U. S. GEOLOGICAL SURVEY
BIOLOGICAL RESOURCES DIVISION
Northern Prairie Science Center
8711 37th Street SE
Jamestown, ND 58401

TASK STUDY PLAN

PROJECT: Headquarters Science Support (3210AKF; Fire Ecology)

TASK 4.2: Wetland Processes: a 10-20 Year Study to Improve Wetland Management Capabilities of the National Wildlife Refuge System Through Integration of Research, Continuing Education, and Adaptive Management

PRINCIPAL INVESTIGATORS:

Murray Laubhan, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND 58401

Ned Euliss, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND 58401

Robert Gleason, U.S. Geological Survey, Northern Prairie Wildlife Research Center, Jamestown, ND 58401

Socheata Lor, U.S. Fish and Wildlife Service, Upper Midwest Environmental Sciences Center, 2630 Fanta Reed Road, La Crosse, WI 54603

BACKGROUND

In the conterminous United States, many wetlands on National Wildlife Refuges (NWR) are embedded within a larger landscape that has been greatly modified by past land use and management. Among these modifications has been the installation of numerous levees, ditches, diversion channels, wells, and water control structures to manipulate the flow and direction of surface and ground waters both within and outside NWR boundaries for varied purposes, including agricultural production, flood storage, navigation, and wildlife habitat improvement. Although man-induced hydrological changes may provide abundant wetland resources for target wildlife organisms in the short-term, research and monitoring programs have documented that significant challenges typically develop in the long-term due to altered ecosystem processes (e.g., sedimentation, water quality) that determine wetland structure and function. Unfortunately, many of these challenges often are not recognized until flora can no longer be

managed successfully using traditional techniques or vertebrate goals consistently are not attained.

Currently, a common wetland issue in the northern portion of the United States is the encroachment of robust, perennial vegetation. Of the NWRs participating in this study (Agassiz NWR, Horicon NWR, Sherburne NWR, Iroquois NWR, and the Leopold Wetland Management District [WMD]), cattail (*Typha* spp.) distribution and biomass have increased in some wetlands to an extent that they have been attributed to declines in the diversity and abundance of waterbirds. Although cattail has an important role in littoral ecosystems (Krattinger 1975), including the provision of breeding habitat for many waterbird species, the historical distribution and biomass of perennial wetland plants varied temporally and spatially depending on climate (e.g., drought/flood cycles) and associated disturbances (e.g., fire; Weller and Spatcher 1965, Weller and Fredrickson 1974). However, past and current land uses have altered processes that historically functioned to control wetland plant succession (van der Valk 1981), including the incidence and spread of cattail. The primary processes that have been altered on the NWRs participating in this study are hydrology and nutrient dynamics, both of which function at the watershed scale and are interrelated. With the exception of Iroquois NWR, wetlands in this study are associated with river systems. Historically, these flowing systems received and transported water and sediments. The volume of flow and sediment entering the system varied seasonally and interannually and were determined by surface runoff and ground water inflows from the surrounding uplands. Given the geographic location of the NWRs (Minnesota, Wisconsin, New York), wet years predominate but occasional drought years also occur. Historically, during extreme wet years, high-energy flows redistributed sediments, altered channel locations, and created numerous floodplain habitats (e.g., oxbows, channel scars, marshes) of value for wildlife. In contrast, many floodplain habitats dry during extended drought and sediments are consolidated and oxidized, releasing valuable nutrients.

Construction of levees in the floodplain changed this dynamic system. The frequency and magnitude of flow events changed (e.g., minimum flows increased, peak flows decreased) and altered the short- and long-term hydrologic conditions that affect nutrient cycling, decomposition rates, water quality, and soil conditions (Gambrell and Patrick 1978, Livingston and Loucks 1979, Wharton et al. 1982, Mitsch and Gosselink 2000). These abiotic conditions in turn influence biotic components, including the composition, distribution, and productivity of

wetland vegetation (Bedinger 1979, van der Valk and Welling 1988, Squires and van der Valk 1992) and invertebrate community composition and structure (Eakin et al. 1976, Kadlec 1982, Duffy and Al-Hassan 1988, Dobrowolski et al. 1990, Williams et al. 1990, Comstock and Ehleringer 1992). Ultimately, vertebrate use of wetlands also is directly and indirectly affected by hydrology (Weller and Spatcher 1965, Weller and Fredrickson 1974, Kaminski and Prince 1981, Ball and Nudds 1989, Weller 1999, Laubhan and Roelle 2001).

Altered hydrology also has affected sediment dynamics, a naturally occurring process that influences formation, structure, and function of wetlands (Saucier 1994, Bornette et al. 1998, Hupp 2000, Johnson 2000). Although the amount of sediment transported by rivers varies depending on many factors, native upland and floodplain vegetation attenuates soil erosion and acts as a filter to limit the amount of sediment that entered the channel. However, increased agricultural activity and other human activities have increased the amount of sediment entering many river systems, and the construction of dams and levees within floodplains has altered deposition patterns by changing flow velocities (Ulrich and Pfeifer 1976). Consequently, in terms of quantity, sediment has become the major pollutant of wetlands, lakes, estuaries, and reservoirs in the United States (Baker 1992). This is evident on many of the wetlands in this study; accumulations of organic sediments range from several centimeters to several meters. Although sediment retention by wetlands often is described as a benefit (e.g., Botto and Patrick 1978, Kuenzler 1990), excessive sediment input can severely impact other wetland processes, including suppression of primary productivity (Rybicki and Carter 1986, Dieter 1991, Hartleb et al. 1993, Jurik et al. 1994, Wang et al. 1994, Gleason and Euliss 1998, Gleason et al. 2003). For example, unconsolidated sediment can increase turbidity, reduce dissolved oxygen concentrations and sunlight penetration, and alter nutrient availability. Above certain thresholds, these changes can eliminate or reduce growth of submerged aquatic vegetation (Robel 1961, Kullberg 1974). Further, suppression of primary production would be expected to negatively impact secondary productivity. For example, wetland invertebrate biomass often is reduced by sedimentation due to loss of vegetative structure (Krull 1970), toxicity (Newcombe and MacDonald 1991), or covering of invertebrate egg banks (Gleason and Euliss 1998, Gleason et al. 2003).

JUSTIFICATION

Historically, cattail mortality or partial dieback occurred primarily due to climatic extremes (drought, flood), and to a lesser extent muskrat herbivory, fire, or a combination of all these factors (Hayden 1939, Bellrose and Brown 1941, Laing 1940a, b, 1941, Uhler 1944, Penfound et al. 1945, Giltz and Myser 1954, Weller and Spatcher 1965, Bedish 1967). However, attempts to simulate these effects by artificially manipulating water levels, using prescribed fire, and employing various herbivores (e.g., cattle, muskrat) have resulted in widely varying results. The reasons for these disparities largely are unknown, but past research has documented that the effectiveness of cattail control by all mechanical means was more a function of the relationship between water depth and height at which cattails were cut than the methodology used (Apfelbaum undated). Similarly, studies have demonstrated that perennial plant species can be controlled by hot fires that kill roots or burn into the substrate (Linde 1969, Beule 1979, Thompson and Shay 1985), but these same species tend to survive surface fires. These results indicate that adapting existing strategies to enhance the control of cattail will require a better understanding of complex interactions involving the physiological traits and growth phenology of cattail, the time and intensity of strategy implementation, and antecedent wetland processes (e.g., hydrology).

Identifying ecological changes that have resulted in reduced effectiveness of existing strategies is an important step in adaptive management. Based on several site visits, the ecological changes that have occurred on the study NWRs include hydrology (i.e., depth, duration, and/or frequency of flooding) and sediment dynamics (i.e., accumulation and distribution). Collectively, these changes have facilitated the potential for increased cattail encroachment by enhancing conditions for both germination and expansion via rhizomes. Cattail germination requirements include high temperature (35° C), low oxygen concentration (2.3 to 4.3 mg/L in oxygen in water), and long light exposure (>10 h exposure of red light) (Sifton 1959, Bonnewell et al 1983). These conditions likely occur more frequently on the study NWRs because the presence of fine sediments coupled with the inability to completely dewater wetlands results in the creation of saturated soils or shallow water that warms quickly and is characterized by reduced oxygen concentrations (Kadlec 1962, Harris and Marshall 1963, Meeks 1969). In contrast, vegetative reproduction (i.e., rhizomes) is the primary means of colony maintenance and expansion (Wang et al. 1994). Rhizome growth dynamics depend on water depth (Grace

and Wetzel 1981, 1982; Grace 1988, 1989), nutrient conditions (Ulrich and Burton 1988), and competition with other species (Grace and Wetzel 1981, 1998; Grace 1987, 1988, 1989; Weisner 1993). All annuals and many perennials require non-saturated environments for establishment; thus, increased depth or duration of flooding often provides a competitive advantage to cattail because rhizomes require only low oxygen concentrations to survive and shoots are capable of enduring anaerobic conditions for up to 13 days during dormancy (Linde et al. 1976). Further, atmospheric oxygen is transferred to rhizomes via arenchyma cells that are present in both rhizomes and shoots; therefore, cattail is capable of obtaining oxygen even under flooded conditions as long as water depth does not exceed shoot height for extended periods (Sojda and Solberg 1993). Accretion of sediment also can dramatically influence cattail growth dynamics. For example, the biomass of broad-leaved and narrow-leaved cattail was enhanced 50-170% and 60-150%, respectively, following nutrient addition (Grace 1988). Similarly, the biomass of both species was three to five times greater when grown in 100% compared to 12.5% eutrophic mud (Szczepanska and Szczepanski 1976). Under ideal conditions, growth can be extremely vigorous. For example, 98 vegetative shoots and 104 crown buds were produced on a single greenhouse grown cattail seedling the first year (Timmons et al. 1963 in Apfelbaum undated) and Fassett (1957) stated that a clone which is an acre in size may consist of only a few plants. Further, cattail does not reach an age where vigor declines because plants grow by continuous renewal of rhizomes, and any specific rhizome never reaches an age of more than 2 years (McDonald 1955).

Given that past alterations on the NWRs involved in this study have increased the potential for cattail germination and expansion, the use of prescribed fire is likely to be ineffective unless the existing hydrology and sediment dynamics are also addressed. Currently, NWRs have difficulty removing water from impoundments and drying soils sufficiently to (1) promote establishment of annual vegetation or (2) control the encroachment rate of perennial vegetation (e.g., cattail, bulrush). Thus, vegetation tends to cycle rapidly between open water and dense stands of perennial emergent vegetation (NWR staff comments and observations). The root of this problem likely is related to the inability to reliably dewater impoundments during the growing season because (1) the volume of water entering the NWR is frequently outside the control of NWR staff, (2) water entering the NWR cannot be diverted from marshes because a river flows through the impoundment, (3) moisture in accumulated organic sediments

cannot be removed with the existing physical infrastructure, and (4) management actions (e.g., drawdown) on one impoundment constrain management options on other impoundments, which in some cases (e.g., Horicon NWR) are under different ownership.

Most knowledge of fire as a wetland management tool is based on generalized observations rather than on scientific or experimental studies (Kantrud 1986). The limited knowledge of the interrelationships between cattail autecology, hydrology, prescribed fire, and soil properties requires that the U.S. Fish and Wildlife Service (USFWS) develop additional information that improves the ability of managers to reliably and predictably apply management strategies. Due to the complexity of interactions involved in evaluating fire, scientific studies will be required to develop techniques for use in modified systems. Not only will this information advance management for wildlife, it also will improve fiscal efficiency. Our overarching goal is to provide the information necessary to improve fire planning by quantifying the effect of fire in relation to different abiotic factors (e.g., hydrology, soils) to facilitate development of more effective management strategies. The expected benefits include more efficient and effective use of fire, development of long-term monitoring protocols, and establishment of an adaptive management process to examine the use of fire in wetland management on NWRs. National Wildlife Refuges represent an ideal location because management actions such as water-level manipulations and prescribed burning, conducted to improve wildlife habitats, offer valuable opportunities to conduct scientific experiments (MacNab 1983, Sinclair 1991).

Our initial efforts will focus on opportunities presently available to investigate the effects of prescribed burning in cattail-dominated marshes on NWRs located in Regions 3 and 5. The purpose is to investigate relationships among cattail autecology, hydrology, prescribed fire, and soil properties in wetlands and develop quantitative information that can be used to determine specific abiotic conditions that contribute to enhanced cattail control. Hydrology and prescribed fire were selected for investigation because these two processes are among the most effective strategies for manipulating the distribution and biomass of robust, perennial wetland vegetation (Ward 1942, Truax and Gunter 1951, Nelson and Dietz 1966, Linde 1969, Fredrickson and Laubhan 1994, Mitsch and Gosselink 2000). In addition, the USFWS currently utilizes both of these techniques extensively as evidenced by levees and ditches on a majority of NWRs in the coterminous United States and, based on 2003 information, the USFWS ranks second only to the

U.S. Forest Service in the area burned by federal agencies (National Interagency Fire Coordination Center, http://www.nifc.gov/news/nicc.html, accessed on 13 November 2003). Thus, the potential for adapting management scenarios involving water-level manipulation and fire is theoretically great. Although various techniques involving water and fire currently are used on NWRs in this study, monotypic cattail stands continue to develop rapidly (1-2 years) following application, which indicates that another fundamental process or processes also has changed.

GOALS AND OBJECTIVES

There are two primary goals of this study: 1) increase communication and collaboration between USGS and USFWS personnel as specified in guidance provided by USGS and USFWS headquarters and 2) provide the information necessary to improve fire planning by quantifying the effect of prescribed fire in relation to wetland abiotic and biotic conditions. The expected benefits during this phase (2004-2008) of the project include increased collaboration between agencies in developing and applying research to address management issues, more efficient and effective use of prescribed fire in wetlands, development of monitoring protocols that will assist the USFWS in evaluating the long-term effects of treatments applied in this study, and establishment of an adaptive management process to examine the use of fire in wetland management on NWRs.

Communication Objectives:

To address the first goal of communication and collaboration from inception of the project through completion, the study will be designed and conducted in close cooperation with personnel in the USFWS Branch of Fire and Division of Refuges. Objectives established to address this goal are:

1. Conduct site visits to NWRs participating in the study to gather and exchange information necessary to ensure the study addresses questions of importance to the USFWS.
2. Correspond with study participants through writing and verbal communication as the study is designed and conducted to ensure that information developed during the course of this study is applicable to the management of NWRs.

Prescribed Fire Objectives:

Partial completion of the communication objectives were required to address the biological (i.e., prescribed fire) goal of this study. Following identification of potential study areas in Regions 3 and 5 of the USFWS and conducting two field trips to these sites, a study entitled "Interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes" was proposed in Fiscal Year (FY) 2004. The results of this study would have provided usable information to the USFWS, but it failed to address fundamental issue that may be responsible for reducing the effectiveness of prescribed fire in cattail-dominated marshes that are the focus of this study. Therefore, the original plan was deemed unacceptable and considerable effort was expended to develop a new approach to evaluate the efficacy of using prescribed fire to control cattail (Appendix A). An additional field trip was conducted to consult with USFWS and state staff responsible for managing the areas that originally agreed to participate in the study (Agassiz NWR, Horicon NWR, Leopold WMD, Sherburne NWR, Iroquois NWR). Following the site visit, the Principal Investigators organized two meetings with USFWS Regional Office (Regions 3 and 5) personnel in December 2004 and January 2005 (Appendix A). Prior to these meetings, the Principal Investigators developed an informational paper on prescribed fire in relation to cattail autecology to facilitate discussion among the partners (Appendix B). The outcome of these meetings included identification of the following four factors that must be incorporated into any study designed to evaluate the effectiveness of prescribed fire in reducing cattail: 1) organic matter accumulation, 2) belowground cattail biomass, 3) release of nutrients, and 4) management capabilities. Another meeting of all participating NWRs and regional office personnel was convened in February 2005 to address these issues and agreement was reached between USGS and USFWS Division of Refuges to focus on methods to pursue more extensive drying of study wetlands prior to applying prescribed fire. The concept underlying this approach was described in another white paper that reflected a new study title (Wetland Processes: a 10-20 Year Study to Improve Wetland Management Capabilities of the National Wildlife Refuge System Through Integration of Research, Continuing Education, and Adaptive Management), provided information on the four factors mentioned above, and explained the rationale for redirection (Appendix C).

