MANAGEMENT STRATEGIES FOR THE REHABILITATION OF THE WEST UNIT OF THE DELTA MARSH

By

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ABSTRACT

Continuing loss of wetlands and wetland habitat has lead to greater interest in the restoration and management of critical sites. The Delta Marsh, a complex of lacustrine wetlands located along the south basin of Lake Manitoba, provides important habitat for staging waterfowl and other wildlife species. A stabilized water regime on Lake Manitoba has resulted in decreased plant diversity, increased abundance of cattail (*Typha* spp.) and a shift in the species composition of waterfowl using the marsh. Although several plans to manage marsh water levels independently of those occurring in Lake Manitoba have been proposed, public concern and financial constraint have prevented their implementation. This study, initiated in response to landowner concerns of continued habitat deterioration, examined the feasibility of rehabilitating the 730-ha West Marsh unit of the Delta Marsh to conditions favoured by staging and resting waterfowl from a biological, engineering, social, and financial perspective.

Wetland management techniques were reviewed to establish their biological impacts and to facilitate the development of management strategies to restore the habitat conditions at the West unit of the Delta Marsh. Drawdown and channel cutting were assessed for spill-over impacts and developed into three management plans. A benefit:cost analysis was conducted by comparing the expected increase in waterfowl numbers after management (valued at $7.55 and $21.50/duck), to the financial costs of construction and operating each plan over a 20-year project life.

Spill-over impacts associated with Drawdown of the Entire PCC Property included crop depredation and flooding. Waterfowl numbers were expected to increase by 3216 ducks and total project costs were $245,493.00 to generate benefit:cost ratios of 0.049 and 0.139. Spill-over impacts associated with Drawdown at Weedy Bay were similar to those of Option 1, but on a smaller scale. The increase in the number of waterfowl predicted to result from management was 1769 ducks, with total project costs of $84,407.00, and benefit:cost ratios of 0.084 and 0.239. Cutting Corners was not expected to produce any spill-over impacts. Waterfowl numbers were expected to increase by 169 ducks as a result of this management option. Total project costs were $63,218.00 and benefit:cost ratios were 0.011 and 0.030. Although all benefit:cost ratios were low, consideration of un-evaluated wetland benefits resulted in the selection of Drawdown at Weedy Bay as the recommended option for wetland management over a 20-year project life. Because each option was considered biologically appropriate, all were presented to enable the landowners to choose among them for the strategy that best suits their needs.

Recommendations for the practice of wetland management include the quantification of wetland values to provide greater financial justification for wetland management and restoration, the establishment of collaborative planning and shared decision making procedures to incorporate the views of multiple interest groups, and the development of habitat monitoring plans to evaluate the results of wetland management.

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CHAPTER 1

INTRODUCTION

1.0 PREAMBLE

The loss of wetlands in Canada continues to be dramatic, as land is reclaimed for agricultural and urban development, and as water regimes are altered to meet human needs (Rubec 1994). Concurrent with loss of habitat is the disturbance of a variety of wetland-dependent ecological systems including biological, chemical, and hydrological processes. Wetland disturbance is often justified for reasons economic in nature, and thus, the opportunity to manage and maintain existing wetlands or restore wetlands that have been altered, will rely upon the identification and acknowledgment of wetland functions and values. Therefore, this study is being undertaken to address these issues, which will assist in the development of management strategies for the West unit of the Delta Marsh.

1.1 BACKGROUND

The habitat available to staging waterfowl at the Delta Marsh has been a concern since the 1960's (Bossenmaier 1968, Jones 1978). At the Delta Marsh, water levels are strongly correlated with those occurring in Lake Manitoba and fluctuate synchronously (de Geus 1987). The Fairford Dam, a control structure designed to dampen water fluctuations on Lake Manitoba has similarly stabilized water levels in the marsh, resulting in lake-like conditions of diminished value to waterfowl. Reports documenting pre- and post-regulation conditions on adjacent Lake Manitoba illustrate that a significant change in species diversity and abundance has occurred in the marsh subsequent to the construction and operation of the Fairford Dam in 1961 (de Geus 1987, Jones and Bazin 1991). Water level variations influence vegetation, wildlife activity, and soil and water chemistry, and are critical for maintaining a healthy, productive wetland (Weller 1994). Although short periods of stability may benefit marsh conditions, long-term stabilization alters the periodic growth and senescence of vegetation to the detriment of the wetland and waterfowl (Weller 1994).

Regulation of Lake Manitoba water levels has meant that marsh water levels fluctuate only as a result of wind-driven seiche effects. Water level fluctuations that once exceeded 2.2 m have been dampened to a range of less than 0.6 m (Crowe 1974). A reduction in flushing ability and the subsequent silting-in of the marsh is evidenced by changes in the contours of the wetland basins. This is especially important when spring flood waters, carrying a heavy load of silt and agricultural run-off carried in the water of the Assiniboine River flow out of the Assiniboine Diversion and into the west portion of the Delta Marsh. High water in 1974 and 1976 resulted in severe flooding and the deposition of 15 to 45 cm of sediment in the lower sloughs of the West unit (Galay 1980). Flooding in the spring of 1996, as yet unquantified, is likely to have contributed to this condition.

Regulation of Lake Manitoba water levels, combined with the effects of periodic flooding and the influence of carp (*Cyprinus carpio*), have been suggested as possible causes of wetland deterioration and decreased use by waterfowl and other wildlife species (Jones 1978, Ould 1980). Attempts to manage any large portions of the marsh have met with limited success and no significant management has been proposed since 1981 (Ducks Unlimited 1981).

1.1.1 STUDY SITE

The Delta Marsh is a large lacustrine wetland complex formed more than 2000 years ago by the retreat of glacial Lake Agassiz. Encompassing about 15,000 hectares (36,000 acres) along the south basin of Lake Manitoba (50°11'N, 98°19'W), Delta Marsh has been designated as a Site of International Importance by the Ramsar Convention, declared a Heritage Marsh by the province of Manitoba, and has historical significance as a staging and feeding area for large numbers of waterfowl (Hochbaum 1944). The area under study is located in the West Marsh unit on 730 ha (1800 acres) of property owned by the Portage la Prairie Country Club. Features of this complex include Weedy Bay and Canvasback Bay as the principal water bodies, and Cram and Deep creeks which facilitate direct exchange of water between the bays and Lake Manitoba (Figure 1.1). The creeks also carry local runoff water from agricultural lands to the south into this portion of the Delta Marsh.

1.2 ISSUE

Members of the Portage la Prairie Country Club (PCC) have reported a decline in habitat for waterfowl and non-game water bird species at the Weedy Bay-Canvasback

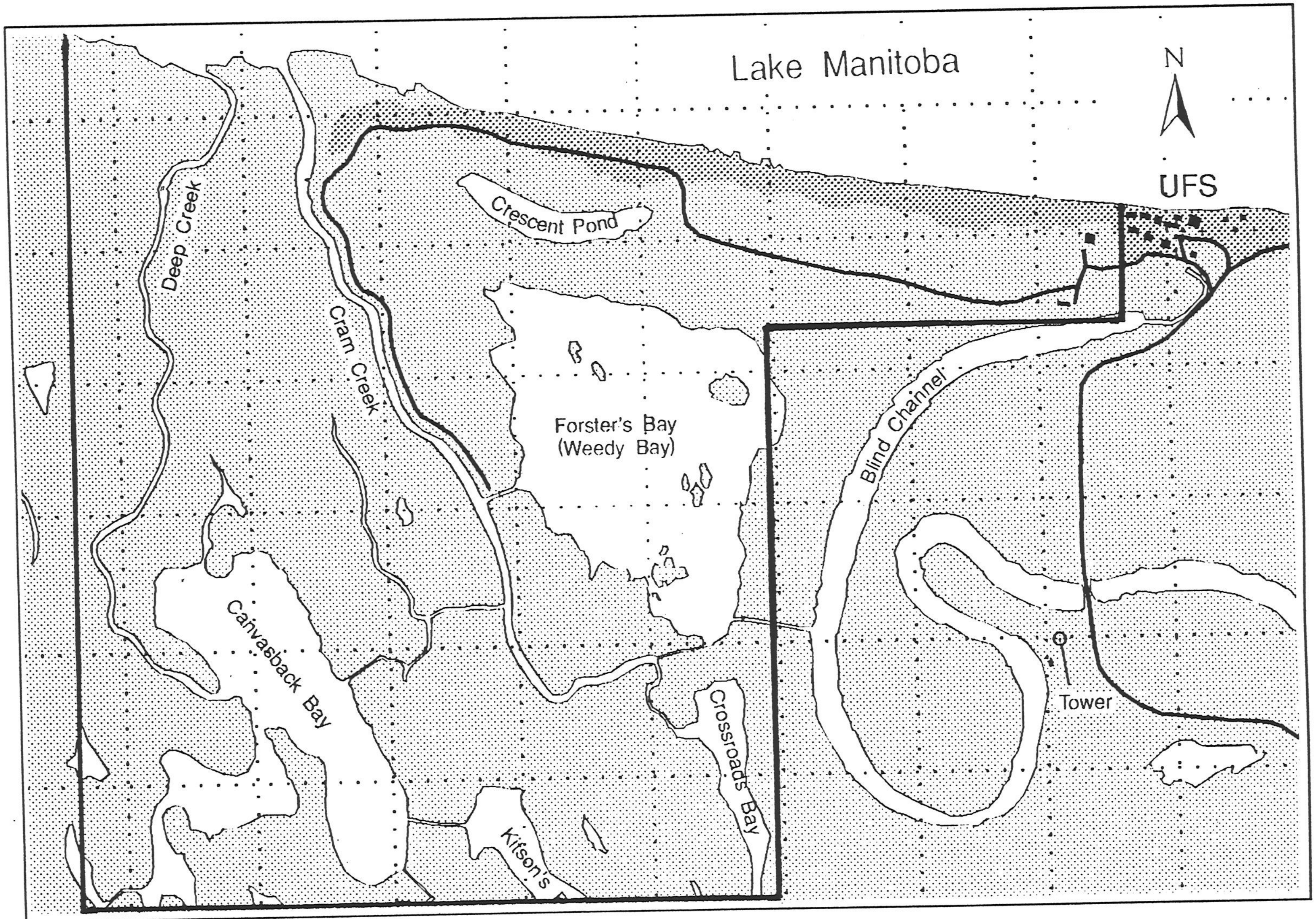

Figure 1.1. Study area at the Portage la Prairie Country Club. Delta Marsh, Manitoba (Courtesy of the University of Manitoba Field Station).

Marsh complex at the West unit of the Delta Marsh. The Manitoba Department of Natural Resources has been approached to determine the factors causing these impacts. A decline in the number of waterfowl and a shift from diving to dabbling duck species was documented by the most recent waterfowl surveys (Jones and Bazin 1991). These changes, symptomatic of deteriorating habitat and conditions less attractive to waterfowl, are represented by decreased plant diversity and decreased basin depth. The actual cause of degradation is likely a combination of a number of factors including a stabilized water regime, periodic flooding and the inundation of silt-laden water, and disturbance caused to aquatic plants by the behaviour of carp.

Habitat degradation and the potential for management at the Delta Marsh have been detailed in several reports describing the costs and benefits of management to the area and its stakeholders (Bossenmaier 1968, Jones 1978, Ould 1980, Ducks Unlimited 1981). While these studies were directed at managing and improving the conditions of the entire Delta Marsh, none dealt specifically with the smaller West unit herein described. Smaller open water bodies, greater fertility, and the potential of periodic flooding over the Assiniboine River Diversion failsafe present management considerations particular to the West unit (Jones 1978).

Management of the West unit is made both difficult and costly by physical and jurisdictional limitations. The absence of water control structures, and the existence of many water inflow and outflow channels are problematic for any development; however, the conflict of interests among area stakeholders (which include two private hunting clubs, the University of Manitoba Research Station, and the owners of agricultural land) make management of the entire West unit difficult. By limiting the study area to one portion of this unit and the financial capabilities of one land owner, this study has built upon past plans with a goal to examine new approaches to management.

1.3 PURPOSE

The purpose of this study was to identify the causes of habitat deterioration for waterfowl at the Weedy Bay-Canvasback Bay complex of the West unit of Delta Marsh, to determine the feasibility of restoring conditions attractive to staging waterfowl, and to recommend management strategies documenting biological, social spill-over, and financial impacts based on these results.

1.4 OBJECTIVES

Specific objectives were to: (1) provide an introduction to the concepts of wetland ecology and wetland management and establish the biological requirements of staging waterfowl; (2) determine historical changes, document current conditions, and predict future conditions at the Weedy Bay-Canvasback Bay complex in terms of water levels, vegetative structure and species composition, and waterfowl and wildlife use; (3) review previous attempts to manage the Delta Marsh and establish the reasons they failed to be implemented; (4) assess various wetland management techniques for their ability to restore the biological conditions favourable for staging waterfowl; (5) document any spill-over impacts, both potential and perceived, associated with the application of these techniques; (6) quantify the financial impacts of these wetland management techniques compared with the benefits received in increased waterfowl use; and (7) recommend feasible management alternatives for wetland rehabilitation of the Weedy Bay-Canvasback Bay complex of the Delta Marsh.

1.5 ORGANIZATION

This practicum is organized into six chapters. The first is an introduction to the research consisting of a preamble, and statements of background, study area, issue, purpose, objectives, the methods used to achieve those objectives, and the limitations encountered during the research.

Chapter 2 presents a review of literature to provide the background necessary for the following chapters. The interrelationships between hydrology, vegetation and wildlife, the role of disturbance, the staging requirements of waterfowl, the theory of wetland management and wetland management techniques are described.

Chapter 3 consists of a more detailed description of the physical setting and the ecological conditions of the study area. A description of recent changes at the Delta Marsh, prevailing conditions, and conditions predicted for the future is provided to establish the need for wetland management.

Chapter 4 is a review of previous management strategies for the Delta Marsh and the reasons they were never implemented. The theory applied in the practice of wetland management is reviewed to establish the context upon which wetland management recommendations in this document are made.

Chapter 5 presents in greater detail the methods used in the analysis of wetland management techniques. Wetland management techniques that produce the biological objectives of the study were developed into management plans, and evaluated to determine their spill-over and financial impacts. Recommended options were presented to enable the client group to choose one or more biologically feasible management strategies.

Chapter 6 summarizes and concludes the research and offers recommendations for further study.

1.6 METHODS

The following methods were used to identify the causes of marsh deterioration, to determine the feasibility of rehabilitating the Weedy Bay-Canvasback Marsh area, and to recommend strategies to facilitate rehabilitation. This information is expected to provide evidence of the need for management at the Delta Marsh, and provide criteria upon which biological, economic, and engineering decisions can be based.

1.6.1 Wetland Ecology and Management

A review of the literature concerning the biological processes of the wetland ecosystem was conducted to provide a background for a discussion of the role of disturbance in wetlands. The biological requirements of staging waterfowl were determined by a review of waterfowl literature, including published reports and books. The methodology described for the theory of management was based on recent literature regarding the management and restoration of wetlands.

A review of wetland management techniques was done to provide a background to the design of management for the West unit of the Delta Marsh. Construction and design specifications for these strategies were drawn primarily from the Techniques handbook of waterfowl habitat development and management (Atlantic Waterfowl Council 1972), and with the guidance of wetland engineers and biologists.

1.6.2 Ecological Condition of the Delta Marsh

The physical setting of the Delta Marsh, including geology, geography, soils, and climate, was determined by a review of literature concerning the Delta Marsh and southern Manitoba. Principal literature sources included University of Manitoba theses and published reports.

Historical changes in marsh water levels were determined from data provided by the Manitoba Department of Natural Resources and thesis reports from the University of Manitoba. Variation in the vegetative structure, including species diversity and density over the past 40 years, was determined by a review of the literature Site inspections were conducted in spring, summer, and fall 1995 to assess the presence of vegetation. Waterfowl and wildlife use was determined from a review of survey data and literature. Long-term use by waterfowl was determined by Manitoba Department of Natural Resources aerial and ground survey data of brood counts, fall staging counts and hunter bag check records. Muskrat (*Ondatra zibethecus*) and white-tailed deer (*Odecoileus virginianus*) records were similarly obtained from the Manitoba

Department of Natural Resources and Delta Marsh literature. Commercial fishing history was determined by a review of Delta Marsh literature.

Conditions within the marsh were monitored several times between May and October 1995, and again in summer of 1996. In addition, several wetlands in southern Manitoba that are currently managed were inspected for comparative purposes.

Predictions as to the future habitat conditions, and patterns of human use at the Delta Marsh were made based on wetland ecology literature, the prevailing conditions at the marsh, and discussions with PCC members. This scenario will also serve as a baseline with which predicted or actual results of management can be compared.

1.6.3 Wetland Management at Delta Marsh

A review of previous management plans and the limitations that prevented their implementation was included to assist in the assessment of the feasibility of utilizing various management techniques. Sources included the Delta Marsh Plan (Jones 1978), the Delta Marsh Conceptual Review (Ould 1980), and the Delta Marsh Development Proposal (Ducks Unlimited 1981). The specific spill-over concerns raised by these studies were reported in the Delta Marsh Development Plan (Ducks Unlimited 1981).

1.6.4 Wetland Management Alternatives

Preliminary selection of wetland management techniques was based on an assessment of their ability to produce the conditions required to meet the biological needs of waterfowl given current conditions at the Delta Marsh. This analysis was based on literature, discussions with wetland management professionals, and site inspections.

Management techniques that would result in improved habitat conditions for waterfowl were developed into management strategies. Consultation with wildlife management, water resources, and economics professionals, and the principal stakeholders assisted in the development of these strategies. To reflect both the needs of the ecosystem and the concerns of local landowners, the biological, social, and financial implications of various wetland management techniques were examined.

The spill-over impacts predicted from these options were developed from those raised by attempts to manage the area in the past. The financial investment required to initiate and operate the management options was calculated in 1996 dollars over a 20 year project life.

Financial figures included materials, equipment, labour, and transportation. Based on discussion with managers, a reasonable life expectancy was assigned to each management endeavour. Long-term project costs were determined by multiplying annual costs by the life expectancy of the project and discounting to 1996 dollars. The financial benefits of management were determined by calculating a per-bird dollar value and multiplying by the net increase in bird use per hectare predicted with the various management options Waterfowl benefits were calculated over the 20 year project life and a ratio of benefits:costs was presented for each option.

1.6.5 Recommendations

Biologically feasible management options for the PCC property in the West unit of the Delta Marsh are presented to enable the clients to choose the strategy they believe will best suit their needs. The management plan with the greatest benefit:cost ratio and that produces the least number of spill-over impacts was selected as the recommended option

1.7 LIMITATIONS

Wetland valuation is most often accomplished through contingent valuation methods. Typically, a dollar figure, determined by research on willingness-to-pay for the resource, is assigned to waterfowl. This figure is multiplied by the number of waterfowl using the wetland in order to apply a monetary value to a non-market value good, and account for economic benefits.

Such studies have never been conducted at the Delta Marsh. Coupled with the absence of long-term annual waterfowl counts, the evaluation of wetland benefits is difficult to quantify. Further, there can be no comparison of waterfowl populations at the West unit of the marsh with those in other units or pre-post-intervention comparison, as pre-management data do not exist. The ability to compare the number of birds using the managed portion of the East marsh to the number in the West would strengthen the mandate for management; although topographically and geographically and hence ecologically, these areas are somewhat different.

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

The study of wetlands is complex and requires input from many disciplines including soil sciences, geography, botany, and zoology. Wetland management, however, becomes more complicated; because, in addition to the ecological aspects of wetlands, management must also address the social, or spill-over, impacts and the financial investment in order to determine the financial benefit:cost ratio. A review of wetland ecology, the role of disturbance in wetlands, and the biological requirements of staging waterfowl provides the background for a discussion on the theory of wetland management. The relevance of spill-over and wetland economics is discussed. The purpose, methods and effects of a variety of wetland management techniques are reviewed.

2.1 WETLAND ECOLOGY

Wetlands are complex ecosystems defined by specific vegetative, soil, and hydrologic conditions. In prairie wetlands, these conditions are sustained by dynamic natural (abiotic and biotic) processes, including water level fluctuation, growth and senescence of vegetation, wildfires, and the impact of wildlife. Wetland plant species are adapted to periodic disturbance that promotes germination or reduces dominance of a small number of species (van der Valk 1981).

While detailed discussions are provided by Mitsch and Gosselink (1986) and van der Valk (1978), this section includes a rudimentary overview of the soil, hydrology, and vegetation specific to wetlands, along with their associated functions and values. Through a review of the interrelated nature of wetland processes and the importance of the role of disturbance in maintaining wetland dynamics, this brief introduction is intended to provide managers with the ecological awareness necessary to make sound habitat management decisions.

2.1.1 Soils

Saturated wetland soils are characterized by anaerobic conditions which exert a marked influence on biochemical transformation (Mitsch and Gosselink 1986). Such hydric soils are defined by the U.S. Soil Conservation Service (1985 p.1) as "a soil that in its undrained condition is saturated, flooded or ponded long enough during the growing season to develop anaerobic conditions that favour the growth and regeneration of hydrotrophic vegetation."

