Hydric soil field indicators in interdunal wetlands of the Great Bend Sand Plains

by

Sydney Love

B.S., Langton University, 2024

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2026

Approved by:

Major Professor
Dr. Colby Moorberg, PhD, CPSS, PWS

Copyright

Abstract

Interdunal wetlands form in low-lying depressions between sand dunes and provide important ecosystem services, but challenges in identifying Field Indicators of Hydric Soils (FIHS) may limit their recognition in wetland delineation and conservation. This study evaluated FIHS expression across interdunal wetlands of the Great Bend Sand Plains (MLRA 79) in south-central Kansas and applied the Hydric Soil Technical Standard (HSTS) to test whether these soils are currently functioning as hydric soils. A total of 34 interdunal wetlands at the Kramer (East and West) and Pfister sites were surveyed for FIHS during 2024, with soil profiles described to 30 cm and verified using automated U.S. Army Corps of Engineers datasheets. Nine wetlands were instrumented with shallow wells, IRIS films, and dipyridyl test strips to document hydrology, anaerobic conditions, and vegetation, while precipitation normality was assessed using the Direct Antecedent Rainfall Evaluation Method (DAREM). All 34 wetlands exhibited at least one FIHS, most commonly S5 Sandy Redox, S6 Stripped Matrix, and A11 Depleted Below Dark Surface, with F3 Depleted Matrix, F6 Redox Dark Surface, and F8 Redox Depression also frequent. The study, which began in 2024, coincided with regional drought in 2022-2025, Normal precipitation amounts were observed during the spring of 2026. Despite widespread FIHS, only East Kramer's three transects met all HSTS criteria for hydrology, anaerobic conditions, and vegetation in 2026. The West Kramer and Pfister sites did not meet the HSTS despite exhibiting FIHS. This suggests FIHS at West Kramer and Pfister largely reflect a legacy of wetter conditions rather than current hydric function, plausibly linked to groundwater decline. These findings indicate FIHS are well expressed and reliable for identifying interdunal wetlands, but wetland vegetation and hydrology should be carefully examined during wetland delineations.

Table of Contents

List of Figures vii

List of Tables xi

Acknowledgements xii

Dedication xiii

Chapter 1 - Literature Review 1

Introduction 1

Overview of interdunal wetlands and their ecological significance 1

Ecological and Geographic Context 3

Description of MLRA 79 – Great Bend Sand Plains 3

Hydrology of Dune Field Wetlands 4

Overview of Quivira National Wildlife Refuge and Cheyenne Bottoms 4

Ogallala Aquifer and the Rattlesnake Creek Watershed 6

Wetland Delineation Criteria 9

Wetland definitions (USACE 1987) 9

Hydric Soils in Interdunal Wetlands 12

Sandy Soils and Field Indicators of Hydric Soil 14

Impact of Sandy Textures on Redoximorphic Feature Development 16

Impacts of Salinity and Alkalinity on Redoximorphic Feature Development 18

Salinity 18

Alkalinity 20

Field Instruments and Surveys according to the Hydric Soil Technical Standard and USACE Wetland Delineation Manual 22

USACE Wetland Delineation Manual and the Hydric Soil Technical Standard 22

Hydrophytic Vegetation Survey 25

Shallow Wells and Water Level Loggers 26

IRIS films 28

Precipitation Normality 30

Conclusion and Research Implications 32

Literature Review Bibliography ... 1
Chapter 2 - Research Chapter ... 7
Introduction ... 7
Materials and Methods ... 9
Study Site ... 9
Experimental Design ... 13
Field Indicators of Hydric Soils Survey ... 13
Applying the Hydric Soil Technical Standard ... 14
Wells ... 14
Anaerobic Soil Conditions ... 17
IRIS Films ... 17
α, α'-Dipyridyl ... 18
Hydrophytic Vegetation Survey ... 19
Direct Antecedent Rainfall Evaluation Method – DAREM ... 19
Results ... 20
Field Surveys ... 20
Application of the Hydric Soil Technical Standard ... 21
Direct Antecedent Rainfall Evaluation Method (DAREM) ... 21
Saturated Conditions ... 22
DAREM ... 25
Anaerobic Soil Conditions ... 26
IRIS Films ... 26
α,α′-Dipyridyl Test Strips ... 27
Hydrophytic Vegetation Survey ... 27
Discussion ... 28
Conclusion ... 34
Research Chapter Bibliography ... 36
Appendix A - Blank Data Sheets ... 42
Appendix B - Soil Survey Completed Data Sheets ... 45
Appendix C - IRIS Information ... 92
Appendix D - Well Data ... 94

Appendix E - WETS Tables and Weather Station Data 97
Appendix F - Vegetation Survey Data 99
Appendix G - Photos 109

List of Figures

Figure 1- Map of East Kramer ... 52
Figure 2- Map of West Kramer ... 53
Figure 3- Map of Pfister ... 54
Figure 4- Illustration of Shallow Well Instrumented with HOBO Sensor ... 58
Figure 5- Frequency of FIHS observed at surveyed interdunal wetlands of Kramer and Pfister sites. The FIHS, in alphabetical order, are A11 – Depleted Below Dark Surface, F1 – Loamy Mucky Material, F3 – Depleted Matrix, F6 – Redox Dark Surface, F8 – Redox Depression, S5 – Sandy Redox, S6 – Stripped Matrix, S7 – Dark Surface ... 62
Figure 9- East Kramer H Hydric and Upland 2026 ... 65
Figure 10- West Kramer U Hydric and Upland 2026 ... 66
Figure 11- Pfister K Hydric and Upland 2026 ... 67
Appendix Figure A.1. Hydric Soil Survey Field Sheet ... 84
Appendix Figure A.2. USACE Automated Data sheet- WETLAND DETERMINATION DATA SHEET – Great Plains Region ... 86
Appendix Figure B.1. Hydric Soil Survey Description Sheet Kramer 1 ... 87
Appendix Figure B.2. Hydric Soil Survey Description Sheet Kramer 2 ... 88
Appendix Figure B.3. Hydric Soil Survey Description Sheet Kramer 3 ... 89
Appendix Figure B.4. Hydric Soil Survey Description Sheet Kramer 4 ... 90
Appendix Figure B.5. Hydric Soil Survey Description Sheet Kramer 5 ... 91
Appendix Figure B.6. Hydric Soil Survey Description Sheet Kramer 6 ... 92
Appendix Figure B.7. Hydric Soil Survey Description Sheet Kramer 7 ... 93
Appendix Figure B.8. Hydric Soil Survey Description Sheet Kramer 8 ... 94
Appendix Figure B.9. Hydric Soil Survey Description Sheet Kramer 9 ... 95
Appendix Figure B.10. Hydric Soil Survey Description Sheet Kramer 10 ... 96
Appendix Figure B.11. Hydric Soil Survey Description Sheet Kramer 11 ... 97
Appendix Figure B.12. Hydric Soil Survey Description Sheet Kramer 12 ... 98
Appendix Figure B.13. Hydric Soil Survey Description Sheet Kramer 13 ... 99
Appendix Figure B.14. Hydric Soil Survey Description Sheet Kramer 14 ... 100
Appendix Figure B.15. Hydric Soil Survey Description Sheet Kramer 15 ... 101

Appendix Figure B.16. Hydric Soil Survey Description Sheet Kramer 16 102
Appendix Figure B.17. Hydric Soil Survey Description Sheet Kramer 17 103
Appendix Figure B.18. Hydric Soil Survey Description Sheet Kramer 18 104
Appendix Figure B.19. Hydric Soil Survey Description Sheet Kramer 19 105
Appendix Figure B.20. Hydric Soil Survey Description Sheet Kramer 20 106
Appendix Figure B.21. Hydric Soil Survey Description Sheet Kramer 21 107
Appendix Figure B.22. Hydric Soil Survey Description Sheet Kramer 22 108
Appendix Figure B.23. Hydric Soil Survey Description Sheet Kramer 23 109
Appendix Figure B.24. Hydric Soil Survey Description Sheet Kramer 24 110
Appendix Figure B.25. Hydric Soil Survey Description Sheet Kramer 25 111
Appendix Figure B.26. Hydric Soil Survey Description Sheet Kramer 26 112
Appendix Figure B.27. Hydric Soil Survey Description Sheet Kramer 27 113
Appendix Figure B.28. Hydric Soil Survey Description Sheet Pfister 1 114
Appendix Figure B.29. Hydric Soil Survey Description Sheet Pfister 2 115
Appendix Figure B.30. Hydric Soil Survey Description Sheet Pfister 3 116
Appendix Figure B.31. Hydric Soil Survey Description Sheet Pfister 4 117
Appendix Figure B.32. Hydric Soil Survey Description Sheet Pfister 5 118
Appendix Figure B.33. Hydric Soil Survey Description Sheet Pfister 6 119
Appendix Figure B.34. Hydric Soil Survey Description Sheet Pfister 7 120
Appendix Figure B.35. Hydric Soil Survey Description Sheet Bengston 1 121
Appendix Figure B.36. Hydric Soil Survey Description Sheet Bengston 2 122
Appendix Figure B.37. Hydric Soil Survey Description Sheet Bengston 3 123
Appendix Figure B.38. Hydric Soil Survey Description Sheet Bengston 4 124
Appendix Figure B.39. Hydric Soil Survey Description Sheet Bengston 5 125
Appendix Figure B.40. Hydric Soil Survey Description Sheet Bengston 6 126
Appendix Figure B.41. Hydric Soil Survey Description Sheet Bengston 7 127
Appendix Figure B.42. Hydric Soil Survey Description Sheet Bengston 8 128
Appendix Figure B.43. Hydric Soil Survey Description Sheet Bengston 9 129
Appendix Figure B.44. Hydric Soil Survey Description Sheet Bengston 10 130
Appendix Figure B.45. Hydric Soil Survey Description Sheet Bengston 11 131
Appendix Figure B.46. Hydric Soil Survey Description Sheet Bengston 12 132

Appendix Figure C.1. Total Number of Analyzed Films 133
Appendix Figure C.2. Hydric locations meeting the anaerobic conditions standard (at least one film with 30% or more Fe removal in a contiguous 15-cm window), by deployment round. "Met standard" reflects whether any analyzed film at that location, in that round, reached the threshold. Films analyzed is shown out of 5 expected; shortfalls are due to unrecovered films (2026 East Kramer and Pfister rounds) or confirmed animal disturbance (West Kramer V, round 2, excluded and marked N/A since no films were analyzed as a result of being unaccounted for). 133
Appendix Figure D.1. East Kramer E Hydric and Upland 2026 135
Appendix Figure D.2. East Kramer P Hydric and Upland 2026 135
Appendix Figure D.3. West Kramer V Hydric and Upland 2026 136
Appendix Figure D.4. West Kramer X Hydric and Upland 2026 136
Appendix Figure D.5. Pfister B Hydric and Upland 2026........ 137
Appendix Figure D.6. Pfister D Hydric and Upland 2026 137
Appendix Figure E.1. Hudson Weather Station Monthly Precipitation in 2024 with WETS table 30th and 70th percentile ranges 138
Appendix Figure E.2. Hudson Weather Station Monthly Precipitation in 2025 with WETS table 30th and 70th percentile ranges 138
Appendix Figure E.3. Sterling Weather Station Monthly Precipitation in 2024 with WETS table 30th and 70th percentile ranges 138
Appendix Figure E.4. Sterling Weather Station Monthly Precipitation in 2025 with WETS table 30th and 70th percentile ranges 139
Appendix Figure F.1. East Kramer E Hydrophytic Vegetation Survey (2025)........ 140
Appendix Figure F.2. East Kramer E Hydrophytic Vegetation Survey (2026)........ 140
Appendix Figure F.3. East Kramer H Hydrophytic Vegetation Survey (2025) 141
Appendix Figure F.4. East Kramer H Hydrophytic Vegetation Survey (2026) 141
Appendix Figure F.5. East Kramer P Hydrophytic Vegetation Survey (2025)........ 142
Appendix Figure F.6. East Kramer P Hydrophytic Vegetation Survey (2026)........ 142
Appendix Figure F.7. West Kramer U Hydrophytic Vegetation Survey (2025)........ 143
Appendix Figure F.8. West Kramer U Hydrophytic Vegetation Survey (2026)........ 143
Appendix Figure F.9. West Kramer V Hydrophytic Vegetation Survey (2025)........ 144

Appendix Figure F.10. West Kramer V Hydrophytic Vegetation Survey (2026) 144
Appendix Figure F.11. West Kramer X Hydrophytic Vegetation Survey (2025) 145
Appendix Figure F.12. West Kramer X Hydrophytic Vegetation Survey (2026) 145
Appendix Figure F.13. Pfister B Hydrophytic Vegetation Survey (2025) 146
Appendix Figure F.14. Pfister B Hydrophytic Vegetation Survey (2026) 146
Appendix Figure F.15. Pfister D Hydrophytic Vegetation Survey (2025) 147
Appendix Figure F.16. Pfister D Hydrophytic Vegetation Survey (2026) 147
Appendix Figure F.17. Pfister K Hydrophytic Vegetation Survey (2025) 148
Appendix Figure F.18. Pfister K Hydrophytic Vegetation Survey (2026) 148
Appendix Figure G.1. East Kramer E α,α′-dipyridyl dye test results. 149
Appendix Figure G.2. East Kramer H α,α′-dipyridyl dye test results. 150
Appendix Figure G.3. East Kramer P α,α′-dipyridyl dye test results. 151
Appendix Figure G.4. West Kramer U α,α′-dipyridyl dye test results. 152
Appendix Figure G.5. West Kramer V α,α′-dipyridyl dye test results. 153
Appendix Figure G.6. West Kramer X α,α′-dipyridyl dye test results. 154
Appendix Figure G.7. Pfister B α,α′-dipyridyl dye test results. 155
Appendix Figure G.8. Pfister D α,α′-dipyridyl dye test results. 156
Appendix Figure G.9. Pfister K α,α′-dipyridyl dye test results. 157

List of Tables

Table 1- Hudson Weather Station Monthly Precipitation in 2026 with WETS table 30th and 70th percentile ranges (June data not recorded, but consistently dry March-May) 63

Table 2- Sterling Weather Station Monthly Precipitation in 2026 with WETS table 30th and 70th percentile ranges 63

Table 3- DAREM scoring for East Kramer. Sum = 13, consistent with Normal rainfall classification (6- 9 = drier than normal, 10- 14 = normal, 15- 18 = wetter than normal)..... 68

Table 4- Summary Table of the hydrologic zones of East Kramer, West Kramer, and Pfister that had Hydrophytic Vegetation 70

Acknowledgements

I would like to thank Dr. Wiley for encouraging me to participate in the 2024 KSRE Fellows Program. This program inspired me to pursue my degree at Kansas State University. I am extremely grateful to my professor Dr. Colby Moorberg for his support, mentorship, and patience during my time spent here. I am extremely grateful to my lab mates and office mates who encouraged me to pursue the best version of myself. I would also like to thank the Kansas State University MANRRS chapter for the multitude of opportunities it provided to my overall professional development.

Dedication

To my Parents, siblings, and friends for their unwavering support throughout my graduate journey.

Chapter 1 - Literature Review

Introduction

Interdunal wetlands are wetlands that form shallow depressions between sand dunes. Here, I examine the scientific understanding of these unique wetlands with a specific focus on the use and limitations of hydric soil field indicators for delineating interdunal wetlands in the Great Bend Sand Plains Major Land Resource Area (MLRA) 79 in south-central Kansas. The following sections will include an overview of the ecological importance of interdunal wetlands and unique considerations for wetland delineation, field indicators of hydric soils (FIHS), and the hydric soil technical standard.

Overview of interdunal wetlands and their ecological significance

Interdunal wetlands provide several ecosystem services, including providing habitat for plants and animals as well as groundwater recharge (Wurster et al., 2003). Based on the Hydrogeomorphic Model (HGM) approach to wetland classification from Smtih et al. (1995), interdunal wetlands are categorized as depressional wetlands and ephemeral wetlands. Smith et al. stated that depressional wetlands are low-lying areas where water collects because the land is shaped like a bowl with no outflow for runoff losses. Ephemeral wetlands are seasonal, often only exhibiting ponding during the wettest months of the year. Rain, shallow groundwater, and water flowing from nearby higher ground are the main sources of water. Some depressional wetlands have streams or channels that bring water in or let water out, but most lack defined channels. Smith et al. also stated that water losses occur either by flowing out an outlet, percolating into the ground contributing to groundwater recharge, or through evapotranspiration. Water levels in these wetlands tend to vary throughout the year, mostly depending on the season.

According to Chow et al. (2016), ephemeral wetlands are seasonally ponded and are sometimes referred to as vernal pools. Chow et al. states that, despite drying out, ephemeral wetlands still serve important ecosystem services, including storing rainwater and floodwater, filtering out pollutants, recharging underground water sources, and providing habitat. Wetlands have experienced substantial and accelerating losses in the United States according to the U.S. Fish and Wildlife Services 2019 National Wetlands Status and Trend Report by Lang et al. (2024). This decline has reduced habitat availability and ecosystem functions that support amphibians such as frogs and salamanders, reptiles, insects, wetland vegetation, and migratory waterfowl.

Together, this section highlights the importance of interdunal wetlands as dynamic and ecologically valuable systems, while emphasizing the challenges associated with identifying and protecting them. These wetlands function as depressional and ephemeral features that support biodiversity, regulate hydrology, and contribute to groundwater recharge, despite experiencing strong seasonal fluctuations in water availability. Their temporary or isolated nature often complicates wetland identification and conservation, particularly when standard indicators, such as hydric soil features, are weakly expressed or absent. Understanding how these wetlands function within their broader landscape is therefore essential for interpreting their ecological role and delineation challenges. The following section builds on this foundation by examining the ecological and geographic context of MLRA 79, providing necessary background on the landscape, soils, and geomorphic processes that influence interdunal wetland formation and behavior in the Great Bend Sand Plains.

Ecological and Geographic Context

Description of MLRA 79 – Great Bend Sand Plains

According to the USDA Natural Resources Conservation Service (NRCS), Major Land Resource Area (MLRA) 79, known as the Great Bend Sand Plains, lies in south-central Kansas and extends across the Great Bend, Wichita, and Hutchinson regions (USDA-NRCS, 2018). The NRCS describes this MLRA as encompassing major areas such as McConnell Air Force Base and the Quivira National Wildlife Refuge. The NRCS states that the Great Bend Sand Plains region formed through the combined influence of fluvial processes associated with the Arkansas River and its tributaries with subsequent eolian activity. River migration and incision created paleo terraces, which the NRCS defines as erosional remnants of former river terraces. Following terrace formation, wind-driven processes reworked sandy sediments across these surfaces, producing dune fields on the abandoned terraces. As a result, the NRCS reports that soils in MLRA 79 developed from a mixture of alluvial deposits laid down by river systems and eolian sands distributed by wind. Over time, changes in river flow, sediment supply, and climate caused older floodplains to be abandoned, allowing wind to further reshape the landscape. According to the NRCS, these geomorphic processes produced the deep, sandy to sandy loam soils that dominate MLRA 79 today and strongly influence drainage, hydrology, and ecological site development throughout the region.

Hydrology of Dune Field Wetlands

Barchyn and Hugenhotlz (2012) describe interdunal wetland hydrology as being tightly controlled by dune geomorphology and interactions with shallow groundwater. They explain that eolian dune fields consist of coarse textured sands that promote rapid infiltration and drainage, while interdunal depressions function as localized zones of water accumulation. They added that dune height, spacing, and arrangement determine the depth and extent of these depressions, which in turn controls the presence and duration of shallow water tables or ponding. They note interdunal wetlands typically exhibit short and highly variable hydroperiods rather than prolonged inundation.

Neff et al. (2020) emphasized the role of groundwater dynamics in controlling the hydropedology of interdunal wetlands. It is explained that groundwater flow in dune field landscapes often moves indirectly from upland to lowlands, with discharge occurring at breaks in slope rather than uniformly across the landscape. Neff and colleagues state that interdunal wetlands may act as temporary groundwater discharge areas during wet periods but shift to recharge conditions as the water table declines. According to their findings, the position of the water table relative to the land surface ultimately governs wetland persistence, connectivity, and the duration of soil saturation, leading to strong seasonal variability in wetland conditions.

Overview of Quivira National Wildlife Refuge and Cheyenne Bottoms

According the U.S. Fish and Wildlife Service (FWS), Quivira National Wildlife Refuge is one of the most significant inland wetland complexes in the central Great Plains (U.S. Fish & Wildlife Service, 2024). The site is recognized under Ramsar Wetlands of International

Importance. The FWS (2024) describes the Ramsar Convention on Wetlands as the oldest modern global intergovernmental environmental agreement. It originated through negotiations throughout the 1960s driven by nations and non-governmental organizations alarmed by the accelerating loss and deterioration of wetland habitats critical to migratory waterbirds. The treaty was formally adopted in Ramsar, Iran in 1971 and entered into force four years later. The FWS (2024) states that the Convention is guided by a mission centered on the conservation and wise use of wetlands worldwide, achieved through action at the local, national, and international levels as part of a broader commitment to sustainable global development. Member countries have the authority to nominate sites as "Wetlands of International Importance", also known as Ramsar Sites, which receive formal recognition and protection based on their ecological rarity, uniqueness, or significance for biodiversity conservation. In the five decades since the Convention's founding, more than 2,400 such sites have been designated across the globe.

The Ramsar Sites Information Services (2002) reports that Quivira National Wildlife Refuge encompasses more than 22,000 acres of inland marsh, salt flats, and sand prairies and was established in 1955 to conserve critical wetland and grassland habitats. Quivira plays a key role in the Central Flyway by providing stopover, nesting, and resting habitat for hundreds of migratory bird species. This includes waterfowl, shorebirds, and several threatened species. Shorebirds specifically rely on its unique and rare inland saltwater marshes, as it provides habitat similar to that of coastal plains (Ramsar Sites Information Services, 2002). Because of its combination of managed wetlands, inland salt marsh, and native prairie, the FWS identifies Quivira as one of the most important inland wetland conservation areas in the Great Plains. Because prairie thunderstorms deliver rainfall erratically across the landscape, Quivira and the nearby Cheyenne Bottoms Ramsar site rarely experience drought or flood conditions simultaneously, providing shorebirds with at least one suitable stopover site at nearly any point during migration (Ramsar Sites Information Services, 2002).

Cheyenne Bottoms is a 41,000 acre wetland complex located northeast of Great Bend, Kansas (The Nature Conservancy, 2026a). The Kansas Department of Wildlife and Parks (KDWP) manages the low-lying area, the Cheyenne Bottoms Wildlife Area (The Nature Conservancy, 2026a) while the adjacent upland area, the “Cheyenne Bottoms Preserve”, is managed by The Nature Conservancy (TNC). The Cheyenne Bottoms Wildlife Area has been extensively modified using the site using dikes, canals, dams, and pump stations to control water levels by diverting water from the Arkansas River and nearby streams. The KDWP explains that this infrastructure allows managers to create and maintain marsh pools that support wetland conditions. The KDWP’s primary management objective at Cheyenne Bottoms is to provide diverse freshwater marsh habitat for migratory waterfowl and shorebirds by supplying food, water, and resting areas while also supporting nesting habitat through active water and vegetation management (Kansas Department of Wildlife and Parks, 2026). Meanwhile, TNC states the upland areas in the Cheyenne Bottoms Preserve, which are mostly rangeland and cropped areas, are managed for stopover habitat for migrating shorebirds (The Nature Conservancy, 2026a).

Ogallala Aquifer and the Rattlesnake Creek Watershed

The Ogallala Aquifer plays a critical role in sustaining the broader water systems of Kansas, including the stream and wetland environments that depend on groundwater connectivity. The aquifer underlies over 100 million acres of the Great Plains. This includes the States Wyoming, South Dakota, Nebraska, Colorado, New Mexico, Texas, Oklahoma, and

Kansas where over a million people depend on it as personal and industrial water supply (Steiner et al., 2021).

In addition to use by humans, creeks and streams rely on the groundwater supplied by the Ogallala Aquifer to feed them during times of low precipitation and drought because they cannot be sustained by surface water alone. These same stream corridors and riparian zones are known to support wetland habitat across the Great Plain region (Yamazaki and Suhr Pierce, 2024). When water levels decline, this baseflow function erodes. Minimum desirable streamflow limits were established in Kansas following legislation passed in 1984, reflecting early recognition that aquifer drawdown threatened not just irrigation but the surface water systems, and by extension the wetland ecosystems tied to those streams (Steiner et al., 2021).

Kansas has developed sophisticated policy tools in its Ogallala region to slow depletion of the aquifer, and some of those efforts have direct implications for wetland-adjacent water sources. The Ogallala will become more difficult to manage as summers become hotter. This leads to increased demand for water from the aquifer, effectively exceeding its recharge rate, and creating a trajectory that puts both agricultural water supplies and wetland ecosystems that depend on a connected groundwater system under growing stress (Yamazaki and Suhr Pierce, 2024). Efforts are being made to extend the life of the aquifer and they require management strategies that account for the broader ecological connections and close collaboration between stakeholders, state and federal agencies, and universities (Taghvaeian et al., 2016).

Rattlesnake creek occupies a vulnerable position within the High Plains Aquifer system. Unlike most streams in the region, which are intermittent, Rattlesnake Creek functions as what the Kansas Geological Survey describes as effectively the “drain or overflow spillway” from the underlying aquifer, historically running as a perennial stream from just north of St. John to its bend near Little Salt Marsh (Sophocleous and McAllister, 1990a). The characteristic of being groundwater fed makes it part of the Great Bend Prairie component of the High Plains Aquifer. This distinct subregion has shallower water tables, high permeability dune sand geology, and natural recharge rates that are already smaller than withdrawal rates (Sophocleous and McAllister, 1990a; Natural Resources Conservation Service, 2025). What makes the watershed particularly unusual is the presence of Permian "red bed" formations at depth, which have no effective barrier separating them from the overlying freshwater aquifer east of Highway 281. This allows ancient saltwater bines to migrate upward and mix with the fresh groundwater that supplies the creek (Sophocleous and McAllister, 1990b; Natural Resources Conservation Service, 2025). This means that, as agricultural pumping draws down the aquifer, it does not merely reduce streamflow, but it alters the salinity balance in the creek itself since lower flows concentrate chloride loads. The lower flows upset the brackish and freshwater gradient the downstream depends on. By 2020, the modeled baseflow had already fallen dramatically from the 30-60 cubic feet per second typical in the 1940s and 1950s, and projections showed a decline to nearly 0 by 2075 if current pumping trends continue (Natural Resources Conservation Service, 2025).

The downstream consequence of Rattlesnake Creek's decline falls mostly on Quivira Wildlife Refuge, whose ecological integrity depends entirely on the creek as its primary surface water source. Quivira's salt marshes form a wetland complex that is hydrologically connected to both area groundwater and Rattlesnake Creek, and freshwater inputs from the creek are critical for moderating the naturally brackish salinity driven upward from the Permian bedrock below the refuge (Sophocleous and McAllister, 1990b; Natural Resources Conservation Service, 2025).

The Nature Conservancy explains that the water stops flowing aboveground in the creek when the aquifer drops too low and this puts the salt marshes at risk of drying up entirely (The Nature Conservancy, 2026b). Because Quivira is designated as a Ramsar Wetland of International Importance, a Globally Important Bird Area, and a Western Hemisphere Shorebird Reserve Network site, and supports a large number of migratory birds annually, the risk of habitat loss is especially detrimental (Natural Resources Conservation Service, 2025; The Nature Conservancy, 2026b). The U.S. Fish and Wildlife Service holds a senior right entitling the refuge to up to 14,632 acre–feet per year from the creek; however, state investigations confirmed this right was regularly impaired by upstream junior groundwater pumping. The impairment exceeded 3,000 acre–feet per year in 18 separate years between 1974 and 2007 alone (Natural Resources Conservation Service, 2025).

Wetland Delineation Criteria

Wetland definitions (USACE 1987)

Wetlands in the United States are afforded federal protection through two complementary regulatory frameworks: Section 404 of the Clean Water Act (CWA) and the Wetland Conservation provisions of the Food Security Act, commonly known as "Swamp buster" (US EPA, 2013, 2015). Enacted in its modern form in 1972, the CWA establishes the foundational structure for regulating discharges of pollutants into waters of the United States, prohibiting the discharge of dredged or fill material into wetlands without a permit issued through the U.S. Army Corps of Engineers. The Swamp buster provisions, added through the Food Security Act of 1985, complement this regulatory framework by withholding federal farm program benefits from producers who convert or modify wetlands for agricultural use (Glaser, 1986). Together, these programs reflect a national policy commitment to reducing wetland loss and maintaining the chemical, physical, and biological integrity of the nation's waters. The practical implementation of these protections, however, depends on the consistent and accurate identification of wetlands in the landscape. This task is carried out through standardized delineation methods developed and overseen by the USACE, USDA- NRCS, and Environmental Protection Agency (EPA).

The U.S. Army Corps of Engineers defines wetlands as areas that are inundated or have water-saturated soils frequently and for long enough periods to support vegetation adapted to wet conditions (U.S. Army Corps of Engineers, 1987). According to the USACE, wetlands typically support plant communities that tolerate low-oxygen soils and include ecosystems such as swamps, marshes, bogs, and similar environments.

Three parameter approach: hydrophytic vegetation, hydrology, hydric soils

The USACE requires delineators to evaluate three parameters when identifying wetlands: hydrophytic vegetation, hydric soils, and wetland hydrology. According to the USACE *Wetlands Delineation Manual,* a site must generally exhibit all three parameters to qualify as a wetland. This three-parameter approach provides a standardized and defensible method for wetland delineation across a wide range of environmental settings.

Hydrophytic vegetation is defined by the USACE (1987) as plant communities dominated by species adapted to grow and persist in saturated, anaerobic soil conditions. In interdunal wetlands, these communities commonly include grasses, sedges, rushes, and other species that tolerate fluctuating water tables. Although plant community composition in dune systems may shift seasonally, the Michigan Natural Features Inventory (2010) explains that the dominance of wetland-adapted species indicates the presence of hydrophytic vegetation, even in environments with variable moisture regimes.

The National Technical Committee for Hydric Soils (NTCHS) defines hydric soils as soils that form under conditions of saturation, flooding, or ponding long enough during the growing season to create anaerobic conditions in the upper part of the soil profile (USDA-NRCS, 2026). In interdunal wetlands, hydric soil indicators may include gleyed soil colors, redoximorphic features, and evidence of reduced iron and manganese. These features develop as groundwater periodically intersects the soil surface in interdunal depressions. According to the USACE (1987), hydric soils provide persistent evidence of long-term wetland conditions, even when surface water is absent at the time of observation.

The USACE describes wetland hydrology as the presence of inundation or saturation at or near the soil surface either permanently or periodically during the growing season. In interdunal wetlands, hydrology is typically controlled by fluctuating groundwater levels rather than frequent surface flooding, which results in alternating wet and dry conditions. The Michigan Natural Features Inventory notes that indicators such as soil saturation, landscape position within dune depressions, and the presence of standing water during wet periods support the identification of wetland hydrology in these systems (Michigan Natural Features Inventory, 2010).

Together, the USACE wetland definition and three-parameter approach provide a comprehensive framework for identifying and delineating interdunal wetlands within MLRA 79. Rather than relying on the constant presence of surface water, this framework emphasizes the interaction among fluctuating hydrology, wetland-adapted vegetation, and soil conditions shaped by repeated saturation and anaerobic processes. While hydrophytic vegetation and wetland hydrology may vary seasonally in interdunal settings, hydric soils remain particularly valuable because they record long term hydrologic conditions and persist during dry periods. For this reason, the following section focuses more closely on hydric soils and their role in wetland delineation within interdunal wetlands of the Great Bend Sand Plains.

Hydric Soils in Interdunal Wetlands

While all soil-forming factors influence soil development, Berkowitz et al. (2021a) emphasizes that hydric soils respond most strongly to the hydrologic regime, particularly the duration and frequency of saturation. Soil redox potential decreases under sustained wet conditions, which promotes the reduction of iron and manganese. According to the National Technical Committee for Hydric Soils (USDA-NRCS, 2026), these reduction processes produce distinctive soil colors and morphological features that serve as observable evidence of long-term wetland hydrology. Typically, a duration of saturation of 14 days or longer is required for soil redox features to form.

In sandy landscapes like interdunal wetlands, the Conservation Effects Assessment Project and United States Natural Resources Conservation Service (2020) explains that hydroperiod duration is strongly influenced by soil texture, permeability, and landscape position. In the wet sub-irrigated Ecological Site Description (ESD) (USDA-NRCS, 2018), it is highlighted that these interdunal soils and the surrounding upland landscapes exhibit high infiltration rates, moderate to rapid permeability, and limited water-holding capacity, all of which promote rapid drainage following precipitation events. Further, Neff et al. (2020) stated that shifts in the regional water table can rapidly transition interdunal soils from recharge areas to discharge areas. As a result, these interdunal soils can be frequently saturated, but often for only short durations, limiting the development of anaerobic conditions. Smith et al. (1995) emphasizes that hydric soil development depends not only on the occurrence of saturation, but also on how long and how consistently saturation persists. It is explained that anaerobic conditions must be maintained long enough for microbial respiration to exhaust available oxygen and allow reduction reactions to proceed. It is added that short or infrequent saturation events may wet the soil profile but do not persist long enough to produce stable redoximorphic features. In sandy, interdunal environments, rapid drainage and reoxygenation could interrupt reduction processes, limiting the transformation and redistribution of iron needed to form diagnostic hydric soil morphology.

Smith et al.(1995) further explains that redoximorphic features reflect the cumulative effects of repeated or prolonged wetting and drying cycles rather than isolated hydrological events. When saturation persists for extended periods during the growing season, microbial activity can consistently reduce iron, allowing these features to develop and stabilize within the soil profile.

Interdunal wetlands represent a specific type of seasonally ponded, depressional wetland system that shares the foundational hydrological and pedological characteristics described for seasonally ponded soils broadly. Both perch water above a restrictive subsurface clay layer and experience seasonal fluctuations in water availability. In interdunal wetlands specifically, this hydrology is controlled by infiltration of surface water through a sandy mantle to an underlying paleo terrace high in clay that causes water to perch and move laterally (USDA-NRCS, 2025a).

Like seasonally ponded soils generally, interdunal wetlands are internally vulnerable to organic matter limitations, sediment aggradation from surrounding uplands, and the suppression of microbial activity during dry periods, all of which reduce the likelihood of redoximorphic feature development and complicate hydric soil identification (USDA-NRCS, 2025b). Additionally, interdunal wetlands can function as flow-through systems where water is gained from groundwater sources on one side and exported on the opposite side of the wetland cell, which may further limit the residence time of reduced iron in the profile and reduce the opportunity for hydric soil morphology to develop (USDA-NRCS, 2025a).

Sandy Soils and Field Indicators of Hydric Soil

The National Technical Committee for Hydric Soils (NTCHS) developed field indicators of hydric soils to facilitate identification of hydric soils for wetland delineation (USDA-NRCS, 2026). These indicators include A-indicators for all soils, S-indicators for sandy soils, and F-indicators for fine soils. The sand indicators were developed specifically for mineral soil layers with textures of loamy fine sand or coarser (Vepraskas, 2013).

The geographic area where a given field indicator can be applied is defined using Land Resource Regions and Major Land Resource Areas (MLRA), because pedogenic processes and morphology differ with climate, parent materials, and other regional factors (Berkowitz et al., 2021). The geographic framework is relevant to sandy wetland systems because the applicability of any given S-indicator is not universal, and the NTCHS acknowledges that some hydric soils lack an approved field indicator entirely as stated by Berkowitz et al (2021). As Vepraskas (2013) notes, some field indicators can be used nationwide, while others are restricted to certain regions. Current NTCHS guidance also states that if a soil fails to meet at least one field indicator, that site could still contain a hydric soil, but does not have a currently recognized field indicator.

There are 11 S-indicators included in the Field Indicators of Hydric Soils in the United States (USDA-NRCS, 2026). Many S-indicators include strict depth requirements, often requiring that features occur within 15 cm (6 inches) of the soil surface, and some specify minimum thicknesses or percentages of redox concentrations (Vepraskas, 2013). The USDA-NRCS (2026) explains these criteria reflect the expectation that hydric soil processes in sandy soils are typically confined to shallow depths due to having a thinner capillary fringe than finer textured soils. However, because sandy soils drain rapidly and reoxygenate quickly, the redox features used to meet these indicators are often weak, discontinuous, or difficult to observe during field evaluations.

The USDA-NRCS (2026) further notes that the inherently subtle nature of redox expression in sands complicates the application of S-indicators. Sandy soils generally contain fewer iron oxide coatings and lower organic matter content, which limits the amount of reducible material available to form visible redoximorphic features (Vepraskas et al., 2002; Vepraskas, 2013). In addition, redox concentrations in sandy soil often appear as faint pore linings or diffuse masses that may only become visible after partial drying. When investigators observe soils while they are fully saturated, reduced iron may remain in solution, and redox features may not yet be apparent, increasing the risk of misclassification.

The USDA-NRCS (2025b) cautions that misapplication of S-indicators can occur when investigators evaluate sandy soils using criteria intended for loamy or clayey soils or when they expect strong redox patterns characteristic of F indicators. Loamy and clayey soils retain water longer, restrict oxygen diffusion, and sustain anaerobic conditions that promote pronounced redox depletions and concentrations (Vepraskas et al., 2002; Vepraskas, 2013). In contrast, sandy soils often meet hydric conditions through frequent but short-duration saturation events that do not consistently produce strong morphological signatures (Vepraskas et al., 2002). The USDA-NRCS(2025b) explicitly acknowledges that, under these conditions, hydric soils in sandy landscapes may fail to meet any approved indicator despite functioning hydrologically as wetlands.

Overall, the NRCS emphasizes that S-indicators are more difficult to apply than indicators for finer-textured soils because they rely on subtle and sometimes transient features that require careful observation and experience to interpret accurately (Vepraskas, 2013). These challenges are especially pronounced in interdunal wetlands, where sandy parent materials, fluctuating water tables, and rapid drainage limit the persistence and visibility of redoximorphic features (Vepraskas et al., 2002). Understanding both the intent and limitations of sandy soil indicators is essential for accurate wetland delineation and for interpreting apparent indicator failure in sandy wetland systems.

Impact of Sandy Textures on Redoximorphic Feature Development

Within MLRA 79, the specific sites of interest; Pfister, Kramer East, and Kramer West, fall within the Wet Sub-irrigated Ecological Site Description (USDA-NRCS, 2018). The Wet Sub-irrigated ecological site is characterized by poorly drained soils with a seasonal or perennial high water table occurring within two feet of the surface, which typically results in ponding or flooding on site. This site is located on floodplains and interdunes and occurs on level to nearly-level eolian and alluvial lands, usually adjacent to major streams. The influencing water features on this ecological site include a seasonal or perennial water table that occurs less than two feet from the surface, which governs the kinds and amounts of vegetation present and distinguishes the site from other ecological sites in the MLRA.

