also had indicators of potential groundwater loss, but some GDE species were still present and the GDE saturation signature was visible on the imagery. Canada thistle was in all the wetlands, a species that often invades floodplains and other wetlands in response to drying trends. Some landowners manage their floodplain as moist soil units, and these also can have lush and native floodplain vegetation patches, particularly in locations that receive groundwater.

Surveyed GDE floodplains received B+ to C- EIA Ranks (Table 14) and had a Mean C from 2.35 to 2.79 (Table 15). There was a visible range in wetland condition and groundwater source health, and the FQA metric scores were relatively similar in this small sample size, potentially from retention of high quality plant species in wetlands with drying. The relative native percent cover was more indicative of condition and management needs than the C-value based metrics in sites surveyed with this study, but a sample size of four for this wetland type is not representative of the range of GDE floodplain wetlands.

Table 14. Plains floodplain wetlands surveyed in GDE study with wetland EIA scores for landscape context, vegetation, hydrology, physiochemistry subscores, and overall score.

Site x EIA Scores	*Site Code*	*Landscape Context*	*Vegetation*	*Hydrology*	*Physio-chemistry*	*EIA Score*
South Republican SWA Upstream	RE09	3.32	3.50	4.00	5.00	**3.67 (B-)**
Messex SWA	SP08	2.67	2.67	2.33	4.00	**2.67 (C-)**
South Platte Ovid	SP13	3.96	3.83	4.33	5.00	**4.07 (B+)**
South Platte Orchard	SP17	4.43	1.75	4.33	5.00	**3.41 (C+)**

Table 15. Plains floodplain wetlands surveyed in GDE study with Floristic Quality Indices and the land use index from the stressor checklist.

Site x FQA	# Native Species	% Native Species	Mean C	Mean C Native	FQAI	Land Use Index
South Republican SWA Upstream	20	72%	2.64	3.70	11.82	**6.26**
Messex SWA	23	67%	2.35	3.48	11.28	**6.70**
South Platte Ovid	28	68%	2.68	3.82	14.15	**7.25**
South Platte Orchard	25	74%	2.79	3.68	13.94	**8.92**

Saline playas

Saline playas are a type of closed-basin saline depressional wetlands smaller than saline lakes and reservoirs and with a more terminal basin than outflow saline riparian drainages with pools (Figure 27). This wetland type was the most unique and least-documented wetland type in the mapping. Seven surveyed AAs were classified as saline playas for this study, and an additional four saline playas were included in the plots analysis. These have a depressional hydrogeomorphic class and both groundwater and surface water sources. Their vegetation is typically in three major concentric bands: open water and bare saturated ground in the wetland center, open-scattered presence of halophyte forbs with sparse salt-tolerant graminoids in low cover in a mudflat zone, and an outer wetted zone with salt-tolerant wetland graminoids with bulrushes such as *Bolboschoenus maritimus, Schoenoplectus* spp., or *Distichlis stricta*. There can be open forb communities with *Sesuvium verrucosum* and *Heliotropium curassavicum* and wet mudflats with Amaranthaceae such as *Oxybasis rubra, Oxybasis glauca, Suaeda* spp., and *Atriplex spp. Typha* is frequently present and can invade and overtake saline playas in sites with more hydrologic alteration and freshwater additions. Saline hydrology needs more study in eastern Colorado, and there may be a gradient between saline and freshwater playas. It is unknown whether the cause of intermediate salinities are natural or anthropogenic. *Iva axillaris* was present in several sites in the Plots analysis with moderate salinity indicators instead of the thick surface salt crusts, and in a borderline saline playa site that had freshwater in the central wetted area, halophytes, and more saline indicators in the outer wetland complex. Overall wetland species richness is naturally low in this wetland type. Saline playas also can have scattered cover of *Kochia* and *Salsola* and other noxious weeds. *Typha* and noxious weeds can invade especially in irrigated and managed hydrologic surrounding landscapes. The ponded area can be unvegetated or can have aquatic vegetation such as *Ruppia cirrhosa.*

Saline playa soil layers typically have mostly clayey or loamy mineral soil with salt crusts, with a biofilm under the salt layer. The wettest areas in the wetland often have dark gray to black muck with high organic content below the crust. Some sites can have lighter color soil values, or layers with sandy or silty loam textures, but most sites have a low chroma of 1 or gley. Salt deposits are present throughout the soil profile.

Figure 27. Photos of saline playa wetlands.

Wetted saline playas have visible seasonal seeps in localized areas in their outer fringe, and they also often have a central zone of soft, unwadeable muck, with connection to the groundwater table. The condition of the saline playa's contributing watershed and the proportion of natural groundwater and surface water inputs affect the function. Water levels fluctuate due to precipitation and runoff; some saline playas dry seasonally, while others retain standing water or muck through the year.

Salinity measurements as evidenced by high YSI electroconductivity (EC) measurements can have high variability within one wetland but often increase towards the center. Their vegetation communities need to be updated in the U.S. National Vegetation Classification (USNVC) descriptions for their occurrences in Colorado plains, to improve tracking of saline playas and to help identify the those with the highest ecological health, hydrology, and native plant composition. Saline playas ranged from very good to fair/poor condition in EIA scores (Table 16). Mean C ranged from 1.75 in a saltgrass-alkali bulrush-cattail site to 3.67 in a wetted saline playa with saltgrass and halophyte forbs, plus kochia and tamarisk in lower cover (Table 17).

Table 16. Saline playa wetlands surveyed in GDE study with wetland EIA scores for landscape context, vegetation, hydrology, physiochemistry subscores, and overall score.

Site x EIA Scores	*Site Code*	*Landscape Context*	*Vegetation*	*Hydrology*	*Physio-chemistry*	*EIA Score*
Black Lake	AR10	4.48	3.00	4.33	4.00	**3.84 (B-)**
Saline Near Hugo	AR53	4.49	3.75	4.33	4.00	**4.13 (B+)**
Swede Lake	AR57	4.66	3.50	4.33	5.00	**4.16 (B+)**
Morgan CO Saline	SP15	3.45	3.00	3.33	5.00	**3.36 (C+)**
Wellington SWA	SP30	3.99	2.00	4.00	4.25	**3.24 (C+)**
Mud Lake	SP42	2.99	2.50	2.33	4.25	**2.73 (C-)**
Greasewood Lake	SP44	4.66	4.00	5.00	4.50	**4.48 (B+)**

Table 17. Saline playa wetlands surveyed in GDE study with Floristic Quality Indices and the land use index from the stressor checklist.

Site x FQA	# Native Species	% Native Species	Mean C	Mean C Native	FQAI	Land Use Index
Black Lake	3	75%	3.50	4.67	6.06	**9.80**
Saline Near Hugo	13	81%	2.94	3.62	10.59	**8.92**
Swede Lake	7	78%	3.67	4.71	9.70	**8.40**
Morgan CO Saline	3	75%	2.75	3.67	4.76	**4.65**
Wellington SWA	12	73%	2.31	3.08	8.01	**7.31**
Mud Lake	5	57%	1.75	2.80	3.91	**6.69**
Greasewood Lake	6	67%	3.11	4.67	7.62	**9.00**

4.4 Vegetation Composition

A total of 404 unique plant taxa, mostly keyed to species, were found in the 51 surveyed groundwater-dependent wetland AAs. The list of taxa is presented in Appendix E. Species richness across all plots averaged 33 plant species, with a range of 5-71 species observed at each plot. Species richness was very similar between Level 3 and Level 2 surveys, with an average richness of 34 in the Level 3 AAs and 32 in the Level 2 AAs. The similar means showed the success and efficiency of Level 2 relevé surveys to capture vegetation diversity, as Level 3 plot surveys can take several hours longer than a Level 2 relevé. The five pilot EIA sites with two visit years (two Level 3 and three Level 2) discovered an average of 28% more species in the second year, with between 16% - 41% more plant species (5 – 20 more species) discovered with more than one vegetation survey year, which demonstrates the value of multiple site visits. At the five pilot sites, Native Mean C was more stable between years than species richness and diversity, with a difference of only 0-0.24 between years. Mean C varied slightly more with a difference of 0-0.54 between years. Standardized plot-based surveys or transects can detect change in vegetation and species cover more accurately for monitoring needs, but for floristic community typing, the relevé survey methods used in this study appear sufficient. Factors besides change in vegetation quality can affect FQA metrics, especially survey dates earlier or later in the growing season.

Common and Dominant Plant Species

The most commonly observed plant species in the surveyed GDEs were generally cosmopolitan wetland and upland species that are common across all plains wetlands. Eight plant species were encountered in >50% of the 51 surveyed AAs: common threesquare, Canada thistle, curly dock, mountain rush, foxtail barley, common spikerush, narrowleaf cattail, and softstem bulrush (Table 18). These species are not unique to plains GDEs and are some of the most common species observed in all Colorado plains wetland types. The most dominant plants species, those with >10% cover in at least two sites, are more indicative of plains GDEs (Table 19). About two-thirds of the most common species were native, but 89% of the dominant species at each surveyed plot were native. Two-thirds of the common species were true hydrophytes with a wetland indicator status of OBL or FACW, and 78% of the dominates were true hydrophytes. The dominants were also often indicators of the wetland type, such as saline halophyte indicators, native floodplain species, cattail marsh, or fen indicators.

The percent cover of native species in the AA ranged from 32% to 98% across the 51 surveyed AAs and averaged 79%. The average GDE wetland native cover was relatively high for working landscapes like the Colorado plains, but it still considered a C- in the EIA relative native cover metric. Narrowleaf cattail (*Typha angustifolia*), hybrid cattail (*Typha* x *glauca*), and reed canarygrass (*Phalaris arundinacea*) are cryptogenic species and were not considered native for this analysis. These species were present in 30 sites, and of the 51 sites surveyed, they comprised more than half of the non-native plant cover in 13 sites.

Table 18. Thirty most commonly observed plants in 51 surveyed plains groundwater-dependent wetlands.

Scientific Name	Common Name	# of AAs	Wetland Status[1]	Native Status	C-Value
Schoenoplectus pungens	Common Threesquare	42	OBL	Native	4
Cirsium arvense	Canada Thistle	40	FACU	Noxious List B	0
Rumex crispus	Curly Dock	34	FAC	Exotic	0
Juncus arcticus var. balticus	Mountain Rush	32	FACW	Native	4
Hordeum jubatum	Foxtail Barley	31	FACW	Native	2
Eleocharis palustris	Common Spikerush	27	OBL	Native	3
Typha angustifolia	Narrowleaf Cattail	26	OBL	Cryptogenic	1
Schoenoplectus tabernaemontani	Softstem Bulrush	26	OBL	Native	3
Carex nebrascensis	Nebraska Sedge	23	OBL	Native	5
Veronica anagallis-aquatica	Water Speedwell	23	OBL	Native	1
Distichlis stricta	Saltgrass	22	FACW	Native	4
Mentha arvensis	Wild Mint	22	FACW	Native	4
Berula erecta	Cutleaf Waterparsnip	21	OBL	Native	5
Asclepias speciosa	Showy Milkweed	20	FAC	Native	3
Asclepias incarnata	Swamp Milkweed	20	FACW	Native	4
Lycopus americanus	American Water Horehound	19	OBL	Native	5
Polypogon monspeliensis	Annual Rabbitsfoot Grass	19	FACW	Exotic	0
Glycyrrhiza lepidota	American Licorice	19	FACU	Native	3
Lactuca serriola	Prickly Lettuce	19	FAC	Exotic	0
Lemna minor	Common Duckweed	19	OBL	Native	2
Spartina pectinata	Prairie Cordgrass	18	FACW	Native	7
Taraxacum officinale	Common Dandelion	18	FACU	Exotic	0
Carex praegracilis	Clustered Field Sedge	18	FACW	Native	5
Equisetum laevigatum	Smooth Horsetail	17	FAC	Native	4
Agrostis stolonifera	Creeping Bentgrass	16	FACW	Exotic	0
Bassia scoparia	Burningbush	16	FACU	Exotic	0
Typha latifolia	Broadleaf Cattail	16	OBL	Native	4
Panicum virgatum	Switchgrass	16	FAC	Native	5
Melilotus albus	Sweetclover	16	FACU	Exotic	0
Verbena hastata	Swamp Verbena	15	FACW	Native	4

[1] Wetland Indicator Status based on the National Wetland Plant List for the Great Plains region. OBL = Obligate Wetland, almost always occur in wetlands; FACW = Facultative Wetland, usually occurs in wetlands; FAC = Facultative, occurs in wetlands and non-wetlands; FACU = Facultative Upland, usually occur in non-wetlands, but may occur in wetlands; UPL = Obligate Upland, almost never occurs in wetlands. --- indicates not included on National Wetland Plant List.

Table 19. List of plant dominants species in 51 surveyed groundwater-dependent wetlands that includes species occurring in a minimum of 2 sites and with an average site cover of > 10%, where present.

Scientific Name	Common Name	Average % Cover	# of AAs	Wetland Status[1]	Native Status	C-value
Schoenoplectus pungens	Common Threesquare	24.5	42	OBL	Native	4
Carex simulata	Analogue Sedge	23.2	3	OBL	Native	6
Eleocharis rostellata	Beaked Spikerush	22.7	11	OBL	Native	6
Carex emoryi	Emory's Sedge	19.7	6	OBL	Native	5
Distichlis stricta	Saltgrass	18.9	22	FACW	Native	4
Typha angustifolia	Narrowleaf Cattail	18.8	26	OBL	Cryptogenic	1
Carex nebrascensis	Nebraska Sedge	18.4	23	OBL	Native	5
Spartina pectinata	Prairie Cordgrass	17.8	18	FACW	Native	7
Salix exigua	Narrowleaf Willow	16.8	13	FACW	Native	3
Juncus arcticus var. balticus	Mountain Rush	16.6	32	FACW	Native	4
Iva axillaris	Povertyweed	16.5	2	FAC	Native	2
Carex utriculata	Northwest Territory Sedge	13.6	3	OBL	Native	5
Typha latifolia	Broadleaf Cattail	12.1	16	OBL	Native	4
Sesuvium verrucosum	Winged Seapurslane	11.3	4	FACW	Native	6
Toxicodendron rydbergii	Western Poison Ivy	11.1	7	FACU	Native	3
Sparganium eurycarpum	Broadfruit Bur-Reed	11.0	5	OBL	Native	6
Sporobolus airoides	Alkali Sacaton	10.8	6	FAC	Native	5
Lolium arundinaceum	Tall Fescue	10.5	2	FACU	Exotic	0
Schoenoplectus acutus	Hardstem Bulrush	10.4	9	OBL	Native	3

[1] Wetland Indicator Status based on the National Wetland Plant List for the Great Plains region. OBL = Obligate Wetland, almost always occur in wetlands; FACW = Facultative Wetland, usually occurs in wetlands; FAC = Facultative, occurs in wetlands and non-wetlands; FACU = Facultative Upland, usually occur in non-wetlands, but may occur in wetlands; UPL = Obligate Upland, almost never occurs in wetlands. --- indicates not included on National Wetland Plant List.

Rare Plant Species

Many of the GDE wetlands also had high quality plant community dominants, rare plants, and indicator species of GDEs that were uncommon or under-documented in the Colorado plains or located in the edge of their range. Seventeen of the 51 surveyed AAs had CNHP-tracked rare plant species. The GDE AAs from the plots analysis had additional tracked rare plant observations, with a total of 20 Biotics-tracked rare species in the 109-site GDE analysis. (Table 20, Figure 28). CNHP also tracks plant communities using USNVC, but this study's plant species data were not mapped by USNVC communities. Most sites had plant community dominants or indicators present that are tracked either at the community level in the plains, somewhere in Colorado, or in similar at-risk ecosystems from another region. The GDE wetland characteristics described in the preceding section, and the lists below of specialized species and indicators of at-risk or rare Colorado plains habitat types can be used to inform Colorado plains vegetation classification.

Table 20. Rare plant observations in plains groundwater-dependent wetland (GDE) assessment areas (AAs) and in GDE Plots Analysis AAs (Plots). Wetland Indicator Status is for the Great Plains Region.

Scientific Name	Common Name	Wetland Status	C-value	CNHP Tracked	# of AAs	# of Plots	CO Rank
Carex crawei	Crawe's Sedge	FACW	8	Y	2	1	G5S1
Phyla lanceolata	Fogfruit	FACW	*	Y	3	-	G5S1
Scutellaria lateriflora	Mad-dog Skullcap	FACW	10	Y	2	-	G5S1
Dichanthelium lanuginosum	Woolly Panicgrass	FAC	8	Y	1	-	GNRS2
Krigia biflora	Two-flower Dwarf-dandelion	FAC	7	Y	1	-	G5S2
Lobelia cardinalis	Cardinal-flower	FACW	7	Y	2	-	G5S2
Sisyrinchium demissum	Stiff Blue-eyed-grass	OBL	7	Y	1	-	G5S2
Sparganium eurycarpum	Broad-fruited Bur-reed	OBL	6	Y	6	1	G5S2
Ambrosia linearis	Linear-leaf Bursage	-	4	Y	1	-	G3S3
Bolboschoenus fluviatilis	River Bulrush	OBL	8	W	1	-	G5S1
Juncus acuminatus	Sharp-fruit Rush	OBL	5	W	1	-	G5S1
Carex gravida	Heavy-fruit Sedge	FACW	4	W	1	1	G5S3
Equisetum variegatum var. variegatum	Variegated Horsetail	FACW	5	W	1	-	G5T5S3
Eustoma exaltatum ssp. russellianum	Showy Prairie-gentian	-	7	W	2	1	G5T5S3
Utricularia minor	Lesser Bladderwort	OBL	9	W	2	-	G5S3
Hypoxis hirsuta	Common goldstar	FACW	10	Y	-	1	G5S1
Ammannia robusta	Grand redstem			Y	-	2	G5S2
Sporobolus texanus	Texas dropseed	FAC	7	Y	-	1	G5S2
Liatris ligulistylis	Rocky Mountain blazing star	FAC	8	Y	-	1	G5?S2
Equisetum variegatum ssp. variegatum	Variegated scouringrush	FACW	5	W	-	1	G5S3

Figure 28. Examples of CNHP-tracked plains groundwater-dependent wetland plant biodiversity. Listed from left to right and top to bottom in their saturated habitat: *Eustoma grandiflorum*, *Sparganium eurycarpum, Phyla lanceolata,* and *Utricularia minor.*

Indicator and Specialized GDE Wetland Plant Species

Many of the plant species observed in GDE indicate specific conditions. The following sections describe which species are abundant in certain GDE types.

Plains GDE Indicator Species

Several plant species were often located in areas of groundwater discharge or groundwater-dependent wetlands. Crews noted the following species to be potential plains GDE indicators by their consistent position in seeps, quaking areas, around springs, and on saturated organic soils, and in drainages with visible groundwater discharge (Figure 29).

- *Berula erecta* - seeps
- *Bidens* spp. – groundwater-rich marsh and seep areas
- *Carex hystericina* – seeps and groundwater-fed wet meadows
- *Carex nebrascensis* – organic soil layers and plains fens when dominant on saturated soil
- *Carex simulata* – organic soils and plains fens
- *Carex utriculata* – plains fens
- *Eleocharis rostellata* – organic soils, quaking mats, and plains fens
- *Glyceria* spp. - seeps
- *Leersia oryzoides* – floating mats and groundwater in streamlets
- *Lobelia cardinalis and Lobelia siphilitica* – organic soils
- *Erythranthe* spp. (formerly *Mimulus* spp.) - seeps
- *Rorippa palustris* - seeps
- *Scutellaria galericulata*, *Scutellaria lateriflora*,– organic soils
- *Sparganium eurycarpum* – surrounding spring depressions and low areas in marshes with groundwater
- Patches with high cover of moss or liverwort spp. in saturated wetlands

There are many more plant taxa common in plains GDEs associated with locations of groundwater-input but with broader ecological niches that both occur regularly in GDE-obligate wetlands and in other wetland types in small-patch seep or saturated soil areas, such as *Alisma* spp., *Lycopus* spp., *Sagittaria* spp., *Veronica anagallis-aquatica, Nasturtium officinale, Ranunculus cymbalaria, Ranunculus scleratus, Rorippa palustris, Alopecurus aequalis*, and sometimes *Spartina pectinata, Carex pellita, Carex praegracilis, Eleocharis* spp., and *Juncus* spp.

Figure 29. Examples of typical plains groundwater-dependent wetland plant biodiversity. Listed from left to right and top to bottom: *Erythranthe* in a *Sparganium-Typha* seep, *Scutellaria galericulata* in a calcareous wet meadow drainage, *Carex nebrascensis* and *Carex hystericina* in a peaty wet meadow, and *Sagittaria* sp. in a seep depression.

Montane Species Observed in Plains GDEs

Many plant species observed in the plains are more commonly found in Colorado's mountains than in the plains, and they may be indictors of fens in the Front Range and plains (Figure 30). Many of these typical montane species are also in Midwestern fens or other low elevation fens (e.g.: Steinauer et al. 1996; Spieles et al. 1999; Amon et al. 2002; Singhurst 2019), such as:

- *Agrostis scabra*
- *Aster (Symphyotrichum spp.).*
- *Calamagrostis spp.*
- *Carex aurea*
- *Carex utriculata*
- *Deschampsia cespitosa*
- *Gentianella acuta* and Gentianaceae spp.
- *Iris missouriensis*
- *Juncus ensifolius*
- *Montia chamissoi*
- *Muhlenbergia filiformis*
- *Primula pauciflora*
- *Packera pseudoaurea*
- *Parnassia palustris* var. *montanensis*
- *Rudbeckia hirta* var. *pulcherrima*
- *Sisryinchium* spp.
- *Valeriana edulis*
- *Viola nephrophylla*
- Groundcover of moss and liverworts

Figure 30. Plant examples from plains fens - *Gentianella amarella* (left), and *Marchantia* with seep plants (right).

Observed Calcareous Peatland and Plains Fen Indicator Species

Some species were observed in wetlands with marl seeps are often associated with plains calcareous wetlands (Figure 31), which also overlap with calcareous fen communities described in the Midwest and higher elevations (e.g.: Sanderson and March 1996; Byers 2000; Amon et al. 2002; MN DNR 2022 and 2025). Of the calcareous wetlands surveyed, the sites were so uniquely diverse that we could not identify all the site diversity outside of the plots in one visit, and so site diversity is likely higher than reported.

- *Carex crawei*
- *Parnassia palustris*
- *Eleocharis quinqueflora*
- *Rudbeckia hirta*
- *Eupatorium perfoliatum*
- *Eleocharis rostellata*
- *Salix bebbiana*
- *Triglochin maritima* and *Triglochin palustris*
- *Utricularia minor*
- *Valeriana edulis*

Figure 31. Indicators of calcareous seep wetlands: *Triglochin* (left) and the light colored soil of marl (right).

Species Associated with Saline Depressions

Saline depressions have unique floristics (Figure 32). Diagnostic halophytes and common native species are listed below for eastern Colorado saline playas:

- *Bolboschoenus maritimus* – dominant graminoid in outer zone of saline depressions
- *Distichlis stricta* - dominant graminoid in outer zone of saline depressions
- *Heliotropium curassavicum* - halophyte wetland indicators
- *Iva axillaris* - potential indicator; plots have saline indicators but unconfirmed salinity
- *Ruppia cirrhosa* - dominant aquatic zone halophyte
- *Salicornia rubra* - halophyte wetland indicator
- *Sesuvium verrucosum* - halophyte wetland indicator
- *Suaeda calceoliformis* - halophyte wetland indicator
- *Suaeda nigra* - halophyte wetland indicator

Figure 32. Photos of saline playa indicator species *Heliotropium curassavicum* and *Ruppia cirrhosa.*

Mean C, Native Mean C, and High C-Value Species

Floristic Quality Assessment (FQA) is analysis of the site plant assemblages using C-values, native species, richness, and other measures of floristic quality to better understand wetland vegetation condition and indicators. In the eastern plains of Colorado, there are variable relationships between FQA scores, overall stressor ratings, and condition ratings at the site level.

The average C-value of all species within a site (Mean C) can indicate site quality in some Colorado wetland types. Each species in the Colorado flora with habitat understood by experts has been assigned a value between 0-10, with higher C-values indicating higher species fidelity to high quality habitat or less disturbance tolerance. Surveyed plains GDEs had Mean C scores ranged from 1.71–4.47 (Tables 9, 11, 13, 15, 17), with an average of 2.89. The fen site with the highest Mean C in the project area (4.47) also scored high in all FQA metrics and had exceptional native plant biodiversity (Table 11). The site with the lowest Mean C site was actively grazed wetland, with good species composition and substrate, but grazing impacts stressed the vegetation structure and water quality. This wetland also had the lowest surveyed FQAI score in the study, due to <50% native species richness. Its other FQA metrics scored variably, with a mid-range Native Mean C of 3.85, and 88% relative native cover. Its native species were similar to a *Carex nebrascensis* fen with *Triglochin maritima, Eleocharis palustris, Schoenoplectus pungens, Juncus arcticus,* and *Veronica anagallis-aquatica*, and some areas of deep organic soil. This vegetation assemblage plus the site history prompts the FQA-interpretation question of whether this peat-accumulating assemblage is normally lower diversity and good quality, or lower quality in response to grazing stress, despite the relatively high-quality vegetation if compared with non-GDE plains wetlands. Sites with mid-range Mean C and native Mean C values had variable relationships with stressor impacts and EIA condition ranks. Variability in C-values within sites and across sites with similar condition highlights the need for further research to inform plains wetland C-value interpretation.

There were 84 observations of species with high-C-values (≥7) occurring across 33 surveyed GDEs (Table 21). The average number of high C-value observations/site was <2, but some sites had more high C-value species. These also had higher conservation significance with potential remnant vegetation from earlier climates and land use eras. The two sites with the greatest richness of high C-value species were a fen at Soapstone Prairie (17 high C-value species) and a peat-accumulating seep and riparian area at Lone Tree Creek (9 high C-values). These sites also had organic soil accumulation (one fen, one histic epipedon), high species richness, and marl indicators. Both wetlands also supported *Carex utriculata*, a fen indicator in the plains region. Another unique shallow-flooded swamp woodland site on Box Elder Creek at Lowry Ranch with 5 high C-value species, is one of the few sandy creeks on the plains that typically washes annually in multiple sections of the creek. That site had tall *Schoenoplectus pungens* - GDE forb wet prairie patches and *Salix amygdaloides*- native seep understory with *Glyceria, Spartina,* and *Carex*.

Sites with the highest plant C-values were slope peat-accumulating wetlands or fens with relatively undisturbed surrounding landscapes. Two site occurrences of *Scutellaria lateriflora* (C-value = 10) were observed at sites with >20 cm of peat-accumulation, and *Utricularia minor* (C-value = 9) was observed in a calcareous fen hummock plant community with *Triglochin maritima* and *Carex nebrascensis*. Slenderleaf false foxglove (*Agalinis tenuifolia*; C-value=10) was also present in a plots Aanalysis slope wetland.

Table 21. List of High C-Value Species observed within 51 surveyed Colorado plains groundwater-dependent wetland assessment areas (AAs).

Scientific Name	Common Name	C-value	# of AAs	Average Cover	Wetland Status
Scutellaria lateriflora	Mad-dog Skullcap	10	2	0.30	FACW
Carex kelloggii	Kellogg's Sedge	9	1	0.13	OBL
Utricularia minor	Lesser Bladderwort	9	1	0.13	OBL
Epilobium palustre	Marsh Willowherb	8	5	2.37	OBL
Erythranthe guttata	Common Monkeyflower	8	4	0.44	OBL
Muhlenbergia filiformis	Pullup Muhly	8	3	0.50	FACW
Valeriana edulis	Hairy Valerian	8	2	1.18	FAC
Eleocharis quinqueflora	Few-flower Spikerush	8	2	0.94	OBL
Carex crawei	Crawe's Sedge	8	2	0.44	FACW
Bolboschoenus fluviatilis	River Bulrush	8	1	3.50	OBL
Dichanthelium lanuginosum	Woolly Panicgrass	8	1	0.50	-
Gentianella amarella ssp. acuta	Autumn Dwarf Gentian	8	1	0.50	FACW
Primula pauciflora var. pauciflora	Few-flower Shootingstar	8	1	0.25	-
Spartina pectinata	Fresh Water Cordgrass	7	18	17.75	FACW
Ranunculus macounii	Macoun's Buttercup	7	5	1.03	OBL
Scutellaria galericulata	Hooded Skullcap	7	4	0.66	OBL
Packera pseudaurea var. flavula	Falsegold Groundsel	7	2	2.06	-
Lobelia cardinalis	Cardinal-flower	7	2	1.00	FACW
Lobelia siphilitica var. ludoviciana	Great Blue Lobelia	7	2	1.00	-
Carex aurea	Golden-fruit Sedge	7	2	0.25	OBL
Maianthemum stellatum	Starflower Solomon's-plume	7	2	0.18	FACU
Eustoma exaltatum ssp. russellianum	Showy Prairie-gentian	7	2	0.10	-
Amorpha fruticosa	False Indigobush	7	1	7.50	FACW
Parnassia parviflora	Small-flower Grass-of-parnassus	7	1	1.00	OBL
Juncus nevadensis	Sierra Rush	7	1	0.63	FACW
Asclepias arenaria	Sand Milkweed	7	1	0.50	-
Atriplex canescens	Four-wing Saltbush	7	1	0.50	-
Baccharis salicina	Great Plains False Willow	7	1	0.50	FAC
Calamagrostis stricta	Slim-stem Small-reedgrass	7	1	0.50	FACW
Krigia biflora	Two-flower Dwarf-dandelion	7	1	0.50	FAC
Lythrum alatum	Winged-loosestrife	7	1	0.50	OBL
Paronychia sessiliflora	Low Nailwort	7	1	0.50	-
Ribes lacustre	Bristly Black Currant	7	1	0.50	FACW
Sisyrinchium demissum	Stiff Blue-eyed-grass	7	1	0.50	OBL
Sisyrinchium idahoense var. occidentale	Idaho Blue-eyed-grass	7	1	0.50	OBL
Symphyotrichum ciliatum	Alkali American-aster	7	1	0.50	FACW

The Floristic Quality Assessment Index (FQAI) can indicate overall floristic quality with the additional metric weight of proportion of native species to the C-value metrics. Most of the surveyed GDE sites had a FQAI >10. In CO plains GDEs, FQAI values over 20 may indicate exceptionally high conservation value based on the biodiversity and seep conditions in the three sites with FQAI >20 in this study. The top three FQAI sites including Soapstone Prairie (30.61), Lone Tree Creek, and a Front Range fen all shared high-quality biodiversity and City of Fort Collins ownership. There may be a regional factor that affected the similarities of the site FQAI values and higher C-value vegetation; or ecological similarities based on signs of remnant vegetation and presence of *Triglochin maritima*, a calcareous wetland and plains wetland biodiversity indicator.

Wetlands with fluctuating hydrology such as floodplain GDEs, depressions, and saline playas may have less fidelity to FQA overall, and some had lower FQAI values in sites with good ecological integrity. All seven saline playas scored in the lower third range of FQAI scores, between 3.91 – 10.59. Playa wetlands naturally have lower cover and diversity and weed invasion can inflate their FQAI values in lower condition sites. The lowest scoring site did have more stress from agriculture surrounding the site. Generally, in more dynamic wetlands like floodplains and saline depressions, understanding of the natural disturbance processes is needed to understand reference conditions, and to determine if FQA values are affected more by natural factors such as fluctuating water levels, than site condition. The lower scoring FQAI site on Horse Creek supported critical wildlife habitat in cattails, a healthy *Eleocharis rostellata* community, and high-quality spring and slope fen areas, and was moderately grazed. In plains wetlands, vegetation communities' overall sensitivity to anthropogenic disturbance may not always mean highest quality habitat and conservation value. Plains GDE wetland assessment with FQA should be complemented with other habitat quality indicators such as presence of seep/springs, peatlands, and overall biodiversity. It is known that high quality fens in higher elevations can have low vegetation diversity, but less understood if that concept applies to lower elevations, for example in peat-accumulating wetlands with high cover of cattail.

More study is especially needed on the natural range of plains GDE marsh vegetation variability. Historical data and aerial imagery both indicate that some plains fens naturally supported cattail, but marsh cover is also known to have increased in some surveyed sites from this study. Valley bottom cattail wetlands are also common in the Midwest and farther east. Several warm water sloughs from this study's plots analysis also had deep peat with cattail, despite changes in their dynamic hydrology. Meanwhile, a curious approach to inventory cattail wetlands with deep organic soils can help avoid GDE biodiversity or carbon loss.

