THE UNIVERSITY OF ALBERTA

ECONOMICS OF FARM DRAINAGE

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF Master of Science

IN

Agricultural Economics

Department of Rural Economy

EDMONTON, ALBERTA

Fall 1986

ISBN 0-315-32430-9

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR RONALD N. WANCHUK

TITLE OF THESIS ECONOMICS OF FARM DRAINAGE

DEGREE FOR WHICH THESIS WAS PRESENTED Master of Science

YEAR THIS DEGREE GRANTED Fall 1986

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ECONOMICS OF FARM DRAINAGE submitted by RONALD N. WANCHUK in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Economics.

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Date Sept 26/86

Abstract

The supply of better quality agricultural land in Alberta is finite and diminishing. Expansion of the land base has conventionally been acheived by land clearing under limited agroclimatic conditions. There are alternatives to this conventional expansion and drainage is one alternative. It has been estimated that under favorable agroclimatic conditions in east central Alberta there are approximately 2 million acres of better quality land affected by excess moisture. Drainage could relieve this constraint. However the substantive capital financing which would be required could only be forthcoming under conditions of economic viability.

The first objective of this research was to assess the economic viability of surface and subsurface types of designs to establish whether drainage could be economically viable and under what conditions. The second objective was to establish whether management intensities influence economic viability. The third and final objective was to establish whether landowners actually receive the benefits they expected to receive from drainage.

From a population of 105 drainers, 20 pairs of similar farms, differing only in the drainage system installed were identified. The landowners of the 20 pairs of farms were interviewed in-person to gather information about the farm, farmer and drainage project. Five pairs of farms were disqualified and the remaining 15 pairs were used in the analysis.

Standard project appraisal techniques were used, following closely the procedure outlined by Gittinger for World Bank project appraisals to establish internal rate of return and net present value. The internal rate of return was used as a dependent variable in a behavioral analysis to explain why some projects may be more viable than others. Four separate scenarios were examined in determining project viability. Two models were examined in the behavioral analysis.

Under the most realistic scenario, considering all costs, cash benefits and taxes, only one of fifteen surface drainage projects, using a 5% opportunity cost of capital, was not viable. Four of fifteen subsurface projects, using the same criteria, were not viable.

Management intensity on the whole farm explained a significant amount of the variation in the viability of subsurface drainage. Viability was related to the capital to labor ratio, the cropping intensity, the land use factor in 1985, the absolute change in the capital expenditure on equipment and the annual change in capital expenditure on equipment. The land use factor is the most important predictor of project viability. If the land being considered for drainage by subsurface means is normally used part of the time, then the chances that the project will be viable are reduced. Significant relationships for the surface projects were found between the project viability and the animal units, the project age and the absolute change in animal units.

Landowners generally seemed satisfied that they had realized benefits from drainage. Of the fifteen surface drainers only two felt their system did not perform as they expected. Of fifteen subsurface drainers four felt their system did not perform as expected. Fourteen of fifteen surface drainers would drain land again. Of fifteen landowners draining by subsurface means, thirteen would drain land again.

Acknowledgements

I am truly grateful to my advisor, Dr. L. P. Apedaile, for his interest, suggestions, encouragement and patience especially at times when I became discombobulated. I would also like to thank committee members Dr. W. E. Phillips, Dr. A. Birch and Professor E. Rapp an[illegible]eman who acted as chairman during the oral defense.

I would like to thank F[illegible]re for the financial support necessary to carry out this research.

I would like to thank Alberta Environment, Edmonton and Red Deer, and C. W. Farmland Reclamation Ltd. for providing the names of individual landowners who had installed drainage on their farms.

A special thanks to Ward Toma for helping with the data collection during the summer of 1985 and the landowners for providing necessary information.

Thank you to Judy Boucher for coding the data. Thank you to Jim Copeland and especially, Claire Shier, for their assistance in analyzing data. I would also like to thank Barb Johnson and Hildegard Zeidler for their library assistance and Wendy Williamson for helping with textform.

Thanks to my roommates, Luis Eleazar, Ron Gietz, Bill Schissel and James Tuamwari and other graduate students for their camaraderie.

Finally, I would like to thank my partner, Janice, for her interest and support for what must have seemed an eternity.

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I. INTRODUCTION

A. Overview

The supply of better quality agriculture land in Alberta is finite[1] and diminishing. Over the past decade concerns have been expressed over the need to maintain and expand the land base[2]. Agricultural uses for new land are only one of several economic options for the use of this land. This thesis addresses the economic viability[3] of this agricultural use option for additions to the land base through drainage but excludes the opportunity cost of displaced uses.

Expansion of the land base has been achieved conventionally by developing some of the poorer quality soils(CLI 4+)(Appendix A) and it has been primarily concentrated in Northwestern Alberta. The Northern Alberta Development Council estimated a requirement of an additional 154,000 acres annually for the next 20 years[4]. Maintaining the agricultural land base may be achieved by controlling activities that contribute to the loss of already developed land. The developed land suffers from two basic forms of removals. The first is removal by non-agricultural activities such as urbanization, roads, gas plants, mines etc. Birch[5] indicates a net removal of 90,900 acres of CLI 1,2 and 3 land and a net addition of 85,000 acres of CLI 4, 5, 6, 7 and organic land. The second form of removal is directly related to human interference with the natural hydrologic cycle through activities such as sod breaking, summerfallowing, deforestation, irrigation canal seepage, over irrigation, over grazing and road construction. This interference with the natural hydrologic cycle has resulted

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[1]Bentley, Fred C. *Agricultural Land and Canada's Future*. Presentation at Agricultural Institute of Canada's 1981-82 Klinck Lecture. Agricultural Institute of Canada. 1981.
[2]Environment Council of Alberta. *Maintaining and Expanding the Agricultural Land Base in Alberta: Technical Report and Recommendations*. ECA85-17/RR2. Environment Council of Alberta. Edmonton. 1985. 198 pages.
[3]A drainage project is considered economically viable if it has the ability to produce benefits sufficient to cover all costs associated with the project and the opportunity cost of the capital used for the project.
[4]Northern Alberta Development Council. *The Development of New Agricultural Land in Northwestern Alberta*. Northern Alberta Development Council. November, 1983.
[5]Birch, A. *An Inventory of Changes in Alberta's Agricultural Land Base Between 1976 and 1980*. Edmonton. Alberta Agriculture. March 1982. page 34.

in the fact that on many agricultural soils the water table or capillary fringe is very close to the soil surface and in some cases results in surface ponded water. This high water table interferes with normal plant growth by reducing the available rooting zone and limiting aeration and generally destroying good soil structure. Both wetlands and slough conditions hamper normal agricultural practices by removing usable land from any agricultural production, by causing unnecessary obstructions to the efficient use of the now common large machinery, by delaying the timeliness of farm operations, causing restrictions on crop choice, lowering the quality and yields of the crops grown and reducing the length of the growing season. In addition, throughout Alberta the underlying parent geological material is a salt bearing strata and the high water table has resulted in the movement of salts from parent geologic material towards the soil surface. Vander Pluym et al.[6] estimate that Alberta has about 500,000 acres of salt affected dryland and another 250,000 acres of salt affected irrigated land. These saline soils are primarily concentrated in the southern portion of Alberta.

Controlling the water table may be accomplished in two ways. The first is by changing from agricultural practices such as summerfallowing to continuous cropping or the growing of deeper rooting crops such as forages that make better use of the existing water. This method of controlling the water table involves institutional change that may take decades. The second method is the installation of artificial drainage systems such as surface drainage systems(ditches) that eliminate the percolation of excess water and alleviate the seasonal flooding problem or subsurface drainage systems(pipe or tile) that result in a lowering of the water table. In this study both types of drainage systems are used for similar purposes and that is for draining sloughs, potholes or wet areas. The installation of drainage systems involves capital investment that may not be economically efficient.

Expansion of the land base by means of drainage may be accomplished on better quality land. The final result is that previously agriculturally unproductive land may now be developed or farmed more intensively.

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[6]Vander Pluym, H. S. A., Paterson, D. and Holm, H. M. "Degradation by Salinization." in *Agriculture Land: Our Disappearing Heritage-A Symposium.* Proceedings of the 18th Annual Alberta Soil Workshop. 1981.

B. Potential for Drainage

This thesis is concerned with the economic viability of surface and subsurface drainage projects from a farm producer perspective only and the research concerns itself with projects that have been installed in east central Alberta. East central Alberta is defined here as an area of 36,288 square miles bounded by the 4th and 5th meredians(west to east) and the 35th and 69th townships(south to north).(Appendix B). It contains 100% of C.D.(Census Division) 10, and approximately 97% of C.D. 7, 50% of C.D. 11, 33% of C.D. 13, 13% of C.D. 12 and 9% of C.D. 4.(Appendix B.)

Apedaile and Rapp[7] reported that east central Alberta contains approximately 13,971 square miles of CLI 1, 2 and 3 land(38.5% of the total land base) and estimated that 24.6% of this better quality land, CLI 1, 2 and 3, is constrained from reaching its full agricultural potential by excess water. Their work established, with 95% confidence,"that the true extent of sloughs and wet lands is between 1.407 and 3.409 million acres on CLI 1, 2 and 3 land with the most likely area being 2.196 million acres or 157 acres out of each section of this better quality land". In preparing a wetland inventory for the drainage potential in Alberta, Birch et al.[8] estimated that the agricultural area(white zone) of the province contained about 10,892,074 acres of wetlands. In three river basins contained wholly or partially within the study area, there were approximately 3,382,336 acres of wetlands. These wetland acres were divided amongst the Battle River basin(957,120 acres), North Saskatchewan River basin(1,637,504 acres) and the Beaver River basin(787,712 acres) and amounted to, as a percentage of the agricultural area(white zone) in each basin, 11.0%, 18.1% and 32.3% respectively. Irrespective of the study, there is a substantial amount of good agricultural land that is not being utilized to its full agricultural potential and drainage is thought to be a remedy to this agricultural underutilization. Apedaile and Rapp[9] estimate that the agricultural

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[7]Apedaile, L. P. and Rapp, E. *Agricultural Potential for Sloughs and Wetland in East Central Alberta*. Occasional Paper No. 7. Department of Rural Economy. University of Alberta. Edmonton. April 1983. page 2.

[8]Birch, A., MacLock, B. and Kemper, L. *An Integrated Study of Alberta's Drainage Potential*. A paper prepared for the C.W.R.A./S.C.S.A. conference on Urban and Rural Runoff Management. Edmonton. October 1985. page 3.

[9]Apedaile, L. P. and Rapp, E. "Areas Affected by Excess Water on Better Quality

potential, based on comparable adjacent production achievements, is conservatively $200 million in revenue per year, to which could be added cost savings from improved field efficiency and economies of size. This study aimed at determining the economic viability of drainage and management factors influencing that viability by examining drainage projects *ex post*.

C. **Characteristics of the Study Area**

As mentioned previously, the study area contains all of C.D. 10 and approximately 97% of C.D. 7. This study assumed that descriptive statistics based on Agricultural Region 4, which contains these two census divisions, is representative of the study area in general. Based on 1981 Census data, the major field crops, listed in descending order of acreage, are wheat(majority spring wheat), barley, canola, oats and tame hay[10]. In 1981 Statistics Canada estimated that the area contained 0.72 million cattle, 0.21 million pigs and 1.47 million hens and chickens[11].

Dark brown, black and gray soils[12] of all CLI land classifications are within the area. The underlying parent geological material is basically a calcareous glacial till. Moisture levels on the study area vary from 51 cm(20 inches) per year on the western edge to 36 cm(14 inches) per year in the south east corner of the region[13]. The frost free period varies from 100 days on the eastern portion of the region to 80 days in the west[14]. Aridity and temperature are two factors that limit full agricultural productivity[15].

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[9](cont'd) Cultivated Land in East Central Alberta." *Agriculture and Forestry Bulletin* (December 1983): page 32.
[10]Statistics Canada. *1981 Census of Canada. Agriculture. Alberta.* October 1982. Catalogue 96-910. Tables 16-1 to 16-8.
[11]ibid. Tables 22-1 to 22-4.
[12]Alberta Agriculture. *Alberta Forage Manual.* Agdex 120/20-4. Edmonton. Alberta Agriculture. page 38.
[13]McGill, W. B. *Soil Fertility and Land Productivity in Alberta.* ECA82-17/IB16. Edmonton. Environment Council of Alberta. July 1982. page 20.
[14]ibid. Page 10.
[15]Thompson, Peggy S. *The Agricultural Land Base in Alberta.* ECA81-17/IB3. Edmonton. Environment Council of Alberta. August 1981. page 16.

Ecologically the area contains portions of the parkland, grassland and Boreal Forest ecological zones[16]. The area is considered to have a high capability for waterfowl[17] often implicated in the wetlands drainage controversy, and for whitetail deer[18].

D. Broader Issues

The landowner is the same as a manager in any other business. This study assumed the landowner was a rational human being with the primary objective of maximizing his well-being(wealth). However the question arises as to the extent that social costs and benefits should be considered. As Howe[19] asks, what is the proper accounting stance to choose in evaluating projects? To what extent should the analysis of private projects concern itself with social costs and benefits[20]? Singh[21] states that until an appropriate legal and accounting framework has evolved, management(landowners) may discharge social obligation only by transgressing legal confines and ethical standards irresponsibly. This implies the private cost-benefit point of view of evaluating projects is socially responsible and appropriate if projects are within legal bounds.

An example of some of the socioeconomic issues that could be considered, as expressed by Brande[22], are that the sloughs being drained are important to groundwater

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[16]Glasgow, W. M. *Fisheries and Wildlife Resources and the Agricultural Land Base in Alberta*. ECA82-17/IB17. Edmonton. Fish and Wildlife Division, Alberta Energy and Natural Resources and Environment Council of Alberta. July 1982. page 3.
[17]ibid. page 7.
[18]ibid. page 10.
[19]Howe, Charles W. *Benefit-Cost Analysis for Water System Planning*. Water Resources Monograph 2. American Geophysical Union. 1978. page 9.
[20]Social costs and benefits include all costs and benefits that are functionally related to a production plan, regardless of incidence. Social costs and benefits are partly private and partly public and exceed private costs and benefits by the value of the external diseconomies and external economies(externalities). Ciriacy-Wantrup, S. V. *Resource Conservation*. Berkeley. Division of Agricultural Sciences. University of California. 1976. page 236 and Turvey, Ralph. "On Divergences between Social and Private Cost." in *Economics of the Environment*. 2nd Edition. Dorfman, Robert and Dorfman, Nancy S. (eds). New York. W. W. Norton and Company. (1977):page 187.
[21]Singh, Shiv Pratap. *Capital Expenditure Decisions(An Analytical Approach)*. Allahabad. Wisdom Publications. 1978. page 18.
[22]Brande, Justin. "Worthless, Valuable, or What?" *Journal of Soil and Water Conservation* (January-February 1980): 12-16.

hydrology and wildlife by providing storage, filtering and recharge for groundwater and habitat for acquatic and terrestrial plants and animals. Whiteley[23] suggests the environmental impacts caused by drainage are; changes in the unsaturated soil zone water content; changes in surface water storage area; changes in water table depth; and changes within and downstream of the drainage channel. Leitch[24] listed flood and erosion control, nutrient recycling, historic, educational and scientific value and aesthetics as some of the social benefits of wetlands. He mentions that the annual social benefits from wetlands may be as high as $2500 per acre for waste assimilation and $2800 per acre for water supply(1981 $US). Surrendi[25] states, "It has been estimated that in a year of good populations and high participation by hunters, that the recreational value of waterfowl hunting to Albertans approaches $39 million."

As mentioned earlier, social costs and benefits exceed private costs and benefits by the value of the external diseconomies or external economies(externalities). These externalities are often intangible and unfortunately seldom considered in private project analysis because they are outside the private entrepreneur's normal accounting stance. The private entrepreneur is generally only concerned with private benefits and costs when deciding whether a drainage project will be economically viable or not. Private benefits that exceed private costs are an incentive for the landowner to drain his land thereby increasing his effective land base and his well being.

E. Statement of Purpose

Drainage requires a substantive commitment to capital financing. Contemplation of drainage on a farm without knowledge of the costs, benefits or consequences of the chosen system or whether or not the system will be economically viable would be tantamount to pure speculation. Yet it would appear that drainage often has been undertaken without reasonable

[23]Whiteley, H. R. "Hydrologic Implications of Land Drainage." *Canadian Water Resources Journal* Vol. 4 No. 2: 12-13.
[24]Leitch, Jay A. "The Wetlands and Drainage Controversy Revisited." *Minnesota Agricultural Economist* No. 626 (March 1981): page 4.
[25]Surrendi, Dennis C. *The North American Waterfowl Management Plan*. A presentation to the conference on urban and rural runoff management. October 1985. page 12.

evidence or understanding of the conditions under which the benefits to farmers would outweigh the costs of the drainage to them.

The purpose of this research is to provide some answers to the relevant economic and management questions regarding the feasibility of drainage projects from a private benefit and cost point of view. The desired result is a decision making approach, easily used by agricultural fieldmen and landowners alike for drainage, that will allow them to make rational decisions regarding projects prior to actually undertaking the project.

F. Objectives of the Research

The objectives of this research are:

1. To explore an effective method of assessing the private economic viability of alternative drainage designs in Alberta and thus establish whether a drainage project may be economically viable and under what conditions;
2. To establish whether an increase in management intensity over the whole farm, proxied by changes in land, capital and input use, influence the economic viability criteria of drainage projects and to determine why some drainage projects are more viable than others; and
3. To examine the differences between landowners' perceived expectations from the drainage prior to drainage and the benefits they actually received from the drainage.

G. Organization of the Thesis

The first chapter of this thesis presents an overview of drainage issues, a description of agriculture and water related issues in east central Alberta, a statement of purpose and the objectives of the research. Chapter two combines a review and discussion of the theoretical aspects involved in the research relating to farm investment analysis and the evaluation of project viability. Also included is a review of the theoretical benefits associated with drainage, a review of drainage studies assessing drainage benefits, a review of the importance of management on production success and a review of the social concerns of drainage.

Chapter three will include a description of research methodology and data analysis. The sampling procedure will be outlined and the behavioral analysis relating the management intensity measures to the economic worthiness criteria will be discussed. Chapter four presents the results of the analysis, a comparison of the economic viabilities of surface and subsurface drainage and the implications of the management changes. Finally, Chapter five summarizes the results, presents implications regarding the economics of drainage and draws some conclusions about the economics of drainage.

Numerous appendices are included at the back of the thesis. Their content includes, the CLI land classification system, a map of the study area, a description of drainage assistance available to landowners, a sample of the questionnaire, some peripheral descriptive statistics of the drainage farms, and a list of variables used in the behavioral analysis. Also included are an assortment of comments regarding drainage made by the landowners either during the initial telephone contact or during the in-person interviews.

II. THEORETICAL REVIEW

A. Review of Farm Investment Analysis

Introduction

According to Aplin et al.[14] "Capital investment decisions may well be the most important judgements undertaken by management. Frequently large sums of money are involved in expenditures for land, equipment, buildings and other assets. Most such expenditures affect operations over a series of years. Capital expenditures often are large, permanent commitments that influence the long-run flexibility and earning power of the business. This emphasizes the importance of basing capital investment decisions on reliable forecasting and evaluation procedures.

