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ECONOMIC ANALYSIS OF WETLANDS DRAINAGE IN CENTRAL ALBERTA

BY

© **MARK A. MYHRE**

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THE UNDERSIGNED CERTIFY THEY HAVE READ, AND RECOMMEND TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH FOR ACCEPTANCE, A THESIS ENTITLED **ECONOMIC ANALYSIS OF WETLANDS DRAINAGE IN CENTRAL ALBERTA** SUBMITTED BY **MARK A. MYHRE** IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF **MASTER OF SCIENCE IN AGRICULTURAL ECONOMICS.**

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Abstract

The economic feasibility of draining non-permanent wetlands in central Alberta is examined by evaluating two drainage systems at a half-section wetland drainage site, 50 kilometers south of Edmonton and conducting a wetlands inventory of the study area.

This wetland drainage site contains a 23 hectare non-permanent wetland that prior to 1988 held up to 45 centimeters of water through more than half the growing season. By the time it dried out in late summer, the grass was too mature to be of any use to livestock. A controlled backflood drainage system was installed at this site in 1988, under the Farmland Development and Reclamation Program. It operated as a traditional uncontrolled drainage system for one year, prior to the control structure being installed in the summer of 1989.

The costs and benefits associated with each drainage system are collected and analyzed from two perspectives: the farmer's and society's. The farm financial analysis includes the on-site costs and benefits of the drainage system. The socio-economic analysis includes the costs of the off-farm drainage works and wildlife habitat losses resulting from the installation of the drainage system along with the on-farm costs and benefits. Sensitivity tests are also conducted on the costs and revenues associated with each drainage system, the size of the wetland associated with each wetland drainage

site and the discount rate associated with each economic perspective.

A wetlands inventory is undertaken using black and white aerial photographs to determine the number and size of non-permanent wetland sites in the study area that are economically feasible to drain.

The results suggest that there are many non-permanent wetland sites in central Alberta that would be economically feasible to drain. This economic feasibility depends on the size of the wetland that is being drained and improved. It depends on the type of drainage system that is being installed. It also depends on whether potentially high off-site costs are included in the analysis.

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I. INTRODUCTION

A. Problem Definition

Wetlands drainage is a controversial issue in Alberta. Environmentalists, sportsmen and other recreational and tourist based interest groups recognize the value of wetlands as a natural resource and oppose their drainage. Many agricultural producers, on the other hand, view non-permanent wetlands as an economic liability and support their drainage.

It has been shown that wetlands provide a continuous, sustainable stream of environmental and social benefits that significantly contribute to the quality of life in the province and can be enjoyed by all members of society (Alberta Water Resources Commission, 1990). They are dynamic, productive ecological systems that are an important source of genetic diversity. In Alberta, roughly 45 species of waterfowl, 81 species of other birds and at least 30 mammals such as beaver, moose and deer use wetlands or wetland margins for all or part of their life cycles. Other important environmental benefits include the control and storage of surface water and the recharge and discharge of groundwater. Social benefits include the wide range of consumptive and non-consumptive recreational and tourism activities that are dependent on wetlands (e.g., hunting, skating, bird-watching and photography).

Wetlands in central Alberta have been steadily disappearing since settlement began. While they are lost for a variety of reasons including climatic fluctuations and urban, industrial and transportation development, the primary cause of wetlands loss is agricultural drainage (Alberta Water Resources Commission, 1990). Land can be brought into production and the efficiency and timing of field operations can often be improved by draining wetlands. Schick (1972) found a 61 percent loss in wetland area in the aspen parkland region of Alberta between 1900 and 1972. Canadian Wildlife Service personnel estimate that between 1981 and 1989, 0.5 percent of Alberta's wetlands were lost each year to agricultural drainage (Turner, 1990).

Agricultural wetlands drainage in central Alberta has traditionally been accomplished through the use of open ditches. Water is allowed to flow down these ditches at an uncontrolled rate. A variety of negative impacts are associated with this type of drainage system including wildlife habitat losses and downstream flooding and erosion problems. The Drainage Potential Study (Alberta Water Resources Commission, 1987) showed that, if only on-site costs and benefits are analyzed, farmers can realize financial gains from uncontrolled drainage in all parts of the province. However, when the off-site costs of drainage works to prevent downstream flooding and erosion problems and wildlife habitat losses are included in the analysis, this type of drainage system is, in many cases, no longer economically feasible to install and maintain.

B. Statement of Purpose

Concern with the environmental and social costs of uncontrolled drainage resulted in the development of alternative drainage techniques. One of these promising alternatives is controlled backflood drainage. This type of drainage system is a relatively new concept in central Alberta, although it has been practised in southern Alberta for many decades. A control structure is placed in the outflow channel. It usually consists of a culvert with a gate on one end. In this way, the flooding of low lying areas in the spring can be controlled. The backflood area is deliberately ponded for a period of 10 to 14 days by keeping the gate on the culvert closed. During this time, the infiltration and percolation of water down through the frozen ground is monitored closely with soil probes. The excess water that does not infiltrate is removed after the flooding period by opening the gate. Controlled drainage has the potential to significantly reduce off-site environmental and social costs by reducing peak downstream flows. Backflooding in the spring can also increase forage yields.

A controlled backflood drainage system was set up, approximately 50 kilometers south of Edmonton, in 1988 under the Farmland Development and Reclamation Program. The land involved is owned by Marvin and Gerald Pohl. This wetland drainage site operated as a traditional uncontrolled drainage system in the spring of 1989. It has operated as a controlled backflood drainage system since the summer of 1989 when the control structure was installed. Data were collected for both of these systems.

The purpose of this study is to examine the economic feasibility of draining non-permanent wetlands in central Alberta. Both uncontrolled (traditional) and controlled backflood (non-traditional) drainage systems will be evaluated.

C. Objectives of the Research

The objectives of this research are:

1) To evaluate the on-site costs and benefits associated with installing either uncontrolled or controlled backflood drainage systems at Pohl's wetland drainage site within a suitable problem solving framework.

2) To provide an assessment of the off-site costs associated with each drainage system at Pohl's wetland drainage site and to evaluate the probable impact of those costs on each system's economic feasibility.

3) To determine the number and size of potential non-permanent wetland drainage sites in the area of study with a view to a broader assessment of the economic feasibility of wetlands drainage in central Alberta.

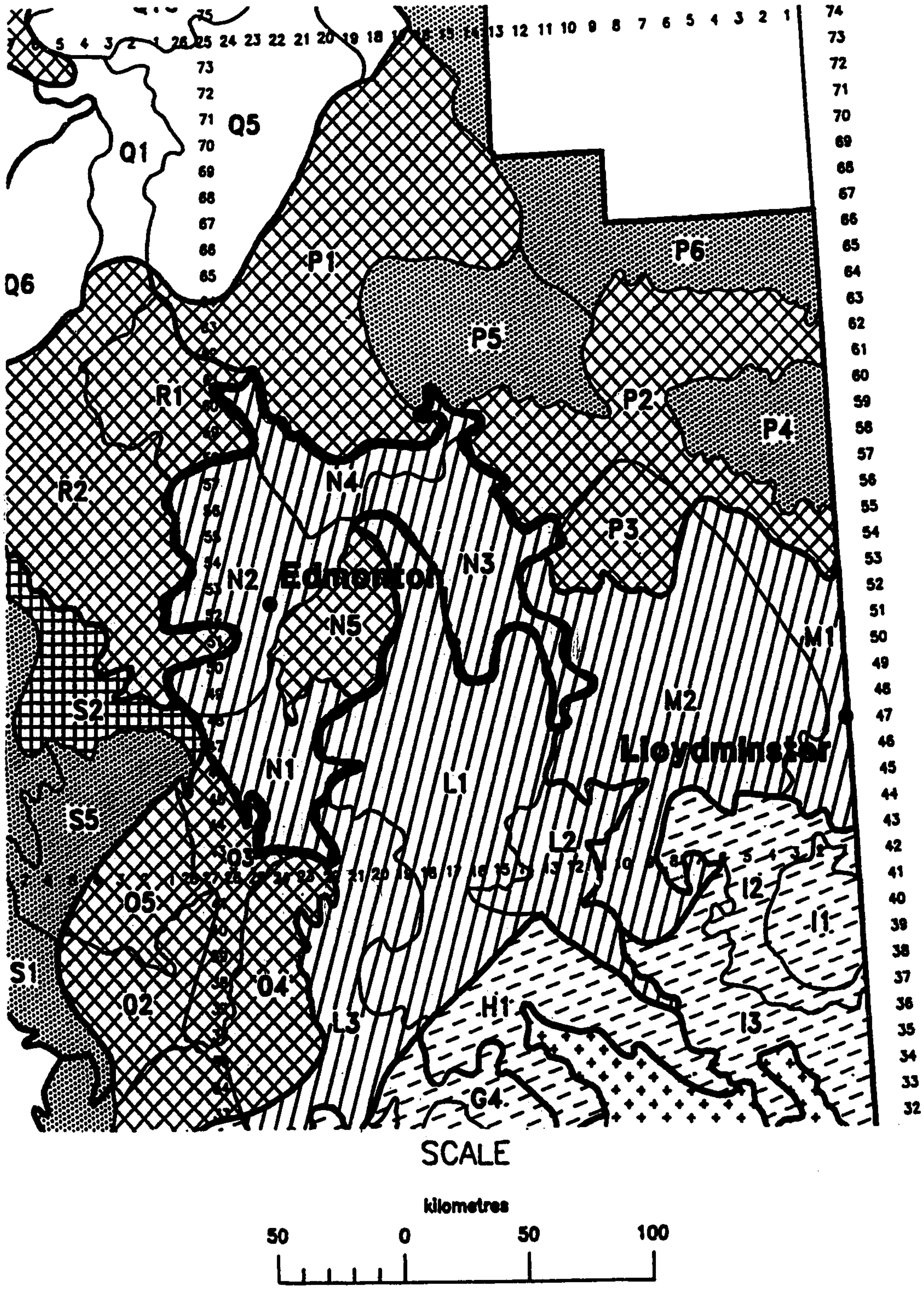
D. Study Area

The study area chosen is the Edmonton-Two Hills agroecological resource region. Agroecological resource regions are large areas with similar agriculture potential and kinds of farming (Agriculture Canada, 1989). They were developed by aggregating agroecological resource areas within a general agro-climatic and physiographic framework. Agroecological resource areas, on the other hand, are areas that are more or less uniform in terms of agro-climate, landform, soils and general agricultural potential. There are 100 agroecological resource areas and 26 agroecological resource regions in Alberta. The Edmonton-Two Hills agroecological resource region (N) is an aggregation of 5 agroecological resource areas: Wetaskiwin (N1), Edmonton (N2), Andrew (N3), Redwater (N4) and Cooking Lake (N5) (see figure 1). There are 155 townships in the Edmonton-Two Hills agroecological resource region. It extends from township 43 in the south to township 61 in the north and from range 12 west of the fourth meridian in the east to range 1 west of the fifth meridian in the west.

E. Sources of Data

The data for the cost benefit analysis are supplied by the Conservation and Development Branch of Alberta Agriculture. Black and white aerial photographs and assorted maps for the wetlands inventory study are obtained from Alberta Forestry, Lands and Wildlife. Other sources of information include the Rural Economy Library at the University of Alberta, the Alberta Environment Library in Edmonton and the Faculty of Extension at the University of Alberta.

Figure 1
Edmonton-Two Hills Agroecological Resource Region



Source: Alberta Agriculture, Conservation and Development Branch, 1990a. Agro-Climatic Classification of Agroecological Resource Areas of Alberta.