The soils of this ecological site are characterized as deep and loamy, and formed in alluvium or eolian deposits over alluvium (USDA-NRCS, 2018). The interdunal depressions in which the study sites are situated form as low-lying topographic positions between stabilized sand dunes, where runoff from precipitation events accumulates and groundwater influence maintains consistently elevated soil moisture conditions throughout much of the year.

According to Vepraskas et al. (2018), redoximorphic features form through predictable biogeochemical reactions that occur when soils become saturated and oxygen is depleted. They describe how microbial respiration rapidly consumes oxygen in water-filled pores, forcing microorganisms to sequentially use alternative electron acceptors under highly reduced conditions in a well-defined order. Oxygen (O_2) is reduced first, followed by nitrate (NO_3^-), manganese oxides (Mn^{4+}), iron oxides (Fe^{3+}), sulfate (SO_4^{2-}), and finally carbon dioxide (CO_2). It is emphasized that the reduction of manganese and iron is especially important for hydric soil identification because these reactions produce visible redoximorphic features, such as iron depletions and concentrations, which serve as Field Indicators of Hydric Soils.

Vepraskas et al. (2018) also notes that the expression of redoximorphic features depends strongly on soil texture and physical structure. In fine-textured soils, small pore sizes slow drainage and restrict oxygen diffusion, allowing anaerobic conditions to persist long enough for iron and manganese reduction to occur repeatedly. It is further explained that fine-textured soils typically contain higher organic matter content and more iron oxide coatings, which support microbial activity and provide sufficient reducible iron to form distinct and stable redox patterns. As a result, Vepraskas and colleagues report that fine-textured soils commonly exhibit well-developed gleyed matrices, iron depletions, and redox concentrations that are readily identified during field delineations.

Impacts of Salinity and Alkalinity on Redoximorphic Feature Development

Salinity

Salinity refers to the total content of soluble salts in the soil or their concentration in the soil solution (Tang et al., 2021). The major cations found in saline soils include Na^+, Ca^{2+}, Mg^{2+}, and K^+, while the primary anions of concern are Cl^-, SO_4^{2-}, HCO_3^-, CO_3^{2-}, and NO_3^- (Sparks et al., 2024). In arid and semiarid regions, carbonates, gypsum, and soluble salts accumulate in soils because mineral dissolution products are concentrated via the evapotranspiration of water, and salts may be derived from the dissolution of soluble salts in salt-bearing sedimentary rocks or from the evapoconcentration of the weathering products of minerals in igneous, metamorphic, or nonsaline sedimentary rocks (Boettinger, 1997).

Salt-affected soils are most found in arid and semiarid climates where evapotranspiration exceeds precipitation, preventing the leaching of soluble salts from the soil profile (USDA-NRCS, 2026). Salinity is most frequently measured using electrical conductivity (EC) of a saturated paste extract (ECe), with soils having an ECe greater than 4 dS/m classified as saline (Fidel, 2025). In saline soils, soluble salt minerals present include halite (NaCl), thenardite (Na_2SO_4), mirabalite ($Na_2SO_4 \cdot 10\ H_2O$), bloedite [$Na_2Mg(SO_4)_2 \cdot 4\ H_2O$], and other Na and Mg sulfates, carbonates, and bicarbonates (Boettinger, 1997).

Secondary salinization caused by human activities, including irrigation with poor-quality water, excessive groundwater extraction, inadequate drainage, and overuse of fertilizers, is present in approximately 20% of irrigated land worldwide and poses a major concern for global food production (Sparks et al., 2024; Tarolli et al., 2024). The effects of salinity on soils and their morphological processes are numerous. Salinity influences soil structure, limits the accumulation of soil organic matter, and restricts plant growth (Tang et al., 2021). It was found that the proportion of water-stable macroaggregates (0.25–2 mm) increased with rising salt content in both silt loam and silty clay soils. They attributed this to salt in the soil solution promoting clay flocculation, which increased cohesion among primary particles to form microaggregates (Tang et al., 2021). Tang et al. (2021) also observed that saturated hydraulic conductivity in silt loam increased alongside macroaggregate proportions, as greater macroaggregate content created larger soil pores and improved overall permeability. Beyond structural effects, salt accumulation drives key morphological soil processes: as Na^+ becomes the dominant cation in the soil solution, Ca^{2+} and Mg^{2+} may precipitate as $CaSO_4$, $CaCO_3$, and $CaMg(CO_3)_2$, causing Na^+ to replace them on the exchanger phase and progressively altering the soil's cation composition (Sparks et al., 2024).

In highly saline systems, redoximorphic features are either lacking, poorly expressed, or occur only in the lower parts of pedons, as high pH environments common in saline soils containing calcium carbonate require lower redox potentials for the reduction of Fe and Mn, and the presence of redoximorphic features may be masked by carbonates, gypsum, and soluble salts (Boettinger, 1997). Additionally, salinization results in the mobilization of soluble salts through the soil profile, which can cause land and water degradation and promote the release and solubilization of heavy metals such as Cd into solution, while leaching of salts from the root zone produces saline drainage waters that can contaminate surface and groundwater (Sparks et al., 2024)

Alkalinity

Soil alkalinity is generally defined by a pH greater than 7, though soils with pH between 7 and 8 produce limited constraints for plants; soils with pH above 8 are considered truly alkaline. Bicarbonate and carbonate ions dominate in alkaline soils with pH above 8, and these are related to carbonate alkalinity (Rengasamy et al., 2022). Very alkaline environments with pH at or above 9 develop when concentrations of bicarbonate and carbonate species in solution are higher than calcium and magnesium concentrations, with soil solutions dominated by sodium and potassium (Rengasamy et al., 2022). The specific constraints in alkaline soils with pH between 8.5 and 10 vary by pH value: bicarbonate toxicity may prevail between pH 8 and 9, while carbonate toxicity dominates above pH 9; iron deficiency may be a problem when pH is between 8 and 9, while iron toxicity can occur above pH 9; and aluminum toxicity can be a problem when soil pH increases above 9 due to the formation of soluble anionic aluminate species (Rengasamy et al., 2022). Rengasamy et al. (2022) states that with increasing pH, monovalent ions, particularly sodium, increase in soil solution while concentrations of divalent calcium and magnesium decrease, leading to high clay dispersivity and soil structural degradation, which renders subsoil susceptible to transient waterlogging and anoxic conditions. Alkaline soils also sequester less organic carbon, with high pH being responsible for increased dissolved organic carbon and reduced microbial activity.

Alkalinity poses significant challenges to the development of redoximorphic features used to identify hydric soils. High pH environments require lower redox potentials for the reduction of iron and manganese, and if chemically reduced, free ferrous iron and divalent manganese may not be chemically stable phases in alkaline soils (Boettinger, 1997; USDA-NRCS, 2025b). As a result, identifiable iron or manganese features may not readily form in saturated alkaline soils (USDA-NRCS, 2025b)

Additionally, alkalinity can be detrimental to microorganisms or can induce nutrient deficiencies, and barren or sparsely vegetated areas populated by halophytes, which are common in alkaline settings, can limit the supply of organic carbon and nitrogen to soil microorganisms, thus limiting the potential for microbial activity and chemical reduction during periods of saturation (Boettinger, 1997; USDA-NRCS, 2025b).

The presence of redoximorphic features may also be masked by carbonates, gypsum, and soluble salts (USDA-NRCS, 2025b). Boettinger (1997) further noted that Aquisalids and related wet soils did not show a positive reaction to alpha-alpha-dipyridyl regardless of season, indicating a lack of reduced iron, and that redoximorphic features in many saline-alkaline and wet desert soils are either lacking, poorly expressed, or occur only in the lower parts of the soil profile. In the absence of a recognized hydric soil indicator due to high pH, Miller et al. (2025b) recommend thoroughly documenting soil conditions including pH alongside landscape position, vegetation, and evidence of hydrology as rationale for identifying a soil as potentially hydric.

Field Instruments and Surveys according to the Hydric Soil Technical Standard and USACE Wetland Delineation Manual

USACE Wetland Delineation Manual and the Hydric Soil Technical Standard

The USACE Wetland Delineation Manual (1987) was developed by the Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station as a product of the Wetlands Research Program, with the work sponsored by the Office of the Chief of Engineers, U.S. Army. The manual was produced to provide users with guidelines and methods to determine whether an area is a wetland for purposes of Section 404 of the Clean Water Act, which authorizes the Secretary of the Army, acting through the Chief of Engineers, to issue permits for the discharge of dredged or fill material into the waters of the United States, including wetlands (U.S. Army Corps of Engineers, 2010b).

The manual describes technical guidelines and methods using a multi-parameter approach to identify and delineate wetlands, requiring positive evidence of hydrophytic vegetation, hydric soils, and wetland hydrology for a determination that an area is a wetland (U.S. Army Corps of Engineers, 2010b). Although the manual was initially approved for voluntary use for a trial period of one year, its use to identify and delineate wetlands potentially subject to regulation under Section 404 subsequently became mandatory. Because the national manual could not adequately address regional differences in climate, geology, soils, hydrology, and plant and animal communities, a series of Regional Supplements were later developed to improve the accuracy and efficiency of wetland delineation procedures. The Great Plains Regional Supplement, applicable to all or portions of 11 states including Kansas, was developed at the request of USACE leadership following National Academy of Sciences recommendations to increase the regional sensitivity of wetland delineation methods (U.S. Army Corps of Engineers, 2010b).

Despite its central role in wetland regulation, the manual and the delineation process it prescribes carry well documented limitations. The methods for determining the wetland border are not intended to result in highly detailed resolution, and wetland delineation methods establish the location of the wetland border based on experience and best professional judgment that involves the application of metrics that can be subjective in nature (Kriegner et al., 2015). Often, the difference between a soil meeting or not meeting the hydric criteria is dependent on a single shade difference on the Munsell Soil Color Chart, which is subject to field conditions at the time of the assessment and the subjectivity and experience of the delineator (Kriegner et al., 2015). Time constraints further compound these methodological issues. Field delineations are often completed within a short period of time without the benefit of long-term studies or observation of seasonal trends in hydrology and vegetative maturity that could help establish more precise wetland boundaries according to Kriegner et al. (2015). The Great Plains Regional Supplement itself acknowledges the persistence of difficult delineation situations in the region, including problematic hydric soils with faint or no indicators, wetlands that periodically lack indicators of wetland hydrology, and wetland/non-wetland mosaics that present challenges to clear boundary determination (U.S. Army Corps of Engineers, 2010b).

At the national mapping scale, a variety of factors can influence the accuracy and precision of three-factor delineations, including difficulty correctly identifying wetland plants outside of the growing season and hydrology indicators that can be unreliable in dry seasons for wetland types with intermittent or ephemeral hydrologic regimes, such as vernal pools, playas, or wet meadows (Gage et al., 2020). This is where the Hydric Soil Technical Standard (HSTS) comes into play.

The U.S. Army Corps of Engineers wetland delineation manual and its ten regional supplements serve as the operational framework for field-based wetland delineation, relying on the three-factor approach of hydric soils, hydrophytic vegetation, and wetland hydrology to establish jurisdictional wetland boundaries (Berkowitz et al., 2021b; USDA-NRCS, 2026) while the field indicators within those supplements function as readily observable, morphology-based proxies for determining hydric soil status at a given location, with the soil descriptions used in HSTS studies considered equivalent to soils data collected as part of a wetland delineation (Berkowitz et al., 2021b; USDA-NRCS, 2025c).

The HSTS, by contrast, provides the quantitative, evidence-based backbone behind those field indicators rather than relying on observable soil colors and redoximorphic features alone. The HSTS requires direct measurement of three technical criteria; anaerobic conditions, saturation within 25 cm of the soil surface for at least 14 consecutive days, and confirmation that those conditions occurred during a period of normal or drier than normal precipitation when soil microbes are active (Berkowitz et al., 2021b; USDA-NRCS, 2025c). Where the regional supplements and FIHS guide rapid field identification suitable for delineation purposes, the HSTS documents whether a soil currently functions as a hydric soil but does not address the historical conditions under which it formed, and critically, it is not designed to overrule or invalidate a hydric soil determination already supported by an approved field indicator.

The two frameworks are considered complementary. Data collected according to the HSTS are required to support any proposed additions, deletions, or changes to the field indicators themselves, with a minimum of three paired hydric and nonhydric study areas required for NTCHS consideration of any such changes (Berkowitz et al., 2021b; USDA-NRCS, 2025c), meaning the USACE regional supplements and the FIHS ultimately depend on the HSTS as the scientific mechanism by which their morphological criteria are validated, refined, and expanded over time, as explicitly stated in the data submission requirements outlined in the FIHS (USDA-NRCS, 2026) guidance for proposing indicator revisions.

Hydrophytic Vegetation Survey

Hydrophytic vegetation surveys are a required component of wetland delineation in the United States, wherein a plot is determined to be within a wetland if it meets criteria for each of three parameters: hydric soils, wetland hydrology, and hydrophytic vegetation (U.S. Army Corps of Engineers, 1987). For vegetation to be considered hydrophytic, more than 50% of the dominant vegetation must consist of wetland species, a determination made by combining abundance measurements with the wetland indicator status ratings assigned to each species present (U.S. Army Corps of Engineers, 1987; Lichvar et al., 2011). Wetland indicator status ratings are obtained from the National Wetland Plant List (NWPL) and include five categories: obligate (OBL), facultative wetland (FACW), facultative (FAC), facultative upland (FACU), and upland (UPL), with OBL, FACW, and FAC species considered hydrophytes for delineation purposes (Lichvar et al., 2011; Photos et al., 2019). Vegetation may be assessed using plots, transects, or points as sampling units, with cover and frequency being the two most common metrics used to evaluate vegetation composition and abundance (Gage et al., 2020).

The two primary methods used to make hydrophytic vegetation determinations are the Prevalence Index (PI) and the Dominance Ratio (DR); a third method, the Facultative-Neutral

Dominance Ratio (FN-DR), is also described in delineation manuals, and a fourth method, the Hydrophytic Cover Index (HCI), has been proposed by the National Technical Committee for Wetland Vegetation (Lichvar et al., 2011; Photos et al., 2019). The Prevalence Index is a weighted average calculated by summing the total percent cover of all species in each wetland indicator category across strata, multiplying each category by its assigned indicator value, and dividing by the total cover of all plant species. Plots with Prevalence Index values of 3.0 or less are considered hydrophytic (Lichvar et al., 2011; Photos et al., 2019).

The Dominance Ratio is calculated by identifying dominant species in each stratum using the 50/20 rule, tallying the number of dominant hydrophytes and total dominants across strata, and dividing the former by the latter. Plots with Dominance Ratio values greater than 50% are considered hydrophytic (Lichvar et al., 2011; Photos et al., 2019). The Facultative-Neutral Dominance Ratio is calculated in the same manner as the Dominance Ratio but omits Facultative species before tallying, dividing the number of obligate and facultative wetland dominants by the total number of obligate, facultative wetland, facultative upland, and upland dominants (Lichvar et al., 2011). The Hydrophytic Cover Index is an unweighted index calculated by summing the cover of all hydrophytic species (obligate through facultative) and dividing by the cover of all species, multiplied by 100. Plots with Hydrophytic Cover Index values greater than 50% are considered hydrophytic (Photos et al., 2019).

Shallow Wells and Water Level Loggers

The USACE emphasizes that wetland hydrology is often the least exact of the three parameters, and that indicators of wetland hydrology are sometimes difficult to find in the field (U.S. Army Corps of Engineers, 1987). Water table position varies with hydrologic zone. Areas that are inundated or saturated to the surface for as little as 5% of the growing season may qualify as wetlands, meaning that surface water may be absent for much of the year even in functioning wetland areas according to the USACE Wetland Delineation Manual.

In scenarios where standard field indicators are absent, such as in problematic or undeveloped soils, or when submitting data to NTCHS to propose additions or changes to existing hydric soil indicators, documenting soil saturation with shallow wells or piezometers may be necessary (USDA-NRCS, 2025c). Shallow wells and piezometers play a direct role in documenting wetland hydrology because saturated water flows into these instruments, providing a measurable record of water-table position within the soil profile (USDA-NRCS, 2025c).

The NTCHS requires that saturation be documented within the upper 25 cm of the soil profile for at least 14 consecutive days during a period of normal or drier than normal precipitation to meet the Hydric Soil Technical Standard (USDA-NRCS, 2025c). Saturation at these shallow depths drives the anaerobic conditions responsible for the redox processes that produce hydric soil morphological features. The HSTS requires that both saturation and measurable anaerobic conditions be documented concurrently (USDA-NRCS, 2025c).

Sprecher (2008) provides guidance on well design for documenting shallow saturation relevant to wetland regulatory studies, recommending 15 inch deep wells and noting that this depth addresses regulations implementing the Federal Clean Water Act while reducing uncertainty about bypass flow and lag time at depths critical for wetland definitions. It is further noted that short term surface wetting does not necessarily represent the sustained saturation captured by monitoring wells. Bypass flow, where precipitation short circuits natural infiltration and travels down the annulus around the well riser, can produce erroneous early responses in well data that do not reflect true subsoil saturation, and bentonite seals are used to minimize this problem. Automatic recording devices, such as pressure transducers, are the preferred method for monitoring water levels because they allow high frequency data collection and enhance the credibility of monitoring records by capturing rapid changes in water table depth (Sprecher, 2008)

IRIS films

Indicator of Reduction in Soils (IRIS) devices are tools developed to document anaerobic soil conditions that are critical for hydric soil identification and wetland assessment (Park and Rabenhorst, 2018; Sapkota et al., 2022). IRIS devices consist of iron oxide or manganese oxide paints applied onto a durable substrate, initially PVC pipes but more recently including plastic films, sheets, and other materials (Sapkota et al., 2022). The film format involves a flexible painted film inserted into the soil within a polycarbonate carrying tube; when retrieved, the film can be laid flat and scanned or photographed for analysis (Park and Rabenhorst, 2018; Sapkota et al., 2022); (Park and Rabenhorst, 2018). Under anaerobic conditions, the redox active oxide paint is chemically reduced and translocated, resulting in visible removal of the coating from the device surface that can be assessed through visual estimation, grid evaluation, or digital image analysis (Sapkota et al., 2022). Unlike point-in-time measurements such as platinum electrodes or α,α′-dipyridyl dye, IRIS devices reflect integrated environmental conditions over space and time (Sapkota et al., 2022; USDA-NRCS, 2025c). To confirm anaerobic conditions under the Hydric Soil Technical Standard (HSTS), a minimum of three of five IRIS devices must display at least 30 percent iron removal from a zone 15 cm or more thick beginning within 15 cm of the soil surface (Sapkota et al., 2022; USDA-NRCS, 2025c).

The scientific basis of IRIS devices rests on fundamental soil redox chemistry. When soils remain saturated long enough for microbial respiration to deplete dissolved oxygen, redox potentials decline and microbes use alternative electron acceptors in a predictable sequence, with manganese and then iron oxides reduced at successively lower redox potentials (Sapkota et al., 2022). This same process of iron and manganese reduction, translocation, and oxidation underlies the formation of redoximorphic features used to identify hydric soils in the field, including redox depletions and concentrations whose type and distribution reflect the duration and depth of water saturation (Vepraskas et al., 2018). Manganese-coated IRIS devices respond under more weakly reducing conditions than iron-coated devices, providing a proxy measure closer to the zone of oxygen depletion (Sapkota et al., 2022). Park and Rabenhorst (2018) demonstrated in a mesocosm study that manganese paint removal was more rapid and extensive than iron paint removal, with at least 80 percent manganese removal after one week while iron removal remained negligible for the first two weeks, and that soil organic carbon content influenced the rate of iron paint removal (Park and Rabenhorst, 2018).

In naturally-occurring problematic soils, including those with high chroma parent materials, low organic carbon, low iron content, or high alkalinity, characteristic redoximorphic features may not develop even when saturation and anaerobic conditions occur which limits the utility of morphological field indicators (Berkowitz and Sallee, 2011). In these situations, IRIS devices provide a direct measure of active reducing conditions that complements or substitutes for morphological evidence (Berkowitz and Sallee, 2011; Sapkota et al., 2022). Berkowitz and Sallee (2011) demonstrated this in a field study of high chroma sandy soils, dark sandy soils, and marl soils in Michigan that did not meet approved field indicators, finding average iron removal of 74 percent in wetland plots compared to 4.8 percent in adjacent uplands, with ten of eleven sites meeting the HSTS during periods of normal or drier than normal rainfall as assessed using the Direct Antecedent Rainfall Evaluation Method (Berkowitz and Sallee, 2011). Those authors specifically noted that high chroma sandy soils in interdunal wetlands and dune and swale complexes represent a persistent delineation challenge because matrix chroma requirements are not met despite the presence of reducing conditions and adequate hydrology, and that the HSTS framework applied alongside IRIS devices and groundwater monitoring provided an effective approach for documenting hydric soil conditions in these settings (USDA-NRCS, 2025c).

Precipitation Normality

Sprecher and Warne (2000) and Sumner et al. (2009) describe the Direct Antecedent Rainfall Evaluation Method (DAREM) and Climate Analysis for Wetlands (WETS) tables as tools used to determine whether precipitation conditions during a wetland or hydric soil investigation reflect typical climate patterns rather than unusual weather events. WETS tables are statistical summaries of monthly precipitation and temperature data compiled for over 8,000 National Weather Service cooperative stations across the United States, with the normal precipitation range defined by the 30th and 70th percentiles of the long-term monthly record calculated over the most recent three decades. Monthly precipitation falling below the 30th percentile is classified as drier than normal, precipitation within the 30th to 70th percentile range is classified as normal, and precipitation above the 70th percentile is classified as wetter than normal (Sprecher and Warne, 2000; Sumner et al., 2009). This information is applied through the DAREM procedure to evaluate the three month period of rainfall occurring prior to observed soil saturation, allowing investigators to determine whether hydrologic conditions developed under climatically representative circumstances (Sprecher and Warne, 2000; Sumner et al., 2009).

Because long term water table records spanning 10 or more years are rarely available, short term monitoring data are frequently used instead. For jurisdictional purposes, wetland hydrology is defined as saturation to within 30 cm of the soil surface for 14 or more consecutive days during the growing season in at least 50% of years, and the Hydric Soils Technical Standard additionally requires that a water table rise to within 20 cm of the soil surface following a three month period of normal or drier than normal rainfall before saturation data can be used to confirm hydric soil status (Sumner et al., 2009; Vepraskas et al., 2019; USDA-NRCS, 2025c).

An analysis of precipitation normality is required to ensure that short term observations reflect long-term climatic conditions rather than anomalous wet periods (Vepraskas et al., 2019). Sumner et al. (2009) demonstrate empirically that method selection has direct consequences for whether a given monitoring period qualifies as representative. Using a 40–45 year long term baseline, they found that the 30-day moving total methods correctly identified wetland hydrology conditions in only approximately 41–50% of years, compared to 78–81% for the DAREM and Modified DAREM approaches. The moving total methods performed poorly because individual large precipitation events within a 30-day window frequently pushed the rolling sum above the 70th percentile, rendering observations unusable for assessment even when true saturation conditions were present. Vepraskas et al. (2019) further illustrate the practical consequences of method selection through case studies in Michigan, Alabama, and California, in which the WETS method classified antecedent conditions as wetter than normal while the U.S. Soil Taxonomy method classified the same periods as normal, concluding that the WETS method is the appropriate sole method for precipitation normality assessment because it is statistically valid, accounts for the non-normal distribution of precipitation data through a percentile-based approach, and produces a narrower normal range that more effectively excludes data collected under anomalously wet conditions.

Conclusion and Research Implications

As shown in the literature described above, interdunal wetlands serve as hydrologically and ecologically significant ecosystems while posing unique problems associated with their delineation. Sandy parent materials, rapid drainage, fluctuating water tables, and soil chemical conditions such as salinity and alkalinity can interact to limit the development of redoximorphic features. While hydrophytic vegetation and wetland hydrology are frequently present, hydric soil morphology may be weak, discontinuous, or absent, creating challenges for standard wetland delineation approaches. Thus, there is a need for surveying interdunal wetlands in MLRA 79 to confirm the presence of field indicators of hydric soils and to apply the hydric soil technical standard to document the efficacy of these field indicators.

Future research should focus on quantifying hydroperiod thresholds required for hydric soil development in sandy and saline systems and evaluating how soil chemistry alters redox pathways and indicator expression. Long term monitoring across a range of interdunal settings would help clarify when and where hydric soil indicators are likely to form. Collaboration with national committees responsible for hydric soil standards is also essential to ensure that findings from regions such as MLRA 79 inform updates to technical guidance. By incorporating region-specific evidence into indicator development and interpretation frameworks, future efforts can improve wetland delineation accuracy and support more equitable conservation outcomes across diverse soil landscapes.

Literature Review Bibliography

ACIS- Regional Climate Centers. 2026a. AgACIS- Stafford County. https://agacis.rcc-acis.org/?fips=20185 (accessed 7 July 2026).

ACIS- Regional Climate Centers. 2026b. AgACIS- Rice County. https://agacis.rcc-acis.org/?fips=20159 (accessed 7 July 2026).

Barchyn, T.E., and C.H. Hugenholtz. 2012. Aeolian dune field geomorphology modulates the stabilization rate imposed by climate. Journal of Geophysical Research: Earth Surface 117(F2). doi: 10.1029/2011JF002274.

Berkowitz, J.F., R.W. Griffin, E. Laboratory (U.S.), P.V.A. University, and W.R.A. Program (U.S.). 2025. Identifying hydric soils using α,α′-dipyridyl dye. https://hdl.handle.net/11681/49932 (accessed 4 July 2026).

Berkowitz, J.F., and J.B. Sallee. 2011. Investigating Problematic Hydric Soils using Hydrology, IRIS Tubes, Chemistry, and the Hydric Soils Technical Standard. Soil Science Society of America Journal 75(6): 2379–2385. doi: 10.2136/sssaj2011.0040.

Berkowitz, J.F., M.J. Vepraskas, K.L. Vaughan, and L.M. Vasilas. 2021a. Development and application of the Hydric Soil Technical Standard. Soil Science Society of America Journal 85(3): 469–487. doi: 10.1002/saj2.20202.

Berkowitz, J.F., M.J. Vepraskas, K.L. Vaughan, and L.M. Vasilas. 2021b. Development and application of the Hydric Soil Technical Standard. Soil Science Society of America Journal 85(3): 469–487. doi: 10.1002/saj2.20202.

Boettinger, J.L. 1997. Aquisalids (Salorthids) and Other Wet Saline and Alkaline Soils: Problems Identifying Aquic Conditions and Hydric Soils. Aquic Conditions and Hydric Soils: The Problem Soils. John Wiley & Sons, Ltd. p. 79–97

Chow, A.T., A.L. Pitt, R.F. Baldwin, D. Suhre, and J.-J. Wang. 2016. Water quality dynamics of ephemeral wetlands in the Piedmont ecoregion, South Carolina, USA. Ecological Engineering 94: 555–563. doi: 10.1016/j.ecoleng.2016.06.075.

Conservation Effects Assessment Project and United StatesNatural Resources Conservation Service. 2020. Soil Influences on water balance in wetlands may impact wetland effectiveness in achieving different restoration objectives. USDA Natural Resources Conservation Service, Washington, D.C.

Fidel, R. 2025. Salt-affected Soils: Salinity and Sodicity. https://iastate.pressbooks.pub/isudp-2025-201/chapter/salt-affected-soils-salinity-and-sodicity/ (accessed 26 March 2026).

Gage, E., D.J. Cooper, and R. Lichvar. 2020. Comparison of USACE Three-Factor Wetland Delineations to National Wetland Inventory Maps. Wetlands 40(5): 1097–1105. doi: 10.1007/s13157-019-01234-y.

Glaser, L. 1986. Provisions of the Food Security Act of 1985 | Economic Research Service. https://www.ers.usda.gov/publications/pub-details?pubid=42003 (accessed 24 March 2026).

Interdunal Wetland - Michigan Natural Features Inventory. 2010. https://mnfi.anr.msu.edu/communities/description/10668/Interdunal-Wetland (accessed 23 December 2025).

Kansas Department of Agriculture. 2023. Quivira National Wildlife Refuge | Department of Agriculture. https://www.agriculture.ks.gov/divisions-programs/division-of-water-resources/water-appropriation/impairment-complaints/quivira-national-wildlife-refuge (accessed 7 July 2026).

Kansas Department of Wildlife and Parks. 2026. Cheyenne Bottoms Wildlife Area | Kansas Department of Wildlife and Parks. https://www.ksoutdoors.gov/home/showpublisheddocument/152/638936327109470000 (accessed 4 June 2026).

Kriegner, C.J., R.P. Chiarello, and K.W. Buelow. 2015. Wetland Delineation: Accuracy Is Not Precision. Journal of Water Resources Planning and Management 141(7): 02515001. doi: 10.1061/(ASCE)WR.1943-5452.0000542.

Lang, M.W., J.C. Ingebristen, and R.K. Griffin. 2024. 2019 Wetlands Status and Trends Report.

Lichvar, R., J. Gillrich, and W. Ochs. 2011. Discrepancies in Hydrophytic Determinations Produced by Three Vegetation Formulas Used for Wetland Delineations. Wetlands 31(3): 603–611. doi: 10.1007/s13157-011-0166-7.

Munsell Soil Color Charts. 2009.

National Integrated Drought Information System. 2026a. Stafford County Conditions | Drought.gov. https://www.drought.gov/states/kansas/county/stafford (accessed 8 July 2026).

National Integrated Drought Information System. 2026b. Rice County Conditions | Drought.gov. https://www.drought.gov/states/kansas/county/Rice (accessed 8 July 2026).

Natural Resources Conservation Service. 2025. Rattlesnake Creek Watershed Draft Plan - EIS.

Neff, B.P., D.O. Rosenberry, S.G. Leibowitz, D.M. Mushet, H.E. Golden, et al. 2020. A Hydrologic Landscapes Perspective on Groundwater Connectivity of Depressional Wetlands. Water 12(1): 50. doi: 10.3390/w12010050.

Nippert, J.B., L. Telleria, P. Blackmore, J.H. Taylor, and R.C. O'Connor. 2021. Is a Prescribed Fire Sufficient to Slow the Spread of Woody Plants in an Infrequently Burned Grassland? A Case Study in Tallgrass Prairie. Rangeland Ecology & Management 78: 79–89. doi: 10.1016/j.rama.2021.05.007.

NTCHS. 2026. National Technical Committee for Hydric Soils (NTCHS) | Natural Resources Conservation Service. https://www.nrcs.usda.gov/conservation-basics/soil/national-technical-committee-for-hydric-soils-ntchs (accessed 7 July 2026).

Official Series Description - CARWAY Series. 2000. https://soilseries.sc.egov.usda.gov/OSD_Docs/C/CARWAY.html (accessed 6 July 2026).

Official Series Description - KINGMAN Series. 1997. https://soilseries.sc.egov.usda.gov/OSD_Docs/K/KINGMAN.html (accessed 6 July 2026).

Park, E., and M.C. Rabenhorst. 2018. Assessing New Developments in IRIS Technology. WSP 35(4): 324–327. doi: 10.1672/UCRT083-244.

Photos, C., L. Lefebvre, J. Klein, C. McKernan, J. Goulet, et al. 2019. Influence of wetland indicator status ratings on the extent of hydrophytic vegetation during wetland delineations. Engineer Research and Development Center (U.S.).

Rabenhorst, M.C. 2018. A System for Making and Deploying Oxide-Coated Plastic Films for Environmental Assessment of Soils. Soil Science Society of America Journal 82(5): 1301–1307. doi: 10.2136/sssaj2018.05.0178.

Ramsar Sites Information Services. 2002. Quivira National Wildlife Refuge | Ramsar Sites Information Service. https://rsis.ramsar.org/ris/1172?__goaway_challenge=meta-refresh&__goaway_id=e17c57401fde2af0da221d37b0faf421 (accessed 24 March 2026).

Rengasamy, P., C. Lacerda, and H. Gheyi. 2022. Salinity, Sodicity and Alkalinity. p. 83–107

Sapkota, Y., C. Duball, K. Vaughan, M.C. Rabenhorst, and J.F. Berkowitz. 2022. Indicator of Reduction in Soil (IRIS) devices: A review. Science of The Total Environment 852: 158419. doi: 10.1016/j.scitotenv.2022.158419.

SC ACIS2. 2024. SC ACIS2. https://scacis.rcc-acis.org/ (accessed 11 June 2026).

Schindelin, J., I. Arganda-Carreras, E. Frise, V. Kaynig, M. Longair, et al. 2012. Fiji: an open-source platform for biological-image analysis. Nat Methods 9(7): 676–682. doi: 10.1038/nmeth.2019.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. U.S. Army Corps of Engineers, Washington, DC.

Sophocleous, M., and J. McAllister. 1990a. KGS--Ground Water Series 11--Rattlesnake Creek Watershed--Introduction. https://www.kgs.ku.edu/Publications/Bulletins/GW11/02_intro.html (accessed 6 June 2026).

Sophocleous, M., and J. McAllister. 1990b. KGS--Ground Water Series 11--Rattlesnake Creek Watershed--Hydrogeologic Environment. https://www.kgs.ku.edu/Publications/Bulletins/GW11/03_envir.html (accessed 6 June 2026).

Sparks, D.L., B. Singh, and M.G. Siebecker. 2024. The Chemistry of Saline and Sodic Soils. Environmental Soil Chemistry. Elsevier. p. 411–438

Sprecher, S.W. 2008. Installing Monitoring Wells in Soils (Version 1.0). https://nrcs.app.box.com/s/wpxih9lg2xy9lavzhxyuwbtzwab8sh0a/file/1588696821078?sb=/details (accessed 19 December 2024).

Sprecher, S.W., and A.G. Warne. 2000. Accessing and Using Meteorological Data to Evaluate Wetland Hydrology: Defense Technical Information Center, Fort Belvoir, VA.

Steiner, J.L., D.L. Devlin, S. Perkins, J.P. Aguilar, B. Golden, et al. 2021. Policy, Technology, and Management Options for Water Conservation in the Ogallala Aquifer in Kansas, USA. Water 13(23): 3406. doi: 10.3390/w13233406.

Sumner, J.P., M.J. Vepraskas, and R.K. Kolka. 2009. Methods to evaluate normal rainfall for short-term wetland hydrology assessment. Wetlands 29(3): 1049–1062. doi: 10.1672/09-026D.1.

Taghvaeian, S., R.S. Frazier, D. Livingston, and G. Fox. 2016. Oklahoma Cooperative Extension Service.

Tang, S., D. She, and H. Wang. 2021. Effect of salinity on soil structure and soil hydraulic characteristics. Can. J. Soil. Sci. 101(1): 62–73. doi: 10.1139/cjss-2020-0018.

Tarolli, P., J. Luo, E. Park, G. Barcaccia, and R. Masin. 2024. Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering. iScience 27(2): 108830. doi: 10.1016/j.isci.2024.108830.

The Nature Conservancy. 2026a. Cheyenne Bottoms Preserve, Kansas. The Nature Conservancy. https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/cheyenne-bottoms-preserve/ (accessed 24 March 2026).

The Nature Conservancy. 2026b. Rattle Snake Creek- Quivira. https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/rattlesnake-creek-kansas/#:~:text=Wildlife%20needs%20the%20wetlands%20at%20Quivira%20National%20Wildlife.

U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual - Corps of Engineers wetlands delineation manual - Technical Reports - USACE Digital Library. https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/4530 (accessed 21 February 2026).

U.S. Army Corps of Engineers. 2010a. Corps of Engineers wetlands delineation manual - Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region (Version 2.0) - Technical Reports. https://usace.contentdm.oclc.org/utils/getfile/collection/p266001coll1/id/7613 (accessed 25 March 2026).

U.S. Army Corps of Engineers. 2010b. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region (Version 2.0). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

US EPA, O. 2013. Summary of the Clean Water Act. https://www.epa.gov/laws-regulations/summary-clean-water-act (accessed 24 March 2026).

US EPA, O. 2015. CWA Section 404 and Swampbuster: Wetlands on Agricultural Lands. https://www.epa.gov/cwa-404/cwa-section-404-and-swampbuster-wetlands-agricultural-lands (accessed 24 March 2026).

U.S. Fish & Wildlife Service. 2024. Quivira National Wildlife Refuge | U.S. Fish & Wildlife Service. https://www.fws.gov/refuge/quivira (accessed 3 December 2024).

USDA-NCSS. 2000. Official Series Description - NINNESCAH Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/N/NINNESCAH.html (accessed 6 July 2026).

USDA-NCSS. 2004. Official Series Description - CARBIKA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/C/CARBIKA.html (accessed 6 July 2026).

USDA-NCSS. 2006. Official Series Description - KANZA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/K/KANZA.html (accessed 21 February 2026).

USDA-NCSS. 2020. Official Series Description - PLEVNA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/P/PLEVNA.html (accessed 6 July 2026).

USDA-NRCS. 2018. Ecological Site R079XY133KS-MLRA 79- Wet Subirrigated. https://edit.sc.egov.usda.gov/catalogs/esd/079X/R079XY133KS (accessed 30 December 2024).

USDA-NRCS. 2024. Field Book for Describing and Sampling Soils, Version 4.0.

USDA-NRCS. 2025a. Kansas Natural Resources Conservation Service (NRCS) Wetland Restoration Criteria and Guidelines (WRCG). https://www.nrcs.usda.gov/sites/default/files/2025-04/KS-FY2025-WRCG_04232025.pdf.

USDA-NRCS. 2025b. Hydric Soils of Problematic Conditions and Altered Materials v1.0.

USDA-NRCS. 2025c. Hydric Soil Technical Standard.

USDA-NRCS. 2026. Field Indicators of Hydric Soils in the United States, Version 9.3.

Vepraskas, M. j. 2013. Morphological Methods to Characterize Hydric Soils. Methods in Biogeochemistry of Wetlands. John Wiley & Sons, Ltd. p. 117–135

Vepraskas, M.J., J.F. Berkowitz, and C. Arellano. 2019. Determining Normal Precipitation Ranges for Hydric Soil Assessments. Soil Science Society of America Journal 83(2): 503–510. doi: 10.2136/sssaj2018.09.0333.

Vepraskas, M.J., X. He, D.L. Lindbo, and R.W. Skaggs. 2002. Predicting Long-Term Wetland Hydrology From Hydric Soil Field Indicators.

Vepraskas, M.J., D.L. Lindbo, and M.H. Stolt. 2018. Chapter 15 - Redoximorphic Features. In: Stoops, G., Marcelino, V., and Mees, F., editors, Interpretation of Micromorphological Features of Soils and Regoliths (Second Edition). Elsevier. p. 425–445

Wurster, F.C., D.J. Cooper, and W.E. Sanford. 2003. Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: influences on interdunal wetland disappearance. Journal of Hydrology 271(1): 77–100. doi: 10.1016/S0022-1694(02)00317-7.

Yamazaki, F., and J.A. Suhr Pierce. 2024. Impacts to the Ogallala Aquifer: How Changes in Long-term Weather Patterns and Shifts in Climate Regions Affect the Aquifer – An Overview of Selected Papers.