The working hypothesis of the new study is based on the assumption that nutrients sequestered in above- and below-ground portions of live cattail, accumulated cattail litter, and organic substrates limit nutrients available for other primary and secondary producers important in wetland food webs. Currently, however, most prescribed fires implemented on NWR wetlands are surface burns conducted during the dormant season. Although fire often results in increased insolation and evaporation, water and substrate temperatures, and changes in soil and water chemistry (nutrients and conductivity; Auclair 1977, Diiro 1982, Faulkner and de la Cruz 1982), surface disturbances probably release only a small portion of nutrients from this large biomass pool because root systems are relatively unaffected. Further, many of the nutrients released likely are recaptured the following growing season in new cattail growth. The supposition that the mobilization of nutrients after surface fires is ephemeral is supported by previous studies that have documented only temporary changes in the concentration of nutrients in various storage pools following burning (Faulkner and de la Cruz 1982, Wilbur and Christensen 1983, Schmalzer and Hinkle 1992, Laubhan 1995). These and other studies (e.g., Auclair 1977, Smith and Kadlec 1985a, Schmalzer and Hinkle 1993) also frequently reported that vegetative biomass immediately began to increase again the first growing season following application of fire. Hence, changes in cattail dominance are short-lived (1–2 yr; Smith and Kadlec 1985b, Taylor et al. 1994, Flores 2003), and wetlands must be burned at short intervals. In contrast, achieving longer-term control of cattail likely will require implementing prescribed fires of greater intensity that not only release bound nutrients from aboveground cattail biomass, but also the belowground cattail biomass and organic sediments. Therefore, we plan to evaluate the effectiveness of prescribed fire based on changes in nutrient concentration within each of the primary nutrient storage pools (sediment, vegetation). Accomplishing increased fire intensity will require reducing the moisture content of organic material prior to ignition. Currently, the amount of sediment drying required is unknown and represents a fundamental question to address. Factors assumed to be important include depth and composition of sediment as well as location of the cattail rhizosphere in relation to the sediment surface. In addition, the time of ignition relative to the growth phenology of cattail also may be important. Previous research has documented that energy readily available for cattail growth is depleted to the greatest extent during mid- to late summer during rhizome bud formation and fruiting head development (Linde et al. 1976). Thus, fires conducted at the onset of flowering may exert more injury compared to

fires conducted during the dormant season. Finally, water-level management strategies implemented following prescribed fire also may be critical given that post-fire abiotic conditions determine which species are recruited from the soil seed bank.

Based on this information, the following objectives were developed for the first phase of this project to determine the effect of fire in relation to the longer-term control of cattail in modified wetland basins:

1. Document the relationship between fire intensity (temperature) in relation to the release of nutrients from the cattail rhizosphere along a moisture gradient.

   H_a: Low fire intensity (i.e., surface burn) will reduce the aboveground biomass of cattail and result in the release of lower nutrient concentrations compared to high fire intensity (i.e., root burn) that reduces both above- and below-ground cattail biomass. Primary determinants of intensity will be substrate moisture content and method of fire application. Sites higher on the hydrologic gradient will have drier substrates following drawdown, which will result in higher fire temperatures and greater oxidation of organic sediments and consumption of cattail rhizomes and litter compared to sites lower on the hydrologic gradient. Similarly, application of backing fires will be more intense than either head or flank fires. To standardize fire application, all prescribed fires applied in the study will be backing fires if possible.

2. Document the relationship between fire intensity (temperature) in relation to organic matter oxidation along a moisture gradient.

   H_a: Low fire intensity (i.e., surface burn) will result in only minimal release of bound nutrients from organic sediments compared to high fire intensity (i.e., root burn) that oxidizes sediments. A primary determinant of intensity will be substrate moisture content. Sites higher on the hydrologic gradient will have drier substrates following drawdown, which will result in higher fire temperatures and greater oxidation of organic sediments as well as cattail rhizomes and litter compared to sites lower on the hydrologic gradient.

3. Document differences among the above relationships when prescribed fire treatments are conducted at two different times during the annual cycle: (a) the period of minimum carbohydrate reserves in rhizomes (i.e., summer flowering) and (b) the period of maximum carbohydrate reserves in rhizomes (i.e., fall/winter dormancy).

H_a: Prescribed fires conducted during the onset of seed formation in summer (when nutrients are primarily in the aboveground portion of cattail biomass) will result in a 1) greater decrease in cattail biomass and cover in the following year; 2) longer cattail recovery time to pre-burn conditions (cover and biomass dominance); and 3) greater release of nutrients from cattail and organic sediments compared to prescribed fires conducted during fall (when nutrients are primarily in belowground biomass).

Following development of objectives, another site visit to NWRs was conducted during April 2005 to develop an approach for implementation. During this trip, members of the USFWS Branch of Fire became concerned about igniting fires in dry organic substrates. The Principal Investigators contacted the Region 3 Fire Ecologist (Tim Hepola), which resulted in the formation of a Region 3 Fire Working Group (hereafter Working Group) to assist the Principal Investigators in evaluating the feasibility of conducting the proposed research (Appendix D). On 31 May 2005, an abstract of the proposed study (Appendix E) was sent to the Regional Fire Ecologist along with a request that the Working Group assist the Principal Investigators in the "formulation of potential questions and problems that may arise from the use of prescribed fire in an impoundment environment along with formulating strategies and answers to these potential questions." Following a Working Group conference call (1 June 2005), the Principal Investigators received a letter (July 2005) from the branch of fire that expressed concern regarding the potential ignition of dry organic sediments due to issues of control, smoke management, cost, and safety. The letter requests that additional data (depth of peat and composition of levee material) be collected before ignition occurs and indicates that the branch of fire would be willing to conduct a “test burn” to evaluate potential risks. The Principal Investigators responded with a letter to the Working Group (August 2005) that (a) explains in more detail the biological rationale of conducting intense summer fires on dry organic substrates, (b) states that all pre-burn data requested by fire personnel will be collected to the extent possible, and (c) advocates conducting a test burn to better understand the risks associated with these types of fire (Appendix G). The Principal Investigators have suggested that this test burn be conducted on a single study wetland during summer (late June to July) of 2006. To emulate the environmental conditions that are of concern with respect to applying prescribed fire, soil moisture (as measured by moisture tension [MT]) in the organic sediment of the wetland selected should be between air dry (MT = 30 atmospheres tension) and the permanent wilting point (MT

= 15 atmospheres tension) to a depth of 50 cm. A complete list of parameters to be monitored will be determined prior to ignition and will include collection of the biological information that will be gathered as part of the full study (See Methods) as well as any pre-burn and post-burn data requested by the Branch of Fire. In addition, the following objective has been added to reflect that this study will assist the USFWS Branch of Fire in development of quantitative guidelines for evaluating risk of conducting prescribed fire on organic substrates.

4. Collect pre-burn data as requested by USFWS fire personnel to facilitate development of guidelines for the safe conduct of prescribed fires involving organic sediments.

Although a response from the Branch of Fire confirming willingness to implement the test burn has not yet been received, the Principal Investigators are assuming this will occur given the idea originally was developed by the Branch of Fire. **If this assumption is correct, a decision regarding full implementation of this study will be made following evaluation of the test burn by the Chief of Refuges for Regions 3 and 5, Branch of Fire personnel, Refuge Managers and Biologists, the Center Director and Ecosystems Branch Chief of Northern Prairie Wildlife Research Center (NPWRC), and the Principal Investigators.** If the decision is to implement the study, the following study design and methods will be used to collect the data necessary to meet the aforementioned objectives. If confirmation is not received, the Principal Investigators will organize additional meetings to determine the future of the study.

METHODS

Full implementation of the study will involve 2 wetlands on each of 5 NWRs that are representative of cattail-dominated wetland systems currently being managed with prescribed fire in USFWS Regions 3 and 5. These areas are Agassiz NWR, Horicon NWR, Sherburne NWR, Iroquois NWR, Tonawanda Wildlife Management Area (administered by the New York State Department of Environmental Conservation), and the Leopold Wetland Management Area. Wetlands on each area were selected based on the presence of cattail and recommendations of management staff relative to drawdown capability and willingness to apply prescribed fire. A single wetland (South Pool) on the Leopold Wetland Management Area has tentatively been selected as the site for conducting the test burn in July of 2006 pending approval by the Refuge Manager and USFWS Branch of Fire.

Study Design:

One wetland on each NWR will randomly be assigned to either a growing-season or dormant-season prescribed fire treatment that will be applied on the entire wetland. Growing-season burns will be conducted as close as possible to the time (typically July) when the color of cattail spikes indicates aboveground nutrient reserves are at their maximum (Linde et al. 1976), whereas dormant-season burns will be conducted in the fall (typically October-November) following full senescence. Following application of fire treatments, management will attempt to keep wetlands dry until the end of the next growing season to promote seed germination and facilitate data collection. Data pertaining to nutrient concentrations in various storage pools (organic sediment, vegetation; see below) will be collected at 3 times: immediately prior to prescribed fire, immediately following prescribed fire, and during the growing season one year following prescribed fire treatments at the time (mid-June to July depending on location) of maximum carbohydrate depletion in cattail rhizomes.

Regardless of prescribed fire treatment, the focus of the test burn, and the complete study, initially will consist of dewatering wetlands to facilitate drying of organic sediments that have accumulated in wetland basins. Thus, drawdowns on all wetlands will be conducted as early as possible in 2006 or, if already dewatered in 2005, will remain in drawdown status until the prescribed fire treatment is applied. Ideally, the target is to remove the surface water and the free water in the sediments to a depth that is equal to or below the cattail rhizosphere. However, it is unrealistic to assume that this degree of drying can occur on an entire wetland given uneven bathymetry, irregular patterns of sediment distribution, and an inadequate infrastructure to effectively and quickly remove water. Therefore, the physical characteristics of each wetland will be evaluated prior to conducting fire treatments to determine the general hydrologic gradient (wet to dry). This gradient subsequently will be used to stratify the wetland into 3 hydrologic zones of equal width, and 3 plots (6-m^2) will be randomly located in portions of the highest (upper 1/3) and lowest (lower 1/3) zones that support cattail (stratified-random). All plots will be permanently marked using aluminum conduit to aid relocation. Within each plot, we also will mark corners of 9 quadrats (2.0 m^2) with aluminum conduit and randomly assign each quadrat to different sampling techniques (Figure 1; see METHODS below). The middle zone will not be sampled because differences in sediment moisture conditions may be difficult to separate from the upper and lower zones.

Although hydrologic characteristics in different portions of the same basin are related, this relationship is not absolute because most wetlands in this study have infrastructures (e.g., levees) that were not constructed along natural hydrogeomorphic boundaries. Hence, wetlands encompass a range of elevations, hydrological influences, and soil properties. For example, the hydrology of a single wetland can be influenced by a combination of river flows, ground-water recharge and discharge, and pumping stations. These factors influence plant dynamics differentially within a leveed area, and variability within one of these wetlands may be as great as that among wetlands. This internal heterogeneity will result in differing responses to prescribed fire treatments. Therefore, each zone will be considered independent in the analysis.

Data Collection:

Physical Characteristics. — A total station global positioning system (GPS) will be used to survey the bathymetry of each wetland. During this survey, a push-rod will be used to estimate the depth (± 5 cm) of organic sediment overburden throughout the basin. Survey information will be processed to produce a 3-dimensional representation of the wetland surface as defined by mineral soil and the organic sediment distribution pattern, and overlaid with a map of cattail distribution created by delineating current cattail stands on an aerial photograph of the wetland. This composite representation will be used to delineate zones of the hydrologic gradient and randomly locate sample plots. In addition, the Branch of Fire has requested this information to prepare a burn plan that meets USFWS safety guidelines.

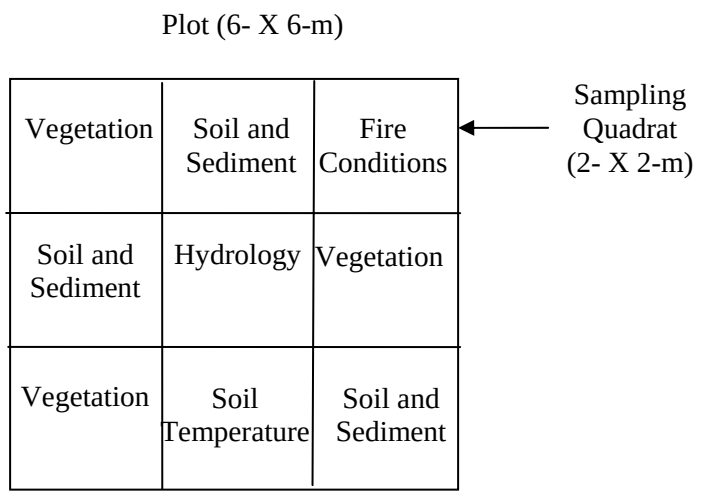

Figure 1. Sample plot schematic illustrating the random location of different sampling procedures.

Hydrology. — Sandpoint wells will be installed in the center quadrat of each plot to monitor the depth to groundwater as wetlands are dewatered (Tom Winter, USGS hydrologist, personal communication). Each well will be installed at a minimum depth of 250 cm or 20 cm below the primary cattail rhizosphere, whichever is deeper. In addition, moisture probes will be installed 100 cm to the north of the sandpoint well to monitor sediment moisture at the surface and at 25-cm increments to the depth of the cattail rhizosphere using a Time Domain Reflectance (TDR) instrument. Following evacuation of surface water from the wetland basin, ground-water wells and sediment moisture will be monitored weekly, immediately prior to and following application of the assigned prescribed fire treatment, weekly post-fire until the end of the growing season, and bi-weekly throughout the subsequent growing season to document the rise and fall of groundwater and soil moisture.

Soils and Sediment. — A 10-cm diameter soil core will be collected to a depth below the A horizon immediately prior to and following application of the assigned fire treatment, as well as at the end of the subsequent growing season. Because of the destructive nature of this sampling, a separate quadrat will be used for each sampling period. Cores will be evaluated in the field to determine the depth of the organic and A horizons. In addition, the physical characteristics and nutrient content of each horizon will be estimated during each sampling campaign by collecting 3 uncompressed soil samples from each horizon. Samples will be obtained by excavating a hole and inserting a stainless steel sampling ring horizontally into the soil at the midpoint of each horizon following established USGS protocols. Samples from each horizon will be composited, air-dried, and transported to a environmental chemistry laboratory to estimate bulk density and analyzed for total nitrogen, total phosphorus, total potassium, nitrate nitrogen, ammonium, total inorganic carbon, total organic carbon, and pH. All laboratory practices and analysis will be conducted to USGS standards and protocols. Finally, we will install a waterproof datalogger (iButtons®) 3 cm below the soil surface in a separate quadrat to record soil temperature during the course of the study.

Vegetation.— The depth of the primary cattail rhizosphere relative to the substrate surface and the biomass and nutrient content of the above- and below-ground portions of cattail will be estimated immediately prior to and following application of prescribed fire treatments and at the end of the subsequent growing season. During each sample period, biomass samples will be collected in 3 of the 2.0-m^2 quadrats using a 50-cm^2 sampling frame. All aboveground

cattail within the frame will be clipped and then sediment will be removed to locate all cattail rhizomes. We will record the minimum and maximum depth to which cattail rhizomes extended. Above-ground cattail biomass will be sorted into live and dead factions, whereas belowground cattail biomass will be washed to remove soil and other material. Factions from each of the 3 quadrats will be pooled into 1 composite sample per plot, placed in labeled bags, and transported to the environmental chemistry laboratory where samples will be oven-dried for 24 hr at 60 C, or until constant mass is achieved, and analyzed for total nitrogen, total phosphorus, total potassium, nitrate nitrogen, ammonium, total inorganic carbon, and total organic carbon.