F. Plan of Study

Following a brief theoretical review in chapter 2, both drainage systems at Pohl's wetland drainage site will be evaluated in chapter 3 using cost benefit analysis. In chapter 4, results of a wetlands inventory of the study area will be reported. Finally, the results of this study will be summarized in chapter 5 and some recommendations made for further study in the area of wetlands drainage.

II. THEORETICAL REVIEW

A. Review of Cost Benefit Analysis

Cost benefit analysis is often used to evaluate drainage systems that have both advantages and disadvantages associated with their installation and maintenance. The following section reviews the theory of cost benefit analysis.

Drainage systems are installed to provide direct economic benefits to the farmer resulting from the removal of water from wetland areas. The main economic benefit they provide is increased gross revenue from crop production (Anderson and Associates, 1986b). Drainage systems also have on-site and off-site costs associated with them. On-site costs include capital (engineering, excavation, materials, and outlet channel seeding costs), drainage area land development and annual production costs. Off-site costs include capital (engineering, excavation, materials, and downstream channel seeding costs) and wildlife habitat loss costs (Anderson and Associates, 1986b). Wetland drainage studies in Alberta have tended to focus on on-site costs and benefits and ignore the off-site costs (Desjardins et al, 1984; Wanchuk, 1986; Macleod, 1988).

The benefits associated with drainage systems usually occur over a period of years, while a majority of the costs are incurred in the first two years. These benefits and costs must be discounted to account for this difference in time perspective. The same amount of money has different values over time (Dymowski and Meszaros, 1986). Money becoming available in the future has less value from a consumption stand-point than at present. Therefore the value of money becoming available later on cannot be compared directly with the money available now. The interest rate on money takes these different values over time into account. Interest is the compensation offered by the borrower for the use of the money. This concept is used in evaluating drainage systems to bring all future costs and benefits to present values, thus making them comparable. This is called discounting and the interest rate used is called the discount rate.

The discount rate can be interpreted as the opportunity cost of capital or as a time preference for current as opposed to future consumption (Anderson and Associates, 1986b). Time preferences for individuals are expressed through market rates of interest. From the farmer's perspective, estimates of the appropriate real discount rate to use range between 5 percent (Alberta Water Resources Commission, 1987) and 10 percent (Anderson and Associates, 1991). Preferences expressed as individuals may not be the same as their preferences expressed when they see themselves part of society. Thus, it is probable that society as a whole has a lower rate of discount in its collective attitude than the observed market rates which reflect the individual's myopia (Dasgupta and Pearce, 1987). From society's perspective, estimates of the appropriate real discount rate to use range between 3 percent and 6 percent

(Rousseau, 1983). Recent studies by the Conservation and Development Branch of Alberta Agriculture have used real discount rates of 5 percent and 3 percent for the farm financial and socio-economic analysis respectively (Ackroyd, 1991).

Three methods directly account for the time value of money and can be used to evaluate the economic feasibility of drainage systems: net present value, internal rate of return and cost benefit ratio. The net present value of a drainage system is the sum of the discounted benefits less the sum of the discounted costs (Anderson and Associates, 1987). To be economically feasible, the system must have a positive net present value. A net present value equal to zero means that a particular system can pay for all its costs, including the cost of capital. A positive net present value shows that it will provide greater than required returns and a negative net present value shows the level of extra funds required to cover its costs. The cost benefit ratio of a drainage system is the sum of the discounted benefits divided by the sum of the discounted costs (Anderson and Associates, 1986b). To be economically feasible, the system must have a cost benefit ratio greater than 1.0. The internal rate of return of a drainage system is the discount rate which equates the present value of a system's expected cash inflows to the present value of its expected costs. To be economically feasible, the system must have an internal rate of return that is higher than the market rate of interest.

The net present value and the internal rate of return methods are closely linked because each uses the same discounting procedure. However, the net present value requires a specified interest rate, while the internal rate of return solves for the interest rate that yields a zero net present value. Both methods give the same information under most circumstances (Barry, Hopkin and Baker, 1988). One drawback of the internal rate of return approach is that it is quite possible to obtain more than one solution rate. This drawback is considered by many to preclude the use of internal rate of return as a decision rule (Dasgupta and Pearce, 1988). The internal rate of return approach is also tedious to calculate when the payments are a non-uniform series.

Cost benefit analysis can be conducted from two different perspectives: the farmer's (farm financial analysis) and society's (socio-economic analysis). The farm financial analysis is used to determine the return to the farmer (Rousseau, 1983). Only the on-site costs of the system that the farmer pays and the on-site benefits that the farmer receives are included in the farm financial analysis. The socio-economic analysis is used to determine the return to society from all the resources committed to the system, regardless of who in society pays the costs and regardless of who in society receives the benefits. The costs of off-site drainage works to prevent downstream flooding and erosion and wildlife habitat losses, in addition to the on-site costs and benefits, are included in the socio-economic analysis.

The significant economic life of a drainage system is the time required to obtain 90 percent or more of the cumulative present value of the benefits and costs, usually 30 years (Anderson and Associates, 1986b). Thus, although Pohl's wetland drainage site may have a physical life in excess of 30 years, for the purposes of the cost benefit analysis, its economic life is assumed to be 30 years, including the construction period. At that point, the salvage value of the existing drainage facility is assumed to be negligible.

To eliminate the problem of changes in the general price level, all prices in cost benefit studies are usually expressed in terms of constant dollars (Anderson and Associates, 1986b). The use of real values in cash flows is consistent with the use of a real discount rate.

Sensitivity testing is an important part of cost benefit analysis. Most of the costs and benefits associated with a drainage system have a range of possible values. The simplest and most common form of dealing with this uncertainty is sensitivity testing. It shows how much net present values and cost benefit ratios will change in response to a given change in an input variable. Ordinarily, input variables are varied one at a time. Each input variable is changed by specific percentages above and below the base case value and new net present values and cost benefit ratios are calculated, holding the other variables constant (Gapenski and Brigham, 1984).

B. Review of Wetland Inventory Methods

Wetland inventories can be conducted using Canada Land Inventory waterfowl and agriculture capability maps, farmland assessment sheets, Landsat satellite imagery or aerial photographs. The following section reviews the advantages and disadvantages associated with each of these methods.

The Canada Land Inventory series was initiated through a federal-provincial agreement under the Agricultural Rehabilitation and Development Act of 1961 (Knight, 1967). It is a comprehensive survey of land capability and use for various purposes (Canada Department of Forestry, 1965). The four resource sectors in the Canada Land Inventory series are agriculture, forestry, wildlife and recreation. Lands assessed were evaluated, classified and mapped separately for each resource sector. Mapping data were compiled from soil surveys, maps and other published sources, aerial photographs and from field studies. Seven classes of land, ranging from very high (Class 1) to virtually zero capability (Class 7) based on the ability of the land to support the specific resource sector, were designed through the cooperative efforts of the federal and provincial governments (McCormack and Duffy, 1971). For the agricultural, forestry and wildlife sectors, the classes are based on the degree of limitation (biological, climatic, physical) of the resource base affecting productivity in the sectors. Subclasses in these sectors (except in Class 1 where there are no subclasses) are identifed by specifying in code symbols the major types of limitations for each class. In the recreational sector, classes are established on the basis of the intensity (quantity) of outdoor recreational use which might be sustained per unit area. Sub-classes in this sector indicate the specific features of the resource providing opportunity for recreational use.

The Canada Land Inventory soil capability for agriculture and wildlife capability series maps at a scale of 1:250,000 are readily available from Alberta Forestry, Lands and Wildlife (Alberta Forestry, Lands and Wildlife, 1990b). However, their usefulness for wetland inventories is limited While these maps provide good regional overviews, they do not provide sufficient detail to accurately identify non-permanent wetland drainage sites and calculate their areas (Alberta Water Resources Commission, 1987). Poor resolution of wetland types and boundaries allows only gross approximations of areas to be made. Greater resolution of boundaries and less variability in area calculations would occur with 1:50,000 scale Canada Land Inventory maps. However, these smaller scale maps are only publicly available for a few areas of the province (Alberta Forestry, Lands and Wildlife, 1990b).

Farm assessment sheets are compiled by the county assessor for each quarter section of patented land in Alberta. The information recorded consists of a sketch map showing agricultural and non-agricultural land use practices which occur within the quarter section, accompanied by an assessment of the agricultural value of each designated area (Kerr and Young, 1984). A strong emphasis is placed on describing the nature of the surface topography and the character of the soil profile in deriving value per acre figures. General assessments are conducted as frequently as once every eight years, but in most cases, longer time intervals are the norm.

Farm assessment sheets provide more detailed information on wetland type, boundaries and area estimations than Canada Land Inventory series maps do. There are two major problems, however, with using them to complete an inventory of non-permanent wetland drainage sites. Firstly, there are a large number of farm assessment sheets required (144 per township). Sixteen townships are used in this study. These sheets must be acquired through direct requests to the municipal districts and counties being studied. Assessment offices are often reluctant to release to private individuals or agencies what they consider to be confidential information. Secondly, there is no consistency between assessment offices and assessors as to how wetlands are classified on farm assessment sheets due to the lack of a standardized waterbody identification guide and the considerable variability that exists among study areas and assessors (Kerr and Young, 1984).

Since 1972, NASA has launched a series of satellites, initially called ERTS (Earth Resources Technology Satellite), subsequently renamed Landsat in 1975, for monitoring and mapping earth's resources. These satellites orbit at high altitudes and are able to scan all regions in a north-south swath 185 kilometres wide (Smith, 1987). Landsats 1, 2 and 3 orbit every 103 minutes at 916 kilometres altitude for a complete global coverage every 18 days. Landsats 4 and 5 orbit every 99 minutes at 705 kilometres altitude for a complete global coverage every 16 days. Data are transmitted to earth and first corrected geometrically to remove distortions. The digital numbers can then be reconstituted to produce a photographic positive original of each band. One can thus acquire monochrome prints for each band, produced by exposing any 3 positions to blue, green and red filtered light. The most common product is a color composite, which consists of a green band printed in blue, a red band in green and an infrared band in red. This imagery is similar to color infrared photography except that each Landsat image is at a much smaller scale and covers a much larger area, about 13,000 square miles (Intera Technologies, 1984b). These images are usually dominated by a red-pink color for vigorous vegetation indicating high infrared reflectance. Other features generally appear as follows: water is black, suspended sediment in water is blue, urban areas and bare soil are pale blue, sand is yellow or white, snow is white and agricultural crops are intermediate red or pink (Smith, 1987).

Landsat satellite imagery is a useful and inexpensive tool to monitor changing wetlands conditions on a wide-scale basis. However, its usefulness for certain types of wetland inventories is severely limited because small non-permanent wetland drainage sites in cultivated areas cannot be resolved on the Landsat image (Alberta Water Resources Commission, 1987).

Aerial photographs are photographs of a portion of the earth's surface taken with a camera mounted in a conventional aircraft. They are available in Alberta in both stereo and pictorial coverage (Alberta Forestry, Lands and Wildlife, 1990b). During a flight, exposures are made at regular intervals in such a way that there is a 60% overlap between photographs. This overlapping area, although of the same portion of ground, is photographed from two different angles, providing two different perspectives of that portion of ground. When adjacent photographs are used, it is the difference in perspective that allows the viewer to see the image in three dimensions, or stereo. Pictorial coverage provides a complete overview of an area with minimal overlap between photographs by using alternate frames. Three main types of film are used in aerial surveys in Alberta: panchromatic (conventional black and white), true color (color negative) and color infrared (color positive) photography (Alberta Forestry, Lands and Wildlife, 1990b).

