EFFECTS OF SEDIMENT REMOVAL ON VEGETATION COMMUNITIES IN PRAIRIE POTHOLE WETLANDS IN NORTH DAKOTA

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Caitlin Langworthy Smith

In Partial Fulfillment of the Requirements
for the Degree of
MASTER OF SCIENCE

Major Program:
Natural Resources Management

May 2011

Fargo, North Dakota

North Dakota State University
Graduate School

Title

Effects of Sediment Removal on Vegetation Communities in Prairie Pothole

Wetlands in North Dakota

By

Caitlin Langworthy Smith

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

ABSTRACT

Smith, Caitlin Langworthy, M.S., Department of Natural Resources Management, College of Graduate and Interdisciplinary Studies, North Dakota State University, May 2011. Effects of Sediment Removal on Vegetation Communities in Prairie Pothole Wetlands in North Dakota. Major Professor: Dr. Edward Shawn DeKeyser.

The goal of this study was to assess effects of sediment removal on vegetation communities in Prairie Pothole wetlands in North Dakota to determine if this management technique is providing desired results to create conditions for ideal vegetation communities in wetlands that will benefit wildlife. This project consists of vegetation surveys from seasonal wetlands located in Benson, Eddy, Towner, and Wells counties in North Dakota. Three types of wetlands were surveyed; natural (reference), excavated (treatment), and converted cropland. Vegetation surveys were completed in the shallow marsh and wet meadow zones of seasonal wetlands. Sites were sampled using a modified Daubenmire method. Aerial photos were assessed to determine the occurrence of drawdown cycles in wetland sites. Plant communities were analyzed using non-metric multidimensional scaling and multi-response permutation procedure was used to make comparisons between sites. The wet meadow zones and shallow marsh zones of the three types of wetlands were all significantly different ($p<0.016$) from one another. In general, restored wetlands show vegetation trends that liken natural wetlands while those that have been allowed to recover without restoration tend to be cattail choked. When examining hybrid cattail specifically, visual obstruction scores were approximately four times greater in converted cropland sites versus treatment or reference sites. Vegetation composition indicates hydrologic conditions (fresh to brackish conditions) of specific sites and regional distribution are likely influential factors in wetland plant establishment.

ACKNOWLEDGEMENTS

I would like to thank the U.S. Fish and Wildlife Service, Ducks Unlimited, and North Dakota State University for providing funding for this project. I want to extend my gratitude to the staff at Devils Lake Wetland Management District for providing housing and equipment during my field season as well as continuous helpful input and assistance. I would especially like to thank Cami Dixon, Mark Fisher, and Paul Halko for their helpful knowledge and expertise as well as continued encouragement throughout my field season. I want to thank my advising committee: Dr. Edward S. DeKeyser, Dr. Jack Norland, Dr. Christina Hargiss, Dr. Thomas DeSutter, and Dr. Marinus Otte for all their helpful input, patience, and guidance as well as assistance in the field. I would like to extend my gratitude to Shawn DeKeyser for his help and encouragement throughout the progression of this project as well as his valuable input on edits. I would like to extend a special thank you to Jack Norland for his patience and guidance while assisting me with statistics and PC-ORD. Nathan Derby was an incredibly valuable asset for his knowledge, time, patience, and being a travel partner while assisting me with the RTK device and computer programs. Lastly, I must extend my appreciation to my officemates for providing support and a fun atmosphere to complete my work. I looked forward to coming into the office each and every day because of you all.

Caitlin Smith

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INTRODUCTION

North Dakota supports some of the most productive wetlands in the world and degradation of these wetlands because of increased sedimentation is a growing concern due to past and current management (Martin and Hartman 1987, Gleason and Euliss 1998, Fisher and Allbee 2010). Sediment removal to extend the lifespan of wetlands is a relatively new management technique. However, little follow-up research has been completed after sediment removal has occurred to track potential improvement in habitat and plant community condition.

North Dakota is located in an agricultural dominated landscape that has resulted in the conversion of grasslands to cropland. It has been impacted by human settlement and intensive agriculture since the early 1900s (Fisher 2011). Extensive cultivation has led to increased erosion and the degradation of wetlands in this area. Increases in agricultural practices like native prairie being converted to agricultural land can accelerate sedimentation which can increase the deposition of nutrients, including nitrogen and phosphorus (Richardson et al. 1994). Soil erosion has also been aggravated due to the cultivation of wetland catchment areas (Gleason and Euliss 1998). Due to excess sedimentation and erosion, many of the wetlands on the landscape have been degraded or have disappeared (Gleason and Euliss 1998). Smaller wetlands are especially susceptible due to shallow basins which tend to dry quickly leaving the margins and basins of these wetlands easily degraded by agricultural practices (Bartzen et al. 2010). It has been estimated that up to 90% of seasonal and temporary wetlands have been lost within the Prairie Pothole Region (PPR) due to the conversion of grasslands to cropland and the drainage of wetlands (Knutsen and Euliss Jr. 2001).

Wildlife, such as waterfowl, rely on these wetlands for both food and cover during their migration as well as for breeding and raising broods (Weller and Spatcher 1965, Kantrud and Stewart 1977, Cox et al. 1998). Primary factors that determine the quantity and diversity of breeding waterfowl that will settle in the PPR are wetland availability and emergent cover conditions (Weller and Spatcher 1965).

Increased disturbance in a wetland, whether natural or anthropogenic, facilitates wetland invasion resulting in a decline of both the number and quality of native vegetation species (Zedler and Kercher 2004). *Typha x glauca,* or hybrid cattail, is one invasive species of prairie wetlands that tends to form robust monocultural stands that choke out native vegetation (Galatowitsch and van der Valk 1995, Galatowitsch et al. 1999, Boers et al. 2007). Wildlife use has been shown to decline in these monocultural wetlands (Kantrud 1986).

Investments in wetland restoration and interest in wetland mitigation has been increasing (Fisher and Allbee 2011). The ecological significance and the decline of these ecosystems have made wetland restoration a priority for many private, state, and federal organizations (Zimmer et al. 2002, Fisher and Allbee 2011). Although this management technique is growing in popularity, there are still many unanswered questions.

The specific objectives of this study include:

1) Compare vegetation communities between native prairie wetlands (reference), wetlands that have been restored through sediment removal (treatment), and wetlands that have been allowed to recover from past tillage practices on their own (converted cropland).

2) Evaluate effects of sediment removal on hybrid cattail establishment.

3) Evaluate post-excavation management practices and the effects on wet meadow vegetation community development.

4) Evaluate regional differences of wetland plant community establishment.

LITERATURE REVIEW

Wetlands

Although there are many definitions for wetlands, the U.S. Army Corps of Engineers definition is used as the legal definition when considering wetland management and regulation (USCOE 1987, Mitsch and Gosselink 2007). This definition is as follows: "The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (33 CFR 328.3(b) 1984). Three characteristics must be present for an area to qualify as a wetland; indicators of hydrology, hydrophytic vegetation, and hydric soils (Mitsch and Gosselink 2007, COE 2008).

The most common wetland type within the PPR is palustrine emergent (PEM) (Cowardin et al. 1979). These wetlands can be further divided into four water regime classes: temporary, seasonal, semi-permanent, and permanent (Stewart and Kantrud 1971, Cowardin et al. 1979, Phillips and Beeri 2008). All sites used for this study are type III freshwater wetlands, i.e., seasonal wetlands (Stewart and Kantrud 1971). Seasonal wetlands, as defined by Stewart and Kantrud 1971, are comprised of a shallow marsh zone, wet meadow zone, and low prairie zone as seen in Figure 1.

Wetlands in the PPR have a shared surface and groundwater hydrology (Phillips and Beeri 2008), however; most wetlands are not connected by overland flow due to few natural surface drainage systems within the region (Richardson et al. 1994, Euliss et al. 1999). These pothole wetlands can function as groundwater recharge, flow-through systems, or groundwater discharge sites (Arndt and Richardson 1988, 1989, Euliss et al. 1999). The hydrologic function that a wetland performs is based on its landscape position, climate variation, the type of underlying substrate, and the arrangement of the affiliated water table (Euliss et al. 1999). Wetlands act as landscape sinks collecting debris, sediments, water, and nutrients from the surrounding landscape (Zedler and Kercher 2004).

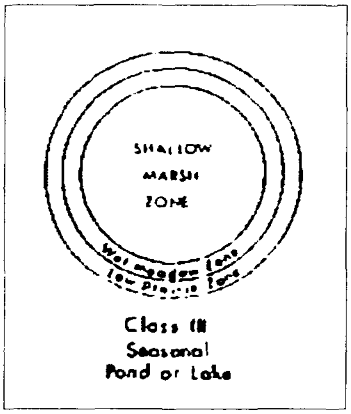


Figure 1. Spatial relation of vegetation zones of Class III seasonal wetlands.

Subclasses of wetlands are based on differences in species composition of vegetation communities within wet-meadow, shallow-marsh, or deep-marsh zones that are correlated with variations in average salinity of surface water and can persist over widely overlapping ranges of salinity (Stewart and Kantrud 1971, Cowardin et al. 1979). These subclasses include fresh, slightly brackish, moderately brackish, brackish, and subsaline. Subclasses are based on ranges in specific conductance (micromhos/cm^3) of surface water (Table 1) (Stewart and Kantrud 1971). Plant community associations are used as reliable indicators of average salinity than single measurements of specific conductance due to unstable water conditions characteristic of most prairie pothole wetlands (Stewart and Kantrud 1971).

Table 1. Approximate normal and extreme ranges in specific conductance (micromhos/cm^3) of surface water in plant communities that are indicators of differences in average salinity.

Plant Community	Normal Range	Extreme Range
Fresh	<40-500	<40-700
Slightly brackish	500-2,000	300-2,200
Moderately brackish	2,000-5,000	1,000-8,000
Brackish	5,000-15,000	1,600-18,000
Subsaline	15,000-45,000	3,500-70,000
Saline	45,000-100,000+	20,000-100,000+

Disturbances

For this paper, "disturbance" is defined as, "any event or series of events that disrupt ecosystem, community, or population structure and alters the physical environment, by natural or unnatural means". Wetlands used for this study have been subject to disturbances including grazing and sedimentation which are common in agricultural settings. Wetland sites located in Wells county have been left idle and therefore are considered to have a lack of disturbance.

Grazing

Ecological systems such as wetlands depend on disturbance which plays a critical role in maintaining diversity, structure, and function (Marty 2005). Disturbance on prairie grasslands occurred naturally over thousands of years through fire and grazing (Kantrud et al. 1989a). Livestock can serve as a functional equivalent to large herbivores that historically grazed grasslands (Marty 2005).

Grazing effects vary depending on the intensity of grazing. Grazing can be effective in controlling invasive wetland plant species such as hybrid cattail (*Typha x glauca)* and reed canary grass (*Phalaris arundinacea*) which often form monocultures in wetlands (Kantrud 1986, Kirby et al. 2002, Marty 2005). Cattle selectively forage on grasses and grass-like plants which help maintain a more open canopy in wetlands (Kantrud 1986, Marty 2005). Higher biodiversity and increased native plant species richness has been shown in grazed versus non-grazed systems (Marty 2005). However, overgrazing can decrease the productivity of plants, reduce plant cover, and increase the amount of bare ground (Reimold et al. 1975, Basset 1980).

Sedimentation

Sedimentation can be from both natural and anthropogenic origin. Sediment can impact wetlands in multiple ways and has been shown to have substantial effects on wetland processes (Jurik et al. 1994, Gleason and Euliss 1998). These effects include shortening of the topographic lifespan of the wetland, the alteration of vegetation communities, altering the soil structure within wetland basins, reducing the microtopography within the wetland, and excess nutrients and contaminants entering the wetland (Martin and Hartman 1987, Jurik et al. 1994, Gleason and Euliss 1998, Werner and Zedler 2002).

Prairie conversion to agricultural lands and agricultural practices can accelerate the sedimentation process which is especially common in the PPR (Gleason and Euliss 1998, Detenbeck et al. 2002). Sediment rates have been found to be nearly twice as high in wetlands with cultivated catchments than with catchments occurring in native or non-native grassland (Martin and Hartman 1987, Gleason and Euliss Jr. 1998). Prolonged drought coupled with wind can increase soil erosion and the deposition of sediment in wetland basins, especially in cultivated catchment areas (Gleason and Euliss Jr. 1998). Every wetland has a finite topographical lifespan; however, increased sedimentation can shorten its topographical lifespan. Sediment accumulation makes wetlands shallower and creates fresh substrate, allowing for species, such as hybrid cattail, to colonize the area that may otherwise be restricted by water depths (Werner and Zedler 2002).

There is a negative correlation between the increase in sediment depth and the decrease in number of plant species in wetlands (Jurik et al. 1994, Werner and Zedler 2002, Gleason et al. 2003). Reports have shown that sediment burial depths as little as 2.5 mm can reduce species richness, emergence, and germination of hydrophytes in wetlands (Jurik et al. 1994, Gleason et al. 2003). This is a minute amount to have such a significant impact on wetland vegetation. Germination success has been shown to be linked to seed size with larger, more robust seeds generally more able to withstand sediment loads like *Typha x glauca* (Jurik et al. 1994). Sedimentation burial of seedbeds prior to the drawdown phase can inhibit the growth and establishment of hydrophytic species and potentially alter the vegetation communities of wetlands (Jurik et al. 1994, Gleason et al. 2003). Sediment not only affects vegetation recruitment from seedbanks, but invertebrate egg banks are also negatively affected by sedimentation (Gleason et al. 2003).

Sedimentation has been shown to significantly alter physical characteristics of wetlands, such as soil structure and moisture regime, by decreasing soil organic matter content and increasing dry soil bulk density which can lower species richness of the wetland basin (Werner and Zedler 2002). This can lead to an increase in invasive species. The expansion of hybrid cattail is a symptom of excessive sedimentation of PPR wetlands (Kantrud 1992). Increased sedimentation can lead to excess deposition of nutrients such as nitrogen (N) and phosphorus (P), commonly found in larger amounts in agricultural areas (Martin and Hartman 1987). Total accumulation rates of total P have been found to be approximately twice as high in wetlands surrounded by cultivation than in grassland complexes, however, total N and organic matter were similar when compared between cultivated and grassed watersheds (Martin and Hartman 1987). Significantly more clay and silt, up to five times more, has been found in the soils of cultivated wetlands versus grassland wetlands (Martin and Hartman 1987). Sedimentation can affect species richness in wetlands by reducing microtopographic relief (Werner and Zedler 2002). Sedimentation reduces microtopographic variation and surface area for native species. A reduction in microtopography due to sedimentation can smother native vegetation and encourages invasive species, such as *Typha x glauca,* to establish and expand, choking out native vegetation (Werner and Zedler 2002).

Idle Wetlands

Areas in the PPR are left idle for different reasons including being a part of national wildlife refuges, waterfowl production areas, state game management areas, and conservation reserve program, or being located under private ownership (Hargiss 2009). The PPR was formed by natural disturbances such as fire, grazing, and climatic fluctuations (Kirby et al. 2002). When left idle, the lack of disturbance can have an effect on present vegetative communities. Opportunities for invasion by woody species are increased when areas are left idle, especially after cultivation (Kantrud and Newton 1996). Allowing lands to idle may decrease overall plant diversity and increase non-native vegetation species abundance in wetlands (Marty 2005).

Hydrology

Hydrologic conditions, especially flooding regimes, are a primary influence on wetland processes and plant community composition (Mitch and Gosselink 2007). Smaller seasonal or temporary wetlands are floristically less stable regarding species richness as these are more susceptible to changes in precipitation patterns (Aronson and Galatowitsch 2008). The natural fluctuation of water levels is likely the most important cause of vegetative change in prairie wetlands (van der Valk 1981, Kantrud 1986). Water levels within wetland basins respond rapidly to changes in weather (Johnson et al. 2004, 2005). Drawdown periods are natural and are critical for the recruitment and germination of emergent species from the seed bank for the re-colonization of emergent vegetation in wetlands (van der Valk and Davis 1978, Johnson et al. 2005). For the same reasons, frequent drawdown periods are also important for invertebrate egg banks (Gleason et al. 2003, 2004).