In addition to the tracked, new-to-state, GDE-indicator, and high C-value taxa observed in plains GDEs, there are several more potentially rare species reported to look out for that could occur in plains GDEs in Colorado, but more information is needed to confirm. Two additional species potentially on CNHP's tracking list were reported by field crews for this study: *Epilobium palustre* (marsh willowherb, observed in 5 sites) is G5S2? Watchlisted (question mark indicates poorly understood) and *Crataegus succulenta* (fleshy hawthorn, now split into the tracked G5S2 *Crataegus chrysocarpa* (fireberry hawthorn, C-value=5) and the more common G5S5 *Crataegus erythropoda* (C-value=6, cerro hawthorn). *Epilobium palustre* may be difficult to discern from the more common *Epilobium leptophyllum* (C=8), as these two species have a similar branchy and narrow-leaved habit, and the Ackerfield willowherb keybreak separates whether the leaf hairs are sparse or dense, which is potentially morphologically variable on the very saturated substrates and seeps where this species was observed. All occurrences of this branching *Epilobium* species were observed in headwater slope wetlands with either histic epipedons (n=2), organic soil fens (n=2), or with beaver established upon a slope wetland (n=1). In this region this narrow-leaf *Epilobium* may be a strong indicator of high-quality groundwater-fed habitat features. The *Crataegus succulenta* observation was in a slope peat-accumulating wetland, and another observation of this species was also observed in a slope peat-accumulating wetlands from the Plots Data Analysis. Interestingly both *Crataegus* sites had drying peat. Collection of voucher documentation in future plains studies of these *Crataegus* and *Epilobium* species will benefit their conservation understanding.

Sesuvium verrucosum was observed in four sites and may have full fidelity to saline playas or lakes in the Colorado plains. Although its distribution needs more study and it is not on the 2025 Colorado tracking list, *Sesuvium*'s association with good condition sites in at-risk to imperiled saline playa wetland type suggests it could be a saline depression-associated native plant community with *Heliotropium.* Other halophytes such as *Suaeda* can also co-occur but are present in more diverse wetland types than just saline playas. Rufous bulrush (*Scirpus pendulus)* was identified in a seep within a wet meadow in the plots analysis. It is a native wet prairie species farther east and rare in several states but is described as non-native in Colorado. The relatively higher presence of disjuncts in plains GDE wet meadows, and the seep location where it was observed, supports this plant's nativity and rarity could use review, and the same for other very uncommon to eastern Colorado GDE seep associated species.

Noxious Weeds and Invasive Species

The Colorado Department of Agriculture Noxious Weed Program and the Colorado Weed Management Association provide lists of noxious weeds. List A plants are required to be eradicated as designated by the State Commissioner. List B plants are treated based on management plans with local governments. List C plants are also treated based on management strategies with local governments and private land holders, with an emphasis on integrated management techniques. Watch List species are suspected of being a potential invasive species.

Tamarisk (*Tamarix* spp.) was the most competitive invasive noxious weed in the surveyed plains GDE wetlands based on percent cover (Table 22). It can overtake saturated areas and transform peat-accumulating and seep herbaceous drainages. Russian olive (*Eleagnus angustifolia*) was another common woody invader, but had low cover and treatment is often manageable. Canada thistle (*Cirsium arvense*) is widespread in plains wetlands and was present in most GDEs. It is less likely to overtake a site with healthy hydrology, but it can take over wetlands with drying hydrology or irrigation stressors. It was encroaching in surveyed floodplain and meadow sites. Quackgrass (*Elymus repens*) similarly invades riparian sites and meadows, and once well-established, it can create a monoculture and has allelochemicals that can suppress other growth. The List A species, hairy willowherb (*Epilobium hirsutum*), was found in two wetlands in the Front Range region, both in cattail seeps with one in a marsh and one in a fen.

Narrowleaf cattail (*Typha angustifolia*), and its hybrid *Typha x glauca*, are often considered non-native in North America (Smith 1993+; Magee et al. 2019) but expert opinion varies (e.g., Shih and

Finkelstein 2008). Regardless of native status, all cattail species can be invasive in wetlands and degrade sites with dense monocultures (McKenzie-Gopsill et al. 2012, Bansal et al. 2019). Broadleaf cattail (*Typha latifolia*) is considered native, is a natural component of many plains GDEs, and provides marsh habitat for at least one rare bird species observed: the eastern black rail. Cattail was present in moderately high cover in some surveyed GDE wetlands, and its historical natural densities are unknown. Historical imagery in many historical meadow sites shows ongoing cattail invasion, but other sites appear less changed with dark marsh imagery that could have been cattail drainages.

Similarly, cryptogenic reed canarygrass (*Phalaris arundinacea*) and *Phragmites* can quickly invade wetlands (e.g., Swearingen and Bargeron 2016). *Kochia scoparia* and Russian thistle (*Salsola* spp.) also are invasive in open environments especially when drying, and this was noted in degraded saline depressions and floodplain areas in the plots. The *Salsola* tumbleweed skeletons can accumulate in plains wetland lowlands and choke live vegetation growth and should be removed.

Targeted monitoring and management of invasive species in GDEs, with efforts to remove aggressive plants particularly early in establishment, can be successful. However, consideration of sensitive aquatic environment species and habitat is critical, as plains GDEs are often in localized depressions with slow or minimal outflow, and spongy organic soil and associated groundwater-dependent biodiversity may be affected by contaminants in ways not fully understood. Strategic planning for risks and benefits of treatment effects to non-target GDE biota, and a long-term management plan that considers the feasibility of control and underlying cause of change are needed to avoid GDE degradation, and to manage for trajectories of hydrologic change.

Table 22. List of the Colorado Noxious Weeds and Watchlisted Plant Species observed within 51 Colorado plains groundwater-dependent wetland assessment areas (AAs).

Species Name	Common Name	# of AAs	Average % Cover	Colorado Noxious List
Tamarix chinensis	Chinese Tamarisk	9	9.39	List B
Elymus repens	Creeping Wild Rye	1	7.50	List C
Cirsium arvense	Creeping Thistle	40	6.43	List B
Sonchus arvensis	Field Sowthistle	3	3.17	List C
Conium maculatum	Poison-hemlock	3	2.71	List C
Dipsacus fullonum	Fuller's Teasel	5	2.70	List B
Epilobium hirsutum	Great Hairy Willowherb	2	2.50	List A
Phragmites australis	Common Reed	2	2.00	Watch List
Elaeagnus angustifolia	Russian Olive	14	1.24	List B
Carduus nutans	Musk Thistle	4	1.16	List B
Lepidium latifolium	Broadleaf Pepper-grass	6	0.79	List B
Bromus tectorum	Cheatgrass	3	0.71	List C
Verbascum thapsus	Common Mullein	8	0.56	List C
Cirsium vulgare	Bull Thistle	7	0.52	List B
Berteroa incana	Hoary False Alyssum	1	0.50	Watch List
Carduus acanthoides	Musk Thistle	1	0.50	List B
Linaria dalmatica	Dalmatian Toadflax	1	0.50	List B
Linaria vulgaris	Butter-and-eggs	1	0.50	List B
Sphaerophysa salsula	Bladder-vetch	1	0.50	Watch List
Arctium minus	Lesser Burdock	4	0.41	List C
Convolvulus arvensis	Field Bindweed	7	0.39	List C
Cynoglossum officinale	Common Hound's-tongue	4	0.31	List B
Potentilla recta	Sulphur Cinquefoil	1	0.13	List B
Hypericum perforatum	Common St. John's-wort	1	0.03	List C

4.5 Water Chemistry and Soil Characteristics

Water Chemistry

Basic field parameters of pH, electrical conductivity (EC), and temperature were collected from 46 GDE sites where surface water was measurable. Measurements were taken with a hand-held YSI 1030 Pro multi-parameter probe shortly after arriving on site. A total of 132 surface water measurements were taken. In 26 sites, soil groundwater chemistry was also taken from 35 measurement locations where water filled the soil pit. Most sites had 1-4 surface water measurements taken in different locations and groundwater measurements in 1-2 soil pits. The average surface water depth where measurements were taken was 11 cm, but water level depths varied widely from the minimum depth possible of 2 cm to deeper pools up to 135 cm. To maximize the number of sites with water data collection, and to include data from shallow water seep sites, measurements were taken in all sites where the YSI probe could be submerged without touching the substrate. Twelve sites with water measurements had all surface water <10 cm of depth. Shallow water measurements taken across the study's wetlands were mostly in clear water (85%) vs. turbid (15%), and shallow water sites were more frequently taken from clear water than the deeper water (10+ cm) site measurements where 42% of measurements were taken in turbid water. Site water chemistry measurements can vary by the time and season taken, so multiple site visit measurements would improve confidence of the variability in site conditions.

Each wetland type surveyed had a broad range of water chemistry variability, with some overlap across each measured variable and measurement location, but there were some general trends by wetland type (Table 23). Fens and peat accumulating wetlands often had cooler surface water temperatures and lower pH and EC values, but there were also unusually high pHs in several sites of ~8+, indicating rich to extreme rich conditions. Site with histic epipedons (20-40 cm organic soil) were summarized separately to see if measurements were more similar to fens than other wetland types. Ranges overlapped with both types but more often with fen ranges, from both surveyed AAs and the plots analysis. Woody wetlands also had a lower range of ECs, but their pool temperatures spiked higher. Saline wetlands had higher pH, EC, and median temperatures.

Wetland water chemistry measurements from the analysis of previously sampled plots mostly overlapped with these ranges, with some exceptions. Two previously sampled wet meadow-marsh sites had pHs > 9.2, with values of 9.4 in refuge pools: one from a Pawnee National Grassland drainage and another at an alkaline drainage with salt crusts and salt-tolerant dominants. Woody canyon plains riparian spring sites added variation to the woody riparian sites; unsurprisingly as only one canyon riparian site was surveyed in this GDE study. Holt Canyon at Pawnee National grassland also had a high pH of 8.8 and low EC values of 365 µS/cm. The range of electroconductivity measurements included lower values from the plots analysis in both woody riparian sites and wet meadow-marsh sites with histic epipedons: In Vogel Canyon, a canyon riparian site with abundant leopard frogs had low EC values of 108-110 µS/cm, and low values <400 were common at other canyon woody spring sites. Additional fen and histic epipedon wet meadow-marsh sites had more low EC values. The high bounds of EC are unknown from past studies due to using a Hanna Meter that only measures to 3999 µS/cm.

Table 23. Water chemistry values observed in surface and groundwater measured in 51 Colorado plains GDEs.

Wetland Type and Measurement	Surface			Ground		
	Min	Median	Max	Min	Median	Max
Temperature (degrees C)						
fen	11.8	19.8	37.1	15.7	19.1	29.5
histic epipedon	15.5	21.35	33.3	13.2	21.7	27.3
wet meadow-marsh drainage	16.5	24.4	36.1	17.5	22	29
plains riparian and floodplain	12.7	25.4	38.4	14.7	19.3	20
saline playa	18.5	27.5	37.2	-	-	-
pH						
fen	5.7	6.7	8.1	5.8	6.6	7.1
histic epipedon	6.5	7.3	8.4	4.4	7.0	7.3
wet meadow-marsh drainage	6.6	7.4	9.2	6.8	7.3	7.6
plains riparian and floodplain	6.7	7.2	8.5	6.8	7.0	7.6
saline playa	7.5	8.3	9.5	-	-	-
Electroconductivity (EC - µS/cm)						
fen	10	780	6080	310	659	712
histic epipedon	174	782	3279	557	1898	5060
wet meadow-marsh drainage	241	2035	31860	305	2507	4015
plains riparian and floodplain	236	844	6985	444	1769	7238
saline playa	63	40062	68250	-	-	-

Water Temperature

There were 132 AA data points on surface water temperatures, and these varied widely between 11.8-38.4 degrees Celsius, with an average surface water temperature of 23.6 degrees. The highest and lowest surface water temperatures varied by site type and surface water location type, but otherwise there was broad overlap between wetland type, time of day, whether the water was standing or flowing, and turbid or clear. The coolest surface water temperatures of ~11-15 degrees C were from five slope headwater wetland sites, sampled either from flowing seep or water track water sources or from vegetated spring locations. These wetlands had active seeps and histic epipedon or fen wetland soils. The sites with the two lowest surface water temperature records had measurements in actively discharging groundwater drainages from calcareous wetlands. The warmest water temperatures measured in this study of > 35 degrees C were all from pools from five sites and from riparian areas and saline playas, with measurements taken in wetland depressional pools. These relatively warmer measured surface water temperatures were all standing and in open and exposed areas, except for one slow-flow pool just downstream of a beaver dam. Groundwater temperatures were not as high, with a range of 13.2-29.5 degrees Celsius, and more moderate overall and cooler soil groundwater temperatures with an average of 21.0 degrees. Within site groundwater temperatures were usually lower than surface water temperatures, or where their ranges overlapped, they were more moderate.

pH Values

Surveyed water chemistry field measurement surface water pH values ranged from 5.67-9.53 with an average of 7.4 (Figure 33). Variability between minimum and maximum pH of surface water locations at a single wetland ranged from a negligible difference (<0.1) to a maximum difference of 1.66, with a mean within-site surface water pH measurement difference of 0.57. Groundwater pH in AAs was generally lower than surface water. Groundwater values were between 4.35-7.55, with an average of 6.9. Soil groundwater measurements were only taken from freshwater (non-saline) wetlands, as the field crew did not have the equipment for soil groundwater measurements in ponded areas.

Mean within site differences in groundwater varied less from a negligible difference (<0.1) maximum difference of 0.88, with a mean difference of 0.32. Site data were mostly from a single visit, except for one site that had two water chemistry visit dates with YSI data, and the purpose of the revisit to get a missing EC measurement from the first visit. At this site, pH measurements were 6.9-7.1 in the early June visit with temperatures averaging two degrees cooler than the late July visit with pH measurements of 7.0-7.2. These water chemistry measurement variations between days were less than the average within-site same-day variation in water chemistry measurements across this study's sites.

Three of the five sites with the highest pH's (pH = 8.45+) were saline depressions, one site was a headwater wetland in Pawnee National Grassland, and the last site was the canyon plains riparian site with surface water measurements taken in a canyon pool. All five surveyed saline depressions with sufficient surface water to use the YSI had some site pH measurements above 8.0. The five sites with the lowest pH's had organic soil accumulation, and three of those were fens, along with one beaver wetland in a large GDE complex and a wet meadow with a histic epipedon.

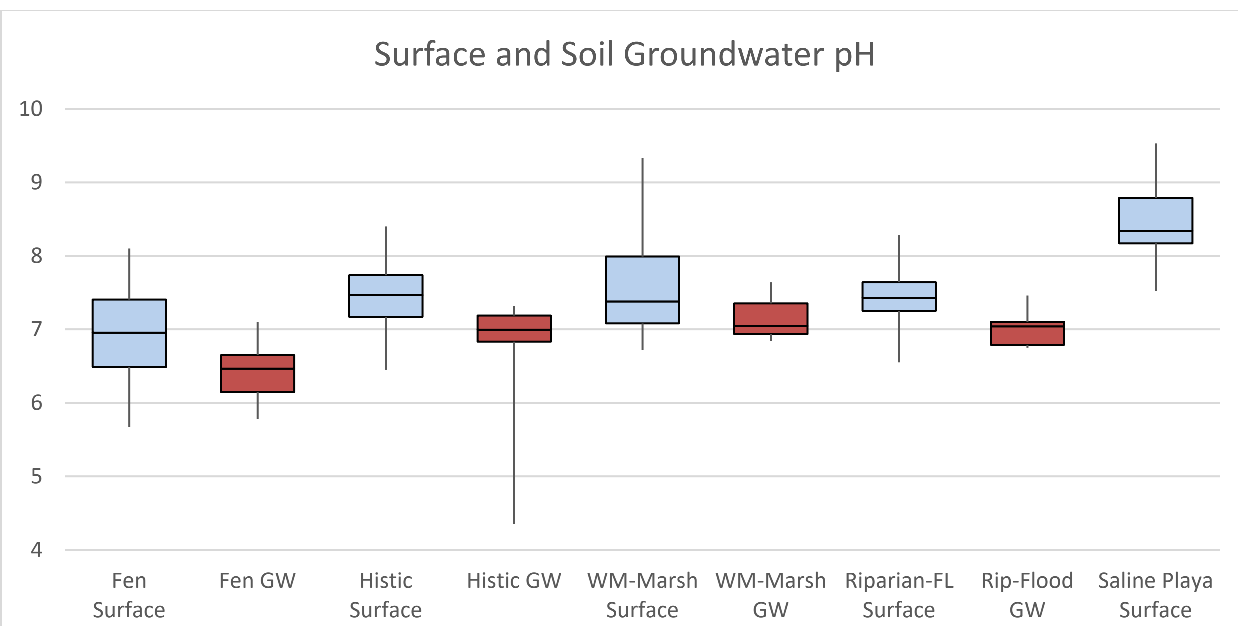

Figure 33. Range of surface water and soil groundwater pH measurements in surveyed plains groundwater-dependent wetlands. Histic=wetland with histic epipedon; WM=wet meadow; FL=floodplain.

Electroconductivity (EC)

Surface water EC values in AAs ranged from 10-68,250 µS/cm (Figure 34). Saline wetlands had EC measurements on larger scale than most of the other surveyed wetlands, and measurements were also highly variable onsite by tens of thousands. One of the five sites sampled with water had visible saline characteristics on the site fringe and aerials, but appeared to have freshwater in the central wetland, despite halophytes growing in that central area. This site might not be a functioning saline playa anymore, may have had different conditions on the site edge than center, and is classified as a saline playa with low confidence based on saline landscape and halophytes. That site is the source of the lower range in the EC values, and the remainder each had site measurements in the tens of thousands with more than half the measurements over 30,000 µS/cm. Fen sites averaged relatively lower EC <1000 µS/cm than average wet meadow-marsh wetlands, but two sites had higher EC values – one with a large range of 10-6080 µS/cm and the other with a narrower measurement range from 1926-2040 µS/cm. Histic epipedon wetland EC measurements were within the range of fen sites. One wet-meadow marsh site had a pool with a high measurement of 31,860 µS/cm, in a saltgrass wet meadow open depressional riparian drainage. Wet meadow marsh sites appeared the most variable in site characteristics, and the EC data was similarly variable between sites, with more values in the hundreds and some site values in the thousands. Woody riparian and floodplain sites only had a few of the low EC measurements <400 µS/cm observed in herbaceous and peat accumulating wetlands, but their values were more moderate, predominately in the mid-hundreds from ~400-850 µS/cm.

The AA groundwater EC value ranges were similar to surface water values, except for slightly higher median values (Figure 28). The freshly dug soil pit water may be affected by soil sediments that did not fully settle below the water column that could influence the EC.

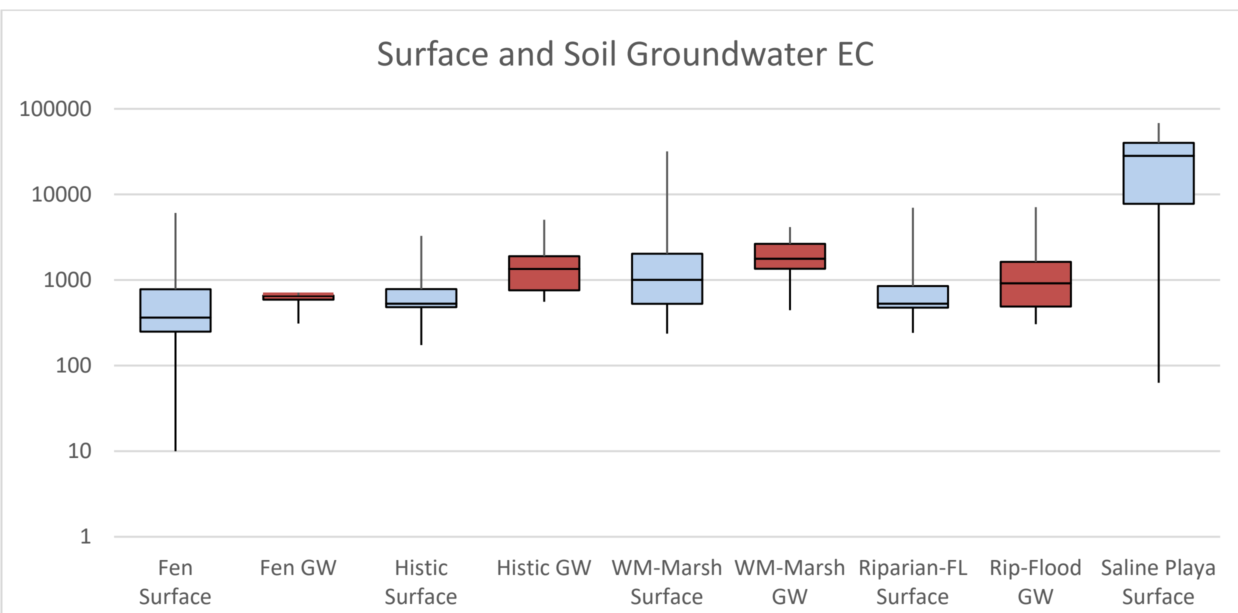

Figure 34. Range of surface water and soil groundwater EC measurements in plains groundwater-dependent wetlands (µS/cm displayed with log scale). Histic=wetland with histic epipedon; WM=wet meadow; FL=floodplain.

Soil Characteristics

Surveyed wetlands were classified into four soil groups based on the soil pit that best represented the site's conditions: clayey/loamy mineral soil (<20 cm organic), sandy mineral soil, histic epipedon (20 to <40 cm organic) or histosol (≥40 cm organic). Two-thirds of the AAs were assigned to mineral soil types and the other third had either a histic epipedon or ≥40 cm organic soil (Table 24). Seven sites with mineral classifications also had 10-20 cm depth organic soil layers in the representative soil pit, which is still significant organic accumulation for the Colorado plains. Most sites had within-site variability in soil pit texture (Figure 35). Nearly half of surveyed GDE wetland sites (47%) had at least one AA soil pit with a histic epipedon or deeper organic soil layers. Many soils had shallow organic layers, but a high percent of organic matter in the underlying mineral layers. Other soil pits had organic layers perched on sand-gravel alluvium, evidence of the alluvial aquifer.

Crews used the smear test (two smears between fingers, smears clean, and without grit) to classify organic soil, which is effective in higher elevations for a rapid estimation of peat. Using this test, about one-quarter of surveyed sites had mineral soils based on fine sediment that smears opaque and had high organic content throughout the full soil profile. However, many of the soil layers observed had colors of organic soil 10 YR 2/2 rich organic, and black mucks with 10 YR 2/1, with presence of some mineral content. Carbon analysis may determine more soils to be organic than classified in this study, and more research on plains wetland soils organic textures are needed in the Colorado plains. Some soil pits had notably light-colored organic soil that may be due to calcareous conditions. Some soils had the color, sparse structure, and vegetation of marl flats, and potential for marl based on geological data. We presume here that these are marl due to these strong indicators (Miner & Ketterling 2003, NYNHP 2025), and lack of reported similar plains wetland indicators in non-marl plains wetland GDE habitats, but soil testing is needed for confirmation. The larger woody riparian and outer floodplain sites had less organic content in the soil layers, and none of the surveyed sites had >20 cm of organic soil in their dominant pit. There were also wetland plots with deeper organic soils in warm water sloughs, and in large outer floodplain herbaceous wetlands. Saline wetland soil profiles were also mineral, and some had a minor surface muck layer (Figure 36).

From the analysis of previously sampled plots, four more sites in the study area had histosol soils and were classified as fens (totaling 11 fens in the 100 GDE plots). This study's surveys did not survey floodplain wet meadows with deep organic soil, due to both challenges to private land survey access, and lower success in targeting those soil types from aerial imagery review. The plots analysis did have floodplain with deep organic soil. Additional sites in the plots analysis had plots with dried peat or were located on the edge of probable fens based on soil pit data.

Table 24. GDE wetland soil characteristics, by counts of soil pits/site with each feature. Organic cm is max. depth of organic in a site soil pit. *Organic content is high through the mineral soil profile.

Wetland Type	Site Code	# Soil Pits	Sandy	Clayey/ Loamy	Histosol	Histic	Organic cm
Plains fen	GDE-AR03	3		1	1	1	45
Plains fen	GDE-SP36	2		1	1		48
Plains fen	GDE-3SOAP	5			2	3	40
Plains fen	GDE-SP50	3				3	36
Plains fen	GDE-RE04	2	*		1	1	40
Plains fen	GDE-AR14	1			1		40
Plains fen	GDE-AR20	2		1	1		45
Woody riparian	GDE-SP19	2	*	1		1	
Woody riparian	GDE-1LOW	1	*	1			8
Woody riparian	GDE-AR58	2		2			10
Woody riparian	GDE-4SREP	1	1				12
Woody riparian	GDE-AR64	1	1				*
Woody riparian	GDE-RE05	1	1				*
Wet meadow-marsh	GDE-AR55	1	*			1	20
Wet meadow-marsh	GDE-AR62	1	*			1	27
Wet meadow-marsh	GDE-2ERAR	2		1		1	23
Wet meadow-marsh	GDE-AR06	1				1	25
Wet meadow-marsh	GDE-AR63	2		1		1	20
Wet meadow-marsh	GDE-SP33	1				1	26
Wet meadow-marsh	GDE-SP46	1				1	20
Wet meadow-marsh	GDE-SP28	2	*			2	24
Wet meadow-marsh	GDE-5KIN	2				2	20
Wet meadow-marsh	GDE-AR60	2	*			2	25
Wet meadow-marsh	GDE-SP34	2				2	21
Wet meadow-marsh	GDE-SP25	2		2			4
Wet meadow-marsh	GDE-AR05	2	*	2			5
Wet meadow-marsh	GDE-AR56	1		1			5
Wet meadow-marsh	GDE-RE07	1	1				10
Wet meadow-marsh	GDE-AR18	1		1			11
Wet meadow-marsh	GDE-AR29	2		2			12
Wet meadow-marsh	GDE-SP43	2		2			12
Wet meadow-marsh	GDE-AR19	2		2			13
Wet meadow-marsh	GDE-SP29	1		1			17
Wet meadow-marsh	GDE-SP35	2		2			17
Wet meadow-marsh	GDE-SP24	1	1				*
Wet meadow-marsh	GDE-AR34	2		2			*
Wet meadow-marsh	GDE-AR46	1		1			*
Wet meadow-marsh	GDE-SP16	1	*	1			
Wet meadow-marsh	GDE-SP47	1		1			
Wet meadow-marsh	GDE-SP49	1		1			*

Figure 35. Variation in plains GDE organic soil layers and depths, from dark brown peat layers to lighter and variably textured layers with organic content.

Figure 36. Soils from saline playa sites: dark mucky loam, clay loams, and sandier soil layers with salts and biofilms.

4.6 Wildlife Observations

Wildlife Observations

A total of 119 total wildlife taxa were recorded from 2021-2022 within or near the groundwater-dependent wetland sites surveyed from a total of 309 wildlife observations (Appendix F). These observed wildlife taxa include both amphibian and reptile species observed during herpetology surveys of the GDE wetland and its surrounding wetland drainage complex, plus incidental sightings of wildlife that were recorded during the wetland surveys, which also included birds, insects, mammals, fish, and mollusks. Sites had a median of 6 wildlife taxa observations per site, and site species ranged from 0 to 20 taxa per site. The most frequently observed species were Red-winged blackbird, Western meadowlark, and American bullfrog (Table 25).

The three sites with the highest observed wildlife diversity (n=19-20 wildlife taxa) were State Wildlife Area sites with field visits both years, and thus more time spent on the sites to record amphibian species and to collect macroinvertebrate samples. However, the median number of species observed across just Level 3 Assessments versus all sites was 5.5 species, similar to the study median, and tracked species were observed in 9 sites with Level 3 data collection and 10 sites with Level 2 data collection, so both targeted survey and reporting of incidentals included detection of rare wildlife species, with a higher percentage of Level 3 sites (47%) detecting tracked wildlife than Level 2 (31%) of sites.

Table 25. Most frequently observed wildlife taxa in plains groundwater-dependent wetland surveyed sites.

Scientific Name	Common Name	# of AAs	Origin	Global Rank	State Rank
Agelaius phoeniceus	Red-winged blackbird	14	Native	G5	S5
Sturnella neglecta	Western meadowlark	12	Native	G5	S5
Lithobates catesbeianus	American bullfrog	11	Exotic	G5	SNA
Charadrius vociferus	Killdeer	10	Native	G5	S5
Danaus plexippus	Monarch	9	Native	G4	S5
Chrysemys picta bellii	Western painted turtle	8	Native	T5	S5
Geothlypis trichas	Common yellowthroat	8	Native	G5	S4
Thamnophis sp.	Gartersnake	8	Native	-	-
Spinus tristis	American goldfinch	8	Native	G5	S5
Anaxyrus woodhousii	Woodhouse's toad	6	Native	G5	S5
Tyrannus verticalis	Western kingbird	6	Native	G5	S5
Zenaida macroura	Mourning dove	6	Native	G5	S5
Lithobates pipiens	Northern leopard frog	6	Native	G5	S3
Lithobates blairi	Plains leopard frog	5	Native	G5	S3
Tyrannus tyrannus	Eastern kingbird	5	Native	G5	S5
Eremophila alpestris	Horned lark	5	Native	G5	S5

*2 leopard frog were identified to genus at the site, resulting in 13 total sites with leopard frog observations.

Rare Wildlife Species

The surveyed sites supported 12 rare and CNHP-tracked wildlife species (Table 26). CNHP-tracked wildlife species were observed in 19 (37%) of the surveyed GDE sites, and the most common tracked species observed were leopard frogs, which were observed at 12 (24%) of the sites.

The federally threatened Eastern Black rail (*Laterallus jamaicensis jamaicensis*) was observed in one marsh fen site, which had both a fen zone that continued outside of the site, and a marsh zone with shallower organic soil layers (Figure 37). Shallow water covered approximately half of the AA with water depths of 3 – 5 centimeters, interspersed with non-flooded but saturated organic soil areas (Figure 36). The black rail was detected from its unique call (recorded by crew and later confirmed by a black rail expert) while obscured within the tall cattails *(Typha latifolia* and *Typha angustifolia*). Vegetation across the site ranged from mid to tall herbaceous cover height classes (0.5 – 2 m ht.) and had dense (99-99% cover) marshy vegetation interspersed with lower-growing groundcover seep species such as *Berula erecta, Veronica anagallis-aquatica*, and *Nasturtium officinale*. *Eleocharis rostellata*, an indicator of saturated wetland and organic soils, was also present in the wetland outside of the cattail in the fen zone. The vegetated drainage with organic soil layers and fen was large, with >10 km length of near-contiguous visibly saturated GDE wetland similar to the plot, and overall >20 km length of the groundwater-fed wetland drainage with more patch diversity. These site characteristics were typical of Eastern Black rail habitat in southeastern Colorado with consistently saturated and moist soil, very shallow water and dense and tall marsh vegetation.

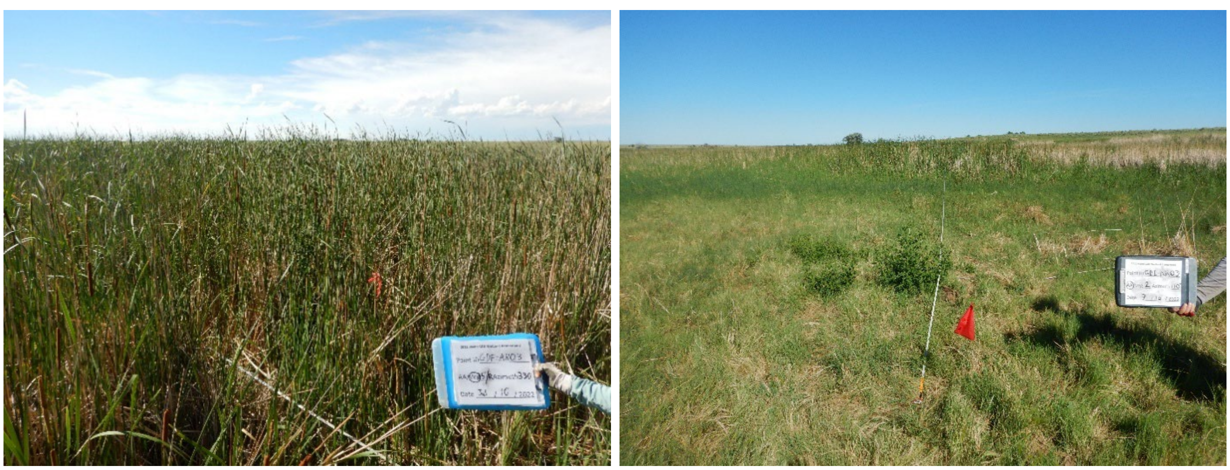

Figure 37. Black rail habitat in dense marsh cattail zone, adjacent to deep peat fen soil with beaked spikerush vegetation, forming a wet meadow-marsh groundwater-dependent wetland.