Wetlands play an important role in the management of both surface and ground waters. By slowing runoff, wetlands reduce the extent of flooding and soil erosion while improving water quality by capturing sediments. Unique characteristics of wetland soils that enable them to hold water are also important in the maintenance of the water table (Government of Saskatchewan 1993), and while flood risks are decreased, the actual amount of water in the water table increases (Banga 1988).

Wetland soils are the primary mechanism for chemical transformation and nutrient storage for use by most wetland plants. Wetlands serve as sources, sinks, and transformers of chemicals depending on wetland type and hydrological condition (Mitsch and Gosselink 1986)

2.1.2 Hydrology

Hydrology is the most important determinant in the creation and maintenance of wetlands and wetland processes (Mitsch and Gosselink 1986). The hydrological regime, or hydroperiod, is defined by the seasonal pattern of water levels which include water depth, flow patterns, and the duration and frequency of flooding, or water recession. Because the hydrological regime determines the characteristics of a given wetland, any alteration to the hydrology will influence the ability of the wetland to perform its associated functions (Hubbard 1988). Species richness and diversity, primary productivity, decomposition, and nutrient cycling are strongly influenced by the hydroperiod.

Hydrology acts as both a limit and a stimulus to plant species richness. Aquatic plant species have different physiological responses to flooding. The establishment of one species over another depends on the tolerance of its seeds to flooding (van der Valk 1981). Primary productivity is enhanced by flowing conditions and a pulsing hydroperiod and is suppressed by stagnant conditions.

Organic accumulation in wetlands is controlled by hydrology through its influence on primary productivity, decomposition, and the export of particulate matter (Mitsch and Gosselink 1986).

Both nutrient cycling and nutrient availability are strongly influenced by hydrological conditions. The major source of nutrients for wetlands is through water input in the form of precipitation and runoff. Wetlands also function to transform chemicals. Many of the organic and inorganic nutrients and toxic materials, including the pesticides and fertilizers carried in agricultural runoff, are neutralized or transformed into non-toxic forms by wetland ecosystem processes (Cowan 1979, Mitsch and Gosselink 1986).

2.1.3 Vegetation

Wetland vegetation are species which are specially adapted to the hydric conditions of wetland soils. Emergent vegetation including cattail (*Typha* spp.) and bulrush (*Scirpus* spp.), and submersed species such as sago pond weed (*Potamogeton pectinatus*), are important components of wetland food webs. Vegetation is both a source of food for waterfowl and a substrate for algae, which then provides food and shelter for invertebrates, all of which in turn may be food for a variety of wildlife (Murkin et al. 1992). The two greatest forces influencing changes in aquatic vegetation, cover and species composition are changing water levels and the activity of herbivores (Weller 1994). Fluctuating hydrological conditions characteristic of wetlands result in plant communities that are very diverse (Kantrud et al. 1989).

The vegetation bordering wetlands is also a vital resource which can provide a source of high quality hay or livestock forage, and helps control salinization, reduce erosion, and trap snow in the winter (Government of Saskatchewan 1992).

2.1.4 Wildlife

In discussions of wetland wildlife, waterfowl are typically regarded as the primary species of interest. However, the diverse and dynamic conditions found in wetlands also support a disproportional number of threatened or endangered species. Approximately half of the 95 species so listed including fish, birds, mammals, and plants rely on wetlands for part of their life cycle (Mitsch and Gosselink 1986, Bond et al. 1992, Dennison and Berry 1993).

2.2 ROLE OF DISTURBANCE

The periodic disturbance characteristic of prairie marshes plays an important role in promoting species richness and diversity, while inhibiting the dominance by a few species (van der Valk 1981). The primary motivators of natural disturbance in wetlands are the hydrological regime and the activity of herbivores (Weller 1994). Muskrats influence the structure and function of wetland vegetation in our latitude more than any other animal (Fritzell 1989). The destruction of emergent vegetation caused by muskrat activity is just one component of a cycle of disturbance observed in wetlands. Non-natural, or human-caused disturbance, may also strongly influence wetland processes by either increasing disturbance via the introduction of non-native species, reducing or increasing long-term water levels, or decreasing disturbance by stabilizing the water regime.

2.2.1 Hydrological Regime

The wet-dry cycles observed in prairie marshes occur every 5-20 years in response to changes in precipitation patterns (van der Valk and Davis 1980). The hydrological regime is the principal factor controlling the distribution and composition of wetland vegetation (Kantrud et al. 1989). van der Valk and Davis (1980) describe the four stages of the wet-dry cycle, including dry marsh, regenerating marsh, degenerating marsh, and lake-like marsh (Figure 2.1).

During the dry marsh stage, receding water exposes mud flats, enabling the seeds of annual and perennial plants to germinate. When precipitation patterns return to normal and the drought period ends, the marsh re-floods.

This regenerating marsh stage is characterized by vegetative propagation and the spread of emergent species along elevation gradients (Kantrud et al. 1989). Higher water levels also enable submersed species to reestablish (Mitsch and Gosselink 1986).

Prolonged high water levels result in the senescence of both submersed and emergent vegetation. Species not tolerant to flooding disappear while those remaining become dominant (Mitsch and Gosselink 1986). Responding to increases in the amount of emergent vegetation cover, muskrat populations increase rapidly in the late regenerating and degenerating marsh. Muskrat populations are highly variable and with densities of 50/ha not unusual, they quickly eliminate the remaining emergent cover (Fritzell 1989).

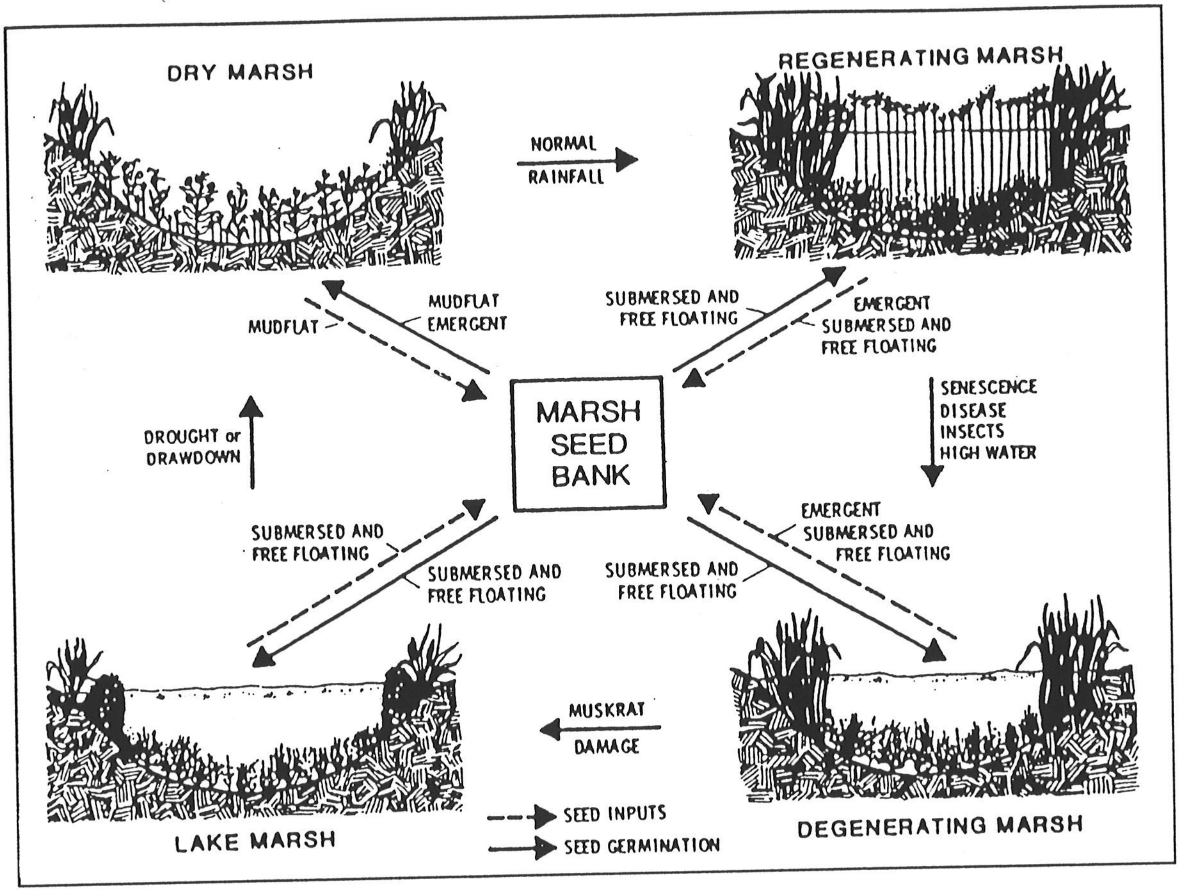

Figure 2.1. The wet-dry cycle observed in prairie wetlands (From van der Valk 1989).

The feeding activity of muskrats and eventual decline in offshore emergents maldadapted to prolonged deep water are the primary agents in the transition between a degenerating marsh and a lake-like marsh (Kantrud et al. 1989). However, marsh plants can similartly decline to lake-marsh phase in the virtual absence of muskrat. Submersed and free-floating plant species are produced during the lake-like stage of a wetland; however, a period of drawdown is then necessary to stimulate new growth and renew this vegetation cycle.

2.2.2 Wetland Alteration

Over the last century, human activity has resulted in the alteration of the natural processes in many wetlands. Urban encroachment and agricultural expansion have resulted in the introduction of new species to wetland systems and the alteration of hydrological regimes. Fires are now more frequent and can alter plant species composition and distribution (Hochbaum 1944).

The expansion of the hybrid species of cattail (*T. glauca*), rapid under a stable water regime, results in dense, monotypic stands of vegetation with limited value to wildlife. The ability to survive and produce seed during several years of flooding enables cattail to spread down elevational gradients into open water. Substantial accumulation of litter from cattail roots, rhizomes, stems, and leaves, reduces water depth and creates habitat into which it can expand vegetatively or by seed (Yeo 1964), while producing habitat of limited value for the establishment of most submersed aquatics.

Carp contribute to the break-down of emergent cover by uprooting vegetation (Bond 1979). While such activity may be beneficial in conditions where emergent vegetation is very dense, it contributes to increased turbidity and hinders the growth of submersed species when high water conditions dominate (Panek 1987, Weller 1994). With an ability to thrive in conditions and at population densities that others cannot tolerate, carp compete with native fish species and waterfowl for food resources (Sigler and Sigler 1987, Weller 1994).

Long-term stabilization alters wetland processes to the detriment of marsh communities, and deterioration is rapid (Weller 1994). Lake-like conditions are perpetuated such that primary productivity, decomposition, and nutrient cycling are slowed. The energy normally in constant flux in functioning wetlands is thus tied up in the detritus and sediments, where it cannot be efficiently tapped by other components of the ecosystem.

2.3 STAGING WATERFOWL REQUIREMENTS

Waterfowl have different habitat requirements at different stages in their life cycle. After the breeding and moulting season, birds begin a fall migration toward their wintering grounds in the southern United States and Central America. En route, flocks of waterfowl stop to rest or stage at wetlands large and open in comparison to those selected for breeding. Birds in fall migration are attracted to a wetland by the quantity and quality of food provided therein, or in the case of cropland field feeders, to uplands near farmland (Weller 1994). Generally, areas with more emergent vegetation cover are used only as protection from wind, although some waterfowl will feed there (Weller 1994).

The dietary needs of waterfowl during fall migration are also different from those of breeding birds. After breeding and brooding the young of the year, ducks shift from insect and crustacean foods to vegetative sources (Weller 1994). Plant species favoured include various seeds, leafy vegetation, and tubers. Seeds of wet-meadow smartweeds (*Polygonum* spp.), or millets (*Echinochloa* spp.), deeper water sago pondweed (*Potamogeton pectinatus*) are consumed by diving duck species, while dabbling ducks feed on either seeds in shallow areas, or in upland areas and consume agricultural crops (Weller 1994). Leafy, or submersed vegetation including sago pondweed, is found in central marsh pools or shallow lakes. The tubers of many plants, such as those of sago pondweed are important for canvasbacks and other diving ducks, and duck potato (*Saggitaria* spp.) is used by various dabbling ducks.(Weller 1994). Seeds from emergent plants or mudflat annuals are important foods for migrant dabblers (Fredrickson and Laubhan 1994).

2.4 THE THEORY OF MANAGEMENT

Wetland loss and degradation observed throughout the world has forced resource managers to place increasing emphasis on protecting wetlands that retain natural ecosystem functions and to manage those disrupted by human activities (Weller 1994). Although the overgrowth of vegetation and the drying out of wetlands is part of a natural marsh cycle, human activity through the alteration of wetland hydrology, has no doubt hastened the rate at which this process occurs (Thomas 1982).

The absence of much commercial activity in wetlands means that they are usually credited with little value, economic or otherwise. Designation as unimproved land or waste-land, and the minimal protection granted by political policy to such land, has hastened wetland loss. Wetland management for waterfowl was the first and is still the predominant goal of the conservation and enhancement of many wetland regions. However, recognition of the many life support functions maintained by wetlands has more recently, prompted more diverse reasons for wetland management.

2.4.1 Philosophy of Wetland Management

Payne (1992) wrote that "wetland management should be aimed at emulating natural marsh processes while providing resources that meet the physiological and behavioural needs of wildlife". This suggests that undisturbed wetlands should be maintained while human-influenced wetlands with diminished productivity should be managed to simulate natural conditions (Weller 1994).

Wetlands are managed for many reasons, including conservation and management of flora and fauna; waterfowl, fish, herpetofauna, and invertebrates, maintaining biodiversity, the economic benefits from fisheries and agricultural industries, water storage and flood control, and the developing areas for tourism and recreation (Weller 1994). All wetland management should be goal oriented, and managers must be cognizant that it may not be possible to manage for all species at all stages of their life cycles. An understanding of the complexity of the wetland ecosystem implies an understanding that changes to one species will induce changes in all other species that inhabit a wetland (Weller 1994).

For example, in wetlands managed for waterfowl, flooding and drawdown are used to simulate natural marsh cycles. Management of water levels in such a way brings about hemi-marsh conditions, when emergent vegetation and open water cover equal areas in a mosaic pattern, which is believed to result in maximum waterfowl use and production (Mallik and Wein 1986). This ratio of vegetation to water increases both emergent and submersed plant productivity and diversity, with a reciprocal increase in the number of invertebrates (Fredrickson and Laubhan 1994). Pollard (1996) suggested, from a review of many published sources that degraded wetlands restored to optimal hemi-marsh conditions experienced as much as a 3 to 5 fold increase in use by waterfowl.

2.4.2 Management Methodology

Selection of the appropriate technique for managing a particular wetland will be determined by the history, characteristics, and potential of the marsh, and the conditions required of the species or process to be managed. Identifying the physiological and biological requirements of the target management species will ensure that the implementation of effective management is both expedient and cost effective (Fredrickson and Laubhan 1994).

Payne (1992) lists several characteristics that must be considered when selecting a site for management. Included are location in the province and flyway, relation to migration routes, wintering grounds and breeding grounds, and the relation to other wetlands and other managed areas. Social and economic factors include accessibility and ownership. Biological and physical factors include vegetative cover, soils, geology, water supply and quality, and wildlife use. If these characteristics are found to facilitate management, engineering studies should proceed (Payne 1992).

An inventory of the area under consideration should be conducted to determine various wetland features and the potential for management (Payne 1992). This involves determining the extent and quality of wetlands including, water supply, inflow and outflow channels, the identification of immediate and adjacent landowners, and the location of special or protected areas (Payne 1992).

Technical Concepts

Methods vary for ecologically sound management of human-made or human-modified wetlands but should emphasize creating or restoring natural wetland functions. Implementation of this concept often requires construction and installation of physical structures (e.g., levees, water control structures, water supply and discharge systems, pumping systems) that enable more exact control of water inflow, distribution, and discharge (Payne 1992, Fredrickson and Laubhan 1994). Water level management is necessary to create soil and water conditions suitable for germination and growth of desirable plant communities, control problem vegetation, stimulate invertebrate production, and make resources available for target wildlife species; however, control of water levels is not feasible in every management project (Fredrickson 1991). Design engineers must clearly understand management goals to construct physical works compatible with desired natural wetland characteristics, processes, and resources (Fredrickson and Laubhan 1994).

Spill-over Impacts

Social and economic factors are responsible for the majority of human-induced wetland disturbances and are, similarly, the limiting factors in wetland management. Payne (1992) states that development incompatible with the activities of the surrounding community should not proceed regardless of appropriate biological and engineering conditions.

Because wetland management often implies the manipulation of area hydrology, managers must ensure that the water rights and riparian rights of neighbouring land owners are not significantly influenced. For this reason, it is suggested that water management of wetlands will be most successful in areas with few land owners (Fredrickson and Laubhan 1994, Payne 1992).

Wetland Economics

Wetland valuation is most often accomplished by examining its production and use by waterfowl. By assigning a dollar figure to waterfowl, the potential value of a wetland may be inferred by the number of birds it produces or is expected to produce under management. This dollar value is based on contingent valuation methodologies which use travel cost or willingness to pay studies to determine the value of, for example, a hunting trip. The problem with basing all wetland benefits on these values is that they are incomplete, because nonuse benefits have not been addressed (Porter and van Kooten 1995).

van Kooten (1993) estimated the hunting value of migratory waterfowl in Saskatchewan to fall between $17.61 and $25.39 per bird. Similar evaluations in Manitoba place an estimate of only $7.55 per bird. The value of waterfowl either produced or hunted at a marsh is calculated to quantify wetland benefits. A project may be evaluated, or projects compared, based on the ratio of benefits in the value of waterfowl generated as a result of management to the costs, or financial investment, necessary to implement the management action. An accurate assessment of project benefits and costs cannot be attained solely from these data because many values are unquantified. The above calculations disregard scenic values, environmental benefits, and nonuse values which are estimated to be as great as four times the hunting value, and thus could contribute substantially to the benefits of a given management project (Prins et al. 1990).

Consumptive and non-consumptive use of wildlife is a growing industry that provides economic and social benefit to thousands of business people (Government of Saskatchewan, 1992). Wetlands are an integral part of these activities, providing support for guiding, hunting, trapping, fishing, and gathering. Wetlands are also popular for the growing industry of ecotourism which relies on natural sites for wildlife observation and photography. Other aspects of recreation include hiking, bird watching, canoeing, education, and research.

The capital investment necessary for wetland rehabilitation is often great. However, the long-term costs associated with maintenance and operation can be substantially reduced and wildlife benefits maximized if developments are designed to function in an ecologically correct manner (Payne 1992).

Short term solutions such as disking, mowing and seeding are considered sub-optimal because they address only the symptoms and not the causal agent. These methods cannot be completely disregarded, however, as a situation indicates short-term, low initial-high long-term cost options may be the only feasible means for management.

It must also be considered that the option for no management will always involve some cost. Wetlands desired for use but left unmanaged, require the prospective users to work in certain ways to receive benefits. For example, annual or semi-annual cutting of channels to allow canoe navigation where a dense band of emergents persist in a lake-marsh phase wetland.

2.5 WETLAND MANAGEMENT TECHNIQUES

Before a management regime is recommended, a review of current management techniques must be conducted to ensure compatibility with the region and the management objectives. The purpose of this section is to provide a description of the various techniques used in the management of wetlands. Management techniques are divided into two groups: management with water control and management without water control. A description of each technique consists of the conditions in which they are used, how they are accomplished, and what their biological impacts are.

2.5.1 Wetland Management with Water Control

Optimal management of wetland ecosystems requires the ability to manipulate water levels (Payne 1992). Simulating the natural water regime in a disturbed wetland will enable the manager to provide the widest range of management for a particular area. Drawdown, or the drainage of water from a wetland, and flooding with high water levels simulate natural stages in the wetland cycle to either create desired vegetation, or eliminate undesired species (Fredrickson and Laubhan 1994).

Control of water levels requires the installation of dams, dikes, or levees and various water control structures to regulate the inflow and outflow of water. Installing water control systems involves high initial costs, low operating costs, and long-term benefits. High start-up costs mean that such techniques are often not feasible for private land owners or in areas with multiple stakeholders (Payne 1992).

2.5.1.1 DRAWDOWN

Drawdown is a valuable management technique for wetlands in which natural wet-dry cycles have been altered by human activity (Scott 1982). Wetlands not subject to periodic drying out rapidly become open and lake-like with little cover or food for waterfowl and other wildlife (Scott 1982). A dry-marsh stage is simulated by removing water from the wetland and exposing mudflats. Removal of standing water, either partially or completely, exposes saturated wetland soils to encourage the development of vegetation from the seed bank and speed the rate of decomposition. (Scott 1982, Fredrickson and Laubhan 1994). Drawdown also stimulates nutrient recycling as it dries, oxidizes sediments, promotes breakdown of partially decomposed organic debris on the marsh bottom, and stimulates seeds to germinate. In this way, plant stands are maintained or are regenerated if they are absent before drying occurs. Subsequent flooding is required in order to maintain marsh plants germinated or previously present, and to permit plants which grew as a result of the drawdown to produce seed (Ducks Unlimited 1981).