Hydrological disturbance affects nutrient availability and salinity levels, not just water levels. Nitrates are quickly leached from oxidized soil during drainage and phosphorus is released upon rewetting (Olde Venterink et al. 2002). Salinity within a wetland basin changes as hydrology fluctuates, for example the wet/dry cycle, impacting vegetation communities present in the wetland basin (Euliss et al. 1999). For example, a wetland classified as a freshwater wetland may become classified as a brackish wetland as salinity increases due to hydrology fluxes. Plant species have varying tolerances to salinity and vegetation communities within wetland basins may shift over time due to changes in these salinity levels (Stewart and Kantrud 1971, 1972, Euliss et al. 1999). However, high salinity usually results in less diversity of wetland vegetation (Kantrud et al. 1989b).

Typha **Species**

Three species of cattail are found in the Northern Great Plains: *Typha latifolia*, *Typha angustifolia*, and *Typha x glauca*. These species can be found in both seasonal and permanent surface water (Goslee et al. 1997). *Typha latifolia*, or broad-leaved cattail, is native to North American wetlands and is typically found upslope in shallower water depths (Grace and Harrison 1986). *Typha angustifolia*, or narrow-leaved cattail, is a European species that was introduced from the early 19th century and spread inland and westward across southern Canada and the northern United States (Grace and Harrison 1986). *Typha angustifolia* can tolerate more saline or alkaline environments as well as deeper water than *Typha latifolia* (Smith 1967, Grace and Harrison 1986, Wilcox 1986, Tanaka et al. 2004) and is usually found in highly disturbed sites versus natural sites (Smith 1967, Grace and Harrison 1986, Olson et al. 2009). *Typha x glauca*, or hybrid cattail or *Typha x*, is a F1 hybrid between *Typha latifolia* and *Typha angustifolia* (Smith 1967, Grace and Harrison 1986) and is also usually found in disturbed sites (Grace and Harrison 1986) and poses the greatest concern from a management perspective.

Typha x is a common invasive species in disturbed wetlands and can tolerate varied water depths (Grace and Harrison 1986. Boers et al. 2007, Vaccaro et al. 2009) and can adapt quickly to altered hydrologic regime and altered soils (Smith 1967, Olson et al. 2009). This species spreads rapidly through rhizomatous growth which allows for quick invasion of aquatic habitats (Grace and Harrison 1986, Woo and Zedler 2002, Boers et al. 2007). *Typha x* is a robust species that can withstand sediment loads unlike a large portion of native vegetation (van der Valk and Davis 1978, Maurer and Zedler 2002, Boers et al. 2007) and will often form monocultural stands unless properly managed (Galatowitsch and van der Valk 1995, Galatowitsch et al. 1999, Boers et al. 2007). Hybrid cattail tends to become more dominant as the average number of flood days increase (Boers et al. 2007). Due to greater tolerance of flooding *Typha x* readily invades many wetland sites, and rapid early growth may contribute to tolerance as well when nutrients are not a factor (Kercher and Zedler 2004).

Typha x can become dominant in wetlands for many reasons. They have tall stature that may potentially block sunlight that would otherwise be available to understory vegetation. *Typha x* exhibits rapid growth and the ability to utilize resources such as light, nutrients and root space more effectively than native plants (Galatowitsch et al. 1999) and tend to create a high-nutrient, low-light environment that benefits itself (Farrer and Goldberg 2009). Hybrid cattail produces large amounts of vegetative litter that can accumulate to great depths. This litter prevents light from penetrating the bottom of the wetland and may inhibit the growth of present vegetation or prevent other species from establishing in the wetland. This results in the decrease of native plant density, diversity, and survival (Hager 2004, Boers et al. 2007, Farrer and Goldberg 2009, Vaccaro et al. 2009). Boers et al. (2007) found a negative correlation between *Typha x* cover and species richness. A study done by Vaccaro et al. (2009) revealed that species density was negatively correlated with litter biomass, but was not related to aboveground live cattail biomass. Not surprisingly, native diversity has been found to be highest in shallow litter depth (Farrer and Goldberg 2009).

Hybrid cattail has been shown to utilize excess nutrients such as N and P and accelerate their vegetative growth and increase aboveground biomass suggesting it is an opportunistic invader (Mack et al. 2000, Woo and Zedler 2002). However, the same study by Woo and Zedler (2002) showed that native graminoids did not respond to excess nutrients in either biomass or percent cover. This allows for *Typha x* to exploit these nutrients within wetland habitats. It is thought that excess N and P in sediment, along with continuous anaerobic water levels, provides a niche for cattails to flourish which then often out-compete native vegetation (Woo and Zedler 2002, Fisher and Allbee 2011). *Typha x* has been shown to not respond to increases in N or P individually, but responds when N and P are added together (Woo and Zedler 2002). Removing these excess nutrients through sediment removal may inhibit the ability of *Typha x* to establish, or re-establish if already present, and form dense stands.

Waterfowl

The PPR provides critical wetland waterfowl habitat in North America. Primary factors that determine the quantity and diversity of breeding waterfowl that will settle in the PPR are wetland availability and emergent cover conditions (Weller and Spatcher 1965). Seasonal wetlands prove to be of utmost importance for habitat for breeding ducks (Kantrud and Stewart 1977). These wetlands are important to waterfowl as they are the some of the first wetlands to thaw in the spring. Water in seasonal wetlands warms early in the spring and these are some of the first wetlands to produce macro-invertebrate populations, which are important to the diets of waterfowl (Gleason et al. 2003). Seasonal wetlands are more productive in the recruitment, abundance and taxon richness than semi-permanent wetlands (Gleason et al. 2003). Aquatic inverts help fulfill a crucial protein –rich diet for nesting hens and are also are an important food source for young broods (Cox et al. 1998).

Cattail choked wetlands may decrease suitable habitat for ducks in the PPR. Dabbling and diving ducks prefer wetlands with openings as well as heterogeneity in vegetation structure in the marsh canopy to nest and raise their broods (Kantrud 1986). Robust, monoculture stands produced by cattails tend to have decreased use by waterfowl

(Kantrud 1986). Structured natural vegetation could ultimately provide more potential habitat and food for wildlife.

Sediment Removal

Sediment removal is implemented to remove undesired vegetation and soil with excess nutrients and to expose the original seedbed that would allow for natural vegetation to re-establish. Restored wetlands regain native plant communities and invertebrate communities similar to reference, or undisturbed, wetlands (Fisher and Allbee 2011). The establishment of native plant communities in restored wetlands is accredited to remnant seed banks and wildlife acting as seed vectors between sites (Wissinger et al. 2001). Prairie wetlands have seed banks that contain high densities of long-lived seeds of native hydrophytic species that enable their vegetation to respond rapidly to hydrologic fluxes (van der Valk and Davis 1978). Some species within these wetland seed banks can survive for decades (Roberts 1981). However, if a site has been in cultivation for 50 years or longer, native seed bank is likely near depletion and the seed bank of potential competitive and invasive species remains (Verhagen et al. 2001). For this reason, restorations are often manually seeded or plugged to aid in the native plant establishment process.

Removing surface soil (0-61cm) not only removes excess nutrients, but also seed banks of undesired vegetation (Verhagen et al. 2001). Hybrid cattail occurs more often in areas of varying depths of alluvium suggesting that they are more successful at establishing and persisting in areas of sediment accumulation (Werner and Zedler 2002). If invasive species are not completely removed from a restored site they are likely to re-invade and out-compete other vegetation (Dalrymple et al. 2003, Boers et al. 2007).

The specific objectives of this study include:

1) Compare vegetation communities between native prairie wetlands, wetlands that have been restored through sediment removal, and wetlands that have been allowed to recover from past tillage practices on their own.

2) Evaluate effects of sediment removal on hybrid cattail establishment.

3) Evaluate post-excavation management practices and the effects on wet meadow vegetation community development.

4) Evaluate regional differences of wetland plant community establishment.

STUDY AREA

This study was completed during 2010 on wetlands located in Benson, Eddy, Towner, and Wells counties in North Dakota located within the PPR (Figure 2). These counties are categorized within the Northern Great Plains Region, Land Resource Region F (USCOE, 2008). Three types of wetlands were surveyed for this study: 1) natural (reference, native prairie), 2) excavated (treatment), and 3) converted cropland (unexcavated, allowed to recover from past tillage practices on their own). Wetlands were chosen based on proximity to the other two types of wetlands.

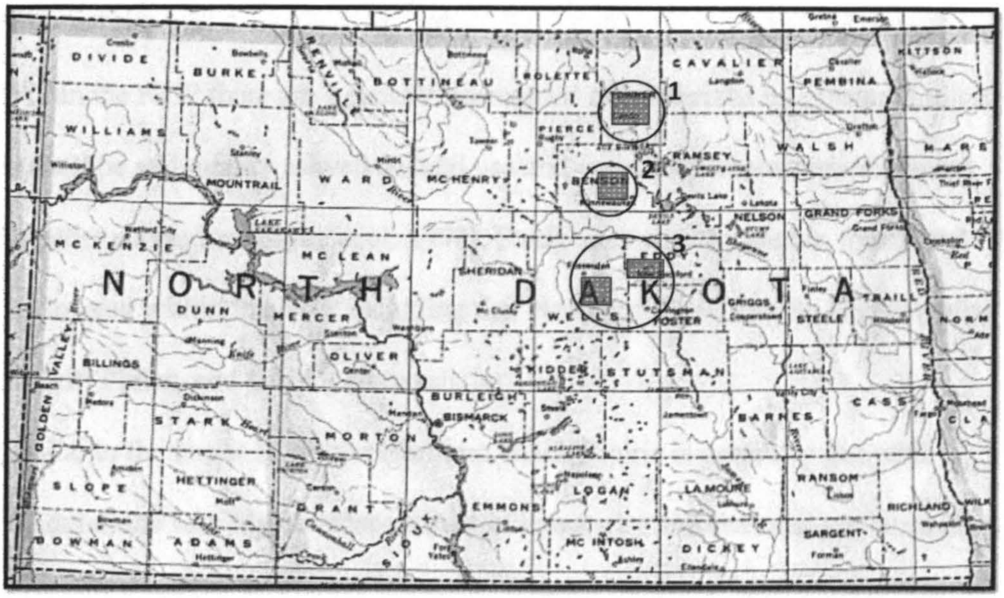


Figure 2. Location of Benson, Eddy, Towner, and Wells county wetland study sites in North Dakota and clusters. Credit: Statetravelmaps.com

Ecoregions

Ecoregions are designed and formatted to provide a spatial framework for the assessment, research, monitoring, and management of ecosystems and their components. Ecoregions are categorized based on biotic and abiotic units and patterns that reflect differences in ecosystem type and quality. These ecological units include geology, physiography, climate, soils, hydrology, vegetation, land use and wildlife (Nesser et al. 1997, Bryce et al. 1998).

This study was conducted in the Level III Northern Glaciated Plains Ecoregion (NGP) of North Dakota (Bryce et al. 1998). This ecoregion is composed of glacial drift and characterized by a flat to gently undulating landscape with a high concentration of temporary and seasonal wetlands. The landscape hosts transitional grassland with mixed grass prairie in the west to tallgrass prairie in the east. Although the NGP possesses subhumid climate and fertile till soil, agricultural success is dependent upon annual climatic fluctuations.

Within the NGP there are Level IV ecoregions characterized by greater similarity in ecosystem type and quality as well as land use and vegetation characteristics found across the entire ecoregion (Bryce et al. 1998). Study sites were located in four Level IV ecoregions located within the NGP including the: Northern Black Prairie, End Moraine Complex, Drift Plains, and Glacial Outwash.

Similar to the larger NGP, the Northern Black Prairie is generally flat with sporadic undulations with high concentrations of temporary and seasonal wetlands (Bryce et al. 1998). This Level IV ecoregion represents a broad transition zone marking the introduction from the north of a boreal influence in climate. Land use is extensively tilled to spring wheat (*Triticum aestivum*) and durum (*Triticum durum*), sunflower (*Helianthus annuus*), alfalfa (*Medicago sativa*), and other small grains and has the shortest growing season.

The End Moraine Complex is a concentration of glacial features and has high temporary and seasonal wetland densities (Bryce et al. 1998). The landscape is of hummocky stagnation moraine, parallel end moraine ridges, and additional glacial features such as kames, thrust ridges, and eskers. Land use includes cultivation of spring wheat (*Triticum aestivum*), oats (*Avena sativa*), barley (*Hordeum vulgare*), flax (*Linum usitatissimum*), and hay, which can be composed of multiple species, as well as range dependent upon slope and presence of rocks in soil.

The Drift Plains is a generally flat glaciated area with thick glacial till and an abundance of temporary and seasonal wetlands (Bryce et al. 1998). Land use is almost entirely used for cultivation of spring wheat and other small grains due to productive soil and level topography.

The Glacial Outwash is glaciated with generally smooth topography amidst ancient channel depressions and relict lakes (Bryce et al. 1998). Soils are highly permeable and possess low water holding capacity. Land use is a mixture of cattle grazing and cultivation of spring wheat (*Triticum aestivum*), oats (*Avena sativa*), barley (*Hordeum vulgare*), rye (*Secale cereale*), and alfalfa (*Medicago sativa*).

Climate

The general climatic pattern for the PPR is short hot summers and long frigid winters with a short growing season (Figure 3). The PPR is subject to extreme variations in temperatures which range from -40°C in the winter to 40°C in the summer (-40°F to 104°F) (Euliss et al. 1999, Jensen no date). North Dakota, in general, is characterized by a relatively dry, but typical continental climate with extreme daily, season, and annual temperature fluctuations (Winter 1989, Jensen no date).

Precipitation in North Dakota primarily occurs in the summer but water present in wetlands mostly comes from spring snowmelt (Winter et al. 1984). During winter months, less than 20% of the total annual precipitation falls as snow resulting in a period of relative drought throughout the Northern Great Plains Region (Barker and Whitman 1988, Jensen no date). Typically 60-80% of total annual precipitation occurs in spring and early summer seasons, peaking in June (Barker and Whitman 1988, Jensen no date).

Figure 3. The Prairie Pothole Region of North America. Shaded area represents the PPR. Credit: U.S. Geological Survey

The PPR's climatic pattern is coupled with alternating wet and dry cycles that last approximately 10-20 years each (Diaz 1983). Northeast North Dakota is currently in a wet cycle and has undergone 18 consecutive years (1994-2011) of excessively wet, annual rainfall conditions (Fisher and Allbee 2011). The wet-dry cycle has pronounced effects on the physical, chemical, and biological properties of wetlands (Euliss et al. 1999, Euliss et al. 2004, Johnson et al. 2005). Alternating weather cycles creates a vegetation cover cycle with vegetation expansion and recruitment during draw-down periods and vegetation deluge and drowning during high waters (Cowardin et al. 1979, van der Valk 1981, Phillips and Beeri 2008). These changes vary and may occur on a weekly, monthly, or annual basis. Variability in temperatures and precipitation are critical climatic factors that influence wetlands and vegetation patterns (Barker and Whitman 1988, Kantrud et al. 1989b).

For the research year 2010, the average temperature for northeastern North Dakota is 5°C (41°F), and the average summer temperature is 18°C (65°F). Temperatures for 2010 ranged from -35 to 36°C (-30 to 98°F) (NDAWN 2011). For the research year 2010, sites received approximately 47 cm (18.5 inches) in precipitation. Average annual precipitation for the region ranges from 36 to 53 cm (14 to 21 inches) (USDA NRCS 2006). Evaporation exceeded precipitation in the study area by 71 cm (28 inches) (NDAWN 2011).