Fire Conditions. — In addition to bathymetry and sediment depth data collected for development of prescribed fire plans, information specific to each prescribed fire will be collected as requested by the USFWS Branch of Fire. On the day of burning, data on fire application (e.g., use of head or flanking fire, nature and location of firebreaks), weather (wind speed, relative humidity, temperature), fire behavior (rate and pattern of spread, flame length, smoke production), and first-order fire effects (percent of area burned, post-burn severity and fuel consumption) will be collected following recommended procedures outlined in the Fire Monitoring Handbook (National Park Service 2001). In addition, we will monitor substrate temperature by installing dataloggers in 1 quadrat of each plot and collect a composite sample of cattail litter and live above-ground cattail from a 2.0-m^2 area adjacent to each plot that will be frozen prior to transport to the environmental chemistry laboratory to determine percent fuel moisture by comparing sample mass before and after drying at 60 C until constant mass is achieved. Within 2 weeks following fire application, wetlands will be revisited to visually estimate percent of the entire wetland and plots burned, aboveground biomass consumed, and distribution of burn pattern, following protocol of the National Parks Fire Monitoring Handbook. Within each plot, we also will rank burn severity for standing vegetation, litter, and substrate (National Park Service 2001). To estimate the amount of substrate burned at each plot, a piece of rebar will be driven into the substrate until it is flush with the existing surface at the corner of 4 quadrats. During the post-fire visit, the exposed length ($\pm$ 1 cm) of the spike will be recorded.

Data Analysis:

Repeated Measures Analysis of Variance (ANOVA) will be used to analyze the data collected as part of this study. The concentrations of nutrients at 3 times (pre-burn, post-burn, and 1 growing season post-burn) will be used as dependent variables to evaluate the effect of

prescribed fire on various storage pools (organic sediment, above-ground and below-ground factions of cattail). Independent classification variables will include refuge, time of prescribed fire (growing-season or dormant-season) and position in the hydrologic gradient (wet or dry). Sources of variation and error terms for the analyses are provided in Table 1.

Table 1. Sources of variation and errors associated with repeated measures Analysis of Variance. Blocks (refuges) are random effects, whereas all other variables are fixed effects.

Variation		
Source	df	Description
Block	4	Refuge (Agassiz, Sherburne, Horicon, Leopold, Iroqois/Tonawanda)
Treatment	1	Fire (growing-season or dormant-season prescribed fire)
Block*Treatment	4	
Zone	1	Hydrologic gradient (wet or dry)
Zone*Treatment	1	
Zone*Treatment*Block	17	
Time	2	Sample period (pre-burn, post-burn, and 1 yr post-burn)
Time*Treatment	2	
Time*Zone	2	
Time*Zone*Treatment	2	
Total	59	

WORK SCHEDULE:

Project duration: Fiscal years 2004 to 2008 (first phase).

Activities	2004	2005	2006	2007	2008
Conduct site visits and meetings to collaborate on project development, design and implementation	Mar-Apr	Jan-Dec	Jan-Dec		
Purchase equipment	Sep-Oct	Jan-Dec	Jan-Mar		
Develop new concept and prepare educational materials		Jan-Dec	Jan-Mar		
Initiate collection of baseline information		May-Oct	Mar-June		
Complete development of study plan		Sep-Oct			
Develop field sampling protocols		Oct-Dec	Jan-Mar		
[1] Conduct drawdowns on study wetlands		Oct-Dec	Jan-Oct		
Conduct test burn of South Pool at Uihlein			June-July		
[2] Apply prescribed fire treatments					
growing season			June-July		
dormant season			Oct-Nov		
Collect data related to prescribed fire			Jul-Nov	Jun-Nov	
Reflood study wetlands				Oct-Nov	
Process samples in laboratory			Aug-Dec	Aug-Dec	
Submit Annual Progress Report	Dec	Dec	Dec	Dec	Dec
Analyze data and prepare products					Jan-Jun

[1] Drawdowns on all study wetlands will be conducted as early as possible in 2006 or, if already dewatered in 2005, will remain in drawdown status until the prescribed fire treatment is applied.

[2] If weather conditions do not permit application of prescribed fires at designated times in 2006, attempts will be made to apply treatments at the appropriate time in 2007.

HAZARD ASSESSMENT

Field work will be conducted in dry and flooded wetlands on foot and in various watercrafts. Burning and most data-collection work will be conducted by U.S. Fish and Wildlife Service personnel, and they will follow appropriate agency safety requirements and training. All USGS staff will be equipped with personal flotation devices when working in and around water.

ANIMAL WELFARE CONCERNS

This study does not involve capture or handling of any animals.

EXPECTED PRODUCTS

Products include annual reports, periodic workshops, monitoring protocols, and scientific publications. Annual progress reports, reviewed and approved at NPWRC, will be submitted annually to Office of Chief Scientist, Chief of Refuges for Regions 3 and 5, and all participating refuges. A final report will be completed following completion of the project. During the course of the study, presentations will be given at workshops sponsored by the USFWS or at annual professional conferences. We will submit at least 1 manuscript for publication in a peer-reviewed journal.

METADATA COMPLIANCE OBJECTIVES

Metadata will be prepared in compliance with the NBII biological metadata standard, the Federal Geographic Data Committee's Content Standards for Digital Geospatial Metadata and Biological Resources Division Policy Issuance Number 8 following completion of the study.

COOPERATORS AND PARTNERS:

Raymond Roy, USGS, Northern Prairie Wildlife Research Center – Conducts or oversees the analyses of soil and nutrient analyses as required as part of the project.

Leigh H. Fredrickson, South Dakota State University – Contributes expertise on wetland ecology and refuge management issues.

Refuge Biologists – Establish sampling scheme; manage water levels; collect field data; and provide additional information relating to management actions or site conditions that affect the study.

Refuge Fire Management Officer and staff – Develop protocols for collection of pre-burn and post-burn data necessary to develop guidelines for conducting prescribed fires on organic substrates, apply fire treatments, and assist with data collection during burns.

BUDGET

FUNDS USED WITHIN USFWS	FY2004	FY2005	FY2006 [a]	FY2007 [b]	Fy2008 [c]
Personnel					
Crew leader (GS-7, 26PP)	21,120.00	38,069.00	39,592.00	41,176.00	0.00
Seasonal technicians (3 x GS-5, 13pp)	43,605.00	45,350.00	47,160.00	0.00	0.00
Seasonal technicians (3x GS-3, 11pp)	28,785.00	29,936.00	31,134.00	0.00	0.00
Travel	750.00	750.00	750.00	1,250.00	0.00
Equipment					0.00
Soil temps - hobotempH8 ($100 x 5/unit)	10,500.00	500.00	500.00	0.00	0.00
Fire temperature dataloggers	11,000.00	0.00	0.00	0.00	0.00
Water conductivity/pH meters ($400 x 3)	1,200.00	0.00	0.00	0.00	0.00
Benthic corer	60.00	0.00	0.00	0.00	0.00
GPS units (3)	1,200.00	0.00	0.00	0.00	0.00
Binoculars (1)	300.00	0.00	0.00	0.00	0.00
Supplies	9,175.00	1,000.00	4,000.00	1,000.00	0.00
Vehicle (fuel)	5,000.00	5,000.00	5,000.00	1,000.00	0.00
USFWS Total	**132,695.00**	**120,605.00**	**128,136.00**	**44,426.00**	0.00
FUNDS TO USGS-NPWRC					
Personnel (Grade: FY06, FY07, FY08)					
Laubhan (GS-13: 2 pp, 3 pp, 3 pp)			6,076.00	9,113.00	9,113.00
Euliss (GS-14: 2 pp, 3 pp, 3 pp)			6,962.00	10,443.00	10,443.00
Gleason (GS-12: 2 pp, 2 pp, 2 pp)			5,109.00	5,109.00	5,109.00
Roy (GS-13: 2 pp, 2 pp, 0 pp)			5,523.00	5,523.00	0.00
Mushet (GS-11: 1 pp, 1 pp, 1pp)			2,067.00	2,067.00	2,067.00
Tangen (Term: 4 pp, 0 pp, 0 pp)			7,776.00	0.00	0.00
Kermes (Term: 1 pp, 0 pp, 0 pp)			2,321.00	0.00	0.00
Transfer to USFWS Term Employee		58,674.00	58,674.00	58,674.00	0.00
Travel	1,000.00	3,000.00	2,000.00	2,000.00	0.00
Vehicle	750.00	750.00	1,500.00	1,450.00	0.00
Equipment	0.00	0.00	5,000.00	2,900.00	0.00
Supplies					
NPWRC Chemistry Lab (estimated)	0.00	0.00	6,000.00	3,000.00	0.00
SAS licenses	2,000.00	1,000.00	2,000.00	2,000.00	0.00
Other software	750.00	0.00	500.00	900.00	0.00
Laptop	1,500.00	0.00	0.00	0.00	0.00
Subtotal	**6,000.00**	**63,424.00**	**111,508.00**	**103,179.00**	**26,732.00**
Cost Center Overhead (4%, 5%, 6%, 7.5%)	240.00	3,171.20	6,690.48	7,738.43	2,004.90
Subtotal	**6,240.00**	**66,595.20**	**118,198.48**	**110,917.43**	**28,736.90**
Bureau Overhead (11%, 10%, 9%, 7.5%)	686.40	6,659.52	10,637.86	8,318.81	2,155.27
NPWRC TOTAL	**6,926.40**	**73,254.72**	**128,836.34**	**119,236.23**	**30,892.17**
GRAND TOTAL	**139,621.40**	**193,859.72**	**256,972.34**	**163,662.23**	**30,892.17**

[a] Based on FY 2006 BASIS+, BRD Headquarters cyclical funds in the amount of $119,265.00 are available; thus, and additional $9,572.00 of NPWRC funds will be required.

[b] Assumes the amount of BRD Headquarters cyclical funds available in FY 2006 will be available in FY2007.

[c] Costs incurred in FY2008 will be paid using NPWRC funds.

In-kind costs contributed by the USFWS are not reflected in the budget, but staff at each refuge will provide vehicles, logistical support (including supervision and field assistance while operating on site) and common field equipment (e.g., boats, personal flotation devices, and other safety equipment) that are already owned to perform normal refuge operations. Costs for burning wetlands in this study are based on an average cost of $49/acre (0.405 ha; USFWS Region 3, Regional Fire Management Officer). Conducting prescribed fires for the purpose of this study should not result in any additional costs, but would require a shift in development of annual burn plans because the areas burned in this study would replace an equivalent area burned elsewhere on each refuge. Finally, during our discussions with refuge staff, both agencies recognize that refuge staff will likely seek additional funding to support seasonal assistance (volunteer or technician) to support data collection each year.

LITERATURE CITED

Apfelbaum, S. I. undated. Cattail (*Typha* spp.) management. Source unknown, Applied Ecological Services, Brodhead, Wisconsin.

Auclair, A. N. D. 1977. Factors affecting tissue nutrient concentrations in a *Carex* meadow. Oecologica 28:233-246.

Baker, L. A. 1992. Introduction to nonpoint source pollution in the United States and prospects for wetland use. Ecological Engineering 1:1-26.

Ball, J. P., and T. D. Nudds. 1989. Mallard habitat selection: experiments and implications for management. Pages 659-671 *in* R. R. Sharitz and J. W. Gibbons, editors. Freshwater wetlands and wildlife. U. S. Department of Energy Symposium Series 61.

Bedinger, M. S. 1979. Relation between forest species and flooding. Pages 427-435 *in* P. C. Greeson, J. R. Clark, and J. E. Clark, editors. Wetland functions and values: the state of our understanding. American Water Resources Association Technical Publication 79-2.

Bedish, J. W. 1967. Cattail moisture requirements and their significance to marsh management. American Midland Naturalist 78:288-300.

Bellrose, F. C., and L. G. Brown. 1941. The effect of fluctuating water levels on the muskrat population of the Illinois River Valley. Journal of Wildlife Management 5:206-212.

Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Wisconsin Department of Natural Resources Technical Bulletin 112.

Bonnewell, V., W. L. Koukkari, and D. C. Pratt. 1983. Light, oxygen and temperature requirements for *Typha latifolia* seed germination. Canadian Journal of Botany 61:1330-1336.

Bornette, G., C. Amoros, H. Piegay, J. Tachet, and T. Hein. 1998. Ecological complexity of wetlands within a river landscape. Biological Conservation 85:35-45.

Botto, J. G., and W. H. Patrick. 1978. Role of wetlands in the removal of suspended sediments. Pages 479-489 *in* P. C. Greeson, J. R. Clark, and J. E. Clark, editors. Wetland functions and values: the state of our understanding. American Water Resources Association Technical Publication 79-2.

Comstock, J. P., and J. R. Ehleringer. 1992. Plant adaptation in the Great Basin and Colorado Plateau. Great Basin Naturalist 52:195-215.

Dieter, C. D. 1991. Water turbidity in tilled and untilled prairie wetlands. Journal of Freshwater Ecology 6:185-189.

Diiro, B. W. 1982. Effects of burning and mowing on seasonal whitetop ponds in southern Manitoba. M.S. thesis, Iowa State University, Ames, Iowa, USA.

Dobrowolski, J. P., M. M. Caldwell, and J. H. Richards. 1990. Basin hydrology and plant root systems. Ecological Studies 80:243-292.

Duffy, C. J., and S. Al-Hassan. 1988. Groundwater circulation in a closed desert basin: topographic scaling and climatic forcing. Water Resources Research 24:1675-1678.

Eakin, T. E., D. Price, and J. R. Harrill. 1976. Summary appraisals of the nation's groundwater resources – Great Basin Region. U. S. Geological Survey, Professional Paper 813-G, Washington, D.C.

Fassett, N. C. 1957. A manual of aquatic plants. University of Wisconsin Press, Madison, Wisconsin.

Faulkner, S. P., and A. A. de la Cruz. 1982. Nutrient mobilization following winter fires in an irregularly flooded marsh. Journal of Environmental Quality 11:129-133.

Flores, C. 2003. Evaluation of vegetative response to fire exclusion and prescribed fire rotation on Blackwater National Wildlife Refuge and Fishing Bay Wildlife Management Area. M.S. thesis. University of Maryland Eastern Shore, Princess Ann, Maryland, USA.

Fredrickson, L. H., and M. K. Laubhan. 1994. Managing wetlands for wildlife. Research and management techniques for wildlife and habitats. Fifth edition. The Wildlife Society, Bethesda, Maryland.

Gambrell, and W. H. Patrick, Jr. 1978. Chemical and microbiological properties of anaerobic soils and sediments. Pages 375-423 *in* D. D. Hook and R. M. M. Crawford, editors. Plant life in anaerobic environments. Scientific Publications, Ann Arbor, Michigan.

Giltz, M. L., and W. D. Myser. 1954. A preliminary report on an experiment to prevent cattail die-off. Ecology 35:418.

Gleason, R. A, and N. H. Euliss, Jr. 1998. Sedimentation of prairie wetlands. Great Plains Research 8:97-112.

Gleason, R. A., N. H. Euliss, Jr., and C. W. Holmes. 2003. Sedimentation rates in the marshes of Sand Lake National Wildlife Refuge. Quick Response Project QR-F6-00-07.

Grace, J. B. 1987. The impact of preemption on the zonation of two *Typha* species along lakeshores. Ecological Monographs 57:283-303.

Grace, J. B. 1988. The effects of nutrient additions on mixtures of *Typha latifolia* L. and *Typha domingensis* Pers. along a water-depth gradient. Aquatic Botany 31:83-92.