Saline playa wetlands have waterfowl mudflat habitat and forage attributes, where birds were observed utilizing the habitat in the margins or inundated areas. Three tracked bird species – the mountain plover (G3S2), the long-billed curlew (G4S2), and the white-faced ibis (G5S2), were each observed in different surveyed saline depression wetlands across the study area. In two of those sites, there were abundant aquatic plant communities of spiral ditchgrass grass (*Ruppia cirrhosa)*, a species known for very high seed set and nutritious waterfowl food and invertebrate cover (Kantrud 1991). These high quality 'duck food' seeds were both visible throughout the water column and abundant in invertebrate samples. *Ruppia maritima* (In CO=*Ruppia cirrhosa,* syn., Ackerfield 2015) communities are a Globally Imperiled (G2) aquatic community described in the Northern Great Plains *Stuckenia pectinata – Ruppia maritima Aquatic Vegetation* community (NatureServe 2025). *Ruppia maritima* can be the only species in highly saline environments such as these saline playas.

Table 26. CNHP-Tracked Wildlife species observed in or near plains groundwater-dependent wetland sites, their conservation tracking status, and their habitats where observed.

Scientific Name	Common Name	CNHP Tracked	G Rank	S Rank	# of Sites	Wetland Types Observed
Anarhynchus montanus	Mountain plover	Yes	G3	S2	1	saline depression
Argynnis idalia	Regal fritillary	Yes	G3	S1	1	herbaceous riparian
Arigomphus cornutus	Horned clubtail	Yes	G4	S1	1	herbaceous riparian
Athene cunicularia	Burrowing owl	Watchlisted	G4	S4	1	wet meadow-marsh (near wetland)
Circus hudsonius	Northern harrier	Watchlisted	G5	S3	1	woody riparian
Laterallus jamaicensis	Black rail	Yes	G3	S1	1	plains fen
Lithobates blairi	Plains leopard frog	Yes	G5	S3	6	peat-accumulating herbaceous, woody riparian
Lithobates pipiens	Northern leopard frog	Yes	G5	S3	6	plains fen, herbaceous riparian, peat-accumulating herbaceous, woody riparian
Lithobates sp.	Leopard frog sp.	-	G5	S3	1	plains fen, beaver riparian
Numenius americanus	Long-billed curlew	Yes	G4	S2	1	saline depression
Peucaea cassinii	Cassin's sparrow	Watchlisted	G5	S4	1	herbaceous riparian
Phrynosoma hernandesi	Hernandez's short- horned Lizard	Watchlisted	G5	S5	1	herbaceous riparian
Plegadis chihi	White-faced ibis	Yes	G5	S2	1	saline depression

Amphibians and Reptiles

Plains GDE wetland complexes supported herpetofauna habitat, and more than half of the surveyed wetlands included herpetofauna observations on the day surveyed. Twenty-two species of amphibians and reptiles were observed within twenty-eight plains groundwater-dependent wetland sites (Table 27).

Table 27. Amphibian and reptile species observed during 2021-2022 plains groundwater-dependent wetland surveys

Common Name		
American Bullfrog	Hernandez's Lizard	Six-lined Racerunner
Barred Tiger Salamander	Lesser Earless Lizard	Spiny Softshell Turtle
Boreal Chorus Frog	Northern Leopard Frog	Wandering Gartersnake
Bullsnake	Ornate Box Turtle	Western Painted Turtle
Checkered Whiptail sp.	Plains Gartersnake	Western Terrestrial Gartersnake
Common Snapping Turtle	Plains Leopard Frog	Woodhouse's Toad
Eastern Yellow-Bellied Racer	Prairie Lizard	
Great Plains Toad	Prairie Rattlesnake	

At sixteen Level 3 GDE wetland sites, herpetofauna were searched for by a herpetologist in areas of potential habitat in the AA and its surrounding upstream and downstream wetland drainage, with five wetland sites surveyed for two years and 11 sites surveyed in one year. Nine of the twelve Level 3 EIA sites were surveyed, plus two additional Level 2 EIA sites were surveyed for manager requests. The three Level 3 EIA saline playas were not surveyed for herpetofauna due to low probability of frogs. Surveys were targeted to be approximately one hour per drainage, but varied based on vegetation density, success in encountering amphibians, and field schedule constraints such as weather. Most surveys were ~1 hour with a median survey time of 55 minutes, and surveys ranged from 25 minutes to 2 hours and 45 minutes. Field crews also noted incidental amphibian and reptile observations during the EIA surveys at all sites.

Amphibians were detected at 18 of the 51 surveyed wetland sites. Leopard frogs were observed in 7 (44%) of the 16 searched sites. Leopard frogs were also incidentally detected in 6 sites without searches, totaling 13 surveyed GDE wetlands with leopard frog observations in either the AA plots or in the surrounding wetland complex (Table 28; Figure 35). In 5 additional sites no leopard frogs were observed but other native amphibians were observed. Native amphibians observed included Woodhouse's Toad (6 sites), boreal chorus frog (4 sites), a barred tiger salamander breeding site with larval juveniles (1 site), and a great plains toad metamorph (1 site). Two additional sites had toad observations not identified to genera or species, and in one saline depression site there were numerous dead unidentifiable young toads.

Table 28. Leopard Frog Habitat Scorecard and Ecological Integrity Assessment Ratings in Plains Groundwater-dependent Wetland Study sites with *Lithobates* frog spp: LIBL =Plains leopard frog, LIPI=Northern leopard frog

Site	Site Code	Survey Type	Bullfrog	Leopard Frog	Foraging Score	Breeding Score	LIBL	LIPI	Bd Pool	EIA Score
Box Elder Cr	GDE_1LOW 2021	Survey	x	x	85	-	-	x	LIPI, ANWO	4.14
Box Elder Cr	GDE_1LOW 2022	Survey	x	-	70.4	-	-	-	-	4.12
South Fork Republican	GDE_4SREP 2021	Survey	x	x	57.3	84.1	x	-	LIBL, ANWO	4.23
South Fork Republican	GDE_4SREP 2022	Survey	-	x	70.8	50.1	x	-	LIBL, ANWO	4.23
Kinney Lake SWA	GDE_5KIN 2021	Survey	x	x	64.8	-	x	-	-	3.75
Kinney Lake SWA	GDE_5KIN 2022	Survey	-	x	77.5	-	x	-	-	3.96
Horse Cr	GDE_AR03	Survey	-	x	70.4	-	-	-	-	3.07
Two Butte Cr	GDE_AR05	Survey	x	x	63.3	50.1	x		-	3.76
Hugo SWA	GDE_AR29 2021	Survey	x	x	NA	-	x	-	LIBL, ANCO	NA
Hugo SWA	GDE_AR29 2022	Survey	x	x	77.5	-	x	-	LIBL	3.52
Apache Cr	GDE_AR55	Incidental	x	x	70.4	59.5	-	-	-	4.41
Steels Fork Lower	GDE_AR56	Incidental	x	x	58.4	59.7	-	x	-	4.37
Perly Canyon	GDE_AR58	Survey	x	-	63.3	45.9	-		-	4.56
Steels Fork Upper	GDE_AR60	Incidental	-	x	53.5		-	x	LIPI	4.48
E Carrizo Cr	GDE_AR62	Incidental	x	x	70.4	64.2	x		PSMA	3.70
Landsman Cr	GDE_RE05	Survey	x	x	56.6	50.1	-	x	LIPI	2.76
Lost Cr	GDE_SP28	Incidental	-	x	52.4	55.7	-	x	-	4.39
Carpenter Cr	GDE_SP36	Incidental	x	x	77.5	59.5	-	x	-	3.43
Erin Arsenault	GDE-2ERAR	Survey	-	-	94	-	-	-	-	3.99
Soapstone Prairie	GDE-3SOAP 2021	Survey	-	-	80.5	-	-	-	-	4.22
Soapstone Prairie	GDE-3SOAP 2022	Survey	-	-	65.5	-	-	-	-	4.25
Messex SWA	GDE-SP08	Survey	-	-	94	-	-	-	-	2.68
S. Platte R Floodplain	GDE-SP13	Survey	-	-	77.5	-	-	-	-	4.07
Lone Tree Creek	GDE-SP19	Survey	-	-	52.4	54.8	-	-	-	4.25
Sheep Draw	GDE-SP25	Survey	-	-	70.4	-	-	-	-	3.17

*Bd testing amphibian species 4-letter codes are first two letters of scientific name genus and first two letters of scientific name species.

Invasive non-native American bullfrogs (*Lithobates catesbeiana*) were the second most common wildlife species observed in all of the surveyed GDE wetlands, with bullfrogs identified at 10 of the 13 sites with leopard frogs, plus one additional site without leopard frogs. The three sites with leopard frogs observed and no bullfrogs were peat-accumulating wetlands; one site had a histosol (a fen rated C+ EIA rank), and the two other sites had deep histic epipedons (wet meadow-marsh both rated B+ ranks). In wetland complexes with leopard frogs observed, the average EIA condition score and rank of the surveyed GDE AA was 3.85/B-, the highest AA score was 4.41/B+, and the lowest AA score was 2.76/C-.

Samples for the pathogenic chytrid fungus (*Batrachochytrium dendrobatidis* = Bd) were collected at six sites where amphibians were observed and captured. One pilot site (Box Elder Cr) had Bd samples collected two years, and the other 5 sites had one Bd sample year. All six Bd samples in sites with leopard frogs tested negative for chytrid, and an additional 7th AA site in a Park Creek wetland also tested negative from a boreal chorus frog. At Kinney Lake, Hugo, and South Fork Republican sites, leopard frogs tested negative both years. GDE sites with chytrid testing and species tested are listed in Table 24 and were provided to Colorado Parks and Wildlife (CPW) as part of our permit requirements, along with the list of amphibian and reptile observations.

Colorado Parks and Wildlife Leopard Frog Scorecards (CPW 2016) were populated for each assessment area (AA) where the field crew members observed foraging, breeding, and/or overwintering leopard frog habitat features within the AA as described in the scorecard. Habitat scorecards were rated only on the assessment area habitat features (AA), not based on the full amphibian survey area (the wetland complex walked around the AA), in order to compare EIA condition scores for the AA to the leopard frog habitat.

All but one of the non-saline GDE wetland AAs were rated for presence of leopard frog foraging habitat (n=42 rated), and 19 of those wetlands were rated for presence of breeding habitat (breeding habitats observed included marshes, pools, and seeps/springs). The freshwater wetland not rated was similar to other peat-accumulating wet meadow-marsh sites, so the lack of foraging habitat scorecard from that AA was likely oversight. Up to ten surveyed AAs were determined by field crews to have overwintering habitat in the AA based on the habitat scorecards, and were rated, but the leopard frog overwintering ratings are not reported due to data variability in the overwintering habitat forms.

The leopard frog foraging and breeding scorecard ratings lacked significant correlation with leopard frog observations in surveyed sites. The averages and ranges of habitat scorecard scores overlapped for sites with and without leopard frog observations. One positive relationship between leopard frog observations and scorecard scores was from a single rating of a highest breeding scorecard score, at the only AA with both non-adult leopard frogs observed and a scorecard populated. (Additional surveyed wetlands supported breeding leopard frogs in the larger AA complex.) In the amphibian survey sites, where documentation of resident amphibians is more likely, foraging wetland habitat scorecards had nearly the same scores, regardless of whether leopard frogs were observed at the wetland complex or not. The average leopard frog foraging scorecard across all 16 surveyed AAs was 68.3 (of 100), the average AA score with frog observations in the wetland complex (n=7) was 68.7, and the average AA score without frog observations in the wetland complex (n=9) was 68.1. The minimum scorecard scores for foraging habitat with frogs were 56.6 and the maximum score was 85 (standard deviation=9.9); while the minimum rating for foraging habitat without leopard frog observations was 52.4 and the maximum rating was 94 (standard deviation 11.9). Three sites were rated both study years for foraging habitat in the AA, and each revisit score had high variability between years, by 12.7 - 14.6. Two pilot wetlands had an experienced herpetologist onsite and no leopard frog observations, and both of these sites had relatively high vegetation density, and relatively smaller areas of open or lightly vegetated seeps with shallow water interspersion where leopard frogs are typically observed more frequently. These two sites scored high and moderately high with 94 and 80.5 on the foraging habitat scorecards. The habitat scorecards may benefit from more details on optimal site conditions such as the combination of the shallow surface water and mudflat habitat metric with lower vegetation density and/or height, and higher weighting on the vegetation height metric. However, lack of amphibian observations from a site visit doesn't mean that frogs do not utilize the habitat, and they also may be more difficult to see in dense vegetation.

There was high variability in leopard frog habitat revisit scores. The breeding leopard frog habitat scorecard with field observations of leopard frog metamorphs and adults in the site (Figure 37) had the highest AA breeding scorecard score of 84.1 in 2021. However, this same site was revisited in 2021, and scored a lower breeding score of 50.1, even with metamorphs also present in the revisit. The foraging scores were mid, with near-average scores with 57.3 and 70.8, but had healthy populations. In two other surveyed amphibian sites, leopard frog metamorphs or tadpoles were also observed, but the breeding scorecards were not populated because the breeding area was in the wetland complex outside of the AA, rather than in the AA plot. A source of potential variability separate from the survey date or surveyor between observations and habitat score, was that the scorecard value from the AA had a narrower focus area than a wetland-complex scale rating. Frogs move across habitat features, and if the habitat scorecard area was based on the full amphibian wetland complex survey area, the habitat scores may have better aligned with the GDE wetland habitat value.

Figure 38. Plains leopard frogs and their groundwater-dependent wetland habitat with abundant breeding and adult populations in the assessment area.

Fritillaries

GDEs have exposed seeps and saturated conditions frequently visited by hydrating butterflies, and some provide violet habitat for breeding fritillaries that are uncommon to rare in the lower Front Range and plains. A large population of silver-bordered fritillary (*Boloria myrina)* that appeared to be potentially breeding, with high groundcover of northern bog violet (*Viola nephrophylla)*, was observed in a plains fen. In addition, a tracked regal fritillary (Figure 39) was observed in a GDE site with bluff outcrops and likely calcareous seeps. In the plots analysis, a third site had a fritillary observation with a histosol soil pit. Presence of fritillary butterflies in plains GDEs may indicate unique or rare groundwater-fed wetland types for the plains.

Figure 39. Regal fritillary butterfly, Weld County, and Mormon fritillary butterfly, Huerfano County.

Beaver

The survey design selected against obvious beaver wetlands in aerial imagery, due to their deep surface water that can obscure the degree of groundwater input, but some beaver wetlands do occur in GDE habitat. Two GDE AAs had small beaver dams revealed at the site visit (Figure 40), and these also had GDE indicators with organic soil layers and content, plus organic sheen, seepage, and seep/springs; so they were surveyed. These sites also had complex hydrology and human alterations. One site appears to be a natural slope wet meadow that was also below a ditch and recently flooded by beaver. The other site was situated in a large natural wet meadow-marsh-fen complex, and historical imagery revealed installed impoundments that had since naturalized and become occupied by beaver. This site had a soil profile with a top layer of 10 cm of peat, and the groundwater-dependent species *Sparganium eurycarpum*. It also organic sheen and visible groundwater discharge into the stream. Both of these sites had more surface flow than most sites in this study, anthropogenic alterations that affected this flow, and also abundant evidence of groundwater.

Figure 40. A mud and herbaceous plant earthen beaver dam that expanded a GDE wet meadow.

5.0 Discussion

This study is the first inventory that describes and compares plains GDE wetlands throughout their eastern Colorado range. It includes detailed mapping with likelihood of groundwater-dependence and field data on plains GDE types and locations, biodiversity, amphibian and invertebrate use, soil and water characteristics, and trends in ecological health. These findings highlight a clear need for continued inventory and coordinated conservation efforts for plains GDEs.

Plains GDEs are sensitive ecosystems facing many threats to their persistence. Despite these pressures, many remain in good condition and provide critical, unique habitat refugia. They support specialized or rare biodiversity, have carbon-rich soils, and are connected to local groundwater sources that are increasingly at-risk and worthy of protection. Groundwater-fed wetlands play a vital role in maintaining ecosystem services and watershed balance by delivering cool groundwater into streams and downslope areas, sustaining streamflow, regulating temperature, expanding floodplain saturation, and sourcing spring and pool ecosystems. During prolonged drought, their contribution to baseflow and intermittent water bodies is essential to maintain critical wetland and aquatic habitat and watershed functions.

This multi-scale survey includes GDE mapping across fifteen quadrangles, fifty-one field surveys, and data synthesis from 109 EIA plots. This study primarily focused on the following groundwater-dependent plains wetland types: wet meadows, peat-accumulating wetlands, and saline depressions. The findings show that while plains GDEs are widespread, they are relatively uncommon and under-documented wetland types. To support effective conservation, the next steps to stewardship should focus on identifying priority areas for mapping, research, and protection. A coordinated approach among wetland stakeholders is needed to integrate plains GDE conservation into long-term biodiversity and ecosystem management strategies. This will become more important as GDEs face growing threats to their water supply and health from climate change, drought, groundwater withdrawals, watershed development, and other land use pressures.

5.1 Plains GDE Ecosystems of Highest Conservation Value

All plains GDEs would benefit from strategic protection. Some GDE types are at higher risk in Colorado and are locally to globally uncommon to imperiled (e.g.: Forsberg 2018; Kost et al. 2007; MN DNR 2018 and 2025). These are peatlands and fens, calcareous wetlands and marl, saline playas, and riparian woody GDEs with native understory vegetation.

Plains Peatlands, Fens, and Calcareous Plant Communities

The classification and understanding of plains peat-accumulating wetlands and fens in eastern Colorado have undergone changes over the past decade as more data are collected. These were initially classified as eastward extensions of montane wet meadows or fens, but more inventory has identified plains peatlands with distinct vegetation and hydrogeomorphic features to the eastern Colorado plains and Front Range prairie. Most of these are mosaics of wet meadows, marshes, seeps, quaking soils, slope pocket fens, and bottomland peatlands ecosystems described in Colorado's Western Great Plains Wet Meadow-Marsh Drainage Network Ecological System (Decker et al. 2020), which is similar to the Western Great Plains Open Depression ecological system described in other states. Earlier plant community classifications (Carsey et al. 2003) included these assemblages mostly in plains depressional wetland associations, or within higher elevation slope wetland associations. Some of the associations identified by the Carsey study as needing more documentation >20 years ago were observed in this study and still need more data, such as seeps and peaty marshes with *Glyceria* spp. and *Catabrosia aquatica*, and peat-accumulating wet meadows with *Calamagrostis stricta*.

The U.S. National Vegetation Classification (USNVC) recently underwent several revisions. One new addition is the Great Plains Alkaline Fen group (NatureServe 2025). The USNVC fen group's component plant communities are not yet fully described for eastern Colorado, but overlap with many of those categorized in Decker et al. (2020)'s Western Great Plains Wet Meadow-Marsh Drainage Network, plus associations in other wetland types surveyed in this study including Western Great Plains Saline Depression, Western Great Plains Floodplain, and Western Great Plains Riparian ecological systems, as well as herbaceous fen community dominants in the Rocky Mountain Subalpine-Montane Fen ecological system and those described in fen plant associations from Gage and Cooper (2013). Refinement of the USNVC finer-scale descriptions in the Colorado eastern plains is needed to include the characteristic and indicator species observed from this study, in fen groups and in other GDE wetland types. The eastern Colorado peatlands and fens may overlap better with USNVC alliance and associations described in other midwestern or northern and cooler regions, by similarities of their species and processes. Not all peatland vegetation communities are fully tracked in the Colorado plains, including some vegetation types present in the Colorado mountains that are less strongly associated with organic soil there, such as *Carex utriculata, Carex pellita, Carex nebrascensis, Eleocharis rostellata, and Carex simulata* dominated wetlands. An updated representation of eastern Colorado GDE wetlands in USNVC classification will ensure their accurate tracking in the state. Further inventory and study of plains fen mosses, floristics, soil and groundwater, their other biota, and ecological processes is needed to capture their variability.

Highly calcareous GDEs with light colored seeps and marl surveyed had exceptional regional biodiversity, as did some spring fens with varying mineral composition. Many plains GDE plant assemblages are characteristic of calcareous wetlands. Carbonates are components of the shale and limestone geology in the eastern Colorado region and are present in variable concentrations in many Colorado plains wetland types. Not all calcareous wetlands are GDEs, and with this study, there are only a few calcareous peat-accumulating wetlands with apparent marl known in the eastern Colorado plains. Those are of highest conservation importance for their unique and sensitive features, and for their biodiversity.

One calcareous wetland vegetation type observed in this study fits the USNVC *Carex spp. – Triglochin maritima – Eleocharis quinqueflora (E. pauciflora)* Alkaline Fen Alliance, which is nested under the Great Plains Alkaline Fen Group. The Great Plains Marl Fen association in this Alliance, attributed to the northeastern and north-central great plains, is a G1 Globally imperiled plant association not yet defined for the Colorado plains (NatureServe 2025). Dominant species and characteristic open calcareous seep vegetation of this association were documented in surveys in this study as well as in previously surveyed plains fen plots, including a site on Black Squirrel Creek intensively surveyed by Kelso et al. (2014). Marl peatland communities are rare to critically imperiled at both the state and global levels; some occur in extreme rich fens such as those in South Park (Gage and Cooper 2013, Sanderson and March 1996, Cohen 2020, NYNHP 2025). These marl communities warrant further study in the Colorado prairie. The floristic quality of calcareous fens can simplify and lose rare and specialist species with impacts to the water table (Bart et al. 2020). Their sensitive substrates are also vulnerable to anthropogenic disturbance and should be avoided where possible when surveying (USFS 2012; USFS 2022).

Fen classification incorporates pH (Gage and Cooper 2013), with approximated classification breaks of poor fens with pH <5.5, intermediate or transitional rich fens with pH 5.5-7, rich fens with pH > approximately 7.0 and extreme rich fens with pH values > approximately 8.0. The site with the highest diversity in this survey exceeded 8.0 in some areas and 7.0 in other areas, and other sites with fen or peatland soils in this study's surveys and the plots analysis had higher pH approaching 8.0. The high pH fen had site characteristics that align with rare types of fens in the region and more broadly. More investigation of the site soil, geology, water chemistry, and hydrology at this site and other plains fens can shed light on the regional and global rarity of these wetland types, as many wetlands are calcareous in the Colorado eastern plains.

The most studied fens in Colorado's eastern plains are known from a paleoecology study of plains fens in Chico Basin (Gilmore and Sullivan 2010), who coined the term pocket fens that characterizes their smaller size and depressional formation. This study is a key primer to the unique conditions of eastern Colorado slope peatlands, and it highlights regional differences between fen soil types in the plains versus higher elevations. The soil stratigraphy is theorized to be formed by rotational and/or translational slumps that create local depressions, which accumulate marsh vegetation in areas of high groundwater discharge, then become terrestrialized with peat-accumulation. The terrestrialization is episodically interrupted by reactivated slumping from intense eastern Colorado precipitation events, followed by periods of erosion and deposition and flow of sediments. Temperature also affects peat accumulation rate, with warmer temperatures supporting more mineral soil development. The climatic combination of regionally low precipitation with high precipitation events, plus periods of higher temperatures and drought, together create more dynamic conditions for plains fen creation than those in high elevation environments. Unlike the more homogeneous peat cores of montane fens with high-organic soils (>80% organic matter), plains fens in Chico Basin had more variable profiles (10–60% organic content), often resembling Midwestern fens with a mosaic profile of interbedded organic and mineral layers (eg; George et al. 2016). Many soils with peat in this GDE study aligned with description of those soils in the Chico Basin study, by having top layers of organic soil, then interspersed organic and mineral content throughout the profile.

The number of peatlands encountered in this study's surveys suggest that many plains GDEs are identifiable from the aerial imagery as potential fens or peat-accumulating wetlands. These wetlands are a very small proportion of the overall Colorado plains landscape, and such wetlands with sapric seep/springs and floating mats surrounded by peatlands across a range of water chemistry are sensitive wetland types with high conservation value. As in high elevations of Colorado, plains fens and peatlands are studied here to document their diversity and location, role as habitat refugia, and to understand their land use pressures that may lead to conversion or loss.

We recommend prioritization of GDE mapping at a management-level scale, and recognizing groundwater-dependent wetlands on the plains as having conservation value comparable to fens in the mountainous and subalpine regions of Colorado.

Peatland Marshes with Cattail and Native Biodiversity

This study revealed that in groundwater-dependent wetland complexes, cattail patches are common, and this habitat can occur on peatlands and organic soils. In the Colorado Front Range and plains, many cattail wetlands are associated with surface water dynamics, especially in common depressional and impounded wetland types. The USNVC includes plains marsh deep-water cattail wetlands, but there is limited documentation on the range of cattail and native plains GDE and peatland marshes of the eastern Colorado plains, or how to manage these carbon-rich wetlands. Wetlands surveyed from the plots analysis included cattail and wet-meadow marsh wetlands on deep organic soils in low areas of warm water sloughs, moderate sized plains riparian drainages, and in headwater complexes, some of which had been excavated for ponds and wildlife habitat management.

More research is needed to better understand cattail seep wetlands from warm water sloughs and large organic-soil rich floodplains, such as along the South Fork Republican River, Horse Creek, and outer areas of big river floodplains such as in Goodale Slough. There is limited information on how to limit the continued expansion of cattail into groundwater-fed wet meadow habitat and saline playas, while avoiding loss of native organic soil and biodiversity. Nonetheless, organic soil marsh wetlands with cattail dominance provide important biodiversity support and carbon accumulation in peat soils. Many other cattail wetlands that are anthropogenically created or fed by surface water have comparatively lower wetland condition and conservation value. While further research is needed on the range of peat-accumulating plains marsh wetlands, it is essential to distinguish organic soil marshes from deep water-impounded marshes to effectively track biodiversity and conservation status.

Herbaceous Riparian Wetlands and Refuge Pools

Most streams on Colorado's eastern plains consists of narrow riparian drainages that flow into the large alluvial floodplains of the South Platte, Arkansas, and Republican Rivers. These drainages occur across variable topography from flat or rolling plains to dissected canyons, in mostly intermittent and ephemeral streams driven by localized precipitation. Many contain in-stream depressions that impound flow for longer within the drainage. Some of these are groundwater-fed refuge pools that retain their water year-round and provide critical habitat for declining and rare native plains fish, amphibian, and other wildlife. As groundwater pumping lowers water tables at both regional and localized scales, native herbaceous GDE drainages and pools are increasingly at-risk. They are also degrading further from a laddered series of impoundments and barriers that partially to fully impede aquatic habitat connectivity, and from subsidence and headcuts due to losing groundwater in the underlying gravel (Wohl 2013). Several species of small fish of greatest conservation need in the state, such as the brassy minnow (*Hybognathus hankisoni*), Arkansas darter (*Etheostoma cragini)*, and red-belly dace (*Phoxinus* spp.), rely on the refuge pools for habitat and benefit from some hydrologic connectivity between pools during dry periods (CPW 2016). Mapping the narrow drainages and pools that remain wet and ponded through both wet and dry periods can support proactive management for critical aquatic-dependent species habitat, from tracking pools and associated changes in sizes and number, to working towards habitat-based water rights in order to protect rare biodiversity refugia.

Saline Wetlands

This study significantly increased the number of documented saline plains wetlands in Colorado (Figure 41), mapping previously unrecorded saline playas in terminal basins, and saline wetland patches with evaporite crusts in slope GDE wetland complexes. Some of these mosaics have contrasting pH levels across plant communities, including peat-accumulating wet meadows and salt flat patches. Many alkaline to saline GDE plains wetlands including playas, salt pans, alkaline sloughs, and saline reservoirs and lakes remain unmapped and under-surveyed in eastern Colorado, and surveyed plots to date have regular occurrences of uncommon and rare species, but with low redundancy between sites, highlighting a need for further inventory. A plains-wide saline wetland mapping effort to document their distribution would take limited time, as saline GDE are a relatively uncommon wetland type.

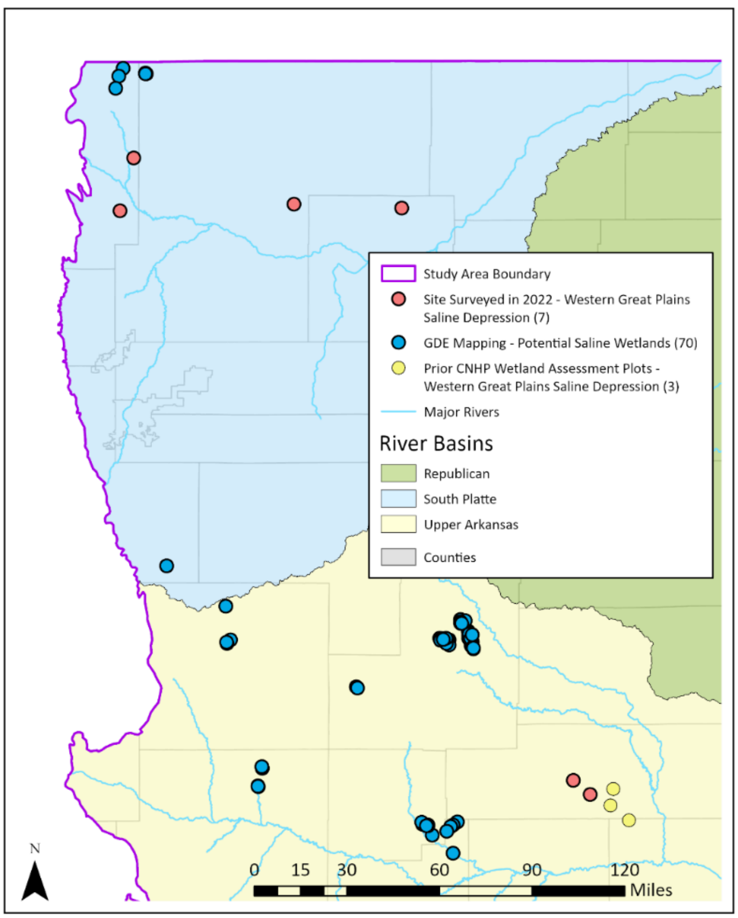

Figure 41. Saline playas surveyed in 2022 in the Plains Groundwater-Dependent Wetland Study, saline playa plots surveyed previously by CNHP in the study area, and GDE-mapped potential saline wetlands. One Boulder County saline playa wetland not mapped.

Comparison of eastern Colorado GDE saline playas with other saline terminal basins can be challenged by varying terminology used for inland saline playas and other wetlands. Terminology used can depend on region of use, whether discharge and/or recharge wetland, and level of study of the wetland type: with names such as playa lake, terminal lake, salt playa, salt flat, salina, saline lake, sabkha, alkali flat, salt flat, etc. (Briere 2000, Baker 2020). In the High Plains, playas typically function as recharge and freshwater wetlands, versus discharge playas in the southwest (Briere 2000). The term saline playa is used for surveyed wetlands in this study to name their groundwater source connection, salt and halophyte characteristics, and larger playa landscape setting, though further research on salinity gradients and hydrologic function in eastern Colorado could inform their regional typing. They have overlapping characteristics with intermountain basin playas, from their invertebrates (Appendix B) to their mixed surface and groundwater sources. Some of these wetlands are visible in wet-year or historical aerials as interconnected wetland complex landscape (Figures 42 and 43), and similarly to prairie potholes farther north. Eastern Colorado saline wetlands may also occur along gradients between groundwater and surface water inputs.

Figure 42. A 2014 Google Earth image with saline and freshwater GDEs in Hugo State Wildlife Area region. Image shows the interconnected plains wetland drainage network including seeps, wet meadows and marshes, herbaceous riparian drainages, and saline and freshwater depressional wetlands.

Inland saline wetlands across the U.S. have increasing research and conservation attention due to their unique species habitats, groundwater-dependence, deep and old aquifer sources, and declining extent (e.g.: Harvey et al. 2007a; Cohen et al. 2020; Jehl 2020). Several states have implemented initiatives to study and protect saline wetlands and their contributing watersheds (e.g.: SWCP 2018; S. 1466, 2022). In Nebraska, Arizona, and Minnesota, similar habitats support ESA-listed and ESA-proposed tiger beetles, and in Nebraska other specialized rare and endangered plants to their state's saline wetlands including saltwort (*Salicornia rubra*), saltmarsh aster (*Aster subulatus* var. *ligulatus*), Texas dropseed (*Sporobolus texanus*), the interior least tern (*Sterna antillarum athalassos*) and the piping plover (*Charadrius melodus*) (MN DNR 2022, SWCP 2018, CBD 2025). Saline wetlands are poorly inventoried in Colorado, with only eleven confirmed EIA-surveyed saline playa wetlands at the time of this report. These sites support regionally uncommon to rare vegetation communities and species, diverse beetles, uncommon aquatic macroinvertebrates, and shorebird use; suggesting that these systems may support more critical biodiversity than currently known (Figure 44). In addition, saline wetland species considered imperiled in other states have similar threats in Colorado with lowering water tables and increasing fragmentation of contributing watersheds. Recent regional collaborative efforts for conservation of eastern Colorado playas is primarily focused on freshwater playas, but saline playa habitats support high biodiversity in similar landscapes, and they need more research and conservation protections.