Geology

The variable landscape of the PPR was shaped by the late Pleistocene Epoch (Wisconsin) glaciations that occurred between 9,000 and 13,000 years ago (Bluemle 1991, Richardson et al. 1994, Richardson and Vepraskas 2001). The glacial action of the last ice age left behind a mosaic of kettles and kames, swales and swells, moraines, outwash plains, and glacial lake basins as well as the formation of millions of small depressions across the landscape (Euliss et al. 1999, Richardson and Vepraskas 2001, Johnson et al. 2005).

Major formations in the study area include the Missouri Coteau, Missouri Escarpment and Drift Prairie. Elevations within the study area range from 453 to 498m above sea level. Wetland sites are located in the Drift Prairie geological region, just on the eastern edge of the Missouri Escarpment geological region, which separates the Drift Prairie from the Missouri Coteau geological region (Young 1923, Bluemle and Clayton

1983). Surface sediments typically found in the PPR include glacial till, glacial outwash, and lacustrine muds formed from the erosion of sedimentary rocks (Richardson and Vepraskas 2001). The Drift Prairie is a plain covered with undulating deposits of glacial till and drift (Young 1923, Aandahl 1982, USCOE 2008). Soil parent materials throughout the PPR tend to be clayey, silty, and calcareous. Most of the soils within the Drift Prairie formed from the residuum from sandstones and shales formed during the Tertiary period (USCOE 2008).

Vegetation

The dominant vegetation in the PPR and the NGP has been grass for the last 6,000 years (Richardson et al. 1994, Richardson and Vepraskas 2001). The governing grassland vegetation is very similar over most of its range in the NGP (Barker and Whitman 1988, 1989). Vegetation is dominated by mixed grass prairie in the west and tall-grass prairie in the east. The mixed grass is mostly dominated by western wheatgrass (*Pascopyrum smithii*), green needlegrass (*Nassella viridula*), needle-and-thread (*Hesperostipa comate*), blue grama (*Bouteloua gracilis*) and the tallgrass prairie is dominated by big bluestem (*Andropogon gerardii*), switchgrass (*Panicum virgatum*), little bluestem (*Schizachyrium scoparium*) and Indian grass (*Sorghastrum nutans*) (USDA NRCS 2006). The United States Department of Agriculture PLANTS database was used as the primary reference for all of the plant species and nomenclature identified in this document (USDA NRCS 2011).

Wetland vegetation will vary dependent upon a variety of factors including climate, season, hydrology and soils. Wetlands are capable of hosting multiple plant communities throughout its zones and boundaries. The type of wetland and how long it ponds water will influence what vegetation species establish as well as how long species are present within the wetland. A seasonal wetland may be characterized freshwater to subsaline and these hydrologic conditions will influence wetland vegetation as wetland plants vary in tolerance. Common wetland communities consist of sedges (*Carex spp.*) and forbs in the shallow marsh with the addition of grasses in the wet meadow (Stewart and Kantrud 1971, 1972).

Soils

Soils throughout the PPR are comprised mostly of Mollisols (Richardson et al. 1994), or dark prairie soils with a relatively deep A horizon (Gardiner and Miller 2004). Mollisols are high in organic matter that develops primarily under grassland vegetation (USCOE 2008. USDA Web Soil Survey 2011). The extensive root systems of the remnant mixed and tall-grass prairie have assisted in the formation of present-day soils by both stabilizing the soil and adding to the soils organic richness through root decomposition (Dahlman and Kucera 1965). The typical upland and wetland soils of the NGP and the four Level IV ecoregions of this study are Mollisols with varying Great Groups and common soil series (Bryce et al. 1998).

The typical soil Order for study sites located in the Northern Black Prairie (Towner County) is Mollisols with Great Groups consisting of Haploborolls. Natriborolls. Calciaquolls. Calciborolls, and Argiaquolls (USDA Web Soil Survey 2011). Common upland soil series include Barnes. Svea. Cresbard. and Buse. with common wetland soil series Hamerly and Parnell (Bryce et al. 1998. USDA Official Soil Series Descriptions 2011). Wetland sites located in Towner County are comprised of the soil series Hamerly-Tonka-Parnell complex, Vallers saline-Parnell complex, and Vallers-Hammerly loams.

Study sites located in the End Moraine (Benson County) are comprised of the soil Order, Mollisols, with Great Groups consisting of Haploborolls, Argiborolls, Calciborolls, and Calciaquolls (USDA Web Soil Survey 2011). Common upland soil series include Heimdal, Emrick, Esmond, Barnes, Buse, Bottineau, and Aastad, with Hamerly as the common wetland soil series (USDA Official Soil Series Descriptions 2011). Specific Benson county wetland soils of are comprised of the soil series Vallers saline-Parnell complex and the Hamerly –Tonka complex.

The typical soil Order for the Drift Plains (Wells County) is Mollisols with Great Groups Haploborolls, Calciaquolls, Natriborolls, Calciborolls, and Argiaquolls (USDA Web Soil Survey 2011). Common upland soil series include Barnes, Svea, Buse, and Cresbard, with Hamerly and Parnell as the common wetland soil series (USDA Official Soil Series Descriptions 2011). Wetland sites are comprised of the soil series Heimdal-Emrick loams, Fram-Tonka complex, and Fram-Wyard loams.

Typical soil Orders for the Glacial Outwash (Eddy County) are Mollisols and Entisols with Great Groups Haploborolls, Natraquolls, and Udipsamments (USDA Web Soil Survey 2011). Common upland soil series include Brantford, Claire, Renshaw, Arvilla, Fordville, and Sioux, with Totten as the common wetland soil series (USDA Official Soil Series Descriptions 2011). Wetland sites are comprised of the soil series Southam silty clay loam, Rauville silty clay loam, Vallers loam, and Colvin silt loam.

Besides wetland sites located within the Glacial Outwash, the most common wetland soil series across study sites is Hamerly and Parnell. The Hamerly series is characterized of very deep, somewhat poorly drained soils (USDA Official Soil Series Descriptions 2011, USDA Web Soil Survey 2011). The taxonomic class for the Hamerly series is fine-loamy, mixed, superactive, frigid Aeric Calciaquolls (USDA Official Soil Series Descriptions 2011). This soil series is found on flats on lake plains and on convex slopes surrounding shallow depressions and on slight rises on till plains. Hamerly soils formed in calcareous loamy till and have moderate permeability. Parnell soils are characterized as very deep and very poorly drained (USDA Official Soil Series Descriptions 2011, USDA Web Soil Survey 2011). The taxonomic class for the Parnell series is fine, smectitic, frigid. Vertic Argiaquolls (USDA Official Soil Series Descriptions 2011). These soils are fine textured and enriched with smectitic clays that have very slow permeability resulting in ponding at the surface. Parnell soils develop in well-sorted glacial sediments within depressions, drainage ways, swales, and along glacial moraines.

The relative youth of the landscape (9,000-13,000 years old), along with distinguishing climatic and landscape features of the PPR, have resulted in an absence of well-developed drainage networks and an abundance of pothole wetlands (Richardson et al. 1994, Richardson and Vepraskas 2001). The prevalence of an abundant amount of small depression pothole wetlands has been significantly influential in the development of hydric soils in the PPR (Richardson et al. 1994). The development of the characteristics of underlying soils is influenced by the hydrology of individual PPR wetlands (Richardson et al. 1994, Richardson and Vepraskas 2001). Due to their landscape position, recharge wetlands generally possess soils that are highly leached, lack highly soluable ions, nonsaline, and free of carbonates (Arndt and Richardson 1989, Richardson et al. 1994). Recharge wetlands generally have well-developed argillic horizons. Flow-through wetlands generally possess soils with thick A-horizons in their center-most zones. The soils in flow-through wetlands may exhibit spatial variation in texture due to sorting by water. Wetland edges may host coarser textured soil particles with finer textured particles at the center of the wetland (Arndt and Richardson 1989). Flow-through wetlands tend to have higher salinity than recharge wetlands and may have an abundance of gypsum and calcite. Discharge wetlands, located lowest on the landscape, possess the most saline soils of these wetland types. Salinity in discharge wetlands typically increases as the distance from the recharge zone increases (Arndt and Richardson 1989).

METHODS

Three area clusters were created within Towner, Benson, Wells, and Eddy counties to account for topographic and geomorphic variation (Figure 2). The clusters were developed so that comparisons could be made among all wetland sites within a cluster and across clusters. Each cluster contains treatment, reference, and past cropland wetlands. All sites used for this study are type III freshwater wetlands, i.e., seasonal wetlands (Stewart and Kantrud 1971).

Seasonal wetlands were chosen because they are declining in numbers the fastest and are usually the type of wetland most affected by agricultural practices and landscape use (Bartzen et al. 2010). These wetlands provide critical habitat to a large portion of North American waterfowl. Seasonal wetlands are important to waterfowl as they are some of the first wetlands to thaw in the spring. Water in seasonal wetlands warms early in the spring and seasonal wetlands are some of the first to produce macro-invertebrate populations. This early thaw provides critical habitat and food for migrating ducks as well as prime brooding habitat (Cox et al. 1998). Seasonal wetlands provide ideal conditions for communities of aquatic and semi-aquatic vertebrates, invertebrates, and hydrophytes to thrive (Kantrud et al. 1989a, Euliss et al. 1999).

Three different treatment categories of wetlands were used for this study: treatment, reference, and converted cropland. Treatment wetlands have been subject to sedimentation in the past due surrounding cultivation and have had their sediment removed. Reference wetlands were selected to meet these three conditions: 1) are located within sites that have had limited cultivation, 2) are on native prairie soil, 3) and have not had sedimentation removed. Converted cropland wetlands were selected to meet these conditions: 1) are located on land that has been cultivated in the past or Conservation Reserve Program (CRP) ground, 2) have not had sediment removed, 3) have been cropped at some time in the past. Study sites were located on private, state land, state school land, and federal land. Individual sampling sites were small, approximately 0.2-0.6 hectares (0.5 to 1.5 acres) in size with a total of 39 sites assessed for this study. Site information and general latitude and longitude coordinates of study sites can be found in Appendix B.

Benson county wetland sites are located on federal and state school land south of Leeds, North Dakota. Sites located on federal land are found on the Hofstrand Waterfowl Production Area (WPA). Treatment sites on the Hofstrand WPA were completed in 2007 and planted the same year with native seed mix in the uplands. These sites are grazed by cattle for management purposes.

Towner wetland sites are located on both federal and private land. Wetland sites located on federal land are found on the Nikolaisen WPA north of Cando, North Dakota. Treatment sites on the Nikolaisen WPA were completed in 2008 and planted the same year with native seed mixes in the uplands. These sites are grazed by cattle for management purposes.

Wells county wetland sites are located on the Robert L. Morgan Wetland Management Area (WMA). Treatment sites on this property were completed in 2003 and planted 2004 with native seed mix in the uplands. This property has not had management techniques implemented since the property's restoration in 2007 (i.e. idle).

Eddy county wetland sites are located on state land at Camp Grafton South. These sites are solely reference sites to include with the Wells county cluster. These wetlands are grazed by cattle for management purposes.

Sampling Methods

Vegetation

A modified Daubenmire sampling method using 1-meter quadrats was used to measure all individual plant species and their percentage vegetation cover (Young 2005). Vegetation sampling was completed during mid-July to August during the peak growing season. Large quadrats were chosen so that rare species would be detected and to provide a better estimate of diversity (Stohlgren 2006). To obtain a thorough species account of vegetation throughout the wetland, a total of 20 random quadrats were done per wetland: 10 in the shallow marsh, 10 in the wet meadow. The shallow marsh and wet meadow zones were targeted for sampling because they contain vegetation communities that are most vulnerable changes in sediment loads and hydrology fluxes. Secondary species within the wetland that were not present in quadrat samples were noted to give a complete species account of the area. In addition, percent standing dead, percent litter cover, depth of litter, percent bare bottom, open water and depth of water were measured.

Visual Obstruction

A visual obstruction score was given for each quadrat in the shallow marsh and wet meadow of each zone after each Daubenmire reading. Scores were assigned 1-4 based on percent visual obstruction (Table 2). Assigning percent visual obstruction by categories was intended to increase consistency among the readings. Although slightly modified, this method has been used before (Young 2005). Average visual obstruction scores within each wetland and each zone were used for analysis.

Table 2. Modified Daubenmire cover class visual obstruction guide.

Score	% Visual Obstruction	Category
1	0-5%	Open
2	5-50%	Open-Dense
3	50-80%	Dense
4	80-100%	Very Dense

Aerial Photos

It is important for wetlands to have drawdown periods so that vegetation regeneration can occur (van der Valk and Davis 1978, Johnson et al. 2005). Aerial photos of wetland sites were obtained through Google Earth (Version 6.0.2). Images used by Google Earth (Version 6.0.2) were obtained from the USDA Farm Service Agency. Google Earth (Version 6.0.2) provides aerial images from spring 1990 to fall 2010. Water within wetlands is visible from aerial photos and is typically represented by dark areas within a basin. When a drawdown cycle occurs, mudflats are exposed and less water is visible on aerial photos. Using these aerial images, restored wetland sites were examined to determine if at least one drawdown cycle has occurred since sediment removal.

Statistics

Multi-response Permutation Procedure and Non-metric Multidimensional Scaling

All comparisons among wetland plant communities for sties and clusters were made using multi-response permutation procedure (MRPP). All analyses used PC-ORD version 5.21 software (McCune and Mefford 1999, McCune and Grace 2002). Species data were listed by proportions and modified using the arcsine square root transformation: $b=2/\pi*\arcsin((x_{i,j})^{1/2})$. A distance matrix was run using a relative

Sørensen index. Wetland sites were compared within each cluster, then across all three clusters. Pairwise comparisons were completed between treatment, control, and reference sites. Significance among the three comparisons was determined by using the Bonferroni correction for multiple comparisons ($p<0.05/3<0.016$).

Non-metric multidimensional scaling (NMS) was used as a graphical tool to display the data and the species correlations. The NMS ordination utilized a random starting point, 50 runs with real data, and 250 runs with randomized data. The best solution was selected based on the following: 1) the highest dimensions with a reduction of 5 or more in the stress of real data, 2) a $p\leq0.05$ for the Monte Carlo test comparing stress for the real data to a randomized dataset, and 3) final solutions with stress < 20, number of iterations <250, and instability <0.0005. All graphical outputs were varimax rotated. Species proportions were correlated with axis scores and those with $r<-0.4$ or $r>0.4$ were selected as driving species (Pearson correlation).