Grace, J. B. 1989. Effects of water depth on *Typha latifolia* and *Typha domingensis*. American Journal of Botany 76:762-768.

Grace, J. B., and R. G. Wetzel. 1981. Habitat partitioning and competitive displacement in cattails (*Typha*): experimental field studies. American Naturalist 118:463-474.

Grace, J. B., and R. G. Wetzel. 1982. Niche differentiation between two rhizomatous plant species: *Typha latifolia* and *Typha angustifolia*. Canadian Journal of Botany 60:46-57.

Grace, J. B., and R. G. Wetzel. 1998. Long-term dynamics of *Typha* populations. Aquatic Botany 51:137-146.

Harris, S. W., and W. H. Marshall. 1963. Ecology of water-level manipulation on a northern marsh. Ecology 44:331-343.

Hartleb, C. F., J. D. Madsen, and C. W. Boylen. 1993. Environmental factors affecting seed germination in *Myriophyllum spicatum* L. Aquatic Botany 45:15-25.

Hayden, A. 1939. Notes on *Typha angustifolia* L. in Iowa. Iowa State College Journal of Science 13:341-351.

Hupp, C. R. 2000. Hydrology, geomorphology, and vegetation of Coastal Plain rivers in the southeastern USA. Hydrological Processes 14:2991-3010.

Johnson, W. C. 2000. Tree recruitment and survival in rivers: influences of hydrological processes. Hydrological Processes 14:3051-3074.

Jurik, T. W., S.-C. Wang, and A. G. van der Valk. 1994. Effects of sediment load on seedling emergence from wetland seed banks. Wetlands 14:159-165.

Kadlec, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267-281.

Kadlec, J. A. 1982. Mechanisms affecting salinity of Great Salt Lake marshes. American Midland Naturalist 107:82-94.

Kantrud, H. A. 1986. Effects of vegetation manipulation on breeding waterfowl in prairie wetlands – a literature review. U.S. Fish and Wildlife Service Technical Report 3. Washington, D.C., USA.

Kaminski, R. M., and H. H. Prince. 1981. Dabbling duck activity and foraging responses to aquatic macroinvertebrates. Auk 98:115-126.

Krattinger, K. 1975. Genetic mobility in *Typha*. Aquatic Botany 1:57-70.

Krull, J. N. 1970. Aquatic plant –macroinvertebrate associations and waterfowl. Journal of Wildlife Management 34:707-718.

Kuenzler, E. J. 1990. Wetlands as sediment and nutrient traps for lakes. Pages 105-112 *in* J. Taggart, editor. Enhancing the States' Lake and Wetland Management Programs. U. S. Environmental Protection Agency, North American Lake Management Society, Northeastern Illinois Planning Commission, Proceedings of a National Conference, Chicago, Illinois.

Kullberg, R. G. 1974. Distribution of aquatic macrophytes related to paper mill effluents in a southern Michigan stream. American Midland Naturalist 91:271-281.

Laing, H. E. 1940a. Respiration of the rhizomes of *Nuphar advenum* and other water plants. American Journal of Botany 27:574-581.

Laing, H. E. 1940b. Respiration of the leaves of *Nuphar advenum* and *Typha latifolia*. Ibid 27:583-586.

Laing, H. E. 1941. Effect of concentrations of oxygen and pressure of water upon rhizomes of some submerged water plants. Botanical Gazette 102:712-724.

Laubhan, M. K. 1995. Effects of prescribed fire on moist-soil vegetation and soil macronutrients. Wetlands 15:159–166.

Laubhan, M. K., and J. E. Roelle. 2001. Managing wetlands for waterbirds. Pages 387-411 *in* R. B. Rader, D. P. Batzer, and S. Wissinger, editors. Biomonitoring and management of North American freshwater wetlands. John Wiley and Sons, New York, New York.

Linde, A. F. 1969. Techniques for wetland management. Wisconsin Department of Natural Resources Research Report 45.

Linde, A. F., T. Janisch, and D. Smith. 1976. Cattail -- the significance of its growth, phenology and carbohydrate storage to its control and management. Wisconsin Department of Natural Resources Technical Bulletin 94.

Livingston, R. J., and O. L. Loucks. 1979. Productivity, trophic interactions, and food web relationships in wetlands and associated systems. Pages 101-119 *in* P. E. Greeson, J. R. Clark, and J. E. Clark, editors. Wetland functions and values: the state of our understanding. American Water Resources Technical Publication 79-2.

MacNab, J. 1983. Wildlife management as scientific experimentation. Wildlife Society Bulletin 11:397–401.

McDonald, M. E. 1955. Cause and effects of a die-off of emergent vegetation. Journal of Wildlife Management 19:24-35.

Meeks, R. L. 1969. The effect of drawdown date on wetland plant succession. Journal of Wildlife Management 33:817-821.

Mitsch, W. J., and J. G. Gosselink. 2000. Wetlands. Third edition. John Wiley and Sons, Inc., New York, New York, USA.

National Park Service. 2001. Fire monitoring handbook. National Interagency Fire Center, Boise, Idaho.

Newcombe, C. P., and D. D. MacDonald. 1991. Effects of suspended sediments on aquatic ecosystems. North American Journal of Fisheries Management 11:72-82.

Penfound, W. T., R. F. Hall, and A. D. Hess. 1945. The spring phenology of plants in and around the reservoirs in northern Alabama with particular reference to malaria control. Ecology 26:332-352.

Robel, R. J. 1961. Water depth and turbidity in relation to growth of sago pondweed. Journal of Wildlife Management 25:436-438.

Rybicki, N. B., and V. Carter. 1986. Effect of sediment depth and sediment type on the survival of *Vallisneria americana* Michx grown form tubers. Aquatic Botany 24:233-240.

Saucier. R. T. 1994. Geomorphology and quaternary geological history of the Lower Mississippi Valley. Volumes I and II. U. S. Department of the Army, U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Schmalzer, P. A., and C. R. Hinkle. 1993. Effects of fir on nutrient concentrations and standing crops in biomass of *Juncus roemerianus* and *Spartina bakeri* marshes. Castanea 58:90–114.

Schmalzer, P. A., and C. R. Hinkle. 1992. Soil dynamics following fire in *Juncus* and *Spartina* marshes. Wetlands 12:8–21.

Sifton, H. B. 1959. Germination of light-sensitive seeds of *Typha latifolia*. Canadian Journal of Botany 37:719-739.

Sinclair, A. R. E. 1991. Science and the practice of wildlife management. Journal of Wildlife Management 55:767–782.

Smith, L. M., and J. A. Kadlec. 1985a. Fire and herbivory in a Great Salt Lake marsh. Ecology 66:259–265.

Smith, L. M., and J. A. Kadlec. 1985b. Comparison of prescribed burning and cutting of Utah marsh plants. Great Basin Naturalist 45:462–466.

Sojda, R. S., and K. S. Solberg. 1993. Management and control of cattails. U.S. Fish and Wildlife Service, Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.13.

Squires, L., and A. G. van der Valk. 1992. Water-depth tolerances of the dominant emergent macrophytes of the Delta Marsh, Manitoba. Canadian Journal of Botany 70:1860-1867.

Szczepanska, W., and A. Szczepanski. 1976. Growth of *Phragmites communis* Trin., *Typha latifolia* L., and *Typha angustifolia* L. in relation to the fertility of soils. Archives of Hydrobiologia 23:233-248.

Taylor, K. L., J. B. Grace, G. R. Guntenspergen, and A. L. Foote. 1994. The interactive effects of herbivory and fire on an oligohaline marsh, Little Lake, Louisiana, USA. Wetlands 14:82–87.

Thompson, D. J., and J. M. Shay. 1985. The effects of fire on *Phragmites australis* in the Delta Marsh. Canadian Journal of Botany 63:1864–1869.

Truax, W. C., and L. F. Gunthier. 1951. The effectiveness of game management techniques employed on Horicon Marsh. North American Wildlife Conference 16:326-330.

Uhler, F. M. 1944. Control of undesirable plants in waterfowl habitat. Transactions of the North American Wildlife Conference 9:295-303.

Ulrich, K. E., and T. Burton. 1988. An experimental comparison of the dry matter and nutrient distribution patterns of *Typha latifolia* L., *Typha angustifolia* L., *Sparganium eurycarpum* Engelum, and *Phragmites australis* (Cav.) Trin. Ex Steudel. Aquatic Botany 32:129-139.

Ulrich, R. A., and F. K. Pfeifer. 1976. Limnological survey of the Souris River and its major tributaries in North Dakota; October 1975. U. S. Fish and Wildlife Service, Division of Fishery Services, Bismarck Area Office, Bismarck, North Dakota.

van der Valk, A. G. 1981. Succession in wetlands: a gleasonian approach. Ecology 62:688-696.

van der Valk, A. G., and C. H. Welling. 1988. The development of zonation in freshwater wetlands: an experimental approach. Pages 145–158 *in* H. During, M. Werger, and J. Willems, editors. Diversity and Pattern in Plant Communities. Academic Publishing, The Hague, Netherlands.

Wang, S.-C., T. W. Jurik, and A. G. van der Valk. 1994. Effects of sediment load on various stages in the life and death of cattail (*Typha X Glauca*). Wetlands 14:166-173.

Ward, E. 1942. Phragmites management. North American Wildlife Conference 7:294–298.

Weisner, S. E. B. 1993. Long-term competitive displacement of *Typha latifolia* by *Typha angustifolia* in a eutrophic lake. Oecologia 94:451-456.

Weller, M. W. 1999. Wetland birds: habitat resources and conservation implications. Cambridge University Press, Cambridge, United Kingdom.

Weller, M. W., and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Agriculture and Home Economics Experiment Station, Department of Zoology. Entomology Special Report 43, Iowa State University, Ames, Iowa.

Weller, M. W., and L. H. Fredrickson. 1974. Avian ecology of a managed glacial marsh. The Living Bird 12:269-291.

Wharton, C. H., W. M. Kitchens, E. C. Pendleton, and T. W. Sipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. U. S. Fish and Wildlife Service, Biological Services Program, FWS/OBS-81/37.

Wilbur, R. B., and N. L. Christensen. 1983. Effects of fire on nutrient availability in a North Carolina pocosin. American Midland Naturalist 110:56–61.

Williams, W. D., A. J. Boulton, and R. G. Taaffe. 1990. Salinity as a determinant of salt lake fauna: a question of scale. Hydrobiologia 197:257-266.

REVIEW:

Principal Investigator	Date
Branch Chief	Date
Chair, Research Advisory Committee	Date
Chair, Animal Care and Use Committee	Date
Center Director	Date

Appendix A

2004 Progress Report: Interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes

The first year of this project presented challenges that slowed progress, but ultimately will improve the study. Considerable effort was expended to develop an approach to evaluate the efficacy of using prescribed fire to control cattail. The initial goal was to develop information necessary to improve fire planning by simultaneously quantifying the effect of fire on all primary wetland food web components. Thus, the study was designed to compare various attributes of the vegetation, invertebrate, and waterbird communities in response to two fire treatments (dormant and growing season burns). Given that changes at higher trophic levels (e.g., vertebrates, invertebrates) are marked by shifts of nutrients (e.g., carbon, nitrogen), our approach also involved documenting nutrient stores in primary pools (e.g., soils, invertebrates, plant rhizomes, plant leaf matter) before and after prescribed fire to facilitate understanding the effects of fire in more detail. Two field trips were conducted to identify study sites at Iroquois, Horicon, Sherburne, and Agassiz National Wildlife Refuges (NWR's), the Uihlein Waterfowl Production Area (Leopold Wetland Management District), and Tonawanda Wildlife Management Area. A study plan was submitted for final approval by the Northern Prairie Wildlife Research Center's (NPWRC) Research Advisory Committee, sampling protocols were developed, and a test sample plot was established at the Horicon NWR. Equipment needed for the project also was purchased. At the beginning of FY05 (October 4, 2004), the Director of NPWRC assigned the responsibility for scientific leadership of the project to Chip Euliss and Murray Laubhan. Euliss and Laubhan visited the sites previously selected for study to assess their suitability and discuss objectives with State and U.S. Fish and Wildlife Service (FWS) staff involved with the study. During this trip, Kari Odefey (FWS) provided valuable insight regarding challenges encountered during the first 2 field trips. With the exception of sites selected at Iroquois NWR, it was determined that existing water management capabilities on the remaining study wetlands were inadequate to sufficiently dry substrates. Further, the inability to dry marsh substrates was exacerbated by deep organic mats under dense cattail stands. The combination of summer rainfall and the movement of water into the organic mat appear to be sufficient to keep substrates beneath cattail saturated. Thus, although sound, the original study design may be inadequate to demonstrate a measurable effect on the fire treatments being evaluated. This problem was discussed at length during the field trip, with personnel at the refuges, and with our co-investigator, Soch Lor (FWS). In addition, discussions to resolve this obstacle were initiated at a meeting with FWS Regional Office (Region 3) personnel in December and again via a conference call with FWS personnel from both FWS Region 3 and Region 5 personnel in January. Results of these discussions include the need to reevaluate the questions to be addressed and identifying means to adequately dewater study sites. Thus, we have scheduled a meeting of all participating refuges and regional office personnel for 23 February 2005 to address these questions. The focus will be on methods to dewater study wetlands to an extent that fire treatments can be applied to provide management information to the FWS. If necessary, we will modify the existing study plan to improve the applicability of results to refuges.

Appendix B

Interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes: a study update

Introduction:

In the conterminous United States, refuges are small, scattered, and embedded within a larger landscape that has been greatly modified by past land use and management. Modern technology has contributed to this disruption by increasing the ability to rapidly and extensively alter landscapes. Land use alterations were readily apparent during a recent visit to refuge lands (Horicon, Iroquois, Leopold, Agassiz, and Sherburne) that have agreed to participate in the joint USGS-FWS fire science project. Numerous levees, ditches, diversion channels, and water control structures have been constructed to manipulate the hydrology of wetlands in an attempt to capture water and provide resources to wildlife. However, these actions also have altered fundamental processes that determine the structure and function of refuge wetlands. Although compromising processes may provide abundant resources for target organisms in the short-term, research and monitoring programs have documented that significant challenges typically develop in the long-term. In many cases, these challenges are not recognized until severe changes in flora or fauna are detected and management goals consistently are not attained. In the case of the refuges participating in the proposed study, declines in the diversity and abundance of waterbirds have been attributed to an overabundance of cattail. Attempts to control cattail have included the use of fire, herbicides, mechanical actions, and construction of additional levees and ditches to further alter hydrology. These actions have required a significant investment in fiscal and human resources, but long-term control of cattail largely has been ineffective. Thus, many of these strategies must be applied on a recurring basis of 2-4 years, which further increases costs. In most cases where success has been reported, the results are short-lived and cattail often is converted to large expanses of open water that only marginally improves wildlife value (Beule 1979).

Review of Existing Information:

A viable cattail control program requires (1) development of explicit objectives regarding what is to be achieved and (2) application of techniques that are matched with current conditions in relation to the autecology of cattail. Explicit objectives are critical to success because it is imperative that both management and research agree on the intended objectives of management and the steps necessary to achieve success. Research has no authority or right to develop objectives; thus, the primary role of these individuals is to assist management by providing unbiased, factual guidance relative to the stated objective. Based on this principle, previous research on wetland ecology suggests managers must not only evaluate management actions in terms of short-term wildlife objectives but also the long-term objectives related to sustainable productivity. In the case of cattail, much research has been conducted on the value of hemi-marshes (e.g., Weller and Spatcher 1965, Weller and Fredrickson 1974, Kaminski and Prince 1981). However, the context under which these research projects were conducted differs. In a spatial context, much of the data was collected in landscapes where the hydrologic regime of semipermanent marshes was disrupted. In a temporal context, some of the research was conducted immediately following a dry cycle, whereas later research was conducted during portions of the wet cycle. Thus, although results indicate bird diversity was greatest with 40-60% emergent cover, no information was collected regarding finer scale attributes that subsequent research has shown to be important (e.g., nutrients, invertebrates). Since these original articles were published, there is much information supporting the claim that hemi-marsh conditions provide structural requirements for a diversity of waterbirds. However, it is also evident from this research that (1) the value of hemi-marshes depends on which wildlife species are of interest, and (2) attempting to maintain the structural conditions of a hemi-marsh over the long-term leads to arresting the wetland cycle, which results in lowered bird use due to lowered productivity (e.g., food web dynamics). Thus, the role of management (e.g., water level manipulations, fire) is to balance providing resources to wildlife with maintaining wetland productivity. This example identifies the need to integrate all information (abiotic and biotic) when making management

decisions to avoid creating conditions that gradually cause changes in processes that are costly and difficult to remedy.