All three types of aerial photographs can be used to complete wetland inventories. Black and white aerial photographs are readily available for the entire province from

Forestry, Lands and Wildlife and are the least expensive of the three types (Alberta Forestry, Lands and Wildlife, 1990b). They are extremely useful for accurately identifying and estimating the areas of potential wetland drainage sites. Apedaile and Rapp (1983) used black and white aerial photographs in their inventory of wetlands in east central Alberta. Color and color infrared aerial photographs are only available for a few select areas of the province and are more expensive than black and white aerial photographs (Alberta Forestry, Lands and Wildlife, 1990b). They are just as effective, however, for use in wetland inventories and give more detailed soils and vegetation information than black and white aerial photographs. Intera Technologies (1984b) used color as well as black and white aerial photographs in their inventory of wetlands in Alberta.

III. CASE STUDY: POHL'S WETLAND DRAINAGE SITE

A. Wetland Drainage Site Definition

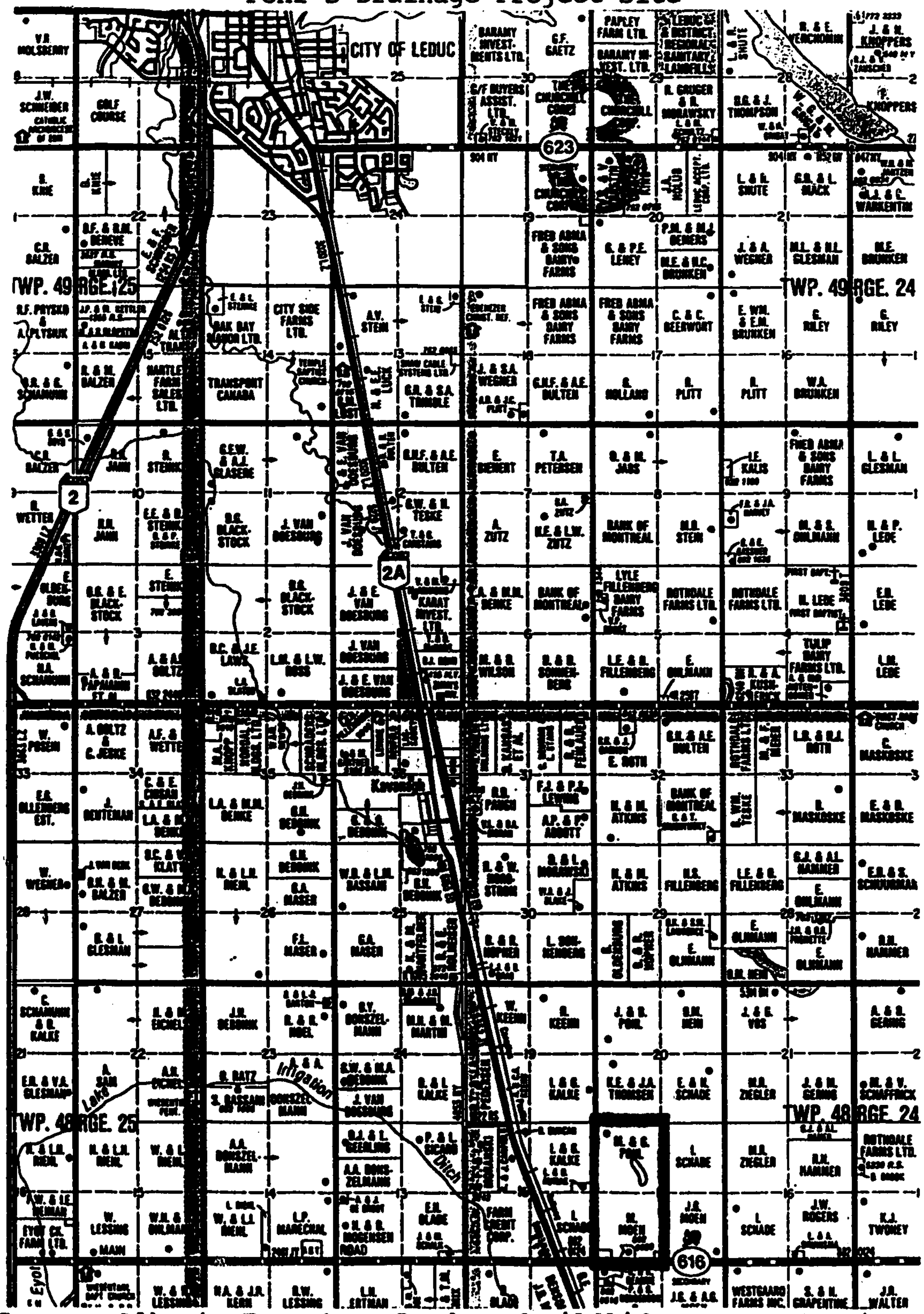
1. Location

The Pohl's wetland drainage site is located within the Edmonton-Two Hills agroecological resource region in the County of Leduc on the W1/2 17-48-24-W4 (see figure 2). A non-permanent grass wetland on the northwest quarter of this half section covers an area of 23.25 hectares (see figure 3). Its outlet channel (Line A on figure 3) on the southwest quarter is 500 meters in length.

2. History of Site

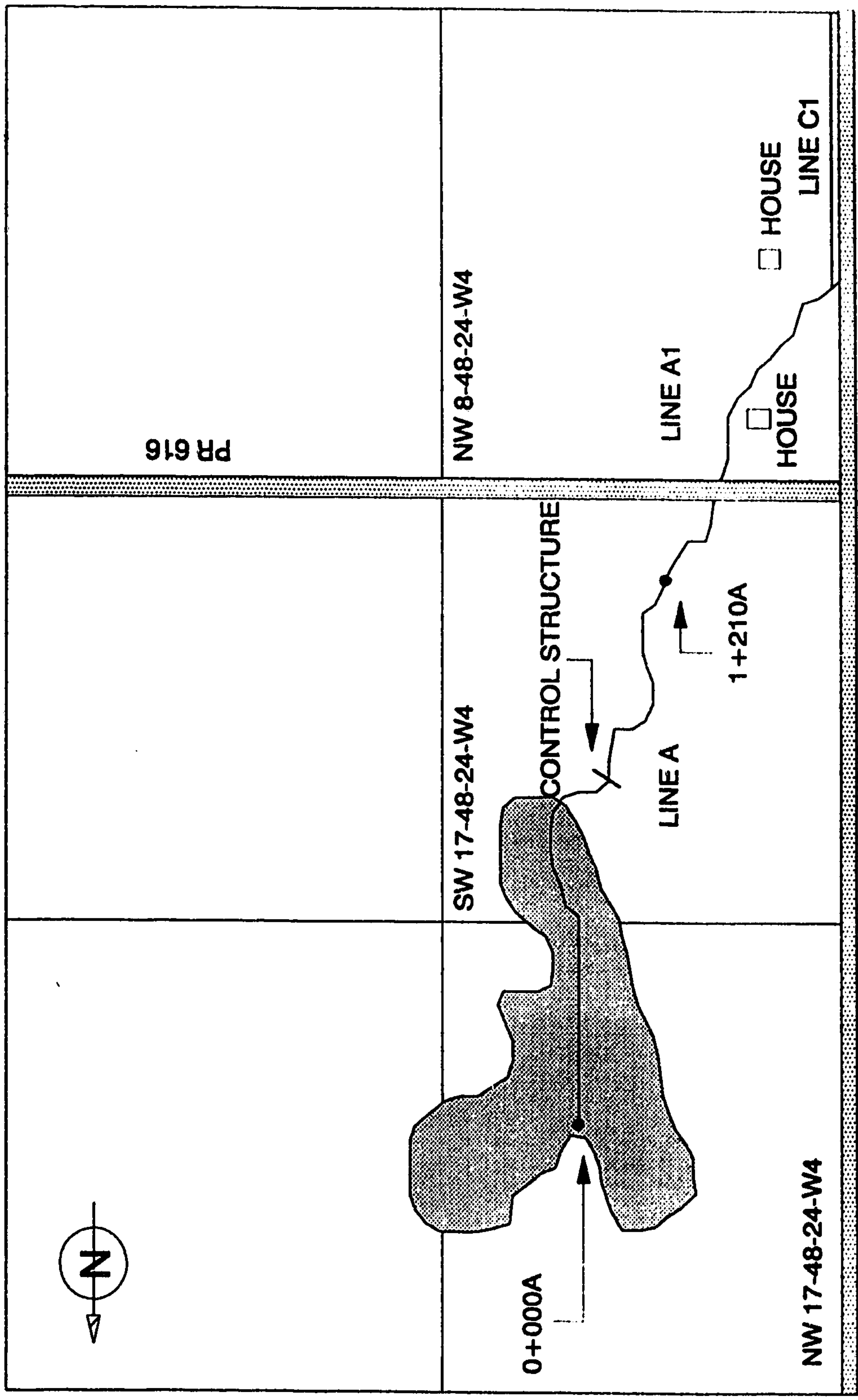
The NW 17-48-24-W4 was purchased by Marvin and Gerald Pohl in 1986. The SW 17-48-24-W4 is owned by Steve Moen. The Pohls applied to the Conservation and Development Branch of Alberta Agriculture, shortly after their land purchase, to drain their newly acquired wetland under the Farmland Development and Reclamation Program. The wetland area was of no value to the Pohls. It held up to 45 centimeters of standing water through more than half the growing season. By the time it dried out in late summer, the grass was too mature to be of any use to livestock. Conservation and Development personnel recommended that a controlled backflood drainage system be set up. This recommendation was readily accepted by the Pohls and Steve Moen. The Pohls were eager to experiment with backflooding to produce forage crops on an area of land that had previously been nonproductive for agriculture.

Figure 2
Pohl's Drainage Project Site



Source: Alberta Forestry, Lands and Wildlife. 1990a. County of Leduc Map.

Figure 3
Pohl's Controlled Backflood Drainage System



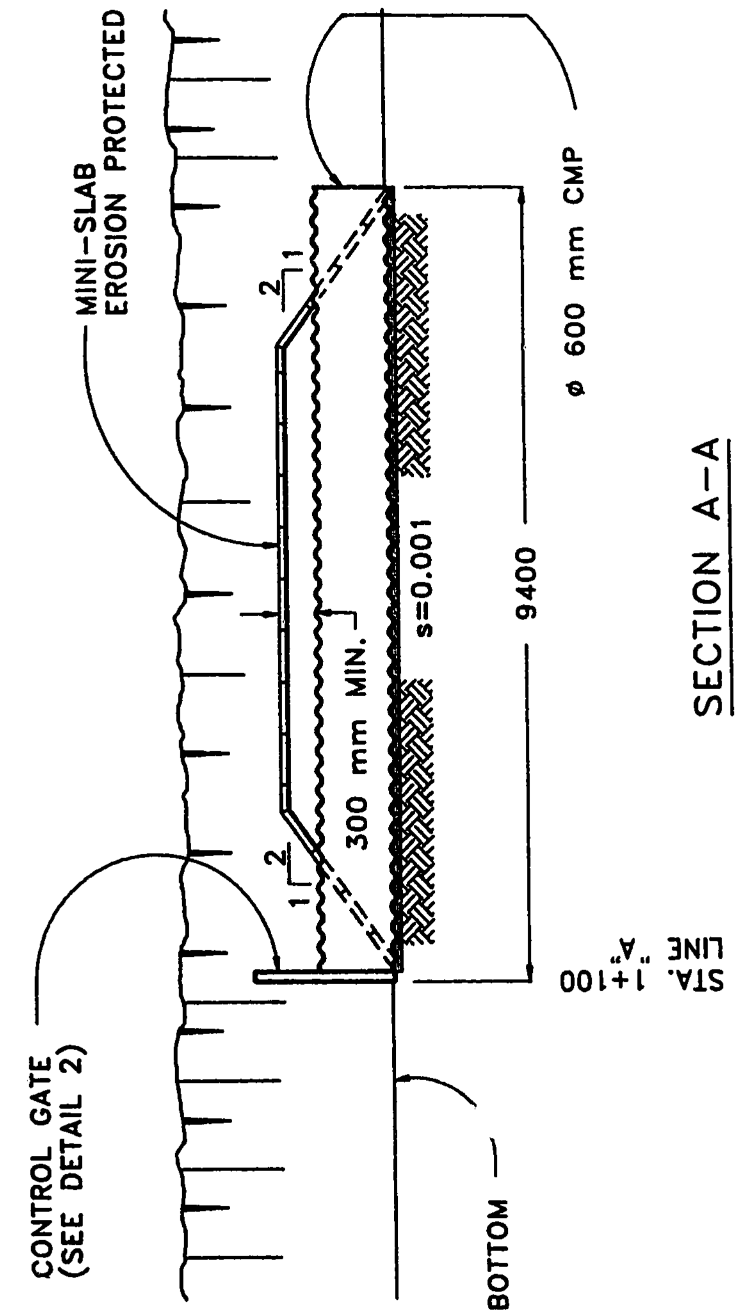
Alberta Agriculture was also anxious to be involved in the first operational controlled backflood drainage system in central Alberta.