Chapter 2 - Research Chapter

Introduction

Interdunal wetlands are depressional wetlands that form in between sand dunes and provide critical ecosystem services including groundwater recharge and wildlife habitat. The Great Bend Sand Plains Major Land Resource Area (MLRA) 79 in south-central Kansas is home to an extensive number of stabilized sand dunes and interdunal depressions, many of which are interdunal wetlands. The interdunal wetlands of this region are of particular importance due to their position along the central flyway for migratory waterfowl and their proximity to the Quivira National Wildlife Refuge, a Ramsar Site of International Importance (Ramsar Sites Information Services, 2002). This MLRA overlies the Great Bend Prairie component of the High Plains Aquifer, a groundwater system in which withdrawal for irrigation has been implicated in reduced baseflow to Rattlesnake Creek and, in turn, to Quivira National Wildlife Refuge, whose senior water right has repeatedly been found impaired by upstream junior groundwater pumping (Sophocleous and McAllister, 1990b; Kansas Department of Agriculture, 2023). Thus, there has been growing interest in conservation of interdunal wetlands in this area. However, local wetland managers and delineators expressed concern about whether Field Indicators of Hydric Soils (FIHS) were being expressed in the local soils.

The National Technical Committee for Hydric Soils defines hydric soils as those "... *that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in their upper part"* (NTCHS, 2026). Because direct observation of saturation and anaerobic conditions is often impractical, wetland delineators rely on FIHS as evidence for these conditions. These FIHS are soil morphological features that develop through repeated saturation and microbial iron and manganese reduction (USDA-NRCS, 2026). These indicators facilitate rapid, standardized wetland delineation. However, the soil morphology required for these FIHS accumulates over time and persists long after formation. Thus, a soil can display strong, well-expressed indicators while the hydrology responsible for creating them is no longer active (Vepraskas, 2013).

In contrast, the Hydric Soil Technical Standard (HSTS) is a set of standard practices by which data can be collected to assess whether a soil is currently functioning as a hydric soil. The HSTS was developed to address this gap by requiring direct, concurrent measurement of the three technical criteria that define an actively functioning hydric soil: soil saturation within 25 cm of the surface for at least 14 consecutive days during the growing season, anaerobic soil conditions, and antecedent precipitation within a normal range so that observed hydrology is representative of typical conditions rather than an artifact of an unusually wet season (Berkowitz et al., 2021b; USDA-NRCS, 2025c). Applying the HSTS alongside a traditional FIHS survey allows us to identify if and which FIHS are present, and whether the soils of these interdunal wetlands are currently functioning as hydric soils today.

The aim of this study was to guide wetland delineators and managers working in MLRA 79 to more effectively identify hydric soils in interdunal wetlands. The two research objectives of this study were to 1) conduct a survey to identify which FIHS were present at three sites, and 2) instrument interdunal wetlands at those three sites according to the HSTS to assess whether hydric soils at the sites were currently functioning as hydric soils.

Interdunal wetlands in MLRA 79 provide critical habitat and groundwater recharge for the Rattlesnake Creek watershed, and thus Quivira NWR. There have been reports of interdunal wetlands meeting wetland vegetation and hydrology indicators but not FIHS. As a result wetlands are being classified as non-wetlands, threatening the water contributions and habitat quality supporting Rattlesnake Creek and Quivira. There are two competing plausible scenarios for why these interdunal wetlands are not meeting FIHS. FIHS occur in interdunal soils of MLRA 79 but are difficult to identify in the landscape or these interdunal soils are so-called "problematic" hydric soils that do not exhibit an existing FIHS. We hypothesized that FIHS are present in interdunal soils of MLRA 79, and Interdunal soils in MLRA 79 are functioning as hydric soils.

Materials and Methods

Study Site

Field investigations were conducted at the Joe Kramer Wildlife Area (Kramer) and at a site known as Pfister. Both Kramer and Pfister occur within MLRA 79 - Great Bend Sand Plains (USDA-NRCS, 2018). The Kramer site is a 196-ha field located in Stafford County, KS, approximately 1.6 km south of the Big Salt Marsh of Quivira National Wildlife Refuge. Kramer is 2.4 km east to west and 0.8 km north to south and consists mostly of native mixed grass prairie. For purposes of this study, Kramer was split into two study sites, East and West Kramer which exhibit representative examples of "low interdunals" and "high interdunals", respectively. Pfister is an approximately 250-ha site located in Rice County, KS, adjacent to the Quivira

National Wildlife Refuge and approximately 6.4 km east-northeast of the Big Salt Marsh. The Pfister site encompasses one section of land 1.6 km north to south and 1.6 km east to west.

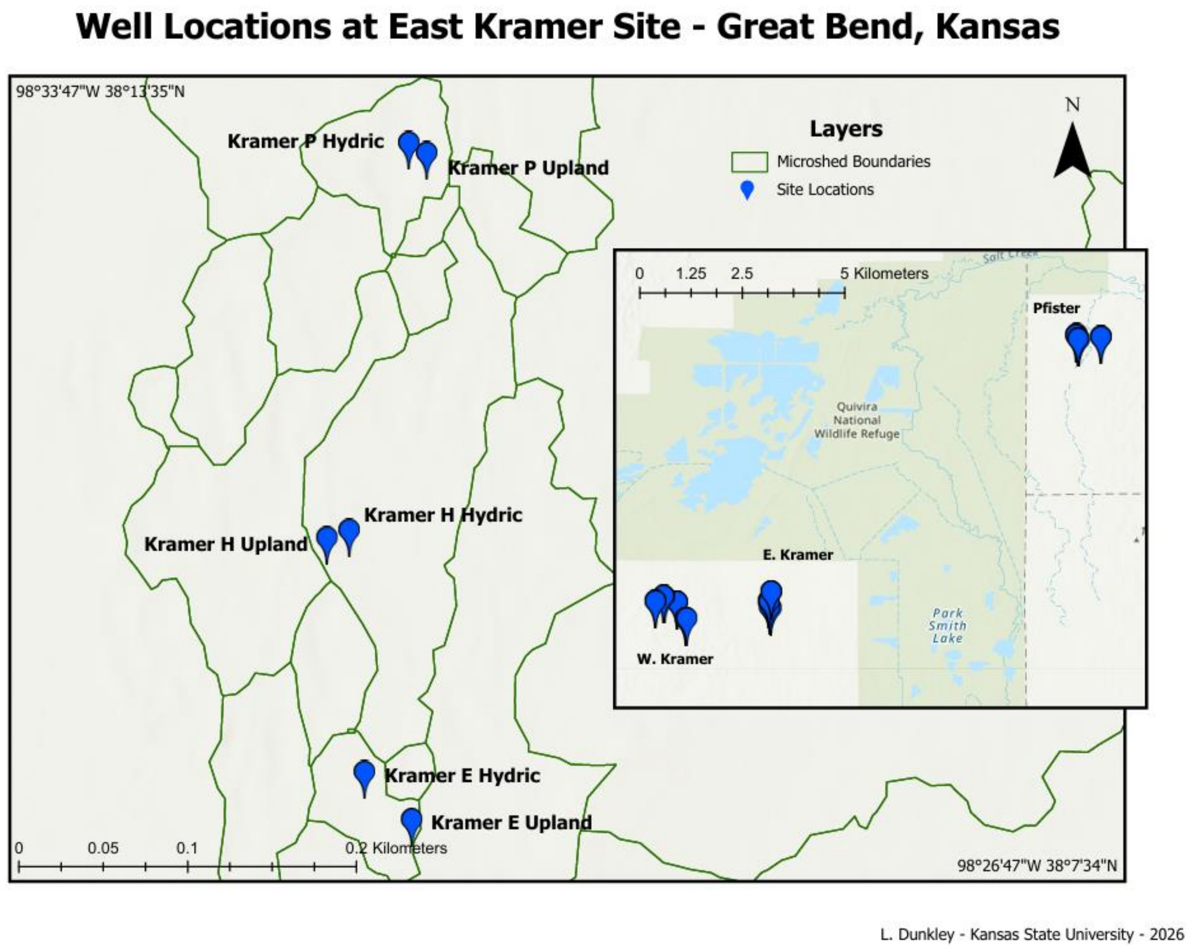


Figure 1- Map of East Kramer

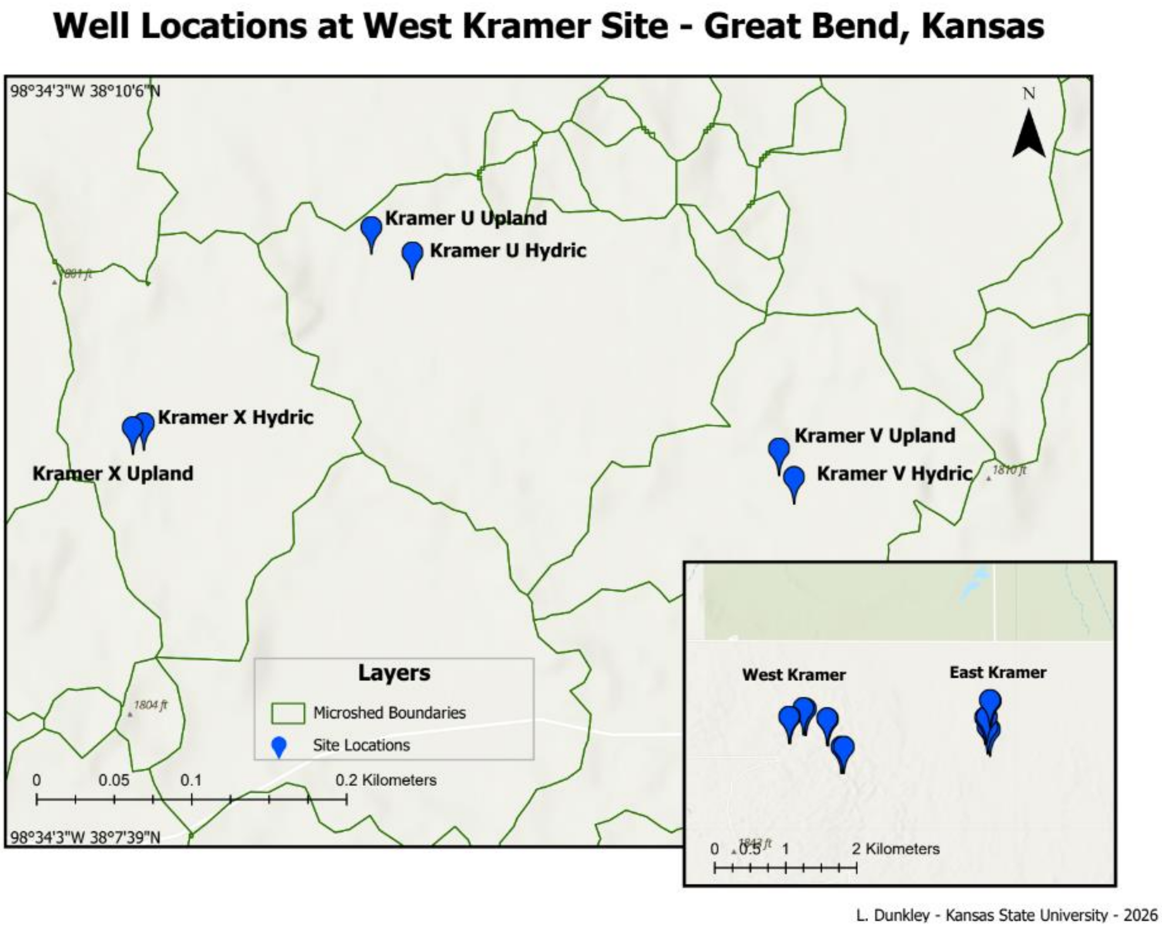


Figure 2- Map of West Kramer

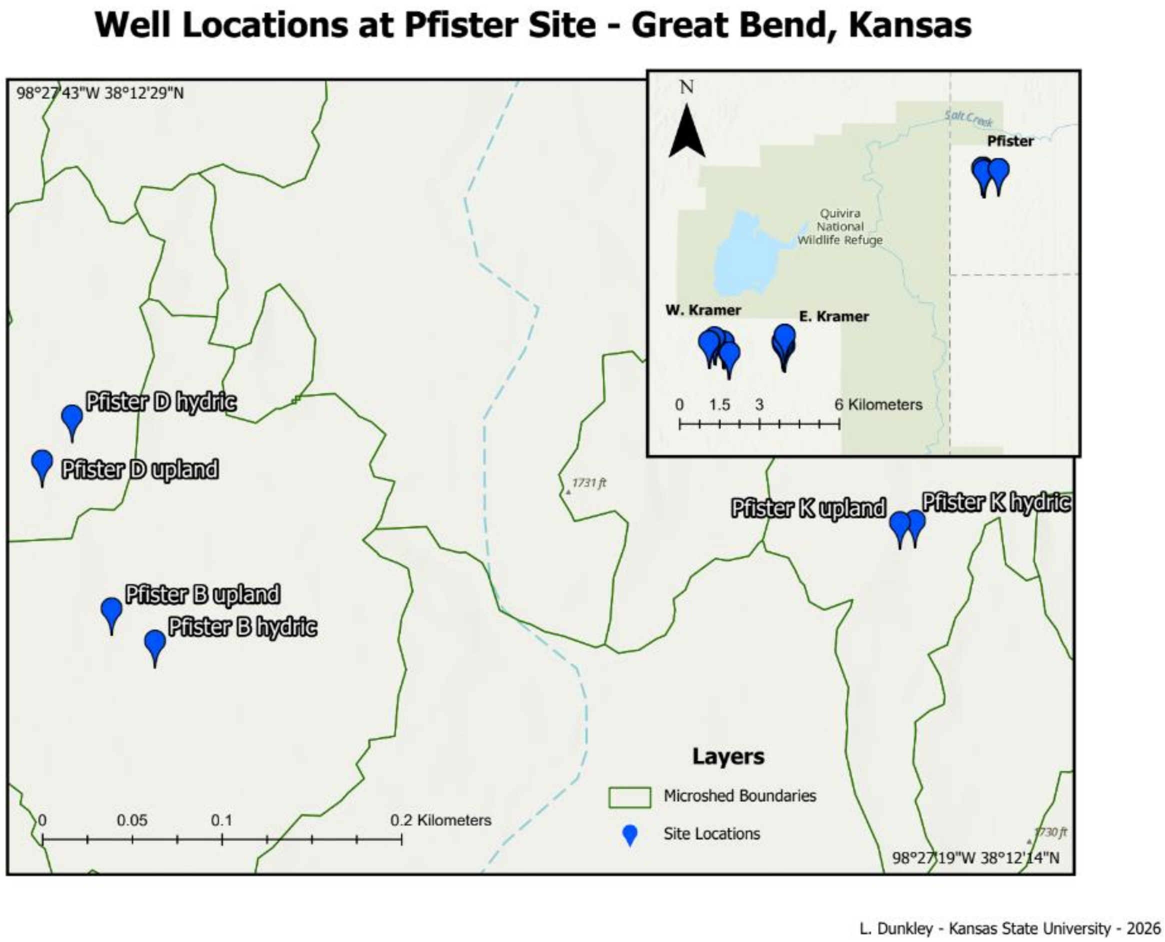


Figure 3- Map of Pfister

The sites exhibit sand dunes with low-lying interdune depressions, most of which are wetlands. The interdunal wetlands are characteristic of the Wet Sub-irrigated Ecological Site Description (USDA-NRCS, 2018), exhibiting poorly drained soils with seasonally or perennially elevated water tables within 0.61 meters of the soil surface and frequent ponding or flooding. The dominant soil series on these sites include the Kanza (Mixed, mesic Mollic Psammaquents), Plevna (Coarse-loamy, mixed, superactive, mesic Fluvaquentic Endoaquolls), Kingman (Fine-silty, mixed, calcerous, thermic Fluvaquentic Endoaquolls), Carway (Fine-loamy, mixed, superactive, calcerous, mesic Fluvaquentic), Ninnescah (Coarse-loamy, mixed, superactive, calcerous, mesic Fluvaquentic Endoaquolls), and Carbika (Fine, smectitic, mesic Vertic

Argiaquolls) series ("Official Series Description - KINGMAN Series," 1997; "Official Series Description - CARWAY Series," 2000; USDA-NCSS, 2000, 2004, 2006, 2020). Plevna fine sandy loam comprises an estimated 24% of the mapped soil area and is associated with frequently flooded interdunal positions. Soil textures across the sites border between sand and sandy loam, indicating the possible presence of both S- indicators and F- Indicators when we evaluated for Field Indicators of Hydric Soils (USDA-NRCS, 2018).

Experimental Design

The study was conducted in two parts. First, we conducted a survey of FIHS across all identifiable interdunal wetland basins on the Kramer and Pfister sites between 2024-2025. Second, we applied the hydric soil technical standard to test whether the soils in these interdunal wetlands were functioning as hydric soils in Spring of 2024-Spring of 2026. To do so, we examined wetland hydrology using shallow wells, documented anaerobic soil conditions using IRIS films and α, α'-Dipyridyl test strips, and conducted a vegetation survey at nine interdunal wetlands.

Field Indicators of Hydric Soils Survey

There were 36 interdunal wetland basins at the study sites. A survey was conducted across each of the 36 interdunal wetlands on the three sites to determine if and which FIHS were present. Maps were provided by the University of Kansas Biologic Survey to assist with the survey. These maps identified micro watersheds (microsheds) and potential wetland areas within closed basis, of which there were 36 total. The depressions within these closed basin (interdunes) were each visited and at least one shallow soil profile was described. Before the soils at the sampling sites were examined, each location was visually assessed for evidence of wetland hydrology and vegetation to provide context for future soil morphological observations.

Landform position, topographic relief, ponding or inundation, and plant community composition were all recorded. Each shallow soil profile was excavated and described following the procedures detailed in the Field Indicators of Hydric Soils in the United States, Version 9.3 (USDA-NRCS, 2026). Soil profiles were described from a small pit excavated to approximately 50 cm depth. Moist soil color for the matrix, iron concentrations, and iron depletions were determined using the Munsell Soil Color Book (2009), and redoximorphic feature presence, type, abundance, size, contrast, and boundaries of redoximorphic features were described following standard pedological conventions (USDA-NRCS, 2024). All the applicable FIHS were evaluated at each point in accordance with the NRCS (2026). The outcomes were recorded in a field survey sheet, which we entered into the USACE automated data sheets to confirm in-field calls on FIHS presence (U.S. Army Corps of Engineers, 2010a).

Applying the Hydric Soil Technical Standard

Nine interdunal wetlands (three at each of the three sites) of the initial 36 that were surveyed were randomly selected for further instrumentation and study. The wetlands were instrumented following the HSTS (Berkowitz et al., 2021b) to confirm wetland hydrology and anaerobic soil conditions. Instrumentation at each wetland included a hydric location (where a FIHS was present) and an adjacent upland location. The pairs were positioned to capture the transition from the depressional wetland to the surrounding upland, since the difference in soil morphology is central to confirming hydric soil status (USDA-NRCS, 2025c, 2026). Precipitation at a nearby weather station was reviewed to assess the nature of antecedent soil moisture conditions prior to data collection.

<u>Wells</u>

Water table depths were monitored continuously at each location using shallow groundwater monitoring wells (Figure 4) following methods by Sprecher (2008). Wells were constructed from 5-centimeter diameter slotted PVC screening, a bottom cap, and a PVC riser (Environmental Manufacturing, Inc., Manhattan, Kansas, US) with a vented well cap (Onset Computer Corporation, Bourne, Massachusetts, US). To install wells, we first collected 5-cm diameter soil cores to approximately 1 m depth using a gas-powered soil sampling kit with a plastic core liner (AMS, Inc., American Falls, Idaho, US). The cores were set aside for subsequent description and characterization. We then enlarged the hole by hand-augering to approximately 110 cm depth using a 10-centimeter diameter Edelman auger (Eijkelkamp North America, Wilmington, North Carolina, US). The depth of the bore hole was recorded. Next, the well casing was inserted into the bore hole and the surrounding space was filled with washed, coarse industrial sand (Pioneer Sands LLC, Irving, Texas, US). The uppermost 10 centimeters of the surrounding space were sealed with bentonite (PDSCo, Inc., El Dorado, Arkansas, US). The wells were installed in May 2024 for the East and West Kramer sites and May 2025 for the Pfister sites.

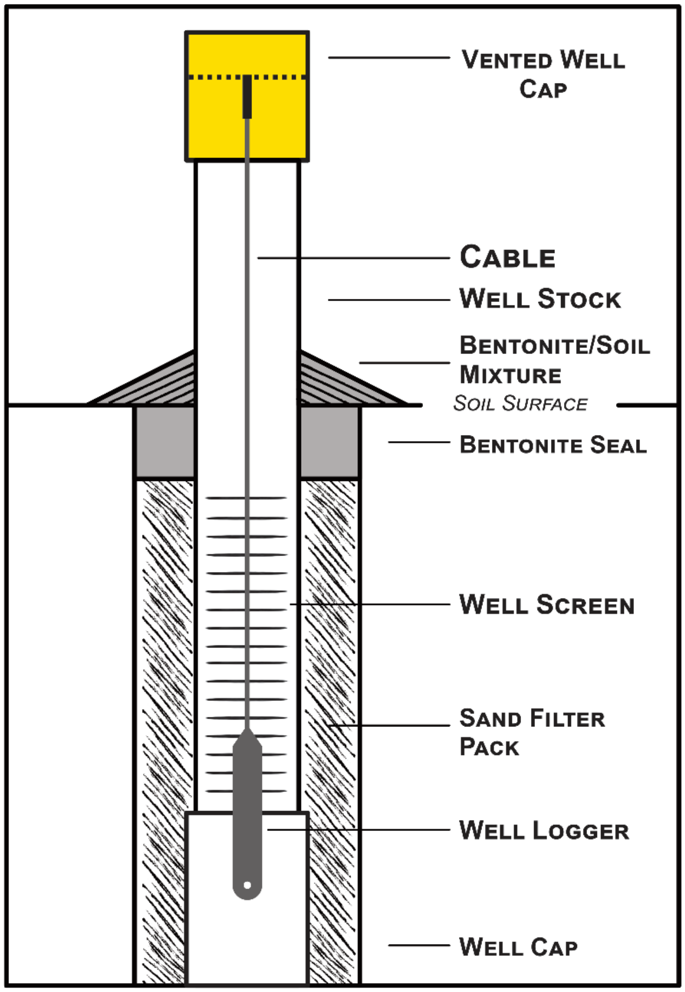


Figure 4- Illustration of Shallow Well Instrumented with HOBO Sensor

Water levels were recorded every 12 hours using a HOBO U20 Water Level Logger (Onset Computer Corporation, Bourne, MA) suspended from the well cap by a stainless-steel cable. Barometric Pressure was recorded using the same model of logger installed aboveground and exposed to the atmosphere at East Kramer, which was used to correct pressure transducer readings to true water depth. Water levels were expressed as depth to the water table from the soil surface. Continuous records were analyzed to determine the cumulative duration of time during which the water table was present within 25 centimeters of the soil surface for a minimum of 14 consecutive days during the growing season, consistent with the saturation criteria of the Hydric Soil Technical Standard (Berkowitz et al., 2021b; USDA-NRCS, 2025c).

Anaerobic Soil Conditions

IRIS Films

We used Indicator of Reduction in Soils (IRIS) films (Rabenhorst, 2018) to document the occurrence of anaerobic soil conditions at each monitoring location following protocols specified in the Hydric Soil Technical Standard (USDA-NRCS, 2025c). IRIS films consist of PVC strips coated with a synthetic iron oxide paint. Under anaerobic condition, iron reducing microbes reduce Fe (III) to soluble Fe (II) causing the removal of the iron oxide coating from the film surface (Berkowitz and Sallee, 2011; Rabenhorst, 2018; Sapkota et al., 2022).

We deployed films in sets of five during the spring and early summer for each year of the study, occurring simultaneously with the period of greatest predicted soil saturation. We installed the films in a circle with a radius of approximately 150 cm centered around the well casing. Pilot holes were created using either a 2.54 cm diameter push probe or 2.54 cm diameter soil auger. We loaded each film into a delivery tube, inserted them in a pilot hole, pushed them out the delivery tube with a deployment rod, allowing the film to expand to make contact with the soil. Films were replaced monthly in 2025. In 2026 we used a single deployment from March to June.

Upon the retrieval of the films we rinsed them gently with clean water, air dried, and scanned them with a portable document scanner (Epson Workforce ES-50, Epson America, Inc., Los Alamitos, California, US). The scanned images were analyzed using the imaging analysis software application, FIJI (Schindelin et al., 2012) to quantify the percentage of iron oxide paint removed across the upper 30 centimeters of each film. Following the evaluation criteria of the Hydric Soil Technical Standard, a majority of films within a set of five films must exhibit removal of at least 30% of the iron oxide paint in a 15-cm section of the film within the upper 30 cm of the film to indicate significant anaerobic conditions during the deployment period (Berkowitz et al., 2021b; Sapkota et al., 2022).

During the 2024 and 2025 field seasons, some films were pulled out of the soil by animals, most likely cattle (*Bos taurus*, Linnaeus) grazing on the site or prairie dogs (*Cynomys socialis*, Rafinesque) or other rodents. Films that were partially pulled, completely removed, or missing were not included in the dataset. In such cases, we reviewed the remaining films and assumed anaerobic conditions were met when a majority of the remaining films met the iron oxide removal standard stated previously. For the 2026 season we folded in the top, white portion of each film over onto the ground, covered it with screen, and fastened it to the ground with a landscape staple to make it more difficult for animals to remove the films. This was moderately successful, though some removal still occurred.

α, α'-Dipyridyl

Soils at each of the nine hydric sites were also tested for anaerobic conditions based on the presence of Fe (II) using α, α'-dipyridyl test strips on July 1, 2026 during a saturation event. In accordance with the Hydric Soils Technical Standard (2025c), soils with sandy textures must have a positive reaction in 60 percent of a layer 6.25 cm thick located in the upper 12.5 cm of the soil profile. A shallow soil pit was dug similar to what was described during the survey. A α, α'-dipyridyl test strip was placed on fresh ped faces that had not been touched with steel tools, and placed so the strip extended from 6 cm to 12.5 cm. This was done to avoid any contamination by metal tools that could introduce Fe (II) and give false-positive reactions (Berkowitz et al., 2025). Next, the strips were pressed firmly against the exposed profile face. If a pink or red color developed immediately, the reaction was scored as positive (Berkowitz et al., 2025).

Hydrophytic Vegetation Survey

We assessed the presence of hydrophytic vegetation at each of the 18 monitoring locations (nine hydric and nine uplands) within the nine instrumented wetland basins. Vegetation surveys were conducted using the methods outlined in the Regional Supplement to the Corps of Engineers Wetland Delineation Manual for the Great Plains Region (U.S. Army Corps of Engineers, 2010a) during the growing season at or near peak aboveground biomass in 2025 and 2026. Hydrophytic vegetation was surveyed across East Kramer, West Kramer, and Pfister. At each site, sampling plots were established within Upland and Hydric hydrologic zones (5 plots per zone per study area). Hydrophytic vegetation status was determined for each plot following the stepwise procedure in the Great Plains Regional Supplement: Indicator 1 (Rapid Test) was applied first; where not met, Indicator 2 (Dominance Test) was applied; and where the Dominance Test failed but indicators of hydric soil and wetland hydrology were both present, Indicator 3 (Prevalence Index) was applied.

Direct Antecedent Rainfall Evaluation Method – DAREM

The Hydric Soil Technical Standard requires that precipitation during the study period be characterized relative to long term climate averages. Abnormally wet or abnormally dry conditions can shift the apparent hydric and non-hydric boundary, and interpretation of hydrologic and IRIS film data (Vepraskas et al., 2019; Berkowitz et al., 2021b). To follow the guidelines of the Hydric Soil Technical Standard, precipitation data was analyzed using the Direct Antecedent Rainfall Evaluation Method (Vepraskas et al., 2019).

We obtained daily precipitation totals for the study area from the Great Bend 3WNW weather, accessed through the NOAA Regional Climate Centers SC ACIS2 database (SC ACIS2, 2024). Monthly and seasonal totals were compiled for each year of the study. Long-term precipitation statistics in the form of the WETS table for the same station were used to calculate the 30th and 70th percentile thresholds for each relevant time window. Study period totals falling between the thresholds were classified as normal, those below the 30th percentile were classified as drier than normal, and those above the 70th percentile were classified as drier than normal. Lastly, we applied these classifications to the period immediately preceding and during each growing season of active soil saturation monitoring.

Results

Field Surveys

A total of 34 interdunal wetlands were surveyed for the presence of Field Indicators of Hydric Soils (FIHS). All 34 sites were located within the Kramer and Pfister study areas, and all 34 exhibited at least one FIHS.

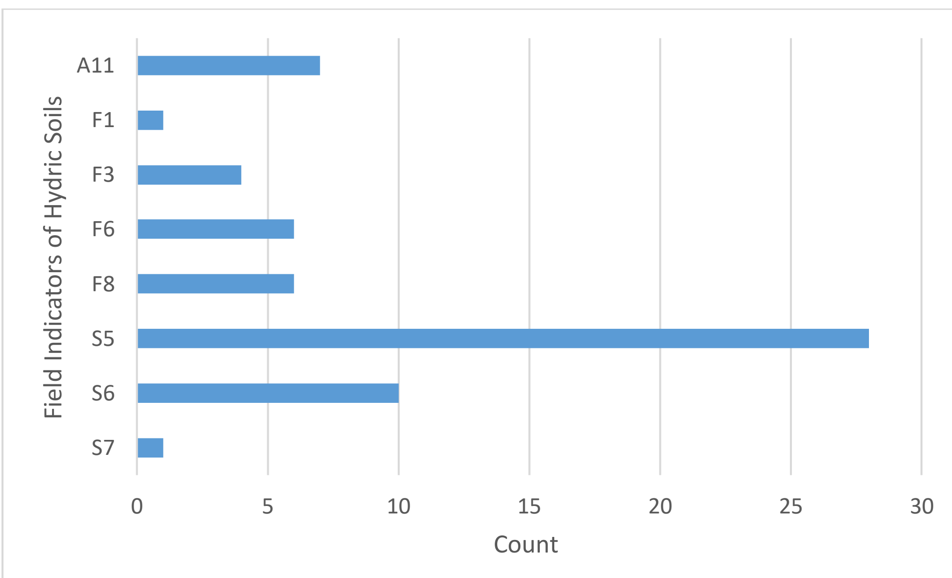


Figure 5- Frequency of FIHS observed at surveyed interdunal wetlands of Kramer and Pfister sites. The FIHS, in alphabetical order, are A11 – Depleted Below Dark Surface, F1 – Loamy Mucky Material, F3 – Depleted Matrix, F6 – Redox Dark Surface, F8 – Redox Depression, S5 – Sandy Redox, S6 – Stripped Matrix, S7 – Dark Surface

The FIHS in this survey are summarized in Figure 5 and the complete collection of surveys is in Appendix B. The three most common FIHS were S5 – Sandy Redox, S6 – Stripped Matrix, and A11 – Depleted Below Dark Surface, which were observed in 28, 10, and 7 interdunal wetlands, respectively. Less common FIHS were primarily F-indicators, including F6 – Redox Dark Surface, F8 – Redox Depression, F3 – Depleted Matrix, which were observed in 6, 6, and 4 interdunal wetlands, respectively. The F1 -Loamy Mucky Material and S7 – Dark Surface were each observed once.

Application of the Hydric Soil Technical Standard

Direct Antecedent Rainfall Evaluation Method (DAREM)

In Table 1 we see the monthly precipitation values for in 2026 for our Kramer sites. The precipitation values are compared to the 30th and 70th percentile values from the WETS table, provided by the Hudson weather station. They precipitation were then classified based on where they fell between the 30th and 70th percentile ranges. In Table 2, the same was done for our Pfister sites with values provided by the Sterling weather station. The WETS Tables and Weather Station data for 2024-2025 for both sites is located in Appendix E.

Table 1- Hudson Weather Station Monthly Precipitation in 2026 with WETS table 30th and 70th percentile ranges (June data not recorded, but consistently dry March-May)

Month	30th Percentile (cm)	70th Percentile (cm)	2026 Monthly Precipitation (cm)	Classification 2026
January	0.79	2.13	2.16	Wet
February	0.53	2.64	0.94	Normal
March	2.67	6.93	0.3	Dry
April	3.3	7.39	0.41	Dry
May	6.45	12.47	6.25	Dry
June	6.1	10.39	-	-
6- Month Total	23.7	51.8	-	-

Table 2- Sterling Weather Station Monthly Precipitation in 2026 with WETS table 30th and 70th percentile ranges

Month	30th Percentile (cm)	70th Percentile (cm)	2026 Monthly Precipitation (cm)	Classification 2026
January	1.07	2.49	2.69	Wet
February	0.61	2.64	1.04	Normal
March	3.56	8.15	0.15	Dry
April	3.63	7.24	0.69	Dry
May	7.04	13.39	9.14	Normal
June	5.61	11.68	12.55	Wet
6- Month Total	26.3	57.23	26.26	Dry

Weather in 2026 for both sites was not under as severe drought conditions as previous years and thus the study focused primarily on data from 2026. Severe to Exceptional drought conditions persisted almost 2 years (2022-2024) before the study began in spring of 2024 for our Kramer sites(National Integrated Drought Information System, 2026a). For our Pfister sites the same is true, however conditions persisted through 2025(National Integrated Drought Information System, 2026b). An accompanying scale was used to classify drought conditions with the respective colors (D0- Abnormally Dry, D1- Moderate Drought, D2- Severe Drought, D3- Extreme Drought, D4- Exceptional Drought).

Saturated Conditions

Shallow groundwater levels from well data in February 19 to July 1 of 2026 (Day of Year 50-180) are shown in Figures 6-8 and Appendix Dhas the well data for the sites not shown below. The East Kramer H, West Kramer U, and Pfister K interdunal well data represent the median wetness of the three respective study sites and are shown in figures 6, 7, and 8. In each figure the soil surface corresponds to a water table depth of zero. Positive water table depths imply ponding and negative depths depict distance below the surface.

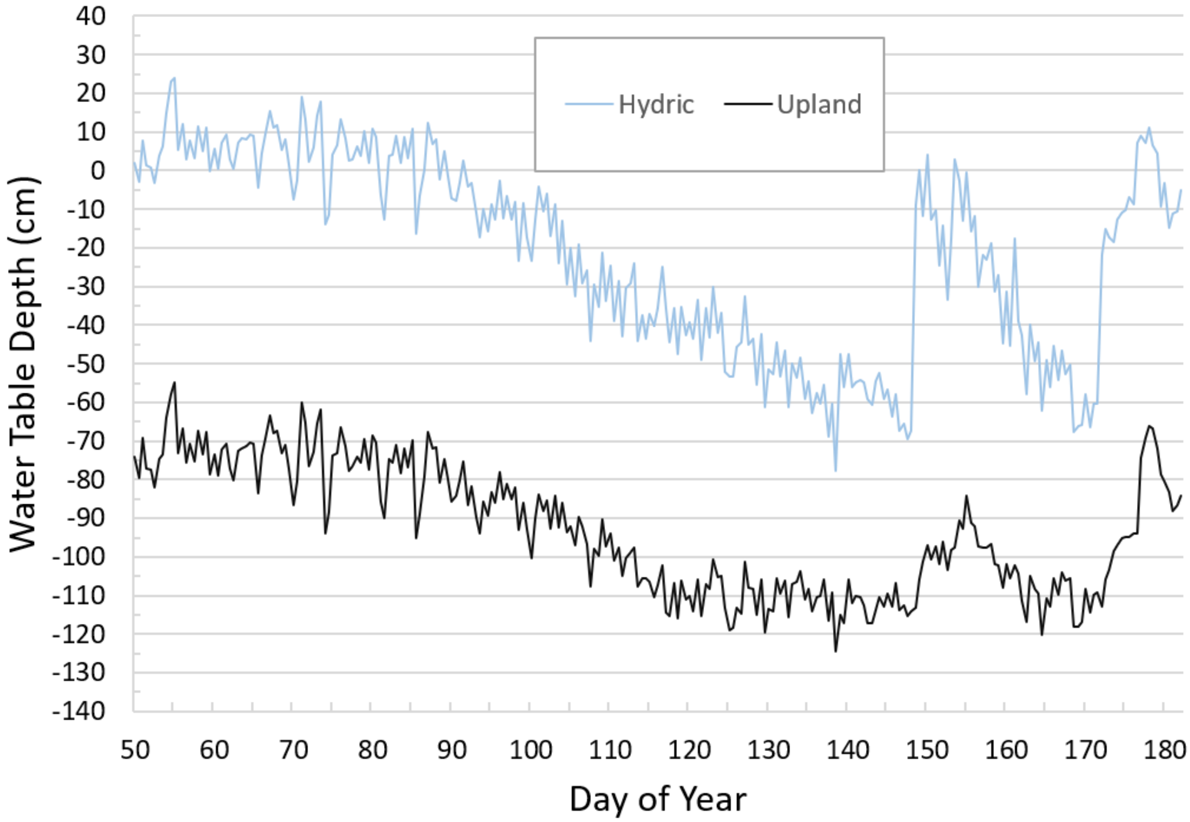


Figure 6- East Kramer H Hydric and Upland 2026

The water level data for East Kramer H show that the hydric well was saturated from day 50 through day 90. During this window the water table fluctuated between -10 cm and +24 cm, briefly resting above the soil surface near day 55. After day 90, the water table declined steadily to a low of approximately -75 cm by day 140. Two significant rainfall events around days 150 and 160 led to saturated conditions again later in the season. The first event was short-lived. The second event was ongoing at the time of the most recent data collection on July 1. The upland well at this transect, by contrast, never approached -25 cm at any point, remaining between -55 and -125 cm for the entire monitoring period.