Decisions on capital expenditures also are among the most difficult managerial problems. A major source of difficulty stems from the fact that the effects of most capital investments occur over a considerable period of time in the future. Because our knowledge of the future is imperfect, it is imperative that considerable effort be made to predict as reliably as possible the probable costs and benefits of each investment alternative. Another difficulty arises because, in the case of many capital expenditures, most, if not all, of the capital must be laid out immediately, whereas the benefits accrue to the business over time. Thus, once management has reliable estimates of costs and benefits, it has the problem of balancing added returns that will accrue to the business in the future years against a capital expenditure that will be made immediately if the decision is made to invest."

[14]Aplin, Richard D., Casler, George L. and Francis, Cheryl P. *Capital Investment Analysis Using Discounted Cash Flows*. Columbus. Grid Publishing, Inc. 1977. page 1.

B. Evaluation of Project Viability

The Accounting Stance

Choosing the proper accounting stance[27], the realm to which the benefits and costs from the project under investigation accrue, is important in establishing what the benefits and costs will be as a result of the project. In instances where the project is large, the output of the project may influence market prices and affect all members of society in general. The ramifications of the increased demand for inputs or increased production from drainage projects being considered here, with respect to society in general, will be insignificant. The landowners are considered price takers and thus subject to market prices. The evaluation of all the benefits and costs attributable to the drainage projects in this study are made using market prices.

Mention is sometimes made of the "social responsibility of the businessman(landowner) when implementing projects. Singh[28] states that "Until an appropriate legal and accounting frame work has evolved management can spend the stockholders money on projects primarily designed to discharge social obligation only by transgressing legal confines and ethical standards irresponsibly." From the private benefit-cost point of view this implies an individual is socially responsible if he stays within legal bounds.

Identifying Benefits and Costs

Quirin[29] suggests the following principles when identifying costs and benefits of projects under investigation:

1. The analysis should embrace all costs and benefits resulting from the adoption of the proposed project, from the standpoint of the optimizing unit, i.e., the firm in the case of

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[27] Howe, Charles W. *Benefit-Cost Analysis for Water System Planning*. Water Resources Monograph No. 2. American Geophysical Union. 1978.
[28] Singh, Shiv Pratap. *Capital Expenditure Decisions(An Analytical Approach)*. Allahabad. Wisdom Publications. 1978. page 18.
[29] Quirin, G. David. *The Capital Expenditure Decision*. Homewood. Richard D. Irwin, Inc. 1967. page 59-60.

private sector decisions and society or the economy as a whole in public sector decisions;

2. It should be on an incremental basis taking into account the difference between the resulting streams of costs and benefits with and without the project respectively;
3. External effects, i.e., indirect benefits and costs, should be taken into account to the extent appropriate to the decision-making unit;
4. Care should be taken to compare total benefits with total costs. The practice of off-setting certain benefits against certain costs or vice versa can in many cases lead to misranking of projects;
5. Double counting should be avoided;
6. Opportunity costs are the relevant standard; and
7. An appropriate period should be considered.

Little and Mirrlees[10] suggest that when considering profitability analysis, using discounted cash flows, all receipts and payments must be considered:

1. All amounts received from the sale of outputs of the project for each year of the life of the project, including the sale of any buildings and equipment remaining at the end of the life of the project; and
2. All payments made for goods and services used by the project according to the year in which they were made, from the date of the first expenditure until the end of the project life. These include payments of capital costs, whether for initial equipment or for replacements, as well as current costs.

There are numerous costs and benefits to be identified when evaluating project viability. Fixed costs are costs that will remain unchanged whether or not a project is implemented. Incremental costs, also known as differential costs or variable costs, are those that arise because a project is implemented. Beenhakker[11] suggests that when analysing projects there is a tendency to underestimate the costs associated with a project, and the prime reasons for this are:

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[10]Little, I. M. D. and Mirrlees, J. A. *Project Appraisal and Planning for Developing Countries*. London. Heinemann Educational Books Ltd. 1974. page 7-8.
[11]Beenhakker, Henri L. *Handbook for the Analysis of Capital Investments*. Westport. Greenwood Press. 1976. page 84.

1. Uncertainties present in analyzing future costs;
2. Changes in the configuration of the product desired by the procurring service during the implementation phase;
3. Changes in quantities of output originally projected;
4. Deliberate underbidding by contractors; and
5. Inflation.

Beenhakker indicates the proper procedure for identifying benefits is the "with and without" test and not the "before and after" test. He states, "Some investment analysts, however, mistakenly apply the "before and after" test. That is, they examine the question, "what are the benefits(and costs) before the new investment and what will they be afterwards, rather than, what will the benefits(and costs) be with the new investment and what would they have been without it.[32]" The difference between the two tests is that the "with and without" test acknowledges that changes would have transpired over time in the absence of the new investment[33]. According to Beenhakker benefits are defined in terms of their effect on fundamental objectives and in the private sector the fundamental objective is either profit maximization or cost minimization[34]. This implies the benefits associated with a project can either be increased revenue associated with the implementation of the project or reduced costs(savings) because of the project.

Comparing Benefits and Costs

There is little argument with the fact that in a relatively uncertain world, a rational human being prefers a dollar today compared to a dollar tomorrow. This basic concept, sometimes referred to as the "time value of money"[35] is necessary in evaluating the cash flows associated with a particular investment decision. It is necessary because in most instances investments involve the outlay of a sum of money at the beginning of the project and the

[32]ibid. page 85.
[33]ibid. page 87.
[34]ibid. page 87.
[35]Bierman, Harold Jr. and Smidt, Seymour. *The Capital Budgeting Decision*. New York. Macmillan Publishing Co., Inc. 1975. page 12.

realization of benefits at some future time. The longer into the future these benefits are from the initiation of the project the greater is the risk, uncertainty and inflation associated with them. These factors necessitate the use of discounted cash principles when comparing benefits and costs that occur at different times throughout the life of the project under investigation.

Discounted cash flow theory is identical to the compound interest rate used by banks in calculating interest charges on mortgage and other self-amortizing bank loans[16]. For calculating a project's rate of return, all cash flows from the project are discounted back to some reference time zero, usually the time when the initial cash outlay to initiate the project was made. The assumption is the exchange rate between money now and money one period in the future is as the rate of 1 now to (1+r) one period hence[17]. Because money today has been historically more valuable than future money, r is always positive. Discounting future values equates all values to a present value. Once present values for all costs and benefits are calculated the discounted benefits and costs can be analyzed using various discounting methods. If the discounted incemental benefits outweigh the discounted incremental costs or if the internal rate of return is greater than the opportunity cost of capital, a project ia assumed viable.

Methods of Investment Appraisal

Four methods of project appraisal will be discussed in the following section. These are the net present value, the internal rate of return, the benefit-cost ratio and the net benefit-investment ratio. Each method employs discounted cash flows.

Net Present Value or Net Present Worth

Merrett and Sykes[18] refer to the net present value(NPV) technique as the classic

[16]Kroeger, Herbert E. *Using Discounted Cash Flow Effectively*. Homewood. Dow Jones-Irwin. 1984.
[17]Merrett, A. J. and Sykes, Allen. *The Finance and Analysis of Capital Projects*. London. Longman Group Limited. 1963. page 4.
[18]ibid. page 21.

economic method of investment appraisal. Schwartzman and Ball[39] call the net present value method the most helpful means of determining the profitability of projects. In order to implement the NPV criterion one must follow steps similar to those outlined by Brigham and Gapenski[40] and Bierman and Smidt[41]:

1. Identify all relevant benefits associated with the project;
2. Choose an appropriate discount rate;
3. Compute the present value of the incremental net benefits(i.e., the present value of the gross benefits minus the present value of the gross costs); or
4. Compute the present value of the gross project benefits; and
5. Compute the present value of the gross project costs.

If the present value of the incremental net benefits or the difference between the present value of the gross benefits minus the present value of the gross costs is greater than zero, the project would be accepted, but if they were less than zero the project would be rejected. The rationale behind rejecting a project with a negative NPV is that the return on the investment is insufficient to cover the opportunity cost of capital(the chosen discount or interest rate) and one would be better off to invest the money in the best alternative use.

Recognized problems associated with the NPV method are the difficulty in choosing the appropriate discount rate and the fact that it is an absolute and not a relative measure and doesn't lend itself to the proper ranking of projects(a small highly attractive project may have a smaller NPW(net present worth) than a larger marginally acceptable project)[42].

[39] Schwartzman, Sylvan D. and Ball, Richard E. *Elements of Financial Analysis*. New York. Van Nostrand Reinhold Company. 1977. page 58.
[40] Brigham, Eugene F. and Gapenski, Louis C. *Intermediate Financial Management*. New York. The Dryden Press. 1984. page 277.
[41] Bierman, Harold Jr. and Smidt, Seymour. *The Capital Budgeting Decision*. New York. Macmillan Publishing Co., Inc. 1975. page 30.
[42] Gittinger, J. Price. *Economic Analysis of Agricultural Projects*. Baltimore. The Johns Hopkins University Press. 1982. page 329.

Internal Rate of Return

The internal rate of return(IRR) method of investment appraisal, also referred to as yield, interest rate of return, rate of return etc.[43], calculates the discount rate which makes the net present value of the incremental cash flow of an investment equal to zero. The usage of the IRR method is often justified on the grounds that it is a "pure number" and thus more useful in allowing projects of different size to be compared directly[44]. It is the maximum interest that a project could pay for the resources used if the project is to recover its investment and operating costs and still break even[45]. This maximum rate is then compared to the opportunity cost of capital, the assumption being that it is known, and if it is greater than the opportunity cost of capital the project is accepted, but if it is less the project is rejected. The IRR and NPV will lead to identical accept/reject decisions on independent projects.

One criticism of the IRR is the necessity of the trial and error approach to its calculation, necessary because one cannot simply guess at the rate which will make the NPV equal to zero. After making an initial estimate, an iterative procedure is followed until the exact IRR is found. A second criticism is the assumption that all funds from the project could be reinvested at the IRR. This criticism is particularly applicable when comparing projects with different IRR's and different lengths of project life. A third criticism is that in some cases, depending on the shape of the incremental cash flow stream, more than one discount rate may make the net present value equal to zero. These situations are apparently rare in agricultural applications[46].

Benefit-Cost Ratio

The Benefit-Cost Ratio(B/C Ratio) is defined as the division of the discounted benefit stream by the discounted cost stream. The accept/reject criteria is a B/C ratio of 1. If

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[43]Bierman, Harold Jr. and Smidt, Seymour. *The Capital Budgeting Decision*. New York. Macmillan Publishing Co., Inc. 1975. page 28.
[44]Irvin, George. *Modern Cost-Benefit Methods*. London. The Macnillan Press. 1978. page 15.
[45]Gittinger, J. Price. *Economic Analysis of Agricultural Projects*. Baltimore. The Johns Hopkins University Press. 1982. page 329.
[46]ibid. page 341.

the present worth of the benefits are greater than the present worth of the costs, the ratio is then greater than one and the project is accepted. Projects with B/C ratios of less than one are rejected.

One major criticism of the B/C ratio is its sensitivity to the way items are netted out of the cost and benefit streams. If, for example, items of expense are subtracted from the benefit stream rather than added to the cost stream, the proportionality of the ratio will change and this may be significant enough to result in wrong decisions or marginally acceptable projects. This difficulty is avoided by rigorous use of incremental analysis. If projects are to be compared, the same netting out procedure must be followed. A second criticism of the B/C ratio is that neither numerator nor denominator can be zero, otherwise the calculation of a ratio is not possible.

The B/C ratio and the IRR will give conflicting rankings of projects. This is no surprise since rankings given by B/C ratios using different discount rates may themselves conflict[47].

Net Benefit Investment Ratio

The net benefit-investment ratio (N/K ratio)[48] is the only criteria mentioned earlier that is acceptable for ranking non mutually exclusive projects. This ratio is the present worth of the net benefits divided by the present worth of the investment. The net benefit is taken to be the present worth of the incremental net benefit stream in those years after the stream has turned positive and the investment is taken to be the present worth of the incremental net benefit in those years of the project when the stream is negative.

It assumes that the incremental net benefit stream is negative in the early years of a project then turns positive and probably remains positive for the remaining life of the project. If in the later years the incremental net benefit stream becomes negative, because of some equipment replacement or the like, this merely reduces the incremental net benefits. The

[47]Quirin, David G. *The Capital Expenditure Decision.* Homewood. Richard D. Irwin, Inc. 1967. page 47.
[48]ibid. page 346.

reason for calculating the N/K ratio is to select projects on the basis of return to investment during the initial phases of the project. Projects with N/K ratios greater than one, when discounted at the opportunity cost of capital, are accepted, and those with N/K ratios less than one are rejected.

The N/K ratio is particularly useful in ranking project investment decisions when funds are not available to impliment all projects.

C. Review of Drainage Benefits

The following section reviews some important theoretical benefits achieved by drainage and highlights why a landowner might want to drain land.

In his opening paragraphs of Chapter One, Luthin[49] writes, "A drainage problem is caused by an excess of water either on the surface of the soil or in the root zone beneath the surface of the soil. If the water stands on the surface of the soil the problem is one of surface drainage. This more obvious type of drainage problem can be remedied by providing some method of removing the surface water.

The other type of drainage problem concerns water that ocurrs beneath the surface of the soil. A high water table is present. Frequently the presence of the high water table is not evident from an inspection of the soil surface. In many instances the soil surface may appear to be dry, but waterlogged soil at depths of two or more feet beneath the soil surface may cause serious damage to the crops which are being grown. Methods of investigating such problems form an important part of the engineering of a drainage system."

As stated earlier, this study is an attempt to compare the economic viability of alternative drainage systems. In this respect the alternative drainage systems are classified as surface, referring to ditch systems, excavated earth channels for the conveyance of unwanted water and subsurface, the installation of plastic pipe or tile beneath the earths surface for the conveyance of unwanted water. The classification of the drainage systems do not refer to the location or type of water being drained, as it is understood that both types of drainage

[49]Luthin, James N. *Drainage Engineering*. Huntington. Robert E. Kreiger Publishing Co., Inc. 1978. page 1.

systems were used for similar drainage purposes. In this study, the main purpose of the system was to drain temporary or permanent sloughs and not to control specifically the height of the ground water table.

The main purpose of drainage is to improve the soil water conditions that result in a healthy root environment and contribute to the maximum growth of the plant, increase crop yields and quality and thus enhance the agricultural use of the land, or as Stallings[50] states, "drainage may make available for cultivation, highly productive acres that were not suitable for cultivation previously." In poorly drained soils the yields are reduced because water fills the voids(soil pores) between the soil particles, reduces the air available to the plants and obstructs the gases which are given off by the plant roots. Poor aeration reduces the likelihood of root extention and growth and since the roots penetrate to within 15 inches of the water table, a high water table allows little room for root development. In extreme cases of poor drainage, the result may be pools of water which stand in the field and cause plant scalding during periods of high temperatures.

Other problems associated with a saturated root zone, that contribute to reduced yields, are cooler soils. The problems associated with cool soils are a reduction in the decomposition of organic matter, the resultant rate at which nutrients from the natural organic matter is made available to the plants and a reduction in the available carbon dioxide, the latter two problems because of reduced microbiological activity. In addition cool damp soils also reduce the effective germination rate of seeds and in some cases the seeds may rot before they have a chance to germinate. If the soil is both dryer and warmer sooner because of improved drainage, the seeding date may be advanced resulting in both a longer growing season and crop flexibility. The reason that damp soil is cool soil is explained by Irwin[51]. Since the specific heat[52] of water is 1 cal/gram and that of a dry mineral soil(with bulk density

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[50]Stallings, J. H. *Soil Conservation*. Englewood Cliffs. Prentice-Hall, Inc. 1957. page 511.

[51]Irwin, Ross W. *On-Farm Drainage Benefit*. Final Report for the Corrugated Plastic Drainage Tubing Association. University of Guelph. February 1981.

[52]Thermodynamic values are generally recorded in calories(cal) or kilocalories(kcal), joules(J) or kilojoules(KJ). The heat capacity of a substance is the amount of heat required to raise the temperature of the substance by 1 degree centigrade. Values

[53] of 2.65 gms/cm3) is 0.2 calories per gram, a dry soil with a porosity[54] of 50% , has a volumetric heat capacity of 0.26 cal/gram. If one half of the pore space were filled with water the volumetric heat capacity would be 0.26 + (0.25 x 1.0) = 0.51 cal/gram, which means that it would take twice as long for the sun's heat to raise the temperature of the wet soil 1 degree centigrade. It also requires extra heat calories to transform the water from a liquid to a gaseous state and the wind action that carries away the evaporated water acts as an additional cooling agent and the higher evaporation rate may cause surface salt accumulation.

Other factors that reduce yield include compacted soil surfaces, that become difficult for young emerging plants to penetrate and an undesireable soil structure which doesn't have the optimum mix of soil particles with air and water filled voids. Wet soils are more easily compacted than dry soils and thus are more likely to have crusted surfaces and poor structure. Soils that remain sat are not subjected to normal drying and rewetting and thus do not form the fissures and cracks necessary to facilitate good drainage. These fissures and cracks also improve the aeration of the soil by allowing fresh oxygen to penetrate the soil.

Regarding water holding capacity, Irwin comments on the paradox of drainage. On one hand drainage removes soil water but the result is that through improved soil structure the actual amount of water available to plant roots increases, partly because the plant roots have a greater volume of soil from which they may obtain their water and nutrients. The nutrients are more readily available from a dryer soil for a number of reasons. The higher microbiological activity, partially due to the warmer soil, leads to higher rates of decomposition of the natural organic matter and thus higher rates of nitrification. Chemical fertilizers are more readily available because they can be applied much earlier when plants

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[52](cont'd) are usually recorded for 1 mol or for 1 gram of the substance considered and in the latter case the value is called the specific heat of the substance. Mortimer, Charles E. *Chemistry A Conceptual Approach*. 3rd Edition. New York. D. Van Nostrand Company. 1975. page 150.

[53]The bulk density is the weight of a soil divided by its volume. Luthin, James N. *Drainage Engineering*. Huntington, N.Y. Robert E. Krieger Publishing Company. 1978. page 57.

[54]Soil porosity is the ratio of the volume of air plus the volume of water divided by the sum of the volume of air, water and soil, multiplied by 100, to express the ratio as a percentage. Luthin, James N. *Drainage Engineering*. Huntington, N.Y. Robert E. Kreiger Publishing Company. 1978. page 57.

utilize them most efficiently and the loss of nutrients due to leaching is reduced. The loss of nitrogen because of denitrification[55] is also reduced in dryer soils.

From a physical standpoint a wet soil limits the type of use that can be made of it by not being able to support agricultural equipment. This wet soil is more susceptible to compaction than a dry soil and this compaction destroys good soil structure, hampers seed emergence and amplifies the problems associated with poor soil structure. In addition, working the soil with modified equipment, flotation tires etc., increases costs because of the increased horsepower requirement and the additional wear and tear on equipment subjected to tougher conditions. Eriksson[56] found that at 16m drain spacings, soil structure was good and draft resistance to fall plowing was low and even. At drain spacings of 32m soil compaction ocurred during spring tillage, resulting in unfavorable soil structure that was difficult to penetrate with a plow share and resulted in clodding[57].