Construction began on the drainage system in the fall of 1988. Central Oilfield Construction of Wetaskiwin was contracted to do the excavation work. The outlet channel was deepened (but not sidesloped) and a preliminary ditch was dug north across the wetland. Two trucks and a loader were then hired to move the freshly excavated soil from the ditch onto the wetland. A Steiger four wheel drive tractor and blade was used to spread the soil as it was dumped in the wetland area.

In the spring of 1989, the site operated as an uncontrolled drainage system and the effects of a sudden, uncontrolled release of water were observed firsthand. Snow and ice that had built up in the outlet channel over the winter months broke loose early on the morning of April 16. In less than 5 hours the wetland was completely drained. Only the low runoff volumes prevented the downstream lands and buildings from sustaining serious damage. As it was, the outlet channel that had been constructed in the fall of 1988 was left with bank erosion in its first 200 meters, the banks of the downstream channel south of the secondary road overflowed at some locations and one farm approach along the county road ended up under water.

In the summer of 1989, the outlet channel was widened and the control structure was installed (see figure 4). On July

Figure 4
Control Structure



Source: Ron Ackroyd, 1991. Economic Analysis of the Golden Glow Backflood Irrigation Project.

12, Central Oilfield Construction moved a tracked hoe and small dozer on-site and began to brush sideslope and deepen the outlet channel. The control structure was fabricated by Central Oilfield Construction and installed on July 13. A scraper was rented and used to bring clay spoil to the control structure to build the ditch berm. The reshaping of the outlet channel was completed on July 14. On July 20, Lafarge Construction Materials delivered the Mini-Slabs (low cost erosion control blocks) to the project site. Installation of these blocks over the control structure's berm was completed in 7 hours. They were installed to prevent the control berm from washing out and flooding downstream landowners in high runoff years. The same day the County of Leduc moved on-site with a tracked loader and 3 gravel trucks to move the channel's spoil piles onto the wetland. A Steiger four wheel drive tractor and blade was again used to spread the spoil as it was dumped in the wetland area. All the earthwork activities were finished on July 21. In late August, the County of Leduc seeded the outlet channel with a mixture of forages.

In the spring of 1990, the site operated as a controlled backflood drainage system. There was a repeat of the snowdamming in the outlet channel for its full 500 meters below the backflood area. Again, the initial elevation of backflooding was set by the snowdams. By March 29, the first flow of water through the collapsing snowdams was beginning.

Approximately 60,000 cubic meters was estimated to be backed up at this point. Without the control structure, the collapse of the snowdams would have led to the same rapid release of water as in 1989. The level of backflooding was almost as high as in 1989 and the snowdams were failing in exactly the same manner. Instead of the previous flooding, the first flow through the snow filled channel went over the top of the control structure for a short period. That ended quickly as the snow blocking the control culvert moved out allowing the rest of the first flows to pass through the culvert. By March 30, controlled flow through the structure's culvert had cleared a channel through the snowdams in the outlet watercourse. The channel velocities were slow enough so that even though the outlet channel was poorly protected by a grass cover that had not been seeded early enough the previous fall, no bank erosion took place. The controlled drainage of the wetland was completed 7 days after runoff had begun and no erosion or flooding problems were observed.

3. Soils

The majority of the wetland is composed of a wet meadow soil with a shallow organic layer on top. It is classified as a Rego Humic Gleysol (Sherstabetoff, 1989). There is also a significant area in the centre of the wetland that is a deep muck soil. It is classified as a deep Terric Humisol. This particular Terric Humisol has two rather unique features. Firstly, it is greater than 1.0 meter in depth. Most organic soils in Alberta only have this level of decomposition from the surface down to a maximum depth of 10 centimeters. Secondly, it has a pronounced marl (shell) layer with a moderate electrical conductivity at the interface of the organic soil and the underlying loam. This marl layer reflects the post-glacial history of this wetland as a shallow lake.

4. Hydrology

A watershed area of 8.11 square kilometers supplies water to the grass wetland. The estimated runoff volume into the wetland based on spring runoff data for this area is 1,029,970 cubic meters from a once in 100 year snowmelt; 843,440 cubic meters from a once in 50 year snowmelt; 665,831 cubic meters from a once in 25 year snowmelt; 609,061 cubic meters from a once in 20 year snowmelt; 437,129 cubic meters from a once in 10 year snowmelt; 274,929 cubic meters from a once in 5 year snowmelt; and 87,588 cubic metres from a once in 2 year snowmelt (Deboer, 1989).

The volume of water in the wetland area on April 16, 1989, when the snow and ice blocking the outlet channel gave way, was approximately 80,000 cubic meters. The runoff in the spring of 1989 was therefore less than a once in two year event. The peak flowrate per watershed unit area was 0.62 cubic meters per second per square kilometer. This puts it above a once in one hundred year event, primarily because of the rapid release of water when the snowdams gave way. The peak runoff rate based on the capacity of a 1,800 millimeter diameter culvert at the secondary road was calculated to be 5.0 cubic meters per second.

The volume of water in the wetland area on March 28, 1990 when the snowdams gave way was approximately 60,000 cubic meters. This was about the same volume as was held back in 1989 by snowdamming. Assuming the control culvert ran full for five to six days, between 150,000 cubic meters and 180,000 cubic meters of water drained from the wetland area and upper watershed in 1990. Thus, the total snowmelt in 1990 was larger than the 1989 event, although initially at the critical time of snow dams failure, the volumes backflooded were equivalent. The runoff in the spring of 1989 was therefore between a once in 2 and a once in 5 year event for the area. The peak flowrate event per watershed unit area was 0.074 cubic meters per second per square kilometre. This puts it between a once in 2 and a once in 5 year event. The estimated peak flowrate into the backflood area was 0.6 cubic meters per second. The average flowrate from the control structure was estimated at 0.3 cubic meters per second.

5. Project Outflow

The outflow from the grass wetland drains south across the southwest quarter in a well defined 500 meter channel to a small second wetland on the south end of the quarter. An 1,800 millimeter diameter culvert carries the flow from this small wetland south under the secondary road onto the NW 8-48-24-W4. From there, a highway bridge passes the flow of water west under Highway 2A. The watercourse then crosses west on the NE 7-48-24-W4 and outlets the water into the Lake Eyot Drain.

6. Downstream Impacts

There are two acreage owners on the NW 08-48-24-W4. The well defined downstream channel runs near both houses. The upstream outlet channel construction in the fall of 1988 improved the drainage of the wetland and released 56,825 cubic meters of water that otherwise would have remained in the wetland. In the spring of 1989, without a control structure in place, downstream acreage owners observed a noticeable increase in total water volumes as a result of this project. They also observed an increase in peak flowrates as a result of sudden releases of uncontrolled runoff when the snow dams gave way. Even in low runoff years, the risk of flooding and erosion occurring downstream would be high, without a permanent control structure to release the backflood snowmelt in a controlled fashion, because of snow damming. Snow dams are a common occurrence in central Alberta. The natural freezing and thawing action over the winter months causes snow and ice to build up in outlet channels. These snow dams act only as temporary chokes. When they break loose in the spring, the sudden release of uncontrolled runoff has the potential to cause damage downstream.

The installation of the control structure in the summer of 1989 raised the overflow elevation to 96.50 meters. The original elevation had been 96.25 meters. As a result, the runoff volume retained in the wetland increased by an additional 41,250 cubic meters to 96,900 cubic meters. There was also 42,380 cubic meters of water that was used in the backflood area. In terms of the flow regime under controlled drainage compared to the flow regime under uncontrolled drainage, there was no reduction in total water volumes. There was, however, a noticeable reduction in volumes and peak flowrates during the initial snowmelt runoff event. Spring runoff volumes were initially reduced by a volume up to 96,900 cubic meters (the maximum retained before the control berm overflows). There was a delayed release following 10 to 14 days of backflooding. However by this time, velocities were controlled and water volumes were relatively low.

B. Drainage Cost Benefit Evaluation

1. Analytical Framework

Both uncontrolled (traditional) and controlled backflood (non-traditional) drainage systems at the Pohl's wetland drainage site are evaluated using benefit cost analysis to examine the economic feasibility of draining non-permanent wetlands. Each analysis is conducted from two different perspectives: the farmer's (farm financial analysis) and society's (socio-economic analysis). Two measures are used to estimate the worth of each system: net present value and cost benefit ratio. In addition, it is assumed in this analysis that (1) prices and costs can all be expressed in terms of constant 1990 dollars, (2) a 30 year period is appropriate for both the farm financial and socio-economic analysis and (3) the appropriate real discount rates (which exclude inflation) are 5 percent and 3 percent for the farm financial and socio-economic analysis respectively.

2. The Data

a. On-Farm Drainage Costs

The on-farm drainage costs are those costs associated with the construction and maintenance of the upstream part of the drainage system. Construction costs for both drainage systems include engineering costs, excavation costs and costs of seeding the outlet channel. Construction costs for the controlled backflood drainage system also includes materials costs.

On-farm engineering costs are $807. They occur in the first year of the project and include costs for surveying ($205 per kilometer), data preparation ($132 per kilometer), design work ($210 per kilometer) and drafting ($120 per kilometer) (Elgert, 1990). The on-farm outlet channel (Line A in figure 3) is 1.210 kilometers long.

On-farm excavation costs are $6,995 in the first year of the project and $8,317 in the second year. They include costs for ditching, trucking spoil to the wetland area and for renting machinery. Initial ditching costs in the wetland and outlet channel are $4,630 (MacAlpine, 1990). Follow-up brushing and channel upgrading costs in year 2 are $3,480

(MacAlpine, 1990). The cost of trucking spoil piles to fill areas in the wetland is $800 in year 1 and $2,579 in year 2 (Gudmundson, 1990). 'V'- ditching costs at the end of the construction phase are $150 (Pohl, 1990). A four wheel drive tractor and operator ($37.80 per hour) and blade ($7.65 per hour) is used for 24 hours in the first year and 28 hours in the second year (Alberta Transportation and Utilities, 1990). A two wheel drive tractor and operator ($30.90 per hour) and loader ($11.10 per hour) is also used for 10 hours in the first year and 16 hours in the second year (Alberta Transportation and Utilities, 1990). Finally, a pull-type scraper ($6.80 per hour) is required for 8 hours in the first year and 24 hours in the second year (Alberta Transportation and Utilities, 1990).