RESULTS

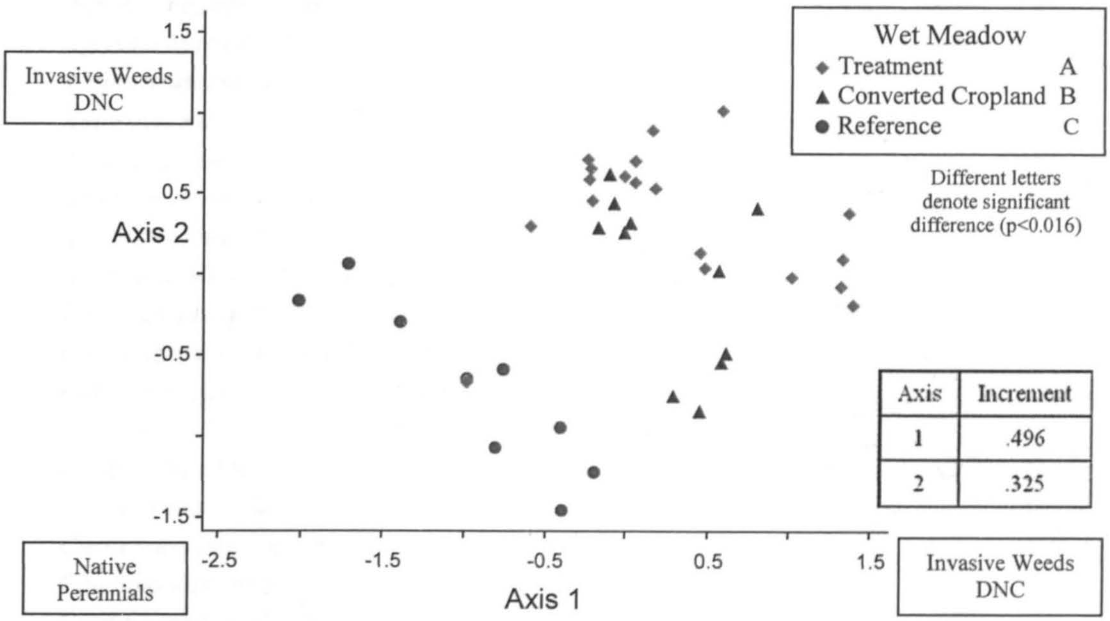
The plant community analysis showed that the shallow marsh and wet meadow zones were significantly different from one another. The NMS ordination and MRPP analysis showed all treatments (treatment, reference, and converted cropland) were significantly different ($p<0.016$). Treatment wetlands were significantly different amongst the three clusters.

Wet Meadow Zone

Multi-response permutation procedure analysis of plant community data for the wet meadow zone revealed a significant difference ($p<0.016$) between the treatment, reference, and converted cropland sites across all three clusters. Non-metric multidimensional scaling analysis of the wet meadow zone dataset produced a final solution with 2 solutions, or 2 dimensions (Figure 4). The 2 dimension solution had a final stress of 15.14, 68 iterations for the final solution, and final instability was 0.00000. Both axes of the final solution are important in explaining the variation within the wet meadow zone dataset. Axis 1 accounted for 49.6% of the variation and axis 2 accounted for 32.5%.

Axis 1 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with thirty-one plant species: the majority (68%) of which were native perennials (Table 3). Field sowthistle (*Soncha arvensis* L.) had the strongest positive correlation (0.748). Lowland yellow loosestrife (*Lysimachia hybrida* Michx.) had the strongest negative correlation (-0.694). Species positively correlated with axis 1 tend to be planted and/or invasive species while those species negatively correlated with axis 1 tend to be desired.

native perennial species. All plant species encountered during this study are listed in Appendix A.



Axis	Increment
1	.496
2	.325

Figure 4. Non-metric multidimensional scaling ordination of the wet meadow zone for treatment, converted cropland, and reference wetland sites showing axes 1 and 2. Points in ordination space represent individual wetland sites.

Axis 2 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with thirty-seven plant species; the majority (92%) of which are native perennials (Table 3). Examining the native perennials correlated with axis 2, 43% had a coefficient of conservatism (C-value) greater than or equal to five. Western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Löve) had the strongest positive correlation (0.617). Silverweed cinquefoil (*Argentina anserina* (L.) Rydb.) had the strongest negative correlation (-0.861). Species positively correlated with axis 2 tend to be planted and/or invasive species while those species negatively correlated with axis 2 tend to be desired, native species.

Table 3. Pearson correlation coefficient between plant species cover and non-metric multidimensional scaling ordination axes for the wet meadow zone.

Species	C[1]	Phys.[2]	r[3] Axis 1	r[3] Axis 2
Achillea millefolium L.	3	Forb		-0.462
Agrostis gigantea Roth	*	Grass	-0.614	
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb.	1	Grass	-0.561	
Alopecurus aequalis Sobol.	2	Grass	-0.612	
Ambrosia psilostachya DC.	2	Forb		-0.612
Andropogon gerardii Vitman	5	Grass		0.612
Anemone canadensis L.	4	Forb	-0.408	-0.532
Argentina anserina (L.) Rydb.	2	Forb		-0.861
Artemisia ludoviciana Nutt.	3	Forb		-0.541
Boltonia asteroides (L.) L'Hér.	3	Forb	-0.438	
Calamagrostis canadensis (Michx.) P. Beauv.	5	Grass	-0.449	
Calamagrostis stricta (Timm) Koeler	5	Grass		-0.724
Carex laeviconica Dewey	6	Sedge	-0.502	
Carex pellita Muhl. ex Willd.	4	Sedge	-0.601	-0.58
Carex praegracilis W. Boott	5	Sedge		-0.513
Carex sartwellii Dewey	5	Sedge		-0.576
Chenopodium album L.	*	Forb	0.496	
Cirsium arvense (L.) Scop.	*	Forb	0.725	
Cirsium flodmanii (Rydb.) Arthur	5	Forb		-0.437
Cirsium vulgare (Savi) Ten.	*	Forb	0.451	
Distichlis spicata (L.) Greene	2	Grass		-0.433
Eleocharis macrostachya Britton	4	Sedge	-0.543	
Elymus repens (L.) Gould	*	Grass	-0.531	
Epilobium ciliatum Raf.	3	Forb	0.421	
Fraxinus pennsylvanica Marsh.	5	Tree		0.413
Glyceria grandis S. Watson	4	Grass	-0.642	
Glycyrrhiza lepidota Pursh	2	Forb		-0.535
Helianthus nuttallii Torr. & A. Gray	8	Forb		-0.602
Hordeum jubatum L.	0	Grass	0.622	
Juncus arcticus Willd. ssp. littoralis (Engelm.) Hultén	5	Forb		-0.741
Juncus interior Wiegand	5	Forb	-0.465	
Juncus nodosus L.	7	Forb		-0.482
Liatris ligulistylis (A. Nelson) K. Schum.	10	Forb		-0.511
Lycopus americanus Muhl. ex W. Bartram	4	Forb	-0.418	
Lycopus asper Greene	4	Forb		-0.581
Lysimachia ciliata L.	6	Forb	-0.441	
Lysimachia hybrida Michx.	5	Forb	-0.694	
Medicago lupulina L.	*	Forb		-0.413
Melilotus officinalis (L.) Lam.	*	Forb		0.499

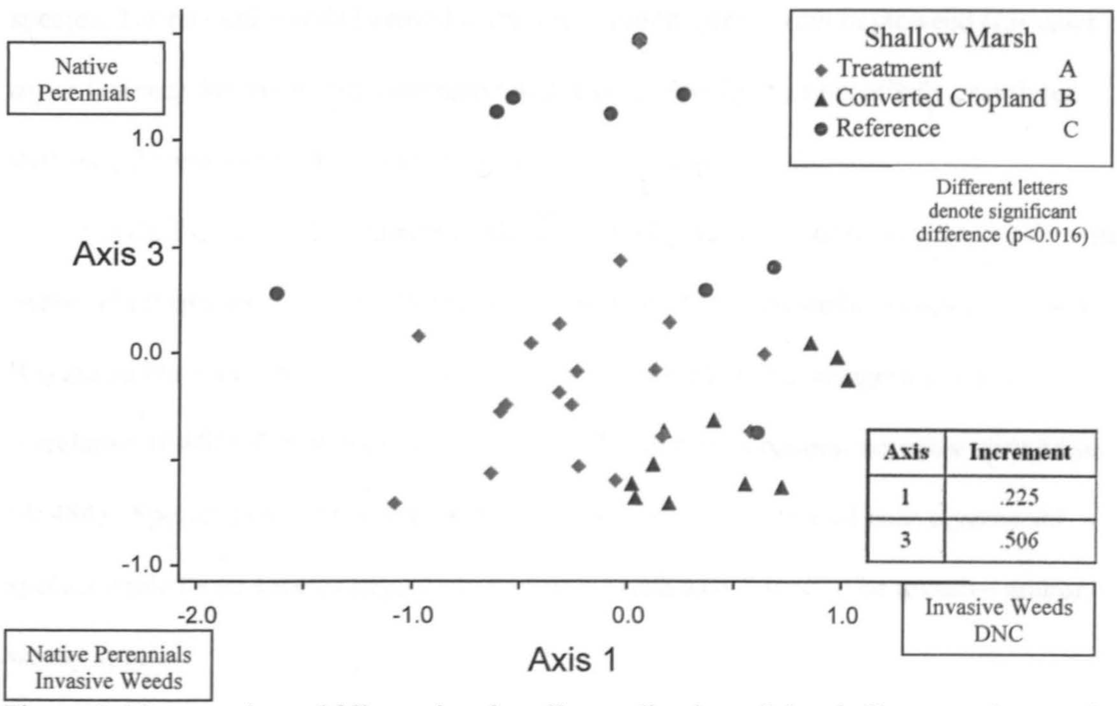
Table 3 (continued)

Species	C[1]	Phys.[2]	r[3]	
			Axis 1	Axis 2
Mentha arvensis L.	3	Forb	-0.426	
Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	2	Grass		-0.447
Muhlenbergia richardsonis (Trin.) Rydb.	10	Grass		-0.631
Packera pseudaurea (Rydb.) W.A. Weber & A. Löve var. semicordata (Mack. & Bush) D.K. Trock & T.M. Barkley	5	Forb		-0.515
Pascopyrum smithii (Rydb.) A. Löve	4	Grass	0.507	0.617
Plantago major L.	*	Forb	-0.515	
Poa palustris L.	4	Grass	-0.672	
Polygonum amphibium L. var. stipulaceum Coleman		Forb		0.4
Ranunculus pensylvanicus L. f.	4	Forb	-0.561	
Rosa woodsii Lindl.	5	Shrub		-0.453
Rumex crispus L.	*	Forb		0.7
Schoenoplectus pungens (Vahl) Palla var. longispicatus (Britton) S.G. Sm.	4	Sedge		-0.469
Solidago canadensis L.	1	Forb		-0.573
Sonchus arvensis L.	*	Forb	0.748	
Sorghastrum nutans (L.) Nash	6	Grass		0.537
Spartina pectinata Bosc ex Link	5	Grass	-0.448	
Stachys tenuifolia Willd.	3	Forb		-0.497
Symphoricarpos occidentalis Hook.	3	Shrub		-0.601
Symphyotrichum ericoides (L.) G.L. Nesom var. ericoides	2	Forb		-0.475
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. lanceolatum var. lanceolatum	3	Forb		-0.484
Taraxacum officinale F.H. Wigg.	*	Forb	-0.478	
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	*	Grass	0.422	
Thinopyrum ponticum (Podp.) Z.-W. Liu & R.-C. Wang	*	Grass	0.5	
Trifolium repens L.	*	Forb	-0.551	
Vicia americana Muhl. ex Willd.	6	Forb		-0.49
Zizia aptera (A. Gray) Fernald	8	Forb		-0.542

[a]Coefficient of conservatism (NGPFQAP 2001).
[b]Physiognomy of plant species.
[c]Pearson correlation with NMS axes.
* Introduced species are not assigned a coefficient of conservatism.

Shallow Marsh Zone

Multi-response permutation procedure analysis of plant community data for the shallow marsh zone revealed a significant difference ($p<0.016$) between the treatment, reference, and converted cropland sites across all clusters. Non-metric multidimensional scaling analysis of the shallow marsh zone dataset produced a final solution with 3 dimensions (Figure 5). The 3 dimension solution had a final stress of 12.21, 250 iterations for the final solution and final instability was 0.00012. Each of the three axes of the final solution is important in explaining the variation within the wet meadow zone dataset. Axis 1 accounted for 22.5% of the variation, axis 2 accounted for 13.4%, and axis 3 accounted for 50.6%. The two axes explaining the most variability, axis 1 and axis 2, are used to display results.



Axis	Increment
1	.225
3	.506

Figure 5. Non-metric multidimensional scaling ordination of the shallow marsh zone for treatment, converted cropland, and reference wetland sites showing axes 1 and 3. Points in ordination space represent individual wetland sites.

Axis 1 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with thirteen plant species; the majority (77%) of which are native perennial species (Table 4). Hybrid cattail (*Typha × glauca Godr.* (pro sp.)) had the strongest positive correlation (0.679). Pale spikerush (*Eleocharis macrostachya* Britton) had the strongest negative correlation (-0.665). Species positively correlated with axis 1 tend to be planted and/or invasive species with few desired native perennial species. Species negatively correlated with axis 1 tend to be desired, native perennial species.

Axis 2 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with thirteen plant species; the majority (85%) of which are native perennial species (Table 4). Rough bugleweed (*Lycopus asper* Greene) had the strongest positive correlation (0.447). White panicle aster (*Symphyotrichum lanceolatum* (Willd.) G.L. Nesom ssp. *lanceolatum var. lanceolatum*) had the strongest negative correlation (-0.615). There were only two species, Turion duckweed (*Lemna turionifera* Landolt.) and rough bugleweed (*Lycopus asper* Greene) that positively correlated with axis 2. Species that negatively correlated with axis 2 were a mix of planted, invasive, and native perennials.

Axis 3 of the NMS ordination had a correlation (Pearson correlation ≥ 0.400) with twelve plant species; the majority (83%) of which are native perennial species (Table 4). Broadfruit bur-reed (*Sparganium eurycarpum* Engelm.) had the strongest positive correlation (0.861). Curly dock (*Rumex crispix* L.) had the strongest negative correlation (-0.484). Species positively correlated with axis 3 tend to be desired native perennial species while those species negatively correlated with axis 3 tend to be invasive and/or weedy species.

Table 4. Pearson correlation coefficient between plant species cover and non-metric multidimensional scaling ordination axes for the shallow marsh zone.

Species	C[1]	Phys.[2]	r[3] Axis 1	Axis 2	Axis 3
Alisma subcordatum Raf.		Forb			0.563
Andropogon gerardii Vitman	5	Grass		-0.48	
Carex atherodes Spreng.	4	Sedge			0.74
Carex laeviconica Dewey	6	Sedge	-0.465		
Carex pellita Muhl. ex Willd.	4	Sedge	0.531		
Cirsium arvense (L.) Scop.	*	Forb	0.537		
Eleocharis acicularis (L.) Roem. & Schult.	3	Sedge		-0.596	
Eleocharis macrostachya Britton	4	Sedge	-0.665		
Glyceria grandis S. Watson	4	Grass	-0.403		0.527
Hordeum jubatum L.	0	Grass		-0.522	
Lemna minor L.	9	Forb			0.786
Lemna trisulca L.	2	Forb			0.429
Lemna turionifera Landolt	1	Forb		0.411	
Lycopus asper Greene	4	Forb		0.447	
Lysimachia hybrida Michx.	5	Forb	-0.436		
Mentha arvensis L.	3	Forb	0.497	-0.42	
Pascopyrum smithii (Rydb.) A. Löve	4	Grass		-0.542	
Polygonum amphibium L. var. stipulaceum Coleman		Forb	0.528	-0.426	-0.44
Potamogeton gramineus L.	6	Forb			0.769
Rumex crispus L.	*	Forb		-0.612	-0.484
Scolochloa festucacea (Willd.) Link	6	Grass	0.45		
Sium suave Walter	3	Forb			0.72
Solidago canadensis L.	1	Forb	0.43		
Sonchus arvensis L.	*	Forb	0.551		
Sparganium eurycarpum Engelm.	4	Forb			0.861
Spartina pectinata Bosc ex Link	5	Grass		-0.405	
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. lanceolatum var. lanceolatum	3	Forb		-0.615	
Teucrium canadense L.	3	Forb	0.43	-0.439	
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	*	Grass		-0.429	
Typha ×glauca Godr. (pro sp.)	*	Forb	0.679		-0.435
Utricularia macrorhiza Leconte	2	Forb			0.756

[a]Coefficient of conservatism (NGPFQAP 2001).
[b]Physiognomy of plant species.
[c]Pearson correlation with NMS axes.
* Introduced species are not assigned a coefficient of conservatism.