Given the above information, explicit objectives relating to cattail must not only include the desired amount and interspersion of cattail, but also other conditions that influence wetland productivity and, ultimately, waterbird diversity and use. Examples that pertain to the refuges involved in the joint fire science project include altered sediment dynamics and water chemistry parameters that indirectly influence wildlife values (e.g., diversity, abundance) by effecting plant and invertebrate composition and structure (see below). These abiotic factors often are those that require manipulation by land managers if control strategies are to be successful. Adopting this perspective does not negate the need to understand wildlife ecology. Rather, wildlife information should be integrated with process-level information. In contrast, failure to address these fundamental shifts in abiotic conditions likely will prevent prescribed fire, or any other single management action, from achieving desired results. Thus, these considerations must be incorporated into any strategy that is developed.

In the context of this research project, incorporation of altered environmental conditions into strategy development is best accomplished by considering the autecology of cattail. This approach facilitates understanding the potential effects of environmental alterations in relation to the challenge being addressed. However, direct measurements of environmental change often are lacking; thus, assessing change often requires considering changes in relation to historic conditions. This may appear unnecessary, but previous research indicates understanding the form and historical context of landscapes is crucial to understanding ecosystems on several temporal and spatial scales (Jensen et al. 1996, Swanson et al. 1988).

It has long been recognized that cattail is a dominant, persistent emergent plant that frequently colonizes wetland habitats. Historically, the extent of cattail in a given basin varied from nonexistent to dominating the entire basin. Cattail often formed large communities in the littoral zone of wetlands and played an important role in littoral ecosystems (Krattinger 1975), including the provision of breeding habitat for many waterbird species and improvement of air and water quality. However, the type and magnitude of these values varied depending on the extent of cattail cover. For example, the greatest bird diversity typically occurs when the interspersion of water and emergent cover is approximately 50:50, whereas cattail cover above about 80% supports fewer species, likely because dense cattail growth and litter may reduce the opportunity for other plants to establish or survive.

Factors determining the extent of cover include hydrology, often coupled with fire and herbivory. Typically, cattail colonizes a new environment via seeds. An average broad-leaved cattail spike can produce 250,000 seeds, of which 125,000 are capable of producing new plants (Claassen 1921). In addition, as many as 1,000 seeds/m^2 may exist in the upper few inches of soil, viability can approach 100% in the year after production, and seeds in the seed bank can remain viable for as long as 100 years (Sojda and Solberg 1993). Thus, the reproductive potential of cattails is enormous. Conditions for germination include high temperature (35° C), low oxygen concentration (2.3 to 4.3 mg/L in oxygen in water), and long light exposure (>10 h exposure of red light) (Bonnewell et al 1983, Sifton 1959). These conditions most often occur during drought periods when bare mudflats are exposed because shallow water warms more quickly than deep water; saturated soils have reduced oxygen concentrations; and natural light filters (vegetation and water) are absent or reduced (Kadlec 1962, Harris and Marshall 1963, Meeks 1969). Numerous wetlands inspected during the site visit exhibit accretion of sediment. The effect of sedimentation on cattail dynamics vary depending on antecedent conditions (e.g., soils) and stage of plant growth. For example, sediment additions as small as 0.25 cm exhibit only minimal effects on mature cattail; however, such additions can significantly reduce cattail seedling emergence and actually may enhance survivorship of older, larger seedlings (Jurik et al. 1994).

Sexual reproduction (i.e., seed) is important for colonization (McNaughton 1968), but colonies are maintained by vegetative reproduction (i.e., rhizomes) (Wang et al. 1994). Growth dynamics depend on water depth (Grace and Wetzel 1981, 1982; Grace 1988, 1989), nutrient conditions (Ulrich and Burton

1988), and competition with other species (Grace and Wetzel 1981, 1998; Grace 1987, 1988, 1989; Weisner 1993). Again, past alterations on refuges participating in the joint fire science project also must be considered in relation to these factors. For example, past alterations have increased the accretion of sediment on many refuges, which alter nutrient dynamics because sediment has the potential to bind and store large amounts of nutrients. In fact, nutrient loadings in large sections of Horicon Marsh substantially exceed amounts required to achieve nutrient enrichment and exceed the permanent soil storage capacity of phosphorous (Browne 2001). The extent of nutrient enrichment in other refuge wetlands is not known, but given the location of most refuges in river floodplains and the degree of human disruption, some alterations are likely. The effects of nutrient enrichment on cattail growth dynamics can be dramatic. For example, the biomass of broad-leaved and narrow-leaved cattail was enhanced 50-170% and 60-150%, respectively, following nutrient addition (Grace 1988). Similarly, the biomass of both species was three to five times greater when grown in 100% than 12.5% eutrophic mud (Szczepanska and Szczepanski 1976). Under ideal conditions, growth can be extremely vigorous. For example, 98 vegetative shoots and 104 crown buds were produced on a single greenhouse grown cattail seedling the first year (Timmons et al. 1963 in Apfelbaum undated) and Fassett (1957) stated that a clone which is an acre in size may consist of only a few plants. Further, cattail does not reach an age where vigor declines because plants grow by continuous renewal of rhizomes, and any specific rhizome never reaches an age of more than 2 years (McDonald 1955). Finally, although not confirmed, cattail growth also may be enhanced by a toxin (i.e., allelopathy) that causes declines in other species with increasing cattail cover (van der Valk and Davis 1978, Szczepanska 1971, McNaughton 1968).

Following establishment, cattail is capable of growth and survival under a wide range of environmental conditions and eventually can form monocultures. For example, the above and below ground seasonal crop of 1,852 individual cattail stems was estimated at 15 tons/acre in a Wisconsin wetland (Klopatec 1974). This capability largely is due to two primary adaptations: rhizomes and arenchyma cells. Rhizomes not only function as the primary means of vegetative propagation, but also act as the principal area of carbohydrate storage. Old rhizomes produced during previous growing seasons seem to be the principal storage organs (primarily starch), but the current years growth also stores carbohydrates. Under normal growing conditions, these reserves are accumulated during growing season, stored through winter, and mobilized the following spring to facilitate new shoot development. Previous research has documented the cycle of energy storage in cattail using total non-structural carbohydrates (TNC), which is a measure of carbohydrate energy readily available to plants. During the early stages of growth in spring, carbohydrate reserves are depleted for a short period as carbohydrates are mobilized for initial shoot growth. The period when the first leaf separates from leaf bundles represents another period of lowered TNC reserves, but recovery occurs as new photosynthetic area is developed. However, as rhizome buds form and fruiting heads begin to develop (mid- to late summer), the growth rate of cattail increases more rapidly than carbohydrates can be manufactured and translocated. This is the period of maximum depletion when cattail is most susceptible to injury.

Rhizomes require oxygen to survive, but only low concentrations are necessary and shoots are capable of enduring anaerobic conditions for up to 13 days during dormancy (Linde et al. 1976). Atmospheric oxygen is transferred to rhizomes via arenchyma cells that are present in both rhizomes and shoots. Further, aerenchyma cells remain functional in dead as well as living leafs, and it is thought that a single leaf can provide sufficient oxygen to rhizomes within a radius of a few feet (Sojda and Solberg 1993). Consequently, cattail is capable of obtaining oxygen even under flooded conditions as long as water depth does not exceed shoot height for extended periods. When conversion of starches occurs under aerobic conditions, the depth of water that cattail shoots can penetrate is virtually unlimited because large stores of energy for initiating shoot growth are available. In contrast, when conversion of starches occurs anaerobically, less energy is available and cattail mortality may occur (Sojda and Solberg 1993). However, due to aerenchyma cells, anaerobic conditions are only achieved when all shoots are under water.

Historically, cattail mortality or partial dieback occurred primarily due to climatic extremes (drought, flood), and to a lesser extent muskrat herbivory, fire, or a combination of these factors (Hayden 1939, Penfound et

al. 1945, Uhler 1944, Bellrose and Brown 1941, Laing 1940a, b, 1941, Giltz and Myser 1954, Weller and Spatcher 1965, Bedish 1967). The mechanisms leading to mortality or dieback following these events likely is related to prolonged energy depletion of rhizomes. However, attempts to simulate these effects by artificially manipulating water levels, using prescribed fire, and employing various herbivores (e.g., cattle, muskrat) have resulted in widely varying results. The reasons for these disparities are unknown, but one possible explanation is that treatments were applied to cattails without consideration of important physiological traits. For example, is has been documented that the effectiveness of cattail control by all mechanical means was more a function of the relationship between water depth and height at which cattails were cut than the methodology used (Apfelbaum undated). Thus, the effectiveness of any control strategy (water, fire, herbivory, disking) is likely dependent on the extent of coverage (all or just a portion of a stand, flooding extends above shoots or not above shoots) and the quantity of stored starches in rhizomes.

Approach:

Although cattail is persistent, spreads aggressively, and has tremendous reproductive potential, control can be achieved if treatments are based on cattail phenology and physiology. However, for a strategy to control cattail it must be capable of stressing the plant for a sufficient period to deplete energy stores and minimize the ability of the plant to develop new photosynthetic surfaces capable of producing and replenishing energy stores. In many cases, however, applications of techniques known to hamper cattail photosynthesis are not feasible due to past land use modifications. First, extensive development of physical structures (e.g., levees, channels, ditches) on many refuge wetlands has altered hydroperiod in a manner that has inadvertently enhanced conditions suitable for cattail germination while simultaneously negating natural processes that controlled growth, expansion, and mortality. For example, numerous wetlands cannot be dewatered to the extent that soils at the depth of the cattail rhizosphere are dry. Concomitantly, many wetlands cannot be flooded to depths that overtop existing cattail shoots (> 8-10 ft) for an entire growing season either because water availability is limited or the infrastructure (levees, control structures) is not designed properly. For example, the general rule is to maintain 3-4 ft of water over the tops of existing shoots in spring (Sojda and Solberg 1993). Thus, in excess of 14 ft of water may be required to effectively use flooding to control cattail in some of the wetlands inspected. Consequently, the ability to simulate either extreme drought or flood conditions is not possible. Further, any attempt to dewater these wetlands likely will result in the creation of mudflat conditions that stimulate germination of cattail seed from the seed bank. Second, these modifications also have resulted in relatively large accumulations of sediment that are high in organics and tend to retain high levels of moisture; thus, the capability of drying wetlands is further constrained. Further, the addition of sediment likely has increased nutrient loading that further enhances the growth and biomass production of existing cattail stands.

Overcoming these challenges on refuges participating in this study will require the use of multiple strategies, one of which must be hydrologic manipulation. Given the inability to sustain water levels at depths that exceed the height of existing cattail for an entire growing season, flooding is not a viable option because anaerobic conditions cannot be achieved. Similarly, with the exception of wetlands on Iroquois NWR, it also is not possible to dry wetland soils to the depth of existing cattail rhizomes. Thus, neither severe flood nor drought events can be simulated. Thus, it also is unlikely that fire, herbivory, or any mechanical action will be effective in the long-term because cattail regrowth would be rapid following treatment.

Given this perspective, existing water management capabilities must be improved to the extent that either prolonged flood or drought can be simulated. Simulation of prolonged flooding would require enhancing the ability to store water in wetlands. Although technologically feasible, this action has several limitations. First, if flooding was used to control cattail, a subsequent drawdown would still be required to stimulate germination of plants from the seed bank. If this drawdown was not implemented, the result would be the conversion of cattail to open water, which still would not achieve the desired objective of providing quality waterbird habitat. Thus, improvements in drainage capabilities also would be required. Second, this action would be cost prohibitive because levee height would have to be increased and existing water control

structures would have to adjusted or replaced. Third, it may be difficult to obtain sufficient water rights to ensure that water depths can be maintained above cattail shoots throughout one or more growing seasons.

In contrast, enhancing current capabilities to remove subsurface water from wetlands seems more plausible and beneficial. First, the technological means (machines, material) of removing subsurface water has advanced greatly in recent years. Second, installation of this system would enable control strategies to be implemented in a single year, rather than attempting to achieve dry conditions over a period of several years. This would not only improve reliability of application, but it also would reduce management costs. Third, a subsurface drainage system would enable soil moisture levels to be manipulated; thereby improving the ability to promote germination of more diverse plant species and also discourage cattail germination. Fourth, the ability to dry surface soils would enhance oxidation and removal of some sediment that has accumulated. Fifth, it is reasonable to assume that concentrations of some nutrients (e.g., phosphorous) would be reduced. Finally, drying surface soils would likely enhance the effectiveness of fire, as well as other mechanical control strategies, in controlling cattail. Thus, greater flexibility would exist in the management of refuge wetlands.

Proposal:

We propose to alter the study design to incorporate valuable information already available pertaining to wetland processes and the control of cattail. Based on our review of the literature, coupled with our experiences in assisting land managers, the ability to adequately dry soils is paramount to restoring processes that will not only enable control of cattail but also provide the management flexibility necessary to stimulate development of a replacement plant community that is more diverse and valuable for wildlife.

Literature Cited

Apfelbaum, S. I. undated. Cattail (*Typha* spp.) management. Source unknown, Applied Ecological Services, Brodhead, Wisconsin.

Bedish, J. W. 1967. Cattail moisture requirements and their significance to marsh management. American Midland Naturalist 78:288-300.

Bellrose, F. C., and L. G. Brown. 1941. The effect of fluctuating water levels on the muskrat population of the Illinois River Valley. Journal of Wildlife Management 5:206-212.

Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Wisconsin Department of Natural Resources, Technical Bulletin Number 112.

Bonnewell, V., W. L. Koukkari, and D. C. Pratt. 1983. Light, oxygen and temperature requirements for *Typha latifolia* seed germination. Canadian Journal of Botany 61:1330-1336.

Browne, B. A.. 2001. Nutrient load assessment report for Horicon Marsh contributions from upland landscape. Final Report, Water and Soil Resources, College of Natural Resources, University of Wisconsin – Stevens Point.

Claassen, P. W. 1921. Typha insects: their ecological relationships. Cornell University Agricultural Experiment Station 47:459-531.

Fassett, N. C. 1957. A manual of aquatic plants. University of Wisconsin Press, Madison, Wisconsin.

Giltz, M. L., and W. D. Myser. 1954. A preliminary report on an experiment to prevent cattail die-off. Ecology 35:418.

Grace, J. B. 1987. The impact of preemption on the zonation of two *Typha* species along lakeshores. Ecological Monographs 57:283-303.

Grace, J. B. 1988. The effects of nutrient additions on mixtures of *Typha latifolia* L. and *Typha domingensis* Pers. along a water-depth gradient. Aquatic Botany 31:83-92.

Grace, J. B. 1989. Effects of water depth on *Typha latifolia* and *Typha domingensis*. American Journal of Botany 76:762-768.

Grace, J. B., and R. G. Wetzel. 1981. Habitat partitioning and competitive displacement in cattails (*Typha*): experimental field studies. American Naturalist 118:463-474.