As the basin is re-flooded in subsequent seasons, the less water tolerant vegetation disappears, resulting in a varying cover-water interspersion over time (Weller and Spatcher 1965, Weller and Fredrickson 1973). Under optimum conditions, the cover:water ratio is about 50:50 across an entire wetland, or a large portion of wetland, and vegetation is distributed in patches throughout the basin. During this hemi-marsh stage, a wetland attracts the greatest diversity and numbers of waterbirds, and muskrat and invertebrate populations often are high (Weller and Fredrickson 1973, Fredrickson and Laubhan 1994).

The establishment of stands of emergents and seeding annuals is the main purpose of drawdowns in wetlands managed as waterfowl habitat (Fredrickson and Taylor 1982). Wetland draining and subsequent reflooding is a well-established tool (Kadlec 1962) practiced in many areas, and known to increase plant species diversity (Mallik and Wein 1986). When water is removed, moist soils are rapidly colonized by perennials, such as hardstem bulrush (*Scirpus acutus*) and softstem bulrush (*Scirpus validus*), and annuals such as sedges (*Carex* spp). The presence of oxygen speeds the process and encourages the production of submergent vegetation by releasing nutrients tied up in the sediments (Weller 1994). Most recruitment during a drawdown comes from the soil seed bank (van der Valk and Davis 1978, Smith and Kadlec 1983) although seedling programs, which involve physical or mechanical planting of wetland vegetation seeds, have been carried out in areas that lack a rich seedbank, such as artificial wetlands.

Water level management in the form of sheetflood irrigation is required to encourage the development of newly established emergents and the re-establishment of dense beds of submergent vegetation in the post drawdown period (Ould 1980). Reflooding after drawdown increases plant and invertebrate diversity, makes the habitat ideal for ducks and other marsh animals, controls the growth of undesirable species, and can set back succession (Weller and Spatcher 1965, Weller and Fredrickson 1974, Weller 1994). The density of vegetation can be greater after reflooding as a result of vegetative expansion throughout the growing season (Merendino 1989).

Scheduling Drawdowns

Some control of the relative abundance of different plant species might be achieved by varying both the timing (Meeks 1969, Fredrickson and Taylor 1982) and extent of drawdown (Smith and Kadlec 1983). Drawdown may be initiated in either the spring or fall, be partial or complete, and may be conducted in coordination with several other types of management. Although there is no straightforward distinction between correct and incorrect water regimes, the goal of a given management project will determine when, how, and to what extent drawdown is to occur (Scott 1982).

Typically, drawdowns are scheduled for early spring or early summer to enable soils to dry and stimulate germination from the seed bank. Recruitment of most emergents and mud-flat annuals from the seed bank during June suggests that recruitment is favoured under conditions of high soil moisture, moderate to high temperatures, and low soil conductivity (Welling et al. 1988a). Because the growing season will be longer, perennial emergent vegetation established during early drawdowns should be more flood tolerant than vegetation established during late drawdowns. If drawdown is delayed there is a risk that annual weeds rather than hydrophytes will become established (Scott 1982).

Some wetland managers believe that fall drawdowns will secure optimal results. Dispersal of seeds to emerging mudbanks could be maximized by lowering water levels in the fall and maintaining low water levels through germination and early seedling growth from May 15 to June 30 the following year (Jones 1978). Continued low water conditions through summer and early fall will further enhance the growth of these plants (Jones 1978).

Management for migratory or wintering waterfowl may also be achieved by later drawdowns. A partial late fall drawdown will expose the seeds and invertebrates used as food by migrant ducks and other species (Kent 1994). Fall drawdowns over several years will eliminate or reduce species that compete with waterfowl for resources, such as muskrat, carp, and black bullhead (*Ictalurus melas*), which will not survive winter freeze-up.

Managed drawdowns usually last for one or two growing seasons (Welling et al. 1988b). A one-year drawdown appears sufficient, however, if the purpose of management is to establish maximum numbers of seedlings of emergent species. In a study conducted at the Delta Marsh, Welling et al. (1988b) found that recruitment of emergents occurred primarily during the first year of a two-year drawdown treatment, and considerable mortality of first year emergent seedlings occurred due to desiccation during the second year of drawdown. This finding is consistent with the observation made by Harris and Marshall (1963) that one-year drawdowns were more successful than two-year drawdowns in establishing emergents.

Drainage, hydrophyte germination, and subsequent reflooding alone may not be capable of establishing the habitat conditions desired. To encourage the establishment of desired species, or to limit the establishment of less desirable species, may require the combination of drawdown with one or more other technique. One such method is a seedling program. The majority of these combination techniques are aimed at reducing dominance by cattail. Nelson and Dietz (1966) and Mallik and Wein (1986) indicate that drainage alone can cause a significant increase in the cover and stem density of cattail. They state that the growth and vigour of cattail can be inhibited by burning a drained marsh in the summer.

2.5.1.2 FLOODING

The distribution of species and plant communities within a wetland is primarily a function of water depth. A long-term change in water level, particularly an increase, can result in dramatic changes in wetland vegetation (van der Valk et al. 1994). In addition to promoting emergent die-off, flooding can also be an effective tool to increase diversity of marsh plants, increase wetland edge, and provide greater habitat for waterfowl and wildlife (McDonald 1955). Loss of emergent vegetation is associated with an increase in the cover of submergent and free-floating species (McDonald 1955, van der Valk et al. 1994). These plants are valuable to staging waterfowl and species that prefer more open marshlands.

When dense stands of cattail are opened-up the wetland edge is increased. The cover available to wildlife is thus improved, and floating blocks of vegetation uprooted from the bottom can provide loafing habitat, although of short-term, as root mats deteriorate (McDonald 1955).

Because timing, depth, and duration of high water conditions play significant roles in the effectiveness of flooding, results are observed only after two to three years of high water (Welling et al. 1988b, van der Valk et al. 1994). Wet-dry cycles have been simulated in several studies including the Marsh Ecology Research Project at the Delta Marsh, Manitoba. High water conditions were simulated by flooding 1.0 m above normal for two years prior to drawdown. Welling et al. (1988 a, b) reported that all upland and emergent vegetation was killed during flood years, and new vegetation including new species, were recruited during the subsequent drawdown.

Flooding a marsh prior to drawdown may also be effective in reducing the density of cattail. Prolonged high water levels cause the die off of emergent vegetation by limiting the oxygen available to the roots. Cutting the vegetation at the ice-surface in expectation of spring flooding is also effective at limiting cattail. The subsequent drawdown and refill would have water levels managed to establish hydrophytes other than cattail.

2.5.1.3 WETLAND EXCAVATION

The ability to manipulate water levels and attain the results possible from either drawdown or flooding often requires building up portions of the wetland to either hold or exclude water, as is the purpose of dikes or levees, or excavating areas to create ditches or borrow pits. The design of any such structure is determined by its purpose and the physical characteristics of the area. As with all forms of management, the habitat manipulation necessary to gain control over water levels should seek to simulate natural conditions, and be designed around the existing physical features.

Dikes and Levees

The terms dikes and levees are used interchangeably in the practice of wetland management; their design standards are similar and both can serve as roads (Payne 1992). However, from an engineering perspective, they serve different functions. Technically speaking, dikes are used to separate impoundments while levees serve to prevent flooding beyond project boundaries (Payne 1992). This section is provided to describe how these structures function, their design specifications, and their construction.

Dikes or levees are described as earthen water impoundments (Atlantic Waterfowl Council 1972), designed to permit control of water levels within wetlands (Fredrickson and Laubhan 1994). Dikes constructed along natural contours maximize the potential to control water on that area at depths that are attractive to waterfowl (Fredrickson and Laubhan 1994). Such contour dikes also allow the entire impounded area to be de-watered. Dikes that cannot be constructed along contours but rather are situated perpendicular to natural slopes may be less effective at water management, and tend to be more costly (Fredrickson and Laubhan 1994).

Dike design will depend on the duration of the project, average and maximum water level and wave action, and the degree of maintenance that is acceptable. In long-term management projects, low maintenance dikes with the capacity to contain flood level waters are recommended. For smaller projects with expected regular maintenance, initial costs can be reduced by constructing dikes that are less massive.

Dike crowns must be broad enough to permit vehicle travel and the transport of maintenance equipment, and sides must be able to withstand waves and erosion (Figure 2.2). Standard designs consist of 4 m crowns and side slopes of no less than 3:1 (Fredrickson and Laubhan 1994). If wave action is a concern, the slope should be further protected with the addition of rip-rap (Payne 1992), grass cover, or a combination of both. Dike height may vary, but is generally designed at elevations 1 m above mean high water levels (Payne 1992).

Simple embankments make use of soil taken directly at the project site. As a result, these dikes are the least expensive type of embankment to construct (Atlantic Waterfowl Council 1972). In contrast, core-type embankments are constructed with an impervious core, often of clay, to reduce seepage (Figure 2.3). Construction costs are higher than those of simple embankments because fill must often be brought from outside the immediate construction site (e.g., borrow pit).

Equipment used commonly in the construction of dikes includes bulldozers, scrapers, hydraulic tracked backhoes, and draglines (Fredrickson and Laubhan 1994).

Borrow Pits

The material used to build a dike comes from excavation or borrow pits. Borrow pits may be located on the higher ground at either end of the dike, run parallel to the dike on one or both sides, or be excavated off-site (Figure 2.4). Pits are constructed

Figure 2.2. Dikes at a Ducks Unlimited Project site are constructed to be used as access trails and withstand the influence of wind and erosion.

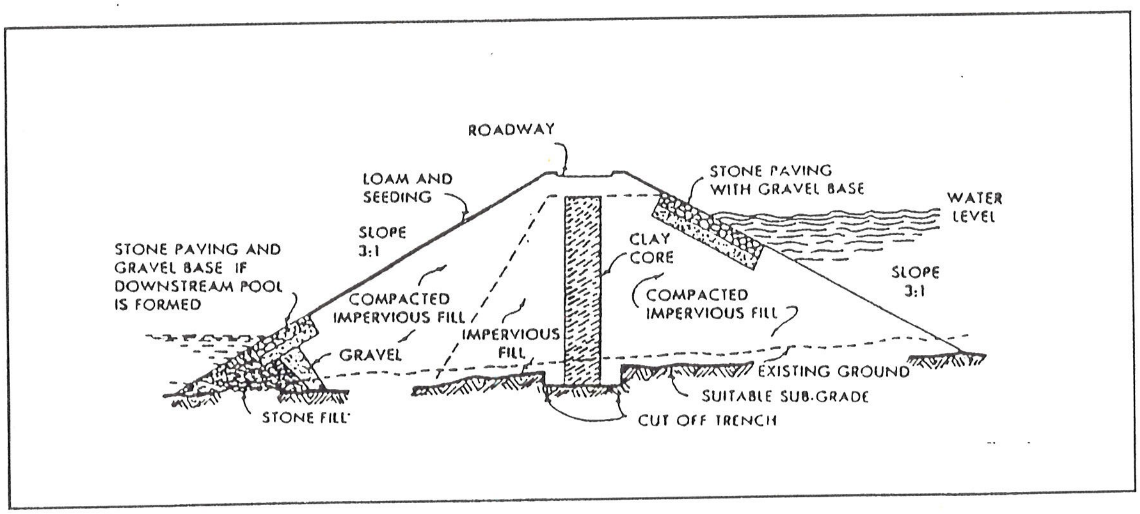

Figure 2.3. Core-type embankments are constructed with a clay core to reduce seepage (From Payne 1992).

with a dragline or backhoe, which removes soil along the side of the dike and adds it to the embankment (Payne 1992). When sufficient material is not available from one pit, another on the opposite side of the dike may be excavated.

The maximum depth of a pit located inside the dike should be approximately two metres (Payne 1992). A berm, or the distance between the top of the borrow pit and the toe of the dike, is useful to reduce slumping and the effect of burrowing mammals such as muskrats. Berm width is recommended to be at least 3 m, or twice the size of the borrow pit (Payne 1992).

Water movement in controlled impoundments is facilitated by water control structures, including pumps, stop-log structures, and gates. Dams and weirs are used to control water movement in larger impoundments. These structures allow management of water through multiple control structures rather than one (Payne 1992).

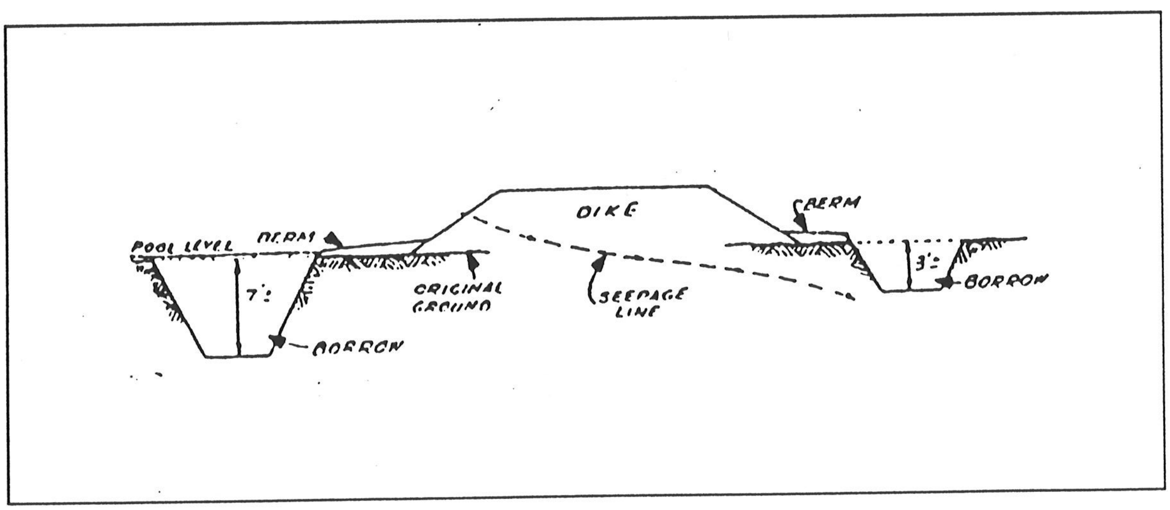

Figure 2.4. Design of a dike with materials excavated from adjacent borrow pit (From Payne 1992).

Pumps

Pumping is used to supplement gravitational drainage or to de-water an area where passive management is ineffective (Payne 1992). The volume of water needed to be moved in a particular time will determine the size and horsepower of the pump (Atlantic Waterfowl Council 1972). Electric pumps are the most economical and require little monitoring and maintenance (Reid et al. 1989); however, unless an energy source is present, installation can be costly relative to the use of other forms of energy. Diesel, bottled gas, and gasoline are also used to power pumps. The principle types of pumps used for wetland management are propeller, mixed flow, and centrifugal (Payne 1992).

Stop-log Structures

Stop-log water control structures are used for controlling water discharge (Figure 2.5). These structures allow precise manipulation of water levels. Adjustments as small as 5 cm can be accomplished with the use of stop-logs (Payne 1992). The ability to pre-set stop-logs at a desired elevation reduces the frequency of monitoring.

Sliding or Screw-gate Structures

In contrast, control of water movement with gate-type structures is less effective. Sliding gates or screw gates require closer monitoring because water discharge is accomplished by removing water from the bottom of the wetland (Figure 2.6). Without careful maintenance, gates left open can result in complete water discharge (Payne 1992).

Figure 2.5. A stop-log structure located at the Duck's Unlimited Lynch Point Project site permits precise manipulation of water levels.

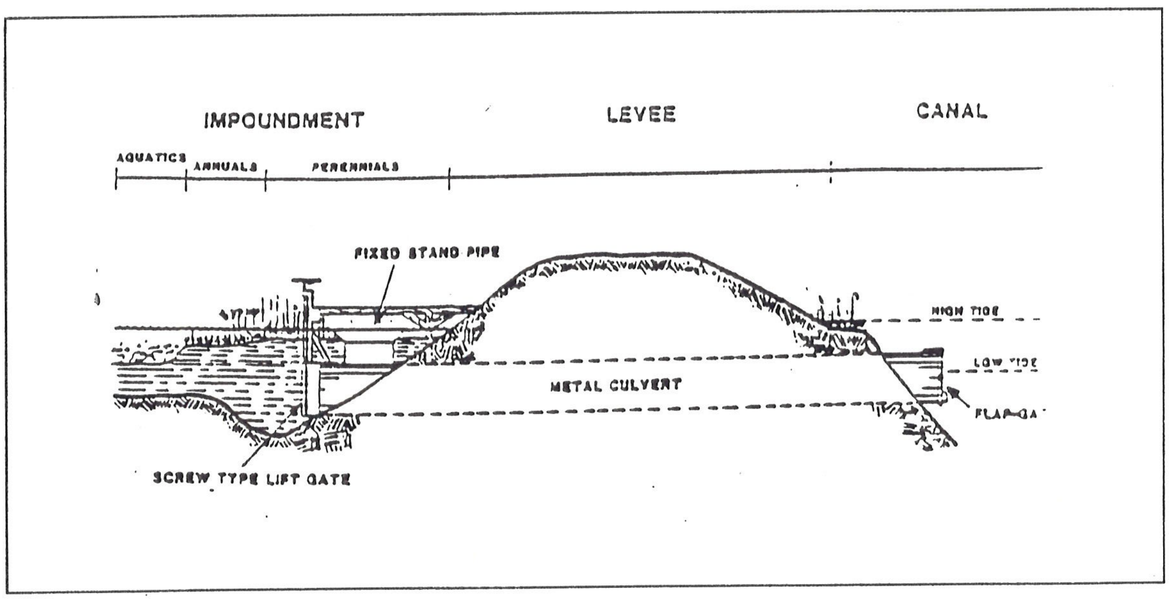

Figure 2.6. Longitudinal section of a screw type lift gate control structure (From Payne 1992).

2.5.2 Wetland Management without Water Control

Physical conditions, financial constraints, and legal restrictions mean that water level control for wetland management is not always possible (Payne 1992). Though not as effective, wetlands can be managed without water control. Several techniques are available to influence both the vegetation and soil, including fire, cutting, disking, and basin deepening. As in all habitat management, the selection of one technique or combination of techniques over another will depend on the habitat conditions and the desired result. Construction or implementation of these techniques generally follows well-established methods (i.e., Atlantic Waterfowl Council 1972) and requires specific equipment.

The initial costs of management without water control may be less than those to establish the infrastructure necessary to manipulate water levels; however, the success of these methods is limited as is the duration of the effect. The cost of annual or semi-annual re-application indicates that long-term expenses can be greater than those of more long-term management. Because there is no control gained over the water regime, these techniques address only some of the symptoms, and thus, only provide short-term improvements.

2.5.2.1 PRESCRIBED BURNS

Where water control is not possible, prescribed burning is a technique used to reduce vegetation density, remove debris, release nutrients, expose soil, increase diversity, and alter the pattern of vegetation (Fredrickson and Laubhan 1994). Burning litter contributes to removal of the ground layer and enables understorey species to germinate in previously unsuitable sites (van der Valk 1986). Changes in the distribution and density of vegetation, and species composition can improve the attractiveness of an area to resting waterfowl (Ward 1991). However, because water levels are not manipulated, prescribed burning will not provide the same food resources that can be produced from drawdown (Sojda and Solberg 1993)

Greenall (1995) states that as fire kills off vegetation and exposes the soil surface to provide suitable conditions for seed germination, it is somewhat analogous to flooding followed by drawdown. However, burning during the dormant season (Kantrud 1986) and during summer (Thompson and Shay 1989) does not eliminate entire plant communities as does flooding.

The season in which a burn is scheduled depends on the purpose of the burn, fuel availability, and the use by wildlife (Fredrickson and Laubhan 1994). However, the use of fire to reduce the density of cattail has met with varying degrees of success (Kantrud 1986). Winter burning of cattail followed by spring flooding in Ontario reduced shoot density and height (Ball 1990). Where water levels cannot be controlled, precipitation must be relied upon to yield spring water levels of a sufficient depth that the entire plant stalk is submerged. The effectiveness of the fire may be inhibited by winter conditions such as frozen or saturated soils, which can limit the spread of the fire through the cattail duff (Sojda and Solberg 1993).

The species of concern for treatment and its location in the wetland relative to water depth can dramatically influence the effectiveness of burning. Spring and fall prescribed burns conducted at the Delta Marsh had little or no effect on the cattail understorey (Greenall 1995). These burns were also found ineffective at decreasing vegetative cover, increasing the amount of open water, and increasing species diversity (Greenall 1995).