On-farm channel seeding costs are $1,236. They occur in the second year after construction is complete. Grass seed costs for the outlet channel are $486. It takes 25 hours to seed the channel at $30 per hour (Gudmundson, 1990).

On-farm materials costs for the controlled backflood drainage system are $3,900. They occur in the second year and include the costs of control structure fabrication and installation ($1,730), erosion control blocks ($1,950) and filter cloth ($220) (MacAlpine, 1990).

On-farm operating and maintenance costs for the uncontrolled drainage system and the controlled backflood drainage system are $347 and $425 per year respectively. They begin in the third year. They involve periodic costs for cleaning, cutting away brush and vegetation and, in the case of the controlled backflood system, replacing any damaged erosion control blocks. Operating and maintenance costs are 2 percent of the capital costs per annum (Anderson and Associates, 1986b). The capital cost of the uncontrolled drainage system and of the controlled backflood drainage system is $17,355 and $21,255 respectively.

b. On-Farm Wetland Development Costs

The on-farm wetland development costs are the costs associated with putting the wetland into forage production. They are $1,868 in the first year of the project and $3,749 in the second year. These costs are the same for both drainage systems. They include the costs of breaking, discing, and seeding the wetland area. Breaking and discing costs occur in the first year. Additional discing and seeding costs occur in the second year. The cost of renting a breaking disc is $300 (Pohl, 1990). A four wheel drive tractor and operator ($37.80 per hour) is used for 24 hours to disc the wetland with the breaking disc (Alberta Transportation and Utilities, 1990). Once that is complete, a field disc can then be used. Two passes are made in the wetland in the first year and eight passes in the second year with a field disc at $14.21 per hectare (Alberta Agriculture, 1990). The forage seed mixture is 6.73 kilograms per hectare of creeping foxtail at $5.00 per kilogram and 1.12 kilograms per hectare of smooth bromegrass at $1.65 per kilogram (Prairie Seeds, 1990). The cost of seeding the wetland is $12.06 per hectare (Alberta Agriculture, 1990).

c. On-Farm Annual Production Costs

Crop production costs include the annual costs of fertilizing, cutting, baling, stacking and hauling the hay that is produced in the wetland area. These annual production costs begin in the third year of the project and most of them continue for the lifetime of the project. One notable exception is fertilizer. Fertilizer is only used in the wetland area for three years, beginning in the third year of the project. On-farm fertilizer costs for both systems are $2,986 in the third year of the project and $867 in each of years 4 and 5. It is anticipated that within that time organic materials in the soil will begin to breakdown, thus releasing nitrogen to the forage crops. Similar organic soils have released the equivalent of 250 kilograms of nitrogen per hectare (Lopetinsky, 1991). Initial fertilizer requirements are 110 kilograms per hectare of 12-51-0 at $345 per tonne, 140 kilograms per hectare of 0-0-60 at $175 per tonne, and 239 kilograms per hectare of 46-0-0 at $245 per tonne (Carrington Fertilizer, 1990). In years 4 and 5, 112 kilograms per hectare of 46-0-0 at $245 per tonne are required in the spring (Carrington Fertilizer, 1990). The annual cost of fertilizing the slough is $7.41 per hectare (Alberta Agriculture, 1990).

Other on-farm annual production costs, beginning in the third year are $2,745 for the uncontrolled drainage system and $4,618 for the controlled backflood drainage system. They include cutting and conditioning the hay ($19.77 per hectare), baling ($5.75 per bale) and stacking and hauling ($2.50 per bale) (Alberta Agriculture, 1990). Increased hay yields as a result of backflooding cause higher baling and stacking and hauling costs for the controlled backflood drainage system. Each bale weighs 544 kilograms (Pohl, 1990).

d. Off-Farm Drainage Costs

The off-farm drainage costs are the costs associated with the construction and maintenance of the downstream part of the drainage system. Construction costs for both systems include engineering costs, excavation costs and costs of seeding the downstream channel. Construction costs for the uncontrolled drainage system also include materials costs.

Off-farm engineering costs are $464. They include costs for surveying ($205 per kilometer), data preparation ($132 per kilometer), design work ($210 per kilometer) and drafting ($120 per kilometer). The off-farm channels (Lines A1, B1 and C1 in figure 3) are 0.386 kilometers, 0.200 kilometers and 0.110 kilometers long respectively.

In order for the watershed to drain without causing flooding or erosion problems downstream, a channel capable of handling the spring runoff must be in place. Estimates of excavation costs required to upgrade the downstream channel to standard expectations were obtained through computer modelling

(MacAlpine, 1990). Even with the control structure in place, portions of the downstream channel with their present contours are not able to handle the anticipated flowrates and some downstream excavation work is required. Off-farm excavation costs are $15,432 for the uncontrolled drainage system and $3,360 for the controlled backflood drainage system (see table 1). With the uncontrolled drainage system, two existing downstream culverts need to be be replaced with larger culverts to handle the increased water flows. One additional culvert is also needed downstream with the uncontrolled drainage system. These off-farm materials costs total $5,850. The downstream excavation and materials costs occur in the first year.

Off-farm channel seeding costs are $700. They occur in the first year after downstream construction is complete. The cost of grass seed for the downstream channel is $280. It takes 14 hours to seed the downstream channel at $30 per hour (Gudmundson, 1990).

Off-farm operating and maintenance costs for the uncontrolled drainage system are $449 per year. Off-farm operating and maintenance costs for the controlled backflood drainage system are $90 per year. These costs begin in the third year of the project. Operating and maintenance costs are 2 percent of the capital costs per annum (Anderson and Associates, 1986b). The capital cost of the downstream part of the uncontrolled drainage system is $22,446. The capital cost of the downstream part of the controlled backflood drainage system is $4,524.

Table 1
Downstream Earthwork Estimates

Reach	Area (sq m)	Length (m)	Volume (cu m)	Cost ($)
Without Control structure				
0+200A-0+230A	1.5	30	45 (cuts)	180
0+230A-0+260A	3.1	30	93 (cuts)	372
0+260A-0+320A	6.8	60	408 (cuts)	1,632
0+320A-0+386A	7.7	66	508 (cuts)	2,033
	5.8	66	383 (fill)	1,531
0+384A-0+000C	1200 mm culvert	10		1,300
	installation	10		1,000
0+386A-0+396A	1400 mm culvert	10		1,550
	installation	10		1,000
0+000B-0+200B	8.8	200	1,760 (cuts)	7,040
	0.6	200	100 (fill)	400
0+000C-0+110C	4.3	110	473 (cuts)	1,892
	0.8	110	88 (fill)	352
0+110C-0+120C	culvert installation	10		1,000
TOTAL				$21,282
With Control Structure				
0+000B-0+000B	3.6	200	720 (cuts)	2,880
	0.6	200	120 (fill)	480
TOTAL				$3,360

Source: Ron Ackroyd, 1991. Economic Analysis of the Golden Glow Backflood Irrigation Project.

e. Off-Farm Wildlife Habitat Losses

The grass wetland was one of the earliest available open bodies of water in the area. Prior to 1988, it provided spring feeding for waterfowl and nesting probably occurred around its perimeter. With the installation of the uncontrolled drainage system, this area was lost to waterfowl as a nesting and staging area, beginning in year 3, following the completion of all construction. There were 5,160 duck-days per annum accruing to the slough prior to the project which are lost as a result of the uncontrolled drainage system being installed. Each duck-day has a value of $0.04 (Young, 1991). The cost to wildlife of the installation of the uncontrolled drainage system is therefore $206 per year.

With spring backflooding and forage development, this area continues to be available to waterfowl for spring feeding. However, with standing water for only two weeks instead of sixty days there is a decrease in the value of the wetland area to the waterfowl, beginning in the third year. There were 5,160 duck-days per annum accruing to the wetland prior to the project and 1,200 duck-days per annum accruing as a result of the controlled spring backflood drainage system, giving a net loss of 3960 duck-days. Each duck day has a value of $0.04 (Young, 1991). The cost to wildlife of the installation of the controlled backflood drainage system is therefore $158 per year.

f. On-Farm Agricultural Benefits

The principal benefit to agriculture of this drainage project is the revenue generated from annual production of forage crops in the wetland area, beginning in the third year. The revenue generated on the backflooded land with the uncontrolled drainage system is $6,045 per year and with the controlled backflood drainage system is $10,974 per year. Forage plots were set up on the SW 17-48-24-W4 in the summer of 1990. These plots were sampled on July 19, 1990. The results are summarized in table 2.

Table 2
Forage Plot Sample Results

Plot No.	Location	Type	Dry Matter (kg/sq m)	Average Dry Matter (kg/sq m)	Forage Production (10% moist) (t/ha)
1	Upper	Alfalfa	0.37		
12	Upper	Alfalfa	0.69	0.56	6.8
17	Upper	Alfalfa	0.62		
4	Upper	Bromegrass	0.61		
8	Upper	Bromegrass	0.51	0.54	6.5
10	Upper	Bromegrass	0.51		
2	Upper	Clover	0.44		
13	Upper	Clover	0.55	0.50	6.0
18	Upper	Clover	0.52		
3	Upper	Timothy	0.39		
9	Upper	Timothy	0.36	0.41	5.0
15	Upper	Timothy	0.49		
6	Lower	Cr Foxtail	0.66		
11	Lower	Cr Foxtail	0.85	0.75	9.3
16	Lower	Cr Foxtail	0.75		
5	Lower	Rd Canary	0.62		
7	Lower	Rd Canary	0.66	0.61	7.5
14	Lower	Rd Canary	0.55		
6	Upper	Cr Foxtail	0.48		
11	Upper	Cr foxtail	0.47	0.41	5.0
16	Upper	Cr Foxtail	0.28		
5	Upper	Rd Canary	0.53		
7	Upper	Rd Canary	0.41	0.44	5.3
14	Upper	Rd Canary	0.39		
4	Lower	Bromegrass	1.27		
8	Lower	Bromegrass	0.79	0.97	11.8
10	Lower	Bromegrass	0.85		

Source: Ron Ackroyd, 1991. Economic Analysis of the Golden Glow Backflood Irrigation Project.

Upper refers to non-irrigated upland plots. Lower refers to irrigated backflood area plots. Four grasses (bromegrass, timothy, creeping foxtail and reed canary grass) and two legumes (alsike clover and alfalfa) were selected for the plots. In the lower plots, the two legumes (alfalfa and clover) were nearly non-existent due to the excessive moisture. The highest producing forage in the lower plot area was bromegrass. Bromegrass yields in the non-irrigated upland plots were 6.5 tonnes per hectare in 1991. The price of good grass hay is $40 per tonne (Pohl, 1991). Backflooding in the spring increases the hay yield in the wetland area. Bromegrass yields in the irrigated backflood area plots were 11.8 tonnes per hectare in 1991.