Grace, J. B., and R. G. Wetzel. 1982. Niche differentiation between two rhizomatous plant species: *Typha latifolia* and *Typha angustifolia*. Canadian Journal of Botany 60:46-57.
Grace, J. B., and R. G. Wetzel. 1998. Long-term dynamics of *Typha* populations. Aquatic Botany 51:137-146.
Harris, S. W., and W. H. Marshall. 1963. Ecology of water-level manipulation on a northern marsh. Ecology 44:331-343.
Hayden, A. 1939. Notes on *Typha angustifolia* L. in Iowa. Iowa State College Journal of Science 13:341-351.
Jensen, M. E., P. Bourgeron, R. Everett, and I. Goodman. 1996. Ecosystem management: a landscape ecology perspective. Water Resources Bulletin 32:203-216.
Jurik, T. W., S.-C. Wang, and A. G. van der Valk. 1994. Effects of sediment load on seedling emergence from wetland seed banks. Wetlands 14:159-165.
Kadlec, J. A. 1962. Effects of a drawdown on a waterfowl impoundment. Ecology 43:267-281.
Kaminski, R. M., and H. H. Prince. 1981. Dabbling duck activity and foraging responses to aquatic macroinvertebrates. Auk 98:115-126.
Klopatec, J. M. 1974. Production of emergent macrophytes and their role in mineral cycling within a freshwater marsh. Masters Thesis, University of Wisconsin-Milwaukee.
Krattinger, K. 1975. Genetic mobility in *Typha*. Aquatic Botany 1:57-70.
Laing, H. E. 1940a. Respiration of the rhizomes of *Nuphar advenum* and other water plants. American Journal of Botany 27:574-581.
Laing, H. E. 1940b. Respiration of the leaves of *Nuphar advenum* and *Typha latifolia*. Ibid 27:583-586.
Laing, H. E. 1941. Effect of concentrations of oxygen and pressure of water upon rhizomes of some submerged water plants. Botanical Gazette 102:712-724.
Linde, A. F., T. Janisch, and D. Smith. 1976. Cattail-the significance of its growth, phenology and carbohydrate storage to its control and management. Wisconsin Department of Natural Resources, Technical Bulletin Number 94.
McDonald, M. E. 1955. Cause and effects of a die-off of emergent vegetation. Journal of Wildlife Management 19:24-35.
McNaughton, S J. 1968. Autotoxic feedback in relation to germination and seedling growth in *Typha latifolia*. Ecology 49:367-369.
Meeks, R. L. 1969. The effect of drawdown date on wetland plant succession. Journal of Wildlife Management 33:817-821.
Penfound, W. T., R. F. Hall, and A. D. Hess. 1945. The spring phenology of plants in and around the reservoirs in northern Alabama with particular reference to malaria control. Ecology 26:332-352.
Sifton, H. B. 1959. Germination of light-sensitive seeds of *Typha latifolia*. Canadian Journal of Botany 37:719-739.
Sojda, R. S., and K. S. Solberg. 1993. Management and control of cattails. U.S. Fish and Wildlife Service, Waterfowl Management Handbook, Fish and Wildlife Leaflet 13.4.13.
Swanson, F. J., T. K. Kratz, N. Caine, and R. G. Woodmansee. 1988. Landform effects on ecosystem patterns and processes; geomorphic features of the earth's surface regulate the distribution of organisms and processes. BioScience 38:92-98.
Szczepanska, W. 1971. Allelopathy among aquatic plants. Archives of Hydrobiologia 18:17-30.
Szczepanska, W., and A. Szczepanski. 1976. Growth of *Phragmites communis* Trin., *Typha latifolia* L., and *Typha angustifolia* L. in relation to the fertility of soils. Archives of Hydrobiologia 23:233-248.
Uhler, F. M. 1944. Control of undesirable plants in waterfowl habitat. Transactions of the North American Wildlife Conference 9:295-303.
Ulrich, K. E., and T. Burton. 1988. An experimental comparison of the dry matter and nutrient distribution patterns of *Typha latifolia* L., *Typha angustifolia* L., *Sparganium eurycarpum* Engelum, and *Phragmites australis* (Cav.) Trin. Ex Steudel. Aquatic Botany 32:129-139.
van der Valk, A. G., and C. B. Davis. 1978. The role of the seed bank in the vegetation dynamics of prairie glacial marshes. Ecology 59:322-335.

Wang, S.-C., T. W. Jurik, and A. G. van der Valk. 1994. Effects of sediment load on various stages in the life and death of cattail (*Typha X Glauca*). Wetlands 14:166-173.

Weisner, S. E. B. 1993. Long-term competitive displacement of *Typha latifolia* by *Typha angustifolia* in a eutrophic lake. Oecologia 94:451-456.

Weller, M. W., and C. E. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Agriculture and Home Economics Experiment Station, Department of Zoology. Entomology Special Report 43, Iowa State University, Ames, Iowa.

Weller, M. W., and L. H. Fredrickson. 1974. Avian ecology of a managed glacial marsh. The Living Bird 12:269-291.

Appendix C

U. S. GEOLOGICAL SURVEY
BIOLOGICAL RESOURCES DIVISION
Northern Prairie Science Center
8711 37th Street SE
Jamestown, ND 58401

REDIRECTION OF MULTIPLE REFUGE STUDY ORIGINALLY ENTITLED
Interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes

TITLE: Wetland Processes: a 10-20 Year Study to Improve Wetland Management Capabilities of the National Wildlife Refuge System Through Integration of Research, Continuing Education, and Adaptive Management

PRINCIPAL INVESTIGATORS:

Murray K. Laubhan, Lead Principal Investigator, U. S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401

Ned H. Euliss, Jr., Lead Principal Investigator, U. S. Geological Survey, Northern Prairie Wildlife Research Center, 8711 37th Street SE, Jamestown, North Dakota 58401

Socheata Lor, Principal Investigator, U. S. Fish and Wildlife Service, Upper Midwest Environmental Sciences Center, 2630 Fanta Reed Rd., La Crosse, Wisconsin 54603

BACKGROUND SUMMARY: In FY2004, the U. S. Geological Survey's Northern Prairie Wildlife Research Center (NPWRC) and Regions 3 and 5 of the U.S. Fish and Wildlife Service (USFWS) developed a partnership to evaluate the interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes. In general, the intent of this study was to evaluate the use of fire to control cattail in marshes and simultaneously monitor the temporal impact of this treatment on other trophic elements. Of particular interest was comparing prescribed fires conducted during the dormant season with those conducted during the growing season to determine if differences occur relative to the extent and duration of cattail reduction. Based on existing autecological information on cattail, the investigators assumed burning prior to translocation of carbohydrates to the rhizosphere may result in greater control and stimulate increased plant community composition by decreasing nutrient stores in the rhizosphere and increasing the availability of nutrients for uptake by other plants. National wildlife refuges in Regions 3 and 5 were invited to participate in this collaborative study and several field trips were conducted to evaluate current conditions on refuges responding favorably to the proposed study. The evaluation focused on selection of individual marshes that met criteria deemed necessary to conduct a valid fire study, including the ability to dry marsh substrates sufficiently to conduct a prescribed fire during the growing season. The result of these site visits was the selection of marshes on four refuges and one wetland management district. However, a subsequent field trip to refuges in October 2004 revealed that substrates in the majority of wetlands remained wet to saturated following attempts to dewater many marshes. Thus, it was unreasonable to assume that application of prescribed fire would result in the desired effect of reducing cattail and stimulating increased plant diversity for a prolonged period. Given that refuge staffs already recognize that benefits associated with burning cattails is short-term under current conditions, it was deemed appropriate to reconsider the objectives of the study.

NEW CONSIDERATIONS: Initially, discussion focused on the importance of furthering knowledge related to the application of fire in wetland systems and potential methods to overcome the challenges

identified during the previous year. Fire is a naturally occurring disturbance and constitutes a primary management strategy used by land managers. Although much is known regarding the technical aspects of fire, much less is known regarding factors that contribute to the success and failure of fire to achieve often stated objectives (e.g., plant control). Thus, conducting additional research on wetland fire ecology is valid. Given this conclusion, the team focused on challenges related to the application of fire in managed marshes of the refuges willing to participate in the study. Based on existing literature, previous experience assisting wetland managers, and inspecting hundreds of managed wetlands, the team identified the inability to achieve the dry marsh phase as a crucial shortcoming and resolution of this issue was considered a prerequisite to understanding fire ecology in wetland systems. After numerous discussions, it was concluded that the primary challenge preventing drying of marsh substrates were related to factors at numerous spatial scales. At the watershed scale, increases in the intensity and extent of human modifications (e.g., tillage, levees, diversion ditches, alluvial wells) have altered hydroperiods (e.g., depth, duration, frequency of flooding), sediment dynamics (e.g., amount, deposition pattern), and nutrient loads entering wetlands systems. These changes, as well as initial construction designs (e.g., type, location, and vertical placement of water control structures and ditches) in relation to the changes in the surrounding landscape, have compromised the existing water transfer infrastructure on many refuges to an extent that they have become largely ineffectual in facilitating the drying of marsh substrates. This is evidenced by the fact that most study wetlands are characterized by an excessive buildup of organic sediments (range = 2-7 feet) since refuge establishment. Direct impacts of sediment accretion include the creation of a physical barrier that alters the abiotic conditions required to allow buried seed and invertebrate egg banks to express themselves in the biotic community. Further, organic mats function like sponges that can sequester large amounts of nutrients and retain water to the extent that flow to adjacent borrow ditches and lower areas within impoundments is prevented. This latter complication makes it virtually impossible to dewater refuge impoundments except during extended drought. Consequently, soil moisture concentrations often approach field capacity for the entire growing season and, ultimately, restrict plant establishment to those species (e.g., cattail, common reed) adapted to saturated environments. Left unchecked, this condition eventually leads to reduced plant and invertebrate community composition and, ultimately to lower wildlife diversity.

These concerns were relayed to all participants in the study during a field trip in late 2004 and on February 23, 2005 during a meeting with all refuge participants in the FWS Regional Office in Minneapolis. One alternative approach discussed was to conduct the study as proposed, but select marshes on other refuges that are not as severely impaired by sediment accretion and inadequate water control. This approach was rejected because the management challenges identified on the original refuges are common and methods to recover these areas should be addressed. Instead, the unanimous decision of refuge personnel at the February 23, 2005 meeting was to refocus the project to develop a better understand of wetland processes and begin developing methods to integrate this information into refuge operations. It was further discussed and agreed that this would require formation of a long-term partnership between staff of participating refuges and the principal investigators because developing cost-effective and efficient marsh restoration techniques may require 10-20 years. This partnership would include incorporating educational opportunities (e.g., workshops, training) into the project and using an adaptive management strategy to integrate a process-based approach into wetland management on refuges.

PROPOSED PROJECT REDIRECTION: During the February 23, 2005 meeting the principal investigators agreed to meet the following week to discuss the technical aspects of redirecting the project and to develop a timeline to allow each refuge to integrate the study into their management plans for FY2005 and beyond. This meeting was conducted on 1 March 2005 and the following items were discussed and tentatively agreed upon pending discussion with refuge staffs participating in the study:

1) Reducing the organic mat is critical to reestablishing marsh function and ensuring long-term sustainability. Sedimentation is a naturally occurring process, but must be balanced with other system functions. Thus, this objective should not be equated with attempting to restore pre-refuge conditions; rather, the challenge is to reduce organic material to an extent necessary to reestablish functional aspects

of the nutrient cycle that will lead to improved plant and animal diversity. Currently, however, the existing mat represents an enormous nutrient pool that is in a relatively inactive state that negatively impacts wetland food webs. Although removal of the entire mat likely is not necessary to enhance functions and values, the amount of sediment removal required is unknown at this time. Actually, this is a question we hope to address with the project. Factors important in determining the reduction required include total depth of sediment, nutrient content of sediments, and location of the cattail rhizosphere in relation to sediment depth. These variables likely differ among the refuges, but Kari could help determine baseline conditions this year, which will be important for development of the study plan (hence, the proposed timeline of a field trip this spring followed by development of the study plan early in FY06).

2) The other large nutrient pool is bound in the cattail rhizosphere. General estimates of some experts suggest that the belowground biomass of rhizomes is roughly twice the aboveground biomass. Although readily available for regrowth and spread of cattail, these nutrients are not available to other plants or invertebrates. Further, monotypic stands of cattail thrive in sediment and effectively shade out other plants adapted for growth in saturated environments.

3) Releasing nutrients bound in the organic mat and cattail rhizosphere will require drying marsh substrates. Although deep flooding or herbicide application may result in a temporal reduction in the extent of aboveground biomass, these treatments do not cause release of nutrients unless multiple treatments are implemented and conditions are suitable for decomposition. Regardless, the dry phase of the marsh cycle is still required to oxidize nutrients into more mobile forms and facilitate germination of most emergent plants from seeds. If this portion of the cycle is not emulated, released nutrients likely will be re-assimilated by either the sediments or cattail.

4) Given the different modifications to wetlands on the refuges that originally agreed to participate in the study, each impoundment is unique within and among refuges. Consequently, it is impossible to establish true replicates.

Based on these considerations, redirection of the fire study will focus on identifying 2 wetlands on each refuge that can be dewatered sufficiently to achieve an “extreme” dry phase of the natural marsh cycle. Following accomplishment of this objective, the project will seek to manipulate abiotic conditions using the extreme dry phase of the marsh cycle to enhance reduction of the organic mat, export excess nutrients, and expose the cattail rhizosphere to the extent necessary to achieve control with fire or other strategies.

Defining the term “extreme” in a quantitative manner cannot be done with certainty at this time because information regarding soil moisture thresholds that promote sediment oxidation or impact the transport of carbohydrates from cattail stems to rhizomes is vague; although it is known to vary depending on antecedent conditions (e.g., type and depth of sediment and underlying soil). This is not a problem because defining such thresholds is, in fact, one of the primary intents of the study in its early stage. Currently, it appears that the ability to dewater wetlands on many refuges is inadequate to achieve extreme dry conditions given comments by refuge staff and some data (e.g., Horicon) on the enrichment status of substrates. Thus, the upper threshold actually is defined. Therefore, the task in the initial phase is to dry substrates to a greater extent than is currently possible and to the extent that moisture content is sufficiently low to facilitate sediment oxidation and impact the cattail rhizosphere. In this context, then, “extreme” constitutes drying to an extent that ensures that measurable effects occur and we are successful in defining thresholds. Since thresholds currently are not known, it is only prudent to dry substrates to the greatest extent possible. In contrast, once thresholds are established it may be determined that the extent of drying sought during the experiment will be required as part of future management activities.

The initial phase will be conducted using a crossover design, which requires two impoundments per refuge that are dedicated to the long-term (10-20 years) study of wetland processes. The crossover design was

selected because it accounts for confounding factors associated with the unique nature of each impoundment. However, a requirement of this design is that both impoundments selected be similar regarding the ability of management to achieve the extreme dry phase of the marsh cycle. Given the current inability to achieve this "extreme" dry phase on the majority of wetlands being used in this study, innovative techniques will need to be developed (e.g., installation of new water control structures, creation of sumps, rehabilitation of ditches). The technique used can differ among refuges and even among impoundments on the refuge. However, the capacity must exist to achieve "extreme" dry on both wetlands. The principal investigators and refuge staff will collectively assess potentially viable methods to achieve "extreme" during a spring site visit to refuges.