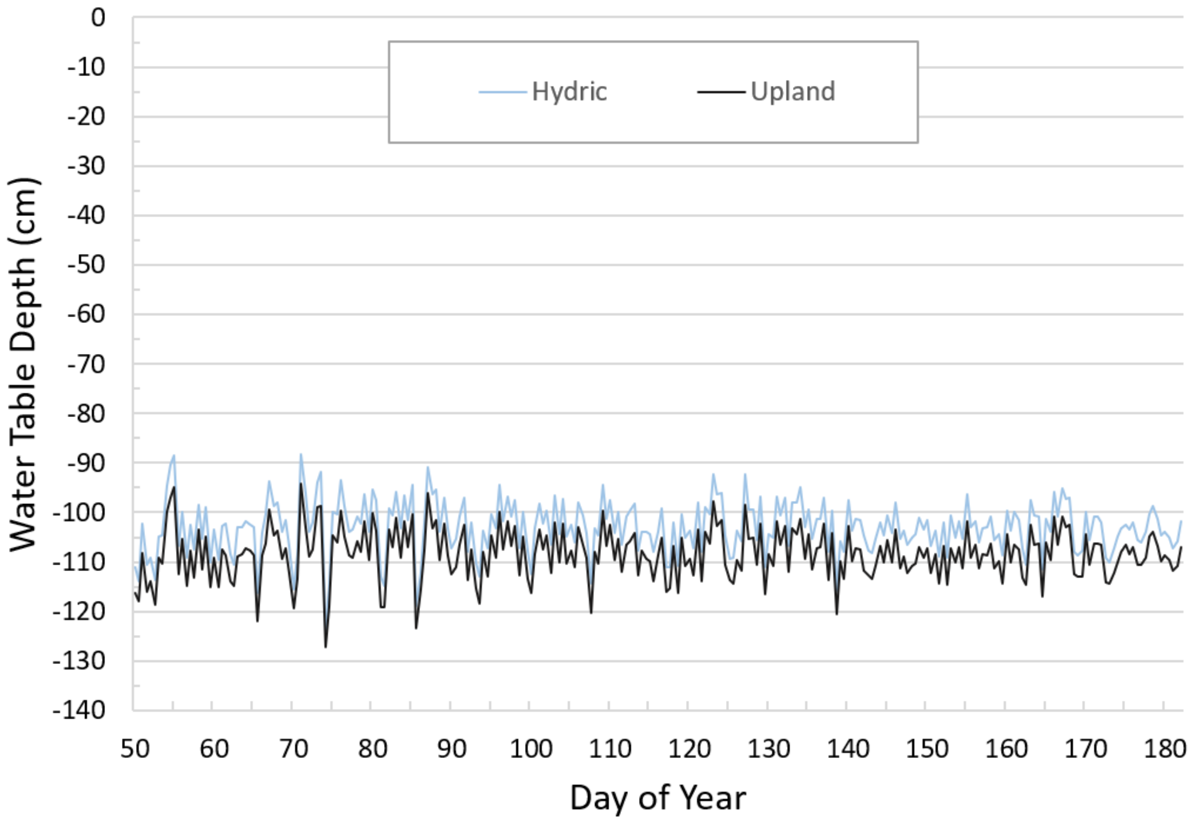


Figure 7- West Kramer U Hydric and Upland 2026

The West Kramer U exhibited dry conditions at both the upland and interdunal sites. Neither the hydric nor the upland well ever reached the -25 cm saturation threshold depth. Results were similar for West Kramer V and X. Thus, the West Kramer site did not achieve saturated conditions in 2026.

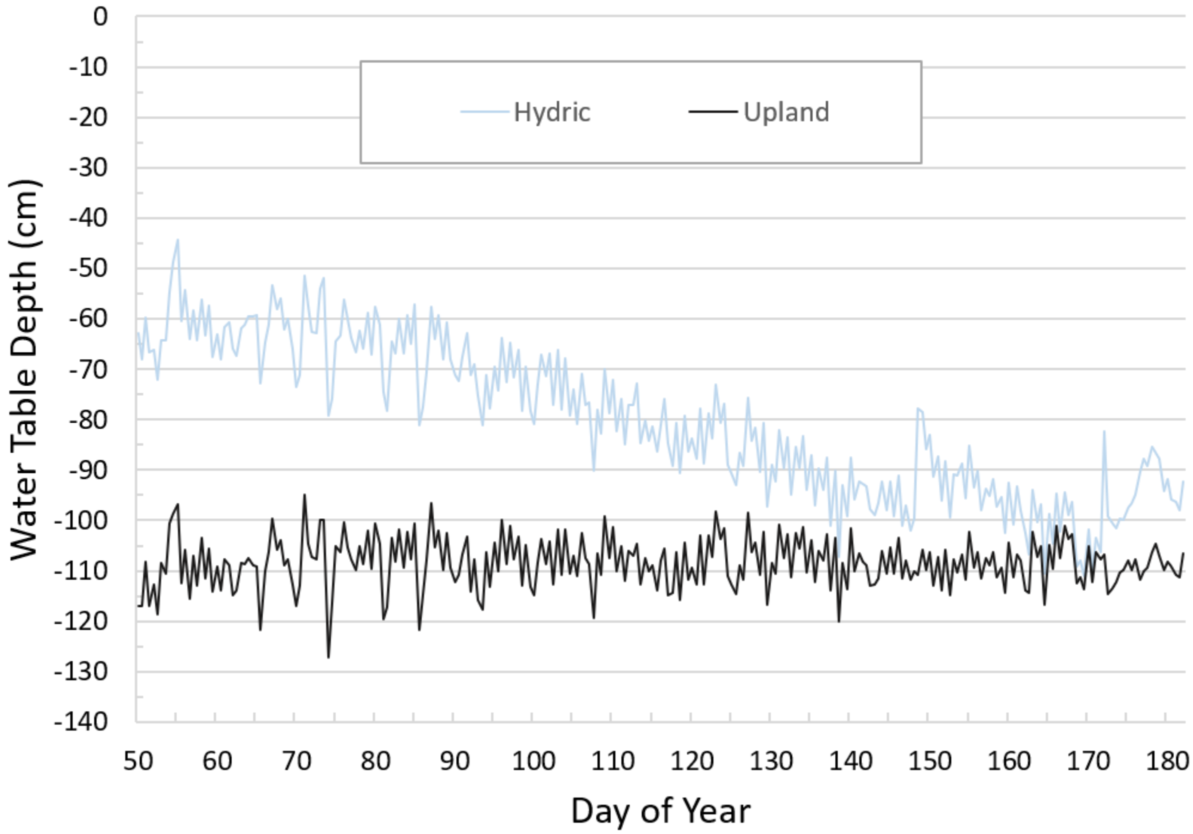


Figure 8- Pfister K Hydric and Upland 2026

Likewise, the Pfister site similarly showed no saturation events meeting the -25 cm threshold (Figure 8). The Pfister K hydric well began the period near -60 cm, rose to a high of approximately -44 cm around day 55, and stayed in the -50 to -70 cm range through roughly day 90 before declining gradually to between -90 and -100 cm by day 150–180. The upland well remained consistently lower, ranging from about -95 to -120 cm, with a persistent 20 to 40 cm separation between the two wells. Although the hydric wells at Pfister exhibited shallower groundwater depths than West Kramer, these interdunal areas never reached -25 cm, so no saturation events were observed.

<u>DAREM</u>

Using the timing of the saturation events described above, we used the DAREM method to characterize the antecedent moisture conditions for the study sites for the spring of 2026. The antecedent 3-month rainfall totals preceding each confirmed saturation event were classified using DAREM with 30th and 70th percentile thresholds developed from two climate stations using 1971–2000 WETS climatology. East and West Kramer were evaluated using the Hudson weather station (ACIS- Regional Climate Centers, 2026a) and Pfister was evaluated using the Sterling weather station (ACIS- Regional Climate Centers, 2026b).

All three East Kramer wells (E, H, and P) met or exceeded the 14 consecutive day saturation criterion, with the water table at or above the 25 cm depth threshold from the first day of monitoring (February 19, 2026). Because monitoring began with the water table already within the qualifying range, the earliest date at which the standard's threshold can be affirmatively confirmed is March 4, 2026 (the 14th consecutive qualifying day). In contrast, none of the West Kramer wells (U, V, or X) or Pfister (B, D, or K) recorded a water table within 25 cm of the surface at any point during the monitoring period. No saturation event occurred at West Kramer during the study period.

Because East Kramer was the only site to record a qualifying saturation event, DAREM was applied to the three months preceding its confirmed saturation date (March 4, 2026): December 2025, January 2026, and February 2026, using Hudson WETS percentiles and measured monthly precipitation (Table 0 and Table 0). Based on the DAREM sum of 13, the antecedent rainfall leading up to the saturation periods is characterized as normal.

Table 3- DAREM scoring for East Kramer. Sum = 13, consistent with Normal rainfall classification (6- 9 = drier than normal, 10- 14 = normal, 15- 18 = wetter than normal).

Month	Monthly Precip. (cm)	Classification	Condition Value	Month Weight	Value x Weight
Dec. 2025	0.03	Dry	1	1	1
Jan. 2026	2.16	Wet	3	2	6
Feb. 2026	0.94	Normal	2	3	6
Sum					13

Anaerobic Soil Conditions

IRIS Films

A total of 270 IRIS films were deployed across three sites, West Kramer, East Kramer, and Pfister, at paired hydric and upland positions across three deployment rounds spanning March 2025 through June 2026 (deployment durations ranging from approximately 24 to 95 days). Of these, 24 films were excluded from the percent-removal analysis because they had been fully or partially dislodged by animal activity prior to retrieval (Appendix C). Exclusions were concentrated at West Kramer (10 films, split evenly between hydric and upland positions, all confirmed dislodged upon retrieval) and East Kramer had 8 films removed (5 upland in first round, 2 hydric and 1 upland in the final round). The remaining 246 films were analyzed for percent removal of iron oxide coating in 1-cm depth increments from the surface to 30 cm, from which mean percent removal, maximum percent removal, and the maximum removal within any contiguous 15 cm window were calculated for each film.

During the March 2026-June 2026 deployment of IRIS films, the hydric sampling points at two of the three interdunal wetlands instrumented at East Kramer met the technical standard for anaerobic conditions, with a majority of five IRIS films showing 30% or more Fe removal in a layer 15 cm or more thick within the top 30 cm. Conversely, no hydric sampling point at West Kramer or Pfister met the standard for the same deployment period in 2026.. In 2025, one of three East Kramer hydric positions met the standard in the early-spring deployment, and two of three East Kramer Hydric positions met the standard in the late-spring deployment. No hydric positions at West Kramer or Pfister met the standard in 2025. No Fe removal was observed for any upland position at any site for any of the IRIS deployments.

α,α′-Dipyridyl Test Strips

Test strips impregnated with α,α′-dipyridyl dye were applied at nine points across the West Kramer, East Kramer, and Pfister sites on July 1, 2026 during an active saturation event (Appendix G). The hydric positions at each of the three interdunal wetlands at East Kramer exhibited positive reactions that met the HSTS. However, West Kramer and Pfister did not immediately react to the α,α′-dipyridyl test strips, and thus, did not meet the HSTS for anaerobic conditions.

Hydrophytic Vegetation Survey

Hydrophytic vegetation was surveyed across three sites, East Kramer, West Kramer, and Pfister. Along each site, 5 quadrat samples were collected within the Upland and Hydric hydrologic zones. During the 2025 and 2026 growing seasons, sampling yielded 170 plots and

539 species occurrence records comprising 42 taxa. At the East Kramer site, all five Hydric-zone plots in both the P and E study areas met Indicator 1 (Rapid Test) criteria for hydrophytic vegetation in 2026.

Table 4- Summary Table of the hydrologic zones of East Kramer, West Kramer, and Pfister that had Hydrophytic Vegetation

Site	Microshed	Hydric 2025	Hydric 2026
East Kramer	E	No	Yes
East Kramer	H	No	Yes
East Kramer	P	No	Yes
West Kramer	U	No	No
West Kramer	V	No	No
West Kramer	X	No	No
Pfister	B	No	No
Pfister	D	No	No
Pfister	K	No	No

East Kramer met a hydrophytic vegetation indicator at every sample plot but 1 at site H in 2026, a majority of West Kramer and Pfister sample plots did not meet hydrophytic a vegetation indicator in both 2025 and 2026 if any at all (Appendix F). This could possibly be a result of the drier conditions observed at these sites.

Discussion

The primary objective of this study was to evaluate whether FIHS were occurring in interdunal wetlands in MLRA 79. We found that FIHS were functioning well. Across the 34 interdunal wetlands surveyed on the Kramer and Pfister sites, every basin exhibited at least one FIHS, confirming that these depressions either are, or once were, hydric soils. The S5 – Sandy Redox was the most common indicator amongst all of our sites.. S6 – Stripped Matrix being the second most common FIHS was interesting due to its relatively infrequent use in wetland delineations in Kansas. Its relative abundance in this study shows that it is an indicator that wetland delineators should be looking for in sandy soils in Kansas, such as those in MLRA 79. However, wetland delineators should note that the stripped matrix pattern was commonly observed in soil layers with textures that fall into loamy and clayey soils where S-indicators do not apply. Since Stripped Matrix is an S-indicator, it can only be used when the pattern is observed in sands or loamy sands where S-indicators apply (USDA-NRCS, 2026). The A11 – Redox Dark Surface was also of note as the third most abundant field indicator observed in the interdunal survey. This is also one of the most common FIHS used in wetland delineations across the country, so its relative abundance was to be expected.

This study coincided with a significant drought in Stafford and Rice Counties based on historical data from the National Integrated Drought Information System (National Integrated Drought Information System, 2026a; b). Both Stafford and Rice Counties were under D3 – Extreme Drought or D4 – Exceptional Drought for the majority of 2023. During the first year of this study in 2024, Rice County was under D2 – Severe Drought, S1 – Moderate Drought, or S0 – Abnormally Dry conditions throughout the entire year. Meanwhile, Stafford County was under the same conditions for the first 10 months. Conditions in 2025 improved, but the two counties still experienced moderate drought during the spring when interdunal wetlands in this region would normally be experiencing wet conditions and shallow water tables or ponding. Finally, drought conditions returned in March and April of 2026 with D3 - Extreme Drought, D2 - Severe Drought, and D1 - Moderate Drought. However, normal wet conditions occurred in January, February, May, and June 2026, which facilitated saturation events at the hydric positions at the East Kramer sites.

The duration and severity of the drought in this region relative to the timing of the survey conducted in 2024, combined with the sandy textures of these soils, could have contributed to the mineralization of carbon from these interdunal wetlands, or the prevention of sulfur reduction. Thus, the absence of some FIHS is noteworthy. Field indicators that we expect could occur in these wetlands but were not observed or were rarely observed were those associated with carbon accumulation or the reduction of sulfur. Carbon-related examples include A7 – Mucky Mineral, A9 – 1 cm Muck, S1 – Sandy Mucky Mineral, S2 - 2.5 cm Mucky Peat or Peat. Examples of indicators associated with sulfur reduction include A4 – Hydrogen Sulfide and A18 – Iron Monosulfide.

While all 34 of the interdunal depressions surveyed on the Kramer and Pfister sites included a hydric soil based on the confirmed presence of FIHS, not all of these soils were functioning as hydric soils. Field Indicators of Hydric Soils are not measures of current function, but rather morphological records that show the soil experienced anaerobic conditions repeatedly, causing the translocation of iron and manganese or accumulation of carbon within the soil (Vepraskas, 2013; USDA-NRCS, 2026). A soil can display strong indicators while no longer experiencing the hydrology that created them, because once established, this morphology can persist through subsequent drier periods (U.S. Army Corps of Engineers, 1987; USDA-NRCS, 2026). That appears to be the case for the West Kramer and Pfister sites which did not meet the hydrology or anaerobic conditions standards of the HSTS. Of the nine instrumented transects in this study, only the three transects at East Kramer met the requirements of the HSTS and are thus functioning as hydric soils under current field conditions.

Three independent data sources converged on this conclusion. Well data showed all three East Kramer transects maintained water tables at or above the 25 cm threshold from the start of monitoring, while no West Kramer or Pfister well ever recorded a water table within 25 cm of the surface. The IRIS films deployed in 2026 and α,α′-Dipyridyl test strips used on July 1, 2026 showed that East Kramer met the anaerobic soil standard at all three hydric positions along the transects, while West Kramer and Pfister had zero hydric transect positions that met the standard.

The contrast between East Kramer and the other two sites regarding wetland function is interesting. There are several possible contributing factors to this, and each are associated with position of these depressions within the surrounding landscape. Interdunal depressions are typically wet due to the land surface being in close proximity to or intersecting the regional water table. Interdunes that intersect the regional water table for periods of 14 days or longer during the growing season will theoretically have interdunal wetlands. However, interdunes that are only in close proximity to the regional water table may have more soil moisture at the center of depressions, but not be classified as wetlands. Given that context, it is important to note that all 34 interdunes sampled in this study contained hydric soils. Thus, at one point in time, those interdunal depressions contained interdunal wetlands. However, West Kramer and Pfister not meeting the HSTS show that these soils are not currently functioning as hydric soils. Further, at East Kramer the FIHS extend further up on the slope than the hydrophytic vegetation and wetland hydrology does. This is likely due to a decrease in the regional water table. Since indicator morphology persists regardless of whether its causal hydrology remains (Vepraskas, 2013; USDA-NRCS, 2026), this suggests the upper part of the depression records a wetter historical regime, while active hydrology and hydrophytic vegetation have since retreated downward, tracking the falling water table, a pattern paralleling wetland retreat documented at the Great Sand Dunes in Colorado (Wurster et al., 2003). East Kramer appears to be in an earlier stage of the same process where the wetland has not disappeared, but its functionally hydric footprint has already contracted below the footprint recorded in the legacy soil morphology. Vegetation data support this, as only East Kramer met the hydrophytic vegetation indicator in both study years.

This decline in the regional water table could be due to intensive groundwater withdrawal from higher up in the watershed. MLRA 79 overlies the Great Bend Prairie component of the High Plains Aquifer, where natural recharge already lags behind withdrawal in many areas (Sophocleous and McAllister, 1990b; USDA-NRCS, 2025a). The interdunal wetlands are hydrologically analogous to depressional systems in which the position of the regional water table relative to land surface governs whether a basin discharges groundwater and stays saturated, or loses water to the subsurface and dries (Neff et al., 2020). Where the regional water table has dropped, low-lying basins like East Kramer would retain hydric function longer than higher basins like West Kramer, simply by sitting closer to the current, lowered water table. This mirrors documented conflict at the nearby Quivira National Wildlife Refuge, where state investigations have repeatedly found that upstream irrigation pumping impairs the refuge's senior water right, with modeled baseflow well below mid-twentieth-century levels (Sophocleous and McAllister, 1990b; Kansas Department of Agriculture, 2023). Because Kramer and Pfister sit within this same groundwater system, a comparable decline plausibly explains why hydric function has retreated to only the lowest interdunal positions. A related contributing factor is that the duration and severity of drought in the region has resulted in a lowered water table due to limited recharge over several years.

Another explanation involves encroachment of phreatophytic woody species, such as cottonwood (*Populus deltoides*, Latin) and black willow (*Salix nigra,* Latin), which we observed at in multiple interdunal areas in this study. Both species tolerate gradual water table decline by rooting deeper to stay in contact with a falling water table, allowing established stands to persist even as the water table that supported their establishment keeps dropping (Amlin and Rood, 2002). Prescribed burning has not been practiced at these three sites. Using fire as a control of woody species would likely prevent further drops in the shallow water table onsite due to excessive water use by these trees (Nippert et al., 2021).

Beyond their technical significance for wetland delineation methodology, these findings speak to the broader hydrologic pressures facing the Great Bend Sand Plains and the Quivira National Wildlife Refuge. If groundwater decline driven by regional irrigation demand is indeed contracting the functionally hydric extent of these interdunal wetlands, then the same processes reducing streamflow to Quivira's senior water right are also likely acting on the smaller, dispersed interdunal wetlands scattered across the surrounding landscape. This raises the possibility that resolving the long standing impairment of Quivira's senior water right impairment (USDA-NRCS, 2025a) could have benefits that extend beyond the refuge boundary itself.

Because Kramer and Pfister sit within the same groundwater-fed system that supplies Rattlesnake Creek and, in turn, Quivira's salt marshes, restoring flows consistent with the refuge's senior priority would likely correspond to a partial recovery of the regional water table. This could potentially allow presently non-hydric basins such as West Kramer and Pfister to regain the shallow water tables and anaerobic soil conditions needed to again function as hydric soils. This would be consistent with the legacy field indicators already present at those sites.

Enforcement of the senior water right that Kansas statute already recognizes (K.S.A. 82a-706b), functions simultaneously as a form of passive wetland restoration across the wider dune and swale landscape, without requiring any additional site-specific intervention (USDA-NRCS, 2025a).

Future work should document how field indicators of hydric soils develop and persist in disturbed soils where former farmland is being restored to interdunal wetland. Because agricultural disturbance alters organic matter content, soil structure, and drainage, it is unclear whether FIHS form on the same timeline, at the same frequency, or through the same redox pathways once hydrology is restored to cultivated ground. Documenting this would give restoration practitioners and delineators a basis for interpreting hydric soil development on the growing acreage of interdunal land being returned to wetland function across the Great Bend Sand Plains.

A more extensive hydrologic study is also needed, including the incorporation of additional wells across a broader network of interdunal depressions and longer-term monitoring beyond the three years captured here. Because this study coincided with a multi-year regional drought, longer-term data are necessary to confirm whether the regional water table is genuinely declining, as the contrast between East Kramer and the other two sites suggests, or whether current conditions instead reflect drought-driven variability that could recover in wetter years. Establishing this distinction is essential before the water management and conservation implications raised here can be applied with confidence across MLRA 79.

Conclusion

In this three-year study, we examined if FIHS were present in 36 interdunal depressions. We found that all 36 interdunal depressions contained FIHS, and thus hydric soils. The three most common indicators were S5 – Sandy Redox, S6 – Stripped Matrix, and A11 – Redox Dark Surface. Nine of the 36 interdunal depressions were instrumented and monitored according to the HSTS. We found that the three interdunal depressions at East Kramer had wetlands and soils currently functioning as hydric soils. In contrast, interdunal depressions at West Kramer and Pfister were not functioning as hydric soils during our study. So we accept the hypothesis that FIHS are present in interdunal soils of MLRA 79, but partially reject the hypothesis that interdunal soils in MLRA 79 are functioning as hydric soil.

At East Kramer, FIHS occurred on hillslope positions higher than that of wetland hydrology and hydrophytic vegetation. That, combined with the lack of current hydric soil function at West Kramer and Pfister, indicates that the regional water table has dropped across each of these three sites, and that only East Kramer retains functioning hydric soils due to a lower position relative to the regional water table. This decrease in the regional water table could be due to irrigation withdrawal higher in the Rattlesnake Creek watershed, prolonged drought conditions in the region before and during the study, and/or encroachment of cottonwood and black willow. This study highlights which FIHS wetland delineators can expect when working on interdunal wetland conservation efforts in MLRA 79 and other dune-interdune systems across the US. It also highlights challenges with water management in these sandy, dynamic interdunal systems.

Research Chapter Bibliography

ACIS- Regional Climate Centers. 2026a. AgACIS- Stafford County. https://agacis.rcc-acis.org/?fips=20185 (accessed 7 July 2026).

ACIS- Regional Climate Centers. 2026b. AgACIS- Rice County. https://agacis.rcc-acis.org/?fips=20159 (accessed 7 July 2026).

Barchyn, T.E., and C.H. Hugenholtz. 2012. Aeolian dune field geomorphology modulates the stabilization rate imposed by climate. Journal of Geophysical Research: Earth Surface 117(F2). doi: 10.1029/2011JF002274.

Berkowitz, J.F., R.W. Griffin, E. Laboratory (U.S.), P.V.A. University, and W.R.A. Program (U.S.). 2025. Identifying hydric soils using α,α′-dipyridyl dye. https://hdl.handle.net/11681/49932 (accessed 4 July 2026).

Berkowitz, J.F., and J.B. Sallee. 2011. Investigating Problematic Hydric Soils using Hydrology, IRIS Tubes, Chemistry, and the Hydric Soils Technical Standard. Soil Science Society of America Journal 75(6): 2379–2385. doi: 10.2136/sssaj2011.0040.

Berkowitz, J.F., M.J. Vepraskas, K.L. Vaughan, and L.M. Vasilas. 2021a. Development and application of the Hydric Soil Technical Standard. Soil Science Society of America Journal 85(3): 469–487. doi: 10.1002/saj2.20202.

Berkowitz, J.F., M.J. Vepraskas, K.L. Vaughan, and L.M. Vasilas. 2021b. Development and application of the Hydric Soil Technical Standard. Soil Science Society of America Journal 85(3): 469–487. doi: 10.1002/saj2.20202.

Boettinger, J.L. 1997. Aquisalids (Salorthids) and Other Wet Saline and Alkaline Soils: Problems Identifying Aquic Conditions and Hydric Soils. Aquic Conditions and Hydric Soils: The Problem Soils. John Wiley & Sons, Ltd. p. 79–97

Chow, A.T., A.L. Pitt, R.F. Baldwin, D. Suhre, and J.-J. Wang. 2016. Water quality dynamics of ephemeral wetlands in the Piedmont ecoregion, South Carolina, USA. Ecological Engineering 94: 555–563. doi: 10.1016/j.ecoleng.2016.06.075.

Conservation Effects Assessment Project and United StatesNatural Resources Conservation Service. 2020. Soil Influences on water balance in wetlands may impact wetland effectiveness in achieving different restoration objectives. USDA Natural Resources Conservation Service, Washington, D.C.

Fidel, R. 2025. Salt-affected Soils: Salinity and Sodicity. https://iastate.pressbooks.pub/isudp-2025-201/chapter/salt-affected-soils-salinity-and-sodicity/ (accessed 26 March 2026).

Gage, E., D.J. Cooper, and R. Lichvar. 2020. Comparison of USACE Three-Factor Wetland Delineations to National Wetland Inventory Maps. Wetlands 40(5): 1097–1105. doi: 10.1007/s13157-019-01234-y.

Glaser, L. 1986. Provisions of the Food Security Act of 1985 | Economic Research Service. https://www.ers.usda.gov/publications/pub-details?pubid=42003 (accessed 24 March 2026).

Interdunal Wetland - Michigan Natural Features Inventory. 2010. https://mnfi.anr.msu.edu/communities/description/10668/Interdunal-Wetland (accessed 23 December 2025).

Kansas Department of Agriculture. 2023. Quivira National Wildlife Refuge | Department of Agriculture. https://www.agriculture.ks.gov/divisions-programs/division-of-water-resources/water-appropriation/impairment-complaints/quivira-national-wildlife-refuge (accessed 7 July 2026).

Kansas Department of Wildlife and Parks. 2026. Cheyenne Bottoms Wildlife Area | Kansas Department of Wildlife and Parks. https://www.ksoutdoors.gov/home/showpublisheddocument/152/638936327109470000 (accessed 4 June 2026).

Kriegner, C.J., R.P. Chiarello, and K.W. Buelow. 2015. Wetland Delineation: Accuracy Is Not Precision. Journal of Water Resources Planning and Management 141(7): 02515001. doi: 10.1061/(ASCE)WR.1943-5452.0000542.

Lang, M.W., J.C. Ingebristen, and R.K. Griffin. 2024. 2019 Wetlands Status and Trends Report.

Lichvar, R., J. Gillrich, and W. Ochs. 2011. Discrepancies in Hydrophytic Determinations Produced by Three Vegetation Formulas Used for Wetland Delineations. Wetlands 31(3): 603–611. doi: 10.1007/s13157-011-0166-7.

Munsell Soil Color Charts. 2009.

National Integrated Drought Information System. 2026a. Stafford County Conditions | Drought.gov. https://www.drought.gov/states/kansas/county/stafford (accessed 8 July 2026).

National Integrated Drought Information System. 2026b. Rice County Conditions | Drought.gov. https://www.drought.gov/states/kansas/county/Rice (accessed 8 July 2026).

Natural Resources Conservation Service. 2025. Rattlesnake Creek Watershed Draft Plan - EIS.

Neff, B.P., D.O. Rosenberry, S.G. Leibowitz, D.M. Mushet, H.E. Golden, et al. 2020. A Hydrologic Landscapes Perspective on Groundwater Connectivity of Depressional Wetlands. Water 12(1): 50. doi: 10.3390/w12010050.

Nippert, J.B., L. Telleria, P. Blackmore, J.H. Taylor, and R.C. O'Connor. 2021. Is a Prescribed Fire Sufficient to Slow the Spread of Woody Plants in an Infrequently Burned Grassland? A Case Study in Tallgrass Prairie. Rangeland Ecology & Management 78: 79–89. doi: 10.1016/j.rama.2021.05.007.

NTCHS. 2026. National Technical Committee for Hydric Soils (NTCHS) | Natural Resources Conservation Service. https://www.nrcs.usda.gov/conservation-basics/soil/national-technical-committee-for-hydric-soils-ntchs (accessed 7 July 2026).

Official Series Description - CARWAY Series. 2000. https://soilseries.sc.egov.usda.gov/OSD_Docs/C/CARWAY.html (accessed 6 July 2026).

Official Series Description - KINGMAN Series. 1997. https://soilseries.sc.egov.usda.gov/OSD_Docs/K/KINGMAN.html (accessed 6 July 2026).

Park, E., and M.C. Rabenhorst. 2018. Assessing New Developments in IRIS Technology. WSP 35(4): 324–327. doi: 10.1672/UCRT083-244.

Photos, C., L. Lefebvre, J. Klein, C. McKernan, J. Goulet, et al. 2019. Influence of wetland indicator status ratings on the extent of hydrophytic vegetation during wetland delineations. Engineer Research and Development Center (U.S.).

Rabenhorst, M.C. 2018. A System for Making and Deploying Oxide-Coated Plastic Films for Environmental Assessment of Soils. Soil Science Society of America Journal 82(5): 1301–1307. doi: 10.2136/sssaj2018.05.0178.

Ramsar Sites Information Services. 2002. Quivira National Wildlife Refuge | Ramsar Sites Information Service. https://rsis.ramsar.org/ris/1172?__goaway_challenge=meta-refresh&__goaway_id=e17c57401fde2af0da221d37b0faf421 (accessed 24 March 2026).

Rengasamy, P., C. Lacerda, and H. Gheyi. 2022. Salinity, Sodicity and Alkalinity. p. 83–107

Sapkota, Y., C. Duball, K. Vaughan, M.C. Rabenhorst, and J.F. Berkowitz. 2022. Indicator of Reduction in Soil (IRIS) devices: A review. Science of The Total Environment 852: 158419. doi: 10.1016/j.scitotenv.2022.158419.

SC ACIS2. 2024. SC ACIS2. https://scacis.rcc-acis.org/ (accessed 11 June 2026).

Schindelin, J., I. Arganda-Carreras, E. Frise, V. Kaynig, M. Longair, et al. 2012. Fiji: an open-source platform for biological-image analysis. Nat Methods 9(7): 676–682. doi: 10.1038/nmeth.2019.

Smith, R.D., A. Ammann, C. Bartoldus, and M.M. Brinson. 1995. An Approach for Assessing Wetland Functions Using Hydrogeomorphic Classification, Reference Wetlands, and Functional Indices. U.S. Army Corps of Engineers, Washington, DC.

Sophocleous, M., and J. McAllister. 1990a. KGS--Ground Water Series 11--Rattlesnake Creek Watershed--Introduction. https://www.kgs.ku.edu/Publications/Bulletins/GW11/02_intro.html (accessed 6 June 2026).

Sophocleous, M., and J. McAllister. 1990b. KGS--Ground Water Series 11--Rattlesnake Creek Watershed--Hydrogeologic Environment. https://www.kgs.ku.edu/Publications/Bulletins/GW11/03_envir.html (accessed 6 June 2026).

Sparks, D.L., B. Singh, and M.G. Siebecker. 2024. The Chemistry of Saline and Sodic Soils. Environmental Soil Chemistry. Elsevier. p. 411–438

Sprecher, S.W. 2008. Installing Monitoring Wells in Soils (Version 1.0). https://nrcs.app.box.com/s/wpxih9lg2xy9lavzhxyuwbtzwab8sh0a/file/1588696821078?sb=/details (accessed 19 December 2024).

Sprecher, S.W., and A.G. Warne. 2000. Accessing and Using Meteorological Data to Evaluate Wetland Hydrology: Defense Technical Information Center, Fort Belvoir, VA.

Steiner, J.L., D.L. Devlin, S. Perkins, J.P. Aguilar, B. Golden, et al. 2021. Policy, Technology, and Management Options for Water Conservation in the Ogallala Aquifer in Kansas, USA. Water 13(23): 3406. doi: 10.3390/w13233406.

Sumner, J.P., M.J. Vepraskas, and R.K. Kolka. 2009. Methods to evaluate normal rainfall for short-term wetland hydrology assessment. Wetlands 29(3): 1049–1062. doi: 10.1672/09-026D.1.

Taghvaeian, S., R.S. Frazier, D. Livingston, and G. Fox. 2016. Oklahoma Cooperative Extension Service.

Tang, S., D. She, and H. Wang. 2021. Effect of salinity on soil structure and soil hydraulic characteristics. Can. J. Soil. Sci. 101(1): 62–73. doi: 10.1139/cjss-2020-0018.

Tarolli, P., J. Luo, E. Park, G. Barcaccia, and R. Masin. 2024. Soil salinization in agriculture: Mitigation and adaptation strategies combining nature-based solutions and bioengineering. iScience 27(2): 108830. doi: 10.1016/j.isci.2024.108830.

The Nature Conservancy. 2026a. Cheyenne Bottoms Preserve, Kansas. The Nature Conservancy. https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/cheyenne-bottoms-preserve/ (accessed 24 March 2026).

The Nature Conservancy. 2026b. Rattle Snake Creek- Quivira. https://www.nature.org/en-us/get-involved/how-to-help/places-we-protect/rattlesnake-creek-kansas/#:~:text=Wildlife%20needs%20the%20wetlands%20at%20Quivira%20National%20Wildlife.

U.S. Army Corps of Engineers. 1987. Corps of Engineers wetlands delineation manual - Corps of Engineers wetlands delineation manual - Technical Reports - USACE Digital Library. https://usace.contentdm.oclc.org/digital/collection/p266001coll1/id/4530 (accessed 21 February 2026).

U.S. Army Corps of Engineers. 2010a. Corps of Engineers wetlands delineation manual - Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region (Version 2.0) - Technical Reports. https://usace.contentdm.oclc.org/utils/getfile/collection/p266001coll1/id/7613 (accessed 25 March 2026).

U.S. Army Corps of Engineers. 2010b. Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Midwest Region (Version 2.0). U.S. Army Engineer Research and Development Center, Vicksburg, MS.

US EPA, O. 2013. Summary of the Clean Water Act. https://www.epa.gov/laws-regulations/summary-clean-water-act (accessed 24 March 2026).

US EPA, O. 2015. CWA Section 404 and Swampbuster: Wetlands on Agricultural Lands. https://www.epa.gov/cwa-404/cwa-section-404-and-swampbuster-wetlands-agricultural-lands (accessed 24 March 2026).

U.S. Fish & Wildlife Service. 2024. Quivira National Wildlife Refuge | U.S. Fish & Wildlife Service. https://www.fws.gov/refuge/quivira (accessed 3 December 2024).

USDA-NCSS. 2000. Official Series Description - NINNESCAH Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/N/NINNESCAH.html (accessed 6 July 2026).

USDA-NCSS. 2004. Official Series Description - CARBIKA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/C/CARBIKA.html (accessed 6 July 2026).

USDA-NCSS. 2006. Official Series Description - KANZA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/K/KANZA.html (accessed 21 February 2026).

USDA-NCSS. 2020. Official Series Description - PLEVNA Series. https://soilseries.sc.egov.usda.gov/OSD_Docs/P/PLEVNA.html (accessed 6 July 2026).

USDA-NRCS. 2018. Ecological Site R079XY133KS-MLRA 79- Wet Subirrigated. https://edit.sc.egov.usda.gov/catalogs/esd/079X/R079XY133KS (accessed 30 December 2024).

USDA-NRCS. 2024. Field Book for Describing and Sampling Soils, Version 4.0.

USDA-NRCS. 2025a. Kansas Natural Resources Conservation Service (NRCS) Wetland Restoration Criteria and Guidelines (WRCG). https://www.nrcs.usda.gov/sites/default/files/2025-04/KS-FY2025-WRCG_04232025.pdf.

USDA-NRCS. 2025b. Hydric Soils of Problematic Conditions and Altered Materials v1.0.

USDA-NRCS. 2025c. Hydric Soil Technical Standard.

USDA-NRCS. 2026. Field Indicators of Hydric Soils in the United States, Version 9.3.

Vepraskas, M. j. 2013. Morphological Methods to Characterize Hydric Soils. Methods in Biogeochemistry of Wetlands. John Wiley & Sons, Ltd. p. 117–135

Vepraskas, M.J., J.F. Berkowitz, and C. Arellano. 2019. Determining Normal Precipitation Ranges for Hydric Soil Assessments. Soil Science Society of America Journal 83(2): 503–510. doi: 10.2136/sssaj2018.09.0333.

Vepraskas, M.J., X. He, D.L. Lindbo, and R.W. Skaggs. 2002. Predicting Long-Term Wetland Hydrology From Hydric Soil Field Indicators.

Vepraskas, M.J., D.L. Lindbo, and M.H. Stolt. 2018. Chapter 15 - Redoximorphic Features. In: Stoops, G., Marcelino, V., and Mees, F., editors, Interpretation of Micromorphological Features of Soils and Regoliths (Second Edition). Elsevier. p. 425–445

Wurster, F.C., D.J. Cooper, and W.E. Sanford. 2003. Stream/aquifer interactions at Great Sand Dunes National Monument, Colorado: influences on interdunal wetland disappearance. Journal of Hydrology 271(1): 77–100. doi: 10.1016/S0022-1694(02)00317-7.

Yamazaki, F., and J.A. Suhr Pierce. 2024. Impacts to the Ogallala Aquifer: How Changes in Long-term Weather Patterns and Shifts in Climate Regions Affect the Aquifer – An Overview of Selected Papers.

Appendix A - Blank Data Sheets

Appendix Figure A.1. Hydric Soil Survey Field Sheet

Sampling Location:		Date:	
Describer:		Wetland/Upland Type or Classification:	
Surface Water Depth:		Water Table Depth:	
Geologic Material(s):		Vegetative Cover:	
Soil Classification:		SSURGO Mapping Unit:	

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment

Hydric Soil Field Indicators Present for Use or Testing in LRR H & M

All Soils

☐ A1—Histosol or Histel

☐ A2—Histic Epipedon

☐ A3—Black Histic

☐ A4—Hydrogen Sulfide

☐ A5—Stratified Layers (For use in M, testing in H)

☐ A9—1 cm Muck (For use in H)

☐ A10—2 cm Muck (For use in M)

☐ A11—Depleted Below Dark Surface

☐ A12—Thick Dark Surface

☐ A18—Iron Monosulfide

Sandy Soils

☐ S2—2.5 cm Mucky Peat or Peat (For use in H)

☐ S3—5 cm Mucky Peat or Peat (For use in M)

☐ S4—Sandy Gleyed Matrix

☐ S5—Sandy Redox

☐ S6—Stripped Matrix

☐ S7—Dark Surface (For use in M)

Loamy and Clayey Soils

☐ F1—Loamy Mucky Mineral

☐ F2—Loamy Gleyed Matrix

☐ F3—Depleted Matrix

☐ F6—Redox Dark Surface

☐ F7—Depleted Dark Surface

☐ F8—Redox Depressions

☐ F12—Iron-Manganese Masses (For testing in M)

☐ F16—High Plains Depressions (For use in MLRA 72 and 73, for testing in other MLRAs of H)

☐ F18—Reduced Vertic

☐ F21—Red Parent Material (For testing in red parent materials)

Other Suspected Indicators Not Currently Applicable to H or M

☐ S8—Polyvalue Below Dark Surface

☐ S9—Thin Dark Surface

☐ S11—High Chroma Sands

Appendix Figure A.2. USACE Automated Data sheet- WETLAND DETERMINATION DATA SHEET – Great Plains Region

SOIL

Sampling Point: ________

Profile Description: (Describe to the depth needed to document the indicator or confirm the absence of indicators.)

Depth (inches)	Matrix Color (moist)	Matrix %	Redox Features Color (moist)	Redox Features %	Type[1]	Loc[2]	Texture	Remarks

[1]Type: C=Concentration, D=Depletion, RM=Reduced Matrix, CS=Covered or Coated Sand Grains. [2]Location: PL=Pore Lining, M=Matrix.