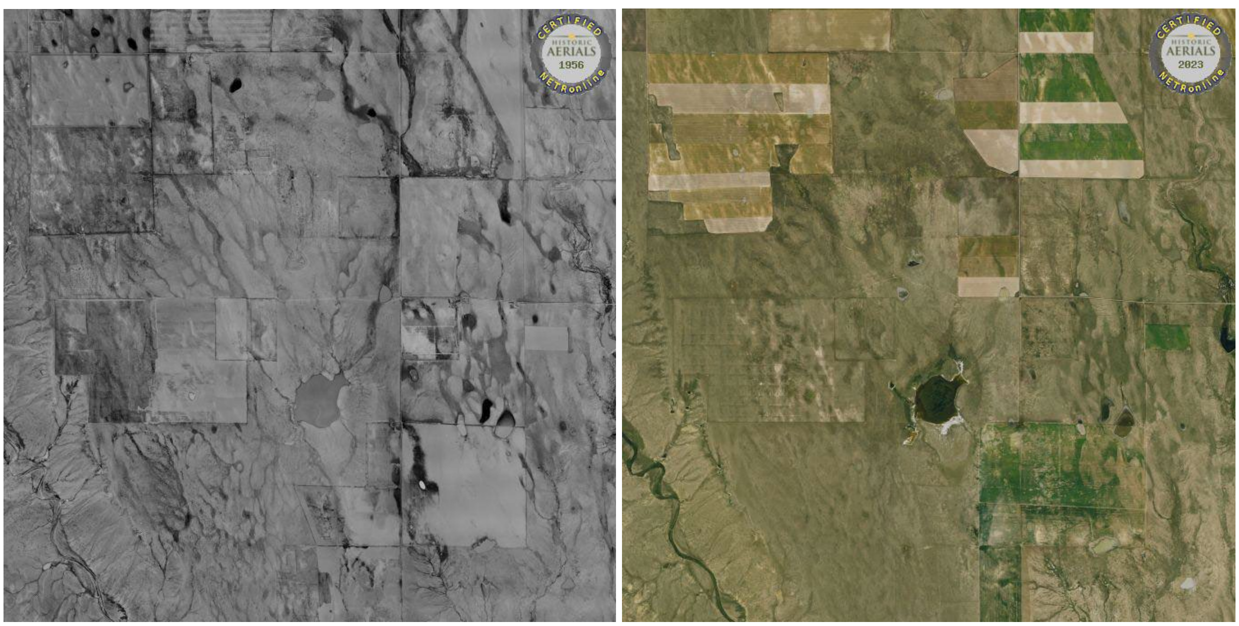

Figure 43. Comparison of the drainage network around the alkali Beckmann Lake from 1956 to 2023 (Historical Aerials).

Figure 44. Tiger beetles in a saline playa in eastern Colorado.

The Colorado plains saline vegetation communities occur in a variety of wetland types from saline playas to flats to reservoir fringes to natural depressional slough marshes, many without USNVC descriptions that fit Colorado plains, and so consistent conservation tracking is challenging. For example, *Salicornia rubra* is endangered in Nebraska, but in Colorado it is more documented in the mountains, so in the plains, where there are few reports, it is not tracked. In addition to *Salicornia*, saline and alkaline plains wetlands support regionally rare species such alkali American-aster (*Symphyotrichum ciliatum*), yerba mansa (*Anemopsis californica;* Boulder plots), and plover. Saline playa plant-community halophytes such as *Suaeda, Sesuvium,* and *Ruppia* species are indicators in at-risk globally imperiled saline wetland types such as *Salicornia rubra* salt flats (G2; NatureServe 2025), Northern Great Plains Saltgrass Saline meadow with *Distichlis spicata-Hordeum jubatum-Puccinellia nuttaliana-Suaeda calceoliformis* (G2), Northern Great Plains *Stuckenia pectinata – Ruppia maritima* aquatic vegetation community (G2), and other key saline depression indicator species such as seaside heliotrope (*Heliotropium curavassicum*) and winged sea-purslane (*Sesuvium verrucosum)*. These are all imperiled to critically imperiled species and communities in neighboring states with similar plains region distributions. More study to inform saline wetland type, vegetation classification, and their ongoing threats in the eastern Colorado plains, and until then, following other regional saline wetland conservation priorities will help prevent further loss.

Multiple factors cause saline playas and other alkaline to saline GDE wetlands to be at-risk. Climate change is a factor, but studies show strong drivers from anthropogenic land use changes including groundwater overuse and decline, hydrologic controls, landscape alterations and impoundments, and especially additions of freshwater and nutrients via ditches and runoff. Landowner reports of significant drying of their saline wetlands are consistent with regional reports of loss of depressional saline wetland area over the last hundred years. Land uses and hydrologic alteration can cause saline wetland conversion to cattail marsh or a more freshwater reservoir, or drying and weed invasion, as observed in several wetland surveys and plots analyzed from this study. Research is needed to understand the factors that affect plains GDE saline wetlands and their contributing watersheds in Colorado, and what can be done to minimize trends of their drying and loss.

Woody Swamps and Wooded Slope Wetlands

This study surveyed relatively few woody GDE wetland types, where groundwater discharges at springs and pools, slope breaks, and within-channels in GDE shrublands and open wooded wetland floodplains. For GDEs in wooded bottomlands, springs, and pools, more focused study will likely uncover more biodiversity, as the few surveyed sites had unique native plant diversity and wildlife habitat. Shrubs also can invade GDE wetlands in less saturated sites, so determining the cause for woody plains GDE wetland vegetation, and whether it is a high-quality native floodplain, or an invaded herbaceous GDE, is also important for management.

Canyon GDE Wetlands

This study did not focus on canyon GDEs, but it aimed to sample several to give an overview of their wetland types in the Colorado plains. Many canyon wetlands are privately owned, and landowner access to canyon GDE wetlands proved difficult. Only two wetland plots in confined canyons were visited and only one of those narrow canyon wetlands were surveyed, with the second dropped due to time and access limitations. Prioritizing landowner relationship-development and working to identify incentives and value for the surveys such as in partnership with easement coalitions, may facilitate site access for future research. A second plains riparian site in a partially confined canyon with an open valley bottom was also surveyed. The highest EIA score from this study's field surveys was from the canyon GDE with pools and ponding in the headwater canyon drainage to the Purgatoire River. Drying trends may be more intense in canyon GDEs, with less irrigation hydrology additions and overall drier landscapes, but more research is needed to understand these dynamics. However, many canyon GDE locations appeared high quality from the imagery, suggesting that plains canyon landowners may also be key resources for investigating successful canyon GDE wetland stewardship techniques. The limited data available from these site types suggest canyon GDEs are relatively high-quality biodiversity refugia.

5.2 Plains GDE Wildlife Habitat

This study supports high diversity by rare and sensitive wildlife species and guilds, including site quality bioindicators such as amphibians and invertebrates. The tendency for plains GDEs to be biodiversity hotspots is well-supported with surveys from this project. Leopard frogs were a focus of this study, and their presence reveals higher quality wetland habitat, but other imperiled wildlife species without targeted searches in this study were also observed in plains GDEs. Additional species guilds not inventoried here such as native plains fish are also known to depend on GDE habitats such as refuge pools.

Plains and Northern Leopard Frog Habitat

Most of the surveyed GDE wetland complexes had data showing current or historical leopard frog species within a couple kilometers of the plots. They were also observed in over a quarter of surveyed GDE plots in a drought year with a single visit. Northern leopard frogs and plains leopard frogs are Colorado CPW species of greatest conservation need. Their populations are declining from impacts by pollutants, fragmentation, site degradation and habitat loss, and predation by invasive wildlife. Plains GDEs and their larger wetland complexes provide a variety of habitats including foraging, breeding, and overwintering habitat, and thus management of these habitats should consider leopard frog needs at the wetland complex scale, as they utilize various features in the complex for different life stages. The seep and spring conditions that provide habitat for plains leopard frogs also support other native amphibian diversity such as the chorus frog (*Pseudacris triseriata*) and the tiger salamander (*Ambystoma tigrinum*) (Wohl 2013).

Natural pools in GDEs may provide shallower water depths suitable for leopard frogs that are less optimal for bullfrogs, and wetland pool size variety also can curb competition from bullfrogs. Leopard frogs also are more often observed in moist and relatively open vegetated wetland areas, which can be threatened by dense cattail invasion. Anecdotally, leopard frogs were observed at least once in an open cattail seep with organic muck; so in sites with cattail, the cattail density and substrate quality may be relatively important. Leopard frogs were not constrained to 'good condition EIA' sites, but their current and past surveyed frequency of observation in GDE wetland complexes includes frequent observations in sites with groundwater inputs that provide desirable habitat patch types for the leopard frogs.

The bullfrog poses a serious threat to leopard frogs from competition and predation, and they are carrier species for chytrid fungus. Bullfrogs were usually observed in this study's sites with leopard frogs. Management to avoid prime conditions for bullfrogs may also support GDEs, such as avoiding impoundments that create deep water wetlands. The chytrid negative samples taken from northern leopard frogs at six sites plus from chorus frogs at one site suggest that some plains GDE habitats are likely without chytrid yet, and to maintain this habitat refugia, ongoing education about equipment cleaning to researchers and recreationists alike will help maintain the leopard frog habitat and avoid spreading chytrid fungus.

Birds, Butterflies and Macroinvertebrates

Plains GDE aquatic habitat features such as mudflats, shallow wadeable open water and springs, and wetland vegetation support a variety of wildlife habitats, including rare and nesting wildlife. Black rail were observed in a large organic soil cattail wetland with adjacent wet meadow-marsh diversity. Fritillaries are indicators of high biodiversity and potential remnant GDEs and were present in peat-accumulating wetlands. The invertebrate sweeps showed unusual regional plains wetland GDE insect biodiversity at the genus level, and more genera were observed with potential for rare species. Saline wetlands support at-risk waterfowl species that rely on inland mudflat and shallow water habitat. The saline wetlands have fluctuating water levels, but wet more predictably and often annual wetted water regime than of a fully surface water fed-freshwater playas. The important waterfowl and shorebird food wigeongrass (*Ruppia cirrhosa*) was found in high cover in the ponded area of good condition saline wetlands, and invertebrate samples from saline wetlands also had an abundance of *Ruppia* seeds. Historical wetlands in the eastern plains had an abundance of mudflat, saturated herbaceous, and shallow water habitat (Wohl 2013), and now these features are a tiny portion of what was, and plains GDEs provide some of these remaining critical habitats.

The GDE surveys resulted in increased regional understanding of GDE aquatic macroinvertebrate taxonomy, adding new, underreported, and relatively uncommon or macroinvertebrate taxa to the eastern Colorado region, known better from the Colorado mountains or Midwest, following a similar trend to some vegetation species observations. For example, a stonefly genus *Amphinemura* was observed at a Soapstone Prairie fen, reported to be only associated with spring-fed or cool water in streams or transitional wetland habitat, and the state-rare horned clubtail dragonfly (*Arigomphus cornutus)* was observed in a riparian area with refuge pools. This study surveyed several more sites in slow groundwater-fed drainages with bluffs with rare or underreported unique taxa to the Colorado plains. Additionally, saline sites had brine fly taxa only known to intermountain basin saline wetlands.

Beaver

Beaver wetlands provide critical watershed ecosystem services and natural disturbances. Beaver wetlands were not prioritized for survey with this study, due to the floodplain-impounded surface water dynamics, and this study's priority of more obligate groundwater-dependent wetland types. However, in the site surveys, beaver were present at three surveyed peat-accumulating floodplain drainage GDEs with groundwater evidence. In GDEs, beaver presence contributes to maintaining groundwater tables, and eradication of beaver at a site can degrade or eliminate GDE wetland groundwater availability. Beaver were also present in other surveyed GDE wetland complexes outside of the AA plots, such as at May Ranch. Beaver wetlands can provide natural ponds for wildlife habitat without loss of organic soil content, expand wetlands in landscapes with past water table loss, and control invasive woody vegetation, and reduce excessive nutrients. They create water and carbon storage, slow runoff into depressions and hydrophilic riparian zones, reduce risk of high severity wildfire, and clean water. This results in prolonged recharge of plains rivers, with intermittent increases in streamflow energy and nutrient cycling to refresh plains plant species habitat that require more room. The beaver dams observed in the AAs provided obvious ecological health assistance – helping buffer anthropogenic hydrologic alterations impacts to GDEs. One dam downstream of a large impounded GDE also provided leopard frog pool habitat and rewetting of floodplain, and another dam situated downslope of a large discharging canal in a historical GDE wet meadow intercepted and slowed unnatural inputs; and another was located in a site in high need of pollutant reduction based on orange odorous water.

Beaver wetlands are at-risk in the plains. Wetland managers have reported regular pressure from water users, at times successful, to remove established beaver wetlands from GDE wetland complexes. Beaver are a key part of the plains GDE wetland-complex landscape, and they have lost much of their historical habitat. Those remaining provide some of the last natural plains wetland disturbance processes. Beaver can transform obligate groundwater-fed wetlands into wetlands with ponds and more surface water inputs, but the formation of plains groundwater-dependent wetlands is cyclic and ponding and successional steps back occur in some wetlands periodically. Conversely, in a Rocky Mountain study (Karran et al. 2017), peatland beaver dams increased peat accumulation. A Missouri soil study of low elevation karst fens found beaver wood in a GDE soil profile thousands of years old (MPF 2024). Historically in Colorado, and in other comparable wetland types from the Midwest, plains groundwater-dependent wetland complexes included beaver wetland in many of their lowlands (Cohen et al. 2020). The healthiest watersheds and their component wetlands will have conservation of beaver wetland presence in wetland types that historically supported beaver. However, in certain plains GDEs with specialized and at-risk fen or seep vegetation, beaver presence can require nuanced management, where GDE species may be able to handle flooding in some cases and not others.

5.3 Wetland Condition of Plains GDEs

Condition Assessment Results

Groundwater-dependent wetlands on the Eastern Colorado plains show relatively high EIA condition in comparison to other plains wetlands. This multi-indicator diversity study highlights added value of plains GDE wetlands that include those with mid-EIA condition that also support unique or rare biota. Biodiversity is an important factor in conservation assessment, and EIA can help identify indicators of both risk and decline, but there is still much to learn about GDE best-management and disturbance dynamics that affect EIA benchmarks. Although hydrology in the plains varies substantially across seasons and years, hydrologic health may be the most important wetland health factor to monitor, as the species utilizing the wetlands and GDE wetland characteristics are unique by their groundwater dependence, and changes in hydrology affect all other aspects of condition.

For regional comparison, wetland condition ranks across the Lower Arkansas River basin (Lemly et al. 2017) and South Platte River basin (Lemly et al. 2014) estimated the majority of mapped wetlands in those basins to be in fair condition and about one-fifth to one-third of wetlands estimated in good condition. Additional wetland plots surveyed from targeted studies from the Front Range in smaller watersheds (Lemly et al. 2013) and in Boulder County (Orthner et al. 2021, Peak et al. 2021) and the cities of Denver (Smith and Kuhn 2015) and Aurora (Gilligan et al. 2020) all scored lower on average than this study's wetlands. The South Platte River basin and urban areas also have more D-ranked wetlands. Overall, wetlands in this GDE study scored higher condition on average, in comparison to all randomized studies as well as the targeted Front Range studies. For targeted reference studies (best-available condition) in the South Platte and Arkansas basins, the GDE surveys had comparable EIA ranks to those targeted as reference condition sites (Lemly et al. 2014, Lemly et al. 2015), ranging A-C's with mostly B's, showing that many plains GDEs are comparable Colorado plains reference condition wetlands.

Plains GDE Ecological Integrity Assessment Methods

The trial refinement of the EIA for plains GDEs provided more insight into the ecological drivers and data needs for assessing GDE condition, but it did not take the next step of testing the assessment methods against condition or stress gradients or critical metric condition thresholds of healthy versus unhealthy GDEs. Limitations to that comparison in this study included a small sample size of 51 wetlands across diverse wetland types, incomplete inventory of GDE vegetation and wetland types, and remaining research needs on natural disturbance regimes and management that mimics trajectories of health and function in absence of natural disturbance. The EIA is based on assessing departure from reference conditions, but in the plains, reference condition is still less understood in absence of natural disturbance regimes and hydrology without anthropogenic impacts. Some GDE processes may require active management to mimic natural functions. However, the optimal strategies for restoring or sustaining these processes remain uncertain.

Testing the success of plains GDE EIAs against a stressor index based on standardized land uses, some of which may support and others degrade wetland health, is limited with the 51-site survey and the diversity of wetland types. That said, this study's findings inform EIA refinement to assess overall health in plains GDEs. The following factors could use further exploration as part of a plains GDE ecological health testing:

- Rare and Sensitive Species: Species presence (e.g.: amphibians, rare CNHP-tracked taxa) doesn't always align with EIA scores in good condition. Sites with sensitive species but lower EIA ratings may indicate gaps in wetland assessment methods, if those GDE-sensitive species are affected by wetland ecological condition. Interspersion features that amphibians and other GDE biodiversity prefer, such as more open groundwater seepage and slow-flow surface water areas within wetlands with higher overall vegetation densities, may be important to emphasize in refinement of EIA and Leopard Frog Habitat Scorecard ratings.
- Larger Targeted Assessment Areas (AAs): Where inventory or resource stewardship is a goal (versus ambient condition assessment of a larger regional resource using a statistical design), standard 0.5 ha plots may miss larger-scale hydrological or vegetation patterns that drive GDE condition in their wetland mosaic. AAs can capture patch diversity using nested or sub-plot survey design across the wetland area with shared groundwater hydrology.
- Soil health is a minor component of current EIA scoring but is critical to GDE function, but is a key indicator of site irreparable degradation. This is in part because soil health is often more difficult to visually assess in wetlands with less sensitive soils. In addition, light land uses that create open interspersion conditions, can cause a range of minimal to serious stress on soil health. The degree of site stress from land use might be more site-specific than rated in a standard stressor index, where a supplemental record of soil health factors could help prioritize site management needs.
- GDE Invasion and Disturbance: Invasion by cattails, tamarisk, Russian Olive, shrubs, and weeds are linked to lack of natural disturbance (e.g.: beaver activity, prairie dogs, and wildfire, and dynamic hydrology). Invasion effects can compound health stress by increased vegetation densities that impact hydrologic flow and GDE plant community diversity. Cattail invasion in peat wetlands needs more study in eastern Colorado.
- FQA measures may perform better in select wetland types such as saturated sloping GDE herbaceous wetlands, but more research by wetland type is needed. Colorado plains C-values need regional review, and not all plains GDEs should be expected to have conditions or species reflective of stable hydrology. Adopting hydrodynamic classification from Washinton EIA, including stagnant/sluggish/mobile/dynamic/very dynamic (Ramm-Granberg and Rocchio 2024) could clarify functional expectations and indicators.
- Invertebrates as Indicators: Invertebrate data from this study can support development of multi-taxa indicators of water quality and GDE health, in comparison with other GDE and invertebrate data sets. These can be used to test the EIA's ability to detect water quality constraints to ecological condition through other metrics.

Level 2 EIA as a Rapid Assessment Tool

Despite some variations between rare and sensitive species GDE habitat and EIA score, the EIA rank results generally align with expert judgment, especially for identifying general wetland degradation and stress. The outcomes of plains GDE EIA ratings may function best as an ambient stressor wetland rating tool for a region, that can be carried out quickly across wetland types, than a site-based ecological health and needs assessment, until more understanding of the optimal plains GDE wetland processes essential for long term function (e.g., natural disturbance needs and overall habitat function needs) are known. It can detect a site seriously impacted by weeds, pugging, or drought, but those states are also difficult to restore. It also could be used as a many-plot assessment method in a small resource area to identify highest management priorities. With the understanding that GDE wetlands have high regional conservation value, investing additional time in mapping of GDEs, indicator checklists for high priority conservation and management needs, may be just as important as rapid EIA in wetland habitat types known as refugia for many potential rare species.

The EIA also helped identify the conceptual indicators of the pervasive GDE threats we observed in this study: a concerning onsite-drying trajectory that will lead to substrate and recent wetted area loss, and less frequently water quality and larger-scale hydrology modification issues. Inventorying response to these threats and critical management areas is the next step to stewardship. For these, ecosystem-tailored methods such as those adapted from the USFS GDE inventories that include directed management notes on: water source and movement function, aquifer function, watershed function GDE impacts, landform stability, seep/spring/spring run/quaking area locations and threats, soil organic depth and functionality, wetland vegetation function and indicators such as dieback, rare or sensitive species presence, and water uses in area (USFS 2012, USFS 2022).

The EIA is strong for comparing relative conditions in a region across wetland types. GDEs are in relatively good condition in comparison to many more altered Colorado plains wetland types, even the GDEs that are likely experiencing loss from intensive land uses and drying. Even more non-native GDE sites such as a floodplain site or cattail wetlands had redeeming characteristics of very high conservation value, offering rare species habitat, organic soils, and groundwater source expression that supports locally higher diversity and overall watershed health. This underscores the value of identification and preservation of the groundwater source.

Floristic Quality and High-Quality Plants

A Floristic Quality Analysis is often used to understand the vegetation condition in wetlands as direct biotic indicator of ecological integrity. In surveyed plains GDEs, relative percent cover of native plant composition was negatively correlated to landscape disturbance and appears to be a reliable measure of vegetation health in this study and others (e.g., Ramm-Granberg and Rocchio 2024). Pairing good relative native cover values with observations of high C-value plants or indicator species of high-quality wetlands can indicate either high conservation value and/or remnant conditions, depending on species prevalence (Bried et al. 2021, Siddig et al. 2015). Fen sites with high cattail cover that also have other high biodiversity are one wetland type that need a multi-indicator review of other species' composition, as cattail cover is interpreted negatively for Colorado floristic quality but is also naturally present, and was present in higher cover even in sites with imperiled species and other vegetation diversity. All plains wetlands with substantial native cover have higher conservation value, especially woody wetlands that typically have invaded understories in eastern Colorado. Plains GDEs generally had higher native cover than other wetland types.

However, interpretating FQA metrics such as Mean C, Native Mean C, and FQAI in eastern Colorado GDEs requires caution and more data is needed to properly assess their fidelity to site condition by wetland ecosystem type. Colorado plant C-values also need review for the eastern Colorado plains region. FQA metrics vary by ecosystem, and should be compared across the same wetland types, or if composite site type scores are compared, this should be reported as the values are often higher (Andreas et al. 2004). The FQAI metric includes richness and can highlight sites with high native biodiversity, but sites with recent disturbance, whether anthropogenic or natural, can also have increased short-term richness. In contrast, some low diversity sites, such as fen and saline depression sites with low nutrients or high salinity that naturally restrict diversity, can still be high quality. Thus, interpretating FQA measures needs consideration of both anthropogenic stressors and the fidelity of FQA metric to the site quality by wetland type.

Site Mean C is the most commonly used FQA measure and was correlated to the wetland landscape disturbance index; but Mean C also scores non-native species by zero, shaping the score in a similar manner to percent native cover; but with lower correlation to landscape disturbance than native relative cover. Targeted study could research eastern Colorado plains benchmarks by plains wetland type and expected natural disturbance regime, to identify which FQA metrics reliably follow a site quality continuum (e.g., Ramm-Granberg and Rocchio 2024; Jarosz and Gibson 2024). For sites with unique conservation value or very degraded condition, FQA can flag sites with unique and potential remnant sites, or with biotic stress such as nutrient loading; but further study in eastern Colorado wetlands with sufficient dataset across a condition gradient by wetland type is needed before using FQA scores to prioritize relative conservation value, or rate ecological integrity across eastern Colorado wetlands.

Wetlands with relatively high wetland FQA scores for their wetland type, particularly those > FQAI of 20, appeared to align with sites with overall high conservation value, like Bried et al. 2021. These were only observed in a small region of the study area, and they also had strong calcareous indicators also linking the plant assemblages. But the lower and mid-range FQA scores are not as consistently related to disturbance, and FQA overall scores are low in comparison to higher elevation wetlands where FQA measures were shown in Colorado to detect site quality more consistently (Rocchio 2007). Colorado plains FQA-based detection of vegetation health may be less robust. If C-value goals are used for management targets without understanding the natural range of variation in high and low condition eastern plains wetland sites, and the role that functioning natural disturbance and hydrology has on plant community FQA values, their use may add confusion to defining desirable plant assemblages for GDE wetland health. Given the high variability in wetland type and characteristics from CNHP datasets of the GDE plots from this study, as more plots are surveyed, trends in FQA scores in relation to GDE condition may become more evident.

5.4 GDE Research and Management

Inventory and Mapping

Colorado's plains GDE wetlands need mapping, and targeted inventory to be able to prevent and slow the ongoing GDE wetland and habitat loss from land uses and groundwater decline. Nearly all sites surveyed in this study had land uses that can stress GDEs such as grazing, vegetation management, water management and development, invasive species; and they also experience passive stressors such as loss of natural disturbance, and drying trends from drought and climate change. These pressures can transform a groundwater-dependent wetland into a surface water fed wetland, and without monitoring, these factors also can obscure signs of GDE wetland loss. Updates to wetland mapping and identification of the most obligate GDE wetlands can support tailored management to prevent loss of high value ecosystems.

Vegetation Community Classification

CNHP tracks rare communities using the USNVC system. Colorado plains wetland community types need accurate classification that reflects regional climatic differences and key hydrologic drivers, that describe highly groundwater-dependent vegetation communities, including some that may be past-documented and remnant now or lost. Recently the USNVC hierarchy was split within Colorado between the Western Great Plains region, and the mountains and arid west regions, where wetlands in eastern Colorado were fit into a Southern Great Plains regional classification. This caused a need to redescribe community types that previously fit plant community descriptions at larger scales. The USNVC treatment of the montane and plains regions separately is needed. For example, wet meadows and fens with high conservation value in the plains such as sites with *Carex nebrascensis* dominance can have similar floristics to degraded ecosystems in other regions with lower conservation value. However, splitting classifications with similar dominants then requires further identification of the ecological drivers that also distinguish communities by region, and how for the plains GDEs surveyed in this study, the species disjuncts or edge types that have more species occurrences in the northern great plains, the Midwest, and the mountains are best described. With changing classifications, care to preserve the accurate classification of past surveyed remnant ecosystems is also important to understanding vegetation change, and the legacy of historical plant assemblages may become increasingly valuable as GDEs change. Colorado does not yet have a state-funded wetland inventory and monitoring program, but there is no better time for projects to comprehensively inventory wetland vegetation throughout the state. The rate of GDE change follows the decline of groundwater tables and human development and alteration, and an understanding of the highest priority GDE habitats and impacts of increased water stress on those habitats in eastern Colorado is needed sooner rather than later to preserve the most imperiled wetland types.

Understanding Disturbance Regimes

The Colorado plains landscapes experienced historic natural disturbance cycles at a more regular frequency than occur now – with large herds of bison, grassland fires, less hydrologic controls and more through-flow and flooding in ephemeral and intermittent drainages and floodplains. Studies suggest that these disturbances played a major role in maintaining more open conditions, diverse forbs, and water features like exposed seeps, water tracks, and pools in low order riparian drainages. There is a need to research what levels and types of disturbance (natural or managed) can maintain high quality vegetation and hydrology without degrading soils or rare species, or irreplaceable wetlands. Plains GDE indicator species such as *Spiranthes diluvialis* and *Eustoma russellianum* were historically more common in groundwater-rich, moist soil and open meadows, peatlands, and floodplains, and are adapted to natural disturbance such as fire (Jennings 2001, Riedel 2002). A site surveyed in this study experienced high severity wildlife the spring prior, yet surveys uncovered range extensions of species into Colorado and persistence of high-quality peatland vegetation. Ecological integrity benchmarks rate "least disturbed" as reference conditions, and anthropogenic land uses that mimic natural disturbance processes may not fit the least-disturbed concept, but they may have important roles in shaping wetland structure that supports the range of plains GDE habitat diversity and functioning wetland types that management aims to protect.

Ditching and Hydrology Management

Much of the eastern plains is influenced by ditching, and there are many examples of plains wetland becoming wetter and with more cattail below ditches. Yet, the interactions of ditches and historical groundwater presence are more complex than that wetlands by ditches are all wetter, or created by ditches. Some ditches add water, others divert and remove flow inputs and water sources, and some replace lost natural hydrology (Figure 45). When natural hydrology is unknown, adaptive management should consider the stakes of groundwater loss even if supplemented by ditches. Ditches and canals can either help and/or hurt plains GDE wetland hydrology, and understanding site-specific hydrologic history is key to management for GDE function.

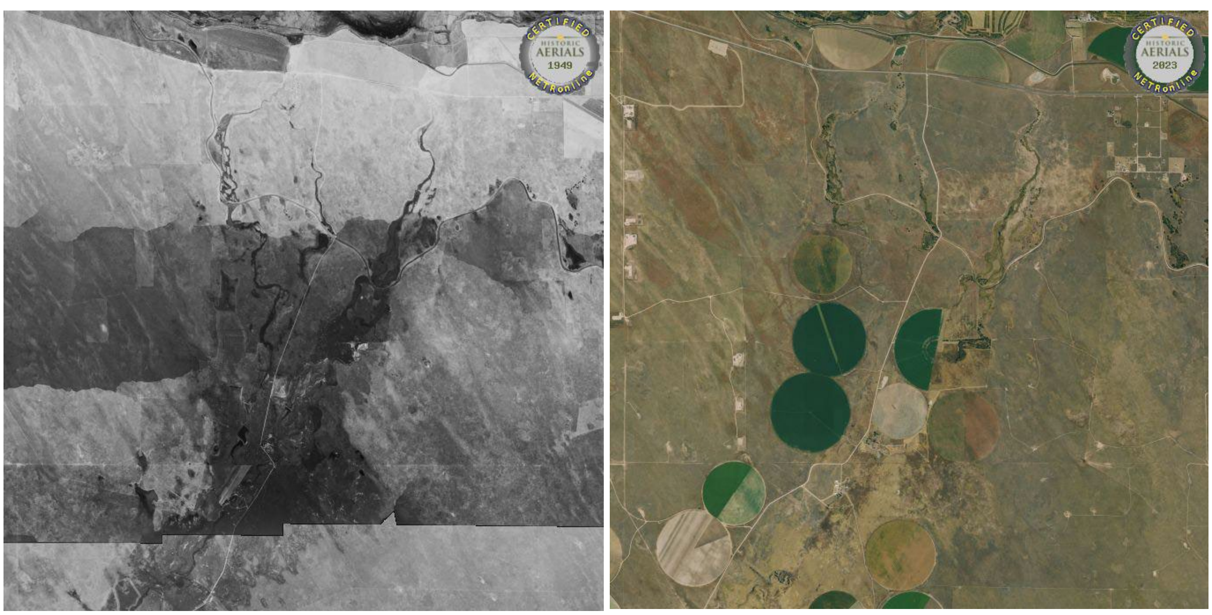

Figure 45. Comparison of wetland hydrology of Lost Creek from 1949 to 2023. Hydrology is now reduced above the canal, but is similar to historical conditions below the canal.

Grazing and Management Trade-offs

Grazing is widespread among surveyed GDE sites, and its effects vary from negligible or beneficial, to serious stress, depending on intensity, substrate sensitivity, hydrology, and vegetation types. Light or moderate grazing can help reduce dense thatch, helping to maintain open water and saturated soil access by small wildlife like leopard frogs and finer vegetation. In contrast, moderate or heavy grazing on sensitive organic soils can damage and remove peat, compact soil, reduce site groundwater access, and degrade GDEs. Some sites had such dense peat it was difficult to sample, and other sites had excellent biodiversity under moderate grazing levels. In some cases, management that mimics the historical regimes using light and controlled grazing, fire, and even conservation of shallow-ditch flood irrigation and upslope ditch seep inputs that support site hydrology could help conserve desired plains GDE wetlands. The most biodiverse GDEs surveys were grazed or have a history of grazing, but these also had visible indicators of condition stress. In other sites, where the soils are intact, the vegetation is diverse, native, and without a trajectory of invasion, continuing management practices as they are with watchful monitoring of hydrology and plant community change is a safe approach.