Initially, one impoundment on each refuge will be selected for dewatering to achieve the "extreme" dry phase, whereas the other member of the pair will be dewatered to the extent possible using the existing infrastructure. **There will be no fire treatments in FY2005.** Following initial exposure of substrates after drawdowns have been initiated, baseline information on the depth and mass of the organic layer, location of the cattail rhizosphere in relation to the soil surface, nutrient content of the organic mat, nutrient content and biomass of the rhizosphere, and invertebrate community composition and biomass will be collected in both impoundments. Soil moisture will be monitored periodically following exposure of sediments on both impoundments to determine extent of drying and verify that substrates dried below the established threshold on the impoundment designated for this treatment. Given the extreme buildup of organic matter in many study wetlands and uncertainty regarding the success of management options that may be employed to dry sediments, we anticipate that several years may be required to achieve a drawdown that meets the criteria. However, given the design, this is not a problem. When the dry criterion is met, the same information mentioned above will be collected again on both members of the wetland pair. Following successful completion of this task, the experiment, including types and timing of data collection, will be reversed (i.e., temporal cross-over) on each refuge: each wetland will be flooded to saturate soils and then substrates in the former control wetland will be dried to the "extreme" dry phase and the other member of the pair will be dewatered using the original infrastructure. This will facilitate a temporal validation of study results, facilitate designing subsequent phases of this adaptive management project, and provide demonstration areas to communicate research findings during workshops.

FY2005 ACTIVITIES: Given the extent of change being proposed, the principal investigators will coordinate a site visit to each refuge considering participation during the spring of 2005 to more completely explain the underlying rationale for the proposed project and discuss potential ramifications with the staff. The change in focus of the project suggests we also should re-evaluate impoundments at each refuge and assess their suitability for a long-term experiment. Pending acceptance of this new proposal by refuge staff, the principal investigators would like to participate with refuge staff in selecting candidate marshes and discuss potential methods available to ensure substrates can be dried to the extent stipulated. During the remainder of FY2005, refuge staff working in concert with the principal investigators will develop the water transfer infrastructure necessary to achieve the "extreme" dry phase on both the selected marshes. Pending progress, the functionality of the altered infrastructure could be tested. By the beginning of FY2006, the principal investigators, based on discussions with refuge staff, will develop a detailed study plan that provides details of the research project, including a timeline, equipment required, and data collection protocols.

Summary of Tentative Timeline for 2005:

March	Distribute white paper for review and comment
April	Visit refuges to discuss new concept, evaluate marshes for inclusion in study, develop approaches for achieving extreme dry
May-July	Develop protocols and initiate collection of baseline information
September	Complete new study plan and distribute for comment

Appendix D

Subject: Joint FWS / USGS partnership on the interaction of prescribed fire, soil and water on the vegetation, invertebrates and wetland birds in emergent marshes.

To: Dan Dearborn, Larry Anderson, Jennifer Rabuck, Troy Boschee

From: Tim Hepola

You are asked to participate on a Region 3 fire working team to assist in the formulation of potential questions and problems that may arise from the use of prescribed fire in an impoundment environment along with formulating strategies and answers to these potential questions.

Region 3 is dedicated to the successful management and restoration of wetlands within our jurisdiction. Within this endeavor, degraded marshes and impoundments need a significant amount of work and thought to once again be restored to a productive state.

What involvement does the branch of fire have in this scenario? Historically, the wetlands of our region burned on a periodic timeframe dependent upon drought and soil moisture conditions. This rotated the wetlands through a natural dry and wet cycle that controlled wetland vegetation conditions and maintained a naturally high productivity rate beneficial to waterfowl. With the advent of impoundments, this natural drying cycle has been upset and the productivity of our marshes is now greatly reduced. Fire is once again being looked at as a necessary element in the adaptive management of our emergent wetlands.

Attached is an abstract prepared by Soch Lor, FWS Biologist, LaCrosse, WI, that explains in detail this joint venture between Regions 3 and 5 of the FWS and the US Geological Survey (USGS). The study seeks to determine what measures need to be taken to restore these impoundments to their former productive state along with incorporating prescribed fire into these wetlands as a management and restorative tool.

Your role in this working group is to assist the regional office in identifying the possible problems and concerns of burning these wetlands along with formulating answers and mitigating measures to these concerns. What information does the branch of fire need in order to successfully re-introduce fire into these wetlands? The questions and concerns that have been raised regarding the use of fire in these wetland environments are described in the attached briefing paper. They include, but are not limited to the following:

- What is the peat (organic layer of fuel) depth within an impoundment?
- What is the composition of the surrounding dike?
- Smoke issues and Air quality?
- Road closures and safety issues?
- How quickly could an impoundment be re-flooded after this drying period?
- Moisture content of organic layer?
- Etc.

You are being asked to participate in this working group due to your knowledge of the issue, proximity to the study and a positive work attitude.

It is not anticipated that this working group will consume any large amount of your time. Initially, our need is to identify those questions and concerns that may negatively impact our use of fire. We need to formulate strategies and remedial measures that will **allow us** to successfully implement fire. A conference call with working group members is planned for Tuesday, May 31 at 8:00 am. Conference call details will be sent shortly.

This is a long term project that illustrates our use of adaptive management to address a biological concern. It will not be completed in 1-3 years but potentially could take a decade or more, including multiple treatments, to implement and arrive at a successful outcome. However, without addressing the problem head on, it will never be solved. Therefore, in order to continue this study, it is imperative that the branch of fire contributes its knowledge and expertise to ensure a successful outcome.

Thank you in advance for your participation. If you are unwilling or unable to participate, please contact Tim Hepola at ph: (612)713-5479, immediately so that an alternate may be found.

Appendix E

Wetland Processes: a 10-20 Year Study to Improve Wetland Management Capabilities of the National Wildlife Refuge System through Integration of Research, Continuing Education, and Adaptive Management

Abstract:

In FY2004, the U. S. Geological Survey's Northern Prairie Wildlife Research Center (NPWRC) and Regions 3 and 5 of the U.S. Fish and Wildlife Service (USFWS) developed a partnership to evaluate the interactions of prescribed burning, soils, and water on nutrient dynamics, vegetation, aquatic invertebrates, and wetland birds in managed emergent marshes. In general, the original intent of this study was to evaluate the use of fire to control cattail in marshes and simultaneously monitor the temporal impact of this treatment on other trophic elements (i.e., waterbirds, vegetation, and invertebrates). Of particular interest was comparing prescribed fires conducted during the dormant season with those conducted during the growing season to determine if differences occur relative to the extent and duration of cattail reduction.

Fire is a naturally occurring disturbance and constitutes a primary management strategy used by land managers. Although much is known regarding the technical aspects of fire, much less is known regarding factors that contribute to the success and failure of fire to achieve often stated objectives (e.g., plant control). Thus, conducting additional research on wetland fire ecology is valid. Given this conclusion, the team focused on challenges related to the application of fire in managed marshes of the refuges that were willing to participate in the study. Based on existing literature, previous experience assisting wetland managers, and inspecting hundreds of managed wetlands, the team identified the inability to achieve the dry marsh phase as a crucial shortcoming and resolution of this issue was considered a prerequisite to understanding fire ecology in wetland systems. After numerous discussions, it was concluded that the primary challenge preventing drying of marsh substrates were related to factors at numerous spatial scales. At the watershed scale, increases in the intensity and extent of human modifications (e.g., tillage, levees, diversion ditches, alluvial wells) have altered hydroperiods (e.g., depth, duration, frequency of flooding), sediment dynamics (e.g., amount, deposition pattern), and nutrient loads entering wetlands systems. These changes, as well as initial construction designs (e.g., type, location, and vertical placement of water control structures and ditches) in relation to the changes in the surrounding landscape, have compromised the existing water transfer infrastructure on many refuges to an extent that they have become largely ineffectual in facilitating the drying of marsh substrates. This is evidenced by the fact that most study wetlands are characterized by an excessive buildup of organic sediments (range = 2-7 feet) since refuge establishment. Direct impacts of sediment accretion include the creation of a physical barrier that alters the abiotic conditions required to allow buried seed and invertebrate egg banks to express themselves in the biotic community. Further, organic mats function like sponges that can sequester large amounts of nutrients and retain water to the extent that flow to adjacent borrow ditches and lower areas within impoundments is prevented. This latter complication makes it virtually impossible to dewater refuge impoundments except during extended drought. Consequently, soil moisture concentrations often approach field capacity for the entire growing season and, ultimately, restrict plant establishment to those species (e.g., cattail, common reed) adapted to saturated environments. Left unchecked, this condition eventually leads to reduced plant and invertebrate community composition and, ultimately to lower wildlife diversity. Ultimately, without achieving dry, applying fire or any other disturbance will not be successful at improving the vegetation, waterbird, and invertebrate communities if the soil or organic layer at the depth of the rhizomes remains moist.

Study Objectives:

As we, both USFWS and USGS staff, learned more about refuge wetlands and management problems during refuge visits, we realized the goal needed to evolve into a multi-phase approach. The first phase in achieving the goal is reclaiming the dry cycle of the wetland succession. Once this “extreme dry” is accomplished,

prescribed fire would be employed to release nutrients bound in the organic layer and cattail rhizome, and to expose the underlying seedbank. The dry condition is required for oxidation of nutrients and seed germination. Additional phases of the study may incorporate future needs the individual refuges request to assist them in making informed decisions on wetland management.

Issues:

- Achieving "dry" wetland conditions is a requirement prior to burning wetlands in order to be effective in controlling the monotypic stand of cattail. Factors contributing to the challenge of achieving "dry" include organic depths, sediment and nutrient loads from surrounding landscapes, and impoundment infrastructure. Refuge managers and biologists are willing to take additional measures to achieve dry conditions. This may include reactivating existing tiles, operating water pumps, dredging ditches, replacing water control structures, etc.

- Peat burns: Primary concern is dealing with national/state policies in regards to containment and safety.

    - Containment and safety
    - Smoke management
    - Burn policies
    - Contingency plan to extinguish peat fires
    - If we must extinguish the peat within 3 days, do we have the option of relighting it multiple times in a season?
    - Summer burns (burn during growing season when rhizomes are more vulnerable because nutrients are aboveground)
        - Fire crews are often on wildland fires at this time
    - Burning wetlands is best during drought conditions because that is when wetlands can achieve the driest phase. However, this is also the time when burn bans are typically enforced. How do we get waiver/support to burn at these times?
    - Fire Funding: Should we classify these wetland burns as "fuel reduction" or "WUI" when possible because this project is a refuge adaptive management project?

This may be a one-time burn. If all goes well and soil is exposed, we shouldn't need to burn the unit again or at least for a very long time

Goal of conference call:

To determine what information the Fire Program needs in order to make a decision on whether or not they can safely burn peat in an impoundment.

- Peat depths within impoundments?
- Composition of dikes?
- Amount of available water within surrounding impoundments for a contingency plan?
- Others?

Appendix F

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Bishop Henry Whipple Federal Building
1 Federal Drive
Fort Snelling, MN 55111-4056

IN REPLY REFER TO:

Fire

Memorandum

To: Soch Lor, Wildlife Biologist, Upper Midwest Environmental Sciences Center through Nita Fuller, Chief, National Wildlife Refuge System

From: Tim Hepola, Regional Fire Ecologist and Acting Regional Fire Management Coordinator (RFMC)

Subject: Region 3 Branch of Fire Comments, Concerns and Questions Pertaining to the Joint FWS/USGS Partnership on the Interaction of Prescribed Fire, Soil, and Water on the Vegetation, Invertebrates and Wetland Birds in Emergent Marshes.

Date: 7/25/05

This memorandum is in response to the request by the Principle Investigators and Working group associated with the subject study involving the Interaction of Prescribed Fire, Soil, and Water on the Vegetation, Invertebrates and Wetland Birds in Emergent Marshes hereinafter referred to as the "cattail study" or "study". This response precipitated the forming of a regional fire working group tasked with further developing the Branch of Fire response to this study. This resulted in a conference call conducted on 6/1/2005, amongst the selected regional participants as listed below.

The purpose of the conference call was to identify the leading issues and concerns that the Branch of Fire has with the proposed study along with identifying the associated mitigating measures that may allow for the safe application of fire into the selected wetlands.

Region 3 Fire Study Working Group – Cattail Marsh Study

Participants:

Larry Anderson, Agassiz NWR
Gary Huschle, Agassiz NWR
Troy Boschee, Fergus Falls WMD
Dan Dearborn, Big Stone NWR
Jennifer Rabuck, Leopold WMD
Jim Lutes, Leopold WMD
Sean Sallman, Horicon NWR
Tim Hepola, Regional Office, Team Leader

Prescribed fire operations imply an inherent risk under the best of conditions. The special environmental conditions considered as optimal for achievement of the desired results from this study suggest an increased level of risk above that normally associated with our prescribed burn program. For that reason, the following issues and concerns are raised along with potentially mitigating solutions for certain applications. This memo does not specifically attempt to answer any of the questions and information needs identified but instead lists them for the purposes of identifying to the principal investigators what information requirements the fire community has in successfully conducting prescribed fire within these wetland environments.

Drawing down the candidate marshes to a dry condition, drying them to the greatest extent possible and then introducing prescribed fire into them requires that we collect and analyze additional data before any ignition takes place. The following list of issues, concerns and mitigating comments are for the knowledge and benefit of the project investigators, refuge biological staff and branch of fire.

1.) The depth of the organic layer within an impoundment is an important variable to the application of fire. Knowledge of this average depth will allow for better contingency planning and result in a safer burn. The organic layer should be considered as a 1000 hour fuel in the context of this study.

2.) What is the composition of the surrounding dike? Is the structure also composed of peat and organic matter or is it mineral soil? This knowledge is also important to the conduct of a safe burn. A dike consisting of a large percentage of peat would provide a potential escape corridor for the burn, jeopardize burn safety and possibly extend the time period of the burn beyond what is optimally planned for.

3.) Smoke and Air Quality: The issue of smoke and the ability to control it or of the possibility of a prolonged multi-day fire event producing excessive smoky conditions was the most often expressed concern of the participants. The potential for extended smoke filled fire operations in areas surrounded by major highways or in close proximity to high population centers aroused the most concern. The potential of burning during excessively dry periods with wind was also a concern. Likewise, burning in zero to low wind conditions is also not conducive to safe fire operations due to the complete lack of any smoke control. Most wetland areas lie in basins, night time pooling of smoke can be anticipated.

4.) Potential for drying an impoundment: Therein lies a major challenge to the success of this project. The ability to dry a wetland area sufficient to burn will require a combination of both treatment methods and cooperation from the weather. The various refuges are planning on utilizing different methods to lower their impoundment water levels, such as;

Horicon NWR plans on running auxiliary pumps to lower water levels,
Leopold WMD may re-activate drain tiles,
Agassiz NWR has the greatest control over managing water levels from their series of water flow structures,
Sherburne NWR plans on managing their water control structures along with the placement of test wells to monitor water levels in selected impoundments, etc.

This leads to the next logical question following removing the water from a unit and successfully igniting it.

5.) How quickly could this unit be re-flooded to put out any lingering peat fire or extinguish a serious escaped fire threat? A question repeated by numerous participants is the concern that the conditions necessary to successfully dry a site and then burn it are also going to be present on the adjoining landscape reducing the possibility of quickly being able to re-flood a site and greatly elevating extreme fire hazard conditions, quite likely taking us out of normal prescribed burning parameters. This is further exacerbated by a disturbing change that has occurred in the fire community the past year, that of an increased liability placed upon the burn boss on either a wildfire or prescribed fire operation. This liability issue further constrains our field staff from “pushing” the existing burn window.

6.) What percent moisture content does the organic layer need to be at in order to successfully burn it? The moisture content of the organic layer is a critical parameter to our ability to successfully burn a unit. How dry is dry enough? Do values obtained at other refuges across the country regarding soil (peat) moisture contents apply here in the Midwest or do we need to collect our own fuel moisture samples in these impoundments to establish our own baseline values?

7.) Fuel treatment on adjacent property to an impoundment. Adjoining grasslands and marshes need pretreatment in order to reduce or eliminate the chance of escaped fire from burning an impoundment. This will require additional advanced planning to coordinate with a selected marsh burn. Likewise, refuge biologists are concerned about a potential for decreased escape cover adjacent to burn units if additional widespread treatments to reduce hazardous fuels are present.