Hydric Soil Indicators: (Applicable to all LRRs, unless otherwise noted.)

___ Histosol (A1)
___ Histic Epipedon (A2)
___ Black Histic (A3)
___ Hydrogen Sulfide (A4)
___ Stratified Layers (A5) **(LRR F)**
___ 1 cm Muck (A9) **(LRR F, G, H)**
___ Depleted Below Dark Surface (A11)
___ Thick Dark Surface (A12)
___ Iron Monosulfide (A18)
___ Sandy Mucky Mineral (S1)
___ 2.5 cm Mucky Peat or Peat (S2) **(LRR G, H)**
___ 5 cm Mucky Peat or Peat (S3) **(LRR F)**
___ Sandy Gleyed Matrix (S4)
___ Sandy Redox (S5)
___ Stripped Matrix (S6)
___ Loamy Mucky Mineral (F1)
___ Loamy Gleyed Matrix (F2)
___ Depleted Matrix (F3)
___ Redox Dark Surface (F6)
___ Depleted Dark Surface (F7)
___ Redox Depressions (F8)
___ High Plains Depressions (F16) **(MLRA 72 & 73 of LRR H)**

Indicators for Problematic Hydric Soils[3]:

___ 1 cm Muck (A9) **(LRR I, J)**
___ High Plains Depressions (F16) **(LRR H outside of MLRA 72 & 73)**
___ Reduced Vertic (F18)
___ Red Parent Material (F21)
___ Very Shallow Dark Surface (F22) Other (Explain in Remarks)

[3]Indicators of hydrophytic vegetation and wetland hydrology must be present, unless disturbed or problematic.

Restrictive Layer (if observed):
Type: ________
Depth (inches): ________

Hydric Soil Present? **Yes** ____ **No** ____

Remarks:

HYDROLOGY

Wetland Hydrology Indicators:

Primary Indicators (minimum of one is required; check all that apply)

___ Surface Water (A1)
___ High Water Table (A2)
___ Saturation (A3)
___ Water Marks (B1)
___ Sediment Deposits (B2)
___ Drift Deposits (B3)
___ Algal Mat or Crust (B4)
___ Iron Deposits (B5)
___ Inundation Visible on Aerial Imagery (B7)
___ Water-Stained Leaves (B9)
___ Salt Crust (B11)
___ Aquatic Invertebrates (B13)
___ Hydrogen Sulfide Odor (C1)
___ Dry-Season Water Table (C2)
___ Oxidized Rhizospheres on Living Roots (C3) **(where not tilled)**
___ Presence of Reduced Iron (C4)
___ Thin Muck Surface (C7)
___ Other (Explain in Remarks)

Secondary Indicators (minimum of two required)

___ Surface Soil Cracks (B6)
___ Sparsely Vegetated Concave Surface (B8)
___ Drainage Patterns (B10)
___ Oxidized Rhizospheres on Living Roots (C3) **(where tilled)**
___ Crayfish Burrows (C8)
___ Saturation Visible on Aerial Imagery (C9)
___ Geomorphic Position (D2)
___ FAC-Neutral Test (D5)
___ Frost-Heave Hummocks (D7) **(LRR F)**

Field Observations:

Surface Water Present? Yes ____ No ____ Depth (inches): ____
Water Table Present? Yes ____ No ____ Depth (inches): ____
Saturation Present? (includes capillary fringe) Yes ____ No ____ Depth (inches): ____

Wetland Hydrology Present? Yes ____ **No** ____

Describe Recorded Data (stream gauge, monitoring well, aerial photos, previous inspections), if available:

Remarks:

ENG FORM 6116-5, SEP 2024 Great Plains – Version 2.0

Appendix B - Soil Survey Completed Data Sheets

Appendix Figure B.1. Hydric Soil Survey Description Sheet Kramer 1

Sampling Location:	UTM 1304122.21E 1852341.81 N Loc. 1	Date:	3/10/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal Wetland
Surface Water Depth:	N/A	Water Table Depth:	
Geologic Material(s):	Eolian Sand	Vegetative Cover:	wet graminoids
Soil Classification:		SSURGO Mapping Unit:	Dillwyn-Tivin Complex 5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	10	10YR 3/2		10YR 4/6 5% VF				~~SL~~ LS	1	m	SBK	N	N	NT	GR	
	20	10YR 4/2		10YR 4/6 10% VF		2.5YR 5/2 40% VF-F		LS	0 to 1	m	Massive SBK	N	N	NT	GR	
	37+	10YR 4/2		10YR 4/6 10% VF		2.5YR 5/2 90%		SL	1	m	SBK	N	N	NT	GR	

Appendix Figure B.2. Hydric Soil Survey Description Sheet Kramer 2

10 m upslope of site 1 (1304066.96E 1852358.34N)

SS

Sampling Location:	1304085.48 E 1852344.18 N	Date:	3/10/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal wetland
Surface Water Depth:	not observed	Water Table Depth:	not observed
Geologic Material(s):	eolian sand	Vegetative Cover:	wet graminoids
Soil Classification:		SSURGO Mapping Unit:	Dillwyn-Tivin Complex 5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
A	4	10YR 2/1 on 10YR 6/1-2 sand grt.		8% fine 10YR 4/6 coatings on sand				S	1	med	GR	N	NT	NT	Clear	60% sand mask w/out hand lens
C1	21	10YR 7/2		10YR 4/6 soft mass 10%		10YR 7/2 80%		S	1	med	SBK	N	NT	NT	Grad	
C2	33+	10YR 6/2 80%		10YR 5/6 soft mass 20%		10YR 6/2 80%		LS	0	—	Mass	N	NT	NT		

Appendix Figure B.3. Hydric Soil Survey Description Sheet Kramer 3

Site 3

Sampling Location:	1304041.49E 1852[illegible]25N	Date:	7/10/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not obs.	Water Table Depth:	no obs
Geologic Material(s):	Eolian	Vegetative Cover:	wet graminoids, willows
Soil Classification:		SSURGO Mapping Unit:	S884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
A	7	10YR 4/2		Coatings on sand 10YR 4/6 5-10%		✓		S	0	-	Loose	N	NT	NT	C	
C	12	10YR 5/2		10YR 4/6 8% sand coatings		✓		LS	0	-	Loose	N	NT	NT	C	
C	~~[illegible]~~ 28	10YR 6/2		10YR 5/6 sand coat ~~[illegible]~~ 8%	10YR 5/6 2%	✓		LS	0	-	Loose	N	NT	NT	G	
C	32+	10YR 6/3		7.5YR 5/8 20%		✓		LS	0	-	Loose	N	NT	NT	-	

SS

Willows present
lots of concentrations @ most
push probe loc.

Appendix Figure B.4. Hydric Soil Survey Description Sheet Kramer 4

Sampling Location:	Watershed A 1303940.71E 1850504.12N	Date:	3/1/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not observed	Water Table Depth:	not observed
Geologic Material(s):	eolian Sand	Vegetative Cover:	grass, willow trees close
Soil Classification:		SSURGO Mapping Unit:	Stafford Co 5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	6	10YR 2/1 6% 10YR 3/2 [illegible]		10YR 4/4 5% Coat on sand VF				S	0	–	Loose					
	18	10YR 6/2		10YR 5/6 VF 7% Coat on Sand	10YR 5/6 2% CO	✓		LS	0	–	Loose					
	33+	10YR 6/2		10YR 5/6 9% VF Coat on Sim				LS	0	–	Loose					

Appendix Figure B.5. Hydric Soil Survey Description Sheet Kramer 5

Sampling Location:	micro watershed B 1302877.05E 185071?.34N	Date:	3/4/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal wetland
Surface Water Depth:	Not obs.	Water Table Depth:	not obs
Geologic Material(s):	eolian sandy	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	Stafford Co 5889

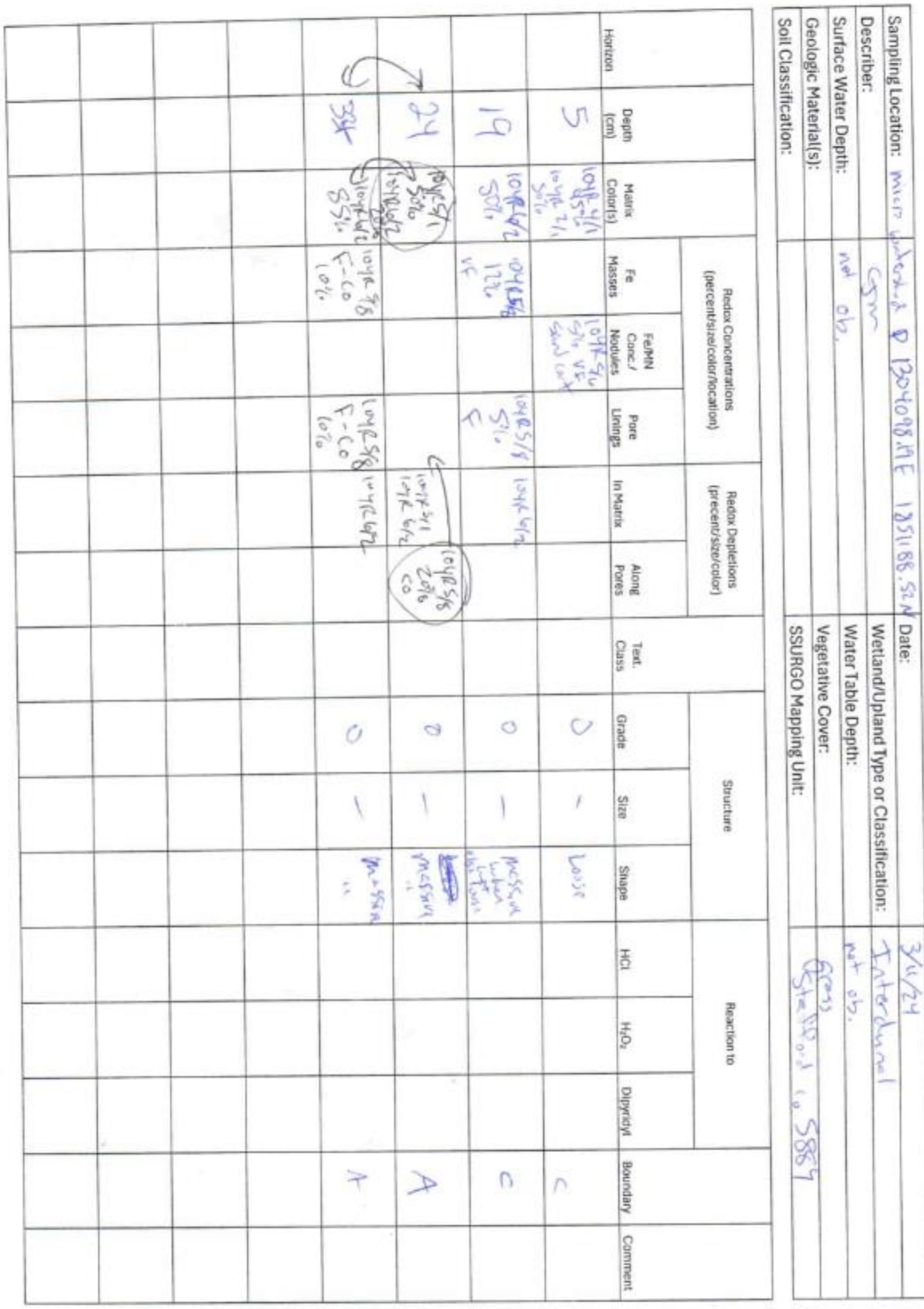
Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	0	10YR 7/1 80%		10YR 5/6 5% sand coating VF		10YR 7/1 80%		S	0	–	Loose				C	om stains fingers w/o ?? less ?% of particles ?? mask.
	17	10YR 5/4 80% 10% stain 10YR 7/1		10YR 5/6 10% VF sand coating		10YR 5/4 50%		LS	0	–	Loose				C	
	31+	10YR 5/2 85%	10YR 5/6 5% ?? soft mass	10YR 5/4 ?% VF sand coating		10YR 5/2 85%		LS	0	–	Loose				–	

Appendix Figure B.6. Hydric Soil Survey Description Sheet Kramer 6

Sampling Location:	micro watershed C 1304202.17E 1851274.14N	Date:	3/11/24
Describer:	EJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not obs.	Water Table Depth:	not ob.
Geologic Material(s):	eolian Sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	Stafford Co. 5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 4/1 10% 10YR 3/2 60% 10YR 2/1 30%		10YR 5/6 5% VF Sand coat				LS	0	—	Loose				C	
	21	10YR 4/1 60% 10YR 5/2 20%		10YR 5/8 VF 10%	10YR 5/8 VF 10%	10YR 4/1		LS	0	—	Loose				C	
	33+	10YR 5/2 80%		10YR 5/8 [illegible] 20%		10YR 8/2 80%		LS	0	—	Loose				C	

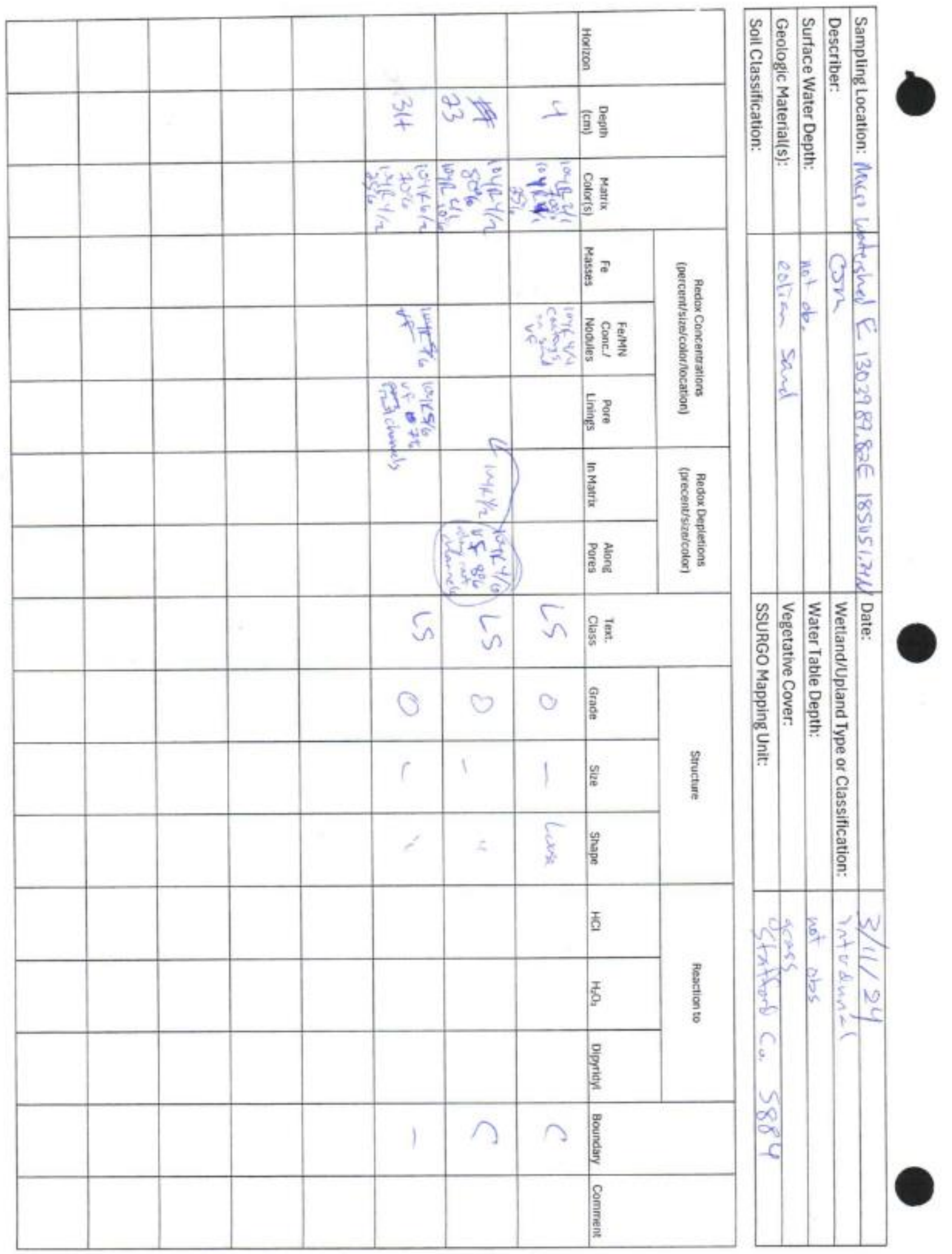
Appendix Figure B.7. Hydric Soil Survey Description Sheet Kramer 7



Sampling Location:	micro wetland @ 1304098.19E 1851188.52N	Date:	3/6/24
Describer:	GJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob.	Water Table Depth:	not ob.
Geologic Material(s):		Vegetative Cover:	Grass
Soil Classification:		SSURGO Mapping Unit:	Stafford Co 5889

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	5	10YR 4/1 45%; 10YR 3/1 50%		10YR 5/6 5% VF sand coat					0	-	Loose				C	
	19	10YR 6/2 50%	10YR 5/6 12% VF		10YR 5/8 5% F	10YR 6/2			0	-	massive when lifted				C	
	24	10YR 5/1 50%; 10YR 6/2 20%				10YR 3/1; 10YR 6/2	10YR 5/8 20% co		0	-	massive				A	
	34	10YR 6/2 85%	10YR 7/8 F-co 10%		10YR 5/8 F-co 10%	10YR 6/2			0	-	massive				A	

Appendix Figure B.8. Hydric Soil Survey Description Sheet Kramer 8



Sampling Location:	Micro Watershed E 130389.82E 185051.74N	Date:	3/11/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob.	Water Table Depth:	not obs
Geologic Material(s):	eolian Sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	Stafford Co. 5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 2/1 75% 10YR 4/1 25%		10YR 4/4 coatings on sand vf				LS	0	—	Loose				C	
	23	10YR 4/2 80% 10YR 4/1 10%				10YR 4/2	10YR 4/6 vf 8% along root channels	LS	0	—	"				C	
	34+	10YR 6/2 70% 10YR 4/2 25%		10YR ?% vf	10YR 5/6 vf 7% root channels			LS	0	—	"				—	

Appendix Figure B.9. Hydric Soil Survey Description Sheet Kramer 9

Sampling Location:	micro wetland E 1303958.45E 1851136.76N	Date:	3/11/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	
Geologic Material(s):	eolian sand	Vegetative Cover:	grass /rush
Soil Classification:		SSURGO Mapping Unit:	Stafford, 5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	3	10YR 2/1	[illegible]					SL	0	—	MA				C	All sand coated w/ om
	10	10YR 2/1 30 10YR 3/1 30 10YR 4/1 30	10YR 5/4 5%					SL	0	—	MA				C	
	25	10YR 3/1 35% 10YR 4/1 60%			10YR 3/6 CO 5% root channels	10YR 7/1 4%		SL	0	—	MA				C	
	37+	10YR 4/2 15% 10YR 5/1 35%		Sand cast 10YR 5/6 5%		10YR 4/2 10YR 5/1		LS	0	—	MA				—	

Appendix Figure B.10. Hydric Soil Survey Description Sheet Kramer 10

Sampling Location:	micro watersheds 1303851.20E 1851227.75N edge	Date:	7/11/24
Describer:	(S)m	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not obs	Water Table Depth:	not obs
Geologic Material(s):	eolian sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	Stafford Co. 5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	3	10YR 2/1 80% 10YR 4/1 20%	10YR5/6 2% coat on vf sand			10YR4/1		S	0	–	Loose				C	
	9	10YR 4/1 10YR 5/2			10YR 5/8 root channels F 5%	10YR 4/1 5/2		LS	0	–	MA				C	
	20	10YR 4/2 40% 10YR 4/1 60%			10YR 5/8 root chan 7% F	10YR 4/2 4/1		LS	0	–	MA				C	
	31+	10YR 6/2 60% 10YR 4/1 30%			10YR 4/6 VF-C root chan 10%	10YR 6/2 4/1		LS	0	–	MA				–	

Appendix Figure B.11. Hydric Soil Survey Description Sheet Kramer 11

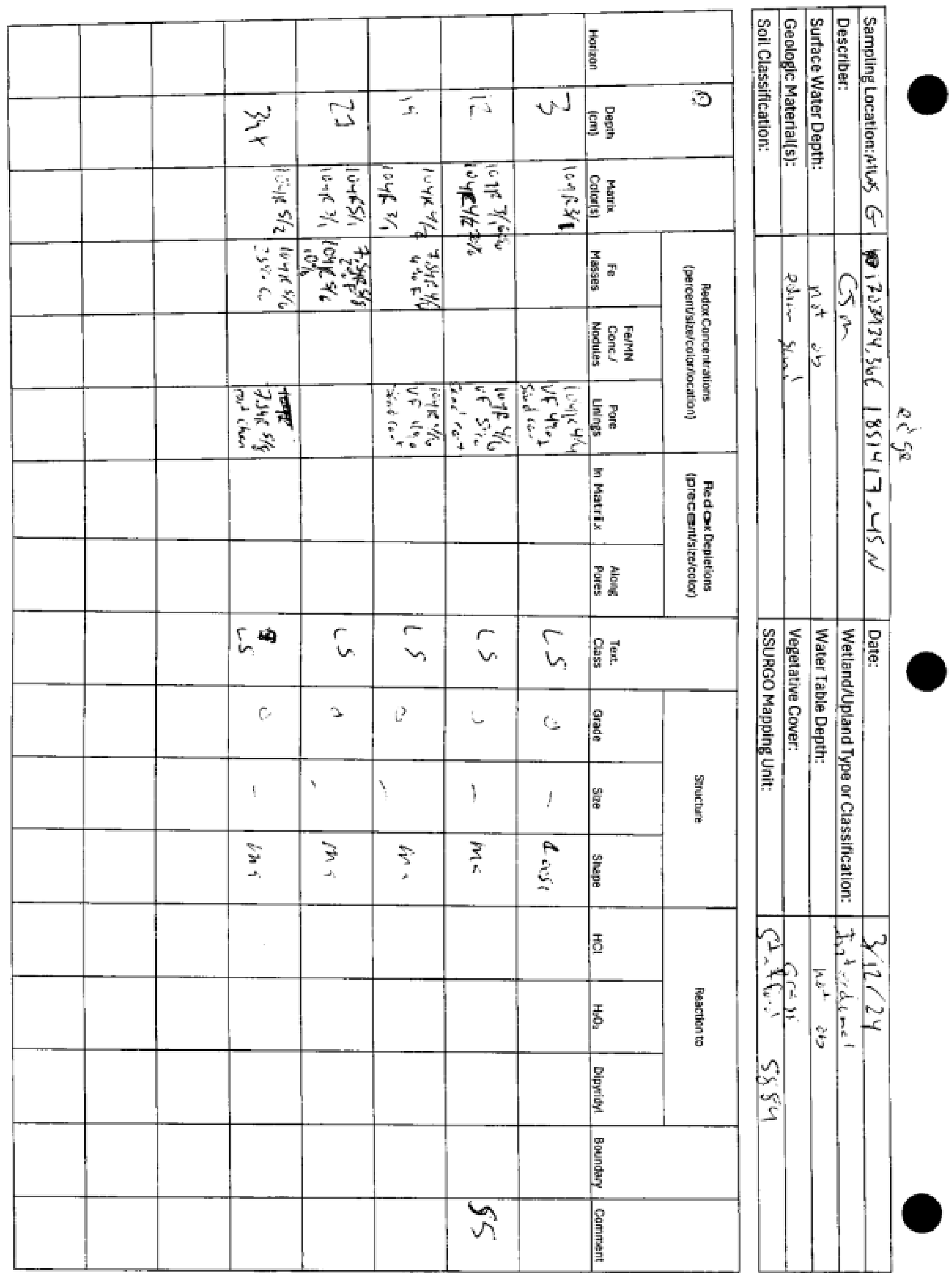
Center of Inter,

Sampling Location:	Micro watershed Y, 303834.66E 1852218.47N	Date:	3/11/24
Describer:	CJh	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	10.5 in
Geologic Material(s):	eolian sand	Vegetative Cover:	grass + sedge
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
A1	5	10YR 2/1			7.5YR 3/4 T%			LS	0	–	MA				C	
A2	12	10YR 3/1			5YR 3/4 15% Root chan	10YR 3/1		LS	0	–	MA				C	
A/C	20	A 10YR 3/1 C 10YR 4/1			7.5YR 4/6 15% C Root ch	10YR 3/1 4/1		A: SL C: LS	0	–	MA				A	
C/A	29+	C 10YR 6/2 A 10YR 3/1 +%			7.5YR 4/6 5% VF + F Root chan	10YR 5/1 in C and A		A: SL C: LS	0	–	MA				A	

A11 F3 S6 F8

Appendix Figure B.12. Hydric Soil Survey Description Sheet Kramer 12



Appendix Figure B.13. Hydric Soil Survey Description Sheet Kramer 13

Sampling Location:	MWS G 1303924.07E 1851926.83N center	Date:	3/12/24
Describer:	GTM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ~~?~~	Water Table Depth:	not ~~?~~
Geologic Material(s):	eolian sand	Vegetative Cover:	grass reeds
Soil Classification:		SSURGO Mapping Unit:	Stafford, 5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H2O2	Dipyridyl	Boundary	Comment
	3	10YR 2/1 70%, 10YR 4/2 [illegible]			10YR 4/6 5%			~~ES~~ SL	1	med	GR	-	—	-	C	
	26	10YR 3/1 70, 10YR 3/2		5YR 3/4 [illegible]	7.5YR 4/6 10%			SL	0	-	MA	-	N	-	A	~~[illegible]~~
	33+	10YR 6/2	10YR 5/6 to 15% [illegible]					LS	0	-	MA	-	[illegible]	-		

Appendix Figure B.14. Hydric Soil Survey Description Sheet Kramer 14

Edge

Sampling Location: MWS H	1304021.96E 1851509.86N	Date:	3/12/24
Describer:	GSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	Not ob.	Water Table Depth:	not ob.
Geologic Material(s):	eolian sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 2/1, 10YR 3/2 25%			10YR 4/4 4% sand coat			SL	1	M	GR				CL	
	19	10YR 4/1 80%, 10YR 6/2			10YR 4/6 10%, 5YR 4/4 2%	10YR 4/2		SL	0	-	MA				CL	
	30+	10YR 6/2	10YR 5/6 7%		10YR 4/6 3%			SL	0	-	MA				—	

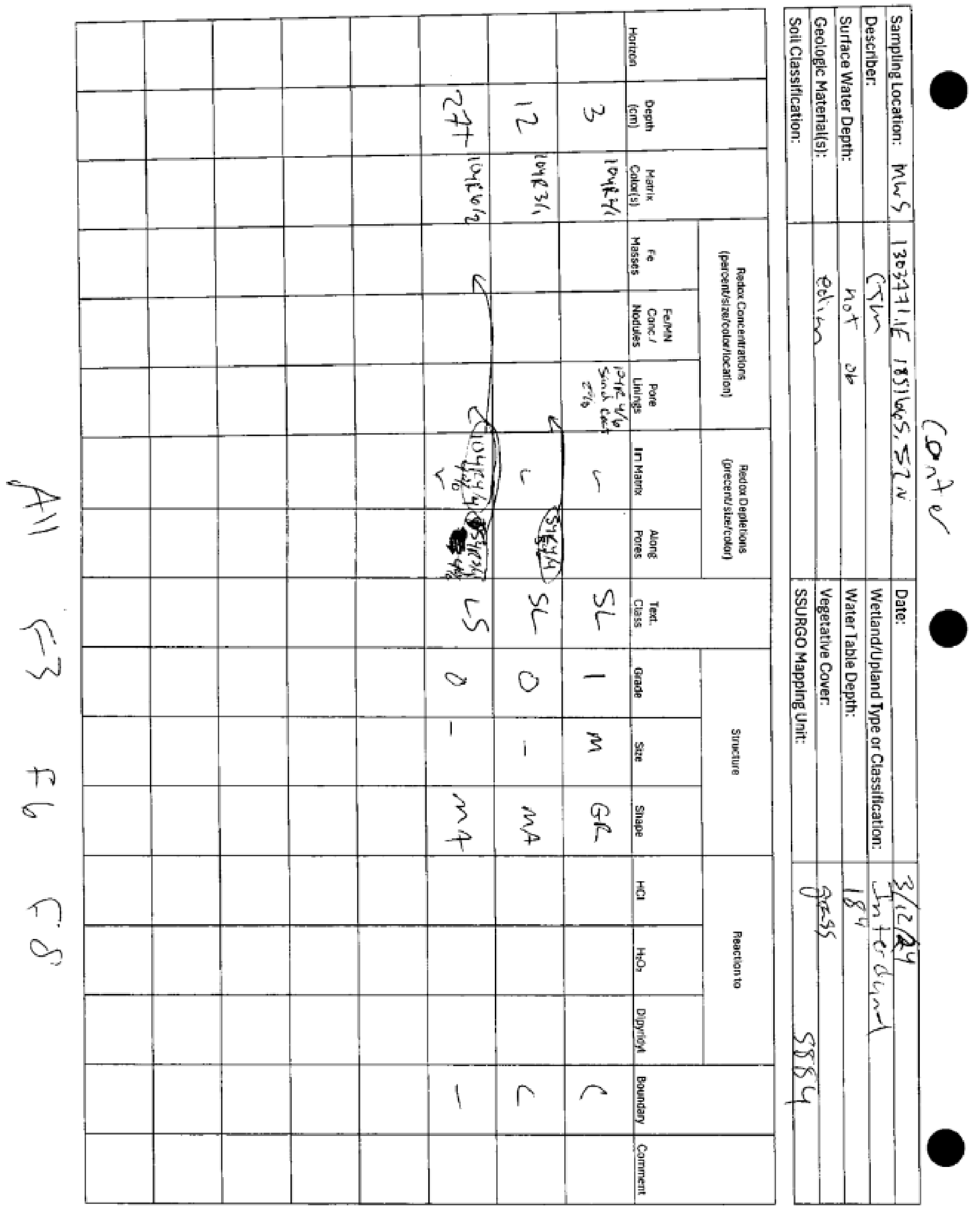
A11 F6 F3 F8

Appendix Figure B.15. Hydric Soil Survey Description Sheet Kramer 15

Sampling Location: MWS I		Date:	3/12/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	16"
Geologic Material(s):	eolian Sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
A	3	10YR 2/1 70% 10YR 3/2 25%			10YR 4/1 4% sand coat	10YR 2/1 10YR 3/2		LS	0	–	Loose				CL	
C	24	10YR 3/1 20% 10YR 4/2 80%	7.5YR 4/4		7.5YR 3/4 7% coat chan.	10YR 7/1 10YR 3/2		LS	0	–	MA				CL	
C	34+	10YR 4/2	2% 7.5YR 4/4		7.5YR 4/4 5% coat chan			SL	0	–	MA				–	

Appendix Figure B.16. Hydric Soil Survey Description Sheet Kramer 16



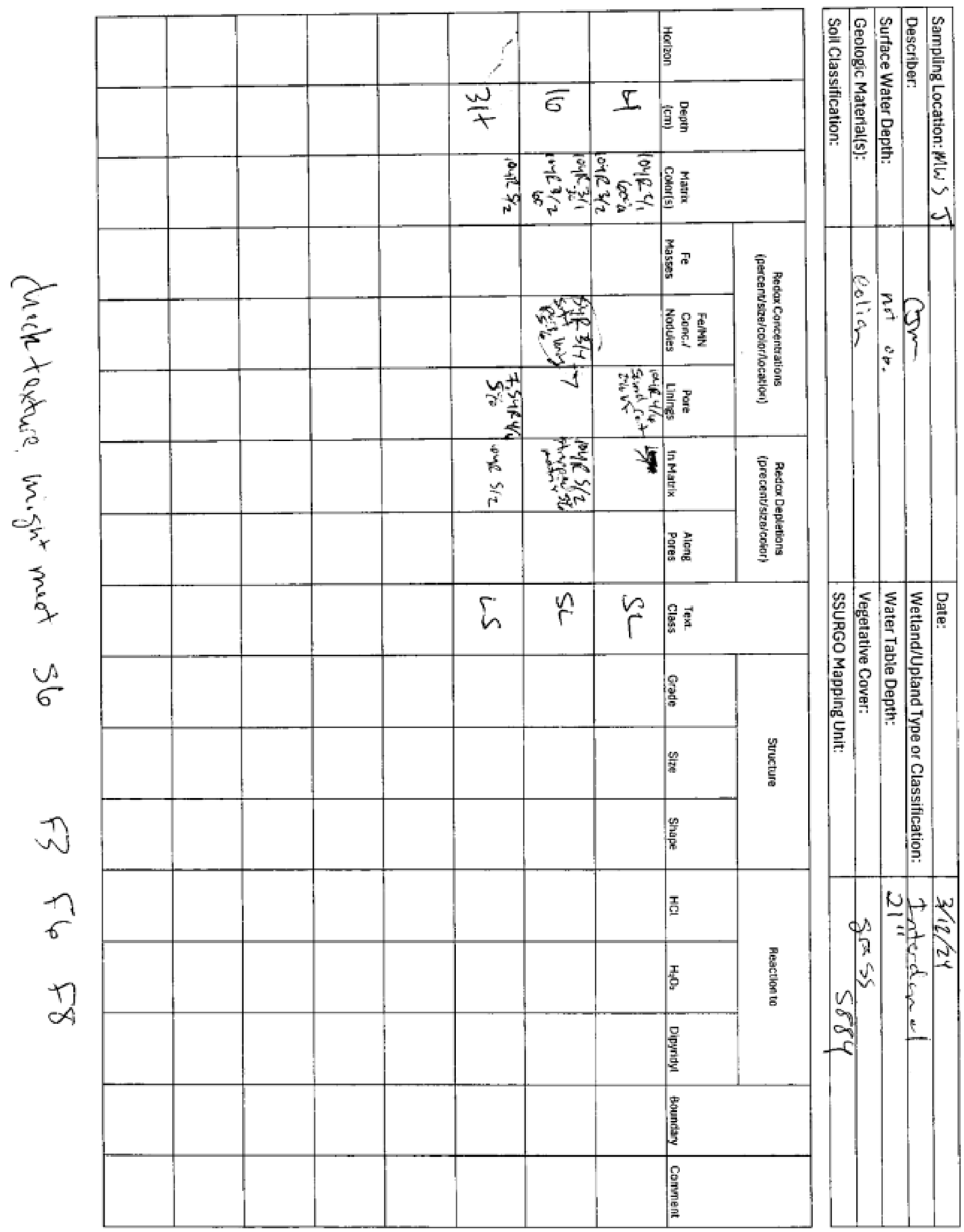
center

Sampling Location: MWS	1303771.1E 1851665.52N	Date:	3/12/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	18"
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	S884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	3	10YR3/1			10YR 4/6 Sand coat 2%	✓		SL	1	M	GR				C	
	12	10YR3/1			←	✓	5Y6/4 3%	SL	0	–	MA				C	
	27+	10YR6/2	←		←	10YR4/4 4% ✓	5YR3/4 4%	LS	0	–	MA				–	

All F3 F6 F8

Appendix Figure B.17. Hydric Soil Survey Description Sheet Kramer 17



Sampling Location: MWS J		Date:	3/12/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob.	Water Table Depth:	21"
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	S884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 4/1 60%, 10YR 3/2			10YR 4/6 [illegible]	[illegible]		SL								
	16	10YR 3/1 30, 10YR 3/2 60		5YR 3/4 [illegible] 5%	→	10YR 5/2 [illegible]		SL								
	31+	10YR 5/2			7.5YR 4/6 5%	10YR 5/2		LS								

check texture, might meet S6 F3 F6 F8

Appendix Figure B.18. Hydric Soil Survey Description Sheet Kramer 18

Sampling Location: MWN K	1303142.16 E 1852018.49 N Edge	Date:	
Describer:		Wetland/Upland Type or Classification:	
Surface Water Depth:		Water Table Depth:	
Geologic Material(s):		Vegetative Cover:	
Soil Classification:		SSURGO Mapping Unit:	

			Redox Concentrations (percent/size/color/location)			Redox Depletions (pr ecent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 2/1 10YR 3/2			5YR 3/4 3cd 4%			~~St~~ LS	0	-	Loose				C	
	19	10YR 3/1 10YR 4/1	10		7.5YR 4/6 + 5YR 3/4 10%	10YR 3/1 4/1		~~St~~ LS	0	-	MA				C	
	34	10YR 5/2	10YR 4/6 15%		10YR 4/6 5%			LS	0	-	MA				-	

I didn't see a St texture @ the center or much of a sig. change in plants

55

Appendix Figure B.19. Hydric Soil Survey Description Sheet Kramer 19

Sampling Location: MWS L	1303872.22 E 1852173.89 N (edge)	Date:	3/12/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	n/t ch	Water Table Depth:	
Geologic Material(s):	Eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	Starks C 5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	5	10YR 2/1 70 10YR 3/1 20			10YR 3/6 Sand coat 2%			LS	0	–	Loose				C	
	21	10YR 4/2 10YR 4/1			10YR 3/6 5% root chan	10YR 4/2 4/1		LS	0	–	Loose				C	
	37+	10YR 4/2	10YR 4/6		+			LS	0	–	Loose				–	
		I looked @ center of this site + did not obs. a change at texture or														
		any diff. indicators														

All S5

Appendix Figure B.20. Hydric Soil Survey Description Sheet Kramer 20

Edge

Sampling Location: MWT M	1304085,42 E 1152119,47 N	Date:	3/12/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	4	10YR 2/1 85%			5YR 4/4 5%	10YR 5/2 5%		LS	0	–	Loose				C	
	21	10YR 4/1			5YR 4/4 10%	10YR 5/2 [illegible]		LS	0	–	MA				C	
	30+	10YR 5/2			5YR 4/4 2%	10YR 6/2		LS	0	–	MA				–	
		no change	in	texture	or indicators			observed @	center							

All 55 56

Appendix Figure B.21. Hydric Soil Survey Description Sheet Kramer 21

Edge

Sampling Location: MWS O	1304245.40E 1852213.99	Date:	3/12/24
Describer:	GJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not obs	Water Table Depth:	not obs
Geologic Material(s):	Eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	3	10YR 5/1 60%, 10YR 4/1 30%			10YR 3/6 [illegible] VF 4%			LS	0	–	Lo				C	
	~~[illegible]~~ 19	10YR 3/1 80%, 10YR 2/1			10YR 5/6 5% M	10YR 5/2 7%		LS	0	–	MA				G	large stripped matrix
	35+	10YR 4/2, 10YR 4/1			10YR 5/8 3% [illegible] VF	10YR 4/1		LS	0	–	MA					