Shallow Marsh Treatments

Multi-response permutation procedure analysis of plant community data for the shallow marsh treatments revealed a significant difference ($p<0.016$) between the treatment sites across all clusters. Non-metric multidimensional scaling analysis of the shallow marsh treatment dataset produced a final solution with 3 dimensions (Figure 6). The 3 dimension solution had a final stress of 9.38, 59 iterations for the final solution and final instability was 0.00000. Each of the three axes of the final solution is important in explaining the variation within the wet meadow zone dataset. Axis 1 accounted for 14.9% of the variation, axis 2 accounted for 41.1%, and axis 3 accounted for 34.7%. The two axes explaining the most variability, axis 2 and axis 3, are used to display results.

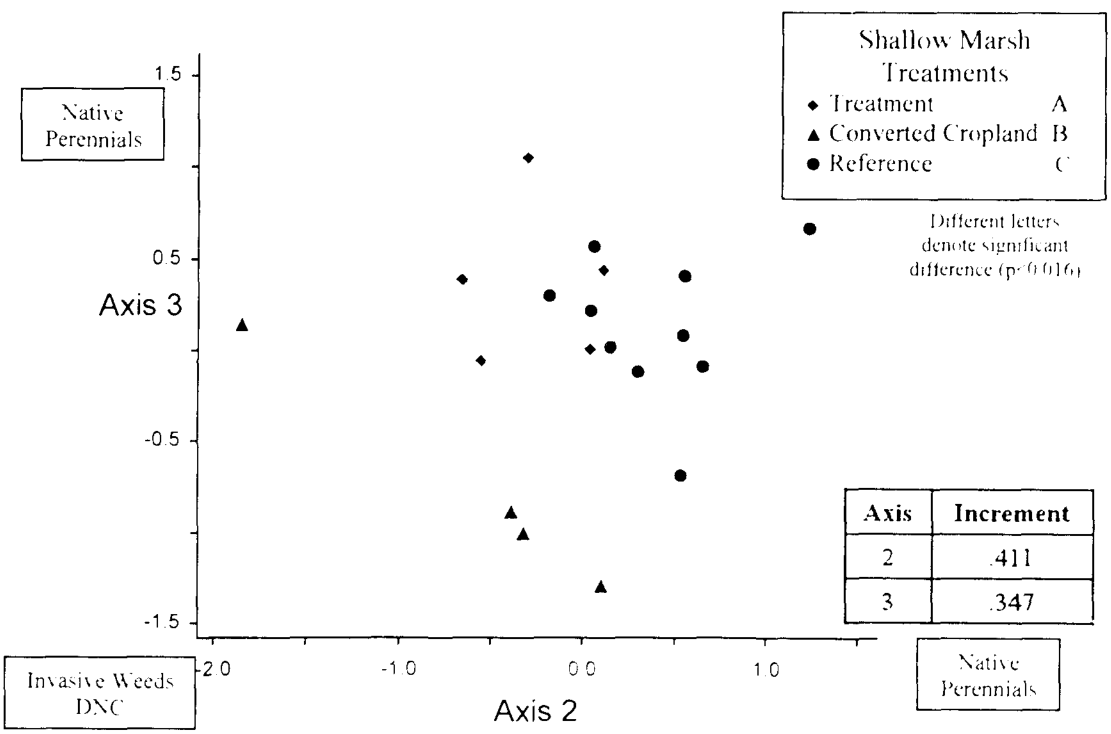


Figure 6. Non-metric multidimensional scaling ordination of the shallow marsh treatment wetland sites showing axes 2 and 3. Points in ordination space represent individual wetland sites.

Axis 1 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with twenty-seven plant species; the majority (67%) of which are native perennial species (Table 5). Wheat sedge (*Carex atherodes* Spreng.), Turion duckweed (*Lemna turionifera* Landolt), and rough bugleweed (*Lycopus asper* Greene) had the strongest positive correlation of 0.678; Curly dock (*Rumex crispus* L.) had the strongest negative correlation (-0.635). Species positively correlated with axis 1 tend to be desired native perennial species while species negatively correlated with axis 1 tend to be planted and/or invasive species.

Axis 2 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with twelve plant species; all of which are native perennial species (Table 5). Prairie cordgrass (*Spartina pectinata* Bosc ex Link.) had the strongest positive correlation (0.650). Star duckweed (*Lemna trisulca* L.) had the strongest negative correlation (-0.758). Species positively correlated with axis 2 tend to be a planted and/or invasive species. Species negatively correlated with axis 2 tend to be desired native perennial species.

Axis 3 of the NMS ordination had a correlation (Pearson correlation ≥ 0.40) with twenty-five plant species; majority (64%) of which are native perennial species (Table 5). Prairie cordgrass (*Spartina pectinata* Bosc ex Link.) had the strongest positive correlation (0.650). Star duckweed (*Lemna trisulca* L.) had the strongest negative correlation (-0.758). Only two species positively correlated with axis 3; pale spikerush (*Eleocharis macrostachya* Britton) and broadleaf cattail (*Typha latifolia* L.) Species negatively correlated with axis 3 tend to be a mixture between planted, weedy, and perennial native plant species.

Table 5. Pearson correlation coefficient between plant species cover and non-metric multidimensional scaling ordination axes for the shallow marsh treatment sites.

Species	C[1]	Phys.[2]	r[3]		
			Axis 1	Axis 2	Axis 3
Alopecurus aequalis Sobol.	2	Grass	-0.434		
Amaranthus retroflexus L.	0	Forb	-0.439		
Ambrosia psilostachya DC.	2	Forb	-0.48		-0.51
Andropogon gerardii Vitman	5	Grass			-0.607
Astragalus canadensis L.		Forb		0.444	
Atriplex subspicata (Nutt.) Rydb.	2	Forb	-0.477		-0.66
Carex atherodes Spreng.	4	Sedge	0.648	-0.69	
Carex pellita Muhl. ex Willd.	4	Sedge	-0.484		
Chenopodium album L.	*	Forb	-0.439		
Chenopodium glaucum L.	*	Forb			-0.408
Cirsium arvense (L.) Scop.	*	Forb			-0.518
Echinochloa crus-galli (L.) P. Beauv.	*	Grass	-0.439		
Echinochloa P. Beauv.	0	Grass			-0.523
Eleocharis acicularis (L.) Roem. & Schult.	3	Sedge			-0.719
Eleocharis macrostachya Britton	4	Sedge			0.435
Epilobium ciliatum Raf.	3	Forb	-0.466		-0.414
Epilobium leptophyllum Raf.	6	Forb			-0.408
Glyceria grandis S. Watson	4	Grass		-0.695	
Gratiola neglecta Torr.	0	Forb			-0.523
Hordeum jubatum L.	0	Grass	-0.483		-0.571
Lemna minor L.	9	Forb		-0.695	
Lemna trisulca L.	2	Forb		-0.758	
Lemna turionifera Landolt	1	Forb	0.648		
Limosella aquatica L.	2	Forb			-0.523
Lycopus asper Greene	4	Forb	0.648		
Melilotus officinalis (L.) Lam.	*	Forb	-0.439		
Mentha arvensis L.	3	Forb	-0.488		-0.65
Panicum virgatum L.	5	Grass	-0.411		
Pascopyrum smithii (Rydb.) A. Löve	4	Grass			-0.543
Phalaris arundinacea L.	0	Grass		0.491	
Polygonum amphibium L. var. stipulaceum Coleman		Forb	-0.434		-0.833
Potamogeton gramineus L.	6	Forb		-0.695	
Potentilla norvegica L.	0	Forb	-0.439		
Ranunculus cymbalaria Pursh	3	Forb			-0.523
Rumex crispus L.	*	Forb	-0.635		-0.561
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. acutus	5	Sedge	0.418		

Table 5 (Continued)

Species	C[1]	Phys.[2]	r[3] Axis 1	Axis 2	Axis 3
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	3	Sedge		0.417	
Scolochloa festucacea (Willd.) Link	6	Grass	0.608		
Sium suave Walter	3	Forb		-0.631	
Solidago canadensis L.	1	Forb	-0.439		
Sonchus arvensis L.	*	Forb	-0.507		-0.797
Sorghastrum nutans (L.) Nash	6	Grass			-0.523
Sparganium eurycarpum Engelm.	4	Forb		-0.695	
Spartina pectinata Bosc ex Link	5	Grass		0.65	
Stuckenia pectinata (L.) Böerner	0	Forb	0.437		
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. lanceolatum var. lanceolatum	3	Forb	-0.519		-0.617
Teucrium canadense L.	3	Forb			-0.753
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	*	Grass			-0.723
Thlaspi arvense L.	*	Forb	-0.439		
Typha ×glauca Godr. (pro sp.)	*	Forb	0.547		
Typha latifolia L.	2	Forb			0.421
Utricularia macrorhiza Leconte	2	Forb		-0.695	
Verbena bracteata Cav. ex Lag. & Rodr.	0	Forb	-0.439		
Veronica peregrina L. ssp. xalapensis (Kunth) Pennell	0	Forb			-0.523

[a]Coefficient of conservatism (NGPFQAP 2001).
[b]Physiognomy of plant species.
[c]Pearson correlation with NMS axes.
* Introduced species are not assigned a coefficient of conservatism.

Canopy Cover and *Typha x glauca*

The canopy cover of *Typha x glauca* has a strong relationship to axis 1 with r = 0.679 and axis 2 r= -0.435 (Figure 7). The converted cropland wetland sites are at the high end of the percent cover and the reference wetland sites are at the low end of the percentage cover with the treatment wetlands positioned between the converted cropland and reference sites.

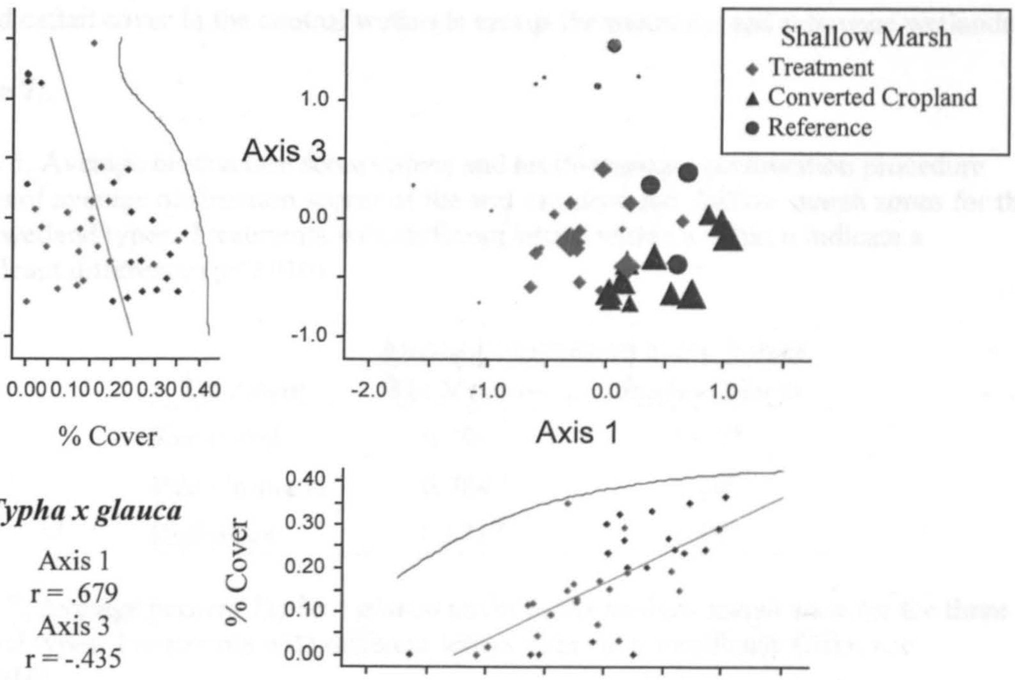


Figure 7. Linear regression analysis of *Typha x glauca* between canopy cover and axis scores across all wetland types in the shallow marsh zone. Each point represents a site. Symbol size (diamond, circle, triangle) is proportional to *Typha x glauca* coverage. Upper right: 2-D ordination of species composition. Lower right: scatterplot of abundance of *Typha x glauca* against score on Axis 1 (horizontal axis). Upper left: scatterplot of abundance of *Typha x glauca* against Axis 3. Superimposed on the two abundance scatterplots are the least squares regression lines and a smoothed envelope. See text for interpretation of *r*.

Density Cover and Visual Obstruction

Multi-response permutation procedure results show that average visual obstruction scores of wetlands over the three wetland types of wetlands were not significantly different ($p<0.016$) for the wet meadow (Table 6). However, results show that average visual obstruction scores for the shallow marsh for treatment and reference sites were significantly lower ($p<0.016$) for the converted cropland sites (Table 6). When looking specifically at *Typha x*, the average percent of *Typha x* cover across the three wetland types shows an increase, approximately four times higher, in the percent of hybrid cattail cover in the control wetlands versus the treatment and reference wetlands (Table 7).

Table 6. Average obstruction score values and multi-response permutation procedure results of average obstruction scores of the wet meadow and shallow marsh zones for the three wetland types. Treatments with different letters within a column indicate a significant difference (p<0.016).

Treatment	Average Obstruction Score Values	
	Wet Meadow	Shallow Marsh
Excavated	0.796[B]	1.12[A]
Past Cropland	0.784[B]	2.24[B]
Reference	0.631[B]	1.58[A]

Table 7. Average percent *Typha x glauca* cover in the shallow marsh zone for the three wetland types. Treatments with different letters indicate a significant difference (p<0.016).

Treatment	Average Percent *Typha* x *glauca* Cover
Excavated	5.94[A]
Past Cropland	19.34[B]
Reference	4.63[A]

Wet Meadow Management

Multi-response permutation procedure analysis of plant community data for the wet meadow management data revealed a significant difference (p<0.016) between the wet meadow zones of excavated sites. Wetland sites used in this study are managed in different ways: either by cattle grazing or no management since restoration efforts. Non-metric multidimensional scaling analysis of the wet meadow management dataset produced a final solution with 2 dimensions (Figure 8). The 2 dimension solution had a final stress of 11.47, 65 iterations for the final solution and final instability was 0.0000. Each axis of the final solution is important in explaining the variation within the wet meadow management dataset. Axis 1 accounted for 28.3% of the variation while axis 2 accounted for 59.6%.

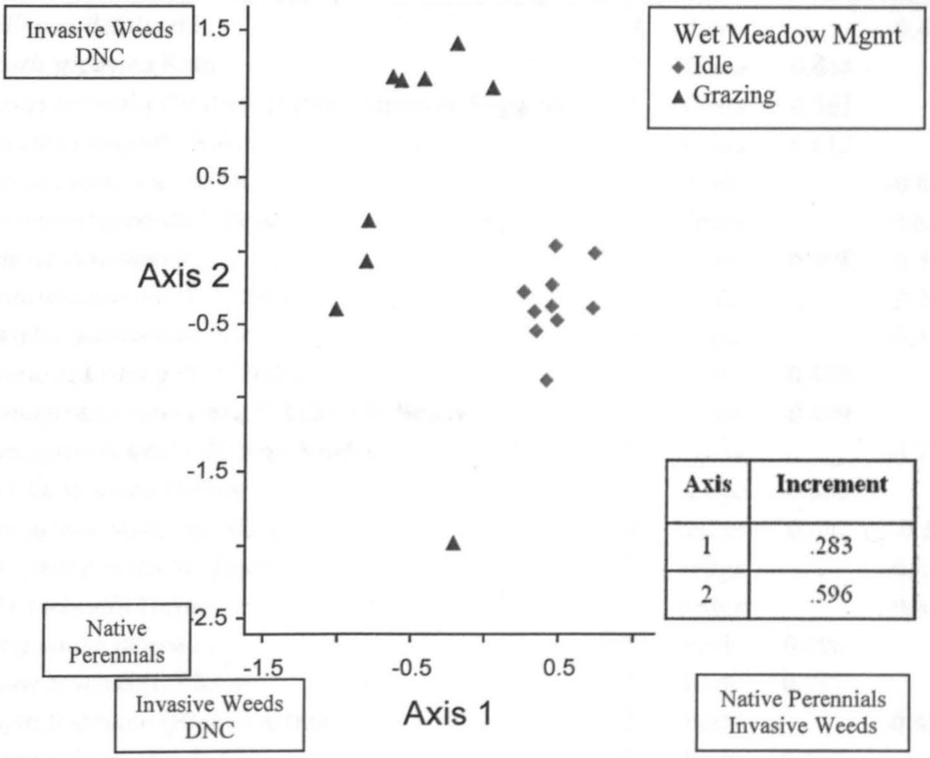


Figure 8. Non-metric multidimensional scaling ordination of the wet meadow management wetland sites showing axes 1 and 2. Points in ordination space represent individual wetland sites.