8.) Herbicide Treatment: The discussion involved the possibility of herbicide treating a selected marsh to kill the cattail, thereby increasing the dry fuel load and increasing fire intensity to further aid in removal of the rhizome layer or root mass of the cattail. Agassiz NWR described their earlier discussion with the USGS staff in this matter. Due to the increased statistical complexity (2-fold increase in sample units) to incorporate measuring this variable it will not be included in this study. Agassiz NWR will, however, independently continue their test study on the use of RODEO herbicide treatments on other, non-related, cattail marsh areas.

9.) Excavation: Discussion centered on the potential to use mechanical equipment to establish a channel or corridor through the center of an impoundment to concentrate water in the center of the unit thus aiding in the drying of the perimeter areas.

10.) Public Outreach: The successful implementation of these marsh burns will require close coordination with local neighbors, partners and the general public. The potential safety hazards will need to be addressed along with the willing cooperation of the local community.

11.) Test Burn Concept: The idea here is to isolate a small section of marsh to conduct a test burn on it. This test burn would better enable us to establish moisture thresholds, smoke generation, suppression tactics, use of mechanical equipment for line construction, etc. in the development of prescriptions for these marshlands. It would also assist us with answering the question as to what fuel moisture these marshes will burn at.

12.) Anticipated Costs: Additional fire support costs to be borne by this project could be;

- extended staffing for project implementation
- extended staffing for smoke monitoring, road patrol
- extended staffing for mop-up operations

These additional costs would directly impact the regional fire program budget.

The issues, concerns, and questions as presented provide the range of information and data needs that are necessary for the development of burn plans for this project. This will need to be an ongoing process so that a workable and viable burn plan can be developed, approved and in place so that the branch of fire is ready to respond if and when the opportunity presents itself.

This will not be an easy task to accomplish. We acknowledge the fact that it truly is a multi-year study and will most likely be years before we have accumulated useable results and data. The branch of fire supports this project, remains committed and within accepted burn parameters will strive to conduct burns safely and successfully to contribute to the success of this project.

For additional information please contact Tim Hepola, Regional Fire Ecologist at ph: (612)713-5479 or by email at: tim_hepola@fws.gov

Sincerely,

S/Tim Hepola

Fire Ecologist

CC: Nita Fuller, Chief, National Wildlife Refuge System
Murray Laubhan, USGS
Ned Euliss, USGS
Kari Odefey, FWS

Appendix G

United States Department of the Interior

U.S. FISH AND WILDLIFE SERVICE
Biological Monitoring Team
2630 Fanta Reed Road
La Crosse, WI 54603

Memorandum

Date: 30 Aug. 2005

To: Tim Hepola, Regional Fire Ecologist and Acting Regional Fire Management Coordinator (RFMC)

From: Soch Lor, Wildlife Biologist, Biological Monitoring Team
Kari Ranallo, Biological Monitoring Team
Murray Laubhan, USGS Northern Prairie Wildlife Research Center, Jamestown, ND
Chip Euliss, USGS Northern Prairie Wildlife Research Center, Jamestown, ND

Subject: Response to Region 3 Fire Study Working Group's memo (dated 7/25/05) regarding the project "Wetland Processes: a 10-20 Year Study to Improve Wetland Management Capabilities of the National Wildlife Refuge System Through Integration of Research, Continuing Education, and Adaptive Management."

We greatly appreciate the time and effort required of the fire branch working group to address the proposed fire project and we look forward to working collaboratively with the fire branch to successfully implement this adaptive management project on refuges. The following are our response and proposed steps to proceed with the project. *Text in italics denotes issues raised by the Fire Working Group*, whereas normal text denotes our response.

Prescribed fire operations imply an inherent risk under the best of conditions. The special environmental conditions considered as optimal for achievement of the desired results from this study suggest an increased level of risk above that normally associated with our prescribed burn program. For that reason, the following issues and concerns are raised along with potentially mitigating solutions for certain applications. This memo does not specifically attempt to answer any of the questions and information needs identified but instead lists them for the purposes of identifying to the principal investigators what information requirements the fire community has in successfully conducting prescribed fire within these wetland environments.

We strongly concur that safety takes precedence over all other aspects of this project. Therefore, we are relying on the assistance of the fire branch to help us determine the data needed to ensure that all safety concerns are adequately addressed. We will collect the requisite pre-burn data necessary to fulfill every aspect of the Prescribed Fire Plan and prescriptions and also for any contingency plans required to implement the burn in a safe manner and, if these concerns cannot be addressed to the satisfaction of the fire branch, the burns will not be conducted.

1.) The depth of the organic layer within an impoundment is an important variable to the application of fire. Knowledge of this average depth will allow for better contingency planning and result in a safer burn. The organic layer should be considered as a 1000 hour fuel in the context of this study.

We will determine the depth of the organic layer within the selected impoundments and composition of the surrounding dikes. However, there are multiple ways this data can be collected depending on the degree of accuracy and precision required. Based on discussions, we are assuming that there are thresholds beyond which conducting a fire will not be possible. If this assumption is correct, then data collection will involve methods that provide binary (yes/no) information. If incorrect, more detailed procedures may be required. Therefore, we are requesting more specific direction from the fire branch regarding the following two items identified in the letter:

1. Dike composition – For example, parameters of interest may include soil composition at various levels of detail (e.g., sand, clay, silt, and peat faction or simply peat/other factions) or soil composition at specific levee depths (e.g., above the water line in ditch line or at 6-inch increments).

2. Peat/soil depth – For example, parameters of interest may include maximum peat depth, average peat depth, or detailed maps illustrating peat depths throughout the marsh. Further, what accuracy is required (e.g., within 6, 12, or 18 inches)?

3.) Smoke and Air Quality: The issue of smoke and the ability to control it or of the possibility of a prolonged multi-day fire event producing excessive smoky conditions was the most often expressed concern of the participants. The potential for extended smoke filled fire operations in areas surrounded by major highways or in close proximity to high population centers aroused the most concern. The potential of burning during excessively dry periods with wind was also a concern. Likewise, burning in zero to low wind conditions is also not conducive to safe fire operations due to the complete lack of any smoke control. Most wetland areas lie in basins, night time pooling of smoke can be anticipated.

We wholeheartedly agree that smoke and air quality issues be addressed adequately relative to Agency standards, especially given that Horicon, Sherburne, and Iroquois are in close proximity to urban areas. Again, we, along with the fire branch, want to ensure that safety takes precedence over all else!

4.) Potential for drying an impoundment: Therein lies a major challenge to the success of this project. The ability to dry a wetland area sufficient to burn will require a combination of both treatment methods and cooperation from the weather. The various refuges are planning on utilizing different methods to lower their impoundment water levels, such as;

Horicon NWR plans on running auxiliary pumps to lower water levels,

Leopold WMD may re-activate drain tiles,
Agassiz NWR has the greatest control over managing water levels from their series of water flow structures, -Yes, but probably has the least capability to achieve dry conditions because of wetland substrate and other factors.

Sherburne NWR plans on managing their water control structures along with the placement of test wells to monitor water levels in selected impoundments, etc.

We acknowledge that reaching the desired dry conditions will not be quick or easy, and likely will require several steps over a period of years. However, our interpretation of past research and the results of past fires conducted to control cattail suggest that the inability to dry substrates to satisfactory levels is a key factor that (1) leads to the development of cattail monocultures and (2) limits the effectiveness of common control techniques, including fire. Thus, quantitatively determining the substrate moisture that must be achieved to use fire effectively to control cattail is a primary purpose of conducting this study. Obviously, this will be a learning process for all involved and likely will generate frustration given that drying organic sediments will undoubtedly require favorable climatic conditions. This is the reason we have altered the title of the project

to reflect a 10-20 year process. Our intent is not to burden refuge or fire staff with 10-20 years of data collection; rather, we recognize the influence of climate and accept the reality that some refuges may have to wait several years for favorable conditions to occur.

5.) How quickly could this unit be re-flooded to put out any lingering peat fire or extinguish a serious escaped fire threat? A question repeated by numerous participants is the concern that the conditions necessary to successfully dry a site and then burn it are also going to be present on the adjoining landscape reducing the possibility of quickly being able to re-flood a site and greatly elevating extreme fire hazard conditions, quite likely taking us out of normal prescribed burning parameters. This is further exacerbated by a disturbing change that has occurred in the fire community the past year, that of an increased liability placed upon the burn boss on either a wildfire or prescribed fire operation. This liability issue further constrains our field staff from "pushing" the existing burn window.

Again, we would like to emphasize that we are not asking the fire branch or the refuge staff to conduct burns in an unsafe manner or extend the burn window into an unsafe practice. We view this burn as part of a normal prescribed burn that is practiced on refuges with the exception that marsh substrates would be dried more extensively prior to burning. Our perspective is that these burns must be possible to conduct within existing Agency standards; otherwise, the research is useless because it cannot be incorporated into future management strategies. Given that outlook, we agree that obtaining information on re-flooding capabilities prior to initiating fires is important and we will work with staff at each refuge to obtain this information. However, we need more direction from the fire branch to identify the criteria of importance. For example,

1. Volume – How are water volume requirements determined? Are they based on the volume of water in the burned marsh at normal water levels, full pool, or some other measure?

2. Rate of flow – Timing of water application likely is important, but how should this be estimated? Rate of flow between units, the number of inlets from adjoining units with water, location of water sources relative to morphometry of burned unit?

6.) What percent moisture content does the organic layer need to be at in order to successfully burn it? The moisture content of the organic layer is a critical parameter to our ability to successfully burn a unit. How dry is dry enough? Do values obtained at other refuges across the country regarding soil (peat) moisture contents apply here in the Midwest or do we need to collect our own fuel moisture samples in these impoundments to establish our own baseline values?

The question of soil moisture levels necessary to control cattail is one of two key parameters (the other being fire variables) that will be addressed in this study. Although much information exists regarding hydrology and cattail germination and growth, little quantitative information exists on the relationship between fire and hydrology in relation to cattail rhizome control. As suggested in the memo from the fire branch, we propose to conduct a test burn during fall 2005. Uihlein WMA is a candidate for this burn because it has a unit with appropriate conditions and is in a fairly remote location if smoke issues arise. Given that substrates within a single unit will vary depending on topography, location relative to ditches, and variable depths of the organic layer, the test burn should provide all of us with much needed information regarding the effectiveness of fire at different levels of substrate moisture as well as fire suppression techniques. This information can then be used to design the complete study, provide refuge staff with more defined targets regarding the extent of substrate drying required, and provide fire staff with information necessary to confirm criteria necessary to conduct future fires in organic materials safely.

7.) Fuel treatment on adjacent property to an impoundment. Adjoining grasslands and marshes need pretreatment in order to reduce or eliminate the chance of escaped fire from burning an impoundment. This will require additional advanced planning to coordinate with a selected marsh burn. Likewise, refuge

biologists are concerned about a potential for decreased escape cover adjacent to burn units if additional widespread treatments to reduce hazardous fuels are present.

Information on conditions on adjacent units and properties will be collected and passed on to the Fire and Refuge Staff for Prescribed Fire Plans and Prescriptions.

8.) Herbicide Treatment: The discussion involved the possibility of herbicide treating a selected marsh to kill the cattail, thereby increasing the dry fuel load and increasing fire intensity to further aid in removal of the rhizome layer or root mass of the cattail. Agassiz NWR described their earlier discussion with the USGS staff in this matter. Due to the increased statistical complexity (2-fold increase in sample units) to incorporate measuring this variable it will not be included in this study. Agassiz NWR will, however, independently continue their test study on the use of RODEO herbicide treatments on other, non-related, cattail marsh areas.

We support the Agassiz staff and their desire to apply herbicide treatments. However, we do not think that it is feasible to incorporate this treatment directly in the study cost and time requirements because the current sample size is only adequate to separate the effects of soil moisture, fire, and the interaction between these two factors, relative to control of cattail. Therefore, adding herbicide treatments would require burning additional marsh units, which would be cost and time prohibitive.

9.) Excavation: Discussion centered on the potential to use mechanical equipment to establish a channel or corridor through the center of an impoundment to concentrate water in the center of the unit thus aiding in the drying of the perimeter areas.

Yes, we agree that this is certainly an option to facilitate drying the marsh as are the other options mentioned in #4 above. Essentially, we have designed this study to concentrate on understanding the effects of soil moisture, fire, and the interaction of these two parameters on cattail. This has been accomplished by stipulating the measurement of various parameters (e.g., soil moisture, rhizome depth, rhizome biomass, substrate composition, organic matter [peat] depth, etc.) both prior to and after the fire. Because we are measuring the abiotic factors and processes (soil, moisture, fire) that influence cattail, we have eliminated the need to conduct all the fires at the same time and can allow increased flexibility in the types of actions used to create drier soil conditions. Therefore, as an example, we will not attribute control of cattail to activities such as “excavation”, but rather attribute control to certain soil moisture.

10.) Public Outreach: The successful implementation of these marsh burns will require close coordination with local neighbors, partners and the general public. The potential safety hazards will need to be addressed along with the willing cooperation of the local community.

Public awareness will be an important step in the success of this study. We agree that the public should have proper knowledge of when, where, and why the burn is being conducted. We are willing to assist the refuge staff in this process if needed.

11.) Test Burn Concept: The idea here is to isolate a small section of marsh to conduct a test burn on it. This test burn would better enable us to establish moisture thresholds, smoke generation, suppression tactics, use of mechanical equipment for line construction, etc. in the development of prescriptions for these marshlands. It would also assist us with answering the question as to what fuel moisture these marshes will burn at.

As we mentioned before, we embrace the test burn concept and plan to implement one at Iroquois and one at either Leopold WMD or Horicon NWR. The criteria that are important for the test burn are:

1. A similar size area as those we are proposing for the study to ensure that we gain experience relative to fire behavior and biological factors at a scale that will occur during typical refuge management operations.

2. A range of soil moisture conditions that includes substrates that do not contain free water at the depth of cattail rhizomes.

12.) Anticipated Costs: Additional fire support costs to be borne by this project could be;
- extended staffing for project implementation
- extended staffing for smoke monitoring, road patrol
- extended staffing for mop-up operations
These additional costs would directly impact the regional fire program budget.

This project is an adaptive management project designed to evaluate existing habitat management practices on refuges, examine methods of improving or enhancing the effectiveness of those practices, and evaluate whether those management practices meet refuge objectives. Thus, prescribed burns of only two wetland units at each of the five refuges is reasonable given that the current design would not greatly exceed or burden the fire management branch's typical burn program. Therefore, we do not expect these burns to require additional costs to conduct.

The issues, concerns, and questions as presented provide the range of information and data needs that are necessary for the development of burn plans for this project. This will need to be an ongoing process so that a workable and viable burn plan can be developed, approved and in place so that the branch of fire is ready to respond if and when the opportunity presents itself.

This will not be an easy task to accomplish. We acknowledge the fact that it truly is a multi-year study and will most likely be years before we have accumulated useable results and data. The branch of fire supports this project, remains committed and within accepted burn parameters will strive to conduct burns safely and successfully to contribute to the success of this project.

To successfully implement this project, we recognize that there are many entities and programs (FWS: Branch of refuges [Washington Office [Dan Ash], chiefs in two regions, and refuge staff], fire branch, USGS (Reston Office and Northern Prairie) involved and we must all work together if the project is to be successful. We too are committed to making this project successful and believe that the interaction between refuge, fire, and research will greatly improve our combined understanding regarding the use of fire to manage wetlands in a safe and biologically meaningful manner.

We appreciate the support of the Fire Study Working Group and intend to supply the information needed to make informed fire safety decisions. However, we request assistance from the fire branch (either FMO or Prescribed Fire Specialist) in the field to help clarify existing, and identify additional, information needs to safely and successfully conduct the prescribed burns. We plan to begin data collection in mid-September and propose to conduct the test burns in early October.

For additional information or comments please contact Soch Lor at ph: (608) 781-6390 or by email at: socheata_lor@fws.gov.