55 56

Appendix Figure B.22. Hydric Soil Survey Description Sheet Kramer 22

west Hooray Edit, this is watershed R

Sampling Location: WS @	1297271.40E 1851084.81N	Date:	3/13/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	
Geologic Material(s):	eolian sand	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 7/1 60% 10YR 4/2 30%			10YR 4/6 sand coat pores VF			LS	1	m	GR				CL	
	21	10YR 4/1 85%			5YR 4/6 2% F 10YR 4/6 3% VF sand coat	10YR 6/2 stripped matrix coarse 7%		LS	0	–	MA				CL	Stripped matrix
	32+	10YR 6/2 60% 10YR 4/1 10%			5YR 4/6 4% VF pore lining sand coat	10YR 4/1		LS	0	–	MA				–	

S5 ~~S6~~ does not meet 10% vol stripped as required for S6 (has 7%)

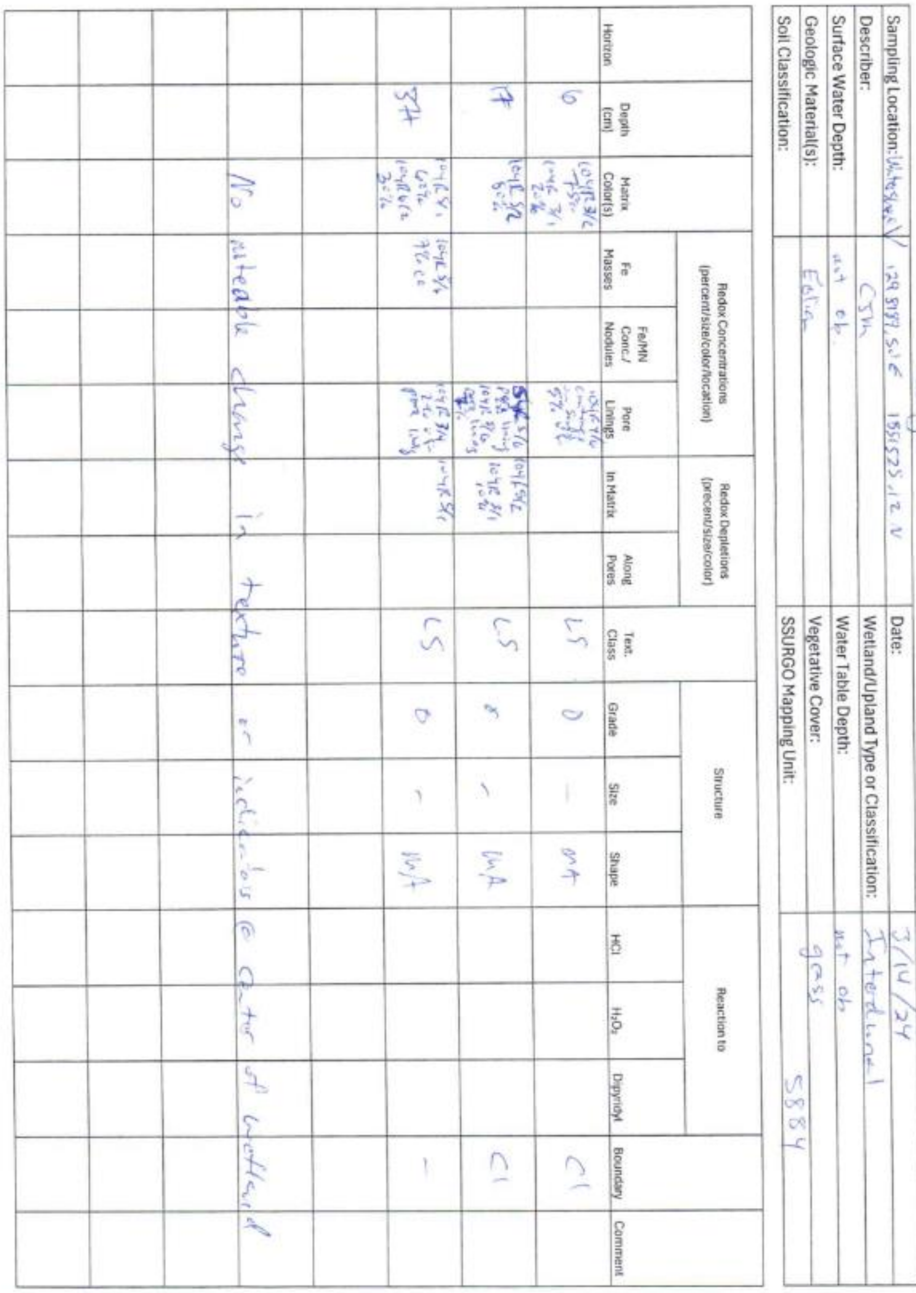
Appendix Figure B.23. Hydric Soil Survey Description Sheet Kramer 23

watershed S

Sampling Location:	1298719.36E 1850180.83N	Date:	3/13/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdune!
Surface Water Depth:	not ob	Water Table Depth:	Not ob
Geologic Material(s):	eolian Sand	Vegetative Cover:	? see pic
Soil Classification:		SSURGO Mapping Unit:	5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 4/2 70% 10YR 3/1 20%			10YR 4/6 sand coat vF 4% vague line			LS	0	—	MA				C1	
	18	10YR 4/1 & 10YR 4/2			5YR 4/6 coat chan 5% vF	10YR 5/2 stripped matrix 10% 10YR 3/2 org. stain		LS	0	-	MA				C1	Stripped matrix
	36+	10YR 6/2	10YR 5/4		5YR 4/6 root chan 7% F to M			LS	0	-	MA				—	

Appendix Figure B.24. Hydric Soil Survey Description Sheet Kramer 24



edge

Sampling Location: Watershed V	1298187.5 E 1551525.12 N	Date:	3/14/24
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob.	Water Table Depth:	not ob
Geologic Material(s):	Eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	6	10YR 3/2 75% 10YR 3/1 20%			10YR 4/6 [illegible] 5%			LS	0	—	MA				Cl	
	17	10YR 5/2 80%			5YR 5/6 pore lining 10YR 4/6 pore linings 5%	10YR 5/2 10YR 3/1 10%		LS	0	—	MA				Cl	
	37	10YR 5/1 65% 10YR 6/2 30%	10YR 5/6 7% cc		10YR 3/4 2% [illegible] pore lining	10YR 5/2		LS	0	—	MA				—	
		No noteable change in texture or indicators @ center of wetland														

Appendix Figure B.25. Hydric Soil Survey Description Sheet Kramer 25

Sampling Location:	Watershed X edge 1298496.28E 1852119.45N	Date:	3/14/24
Describer:	CTh	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	S884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location): Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color): In Matrix	Along Pores	Text. Class	Structure: Grade	Size	Shape	Reaction to: HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 4/2 75%			10YR 4/6 sand coat 5% vf			LS	0	–	MA				CL	
	14	10YR 4/2 65% 10YR 5/2	10YR 4/6 7% med		5YR 4/6 root chan 4% vf	10YR 4/2 matrix 10YR 5/2 20% co	10YR 5/2	LS	0	–	MA				CL	
	33+	10YR 6/2 75%	10YR 4/6 7% med		5YR 4/6 2% vf			LS	0	–	MA				–	
		no visible veg change @ center, did not check for change in texture														

S5 Sandy redox S6 Stripped matrix

Appendix Figure B.26. Hydric Soil Survey Description Sheet Kramer 26

Cdgr

Sampling Location: WS U	1297411.24E 1851952.18N	Date:	3/14/24
Describer:	MSM	Wetland/Upland Type or Classification:	Intergrade
Surface Water Depth:	not obs	Water Table Depth:	not obs
Geologic Material(s):	Eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	SS84

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 5/2 70%			10YR 4/6 sand coat 5% [illegible]			LS	0	—	LO				CI	
	14	10YR 5/2			10YR 4/6 pore line 5% F 5YR 4/6 [illegible] 2% [illegible]	10YR 5/2 10%		LS	0	—	MA				GR	
	35+	10YR 4/2 60%			5YR 4/6 Med. 10% 10YR 4/4 [illegible]	10YR 5/2 30%		LS	0	—	MA				—	
no visible change in veg or texture @ center																

S5 Sandy redox S6 stripped matrix

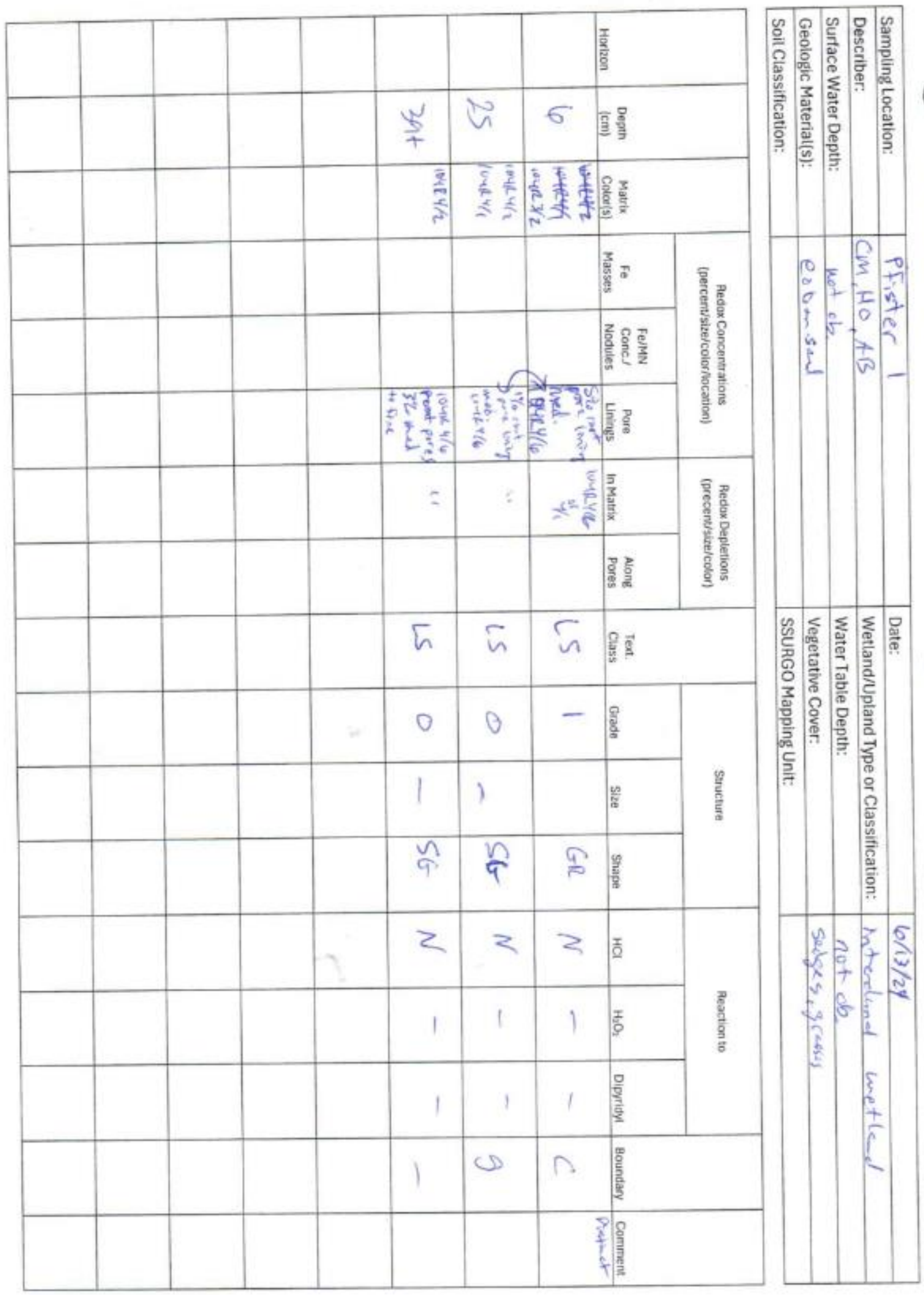
Appendix Figure B.27. Hydric Soil Survey Description Sheet Kramer 27

Watershed T center

Sampling Location:	1296872.636 1851510.82N	Date:	3/14/2024
Describer:	GJm	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	Eolian	Vegetative Cover:	SP-S)
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	6	10YR 4/2 50%	10YR 3/4 2% F		10YR 3/4 5% FP [illegible]	10YR 3/1		LS	0	–	~~[illegible]~~ Loose				C1	
	18	10YR 4/2 50%			5YR 4/6 F [illegible] 5% 5YR 4/3 2% 10YR 4/6 3%	10YR 4/2 4% C0		LS	0	–	MA				GR	
	33+	10YR 5/2 60%	10YR 4/6 10% C0		5YR 4/6 [illegible] 3% [illegible]	10YR 4/2 15%		LS	0	-	MA				—	

Appendix Figure B.28. Hydric Soil Survey Description Sheet Pfister 1



N 38° 12.4456'
W 098° 27.45041

Sampling Location:	Pfister 1	Date:	6/13/24
Describer:	CM, HO, AB	Wetland/Upland Type or Classification:	Inland wetland
Surface Water Depth:	not ob.	Water Table Depth:	not ob.
Geologic Material(s):	eolian sand	Vegetative Cover:	sedges, grasses
Soil Classification:		SSURGO Mapping Unit:	

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location): Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color): In Matrix	Along Pores	Text. Class	Structure: Grade	Size	Shape	Reaction to: HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 3/2			5% root pore lining med. 7.5YR 4/6	10YR 4/6 5% 4/1		LS	1		GR	N	–	–	C	Distinct
	25	10YR 4/1, 10YR 4/1			1% root pore lining med. 7.5YR 4/6	"		LS	0	–	SG	N	–	–	G	
	39+	10YR 4/2			10YR 4/6 root pores 3% med to fine	"		LS	0	–	SG	N	–	–	–	

Appendix Figure B.29. Hydric Soil Survey Description Sheet Pfister 2

Sampling Location:	Pfister 2	Date:	6/13/24
Describer:	CM, HO, AB	Wetland/Upland Type or Classification:	interdunal
Surface Water Depth:	Not ob.	Water Table Depth:	not ob
Geologic Material(s):	eolian Sand	Vegetative Cover:	
Soil Classification:	–	SSURGO Mapping Unit:	

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	12	10YR 3/2 80%	F3m 1% 10YR 4/6					SL	0	–	SG	-	-	-	Cl	
	30	10YR 4/2 70%	[illegible]			10YR 4/2	F2 10YR 3/2 depletions [illegible] 15%	SL	0	–	SG	–	–	–	Cl	Iron Mn Conc. surrounded by Fe Conc.
	40+	10YR 4/2 70%	F Mm 3% [illegible] F3m 3% 10YR 4/6			10YR 4/2		SL	0	–	SG	–	–	–	–	

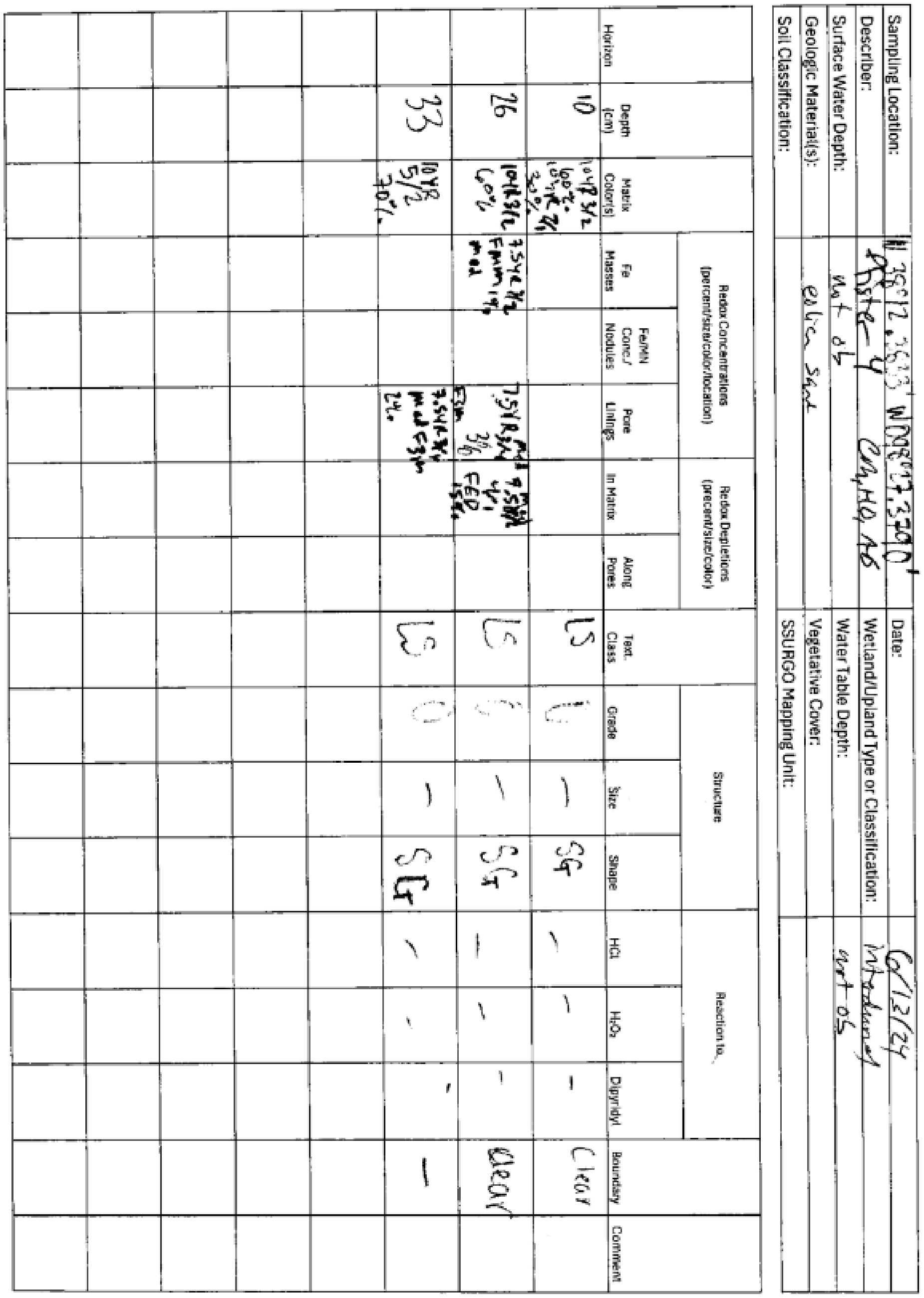
Appendix Figure B.30. Hydric Soil Survey Description Sheet Pfister 3

N 38°12.3791'
W 098°27.4404'

Sampling Location:	Pfister 3	Date:	06/13/24
Describer:	HO, AB, CM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob.
Geologic Material(s):	eolian	Vegetative Cover:	Sedges, bluestem Bluestem
Soil Classification:		SSURGO Mapping Unit:	

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	9	10YR 3 2						LS	1	-	GR	-	-	-	C	
	18	10YR 3 2			2% fine 10YR 4/4			LS	0	-	SG	-	-	-	G	
	28+	10YR 4 3			7% 10YR5/8 m			LS	0	-	SG	-	-	-	-	

Appendix Figure B.31. Hydric Soil Survey Description Sheet Pfister 4



Sampling Location:	N 38°12.3633' W098°27.3790'	Date:	6/13/24
Describer:	Pfister 4 CM, HO, AG	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian sand	Vegetative Cover:	
Soil Classification:		SSURGO Mapping Unit:	

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	10	10YR 3/2 60% 10YR 2/1 30%						LS	0	—	SG	—	—	—	Clear	
	26	10YR 3/2 60%	7.5YR 3/2 FMM 1% mod		7.5YR 3/4 mod 3/6 F3m	7.5YR 4/1 mod FED 15%		LS	0	—	SG	—	—	—	Clear	
	33	10YR 5/2 70%			7.5YR 3/4 mod F3m 2%			LS	0	—	SG	—	—	—	—	

Appendix Figure B.32. Hydric Soil Survey Description Sheet Pfister 5

N 38°12.6151' W098°27.5058'

towards center of depression on edge of [illegible] catchment

Sampling Location:	Pfister 5	Date:	6/13/24
Describer:	Cm, Ho, AB	Wetland/Upland Type or Classification:	Interdund
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian sand	Vegetative Cover:	grasses, short juncess
Soil Classification:		SSURGO Mapping Unit:	

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
A	7	10YR3/2 60%; 10YR 2/1 20%						SL	1	M to C	GR	–	–	–	C1	
C1	24	10YR3/1 70%			10YR 3/4 3% med F3m	10YR 3/1		SL	0	–	MA	–	–	–	C1	
C2	33+	10YR 4/2 60%			10YR 4/3 3% med F3m	10YR 4/4		SL	0	.	MA	–	–	–	–	

Appendix Figure B.33. Hydric Soil Survey Description Sheet Pfister 6

N 38°17.6616'
W 098°27.4079

Sampling Location:	Pfister 6	Date: 06/13/24	
Describer:	CM HO AB	Wetland/Upland Type or Classification:	interdunal
Surface Water Depth:	not ob.	Water Table Depth:	not ob.
Geologic Material(s):	eolian sand	Vegetative Cover:	sedges, broomsedge bluestem
Soil Classification:		SSURGO Mapping Unit:	

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	10	10YR 3/2						LS	0	-	SG	-	-	-		
	22	10YR 4/1 60%	7.5YR 4/4 fine 5%		7.5YR 3/4 med 3%	FED 10YR 4/1 60%		LS	0	-	SG	-	-	-		
	34+	10YR 6/2 60%			7.5YR 4/4 med 7%			LS	0	-	SG	-	-	-		

Appendix Figure B.34. Hydric Soil Survey Description Sheet Pfister 7

N 38°12.7059 W098°.27.3631

Location:	Pfister 7	Date:	6/13/24
	CM, HO, AB	Wetland/Upland Type or Classification:	Interdune
ater Depth:	not ob	Water Table Depth:	not ob
Material(s):	eolian sand	Vegetative Cover:	
ification:		SSURGO Mapping Unit:	

Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
		Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
9	10YR 3/2						LS	0	-	SG	-	-	—		
21	10YR 3/2			10YR 3/3 5% med			SL	0	-	SG	-	-	—		
30+	10YR 3/1 60%			7.5YR 4/6 5% med	FED 80% 10YR 3/1		SL	0	-	SG	-	-	—		

Appendix Figure B.35. Hydric Soil Survey Description Sheet Bengston 1

Bengston

Sampling Location:	38.267214° N 97.994331° W	Date:	3/14/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal edge
Surface Water Depth:	not ob	Water Table Depth:	not obs
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

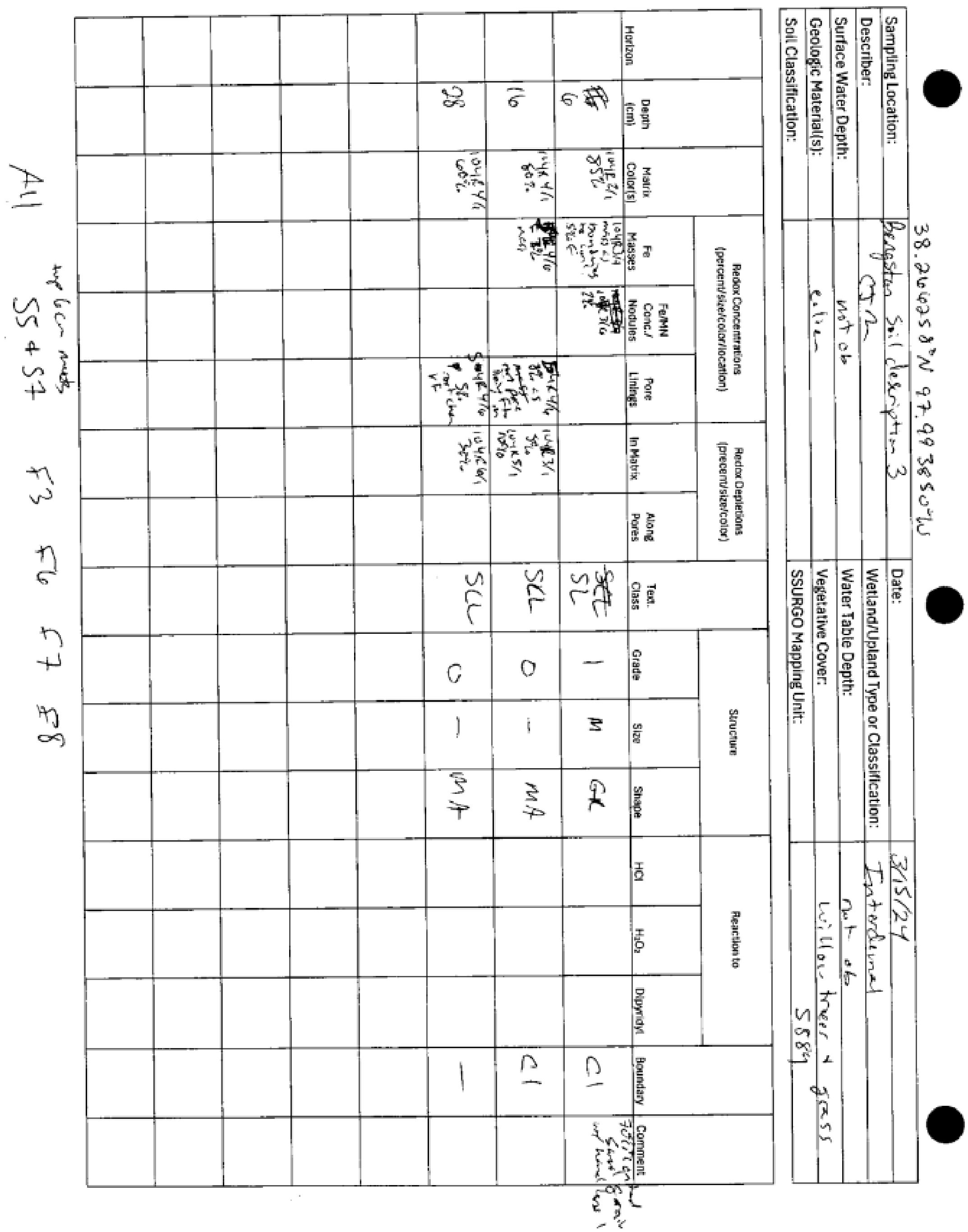
Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCL	H_2O_2	Dipyridyl		
	6	10YR 3/1 80%			10YR 3/6 2% [illegible]			LFS	0		Lo				C1	
	39+	10YR 3/1 60%			5YR 3/4 3% F pore lining [illegible]			LFS	0	-	MA				-	
								LFS	0	-	MA					

Appendix Figure B.36. Hydric Soil Survey Description Sheet Bengston 2

Sampling Location: Bengston	38.246881°N 97.994395W	Date:	3/14/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal center
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	willow trees
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location): Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color): In Matrix	Along Pores	Text. Class	Structure: Grade	Size	Shape	Reaction to: HCl	H_2O_2	Dipyridyl	Boundary	Comment
	8	10YR 3/1 ~~60~~ 10YR 2/1, 30%			10YR 7/6 VF [illegible] [illegible] 2%	10YR 6/2 20% coarse		F~~L~~S	0	–	~~MA~~				C1	
	16	10YR 2/1 20% 10YR 3/1, 60%			7.5YR 3/4 3% F [illegible] [illegible]	10YR 3/1 10YR 5/2 [illegible] 5% stripped matrix		FLS	0	–	MA				C1	
	32+	10YR 5/2 70% ~~[illegible]~~			7.5YR 3/4 5% F pore line	10YR 3/2 60% 10YR 2/1 10%		FLS	0	–	MA				–	

Appendix Figure B.37. Hydric Soil Survey Description Sheet Bengston 3



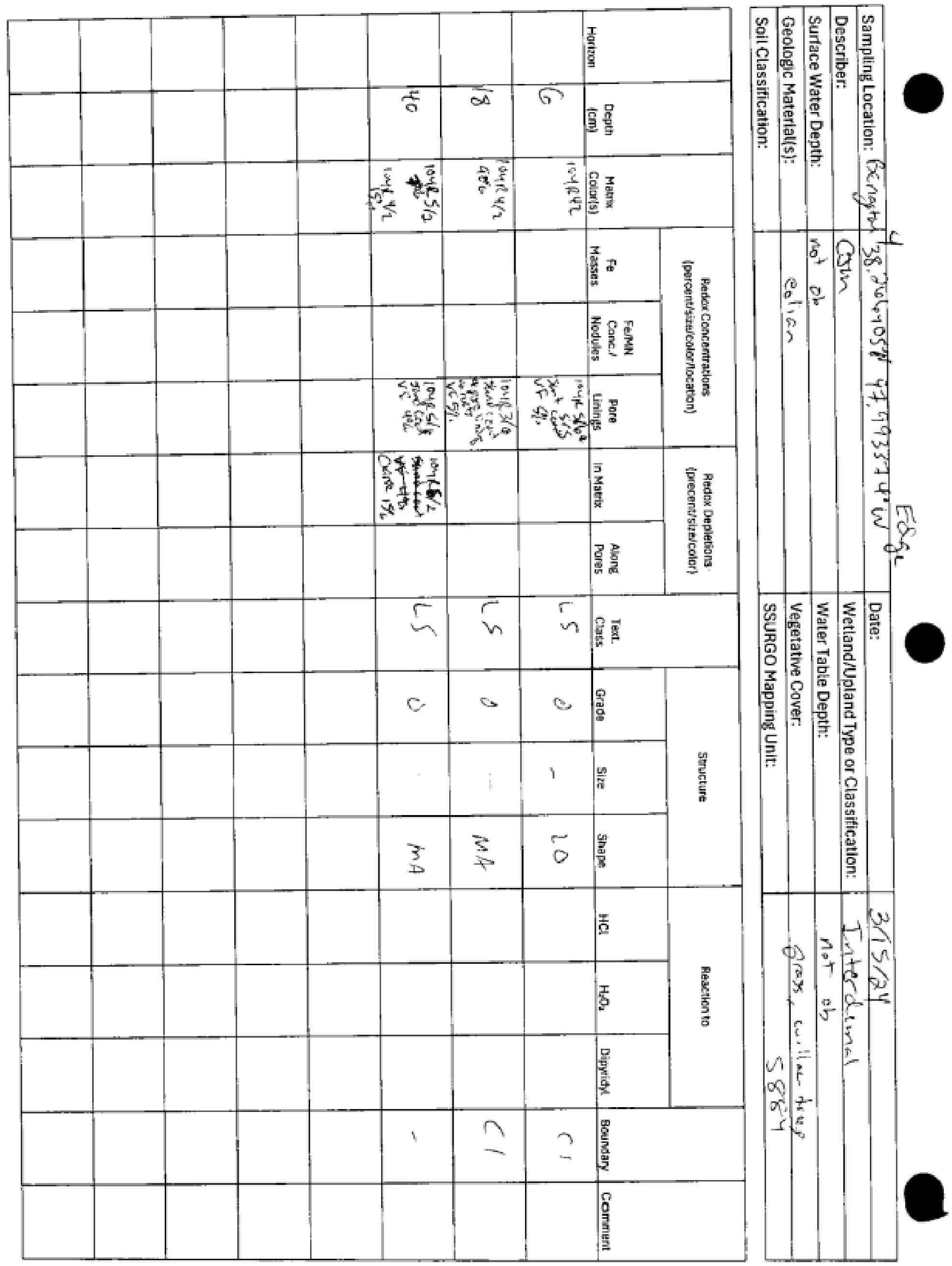
38.266258°N 97.993850°W

Sampling Location:	Bengston Soil description 3	Date:	3/15/24
Describer:	CJR	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	willow trees + grass
Soil Classification:		SSURGO Mapping Unit:	5889

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 2/1 85%	10YR 3/4 [illegible]	10YR 3/6 2%				SL	1	M	GR				C1	[illegible]
	16	10YR 4/1 80%	10YR 4/6 [illegible]		10YR 4/6 [illegible]	10YR 3/1 5%, 10YR 5/1 10%		SCL	0	–	MA				C1	
	28	10YR 4/1 60%			10YR 4/6 5% [illegible]	10YR 6/1 30%		SCL	0	–	MA				–	

A11 top 6cm mucks S5 + S7 F3 F6 F7 F8

Appendix Figure B.38. Hydric Soil Survey Description Sheet Bengston 4

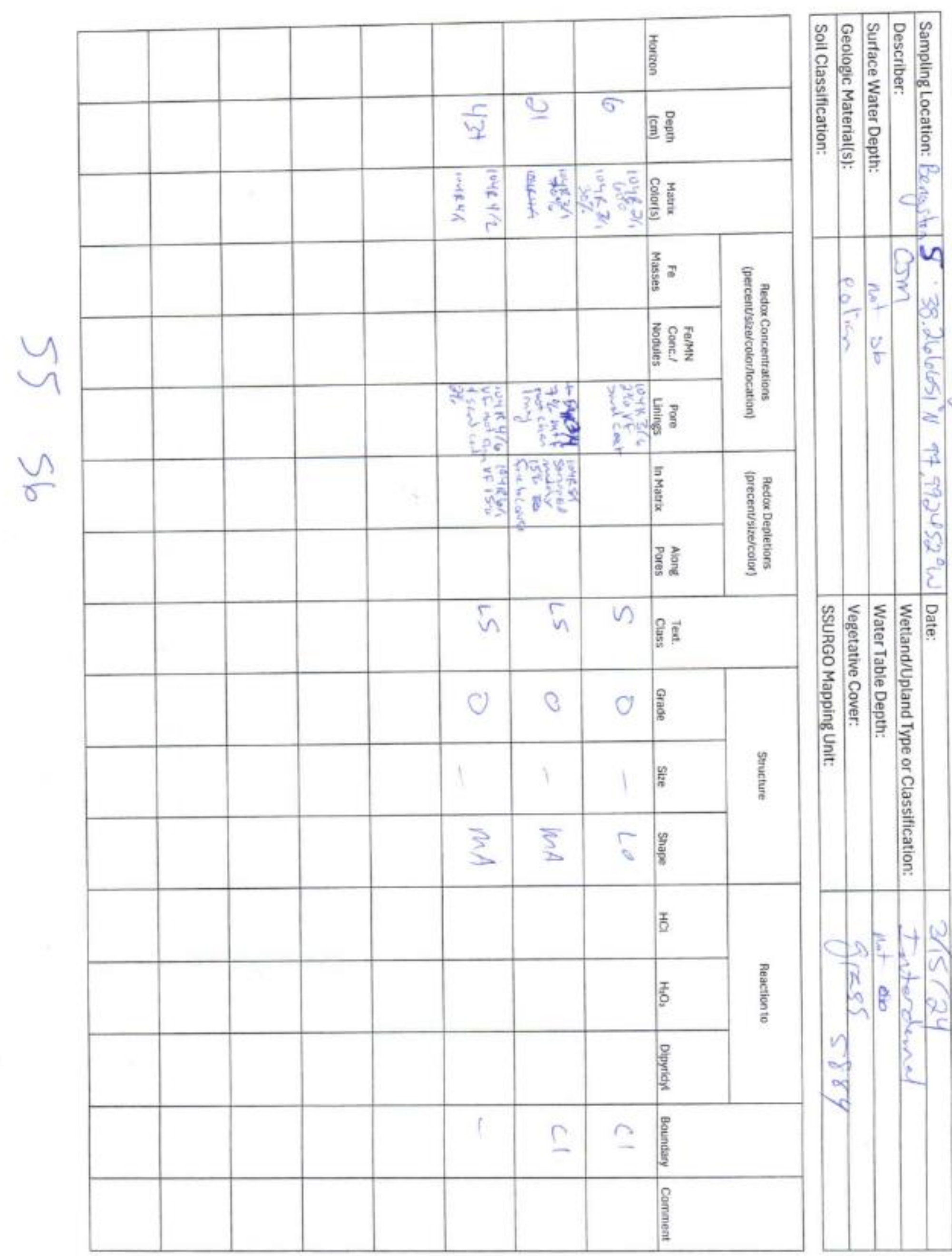


Sampling Location:	Bengston 4 38.2664058 97.993374°W Edge	Date:	3/15/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass, willow tree
Soil Classification:		SSURGO Mapping Unit:	5884

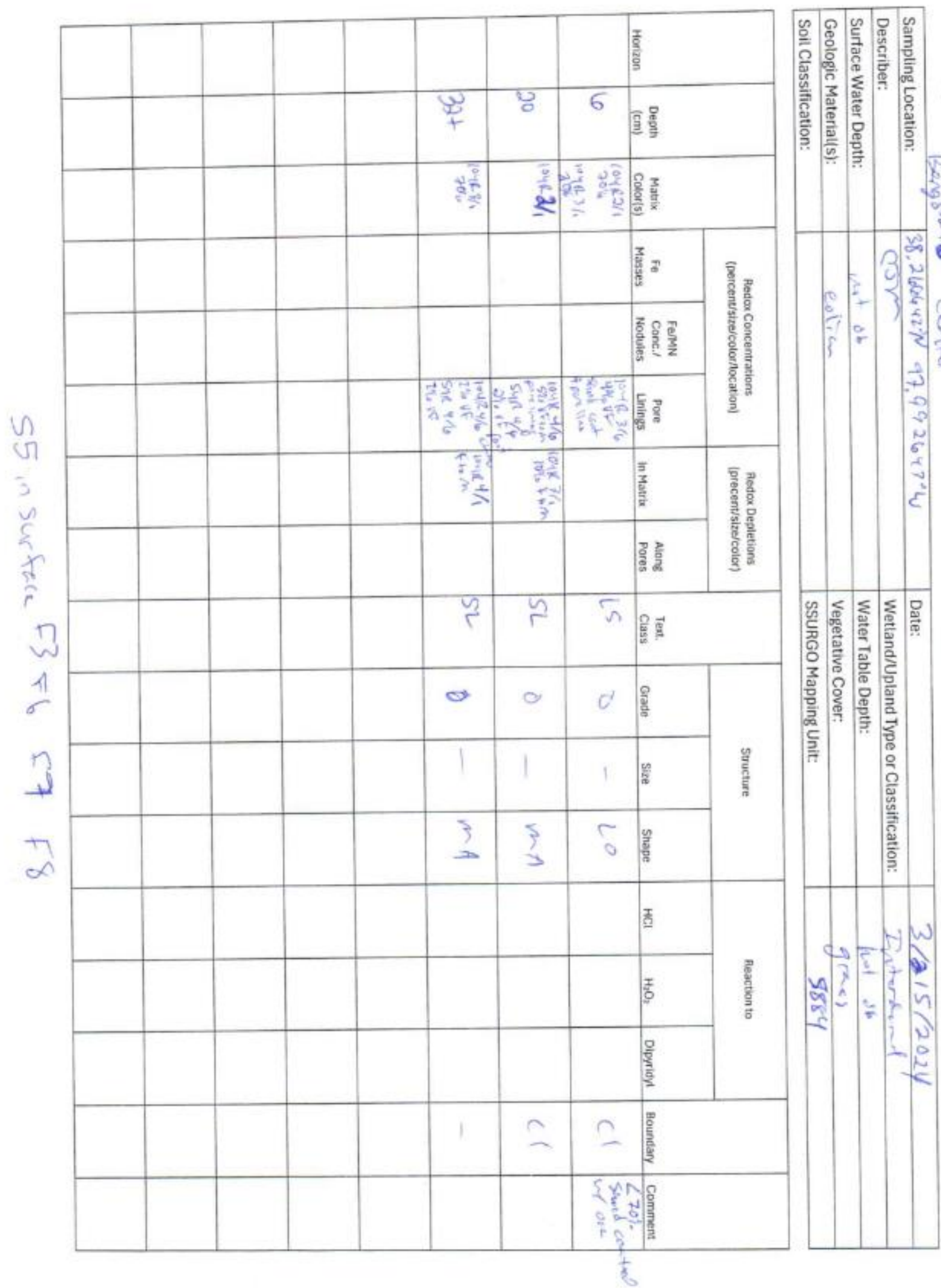
Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	6	10YR 4/2			10YR 5/6 faint conc VF 5%			LS	0	–	20				C1	
	18	10YR 4/2 95%			10YR 3/6 faint conc pore linings VF 5%			LS	0	–	MA				C1	
	40	10YR 5/2 85% 10YR 4/2 15%			10YR 5/6 faint conc VF 4%	10YR 6/2 coarse 1%		LS	0		MA				–	