2.5.2.2 CUTTING

Mowing or cutting is a technique used to modify the density and distribution of emergent vegetation (Fredrickson and Laubhan 1994). Emergent vegetation, such as cattail, that is clipped in winter or early spring and then flooded, will experience limited regrowth that season (Weller 1975, Kaminski et al. 1985). When wetlands have frozen over, tractors are used to clip the stems of emergent vegetation at ice level. High spring water levels are necessary to inundate cut stems and eliminate the oxygen supply to roots, required for spring growth. Successive annual cutting is recommended for 2 to 3 years in order to obtain more than just temporary results (Larsson 1982).

The effects of cutting may also improve the diversity of the food web in a wetland. Murkin et al. (1989) reported an increase in invertebrate populations after cutting. The decomposition of the litter remaining in recently mowed wetlands and the associated increase in the food resources available to invertebrates, increased use of the wetland by dabbling duck species (Murkin et al. 1981).

Cutting is accomplished in a variety of ways. Hand tools such as scythes, sickles, and grass hooks are more laborious than mechanical mowing through the use of floating machines equipped with mowing bars like those used on agricultural machinery (Payne 1992). Cutting may be used in collaboration with blasting or excavated level ditching to create sizable ponds, or with winter cutting to reduce emergent vegetation cover. In the latter case, sufficient spring flooding above cut stubble may not occur, negating any expenditure as a control method.

Another form of cutting is used to clear existing channels, cut new channels, or create open water using dredges, backhoes, or a cookie cutter. A cookie-cutter is a device consisting of a power boat equipped with two rotary cutting and propelling blades (Payne 1992). Floating, submersed, and emergent vegetation including cattail are removed to expose more open water. This technique is commonly used in situations where silting-in of channels and the overgrowth of emergent vegetation has reduced the attractiveness of habitat for wildlife (Payne 1992). The results of this technique may be short-lived in areas where the seed bank is dominated by cattail and where water control is not possible (Sojda and Solberg 1993). Because water level conditions are favourable for the recolonization of cattail at the Delta Marsh, it is likely that reapplication of this technique would be required every three to five years.

2.5.2.3 DISKING

Disking is used to break up dense stands of vegetation that have limited value for wildlife (Payne 1992), and to reduce problems associated with oxygen depletion (Thomas 1982). By reducing the density in such areas, disking can accelerate aeration, improve nutrient cycling and stimulate plant and animal production (Payne

1992). Sojda and Solberg (1993) state that disking in the fall for three successive years resulted in only temporary reductions in the density of cattail stands. To be effective, the wetland must be de-watered for successive seasons to allow disking in the fall and again in the following spring and summer (Sojda and Solberg 1993). However, like most types of management that exert no control over the water regime, disking treats only the symptoms.

2.5.2.4 BASIN DEEPENING

Level ditching, blasting, and dredging are used to remove dense vegetation and create deeper, open areas of water. This is achieved by one or more of, deepening basins, digging out dense vegetation, or breaking up sediments or organic deposits. These techniques result in the creation of open water and basins of greater depth required for feeding and breeding waterfowl, and increased water depth for use by ground dwelling wildlife in shallow marsh and wet meadow habitat (Payne 1992).

Level Ditches

When water levels cannot be managed with water controls, the construction of level ditches may be used to simulate basin impoundments. Level ditches are ungraded ditches excavated with a variety of equipment, that fill with ground water to provide habitat for wildlife. Constructed primarily to create areas of open water, level ditches may serve several other functions including improving the water to vegetation ratio to that most attractive to wildlife, creating habitat favourable for the production of muskrats, mink and other fur bearers, invertebrates, waterfowl and amphibians, providing open water for waterfowl courtship and brood rearing, increasing the production of aquatic plants, and providing access for management, harvest, or recreation (Payne 1992).

Once established, water control structures may be installed to manipulate the water levels within the ditched area. Water control structures can be used at the connecting points to allow floodwater in or to regulate the inflow of water (Payne 1992). If an ample seed bank is absent at the site, a seedling or planting program may be necessary to stimulate the growth of desired wetland plants. The ditch then becomes a created wetland, with water levels controlled to simulate natural wetland cycles.

Blasting

Blasting is an inexpensive way to create openings in dense emergent vegetation or in upland areas, that are seldom inundated. It is best applied in mineral soils when water level is at, to 20 cm below, the soil surface (Hopper 1971). Blasting is accomplished with an electric or nonelectric firing system, or with a detonating cord to detonate an explosive (Payne 1992). Explosives typically used are dynamite, waterproof gel and ammonium nitrate fertilizer mixed with fuel oil (Payne 1992).

There is generally little control over the size and shape of the area created; however, to some extent, the choice of explosive can influence basin shape. Basins created by blasting are generally bowl, cone shaped, or linear with steep sides that may require maintenance to shape the edges. Sloughing of sides is likely to occur in the first or second year causing refilling which may require a repeat of the process. In general, blasted potholes do not last as long as level ditches, but are cheaper to create

(Payne 1992).

Dredging

Wetlands are dredged primarily to deepen areas that have silted-in, but can also be used to reduce populations of aquatic plants (Payne 1992), and decrease the nutrient outflow from the bottom by elimination of sediments (Thompson 1982). In water less than 1 m deep, this must be done every two years because undesired emergent macrophytes can return the season after treatment.

Dredging can be either mechanical or hydraulic. Land based mechanisms for dredging, where dredging is accomplished mechanically from upland areas or on a de-watered pond bottom, most often use draglines (Payne 1992). Draglines consist of a crane with a perforated bucket that is cast into the wetland and then dragged back to the crane by another cable as it picks up sediment.

Water-based or floating dredging is conducted from a barge. The difficulty associated with floating dredging is that dredge material cannot be transported directly to the shore. Rather, operators must use adjacent barges for depositing dredged material which are then moved to a disposal site, or deposit materials in piles on adjacent sites (Payne 1992).

Hydraulic dredging is accomplished similarly to mechanical dredging although it usually takes place by means of a floating suction dredger and is not recommended for areas less than 1.1 m deep (Payne 1992).

Dredging is the most costly of these techniques, availability is often limited, and it is generally considered impractical except in very large projects (Kent 1994). Because of the high cost of transport, dredge material is usually disposed of close to wetland; however, this requires an area large enough to allow the sludge to dry (Thompson 1982). Deposition of dredged or excavated material immediately adjacent to the excavation can result in variations in the topography and the resultant plant communities, resulting in a mosaic of plants. However, the dredge material most often creates a dry land like area at least as large as the excavated over water area, thereby effectively reducing the overall area of marshland.

CHAPTER 3

ECOLOGICAL CONDITION OF THE DELTA MARSH

3.0 INTRODUCTION

Since the early 1960's regulated water levels on adjacent Lake Manitoba have meant the demise of cyclic water level fluctuations at the Delta Marsh. Changes in the conditions at the marsh have been marked, and have been the impetus for the generation of numerous theses, papers, and management plans (Walker 1959, Walker 1965, Bossenmaier 1968, Jones 1978, Ould 1980, Ducks Unlimited 1981, de Geus 1987, Shay and Shay 1989, Waters and Shay 1990, Greenall 1995). In addition to a review of the geology, geography, soils, and climate of the Delta Marsh, this section includes a review of the current water regime, the vegetation and wildlife at the marsh, and predictions as to the condition of the marsh in 20 years should the current regime persist.

3.1 PHYSICAL SETTING

3.1.1 Geology

The ground underlying the Delta Marsh area consists of Devonian, Silurian, and Ordovician bedrock overlain by up to 100 m of Quaternary sediments of glacial, fluvial, and lacustrine origin (Last 1984). These sediments were influenced by Glacial Lake Agassiz, which was created by glacial meltwater approximately 12,000 years ago

(Greenall 1995). Alluvial sediment carried into the western end of Lake Manitoba by the Assiniboine River from 4500 to 2000 years ago created a sand delta, which, under the influence of wind and wave action, was redistributed to form the now forested barrier ridge at the south basin of the Lake.

Sproule (1972) used sediment cores to determine the post-glacial history of the marsh. Evidence from macrofossils and pollen indicate approximately 2400 years of marsh conditions. Fluctuations in pollen composition reveal that the marsh alternated between upland and wetland vegetative cover depending on water levels.

3.1.2 Geography

Delta Marsh is comprised of several large and small shallow bays with many interconnecting channels separated by various natural and human-made barriers. The West unit of the marsh is situated between the Assiniboine Diversion to the east, Lynch Point to the west, and is bordered on the south by privately owned agricultural land. The forested ridge to the north of the marsh is breached by several channels which facilitate direct exchange of water between the marsh and Lake Manitoba.

Weedy Bay and Canvasback Bay are open, windswept bodies of water of approximately 25 ha and 20 ha respectively, connected directly to Lake Manitoba via Cram and Deep Creeks. The direct exchange of water between lake and wetland allows water levels to fluctuate synchronously. Dramatic fluctuations produced by wind and wave action on Lake Manitoba exerted a scouring effect on wetland basins which prevented the natural silting-in process common in prairie marshes. However, since lake levels were regulated in the early 1960's, significant amounts of sediment have accumulated on the marsh bottom (Jones 1978). The elevation of the basins in the West unit were mapped by Ducks Unlimited in 1979 (Figure 3.1).

3.1.3 Soils

Soils of the Delta Marsh have been described by Ehrlich et al. (1957) as undifferentiated muck and peat soils. The deposition of alluvial, lacustrine, and deltaic material in the west portion of the marsh has resulted in soil that is more fertile than that of eastern portions (Ducks Unlimited 1981). Soil texture ranges from sandy loam to silty clay. Soils of the forested ridge are composed of gravel, coarse sand, and silty sand. The open water areas of the marsh are overlain with up to 6 cm of detritus overlying silt, while areas dominated by emergent vegetation are covered by 30-60 cm of organic material over clay and silt (Ould 1980).

3.1.4 Climate

The climate at the Delta Marsh is classed as cool to mild continental (Weir 1960). Measurements at the Delta Meteorological Station indicate an average temperature of -18.1°C in January, 19.2°C in July, and 1.9°C annually (Environment Canada 1993). Annual precipitation is approximately 515 mm, 74% of which falls as rain between April and October. The marsh has a negative water budget meaning that evaporation exceeds precipitation during the summer (Greenall 1995).

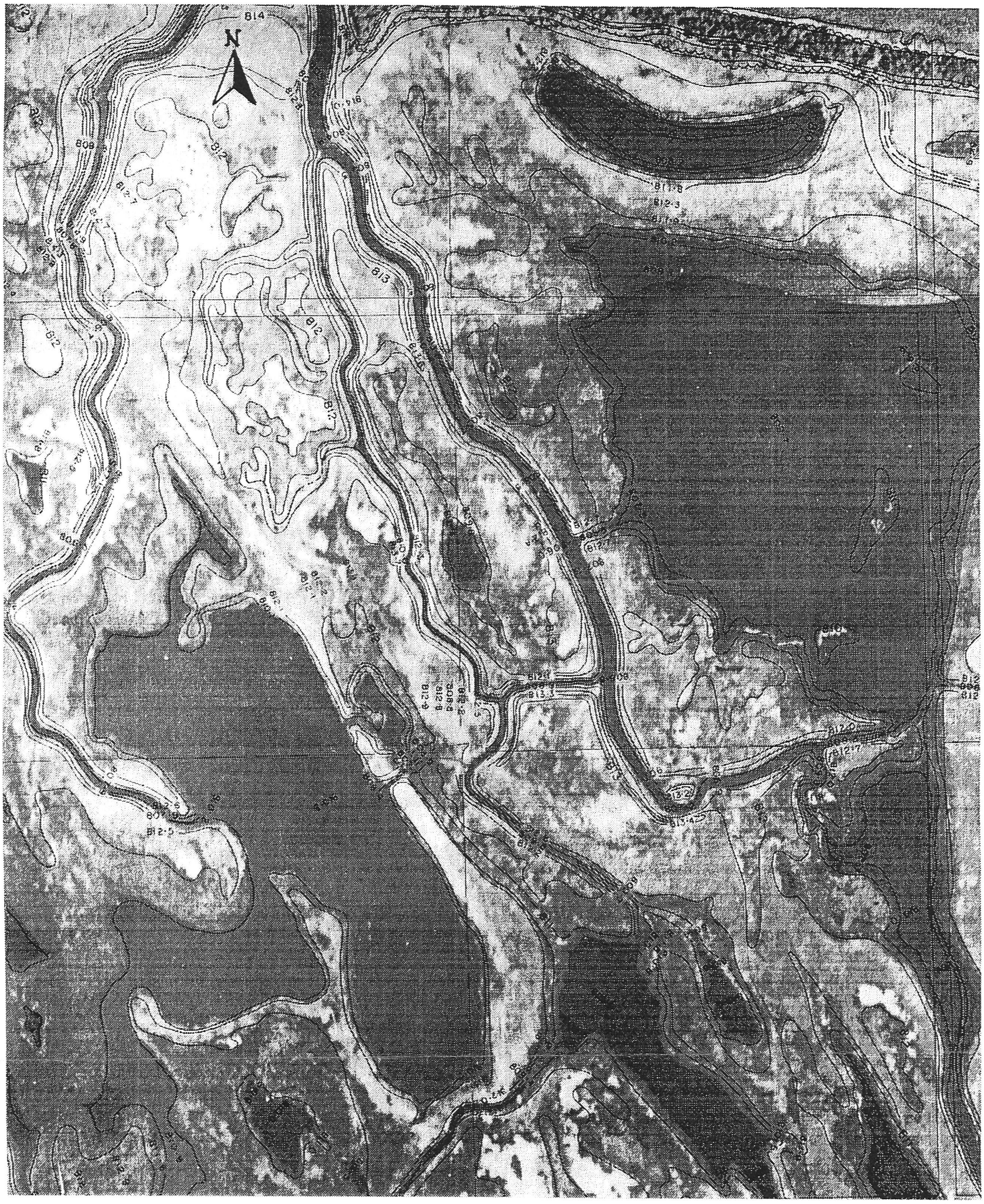

Figure 3.1. Contour plan of Weedy Bay and Canvasback Bay at the Delta Marsh (Courtesy of Ducks Unlimited, Canada).

3.2 RECENT CHANGES AT THE DELTA MARSH

3.2.1 Water Regime

The Delta Marsh receives water from Lake Manitoba, by periodic flooding over the Assiniboine Diversion failsafe, and as runoff from adjacent land. Delta Marsh water levels are perfectly correlated to Lake Manitoba water levels (de Geus 1987). Historically, water levels in the lake and the marsh were influenced by cyclical climatic changes of approximately 20 years, which occurred in response to changes in annual precipitation (Walker 1965). Water levels on Lake Manitoba once fluctuated within a range greater than 2.2 m (de Geus 1987), which would have resulted in water levels in Weedy Bay and Canvasback Bay ranging from almost dry to over 1.5 m deep.

During years of heavy precipitation or spring runoff, the low elevational gradient of the marsh basin allowed excess water to spill onto agricultural and privately owned land. To reduce the risk of flooding, Lake Manitoba was regulated in 1961 to a mean target level of 247.6 m (812.1 ft) ASL. A control structure located at Fairford on the east side of the lake has dampened water fluctuations to a range of less than 0.6 m (de Geus 1987) (Figure 3.2). In 1995, annual water levels fluctuated from 247.4 m (811.5 ft) in October, to 247.92 m (813.18 ft) in June, with an average of 247.6 m (812.14 ft) above sea level (see Appendix A).

Thee Assiniboine Diversion went into operation in 1969 to divert high spring melt water flows in the Assiniboine River away from urban areas and into Lake Manitoba. The north west portion of the diversion dike was constructed at a lower elevation

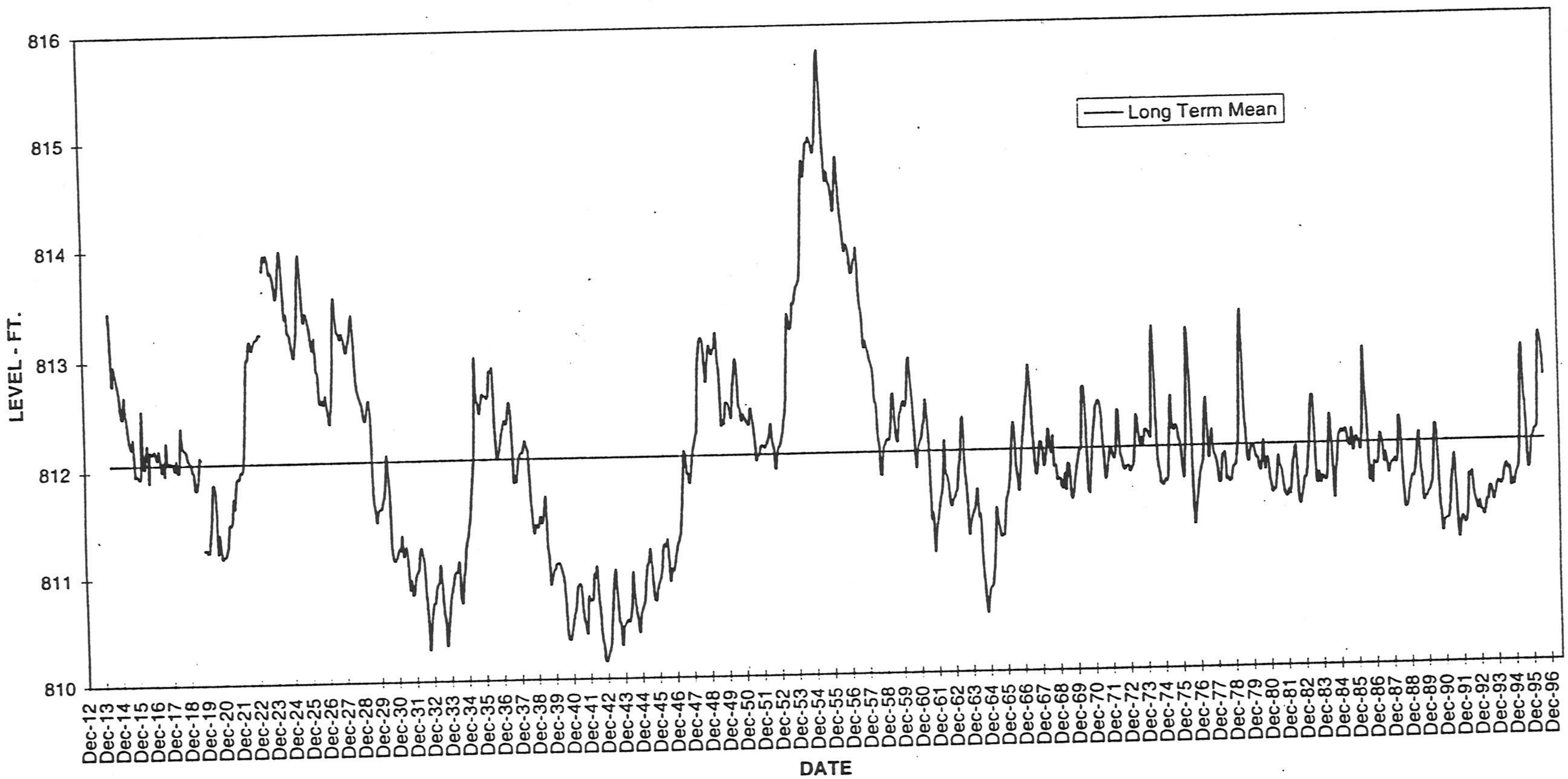

Figure 3.2. Mean yearly water levels on Lake Manitoba from 1912 to 1996 (Courtesy of the Manitoba Department of Natural Resources).

(referred to as a failsafe) in order that on the occasion of very high flows, waters would run into the marsh rather than to the cottage area to the east Lake shore. Such flooding was expected to occur about once every 11 years (Ducks Unlimited 1981). Between 1971 and 1981 the failsafe was overtopped twice (Figure 3.3), and flood waters were substantial enough to overtop the failsafe in 1996.

This periodic, short-term flooding has ramifications that are both ecological and financial. The Assiniboine River is known to carry a heavy load of silt (Miller and Moore 1967) with an estimated 544,308 metric tons (600,000 tons) present in the

Figure 3.3. Spring melt water overtopping the Assiniboine Diversion in 1976 resulted in severe flooding throughout much of the West unit at the Delta Marsh.

river at Portage la Prairie during April and May (Crowe 1974). Use of the failsafe in 1976 resulted in the deposition of 15 to 45 cm of sediment in the lower sloughs of the West unit including Weedy and Canvasback Bays (Galay 1980), and extensive flooding in the surrounding farmlands (Ducks Unlimited 1981).

Nearly $48,000 was paid in compensation to farmers for flood damage in 1974, with an estimated $212,000 required in 1976. Undetermined was the impact on aquatic vegetation in the West unit, including burying of seeds and plant shoots beneath silt, the in-filling of areas dominated by submersed aquatics, or the effects of scouring or erosion of detritus layers along flow paths. The annual costs of the failsafe maintenance were computed at $25,000 per year in 1980 dollars (Ducks Unlimited 1981).

3.2.2 Vegetation

Pre-regulation

Love and Love (1954) described the vegetation of the Delta Marsh as giant reed grass (*Phragmites*)-dominated, interspersed with patches of white-top (*Scolochloa festucacea*). Open water areas were fringed by bulrush (*Scirpus* spp). and broad-leafed cattail (*Typha latifolia*).