To the landowner improved drainage means reduced costs, increased benefits and more flexible management strategies. One advantage is the ability of landowners to perform tillage operations earlier in spring. This will allow earlier seeding dates of between one and two weeks. Because the land is prepared earlier, the soil is warmer and drier sooner. Delays in field operations because of spring rains are also reduced. Earlier seeding dates also mean earlier harvesting dates and this is critical in areas that have short growing seasons and wet fall weather. The earlier seeding also allows for a broader choice of crops or crop hybrids and thus directly affects potential yield and returns. The second advantage allows for a more

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[55]Studies have shown that there are losses of nitrogen from the soil in ways other than leaching and plant use. One of these is denitrification, which is the biochemical reduction of nitrates under anaerobic conditions. When soils become water logged, oxygen is excluded and anaerobic decomposition takes place. Some anaerobic organisms have the ability to obtain their oxygen from nitrates and nitrites with the accompanying release of nitrogen and nitrous oxide. Tisdale, Samuel L. and Nelson, Werner L. *Soil Fertility and Fertilizers*. 3rd. Edition. New York. Macmillan Publishing Co., Inc. 1975. page 145-148.

[56]Irwin, Ross W. *On-Farm Drainage Benefit*. Final Report for the Corrugated Plastic Drainage Tubing Association. University of Guelph. February 1981. page 9.

[57]A clod is an artificially produced compact coherent mass of soil ranging in size from 5 or 10 mm to as much as 8 or 10 inches. Hausenbuillet, R. L. *Soil Science, Principles and Practices*. Dubuque. Wm. C. Brown Company Publishers. 1972. page 463.

economical method of disease and weed control, because plants are more vigorous and better able to compete with weeds for nutrients and available water and better able to resist infection by disease. Weed control methods whether mechanical or chemical are more effective due to earlier application on a dryer soil. The third management advantage allows for energy conservation and efficient machine use. Since field operations are performed over the entire field at one time, doubling of operations and inefficient field patterns are eliminated. The number and type of required field operations necessary to insure a proper seed bed are reduced and it is not necessary to go back and work areas that were initially to damp. Costs are reduced because there is a more efficient use of fuel and equipment, the required draft power is reduced due to lower draft resistance of a dryer soil and labor and equipment costs are lower due to reduced wear and tear on equipment. Wear and tear can be severe in situations where equipment becomes stuck when trying to encroach upon a wet area.

Smedema[58] summarizes the benefits of drainage as follows. "Benefits from drainage of agricultural land may accrue from the improved crop growth conditions created by drainage(earlier, higher, more dependable, better quality yields; wider range of more demanding/attractive crops, etc.) or from the improved soil workability conditions(earlier planting, more workable days, lower draught requirements, less damage to soil structure by farm machinery, increased scope for spreading and planning of work, etc.). All in all, land drainage may be expected to result in better yields at lower costs, in other words higher net returns to the farmer. These returns should always be considered in relation to the costs of drainage improvements."

An economically viable drainage project will offer the landowner an improvement in his well being. This improvement in well being can come from increased returns, because of an increased land base, improved crop quality or a more diversified choice of crops or from reduced costs through more efficient use of inputs such as fertilizers, herbicides, fuel and time. These benefits are easily assigned a monetary value. In addition to these are

[58]Smedema, Lambert K. and Rycroft, David W. *Land Drainage - Planning and design of agricultural drainage systems*. London. Batsford Academic and Educational Ltd. 1983. page 44.

non-monetary(intangible) benefits. An example of these benefits may be pride of ownership or as Leitch[59] found, farmers willingness to accept a loss to be rid of the real or imagined nuisance of wetlands in their fields because the increase in their satisfaction was more valuable than any monetary loss they may have incurred.

D. Review of Drainage Studies

The following section contains a review of literature that has addressed the benefits, both physical and economical, associated with drainage projects of different sizes i.e., ranging from on-farm projects to drainage of entire watersheds.

Menz[60] evaluated the incremental benefits associated with drainage projects at various stages of project development against the all or nothing approach. On a 10,000 acre farm in California devoted to crops of alfalfa, cotton, barley, canteloupes and lettuce, Menz stratified the area into composite acreage by crop and depth to water table and calculated the net incomes as a function of the depth to water table. Calculations were based on probable per acre crop yields as a function of the depth to ground water. Menz calculated the annual total and incremental benefits associated with the different water table levels. He found the optimum level of the water table to be between three and four feet, the point of intersection of incremental net income and cost curves.

Rigaux and Singh[61] studied the benefits and costs of improved levels of agricultural drainage in south Manitoba. The [illegible]ted into three phases, each resulting in a published volume. Volume one [illegible]ing precipitation excess in terms of a storms precipitation, the maximum potential moisture retention of the soil and the average gradient

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[59]Leitch, J. A. *Economics of Prairie Wetland Drainage*. A presentation at the 1982 Winter Meeting of American Society of Agricultural Engineers. Paper No. 82-2543. December 1982.

[60]Menz, John A. "The Economic Evaluation of a Drainage Project." *Journal of Soil and Water Conservation* (Jan-Feb 1964): 12-14.

[61]Rigaux, L. R. and Singh, R. H. *Benefit Cost Evaluation of Improved Levels of Agricultural Drainage in Manitoba Precipitation Excess on Agricultural Land*, Research Bulliten No. 77-1(Volume 1), *Crop Damage Analysis-The Impact of Precipitation Excess*, Research Bulliten No. 77-1(Volume 2), *Economic Feasibility of Investment*, Research Bulliten No. 77-1(Volume 3). 1977.

of the watershed area. Precipitation excess in this study was defined as "a relative concept wherein moisture is excessive when the soil moisture level is greater than what is adequate, optimal or tolerable for the plants." They conclude volume one by stating that the model developed is capable of generating precipitation excess data which will be suitable in subsequent analysis of the effects of improved drainage capacity on precipitation excess and the resulting averted crop damage.

In volume two Rigaux and Singh examined the relationship between crop yield for wheat, oats, barley and flax, and precipitation excess in order to determine an estimate of crop damage. They recognized loss, because of precipitation excess as resulting from numerous reasons; delayed seeding, flooding during the growing season(losses vary with the particular growth stage of the plant), delayed field operations(fertilizer, spraying, harvesting), increased operating expenses(machinery,fuel,labor) and reduction in crop quality. Rigaux and Singh mentioned that crop damage in terms of yield reduction was directly related to the duration of flooding and varied with plant age, soil type(clay is worst, sandy loam best), temperature, wind factor, fertilizer application, a management aspect, weather composition, insect and disease control techniques and, in general, the input mix and its combination with management and physical factors. A regression model with the dependent variable of average yield and independent variables of nitrogen fertilizer application, phosphorous fertilizer application, soil productivity index(based on a general productivity of soils) and precipitation excess for the months of May, June, July and August was specified. The results showed that yields in most cases were positively related to the application of nitrogen, phosphorous, soil productivity and May moisture excess but negatively related to precipitation in June, July and August. Variations existed among different equations for the same crop depending on the soil texture classification, some crops showing greater sensitivity than others. Volume two concludes with a statement of the use of the regression results in an attempt to assess the economic feasibility of drainage improvement based on the ability of drainage to reduce precipitation excess.

The objectives of volume three of this study were to identify the benefits and costs associated with improved drainage, including interpretion of crop damage factors, identification of benefits and costs for specific design and levels of development and provision of guidelines using the approaches developed for evaluation and improvement of drainage projects in agro-Manitoba. Steps in the analysis involved identification of existing drainage capacity for a particular area and estimation of the present value of construction and maintenance costs, based on incremental values for the three levels of drainage improvement. Only direct economic benefits resulting from the increased crop yields were estimated. Rigaux and Singh found that increased drainage capacity was feasible on in only six out of fifteen selected drainage areas. Sensitivity analysis involved varying the project life, segmenting a watershed area, changing the incremental cost schedule and investigating more intensive land use. They found that increasing the project life from 15 years to 50 years altered the B/C ratio on one drain from 1.4 to 1.6, a change of about one-seventh and stated that the length of project life may be important if the B/C ratios are near one. They found changes in the B/C ratios, within a watershed, if that watershed's B/C ratios were calculated for the whole watershed. They reasoned that lower segments of the watershed required greater technical development in order to handle the upstream flows and the ratio of costs to benefits increased as the segmented area near the outlet decreased. Original B/C ratios were derived under the assumption that incremental costs in going from one level of development to another were just the difference between the costs of development of the two levels. When a sensitivity analysis was done, specifically in going from no drainage to the first level of drainage development, in which case the assumption of 100% salvagibility of no drainage was omitted, only one of three projects with B/C ratios of greater than one remained feasible. In the sensitivity of more intensive land use Rigaux and Singh found that the change in the B/C ratio was insufficient to make this particular watershed economically feasible. This watershed was characterized by a large upstream portion, which imposed large downstream costs and relatively little original crop damage because of existing heavy loam soil.

Rigaux and Singh report a wide range of B/C ratios which were influenced by watershed soil type, topography, proportion of land in the watershed that was used in non-agricultural production and extent of existing drainage protection. An important difference between the accounting stance taken by Rigaux and Singh and that taken herein is one of social benefits and costs versus private benefits and costs and the development of drainage projects on a watershed scale versus on-farm drainage only.

Irwin[42] surveyed a randomly selected sample of one hundred farmers to determine their perceptions of drainage benefits. Because of non-installation in some cases data were collected from only 81 farms. The questions on the survey dealt with the farm and farmer biographics, scale and type of farm operations and characteristics of the drainage system. Some of the benefits achieved by drainage were, alleviation of spring and fall flooding conditions(80% of the respondents), the ability to grow a wider variety of crops, increased yields, a general trend to growing higher value crops, increased acreage, time saving because of larger fields, and some indication of increased management intensity based on increased fertilizer use(nearly one half of the farmers). Irwin found that no respondents were dissatisfied with drainage as an investment, 6% did not comment and 94% were well satisfied. Over one half of the respondents, as he states were "extremely enthusiastic" in their endorsement of drainage.

Irwin[43] in a descriptive paper on drainage in Ontario outlined in detail the benefits achieved by on farm drainage. Benefits include possible land use changes and more intensive use, reduced production costs, improved resource allocation, improved soil conditions including improved structure, moisture regimes, temperature, trafficability and soil erosion and pollution control. General benefits include minimizing the risks associated with weather, improved timeliness of field operations, improved disease and weed control, energy conservation and efficient machinery use and improved crop quality and yields. Irwin also found that drainage improved the uniformity of livestock grazing. In the section on on-farm

[42] Irwin, R. W. "Field Survey of Drainage Benefits in Ontario." *1979 Winter Meeting-American Society of Agricultural Engineers* Paper No. 79-2554. 1979.
[43] Irwin, Ross W. *On-Farm Drainage Benefit, Final Report for the Corrugated Plastic Drainage Tubing Association* University of Guelph, School of Engineering. 1981.

drainage costs. Irwin mentioned the different types of costs involved in a drainage project, namely the initial investment in ditches, pipes, pumps, structures, land clearing, land treatment, financing and maintenance costs. He also mentioned that drainage has been important to Ontario farmers because they have shifted toward the production of high energy crops, corn, soybeans and white beans, which respond favorably to good drainage. The drainage of farm land is consistent with naturally increasing land values that ocurred between 1961 and 1976 and the notion that expensive land should be used as productively as possible. Irwin concludes that even though numerous attempts have been made to show the worthiness of drainage in terms of increases in yield needed to offset the cost of drainage, given an interest rate and project life and that this method shows that it will pay for itself in a few years, the real attractiveness of drainage is that it, as a method of expanding the land base, is sometimes only one-tenth the cost of obtaining new land through purchase in Ontario. In real terms, in the 20 years between 1960 and 1979, drainage costs per acre in Ontario have increased by a factor of only 3.3 times whereas the price of land per acre over the same period has increased by a factor of 8.9 times. During this same period in Ontario, gross farm receipts per acre have increased by a factor of 4.0 times.

Leitch[44] utilized a farm survey of farm operators who drained land, to estimate the costs of constructing wetland drains, to estimate the returns from wetland drainage and to examine the economic feasibility of on-farm drainage. Benefits from drainage included increased crop sales, decreased nuisance or avoidance costs and a component for the net influence of intangibles. Analysis was accomplished using variable costs(cash costs), land was treated as a sunk cost and machinery ownership cost were excluded on the basis that a marginal addition to cropland would not change the machinery complement. Leitch considered three combinations of the above, the first with land and machinery included, the second with only land included and the third, thought to be the most likely, with land and machinery excluded. Of fifteen respondents to the survey who drained land using ditches, all had returns greater than costs before taxes at a real 12% discount rate with one exception. This one

[44]Leitch, Jay A. *Economics of Prairie Wetland Drainage.* 1982 Winter Meeting-American Society of Agricultural Engineers. Paper No. 82-2543. 1982.

exception showed a small gain when taxes were considered. At a real 8% discount rate all drainage costs were recovered in five years. By extending the project life from the standard 15 year period to 25 years and by including maintenance, net benefits rose by 17% at an 8% discount rate and by 10% at a 12% discount rate.

Nineteen respondents from two sub-areas, drained land using tile drainage and five of nine in sub-area N, had a net loss under all discount rates and tax scenarios. Benefit cost ratio averages were .6 at the 8% discount rate and .7 at the 12% discount rate with a payback period of greater than 50 years for both the tax and no tax scenarios. Of the ten respondents from sub-area S, six showed positive net benefits. Under the before tax scenario, the B/C ratio was 1.5 at an 8% discount rate and 1.2 at a 12% discount rate, with a payback period of nine and twelve years respectively. After taxes the B/C ratios were 1.2 at an 8% discount rate and 1.1 at a 12% discount rate with a payback period of ten and fifteen years respectively.

In a study of 58 drainage projects in south central Minnesota, Leitch found that wetland drainage was viable on a cash flow basis in all but one instance at an 8% discount rate and all but two instances at a 12% discount rate. When supplemental field drainage is considered(the general drainage of a whole field, including the wetland area), 52 out of the 58 projects were viable at an 8% discount rate and 47 out of 52 were feasible at a 12% discount rate.

Leitch included an interesting perspective on the social vs private value issue. Even though in 1980, the U.S. Fish and Wildlife Service(FWS) paid an average of $847 per hectare in incentive payments for wetland easements and this was greater than about one-half of the net dollar benefits realized by the projects evaluated in west central Minnesota, farmers seemed willing to drain regardless. He theorizes that there must exist some ophelimity from drainage, beside the usual advantages(soil benefits, time and input savings, field operation timeliness, increased yield, reduced weed and wildlife problems) such that the farm operator is willing to pay to get rid of a real or imagined nuisance. He suggests that those involved in policy decisions regarding the social aspects of drainage may have to compensate wetland owners the full cost, including monetary and non-monetary costs, to maintain wetlands.

Ruff[63] evaluated surface and tile drainage assuming surface drainage costs at $60 per acre and tile drainage costs at $500 per acre. Because surface drainage is eligible for a deduction as a conservation expense up to 25% of gross income from farming, installation costs are fully recovered in the year of installation if the yield is increased by 30% or more. Tile drainage was eligible for a 10% investment tax credit. Based on higher initial installation costs amortized over the life of the project(20 years in this case), and based on a 14% interest rate and maintenance costs of 0.2% of the total system installation costs per year of life, the tile drainage offered the following returns on investment. With a 30% increase in yield the return was 7.5% and with a 60% increase in yield the return was 20.8%.

Considering a 50-50 share lease arrangement in his example, there were no net benefits until yields had increased at least 60%. Advantages do exist because of increased land values such that potential buyers are aware that drainage costs add to the effective price of the land. Ruff[64] concludes by stating that "Good management practices reduce risk factors. Poor drainage is one factor which can negate most other recommended management or cultural practices."

Pedology Consultant's[67] principal objective was "to develop a workable, meaningful methodology which would allow for systematic appraisal of the benefits and costs of drainage for all agricultural lands in Alberta." They intended to conduct both a financial analysis, at a nominal 12% discount rate and a ten year time frame and an economic analysis at a nominal 7% discount rate and a thirty year time frame. Costs considered were, initial drainage costs(including maintenance and operating costs), annual cost of lost ~~production~~, initial land preparation costs and annual wetland crop production. Benefits from annual wetland crop production revenue, improved timing, improved weed control, lower farm production costs, improved crop quality and less wildlife damage were considered. Benefits were assumed to

[63]Ruff, Carl F. "Farm Drainage Economics." *Farm Drainage Handbook*. FMH 11 01. ESO 885. Agdex 822. 1982.
[64]ibid. page 6.
[67]Pedology Consultants and Marv Anderson and Associates Ltd. *Farmland Drainage in Central and Northern Alberta*. Farming for the Future. Research Project No. 82-0070. 1984.

begin in year two or three of the project life depending on the wetland classification. They found that in the Silver Creek area(near Camrose) the B/C ratio, for surface drainage, for all wetland classifications and soil management groups was 1.03, varying from a B/C ratio of 1.65 where average drain depths were 0.5 meters to a B/C ratio of 0.60 where drains averaged a depth of 2.0 meters. Sensitivity analysis, allowing prices or yields to decrease by 20%, lowered the overall B/C ratio to 0.87 and, excluding auxiliary benefits, to 0.68.

In the Lalby Creek area(near Peace River) the overall average B/C ratio for all soil management groups and wetland area classifications was 1.77. The B/C ratio with yields or prices reduced by 20% was 1.49 and 1.15 when auxiliary benefits were excluded. They found that the key parameter influencing the feasibility was not the wetland classification but the combination of wetland features and the characteristics of the surrounding highlands.

The socio-economic analysis of drainage differed from the financial analysis in four fundamental ways, namely the use of shadow prices and costs, the addition of purely public costs and benefits, a longer inter-generational time-frame and the use of a social discount rate. The overall B/C ratio for the Silver Creek basin for all soil management groups was 0.87. All sensitivity analysis reduced this B/C ratio. For the Lalby Creek basin socio-economic analysis, they found an average B/C ratio of 1.03, a very marginal investment decision.

In the summary of the economic analysis, Pedology Consultants state that looking at only the potential increases in production in the wetland areas is totally inadequate and will greatly underestimate the total net benefits of surface drainage. They feel that about one third of all benefits are auxilliary benefits and, although hard to quantify, are very important. They put forward a rule of thumb for calculating approximate B/C ratios: for financial analysis the B/C ratio=(10 times the net return to wetland crop/ha) divided by the on farm drainage costs per hectare; for public decision making the B/C ratio=(20 times the net return to wetland crop/ha.) divided by the public and private drainage costs per hectare.

Desjardins et al.[61] wrote that "the results have shown that sub-surface drainage of

[61]Desjardins, Ronald, MacDonald, Kathleen and Wutzke, Darren. *The Economics of Drainage in Alberta*. Edmonton. Production and Resource Economics Branch. Alberta Agriculture. 1984. page 57.

irrigated saline areas is economically justifiable under most conditions. However under dryland conditions, sub-surface drainage is not justified except over the very long term and with relatively high precipitation levels. Both sub-surface and surface drainage were shown to be economically feasible for non-saline conditions except for specific cases."

The objectives of the Desjardins study were to develope a simple computer model which could be used to determine the economic feasibility of a drainage project and to determine the conditions under which drainage would be economically feasible. Irrigated and dryland saline and non-saline areas were considered. The effects of obstacles and their position in the field were also taken into account. Drainage costs were taken to be $121 per acre for surface drainage and $525($523) per acre for subsurface drainage. Pumping costs for leaching saline areas was considered. Production costs were cash costs required to produce a given crop with summerfallow costs included if applicable. Benefits were calculated from the product of the yields and prices expressed as an average revenue increase per improved acre over the life of the project, assumed in the base case to be ten years. The net difference between the costs and benefits were used as the yearly estimate of cash flow for the life of the project. The net present values for the project were calculated using two scenarios, one assuming no crop before drainage and the second assuming a crop prior to drainage at frequencies of 50, 33, 25, 20 and 0%(equivalent to no crop previously). The sensitivity analysis involved combinations of project lives of 5, 10, 20 and 30 years and real discount rates of 3.5, 5, 7 and 10%.