3. Farm Financial Analysis

The farm financial analysis includes only on-farm costs and benefits. Costs in the first year for the uncontrolled drainage system include on-farm engineering costs ($807), on-farm excavation costs ($6,995) and on-farm wetland development costs ($1,868) for a total of $9,670 (see table 3). Costs in the second year include additional on-farm excavation costs ($8,317), additional on-farm wetland development costs ($3,749) and on-farm outlet channel seeding costs ($1,236) for a total of $13,302. Costs in the third year include on-farm production costs ($5,731) and upstream operating and maintenance costs ($347.11) for a total of $6,078. Costs in the fourth and fifth years include on-farm production costs ($3,612) and upstream operating and maintenance costs ($347) for a total of $3,959. Costs beginning in the sixth year and continuing annually over the lifetime of the drainage system include on-farm production costs ($2,745) and upstream

Table 3
Uncontrolled Drainage System:
Farm Financial Analysis

Year	5% Rate	Benefits	Discounted Benefits	Costs	Discounted Costs
1990	1.05	0	0	9,670	9,210
1991	1.10	0	0	13,302	12,065
1992	1.16	6,045	5,222	6,078	5,250
1993	1.22	6,045	4,973	3,959	3,257
1994	1.28	6,045	4,736	3,959	3,102
1995	1.34	6,045	4,511	3,092	2,307
1996	1.41	6,045	4,296	3,092	2,197
1997	1.48	6,045	4,091	3,092	2,093
1998	1.55	6,045	3,897	3,092	1,993
1999	1.63	6,045	3,711	3,092	1,898
2000	1.71	6,045	3,534	3,092	1,807
2001	1.80	6,045	3,366	3,092	1,722
2002	1.89	6,045	3,206	3,092	1,640
2003	1.98	6,045	3,053	3,092	1,562
2004	2.08	6,045	2,908	3,092	1,487
2005	2.18	6,045	2,769	3,092	1,416
2006	2.29	6,045	2,637	3,092	1,349
2007	2.41	6,045	2,512	3,092	1,285
2008	2.53	6,045	2,392	3,092	1,224
2009	2.65	6,045	2,278	3,092	1,165
2010	2.79	6,045	2,170	3,092	1,110
2011	2.93	6,045	2,066	3,092	1,057
2012	3.07	6,045	1,968	3,092	1,007
2013	3.23	6,045	1,874	3,092	959
2014	3.39	6,045	1,785	3,092	913
2015	3.56	6,045	1,700	3,092	870
2016	3.73	6,045	1,619	3,092	828
2017	3.92	6,045	1,542	3,092	789
2018	4.12	6,045	1,468	3,092	751
2019	4.32	6,045	1,399	3,092	715
TOTAL			81,686		67,030

operating and maintenance costs ($347) for a total of $3,092. On-farm benefits beginning in year 3 are $6,045 per year.

Costs in the first year for the controlled backflood drainage system include on-farm engineering costs ($807), on-farm excavation costs ($6,995) and on-farm drainage area land development costs ($1868) for a total of $9,670 (see table 4). Costs in the second year include additional on-farm excavation costs ($8,317), additional on-farm drainage area land development costs ($3,749), on-farm outlet channel seeding costs ($1,236) and on-farm materials ($3,900) costs for a total of $17,202. Costs in the third year include on-farm production costs ($7,603) and upstream operating and maintenance costs ($425) for a total of $8,028. Costs in the fourth and fifth years include on-farm production costs ($5,485) and upstream operating and maintenance costs ($425) for a total of $5,910. Costs beginning in the sixth year and continuing annually over the lifetime of the drainage system include on-farm production costs ($4,618) and upstream operating and maintenance costs ($425) for a total of $5,043. On-farm benefits beginning in year 3 are $6,045 per year.

a. Results

From the farmer's perspective (farm financial analysis), both drainage systems at Pohl's wetland drainage site are economically feasible (see table 5). The uncontrolled drainage system, with discounted costs of $67,030 and discounted benefits of $81,686, has a net present value of $14,657 and a

Table 4
Controlled Drainage System:
Farm Financial Analysis

Year	5% Rate	Benefits	Discounted Benefits	Costs	Discounted Costs
1990	1.05	0	0	9,670	9,210
1991	1.10	0	0	17,202	15,603
1992	1.16	10,974	9,480	8,028	6,935
1993	1.22	10,974	9,028	5,910	4,862
1994	1.28	10,974	8,598	5,910	4,631
1995	1.34	10,974	8,189	5,043	3,763
1996	1.41	10,974	7,799	5,043	3,584
1997	1.48	10,974	7,428	5,043	3,413
1998	1.55	10,974	7,074	5,043	3,251
1999	1.63	10,974	6,737	5,043	3,096
2000	1.71	10,974	6,416	5,043	2,948
2001	1.80	10,974	6,111	5,043	2,808
2002	1.89	10,974	5,820	5,043	2,674
2003	1.98	10,974	5,543	5,043	2,547
2004	2.08	10,974	5,279	5,043	2,426
2005	2.18	10,974	5,027	5,043	2,310
2006	2.29	10,974	4,788	5,043	2,200
2007	2.41	10,974	4,560	5,043	2,095
2008	2.53	10,974	4,343	5,043	1,996
2009	2.65	10,974	4,136	5,043	1,901
2010	2.79	10,974	3,939	5,043	1,810
2011	2.93	10,974	3,751	5,043	1,724
2012	3.07	10,974	3,573	5,043	1,642
2013	3.23	10,974	3,403	5,043	1,564
2014	3.39	10,974	3,241	5,043	1,489
2015	3.56	10,974	3,086	5,043	1,418
2016	3.73	10,974	2,939	5,043	1,351
2017	3.92	10,974	2,799	5,043	1,286
2018	4.12	10,974	2,666	5,043	1,225
2019	4.32	10,974	2,539	5,043	1,167
TOTAL			148,292		96,928

Table 5
Farm Financial Analysis Results

Type of System	Discounted Costs	Discounted Benefits	NPV	B/C
Uncontrolled Drainage	67,030	81,686	14,657	1.22
Controlled Drainage	96,928	148,292	51,365	1.53

cost benefit ratio of 1.22. The controlled backflood drainage system, with discounted costs of $96,928 and discounted benefits of $148,292, has a net present value of $51,365 and a cost benefit ratio of 1.53.

b. Sensitivity Testing

From the farmer's perspective (farm financial analysis), installing an uncontrolled drainage system at Pohl's wetland drainage site is no longer economically feasible if the costs associated with the system are increased 22 percent or the revenue is decreased 18 percent (see tables 6 and 7).

Table 6
Sensitivity of Uncontrolled Drainage System to Changes in Costs: Farm Financial Analysis

Uncontrolled Drainage	NPV	B/C
Costs increase 21%	581	1.01
Costs increase 22%	-90	1.00
Costs increase 23%	-760	0.99

Table 7
Sensitivity of Uncontrolled Drainage System to Changes in Revenue: Farm Financial Analysis

Uncontrolled Drainage	NPV	B/C
Revenue decreases 17%	770	1.01
Revenue decreases 18%	-47	1.00
Revenue decreases 19%	-864	0.99

Installing an uncontrolled drainage system at Pohl's wetland drainage site is also no longer economically feasible if the wetland area is less than 13.72 hectares or the discount rate is more than 9.75 percent (see tables 8 and 9).

Table 8
Sensitivity of Uncontrolled Drainage System to Changes in Wetland Size: Farm Financial Analysis

Uncontrolled Drainage	NPV	B/C
Size decreases 41% (13.72 ha)	56	1.00
Size decreases 42% (13.49 ha)	-387	0.99
Size decreases 43% (13.25 ha)	-719	0.98

Table 9
Sensitivity of Uncontrolled Drainage System to Changes in Discount Rate: Farm Financial Analysis

Uncontrolled Drainage	NPV	B/C
Rate increases 95% (9.75%)	31	1.00
Rate increases 96% (9.80%)	-66	1.00
Rate increases 97% (9.85%)	-162	1.00

Installing a controlled backflood drainage system at Pohl's wetland drainage site is no longer economically feasible if the costs associated with the system are increased 53 percent or the revenue is decreased 35 percent (see tables 10 and 11).

Table 10
Sensitivity of Controlled Drainage System to Changes in Costs: Farm Financial Analysis

Controlled Drainage	NPV	B/C
Costs increase 52%	962	1.01
Costs increase 53%	-7	1.00
Costs increase 54%	-976	0.99

Table 11
Sensitivity of Controlled Drainage System to Changes in Revenue: Farm Financial Analysis

Controlled Drainage	NPV	B/C
Revenue decreases 34%	945	1.01
Revenue decreases 35%	-538	0.99
Revenue decreases 36%	-2021	0.98

Installing a controlled backflood drainage system at Pohl's wetland drainage site is also no longer economically feasible if the wetland area is less than 7.91 hectares or the discount rate is more than 18.15 percent (see tables 12 and 13).

Table 12
Sensitivity of Controlled Drainage System to Changes in Wetland Size: Farm Financial Analysis

Controlled Drainage	NPV	B/C
Size decreases 66% (7.91 ha)	566	1.01
Size decreases 67% (7.67 ha)	-208	1.01
Size decreases 68% (7.44 ha)	-983	0.98

Table 13
Sensitivity of Controlled Drainage System to Changes in Discount Rate: Farm Financial Analysis

Controlled Drainage	NPV	B/C
Rate increases 263% (18.15%)	51	1.00
Rate increases 264% (18.20%)	-12	1.00
Rate increases 265% (18.25%)	-74	1.00

4. Socio-Economic Analysis

The socio-economic analysis, in addition to on-farm costs and benefits, includes costs of off-farm drainage works and wildlife habitat losses. Costs in the first year for the uncontrolled drainage system include on-farm engineering costs ($807), on-farm excavation costs ($6,995) on-farm wetland development costs ($1,868), off-farm engineering costs ($464), off-farm excavation costs ($15,432), off-farm materials costs ($5,850) and off-farm channel seeding costs ($700) for a total of $32,116 (see table 14). Costs in the second year include additional on-farm excavation costs ($8,317), additional on-farm wetland development costs ($3,749), on-farm outlet channel seeding costs ($1,236) and downstream operating and maintenance costs ($449) for a total of $13,751. Costs in the third year include production costs ($5,731), wildlife habitat loss costs ($206.40), downstream operating and maintenance costs ($449) and upstream operating and maintenance costs ($347) for a total of $6,733. Costs in the fourth and fifth years include production costs ($3,612), wildlife habitat loss costs ($206.40), downstream operating and maintenance costs ($449) and upstream operating and maintenance costs ($347) for a total of $4,615. Costs beginning in the sixth year and continuing annually over the lifetime of the drainage system include production costs ($2,745), wildlife habitat loss costs ($206.40), downstream operating and maintenance costs ($449) and upstream operating and maintenance costs ($347) for a total of $3,747. On-farm benefits beginning in year 3 are $6,045 per year.