55

Appendix Figure B.39. Hydric Soil Survey Description Sheet Bengston 5



Appendix Figure B.40. Hydric Soil Survey Description Sheet Bengston 6



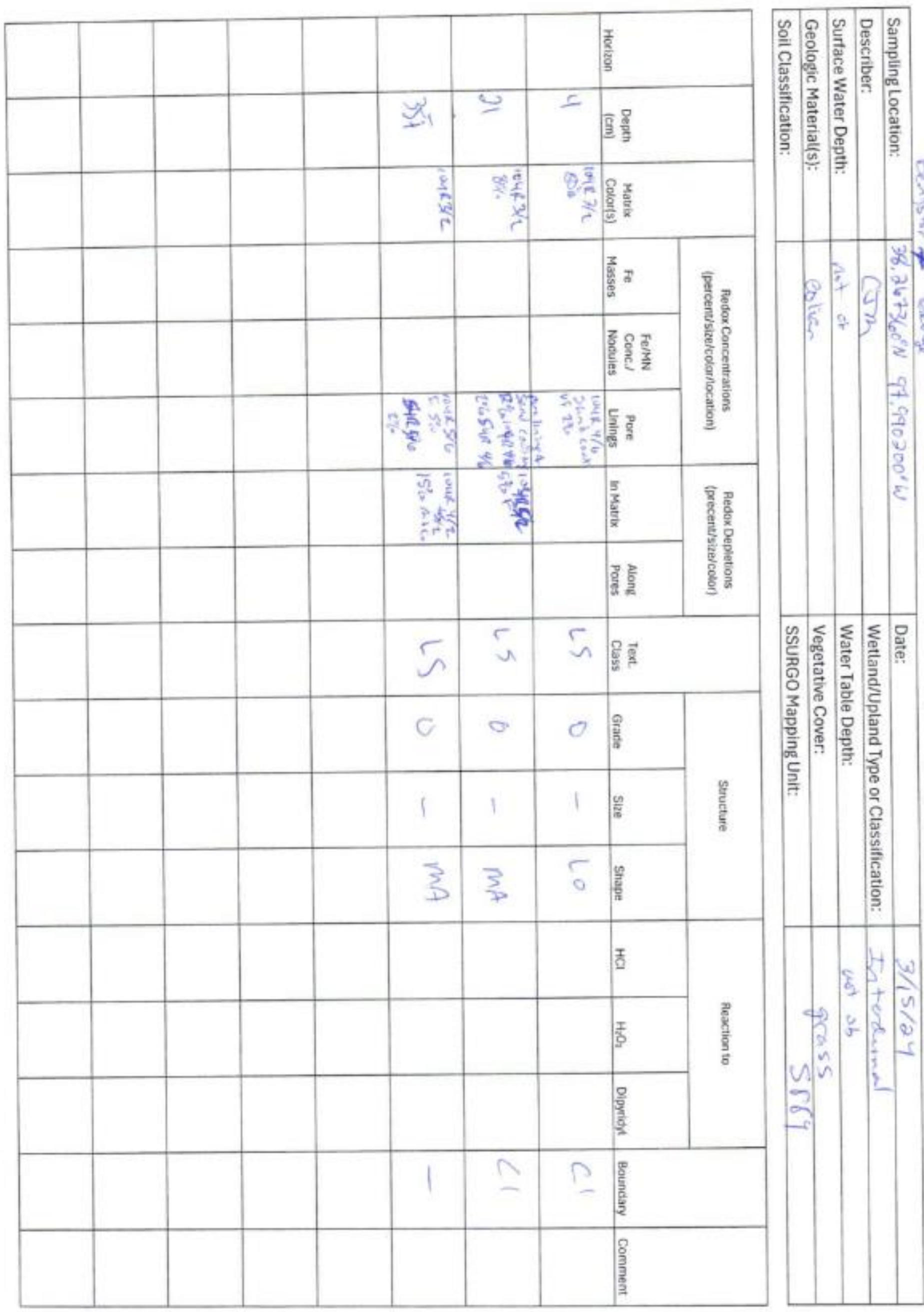
Bengston 6 Center

Sampling Location:	38.266642°N 97.992647°W	Date:	3/15/2024
Describer:	CSM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	6	10YR 2/1 70% 10YR 3/1 20%			10YR 3/6 4% VF [illegible]			LS	0	—	Lo				cl	<70% Sand coated w/ OM
	20	10YR 2/1			10YR 4/6 5% VF [illegible] pore linings 5YR 4/4 2% VF [illegible]	10YR 7/1 10% F [illegible]		SL	0	—	mA				cl	
	32+	10YR 8/1 70%			10YR 4/6 1% VF 5YR 4/6 1% VF	10YR 4/1 F [illegible]		SL	0	—	mA				—	

S5 in surface F3 F6 F7 F8

Appendix Figure B.41. Hydric Soil Survey Description Sheet Bengston 7

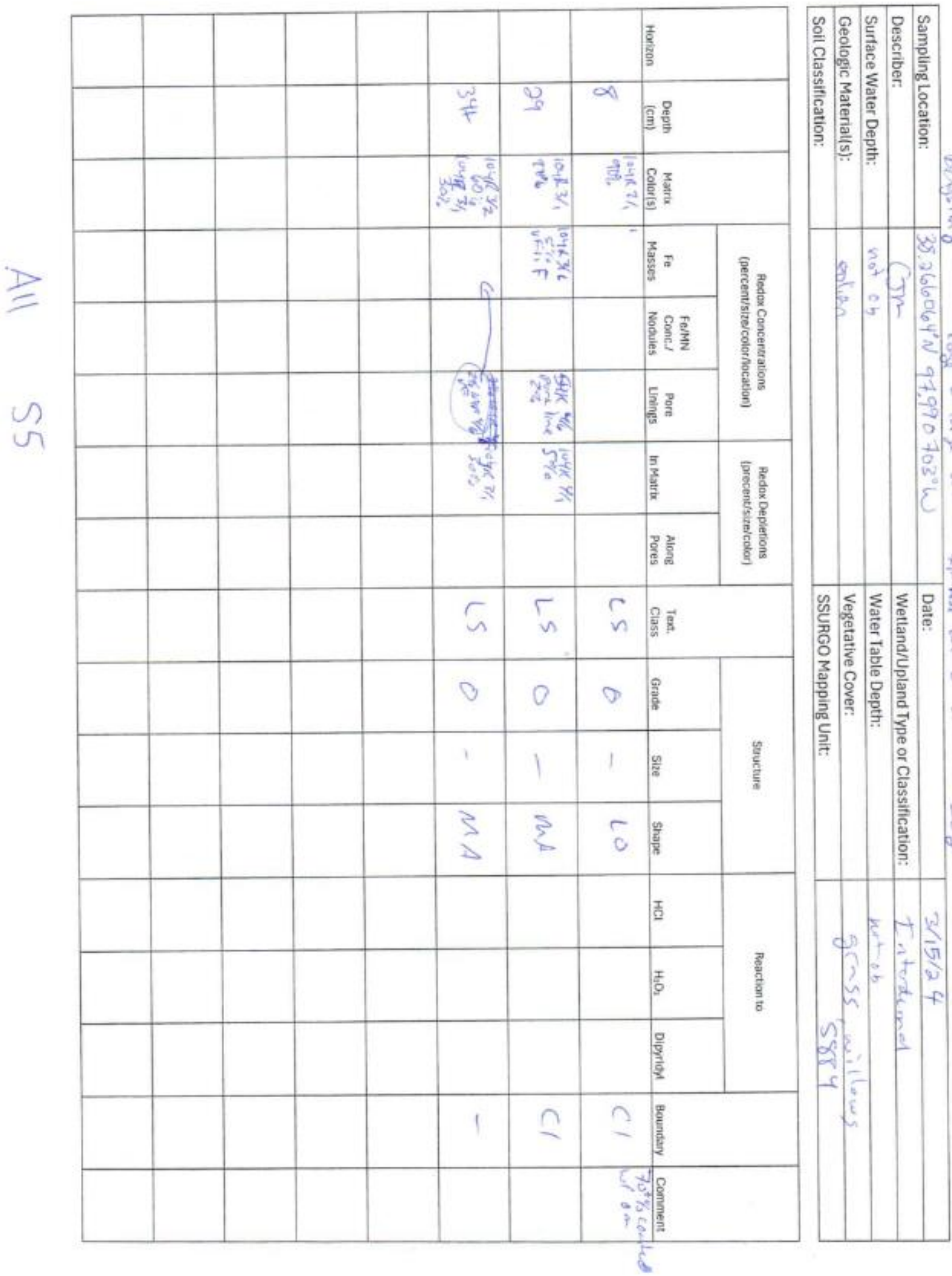

Bengston 7 edge

Sampling Location:	38.267360°N 97.990200°W	Date:	3/15/24
Describer:	CJM	Wetland/Upland Type or Classification:	Intertidal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	Eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5869

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	4	10YR 7/2 85%			10YR 4/6 [illegible] vf 2%			LS	0	–	LO				C1	
	21	10YR 3/2 89%			[illegible] 2% 10YR 4/4 2% 5YR 4/6	10YR 5/2 5% F		LS	0	–	MA				C1	
	35+	10YR 3/2			10YR 5/6 F 5% 5YR 5/6 2%	10YR 4/2 [illegible] 15% [illegible]		LS	0	–	MA				–	

55

Appendix Figure B.42. Hydric Soil Survey Description Sheet Bengston 8



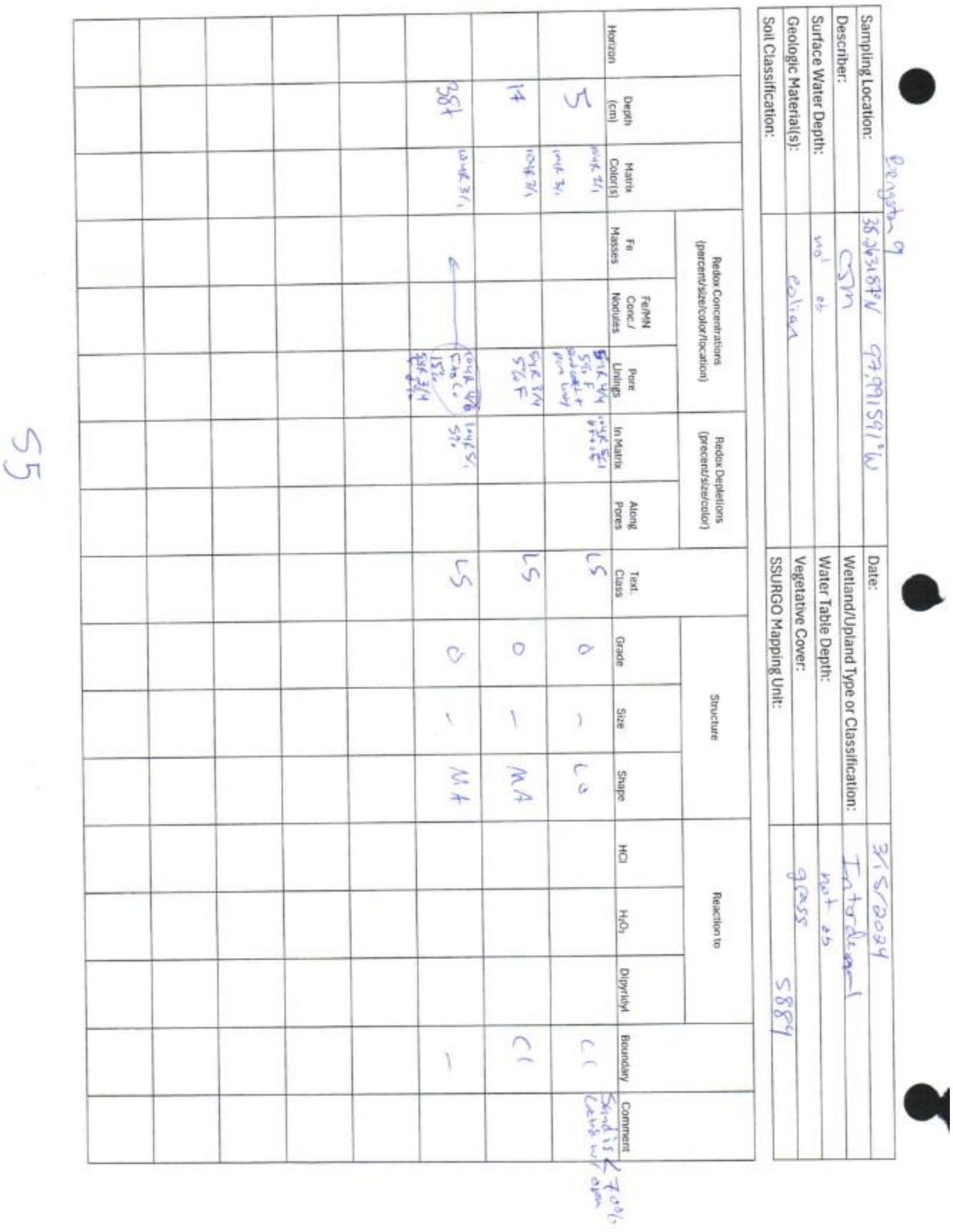
Bengston 8 Edge of large wetland expanse on E side of Bengston

Sampling Location:	35.266064°N 97.990703°W	Date:	3/15/24
Describer:	CJR	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass, willows
Soil Classification:		SSURGO Mapping Unit:	S884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)		Text. Class	Structure			Reaction to			Boundary	Comment
			Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores		Grade	Size	Shape	HCl	H_2O_2	Dipyridyl		
	8	10YR 7/1 90%						CS	0	–	LO				C/	70+% coated w/ om
	29	10YR 3/1 70%	10YR 3/6 5% vF:i F		5YR 5/6 Pore line 2%	10YR 4/1 5%		LS	0	–	MA				C/	
	34+	10YR 3/2 60% 10YR 3/1 30%			[illegible]	10YR 7/1 30%		LS	0	–	MA				–	

All S5

Appendix Figure B.43. Hydric Soil Survey Description Sheet Bengston 9



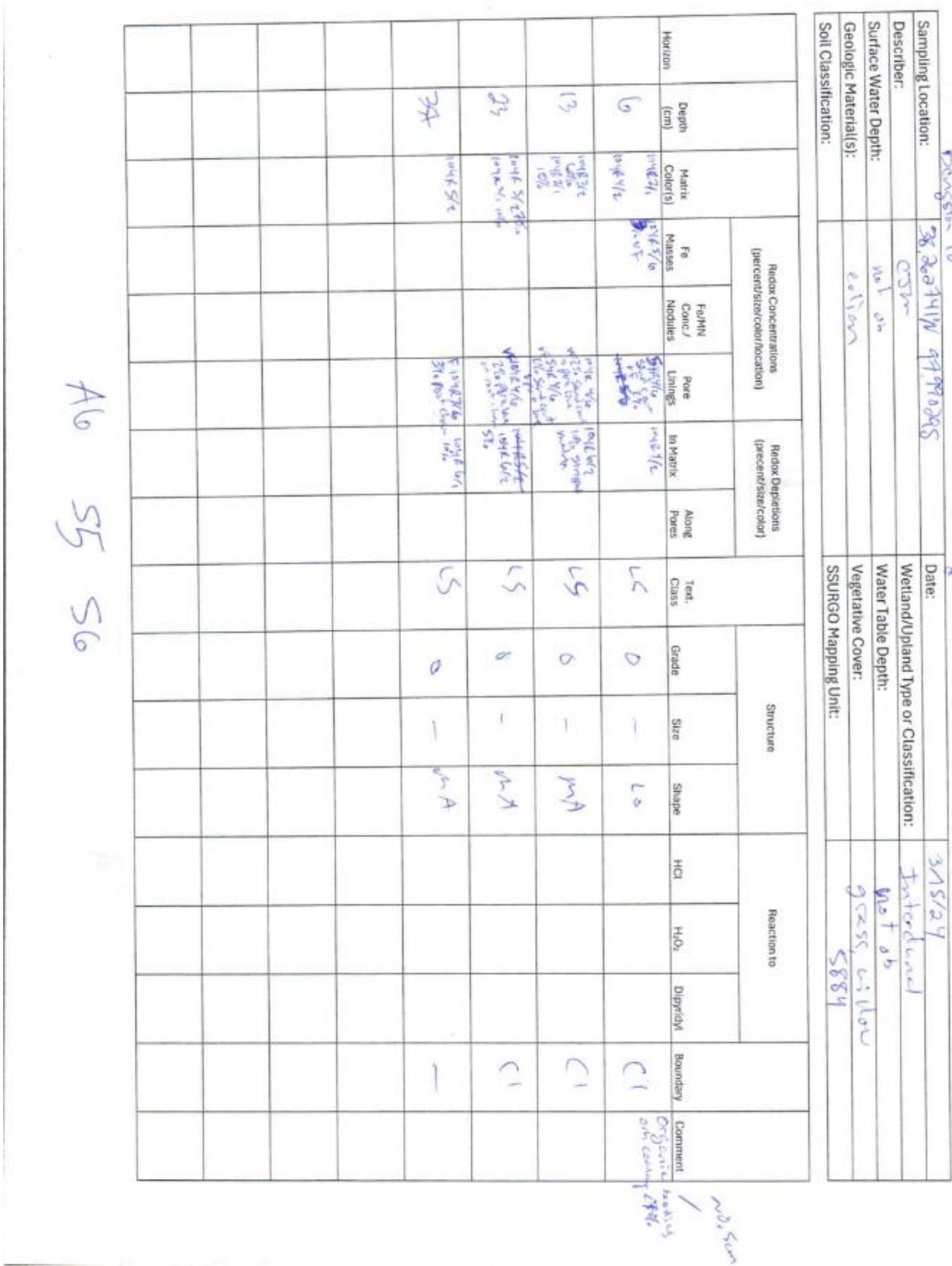
Bengston 9

Sampling Location:	35.263187°N 97.991591°W	Date:	3/15/2024
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

Horizon	Depth (cm)	Matrix Color(s)	Redox Concentrations (percent/size/color/location) Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	Redox Depletions (precent/size/color) In Matrix	Along Pores	Text. Class	Structure Grade	Size	Shape	Reaction to HCl	H_2O_2	Dipyridyl	Boundary	Comment
	5	10YR 2/1 10YR 3/1			5YR 4/4 5% F [illegible] pore lining	10YR 5/1 [illegible]		LS	0	–	LO				CL	Sand is < 70% Coated w/ OM
	17	10YR 3/1			5YR 3/4 5% F			LS	0	–	MA				CL	
	38+	10YR 3/1	←		10YR 4/6 F to C 15% 5YR 3/4 [illegible]	10YR 5/1 5%		LS	0	–	MA				–	

55

Appendix Figure B.44. Hydric Soil Survey Description Sheet Bengston 10



Appendix Figure B.45. Hydric Soil Survey Description Sheet Bengston 11

Bengston 11

Sampling Location:	38.263132°N 97.993395°W	Date:	3/15/24
Describer:	CJM	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass
Soil Classification:		SSURGO Mapping Unit:	5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	8	10YR 3/1 10YR 2/1			10YR 4/6 VF 2% sand coats			LS	0	–	LO				Cl	<70% sand coated w/ OM
	23	10YR 3/2 70%	10YR 4/6 2% VF soft masses		5YR 4/6 5% F root pore lining	10YR 5/2 10% F		LS	0	–	mA				Cl	Stripped matrix
	40+	10YR 5/2	10YR 3/6 3% F			10YR 6/2 15% C		LS	0	–	mA				–	

55 56

Appendix Figure B.46. Hydric Soil Survey Description Sheet Bengston 12

Bengston 12

Sampling Location:	38.2635659N 97.995029' W	Date:	3/15/24
Describer:	QJh	Wetland/Upland Type or Classification:	Interdunal
Surface Water Depth:	not ob	Water Table Depth:	not ob
Geologic Material(s):	eolian	Vegetative Cover:	grass, willows
Soil Classification:		SSURGO Mapping Unit:	5884

			Redox Concentrations (percent/size/color/location)			Redox Depletions (precent/size/color)			Structure			Reaction to				
Horizon	Depth (cm)	Matrix Color(s)	Fe Masses	Fe/MN Conc./ Nodules	Pore Linings	In Matrix	Along Pores	Text. Class	Grade	Size	Shape	HCl	H_2O_2	Dipyridyl	Boundary	Comment
	5	10YR 5/2 45% 10YR 3/2 40%	10YR 4/6 5%		10YR 4/6 2%	10YR 5/2 10%		LS	0	-	Lo					
	15	10YR 3/1 60%			5YR 4/6 5% F [illegible]	10YR 5/2 5% Com		SL	0	—	mA					
	25	10YR 3/1 70%	7.5YR 3/4		5YR 4/6 2% [illegible] root chan	10YR 5/2 20%		LS	0	-	mA					
	30+	10YR 6/2 70%			10YR 5/6 root chan + 5% [illegible] 3%	10YR 5/1 15%		LS	0	-	mA					

S5 S6 F3 F6 F8

Appendix C - IRIS Information

Appendix Figure C.1. Total Number of Analyzed Films

Site	Total Films	Pulled Films (Animal Activity)	Analyzed
East Kramer	90	8	82
West Kramer	90	10	80
Pfister	90	6	84
Total	270	24	246

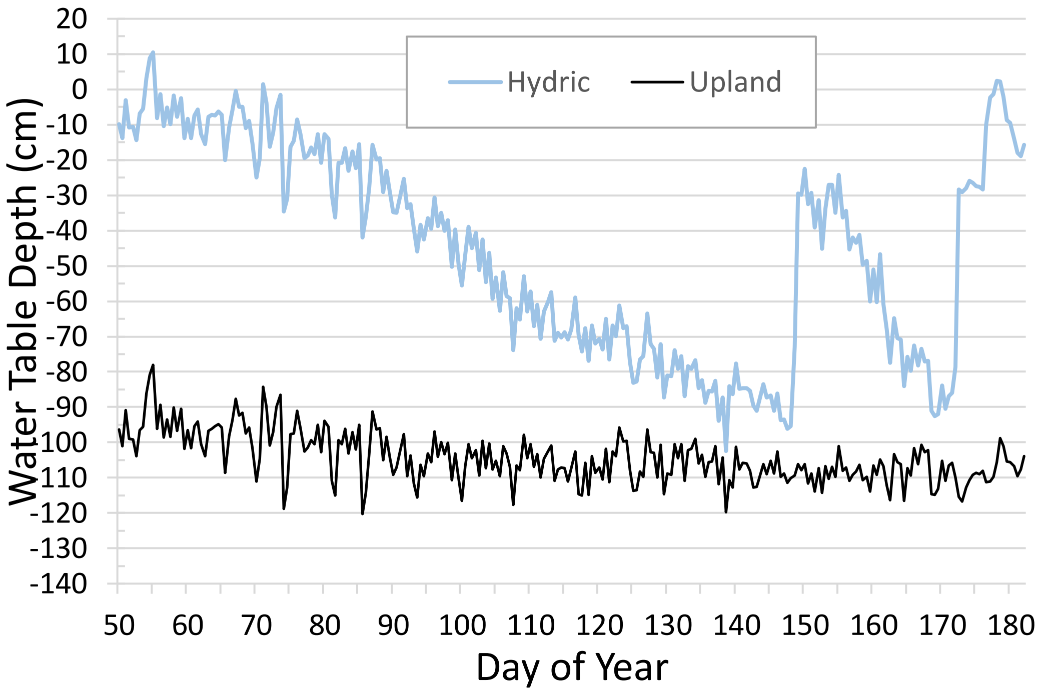
Appendix Figure C.2. Hydric locations meeting the anaerobic conditions standard (at least one film with 30% or more Fe removal in a contiguous 15-cm window), by deployment round. "Met standard" reflects whether any analyzed film at that location, in that round, reached the threshold. Films analyzed is shown out of 5 expected; shortfalls are due to unrecovered films (2026 East Kramer and Pfister rounds) or confirmed animal disturbance (West Kramer V, round 2, excluded and marked N/A since no films were analyzed as a result of being unaccounted for).

Sites	Location	Round 1: early spring 2025		Round 2: late spring 2025		Round 3: 2026	
		Films analyzed	Met standard	Films analyzed	Met standard	Films analyzed	Met standard
East Kramer	H	5 of 5	Yes	5 of 5	Yes	5 of 5	Yes
East Kramer	P	5 of 5	No	5 of 5	No	5 of 5	Yes
East Kramer	E	5 of 5	No	5 of 5	Yes	3 of 5	No
West Kramer	U	5 of 5	No	5 of 5	No	5 of 5	No
West Kramer	V	5 of 5	No	0 of 5*	N/A	5 of 5	No
West Kramer	X	5 of 5	No	5 of 5	No	5 of 5	No

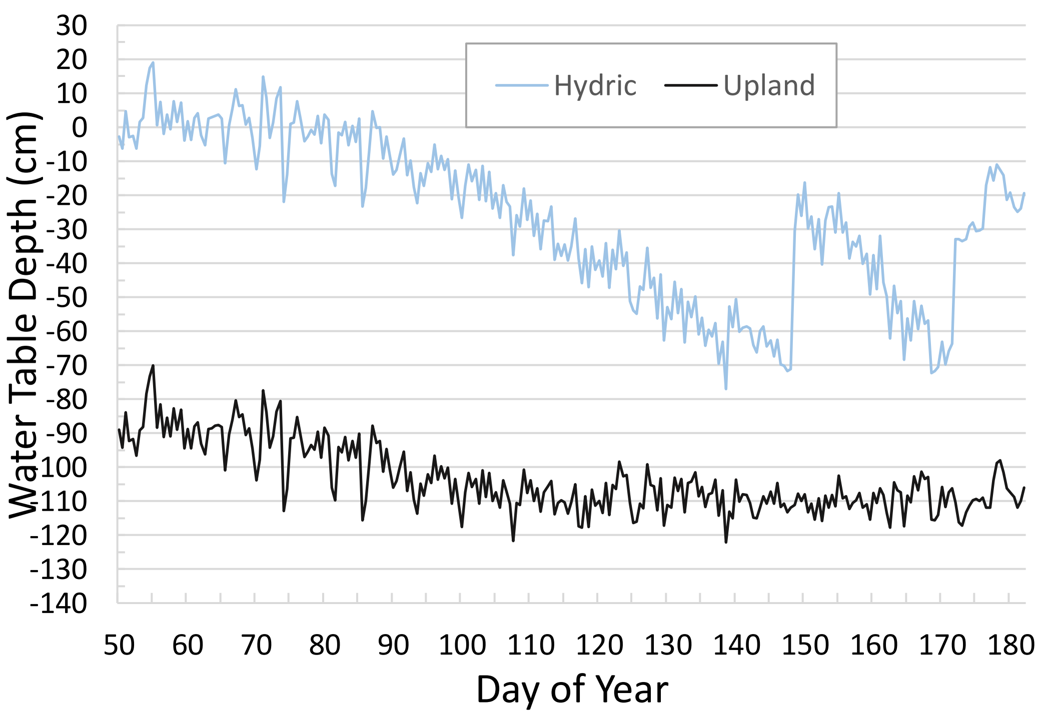
Pfister	**B**	**5 of 5**	**No**	**5 of 5**	**No**	**4 of 5**	**No**
Pfister	**D**	**5 of 5**	**No**	**5 of 5**	**No**	**4 of 5**	**No**
Pfister	**K**	**5 of 5**	**No**	**5 of 5**	**No**	**3 of 5**	**No**

Appendix D - Well Data

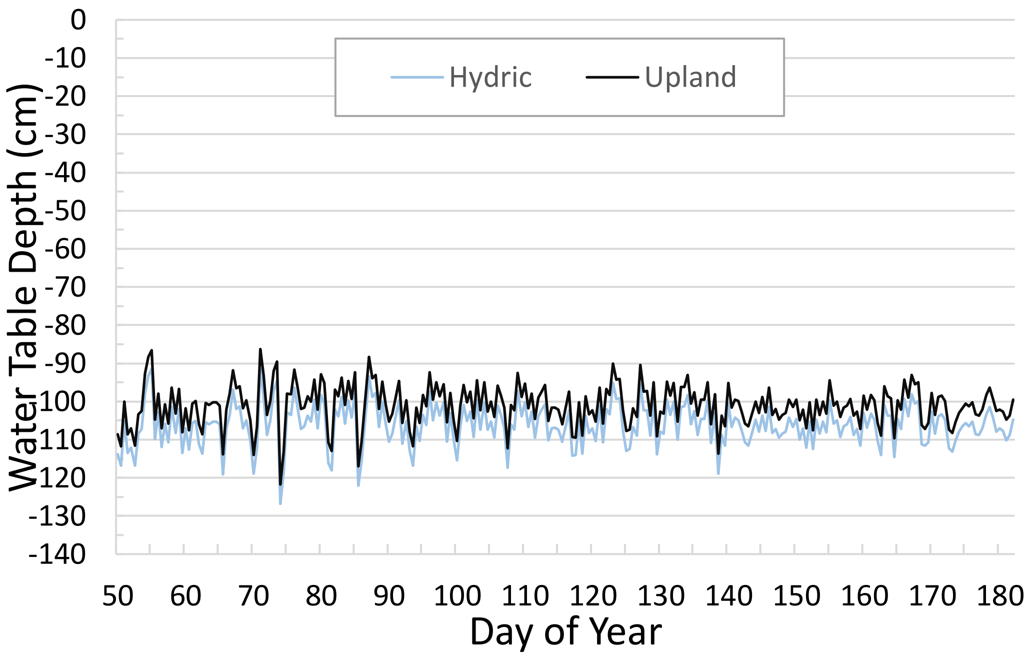
Appendix Figure D.1. East Kramer E Hydric and Upland 2026



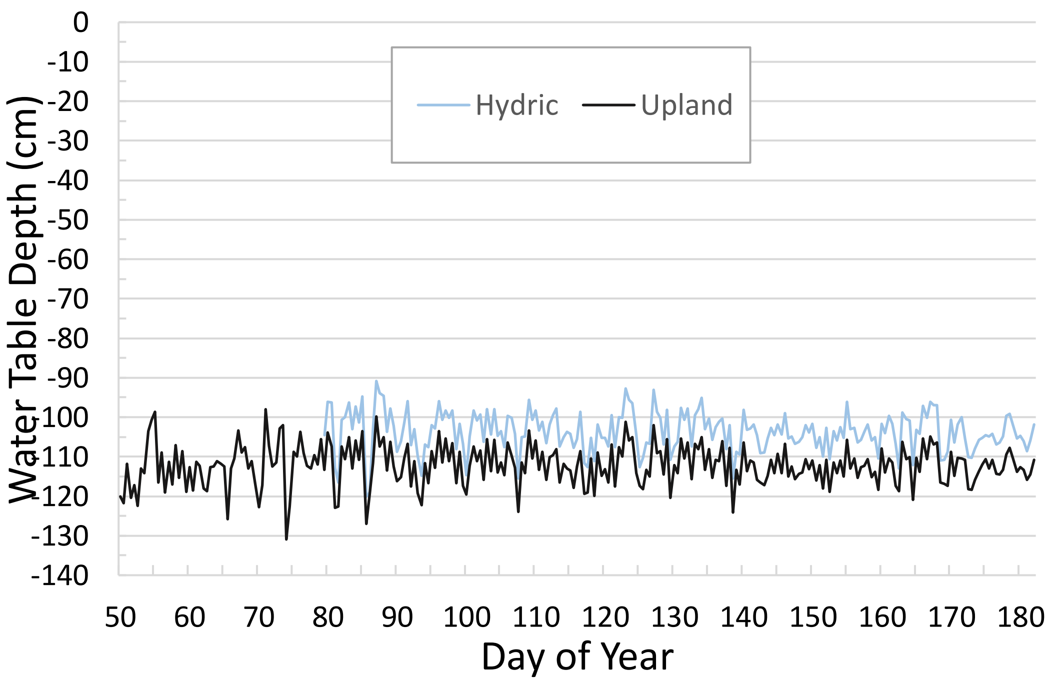
Appendix Figure D.2. East Kramer P Hydric and Upland 2026



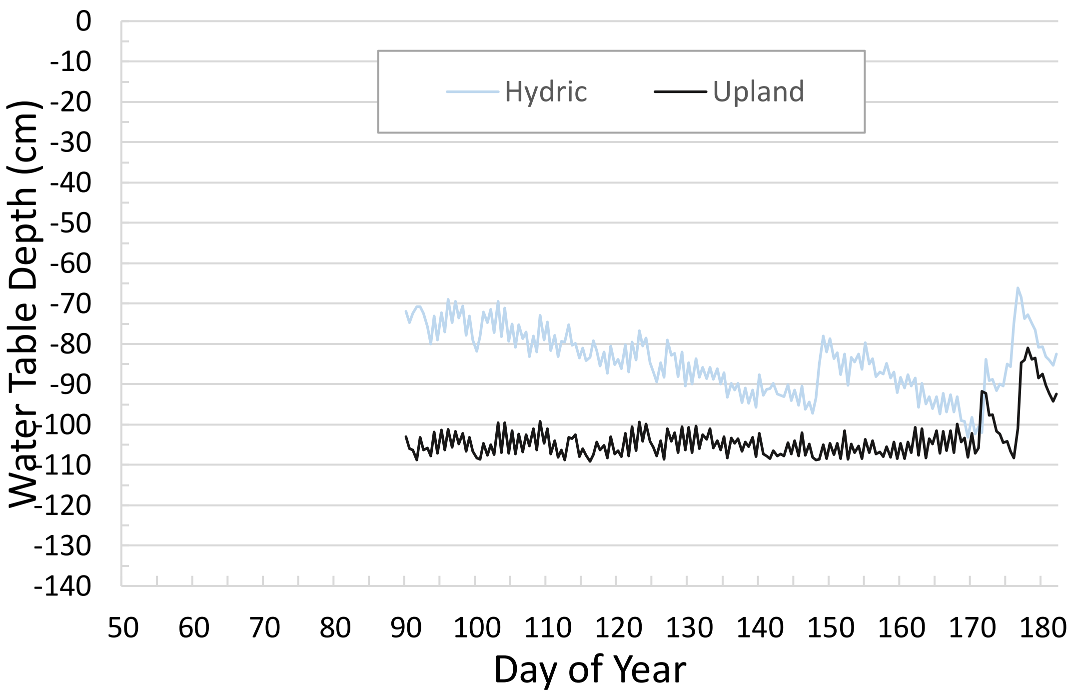
Appendix Figure D.3. West Kramer V Hydric and Upland 2026



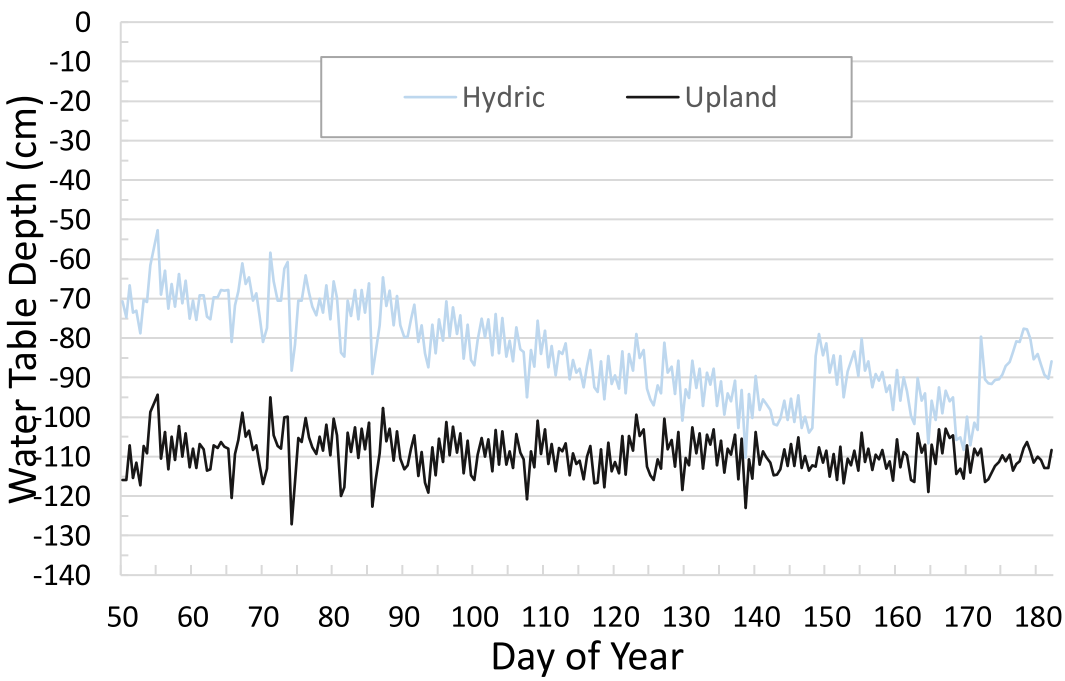
Appendix Figure D.4. West Kramer X Hydric and Upland 2026



Appendix Figure D.5. Pfister B Hydric and Upland 2026



Appendix Figure D.6. Pfister D Hydric and Upland 2026



Appendix E - WETS Tables and Weather Station Data

Appendix Figure E.1. Hudson Weather Station Monthly Precipitation in 2024 with WETS table 30th and 70th percentile ranges

Month	30th Percentile (cm)	70th Percentile (cm)	2024 Monthly Precipitation (cm)	Classification 2024
January	0.79	2.13	5.26	Wet
February	0.53	2.64	1.52	Normal
March	2.67	6.93	0	Dry
April	3.3	7.39	0.38	Dry
May	6.45	12.47	9.78	Normal
June	6.1	10.39	12.19	Wet
6- Month Total	23.7	51.8	29.13	Normal

Appendix Figure E.2. Hudson Weather Station Monthly Precipitation in 2025 with WETS table 30th and 70th percentile ranges

Month	30th Percentile (cm)	70th Percentile (cm)	2025 Monthly Precipitation (cm)	Classification 2025
January	0.79	2.13	2.44	Wet
February	0.53	2.64	1.14	Normal
March	2.67	6.93	0.3	Dry
April	3.3	7.39	6.17	Normal
May	6.45	12.47	12.22	Normal
June	6.1	10.39	16.99	Wet
6- Month Total	23.7	51.8	39.26	Normal

Appendix Figure E.3. Sterling Weather Station Monthly Precipitation in 2024 with WETS table 30th and 70th percentile ranges

Month	30th Percentile (cm)	70th Percentile (cm)	2024 Monthly Precipitation (cm)	Classification 2024
January	1.07	2.49	4.78	Wet
February	0.61	2.64	2.49	Normal
March	3.56	8.15	3.3	Dry
April	3.63	7.24	0.41	Dry
May	7.04	13.39	7.98	Normal
June	5.61	11.68	14.33	Wet
6- Month Total	26.3	57.23	33.29	Normal

Appendix Figure E.4. Sterling Weather Station Monthly Precipitation in 2025 with WETS table 30th and 70th percentile ranges

Month	30th Percentile (cm)	70th Percentile (cm)	2025 Monthly Precipitation (cm)	Classification 2025
January	1.07	2.49	3.4	Wet
February	0.61	2.64	1.73	Normal
March	3.56	8.15	0.33	Dry
April	3.63	7.24	4.88	Normal
May	7.04	13.39	11.15	Normal
June	5.61	11.68	22.68	Wet
6- Month Total	26.3	57.23	44.17	Normal

Appendix F - Vegetation Survey Data

Appendix Figure F.1. East Kramer E Hydrophytic Vegetation Survey (2025)

E - E Kramer, 2025 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Pitcher sage	Salvia azurea	5%	UPL	0
Buffalograss	Bouteloua dactyloides	3%	UPL	
Sample Two				
Deertongue	Dichanthelium clandestinum	8%	FAC	0
Buffalograss	Bouteloua dactyloides	12%	UPL	
Indiangrass	Sorghastrum nutans	2%	UPL	
Sample Three				
Deertongue	Dichanthelium clandestinum	1%	FAC	0
Buffalograss	Bouteloua dactyloides	9%	UPL	
Green foxtail	Setaria viridis	3%	UPL	
Sample Four				
Common mullein	Verbascum thapsus	3%	UPL	0
Indiangrass	Sorghastrum nutans	3%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Green foxtail	Setaria viridis	3%	UPL	
Yellow nutsedge	Cyperus esculentus	1%	FACW	
Sample Five				
Hemp dogbane	Apocynum cannabinum	8%	FAC	0
Buffalograss	Bouteloua dactyloides	18%	UPL	
Indiangrass	Sorghastrum nutans	3%	UPL	

E - E Kramer, 2025 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Pitcher sage	Salvia azurea	10%	UPL	0
Canadian horseweed	Conyza canadensis	20%	UPL	
Western ragweed	Ambrosia psilostachya	8%	UPL	
Little green sedge	Carex viridula	3%	OBL	
Sample Two				
Hemp dogbane	Apocynum cannabinum	5%	FAC	0
Western ragweed	Ambrosia psilostachya	15%	UPL	
Canadian horseweed	Conyza canadensis	18%	UPL	
Perennial ryegrass	Lolium perenne	9%	FACU	
Western tansymustard	Descurainia pinnata	5%	UPL	
Sample Three				
Western ragweed	Ambrosia psilostachya	15%	UPL	0
Prairie cordgrass	Spartina pectinata	2%	FACW	
Pitcher sage	Salvia azurea	4%	UPL	
Canadian horseweed	Conyza canadensis	8%	UPL	
Downy brome	Bromus tectorum	6%	UPL	
Sample Four				
Black willow	Salix nigra	15%	FACW	3
Pitcher sage	Salvia azurea	9%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Downy brome	Bromus tectorum	3%	UPL	
Western ragweed	Ambrosia psilostachya	4%	UPL	
Prairie cordgrass	Spartina pectinata	9%	FACW	
Sample Five				
Western ragweed	Ambrosia psilostachya	9%	UPL	0
Three-square bulrush	Schoenoplectus pungens	3%	OBL	
Deertongue	Dichanthelium clandestinum	15%	FAC	

Appendix Figure F.2. East Kramer E Hydrophytic Vegetation Survey (2026)

E - E Kramer, 2026 — UPLAND

U.S. Army Corps materials that in the event of the hydric zone (zone one) meeting rapid test (1) conditions, that an upland survey is unnecessary.