Adaptive and Site-Specific Management

With cumulative changes in natural processes and disturbances, changing climate and groundwater levels, and variation in individual site histories, adaptive and research-based plains GDE management has benefits. First, identification and protection of rare and sensitive wetland features such as seeps, fens, saline playas, and other at-risk wetlands is needed to prevent critical loss; then management to maintain groundwater, avoid organic soil harm, and strategize land uses in sites showing signs of degradation or increasing uniformity may be needed. Evaluation of historical aerial imagery provides critical information on site history and potential, from understanding watershed-scale change, to detecting areas with drying or lost seeps and springs or areas of concentrated increased wetness. For example, the Rush Creek floodplain has lost its outer floodplain seeps and significant extent of its contributing saturated narrow drainage network, while the sandy channel has narrowed; but some areas of dark saturated floodplain still persist and may support remnant habitat (Figure 46). Management considerations are generally complex. It is important to consider the value of peat structure for carbon storage and its structural role in groundwater storage and outflow, and how compacting or excavating management techniques can affect site hydrology and native diversity. Management of invasives is important, but the underlying processes that affect the invasives and site biodiversity sensitivity to treatments, are contributing factors to managing wetland health. Heavy wetland impacts and even mowing can increase the rate of evapotranspiration and change the soil structure that maintains highly saturated and cooling groundwater. Seasonality, frequency, and intensity of grazing management, shapes substrate and native vegetation condition and structure. Woody shrub invasion, both native and non-native tamarisk invasion are known to invade plains fens and wet meadows. Some springs and areas with high groundwater discharge such as quaking mounds can provide conditions that restrict invasion of non-fen species. For those areas, exclosures and efforts to preserve the natural hydrology may be necessary. Even so, more study may be needed on optimal disturbance levels and if that can be met by exclosures, as in the plains even GDEs experienced some natural disturbance. For example, an exclosure at a Boulder County site had more shrubs and fewer GDE species, but supported higher site diversity. Introducing disturbance ecology to a site, such as prescribed fire, can be higher risk, but management that considers historical processes can support native biodiversity.

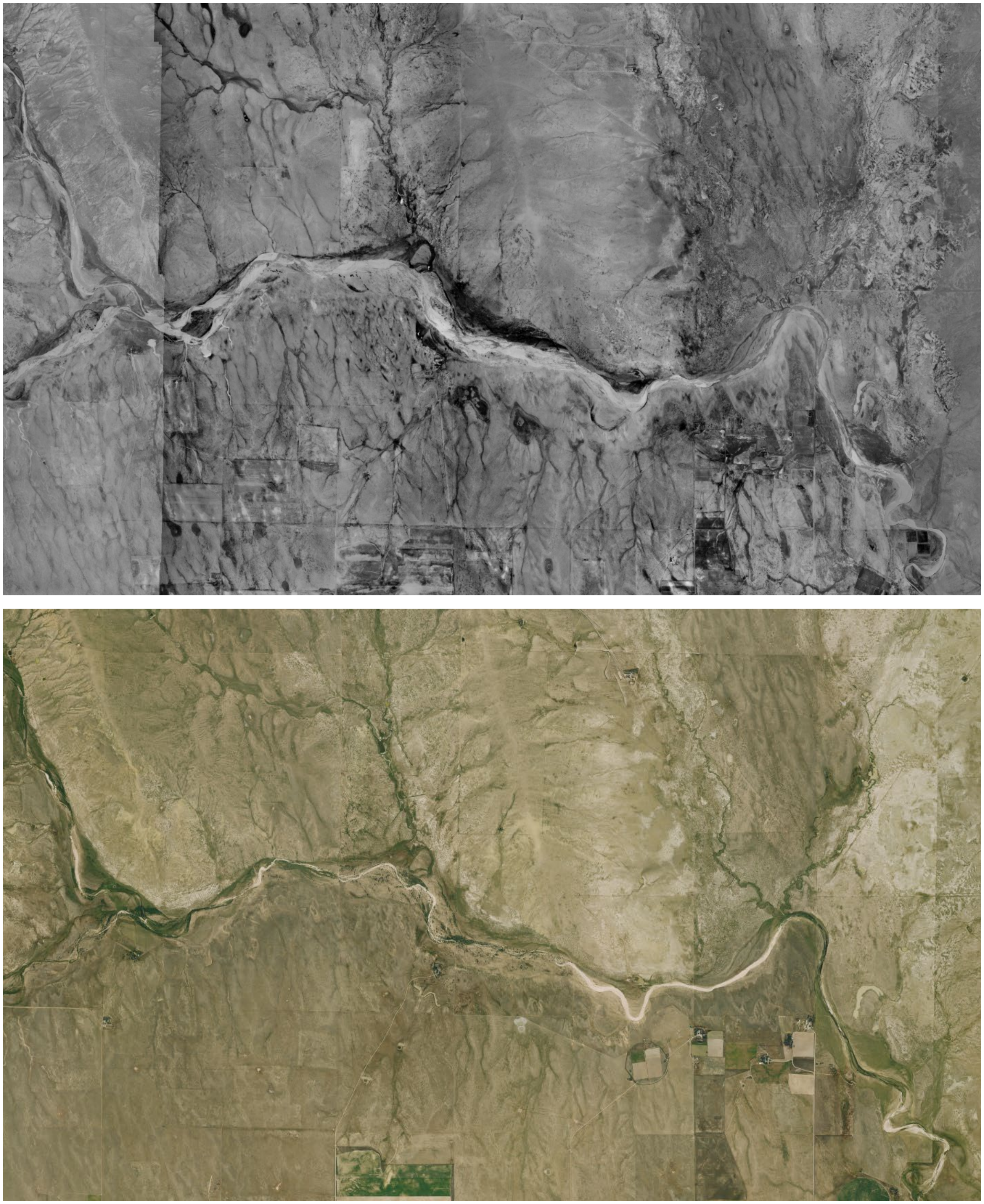

Figure 46. Comparison of Plains Groundwater-Dependent wetland drainage network around Rush Creek Floodplain from 1956 (top) to 2023 (bottom, Historical Aerials Viewer).

Human Dimensions

Many of the obligate plains GDEs are in large open landscapes managed for multiple uses such as ranching or wildlife and recreation use. Plains GDEs often face multiple sustainability challenges: pumping and water consumption that depletes accessible groundwater from basins and alluvial resources, management to create ponds at the expense of the surrounding wetland complex connectivity, and limited funding for ecological stewardship in rural working lands, and pressure to use the open space or GDE wetland water for other uses. Working landscapes often face significant time and financial constraints in maintaining the ecological health of sensitive wetlands, especially in the wettest rangeland, or in areas used for wildlife recreation. The overall good to fair condition of the surveyed wetlands indicates functioning plains GDE wetlands, but loss is ongoing.

Conversations with site managers and ranchers revealed a common pattern that lands with GDEs face increasing pressure from water demand and land use, threatening wetland health. There is an urgent need to inventory high quality and imperiled plains wetlands, including rare and sensitive wetland types and their contributing watershed areas. Since these surveys, several sites have already experienced significant wetland pressures: a beaver dam removal altered hydrology in a wetland with pools used by leopard frogs; groundwater loss from an adjacent landowner's pumping visibly altered a rare flooded wet prairie–wooded swamp and increased weed cover; a leased site rich with fen wetlands was re-leased to new rancher for a higher price, risking setback of 25+ years of ecologically-minded rancher site-based knowledge to a lower cost that could intensify grazing; and a site with *Eleocharis rostellata* peatland seeps and newly documented-to-Colorado plant species has wetland and its contributing watershed connectivity threatened by development pressure for energy and water conveyance corridors.

Unmapped or poorly understood GDE wetlands, particularly saturated organic soil types, are vulnerable even under well-meaning management. At one site, organic soil wetland fringe was observed being excavated for pond maintenance or restoration and willows were planted that would not likely be at that wet meadow-marsh. Other sites have had excavation of peat for restoration of groundwater flow areas in sloughs, but declining water tables add complexity to sites with organic soil, such as an organic soil site in the plots analysis from Goodale Slough where the peat was drying (Figure 47). While enhancement projects can benefit both wildlife and recreation, peat and muck wetlands and soils that may support both rare biodiversity and long-term carbon storage need inventory prior to groundwork and planning to ensure the project goal incorporates the rarity of the site conditions.

None of these impacted wetlands were accurately mapped by NWI, and the most sensitive wetland areas at these sites were not mapped. Groundwater-dependent wetlands are among the most biodiverse ecosystems in the Colorado plains and inventory is investment in data support for water resource conservation.

Figure 47. Photos counterclockwise from top left of a drying peat soil core from an outer floodplain slough in eastern Colorado, showing its landscape position (red dot) in the outer historical floodplain at a slope break, and an overview landscape photo with the wet-meadow marsh in the background.

Despite these challenges, many land managers are also using adaptive management strategies, protecting sensitive seeps and wetland hydrology, and using tools like controlled grazing, recreation limits, cattail control, and disturbance-mimicking practices from controlled burning to allowing beaver. Wetlands with rare species and irreplaceable wetland attributes need protection, and GDEs that show signs of increasing uniformity and loss of imperiled biodiversity and hydrology can benefit from targeted and low impact management. As plains GDEs have more spotlight on their biodiversity, reporting on adaptive management techniques and results will help successful management.

5.5 Research Implications

Successful Management of Plains GDE Wetlands Exists

Based on the GDE sites surveyed in this study and their overall good condition, there are examples of many plains landscapes that sustain high quality GDEs, proving that successful management for ecological health and biodiversity is possible, from natural areas to working landscapes. Tailored local inventory and adaptive stewardship is key to understanding local conditions and sensitive wetland features, and how anthropogenic stressors and land management practices can influence conservation of sensitive wetlands, and their features such as organic soils, quaking seeps, and native biodiversity habitat needs.

Protect and Conserve Irreplaceable GDE Wetlands

Plains GDEs are old (Harvey et al. 2007a, Harvey et al. 2007b, Gilmore and Sullivan 2010), they are biodiversity hotspots, they support rare species and their habitat, they require groundwater sources to be able to seep and flow into their wetland, and many have irreplaceable ecosystem characteristics. A proactive investment in maintenance of healthy wetlands where there are GDEs is more likely to achieve GDE conservation success than trying to restore degraded or lost ecosystem features once the organic soils, water sources, or native biodiversity is lost. Sharing successful management techniques of plains GDEs across landscapes and valuing their conservation stewardship in the recreation and ranching landscapes is also needed.

Groundwater-dependent wetlands are a critical part of a drainage network that sources, buffers, and maintains watershed hydrology. However, historical photo review of landscapes near the GDE AAs suggests they are experiencing ongoing decline, based on review of historical photos near the GDE sites. Some GDE watersheds have rapid rates of new construction and other ground disturbance in the upslope and upstream drainage network, from suburban expansion in the Front Range to extractive or renewable energy road and corridor development in the plains. Even in the absence of direct land conversion, human intensive use, or water withdrawals, there is uncertainty about the risk of GDE loss under a hotter, drier climate with more frequent drought. GDE watersheds also need protection, as development and fill remove and obstruct the wetland water source and drainage network. Conserving landscape integrity helps create a buffer in both time and space against the many stressors that can negatively affect wetland conditions. At a minimum, seepage zones, springs, and groundwater emergence areas within baseflow-dominated streams need mapping and protection, along with adequate buffer zones for their sustainability.

Sensitive Organic and Muck Soil Substrates

Most plains GDEs have some organic soil content. More research is needed on Colorado plains GDE soil age, formation, organic content, and distribution to best manage this important carbon and biodiversity habitat resource. However, organic soils in Colorado have been shown to be slow-to-accumulate, to be old, and often small resources such as deep peat pockets in Chico basin (Gilmore and Sullivan 2010). A study aging karst fens in Missouri averaged 1,300 years old and up to >6,000 years (including soil profiles with <40 cm peat); with shallower organic soil layers >10 cm also pre-dating hydrologic management (MPF 2024). Many of the surveyed sites have signs of stress to their organic soil by compaction, erosion and disturbance that separate soil clods causing them to dry and disappear, mixing mineral soil with organic and transforming the soil hydrology, and converting areas of the wetland to surface water. Some sites had such severe soil disturbance from grazing that instead of organic hummocks with steeper sides and reduced organic depth hummock interspace,, there were exposed mineral soils well below the height of the organic soil zone, and some sites also had clods of dried organic soils in areas of transition from organic to mineral, showing active and continued organic soil loss (Figure 48). There appears to be a trend of wetland loss where very saturated organic soils are too fragile to withstand certain grazing management regimes, or where grazing occurs in the most sensitive substrate types. Organic soils also can experience loss from natural disturbance, and supporting their health from moisture, vegetation, and bulk density can help site hydrologic resilience to disturbance.

Figure 48. Photos of a site with active major organic soil loss from overgrazing, showing deep erosion, soil compaction, and organic loss, with a clod of detached peat.

Grazing can be beneficial in some types of wetlands and can hold back cattail invasion, such as in a surveyed Boulder County GDE plot with wet meadow in good condition on one side of a grazed fenceline and dense cattail in the ungrazed side (Figure 49). The challenge is implementing stocking densities and rotation that optimize desired biodiversity and health, exclusion of grazing from sensitive substrates that will be affected to the point of organic soil loss and wetland transformation, and proper timing and seasonality where the grazing will have a minimized effect on desirable vegetation. More research on the benefits and disadvantages of grazing, specifically on eastern Colorado GDE health and biodiversity is needed.

Figure 49. Grazed wet meadow on left versus ungrazed side with cattail dominance on right. (Photo credit: Boulder County).

Research CO Plains GDE Wetlands

This study uncovered many examples of the important biodiversity that plains GDE wetlands support, identifying their unique conservation value in comparison to the more researched non-obligate GDE and surface-water wetland types in the Colorado plains. Plains GDEs have more organic soil content and unique-to-the-plains species and communities, but they are often managed similarly to these more common wetland types. The state of research on GDE hydrology dynamics, water sources, wetland age, and characteristics and biota of groundwater-dependent wetlands is more comprehensive in higher elevations of Colorado and in the Midwest. This study focused primarily on vegetation biodiversity and secondarily on GDE wetland characteristics, condition, and wildlife biodiversity. However, the larger scale hydrology, geology, soil and GDE wetland formation processes contribute shaping roles that created and maintain these plains GDEs. Three new-to-Colorado species were reported in these 51 surveys, and many observed species expanded the understanding of GDE types, distribution, degree of imperilment, and habitat health. The highest needs are GDE mapping of high confidence GDE areas and site locations of imperiled groundwater-dependent biodiversity. In addition, the Colorado plains remain a location of primary scientific biodiversity discoveries, and more species inventory and research on regional ecological processes is needed to form a comprehensive baseline understanding of eastern Colorado plains wetlands.

Focus Management on Conservation of GDE Biodiversity and Hydrologic Function

Regional condition assessment methods such as the EIA wetland rate wetlands with the least anthropogenic alteration as in good condition. However, in the plains, there are few watersheds without major hydrologic change, and groundwater effects can be both localized and regional (Wohl 2013), so GDE complexes along a drainage network can have upstream withdrawals and impoundments, and downstream seepage addition that maintains compensatory wetland hydrology. The hydrologic alterations that collect and move water to a desired location via ditches or reservoirs, also remove and interrupt surface and groundwater movement into native GDE wetlands. Hydrologic alteration is so extensive and layered in the Front Range and plains that assessment of the role of flood irrigation or irrigation seepage towards wetland health is difficult to detect visually, and data on field interpretation of wetland origin has varied from historical aerial imagery. Thus, targeting preservation of GDE wetlands by whether they are deemed to be native versus irrigation-influenced, may target a drier suite of GDE wetlands and only a portion of the good-quality plains GDE population. Some ditch or canal hydrological inputs are needed to return and sustain wetland flow where hydrology is altered, and some sites with managed water from flood irrigation to ditch seepage along historical intermittent drainages support high quality biodiversity. A focus on biotic integrity and hydrologic function may help conserve the highest functional GDEs.

The plains have ever-changing and cumulative water and land use histories. Nearly a century has passed since the intensive transformative land use impacts of the dust bowl to energy development and intensive grazing impacts of today. This history paired with the current state of no-analog and nonequilibrium ecosystem theory, in the unknown future of climate change, do not lend practicality of restoration to a pre-Euro-American settlement condition of reference GDE wetlands. Rather, identification and preservation of native ecosystems and obligate GDE wetlands as potential remnant biodiversity refugia, and dedicated efforts to identifying habitat locations of GDE-dependent species; together with consideration of any anthropogenic roles needed in maintaining water sources and wetland processes, may align more with long-term GDE wetland sustainability in changing plains landscapes. Research from other montane and Midwest regions and from Chico Basin point to that many of these sensitive and irreplaceable ecosystems were here before the intensive human-use time scale. As such, careful management changes only when needed, together with monitoring and continued adaptive management are less risky. Organic soils are old, sensitive, and are increasingly rare in the plains, and some of these habitats on trajectories of degradation need management change and others are the last of their region. Some GDE habitats are known habitat biodiversity refugia - such as calcareous wetlands, fens, and natural groundwater-maintained springs and riparian pools, and others are less-known such as organic soil cattail wetlands or high salinity depressional playa wetlands, native stretches of woody plains riparian streams, and woody swamps. Many of these are deserving of floristic and biodiversity studies in the Front Range prairie and eastern Colorado to better understand the spectacular diversity and ecological importance of plains groundwater-dependent wetlands. Finally, a site-specific management approach might create better management success than a one size-fits-all in these diverse landscapes that support GDEs.

This study provides a baseline regional inventory that can be used to guide more mapping and ecosystem-specific research on plains GDE ecosystem needs, and to describe Colorado eastern plains GDEs biodiversity and habitats that serve as at-risk species refugia and potentially remnant ecosystems. Managing landscapes with GDEs for ecological health and hydrologic sustainability, together with monitoring and adaptive management, will help support the long-term persistence of these important eastern Colorado wetland habitats.

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Appendix A: Level 3 EIA Field Form used in GDE Study

QC________

2022 PLAINS GDE WETLAND ASSESSMENT – SITE INFORMATION

LOCATION AND GENERAL INFORMATION

Point Code: ____________________ Site Name: ____ LEVEL 3 ASSESSMENT

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

General Location: ____

General Ownership: _____________________ Specific Ownership: ____

Directions to Point:

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

GPS COORDINATES OF TARGET POINT AND ASSESSMENT AREA

Original Point WP #: ________ Target?: ☐ Yes ☐ No Surveyed?: ☐ Yes ☐ No Cowardin:_________

Dimensions of AA:	
____40 m radius circle ____Rectangle (Dimensions____x____m)	Elevation (m):
____Large area circle *(saline depressions only; up to 2 ha)*	Slope (deg):
____Freeform, document shape and take a GPS Track	Aspect (deg):

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

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

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

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

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

AA-Track Track Name: ____ Area: ____

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

AA Placement Comments:

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

AA-1 Photo #: _____________ Azimuth: _____________

AA-2 Photo #: _____________ Azimuth: _____________

AA-3 Photo #: _____________ Azimuth: _____________

AA-4 Photo #: _____________ Azimuth: _____________

Overview Photo #: ______ Azimuth: _______ WP#: _______

Photo Range:

Other WPs:

Comments:

Point Code__________________ QC_________

ENVIRONMENTAL DESCRIPTION AND CLASSIFICATION OF ASSESSMENT AREA

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

Ecological System Subtype: GDE Type:

Cowardin Classification Fidelity: High Med Low Dominant: Note Codominant(s) if any:	HGM Class: (pick *one*) Fidelity: High Med Low ____Riverine ____Lacustrine Fringe ____Depressional ____ Slope ____ Flats ____ Novel (Irrigation-Fed) Riverine / Slope

RIPARIAN STREAM CLASSIFICATION OF THE ASSESSMENT AREA

Confined vs. Unconfined Valley Setting ______ Confined Valley Setting (valley width < 2x bankfull width) ______ Unconfined Valley Setting (valley width ≥ 2x bankfull width) Stream Flow Duration ______ Perennial ______ Intermittent ______ Ephemeral	Proximity to Channel ______ AA includes the channel and both banks ______ AA is adjacent to or near the channel (< 50 m) and evaluation includes one or both banks ______ AA is > 50 m from the channel and banks were not evaluated Stream Depth at Time of Survey (if evaluated) ______ Wadeable ______ Non-wadeable
Wetland / riparian / upland inclusions: *(should Total to 100%)* _________ % AA with true wetland and/or water _________ % AA with non-wetland riparian area _________ % AA with upland inclusions	Mapping: AA Center Mapped ☐ Yes ☐ No Cowardin ______ *Structure Descriptions: forest/woodland; shrubland; herbaceous; submerged/floating; sparsely vegetated; open water; bare ground/rock, moss.*

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

Zone 1 Cowardin ______ Structure____________ Dom spp: ____ % of AA: _______

Zone 2 Cowardin ______ Structure ___________ Dom spp: ____ % of AA: _______

Zone 3 Cowardin ______ Structure ___________ Dom spp: ____ % of AA: _______

Zone 4 Cowardin ______ Structure ___________ Dom spp: ____ % of AA: _______

Zone 5 Cowardin ______ Structure ___________ Dom spp: ____ % of AA: _______

ENVIRONMENTAL AND CLASSIFICATION COMMENTS

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

GDE INDICATORS

__Shallow surface water (secondary)	__Baseflow woody riparian stream	__GDE Phreatophytes, spp:__________________________
__ Surface saturation in dry period	__Diffuse groundwater discharge	__ Sphagnum __ other moss (____%)
__Organic Sheen	__Seep/spring	__Marl __ Travertine
__Organic Soil Layers (tot ____cm)	__Gaining stream	__Topography: ___slope break ___stratigraphy change
__ Floating or Quaking Substrate	__ Groundwater discharge in stream	__Permanent pools ___Refuge pools
__Muck	__Wetland in localized headwater location	__Other____

ASSESSMENT AREA DRAWING

Add north arrow and approx. scale bar. Document **biotic and abiotic zones** (particularly open water), water source, inflows and outflows, and indicate direction of drainage. Include location of **AA points, soil pits,** and **water chemistry** measurements, and structures in and abutting AA. If appropriate, add a **cross-sectional diagram** and indicate slope of side, and if AA is rectangle, note side lengths and any plots if applicable.

ASSESSMENT AREA DESCRIPTION AND COMMENTS

Site description including of AA wetland, surrounding landscape, and of AA hydrology, soil, vegetation, and GDE indicators.

Point Code__________________ QC_________

LEVEL 3 VEGETATION AND SOIL DATA COLLECTION

VEGETATION PLOT

GPS COORDINATES AND PHOTOS OF VEGETATION PLOT (Taken at SE-most corner of each vegetation plot.)

Plot 1 WP #: __________ Photo #: _____________ Aspect: _____________ Plot 2 WP #: __________ Photo #: _____________ Aspect: _____________ Plot 3 WP #: __________ Photo #: _____________ Aspect: _____________ Plot 4 WP #: __________ Photo #: _____________ Aspect: _____________ Plot 5 WP #: __________ Photo #: _____________ Aspect: _____________	Comments:

LAYOUT OF VEGETATION PLOT (See reference card for more details. Include vegetation plot on site sketch.)

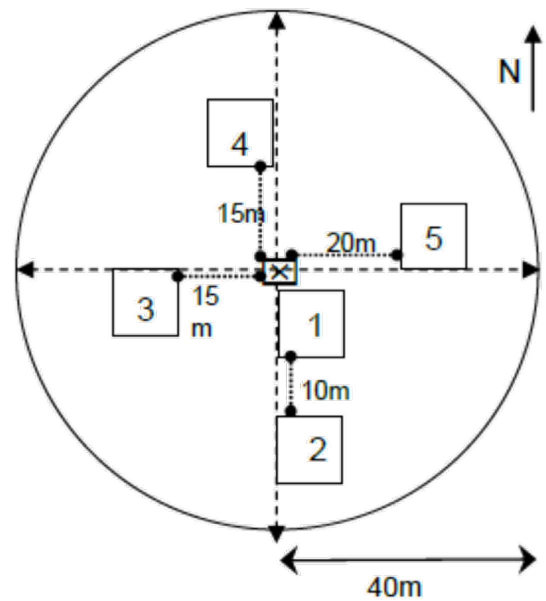
____ Standard Layout (see figure to right)

____ Wide Polygon Layout (plots on two axes)

____ Narrow Polygon Layout (plots on one axis)

____ Partial Boundary AA (plots distributed)

____ Wetland Boundary AA (plots distributed)



Plot Layout Comments (note which plot is treated as residual):

Alternative Layout Veg Plots:

VEGETATION PLOT REPRESENTATIVENESS

Are veg plots representative of AA? ☐ Yes ☐ No

Comments:

Point Code__________________ QC_________

2022 PLAINS GDE WETLAND ASSESSMENT – VEGETATION, SOILS, BASIC WATER CHEMISTRY

VEGETATION PLOT SPECIES TABLE													
Plot →												**R**	
Presence / Cover →				**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%													
Scientific Name or Pseudonym **(If repeated/common pseudonym, mark with *)**	**Coll #**	**Press (√)**	**Photos and Notes**										

Point Code__________________ QC_________

VEGETATION PLOT SPECIES TABLE													
Plot →												**R**	
Presence / Cover →				**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**	**P**	**C**
Cover Classes 1: trace **2:** <1% **3:** 1–<2% **4:** 2–<5% **5:** 5–<10% **6:** 10–<25% **7:** 25–<50% **8:** 50–<75% **9:** 75–<95% **10:** >95%													
Scientific Name or Pseudonym (If repeated/common pseudonym, mark with *)	**Coll #**	**Press (√)**	**Photos and Notes**										

Point Code__________________ QC_________

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

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

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

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

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

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

If representative pit:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

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

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

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

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

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

Comments:

Other Pits: WP/Photo/Profile:

Major Soil Type:
____Histosol
____Histic Epipedon
____Clayey/Loamy
____Sandy

BASIC WATER CHEMISTRY - PH, EC, AND TEMPERATE MEASUREMENTS

☐ **No water observed**

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

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

Water chemistry measurement comments:

Weather. Current Conditions (temp/clarity/precip):

Recent (last 3 days) Precipitation:

INVERTEBRATES

Take sweep location details. If different than water location above, note pH, EC, temp, turbid, open/shade. Take GPS Waypoints at each location. Habitat is wet meadow, marsh, pool, seep, spring, stream, shrub, wooded/forested, or impoundment.

Sweep #	GPS WP#	Dom. Depth	Max Depth	Sample Wetland Habitat	Biofilm	Fila-mentous	Bloom	Dominant Veg, %	Notes (plus pH, above metrics, etc. if different)

Samples___. Invertebrate Comments:

Point Code__________________ QC_________

2022 PLAINS GDE WETLAND ASSESSMENT – HABITAT AND STRUCTURE

HABITAT SCORECARD FOR LEOPARD FROG DATA WITHIN THE ASSESSMENT AREA (Amphibian Habitat Not Recorded In Saline Depressions)					
CPW Habitats (+visible from aerial in drainage):					
Dominant Habitat Type in AA, %:					
Other Habitat Types, %:					
Breeding Wetlands **emergent marshes, ponds, playas, seeps, springs, MSUs, reservoirs, other impoundments**					
Water availability: Water lasts to depth of > _cm during most years through mid-_	>12.7, Aug	>6.3, Aug	>6.3, July		
Water quality: Visual evidence of turbidity or other pollutants or cloudiness	None	Slightly or local	Cloudy or sheen	Bottom Not Visible	
Canopy cover > 2m (% cover)	0-30	>30-50	>50-100		
Emergent and/or submergent vegetation (% cover)	>50 - 90	>30 - 50	10 - 30		
Height of emergent vegetation (m)	0.2 - 1	1 - 2	>2		
Distance to good over-wintering habitat (km)	<0.8	0.8 - 1.6	1.6 – 2.4		
Distance to good foraging habitat (km)	<0.8	0.8 - 1.6	1.6 – 2.4		
Foraging Wetlands **wet meadows, emergent marshes, small streams, shallow areas of other wetlands**					
Height of herbaceous cover (m)	0.05-0.5	0.5 – 1	1 - 2		
Predominant depth of water	Moist soil - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.64	0.64 - 1.0
Distance to good breeding habitat (km)	<0.8	0.8 - 1.6	1.6 – 2.4		
Herbaceous cover in wet meadows (only this or below, best option), (% cover)	>80	60 - 80	40 - 60		
Herbaceous cover in other wetlands (only this or above), (% cover)	25 – 50	50 – 75	<25 or >75		
Overwintering Wetlands **oxbows, deep ponds and emergent wetlands, stream channels, warm water sloughs, gravel pits, and reservoirs**					
Freezing potential	25 – 50	50 – 75	<25 or >75		
% Submergent vegetation	25 – 50	50 – 75	<25 or >75		
->Herbaceous cover in other wetlands (only pick this or above) (% cover)	25 – 50	50 – 75	<25 or >75		
Presence of predatory fish, salamanders, and bullfrogs (Y/N)					
Occurrence of deformed frogs (Y/N)					
Occurrence of dead frogs (Y/N)					

VERTICAL STRATA BY HABITAT TYPE **PLOT**										
Estimate cover of each vertical strata by habitat type. Estimate height using classes. Estimate cover base on 1% or 5% increments (not classes).										
Height Classes 0: <0.2 m **1:** 0.2–0.5 m **2:** 0.5–1m **3:** 1–2 m **4:** 2–5 m **5:** 5–10 m **6:** 10–15 m **7:** 15–20 m **8:** 20–35 m **9:** 35–50 m **10:** >50 m										
Vertical Vegetation Strata (live or very recently dead) **Height / Cover →**	**H**	**C**	**H**	**C**	**H**	**C**	**H**	**C**	**H**	**C**
(T1) Dominant canopy trees (>5 m and >~ 30% cover)										
(T2) Sub-canopy trees (> 5m but < dominant canopy height) or trees with sparse cover										
(S1) Tall shrubs, tree saplings or seedling (>2 m)										
(S2) Short shrubs (<2 m)										
(HT) Herbaceous total										
(H1) Graminoids (grass and grass-like plants)										
(H2) Forbs (all non-graminoids)										
(AQ) Submergent or floating aquatics										

GROUND COVER					
Estimate cover of each ground cover by habitat type. Estimate cover based on 1% or 5% increments (not cover classes).					
PLOT, Cover (unless otherwise noted) →					
Actual cover of water (any depth, vegetated or not, standing or flowing) (A+B+C below)					
Actual cover of open water zone and no vegetation (or only algae) (A)					
Actual cover of water zone with emergent vegetation (B)					
Actual cover of water zone with submergent / floating vegetation (C)					
Actual predominant depth of water (cm)					
Actual max depth of water (cm)					
Potential cover of low gradient open habitat for shallow water (<10 cm)					
Potential cover of water at ordinary high water					
Potential predominant depth at ordinary high water (cm)					
Stability of water level (*Pick one:* A: permanent and stable / B: permanent but fluctuates / C: intermittent or ephemeral)					
Cover of exposed bare ground (any substrate, can have algae cover)					
Predominant substrate texture (*Pick one:* organic / silt / clay / sand / soft mud / muddy sand / gravel / cobble / pebble / boulders / bedrock / rip-rap / concrete)					
Cover of litter (all cover, including under water or vegetation)					
Depth of litter (cm) – average of four non-trampled locations where litter occurs					
Count of standing dead trees (>25 cm diameter at breast height)					
Cover of standing dead shrubs or small trees (<25 cm diameter at breast height)					
Cover of downed coarse woody debris (fallen trees, rotting logs, >25 cm diameter)					
Cover of downed fine woody debris (<25 cm diameter)					
Cover bryophytes (all cover, including under water, vegetation or litter cover)					
Cover lichens (all cover, including under water, vegetation or litter cover)					
Cover algae (all cover, including under water, vegetation or litter cover)					
Cover of sedges (*Carex* spp.)					
Cover of duck food species (High/Med/Low): AA-scale	H:		M:		L:

INCIDENTAL WILDLIFE SPECIES OBSERVATIONS			
Include photo #'s, GPS if applicable, and for birds, if overhead or on vegetation/substrate.			
WP #	**Species, Photo, Detail**	**WP #**	**Species, Photo, Detail**

STRESSORS

Using the table below, estimate the scope of each **landscape stressor within the 500 m envelopes** surrounding the AA. Stressors can overlap and do not need to total 100%. Base on visible evidence, or management. Consider cover, location, and intensity of stressor in health impact rating to watershed or wetland. ***Wetland Health Impact: 1 = slight, 2 = moderate, 3 = major, 4 = serious.*** Include photo numbers in notes. Cover classes 1-10%,>10-30%, >30-70%, >70% can inform impact ratings of non-point stressors.