Axis 1 of the NMS ordination had a correlation (Pearson correlation ≥0.40) with twenty-four plant species; with only about half (54%) being native perennial species (Table 8). Prairie cordgrass (*Spartina pectinata* Bosc ex Link) had the strongest positive correlation (0.709). Intermediate wheatgrass (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) had the strongest negative correlation (-0.871). Species positively correlated with axis 1 tend to be a mixture of introduced and desired native perennial species while species negatively correlated with axis 1 tend to be planted and/or invasive species.

Table 8. Pearson correlation coefficient between plant species cover and non-metric multidimensional scaling ordination axes for the wet meadow management sites.

			r[3]	
Species	**C[1]**	**Phys.[2]**	**Axis 1**	**Axis 2**
Achillea millefolium L.	3	Forb		-0.462
Agrostis gigantea Roth	*	Grass	-0.614	
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb.	1	Grass	-0.561	
Alopecurus aequalis Sobol.	2	Grass	-0.612	
Ambrosia psilostachya DC.	2	Forb		-0.612
Andropogon gerardii Vitman	5	Grass		0.612
Anemone canadensis L.	4	Forb	-0.408	-0.532
Argentina anserina (L.) Rydb.	2	Forb		-0.861
Artemisia ludoviciana Nutt.	3	Forb		-0.541
Boltonia asteroides (L.) L'Hér.	3	Forb	-0.438	
Calamagrostis canadensis (Michx.) P. Beauv.	5	Grass	-0.449	
Calamagrostis stricta (Timm) Koeler	5	Grass		-0.724
Carex laeviconica Dewey	6	Sedge	-0.502	
Carex pellita Muhl. ex Willd.	4	Sedge	-0.602	-0.58
Carex praegracilis W. Boott	5	Sedge		-0.513
Carex sartwellii Dewey	5	Sedge		-0.576
Chenopodium album L.	*	Forb	0.496	
Cirsium arvense (L.) Scop.	*	Forb	0.725	
Cirsium flodmanii (Rydb.) Arthur	5	Forb		-0.437
Cirsium vulgare (Savi) Ten.	*	Forb	0.451	
Distichlis spicata (L.) Greene	2	Grass		-0.433
Eleocharis macrostachya Britton	4	Sedge	-0.543	
Elymus repens (L.) Gould	*	Grass	-0.531	
Epilobium ciliatum Raf.	3	Forb	0.421	
Fraxinus pennsylvanica Marsh.	5	Tree		0.413
Glyceria grandis S. Watson	4	Grass	-0.642	
Glycyrrhiza lepidota Pursh	2	Forb		-0.535
Helianthus nuttallii Torr. & A. Gray	8	Forb		-0.602
Hordeum jubatum L.	0	Grass	0.622	
Juncus arcticus Willd. ssp. littoralis (Engelm.) Hultén	5	Forb		-0.741
Juncus interior Wiegand	5	Forb	-0.465	
Juncus nodosus L.	7	Forb		-0.482
Liatris ligulistylis (A. Nelson) K. Schum.	10	Forb		-0.511
Lycopus americanus Muhl. ex W. Bartram	4	Forb	-0.418	
Lycopus asper Greene	4	Forb		-0.581
Lysimachia ciliata L.	6	Forb	-0.441	
Lysimachia hybrida Michx.	5	Forb	-0.694	

Table 8 (Continued)

Species	C[1]	Phys.[2]	r[3] Axis 1	Axis 2
Medicago lupulina L.	*	Forb	-0.413	
Melilotus officinalis (L.) Lam.	*	Forb	0.409	0.499
Mentha arvensis L.	3	Forb	-0.426	
Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	2	Grass		-0.447
Muhlenbergia richardsonis (Trin.) Rydb.	10	Grass		-0.631
Packera pseudaurea (Rydb.) W.A. Weber & A. Löve var. semicordata (Mack. & Bush) D.K. Trock & T.M. Barkley	5	Forb		-0.515
Pascopyrum smithii (Rydb.) A. Löve	4	Grass	0.507	0.617
Plantago major L.	*	Forb	-0.515	
Poa palustris L.	4	Grass	-0.672	
Polygonum amphibium L. var. stipulaceum Coleman		Forb		0.4
Ranunculus pensylvanicus L. f.	4	Forb	-0.561	
Rosa woodsii Lindl.	5	Shrub		-0.453
Rumex crispus L.	*	Forb		0.7
Schoenoplectus pungens (Vahl) Palla var. longispicatus (Britton) S.G. Sm.	4	Sedge		-0.469
Solidago canadensis L.	1	Forb		-0.573
Sonchus arvensis L.	*	Forb	0.748	
Sorghastrum nutans (L.) Nash	6	Grass		0.537
Spartina pectinata Bosc ex Link	5	Grass	-0.448	
Stachys tenuifolia Willd.	3	Forb		-0.497
Symphoricarpos occidentalis Hook.	3	Shrub		-0.601
Symphyotrichum ericoides (L.) G.L. Nesom var. ericoides	2	Forb		-0.475
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. lanceolatum var. lanceolatum	3	Forb		-0.484
Taraxacum officinale F.H. Wigg.	*	Forb	-0.478	
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	*	Grass	0.422	
Thinopyrum ponticum (Podp.) Z.-W. Liu & R.-C. Wang	*	Grass	0.5	
Trifolium repens L.	*	Forb	-0.551	
Vicia americana Muhl. ex Willd.	6	Forb		-0.49
Zizia aptera (A. Gray) Fernald	8	Forb		-0.542

[a]Coefficient of conservatism (NGPFQAP 2001).
[b]Physiognomy of plant species.
[c]Pearson correlation with NMS axes.
* Introduced species are not assigned a coefficient of conservatism.

Axis 2 of the NMS ordination had a correlation (Pearson correlation > 0.40) with forty-one plant species; the majority (71%) of which are native perennial species (Table 8). Canada thistle (*Cirsium arvense* (L.) Scop.) had the strongest positive correlation (0.819). Prairie cordgrass (*Spartina pectinata* Bosc ex Link) had the strongest negative correlation (-0.702). Species positively correlated with axis 2 tend to be planted and/or invasive weedy species while those species negatively correlated with axis 2 tend to be desired native perennial species.

Aerial Photos

Aerial images revealed that all restored wetland sites in Towner, Benson, and Wells counties have had at least one drawdown cycle since sediment removal. Past cropland sites in all three clusters also experienced at least one drawdown cycle since wetland restoration dates.

DISCUSSION

Wet Meadow Zone

The wet meadow zone of treatment, converted cropland, and reference sites were all significantly different from one another. Looking further at Figure 4, reference sites separate from the treatment and converted cropland sites, indicating higher quality wet meadow vegetation. Wet meadow communities of reference sites have more native perennials than treatment or converted cropland wet meadow communities, which tend to have more invasive weeds and planted dense nesting cover. Wetlands are unstable ecosystems and stresses from agricultural add to the instability by tillage and indirectly through siltation, chemical runoff, elimination of native seedbed through continuous cultivation (Kantrud and Newton 1996). The wet meadow zone is difficult to re-establish once lost and are vulnerable to agricultural stresses. (Kantrud and Newton 1996). Wet meadow communities of reference sites are typically less disturbed by agricultural practices, thus, creating the potential for more native species to establish and thrive.

Shallow Marsh Zone

The shallow marsh zone of treatment, converted cropland, and reference sites were all significantly different from one another. Looking further at Figure 5, the three wetland types tend to separate out into groups with the treatment sites positioned between the reference and converted cropland sites. Treatment sites are developing characteristics similar to those of reference wetlands, indicating the plant communities of treatment sites are transitioning away from the converted cropland plant communities which are generally undesired cattail choked wetlands. Treatment sites are between two and seven years old. The greatest input of growth from wetland seed banks occurs in the first two years after restoration when exposed sediments are quickly colonized by communities of mudflat annual species (Wienhold and van der Valk, 1989). Wetland vegetation communities typically begin to stabilize approximately two to three years after excavation (Aronson and Galatowitsch 2008, Fisher and Allbee 2010) but have been known to continue to develop and accumulate species for up to 19 years (Aronson and Galatowitsch 2008). These treatment sites will likely continue to develop and establish plant communities for up to the next two decades.

Shallow Marsh Treatments

These results are interesting as these are the plant species that are establishing after excavation. Plant species that are favored for valuable wildlife habitat are establishing, however, there are still invasive species colonizing. Seabloom and van der Valk (2003) showed that recently restored wetlands, five to seven years old, had lower vegetative cover and species richness than natural wetlands. Native perennials may have a tendency to be absent from restored wetlands, and manually introducing seeds or vegetative propagules during the restoration process may help overcome any vegetative dispersal barrier when located in an agricultural dominated landscape. It is also thought that positioning restored wetlands near others will decrease seed dispersal limitation and increase native propagule pressure of native perennials (Aronson and Galatowitsch 2008).

Propagules of shallow marsh species have been shown to survive decades in extant wetlands in the PPR. However, wet meadow species have been shown to be not so resilient (Weinhold and van der Valk, 1989). Mean seed density numbers tend to decline over time in a wetland that it is drained. Due to seed density declining over time, the best candidates for wetland restoration may be those that have been drained less than 20 years ago and have seed banks that still contain viable seeds of many wetland species (Weinhold and van der Valk, 1989).

Canopy Cover and *Typha x glauca*

The presence of hybrid cattail expresses a strong regression in regards to canopy cover revealing a link between hybrid cattails and obstruction of canopy cover in the shallow marsh. Converted cropland sites had the most hybrid cattail present while reference sites had the least amount of hybrid cattail. Treatment sites did not have nearly as much hybrid cattail present as converted cropland sites, however, treatment sites did have more hybrid cattail present than reference sites. Aronson and Galatowitsch (2008) suggest that wetlands should not be a top restoration priority if located near other cattail choked areas due to the ability of hybrid cattail seed to easily transfer to these newly exposed areas. Hybrid cattail communities in treatment sties could potentially be a result of wetland placement as *Typha x* communities have spread rapidly in the study area over the last decade (Fisher 2011). The greater the abundance of *Typha x*, the less light will be able to penetrate the wetland and the potential for litter abundance and depth will increase. The increasing obstruction of canopy cover can affect a native plant species' ability to establish and survive (Vaccaro et al. 2009).

Density Cover and Visual Obstruction

Visual obstruction scores for the wet meadow zone did not show significance. This is not surprising as there tends to be less vegetative structural height difference between plant communities in the wet meadow zone. However, visual obstruction scores for the shallow marsh zone of the study sites revealed a significant difference between treatment and reference sites from converted cropland sites. When examining hybrid cattail cover specifically in the shallow marsh zone of the study sites, the percent of *Typha x* cover across all wetlands shows a drastic increase in the percent of cattail cover in converted cropland wetlands, almost four times the percent of *Typha x* cover in treatment or reference wetlands. Not only are cattails affecting canopy cover within wetlands, the density of cattail stands is affecting the openness and structural variation of the vegetation. The lack of openness and structural variation within the vegetation decreases habitat quality by making it difficult for wildlife to move throughout the wetland and decreases visibility to see potential food and predators (Kantrud 1986).

Wet Meadow Management

All excavated wetlands are grazed by cattle except those located on the Robert L. Morgan property in Wells county. Sites located in Wells county have not had any management techniques implemented since excavation. Wetland sites showed significant differences in the wet meadow plant communities amongst excavated wetlands located in Towner and Benson counties although planted with similar native seed mixes containing grasses and forbs. Axis 1 is represented by a mixture of weedy and planted species as well as native perennials. However, it does have a few desired species on the positive end of the axis that separate the excavated sites in Wells county from the other excavated wetland sites located in Towner and Benson counties, indicating a higher quality wet meadow zone for those sites in Wells county.

These results are unexpected since it has been shown that grazing is typically beneficial to wetland plant communities and often promotes native growth and suppresses invasive species (Kantrud et al. 1989b, Kirby et al. 2002, Marty 2005).

Leaving land idle may increase non-native species abundance and allow for woody species to increase (Marty 2005). Similar to excavated sites located in Towner and Benson counties, they are surrounded by cropland. It is unclear why this property has acquired a high abundance of natives without any implemented management. Reasons why Wells county wetland sites may have higher quality wet meadow plant communities could be due to local wet and dry cycles, the amount of sediment removed, hydrologic conditions, local soils, the amount of time since restoration, or a combination of these events.

Aerial Photos

Despite recurrent wet years, all seasonal wetlands used in this study have had at least one drawdown cycle potentially allowing for adequate vegetation regeneration. Drawdown periods expose mudflats that allow seedbank recruitment and regeneration (van der Valk and Davis 1978, Johnson et al. 2005). Without drawdown periods, seeds may not be given the opportunity to germinate, preventing new plant growth (van der Valk 1981). It is important that all treatment sites used in this study have had at least one drawdown period so that the site has been given the opportunity to re-establish vegetation communities and be an appropriate example of an excavated wetland.

Regional Distribution

Certain plant species are correlated with different regional clusters and the hydrologic conditions associated with those clusters used in this study. Plant species that are re-establishing in wetlands can be examined by using excavated sites. In the shallow marsh treatment sites, those found in Towner county were heavily dominated by wetland vegetation found in slightly to moderately brackish waters (Stewart and Kantrud 1971).

Benson county had wetland regeneration that favors species found in both fresh to moderately brackish conditions. Excavated sites located in Wells county are more heavily dominated towards wetland vegetation found in slightly to moderately brackish water but is fairly represented by fresh water species.

Similar to the results of Hargiss (2009), hydrologic conditions appear to be an influencing factor and affects what species are present at wetland sites. Differences in salinity at sites are likely due to landscape position indicating water regimes of discharge, flow-through, or recharge wetlands (Richardson and Vepraskas 2001) and may also be influenced by regional distribution. Restoration sites located in urban or agricultural settings, such as the control sites in this study, may be more prone to varying hydrologic conditions due to increased storm water runoff which may influence vegetation communities (Kercher and Zedler 2004). Wetlands that obtain surface water from agricultural watersheds tend to have many invasive species (Galatowitsch et al. 1999). These results indicate that it is important to consider hydrologic conditions when planning a restoration to generate desired vegetation. Hydrologic condition will vary and may shift over time due to climate fluxes.

Summary

This is a general baseline study and these results may change over time. Sediment removal is changing the plant community and structure of these wetlands. There is a significant difference in plant communities between the wet meadow and shallow marsh zones. The treatment sites are closer to the reference condition as compared to cattail choked wetlands. Results show that sediment removal is aiding in removing cattails, however, it may still be too early to tell if the sediment removal process prevents cattails from re-establishing in treatment sites. Restoration sites used in this study are rather young and as weather cycles change and time is allowed to lapse, results of plant community establishment may shift. It is not clear whether post-excavation management practices have a positive or negative effect on wet meadow community development. However, regional differences did have an effect on wetland plant community development which was likely influenced by hydrological conditions.