The Desjardins results which are corroborated by the work reported here for non-saline dryland conditions, are that the cost of subsurface drainage would be prohibitive if there were a 50% chance of producing a crop without drainage and may be infeasible if one could produce a crop 33% of the time without drainage. If the chance of producing a crop without drainage was only 25% or lower, then the costs of subsurface drainage were justified most of the time. Surface drainage was justifiable under all previous crop scenarios. The above results were found using a real 5% discount rate and a ten year project life.

Sensitivity analysis revealed that on non-saline dryland conditions, at a 5% discount rate and a five year project life none of the previous cropping frequency scenarios were feasible but for a twenty or thirty year project life all were feasible. Changing the cost of capital to 3.5% made only the 50% previously cropped frequency infeasible and the 7% discount rate made only the 20% or less previously cropped frequency feasible. Desjardins et al. concluded that "both sub-surface and surface drainage were shown to be economically feasible for non-saline conditions except for specific cases."[69]

E. Review of Management

Farm management is sometimes defined as the art and science of making decisions about the use of available resources and acting upon these decisions in an uncertain world so that the long term goals of the farm and farm family are as fully satisfied as possible. One may ask why certain managers are more likely to achieve their desired goals than others. What is the quality they have that other managers lack and is it possible to quantify these managerial qualities. Unfortunately managerial ability is not easily quantified but numerous individuals have attempted to explain the important effects of management on various aspects of production. Following is a review of a few of these attempts.

According to Heady,[70] "The most difficult input to measure in farm-firm studies is the management or entrepreneurial factor. Unlike experimental studies where the managerial function is excercised by the investigator and remains fixed, the farm-firm research worker is faced with observations whose genesis rests not with him but with many decision makers, each possessing a different degree of entrepeneurial ability. Such differences would be unimportant if management could be measured directly in physical terms. It could then be handled in the manner of other physical inputs. However, a general applicable scale for measuring management has not yet been devised. Likely it never will be, except in terms of interaction of such factors as time and intensity of cerebration, intelligence level, problem handling ability,

[69] ibid. page 57.

[70] Heady, Earl O. and Dillon, John L. *Agricultural Production Functions.* Ames. Iowa State University Press. 1961. page 223.

etc." Heady also mentions that even though perfect correlations will not exist there is probably a systematic relationship between the managerial input and the variations in the inputs of other factors.

Dawson and Lingard[71] state the following. "For an expected profit maximizing farm with a Cobb-Douglas production function, a positive relationship exists between management and the variable inputs, that is, "good" managers use more of all variable inputs than do "bad" managers. Further, it seems likely that a positive relationship exists between management and the fixed input since "good" managers would purchase more of this fixed input if it became available than would "bad" managers. Hence the omission of the management input would lead to (upward) biases in the estimated parameters." Dawson and Lingard conclude that management is an important input into the production process and inclusio[illegible] management variable should improve the statistical fit of the estimated production function.

Griliches[72] set out to show that the omission of managerial inputs from the production function biases the estimate of the elasticity of output with respect to capital inputs upwards and the estimate of returns to scale downwards. The problem stems from the fact that the managerial input does not vary(increase) proportionally with an increase in total inputs(i.e., a farmer who farms on twice the scale of his neighbor is not necessarily twice as good a manager nor does he have to do twice the amount of managerial work) and this leads to an underestimate of the returns to scale. According to Griliches the overestimation of the elasticity of output with respect to capital inputs stems from the probability that firms(farms) with higher levels of managerial inputs are less restricted by capital inputs and are able to substitute quality for quantity. These firms will use less labor, leading to an overestimate of returns to capital and an underestimate of returns to labor.

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[71]Dawson, P. J. and Lingard, J. "Management Bias and Returns to Scale in a Cobb-Douglas Production Function for Agriculture." *European Review of Agricultural Economics* Vol. 9 (1982): 1-24.
[72]Griliches, Zvi. "Specification Bias in Estimates of Production Functions." *Journal of Farm Economics* (1957): 8-20.

Reiss[73] disagrees with the measurement of management as a residual value after contribution of all other inputs have been considered. He feels that this method is not satisfactory because it is an after the fact method(has no predictive value), reflects anomalies (windfalls and tragedies apart from management) and measures a residual output rather than a managerial input. Reiss was interested in finding a measure for management that was able to predict the level of management prior to completion of a successful process but expressed concern as to how one would go about quantifying what success was in light of the fact that each individual has his own interpretation. In an attempt to gather descriptive information on managers, a questionnaire was designed that asked the participants to describe characteristics of different types of managers. This information was in the process of being collated at the time of writing the article.

Yetley and Hoy[74] examined a theoretical model for estimating the direct independent impact of managerial influence on the efficiency of small agribusinesses. In this study they regressed internal variables(lowest salary, needed job training, pervasiveness) and external variables(price leadership, market value of farms, market share) against the observed organizational efficiency of the firm. The residual was thought to contain variation due to the managers effectiveness and error variance that represents the organizational efficiency which the managers can potentially influence in the short term. They were successful in identifying a model that was useful in evaluating managerial performance and in identifying the characteristics of managers who are successful in acheiving their goal of higher levels of organizational efficiency.

Johnson[75] disagrees with the notion that a managerial input has the capability of altering the output acheived by an exactly similar amount of inputs used under exactly the

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[73]Reiss, Frank. "Measuring the Management Factor." *Journal of Farm Economics* (1949): 1065-1072.
[74]Yetley, Mervin J. and Hoy, Frank. "Managerial Influence on Organizational Efficiency: An Analysis of Local Farmer Cooperatives." *Rural Sociology* 43 (1) (1978): 48-69.
[75]Johnson, Glenn L. "A Note on Nonconventional Inputs in Conventional Production Functions." in *Agriculture in Economic Development*. Eicher, C. K. and Witt, L. W.(eds). New York. McGraw Hill Book Company. 1964. pages 120-124.

same conditions. Rather he feels that the superior manager is able to make superior decisions about the amounts and combinations of conventional factors of production which will be employed. In this way the researcher is able to concentrate on the production function in conventional terms and not bias the results because of some subjective managerial input index.

Fane[76] used a Cobb-Douglas relationship to examine a measure of managerial failure which was defined as the difference between estimates of the theoretical minimum cost of factor inputs required for some desired level of production and the actual costs of using the inputs. The idea is based on the assumption that the farmer is a price taker and attempts to achieve some level of production at a minimum cost but because each player does not have perfect information he must base his managerial decisions on imperfect forecasts and thus is not likely to acheive the minimum cost. The developed relationship involved the dependent, proportionate loss, regressed against the independents, years of education, scale of production measured by average sales per farm and other variables. The educational variable was used as a proxy for managerial efficiency and Fane found that the more highly educated farmers had superior managerial efficiency.

Viljoen and Groenewald[77] used a Cobb-Douglas type cross-sectional production function fitted to sample data to relate an output Y(gross farm revenue) against various formulations of variable inputs such as soil, labor, capital and livestock. Six different functions were established. A geometric average of the six functions was calculated and assumed to be the farmers expected return(Ye). The next step was the calculation of his actual return(Ya). A management index was devised by calculating MI where MI=(100((Ya-Ye)/Ya)) and from which a positive index indicated an above average result and a negative index meant a below average result. They divided the original group of farmers into three groups, above average(most efficient),average and below average(least efficient) and made comparisons between the groups on characteristics such as land use, capital

[76]Fane, George. "Education and the Managerial Efficiency of Farmers." *Review of Economics and Statistics* 57 (4) (1975): 452-461.
[77]Viljoen, P. and Groenewald, J. A. "An Approach to Farming Efficiency Analysis as Applied in Ruens." *Agrekon* 16 (4) (1978): 6-13.

investment and application, burden of debt, cost distribution, enterprise ratios and efficiency factors. In the conclusion they write that the most efficient group, when compared to the other two groups, is more realistic and economical about mechanization, does better qualitatively in wheat(measured by price) and is better in livestock production(sheep).

Martinson and Groenewald[78] used cross-sectional production functions in a very similar manner to that of Viljoen(where a high indexed entrepreneur produces more from a certain application of resources than does an entrepreneur with a low index) to test the validity of this index approach in terms of traditional parameters. The hypothesis is that if the index number reflects the same general trend as that provided by traditional parameters, it will serve as an illustration of the validity of such an index as a parameter of farming efficiency. Using the categories as established by the managerial index, comparisons between groups were made regarding financial results(significant differences) and between yield per unit(yields per hectare etc.) where there was no significant difference between the two more efficient groups. A multiple regression, for the whole sample, related the management index to a capital yield index and a cost yield index and revealed that the latter had a greater effect on the management index than did the capital yield index. They conclude that management or efficiency indexes as derived from cross-sectional production functions are a realistic parameter of farming efficiency.

Bowman et al.[79] examined the relationship between 37 farm mangement factors and the variation in herd average production and income over feed costs. On a random sample of 640 dairy farms they found that the 37 management factors explained 79.9% of the variation in the herd average 4% fat-corrected milk and 69.5% of the income over feed costs. The management factors were divided into categories such as general(yrs. farming experience), land and crop management, cow nutrition, calf nutrition and management, mastitis and milking management and production efficiency. They found that the management factor

[78]Martinson, T. J. and Groenewald, J. A. "Management Indices from Cross-Sectional Production Functions: An Empirical Evaluation." *Agrekon* 17 (1) (1978): 1-4.
[79]Bowman, J. S. T., Moxely, J. E., Kennedy, B. W. and Downey, B. R. "The Dairy Herd Management System and Farm Productivity." *Canadian Journal of Animal Science* 60 (1980): 495-502.

associated with the greatest variation in production and income per cow was the amount of meal fed per cow, followed by factors related to efficiency of production.

F. Review of Social Concerns of Drainage

Water related issues, such as slough drainage, generally cause concern about the effects this drainage might have on groundwater and wildlife. As Boulding[10] writes, "......studies of water, though free from aridity, are apt to produce a good deal of turbidity." Therefore, even though one may attempt to assess drainage projects from the private(landowners) point of view, he must be aware of the associated social costs. Unfortunately in many cases some social costs are intangible.

Historically environmental concerns didn't always exist. According to Brande[11], Hippocrates wrote that marshy, stagnant waters were bad for every purpose, and the USDA in 1912, thought there were 70 million acres of unreclaimed land awaiting the touch of the engineer and the activity of the ambitious and enterprising farmer. By 1955 the USDA had a change of attitude and stated that at least 75 million acres of wetland in the United States were unsuited to agriculture but could be used for wildlife, forests and recreation. Brande writes thát wetlands improve water quality by acting as filters, act as storage for excess water, recharge groundwater, provide habitat, prevent erosion, provide recreation, aesthetics, educational and research benefits, filter air and sound, are genetic reservoirs and provide margins of environmental safety. Further he feels that private market values, although adequate to express values to their owners, are inadequate to express public or social values. He urges that proper evaluation of natural acquatic systems should be made applying the tools of economics and other social disciplines.

Whiteley[12] was concerned that drainage projects alter the natural distribution of water

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[10] Boulding, Kenneth E. "The Feather River Anthology" *Industrial Water Engineering* 3 (December 1966): 32-33.
[11] Brande, Justin. "Worthless Valuable or What? An Appraissal of Wetlands." *Journal of Soil and Water Conservation* (January-February 1980): pages 13 & 15.
[12] Whiteley, H. R. "Hydrologic Implications of Land Drainage." *Canadian Water Resources Journal* Vol. 4 No. 2(1979): 12-13.

and will have hydrologic implications and the following effects: 1)changes in the unsaturated soil zone soil water content; 2) changes in surface water storage areas; 3) changes in the water table depth; and 4) changes within and downstream of the drainage channel and will cause deterioration in water quality. Interestingly, items 1, 2 and 3 described as environmental impacts in Whiteleys' article are described as benefits in most drainage studies.

In addition to the above, Leitch[13] feels that some of the social benefits of wetlands include nutrient recycling, firebreaks, historic value, global nitrogen and sulfur cycling and ecological diversity. He states that these benefits have been identified in literature and annual benefits as high as $2500 per acre for water assimilation and $2800 per acre for water supply have been estimated, but he suggests that the pressure to drain land will continue until a proper mechanism is developed to value the benefits of natural wetlands and until wetland owners are given satisfactory monetary incentive to preserve wetlands.

Hammack and Brown[14] have identified the wetlands of east central Alberta as an important waterfowl habitat area. They write, "The rolling, pothole-pocked farmlands of central and southern Alberta, Saskatchewan and Manitoba, together with parts of the neighboring states of North Dakota, South Dakota amd Minnesota, provide the prime duck producing areas of the continent. The region comprises only 10% of the total continent breeding area, yet produces upwards of 55% of the total duck population in an average year."

Schick[15] studied wetland changes from 1900 to 1970 on a 270 square mile block in the Alberta Parkland, within the boundaries of the area under study in this research, and concluded that "the loss of wetland was a serious problem in this area with over 60% of the original water having disappeared in only 70 years. This situation could be true for other areas as well. Much of the drainage that has occurred represents an irrevocable loss of habitat for waterfowl and a myriad of other wildlife species."

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[13]Leitch, Jay A. "The Wetlands and Drainage Controversy - Revisited." *Minnesota Agricultural Economist* No. 626 (March 1981): 1-5.
[14]Hammack, Judd and Brown, Gardner, Mallard, Jr. *Waterfowl and Wetlands: toward bioeconomic analysis.* Baltimore. The Johns Hopkins University Press. 1974.
[15]Schick, Craig, D. *A Documentation and Analysis of Wetland Drainage in the Alberta Parkland.* Unpublished. Canadian Wildlife Service. March 1972.

Alberta Environment[16] is aware of the above concerns regarding wetlands and their policy is to manage the Provinces water resources in support of the overall economic and social objectives of the province and these objectives are described as a "committment to a program of balanced economic growth, the general welfare of Albertans and the present and future quality of life." Some philosophies practiced by the Department of Environment include:

1. Multipurpose use of water vs single purpose use;
2. The responsibility for the initiation of the project lies within the local government or the individual;
3. The department is responsible to protect permanent water bodies from indiscriminant drainage; and
4. This department is responsible for protecting the environment and landowners from indiscriminant drainage by other landowners.

One of the suggestions for reducing social costs imposed by land drainage, slough consolidation, is proposed by Jensen[17]. Consolidation involves establishing one larger slough, in an out of the way corner of the field, from the numerous smaller ones that are causing the problem. It is thought that both ends could be met, i.e., getting rid of the field obstacle and maintaining a wildlife habitat. Projects of this type would involve cooperation between landowners and government people and would undoubtedly be costly and time consuming, but would mitigate the overall social costs of draining.

[16]Alberta Environment. *Drainage in Alberta - A Discussion Paper.* Unpublished. Alberta Environment. December 1983. page 22-23.
[17]Jensen, N. E. and Green, J. E. *Slough Consolidation for Farm Drainage and Wildlife Mitigation.* Presentation at the Canadian Water Resources Association Annual Conference. Lethbridge. June 1985.

III. FINANCIAL METHODOLOGY, SAMPLING AND BEHAVIORAL ANALYSIS

This chapter outlines the methodological procedure used in establishing project viability. The methodological procedure closely follows the method of analysis outlined by Gittinger[11] and is the method generally used by the World Bank in *a priori* appraisal of projects connected with agricultural and rural development.

A. Farm Investment Analysis

A financial or economic appraisal of a proposed project is properly conducted prior to undertaking that project. The drainage projects dealt with in this paper have been completed already and are providing returns to the investors. Therefore the research reported here amounts to an *ex post* appraisal of drainage projects to determine exactly how profitable or potentially profitable they really are based on known costs and actual experience with benefits.

Gittinger[12] suggests that there are six major objectives in *a priori* financial analysis of agricultural projects. The first objective is to assess the financial effects that the project will have on all parties involved in the project. Depending on the accounting stance taken, this may involve one or more of the following, farmers, public and private firms or government. The second objective is to make an overall judgement of the efficiency of resource use. This is an examination of the overall returns to the project using farm investment analysis and financial ratios . A third objective of financial analysis is the assessment of incentives. Basically this addresses the issue of whether or not the incremental returns from the project are large enough to compensate the investor for the additional effort and risk incurred. The fourth objective of the financial analysis is to work out a plan that projects the financial situation and sources of funds of the project participants and the project. This plan should consider the timing of the investment, the repayment terms, the conditions for credit and the effects of inflation on both revenues and costs.

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[11] Gittinger, J. Price. *Economic Analysis of Agricultural Projects*. 2nd Edition. Baltimore. The Johns Hopkins University Press. 1982.

[12] ibid. page 86-87.

The fifth objective of the financial analysis provides a vehicle for coordinating the financial contributions of the various project participants and addresses questions pertaining to the availability of funds and investment capacities. The sixth objective of financial analysis is to assess the financial management capability of the manager of the project and to judge whether or not this individual will require additional training to effectively manage this project.

The above paragraphs describe the objectives of *a priori* financial analysis of agricultural projects. The research undertaken by this study was an *ex post* assessment of individual drainage projects and although the six major objectives cannot be followed precisely, the objectives that apply to the drainage project assessments will be highlighted.

Firstly, the main objective of this study, was to assess the economic viability of on-farm drainage projects and to determine, through detailed financial analysis using private benefits and costs, whether drainage projects were worthwhile for the landowner(i.e., to determine the rate of return on investment). All sources of funding were treated as private funds even though some projects received grants provided by the provincial government through the municipalities or counties via a cost sharing scheme(Appendix C).

The judgement of efficient resource use and assessment of incentives were both judged on the basis of the internal rate of return criterion. If the IRR was sufficiently high, such that it was higher than the opportunity cost of capital(either the interest on borrowing money or the return on the best alternative investment) and provided compensation for the risk and effort incurred by the landowner, the project is considered economically viable. The fourth objective, providing a sound financial plan and the fifth objective, coordination of financial contributions, were not relevant to the projects considered by this study.

Rather than as the sixth objective suggests, to assess the financial management capability of the project manager, this study attempted to relate *ex post*, management intensities to the calculated internal rate of return of the projects. Information on input use, capital use, land use, characteristics of the farming system before and after project implementation and changes of the use of the above during the life of the project, were used as proxies for management intensity. A good manager is assumed to use more of a variable input than a bad manager[10] and a landowner who manages his farm more intensely is hypothesized to have a better project return than the landowner who managed less intensely.

B. Preparing the Drainage Viability Analysis

In this study farm investment analysis is undertaken to establish the financial attractiveness *ex post* of individual drainage projects to individual land owners. This study looks at the actual costs and returns attributable to the project and follows the principles of discounted cash flows over the projected useful life of the project. The cash flows include actual cash returns because of the project, such as crop revenues from the increased acreage. The cash flow also examines the non-cash components such as the farmer's own labor used to complete the project and the labor time saved because of the project, the estimated equipment time savings and an estimate of the dollar savings because of the elimination of grain damage due to waterfowl. Returns to a project are calculated based on strictly cash benefits and based on a combination of both cash and non-cash benefits.