Landscape stressor	**In Wetland**	**500m Impact**	**Notes**
Development: Paved roads, parking lots, railroad tracks, buildings, concrete			
Development: Unpaved roads (e.g., driveway, tractor trail, 4wd)			
Development: Urban - Parks, Sport Fields, Lawns, Golf Courses			
Resource extraction: Active gravel pit operation, mining, mines			
Resource extraction: Oil and gas wells and surrounding footprint			
Resource extraction: Power lines and/or other utility lines			
Resource extraction: Logging			
Agriculture: Tilled crop production (sometimes duck food plots)			
Agriculture: Permanent crop (vineyard, orchard, tree plantation)			
Agriculture: Hay fields, haying of native or non-native grasses			
Recreation: Active -ATV use / camping / popular fishing spot, etc.			
Recreation: Passive - hiking trail, birding, low-use fishing			
Vegetation: Light Grazing by livestock__ or native ungulates__			
Vegetation: Moderate to Heavy Grazing by livestock__ or native ungulates__			
Vegetation: Browse: by livestock__ or native ungulates__			
Vegetation: Invasive non-native species dominant in fallow land			
Vegetation: Evidence of recent fire (<5 years old, visible impact)			
Vegetation: Insect infestation (pine beetle, spruce bud worm)			
Vegetation: Planted			
Vegetation: Probable or known herbicide use			
Vegetation: Prairie dog colony			
Hydrology: Dam / reservoir			
Hydrology: Stock ponds			
Hydrology: Gravel ponds – reclaimed or not			
Hydrology: Spring box			
Hydrology: Wells in the surrounding area (including cattle wells)			
Hydrology: Pumps, ditches that move water *out of* wetland/source			
Hydrology: Pumps, ditches that move water *into* the wetland			
Hydrology: Ditches that move water *through* the wetland			
Hydrology: Berms, dikes, levees that hold water in the wetland			
Hydrology: Roads without culvert or other flow obstructions			
Hydrology: Weir or drop structure: impounds and controls flow			
Hydrology: Dredged inlet or outlet channel			
Hydrology: Engineered channel (e.g., riprap on banks, outlet, inlet)			
Hydrology/Physiochemical: Observed or potential agricultural runoff			
Hydrology/Physiochemical: Observed or potential urban runoff or chemicals			

STRESSORS

Landscape Stressors, Continued. Using the table below, estimate the scope of each **landscape stressor within the 500 m envelopes** surrounding the AA. ***Wetland Health Impact: 1 = slight, 2 = moderate, 3 = major, 4 = serious.*** Include photo numbers in notes.

Landscape stressor	In Wetland	500m Impact	Notes
Hydrology/Physiochemical: Point source pollutants and discharges (treatment water, non-storm discharge, factories)			
Hydrology/Physiochemical: Stormwater discharge			
Physiochemical: Construction			
Physiochemical: Erosion			
Physiochemical: Sedimentation			
Physiochemical: Localized fill (pipelines, powerlines, trails, soil)			
Physiochemical: Current plowing or disking			
Physiochemical: Historic plowing or disking (evident by abrupt A horizon boundary at plow depth)			
Physiochemical: Substrate removal (excavation, non-construction)			
Physiochemical: Trash or refuse dumping			
Physiochemical: Compaction and soil disturbance by livestock or native ungulates			
Physiochemical: Compaction and soil disturbance by human use (trails, ORV use, camping)			
Physiochemical: Historic mining activities			
Physiochemical: Discharge or runoff from feedlots			
Physiochemical: Excess salinity (salt encrustations, plant stress from salts. If high salinity but appears healthy, note w/o rating as stress)			
Other:			
Other:			
Comments:			

2015 PLAINS GDE WETLAND ECOLOGICAL INTEGRITY ASSESSMENT (EIA) – METRICS

LANDSCAPE METRICS

L1A. CONTIGUOUS NATURAL LAND COVER		**L2. LAND USE INDEX**	
Select the statement that best describes the **contiguous natural land cover** within the 500 m envelope surrounding the AA. See list of natural land covers in the field manual.		Select the statement that best describes the intensity of surrounding land use. Use the **Land Use Index** Worksheet (last page) to calculate the Land Use Index score.	
Intact: AA embedded in 90–100% contiguous natural land cover.	**A**	Land Use Index = 9.5–10.0	**A**
Variegated: AA embedded in 60–90% contiguous natural land cover.	**B**	Land Use Index = 8.0–9.4	**B**
Fragmented: AA embedded in 20–60% contiguous natural land cover.	**C**	Land Use Index = 4.0–7.9	**C**
Relictual: AA embedded within <20% contiguous natural land cover.	**D**	Land Use Index = <4.0	**D**

L1B. RIPARIAN CORRIDOR CONTINUITY *(RIPARIAN WETLANDS ONLY) OR CONTRIBUTING WATERSHED CONNECTIVITY (NON-RIPARIAN)*			
For riverine wetlands, select the statement that best describes the **riparian corridor continuity** within 500 m upstream and downstream of the AA. To determine, identify any fragmentation within the potential upstream riparian corridor (natural geomorphic floodplain); focusing half on 500m upstream, and half on upstream up to 2km. Estimate the percentage of the riparian corridor non-fragmented. *For non-riparian wetlands,* do this exercise upslope of wetland to topographic peak (shift downslope) or above areas.		Intact: >95–100% natural habitat within the riparian corridor both upstream and outside envelope or upslope	**A**
		Variegated: >80–95% natural within the riparian corridor both upstream and outside envelope or upslope	**B**
		Fragmented: >50–80% natural habitat within the riparian corridor both upstream and outside envelope or upslope	**C**
		Relictual: ≤50% natural habitat within the riparian corridor both upstream and outside envelope or upslope	**D**

Landscape comments:

BUFFER METRICS

B1. PERIMETER WITH NATURAL BUFFER		**B2. WIDTH OF NATURAL BUFFER**	
Select the statement that best describes the **perimeter of the AA with natural buffer**. Buffer land covers must be ≥ 5 m wide and extend along ≥ 10 m of the AA perimeter. See list of buffer land covers in the field manual.		Select the statement that best describes the **width of the natural buffer**. Estimate the width of buffer land covers along eight lines radiating out from the AA at the cardinal and ordinal directions (N, NE, E, SE, S, SW, W, NW) and average their width. Estimate up to 100 m.	
Natural buffer surrounds 100% of the AA perimeter.	**A**	Average buffer width is 100 m	**A**
Natural buffer surrounds 75–99% of the AA perimeter.	**B**	Average buffer width is 75–99 m	**B**
Natural buffer surrounds 25–74% of the AA perimeter.	**C**	Average buffer width is 25–74 m	**C**
Natural buffer surrounds <25% of the AA perimeter.	**D**	Average buffer width is <25 m	**D**

B3. CONDITION OF NATURAL BUFFER			
Select the statement that best describes the **natural buffer condition**. Select one statement per column. Only consider <u>the actual natural buffer</u> measured in metrics above. *Remember to look for **non-native hay grasses** when evaluating native / non-native vegetation in the buffer.*			
Abundant (≥95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.	**A**	Intact soils, no water quality concerns, little or no trash, AND little or no evidence of human visitation.	**A**
Substantial (75–95%) relative cover of native vegetation and low (5–25%) cover of non-native plants.	**B**	Intact or minor soil disruption, minor water quality concerns, moderate or lesser amounts of trash, AND/OR minor intensity of human visitation or recreation.	**B**

Low (25–75%) relative cover of native vegetation and moderate to substantial (25–75%) cover of non-native plants.	**C**	Moderate or extensive soil disruption, moderate to strong water quality concerns, moderate or greater amounts of trash, AND/OR moderate intensity of human use.	**C**
Very low (<25%) relative cover of native vegetation and dominant (>75% cover) of non-native plants OR no buffer exists.	**D**	Barren ground and highly compacted or otherwise disrupted soils, significant water quality concerns, substantial amounts of trash, extensive human use, OR no buffer exists.	**D**

Buffer comments:

VEGETATION COMPOSITION METRICS

V1. NATIVE PLANT SPECIES COVER (RELATIVE)		**V2. INVASIVE NONNATIVE PLANT SPECIES COVER (ABSOLUTE)**	
Select the statement that best describes the <u>relative cover</u> of **native plant species** within the AA.		Select the statement that best describes the <u>absolute cover</u> of **invasive nonnative plant species** within the AA. Use list provided in the manual.	
AA contains >99% relative cover of native plant species.	**A**	Invasive nonnative species are absent from all strata.	**A**
AA contains 95–99% relative cover of native plant species.	**B**	Invasive species present, but sporadic (<4% absolute cover).	**B**
AA contains 85–95% relative cover of native plant species.	**C**	Noxious weeds somewhat abundant (4–10% cover).	**C**
AA contains 60–85% relative cover of native plant species.	**C-**	Noxious weeds abundant (10–30% cover).	**C-**
AA contains <60% relative cover of native plant species.	**D**	Noxious weed very abundant (>30% cover).	**D**

V3. NATIVE PLANT SPECIES COMPOSITION

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

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

Vegetation composition comments:

VEGETATION STRUCTURE METRICS

V4. VEGETATION STRUCTURE (VERTICAL AND HORIZONTAL)

Select the statement below that best describes the **overall vertical and horizontal structure** within the AA. Rate structure on the complexity of biotic and abiotic patches within the wetland/riparian area, based on the expected conditions within its wetland type. For woody systems, also consider regeneration/coarse and fine WD ratings in the overall assessment of structure.

Point Code__________________ QC_________

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

V5. REGENERATION OF NATIVE WOODY SPECIES		V6. COARSE AND FINE WOODY DEBRIS	
Select the statement that best describes the **regeneration of native woody species** within the AA.		Select the statement that best describes **coarse and fine woody debris** within the AA.	
Woody species are naturally uncommon or absent.	**NA**	There are no obvious inputs of woody debris or woody species are naturally uncommon.	**NA**
All age classes of *native* woody species present. Native tree saplings /seedlings and shrubs common to the type present in expected amounts and diversity and regeneration.	**A**	AA characterized by moderate amount of coarse and fine woody debris, relative to expected conditions. Wide size- and decay- class diversity of standing snags and downed logs. For riverine wetlands, debris is sufficient to trap sediment, but does not inhibit stream flow. For non-riverine wetlands, woody debris provides complexity, but is not overwhelming.	**A/B**
Age classes of *native* woody species restricted to mature individuals and young sprouts. Middle age groups appear to be absent or some indication that regeneration is impacted.	**B**		
Native woody species comprised of mainly mature individuals OR mainly evenly aged young sprouts that choke out other vegetation. Regeneration is obviously impacted. Site may contain Russian Olive and/or Salt Cedar.	**C**	AA characterized by small amounts of woody debris OR debris is somewhat excessive. For riverine wetlands, lack of debris may affect stream temperatures and reduce available habitat.	**C**
Native woody species predominantly consist of decadent or dying individuals OR are absent from an area that should be wooded. Site may be dominated by Russian Olive / Salt Cedar.	**D**	AA lacks woody debris, even though inputs are available.	**D**

Vegetation structure comments (including regeneration and woody debris):

HYDROLOGY METRICS

H1. WATER SOURCE

Check off all *major* water sources in the table to the right. Select the statement below that best describes the **water sources** feeding the AA during the growing season.	_____ Overbank flooding _____ Alluvial aquifer _____ Groundwater discharge _____ Natural surface flow _____ Precipitation _____ Snowmelt	_____ Irrigation via direct application _____ Irrigation via seepage _____ Irrigation via tail water run-off _____ Urban run-off / culverts _____ Pipes (directly feeding wetland) _____ Other:

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

Water source comments:
Are there signs of drying: Y / N? Describe:

H2. HYDROPERIOD

Select the statement below that best describes the **hydroperiod** within the AA (extent and duration of inundation and/or saturation). Search the AA and 500 m envelope for hydrologic stressors (see list on following pages). Use best professional judgment to determine the overall condition of the hydroperiod. For some wetlands, this may mean that water is being channelized or diverted away from the wetland. For others, water may be concentrated or increased. <u>*Please add comments on next page.*</u>

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

Hydroperiod comments:

H3. HYDROLOGIC CONNECTIVITY

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

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

Hydrologic connectivity comments:

Are there differences in connectivity between AA edge and wetland edge? Detail score and why if would score differently at wetland scale:

PHYSIOCHEMICAL METRICS

S1. SUBSTRATE / SOIL DISTURBANCE

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

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

Substrate / soil comments and photo #'s:

S2. SURFACE WATER TURBIDITY / POLLUTANTS		**S3. ALGAL GROWTH**	
Select the statement that best describes the **turbidity or evidence or pollutants** in surface water within the AA.		Select the statement that best describes **algal growth** within surface water in the AA. Exclude *Chara* (multicellular algae) in cover estimate.	
No open water in AA	**NA**	No open water in AA or evidence of open water.	**NA**
No visual evidence of turbidity or other pollutants.	**A**	Water is clear with minimal algal growth.	**A**
Some turbidity in water (such as turbidity caused by high flows or naturally occurring in playas) OR presence of other pollutants, but limited to small and localized areas within the wetland. Water may be slightly cloudy.	**B**	Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	**B**
Water is cloudy or has unnatural oil sheen, but the bottom is still visible. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	**C**	Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen.	**C**
Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. *Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.*	**D**	Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see.	**D**

Water quality comments and photo #'s:

Turbidity and algal growth may be natural depending on recent weather patterns and flow timing (i.e., higher flows are often more turbid). Please rank the system as you see it, regardless of whether the conditions are natural. Include good notes and take photos.

Land Use Categories[1]	***Coefficient***	***500 m Envelope***	
		% Area	***Score***
Paved roads, parking lots, domestic, commercial, and industrial buildings	0		
Gravel pit operation, open pit mining, strip mining, abandoned mines	0		
Unpaved roads (e.g., driveway, tractor trail, 4-wheel drive roads)	1		
Resource extraction (oil and gas)	1		
Tilled agricultural crop production (corn, wheat, soy, etc.)	2		
Intensively managed golf courses, sports fields, lawns	2		
Vegetation conversion (chaining, cabling, rotochopping, clearcut)	3		
Heavy grazing by livestock	3		
Logging or tree removal with 50-75% of large trees removed	4		
Intense recreation (ATV use / camping / popular fishing spot, etc.)	4		
Permanent crop agriculture (hay pasture, vineyard, orchard)	4		
Dam sites and disturbed shorelines around water storage reservoirs. Include open water of reservoir is there is intensive recreation, such as boating.	5		
Old fields and other disturbed fallow lands dominated by non-native species	5		
Moderate grazing on rangeland	6		
Moderate recreation (high-use trail)	7		
Selective logging or tree removal with <50% of large trees	8		
Light grazing on rangeland	9		
Light recreation (low-use trail)	9		
Natural area / land managed for native vegetation	10		
Total Land Use Score			

APPENDIX B: MACROINVERTEBRATE SAMPLING

Methods

Benthic macroinvertebrate sweeps were used to sample macroinvertebrates in this study's groundwater-dependent wetland (GDE) sites, to build baseline datasets on macroinvertebrate diversity and composition in vegetated plains groundwater-dependent wetlands. In comparison with much of the United States, there are fewer data points in eastern Colorado in the National Aquatic Monitoring Center's (NAMC) macroinvertebrate data map (NAMC 2025). Sweep sites in this study include a corresponding wetland Ecological Integrity Assessment rating. The condition and taxa data from these sweeps can be used as part of a baseline dataset to develop Colorado plains vegetated wetland macroinvertebrate water quality indicators, including in plains GDEs. Funding for these invertebrate data collection and analysis is from Wild Earth Guardians.

Sweep Sites

Twenty-one groundwater sweep samples were collected and analyzed for macroinvertebrate taxa in sixteen different wetland sites surveyed in this GDE study. The study's invertebrate sweep sites were from the thirteen Level 3 EIA AAs, plus the 3 pilot sites that were surveyed with Level 2 EIA. Four pilot sites with data collection from both 2021-2022 were sampled two separate times, once each survey year. One of these four resamples was damaged so only three pilot sites were analyzed with resamples: a fen in the South Platte River basin, a wet meadow in the Lower Arkansas River basin, and a woody plains riparian site in the Republican River basin. Two additional impounded ponds in riparian areas were also sampled from two of those GDE wetland complexes in different locations and wetland types than the AAs - in deeper and ponded water (estimated > 1m), with the purpose to add to the range of sampled wetland condition at sampled macroinvertebrate sites. These pond samples were also taken from pilot site wetland complexes: from Hugo SWA and from Lowry Ranch on Box Elder Creek, but were not resamples due to being in different locations, despite that the pond samples were taken in 2021 and the AA samples were taken in 2022.

Across all 16 macroinvertebrate wetland sites, there were invertebrate samples collected from:

- 2 fens
- 6 wet meadows (3 herbaceous riparian wet meadows, 3 wet meadows in a slope-seep wetland complex)
- 5 woody riparian/floodplain (2 woody floodplains on the Arikaree River and South Platte Rivers, 2 narrower open woody riparian drainages with herbaceous seeps, and 1 canyon riparian area)
- 3 saline playas
- 2 pond marshes from outside of the AA in impounded herbaceous plains riparian drainages

Invertebrate samples were collected from wetlands that spanned the full range of EIA (Ecological Integrity Assessment) wetland condition: the EIA score from samples in GDE AAs ranged from A to C-, and the ponds sampled outside of the AAs were in low condition. EIA scorecards were not populated for those two pond sites, but at least one wetland would have scored a 'D' condition rank, and the other would have scored a C or D. Overall, there were nineteen invertebrate samples from the surveyed GDE AAs: from thirteen AAs with single-year samples and three AAs with two-sample years, plus the two pond samples outside of the AAs; totaling 21 samples. The pond samples were depressional wetlands that stored surface water, so they were not obligate GDEs, with a major wetland water source from impounded creek flow. Nonetheless these pond sites were also connected to wetland complexes with GDEs and may have received some direct groundwater inputs.

Sweep Methods

Invertebrate sweeps were taken early in the field survey day and were the second type of data collected, taken after measuring water chemistry YSI probe data. The sites were flagged during plot layout to avoid disturbance by the field crew during other data collection, and each sweep was taken in order from the most downstream to upstream location. Sample site locations were positioned to represent the most representative and range of water body types that also had open enough water to sweep a D-net back and forth. If the site had flowing water, at least one sample was taken in that water type. Shallow water hummock interspace was a water body type present at some sites, but because it did not usually offer a 1m length of open water for a sweep, and the water was typically too shallow to sample effectively with a D-net, the samples did not represent that water body type when present in a wetland. Three sweeps were taken at each site from three water locations, and these were combined into a single invertebrate sample. Each sweep was timed for one minute and the net was swept back and forth across a meter of length at the sample location. The D-net was swept across the water to catch invertebrates in the water column and disturbed surface sediment. Prior to beginning the sweep, the substrate was disturbed with a few kicks, and during the sample collection, the data collector continued to bump vegetation attached to the substrate with the D-net to dislodge invertebrates.

The field processing of net contents followed the NAMC Field Processing method in their benthic field sampling protocol. The combined sample in the net was then emptied into a sieve and invertebrates and other sample material larger than the sieve were separated from the sample water and mud through the sieve, using water in a plastic dish tub and a squeeze bottle to carefully consolidate the sample. Some samples were more muddy, especially from the saline site at Wellington SWA, which may have affected the counted taxa from the sample. When sufficiently separated, the contents of the sieve were removed into cleaned peanut butter jars with ethanol. Finer invertebrates were separated from the sieve corner using the squeeze-bottle, then were carefully removed and put into the ethanol sample jar. If a sample filled more than one-third of the peanut butter jar, it was split into two jars that later would be combined prior to splits. These unsorted invertebrate jars were labeled with site and date and were sealed tightly with electrical tape and stored unrefrigerated until counting.

Invertebrate Processing and Identification

Fourteen invertebrate samples jars were sorted out from their debris in a CNHP lab and placed into fresh ethanol vials. These CNHP sorted sites were split repeatedly until reaching a sample size small enough to sort efficiently and count, usually by portions about 3.5% of the sample. These invertebrates were sorted until reaching a count of 300 in a split but attempting not to go over 350. The variable count number is to ensure finishing a split or cell grid to be able to extrapolate the sorted and identified taxa and richness to the full sample. The remaining nine of the sites were both sorted from their debris in the Timberline Aquatics Lab in Fort Collins, then counted and identified in their lab using a cell grid with a similar method of counting up to 300 individuals and finishing a cell-grid count but attempting not to go over 350. Two of the nine lab-sorted samples had counts >350: one a plains riparian woody site counted to 605, and the other was a plains woody floodplain site counted to 476. Although we are unsure of the cause for the high count, it appears that the woody site counts were high because the last grid cells counted had atypically high invertebrate density with 220 individuals in one site's last grid cell, and 244 individuals in the other site's last grid cell. In addition, big or rare sample individuals that did not make the subsample of split or gridded sorted invertebrates were put in a separate big-and-rare sample category and identified. Timberline Aquatics (Fort Collins, CO) identified all invertebrate samples to the finest level practical, which was usually to genus and less frequently was to family or to species.

Results

The total number of sampled, sorted and counted, and identified invertebrates from the 21 samples was 5,441 individuals from 144 taxa (Table 29). These taxa were separated into general groups by Insect Order and also by Non-Insect groups at an Order or higher taxonomy level. Collected Insecta taxa were from six orders: Coleoptera, Ephemeroptera, Plecoptera, Diptera, Hemiptera, Odonata; and non-insect taxa were grouped into these taxa: Acari, Amphipoda, Bivalvia, Branchiopoda, Decapoda, Gastropoda, Nematoda, Oligochaeta, Trombidiformes, and Turbellaria. Ostracods were also observed in many samples but are not macroinvertebrates thus were not reported on.

All wetland types had a combination of insect and non-insect taxa from the benthic macroinvertebrate samples. The range of taxon diversity was 6 – 29 taxa per sample, with a median richness of 20 taxa. Overall samples had low percentages of intolerant organisms, with the median % intolerant close to zero at 0.34%, and a range of 0% - 15.8%. Three sites scored >3% intolerant species: the pilot sites on Box Elder Creek, at Soapstone Prairie, and at the South Republican SWA. The latter two were sampled both years, and the first year sample was higher than average at 1-2% intolerant in 2021, but very different than 10% and 13% in 2022. The site with the highest percent intolerant also had a high count to 605 individuals, versus the 300 – 350 target maximum count of individuals per the protocol. One other exception with a high count to 476 individuals did not have any notable diversity, richness, or other metrics.

Playas had the fewest taxa-group diversity, and the lowest site-level richness with 1-7 taxa/site. These included one site with all sampled individuals from three taxa in Branchiopoda in higher counts in the hundreds. The sampled area of the site may have been functionally freshwater based on the low YSI EC measurements of 63-562, which indicated the sampled area was likely filled by rainwater, despite visible salts and salinity indicators in the outer wetland and halophyte cover in the wetland. Water testing would be needed in various locations of the playa to understand the site, and if the site has fluctuating salinity based on water levels, and salts concentrated in the outer wetland with corresponding changes in taxa. Longtailed tadpole shrimp (*Triops longicaudatus*), an ancient species, was observed as 15% of the counted sample. This shows that the ponded area sampled had freshwater, but the playa fringe also had different EC and appeared to have seeps, which may or may not have had higher salinity. The other two saline playas were clearly saline in the sampled area, with thicker salt deposits in the wetted area along with the high EC measurements between 8690-45,100 uS at one site and 13,400 – 67,400 uS at another site. One site was in Wellington SWA, and it had the highest EC in the study and the lowest invertebrate count of twelve brine fly individuals of the single taxon *Ephydra sp*. in the family Ephydridae in Diptera. The site had a condition EIA rank of C-, primarily related to impacts from surrounding development and water management affecting the wetland's contributing watershed. Brine flies are common in salt lakes and saline playas and can indicate good site health (Leachman 2023; ONDA 2025), but this taxon is only reported in three general locations in Colorado on NAMC (2025): one in a single occurrence in Rocky Mountain National Park along a groundwater-fed drainage, another area with observations from many water sample points in the Blanca Wetlands among saline playas in the San Luis Valley, and the third location in a groundwater-fed area in the Dolores River Basin in Salt Creek and also downstream in the Dolores River. The Blanca wetlands where *Ephedra* was common are also similar to Wellington SWA by having complex water management in the general area that includes both loss, ditching, and conveyance. It is unknown if saline playa macroinvertebrate surveys are few if any in the Colorado plains, and there is much more diversity to discover in this region, or that this is a very uncommon taxon. Some of the *Ephydra* species are adapted to extreme salinity. The third saline playa site at Greasewood Lake, in very good condition had more diversity with seven taxa from non-Chironomid Diptera, Coleoptera, Ephemeroptera and Trobidiformes.

Fens had the most diversity at the Order taxa level or higher and had individuals from each of the taxa groups observed in this study except for Branchiopoda, Decapoda, and Nemotoda. The two fens had three samples, one being a revisit. Each sample had 20-21 unique taxa. The most common taxa in the two fens were Gastropoda and Amphipoda. One fen, with a B+ EIA and high overall diversity, had multiple occurrences that are either underreported or rare in the plains. One observation was the only occurrence of a Plecoptera taxon observed in the study, a spring stonefly species (*Amphinemura* sp.) associated with groundwater in stream and river systems in Colorado from the Front Range and west. It is a higher elevation taxon in Colorado and is the east-most occurrence of the species reported on NAMC. It is both more typically associated with cool groundwater-fed streams than a fen wetland and is very uncommon for wetlands in the plains prairie region. A single individual in the cranefly taxa (*Pseudolimnophila*) was reported in the same fen. This taxon is sparsely reported in NAMC throughout the United States, with two samples reported in the Colorado Rocky Mountains. A planarid worm (*Polycelis coronata*) was also observed which is very sparsely reported on NAMC, is not reported in Colorado but is presumed to be not rare and is usually in the mountains. This diverse fen site had macroinvertebrate species associated with cool and cold clean water; with species often detected in macroinvertebrate samples from the mountains. The macroinvertebrate observations outside of typical range align with the other uncommon taxonomic observations at the site, such as plant species in the fen that were uncommon to rare to the Western Great Plains region, and that were more common in higher elevations of Colorado. This site also had unusually high pH (= 8) for Colorado fens, in some water chemistry measurement locations. The other fen with an EIA rating of C+ did not have species of note but had good macroinvertebrate diversity.

The most commonly observed taxa in wet meadows were in the Diptera family of Chironomids, with nearly half of individuals from this taxon. Other common taxa in wet meadows were Bivalvia then Coleoptera and non-Chironomid Diptera.

The most commonly observed taxa in woody riparian areas were Gastropoda, which was also the case in the pond samples from impounded riparian areas. Woody riparian areas also had higher diversity of higher level taxa, with observations in most higher taxa observed in this study except Odonata, Branchiopoda, Nematoda, and Trombidiformes. Second to Gastropoda, Odonata were the most frequently observed taxa in the ponds. In Two Butte Creek, on a State Land Board parcel, the state-rare horned clubtail dragonfly nymph (*Arigomphus cornutus)* was observed. This species is associated with slow streams and marshes and muddy ponds more regularly associated with the Midwest (WIATRI 2025), and is also tracked as S1 in Illinois and Indiana and New York, and is vulnerable in Montana and has been recorded in northern Colorado (Natureserve 2025). This site had typical wet meadow-marsh drainage vegetation of *Typha, Schoenoplectus pungens, Schoenoplectus acutus*, and high forb species diversity and scattered pools. Some areas had muck and others had mud.

Several higher taxa were only observed in one wetland type group: the Plecoptera genus only in a fen, the Branchiopoda only in saline playas, and the Decapoda order had a single crayfish genus *Orconectes sp*. observed from one woody riparian site. This site was sampled both years, and the genus was observed in both samples. This taxon is reported in many waterbodies and streams in plains region where it was observed. There are both invasive and native species in Colorado in this genus, and so identifying which species is present may be of management interest.

These data can be used to add to the baseline understanding of macroinvertebrates present in a variety of wetland types and conditions. As more plains wetland macroinvertebrate samples are collected, taxa can be compared with metrics to identify potential indicators of health in plains GDEs. There is still much to learn about macroinvertebrate composition first in these wetlands. In sites with relatively higher macroinvertebrate taxa diversity, one of the stronger indicators for wetland health (WHEP 2025) were observed across a range of ecological condition. Saline depressions also had low taxa diversity, which is not surprising due to the saline conditions that also limit plant species richness.

Table 29. List of macroinvertebrate taxa documented in Colorado plains GDEs.

Taxa Order or Group	Scientific Taxa Name	Taxa Order or Group	Scientific Taxa Name
Ephemeroptera	*Baetis tricaudatus*	Diptera - Chironomidae	*Procladius* sp.
Ephemeroptera	*Callibaetis* sp.	Diptera - Chironomidae	*Psectrocladius* sp.
Ephemeroptera	*Fallceon* sp.	Diptera - Chironomidae	*Pseudochironomus* sp.
Ephemeroptera	*Caenis* sp.	Diptera - Chironomidae	*Radotanypus* sp.
Ephemeroptera	*Ephemerella excrucians*	Diptera - Chironomidae	*Stempellinella* sp.
Ephemeroptera	*Tricorythodes* sp.	Diptera - Chironomidae	Tanypodinae
Trichoptera	*Cheumatopsyche* sp.	Diptera - Chironomidae	*Tanypus* sp.
Trichoptera	*Agraylea* sp.	Diptera - Chironomidae	*Tanytarsus* sp.
Trichoptera	*Hydroptila* sp.	Diptera - Chironomidae	*Thienemanniella* sp.
Trichoptera	*Triaenodes* sp.	Diptera - Chironomidae	*Thienemannimyia* genus
Trichoptera	*Hesperophylax* sp.	Diptera - Chironomidae	*Tvetenia* sp.
Trichoptera	*Limnephilus* sp.	Diptera - Non-Chironomidae	Ceratopogonidae
Trichoptera	*Oxyethira* sp.	Diptera - Non-Chironomidae	Ceratopogoninae
Trichoptera	*Nectopsyche* sp.	Diptera - Non-Chironomidae	*Dasyhelea* sp.
Plecoptera	*Amphinemura* sp.	Diptera - Non-Chironomidae	*Atrichopogon* sp.
Diptera - Chironomidae	*Ablabesmyia* sp.	Diptera - Non-Chironomidae	*Aedes* sp.
Diptera - Chironomidae	*Acricotopus* sp.	Diptera - Non-Chironomidae	*Culex* sp.
Diptera - Chironomidae	*Apedilum* sp.	Diptera - Non-Chironomidae	*Dixa* sp.
Diptera - Chironomidae	*Chironomus* sp.	Diptera - Non-Chironomidae	Dolichopodidae
Diptera - Chironomidae	*Clinotanypus* sp.	Diptera - Non-Chironomidae	Ephydridae
Diptera - Chironomidae	*Corynoneura* sp.	Diptera - Non-Chironomidae	*Ephydra* sp.
Diptera - Chironomidae	*Cricotopus/Orthocladius* sp.	Diptera - Non-Chironomidae	*Pericoma* sp.
Diptera - Chironomidae	*Dicrotendipes* sp.	Diptera - Non-Chironomidae	Sciomyzidae
Diptera - Chironomidae	*Larsia* sp.	Diptera - Non-Chironomidae	*Simulium* sp.
Diptera - Chironomidae	*Lauterborniella* sp.	Diptera - Non-Chironomidae	*Stratiomys* sp.
Diptera - Chironomidae	*Limnophyes* sp.	Diptera - Non-Chironomidae	*Eristalis* sp.
Diptera - Chironomidae	*Metriocnemus* sp.	Diptera - Non-Chironomidae	*Tabanus* sp.
Diptera - Chironomidae	*Micropsectra/Tanytarsus* sp.	Diptera - Non-Chironomidae	*Pseudolimnophila* sp.
Diptera - Chironomidae	*Nilotanypus* sp.	Coleoptera	Coleoptera sp.
Diptera - Chironomidae	*Parachironomus* sp.	Coleoptera	Dytiscidae
Diptera - Chironomidae	Orthocladiinae	Coleoptera	*Agabus* sp. adults
Diptera - Chironomidae	*Paraphaenocladius* sp.	Coleoptera	Hydroporinae adults
Diptera - Chironomidae	*Paramerina* sp.	Coleoptera	*Hygrotus* sp.
Diptera - Chironomidae	*Paratanytarsus* sp.	Coleoptera	*Hygrotus* sp. adults
Diptera - Chironomidae	*Paratendipes* sp.	Coleoptera	*Laccophilus* sp.
Diptera - Chironomidae	*Pentaneura* sp.	Coleoptera	*Liodessus* sp.
Diptera - Chironomidae	*Phaenopsectra* sp.	Coleoptera	*Liodessus* sp. adults
Diptera - Chironomidae	*Polypedilum* sp.	Coleoptera	*Stictotarsus* sp. adults
Diptera - Chironomidae	*Procladius* sp.	Coleoptera	*Uvarus* sp. adults
Diptera - Chironomidae	*Psectrocladius* sp.	Coleoptera	*Dubiraphia* sp.