Walker (1965) reported that the vegetation at the Delta Marsh from 1959 to 1961 was distributed along elevational gradients, with giant reed grass and white top the dominant vegetation types, and bulrush (*Scirpus*) growing in the shallow water of the bays. Walker (1959, 1965) reported that prior to regulation there was a direct response observed in all cover types to fluctuations in water levels at the Delta Marsh. Alternating periods of flooding and drawdown thus served to maintain the marsh ecosystem in a highly productive state by causing a cycle of vegetative change.

Post regulation

The influences of a dampened water regime, including changes in the diversity and structure of vegetation, are evident in the prevailing conditions (Ould 1980). de Geus (1987) found that significant changes in the vegetative composition of the marsh have occurred since the early 1960's. As water levels change, individual species are redistributed independently along elevational gradients depending on their tolerance to flooding (Figure 3.4). The range within which water levels are now held is insufficient for a cycle of dynamic vegetation change to occur and has resulted in decreased diversity (de Geus 1987). Static water levels have prevented wide-spread establishment of offshore emergent vegetation within bays. Currently, only sparse stands of hardstem bulrush are found along the water's edge in Weedy and Canvasback Bay, and at a few locations in the centre of Weedy Bay (Figure 3.5). As a result, the bays are lake-like bodies of open water, bounded by dense, monotypic stands of cattail and phragmites, backed by white top in adjacent uplands (Ould 1980). Such stabilization has allowed the dominance of a few species, most notably, *Typha glauca.*

Figure 3.4. Infrared aerial photographs of the West Unit of the Delta Marsh (Courtesy of the University of Manitoba Field Station).

Figure 3.5. Sparse stands of hardstem bulrush located in the open water of Weedy Bay.

Cattail

The hybrid species of cattail, *Typha glauca* has a competitive advantage over both parent species (*T. latifolia* and *T. angustifolia*) and *Phragmites*, which enables it to germinate and establish in water 2-15 cm deep (de Geus 1987, Waters and Shay 1990). This advantage, coupled with shading and crowding effects, led *Typha glauca* to become the dominant emergent species at the Delta Marsh. Between 1972 and 1980, cattail continued to increase along the entire range at the expense of both water and *Phragmites* (de Geus 1987). Because water levels have not exceeded the tolerance dieback of vegetation. As a result, stands of macrophytes, particularly cattail, have slowly continued to invaded shallow marsh shores (de Geus 1987).

Submersed Vegetation

Several species of submersed vegetation are present at the Delta Marsh, including sago pond weed (*Potamogeton pectinatus*), water milfoil (*Myriophyllum exalbescens*), coontail (*Ceratophyllum demersum*), and bladderwort (*Utricularia vulgaris*). However, the productivity of these plants is disturbed by the activity of carp, depressed by the stability of the water level, and limited by a lack of available nutrients. Flood water and water running north into the marsh from adjacent farms, may carry with it chemicals and fertilizers. While fertilizers typically contribute to the growth of vegetation, the growth of submergent species may be diminished by the addition of these chemicals as nutrients are diverted from plant production to the growth of algae (Jones and Bazin 1991).

3.2.3 Wildlife

Wetlands provide habitat to a wide variety of wildlife. The Delta Marsh has long been recognized as an important fall staging area for waterfowl; however, use of the marsh by other animals including muskrat and fish is also of importance. These species too have been impacted by the conditions resulting from a dampened water regime. Some populations, once rich and productive, have decreased or been altered, while others, such as carp, have exacerbated already declining habitat conditions.

Waterfowl

The Delta Marsh is known historically as an important staging area for waterfowl. Surveys conducted at the marsh since 1949 indicate that between 45,000 and 150,000 ducks and from 10,000 to 150,000 geese stage at Delta in the spring and fall (Ducks Unlimited 1981). Waterfowl counts conducted in 1991 observed an average of 33,970 birds at the Delta Marsh during September and October (Jones and Bazin 1991). Species observed in large numbers during the fall are canvasback (*Aythya valisineria*), redhead (*Aythya americana*), mallard (*Anas platyrhynchos*), blue-winged teal (*Anas discors*), northern shoveler (*Anas clypeata*), lesser scaup (*Aythya affinis*), ruddy duck (*Oxyura jamaicensus*), and gadwall (*Anas strepera*).

Systematic counts of waterfowl were conducted at the marsh almost annually from 1970 to 1981; however, financial constraints prevented fall counts for the next decade. The most recent surveys, conducted in 1991, indicated that substantial changes had occurred in the population of waterfowl at the marsh within that time (Jones and Bazin 1991). The absence of consecutive yearly data makes it difficult to establish a trend in waterfowl use; however, such changes cannot be overlooked.

Jones and Bazin (1991) report a considerable change in the composition and number of waterfowl using the marsh during the fall. While a decline in the overall number of waterfowl was reported, more serious was a shift in the species of ducks making up the waterfowl population. Diving ducks comprised only 15 percent of the waterfowl count in 1991, compared to 45 percent in 1966 and 1980 (Jones and Bazin

1991). This suggests either a substantial change in the type and availability of aquatic food resources or a change in overall waterfowl populations (Jones and Bazin 1991). The number of ducks observed on the West unit in 1991 was 498.

Because of the different fall feeding strategies observed in these two families of waterfowl, a reduction in aquatic seed-feeding birds and an increase in field-feeding birds may be symptomatic of other changes occurring in the marsh. Jones and Bazin (1991) list several explanations for lower use of the Delta Marsh by diving ducks during the fall, including reduced productivity resulting from stabilized water levels, increased turbidity and competition caused by the activity of carp, and the addition of chemicals, fertilizers, and silt from surrounding agricultural systems.

The Delta Marsh does not have the characteristics necessary to make it a major producer of waterfowl, although some species such as the blue winged teal, canvasback, northern shoveler, and redhead, nest there regularly (Fisher et al. 1988). Several characteristics including the absence of offshore emergent vegetation, wave action, turbidity, water depth, and dense stands of shore-line emergent vegetation make many areas of the marsh unattractive to breeding and brood-rearing waterfowl (Ould 1980).

Mammals

White-tailed deer (*Odocoileus virginianus*) are found throughout the Delta Marsh in numbers that have increased annually over the past decade.

Muskrat (*Ondatra zibethicus*) populations at the Delta Marsh once contributed substantially to the commercial trapping industry in Manitoba (Ould 1980). Although trapping is less common now, the population of muskrat has been in decline since the 1960's (Jones 1978, Ducks Unlimited 1981). Concurrent with changes observed in waterfowl are those reported in the populations of muskrat and carp. Fur production and harvests at the Delta Marsh from the 1940's to the 1960's fluctuated in response to changes in water level (Ducks Unlimited 1981). The decline of muskrat populations since the 1960's has been attributed to habitat loss due to the stabilization of water levels (Jones 1978, Ducks Unlimited 1981).

Fish

The open water bays of the Delta Marsh that serve as both spawning and nursery grounds for several species of fish, including northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), and carp, led to the establishment of a commercial fishery on the east side of the marsh. While the success of the commercial fishery at the marsh has declined in recent years, the Delta Marsh is credited with increasing the fish resource available in Lake Manitoba (Ducks Unlimited 1981). The introduction of carp into the wetland has created recurring management problems. Entrance to the marsh from Lake Manitoba was restricted previously by fish fences (until the 1960's); however, carp now have easy access into the marsh to spawn and feed.

Carp were introduced to the marsh in 1947 and populations increased significantly following periods of high water between 1955 and 1966 (Jones 1978). Currently, carp are abundant in the marsh, and contribute to habitat deterioration by increasing turbidity and competing with waterfowl for food resources (Panek 1987, Weller 1994). The feeding and spawning habits of carp are thought to have had considerable impact on the quality of the marsh for waterfowl (Jones and Bazin 1991). Feeding behaviour is particularly disruptive as it uproots and destroys aquatic vegetation used as cover by fish, invertebrates, and waterfowl (Bond 1979), and stirs up bottom sediments which increases turbidity. These two factors contribute to further degradation by reducing light penetration, thereby hindering the development of submergent macrophytes (Panek 1987).

3.3 PREDICTED FUTURE CONDITIONS

Because of the many social and financial consequences associated with the restoration of natural water level conditions on Lake Manitoba, there is no reason to believe that this will occur. As long as water levels on Lake Manitoba are regulated, the lake-like conditions present at the Delta Marsh will persist. Although a continued decline in overall marsh habitat conditions is predicted under this influence, the most dramatic changes have likely already occurred. The purpose of this section is to predict what wetland conditions will exist after the next 20 years if no management is implemented. Predicted changes in the ecological condition of the Delta Marsh, including the structure and distribution of vegetation, the influence of periodic flooding and the deposition of silt, and the continued influence of carp, as well as changes in use occurring by the client will be outlined (ie. increasing and diversified use by PCC membership). These conditions will establish a baseline from which the impacts resulting from management may be compared.

3.3.1 ECOLOGICAL CONDITIONS

Vegetation

These conditions will continue to encourage the dominance of a few species of vegetation, most notably the hybrid species of cattail. Dense, monotypic stands of cattail will persist within the elevational gradient created by a stabilized water regime. These stands of emergent vegetation will continue to be of little value for waterfowl because they provide neither the cover to water ratio, nor the food resources required by staging and resting waterfowl (Weller 1994).

Emergent stands of bulrush now present in open water areas of the marsh will continue to decline as conditions unfavourable for seed germination or vegetative expansion persist. Loss of this offshore vegetation will result in decreased habitat for waterfowl and other wildlife such as muskrats, but will similarly impact the algal and invertebrate communities for which it is a substrate.

Operation of the Assiniboine Diversion failsafe is predicted once in 11 years (Ould 1980). Flood water which inundates much of the West unit has and will continue to result in the deposition of silt from agricultural runoff. The absence of fluctuating water levels will facilitate basin in-filling; however, over the next 20 years this is unlikely to be substantial enough to cause the wetlands to dry out. A decrease in basin depth though, can compound the growth of cattail which colonizes rapidly in shallow water (de Geus 1987).

Carp are and will continue to be a serious management issue for the Delta Marsh. Because the marsh is valued as a spawning and nursery ground for commercial fisheries, the exclusion of carp would likely exclude preferred fish species as well, and therefore, would not be feasible.

3.3.2 SOCIAL CONDITIONS

Property Use

A change in the pattern of use is already occurring at the Portage La Prairie Country Club. Use of the PCC by families is increasing and the property is no longer limited to waterfowl hunting. The trend toward other recreational activities including bird watching, deer hunting, canoeing, and cottaging are expected to continue and will likely expand to new activities in greater numbers over the next 20 years. Additional use of the PCC lodge and its facilities will raise the value of the complex to its members, who may then choose to invest in additional marshland maintenance and improvements. The area will continue to require annual or semi annual maintenance to allow navigation of canoes by hunters; however, increased use of canoe channels for purposes other than hunting may induce owners to invest in management with a more permanent impact.

CHAPTER 4

WETLAND MANAGEMENT

4.0 INTRODUCTION

Degraded habitat conditions existing at the Delta Marsh as a result of human involvement have provided a mandate for management. The purpose of this chapter is to establish concerns specific to management at the Delta Marsh, and provide a systematic account of the biological, spill-over, and financial impacts that must be considered prior to management. A review of previous plans to manage the Delta Marsh was done to establish their potential and limitations, and is followed by a discussion on the theory of wetland management.

4.1 PAST MANAGEMENT AT THE DELTA MARSH

In areas such as the Delta Marsh, where several elements of natural systems have been modified by human activity, the ability to provide wildlife resources in a consistent manner often depends on active management. While this concept is not novel, it is true that attempts to mitigate the prevailing conditions at the Delta Marsh in the past have met with limited success. Although some small-scale projects have been implemented, the West Marsh has had the least development, primarily due to the large percentage of privately owned land. The greatest obstacle preventing habitat restoration is the conflict of interest that exists between the region's different stakeholder groups, including farmers, sport hunters, and University researchers.

Management plans by Bossenmaier (1968), Jones (1978), Ould (1980), and Ducks Unlimited, Canada (1981), proposed to manage the entire 18,000 hectares of the Delta Marsh. This section includes a review of The Delta Marsh Plan (Jones 1978), The Delta Marsh Conceptual Review (Ould 1980), and The Delta Marsh Development Proposal (Ducks Unlimited 1981), to establish their purpose, design, and predicted benefits and costs. Determining the reasons these plans failed to be implemented will assist in the development of management options are more feasible.

4.1.1 The Delta Marsh Plan

The primary objective of the Delta Marsh Plan (Jones 1978) was to increase fish and wildlife production throughout the marsh (Jones 1978). Secondary benefits from the project, including greater hunting success and recreation were predicted to generate greater interest in the region.

Management of the West unit involved the development of six subunits that would encompass 3200 hectares (8000 acres) of uplands and wetlands. Contingencies such as dikes and ditches were included in the plan because of the close proximity to private agricultural land. The cost associated with the development was estimated at $500,000 in 1978 dollars, with an additional $926,200 recommended for land purchase (Jones 1978). The total costs associated with management of the Delta Marsh from 1979 to 1984 was estimated at $7,418,700 in 1979 dollars; however, public concerns regarding spill-over impacts was great and the development was never initiated.

4.1.2 The Delta Marsh Conceptual Review

The Delta Marsh Conceptual Review (Ould 1980) provided a history of the marsh and its characteristics along with recommendations for management. Increasing habitat for waterfowl production was a primary objective of this plan.

In the West unit, level ditches and loafing or resting sites were planned to increase habitat available for breeding waterfowl and brood rearing (Ould 1980). Management impoundments within the unit were to operate independently and have no adverse effects on the trapping, fishing, or farming industries. Seventeen impoundments ranging in size from 57 to 400 acres and encompassing 1044 ha (2609.3 acres), were recommended for the West unit. A period of flooding was prescribed prior to a fall drawdown once in a seven to ten year cycle. The cost associated with this development were not provided.

4.1.3 The Delta Marsh Development Proposal

The Delta Marsh Development Proposal was submitted in 1981 by Ducks Unlimited, Canada based on a modification of Ould's (1980) work . The objective of this plan was to restore habitat conditions to those existing prior to Lake regulation. Restoring water level fluctuations in the marsh would require the installation of water control structures. Cognizant of the failures of previous plans, this study embarked on an extensive public relations investigation in addition to its biological and engineering studies.

The West unit would be divided into four individual cells in order that periodic drawdown could be accomplished in one cell without disrupting waterfowl and muskrat production, or hunting opportunities in the remaining areas (Ducks Unlimited 1981). The recommended regime consisted of maintaining high water levels (248.2 m) through the spring and gradually lowering to Lake Manitoba level by July 1. Fall drawdowns scheduled between August 1 and October 15 would be accomplished by pumping water into adjacent cells or into Lake Manitoba, with water levels to be held low the following year. A seven to ten year drawdown was recommended to simulate those experienced by a typical prairie marsh (Ducks Unlimited 1981). To prevent further flooding from the Assiniboine River Diversion, its dyke heights and failsafe were to be upgraded.

The capital and operating costs associated with management of the entire marsh were estimated at $14,800,000 over 50 years; however, management of the West marsh itself was not provided. Ducks Unlimited estimated that the cost of its studies until the publication of the 1981 document was over $400,000 in 1981 dollars.

4.2 PAST MANAGEMENT LIMITATIONS

The management plans described above present biologically appropriate strategies to improve the quality of the Delta Marsh for waterfowl and wildlife. Although the costs associated with development were substantial, it was the public response generated by the perceived spill-over impacts of the proposed developments rather than the financial impacts that proved prohibitive. Efforts to gain interest and input from local stakeholders were made during the Delta Marsh Proposal to facilitate the transfer of information among all groups, and to establish a forum for community discussion.

4.2.1 SPILL-OVER IMPACTS

In 1979, Ducks Unlimited and the Government of Manitoba initiated extensive discussions with nearly 200 local landowners, trappers, hunters, lodge owners, cottagers, and commercial fishermen to examine the potential for management at the Delta Marsh. Although response in general was reported to be positive (Ducks Unlimited 1981), several issues were raised. The general concerns of area residents related to impacts on salinity and ground water, crop depredation, hunter management, and public access.

Salinity and Water Seepage

Residents expressed concern that any alteration of the region's hydrological regime resulting from drawdowns or water impoundments could influence their water quantity and quality. Studies were done to determine the effects of maximum and minimum water levels on soil salinity and well water. Results of these indicated that the proposed concept would not affect well levels or jeopardize farm water supply. Salinity problems were not as well defined, but impacts were predicted to be minimal (Ducks Unlimited 1981).

Water Supply

Management of the West unit could be very simple technically; however, when flooding did occur, any attempt at management would be lost, and the associated risks of flooding increased. During years of high water, flood water will be directed over the Assiniboine Diversion failsafe into the West marsh. Compartmentalization of the larger bays in the West unit would block access to flood water, preventing drainage into these basins, and forcing water outward onto adjacent land. Similarly, any form of management that impeded water flow on Cram or Deep Creek would not be possible as the water rights of adjacent land owners would be impacted.

Crop Depredation

Depredation by waterfowl and blackbirds is a serious issue for farm lands that border wetland areas, and proposals to improve habitat to attract more wildlife are an obvious concern for local farmers. Ducks Unlimited's plan stated that a solution to this problem could only be accomplished through improvements to the existing crop depredation prevention and compensation program (1981). Other methods including bait stations, lure crops, and bangers were suggested to minimize crop damage by wildlife.

Hunter Management

The tradition of deep water waterfowl hunting at the Delta Marsh has shifted in response to changes in the composition of waterfowl populations, to hunting in more upland areas. This practice presents a source of conflict for farmers who lose crops annually to field-feeding birds, and who must routinely deal with trespassers. As a result, hunter-landowner relations require careful attention. Although hunters require permission to hunt on private land and gain access to Crown land via private land, the potential for greater hunting opportunities as a result of improved habitat quality made trespassing a concern to area farmers, and resident hunters. It was also suggested that the dike systems created for management purposes could compound this concern by creating hunting spots that are easily accessed. To solve this problem, it was recommended that hunting from dikes be restricted.

Because the area under study is owned by a hunting club, development must not be so intrusive as to restrict access to club membership. This suggests that while access by motorized vehicles may be improved by the development of dike systems, navigation by canoe must also be maintained or improved.

Public Access

Concerns that any improvements at the Delta Marsh would be reduced by increases in the number of visitors to the area were also expressed. If one of the objectives of management is to retain the natural and aesthetic appeal of the marsh, public access, particularly by motorized vehicles must be restricted. Although some legislation to support this concept is in place, it would require bolstering by the provincial government (Ducks Unlimited 1981).

4.2.2 FINANCIAL CONSTRAINTS

Although the primary reason for the failure to implement management at the Delta Marsh was the predicted spill-over impacts, the expense of habitat restoration was also formidable. The management plans discussed proposed to manage the entire marsh as a natural system by reestablishing water level fluctuations that were independent between compounds and precisely controlled. Because there were and still are no water control structures established at the marsh, initiation of this sort of project requires very high start up costs, in addition to the long term-costs associated with maintenance and monitoring. Ducks Unlimited recommended a cost-sharing strategy between the provincial government and their organization in order that the expense might be spread, and the project made financially feasible (Ducks Unlimited 1981).

CHAPTER 5

WETLAND MANAGEMENT ALTERNATIVES

5.0 INTRODUCTION

The failure to implement management in the past means that generating new management strategies for this area will require a creative approach both in project design, and in discussions with local landowners. Past management plans demonstrate that certain styles of management are socially unfeasible for the residents of the Delta Marsh. Attempts to manage the entire West unit is such an example, where predicted spill-over impacts, whether actual or perceived, proved significant enough to restrict large-scale management. The purpose of this chapter is to develop management options that will restore wetland conditions in the Delta Marsh to provide habitat for staging waterfowl. Biologically appropriate management techniques were determined by an assessment of their purpose and effect. Those producing conditions favourable for staging and brood-rearing waterfowl were further evaluated to determine their spill-over and financial impacts. Establishing the social concerns, the financial investment required, and the benefits determined by increased waterfowl production will assist the client in the selection of one or a combination of management options.

5.1 DESCRIPTION OF ANALYSIS

Building on the information presented in the literature review and on the chapters on the Delta Marsh and wetland management, this section describes the analysis done to select management strategies for the West unit of the Delta Marsh. The ability to produce the desired biological effects, restated below, were the primary agent of analysis; however, the effectiveness of a technique over time, and the need for reapplication were also considered. Impacts were judged as either positive or negative depending on their influence on the habitat conditions favoured by waterfowl. The results of the preliminary analysis to determine the biological effects of various wetland management techniques are summarized in Table 5.1.