Since the drainage project occurs on land already owned by the farmer and since he is already paying taxes on this land, only variable costs involved in putting the land into production were considered. In some cases the cost of going around a wet area and the resulting wasted inputs are equal to the cost of inputs necessary to put the area into production. In one sense this analysis is a partial budgeting procedure[11], a method of assessing alternatives, in which the present values of all the costs and benefits are presented for the two alternatives, with the drainage project and without the drainage project. This is a budget that applies to only some particular investment activity and doesn't generally affect the whole

[10]For this assumption to hold one must also assume that the particular manager is aware of the classical production function theory and its' three stages and is operating in Stage II, that is some point on the production curve where the MPP is decreasing, less than the APP, but greater than zero. Doll, John P. and Orazem, Frank. *Production Economics*. 2nd Edition. New York. John Wiley and Sons, Inc. 1984. page 37.

[11]Petersen, T. A. *Advise on Methods and Techniques for Evaluating Alternatives. Prepare and Use Partial Budgets.* A Canada Farm Management Committee Project. August 1975.

farm operation.

A crucial source of information in project analysis is the farmers themselves. Interviews of farmers are necessary to gather information about a project, with the interview being preferably in the field where the project took place.

C. Elements of Drainage Viability Analysis

The following section outlines the principal elements of drainage viability analysis. The accounting stance, accounting convention, farm resource use, farm production and farm inputs will be examined in the context of this study.

Accounting Stance

Discussion on chosing the proper accounting stance was presented in the previous chapter. In brief, only private costs and benefits, valued at private market values, are considered in this financial appraisal of projects.

Accounting convention for farm investment analysis

This farm investment analysis follows the principles of discounted cash flows. This adopted accounting convention has been called the "time adjusted" convention. Year one in the project analysis is the accounting period in which the project investment takes place and year two is usually the first accounting period in which there may be incremental operating costs or incremental benefits because of the project. An accounting period is equivalent to one year. All benefits and costs are also assumed to fall at the end of the year. An exception to this rule is the necessity of having operating funds available at years end to cover production expenses for the next cropping year, i.e., the following spring. In this case if the production on the drained land were to begin in year two, then enough funds would have to be available at the end of year one to cover all costs associated with the project plus the costs associated with the production of year two's crops. This process would continue over the total life of the project. Operating funds for the last year would be entered in the cash flow at the end of the penultimate year, but the benefits from the last year won't appear until the end of year fifteen. This concept reflects real resource use in the sense that seed, fertilizers, chemicals, fuels etc. must be available prior to sowing the crop in order to ensure a crop the following fall.

Gittinger[97] explains that this accounting convention is not much different from those most commonly used. The most important differences however are the rule reserving year one for investment only, except when operating costs are required for year two, and the assumption that the investment will fall at the end of the year. He claims that it is more common to include investment in year one but to assume that it will fall at the beginning of the year, even though the discounting process assumes it falls at the end of the year. Production is then assumed to be increased in year one, an assumption that leads to an overestimate of the rate of return on the capital used by overestimating the income available to the farmer in the early years of the project. Another difference between the accounting convention adopted here and that most commonly used is a matter of completeness such that it is easy to inadvertantly omit or underestimate working capital unless the working capital is specifically included in the convention.

Farm Resource Use

Land use in this study involved determining what use was made of the land involved in the project prior to drainage and what use was made of the land after drainage. Based on the after project cropping intensity, a land use factor was established that represented the difference between the land use before and after. For example, if the land was not used before and was used every year after, the land use factor was 1. If the land was previously used in one out of two years and after the project was used in every year, the land use factor is .5. From this information one was able to obtain the incremental benefits that could be attributed directly to the project and the incremental working capital required to put this additional area into production.

[97]Gittinger, J. Price. *Economic Analysis of Agricultural Projects.* 2nd Edition. Baltimore. The Johns Hopkins University Press. 1982. page 99.

The second aspect of resource use considered is labor. In drainage projects, labor is required in the construction, operation and maintenance of the project and in putting the additional area into production. Labor, in the behavioral analysis, is a person day. A person day is equivalent to 8 hours of work. No attempt was made to distinguish between the different qualities of the labor input. Hired employees work under supervision and receive wages, presumably corresponding to their input. All labor was valued at $7.50 per hour[93]. Machinery costs in most cases included labor if necessary. Labor costs were charged as incremental costs in the year in which the costs occurred. In some cases the removal of the obstacle(wet area) was a labor saver and this labor saving was treated as a non-cash benefit, valued at the same value as labor costs. This study assumed the project was not so large that additional outside labor would be required, but if it were required it would be available at the going rate.

The third aspect of resource use is the use of capital. Capital was initially required for the costs of the drainage system and the rehabilitation of the drained area at the outset of the project. Incremental working capital, operating funds required to produce a crop in any given year, had to be made available at the end of the preceeding year. Capital for operating and maintaining the system was to be available as required.

Farm Production and Valuation

This subsection considers the valuation of farm production and the incremental residual value on the farm resulting from the project.

The value of production of grains and oilseeds were established by multiplying the yearly market price[94](Appendix D)[95] per bushel of produced crop(converted to constant 1985

[93]Alberta Agriculture. *Farm Machinery Costs as a Guide to Custom Rates-Spring 1985*. Edmonton. Alberta Agriculture. Agdex No. 825-4. Spring 1985.
[94]Prices supplied by Statistics Branch, Alberta Agriculture. Appendix D.
[95] Note that projected 1984 prices were used as a proxy for 1985 prices. From available 1985 data it appears actual 1984 prices are slightly higher than the projected 1984 prices and projected 1985 prices are lower than the 1985 prices used in this study.

dollars via the Farm Input Price Index[96](Appendix E) times the number of acres gained by the project times the land use factor for the drained area. For example if the area yielded 60 bu. of wheat per acre on 20 acres of gained land in 1982(adjusted to $1985 using the FIPI(0.951)) that was not used prior to the drainage(land use factor 1), the incremental gross benefit from production would be $5729.(60 bu/ac x 20 ac x ($4.54/bu /0.951) x 1)

The value of tame hay was established from hay production information provided by farmers based on the land gained, the land use factor and the prices for tame hay supplied by Statistics Branch, Alberta Agriculture(Appendix D). Prices for areas of native hay and greenfeed were not available, therefore prices were established by multiplying the nutritional value ratios of native hay and greenfeed to tame hay times the price of [illegible]. This study assumes the nutritional value is proportional to the dollar value. For [illegible] according to the Beef Cow - Calf Manual[97] the average nutritional value of ta[illegible] 1.09 Mcal/lb. of feed and that of greenfeed(based on the average of barley and oats) is 1.18 Mcal/lb. of feed. Therefore if tame hay is valued at $81.00 per ton, the value of greenfeed is assumed to be $81.00/ton x (1.18 Mcal/lb)/(1.09 Mcal/lb) = $87.69/ton. The nutritional value of native hay is 0.97 Mcal/lb. of feed and would therefore command a price on the market that is less than either the price for tame hay or greenfeed(i.e., the price of native hay would be (.97 Mcal/lb)/(1.09 Mcal/lb) x $81.00 = $72.08).

There was some difficulty in establishing what the benefits would be from drained land that was used as livestock pasture. Information was available from the survey that indicated approximately how many cattle were pastured on the gained land and for what length of time. This information was established in most cases by determining the change in animal units or the change in the length of grazing time, by establishing both the with and without drainage scenarios. If the length of grazing season was not specified, a time frame of six months was used. The livestock numbers were converted into animal units. One animal

[96] Statistics Canada. *Farm Input Price Index*. Catalogue 62-004. Quarterly. Statistics Canada. 1971-1985.

[97] Alberta Agriculture. *Beef Cow-Calf Manual*. Edmonton. Alberta Agriculture. 1981. page 36.

unit(au) is described as a 1000 lb. cow with calf. Other animals vary in their animal unit equivalents[98]. The assumption that all animal units at least maintained their body weight while on the pasture was made. In order to accomplish weight maintainance the animal unit requires 26 lbs of dry matter per day or 800 lbs of dry matter per month[99]. Therefore if an extra 10 animal units were placed on a pasture of 20 acres in size for 6 months, it is estimated that this pasture would yield (800 lbs/au x 6 mo. x 10 au) / 2000 lbs/ton / 20 ac = 1.2 tons per acre of pasture. This pasture yield is then valued at the calculated market value for native hay. For example, in the preceding, native hay was valued at $72.08, and based on this value the benefit per acre of pasture gained would be 1.2 tons/ac. x $72.08/ton = $86.50/ac. The above assumptions simplify the benefit calculations by eliminating the need to determine the portion of the herd composition gains that can be attributed to the gained land. Underlying these rather simplistic assumptions are some rather strong technological and economic assumptions. First, the production on the pasture is capable of being harvested and, second, the production could be sold in the market at the market price.

Non-Cash Benefits

Two basic types of non-cash benefits exist. The first type, for which a value can be imputed, is the landowners subjective estimate of the labor time, machinery time and input savings because of the removal of the obstacle(wet area) and his estimate of the reduced losses due to waterfowl damage, once the wet area that may have been attracting waterfowl has been removed. Values for machinery time were calculated using the landownners estimate of the time savings for each particular field operation multiplied by the 1985 Farm Machinery Costs'[100] value for his particular machinery complement. For example the landowners tractor power was matched against the implement required for the specific operation and the approximate size appropriate for the tractor horse power. Estimates of labor savings were

[98]Alberta Agriculture. *Beef Cow-Calf Manual.* Edmonton. Alberta Agriculture. 1976. pages G-1 & G-2.
[99]ibid. pages G-1 & G-2.
[100] Alberta Agriculture. *Farm Machinery Costs as a Guide to Custom Rates.* Edmonton. Alberta Agriculture. Agdex No. 825-4. Spring 1985.

converted to monetary values by multiplying the labor hours by the estimated cost of labor as supplied in the 1985 Farm Machinery Costs Manual(7.50 per hour). Input savings were the landowners estimate of the fertilizer, seed, herbicides etc. that was not wasted either because of overlapping operations or from initial application that, in a wet year, may have become flooded out after application. Waterfowl damages were the landowners estimate of the quantity of products lost(bushels of grain etc.) and converted to dollar values at the market value for the crop in a particular year. Waterfowl damage was usually given as a loss in a particular year that seemed to stand out in their memory. In these cases these values were converted to yearly flows using information on waterfowl damage supplied by McConnell[101]. McConnell found that in 2105 townships in Alberta, damage claims were made on an average of 4.56 years out of a maximum of 18 claimable years or in 25.3% of the years. Of these claims 70% were attributable to waterfowl depredation. Therefore, waterfowl damage occurred in 17.7%(25.3 x .7) of the years or in one out of 5.65 years(a spokesman from Alberta Fish and Wildlife estimated waterfowl damage in one out of fifteen years.[102]). The yearly damage was then calculated as the estimated damage divided by 5.65.

The second type of non-cash benefits are those for which it would be difficult to impute values. These benefits include improvements in soil structure and salinity conditions, improvements in seed germination rates and plant drought resistance, reduced dockage, reduced plant parasites, reduced weed problems, advancements in seeding time, an extended harvest season, the ability to change species grown, greater evenness in maturity of crops and the ability to get on a drained field sooner after a heavy rain.

Incremental Residual Value

The incremental residual(terminal) value[103] is treated as an inflow in the last year of

[101]McConnell, R. D. "Compensation for Waterfowl Depradation in Alberta with Particular Reference to Habitat Availability." MSc. Thesis. University of Alberta. 1984.

[102]Lungle. Ken. Alberta Fish and Wildlife. Verbal communication. Summer 1985.

[103]Gittinger J. Price. *Economic Analysis of Agricultural Projects*. 2nd Edition. Baltimore. The Johns Hopkins University Press. 1982. page 117.

the farm investment analysis and is credited to the project investment. Three types of residuals are normally considered. The first is the salvage value, the assumption being that the life of the investment is almost used up and is only worth an amount it could be sold for as scrap. In this study neither the ditches nor the buried tile are likely to have any scrap value. The second type of residual value is the working capital which is automatically allowed for under the accounting convention adopted for the farm invetment analysis. This involves the addition of increases and the subtraction of decreases in working capital to obtain the residual of working capital in the final year. The third type of residual value is the value of the items that have a substantial life remaining at the end of the project and may even have increased in value as a result of the project investment; land with associated improvements and a livestock herd are examples.

No incremental residual value was included in this farm investment analysis because the useful life of the project was assumed to be 15 years after which time the investment is worth zero(i.e., without maintenance) because the drainage system is no longer functional[104]. This assumption also eliminates the need to establish a residual value for the increased land value[105].

D. Farm Inputs

The inputs required in implementing the drainage projects were the required investment for construction, rehabilitation, operation, maintenance and the incremental working capital(production costs) for the project.

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[104]In the sensitivity analysis yearly maintenance costs equivalent to 3% of the system cost were considered. Theoretically a well maintained system would have an indefinite project life but because the longer into the future the benefits and costs occur and the less is their present value and there was a desire to obtain a conservative estimate, a 15 year project life was maintained even with yearly maintenance.
[105]It is acknowledged the land improvement made by the drainage system may increase the value of the land, since land value is a function of its' potential agricultural productivity and drained land is more productive than undrained land. The assumption that after 15 years the system is no longer functional and thus no lomger contributes to productivity, eliminates the need for speculating as to the value added to the land by the drainage system. Again, this will contribute to a more conservative estimate of the project returns.

Investment

From the information obtained through the interviews, the year of the drainage installation and the costs of the project system were established. This year served as year one in the cash flow. The first set of costs involved the drainage system itself. The set included, where obtainable, separate costs for survey and design, and often, especially in most surface drainage projects, these were obtained from Alberta Environment. Landowners supplied installation and construction costs, special equipment costs and other costs if any. In cost sharing schemes, the representatives of the local authority supplied the value of the grants. Landowners with subsurface drainage projects were usually unable to differentiate between the costs attributable to survey, design, installation and construction, special equipment and other components. They usually paid for the system as a package that included all of the previously mentioned costs.

The second type of costs established were rehabilitation costs, those costs necessary to ready the drained land for production. Rehabilitation costs usually involve brushing, breaking, rock picking, extra weed control and extra(more than normal) seed bed preparation. Most of the time it involved the landowners labor and equipment and in some cases, special hired equipment as well. Costs of the hired equipment were obtained and usually labor and equipment hours for the landowners own equipment were obtained. The latter items were costed out according to the 1985 Farm Machinery Costs[106]. If any other costs were involved(e.g. lowland grass seed, in special cases), these were included under rehabilitation costs.

The third type of costs considered were the operating costs of the system if there were any. These costs may have been for special equipment with variable costs necessary to keep the system operational on a yearly basis.

The final costs considered were maintenance costs. These involved any repairs that may have been required during the life of the project to keep the system functional. Landowners reported actual costs they had incurred during the life of the project. Most

[106]Alberta Agriculture. *Farm Machinery Costs as a Guide to Custom Rates.* Edmonton. Alberta Agriculture. Agdex No. 825-4. Spring 1985.

projects were in the early stages of their fifteen year life and major maintenance costs had not yet been incurred. The effect of maintenance costs are discussed in the measurements of project worth.

The timing of all costs was important to the cash flows and each cost was entered under the project year in which it occurred.

Production Costs(Incremental Working Capital)

Incremental working capital entered cash flow as production costs in the year previous to the one in which the production was to take place. The exception to this situation was the case in which a crop was produced on the drained land in the first year of the project. In this case the timing of the benefits from crop production and the costs of crop production occurred at the same time the result is a slight understatement of the production costs.

In calculating costs only the variable(cash) costs of production are consisdered. The assumption was made that fixed costs have been absorbed by the rest of the farm operation previous to the project and will continue to be so covered. Production costs involved the costs of seed, fertilizer, fungicides, herbicides, crop insurance, field operations and transportation. Costs, in 1985 dollars, were based on prices supplied by the Statistics Branch, Alberta Agriculture(Appendix D), the 1985 Farm Machinery Costs[107], the Guide to Crop Protection in Alberta(Bluebook)[108] and the Alberta Hail and Crop Insurance Corporation rates[109].

Seed was valued at 1.5 times the market price for grains and 2 times the market price for canola[110]. Seeding rates were 1.5 bu/ac grains and 10 lbs/ac canola. Fertilizer costs were the amount of actual product applied in pounds per acre multiplied by $0.29 per pound. Herbicide and fungicide costs were based on the stated application rate if avaliable or the recommended Blue Book rate multiplied by the Blue Book product cost. The cost of crop

[107]Alberta Agriculture. *Farm Machinery Costs as a Guide to Custom Rates.* Edmonton. Alberta Agriculture. Agdex No. 825-4. Spring 1985.
[108]Alberta Agriculture. *Guide to Crop Protection in Alberta. Part I-Chemical.* Edmonton. Alberta Agriculture. Agdex No. 606-1. 1985.
[109]Alberta Hail and Crop Insurance Corporation. *Canada-Alberta Crop Insurance Premium Rates.* Lacombe. Alberta Hail and Crop Insurance Corporation. 1985.
[110]see Appendix E.

insurance, if used by the landowner, was based on the site and crop specific rates as supplied by Alberta Hail and Crop Insurance Corporation. Transportation costs were based on the rates in the 1985 Farm Machinery Costs. The number of field operations were based on a group average as calculated on the information supplied from the survey. Because the survey did not gather information on all the necessary pieces of equipment, average variable costs for each type of equipment(labor included) were calculated from data supplied in the 1985 Farm Machinery Costs. For example, the sum of the variable costs and the capacities for various widths of cultivators were averaged to obtain an average cost per acre of a cultivating operation. The summation of the variable costs gave a total per acre cost of producion. This total was multiplied by the land use factor(an indicator of the proportional increase in land use between the with and without drainage scenarios) and by the total number of acres on which production was to occur. This resulted in total production costs for the next years production on the land gained from the drainage project.

E. The Role of Depreciation in Discounted Cash Flow Analysis

Depreciation is defined as the anticipated reduction in the value of an asset over time, that is brought about through physical use or obsolescence. The question often arises as to how the depreciation cost is accounted for in the discounted measurement of project worth.

Depreciation is not a cash outflow and is not considered in forecasting cash flows. The cash outflow takes place at the time of the investment and depreciation merely represents an amortization of this original expenditure---the accountants attempt to allocate the original outlay over the expected life of the asset. To include both the initial outlay and the amortization of it would be incorrect[111]. In this study the cash outflow is considered at the time of the original investment.

[111]Aplin, Richard D., Casler, George L. and Francis, Cheryl P. *Capital Investment Analysis Using Discounted Cash Flows*. 2nd Edition. Columbus. Grid Publishing, Inc. 1977.

F. Income Taxes

The Canadian Farmers Income Tax Guide[112], under the section entitled, "Clearing or Improving Land" states that, "Amounts paid for clearing or levelling land, for tile drainage,or constructing an unpaved road on the farm property are deductible expenses in the year in which they were paid by a taxpayer who was engaged in a farming business[113]." Although tile drainage(subsurface) is specifically mentioned, ditch drainage(surface) is also tax deductible as an expense for improving land. During the survey, information was gathered from the land owners regarding whether or not they used the cost of the project as an income tax deduction in the year in which it was installed and they were asked to recall their marginal income tax rate for that year. If they could not specify the exact percentage, they were asked, in what income tax bracket they thought they were(i.e., low, medium or high). Using this Farmers Income Tax Guide, average low, medium and high marginal tax rates were calculated and used in the cash flow analysis if the actual rates were not available.