Taxa Order or Group	Scientific Taxa Name	Taxa Order or Group	Scientific Taxa Name
Coleoptera	*Optioservus* sp.	Hemiptera	*Ranatra* sp.
Coleoptera	*Haliplus* sp.	Hemiptera	*Notonecta* sp.
Coleoptera	*Haliplus* sp. adults	Hemiptera	*Notonecta undulata*
Coleoptera	*Peltodytes* sp.	Hemiptera	Veliidae
Coleoptera	*Peltodytes* sp. adults	Hemiptera	*Microvelia* sp.
Coleoptera	*Hydraena* sp.	NON-INSECTS	
Coleoptera	*Ochthebius* sp.	Acari	*Arrenurus* sp.
Coleoptera	Hydrophilidae	Acari	*Atractides* sp.
Coleoptera	*Anacaena* sp. adults	Acari	*Lebertia* sp.
Coleoptera	*Berosus* sp.	Acari	*Sperchon* sp.
Coleoptera	*Berosus* sp. adults	Amphipoda	*Gammarus* sp.
Coleoptera	*Cymbiodyta* sp. adults	Amphipoda	*Crangonyx* sp.
Coleoptera	*Enochrus* sp.	Amphipoda	*Hyalella azteca*
Coleoptera	*Enochrus* sp. adults	Bivalvia	*Pisidium* sp.
Coleoptera	*Helophorus* sp. adults	Bivalvia	*Sphaerium* sp.
Coleoptera	*Hydrobius* sp.	Branchiopoda	Anostraca
Coleoptera	*Hydrobius* sp. adults	Branchiopoda	Diplostraca
Coleoptera	*Hydrophilus* sp. adults	Branchiopoda	*Triops longicaudatus*
Coleoptera	*Paracymus* sp. adults	Decapoda	*Orconectes* sp.
Coleoptera	*Tropisternus* sp.	Gastropoda	*Lymnaea (Stagnicola)* sp.
Coleoptera	*Tropisternus* sp. adults	Gastropoda	Lymnaeidae
Coleoptera	Scirtidae	Gastropoda	*Physa sp.*
Odonata	*Aeshna* sp.	Gastropoda	*Gyraulus* sp.
Odonata	Aeshnidae	Gastropoda	*Helisoma* sp.
Odonata	Calopterygidae	Nematoda	Nematoda
Odonata	*Rhionaeschna* sp.	Oligochaeta	Tubificidae
Odonata	*Amphiagrion* sp.	Trombidiformes	Trombidiformes
Odonata	*Argia* sp.	Trombidiformes	*Arrenurus* sp.
Odonata	*Enallagma* sp.	Trombidiformes	*Hygrobates* sp.
Odonata	Gomphidae	Trombidiformes	*Sperchon* sp.
Odonata	Libellulidae	Turbellaria	*Dugesia* sp.
Odonata	*Libellula* sp.	Turbellaria	*Polycelis coronata*
Odonata	*Ischnura* sp.		
Odonata	*Arigomphus cornutus*		
Odonata	*Lestes* sp.		
Odonata	*Sympetrum* sp.		
Hemiptera	Belostomatidae		
Hemiptera	*Belostoma* sp.		
Hemiptera	*Sigara* sp.		
Hemiptera	Gerridae		
Hemiptera	*Aquarius* sp.		

APPENDIX C. SCORING FORMULAS FOR ECOLOGICAL INTEGRITY ASSESSMENT (EIA)

See Lemly et al. (2016) for more details.

	Key Ecological Attribute	Indicator / Metric	Metric Rating Criteria			
		Rank / Score	A / 5	B / 4	C / 3	D / 1
		Interpretation	Reference (No or Minimal Human Impact)	Slight Deviation from Reference	Moderate Deviation from Reference	Significant Deviation from Reference
LANDSCAPE CONTEXT	**Landscape**	*L1. Contiguous Natural Land Cover within 500 m*	Embedded in 90-100% contiguous natural landscape.	Embedded in 60–90% contiguous natural landscape.	Embedded in 20–60% contiguous natural landscape.	Embedded in <20% contiguous natural landscape.
		L2. Land Use Index[2]	Land Use Index = 9.5–10.0.	Land Use Index = 8.0–9.49.	Land Use Index = 4.0–7.99.	Land Use Index = <4.0.
	Buffer	*B1. Perimeter with Natural Buffer*	Natural buffer at least 5 m wide surrounds 100% of AA.	Natural buffer at least 5 m wide surrounds 75–99% of AA.	Natural buffer at least 5 m wide surrounds 25–74% of AA.	Natural buffer at least 5 m wide surrounds <25% of AA.
		B2. Buffer Width	Average buffer width is >100 m.	Average buffer width is 75-99 m.	Average buffer width is 25-74 m.	Average buffer width is <25 m.
		B3. Buffer Condition: Vegetation	Abundant (>95%) relative cover native vegetation and little or no (<5%) cover of non-native plants.	Substantial (75–95%) cover of native vegetation and low (5–25%) cover of non-native plants.	Low (25–75%) cover of native vegetation and moderate to substantial (25-75%) cover of non-native plants.	Dominant (>50%) cover of non-native plants.
		B4. Buffer Condition: Soils/Substrate	Intact soils, no water quality concerns, little or no trash, AND little or no evidence of human visitation.	Intact or minor soil disruption, minor water quality concerns, moderate or lesser amounts of trash, AND/OR minor intensity of human visitation or recreation.	Moderate-or extensive soil disruption, moderate to strong water quality concerns, moderate and greater amounts of trash, AND/OR moderate intensity of human use.	Barren ground and highly compacted or otherwise disrupted soils, significant water quality concerns, substantial amounts of trash, extensive human use, OR no buffer exists.

VEGETATION CONDITION

Key Ecological Attribute	Indicator / Metric	Metric Rating Criteria				
	Rank / Score	**A / 5**	**B / 4**	**C / 3**	**C- / 2 –OR– D / 1**	
	Interpretation	**Reference (No or Minimal Human Impact)**	**Slight Deviation from Reference**	**Moderate Deviation from Reference**	**Significant or Severe Deviation from Reference**	
Vegetation	*V1. Relative Cover Native[3] Plant Species*	Relative cover native plants > 99%	Relative cover native plants >95-99%	Relative cover native plants >85-95%	**C-:** Relative cover native plants 60-85%	**D:** Relative cover native plants <60%
	V2. Invasive Non-native[3] Absolute Cover	Absolute cover noxious weeds and invasive cryptogenics = 0%	Absolute cover noxious weeds and invasive cryptogenics <4%	Absolute cover noxious weeds and invasive cryptogenics >4-10%	**C-:** Noxious weeds and invasive cryptogenics 11-30%	**D:** Noxious weeds and invasive cryptogenics >30%
	V3. Native[3] Plant Species Composition	Native plant species composition with expected natural conditions:	Native plant species composition with minor disturbed conditions.	Native plant species composition with moderately disturbed conditions:	**D:** Native plant species composition with severely disturbed conditions.	
	V4. Vegetation Structure[4]	Vegetation structure is at or near minimally disturbed natural conditions. Little to no structural indicators of degradation evident	Vegetation structure shows minor alterations from natural conditions.	Vegetation structure is moderately altered from natural conditions.	**D:** Vegetation structure is greatly altered from natural conditions.	
	V5. Regeneration of Native Woody Species (**N/A** if woody spp. naturally uncommon/absent)	All age classes of native woody species present. Native tree saplings /seedlings and shrubs common to the type present in expected amounts and diversity. Regeneration in obvious.	Age classes of native woody species restricted to mature individuals and young sprouts. Middle age groups appear to be absent or there is some other indication that regeneration is moderately impacted.	*Native* woody species comprised of mainly mature individuals OR mainly evenly aged young sprouts that choke out other vegetation. Regeneration is obviously impacted. Site may contain Russian Olive and/or Salt Cedar.	**D:** Native woody species predominantly consist of decadent or dying individuals OR are absent from an area that should be wooded. Site may be dominated by Russian Olive / Salt Cedar.	
	V6. Coarse and Fine Woody Debris (**N/A** if no obvious inputs of woody debris)	**A/B Score 4:** Moderate amount of coarse and fine woody debris, relative to expected conditions.		Moderate amount of coarse and fine woody debris relative to expected conditions.	Small amounts of woody debris OR debris is somewhat excessive.	

	Key Ecological Attribute	Indicator / Metric	Metric Rating Criteria			
		Rank / Score	A / 5	B / 4	C / 3	D / 1
		Interpretation	**Reference (No or Minimal Human Impact)**	**Slight Deviation from Reference**	**Moderate Deviation from Reference**	**Significant Deviation from Reference**
HYDROLOGIC CONDITION[1]	**Hydrology**	*H1. Water Source*	Water sources are natural. Site hydrology is fed by precipitation, groundwater, natural runoff, or natural flow from an adjacent freshwater body.	Water sources are mostly natural, but also include occasional or small amounts of inflow from anthropogenic sources.	Water sources are moderately impacted by anthropogenic sources, but are still a mix of natural and non-natural sources.	Water sources are primarily from anthropogenic sources (e.g., urban runoff, direct irrigation, pumped water, artificially impounded water, or another artificial hydrology).
		H2. Hydroperiod	Hydroperiod is characterized by natural patterns of inundation/saturation and drawdown and/or flood frequency, duration, level and timing.	Filling and drying patterns deviate slightly from natural conditions due to presence of stressors such as: flood control/water storage dams upstream; berms or roads at/near grade; minor pugging by livestock; small ditches or diversions removing water; or minor flow additions from irrigation return flow or storm water runoff. Outlets may be slightly constricted, but not to significantly slow outflow.	Filling and drying patterns deviate moderately from natural conditions due to presence of stressors such as: flood control/water storage dams upstream or downstream that moderately effect hydroperiod; two lane roads; culverts adequate for base stream flow but not flood flow; moderate pugging by livestock that could channelize or divert water; shallow pits within playas; ditches or diversions 1–3 ft. deep; or moderate flow additions. Outlets may be moderately constricted, but flow is still possible.	Filling and drying patterns deviate substantially from natural conditions due to high intensity alterations such as: significant flood control / water storage das upstream or downstream; a 4-lane highway; large dikes impounding water; diversions > 3ft. deep that withdraw a significant portion of flow, deep pits in playas; large amounts of fill; significant artificial groundwater pumping; or heavy flow additions. Outlets may be significantly constricted, blocking most flow.
		H3. Hydrologic Connectivity[4] *(continued below)*	**Riparian:** completely connected to floodplain (backwater sloughs and channels). No geomorphic modifications made to contemporary floodplain. Channel is not entrenched.	**Riparian:** minimally disconnected from floodplain. Up to 25% of stream banks may be affected by dikes, rip rap, and/or elevated culverts. Channel may be somewhat entrenched, but overbank flow occurs during most floods.	**Riparian:** moderately disconnected from floodplain due to multiple geomorphic modifications. Between 25-75% of stream banks may be affected by dikes, rip rap, concrete, and/or elevated culverts. Channel may be moderately entrenched and disconnected from the floodplain except in large floods.	**Riparian:** channel is severely entrenched and entirely disconnected from the floodplain. More than 75% of stream banks may be affected by dikes, rip rap, concrete and/or elevated culverts. Overbank flow never occurs or only in severe floods.

	Hydrology	*H3. Hydrologic Connectivity[4] (continued from above)*	**Marsh**: no unnatural obstructions to lateral or vertical movement of surface or ground water. Rising water in the site has unrestricted access to adjacent upland, without levees, excessively high banks, artificial barriers, or other obstructions to the lateral movement of flood flows.	**Marsh**: minor restrictions to the lateral or vertical movement of surface and ground water by unnatural features such as levees, road grades or excessively high banks. Up to 25% of the site may be restricted by barriers to drainage. Restrictions may be intermittent along the margins of the AA, or they may occur only along one bank or shore. Flood flows may exceed the impoundments, but drainage back into the wetland may be incomplete due to the impoundments.	**Marsh**: moderate restrictions to the lateral or vertical movement of surface and ground water by unnatural features such as levees, road grades or excessively high banks. Between 25−75% of the site may be restricted by barriers to drainage. Flood flows may exceed the impoundments, but drainage back into the wetland may be incomplete due to the impoundments.	**Marsh**: essentially no hydrologic connection to adjacent landscape. Most or all stages may be contained within artificial banks, levees, or comparable features. Greater than 75% of the site is restricted by barriers to drainage.

PHYSIOCHEMICAL CONDITION	Metric Rating Criteria				
	Rank / Score	A / 5	B / 4	C / 3	D / 1
	Interpretation	Reference (No or Minimal Human Impact)	Slight Deviation from Reference	Moderate Deviation from Reference	Significant Deviation from Reference
	S1. Substrate / Soil Disturbance	No soil disturbance within AA. Little bare soil OR bare soil areas are limited to naturally caused disturbances such as flood deposition or game trails OR soil is naturally bare (e.g., playas). No pugging, soil compaction, or sedimentation.	Minimal soil disturbance within AA. Some amount of bare soil, pugging, compaction, or sedimentation present due to human causes, but the extent and impact are minimal. The depth of disturbance is limited to only a few inches and does not show evidence of altering hydrology. Any disturbance is likely to recover within a few years after the disturbance is removed.	Moderate soil disturbance within AA. Bare soil areas due to human causes are common and will be slow to recover. There may be pugging due to livestock resulting in several inches of soil disturbance. ORVs or other machinery may have left some shallow ruts. Sedimentation may be filling the wetland. Damage is obvious, but not excessive. The site could recover to potential with the removal of degrading human influences and moderate recovery times.	Substantial soil disturbance within AA. Bare soil areas substantially degrade the site and have led to altered hydrology or other long-lasting impacts. Deep ruts from ORVs or machinery may be present, or livestock pugging and/or trails are widespread. Sedimentation may have severely impacted the hydrology. The site will not recover without active restoration and/or long recovery times.
	S2. Surface Water Turbidity/Pollutants (**N/A** if no open water in AA)	No visual evidence of degraded water quality. No visual evidence of turbidity or other pollutants.	Some negative water quality indicators are present, but limited to small and localized areas within the wetland. Water is slightly cloudy, but there is no obvious source of sedimentation or other pollutants.	Water is cloudy or has unnatural oil sheen, but the bottom is still visible. Sources of water quality degradation are apparent (identify in comments below). Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.	Water is milky and/or muddy or has unnatural oil sheen. The bottom is difficult to see. There are obvious sources of water quality degradation. Note: If the sheen breaks apart when you run your finger through it, it is a natural bacterial process and not water pollution.
	S3. Algal Growth (**N/A** if no open water in AA)	Water is clear with minimal algal growth.	Algal growth is limited to small and localized areas of the wetland. Water may have a greenish tint or cloudiness.	Algal growth occurs in moderate to large patches throughout the AA. Water may have a moderate greenish tint or sheen.	Algal mats are extensive, blocking light to the bottom. Water may have a strong greenish tint and the bottom is difficult to see.

[1] The 5-point scale scoring method described in Field Manual Version 1.0 (Lemly and Gilligan 2013) and shown above was used instead of the 4 point scale described in Field Manual Version 2.1 (Lemly et al. 2016).
[2] See EIA Field Form in Appendix C or Lemly et al. (2016) for Land Use Index Scoring.
[3] EIA 2.2, In-prep, will detail EIA treatment of cryptogenic species as invasive and non-native in metrics V1, V2, and V3.
[4] See Lemly et al. (2016) for Specific Guidance for Marshes, Meadows and Playas, and Specific Guidance for Riparian Areas.

EIA Scoring Formulas:

Landscape Context Score = [Average (L1, L2)] * 0.33 + [(B1*B2)$^{1/2}$ * Average (B3.1, B3.2)]$^{1/2}$ *0.67

Vegetation Condition Score = Average (V1, V2, V3, V4, V5, V6)

Hydrologic Condition Score = Average (H1, H2, H3)

Physiochemistry Condition Score = (S1+(S2+S3)/2)/2

Overall EIA Score = (Landscape Context Score * 0.3) + [(Vegetation Condition Score * 0.55) + (Hydrologic Condition Score * 0.35) + (Hydrologic Condition Score * 0.1)] * 0.7

Overall Score to Rank Conversion:

A = >4.5[1] – 5.0   B = >3.5 – 4.5   C= >2.5 - 3.5   D= 1.0 - 2.5

[1] The rank threshold uses the scoring method of rank breaks with the higher rank minimum set at the greater than 0.5 mark, as described in Field Manual Version 1.0 (Lemly and Gilligan 2013), instead of the higher rank minimum set at the 0.5 mark as described in Field Manual Version 2.1 (Lemly et al. 2016). This change will be updated in EIA 2.2, in-prep.

APPENDIX D. NATURAL HERITAGE PROGRAM METHODOLOGY

To determine the status of species within Colorado, CNHP gathers information on plants, animals and plant communities. Each of these elements of natural diversity is assigned a rank that indicates its relative degree of imperilment on a five-point scale (for example, 1 = extremely rare/imperiled, 5 = abundant/secure). The primary criterion for ranking elements is the number of occurrences (in other words, the number of known distinct localities or populations). This factor is weighted more heavily than other factors because an element found in one place is more imperiled than something found in twenty-one places. Also of importance are the size of the geographic range, the number of individuals, the trends in both population and distribution, identifiable threats and the number of protected occurrences.

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within Colorado (its State-rank or S-rank) and the element's imperilment over its entire range (its Global-rank or G-rank). Taken together, these two ranks indicate the degree of imperilment of an element. CNHP actively collects, maps and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 - S3). Several factors, such as rarity, evolutionary distinctiveness and endemism (specificity of habitat requirements), contribute to the conservation priority of each species. Certain species are "watch listed," meaning that specific occurrence data are collected and periodically analyzed to determine whether more active tracking is warranted. A description of each of the Natural Heritage ranks is provided in Table D-1.

This single rank system works readily for all species except those that are migratory. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding and resident species. Ranks followed by a "B," for example S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N," for example S4N, refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 30. Definition of Natural Heritage imperilment ranks.

G/S1	Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range.
G/S3	Vulnerable throughout its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals).
G/S4	Apparently secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals.
G/S5	Demonstrably secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed extinct globally, or extirpated within the state.
G#?	Indicates uncertainty about an assigned global rank.
G/SU	Unable to assign rank due to lack of available information.
GQ	Indicates uncertainty about taxonomic status.
G/SH	Historically known, but usually not verified for an extended period of time.
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents.
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents.
SC	Element is extant only in captivation or cultivation.
S	Migrant whose occurrences are too irregular, transitory and/or dispersed to be reliably identified, mapped and protected.
SA	Accidental in the state.
SR	Reported to occur in the state but unverified.
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

Legal Designations for Rare Species

Natural Heritage imperilment ranks should not be interpreted as legal designations. Although most species protected under state or federal endangered species laws are extremely rare, not all rare species receive legal protection. Legal status is designated by both the U.S. Fish and Wildlife Service under the Endangered Species Act or by the Colorado Division of Wildlife under Colorado Statutes 33-2-105 Article 2. In addition, the U.S. Forest Service recognizes some species as “Sensitive,” as does the Bureau of Land Management. Table D-2 defines the special status assigned by these agencies and provides a key to abbreviations used by CNHP.

Table 31. Federal and state agency special designations for rare species.

Federal Status:

1. U.S. Fish and Wildlife Service (58 Federal Register 51147, 1993) and (61 Federal Register 7598, 1996)

LE	Listed Endangered: defined as a species, subspecies, or variety in danger of extinction throughout all or a significant portion of its range.
LT	Listed Threatened: defined as a species, subspecies, or variety likely to become endangered in the foreseeable future throughout all or a significant portion of its range.
P	Proposed: taxa formally proposed for listing as Endangered or Threatened (a proposal has been published in the Federal Register, but not a final rule).
C	Candidate: taxa for which substantial biological information exists on file to support proposals to list them as endangered or threatened, but no proposal has been published yet in the Federal Register.
PDL	Proposed for delisting.
XN	Nonessential experimental population.

2. U.S. Forest Service (Forest Service Manual 2670.5) (noted by the Forest Service as S")

FS	Sensitive: those plant and animal species identified by the Regional Forester for which population viability is a concern as evidenced by: Significant current or predicted downward trends in population numbers or density. Significant current or predicted downward trends in habitat capability that would reduce a species' existing distribution.

3. Bureau of Land Management (BLM Manual 6840.06D) (noted by BLM as "S")

BLM	Sensitive: those species found on public lands designated by a State Director that could easily become endangered or extinct in a state. The protection provided for sensitive species is the same as that provided for C (candidate) species.

4. State Status:

Colorado Parks and Wildlife has developed categories of imperilment for non-game species (refer to the Colorado Division of Wildlife's Chapter 10 – Nongame Wildlife of the Wildlife Commission's regulations). The categories being used and the associated CNHP codes are provided below.

E	Endangered: those species or subspecies of native wildlife whose prospects for survival or recruitment within this state are in jeopardy, as determined by the Commission.
T	Threatened: those species or subspecies of native wildlife which, as determined by the Commission, are not in immediate jeopardy of extinction but are vulnerable because they exist in such small numbers, are so extremely restricted in their range, or are experiencing such low recruitment or survival that they may become extinct.
SC	Special Concern: those species or subspecies of native wildlife that have been removed from the state threatened or endangered list within the last five years; are proposed for federal listing (or are a federal listing "candidate species") and are not already state listed; have experienced, based on the best available data, a downward trend in numbers or distribution lasting at least five years that may lead to an endangered or threatened status; or are otherwise determined to be vulnerable in Colorado.

Appendix E. List of Vascular Plant Taxa Documented in Plains GDEs

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Achillea millefolium	Common Yarrow	FACU	Native	4	N	G5 SNR
Agrostis gigantea	Giant Bentgrass	FACW	Exotic	0	N	G4G5 SNA
Agrostis scabra	Rough Bentgrass	FAC	Native	4	N	G5 SNR
Agrostis stolonifera	Creeping Bentgrass	FACW	Exotic	0	N	G5 SNA
Alisma triviale	Northern Water-plantain	OBL	Native	3	N	G5 SNR
Allium	Onion		N/A		N/A	N/A
Almutaster pauciflorus	Alkali Marsh Aster	FACW	Native	4	N	G4 SNR
Alopecurus	Foxtail		N/A		N/A	N/A
Alopecurus aequalis	Short-awn Foxtail	OBL	Native	4	N	G5 SNR
Alopecurus arundinaceus	Creeping Foxtail	FACW	Exotic	0	N	GNR SNA
Alopecurus pratensis	Meadow Foxtail	FACW	Exotic	0	N	GNR SNA
Amaranthus albus	White Pigweed	FACU	Exotic	0	N	GNR SNA
Ambrosia	Ragweed		N/A		N/A	N/A
Ambrosia artemisiifolia	Annual Ragweed	FACU	Native	1	N	G5 SNR
Ambrosia linearis	Linear-leaf Bursage		Native	4	Y	G3 S3
Ambrosia psilostachya	Perennial Ragweed	FACU	Native	3	N	G5 SNR
Ambrosia trifida var. trifida	Great Ragweed		Native	3	N	G5T5 SNR
Amelanchier alnifolia	Saskatoon	FACU	Native	6	N	G5 SNR
Amorpha fruticosa	False Indigobush	FACW	Native	7	N	G5 SNR
Antennaria microphylla	Small-leaf Cat's-foot		Native	5	N	G5 SNR
Antennaria parvifolia	Nuttall's Pussytoes		Native	5	N	G5 SNR
Apiaceae	Family - Carrot		N/A		N/A	N/A
Apocynum cannabinum	Clasping-leaf Dogbane	FAC	Native	2	N	G5 SNR
Arctium minus	Lesser Burdock	FACU	List C	0	N	GNR SNA
Artemisia ludoviciana	White Sagebrush	UPL	Native	4	N	G5 SNR
Asclepias arenaria	Sand Milkweed		Native	7	N	G5? SNR
Asclepias incarnata	Swamp Milkweed	FACW	Native	4	N	G5 SNR
Asclepias speciosa	Showy Milkweed	FAC	Native	3	N	G5 SNR
Asclepias subverticillata	Bedstraw Milkweed	FACU	Native	3	N	G4G5 SNR
Aster	Aster		N/A		N/A	N/A
Asteraceae	Family - Sunflower		N/A		N/A	N/A
Astragalus	Milk vetch		N/A		N/A	N/A
Atriplex	Saltbush		N/A		N/A	N/A
Atriplex argentea	Silver Saltbush	FAC	Native	5	N	G5 SNR
Atriplex canescens	Four-wing Saltbush		Native	7	N	G5 SNR
Atriplex heterosperma	Two-scale Orache		Exotic	0	N	G5 SNA
Baccharis salicina	Great Plains False Willow	FAC	Native	7	N	G5 SNR
Bassia scoparia	Mexican Fireweed	FACU	Exotic	0	N	GNR SNA
Beckmannia syzigachne	American Sloughgrass	OBL	Native	4	N	G5 SNR

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Berteroa incana	Hoary False Alyssum		Watch List	0	N	GNR SNA
Berula erecta	Wild Parsnip	OBL	Native	5	N	G4G5 SNR
Bidens	Beggarticks		N/A		N/A	N/A
Bidens cernua	Nodding Beggarticks	OBL	Native	5	N	G5 SNR
Bidens frondosa	Devil's Beggarticks	FACW	Native	3	N	G5 SNR
Bidens tripartita	Three-lobe Beggarticks	FACW	Native	3	N	G5 SNR
Bidens vulgata	Tall Bur-marigold	FAC	Native	3	N	G5 SNR
Bolboschoenus	Saltmarsh bulrush		N/A		N/A	N/A
Bolboschoenus fluviatilis	River Bulrush	OBL	Native	8	W	G5 S1
Bolboschoenus maritimus ssp. paludosus	Alkali Bulrush	OBL	Native	5	N	G5T5 SNR
Bothriochloa laguroides	Silver Bluestem		Native	2	N	G5 SNR
Bouteloua curtipendula	Sideoats Grama		Native	6	N	G5 SNR
Bouteloua gracilis	Blue Grama		Native	4	N	G5 SNR
Brassicaceae	Family - Mustard		N/A		N/A	N/A
Bromus	Brome		N/A		N/A	N/A
Bromus commutatus	Hairy Brome		Exotic	0	N	GNR SNA
Bromus inermis	Awnless Brome	UPL	Exotic	0	N	G5 SNA
Bromus japonicus	Japanese Brome	FACU	Exotic	0	N	GNR SNA
Bromus racemosus	Spiked Brome		Exotic	0	N	GNR SNA
Bromus squarrosus	Corn Brome		Exotic	0	N	GNR SNA
Bromus tectorum	Cheatgrass		List C	0	N	GNR SNA
Calamagrostis canadensis	Blue-joint Reedgrass	FACW	Native	6	N	G5 SNR
Calamagrostis stricta	Slim-stem Small-reedgrass	FACW	Native	7	N	G5 SNR
Cannabis sativa ssp. sativa	Marijuana		Exotic	0	N	GNRTNR SNA
Carduus acanthoides	Spiny Plumeless-thistle		List B	0	N	GNR SNA
Carduus nutans	Musk Thistle	FACU	List B	0	N	GNR SNA
Carex	Sedge		native		N/A	N/A
Carex aurea	Golden-fruit Sedge	OBL	Native	7	N	G5 SNR
Carex bebbii	Bebb's Sedge	OBL	Native	7	N	G5 SNR
Carex brevior	Fescue Sedge	FAC	Native	5	N	G5 SNR
Carex crawei	Crawe's Sedge	FACW	Native	8	Y	G5 S1
Carex emoryi	Emory's Sedge	OBL	Native	5	N	G5 SNR
Carex gravida	Heavy-fruit Sedge	FACW	Native	4	W	G5 S3
Carex hystericina	Porcupine Sedge	OBL	Native	6	N	G5 SNR
Carex kelloggii	Kellogg's Sedge	OBL	Native	9	N	GNR SNR
Carex nebrascensis	Nebraska Sedge	OBL	Native	5	N	G5 SNR
Carex pellita	Woolly Sedge	OBL	Native	6	N	G5 SNR
Carex praegracilis	Clustered Field Sedge	FACW	Native	5	N	G5 SNR
Carex scoparia	Broom Sedge	FACW	Native	6	N	G5 SNR
Carex simulata	Copycat Sedge	OBL	Native	6	N	G5 SNR
Carex utriculata	Beaked Sedge	OBL	Native	5	N	G5 SNR
Carex vulpinoidea	Fox Sedge	FACW	Native	5	N	G5 SNR
Centaurium pulchellum	Branching Centaury	FACU	Exotic	0	N	GNR SNA

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Ceratophyllum demersum	Common Hornwort	OBL	Native	1	N	G5 SNR
Chenopodium album	White Goosefoot	FACU	Exotic	0	N	G5 SNA
Chenopodium berlandieri var. zschackei	Zschacke's Goosefoot		Native	2	N	G5T5 SNR
Chenopodium desiccatum	Narrowleaf Goosefoot		Native	3	N	G5 SNR
Chenopodium fremontii	Fremont's Goosefoot	FACU	Native	6	N	G5 SNR
Chenopodium simplex	Giant-seed Goosefoot		Native	2	N	G5 SNR
Chloris verticillata	Tumble Windmill Grass		Native	1	N	G5 SNR
Chrysothamnus	Rabbitbrush		N/A		N/A	N/A
Cicuta maculata	Spotted Water-hemlock	OBL	Native	3	N	G5 SNR
Cirsium	Thistle		N/A		N/A	N/A
Cirsium arvense	Creeping Thistle	FACU	List B	0	N	G5 SNA
Cirsium flodmanii	Flodman's Thistle	FAC	Native	3	N	G5 SNR
Cirsium undulatum	Nodding Thistle	FACU	Native	5	N	G5 SNR
Cirsium vulgare	Bull Thistle	UPL	List B	0	N	GNR SNA
Cleome serrulata	Bee Spider-flower	FACU	Native	2	N	G5 SNR
Commelina erecta	Slender Dayflower	FACU	Native	5	N	G5 S3
Conium maculatum	Poison-hemlock	FACW	List C	0	N	G5 SNA
Convolvulus arvensis	Field Bindweed		List C	0	N	GNR SNA
Conyza canadensis	Canada Horseweed	FACU	Native	1	N	G5 SNR
Crataegus	Hawthorn		N/A		N/A	N/A
Crataegus succulenta	Fleshy Hawthorn		Native	5	Y	G5 S2
Crepis runcinata	Naked-stem Hawk's-beard	FAC	Native	6	N	G5 SNR
Crepis runcinata ssp. runcinata	Naked-stem Hawk's-beard		Native	6	N	G5T5 SNR
Cucurbita foetidissima	Missouri Gourd		Native	2	N	G5 S4
Cuscuta	Dodder		N/A		N/A	N/A
Cynoglossum officinale	Common Hound's-tongue	FACU	List B	0	N	GNR SNA
Cyperaceae	Family - Sedge		N/A		N/A	N/A
Cyperus odoratus	Rusty Flatsedge	FACW	Native	2	N	G5 SNR
Dactylis glomerata	Orchard Grass	FACU	Exotic	0	N	GNR SNA
Deschampsia cespitosa	Tufted Hairgrass	FACW	Native	4	N	G5 SNR
Descurainia sophia	Herb Sophia		Exotic	0	N	GNR SNA
Desmanthus illinoensis	Prairie Mimosa	FACU	Native	6	N	G5 SNR
Desmodium illinoense	Illinois Tick Trefoil		N/A		-	-
Dichanthelium lanuginosum	Woolly Panicgrass		Native	8	Y	GNR S2
Dipsacus fullonum	Fuller's Teasel	FACU	List B	0	N	GNR SNA
Distichlis stricta	Inland Saltgrass	FACW	Native	4	N	G5TNR S5
Echinochloa	Barnyard Grass		N/A		N/A	N/A
Echinochloa crus-galli	Barnyard Grass	FAC	Exotic	0	N	GNR SNA
Echinochloa muricata var. microstachya	Rough Barnyard Grass		Native	4	N	G5T5 SNR
Elaeagnus angustifolia	Russian Olive	FACU	List B	0	N	GNR SNA
Eleocharis acicularis	Least Spikerush	OBL	Native	5	N	G5 SNR
Eleocharis palustris	Creeping Spikerush	OBL	Native	3	N	G5 SNR