Future Research Needs

There are many questions left to answer as there may be many factors influencing native plant community establishment after restoration. Areas that need to be further investigated are wetland soils and proper excavation depth, nutrient fluxes above and below the surface, whether natural and excavated wetlands differ enough in landscape formations that it can affect plant communities. All these factors likely play a role in plant community establishment after the restoration process. Knowing how these factors are related can be a valuable tool for determining proper restoration management techniques.

When restoring a wetland through sediment removal, it is not certain if there is a proper depth that will increase chances for native species establishment. Different excavation depths have been used in wetland restorations (Dalrymple et al. 2003, Fisher and Allbee 2011) that have yielded varying results. Different strategies include removing the A horizon, removing part of the B horizon to expose the original seedbed, and even excavating down to the original bedrock where plausible. Proper excavation depth is likely site specific and dependent upon site characteristics.

Increases in agricultural practices and prairie land being converted to agricultural land can accelerate sedimentation which can increase the deposition of nutrients, including N and P (Richardson et al. 1994). Due to North Dakota being located in an agriculturally dominated landscape, nutrient levels may be elevated by the addition of fertilizers or other chemical applications. This influx of soil nutrients may be a critical factor in restoration. It is thought that an increase of phosphorus may provide a niche for cattails to flourish (Mack et al. 2000, Woo and Zedler 2002, Fisher and Allbee 2011). Surrounding land use must be taken into consideration not only during the selection and design process, but also during the implementation and monitoring process.

It has been questioned whether or not it is possible to reestablish the wet meadow zone after it has been destroyed. Kantrud and Newton (1996) raise this question and suggest that it may be difficult to gain the wet meadow zone back after native wetlands have been altered by agricultural practices. One of the characteristics of native pothole wetlands is a characteristic topography (Richardson and Verpraskas 2001). For example, the location of the toe-slope is usually near or within the wet meadow plant community and sedimentation may alter the toe-slope position and shape. The re-establishment of a toe-slope may be a factor to consider when attempting the re-establishment of the wet meadow zone.

Data from a Real-Time Kinematic device can be used to show an example of topographical differences between natural and excavated wetlands. For example, wetland topography from a natural and an excavated wetland such as two wetlands surveyed in Benson county can differ a great deal (Figures 9 and 10). In the profile of the natural wetland, a distinct toe-slope, is visible surrounding the wetland. This same toe-slope is not represented in the excavated wetland. This toe-slope is located consistently on the edge or within the wet meadow vegetation community and zone. As seen in the figures, the toe-slope is found in the natural wetland, yet is lacking in the excavated wetland. Further research must be completed to determine if it is possible to regain a more natural topography whether through the design and restoration process or if it only can naturally develop over time.

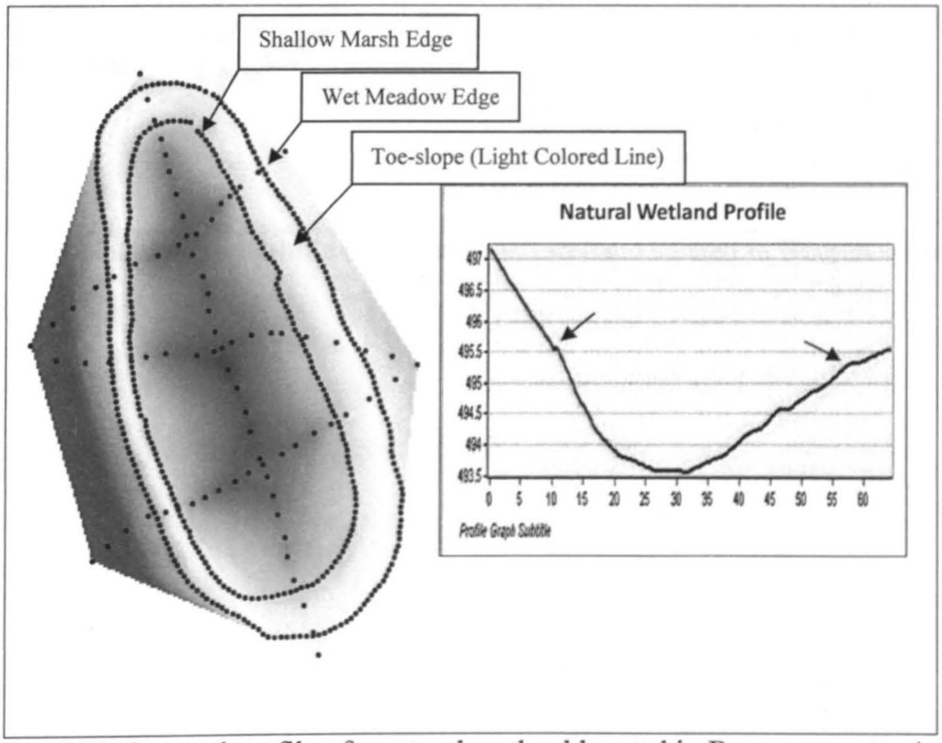


Figure 9. Aerial view and profile of a natural wetland located in Benson county. Arrows indicate potential toe-slope formation.

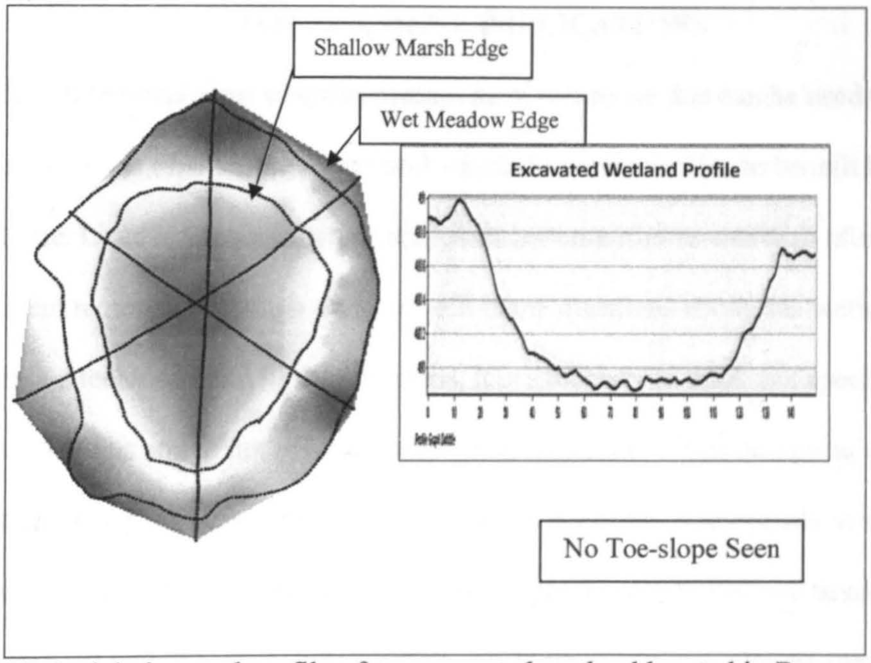


Figure 10. Aerial view and profile of an excavated wetland located in Benson county.

MANAGEMENT IMPLICATIONS

Sediment removal is an adaptive management technique that can be used to create ideal conditions to obtain desired wetland vegetation communities to benefit both people and wildlife. Little is known how wetland plant communities re-establish after restoration by sediment removal. Although there are still many questions about this wetland management technique and its effectiveness, it is necessary to think site specific when doing restorations and to not assume broad generalizations. When designing wetland restorations, many variables should be taken into consideration in regards to site expectations and restoration designs to obtain the plant communities we desire to manage for targeted wildlife. These include location, geologic conditions, climate (wet/dry cycle), hydroperiod, hydrologic conditions, soils, and surrounding land use.

Results of this study can be used as baseline data for future monitoring of restored wetlands within North Dakota. Continuous adaptive management is necessary to successfully restore a wetland and establish native plant communities. Repeat assessment of restored wetlands within North Dakota can indicate the vegetative trend in relation to the present and future land practices and climate. Vegetation communities in sites may change over time and with climatic cycles. Additional studies must be done to obtain a general time line of plant community reestablishment.

Without long term invasive species control, hybrid cattail will likely reestablish and replace the native communities (Boers et al. 2007). Additional long-term monitoring is necessary to better understand and accurately describe the effects of sediment removal on plant communities on wetlands. When managing a restored wetland, it may be important for it not to be in close proximity to an unmanaged wetland with hybrid cattails as it is more likely to develop a native plant community before hybrid cattail is able to re-invade (Boers 2007). Information from the project can also be used in other wetland restoration projects across the United States to determine the appropriate location and effectiveness of restorations based on project needs and goals.

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APPENDIX A. PLANT SPECIES ENCOUNTERED DURING TESTING

Scientific Name[1]	Common Name	Origin[2]	Life[3]	Phys.[4]	C-Val[5]
Achillea millefolium L.	Common yarrow	Native	P	FORB	3
Agalinis tenuifolia (Vahl) Raf.	Slenderleaf false foxglove	Native	A	FORB	8
Agrostis gigantea Roth	Redtop	Introduced	P	GRASS	*
Agrostis hyemalis (Walter) Britton, Sterns & Poggenb.	Winter bentgrass	Native	P	GRASS	1
Alisma gramineum Lej.	Narrowleaf water plantain	Native	P	FORB	2
Alisma subcordatum Raf.	American water plaintain	Native	P	FORB	
Alopecurus aequalis Sobol.	Shortawn foxtail	Native	P	GRASS	2
Amaranthus retroflexus L.	Redroot amaranth	Native	A	FORB	0
Ambrosia artemisiifolia L.	Annual ragweed	Native	A	FORB	0
Ambrosia psilostachya DC.	Cuman ragweed	Native	P	FORB	2
Andropogon gerardii Vitman	Big bluestem	Native	P	GRASS	5
Anemone canadensis L.	Canadian anemone	Native	P	FORB	4
Apocynum cannabinum L.	Indianhemp	Native	P	FORB	4
Argentina anserina (L.) Rydb.	Silverweed cinquefoil	Native	P	FORB	2
Artemisia absinthium L.	Absinthium	Introduced	P	FORB	*
Artemisia biennis Willd.	Biennial wormwood	Introduced	B	FORB	*
Artemisia cana Pursh	Silver sagebrush	Native	P	SHRUB	7
Artemisia frigida Willd.	Prairie sagewort	Native	P	SHRUB	4
Artemisia ludoviciana Nutt.	White sagebrush	Native	P	FORB	3
Asclepias incarnata L.	Swamp milkweed	Native	P	FORB	5
Asclepias syriaca L.	Common milkweed	Native	P	FORB	0
Astragalus canadensis L.	Canadian milkvetch	Native	P	FORB	5
Atriplex subspicata (Nutt.) Rydb.	Saline saltbush	Native	A	FORB	2
Beckmannia syzigachne (Steud.) Fernald	American sloughgrass	Native	A	GRASS	1
Bidens cernua L.	Nodding beggartick	Native	A	FORB	3
Bidens frondosa L.	Devil's beggartick	Native	A	FORB	1
Boltonia asteroides (L.) L'Hér.	White doll's daisy	Native	P	FORB	3
Bouteloua curtipendula (Michx.) Torr.	Sideoats grama	Native	P	GRASS	5
Bromus inermis Leyss.	Smooth brome	Introduced	P	GRASS	*
Calamagrostis canadensis (Michx.) P. Beauv.	Bluejoint	Native	P	GRASS	5
Calamagrostis stricta (Timm) Koeler	Slimstem reedgrass	Native	P	GRASS	5
Callitriche palustris L.	Vernal water starwort	Native	P	FORB	7
Carex atherodes Spreng.	Wheat sedge	Native	P	SEDGE	4
Carex athrostachya Olney	Slenderbeak sedge	Native	P	SEDGE	7
Carex aurea Nutt.	Golden sedge	Native	P	SEDGE	8
Carex brevior (Dewey) Mack.	Shortbeak sedge	Native	P	SEDGE	4

Scientific Name[1]	Common Name	Origin[2]	Life[3]	Phys.[4]	C-Val[5]
Carex laeviconica Dewey	Smoothcone sedge	Native	P	SEDGE	6
Carex pellita Muhl. ex Willd.	Woolly sedge	Native	P	SEDGE	4
Carex praegracilis W. Boott	Clustered field sedge	Native	P	SEDGE	5
Carex sartwellii Dewey	Sartwell's sedge	Native	P	SEDGE	5
Carex sychnocephala Carey	Manyhead sedge	Native	P	SEDGE	7
Carex vulpinoidea Michx.	Fox sedge	Native	P	SEDGE	2
Chenopodium album L.	Lambsquarters	Introduced	A	FORB	*
Chenopodium glaucum L.	Oakleaf goosefoot	Introduced	A	FORB	*
Chenopodium rubrum L.	Red goosefoot	Native	A	FORB	2
Cirsium arvense (L.) Scop.	Canada thistle	Introduced	P	FORB	*
Cirsium flodmanii (Rydb.) Arthur	Flodman's thistle	Native	P	FORB	5
Cirsium vulgare (Savi) Ten.	Bull thistle	Introduced	B	FORB	*
Convolvulus arvensis L.	Field bindweed	Introduced	P	FORB	*
Conyza canadensis (L.) Cronquist	Canadian horseweed	Native	A	FORB	0
Coreopsis tinctoria Nutt.	Golden tickseed	Native	P	FORB	3
Cyclachaena xanthifolia (Nutt.) Fresen.	Marsh elder	Native	A	FORB	0
Dalea purpurea Vent.	Purple prairie clover	Native	P	FORB	8
Descurainia sophia (L.) Webb ex Prantl	Flixweed	Introduced	A	FORB	*
Distichlis spicata (L.) Greene	Saltgrass	Native	P	GRASS	2
Echinochloa crus-galli (L.) P. Beauv.	Barnyardgrass	Introduced	A	GRASS	*
Echinochloa P. Beauv.	Cockspur grass	Native	A	GRASS	0
Eleocharis acicularis (L.) Roem. & Schult.	Needle spikerush	Native	P	SEDGE	3
Eleocharis compressa Sull.	Flatstem spikerush	Native	P	SEDGE	8
Eleocharis macrostachya Britton	Pale Spikerush	Native	P	SEDGE	4
Elymus canadensis L.	Canada wildrye	Native	P	GRASS	3
Elymus repens (L.) Gould	Quackgrass	Introduced	P	GRASS	*
Elymus trachycaulus (Link) Gould ex Shinners ssp. subsecundus (Link) A. Löve & D. Löve	Slender wheatgrass	Native	P	GRASS	6
Epilobium ciliatum Raf.	Fringed willowherb	Native	P	FORB	3
Epilobium leptophyllum Raf.	Bog willowherb	Native	P	FORB	6
Equisetum arvense L.	Field horsetail	Native	P	FERN	4
Equisetum laevigatum A. Braun	Smooth horsetail	Native	P	FERN	3
Euphorbia esula L.	Leafy spurge	Introduced	P	FORB	*
Euthamia graminifolia (L.) Nutt.	Flat-top goldentop	Native	P	FORB	6
Fragaria virginiana Duchesne	Virginia strawberry	Native	P	FORB	4
Fraxinus pennsylvanica Marsh.	Green ash	Native	P	TREE	5
Galium boreale L.	Northern bedstraw	Native	P	FORB	4
Glyceria borealis (Nash) Batchelder	Small floating mannagrass	Native	P	GRASS	8