E - E Kramer, 2026 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Three-square bulrush	Schoenoplectus pungens	80%	OBL	
Black willow	Salix nigra	5%	FACW	
Sample Two				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Three-square bulrush	Schoenoplectus pungens	80%	OBL	
Black willow	Salix nigra	5%	FACW	
Sample Three				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Three-square bulrush	Schoenoplectus pungens	80%	OBL	
Black willow	Salix nigra	5%	FACW	
Sample Four				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Three-square bulrush	Schoenoplectus pungens	80%	OBL	
Black willow	Salix nigra	5%	FACW	
Sample Five				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Three-square bulrush	Schoenoplectus pungens	80%	OBL	
Black willow	Salix nigra	5%	FACW	

Appendix Figure F.3. East Kramer H Hydrophytic Vegetation Survey (2025)

H - E Kramer, 2025 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Canadian horseweed	Conyza canadensis	2%	UPL	0
Yellow foxtail	Setaria pumila	7%	UPL	
Kentucky bluegrass	Poa pratensis	9%	FACU	
Sample Two				
Pitcher sage	Salvia azurea	3%	UPL	0
Green foxtail	Setaria viridis	8%	UPL	
Canadian horseweed	Conyza canadensis	2%	UPL	
Sample Three				
Pitcher sage	Salvia azurea	3%	UPL	0
Tall dropseed	Sporobolus compositus	2%	FACU	
Yellow foxtail	Setaria pumila	5%	UPL	
Sample Four				
Canadian horseweed	Conyza canadensis	6%	UPL	0
Orange foxtail	Alopecurus aequalis	10%	OBL	
Western ragweed	Ambrosia psilostachya	9%	UPL	
Common woodsorrel	Oxalis acetosella	1%	FAC	
Sample Five				
Western tansymustard	Descurainia pinnata	11%	UPL	0
Pitcher sage	Salvia azurea	4%	UPL	
Canadian horseweed	Conyza canadensis	2%	UPL	
Tall dropseed	Sporobolus compositus	5%	FACU	

H - E Kramer, 2025 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Yellow foxtail	Setaria pumila	5%	UPL	0
Western ragweed	Ambrosia psilostachya	6%	UPL	
Yellow nutsedge	Cyperus esculentus	2%	FACW	
Canadian horseweed	Conyza canadensis	1%	UPL	
Bluestem broomsedge	Andropogon virginicus	80%	FACU	
Sample Two				
Canadian horseweed	Conyza canadensis	5%	UPL	2
Western ragweed	Ambrosia psilostachya	3%	UPL	
Little green sedge	Carex viridula	7%	OBL	
Prairie cordgrass	Spartina pectinata	46%	FACW	
Sample Three				
Common woodsorrel	Oxalis acetosella	9%	FAC	0
Common milkweed	Asclepias syriaca	4%	UPL	
Western ragweed	Ambrosia psilostachya	4%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Scouringrush horsetail	Equisetum hyemale	3%	FACW	
Prairie cordgrass	Spartina pectinata	10%	FACW	
Sample Four				
Pitcher sage	Salvia azurea	5%	UPL	0
Tall dropseed	Sporobolus compositus	13%	FACU	
Hemp dogbane	Apocynum cannabinum	1%	FAC	
Sample Five				
Western ragweed	Ambrosia psilostachya	7%	UPL	0
Yellow nutsedge	Cyperus esculentus	5%	FACW	
Little green sedge	Carex viridula	3%	OBL	
Tall dropseed	Sporobolus compositus	4%	FACU	

Appendix Figure F.4. East Kramer H Hydrophytic Vegetation Survey (2026)

H - E Kramer, 2026 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Canadian horseweed	Conyza canadensis	15%	UPL	0
Little bluestem	Schizachyrium scoparium	15%	UPL	
Sample Two				
Canadian horseweed	Conyza canadensis	10%	UPL	0
Little bluestem	Schizachyrium scoparium	40%	UPL	
Sample Three				
Canadian horseweed	Conyza canadensis	10%	UPL	0
Western ragweed	Ambrosia psilostachya	10%	UPL	
Little bluestem	Schizachyrium scoparium	15%	UPL	
Sample Four				
Canadian horseweed	Conyza canadensis	8%	UPL	0
Western ragweed	Ambrosia psilostachya	8%	UPL	
Little bluestem	Schizachyrium scoparium	10%	UPL	
Sample Five				
Canadian horseweed	Conyza canadensis	15%	UPL	0
Western ragweed	Ambrosia psilostachya	3%	UPL	
Little bluestem	Schizachyrium scoparium	5%	UPL	
Indiangrass	Sorghastrum nutans	3%	UPL	

H - E Kramer, 2026 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Kentucky bluegrass	Poa pratensis	45%	FACU	0
Little green sedge	Carex viridula	20%	OBL	
Canadian horseweed	Conyza canadensis	10%	UPL	
Sample Two				
Yellow nutsedge	Cyperus esculentus	50%	FACW	2
Bluestem broomsedge		5%	FACU	
Sample Three				
Little green sedge	Carex viridula	20%	OBL	1
Yellow nutsedge	Cyperus esculentus	40%	FACW	
Sample Four				
Little green sedge	Carex viridula	20%	OBL	1
Yellow nutsedge	Cyperus esculentus	40%	FACW	
Bottlebrush sedge	Carex comosa	10%	OBL	
Sample Five				
Yellow nutsedge	Cyperus esculentus	60%	FACW	2
Bluestem broomsedge		20%	FACU	

Appendix Figure F.5. East Kramer P Hydrophytic Vegetation Survey (2025)

P - E Kramer, 2025 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Deertongue	Dichanthelium clandestinum	5%	FAC	0
Yellow foxtail	Setaria pumila	6%	UPL	
Canadian horseweed	Conyza canadensis	1%	UPL	
Little green sedge	Carex viridula	3%	OBL	
Indiangrass	Sorghastrum nutans	2%	UPL	
Sample Two				
Canadian horseweed	Conyza canadensis	1%	UPL	3
Little bluestem	Schizachyrium scoparium	5%	UPL	
Little green sedge	Carex viridula	13%	OBL	
Kentucky bluegrass	Poa pratensis	5%	FACU	
Sample Three				
Canadian horseweed	Conyza canadensis	4%	UPL	0
Little bluestem	Schizachyrium scoparium	20%	UPL	
Little green sedge	Carex viridula	5%	OBL	
Sample Four				
Indiangrass	Sorghastrum nutans	12%	UPL	0
Little green sedge	Carex viridula	3%	OBL	
Sample Five				
Smooth sumac	Rhus glabra	1%	UPL	0
Canadian horseweed	Conyza canadensis	2%	UPL	
Indiangrass	Sorghastrum nutans	4%	UPL	
Kentucky bluegrass	Poa pratensis	5%	FACU	
Little green sedge	Carex viridula	3%	OBL	

P - E Kramer, 2025 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Pitcher sage	Salvia azurea	25%	UPL	0
Deertongue	Dichanthelium clandestinum	10%	FAC	
Western ragweed	Ambrosia psilostachya	2%	UPL	
Kentucky bluegrass	Poa pratensis	5%	FACU	
Sample Two				
Pitcher sage	Salvia azurea	22%	UPL	0
Smooth sumac	Rhus glabra	15%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Western ragweed	Ambrosia psilostachya	10%	UPL	
Deertongue	Dichanthelium clandestinum	7%	FAC	
Sample Three				
Pitcher sage	Salvia azurea	13%	UPL	0
Sample Four				
Pitcher sage	Salvia azurea	9%	UPL	0
Smooth sumac	Rhus glabra	11%	UPL	
Western ragweed	Ambrosia psilostachya	8%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Sample Five				
Green foxtail	Setaria viridis	13%	UPL	0
Deertongue	Dichanthelium clandestinum	5%	FAC	
Henbit deadnettle	Lamium amplexicaule	6%	UPL	
Canadian horseweed	Conyza canadensis	10%	UPL	
Western ragweed	Ambrosia psilostachya	8%	UPL	

Appendix Figure F.6. East Kramer P Hydrophytic Vegetation Survey (2026)

P - E Kramer, 2026 — UPLAND

U.S. Army Corps states that in the event of the hydric zone (zone one) meeting rapid test (1) conditions, that an upland survey is unnecessary.

P - E Kramer, 2026 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Slender rush	Juncus tenuis	15%	FACW	
Three-square bulrush	Schoenoplectus pungens	70%	OBL	
Sample Two				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Slender rush	Juncus tenuis	15%	FACW	
Three-square bulrush	Schoenoplectus pungens	70%	OBL	
Sample Three				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Slender rush	Juncus tenuis	15%	FACW	
Three-square bulrush	Schoenoplectus pungens	70%	OBL	
Sample Four				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Slender rush	Juncus tenuis	15%	FACW	
Three-square bulrush	Schoenoplectus pungens	70%	OBL	
Sample Five				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	1
Slender rush	Juncus tenuis	15%	FACW	
Three-square bulrush	Schoenoplectus pungens	70%	OBL	

Appendix Figure F.7. West Kramer U Hydrophytic Vegetation Survey (2025)

U - W Kramer, 2025					U - W Kramer, 2025				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little green sedge	Carex viridula	3%	OBL	0	Hemp dogbane	Apocynum cannabinum	5%	FAC	0
Indiangrass	Sorghastrum nutans	2%	UPL		Canadian horseweed	Conyza canadensis	15%	UPL	
Canadian horseweed	Conyza canadensis	3%	UPL		Western tansymustard	Descurainia pinnata	2%	UPL	
					Tall dropseed	Sporobolus compositus	10%	FACU	
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Yellow foxtail	Setaria pumila	3%	UPL	0	Little green sedge	Carex viridula	5%	OBL	0
Canadian horseweed	Conyza canadensis	3%	UPL		Yellow foxtail	Setaria pumila	7%	UPL	
Little bluestem	Schizachyrium scoparium	20%	UPL		Tall dropseed	Sporobolus compositus	8%	FACU	
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	3%	UPL	0	Canadian horseweed	Conyza canadensis	15%	UPL	3
Canadian horseweed	Conyza canadensis	9%	UPL		Prairie cordgrass	Spartina pectinata	22%	FACW	
Cranesbill	Geranium richardsonii	7%	FAC						
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Canadian horseweed	Conyza canadensis	11%	UPL	0	Canadian horseweed	Conyza canadensis	17%	UPL	0
Little bluestem	Schizachyrium scoparium	5%	UPL		Prairie cordgrass	Spartina pectinata	6%	FACW	
Western tansymustard	Descurainia pinnata	7%	UPL						
Musk thistle	Carduus nutans	20%	UPL						
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	9%	UPL	0	Canadian horseweed	Conyza canadensis	9%	UPL	0
Deertongue	Dichanthelium clandestinum	11%	FAC		Western tansymustard	Descurainia pinnata	2%	UPL	
Musk thistle	Carduus nutans	5%	UPL		Western wallflower	Erysimum capitatum	3%	UPL	
Canadian horseweed	Conyza canadensis	4%	UPL		Tall dropseed	Sporobolus compositus	10%	FACU	
Little green sedge	Carex viridula	7%	OBL						
Tall dropseed	Sporobolus compositus	6%	FACU						

Appendix Figure F.8. West Kramer U Hydrophytic Vegetation Survey (2026)

U - W Kramer, 2026					U - W Kramer, 2026				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Switchgrass	Panicum virgatum	45%	UPL	0	Switchgrass	Panicum virgatum	15%	UPL	0
Canadian horseweed	Conyza canadensis	10%	UPL		Cranesbill	Geranium richardsonii	15%	FAC	
Bottlebrush sedge	Carex comosa	5%	OBL						
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Switchgrass	Panicum virgatum	25%	UPL	0	Switchgrass	Panicum virgatum	50%	UPL	0
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	25%	UPL	0	Bluestem broomsedge	Andropogon virginicus	30%	FACU	0
Switchgrass	Panicum virgatum	20%	UPL		Cranesbill	Geranium richardsonii	5%	FAC	
Bottlebrush sedge	Carex comosa	10%	OBL						
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Canadian horseweed	Conyza canadensis	10%	UPL	0	Switchgrass	Panicum virgatum	25%	UPL	0
Western ragweed	Ambrosia psilostachya	15%	UPL		Western tansymustard		5%	UPL	
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	80%	UPL	0	Switchgrass	Panicum virgatum	15%	UPL	0
Western ragweed	Ambrosia psilostachya	5%	UPL						
Bottlebrush sedge	Carex comosa	5%	OBL						
Canadian horseweed	Conyza canadensis	5%	UPL						

Appendix Figure F.9. West Kramer V Hydrophytic Vegetation Survey (2025)

V - W Kramer, 2025

UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Yellow foxtail	Setaria pumila	10%	UPL	0
Western tansymustard	Descurainia pinnata	2%	UPL	
Perennial ryegrass	Lolium perenne	2%	FACU	
Bottlebrush sedge	Carex comosa	4%	OBL	
Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little green sedge	Carex viridula	15%	OBL	3
Indiangrass	Sorghastrum nutans	5%	UPL	
Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Indiangrass	Sorghastrum nutans	4%	UPL	0
Little green sedge	Carex viridula	5%	OBL	
Little bluestem	Schizachyrium scoparium	7%	UPL	
Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Cranesbill	Geranium richardsonii	7%	FAC	0
Little bluestem	Schizachyrium scoparium	6%	UPL	
Indiangrass	Sorghastrum nutans	3%	UPL	
Little green sedge	Carex viridula	3%	OBL	
Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	10%	UPL	0
Indiangrass	Sorghastrum nutans	5%	UPL	
Little green sedge	Carex viridula	1%	OBL	

V - W Kramer, 2025

HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Perennial ryegrass	Lolium perenne	15%	FACU	0
Little green sedge	Carex viridula	10%	OBL	
Yellow foxtail	Setaria pumila	40%	UPL	
Scouringrush horsetail	Equisetum hyemale	15%	FACW	
Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	3%	UPL	0
Perennial ryegrass	Lolium perenne	15%	FACU	
Musk thistle	Carduus nutans	7%	UPL	
Common woodsorrel	Common woodsorrel	11%	FAC	
Henbit deadnettle	Lamium amplexicaule	10%	UPL	
Little green sedge	Carex viridula	15%	OBL	
Deertongue	Dichanthelium clandestinum	30%	FAC	
Indiangrass	Sorghastrum nutans	7%	UPL	
Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Perennial ryegrass	Lolium perenne	18%	FACU	0
Henbit deadnettle	Lamium amplexicaule	3%	UPL	
Yellow foxtail	Setaria pumila	9%	UPL	
Musk thistle	Carduus nutans	5%	UPL	
Western tansymustard	Descurainia pinnata	3%	UPL	
Western ragweed	Ambrosia psilostachya	3%	UPL	
Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	8%	UPL	0
Perennial ryegrass	Lolium perenne	5%	FACU	
Little green sedge	Carex viridula	7%	OBL	
Indiangrass	Sorghastrum nutans	3%	UPL	
Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Perennial ryegrass	Lolium perenne	5%	FACU	0
Musk thistle	Carduus nutans	3%	UPL	
Yellow foxtail	Setaria pumila	5%	UPL	
Little green sedge	Carex viridula	10%	OBL	
Canadian horseweed	Conyza canadensis	10%	UPL	
Western tansymustard	Descurainia pinnata	5%	UPL	
Henbit deadnettle	Lamium amplexicaule	5	UPL	

Appendix Figure F.10. West Kramer V Hydrophytic Vegetation Survey (2026)

V - W Kramer, 2026 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Little bluestem	Schizachyrium scoparium	20%	UPL	0
Bottlebrush sedge	Carex comosa	10%	OBL	
Sample Two				
Bottlebrush sedge	Carex comosa	20%	OBL	0
Little bluestem	Schizachyrium scoparium	30%	UPL	
Sample Three				
Bottlebrush sedge	Carex comosa	5%	OBL	0
Prairie petunia	Ruellia humilis	5%	FAC	
Little bluestem	Schizachyrium scoparium	25%	UPL	
Sample Four				
Little bluestem	Schizachyrium scoparium	15%	UPL	3
Bottlebrush sedge	Carex comosa	20%	OBL	
Sample Five				
Bottlebrush sedge	Carex comosa	10%	OBL	0
Little bluestem	Schizachyrium scoparium	20%	UPL	

V - W Kramer, 2026 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Western ragweed	Ambrosia psilostachya	25%	UPL	0
Bottlebrush sedge	Carex comosa	10%	OBL	
Cranesbill	Geranium richardsonii	5%	FAC	
Canadian horseweed	Conyza canadensis	10%	UPL	
Foxtail barley	Hordeum jubatum	5%	FACW	
Sample Two				
Western ragweed	Ambrosia psilostachya	15%	UPL	0
Bottlebrush sedge	Carex comosa	15%	OBL	
Bluestem broomsedge	Andropogon virginicus	5%	FACU	
Sample Three				
Western ragweed	Ambrosia psilostachya	30%	UPL	0
Bottlebrush sedge	Carex comosa	20%	OBL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Bluestem broomsedge	Andropogon virginicus	10%	FACU	
Sample Four				
Prairie cordgrass	Spartina pectinata	30%	FACW	3
Cranesbill	Geranium richardsonii	10%	FAC	
Western ragweed	Ambrosia psilostachya	20%	UPL	
Bottlebrush sedge	Carex comosa	10%	OBL	
Sample Five				
Switchgrass	Panicum virgatum	30%	UPL	0
Western ragweed	Ambrosia psilostachya	20%	UPL	

Appendix Figure F.11. West Kramer X Hydrophytic Vegetation Survey (2025)

X - W Kramer, 2025 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Tall dropseed	Sporobolus compositus	6%	FACU	0
Indiangrass	Sorghastrum nutans	2%	UPL	
Western ragweed	Ambrosia psilostachya	4%	UPL	
Sample Two				
Canadian horseweed	Conyza canadensis	4%	UPL	0
Little green sedge	Carex viridula	4%	OBL	
Field bindweed	Convolvulus arvensis	2%	UPL	
Tall dropseed	Sporobolus compositus	5%	FACU	
Sample Three				
Deertongue	Dichanthelium clandestinum	5%	FAC	0
Tall dropseed	Sporobolus compositus	4%	FACU	
Western ragweed	Ambrosia psilostachya	2%	UPL	
Little green sedge	Carex viridula	1%	OBL	
Yellow foxtail	Setaria pumila	5%	UPL	
Sample Four				
Western ragweed	Ambrosia psilostachya	10%	UPL	0
Tall dropseed	Sporobolus compositus	10%	FACU	
Sample Five				
Western ragweed	Ambrosia psilostachya	3%	UPL	0
Indiangrass	Sorghastrum nutans	3%	UPL	
Little bluestem	Schizachyrium scoparium	10%	UPL	

X - W Kramer, 2025 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Western ragweed	Ambrosia psilostachya	9%	UPL	0
Little green sedge	Carex viridula	3%	OBL	
Yellow foxtail	Setaria pumila	5%	UPL	
Tall dropseed	Sporobolus compositus	11%	FACU	
Sample Two				
Prairie cordgrass	Spartina pectinata	2%	FACW	0
Yellow foxtail	Setaria pumila	4%	UPL	
Tall dropseed	Sporobolus compositus	7%	FACU	
Sample Three				
Yellow foxtail	Setaria pumila	10%	UPL	0
Tall dropseed	Sporobolus compositus	3%	FACU	
Sample Four				
Perennial ryegrass	Lolium perenne	30%	FACU	0
Western ragweed	Ambrosia psilostachya	5%	UPL	
Sample Five				
Prairie cordgrass	Spartina pectinata	10%	FACW	3
Little green sedge	Carex viridula	5%	OBL	
Western ragweed	Ambrosia psilostachya	4%	UPL	

Appendix Figure F.12. West Kramer X Hydrophytic Vegetation Survey (2026)

X - W Kramer, 2026					X - W Kramer, 2026				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	20%	UPL	0	Western ragweed	Ambrosia psilostachya	10%	UPL	0
Bottlebrush sedge	Carex comosa	15%	OBL		Canadian horseweed	Conyza canadensis	10%	UPL	
Western ragweed	Ambrosia psilostachya	5%	UPL		Switchgrass	Panicum virgatum	10%	UPL	
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	10%	UPL	0	Kentucky bluegrass	Poa pratensis	20%	FACU	0
Switchgrass	Panicum virgatum	20%	UPL		Little green sedge	Carex viridula	10%	OBL	
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	5%	UPL	0	Kentucky bluegrass	Poa pratensis	30%	FACU	0
Canadian horseweed	Conyza canadensis	15%	UPL						
Bottlebrush sedge	Carex comosa	5%	OBL						
Western ragweed	Ambrosia psilostachya	5%	UPL						
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Common woodsorrel	Oxalis acetosella	15%	FAC	0	Switchgrass	Panicum virgatum	20%	UPL	0
Switchgrass	Panicum virgatum	20%	UPL		Kentucky bluegrass	Poa pratensis	10%	FACU	
Kentucky bluegrass	Poa pratensis	5%	FACU		Prairie cordgrass	Spartina pectinata	5%	FACW	
					Western ragweed	Ambrosia psilostachya	8%	UPL	
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Kentucky bluegrass	Poa pratensis	35%	FACU	0	Canadian horseweed	Conyza canadensis	10%	UPL	0
Switchgrass	Panicum virgatum	15%	UPL		Prairie cordgrass	Spartina pectinata	25%	FACW	
Indiangrass	Sorghastrum nutans	10%	UPL		Switchgrass	Panicum virgatum	15%	UPL	

Appendix Figure F.13. Pfister B Hydrophytic Vegetation Survey (2025)

B - Pfister, 2025					B - Pfister, 2025				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Henbit deadnettle	Lamium amplexicaule	3%	UPL	0	Downy brome	Bromus tectorum	20%	UPL	0
Western ragweed	Ambrosia psilostachya	4%	UPL		Western ragweed	Ambrosia psilostachya	7%	UPL	
Tall dropseed	Sporobolus compositus	35%	UPL		Henbit deadnettle	Lamium amplexicaule	9%	UPL	
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Tall dropseed	Sporobolus compositus	38%	UPL	0	Western ragweed	Ambrosia psilostachya	40%	UPL	0
Western tansymustard	Descurainia pinnata	6%	UPL		Canadian horseweed	Conyza canadensis	9%	UPL	
Canadian horseweed	Conyza canadensis	10%	UPL		Henbit deadnettle	Lamium amplexicaule	6%	UPL	
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Tall dropseed	Sporobolus compositus	4%	UPL	0	Western ragweed	Ambrosia psilostachya	5%	UPL	2
Little green sedge	Carex viridula	6%	OBL		Scouringrush horsetail	Equisetum hyemale	10%	FACW	
Western wallflower	Erysimum capitatum	3%	UPL						
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Western ragweed	Ambrosia psilostachya	30%	UPL	0	Western ragweed	Ambrosia psilostachya	7%	UPL	0
Indiangrass	Sorghastrum nutans	7%	UPL		Tall dropseed	Sporobolus compositus	30%	FACU	
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little green sedge	Carex viridula	8%	OBL	0	Western ragweed	Ambrosia psilostachya	10%	UPL	2
Western tansymustard	Descurainia pinnata	3%	UPL		Prairie cordgrass	Spartina pectinata	20%	FACW	
Henbit deadnettle	Lamium amplexicaule	6%	UPL						

Appendix Figure F.14. Pfister B Hydrophytic Vegetation Survey (2026)

B - Pfister, 2026 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Switchgrass	Panicum virgatum	60%	UPL	0
Three-square bulrush	Schoenoplectus pungens	10%	OBL	
Sample Two				
Cranesbill	Geranium richardsonii	10%	UPL	0
Switchgrass	Panicum virgatum	40%	UPL	
Common woodsorrel	Oxalis acetosella	5%	UPL	
Three-square bulrush	Schoenoplectus pungens	10%	OBL	
Sample Three				
Little bluestem	Schizachyrium scoparium	20%	UPL	0
Cranesbill	Geranium richardsonii	5%	UPL	
Western ragweed	Ambrosia psilostachya	10%	UPL	
Sample Four				
Little bluestem	Schizachyrium scoparium	20%	UPL	0
Louisiana sage	Artemisia ludoviciana	10%	UPL	
Western ragweed	Ambrosia psilostachya	5%	UPL	
Three-square bulrush	Schoenoplectus pungens	10%	OBL	
Sample Five				
Western ragweed	Ambrosia psilostachya	25%	UPL	0
Switchgrass	Panicum virgatum	20%	UPL	

B - Pfister, 2026 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Cranesbill	Geranium richardsonii	10%	FAC	0
Prairie cordgrass	Spartina pectinata	40%	FACW	
Canadian horseweed	Conyza canadensis	50%	UPL	
Sample Two				
Prairie cordgrass	Spartina pectinata	20%	FACW	0
Canadian horseweed	Conyza canadensis	20%	UPL	
Western ragweed	Ambrosia psilostachya	10%	UPL	
Cranesbill	Geranium richardsonii	8%	FAC	
Sample Three				
Downy brome	Bromus tectorum	5%	UPL	0
Prairie cordgrass	Spartina pectinata	20%	OBL	
Cranesbill	Geranium richardsonii	15%	FAC	
Canadian horseweed	Conyza canadensis	20%	UPL	
Softstem bulrush		5%	OBL	
Sample Four				
Western ragweed	Ambrosia psilostachya	15%	UPL	0
Canadian horseweed	Conyza canadensis	10%	UPL	
Downy brome	Bromus tectorum	5%	UPL	
Cranesbill	Geranium richardsonii	5%	FAC	
Prairie cordgrass	Spartina pectinata	15%	OBL	
Sample Five				
Foxtail barley	Hordeum jubatum	15%	FACW	0
Prairie cordgrass	Spartina pectinata	25%	FACW	
Western ragweed	Ambrosia psilostachya	15%	UPL	
Canadian horseweed	Conyza canadensis	10%	UPL	

Appendix Figure F.15. Pfister D Hydrophytic Vegetation Survey (2025)

D - Pfister, 2025 — UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Indiangrass	Sorghastrum nutans	5%	UPL	0
Canadian horseweed	Conyza canadensis	2%	UPL	
Sample Two				
Bluestem broomsedge	Andropogon virginicus	13%	FACU	0
Indiangrass	Sorghastrum nutans	4%	UPL	
Sample Three				
Canadian horseweed	Conyza canadensis	7%	UPL	0
Yellow foxtail	Setaria pumila	5%	UPL	
Sample Four				
Bluestem broomsedge	Andropogon virginicus	15%	FACU	0
Deertongue	Dichanthelium clandestinum	3%	FAC	
Sample Five				
Western tansy mustard	Descurainia pinnata	15%	UPL	0
Canadian horseweed	Conyza canadensis	5%	UPL	
Bluestem broomsedge	Andropogon virginicus	12%	FACU	

D - Pfister, 2025 — HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Canadian horseweed	Conyza canadensis	20%	UPL	0
Yellow foxtail	Setaria pumila	8%	UPL	
Sample Two				
Deertongue	Dichanthelium clandestinum	85%	FAC	0
Canadian horseweed	Conyza canadensis	9%	UPL	
Sample Three				
Yellow foxtail	Setaria pumila	11%	UPL	0
Canadian horseweed	Conyza canadensis	5%	UPL	
Sample Four				
Prairie cordgrass	Spartina pectinata	2%	FACW	0
Bluestem broomsedge	Andropogon virginicus	5%	FACU	
Deertongue	Dichanthelium clandestinum	10%	FAC	
Sample Five				
Scouringrush horsetail	Equisetum hyemale	15%	FACW	3
Pitcher sage	Salvia azurea	8%	UPL	

Appendix Figure F.16. Pfister D Hydrophytic Vegetation Survey (2026)

D - Pfister, 2026					D - Pfister, 2026				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	40%	UPL	0	Deertongue	Dichanthelium clandestinum	35%	FAC	0
					Western ragweed	Ambrosia psilostachya	15%	UPL	
					Canadian horseweed	Conyza canadensis	35%	UPL	
					Cranesbill	Geranium richardsonii	5%	FAC	
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Canadian horseweed	Conyza canadensis	20%	UPL	0	Cranesbill	Geranium richardsonii	25%	FAC	0
Little bluestem	Schizachyrium scoparium	15%	UPL		Western ragweed	Ambrosia psilostachya	15%	UPL	
					Slender rush	Juncus tenuis	5%	FACW	
					Canadian horseweed	Conyza canadensis	10%	UPL	
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Canadian horseweed	Conyza canadensis	12%	UPL	0	Canadian horseweed	Conyza canadensis	7%	UPL	0
Cranesbill	Geranium richardsonii	6%	UPL		Cranesbill	Geranium richardsonii	7%	FAC	
Western ragweed	Ambrosia psilostachya	10%	UPL		Western ragweed	Ambrosia psilostachya	12%	UPL	
Little bluestem	Schizachyrium scoparium	25%	UPL		Bluestem broomsedge	Andropogon virginicus	40%	FACU	
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Longstem spikerush	Eleocharis palustris	17%	OBL	0	Western ragweed	Ambrosia psilostachya	30%	UPL	0
Canadian horseweed	Conyza canadensis	12%	UPL		Bluestem broomsedge	Andropogon virginicus	20%	FACU	
Little bluestem	Schizachyrium scoparium	10%	UPL		Longstem spikerush	Eleocharis palustris	17%	OBL	
Cranesbill	Geranium richardsonii	10%	UPL		Canadian horseweed	Conyza canadensis	7%	UPL	
					Cranesbill	Geranium richardsonii	15%	FAC	
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	80%	UPL	0	Western ragweed	Ambrosia psilostachya	7%	UPL	0
Longstem spikerush	Eleocharis palustris	8%	OBL		Canadian horseweed	Conyza canadensis	12%	UPL	
					Cranesbill	Geranium richardsonii	15%	FAC	
					Kentucky bluegrass	Poa pratensis	60%	FACU	
					Prairie petunia	Ruellia humilis	5%	FAC	

Appendix Figure F.17. Pfister K Hydrophytic Vegetation Survey (2025)

K - Pfister, 2025					K - Pfister, 2025				
UPLAND					HYDRIC				
Sample One					Sample One				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Common mullein	Verbascum thapsus	9%	UPL	3	Western ragweed	Ambrosia psilostachya	8%	UPL	0
Scouringrush horsetail	Equisetum hyemale	20%	FACW		Deertongue	Dichanthelium clandestinum	27%	FAC	
Canadian horseweed	Conyza canadensis	5%	UPL						
Sample Two					Sample Two				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Little bluestem	Schizachyrium scoparium	40%	UPL	0	Deertongue	Dichanthelium clandestinum	10%	FAC	0
Common mullein	Verbascum thapsus	8%	UPL		Western ragweed	Ambrosia psilostachya	6%	UPL	
Canadian horseweed	Conyza canadensis	2%	UPL		Scouringrush horsetail	Equisetum hyemale	3%	FACW	
					Prairie cordgrass	Spartina pectinata	7%	FACW	
Sample Three					Sample Three				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Canadian horseweed	Conyza canadensis	5%	UPL	0	Canadian horseweed	Conyza canadensis	10%	UPL	0
Indiangrass	Sorghastrum nutans	6%	UPL		Pitcher sage	Salvia azurea	6%	UPL	
Deertongue	Dichanthelium clandestinum	4%	FAC						
Sample Four					Sample Four				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Indiangrass	Sorghastrum nutans	3%	UPL	0	Deertongue	Dichanthelium clandestinum	12%	FAC	0
Tall dropseed	Sporobolus compositus	8%	UPL		Louisiana sagewort	Artemisia ludoviciana	5%	UPL	
					Tall dropseed	Sporobolus compositus	4%	UPL	
Sample Five					Sample Five				
Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed	Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Deertongue	Dichanthelium clandestinum	5%	FAC	0	Louisiana sagewort	Artemisia ludoviciana	9%	UPL	0
Indiangrass	Sorghastrum nutans	47%	UPL		Deertongue	Dichanthelium clandestinum	8%	FAC	
Canadian horseweed	Conyza canadensis	2%	UPL		Common bulrush	Scirpus atrovirens	12%	OBL	

Appendix Figure F.18. Pfister K Hydrophytic Vegetation Survey (2026)

K - Pfister, 2026

UPLAND

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Little bluestem	Schizachyrium scoparium	15%	UPL	0
Slender rush	Juncus tenuis	7%	FACW	
Canadian horseweed	Conyza canadensis	4%	UPL	
Sample Two				
Little bluestem	Schizachyrium scoparium	30%	UPL	0
Canadian horseweed	Conyza canadensis	15%	UPL	
Sample Three				
Canadian horseweed	Conyza canadensis	20%	UPL	0
Indiangrass	Sorghastrum nutans	15%	UPL	
Sample Four				
Canadian horseweed	Conyza canadensis	10%	UPL	0
Western ragweed	Ambrosia psilostachya	10%	UPL	
Little bluestem	Schizachyrium scoparium	20%	UPL	
Sample Five				
Switchgrass	Panicum virgatum	15%	UPL	0
Indiangrass	Sorghastrum nutans	5%	UPL	
Little bluestem	Schizachyrium scoparium	10%	UPL	

K - Pfister, 2026

HYDRIC

Common Name	Scientific	Area % Cover	H.V. Rating	Test Passed
Sample One				
Torrey's rush	Juncus torreyi	20%	FACW	0
Prairie petunia	Ruellia humilis	10%	FAC	
Western ragweed	Ambrosia psilostachya	15%	UPL	
Kentucky bluegrass	Poa pratensis	5%	FACU	
Canadian horseweed	Conyza canadensis	5%	UPL	
Sample Two				
Kentucky bluegrass	Poa pratensis	20%	FACU	0
Western ragweed	Ambrosia psilostachya	20%	UPL	
Canadian horseweed	Conyza canadensis	5%	UPL	
Sample Three				
Kentucky bluegrass	Poa pratensis	30%	FACU	2
Torrey's rush	Juncus torreyi	5%	FACW	
Foxtail barley	Hordeum jubatum	10%	FACW	
Western ragweed	Ambrosia psilostachya	5%	UPL	
Sample Four				
Canadian horseweed	Conyza canadensis	20%	UPL	0
Orange foxtail	Alopecurus aequalis	15%	OBL	
Western ragweed	Ambrosia psilostachya	5%	UPL	
Sample Five				
Torrey's rush	Juncus torreyi	5%	FACW	2
Little green sedge	Carex viridula	70%	OBL	
Prairie petunia	Ruellia humilis	5%	FAC	
Western ragweed	Ambrosia psilostachya	10%	UPL	

Appendix G - Photos

Appendix Figure G.1. East Kramer E α,α′-dipyridyl dye test results.

Appendix Figure G.2. East Kramer H α,α′-dipyridyl dye test results.

Appendix Figure G.3. East Kramer P α,α′-dipyridyl dye test results.

Appendix Figure G.4. West Kramer U α,α′-dipyridyl dye test results.

Appendix Figure G.5. West Kramer V α,α′-dipyridyl dye test results.

Appendix Figure G.6. West Kramer X α,α′-dipyridyl dye test results.

Appendix Figure G.7. Pfister B α,α′-dipyridyl dye test results.

Appendix Figure G.8. Pfister D α,α′-dipyridyl dye test results.

Appendix Figure G.9. Pfister K α,α′-dipyridyl dye test results.