5.1.1 DESIRED BIOLOGICAL EFFECTS

The biological conditions desired by the owners of the study area are based on those existing at the Delta marsh prior to the regulation of Lake Manitoba water levels. These conditions, favourable for a number of species of wildlife, but particularly attractive to staging and brood-rearing waterfowl, are described in Chapter 2. Specifically, features of desirable habitat include some open water with a 50:50 interspersion of water and vegetation, and the production of submersed vegetation.

5.2 RESULTS OF BIOLOGICAL ANALYSIS

Wetland management techniques were evaluated to determine the effects of their application at the West unit of the Delta Marsh based on the biological conditions described in Chapter 3.

5.2.1 Techniques with Water Control

Drawdown and flooding are used to simulate natural wetland cycles, and to

Table 5.1. Biological impacts of various wetland management techniques (Scott 1982, Payne 1992, Sojda and Solberg 1993, Fredrickson and Laubhan 1994, van der Valk et al. 1994, Greenall 1995.

MANAGEMENT TECHNIQUES	BIOLOGICAL IMPACTS	
WATER CONTROL	**POSITIVE IMPACTS**	**NEGATIVE IMPACTS**
Drawdown	Simulates natural wetland cycles Exposes mudflats to stimulate germination of desired vegetation Results in improved water:cover ratio Creates conditions for increased use by, and diversity of wildlife Speeds the rate of decomposition and nutrient cycling Plant stands maintained in desired condition Reduces the presence of disturbance species such as carp Results occur within first year Repeated once every 7-10 years	Requires manipulation of system to allow control of water Can result in growth of undesired vegetation Eliminates spawning and nursery habitat for fish May cause salinity problems Extent of vegetation may be excessive
Flooding	Stimulates natural wetland cycles Applied to reduce the density of emergent vegetation Increases diversity of vegetation Increases the water:cover ratio	Requires manipulation of habitat to prevent off-site flooding Requires 2-3 years of high water Prevents the establishment of mudflat annuals
WITHOUT WATER CONTROL		
Controlled Burn	Applied to reduce density of emergent vegetation Creates habitat attractive to resting waterfowl Alters the pattern of vegetation and may increase diversity Removes debris, releases nutrients and may expose soil	Success of burning cattail has been variable Requires flooding afterward to kill cattail Does not produce waterfowl foods
Cutting	Applied to create habitat for breeding and resting waterfowl Reduces the density of emergent vegetation May increase the diversity of the wetland food web	Successive annual cutting recommended for 2-3 years Requires flooding afterward to kill cattail

Disking	Applied to break up dense stands of emergent vegetation Stimulates conditions for plant and animal production Increases decomposition and nutrient cycling	Must be reapplied every 3-4 years Requires a dry site and sufficient time for aeration
Basin Deepening	Applied to reduce dense vegetation to create open water May improve water:vegetation ratio Deepens areas that have silted in Decreases nutrient outflow by removing sediments Reduces the population of aquatic plants	Little control over size and shape of area blasted Requires maintenance to shape basin Must be repeated every 3-10 years in shallow water Production of waterfowl foods depends on submersed colonization Excavation may require winter access and ice removal

produce and maintain highly productive habitat conditions. Drawdown is used to stimulate the growth of vegetation in areas where lake-like conditions persist, whereas flooding is effective at eliminating vegetation in areas where the cover has become too thick (Fredrickson and Laubhan 1994).

5.2.2 Techniques Without Water Control

Controlled burns are applied to reduce the density of emergent vegetation and create habitat that is attractive to waterfowl. However, the effectiveness of burning is variable and depends on the type of vegetation being burned and the seasonal conditions during which a burn is applied. A period of high water sufficient to cover stalks is often required after a prescribed burn in order to kill-off remaining vegetation. No waterfowl food resources are produced following a winter burning of cattail.

Cutting is also used to reduce the density of emergent vegetation cover and increase the habitat for breeding and resting waterfowl. Channel creation using a cookie cutter is one method to increase the area available for use by waterfowl. Because cattail recolonize rapidly, cutting must be reapplied every two to three years.

Disking is used to break up stands of dense emergent vegetation, but requires drainage of water from the site, and sufficient time for aeration in order to be effective.

Techniques used to deepen wetland basins including level ditching, blasting, and dredging are effective at removing vegetation, creating areas of open water, and deepening areas that have silted-in. These techniques alter the physical landscape, require considerable maintenance, and must be repeated every three to ten years to be effective. Excavation to create level ditches may require winter access and ice removal which can become costly.

5.3 DISCUSSION

Based on the expectations versus known results of treatments, drawdown and channel cutting were selected as biologically appropriate methods to improve the habitat for staging waterfowl at the Delta Marsh.

Drawdown was selected because it simulates natural wetland processes. By progressing from a lake marsh stage to a dry marsh, the water to vegetation ratio can be improved, and conditions favoured by staging waterfowl can be produced without posing serious negative impacts.

Cutting vegetation and channels using a cookie cutter was selected because the intensity of its application can be varied depending on yearly conditions, because it creates new habitat for wildlife, and because it reduces the density of emergent cover by removing the entire plant rather than just those parts above the water.

5.4 ANALYSIS OF SPECIFIC ALTERNATIVES

With the biological impacts of wetland management techniques described in the previous section, this analysis refers to the biological impacts of the selected options, but focuses on the social spill-over impacts and the financial impacts resulting from the application of these techniques over a 20 year life-span. Drawdown and cutting were developed into three management options of varying scale and permanence, based on the conditions and limitations established in Chapters 2, 3, and 4. Conditions of particular consideration were the water supply, inflow and outflow channels, the identification of immediate and adjacent landowners, and the location of special or protected areas (Payne 1992).

5.4.1 SPILL-OVER IMPACTS

Past management at the Delta Marsh was reviewed in Chapter 4 to examine the goals of the various management plans and to determine the reasons they were never implemented. Although these plans were designed to rejuvenate the biological conditions that existed historically in the marsh, concerns voiced by area residents over spill-over impacts were of such significance so as to prevent any large-scale management. By reviewing the concerns known to exist among landowners, it was possible to select more appropriate wetland management techniques. A comparison of the spill-over impacts predicted for each management strategy is presented in table 5.6.

5.4.2 WETLAND ECONOMICS

The third variable used in this analysis was the financial investment required to implement biologically appropriate management strategies. Because the area under study is privately owned, and the membership of the Portage la Prairie Country Club is to be the sole beneficiary of direct management results, the analysis is financial rather than economic. Financial cost estimates were based on discussions with wetland managers and engineers and were totalled over a 20-year project operating life. Construction costs were provided in 1996 dollar values, and operating costs were discounted to present value figures at a rate of 7 percent. The cost of management was assessed for every five years of operation.

The process of wetland valuation based on the application of a dollar value to waterfowl was outlined in the section on wetland economics reviewed in Chapter 2. The economic benefits of hunting obtained from Government publications (Filion 1991) were compared with the number of birds taken by hunters annually (Caswell et al. 1996). The value per bird was calculated by dividing the average annual value of waterfowl hunting per participant by the average annual waterfowl bag.

A three-fold increase in the number of waterfowl using a marsh can occur when management results in restored habitat conditions (Pollard 1996). The number of ducks present at the marsh was generated by multiplying the current number/ha by three. To obtain an economic value for the managed wetland, the net increase in birds/ha was multiplied by the dollar figures provided by this analysis and the average value calculated by van Kooten (1993). This process was conducted for each management option over a 20 year life (Tables 5.2, 5.3, and 5.4). Total values were compared with total financial costs to generate a benefit to cost ratio for each option (Table 5.6).

5.5 OPTION 1: DRAWDOWN OF ENTIRE PCC PROPERTY

Drawdown or partial drawdown as the means to affect the distribution of aquatic plants, is recommended as a method to manage the PCC property of the West unit of the Delta Marsh because it will satisfy the biological requirements of the area, yet will not demand as much development as would be required if high water levels were to be maintained. The management plan was developed, and the spill-over impacts and the economic benefits predicted to result are discussed.

Drawdown should occur in a 30 to 45 day period as soon as possible after ice-out to provide the greatest opportunity for the germination and establishment of persisting perennial emergent vegetation. The ability to exclude water from either Canvasback Bay or Weedy Bay for more than one season in order to give seedlings a chance to grow is unlikely, as water from adjacent areas will quickly re-fill the basin due to seepage. This factor, along with the historical behaviour of the marsh, would favour a one-year partial drawdown to expose areas of higher contours while letting deeper areas retain standing water. The anticipated effect will be to vegetate the exposed areas with a variety of emergent plants and to increase the distribution and density of submergent species in the areas that remain shallowly flooded.

Unlike Weedy Bay, Canvasback Bay is not accessible by road. This is perhaps the greatest obstacle restricting development. Because the area surrounding the basin is also of low elevation, the ability to lower water levels in the marsh would necessitate the construction of a road-dike around the entire perimeter of the Canvasback Bay. Connecting this dike system to Weedy Bay, and constructing a continuation of the existing dike road along the south-west side of Weedy Bay would serve not only to exclude water, but would provide direct vehicle access between the PCC and the area's two major bodies of water.

Approximately 3 km of dike are required to enclose Canvasback Bay. This dike could be constructed in several ways. To enclose the wetland completely, the dike would originate at the north side of the Cram Creek road, cross over to the west side of the Deep Creek, continue south and around the whole bay to the north water control pumping station. The addition of the dike road south of Weedy Bay could fork west to follow the canoe channel to Canvasback Bay (Figure 5.1).

Design specifications for this dike consist of a surface width of 4.0 m with side slopes at a 3:1 ratio. Elevation specified at 0.90 m above average water levels of 247.84 m (812.92 ft), and ground elevation at 247.5 m (812.0 ft) would result in an embankment 1.24 m in height {(247.84+0.90)-(247.50)}, with a top width of 4.0 m and a base width of 11.44 m. The length of this dike would be approximately 4000 m. With a volume calculated at 9.57 m^3/ m of dike, construction materials are calculated at 38,300 m^3. However, because marsh soils would comprise the majority of those used to construct the dike, a contingency of 30% must be added to account for loss due to slumping and erosion. This would require the addition of 11,490 m^3 to the original estimate to equal 49,800 m^3 of materials. Some additional organic soils should be added to dike crowns after construction to promote the growth of grasses in order to prevent erosion. These could be provided from the stockpiled surface strippings at the borrow area. Because existing subsoil beneath the organic sediments is composed of clay (Underwood McLellan 1980), it would not be necessary to construct a impermeable core to prevent dike seepage.

A borrow pit no deeper than 2 m, will be established on the inside of the dike to reduce the inflow of water. Slopes of the borrow pit like those of the dyke will be 3:1 to limit slumping and erosion. Erosion and burrowing by muskrat will be reduced by establishing a berm approximately 6 m wide between the dike and the borrow pit. Canvasback Bay is connected to Lake Manitoba by Deep and Cram Creeks. While the exchange of water between Canvasback Bay and Cram Creek is indirect, Deep Creek flows directly into and out of Canvasback Bay, such that any control structures designed to regulate the flow of water into Canvasback Bay, must do so without

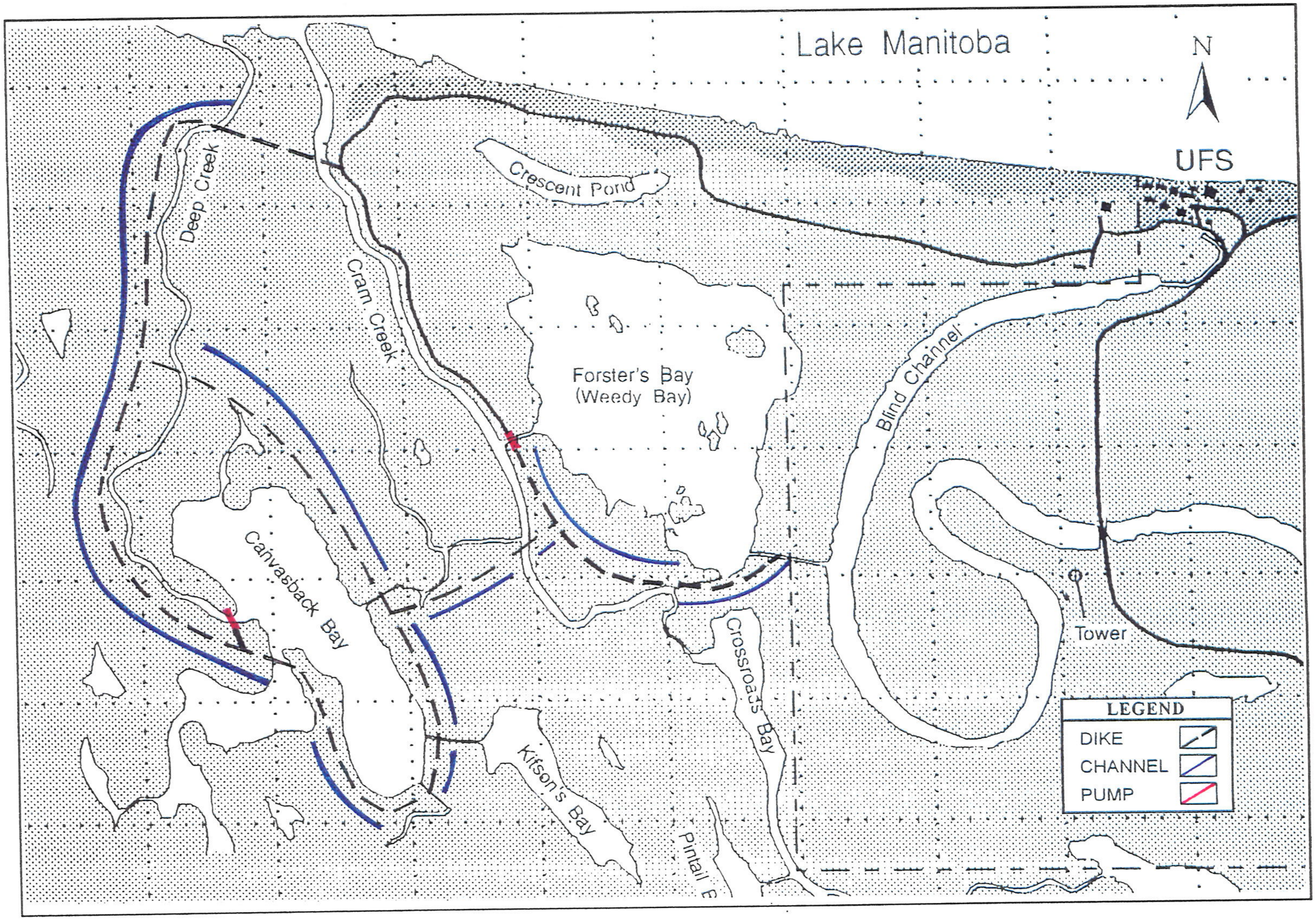

Figure 5.1. Map of management area for Drawdown of Entire PCC Property.

disturbing the flow either from farmland located south of the marsh, or north to Lake Manitoba. As a result, the flow of Deep Creek must be diverted around project developments. This diversion could be created by excavating borrow pits outside the perimeter dike between Deep Creek and south-west Canvasback Bay.

Five earthen plugs are recommended to halt the entrance of water into Canvasback Bay from inflow channels. A pump control and a screw gate water control structure would be placed at the north edge of the Canvasback Bay to facilitate the discharge of water into other portions of the marsh.

Four inflow and outflow channels will be blocked to contain the water volume within Weedy Bay, and minimize disturbance in the water systems of the University of Manitoba Field Station and Cram Creek. A bottom-opening gate control structure (screw gate) is recommended at the Cram Creek channel to Weedy Bay in order that post-drawdown refilling might occur passively via gravity flow.

A portable diesel generator would provide power to a pump which will run 24 hours/day during the drawdown period. At average water level for May, Canvasback Bay contains approximately 469 dkm^3 (380 acre-ft) of water, and Weedy Bay approximately 526 dkm^3 (427 acre-ft) of water. A 45-day drawdown period would require a pump capable of discharging 136 litres/second (3200 U.S.gal/min, 4.78 cfs). An operator must inspect the equipment every 8 to 12 hours to ensure that it is appropriately maintained. Because only one bay would be de-watered in a given year, only one portable pump is required. A low level pump with a 25 cm (10 inch) discharge is recommended for these basins.

Carp should be excluded from the system when possible. While elimination of carp may be accomplished by lowering water levels causing mortality, temporary fish fences should be installed at the pumping station to limit entry of fish immediately prior to drawdown. These fences would be sized to prohibit access by carp, while enabling smaller fish and fry to enter and exit the marsh.

To limit the potential for flooding across the Cram Creek road, its elevation should be increased slightly. The addition of 10 cm of gravel to the top of the 2000 metre road will require the import of 800 m^3 of gravel plus a 30 percent contingency to account for consolidation.

To prevent impeding the flow of water at the University of Manitoba Field Station, a channel must be cut to allow water to travel between the Blind Channel and Cram Creek. Excavating a channel of this sort would be facilitated by transferring the borrow bit used to build the dike from the inside to outside the diked-in area.

SPILL-OVER IMPACTS

Resident concerns were reviewed in the section on past management at the Delta Marsh in Chapter 4. Any form of management that requires the manipulation of water levels is likely to result in land owner concerns, particularly at the Delta Marsh where attempts to manage have been so long-standing. Managing both Weedy Bay and Canvasback Bay would be accomplished by alternating the schedule for drawdown over the 7 to 10 year cycle. This alternating regime could provide long-term increase in productivity and diversity, thus increasing the habitat value for wildlife. At the same time, it would improve the opportunity for hunters, giving them alternative sites most years and at least one site in any given drawdown year.

Water Supply and Runoff

Water runoff is a likely concern for area residents as dike construction would impede the flow of Deep Creek. However, operation of a diversion to facilitate the flow of water around Canvasback Bay would mitigate this concern. During years the Assiniboine diversion is over-topped, there is a risk that flood water could be impeded by the dikes bordering Canvasback Bay and part of Weedy Bay, and back up south on to farmland.

Water Quality and Quantity

The concern of increased salinity and diminished water quality was addressed by the previous management studies, and impacts were predicted to be minimal. Management of Canvasback Bay and Weedy Bay is considerably less intrusive than management of the entire West unit, and thus the associated impacts on water quality and quantity are predicted to have no impact on private land outside of the PCC.

Crop Depredation

If the three-fold increase in the number of ducks using the marsh predicted by wetland management literature occurs, these numbers could result in a substantial increase in crop damage and depredation. However, it is also likely that marsh management will attract field feeding Canada geese, whose staging populations have increased by 3 to 10 times the number in Southern Manitoba 20 years ago, and which may impact crop depredation to a greater extent than populations of ducks. Insurance programs dealing with crop depredation have changed since the management strategies of the early 1980's, and now provide greater coverage against crop damage. Although it is beyond the scope of this study, consideration must be given to this issue.

The conservation of local lure crops, and the operation of bangers and scarecrows to divert waterfowl from crop fields is necessary to reduce crop damage; however the responsibility for maintenance, rental or purchase of these techniques must be determined and agreed upon by local landowners.

Hunter access

The system of dikes proposed will improve access within the marsh by connecting Canvasback Bay to Weedy Bay. Improved hunter access is considered both a benefit and a cost of this option. For members of the PCC, a system of dikes that facilitates access to hunting sites is considered beneficial, while local landowners may be concerned about the risk of trespassing. Conversely, hunters may be concerned about additional trespass hunters who, observing easy access to hunting, may reduce the success of PCC members.

University of Manitoba

Changing the water regime of the area could affect the research that is conducted yearly at the University of Manitoba Field Station. Whether any such impact would be perceived as beneficial or negative though, is likely dependent on a number of factors, including the degree of the impact, the nature of the studies being conducted, and the extent of involvement researchers are afforded with regard to decision making.

Recreational Activities

As established, the use of the PCC is diversifying, from a membership based solely on waterfowl hunting, to one desiring forms of recreation in addition to waterfowl hunting. Management of Canvasback Bay and Weedy Bay could contribute substantially to these interests by providing areas for and access to bird watching and nature trails, as well as increasing the opportunity for hunting other species of game.

FINANCIAL IMPACTS

The costs associated with this development are great because substantial construction is required for operation. A budget outlining the costs of the materials and works required for construction and the costs of operation are provided in Table 5.2.

Construction costs, including dike construction, installation of water control structures, and pump installation to facilitate drawdown capability of two individual units is approximately $213,400.00.

Operating costs for maintenance and equipment including pump and generator rental calculated at $10,475.00, were evaluated every 5 years over 20 years and added to construction costs for a total cost of $245,493.00.

131.25 hectares of habitat are expected to be improved by this development; however; during the first year, only Canvasback Bay will be impacted and thus, the number of hectares you be impacted is 66.25.

Table 5.2. Costs and benefits associated with Drawdown of the Entire PCC Property over 20 years.