For analytical purposes, both income tax and non-income tax cases were considered in the cash flows to evaluate the economic viability of the drainage projects. Tax deductable expenses considered were all the costs associated with the drainage system and production except grants and the farmer's own or families labor. All cash benefits were taxable. Non-cash benefits, since they were subjective values, were not included in the income tax calculations. In the years of a negative cash flow, negative income tax was paid(i.e., a deduction) but in the years of positive cash flows, positive income taxes were paid.

G. Establishment of Project Worth

Once all of the farm costs and benefits have been identified, the procedure for establishing the project viability can continue. Of the four criteria discussed earlier, only two, the net present value criterion and internal rate of return criterion were used in actual project

[112] Revenue Canada. *Canadian Farmers Income Tax Guide*. Ottawa. Revenue Canada. 1970-1985.
[113] Revenue Canada. *Canadian Farmers Income Tax Guide*. Ottawa. Revenue Canada. 1984. page 8.

appraisals in this study.

H. Choosing the Project Life

The project life is the length of time over which the economic analysis should be carried out. The project life is the length of time the investor has to try to recover his investment and opportunity cost. A general rule is to choose a period of time that will be roughly comparable to the economic life of the project. For some projects the technical life may be quite long even though the economic life, because of technological obsolescence, is short. Based on theoretical information supplied by Leitch[114] and Rigaux and Singh[115] a project life of fifteen years was assumed for both surface and subsurface drainage projects. This project life was considered to be technically realistic and did not extend so far into the future that the net present value of distant benefits was meaningless.

I. Sampling Method

The process of data collection for this research began in April 1985, with the preparion of an inventory of on-farm drainage projects undertaken in east central Alberta and was finished with the completion of on farm interviews during early September 1985.

Names of people who had actually drained land had to be gathered. Initial contact was made with Water Resources Administration Division, Alberta Environment, Edmontón, who are in charge of licensing all projects. They supplied a list of project names under their Farm Surface Water Program and provided open access to their licensing files. The list also contained the legal discription of the drainage project and made elimination of the projects that did not fall within the boundaries of the study area easy. The applicable files were examined and all names and addresses were listed for future telephone contact. Because the

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[114]Leitch, Jay A. *Economics of Prairie Wetland Drainage*. For presentation at the 1982 Winter Meeting. American Society of Agricultural Engineers. Paper No. 82-2543. December 1982. page 5.

[115]Rigaux, L. R. and Singh, R. H. *Benefit Cost Evaluation of Improved Levels of Agricultural Drainage in Manitoba-Economic Feasibility of Investment*. Research Bulletin No. 77-1(Volume 3) page 137.

Edmonton region of Alberta Environment did not extend to the southern part of the study area additional names were gathered from the Red Deer regional office.

The Water Resources Administration Division, Alberta Environment, Red Deer also allowed open access to their licensing files. The same procedure as previously mentioned was used and a list of drainage projects that fell within the boundaries of the study area made.

The third major contact was C. W. Farmland Reclamation Ltd., a drainage contractor in Olds, Alberta. This contractor had just compiled a list of all the drainage projects in Alberta that he had completed, at the request of the Drainage Branch, Alberta Agriculture, in Lethbridge. In compiling this list the firm had informed their clients that Alberta Agriculture was doing an inventory of drainage projects and that they would be mailing them a questionnaire for more detailed information and that all information would be kept strictly confidential. The list of drainage projects was supplied but permission to contact the individuals, at least until they had a chance to contact them, was not given. The drainage projects that fell within the boundaries of the study area were listed and returned to the contractor with the request for permission to contact these people. Some names that appeared on the contractors list also appeared in Alberta Environments files, usually because some complaint had been filed by a neighbor for example. The people whose names appeared in the public files were contacted directly. Permission to contact the rest of the people was finally given in June 1985.

For additional names the Drainage Branch, Alberta Agriculture, Lethbridge, was contacted but they would not release names of individuals who had drained land, because of a promised confidentiality. They did say however, that the names supplied by the previously mentioned contractor represented about 95% of the completed subsurface drainage projects within the boundaries of the study area.

District agriculturalists and agricultural fieldmen, from the counties and municipalities within the study area were contacted in a final attempt to gather names and were asked if they were aware of any drainage projects in their area. These individuals were generally not able to supply any additional names.

Telephone contact with the names that were gathered began in late May 1985 and continued until July 1985. Individuals who were contacted were also asked if they were aware of any other drainage projects in or around their area. Many of the names that had appeared in Alberta Environments files were not directly involved with drainage on their farm, but rather appeared on file because an easement on their land was required.

During the initial telephone contact with approximately 150 individuals, the following information was gathered and recorded. Name, address, phone number, legal location of drained land, the type of drainage system, contractor if applicable, size of farm, cultivated acreage, size of the drained area, soil type and any additional information, including the year of drainage, the horse power of the largest tractor and the use made of the land since drainage.

Of the 150 contacts initially made, only 105 were considered usable. Of the 105 usable sites, 58 were surface drainage and 47 were subsurface drainage projects. The unusable contacts had to be eliminated because their project had never been completed, they were only involved through an easement or the individuals were deceased.

The following limits were set in order to remove very large or very small farms. The decision to include only farms of a size between 320 acres and 2560, and with a drained area of at least ten acres in size, was made. Drained areas smaller than ten acres were assumed to have no effect on the farm operation. With the limits set, the final set consisted of 39 surface and 27 subsurface drainage projects.

Because one of the objectives of the study was to assess the economic viability of the alternative drainage systems based only on the drainage system, a matched-paired analysis approach was chosen. From the 66 acceptable projects twenty pairs of farms were established, matched primarily on the total size category (i.e., between 320 and 639 acres etc.). Within this primary category the farms were matched based on similar cultivated acres, tractor horsepower, size of drainage project, soil type and crop grown on the drained land. The operators of these twenty pairs of farms were interviewed in person.

From these twenty interviewed pairs, five pairs had to be disqualified because four operators were unable to supply complete information and one operator would not cooperate in providing information.

The final result was fifteen usable pairs on which frequency and management data were compiled.

J. Questionnaire Design

The questionnaire was designed to obtain information necessary to fulfill the objectives of the research. Of particular interest was descriptive information about the particular farm before and after the drainage system had been installed, use of the land before and after the system was installed as an indicator of the benefits that resulted because of the drainage system, cost of the drainage system and particulars about the drainage system itself. The first draft of the questionnaire was pretested on three interviews and modified slightly before the final questionnaire was ready. A copy of the final form of the questionnaire used in on-farm interviews can be found in Appendix F. It was divided into seven sections as follows.

Section A, history of drainage, provided some general background information about the drained area, about perceived expectations and benefits from drainage, and about the timing of drainage and about the length of time required before the drained area was put into production.

Section B, biographics, provided some information about the physical make up of the farm, the size of the farm family and an indication of the labor intensity on the farm.

Section C, capital cost, operation, maintenace and rehabilitation, provided information on the cost of getting the drained area into production. Although this section was completed during the interviews, it proved to be one of the sections that had to be modified to allow for proper data entry. The pre-test did not subject the questionnaire to multiple installation and rehabilitation year situations. A modified form which allowed for up to four different years of installation, rehabilitation, maintenance and operating costs was designed to aid in data collating. System cost information in this section had to be supplemented with information from repesentatives of the local authority in those projects where cost sharing occurred.

Section D, dimensions of the drainage, was an attempt to find out technical specifics about the drainage system. Landowners with subsurface drainage projects were generally unable to remember or never knew the lengths of the different diameters of tile installed. Total tile length was obtained from information supplied by the contractor. Landowners with surface systems were better able to "estimate" the lengths, widths and depths of ditches. Of interest was the amount of land actually lost to these ditches.

Section E, benefits, provided information about the benefits gained from the drainage system. Benefits ranged from income tax savings, areas gained and improved and frequencies of land use before and after(land use factor), to non-cash savings such as input and time savings, soil and plant improvements and waterfowl damage savings. Modifications to aid the collating of data presented in Section E, question ten and question 29 had to be made. The possibility of more than one use of the drained area in any given year was unanticipated in question ten. The most extreme case involved up to three different uses per year on the drained land for the past thirteen years. The format of question 29 was modified to allow for the calculation of machinery time savings and the dollar equivalent benefits that resulted.

Section F, intensity of farming, provided some additional information about the structure of the farm, the machinery complement and the livestock on the farm both before and after drainage. The landowner provided information about the machinery complement. Machinery values were obtained from Official Guide: Tractors and Farm Equipment[116].

Section G, management intensity, was designed to obtain information about the intensity of land use, use of herbicides, fungicides and fertilizers both before and after the drainage. This study assumed that these data would provide a key to the relationship if any between management intensity and drainage payoff.

[116]National Farm and Power Equipment Dealers Association. *Official Guide: Tractors and Farm Equipment*. St. Louis. National Farm and Power Equipment Dealers Association. ISSN 0162-6809. 1972-1985.

K. In-Person Interviews

In addition to the twenty pairs of landowners two extra landowners were selected to act as replacements in the case where the originals weren't acceptable. Interviews were arranged via telephone calls and attempts were made to interview people located in approximately the same area at different times of the same day. Setting interviews in approximately the same location on the same day allowed for as many as three interviews in one day. The interviews were divided into two groups, based roughly on similar areas and interviewed by one of two interviewers. Approximately half of the landowners were interviewed by each interviewer.

Interviews started on August 15, 1985 and were completed by September 09, 1985. Each interview usually took an hour to complete provided the session was a straight question and answer one. Generally, the landowners were very cooperative and available once the interview was arranged. There were, at times, difficulties in arranging the interviews via telephone because some of the interviewing took place during the harvest season. Information obtained was mostly from the landowners memory[11] and in cases in which the drainage had taken place some time ago, respondents had difficulty remembering how the land had been used over the few years preceding the project. At these times, if one started with the land use in 1985, the current year, everyone could remember their rotation and backtrack to the year before drainage. Information on yields were mostly averages but particularly good and bad years seemed to stand out in the persons memories.

The impressions obtained from the landowners were that they had a genuine belief that drainage projects were economically worthwhile, especially if some of the technical problems could be eliminated. To estimate the satisfaction or importance of the drainage to

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[11]Unlike experimental data, non-experimental data is generated independently of the researcher; the only control he may exercise is to use some purposive method of data collection *ex post*. Such control, being *ex post*, cannot be nearly so effective as the *ex ante* control that is possible over experimental data. For instance, real-world data generally being collected "after the event", errors of observation are to be expected in the explanatory variables. This state of affairs is particularly apt to be true with survey data where the researcher has to rely on the respondents recall of his past actions. Heady, Earl O. and Dillon, John L. *Agricultural Production Functions*. Ames. Iowa State University Press. 1961. page 145.

the landowner, a question was asked regarding the amount someone would have to pay them not to have drained this land. Answers varied from nothing, in the case where a landowner felt it wasn't feasible to drain the land and was better off left for waterfowl habitat to the extreme of having the person or agency not wanting the land drained to purchase the whole quarter at the market price.

L. Statistical Tests, Transformations and Behavioral Analysis Procedure

The following sections of this chapter describe procedures employed to test for correct pairing of farms and normality of dependent variables. Also included are descriptions of procedures used to normalize the dependent variable and to determine which independent variables were correlated with the dependent variable. The last two sections outline the stepwise regression procedure and behavioral analysis.

Kolmogorov-Smirnov Two-Sample Test

Kolmogorov-Smirnov two-sample test is used to establish whether two samples have been drawn from the same population with the same probability distribution functions. The two-tailed test is sensitive to any kind of differences between the two distributions, including differences in location(central tendancy), dispersion, skewness and kurtosis[118]. When compared to the t-test, the Kolmogorov-Smirnov two-sample test has a high power efficiency(about 96 per cent) for small samples and seems to be more powerful in all cases than either the chi-square test or the median test[119]. This test provides a comparison between the cumulative frequency distributions of the surface and subsurface drainers and verifies or refutes that they came from the same parent population. If two independent random samples are drawn from the same continuously distributed parent populations, and if their cumulative frequencies(or relative cumulative frequencies) are plotted on a single graph, the difference

[118]Siegel, Sidney. *Nonparametric Statistics for the Behavioral Sciences.* New York. McGraw-Hill Book Company, Inc. 1956. page 127.
[119]ibid. page 136.

between the two curves are independent of the distribution of the population[120]. The purpose of the procedure is to determine the maximum difference between the cumulative frequencies of the two samples and compare that difference to a tabulated value to establish whether or not it is too large to be reasonably attributed to chance. There are two basic procedures to be followed, the procedure for small samples of equal size(i.e., N lt. or eq. 40) and the procedure for large samples or samples of unequal size. There is some discrepency about when to apply the large sample size procedure. For example Siegel[121] and Mason[122] state that the large sample procedure should be used if N is greater than forty or the samples are of unequal size but Roscoe[123] states that this procedure can be used if N is twenty or greater or the samples are of unequal size.

The steps to be followed for each procedure are similar and outlined below[124].

1. Theoretically two independent samples are drawn from the same parent population(size N is optional), subjected to different treatments, and compared on some criterion.
2. The cumulative frequency or relative cumulative frequency distributions are established in such a fashion that the intervals of the two samples are directly compared and the differences between the cumulative frequencies or relative cumulative frequencies are established and the largest of these differences are designated K_D for the small sample cumulative frequency distribution procedure or D for the large or unequal size samples relative cumulative frequency distribution.
3. The established K_D or D are compared to a tabulated value for the appropriate sample size and level of significance. If the established values of K_D or D are equal to or larger than the tabled value the finding is significant and the null hypothesis that there is no

[120]Roscoe, John T. *Fundamental Research Statistics for the Behavioral Sciences*. New York. Holt, Rinehart and Winston, Inc. 1975. page 276.
[121]Siegel, Sidney. *Nonparametric Statistics for the Behavioral Sciences*. New York. McGraw-Hill Book Company, Inc. 1956. page 131.
[122]Mason, Robert D. Statistical Techniques in Business and Economics. Fifth Edition. Homewood. Richard D. Irwin, Inc. 1982. page 434.
[123]Roscoe, John T. *Fundamental Research Statistics for the Behavioral Sciences*. 2nd Edition. New York. Holt, Rinehart and Winston, Inc. 1975. page 278.
[124]ibid.. page 277-278.

difference in the distributions of the two treatments is rejected.

The Kolmogorov-Smirnov two-sample test was used in this study to establish whether the surface and subsurface farms were drawn from the same parent population.

Wilcoxon Matched-Pairs Signed Ranks Test

The Wilcoxon matched-pairs signed-ranks test[125] sometimes referred to as the Wilcoxon matched-pair signed ranks test of Differences[126] is a nonparametric alternative to the t-test, frequently used to determine if two samples are related, when the underlying assumptions for the latter test cannot be met. The relative power of the Wilcoxon matched-pairs signed ranks test is approximately 95 per cent of the t-test with small samples and somewhat less for larger samples[127]. Nonparametric statistics dispense with the need to know about the form of the population distribution. It does not matter whether the population is normal or binomial or beta or uniform or some other distribution. No information is needed about the form of the population distribution and no assumptions need be made about the form of the population distribution. Nonparametric methods are "distribution-free" in that they apply to all distributions rather than only those of some particular form[128].

The procedure in employing the test is as follows. The differences between any pair, di, is taken and ranked from one to N(N is the number of pairs, fifteen in this study) with respect to magnitude, but without respect to sign. The ranks are separated into two groups, negative and positive differences, and assigned a sign corresponding to the differences. Each group is summed and assigned a T value, where Ta is the sum of the positive differences and Tb is the sum of the negative differences. The smaller of these differences is taken as the T value and compared to the table T value. If the relationship between the pairs is completely

[125]ibid. page 238.
[126]Mason, Robert D. *Statistical Techniques in Business and Economics*. 5th. Edition. Richard D. Irwin, Inc. 1982. page 439.
[127]Roscoe, John, T. *Fundamental Research Statistics for the Behavioral Sciences*. 2nd Edition. New York. Holt, Rinehart and Winston, Inc. 1975. page 241.
[128]Chou,Ya-Lin. *Statistical Analysis*. 2nd. Edition. New York. Holt, Rinehart and Winston. 1975. page 536.

random the value of Ta and Tb should be the same and the value of T would be maximum in this situation. If there is a systematic tendancy for the positive differences to be larger or less than the negative differences the T value will tend to be small. A T value of 0 represents maximally different samples. If the calculated T value(the smaller of either Ta or Tb) is less than or equal to the table.T, the null hypothesis, that there is no difference in the ranks of the two samples is rejected and the alternative hypothesis that higher ranks are associated with one of the methods is accepted. The table T value for N=15 at the 5% level of significance is 25, and at the 1% level of significance is 16. Pairs with tie scores are rejected from the test and N becomes smaller. The Wilcoxon matched-pairs signed ranks test was used in this study to confirm the success of the pairing of the surface and subsurface drainage farms.

Kolmogorov-Smirnov One-Sample Test for normality of the dependent variable

One of the basic assumptions of OLS is that the dependent variable is normally distributed[129]. The dependent variable was tested for normality of distribution using the Kolmogorov-Smirnov one sample test. This test of goodness of fit is used to determine whether an observed frequency distribution departs significantly from a hypothesized frequency distribution. The Kolmogorov-Smirnov one-sample test is suggested as an alternative to the chi-square approximation of the multinomial for testing goodness of fit to a hypothesized distribution[130]. When samples are small the chi-square test is definitely less powerful than the Kolmogorov-Smirnov test and for large samples the chi-square test is not applicable at all, but the Kolmogorov-Smirnov test is. These facts suggest that the Kolmogorov-Smirnov test may in all cases be more powerful than its alternative, the chi-square test[131]. The maximum difference between the two cumulative frequency distributions at each interval is determined and compared to a tabulated difference for a

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[129]Kl[illegible]m, David G. and Kupper, Lawrence L. *Applied Regression Analysis and Other Multivariable Methods.* North Scituate. Duxbury Press. 1978. page 41-44.
[130]Roscoe, John T. *Fundamental Research Statistics for the Behavioral Sciences.* 2nd Edition. New York. Holt, Rinehart and Winston, Inc. 1975. page 274.
[131] Siegel, Sidney. *Nonparametric Statistics for the Behavioral Sciences.* New York. McGraw-Hill Book Company, Inc. 1956. page 51.

particular sample size and chosen level of significance. If the calculated difference is greater than the allowable difference for chosen levels of confidence the null hypothesis of normality is rejected and the alternative hypothesis that the sample is not normally distributed is accepted[132]. The dependent variable tested in this manner was found to be not normally distributed. This circumstance is commonly associated with the small sample for each of the drainage types(fifteen surface, fourteen subsurface). The dependent variable was subsequently normalized using the Box-Cox transformation procedure.