Costs in the first year for the controlled backflood drainage system include on-farm engineering costs ($807), on-farm excavation costs ($6,995), on-farm wetland development costs ($1,868), off-farm engineering costs ($464), off-farm

Table 14
Uncontrolled Drainage System:
Socio-Economic Analysis

Year	3% Rate	Benefits	Discounted Benefits	Costs	Discounted Costs
1990	1.03	0	0	32,116	31,181
1991	1.06	0	0	13,751	12,962
1992	1.09	6,045	5,532	6,733	6,162
1993	1.13	6,045	5,371	4,615	4,100
1994	1.16	6,045	5,214	4,615	3,981
1995	1.19	6,045	5,063	3,747	3,138
1996	1.23	6,045	4,915	3,747	3,047
1997	1.27	6,045	4,772	3,747	2,958
1998	1.30	6,045	4,633	3,747	2,872
1999	1.34	6,045	4,498	3,747	2,788
2000	1.38	6,045	4,367	3,747	2,707
2001	1.43	6,045	4,240	3,747	2,628
2002	1.47	6,045	4,116	3,747	2,552
2003	1.51	6,045	3,996	3,747	2,477
2004	1.56	6,045	3,880	3,747	2,405
2005	1.60	6,045	3,767	3,747	2,335
2006	1.65	6,045	3,657	3,747	2,267
2007	1.70	6,045	3,551	3,747	2,201
2008	1.75	6,045	3,447	3,747	2,137
2009	1.81	6,045	3,347	3,747	2,075
2010	1.86	6,045	3,249	3,747	2,014
2011	1.92	6,045	3,155	3,747	1,956
2012	1.97	6,045	3,063	3,747	1,899
2013	2.03	6,045	2,974	3,747	1,843
2014	2.09	6,045	2,887	3,747	1,790
2015	2.16	6,045	2,803	3,747	1,738
2016	2.22	6,045	2,721	3,747	1,687
2017	2.29	6,045	2,642	3,747	1,638
2018	2.36	6,045	2,565	3,747	1,590
2019	2.43	6,045	2,490	3,747	1,544
TOTAL			106,918		114,672

excavation costs ($3,360) and off-farm channel seeding costs ($700) for a total of $14,194 (see table 15). Costs in the second year include additional on-farm excavation costs ($8,317), additional on-farm wetland development costs ($3,749), on-farm materials costs ($3,900), on-farm outlet channel seeding costs ($1,236) and downstream operating and maintenance costs ($90) for a total of $17,292. Costs in the third year include production costs ($7,603), wildlife habitat loss costs ($158.40), downstream operating and maintenance costs ($90) and upstream operating and maintenance costs ($425) for a total of $8,119. Costs in the fourth and fifth years include production costs ($5,485), wildlife habitat loss costs ($158.40), downstream operating and maintenance costs ($90) and upstream operating and maintenance costs ($425) for a total of $6,000. Costs beginning in the sixth year and continuing annually over the lifetime of the drainage system include production costs ($4,618), wildlife habitat loss costs ($158.40), downstream operating and maintenance costs ($90) and upstream operating and maintenance costs ($425) for a total of $5,133. On-farm benefits beginning in year 3 are $6,045 per year.

a. Results

From society's perspective (socio-economic analysis), only the controlled backflood drainage system at Pohl's wetland drainage site is economically feasible (see table 16). The uncontrolled drainage system, with discounted costs of

Table 15
Controlled Drainage System:
Socio-Economic Analysis

Year	3% Rate	Benefits	Discounted Benefits	Costs	Discounted Costs
1990	1.03	0	0	14,194	13,781
1991	1.06	0	0	17,292	16,300
1992	1.09	10,974	10,043	8,119	7,575
1993	1.13	10,974	9,750	6,000	5,472
1994	1.16	10,974	9,466	6,000	5,313
1995	1.19	10,974	9,191	5,133	4,432
1996	1.23	10,974	8,923	5,133	4,303
1997	1.27	10,974	8,663	5,133	4,177
1998	1.30	10,974	8,411	5,133	4,056
1999	1.34	10,974	8,166	5,133	3,937
2000	1.38	10,974	7,928	5,133	3,823
2001	1.43	10,974	7,697	5,133	3,711
2002	1.47	10,974	7,473	5,133	3,603
2003	1.51	10,974	7,255	5,133	3,498
2004	1.56	10,974	7,044	5,133	3,397
2005	1.60	10,974	6,839	5,133	3,298
2006	1.65	10,974	6,639	5,133	3,202
2007	1.70	10,974	6,446	5,133	3,108
2008	1.75	10,974	6,258	5,133	3,018
2009	1.81	10,974	6,076	5,133	2,930
2010	1.86	10,974	5,899	5,133	2,845
2011	1.92	10,974	5,727	5,133	2,762
2012	1.97	10,974	5,560	5,133	2,681
2013	2.03	10,974	5,398	5,133	2,603
2014	2.09	10,974	5,241	5,133	2,527
2015	2.16	10,974	5,089	5,133	2,454
2016	2.22	10,974	4,940	5,133	2,382
2017	2.29	10,974	4,796	5,133	2,313
2018	2.36	10,974	4,657	5,133	2,245
2019	2.43	10,974	4,521	5,133	2,180
TOTAL			194,097		127,925

Table 16
Socio-Economic Analysis Results

Type of System	Discounted Costs	Discounted Benefits	NPV	B/C
Uncontrolled Drainage	114,672	106,918	-7,754	0.93
Controlled Drainage	127,925	194,097	66,172	1.52

$114,672 and discounted benefits of $106,918, has a net present value of -$7,754 and a benefit cost ratio of 0.93. The controlled backflood drainage system, with discounted costs of $127,925 and discounted benefits of $194,097, has a net present value of $66,172 and a benefit cost ratio of 1.52.

b. Sensitivity Testing

From society's perspective (socio-economic analysis), installing an uncontrolled drainage system at Pohl's wetland drainage site becomes economically feasible if the costs associated with the system are decreased 7 percent or the revenue is increased 8 percent (see tables 17 and 18).

Table 17
Sensitivity of Uncontrolled Drainage System to Changes in Costs: Socio-Economic Analysis

Uncontrolled Drainage	NPV	B/C
Costs decrease 6%	-874	0.99
Costs decrease 7%	273	1.00
Costs decrease 8%	1419	1.01

Table 18
Sensitivity of Uncontrolled Drainage System to Changes in Revenue: Socio-Economic Analysis

Uncontrolled Drainage	NPV	B/C
Revenue increases 7%	-270	1.00
Revenue increases 8%	799	1.01
Revenue increases 9%	1868	1.02

Installing an uncontrolled drainage system at Pohl's drainage site also becomes economically feasible if the wetland area is more than 26.74 hectares or the discount rate is less than 1.68 percent (see tables 19 and 20).

Table 19
Sensitivity of Uncontrolled Drainage System to Changes in Wetland Size: Socio-Economic Analysis

Uncontrolled Drainage	NPV	B/C
Size increases 15% (26.74 ha)	-346	1.00
Size increases 16% (26.97 ha)	112	1.00
Size increases 17% (27.20 ha)	570	1.00

Table 20
Sensitivity of Uncontrolled Drainage System to Changes in Discount Rate: Socio-Economic Analysis

Uncontrolled Drainage	NPV	B/C
Rate decreases 44% (1.68%)	-19	1.00
Rate decreases 45% (1.65%)	184	1.00
Rate decreases 46% (1.62%)	388	1.00

Installing a controlled backflood drainage system at Pohl's wetland drainage site is no longer economically feasible if the costs associated with the system are increased 52 percent or the revenue is decreased 35 percent (see tables 21 and 22).

Table 21
Sensitivity of Controlled Drainage System to Changes in Costs: Socio-Economic Analysis

Controlled Drainage	NPV	B/C
Costs increase 51%	931	1.00
Costs increase 52%	-348	1.00
Costs increase 53%	-1628	0.99

Table 22
Sensitivity of Controlled Drainage System to Changes in Revenue: Socio-Economic Analysis

Controlled Drainage	NPV	B/C
Revenue decreases 34%	179	1.00
Revenue decreases 35%	-1762	0.99
Revenue decreases 3[illegible]	-3703	0.97

Installing a controlled backflood drainage system at Pohl's wetland drainage site is also no longer economically feasible if the wetland area being improved is less than 8.37 hectares or the discount rate is more than 14.85 percent (see tables 23 and 24).

Table 23
Sensitivity of Controlled Drainage System to Changes in Wetland Size: Socio-Economic Analysis

Controlled Drainage	NPV	B/C
Size decreases 64% (8.37 ha)	277	1.00
Size decreases 65% (8.14 ha)	-761	0.99
Size decreases 66% (7.91 ha)	-1799	0.97

Table 24
Sensitivity of Controlled Drainage System to Changes in Discount Rate: Socio-Economic Analysis

Controlled Drainage	NPV	B/C
Rate increases 395% (14.85%)	37	1.00
Rate increases 396% (14.88%)	-18	1.00
Rate increases 397% (14.91%)	-73	1.00

IV. WETLANDS INVENTORY

A. Methodology

Townships are selected for the wetlands inventory using the technique of simple random sampling. Simple random sampling is a basic probability selection scheme in which a predetermined number of units from a population list is selected so that each unit on that list has an equal chance of being included in the sample (Satin and Shastry, 1983). The population list in this study contains the 155 townships in the study area (see table 25). A sample of 10 percent (16 townships) is required. Selection of this sample is undertaken using a table of random numbers (see Appendix A). The selection process is described in Satin and Shastry (1983). It involves arbitrarily selecting a three digit number anywhere in the table and then proceeding in any direction. In this study, row 00 and columns 50 to 53 are selected as the starting point and the decision is made to proceed down the column. The first 16 three digit numbers that do not exceed 155 are selected (see table 25).

Standard 1:30,000 scale black and white aerial photographs for these 16 randomly selected townships are then obtained from Forestry, Lands and Wildlife in Edmonton. Wetland areas that are located in cultivated fields, non-permanent in nature and of no apparent economic value to the farmer are identified as potential drainage sites and outlined on the aerial photographs. The areas of these potential

Table 25
Township Numbers Table

Township	No.	Township	No.	Township	No.	Township	No.
60-25-W4	1	55-23-W4	48	52-16-W4	95	46-26-W4	142
60-24-W4	2	55-22-W4	49	52-15-W4	96	46-25-W4	143
60-17-W4	3	55-21-W4	50	52-14-W4	97	46-24-W4	144
59-24-W4	4	55-20-W4	51	51-25-W4	98	46-23-W4	145
59-23-W4	5	55-18-W4	52	51-24-W4	99	46-22-W4	146
59-16-W4	6	55-17-W4	53	51-23-W4	100	45-25-W4	147
59-15-W4	7	55-16-W4	54	51-22-W4	101	45-24-W4	148
58-25-W4	8	55-15-W4	55	51-21-W4	102	45-23-W4	149
58-24-W4	9	55-14-W4	56	51-20-W4	103	45-22-W4	150
58-23-W4	10	55-13-W4	57	51-19-W4	104	44-24-W4	151
58-22-W4	11	55-12-W4	58	51-16-W4	105	44-23-W4	152
58-20-W4	12	54-27-W4	59	51-15-W4	106	43-24-W4	153
58-19-W4	13	54-26-W4	60	51-14-W4	107	43-23-W4	154
58-18-W4	14	54-25-W4	61	51-13-W4	108	43-22-W4	155
58-17-W4	15	54-24-W4	62	51-12-W4	109		
58-16-W4	16	54-23-W4	63	50-27-W4	110		
57-27-W4	17	54-22-W4	64	50-26-W4	111		
57-26-W4	18	54-21-W4	65	50-25-W4	112		
57-25-W4	19	54-20-W4	66	50-24-W4	113		
57-24-W4	20	54-17-W4	67	50-23-W4	114		
57-23-W4	21	54-16-W4	68	50-22-W4	115		
57-22-W4	22	54-15-W4	69	50-21-W4	116		
57-21-W4	23	54-14-W4	70	50-20-W4	117		
57-20-W4	24	54-13-W4	71	50-16-W4	118		
57-19-W4	25	53-27-W4	72	50-15-W4	119		
57-18-W4	26	53-26-W4	73	50-13-W4	120		
57-17-W4	27	53-25-W4	74	50-12-W4	121		
57-16-W4	28	53-24-W4	75	49-27-W4	122		
57-15-W4	29	53-23-W4	76	49-26-W4	123		
56-27-W4	30	53-22-W4	77	49-25-W4	124		
56-26-W4	31	53-21-W4	78	49-24-W4	125		
56-25-W4	32	53-20-W4	79	49-23-W4	126		
56-24-W4	33	53-19-W4	80	49-22-W4	127		
56-23-W4	34	53-17-W4	81	49-21-W4	128		
56-22-W4	35	53-16-W4	82	49-20-W4	129		
56-21-W4	36	53-15-W4	83	49-12-W4	130		
56-20-W4	37	53-14-W4	84	48-27-W4	131		
56-19-W4	38	52-01-W5	85	48-26-W4	132		
56-18-W4	39	52-27-W4	86	48-25-W4	133		
56-17-W4	40	52-26-W4	87	48-24-W4	134		
56-16-W4	41	52-25-W4	88	48-23-W4	135		
56-15-W4	42	52-24-W4	89	48-22-W4	136		
56-14-W4	43	52-23-W4	90	48-12-W4	137		
55-27-W4	44	52-22-W4	91	47-26-W4	138		
55-26-W4	45	52-21-W4	92	47-25-W4	139		
55-25-W4	46	52-20-W4	93	47-24-W4	140		
55-24-W4	47	52-19-W4	94	47-23-W4	141		

drainage sites are then calculated using the grid paper method.