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Eleocharis quinqueflora	Few-flower Spikerush	OBL	Native	8	N	G5 SNR
Eleocharis rostellata	Beaked Spikerush	OBL	Native	6	N	G5 S3
Elodea canadensis	Broad Waterweed	OBL	Native	3	N	G5 SNR
Elymus canadensis	Canada Wild Rye	FACU	Native	4	N	G5 SNR
Elymus repens	Creeping Wild Rye	FACU	List C	0	N	GNR SNA
Elymus trachycaulus	Slender Wild Rye	FACU	Native	4	N	G5 SNR
Epilobium	Willowherb		N/A		N/A	N/A
Epilobium brachycarpum	Panicled Willowherb	OBL	Native	2	N	G5 SNR
Epilobium ciliatum	Hairy Willowherb	FACW	Native	4	N	G5 SNR
Epilobium hirsutum	Great Hairy Willowherb	FACW	List A	0	N	GNR SNA
Epilobium palustre	Marsh Willowherb	OBL	Native	8	W	G5 S2?
Equisetum arvense	Field Horsetail	FAC	Native	4	N	G5 SNR
Equisetum hyemale var. affine	Scouring-rush	FACW	Native	4	N	G5T5 SNR
Equisetum laevigatum	Smooth Scouring-rush	FAC	Native	4	N	G5 SNR
Equisetum variegatum var. variegatum	Variegated Horsetail	FACW	Native	5	W	G5T5 S3
Erythranthe	Monkeyflower		native		N/A	N/A
Erythranthe geyeri	Geyer's Monkeyflower	OBL	Native	5	N	GNR S3
Erythranthe guttata	Common Monkeyflower	OBL	Native	8	N	G5 S4
Euphorbia corrolata	Flowering Spurge		N/A		N/A	N/A
Euphorbia davidii	David's Spurge		Native	1	N	GNR SNR
Euphorbia marginata	Snow-on-the-mountain	FACU	Native	1	N	G5 SNR
Euphorbia virgata	Russian Leafy Spurge		Exotic	0	N	GNR SNA
Eustoma exaltatum ssp. russellianum	Showy Prairie-gentian		Native	7	W	G5T5 S3
Euthamia occidentalis	Western Fragrant Goldenrod	OBL	Native	4	N	G5 SNR
Fabaceae	Family - Pea		N/A		N/A	N/A
Fallopia convolvulus	Black Bindweed	FACU	Exotic	0	N	GNR SNA
Festuca	Fescue Sedge		N/A		N/A	N/A
Fraxinus pennsylvanica	Green Ash	FAC	Native	0	N	G4 SNR
Gaillardia pinnatifida	Tansy Blanket-flower		Native	6	N	G5 SNR
Galium	Bedstraw		N/A		N/A	N/A
Galium aparine	Catchweed Bedstraw	FACU	Exotic	1	N	G5 SNA
Gaura coccinea	Scarlet Gaura		Native	5	N	G5 SNR
Gaura mollis	Velvet-leaf Gaura	UPL	Native	1	N	G4G5 SNR
Gentianella amarella ssp. acuta	Autumn Dwarf Gentian	FACW	Native	8	N	G5T5 SNR
Geum aleppicum	Yellow Avens	FACU	Native	6	N	G5 SNR
Geum macrophyllum var. perincisum	Largeleaf Avens		Native	6	N	G5T5 SNR
Gleditsia triacanthos	Honey-locust	FACU	Exotic	0	N	G5 SNA
Glyceria	Mannagrass	OBL	Native		N/A	N/A
Glyceria elata	Tall Mannagrass	OBL	Native	6	N	G5 SNR
Glyceria grandis	American Mannagrass	OBL	Native	6	N	G5 SNR
Glyceria striata	Fowl Mannagrass	OBL	Native	5	N	G5 SNR

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Glycyrrhiza lepidota	Wild Licorice	FACU	Native	3	N	G5 SNR
Grindelia squarrosa	Broadleaf Gumweed	UPL	Native	3	N	G5 S4
Hedeoma drummondii	Drummond's False Pennyroyal		Native	6	N	G5 SNR
Helenium autumnale	Common Sneezeweed	FACW	Native	5	N	G5 SNR
Helianthus annuus	Common Sunflower	FACU	Native	1	N	G5 SNR
Helianthus nuttallii	Nuttall's Sunflower	FACW	Native	3	N	G5 SNR
Helianthus petiolaris	Prairie Sunflower		Native	2	N	G5 SNR
Heliotropium curassavicum	Seaside Heliotrope	OBL	Native	4	N	G5 SNR
Heterotheca villosa	Hairy False Goldenaster		Native	3	N	G5 SNR
Hippuris vulgaris	Common Mare's-tail	OBL	Native	6	N	G5 SNR
Hordeum jubatum	Foxtail Barley	FACW	Native	2	N	G5 SNR
Hypericum perforatum	Common St. John's-wort	UPL	List C	0	N	GNR SNA
Iris missouriensis	Western Blue Iris	FACW	Native	4	N	G5 SNR
Iva annua	Marsh-elder		New to CO		-	-
Iva axillaris	Small-flowered Marsh-elder	FAC	Native	2	N	G5 SNR
Iva xanthifolia	Coarse Sumpweed	FAC	Native	2	N	G5 SNR
Juncus	Rush		Native		N/A	N/A
Juncus acuminatus	Sharp-fruit Rush	OBL	Native	5	W	G5 S1
Juncus arcticus var. balticus	Mountain Rush	FACW	Native	4	N	G5 SNR
Juncus compressus	Flattened Rush	FACW	Exotic	0	N	G5 SNA
Juncus dudleyi	Dudley's Rush	FACW	Native	5	N	G5 SNR
Juncus ensifolius	Three-stamen Rush	FACW	Native	6	N	G5 SNR
Juncus interior	Inland Rush	FACW	Native	5	N	G4 SNR
Juncus longistylis	Long-styled Rush	FACW	Native	6	N	G5 SNR
Juncus nevadensis	Sierra Rush	FACW	Native	7	N	G5 SNR
Juncus nodosus	Knotted Rush	OBL	Native	6	N	G5 SNR
Juncus tenuis	Slender Rush	FAC	Native	6	N	G5 SNR
Juncus torreyi	Torrey's Rush	FACW	Native	5	N	G5 SNR
Juniperus scopulorum	Rocky Mountain Juniper		Native	5	N	G5 SNR
Juniperus virginiana var. virginiana	Eastern Red-cedar		Native	4	N	G5T5 SNR
Krigia biflora	Two-flower Dwarf-dandelion	FAC	Native	7	Y	G5 S2
Lactuca serriola	Prickly Lettuce	FAC	Exotic	0	N	GNR SNA
Lactuca tatarica var. pulchella	Blue Lettuce	UPL	Native	3	N	G5T5 SNR
Lamiaceae	Family - Mint		N/A		N/A	N/A
Lathyrus lanszwertii var. leucanthus	Nevada Peavine		Native	6	N	G4G5TNR SNR
Leersia oryzoides	Rice Cutgrass	OBL	Native	5	N	G5 SNR
Lemna minor	Lesser Duckweed	OBL	Native	2	N	G5 SNR
Leonurus cardiaca	Common Motherwort		Exotic	0	N	GNR SNA
Lepidium latifolium	Broadleaf Pepper-grass	FACW	List B	0	N	GNR SNA
Liatris punctata	Dotted Gayfeather		Native	6	N	G5 SNR
Linaria dalmatica	Dalmatian Toadflax		List B	0	N	G5 SNA
Linaria vulgaris	Butter-and-eggs		List B	0	N	GNR SNA

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Linum berlandieri	Berlandier's Yellow Flax		Native	6	N	G5 S3
Linum lewisii	Prairie Flax		Native	4	N	G5 SNR
Lithospermum	Puccoon		N/A		N/A	N/A
Lobelia cardinalis	Cardinal-flower	FACW	Native	7	Y	G5 S2
Lobelia siphilitica var. ludoviciana	Great Blue Lobelia		Native	7	N	G5T5? SNR
Lolium	Fescue		Exotic	0	N/A	N/A
Lolium arundinaceum	Tall Fescue	FACU	Exotic	0	N	GNR SNA
Lonicera tatarica	Tatarian Honeysuckle	FACU	Exotic	0	N	GNR SNA
Lotus corniculatus	Garden Bird's-foot-trefoil	FACU	Exotic	0	N	GNR SNA
Lycopus americanus	American Bugleweed	OBL	Native	5	N	G5 S3
Lycopus asper	Rough Bugleweed	OBL	Native	5	N	G5 SNR
Lythrum alatum	Winged-loosestrife	OBL	Native	7	N	G5 S3
Madia glomerata	Mountain Tarweed	FACU	Native	3	N	G5 SNR
Maianthemum stellatum	Starflower Solomon's-plume	FACU	Native	7	N	G5 SNR
Medicago lupulina	Black Medic	FACU	Exotic	0	N	GNR SNA
Melilotus	Sweet-clover		Exotic	0	N/A	N/A
Melilotus albus	White Sweet-clover	FACU	Exotic	0	N	G5 SNA
Melilotus officinalis	Yellow Sweetclover	FACU	Exotic	0	N	GNR SNA
Mentha arvensis	Wild Mint	FACW	Native	4	N	G5 SNR
Mirabilis	Four O-Clock		N/A		N/A	N/A
Muhlenbergia asperifolia	Alkali Muhly	FACW	Native	4	N	G5 SNR
Muhlenbergia cuspidata	Plains Muhly		Native	6	N	G5 SNR
Muhlenbergia filiformis	Pullup Muhly	FACW	Native	8	N	G5 SNR
Muhlenbergia racemosa	Green Muhly	FACW	Native	5	N	G5 SNR
Musineon divaricatum	Wild Parsley		Native	5	N	G5 S3
Nasturtium officinale	Watercress	OBL	Exotic	0	N	GNR SNA
Nepeta cataria	Catnip	FACU	Exotic	0	N	GNR SNA
Oenothera	Evening-primrose		N/A		N/A	N/A
Oenothera biennis	Common Evening-primrose	FACU	Native	3	N	G5 SNR
Oenothera canescens	Spotted Evening-primrose	FAC	Native	4	N	G4G5 S3
Oenothera villosa	Hairy Evening-primrose	FACU	Native	4	N	G5 SNR
Onosmodium molle ssp. occidentale	Western False Gromwell		Native	5	N	G4G5T4? SNR
Opuntia	Prickly Pear		N/A		N/A	N/A
Opuntia imbricata var. imbricata	Tree Cholla		Native	4	N	G5T4T5 SNR
Oxalis	Wood sorrel		N/A		N/A	N/A
Oxybasis glauca	Oak-leaf Goosefoot	FAC	Exotic	0	N	GNR SNA
Oxybasis rubra	Red Pigweed	OBL	Native	2	N	G5 SNR
Packera	Groundsel		N/A		N/A	N/A
Packera pseudaurea var. flavula	Falsegold Groundsel		Native	7	N	G5T4 S4
Panicum	Panicgrass		N/A		N/A	N/A
Panicum capillare	Old Witch Panicgrass	FAC	Native	1	N	G5 SNR
Panicum obtusum	Blunt Panicgrass	FAC	Native	4	N	G5 SNR

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Panicum virgatum	Old Switch Panicgrass	FAC	Native	5	N	G5 SNR
Parnassia parviflora	Small-flower Grass-of-parnassus	OBL	Native	7	N	G5? SNR
Paronychia sessiliflora	Low Nailwort		Native	7	N	G5 SNR
Parthenocissus quinquefolia	Virginia Creeper	FACU	Exotic	0	N	G5 SNA
Pascopyrum smithii	Western Wheatgrass	FACU	Native	5	N	G5 SNR
Pediomelum tenuiflorum	Few-flowered Scurfpea		Native	5	N	G5 SNR
Persicaria	Lady's-thumb		N/A		N/A	N/A
Persicaria maculosa	Spotted Lady's-thumb	FACW	Exotic	0	N	G3G5 SNA
Phalaris arundinacea	Reed Canarygrass	FACW	Cryptogenic	1	N	G5 SNR
Phleum pratense	Meadow Timothy	FACU	Exotic	0	N	GNR SNA
Phragmites australis	Common Reed	FACW	Watch List	1	N	G5 SNR
Phyla cuneifolia	Wedge-leaf Fogfruit	FAC	Native	4	N	G5 SNR
Phyla lanceolata	Fogfruit	FACW	Native	1	Y	G5 S1
Physalis longifolia	Longleaf Ground-cherry		Native	4	N	GNR SNR
Plantago eriopoda	Saline Plantain	FAC	Native	5	N	G5 SNR
Plantago major	Nipple-seed Plantain	FAC	Exotic	0	N	G5 SNA
Poa	Bluegrass		N/A		N/A	N/A
Poa compressa	Canada Bluegrass	FACU	Exotic	0	N	GNR SNA
Poa palustris	Fowl Bluegrass	FACW	Native	6	N	G5 SNR
Poa pratensis	Kentucky Bluegrass	FACU	Exotic	0	N	G5 SNA
Poaceae	Family - Grass		N/A		N/A	N/A
Polygonaceae	Family - Grass		N/A		N/A	N/A
Polygonum amphibium	Water Smartweed	OBL	Native	4	N	G5 SNR
Polygonum aviculare	Prostrate Knotweed	FACU	Exotic	0	N	GNR SNA
Polygonum ramosissimum	Bushy Knotweed	FACW	Native	2	N	G5 SNR
Polypogon monspeliensis	Annual Rabbit's-foot Grass	FACW	Exotic	0	N	GNR SNA
Populus deltoides	Eastern Cottonwood	FAC	Native	4	N	G5 SNR
Portulaca oleracea	Common Purslane	FAC	Exotic	0	N	GU SNA
Potamogeton	Pondweed		N/A		N/A	N/A
Potentilla anserina	Common Silverweed	FACW	Native	3	N	G5 SNR
Potentilla hippiana	Horse Cinquefoil		Native	5	N	G5 SNR
Potentilla pensylvanica	Pennsylvania Cinquefoil	FACU	Native	6	N	G5 SNR
Potentilla plattensis	Platte River Cinquefoil	FACW	Native	7	N	G4 S3
Potentilla pulcherrima	Soft Cinquefoil	FAC	Native	5	N	G5 SNR
Potentilla recta	Sulphur Cinquefoil		List B	0	N	GNR SNA
Primula pauciflora var. pauciflora	Few-flower Shootingstar		Native	8	N	G5T5 SNR
Prunella vulgaris	Self-heal	FAC	Native	4	N	G5 SNR
Prunus americana	American Plum	UPL	Native	6	N	G5 SNR
Prunus virginiana var. melanocarpa	Choke Cherry		Native	4	N	G5T5 SNR
Puccinellia nuttalliana	Nuttall's Alkali Grass	OBL	Native	6	N	G5 SNR
Ranunculus	Buttercup		N/A		N/A	N/A

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Ranunculus aquatilis var. diffusus	Whitewater Crowfoot	OBL	Native	3	N	G5T5 S4
Ranunculus cymbalaria	Seaside Crowfoot	OBL	Native	4	N	G5 SNR
Ranunculus macounii	Macoun's Buttercup	OBL	Native	7	N	G5 SNR
Ranunculus sceleratus var. multifidus	Cursed Crowfoot		Native	1	N	G5T5 SNR
Ratibida columnifera	Upright Prairie Coneflower		Native	4	N	G5 SNR
Ratibida tagetes	Short-ray Prairie Coneflower		Native	4	N	G4G5 SNR
Rhamnus cathartica	Buckthorn	FACU	Exotic	0	N	GNR SNA
Rhus trilobata	Skunkbush		Native	5	N	G5 SNR
Ribes	Currant		N/A		N/A	N/A
Ribes aureum	Golden Currant	FACU	Native	6	N	G5 SNR
Ribes inerme	White-stem Gooseberry	FACW	Native	5	N	G5 SNR
Ribes lacustre	Bristly Black Currant	FACW	Native	7	N	G5 SNR
Rorippa	Yellowcress		N/A		N/A	N/A
Rorippa palustris	Bog Yellowcress	OBL	Native	4	N	G5 SNR
Rorippa sinuata	Spreading Yellowcress	FACW	Native	4	N	G5 SNR
Rosa acicularis ssp. sayi	Prickly Rose		Native	5	N	G5T5 SNR
Rosa arkansana	Prairie Rose	FACU	Native	5	N	G5 SNR
Rosa woodsii	Woods' Rose	FACU	Native	5	N	G5 SNR
Rudbeckia hirta var. pulcherrima	Black-eyed Susan		Native	6	N	G5T5 SNR
Rumex	Dock		N/A		N/A	N/A
Rumex crispus	Curly Dock	FAC	Exotic	0	N	GNR SNA
Ruppia cirrhosa	Widgeon-grass	OBL	Native	5	N	G5 SNR
Sagittaria	Arrowhead	OBL	Native		N/A	N/A
Sagittaria cuneata	Wapatum Arrowhead	OBL	Native	6	N	G5 SNR
Sagittaria latifolia	Broadleaf Arrowhead	OBL	Native	5	N	G5 SNR
Salicornia rubra	Red Glasswort	OBL	Native	4	N	G5 SNR
Salix	Willow		N/A		N/A	N/A
Salix amygdaloides	Peachleaf Willow	FACW	Native	5	N	G5 SNR
Salix bebbiana	Bebb's Willow	FACW	Native	6	N	G5 SNR
Salix eriocephala	Missouri River Willow	FACW	Native	6	-	-
Salix exigua	Narrowleaf Willow	FACW	Native	3	N	G5 SNR
Salsola collina	Slender Russian-thistle		Exotic	0	N	GNR SNA
Salsola kali ssp. tragus	Russian-thistle		Exotic	0	N	GNRTNR SNA
Sarcobatus vermiculatus	Greasewood	FAC	Native	4	N	G5 SNR
Schedonorus pratensis	Meadow Fescue	FACU	Exotic	0	N	G5 SNA
Schoenoplectus acutus	Hardstem Bulrush	OBL	Native	3	N	G5 SNR
Schoenoplectus pungens	Three-square Bulrush	OBL	Native	4	N	G5 SNR
Schoenoplectus tabernaemontani	Softstem Bulrush	OBL	Native	3	N	G5 SNR
Scirpus microcarpus	Small-fruit Bulrush	OBL	Native	5	N	G5 SNR
Scirpus pallidus	Pale Bulrush	OBL	Native	5	N	G5 SNR
Scutellaria galericulata	Hooded Skullcap	OBL	Native	7	N	G5 SNR

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Scutellaria lateriflora	Mad-dog Skullcap	FACW	Native	10	Y	G5 S1
Sesuvium verrucosum	Winged Sea-purslane	FACW	Native	6	N	G5 S3
Setaria pumila	Yellow Bristle Grass	FACU	Exotic	0	N	GNR SNA
Sisymbrium altissimum	Tall Tumble-mustard	FACU	Exotic	0	N	GNR SNA
Sisyrinchium	Blue-eyed-grass		Native		N/A	N/A
Sisyrinchium demissum	Stiff Blue-eyed-grass	OBL	Native	7	Y	G5 S2
Sisyrinchium idahoense var. occidentale	Idaho Blue-eyed-grass	OBL	Native	7	N	G5T3T5 SNR
Sisyrinchium montanum var. montanum	Strict Blue-eyed-grass	FAC	Native	6	N	G5T5 SNR
Solanum rostratum	Buffalo Bur		Native	2	N	G5? S4
Solidago	Goldenrod		Native		N/A	N/A
Solidago altissima	Tall Goldenrod	FACU	Native	0	N	G5 SNR
Solidago gigantea	Smooth Goldenrod	FAC	Native	6	N	G5 SNR
Solidago missouriensis	Missouri Goldenrod		Native	5	N	G5 SNR
Sonchus	Sowthistle		Exotic	0	N/A	N/A
Sonchus arvensis	Field Sowthistle	FAC	List C	0	N	GNR SNA
Sonchus asper	Spiny-leaf Sowthistle	FAC	Exotic	0	N	GNR SNA
Sparganium eurycarpum	Broad-fruited Bur-reed	OBL	Native	6	Y	G5 S2
Spartina pectinata	Fresh Water Cordgrass	FACW	Native	7	N	G5 SNR
Spergularia rubra	Purple Sandspurry	FACU	Exotic	0	N	G5 SNA
Sphaeralcea angustifolia	Narrowleaf Globemallow		Native	5	N	G5 SNR
Sphaerophysa salsula	Bladder-vetch	FACU	Watch List	0	N	GNR SNA
Sphenopholis obtusata	Prairie Wedgegrass	FAC	Native	5	N	G5 S3
Spirodela polyrhiza	Common Water-flaxseed	OBL	Native	6	N	G5 S3
Sporobolus	Sacaton		N/A		N/A	N/A
Sporobolus airoides	Alkali Sacaton	FAC	Native	5	N	G5 SNR
Stachys pilosa	Hairy Hedge-nettle	FACW	Native	6	N	G5 SNR
Stellaria	Starwort		N/A		N/A	N/A
Suaeda calceoliformis	American Sea-blite	FACW	Native	3	N	G5 SNR
Suaeda moquinii	Shrubby Seepweed	OBL	Native	3	N	G5 SNR
Symphoricarpos occidentalis	Northern Snowberry	UPL	Native	3	N	G5 SNR
Symphyotrichum	Aster		N/A		N/A	N/A
Symphyotrichum ×amethystinum	Amethyst aster		Native		-	-
Symphyotrichum ciliatum	Alkali American-aster	FACW	Native	7	N	G5 SNR
Symphyotrichum ericoides	White Heath Aster	FACU	Native	4	N	G5 SNR
Symphyotrichum falcatum	White Prairie Aster	FACU	Native	4	N	G5 SNR
Symphyotrichum lanceolatum var. hesperium	Siskiyou Aster		Native	5	N	G5T5 SNR
Tamarix chinensis	Chinese Tamarisk	FACW	List B	0	N	GNR SNA
Taraxacum officinale	Common Dandelion	FACU	Exotic	0	N	G5 SNA
Teucrium canadense var. occidentale	American Germander		Native	3	N	G5T5? SNR
Thermopsis rhombifolia	Roundleaf Thermopsis	UPL	Native	5	N	G5 SNR
Thinopyrum elongatum	Rush Wheatgrass		Exotic	0	N	GNR SNA

Scientific Name	Common Name	Wetland Status	Native Status	C-Value	CNHP Tracked	CO Rank
Thinopyrum intermedium	Intermediate Wheatgrass		Exotic	0	N	GNR SNA
Thlaspi arvense	Field Pennycress	FACU	Exotic	0	N	GNR SNA
Torreyochloa pallida	Pale Manna Grass	OBL	Native	5	N	G5 SNR
Toxicodendron rydbergii	Northern Poison-oak	FACU	Native	3	N	G5 SNR
Tragopogon dubius	Meadow Goat's-beard		Exotic	0	N	GNR SNA
Trifolium fragiferum	Strawberry-head Clover	FAC	Exotic	0	N	GNR SNA
Trifolium pratense	Red Clover	FACU	Exotic	0	N	GNR SNA
Trifolium repens	White Clover	FACU	Exotic	0	N	GNR SNA
Triglochin maritima	Common Bog Arrow-grass	OBL	Native	6	N	G5 SNR
Triglochin palustris	Slender Bog Arrow-grass	OBL	Native	7	N	G5 SNR
Typha angustifolia	Narrowleaf Cattail	OBL	Cryptogenic	1	N	G5 SNR
Typha domingensis	Southern Cattail	OBL	Native	4	N	G4G5 SNR
Typha latifolia	Broadleaf Cattail	OBL	Native	4	N	G5 SNR
Unknown aquatic	Unknown aquatic		N/A		N/A	N/A
Unknown forb	Unknown forb		N/A		N/A	N/A
Unknown graminoid	Unknown graminoid		N/A		N/A	N/A
Unknown woody	Unknown woody		N/A		N/A	N/A
Urtica dioica	Stinging Nettle	FAC	Native	3	N	G5 SNR
Utricularia minor	Lesser Bladderwort	OBL	Native	9	W	G5 S3
Valeriana edulis	Hairy Valerian	FAC	Native	7	N	G5 SNR
Verbascum thapsus	Common Mullein	UPL	List C	0	N	GNR SNA
Verbena bracteata	Large-bract Vervain	FACU	Native	2	N	G5 SNR
Verbena hastata	Blue Vervain	FACW	Native	4	N	G5 SNR
Verbena stricta	Hoary Vervain		Native	3	N	G5 SNR
Veronica anagallis-aquatica	Brook-pimpernel	OBL	Native	1	N	G5 SNR
Vicia americana ssp. minor	American Purple Vetch		Native	5	N	G5T5 SNR
Viola	Violet		N/A		N/A	N/A
Viola nephrophylla	Northern Bog Violet	FAC	Native	8	N	G5 SNR
Vitis riparia	Riverbank Grape	FAC	Native	5	N	G5 SNR
Xanthium strumarium	Rough Cocklebur	FAC	Native	1	N	G5 S4
Zannichellia palustris	Horned Pondweed	OBL	Native	2	N	G5 SNR

APPENDIX F. LIST OF WILDLIFE DOCUMENTED IN PLAINS GDES

Scientific Name	Common Name	ESA	Sensitive Status	CNHP Tracked	CO Rank
Acronicta insularis	Cattail caterpillar			-	-
Agelaius phoeniceus	Red-winged blackbird			N	G5 S5
Ambystoma mavortium	Barred tiger salamander			N	G5 S5
Ammodramus savannarum	Grasshopper sparrow		SWAP Tier 2 / USFS	N	G5 S3S4B
Anarhynchus montanus	Mountain plover		BLM / SWAP Tier 1 / USFS	Y	G3 S2B
Anas platyrhynchos	Mallard			N	G5 S5
Anaxyrus cognatus	Great plains toad			N	G5 S4
Anaxyrus woodhousii	Woodhouse's Toad			N	G5 S5
Apalone spinifera	Spiny softshell turtle			N	G5 S4
Araneidae	Banded garden spider			-	-
Ardea herodias	Great blue heron			N	G5 S3B
Argynnis idalia	Regal fritillary		SWAP Tier 2 / USFS	Y	G3 S1
Aspidoscelis sexlineatus	Six-lined racerunner			N	G5 S5
Aspidoscelis sexlineatus viridis	Six-lined racerunner			G5	G5 S5
Athene cunicularia	Burrowing owl		BLM / SWAP Tier 1/ USFS	W	G4 S4B
Boloria myrina	Silver bordered-fritilliary			-	-
Botaurus lentiginosus	American bittern		SWAP Tier 2	N	G5 S3S4B
Burnsius communis	Checkered skipper			-	-
Buteo jamaicensis	Red-tailed hawk			N	G5 S5B,S5N
Buteo swainsoni	Swainson's hawk		SWAP Tier 2	N	G5 S5B
Canis latrans	Coyote			-	-
Carabideae	Tiger beetle			-	-
Cardinalis cardinalis	Northern cardinal			N	G5 SNA
Charadrius vociferus	Killdeer			N	G5 S5
Chelydra serpentina	Common snapping turtle			-	-
Chondestes grammacus	Lark sparrow			N	G5 S4
Chordeiles minor	Common nighthawk			N	G5 S5
Chrysemys picta bellii	Western painted turtle			N	T5 S5
Circus hudsonius	Northern harrier		SWAP Tier 2/ USFS	W	G5 S3B
Colaptes auratus	Northern flicker			N	G5 S5
Colinus virginianus	Northern bobwhite		SWAP Tier 2	N	G4 S4
Contopus sordidulus	Western wood-pewee			N	G5 S5
Corbicula fluminea	Asiatic clam			N	G5 SNA
Cynomys sp.	Prairie dog			-	-
Danaus plexippus	Monarch	PT	BLM / SWAP Tier 2 / USFS	N	G4 S5
Dasymutilla sp.	Velvet ant			-	-
Dryobates scalaris	Ladder-backed woodpecker			N	G5 S3

Scientific Name	Common Name	ESA	Sensitive Status	CNHP Tracked	CO Rank
Eleodes sp.	Darkling beetle			-	-
Eremophila alpestris	Horned lark			N	G5 S5B
Falco sparverius	American kestrel			N	G5 S5B
Fundulus kansae	Plains killifish			N	G5 S5
Gallinago delicata	Wilson's snipe			N	G5 S5
Geothlypis trichas	Common yellowthroat			N	G5 S4B
Himantopus mexicanus	Black-necked stilt			N	G5 S3B
Hirundo rustica	Barn swallow			N	G5 S5
Holbrookia maculata	Lesser earless lizard			N	G5 S5
Hymenoptera sp.	European honeybee			-	-
Icteria virens	Yellow-breasted chat			N	G5 S4B
Icterus bullockii	Bullock's Oriole			N	G5 S5
Icterus spurius	Orchard oriole			N	G5 S4B
Lanius ludovicianus	Loggerhead shrike		BLM / SWAP Tier 2 / USFS	N	G4 S3S4B
Laterallus jamaicensis	Black rail	LT		Y	G3 S1B
Lepomis cyanellus	Green sunfish			N	G5 S5
Lepomis macrochirus	Bluegill			N	G5 SNA
Lepus californicus	Black-tailed jackrabbit			N	G5 S5
Lithobates blairi	Plains leopard frog		BLM / SWAP Tier 2 / USFS	Y	G5 S3
Lithobates catesbeianus	American bullfrog			N	G5 SNA
Lithobates pipiens	Northern leopard frog		BLM / SWAP Tier 1 / USFS	Y	G5 S3
Lithobates sp.	Leopard frog sp.			-	-
Melanerpes erythrocephalus	Red-headed Woodpecker			N	G5 S3B
Meleagris gallopavo	Wild turkey			N	G5 S5
Melospiza melodia	Song sparrow			N	G5 S5
Mimus polyglottos	Northern mockingbird			N	G5 S5
Molothrus ater	Brown-headed cowbird			N	G5 S5
Mutillidae sp.	Velvet ant			-	-
Numenius americanus	Long-billed curlew		BLM / SWAP Tier 2 / USFS	Y	G4 S2B
Odocoileus hemionus	Mule deer			N	G5 S4
Odocoileus virginianus	White tailed deer			-	-
Ondatra zibethicus	Muskrat			N	G5 S5
Order - Diptera	Cranefly larvae			-	-
Papilio polyxenes	Black swallowtail butterfly			-	-
Passerina caerulea	Blue grosbeak			N	G5 S4B
Petrochelidon pyrrhonota	Cliff swallow			N	G5 S5B
Peucaea cassinii	Cassin's sparrow		SWAP Tier 2 / USFS	W	G5 S4B
Phasmatodea	Stick insect			-	-
Phrynosoma hernandesi	Hernandez’s short-horned lizard			W	G5 S5
Phyciodes pulchella	Field crescent			N	G5 S5
Pica hudsonia	Black-billed magpie			N	G5 S5

Scientific Name	Common Name	ESA	Sensitive Status	CNHP Tracked	CO Rank
Pieris rapae	Cabbage white butterfly			-	-
Pipilo maculatus	Spotted towhee			N	G5 S5
Pituophis catenifer sayi	Bullsnake			N	T5 S5
Plebejus melissa	Melissa blue			N	G4 S5
Plegadis chihi	White-faced ibis		BLM / SWAP Tier 2	Y	G5 S2B
Pompilidae	Tarantula hawk wasp			-	-
Pseudacris maculata	Boreal chorus frog			N	G5 S5
Pyrrharctia isabella	Isabella tiger moth			N	G5 SNR
Quiscalus sp.	Grackle			-	-
Rallus limicola	Virginia rail			N	G5 S4B
Recurvirostra americana	American avocet			N	G5 S4B,S4N
Salmonidae	Trout			-	-
Salpinctes obsoletus	Rock wren			N	G5 S4
Sayornis saya	Say's phoebe			N	G5 S5B
Sceloporus consobrinus	Prairie lizard			N	G5 S5
Semotilus atromaculatus	Creek chub			N	G5 S5
Spinus psaltria	Lesser goldfinch			N	G5 S4B
Spinus tristis	American goldfinch			N	G5 S5
Spiza americana	Dickcissel			N	G5 S3B
Sturnella neglecta	Western meadowlark			N	G5 S5
Sturnus vulgaris	European starling			N	G5 SNA
Terrapene ornata ornata	Ornate box turtle			N	T4 S4
Tetraopes tetrophthalmus	Red milkweed beetle			-	-
Thamnophis elegans	Western terrestrial gartersnake			-	-
Thamnophis radix	Plains gartersnake			N	G5 S5
Thamnophis sp.	Gartersnake			-	-
Tringa solitaria	Solitary sandpiper			N	G5 S4N
Troglodytes aedon	House wren			N	G5 S5
Turdus migratorius	American robin			N	G5 S5
Tyrannus tyrannus	Eastern kingbird			N	G5 S5B
Tyrannus verticalis	Western kingbird			N	G5 S5B
Tyrannus vociferans	Cassin's kingbird			N	G5 S4B
Xanthocephalus xanthocephalus	Yellow-headed blackbird			N	G5 S5
Zenaida macroura	Mourning dove			N	G5 S5