Option 1 Year	Construction Discounted Cost	Operating Discounted Cost	Area Impacted (Ha)	Number Ducks	Value at $7.55 per Duck	Value at $21.50 per Duck	Discounted Benefits at $7.55	Discounted Benefits at $21.50
1	$213,400.00	$10,475.00	66.25	90.01	$679.58	$1,935.22	$635.12	$1,808.61
2	$0.00	$0.00	66.25	90.01	$679.58	$1,935.22	$593.57	$1,690.29
3	$0.00	$0.00	66.25	90.01	$679.58	$1,935.22	$554.74	$1,579.71
4	$0.00	$0.00	66.25	90.01	$679.58	$1,935.22	$518.44	$1,476.37
5	$0.00	$9,789.72	131.25	178.59	$1,348.35	$3,839.69	$961.36	$2,737.64
6	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$898.47	$2,558.54
7	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$839.69	$2,391.16
8	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$784.75	$2,234.73
9	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$733.42	$2,088.53
10	$0.00	$5,324.96	131.25	178.59	$1,348.35	$3,839.69	$685.44	$1,951.90
11	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$640.59	$1,824.21
12	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$598.69	$1,704.87
13	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$559.52	$1,593.33
14	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$522.92	$1,489.10
15	$0.00	$3,796.62	131.25	178.59	$1,348.35	$3,839.69	$488.71	$1,391.68
16	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$456.73	$1,300.63
17	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$426.85	$1,215.55
18	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$398.93	$1,136.02
19	$0.00	$0.00	131.25	178.59	$1,348.35	$3,839.69	$372.83	$1,061.70
20	$0.00	$2,706.94	131.25	178.59	$1,348.35	$3,839.69	$348.44	$992.25
Totals	$213,400.00	$32,093.24					$12,019.19	$34,226.84

A three-fold increase in the number of birds currently using the marsh, would result in 2.04 ducks/ha, and an increase in the population by 90.01 ducks during the first year of management within this area. Subtracting the number of birds already present, and multiplying this figure by the waterfowl valuations described above ($7.55) and of van Kooten ($21.5)(1993), result in benefits estimated at $635.12 and $1,808.61 during the first year of operation, and total values of $12.019.19 and $34,226.84 over 20 years.

A benefit:cost ratio generated values of 0.049 and 0.139 for the two valuations respectively.

5.6 OPTION 2: DRAWDOWN AT WEEDY BAY

The characteristics present at Canvasback Bay are quite different from those at Weedy Bay and pose greater challenges for management. Controlling water levels on Canvasback Bay requires much more labour and expense. By limiting the area of management to a single water-body of water with physical characteristics conducive to independent management, negative spill-over and financial impacts can be dramatically reduced while producing the desired biological results.

Drawdown of Weedy Bay will be as described in the previous section to manage the PCC property. The removal of water will be accomplished by pumping water from Weedy Bay into Cram Creek. A dike constructed at the southwest edge of Weedy Bay along Cram Creek and continuing from the existing Cram Creek road, will serve as an access road to water control structures, and will form an additional barrier to reduce the flow of water and the risk of flooding (Figure. 5.2).

This will require the construction of a dike approximately 650 m long, extending from the end of the Cram Creek road to the east water control structure at the Blind Channel. With a volume calculated at 9.57 m^3 / m of dike, construction materials are calculated at 6220 m^3. As in Option one, a contingency of 30% must be added to account for loss due to slumping and erosion, adding 1870 m^3 to the original estimate to equal 8090 m^3 of materials. Organic soils added to dike crowns after construction to promote the growth of grasses and prevent erosion can be provided from the stockpiled surface strippings at the borrow area.

The inflow and outflow channels to Weedy Bay would be blocked as described in Option one, and a bottom-opening, gate control structure (screw gate) is recommended at the Cram Creek channel to Weedy Bay.

A portable diesel generator and pump, the same as described for Option one are required to drawdown the approximately 526 dkm^3 (427 acre-ft) of water within Weedy Bay.

Fish fences, development of the Cram Creek road, and diversion of Blind Channel and Cram Creek water would be as outlined in Option one.

SPILL-OVER IMPACTS

The spill-over impacts resulting from drawdown at Weedy Bay would be much the same as those of the drawdown scenario in option one, although at a diminished scale.

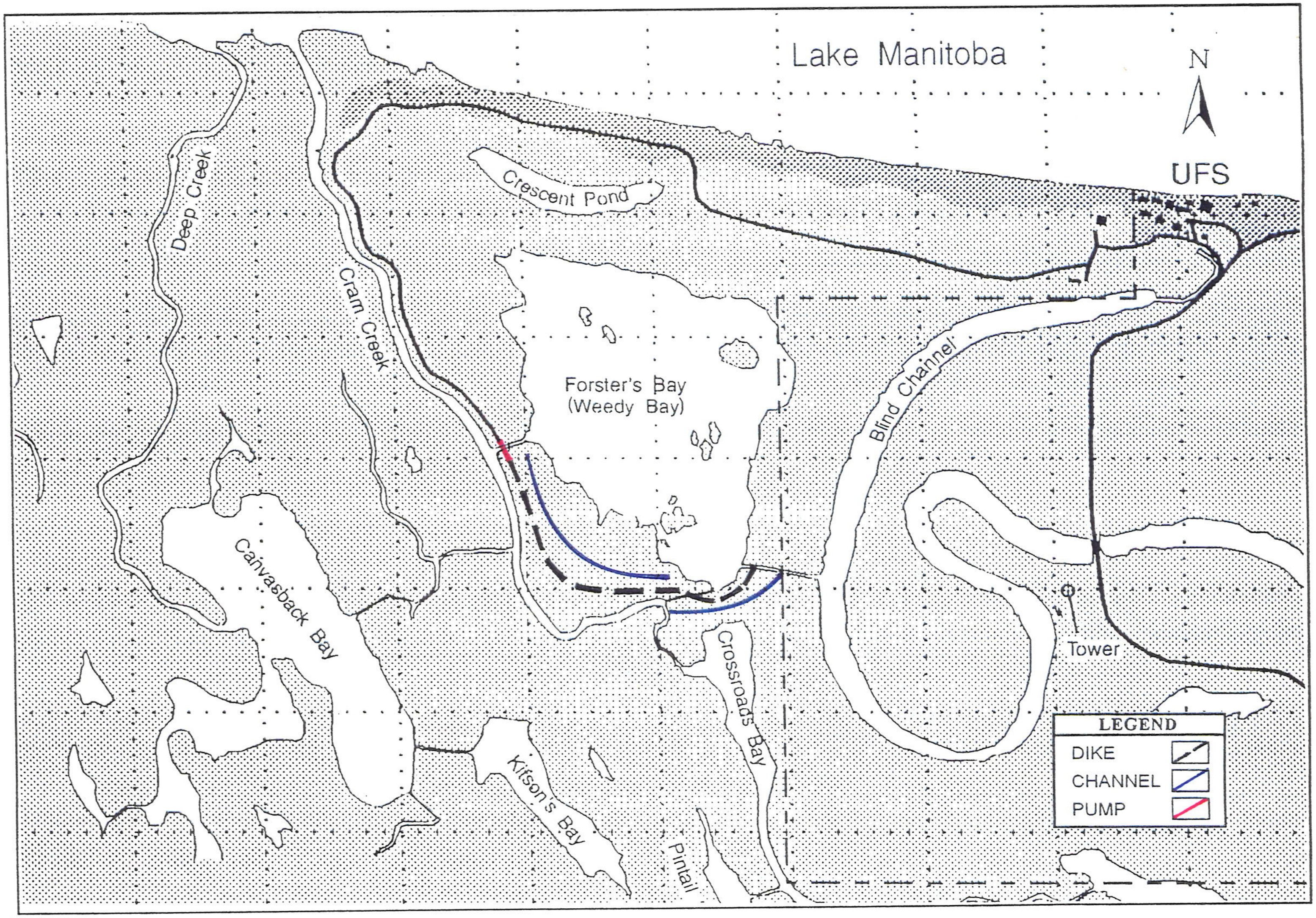

Figure 5.2. Map of management area for Drawdown at Weedy Bay.

The greatest concerns likely to develop involve research at the University Field Station that may be disrupted by construction and by changes in the flow pattern of water, and concerns of hunters over reduced canoe access.

Members of the PCC may be concerned that development and drawdown will inhibit their access to hunting areas. However, access is only restricted by the pump and control structure at the Cram Creek-Weedy Bay connection, and the benefits predicted from management are likely substantial enough that little opposition would be raised.

FINANCIAL IMPACTS

This option produces results similar to those of option one; however, the area impacted and the costs of development are considerably less. Financial costs and benefits are summarized in Table 5.3.

Construction costs for a 650 m dike, installation of water control structures and a pump are $65,900.00. Operating costs, including pump and generator rental and fuel, were approximately $10,475.00. With a cycle of drawdown once every 7 to 10 years, operating costs were evaluated every 5 years of the project. Total operating costs were $18,506.90, and total project costs were $84,406.90.

Drawdown of the Weedy Bay would improve approximately 65 ha of habitat to increase the number of ducks by 88.44. At the dollar values provided, the benefits of management were $7,073.86 and $20,144.09, to generate benefit:cost ratios of 0.084 and 0.239.

Table 5.3. Costs and benefits associated with Drawdown at Weedy Bay over 20 years.

Option 2								
Year	Construction Discounted Cost	Operating Discounted Cost	Area Impacted (Ha)	Number Ducks	Value at $7.55 per Duck	Value at $21.50 per Duck	Discounted Benefits at $7.55	Discounted Benefits at $21.50
1	$65,900.00	$10,475.00	65	88.44	$667.72	$1,901.46	$624.04	$1,777.07
2	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$583.21	$1,660.81
3	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$545.06	$1,552.16
4	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$509.40	$1,450.61
5	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$476.08	$1,355.71
6	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$444.93	$1,267.02
7	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$415.82	$1,184.13
8	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$388.62	$1,106.67
9	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$363.20	$1,034.27
10	$0.00	$5,324.96	65	88.44	$667.72	$1,901.46	$339.44	$966.61
11	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$317.23	$903.37
12	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$296.48	$844.27
13	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$277.08	$789.04
14	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$258.95	$737.42
15	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$242.01	$689.18
16	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$226.18	$644.09
17	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$211.38	$601.95
18	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$197.55	$562.57
19	$0.00	$0.00	65	88.44	$667.72	$1,901.46	$184.63	$525.77
20	$0.00	$2,706.94	65	88.44	$667.72	$1,901.46	$172.55	$491.37
Totals	$65,900.00	$18,506.90					$7,073.86	$20,144.09

5.7 OPTION 3: CUTTING CORNERS

If water levels cannot be managed, some elimination of cattail must occur in specific sites to improve its attractiveness to wildlife. The stabilization of water levels in the Delta Marsh for the past 30 years has produced conditions favouring the establishment of dense, monotypic stands of cattail with reduced value to wildlife. Improved habitat conditions could result through the use of a cookie cutter to break up closed areas of vegetation and allow inundation.

A cookie-cutter, described earlier, removes floating, submerged and emergent vegetation including cattail to facilitate the flow of water and provide open channels and pools. The cutter can remove all species of submerged and floating vegetation and brush up to 5 cm in diameter in water up to 46 cm deep (Payne 1992). A cookie cutter is more effective than a dragline and can be used in areas where draglines cannot. This technique is commonly used in situations where silting-in of channels and the overgrowth of emergent vegetation has reduced the attractiveness of habitat for wildlife (Payne 1992). The primary limitation to this technique is gaining access to the equipment required. A limited number of cookie cutters exist in Canada and thus, the cost of transport to the site must be considered on top of rental and operation costs.

Any wetland management technique that attempts to create openings or excavations in the emergent vegetation cover is fraught with difficulties in gaining access to the management area, and in locating suitable machinery from rental contractors. Once this is accomplished, a layout of the site to be excavated or moved requires careful consideration as to the objectives. Design specifications for created ponds or sinuous channels are based on establishing optimal habitat value. Thus, designs should seek to maximize the water:vegetation ratio, opening up thick cover to improve diversity and productivity while still enabling navigation by canoe.

A series of constructed pools and channels can be created in areas adjacent to open water on the north edge of the marsh (Figure 5.3), much like those found directly west of the Portage la Prairie Country Club Lodge. Approximately 1500 m of channels and donuts, with widths ranging from 2 to 3 m would be created. Ould (1980) recommended that channels run in an `S' shaped pattern to improve the amount of wetland edge, and consequently, the amount of habitat for wildlife.

SPILL-OVER IMPACTS

The spill-over impacts of cutting channels in a privately owned area of the Delta Marsh are minimal, primarily because the members of the PCC own the land and the water within their property boundaries. Management of this sort is common at the Delta Marsh and is not considered significant enough to pose a threat to adjoining area residents.

FINANCIAL IMPACTS

The financial investment required for developing water control works in wetlands is great, and landowners without the financial capital, or even the desire for such investment must resort to other options.

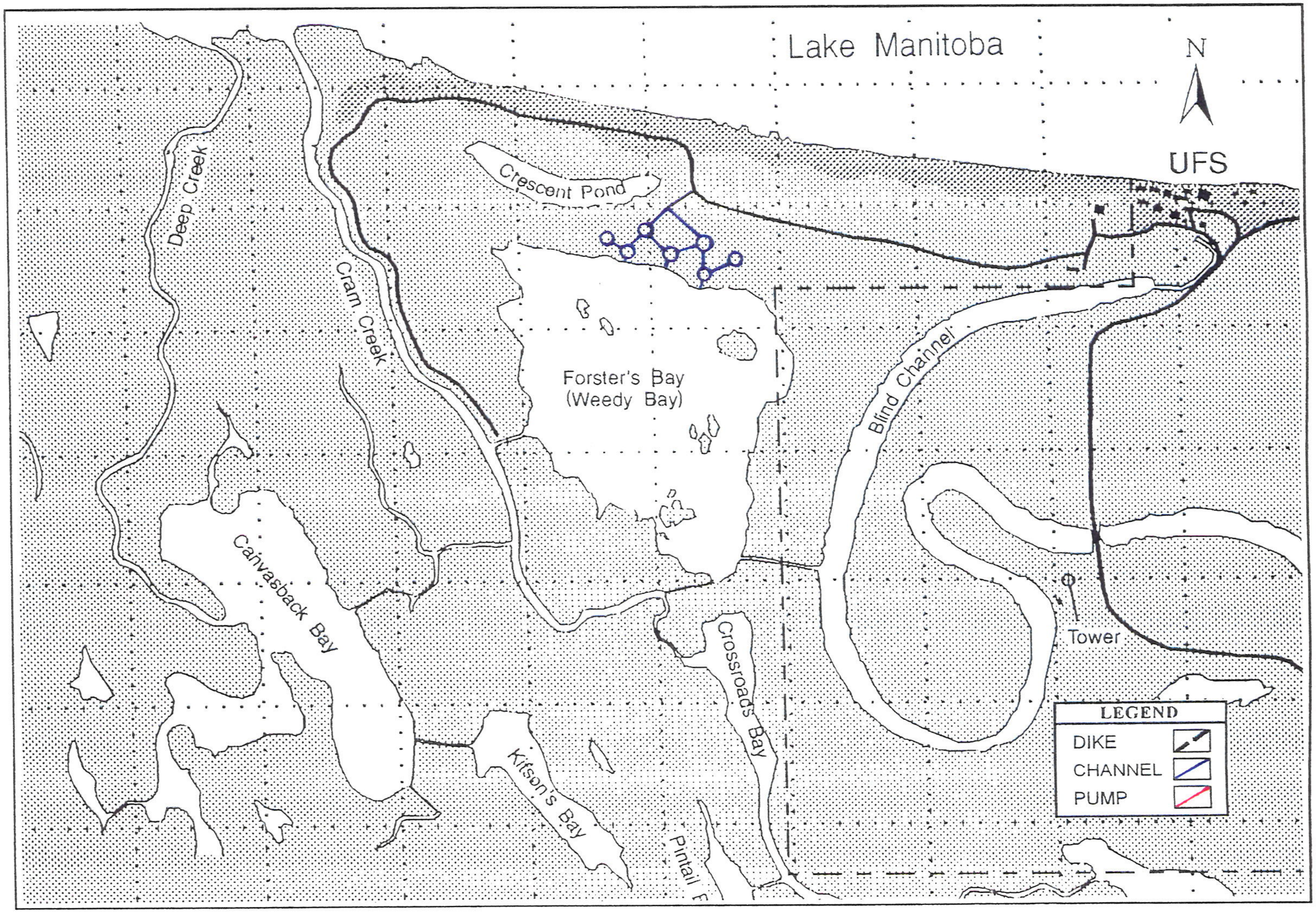

Figure 5.3. Map of management area for Cutting Corners.

The versatility afforded by this technique enables managers to select the area they want excavated in addition to the extent of the excavation. Unlike other forms of management, such as drawdown, where the installation of control structures implies a fixed cost, in the case of the cookie cutter, the total finances available for management can determine the amount of management that occurs. This provides the land owner or manager with the ability to weigh the extent of the management activity desired on various factors, including climatic conditions, available funding, expected use of the area, and availability of other areas. Because there are no construction costs, total costs for one application are significantly less than one application of a drawdown. However, the cost of reapplication every 2 to 3 years becomes substantially greater over the 20 year life of the project. Total project costs and benefits are outlined in Table 5.4.

Financial costs for a cookie cutter were assessed at approximately $200.00 per hour for 10 hours, and transport costs of $3.33/km over a 5000 km round trip. Total operating costs are $18,670.00 for the first year of operation. Operating costs were assessed every four years of the project, for total costs of $63,217.91.

1500 m of channels would improve 6.2 ha of habitat, and increase waterfowl by 8.44 at every year. The benefits of management observed in increased waterfowl was thus assessed at $675.07 and $1,922.39. The benefit-cost ratio was calculated at 0.011 and 0.030.

Table 5.4. Costs and benefits associated with Cutting Corners over 20 years.

Option 3 Year	Construction Discounted Cost	Operating Discounted Cost	Area Impacted (Ha)	Number Ducks	Value at $7.55 per Duck	Value at $21.50 per Duck	Discounted Benefits at $7.55	Discounted Benefits at $21.50
1	$0.00	$18,670.00	6.2	8.44	$63.72	$181.46	$59.55	$169.59
2	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$55.66	$158.49
3	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$52.02	$148.13
4	$0.00	$14,243.25	6.2	8.44	$63.72	$181.46	$48.61	$138.43
5	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$45.43	$129.38
6	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$42.46	$120.91
7	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$39.68	$113.00
8	$0.00	$10,866.11	6.2	8.44	$63.72	$181.46	$37.09	$105.61
9	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$34.66	$98.70
10	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$32.39	$92.25
11	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$30.27	$86.21
12	$0.00	$8,289.70	6.2	8.44	$63.72	$181.46	$28.29	$80.57
13	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$26.44	$75.30
14	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$24.71	$70.37
15	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$23.10	$65.77
16	$0.00	$6,324.17	6.2	8.44	$63.72	$181.46	$21.58	$61.47
17	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$20.17	$57.45
18	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$18.85	$53.69
19	$0.00	$0.00	6.2	8.44	$63.72	$181.46	$17.62	$50.18
20	$0.00	$4,824.68	6.2	8.44	$63.72	$181.46	$16.47	$46.89
Totals	$0.00	$63,217.92					$675.07	$1,922.39

Table 5.5. Spill-over impacts of three strategies to manage the PCC property.

MANAGEMENT STRATEGIES	SPILL-OVER IMPACTS
Drawdown of the PCC Property Function: To stimulate the germination of desired vegetation	Does not restrict annual waterfowl hunting Would require diversion of Deep Creek Concern of increased salinity and diminished water quality Increased risk of crop depredation Risk of trespassing on private land to gain access to hunting Increased access by motorized vehicles Concern that research at University Station would be disrupted Disruption of natural, aesthetic appeal during construction Could impede flow of water in years of flooding Could provide increased opportunity for research Greater opportunity for recreational activities
Drawdown at Weedy Bay Function: To stimulate the germination of desired vegetation	May restrict waterfowl hunting during construction Will not impede flow of water in years of flooding Concern that research at University Station would be disrupted Increased risk of crop depredation Increased access by motorized vehicles Could provide increased opportunity for research Greater opportunity for recreational activities
Cutting Corners Function: To create new areas to be used by waterfowl	Concerns that habitat is being altered Concern that research at University Station would be disrupted Increased risk of crop depredation by wildlife Could provide increased opportunity for research Greater opportunity for recreational activities

Table 5.6. Financial costs and benefits for three strategies to manage the PCC property.

Options	B/C @ $7.55	B/C @ $21.50
Drawdown of Entire PCC Property	0.049	0.139
Drawdown at Weedy Bay	0.084	0.239
Cutting Corners	0.011	0.030

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

The purpose of this practicum was to identify the causes of habitat deterioration for staging waterfowl at the Delta Marsh, and specifically at the Weedy Bay-Canvasback Bay complex owned by the Portage la Prairie Country Club, to determine if management of the West unit of the Delta Marsh is possible, and to develop strategies to do so.

A conceptual review of wetland ecology and the practice of their management established the complexity of wetland ecosystems and the methodology upon which practical and effective management decisions are made. These issues were addressed and resulted in the generation of three biologically appropriate management options to restore the degraded conditions persisting at the Delta Marsh. That management is in fact feasible is only an assessment; however, it is an assessment grounded in both theory and in fact.