Box-Cox Transformations

The Box-Cox procedure is an iterative process to calculate the optimal power transformation to normalize data. According to Dolby[133] one of the most obvious reasons to apply transformations is when the relationship between the dependent variable is not linearly related to the independent variable and there is no particular reason to assume that the particular relationship is a polynomial of a particular degree. "Linearization of the functional form is not of course, the only reason for using a transformation, since the introduction of a transformation also may be necessary or desirable to normalize the error distribution or to achieve greater constancy of variance" and "the problem in dealing with transformations consists simply in determining which one should be used for a particular set of data." Tukey[134] defines a simple family of transformations that "consists of all transformations which can be obtained by compounding linear transformations with one(integral or fractional) power transformation and of all limiting forms of such transformations." "The transformations take on the form $Tx=(c+x)^p$, where p is any real number and c is sufficiently large that c + x is gr[illegible]n zero over the range of data. By changing the value of p we obtain $(c+x)^2$, c + x[illegible] number of useful transformations.[135]." The

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[132]Roscoe, John T. *Fund[illegible]earch Statistics for the Behavioral Sciences*. 2nd. Edition. New York. Holt, [illegible]art and Winston, Inc. 1975. page 271.
[133][illegible]y, James L. "A Quick Method for Choosing a Transformation." *Technometrics* Vol 5. No. 3 (August 1963): page 317-318.
[134]Tukey, John W. "On the Comparitive Anatomy of Transformations." *Annals of Mathematical Statistics* 28 (1957): page 619.
[135]Dolby, James L. "A Quick Method for Choosing a Transformation." *Technometrics*

choice of c(the constant added to variable x, sufficiently large such that c + x is always greater than zero) made a difference as to how easily the proper transformation could be choosen. Typical difficulties that result with different values of c are, local minimums, non-convergence, large variances or zero variances. Situations could usually be resolved by changing the value of the constant.

Once the optimal transformation of the dependent variable was found, the Spearman rank correlation coefficient procedure was used to determine the correlation between the chosen dependent and explanatory variables.

Spearman Rank Correlation Coefficient

The Spearman rank correlation coefficient is a nonparametric alternative to the parametric Pearson product-moment correlation coefficient and is approximately 91 per cent as efficient as the Pearson coefficient[136]. The Spearman rank correlation coefficient procedure[137] lists the two variables to be compared, ranks each of them from one to N, where N is the sample size, takes the difference(di) betweeen each pair of ranks(paired precisely as the original data), squares this difference(di^2), sums the squared difference(sum di^2) and calculates r or rho(p) by subtracting the product of 6 and the sum of di^2($6 \cdot$sum di^2), divided by N^3 minus N, from one. The r has the ability to take on all values between -1 and +1. Variables that have a calculated r of less than -0.2 or greater than 0.2 or were significant at the 25% level of significance are considered for further analysis.

Stepwise Regression Procedure

Once the important explanatory variables were established, using the Spearman analysis, they were regresssd against the transformed dependent(IRR) to establish if there were any concrete relationships. Based on the new regression correlation coefficients, variables

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[135](cont'd) Vol. 5 No. 3 (August 1963): page 318.
[136]Siegel, Sidney. *Nonparametric Statistics for the Behavioral Sciences*. New York. McGraw-Hill Book Company, Inc. 1956. page 239.
[137] Roscoe, John T. *Fundamental Research Statistics for the Behavioral Sciences*. 2nd Edition. New York. Holt, Rinehart and Winston, Inc. 1975. page 106.

with weak correlations were removed and discarded. The remainder of the explanatory variables were regressed against the dependent variable using the stepwise procedure. This procedure is particularly useful in cases where the pool of potential X variables(explanators) is large and the desire is to eliminate the non-relevant variables. The remaining variables constitute a reasonably "good" subset of independent variables[138].

According to Kleinbaum[139] the stepwise procedure is an automatic search procedure that permits re-examination, at every step, of the variables incorporated in the model in previous steps. The first variable to enter the model is the variable that is most highly correlated with the dependent variable but as each additional variable is added to the model in the stepwise procedure, a partial F test for each variable in the model is made treating it as if it were the most recent variable to enter. The variable with the smallest non-significant partial F statistic(if there is such a variable) is removed, the model is refitted with the remaining variables, the partial F's are obtained and similarly examined and so on until no more variables can be entered or removed.

Procedure for Behavioral Analysis of Economic Viability

Behavioral analysis using a linear functional form and ordinary least squares procedure was used in an attempt to relate the dependent variable, internal rate of return, to various independent variables which are representative of characteristics of either the intensity of farm management, the drainage project or the landowner. The hypothesis to be tested was that economic viability of a drainage project may be influenced by some physical characteristics of the farm or drained area and of special interest, by some aspect of the way in which the land owner manages his entire farm. As stated earlier, some believe that successful managers use more of variable inputs than do bad managers. Managers rated as good, are those who manage their farm more intensely by using more of variable inputs or have shown

[138]Neter, John, Wasserman, William and Kutner, Michael, H. *Applied Linear Regression Models*. Homewood. Richard D. Irwin, Inc. 1983. page 430.
[139]Kleinbaum, David G. and Kupper, Lawrence L. *Applied Regression Analysis and Other Multivariable Methods*. North Scituate. Duxbury Press. 1978. pages 231-232.

a greater tendancy to increase their input use practices over time. These managers should have a better return from their drainage project. This approach amounts to the use of these physical inputs as a proxy for management intensity in the behavioral analysis.

Briefly, two models using a linear functional form to relate the dependent and independent variables were used in the behavioral analysis. In the first model, a strictly comparative model, a few variables thought to be important to each type of drainage system were identified. These variables were combined to form one identical equation that represented both types drainage systems. Four assumptions were considered. The first assumption(Assumption I) regressed the dependent variable, internal rate of return, against independent variables representing farm and farmer characteristics before drainage. This same dependent variable was also regressed against the independent variables representing farm, farmer and project characteristics after drainage(1985)(Assumption II), absolute change in these characteristics during the life of the project(Assumption III) and the average annual change during the life of the project(Assumption IV). A list of variables can be found in Appendix H.

In the second model, referred to as an exploratory model, the equations of both types of drainage systems were not restricted to the same independent variables. In the second model many more variables were considered. For example rather than having an input expenditure variable representing the summation of the expenditures on fertilizer, fungicides and herbicides, each of these inputs was treated as a separate variable. In addition to the previously mentioned four assumptions, the importance of the soil classification, project size and land use factor were examined in Assumptions V and IV. Variables considered in the second model are listed in Appendix I.

The behavioral analysis used in this study was an attempt to relate farm, farmer and project characteristics to the internal rate of return of a project. This study assumed these characteristics were a proxy for management intensity, that is, they represented the behavior of the farmer in choosing to farm at his particular level of intensity.

IV. RESULTS AND DISCUSSION

A. Introduction

The research design was a matched-pair comparison of economic viablities for surface and subsurface drainage projects. A sample was drawn of pairs of farms with drainage projects completed within the last fifteen years. The pairing was accomplished on the basis of CLI land classification, size of farm and agroclimatic location. The first section of this chapter presents a comparison of some characteristics of landowners and farms used in the analysis.

The first step in the analysis of sample data was to test the pairing of farms. The Kolmogorov-Smirvov and the Wilcoxon matched-pairs tests were used for this purpose. The results are reported here. The analysis portion of the chapter also presents results of the measurement of project viability. The internal rate of return and net present value are calculated under four separate scenarios. These scenarios examine the effect non-cash benefits, a 50% grant or a 25% reduction in cash benefits have on drainage project viability. Two maintenance cost situations are examined under each scenario.

The results of the behavioral analysis report the relationships between the management intensity variables and the projects' internal rate of returns. Two models, both having a linear functional form and using ordinary least squares procedures for estimation, were used in establishing these relationships. Four assumptions were examined by Model I and six assumptions were examined by Model II.

B. A Comparison of Landowners that used Surface and Subsurface Drainage Systems

The following section describes some of the characteristics of the landowners, their families, farm labor requirements and equipment investments of the individuals that drained their land using surface versus subsurface drainage methods. Also included in this section is a description of the perceived reasons for draining the wet area, a description of the drained area, a description of the drainage system, its cost and effectiveness and the landowners opinion as to whether or not the drainage system was worthwhile.

All descriptive statistics are based on a sample size of fifteen for each type of drainage(15 pairs).

Years of Farming the Property on which Drainage Occurred

The mean years of farming the land where the drainage took place was 23.0 years for surface draihers with a minimum of 4.0 and a maximum of 48.0 years. The subsurface drainers mean years of farming the land where the drainage took place was 13.5 years with a minimum of 3.0 and a maximum of 28.0 years.

At the 5% level of significance the number of years of farming the drained land was not significantly different, but they were different at the 6% level of significance.

Family Size, Hired Help and Labor Use

Surface drainers had family households of mean size 3.8(range 2 to 6) persons of which a mean of 2.5 persons were involved in farm labor contributing a mean of 585.1(range 120 to 1235) person days per year to farm labor(one person day is 8 hours). A mean of 0.4(range 0 to 2) persons were hired to help and this hired help contributed a mean of 39.1(range 0 to 441) person days per year towards the total farm labor. The total mean farm labor used per year was 624.2(range 120 to 1235) person days.

Subsurface drainers had family households of mean size 3.9(range 2 to 6) persons of which a mean of 2.3 persons were involved in farm labor contributing a mean of 485.5(range 98 to 1105) person days per year to farm labor. A mean of 0.3(range 0 to 2) persons were hired to help and this hired help contributed a mean of 60.1(range 0 to 520) person days per year towards the total farm labor. The mean total farm labor used per year was 545.6(range 98 to 1105) person days.

Neither the mean family household size, the number of family members contributing to farm labor, the number of hired persons nor the total person labor days used on the farm were significantly different between surface and subsurface drainers at the 5% level of significance.

Classification of Farms

Four of fifteen of the surface drainers classified their farms as a cash crop enterprise, six of fifteen were considered as cash crop and livestock, one of fifteen was considered a dairy operation, none were considered beef enterprises, four of fifteen were considered to be mixed livestock and none considered their farms to be strictly swine orientated.

Of the fifteen subsurface drainers, six considered their farms to be cash crop enterprises, four considered their farms to be cash crop and livestock, one was considered a dairy operation, none were strictly beef enterprises, four were considered mixed livestock operations and none considered their operations to be swine operations.

Farm Sizes

The mean size of the surface drained farms was 828.3(range 316 to 1600) acres of which a mean of 671.9 acres or 81.1% were owned and 156.3 or 18.9% of the acres were rented. Of the mean total farm size 48.4%(401.0 acres) were seeded, 5.8%(48.3 acres) were fallow, 21.9%(181.7 acres) were pasture, 13.2%(109.3 acres) were devoted to forage production and the remainder 10.8%(89.9 acres) were a combination of houseplot, sloughs and wetlands, bush and wasteland(Table IV.1).

The mean size of the subsurface drained farms was 847.3(range 270 to 1920) acres of which 71.9%(609.1 acres) were owned and 28.1%(238.1 acres) were rented. Of the mean total farm size 71.4%(604.9 acres) were seeded, 3.4%(29.0 acres) were fallow, 9.1%(76.9 acres) were pasture, 4.8%(40.7 acres) were devoted to forage production and the remaining 11.4%(96.4 acres) were a combination of houseplot, sloughs and wetlands, bush and wasteland(Table IV.1).

The Wilcoxon matched-pairs signed ranks test on he above mentioned comparisons found only seeded acres different at the 5% level of significance. The acres devoted to forage were different at a 7% level of significance. If one were to choose a 1% level of significance

Table IV.1: **Farm Size and Acreage Distribution**

	Surface Drainage			Subsurface Drainage		
	Min	Max	Mean	Min	Max	Mean
Acres total	316	1600	828.3	270	1920	847.3
Acres owned	316	1120	671.9	0	1600	609.1
Acres rented	0	800	156.3	0	1015	238.1
Acres seeded	85	1100	401.0	85	1350	604.9
Acres houseplot	5	20	9.4	0	80	13.9
Acres fallow	0	350	48.3	0	400	29.0
Acres bush	0	160	22.2	0	290	52.2
Acres pasture	0	914	181.7	0	217	76.9
Acres forage	0	470	109.3	0	200	40.7
Acres sloughs & wetlands	0	130	23.3	0	101	30.3
Acres wasteland	0	405	35.0	0	0	0

Source: Survey Results.

level these differences would not exist.

Appendix G contains a detailed description of evidence peripheral to this research gathered in the questionnaire. This evidence concerned the reasons for draining, classification of the wet areas, other problems associated with the wet area, the perceived benefits of drainage, whether the system is perceived to work, problems associated with the system, frequency of harvest before and after drainage, whether the landowner would drain land again, the influence of literature on the decision to drain and the level of compensation which would be required to cause the decision not to drain land.

Appendix G also contains some data related to the drainage system. Included is information on the size of the drained area, assorted costs associated with drainage, benefits of drainage(cash and non-cash), removal of inconveniences, impressions of the usefulness of drainage before and after and other improvements made to compliment the drainage system.

Management information on the whole farm in Appendix G includes topics relating to farm size(before and after), acres improved and fallow, capital investment, the machinery complement, the livestock numbers and the use of herbicides, fungicides, better seed and fertilizers.

C. Results of the Kolmogorov-Smirnov Two-Sample Test

The Kolmogorov-Smirnov two-sample test results apply to the major characteristics of the farms, their landowners and management intensity variables. The sample size to be compared was fifteen for each type of drainage, and would have been compared using the small sample size procedure outlined earlier but the SPSSX package uses the large sample size procedure for the comparison. In cases of closeness of result of the test statistic from the large sample size procedure to the critical value for a sample size of fifteen the tests were verified manually using the small sample procedure. That is, if acceptance or rejection of the null hypothesis was to be made on a calculated large D sample statistic being marginally different(+ ,-10%) from the tabulated D, for the choosen level of significance, 5%, the test was repeated using the small sample procedure.

The results of the Kolmogorov-Smirnov two-sample test show, at the 5% level of significance, that the two types of farms have the same relative cumulative frequency distribution with respect to 1) total acres, 2) acres owned, 3) acres rented, 4) acres cultivated, 5) acres seeded, 6) acres fallow, 7) acres pasture, 8) acres forage, 9) family size, 10) family labor, 11) hired labor, 12) animal units, 13) cropping intensity, 14) capital expenditure on equipment and 15) capital expenditure on herbicides, fungicides and fertilizer.

The test for differences between the two types of farms regarding drainage system variables confirmed differences at the 5% level of significance but not at the 1% level of significance for 1) the acres gained directly from drainage, 2) total acres gained(the summation of acres directly gained and those acres improved), 3) the system cost per total acres gained, 4) the total cost of drainage per total acres gained and 5) the rehabilitation time(the time required to get the first crop off). Similarities at the 5% level of significance were present for 1) acres improved by drainage, 2) the total system cost of drainage, 3) the rehabilitation costs per acre gained and improved, 4) the maintenance costs per acre gained and improved and 5) the operating costs per acre gained and improved.

The test results confirmed the success of the pairing and sample design in achieving the intended evidential basis for the research. Comparisons between the farms could be made based on the different drainage systems. The characteristics of the two drainage types were different for five variables and similar for five. The differences relate to the size of the area gained directly, the size of the total acres gained(the acres gained directly plus the acres improved), the system costs per total acres gained, the total cost per total acres gained and the rehabilitation time. The similarities are in the size of the improved area, the total cost of drainage and the rehabilitation, maintenance and operating costs per total acres gained[140].

D. Results of the Wilcoxon Matched-Pairs Signed Ranks Test

The Wilcoxon matched-pairs signed ranks test was applied to the management and structural information compiled through the questionnaire. Structurally the pairs of farms were determined to come from the same population. There was no difference in the ranks of the pairs for the two types of drainage at the 5% level of significance for 1) total acres, 2) acres owned, 3) acres rented, 4) acres cultivated, 5) acres fallow, 6) acres pasture, 7) acres forage, 8) capital expenditure on equipment, 9) animal units, 10) the capital expenditure on herbicides, fungicides and fertilizer per acre or 11) improved acres(cultivated acres including summerfallow).

At the 5% level of significance 1) acres seeded and 2) cropping intensity were greater for farms with subsurface drainage. At the 1% level of significance and a higher risk of committing a type II error, it would not be possible to reject the null hypothesis for the above

[140] The total acres gained refers to the summation of the actual acres gained from the drainage system and the acreage surrounding the system that was improved because of the drainage.

comparisons.

Differences at both the 5% and 1% levels of significance existed between the pairs with respect to the CLI land classification as interpolated from CLI maps[141]. Of the fifteen pairs, the subsurface drainage soils had lower CLI land classifications nine times, there were three ties and they had a lower classification for the three cases where the drained organic soil was given an arbitrary CLI 5 rating[142]. Considering the twelve pairs of farms with legitimate CLI land classifications, the mean CLI land classification difference was 1.1[143]. The mean CLI land classification was 1.96 for farms with subsurface drainage and 3.08 for farms with surface drainage.

Differences in the characteristics of the two types of drainage projects were apparent at both the 5% and 1% levels of significance. Differences existed in 1) acres gained directly and in 2) the total acres gained, with surface drainage farms having higher drained acres than subsurface farms, and in 3) the total costs per acre gained and improved with subsurface drainage having higher system costs. System costs exclude rehabilitation, maintenance and operating costs. A difference existed at the 5% level but not at the 1% level of significance between the two types of farms with respect to rehabilitation times. Surface drained land took longer to rehabilitate than did subsurface drained land in the projects examined by this study. This difference is probably more closely related to the nature of the area being drained than to the type of drainage system.

The drainage projects were not different at the 5% level of significance with respect to the 1) total system costs, 2) rehabilitation costs, 3) maintenance costs, 4) operation costs or 5) the acres improved by drainage.

[141]Note that caution must be exercised in assuming that the general CLI classification as found on a CLI map is representative of the land in question and especially the drained area.
[142]The arbitrary classification of drained organic soils to avoid the problem of missing data for susequent analysis affected the signed ranks for the CLI variable.
[143]The CLI land classifications are measurements at an ordinal level and means have little significance beyond illustrative purposes. It is safe to assume that CLI 1 land is superior to CLI 2 land but this does not mean that CLI 1 land is twice as good as CLI 2 land. In addition, the difference between CLI 1 land and CLI 2 land is not necessarily equivalent to the difference between CLI 2 land and CLI 3 land.

Differences that existed between the surface and subsurface farms before the drainage was installed and which disappear after drainage were of interest. For example at the 5% level of significance the capital expenditure on equipment and the capital expenditure per acre on herbicides, fungicides and fertilizers were greater for farms with subsurface drains before drainage but the same as the surface drained farms after drainage.

Contrasting to increased similarities between the two groups following drainage were differences that appeared after drainage. One example of this phenomenon is cropping intensity after drainage(different [illegible] but the same at the 1% level of significance) compared to before drainage(the same at the 5% level of significance).

Considering the extensive testing of comparisons within the pairs of farms, differences were few. The differences that did exist at the 5% level of significance were related to grain production. At the 1% level of significance, these differences did not exist. Basic differences between the drainage projects, on the other hand, did exist at both the 5% and 1% levels of significance and these differences were related to the fundamental characteristics of size and cost of the drainage systems.

E. Measurements of Project Viability

As mentioned in Chapter III, NPV and IRR were calculated for four separate scenarios. The first scenario was the consideration of all farm costs associated with the project, and all farm benefits(cash and imputed non-cash) and all taxes. The second was the consideration of all farm costs associated with the drainage project and only the cash benefits plus all ~~taxes~~. The third was a consideration of a government cost share grant covering 50% of system costs, cash benefits and taxes. The fourth involving a sensitivity test was the consideration of all farm costs and only 75% of the cash benefits.