The grid paper method is the most accurate method available for calculating the areas of small wetlands (Elgert, 1991). Each wetland site is expressed in terms of squares. One inch grid paper is commonly used. Each square is 0.01 square inches in area. These squares are converted from squares to hectares using a conversion factor of 0.58. The first step in calculating this conversion factor involves dividing 0.1 inch by 12 inches per foot to get 0.0083 feet. Multiplying 0.0083 feet by 0.3048 meters per foot to get 0.0025 meters is the second step. The third step in the conversion process involves multiplying 0.0025 meters by 30,000 (aerial photograph scale) to get 76.2 meters. The fourth step is squaring 76.2 meters to get 5806.44 square meters and the fifth step involves dividing 5806.44 square meters by 10,000 square meters per hectare to get 0.58 hectares per square.

C. Results

There are 2,232 wetland areas identified in the random sample of 16 townships as being non-permanent in nature, located in cultivated fields and of no apparent economic value to the farmer. Most of them are small, with the average size being 3.02 hectares. There are, however, 80 of these wetland areas that are larger than 13.49 hectares. From the farmer's perspective (farm financial analysis), these 80 sites in the random sample (800 in the study area) are economically feasible to drain with an uncontrolled drainage system. There are 170 wetland areas that are larger than 7.67 hectares in size. From the farmer's perspective (farm financial analysis), these 170 sites in the random sample (1700 in the study area) are economically feasible to drain with a controlled backflood drainage system. There are 29 wetland areas that are larger than 26.97 hectares. From society's perspective (socio-economic analysis), these 29 sites in the random sample (290 in the study area) are economically feasible to drain with an uncontrolled drainage system. There are also 167 wetland areas that are larger than 8.14 hectares. From society's perspective (socio-economic analysis), these 167 sites in the random sample (1670 in the study area) are economically feasible to drain with a controlled backflood drainage system.

V. SUMMARY AND RECOMMENDATIONS

A. Summary

This study examines the economic feasibility of draining non-permanent wetlands in central Alberta by evaluating two drainage systems at a half-section wetland drainage site, 50 kilometers south of Edmonton and conducting a wetlands inventory of the study area.

This wetland drainage site contains a 23 hectare non-permanent wetland that prior to 1988 held up to 45 centimeters of water through more than half the growing season. By the time it dried out in late summer, the grass was too mature to be of any use to livestock. A controlled backflood drainage system was installed at this site in 1989, under the Farmland Development and Reclamation Program. With a controlled backflood drainage system, an outflow channel is dug and a culvert with a gate on one end is placed in this channel. The water is deliberately backed up by keeping the gate on the culvert closed. The backflood area is ponded for a period of 10 to 14 days. The excess water that does not infiltrate after the flooding period is removed at a controlled rate by opening the gate. This site operated as a traditional uncontrolled drainage system for one year, prior to the control structure being installed in the summer of 1989. With an uncontrolled drainage system, an outflow channel is dug. Water from the wetland is allowed to flow unchecked down the open ditch.

The costs and benefits associated with each drainage system are collected and examined from two perspectives: the farmer's and society's. The farm financial analysis includes the on-farm costs and benefits of the drainage system. The socio-economic analysis includes the costs of off-farm drainage works to prevent downstream flooding and erosion problems and wildlife habitat losses resulting from the installation of the drainage system, along with the on-farm costs and benefits. Sensitivity testing is also conducted on the costs and revenue associated with each drainage system, the size of the wetland associated with the drainage project site and the discount rate associated with each economic perspective.

From the farmer's perspective (farm financial analysis), both drainage systems at Pohl's wetland drainage site are economically feasible. The uncontrolled drainage system is no longer economically feasible if there is a 22 percent increase in costs or an 18 percent decrease in revenue. It is also no longer economically feasible if the wetland area is less than 13.72 hectares or the discount rate is more than 9.75 percent. The controlled backflood drainage system is no longer economically feasible if there is a 53 percent increase in costs or a 35 percent decrease in revenue. It is also no longer economically feasible if the wetland area is less than 7.91 hectares or the discount rate is more than 18.15 percent.

From society's perspective (socio-economic analysis), only the controlled backflood drainage system at Pohl's wetland drainage site is economically feasible. The uncontrolled drainage system becomes economically feasible if there is a 7 percent decrease in costs or an 8 percent increase in revenue. It also becomes economically feasible if the wetland area is more than 26.74 hectares or the discount rate is less than 1.68 percent. The controlled backflood drainage system is no longer economically feasible if there is a 52 percent increase in costs or a 35 percent decrease in revenue. It is also no longer economically feasible if the wetland area is less than 8.37 hectares or the discount rate is more than 14.85 percent.

A random sample of black and white aerial photographs from the Edmonton-Two Hills agroecological resource region is also studied. Many non-permanent wetland sites are identified that are economically feasible to drain. From the farmer's perspective (farm financial analysis), there are 800 wetland sites in the study area that are economically feasible to drain with an uncontrolled drainage system and 1700 wetland sites that are economically feasible to drain with a controlled backflood drainage system. From society's perspective (socio-economic analysis), there are 290 wetland sites in the study area that are economically feasible to drain with an uncontrolled drainage system and 1670 wetland sites that are economically feasible to drain with a controlled backflood drainage system.

There are several areas of this study that could benefit from additional information that was not available during the time this study was being written. One such area is the on-farm agricultural benefits section. The specific concern is the accuracy of the forage yield estimates that are used in this section. They are based on yield measurements taken from plots. These plots were set up in the summer of 1990. Only one sampling of the plots was done, in the summer of 1991. Since on-site yields are such an important component of the analysis, multiple plot samplings would provide a vital degree of confidence in the results.

Another area that could benefit from additional information is the off-farm wildlife losses section. The specific concern is the degree to which the results in this section accurately reflect the project's impact on wildlife. The estimates of the Ducks Unlimited wildlife biologist are not based on a personal site visit. Standing water is valued at $0.04 per duck day. With the loss of 5,160 duck days assigned to the uncontrolled drainage system and the loss of 3,960 duck days assigned to the controlled backflood drainage system, the cost to wildlife of the installation of the uncontrolled drainage and controlled backflood drainage systems is $206 per year and $158 per year respectively. The degree of accuracy of the $0.04 per duck day valuation at this particular drainage project site, without a personal site visit by a wildlife biologist, is unknown. There is also the question of whether those 10 to 14 days of backflooding early in the spring provide any benefit to ducks. If not, then the cost to wildlife would be the same for both the uncontrolled and the controlled backflood drainage systems.

It is also possible that this non-permanent wetland acted as a duck trap, prior to the project. By summer, the closest water to the site was a dugout a mile away and the only permanent source of water was almost a mile beyond that. Once the wetland dried up in early summer, the majority of the ducklings probably did not survive the trek to other sources of water. A personal site visit by a wildlife biologist would be required to confirm whether or not this was the case. If this slough was acting as a duck trap, then the continual loss of potentially viable duck populations might actually outweigh the advantages of retaining the slough and thus this project could be a benefit rather than a detriment. The results of this section, under these circumstances, would be considerably different.

B. Recommendations for Further Study

Controlled backflood drainage and uncontrolled drainage are two water management techniques that are practised in Alberta. There are other techniques, however, such as wetlands consolidation, that are also considered to have potential in central Alberta. Further work is needed to look at the economic feasibility of wetland drainage sites in central Alberta that have used some of these other water management techniques.

This study evaluates the economic feasibility of drainage systems in central Alberta that are put into forage production and the results can be interpreted only in that context. Some producers would undoubtedly be interested in draining wetlands for grain production. Further work is needed to evaluate the economic feasibility of installing and maintaining drainage systems in central Alberta, when the objective is to put the land into grain production.

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APPENDIX A

Table 1
Table of Random Numbers

	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94
00	59391	58030	52098	82718	87024	82848	04190	96574	90464
01	99567	76364	77204	04615	27062	96621	43918	01896	83991
02	10363	97518	51400	25670	98342	61891	27101	37855	06235
03	86859	19558	64432	16706	99612	59798	32803	67708	15297
04	11258	24591	36863	55368	31721	94335	34936	02566	80972
05	95068	88628	35911	14530	33020	80428	39936	31855	34334
06	54463	47237	73800	91017	36239	71824	83671	39892	60518
07	16874	62677	57412	13215	31389	62233	80827	73917	82802
08	92494	63157	76593	91316	03505	72389	96363	52887	01087
09	15669	56689	35682	40844	53256	81872	35213	09840	34471
10	99116	75486	84989	23476	52967	67104	39495	39100	17217
11	15696	10703	65178	90637	63110	17622	53988	71087	84148
12	97720	15369	51269	69620	03388	13699	33423	67453	43269
13	11666	13841	71681	98000	35979	39719	81899	07449	47985
14	71628	73130	78783	75691	41632	09847	61547	18707	85489
15	40501	51089	99943	91843	41995	88931	73631	69361	05375
16	22518	55576	98215	82068	10798	82611	36584	67466	69377
17	75112	30485	62173	02132	14878	92879	22281	16783	86352
18	08327	02671	98191	84342	90813	49268	95441	15496	20168
19	60251	45548	02146	05597	48228	81366	34598	72856	66762
20	57430	82270	10421	00540	43648	75888	66049	21511	47676
21	73528	39559	34434	88596	54086	71693	43132	14414	79949
22	25991	65959	70769	64721	86413	33475	42740	06175	82758
23	78388	16638	09134	59980	63806	48472	39318	35434	24057
24	12477	09965	96657	57994	59439	76330	24596	77515	09577
25	83266	32883	42451	15579	38155	29793	40914	65990	16255
26	76970	80876	10237	39515	79152	74798	39357	09054	73579
27	37074	65198	44785	68624	98336	84481	97610	78735	46703
28	83712	06514	30101	78295	54656	85417	43189	60048	72781
29	20287	56862	69727	94443	64936	08366	27227	05158	50326
30	74261	32592	86538	27041	65172	85532	07571	80609	39285
31	64081	49863	08478	96001	18888	14810	70545	89755	59064
32	05617	75818	47750	67814	29575	10526	66192	44464	27058
33	26793	74951	95466	74307	13330	42664	85515	20632	05497
34	65988	72850	48737	54719	52056	01596	03845	35067	03134
35	27366	42271	44300	73399	21105	03280	73457	43093	05192
36	56760	10909	98147	34736	33863	95256	12731	66598	50771
37	72880	43338	93643	58904	59543	23943	11231	83268	65938
38	77888	38100	03062	58103	47961	83841	25878	23746	55903
39	28440	07819	21580	51459	47971	29882	13990	29226	23608
40	63525	94441	77033	12147	51054	49955	58312	76923	96071
41	47606	93410	16359	89033	89696	47231	64498	31776	05383
42	52669	45030	96279	14709	52372	87832	02735	50803	72744
43	16738	60159	07425	62369	07515	82721	37875	71153	21315
44	59348	11695	45751	15865	74739	05572	32688	20271	65128
45	12900	71775	29845	60774	94924	21810	38636	33717	67598
46	75086	23537	49939	33595	13484	97588	28617	17979	70749
47	99495	51434	29181	09993	38190	42553	68922	52125	91077
48	26075	31671	45386	36583	93459	48599	52022	41330	60651

Source: Satin and Shastry. 1983. Survey Sampling: A Non-Mathematical Guide.