The ability to meet the goals of wetland management is dependent on the compatibility of the stated objectives and the natural capacity of the habitat. Determining the conditions that existed historically at the Delta Marsh established that at one time, wetland conditions were optimal for waterfowl staging and resting. Habitat degradation, occurring primarily as a result of a stabilized water regime on Lake Manitoba, has diminished the ability of the Delta Marsh to provide these conditions; however, they are not beyond restoration.

Large scale management plans developed in the past to reverse habitat deterioration at the Delta Marsh established appropriate goals for the marsh, and technologically feasible methods to achieve them. However, the spill-over impacts of management raised by local landowners were significant enough to halt management on three past occasions.

By reducing the scope of the management area spill-over impacts could similarly be reduced. When limiting a project design though, it is necessary to consider the overall benefits and costs associated with the development. Management strategies that produce the greatest returns do not necessarily have the fewest social constraints, nor do those with the fewest social constraints necessarily produce the greatest returns.

6.2 CONCLUSIONS

Stabilized water levels, periodic flooding, and the activity of carp have disrupted natural wetland cycles and are the causes of habitat degradation at the Delta Marsh. Dense monotypic stands of cattail border the open water areas where bulrush and submersed species are sparse. Seedbank analyses conducted at the marsh indicate that a diverse flora had been present historically, and that large seed banks are located in the shore line zone (Pederson and van der Valk 1984). Waterfowl and wildlife use of the marsh has decreased or has changed to reflect the unproductive lake marsh stage. The results of several reports state that the restoration of long-term fluctuations in water levels is necessary to restore conditions at the Delta Marsh to those existing prior to Lake Manitoba regulation (Bossenmaier 1968, Jones 1978, Ould 1980, Ducks Unlimited 1981, Pederson and van der Valk 1984, Merendino and Smith 1991).

Management implications drawn from the literature suggest that drawdown or partial drawdown could be successful at increasing the diversity and productivity necessary to attract staging waterfowl within the West unit of the Delta Marsh. Exposing mudflats to promote the germination of desired emergent species and lowered water levels causing greater seed production in submersed species would restore the conditions favourable to staging waterfowl.

Goal directed management does not mean that the species interactions and interdependencies that occur in an ecosystem as complex as a wetland are overlooked. Rather, the collaboration of all applicable disciplines, including biology, engineering and economics is required if effective management decisions are to be made. In this case, the objective is to manage for staging waterfowl by mitigating or restoring natural conditions to a human-altered system. However, as established by past management attempts at the Delta Marsh, the decision to manage is accompanied with numerous social considerations that have too often been absent from the early stages of management planning (Payne 1992).

Designing and implementing an effective management plan would be greatly simplified by the absence of jurisdictional boundaries and multi-stakeholder interests, and the existence of endless financial support. This stated, the inability to implement a plan of management at the Delta Marsh in the past is almost justified. The need for management cannot be diminished though, and must be adapted to function within such confines.

6.3 RECOMMENDATIONS

An evaluation of the benefits and costs of the three management options shows that Option 2, Drawdown at Weedy Bay, has the greatest ratio of benefits to costs over a 20 year project life. The benefits represented by increased waterfowl numbers are bleak in comparison to the costs involved in management, thus, none of these options can be justified based on waterfowl benefits alone. However, this is only a cursory study and many factors have been left unexplored. When wetland management strategies are evaluated solely on the value of waterfowl produced, other wetland benefits, estimated by Prins et al. (1993) to be as much as four times greater, are ignored. These values, particularly those attributed by the clients, must be considered to make the evaluation of wetland benefits more accurate.

The value of wetlands is not established by economic markets. Rather, the extrapolation of benefits and costs must be obtained from studies of willingness to pay for the resource. Research to quantify the non-market and non-use values of the Delta Marsh and of all wetlands is lacking. The absence of this literature makes difficult the justification for wetland management and restoration.

The management strategies presented in this study are conceptual ideas that must be developed prior to implementation. Engineers with experience constructing wetland projects and who can consult directly with wetland managers and biologists should be engaged and more detailed designs developed.

Previous attempts to gain the ability to manipulate water levels in the Delta Marsh, were halted only after the concerns of landowners were recognized. The legacy of failed management attempts at the Delta Marsh may not be altered easily by new strategies that are both biologically and technically feasible. Other interest groups in this complex of the Delta Marsh, principally the farmers to the north, the University of Manitoba to the east, and the Lakewood Country Club to the west, should be consulted during the design of management strategies. Collaborative planning and shared decision making can address social concerns early and provide a forum for compromise.

There is a paucity of literature concerning the monitoring of wetland management. While countless studies are conducted to determine recommendations for management, little effort has been made to evaluate the successes or failures of their practical application. In an effort to reduce this gap, a monitoring plan should be initiated at the Delta Marsh prior to and throughout the duration of management.

Baseline information collected before management is put in place will be used to judge the impacts of the management action. Assessing the effects of the project as it is ongoing will also foster wise management decisions. The concept of adaptive management has only recently been embraced by resource managers. This form of management can result in decision making based on changes in local conditions rather than on the ideals established before active management occurred.

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APPENDIX A
MEAN MONTHLY WATER LEVELS ON LAKE MANITOBA

MEAN MONTHLY LEVELS IN FEET   Lake Manitoba at Steep Rock
1211205LK002******* PROVISIONAL WATER SURVEY OF CANADA DATA *******

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MEAN
1950	812.54	812.52	812.46	812.39	812.66	812.78	812.93	812.86	812.52	812.48	812.36	812.43	812.58
1951	812.41	812.36	812.35	812.33	812.48	812.43	812.33	812.18	812.01	812.05	812.05	812.13	812.26
1952	812.13	812.13	812.12	812.15	812.19	812.26	812.33	812.17	812.11	811.93	811.99	812.11	812.13
1953	812.13	812.19	812.25	812.37	812.48	812.90	813.32	813.29	813.19	813.22	813.42	813.40	812.85
1954	813.51	813.58	813.59	813.67	813.99	814.46	814.73	814.58	814.68	814.89	814.89	814.95	814.29
1955	814.91	814.86	814.80	814.91	815.26	815.68	815.77	815.42	814.99	814.72	814.54	814.63	815.04
1956	814.53	814.49	814.38	814.26	814.48	814.76	814.61	814.33	814.16	814.02	813.89	813.95	814.32
1957	813.92	813.81	813.69	813.70	813.79	813.81	813.91	813.57	813.39	813.30	813.03	813.08	813.58
1958	813.02	812.96	812.90	812.85	812.77	812.52	812.51	812.19	812.11	811.86	811.85	812.10	812.47
1959	812.12	812.16	812.17	812.15	812.30	812.58	812.59	812.31	812.17	812.15	812.38	812.43	812.29
1960	812.50	812.52	812.47	812.54	812.84	812.91	812.70	812.53	812.27	812.02	811.91	812.08	812.44
1961	812.14	812.18	812.29	812.34	812.53	812.40	812.15	811.85	811.44	811.49	811.13	811.29	811.94
1962	811.40	811.49	811.60	811.68	811.82	812.15	811.87	811.82	811.74	811.60	811.55	811.60	811.69
1963	811.63	811.68	811.71	811.91	812.01	812.34	812.36	811.96	811.77	811.59	811.29	811.37	811.80
1964	811.44	811.49	811.53	811.60	811.70	811.44	811.47	811.07	810.86	810.65	810.55	810.68	811.21
1965	810.77	810.79	810.82	810.98	811.20	811.52	811.43	811.34	811.26	811.27	811.27	811.43	811.17
1966	811.60	811.65	811.72	811.88	812.19	812.30	812.22	811.91	811.81	811.68	811.82	812.07	811.90
1967	812.24	812.41	812.54	812.64	812.82	812.64	812.32	812.11	811.92	811.83	811.93	812.11	812.29
1968	812.12	812.05	811.91	811.94	812.10	812.23	812.07	812.02	812.17	811.90	811.91	811.78	812.02
1969	811.79	811.78	811.72	811.70	811.83	811.68	811.92	811.91	811.71	811.60	811.64	811.79	811.76
1970	811.89	811.97	812.04	812.05	812.61	812.62	812.44	812.04	811.69	811.65	811.86	-	-
1971	812.29	812.43	812.46	812.49	812.47	812.37	812.11	811.96	811.78	811.81	811.95	812.04	812.18
1972	-	-	811.96	812.05	812.40	812.36	812.02	811.96	811.90	811.86	811.88	811.89	-
1973	811.89	811.84	811.87	811.90	812.06	812.35	812.30	812.16	812.08	812.14	812.08	-	-
1974	812.21	812.20	812.16	812.14	812.96	813.15	812.69	812.21	811.93	811.84	811.73	811.71	812.24
1975	811.70	811.76	811.74	811.81	812.27	812.52	812.23	812.20	812.25	812.23	812.12	812.09	812.08
1976	812.00	811.85	811.78	812.25	813.12	813.02	812.64	812.13	811.62	-	811.47	811.61	-
1977	811.73	811.82	811.88	811.94	812.39	812.49	812.19	811.95	812.11	812.21	812.01	811.97	812.06
1978	811.92	811.82	811.72	811.73	811.95	811.98	811.99	811.75	811.76	811.73	811.74	811.83	811.83
1979	811.87	811.88	811.98	812.18	813.05	813.28	812.93	812.36	812.17	811.97	811.91	812.02	812.30
1980	812.05	812.05	812.00	811.94	811.94	811.86	811.83	811.94	812.09	811.84	811.91	811.94	811.95
1981	811.77	811.69	811.62	811.65	811.64	811.80	811.95	811.87	811.83	811.73	811.63	811.59	811.73
1982	811.58	811.64	811.60	811.72	811.89	811.95	812.03	811.83	811.56	811.51	811.58	811.67	811.71
1983	811.75	811.74	811.88	812.06	812.36	812.50	812.49	812.05	811.72	811.70	811.80	811.70	811.98
1984	811.76	811.75	811.72	811.74	812.07	812.32	812.16	811.88	811.56	811.78	811.89	812.10	811.89
1985	812.15	812.17	812.15	812.17	812.18	812.09	812.04	812.03	812.18	811.99	812.08	-	-
1986	812.09	812.04	812.01	812.25	812.92	812.61	812.38	812.04	811.72	811.84	811.69	811.88	812.12
1987	811.87	811.86	811.94	812.13	812.10	812.01	811.88	811.97	811.86	811.78	811.84	811.87	811.93
1988	811.88	811.91	811.87	811.92	812.28	812.21	811.94	811.64	811.46	811.47	811.51	811.62	811.81
1989	811.70	811.75	811.74	811.80	811.92	812.07	812.13	811.84	811.73	811.52	811.55	811.55	811.78
1990	811.59	811.62	811.65	811.72	812.03	812.21	812.16	811.87	811.52	811.37	811.23	811.32	811.69
1991	811.34	811.34	811.36	811.48	811.70	811.83	811.93	811.68	811.32	811.17	811.27	811.36	811.48
1992	811.34	811.30	811.32	811.46	811.75	811.73	811.77	811.60	811.52	811.44	811.35	811.39	811.50
1993	811.42	811.41	811.38	811.42	811.50	811.51	811.63	811.63	811.57	811.51	811.56	811.65	811.52
1994	811.68	811.67	811.65	811.68	811.77	811.82	811.84	811.79	811.81	811.64	811.69	811.64	811.72
1995	811.74	811.78	811.83	812.18	812.76	812.92	812.50	812.33	811.89	811.80	811.86	812.10	812.14
1996	812.11	812.18	812.26	-	-	-	-	-	-	-	-	-	-

Levels in feet

Lake Manitoba at Steep Rock
1211105LK002 ******* PROVISIONAL WATER SURVEY OF CANADA DATA *******

1995	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	811.68	811.77	811.80	811.96	812.54	813.07	812.57	812.44	812.14	811.79	811.72	812.00
2	811.67	811.78	811.82	811.98	812.57	813.03	812.59	812.40	812.06	811.81	811.61	812.03
3	811.67	811.78	811.81	811.98	812.59	813.07	812.52	812.34	812.10	811.85	811.60	812.04
4	811.68	811.77	811.80	812.00	812.58	813.16	812.48	812.34	812.05	811.85	811.70	812.06
5	811.68	811.78	811.77	812.01	812.61	813.18	812.43	812.39	811.96	811.82	811.79	812.08
6	811.67	811.78	811.78	812.03	812.64	812.91	812.45	812.47	811.67	811.76	811.60	812.06
7	811.67	811.77	811.78	812.04	812.64	812.76	812.52	812.52	811.86	811.77	811.62	812.04
8	811.67	811.78	811.80	812.04	812.66	812.92	812.53	812.52	811.90	811.84	811.67	812.03
9	811.68	811.78	811.80	812.04	812.66	812.94	812.59	812.83	811.89	811.94	811.74	812.03
10	811.68	811.78	811.81	812.05	812.70	812.81	812.53	812.80	812.02	811.97	811.77	812.04
11	811.70	811.79	811.80	812.06	812.61	812.89	812.61	812.40	812.07	811.95	811.81	812.04
12	811.72	811.79	811.80	812.06	812.47	812.94	812.62	812.23	812.08	811.69	811.85	812.04
13	811.73	811.78	811.79	812.08	812.54	812.96	812.57	812.27	811.93	811.50	811.90	812.03
14	811.74	811.79	811.79	812.08	812.63	813.01	812.46	812.40	811.96	811.63	811.93	812.06
15	811.74	811.79	811.78	812.10	812.63	813.00	812.53	812.29	812.00	811.71	811.96	812.07
16	811.75	811.78	811.77	812.15	812.63	813.04	812.53	812.14	811.89	811.83	811.96	812.06
17	811.75	811.78	811.79	812.18	812.78	813.11	812.45	812.22	811.87	811.84	811.97	812.06
18	811.79	811.78	811.82	812.19	812.85	813.15	812.42	812.38	811.80	811.84	811.98	812.07
19	811.79	811.79	811.83	812.22	812.87	813.15	812.44	812.50	811.77	811.66	812.00	812.11
20	811.78	811.79	811.83	812.26	812.77	813.00	812.42	812.39	811.62	811.72	811.99	812.14
21	811.78	811.80	811.83	812.26	812.74	813.05	812.42	812.19	811.61	811.78	811.97	812.15
22	811.78	811.80	811.83	812.31	812.72	813.00	812.39	812.16	811.72	811.77	811.97	812.16
23	811.79	811.79	811.84	812.34	812.77	812.81	812.43	812.12	811.75	811.79	811.95	812.18
24	811.79	811.79	811.84	812.37	812.82	812.64	812.37	812.18	811.84	811.87	811.96	812.18
25	811.80	811.78	811.84	812.37	812.93	812.70	812.40	812.24	811.82	811.88	811.96	812.18
26	811.80	811.79	811.88	812.40	813.00	812.78	812.45	812.18	811.82	811.88	811.96	812.18
27	811.79	811.78	811.90	812.43	813.03	812.81	812.56	812.20	811.87	811.87	811.96	812.17
28	811.79	811.79	811.89	812.47	813.05	812.72	812.69	812.16	811.93	811.81	811.97	812.18
29	811.79	-	811.91	812.48	813.11	812.49	812.52	812.15	811.93	811.78	811.97	812.18
30	811.80	-	811.92	812.50	813.17	812.44	812.52	812.15	811.85	811.84	811.99	812.18
31	811.79	-	811.95	-	813.16	-	812.46	812.15	-	811.89	-	812.18

ANNUAL SUMMARY OF DATA

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
MIN	811.67	811.77	811.77	811.96	812.47	812.44	812.37	812.12	811.61	811.50	811.60	812.00	811.50
MAX	811.80	811.80	811.95	812.50	813.17	813.18	812.69	812.83	812.14	811.97	812.00	812.18	813.18
AVG	811.74	811.78	811.83	812.18	812.76	812.92	812.50	812.33	811.89	811.80	811.86	812.10	812.14

Flows in cfs

PORTAGE DIVERSION NEAR PORTAGE LA PRAIRIE
1111105LL019 ******* PROVISIONAL WATER SURVEY OF CANADA DATA *******

1995	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC
1	-	-	0.00	3128	13631	3001	-	-	-	-	-	-
2	-	-	0.00	3220	13348	3001	-	-	-	-	-	-
3	-	-	0.00	2606	13137	2588	-	-	-	-	-	-
4	-	-	0.00	1921	12889	2178	-	-	-	-	-	-
5	-	-	0.00	1288	12218	1769	-	-	-	-	-	-
6	-	-	0.00	1310	11689	1299	-	-	-	-	-	-
7	-	-	0.00	1334	11689	769	-	-	-	-	-	-
8	-	-	0.00	1536	12289	501	-	-	-	-	-	-
9	-	-	0.00	1882	12748	E 259	-	-	-	-	-	-
10	-	-	0.00	1938	12925	0.00	-	-	-	-	-	-
11	-	-	0.00	1995	13596	0.00	-	-	-	-	-	-
12	-	-	0.00	2341	13702	0.00	-	-	-	-	-	-
13	-	-	0.00	9605	13631	-	-	-	-	-	-	-
14	-	-	0.00	7910	13490	-	-	-	-	-	-	-
15	-	-	0.00	7204	13278	-	-	-	-	-	-	-
16	-	-	0.00	8369	13101	-	-	-	-	-	-	-
17	-	-	0.00	10735	13172	-	-	-	-	-	-	-
18	-	-	0.00	11865	12854	-	-	-	-	-	-	-
19	-	-	0.00	11406	12289	-	-	-	-	-	-	-
20	-	-	0.00	10806	11618	-	-	-	-	-	-	-
21	-	-	0.00	11018	11088	-	-	-	-	-	-	-
22	-	-	0.00	11336	E 10594	-	-	-	-	-	-	-
23	-	-	0.00	11194	E 10064	-	-	-	-	-	-	-
24	-	-	0.00	11018	E 9111	-	-	-	-	-	-	-
25	-	-	289	10947	E 8404	-	-	-	-	-	-	-
26	-	-	557	10488	E 7451	-	-	-	-	-	-	-
27	-	-	709	10417	5473	-	-	-	-	-	-	-
28	-	-	1398	11689	4237	-	-	-	-	-	-	-
29	-	-	1935	13242	3708	-	-	-	-	-	-	-
30	-	-	3065	13772	2977	-	-	-	-	-	-	-
31	-	-	3153	-	3082	-	-	-	-	-	-	-

ANNUAL SUMMARY OF DATA

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL
MIN	-	-	0.00	1288	2977	0.00	-	-	-	-	-	-	0.00
MAX	-	-	3153	13772	13702	3001	-	-	-	-	-	-	13772
AVG	-	-	358	7251	10757	1280	-	-	-	-	-	-	5553
VOL	-	-	22035	431473	661482	-	-	-	-	-	-	-	1145480

MONTHLY SUMMARY FOR PERIOD OF RECORD

	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	MEAN
MIN	810.77	810.79	810.82	810.98	811.20	811.44	811.43	811.07	810.86	810.65	810.55	810.68	811.17
MAX	814.91	814.86	814.80	814.91	815.26	815.68	815.77	815.42	814.99	814.89	814.89	814.95	815.04
MEAN	812.09	812.10	812.10	812.17	812.42	812.51	812.43	812.22	812.06	812.00	811.97	812.05	812.19

APPENDIX B
CONSTRUCTION AND OPERATING COSTS OF MANAGEMENT TECHNIQUES

SELECTED MANAGEMENT TECHNIQUES	FINANCIAL IMPACTS					
	CONSTRUCTION COSTS		OPERATING COSTS			
Drawdown of PCC Property Function: To stimulate the germination of desired vegetation	Dike x 4000 m Trimming, seeding Screwgate x 2 Fish fence x 2 Pump installation Road upgrade Total	149300.00 5000.00 31000.00 3000.00 4000.00 21100.00 213400.00	Pump rental Generator Fuel Total	4050.00 3225.00 3200.00 10475.00	Year 1 Year 5 Year 10 Year 15 Year 20 Total **Total Costs**	10475.00 9789.72 5324.96 3796.62 2706.94 32093.24 245493.24
Drawdown of Weedy Bay Function: To stimulate the germination of desired vegetation	Dike x 650 m Trimming, seeding Screwgate x 1 Fish fence x 1 Pump installation Road upgrade Total	24300.00 1500.00 15500.00 1500.00 2000.00 21100.00 65900.00	Pump rental Generator Fuel Total	4050.00 3225.00 3200.00 10475.00	Year 1 Year 5 Year 10 Year 15 Year 20 Total **Total Costs**	10475.00 0.00 5324.96 0.00 2706.94 18506.9 84406.9
Cutting Corners Function: To create new areas to be used by waterfowl			Equipment Transport	2000.00 16670.00 18670.00	Year 1 Year 4 Year 8 Year 12 Year 16 Year 20 **Total Costs**	18670.00 14243.25 10866.11 8289.70 6324.17 4824.68 **63217.91**
All prices provided in present value figures at a discount rate of 7%						