Scientific Name[1]	Common Name	Origin[2]	Life[3]	Phys.[4]	C-Val[5]
Glyceria grandis S. Watson	American mannagrass	Native	P	GRASS	4
Glyceria striata (Lam.) Hitchc.	Fowl mannagrass	Native	P	GRASS	6
Glycyrrhiza lepidota Pursh	American licorice	Native	P	FORB	2
Gratiola neglecta Torr.	Clammy hedgehyssop	Native	A	FORB	0
Helianthus annuus L.	Common sunflower	Native	A	FORB	0
Helianthus maximiliani Schrad.	Maximilian sunflower	Native	P	FORB	5
Helianthus nuttallii Torr. & A. Gray	Nuttall's sunflower	Native	P	FORB	8
Helianthus pauciflorus Nutt. ssp. pauciflorus	Stiff sunflower	Native	P	FORB	8
Hierochloe odorata (L.) P. Beauv. ssp. *arctica* (J. Presl) Tzvelev	Northern sweetgrass	Native	P	GRASS	10
Hordeum jubatum L.	Foxtail barley	Native	P	GRASS	0
Hypericum majus (A. Gray) Britton	Large St. John'swort	Native	P	FORB	10
Juncus arcticus Willd. ssp. littoralis (Engelm.) Hultén	Mountain rush	Native	P	FORB	5
Juncus bufonius L.	Toad rush	Native	A	FORB	1
Juncus interior Wiegand	Inland rush	Native	P	FORB	5
Juncus nodosus L.	Knotted rush	Native	P	FORB	7
Juncus torreyi Coville	Torrey's rush	Native	P	FORB	2
Lactuca tatarica (L.) C.A. Mey. var. pulchella (Pursh) Breitung	Blue lettuce	Native	P	FORB	1
Lemna minor L.	Common duckweed	Native	P	FORB	9
Lemna trisulca L.	Star duckweed	Native	P	FORB	2
Lemna turionifera Landolt	Turion duckweed	Native	P	FORB	1
Liatris ligulistylis (A. Nelson) K. Schum.	Rocky Mountain blazing star	Native	P	FORB	10
Liatris pycnostachya Michx.	Prairie blazing star	Native	P	FORB	8
Limosella aquatica L.	Water mudwort	Native	P	FORB	2
Lobelia spicata Lam.	Palespike lobelia	Native	P	FORB	6
Lotus unifoliolatus (Hook.) Benth. var. unifoliolatus	American bird's-foot trefoil	Native	A	FORB	3
Lycopus americanus Muhl. ex W. Bartram	American bugleweed	Native	P	FORB	4
Lycopus asper Greene	Rough bugleweed	Native	P	FORB	4
Lysimachia ciliata L.	Fringed loosestrife	Native	P	FORB	6
Lysimachia hybrida Michx.	Lowland yellow loosestrife	Native	P	FORB	5
Matricaria matricarioides auct. non (Less.) Porter	Disc mayweed	Introduced	A	FORB	*
Medicago lupulina L.	Black medick	Introduced	P	FORB	*
Melilotus alba Medikus. orth. var.	White sweetclover	Introduced	A	FORB	*
Melilotus officinalis (L.) Lam.	Yellow sweetclover	Introduced	A	FORB	*
Mentha arvensis L.	Wild mint	Native	P	FORB	3
Monarda fistulosa L.	Wild bergamot	Native	P	FORB	5

Scientific Name[1]	Common Name	Origin[2]	Life[3]	Phys.[4]	C-Val[5]
Muhlenbergia asperifolia (Nees & Meyen ex Trin.) Parodi	Scratchgrass	Native	P	GRASS	2
Muhlenbergia richardsonis (Trin.) Rydb.	Mat muhly	Native	P	GRASS	10
Nassella viridula (Trin.) Barkworth	Green needlegrass	Native	P	GRASS	5
Oligoneuron riddellii (Frank ex Riddell) Rydb.	Riddell's goldenrod	Native	P	FORB	10
Oligoneuron rigidum (L.) Small var. humile (Porter) G.L. Nesom	Stiff goldenrod	Native	P	FORB	4
Oxalis dillenii Jacq.	Slender yellow woodsorrel	Native	P	FORB	0
Packera pseudaurea (Rydb.) W.A. Weber & A. Löve var. semicordata (Mack. & Bush) D.K. Trock & T.M. Barkley	Falsegold groundsel	Native	P	FORB	5
Panicum virgatum L.	Switchgrass	Native	P	GRASS	5
Pascopyrum smithii (Rydb.) A. Löve	Western wheatgrass	Native	P	GRASS	4
Phalaris arundinacea L.	Reed Canarygrass	Native	P	GRASS	0
Phleum pratense L.	Timothy	Introduced	P	GRASS	*
Plantago eriopoda Torr.	Redwool plantain	Native	P	FORB	5
Plantago major L.	Common plantain	Introduced	P	FORB	*
Poa palustris L.	Fowl bluegrass	Native	P	GRASS	4
Poa pratensis L.	Kentucky bluegrass	Introduced	P	GRASS	*
Polygonum amphibium L. var. emersum Michx.	Longroot smartweed	Native	P	FORB	0
Polygonum amphibium L. var. stipulaceum Coleman	Marsh smartweed	Native	P	FORB	6
Polygonum lapathifolium L.	Pale smartweed	Native	A	FORB	1
Polygonum ramosissimum Michx	Bushy knotweed	Native	A	FORB	3
Potamogeton gramineus L.	Variableleaf pondweed	Native	P	FORB	6
Potamogeton pusillus L.	Small pondweed	Native	P	FORB	2
Potentilla norvegica L.	Norwegian cinquefoil	Native	A	FORB	0
Ranunculus cymbalaria Pursh	Alkali buttercup	Native	P	FORB	3
Ranunculus gmelinii DC.	Gmelin's buttercup	Native	P	FORB	8
Ranunculus longirostris Godr.	Longbeak buttercup	Native	P	FORB	7
Ranunculus pensylvanicus L. f.	Pennsylvania buttercup	Native	A	FORB	4
Ratibida columnifera (Nutt.) Woot. & Standl.	Upright prairie coneflower	Native	P	FORB	3
Rorippa palustris (L.) Besser	Bog yellowcress	Native	A	FORB	2
Rosa arkansana Porter	Prairie rose	Native	P	SHRUB	3
Rosa woodsii Lindl.	Woods' Rose	Native	P	SHRUB	5
Rudbeckia hirta L.	Blackeyed susan	Native	B	FORB	5
Rumex aquaticus L. var. fenestratus (Greene) Dorn	Western dock	Native	P	FORB	7

Scientific Name[1]	Common Name	Origin[2]	Life[3]	Phys.[4]	C-Val[5]
Rumex crispus L.	Curly dock	Introduced	P	FORB	*
Rumex maritimus L.	Golden dock	Native	A	FORB	1
Rumex salicifolius Weinm. var. mexicanus (Meisn.) C.L. Hitchc.	Willow-leaved dock	Native	P	FORB	1
Sagittaria cuneata Sheldon	Arumleaf arrowhead	Native	P	FORB	6
Sagittaria latifolia Willd.	Broadleaf arrowhead	Native	P	FORB	6
Salix exigua Nutt. ssp. interior (Rowlee) Cronquist	Sandbar willow	Native	P	SHRUB	3
Salix lutea Nutt.	Yellow willow	Native	P	SHRUB	5
Schizachyrium scoparium (Michx.) Nash	Little bluestem	Native	P	GRASS	6
Schoenoplectus acutus (Muhl. ex Bigelow) A. Löve & D. Löve var. acutus	Hardstem bulrush	Native	P	SEDGE	5
Schoenoplectus fluviatilis (Torr.) M.T. Strong	River bulrush	Native	P	SEDGE	2
Schoenoplectus maritimus (L.) Lye	Cosmopolitan bulrush	Native	P	SEDGE	4
Schoenoplectus pungens (Vahl) Palla var. longispicatus (Britton) S.G. Sm.	Common threesquare	Native	P	SEDGE	4
Schoenoplectus tabernaemontani (C.C. Gmel.) Palla	Softstem bulrush	Native	P	SEDGE	3
Scolochloa festucacea (Willd.) Link	Common rivergrass	Native	P	GRASS	6
Scutellaria galericulata L.	Marsh Skullcap	Native	P	FORB	7
Setaria pumila (Poir.) Roem. & Schult. ssp. pumila	Yellow foxtail	Introduced	A	GRASS	*
Silene noctiflora L.	Nightflowering silene	Introduced	A	FORB	*
Sinapis arvensis L. ssp. arvensis	Wild mustard	Introduced	A	FORB	*
Sisyrinchium montanum Greene	Strict blue-eyed grass	Native	P	FORB	8
Sium suave Walter	hemlock waterparsnip	Native	P	FORB	3
Solidago canadensis L.	Canada goldenrod	Native	P	FORB	1
Solidago gigantea Aiton	Late goldenrod	Native	P	FORB	4
Solidago missouriensis Nutt.	Missouri goldenrod	Native	P	FORB	5
Solidago mollis Bartlett	Velvety goldenrod	Native	P	FORB	6
Sonchus arvensis L.	Field sowthistle	Introduced	P	FORB	*
Sorghastrum nutans (L.) Nash	Indian grass	Native	P	GRASS	6
Sparganium eurycarpum Engelm.	Broadfruit bur-reed	Native	P	FORB	4
Spartina gracilis Trin.	Alkali cordgrass	Native	P	GRASS	6
Spartina pectinata Bosc ex Link	Prairie cordgrass	Native	P	GRASS	5
Spiraea alba Du Roi	White meadowsweet	Native	P	SHRUB	7
Stachys tenuifolia Willd.	Smooth hedgenettle	Native	P	FORB	3
Stuckenia pectinata (L.) Böerner	Sago pondweed	Native	P	FORB	0
Symphoricarpos albus (L.) S.F. Blake	Common snowberry	Native	P	SHRUB	8

Scientific Name[1]	Common Name	Origin[3]	Life[2]	Phys.[4]	C-Val[5]
Symphoricarpos occidentalis Hook.	Western snowberry	Native	P	SHRUB	3
Symphyotrichum ciliatum (Ledeb.) G.L. Nesom	Rayless alkali aster	Native	A	FORB	0
Symphyotrichum ericoides (L.) G.L. Nesom var. ericoides	White heath aster	Native	P	FORB	2
Symphyotrichum lanceolatum (Willd.) G.L. Nesom ssp. lanceolatum var. lanceolatum	White panicle aster	Native	P	FORB	3
Taraxacum officinale F.H. Wigg.	Common dandelion	Introduced	P	FORB	*
Teucrium canadense L.	Canada germander	Native	P	FORB	3
Thalictrum dasycarpum Fisch. & Avé-Lall.	Purple meadow-rue	Native	P	FORB	7
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	Intermediate wheatgrass	Introduced	P	GRASS	*
Thinopyrum ponticum (Podp.) Z.-W. Liu & R.-C. Wang	Tall wheatgrass	Introduced	P	GRASS	*
Thlaspi arvense L.	Field pennycress	Introduced	A	FORB	*
Trifolium repens L.	White clover	Introduced	P	FORB	*
Triglochin maritima L.	Arrowgrass	Native	P	FORB	5
Typha ×glauca Godr. (pro sp.)	Hybrid cattail	Introduced	P	FORB	*
Typha angustifolia L.	Narrowleaf cattail	Introduced	P	FORB	*
Typha latifolia L.	Broadleaf cattail	Native	P	FORB	2
Urtica dioica L.	Stinging nettle	Native	P	FORB	0
Utricularia macrorhiza Leconte	Common bladderwort	Native	P	FORB	2
Verbena bracteata Cav. ex Lag. & Rodr.	Bigbract verbena	Native	A	FORB	0
Vernonia fasciculata Michx.	Prairie ironweed	Native	P	FORB	3
Veronica peregrina L. ssp. xalapensis (Kunth) Pennell	Purslane speedwell	Native	A	FORB	0
Veronica scutellata L.	Skullcap speedwell	Native	P	FORB	10
Vicia americana Muhl. ex Willd.	American vetch	Native	P	FORB	6
Viola nephrophylla Greene	Northern bog violet	Native	P	FORB	8
Xanthium strumarium L.	Cocklebur	Native	A	FORB	0
Zizia aptera (A. Gray) Fernald	Meadow zizia	Native	P	FORB	8

[1]Species scientific names follow the nomenclature of the USDA Plants Database (USDA, NRCS 2011).
[2]Life-form – P = Perennial, A = Annual, B = Biennial
[3]Origin of plant species
[4]Physiognomy of plant species
[5]C-Values were assigned by the Northern Great Plains Floristic Quality Assessment Panel (TNGPFQAP 2001).
* Introduced species are not assigned a coefficient of conservatism.

APPENDIX B: INDIVIDUAL WETLAND SITE INFORMATION

Study Site	County	Wetland Type	Year Excavated	Amount Sediment Removed (Inches)	Location	
					Latitude	**Longitude**
Nik 1	Towner	Treatment	2008	10"	48°36'04	99°14'09
Nik 3	Towner	Treatment	2008	18"	48°35'17	99°14'33
Nik 4	Towner	Treatment	2008	14"	48°35'16	99°14'20
Nik 5	Towner	Treatment	2008	20"	48°35'17	99°14'91
Nik 6	Towner	Treatment	2008	10"	48°35'20	99°14'16
NikSE1	Towner	Converted Cropland	—	—	48°34'36	99°12'02
NikSE2	Towner	Converted Cropland	—	—	48°34'36	99°12'09
NikSE3	Towner	Converted Cropland	—	—	48°35'15	99°11'43
NikSE4	Towner	Converted Cropland	—	—	48°35'14	99°11'36
MS 2	Towner	Reference	—	—	48°33'05	99°13'27
MS 3	Towner	Reference	—	—	48°33'05	99°13'30
MS 4	Towner	Reference	—	—	48°33'17	99°13'31
HOFF 1	Benson	Treatment	2007	8-12"	48°12'58	99°27'22
HOFF 2	Benson	Treatment	2007	8-12"	48°13'02	99°27'06
HOFF 5	Benson	Treatment	2007	8-12"	48°12'38	99°28'00
HOFF 4	Benson	Converted Cropland	—	—	48°12'42	99°27'36
HOFF 6	Benson	Converted Cropland	—	—	48°12'35	99°27'45
BEN 1	Benson	Reference	—	—	48°12'22	99°28'17
BEN 2	Benson	Reference	—	—	48°12'31	99°28'22
BEN 3	Benson	Reference	—	—	48°12'30	99°28'30
CW 47	Wells	Treatment	2003	8"	47°30'37	99°27'38
CW 48	Wells	Treatment	2003	12"	47°30'35	99°27'43
CW 57	Wells	Treatment	2003	16"	47°30'42	99°27'55
CW 58	Wells	Treatment	2003	5"	47°30'42	99°27'57
CW 61	Wells	Treatment	2003	8"	47°30'42	99°27'33
CW 62	Wells	Treatment	2003	4"	47°30'42	99°27'34
CW 63	Wells	Treatment	2003	14"	47°30'45	99°27'33
CW 64	Wells	Treatment	2003	4"	47°30'48	99°27'34
CW 65	Wells	Treatment	2003	10"	47°30'48	99°27'36
CW 66	Wells	Treatment	2003	16"	47°30'51	99°27'33
CW 7	Wells	Converted Cropland	—	—	47°30'16	99°27'33
CW 15	Wells	Converted Cropland	—	—	47°30'28	99°27'38
CW 46	Wells	Converted Cropland	—	—	47°30'37	99°27'32
CW 51	Wells	Converted Cropland	—	—	47°30'34	99°27'53
CW 59	Wells	Converted Cropland	—	—	47°30'43	99°27'55

Study Site	County	Wetland Type	Year Excavated	Amount Sediment Removed (Inches)	Location	
					Latitude	Longitude
CGS 1	Eddy	Reference	—	—	47°43'20	98°40'25
CGS 2	Eddy	Reference	—	—	47°42'40	98°39'49
CGS 3	Eddy	Reference	—	—	47°39'36	98°40'19

* Exact excavation depths were not recorded but best estimation was given by contractor.