For all scenarios the NPV at a 5% discount rate and the IRR were calculated. In addition the NPV at 5% and the IRR were calculated when a yearly maintenance cost based on 3% of the original system(construction) cost was considered in place of the reported maintenance costs. According to Leitch[144] "Estimates of the cost of ditch maintenance range from 3% of the initial cost per year(U.S. SCS, 1978) to one third of the original cost every seven years(Goldstein, 1967)." Benchmark comparisons are made to a fictitious risk free 5% real interest paying investment(e. g. Canada Savings Bonds). The number of individuals draining land that would have done better in this type of investment, are given. Mumey[145] recently suggested that "a reasonable discount rate might be a little more than the historical annual return, after-tax-and-inflation, on a broadly-diversified common share portfolio--perhaps eight to ten percent would be appropriate." An advantage of the IRR is that should a particular opportunity cost of capital be higher than the standard used for comparison(i.e., 5%), it is a simple matter to look at the IRRs of the projects and evaluate the success rate.

When calculation of the IRR was not computationally possible because of a negative-positive-negative cash flow this cash flow was assigned an IRR of -100% and shown as -100*%.

Scenario I - All costs, All benefits and Taxes

All costs associated with a project were considered to be paid by the individual installing the drainage system(landowner), regardless of who actually paid them. Government grants were occasionally given towards surface drainage projects but were treated as private funds. Tax exemptions accrued on all costs in the year in which they were incurred. All cash benefits and non-cash benefits for which values were estimated were considered and taxed appropriately.

The NPV at 5% for the surface drainage projects ranged from $-724 to $189,394 with a mean value of $51,863(Table IV.2). When the 3% yearly maintenance costs were considered

[144] Leitch, Jay A. *Economics of Prairie Wetland Drainage*. For presentation at the 1982 Winter Meeting. American Society of Agricultural Engineers. Paper No, 82-2543. December 1982. page 8.
[145] Mumey, G. A. "Financial Management; and Could Better Methods Have Saved Some Farms?" *Agriculture and Forestry Bulletin* Vol. 9 No. 2 (Summer 1986): page 7.

the NPV at 5% ranged between $-9,342 and $182,109 with a mean value of $48,822(Table IV.3). The IRR ranged from 5% to 166% with a mean of 63.1%. Only one of fifteen landowners could have done better with the 5% interest paying investment(i.e., the IRR was 5% but th[illegible] was $-724)(Table IV.2). When the 3% yearly maintenance costs were [illegible] ranged between 0 and 165% with a mean of [illegible]. Only one of fifteen could [illegible]er with the 5% interest paying investment(Table IV.3).

[illegible]V at 5% for the subsurface drainage projects ranged from $-4,860 to $45,715 with a mean of $14,302(Table IV.4). When the 3% yearly maintenance costs were considered the NPV at 5% ranged between $-7,967 and $42,298 with a mean of $11,309(Table IV.5). The IRR ranged from -7% to 49% with a mean of 20.1%. Four of fifteen investors could have done better on a 5% interest paying investment(Table IV.4). When the 3% yearly maintenance costs were considered the IRR ranged between -100*% and 46% with a mean of 11.0%. Four of fifteen could have done better on the less risky 5% interest paying investment(Table IV.5).

Scenario II - All Costs, Cash Benefits and Taxes

In this scenario all costs were included and taxed as above. The only benefits included were the actual cash benefits from the increased production associated with the additional land gained because of the drainage project. These benefits were taxed at the individual's marginal tax rate. This scenario most conservatively represents the real worth of the drainage project, simply because it does not include the subjective estimates of the less tangible benefits from machinery and labor time saving, input cost savings and savings due to eliminated waterfowl damage. The IRR calculated under this scenario was used as the dependent variable in the subsequent behavioral analysis of economic viability.

The surface drainage projects showed a NPV at 5% ranging from $-724 to $189,394 with a mean of $47,440(Table IV.2). When the 3% yearly maintenance costs were considered the NPV@5% ranged between $-9,342 and $182,109 with a mean of $44,399(Table IV.3). The IRR ranged from [illegible]5% to 142% with a mean of [illegible]3%. Only one of fifteen investors could have done better on the 5% interest paying investment(the IRR was 5% but the NPV at 5% was

Table IV.2: **Measurements of Project Viability for Surface Drainage Projects Without Maintenance, East Central Alberta for the Period 1972-1984.**

PSU	Scenario I		Scenario II		Scenario III		Scenario IV	
	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $
1-1	29	18194	23	13491	25	13972	12	4747
2-1	131	48271	107	41041	112	41397	67	24593
3-1	47	61616	44	56137	55	59011	32	35814
4-1	34	52137	30	45378	58	55015	21	26786
5-1	74	138223	74	138223	95	140322	57	94595
7-1	26	16248	8	1796	18	5874	-1	-3795
8-1	44	32002	44	32002	72	35158	32	20136
9-1	85	13993	85	13993	165	14832	60	9826
10-1	[illegible]	-724	5	-724	[illegible]	[illegible]	-1	-9465
11-1	166	87747	142	75048	152	75375	90	46132
12-1	85	20423	49	10176	77	11217	30	5440
13-1	37	48137	37	48137	[illegible]	51742	30	32756
14-1	87	22746	87	22746	[illegible]	24054	63	15785
15-1	77	189394	77	189394	83	191235	87	131308
16-1	19	29537	17	24757	28	33777	9	8183
Mean	63.1	51863	55.3	47440	77.9	51115	39.2	29523
Min	5	-724	5	-724	17	5874	-1	-9465
Max	166	189394	142	189394	165	191235	90	131308

Source: Survey Results.

Table IV.3: **Measurements of Project Viability for Surface Drainage Projects With Maintenance, East Central Alberta for the Period 1972-1984.**

PSU	Scenario I		Scenario II		Scenario III		Scenario IV	
	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $
1-1	26	16215	21	11512	22	11993	9	2768
2-1	131	47881	106	40652	111	41008	66	24204
3-1	45	58314	42	52836	52	55709	30	32512
4-1	31	46043	27	39284	52	48921	18	20692
5-1	72	136299	72	136299	93	138398	56	92670
7-1	23	13741	4	-711	16	3366	[illegible]	-6302
8-1	42	30127	42	30127	68	33283	[illegible]	18261
9-1	81	13233	81	13233	158	14073	57	[illegible]
10-1	0	-9342	0	-9342	10	5130	-7	-18083
11-1	165	87298	142	74600	151	74927	89	45684
12-1	83	19746	46	9498	73	10540	27	4763
13-1	35	45974	35	45974	48	49579	28	30593
14-1	84	21967	84	21967	156	23275	60	15006
15-1	74	182109	74	182109	81	183950	54	124053
16-1	16	22729	14	17949	24	26968	6	1375
Mean	60.5	48822	52.7	44399	74.3	48075	34.5	26484
Min	0	-9342	0	-9342	10	3366	-7	-18083
Max	165	182109	142	182109	158	183950	89	124053

Source: Survey Results.

Table IV.4: Measurements of Project Viability for Subsurface Drainage Projects Without Maintenance, East Central Alberta for the Period 1972-1[illegible]4.

PSU	Scenario I		Scenario II		Scenario III		Scenario IV	
	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $
1-2	49	9375	46	8743	90	10042	31	5678
2-2	47	23224	14	4257	24	6303	-9	-5737
3-2	2	-258	-100	-1615	-100	-808	-100	-1615
4-2	15	24812	8	6165	13	14909	1	-8401
5-2	12	9868	3	-2368	13	6926	-1	-7408
7-2	37	13816	30	10280	41	11436	21	5909
8-2	46	45715	38	36052	58	40450	23	18188
9-2	13	5588	12	4336	26	8260	5	255
10-2	40	42843	39	42164	57	46361	29	27847
11-2	10	4340	8	2718	17	6756	-3	-1674
12-2	2	-1490	-9	-5770	-2	-1732	-13	-6828
13-2	17	17666	15	14258	24	19386	7	2603
14-2	-7	-4860	-9	-6526	0	-1295	-13	-7809
15-2	26	27434	12	8250	22	14261	3	-1762
16-2	-4	-3548	-12	-5933	-8	-3309	-19	-7116
Mean	20.3	14302	6.3	7667	18.3	11863	-2.1	808.67
Min	-7	-4860	-100	-6526	-100	-3309	-100	-8401
Max	49	45715	46	42164	90	46361	31	27847

Source: Survey Results.

Table IV.5: Measurements of Project Viability for Subsurface Drainage Projects With Maintenance, East Central Alberta for the Period 1972-1984.

PSU	Scenario I		Scenario II		Scenario III		Scenario IV	
	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $	IRR %	NPV@5% 1985 $
1-2	46	8603	43	7971	84	9270	28	4906
2-2	45	22004	12	3036	20	5083	-12	-6957
3-2	-3	-740	-100*	-2097	-100*	-1289	-100*	-2097
4-2	12	17131	4	-1516	9	7229	-3	-16082
5-2	8	4268	-2	-7968	7	1326	-8	-13008
7-2	35	12579	28	9044	38	10200	18	4672
8-2	43	42298	36	32635	54	37033	20	14770
9-2	10	3308	8	2056	20	5981	1	-2025
10-2	37	39764	37	39085	54	43282	26	24768
11-2	7	1590	5	-32	12	4005	-1	-4424
12-2	-3	-3900	-23	-8180	-19	-4143	-56	-9239
13-2	15	13323	12	9915	20	15043	4	-1740
14-2	-100*	-7967	-100*	-9634	-100*	-4402	-100*	-10916
15-2	23	22911	8	-3727	17	9739	-1	-6285
16-2	-10	-5543	-27	-7928	-2[illegible]	-5305	-54	-9112
Mean	11.0	11309	-3.9	4674	6.0	8870	-15.9	-40
Min	-100*	-7967	-100*	-9634	-100*	-5305	-100*	-13008
Max	46	42298	43	39085	84	43282	28	24768

Source: Survey Results.

$-724)(Table IV.2). When the 3% yearly maintenance costs were considered the IRR ranged between 0% and 142% with a mean of 52.7%. Two of fifteen investors could have done better in the 5% interest paying investment(Table IV.3).

Subsurface drainage projects showed a NPV at 5% ranging from $-6,526 to $42,164 with a mean of $7,667(Table IV.4). When the 3% yearly maintenance costs were considered the NPV at 5% ranged from $-9,634 to $39,085 with a mean of $4,647(Table IV.5). The IRR ranged between -100% and 46% with a mean of 6.3%. Five of fifteen investors could have done better on the 5% interest paying investment(Table IV.4). When the 3% yearly maintenance costs were considered the IRR ranged from -100% to 43% with a mean of -3.[illegible] of fifteen investors could have done better in the 5% interest paying investment(Table IV.5).

The exclusion of the non-cash benefits did not alter the number of nonviable projects at an NPV at 5%, without the 3% maintenance, for the surface drainers, but it did increase the number of nonviable subsurface projects from four to five of fifteen.

Scenario III - All Costs, Cash Benefits, Taxes and a 50% Grant

The third scenario considers a situation where the government or other agency would subsidize 50% of the system costs. This grant of course would not be subject to any tax concessions.

Surface drainage projects showed a NPV at 5% ranging from $5,874 to $191,235 with a mean of $51,115(Table IV.2). When the 3% yearly maintenance costs were considered the NPV at 5% ranged from $3,366 to $183,950 with a mean of $48,[illegible]75(Table IV.3). The IRR ranged between 17% and 165% with a mean of 77.9%. None of the investors could have done better on the 5% interest paying investment(Table IV.2). When the 3% yearly maintenance costs were considered the IRR ranged between 10% and 158% with a mean of 74.3%. None of the investors could have done better on the 5% interest paying investment(Table IV.3).

Subsurface drainage projects showed a NPV at 5% ranging from $-3,309 to $46,361 with a mean of $11,863(Table IV.4). When the 3% yearly maintenace costs were considered the NPV at 5% ranged between $-5,305 to $43,282 with a mean of $8,870(Table IV.5). The IRR varied between -100*% and 90% with a mean of 18.3%. Four of fifteen investors could have done better on the 5% interest paying investment(Table IV.4). When the 3% yearly maintenance costs were considered the IRR varied between -100*% and 84% with a mean of 6.0%. Four of fifteen investors could have done better on the 5% interest paying investment(Table IV.5).

Scenario IV - All Costs, 75% of Cash Benefits and Taxes

The fourth scenario considers all the project costs, as in scenarios I and II, with tax concessions, 75% of all cash benefits and all tax assessments on the net benefits. This situation tests the sensitivity of project worth to an overstatement of benefits, to downside risk on prices or yields and to general downside risk and uncertainty that may be encountered over the projected fifteen year life of a project.

Surface drainage projects showed a NPV at 5% ranging between $-9,465 and $131,308 with a mean of $29,523(Table IV.2). With the 3% yearly maintenance costs considered the NPV at 5% ranged between $-18,083 and $124,053 with a mean of $26,484(Table IV.3). The IRR ranged between -1% and 90% with a mean of 39.2%. Two of fifteen investors could have done better on the 5% interest paying investment(Table IV.2). When 3% yearly maintenance costs were considered the IRR ranged between -7% and 89% with a mean of 34.5%. Two of fifteen investors could have done better on the 5% interest paying investment(Table IV.3).

Subsurface drainage projects had NPV at 5% ranging between $-8,[illegible]01 and $27,847 with a mean of $11,863(Table IV.4). [illegible] 3% yearly maintenance costs [illegible] considered the NPV at 5% ranged between $-13,00[illegible] mean [illegible](Table IV.5). The IRR ranged between -100*% and 31% with a mean of -2.1%. Nine of fifteen investors could have done better on the 5% interest paying investment. One of fifteen investors showed an IRR of 5% with an NPV at 5% of $255 indicating the drainage project paid marginally above 5%(Table IV.4). When the 3% yearly maintenance costs were considered the IRR ranged between -100*% and 28% with a mean of -15.9%. Eleven of fifteen investors could have done better on the 5% interest pay[illegible]ment(Table IV.5).

For surface drainage [illegible] only one project in Scenario II, considered the most likely scenario, had an IRR [illegible] and a NPV at 5% of $-724. Including non-cash benefits, Scenario I, did not alter th[illegible]ojects viability. In Scenario III in which a landowner is given a grant to cover 50% of the system costs, all projects were viable at the 5% opportunity cost of capital benchmark. In some cases the IRR nearly doubled and the mean IRR increased from 55.3% to 77.9%. Public subsidies of projects with these high returns is not warranted. A 25% reduction in cash benefits made two projects nonviable and decreased the mean expected IRR to 39.2%. Surface drainage projects on the whole seem viable and not overly sensitive to changes in the structure of the benefit stream.

Inclusion of the 3% yearly maintenance costs only increased the number of nonviable projects in Scenario II to two. The number of nonviable projects in Scenarios I and IV remained the same at one and two respectively. All projects in Scenario III remained viable. In all four Scenarios there was only an incremental change in the IRR.

Under Scenario II, without the 3% yearly maintenance costs, five projects were nonviable. Inclusion of the non-cash benefits decreased the nonviable projects to four and increased the mean IRR from 6.3% to 20.3%. The application of the 50% grant increased the mean IRR from 6.3% in Scenario I to 18.3% in Scenario III and reduced the number of nonviable projects by one. If cash benefits decreased by 25% as in Scenario IV, the number of nonviable projects increased to nine. Also under Scenario IV was a marginally viable project with an IRR of 5% and a NPV at 5% equal to $255. Subsurface drainage projects seem particularly sensitive to reductions in cash benefits and not particularly sensitive to reductions in costs. Inclusion of the 3% yearly maintenance costs increased the number of nonviable projects from five to seven under Scenario II and from nine plus the marginally viable project to eleven under Scenario IV. The number of nonviable projects did not change under Scenario I. The viability of a subsurface drainage project is sensitive to maintenance costs.

F. Behavioral Analysis of Economic Viability

Introduction

The main purpose of this research is to shed some light on why some projects achieve a better payback than others. Characteristics of the project farms and their landowners use of inputs and land were related to the IRR of Scenario II when all costs, taxes and cash benefits were considered. Six approaches to behavioral estimation were executed for each type of drainage. Data was based on fifteen observations for the surface drainage landowners and on fourteen for the subsurface drainage landowners. The subsurface systems have one less observation because one landowner was not able to achieve any cash benefits from draining, resulting in an IRR of -100%. Acreage was only improved and there was no change in the way the land was farmed. Methodologically there is a reluctance to discard an outlier, especially when the sample size is small. According to Neter et al.[144] outliers are extreme observations which, in residual plots, lie beyond the scatter of the remaining residuals, sometimes four or more standard deviations from zero. They can cause great difficulty. The main reason for discarding outliers, is that under the least squares method the fitted line may be pulled disproportionately toward the outlying observation causing a misleading fit. In the case of this landowner's failure to realize any benefits, the two plots of IRR versus cost per acre under the two situations, with and without the outlier, demonstrated a complete reversal of slopes. Nevertheless under other circumstances outliers may convey significant information.

In this particular instance the landowner only drained the land for the convenience of getting on the drained area earlier in the spring. Before drainage this area would normally be seeded later, but yields, unless the falls were extremely adverse, would be the same. The final result from this case was that incremental cash benefits realized from the drainage, were nonexistent, although intangible satisfaction may have been substantial.

[144]Neter, John, Wasserman, William and Kutner, Michael H. *Applied Linear Regression Models*. Homewood. Richard D. Irwin, Inc. 1983 pages 114-115.

Choice of the Dependent Variable

The IRR from Scenario II which considered all costs, only cash benefits and taxes was selected as the dependent variable. None of the non-cash benefits were included even though these have proven to be significant benefits, in the eyes of the landowners, but generally not the main reason for draining land.

Identification of the Explanatory Variables

From the information gathered about the farms and landowners in the year before drainage and in 1985, a number of variables that were thought to be useful in explaining why some projects had better paybacks than others were identified and manipulated to simulate different possible behavioral hypothesis for economic viability. Some of the variables identified were the size of the farm, the number of acres or proportion devoted to different uses, the cropping intensity(a ratio of the improved acres[14] minus the summerfallow to the improved acres), the use of labor and capital with regards to capital investment in machinery, fertilizers, herbicides, fungicides and the number of livestock on the farm, converted to animal units. These variables were considered to be proxies of the landowners' management qualities, reflecting the choice of combinations of inputs. This choice is assumed to be representative of management intensity. The hypothesis tested is that so called "good" managers will be more successful in making their drainage viable. Other identifiable explanatory variables are those which are directly related to the drainage project. These variables include size of project and extent of land use before and after drainage was installed. A list of identified variables can be found in Appendix H and I.

G. Results of the Behavioral Analysis

Two models, both having a linear functional form and using ordinary least squares for estimation, were used to relate explanatory variables to the IRR achieved by the drainage

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[14] The improved acres are all acres that have been cultivated and include the acres sown to tame hay.

projects. Model I referred to as "a strictly comparative behavioral model" used prespecified farm, project and management intensity characteristics chosen on theoretical grounds as important in explaining why some projects had a better pay back than others. The IRR was regressed against these specified explanators for both the surface and subsurface projects. Examination of the resulting equations constitutes the basis for a comparison between the viability behaviors of the different drainage types. Four assumptions within Model I were made and these assumptions were that the internal rate of return was related to:

1. Characteristics associated with the farm and farmer in the year before the drainage was installed were used in an attempt to identify factors which, prior to drainage installation, could predict the likelihood of economic viability;
2. *Ex post* characteristics associated with the farm, farmer and project in 1985, which could explain what made some projects more viable;
3. The absolute difference between the characteristics found in 1985 and those in the year prior to drainage, combined with the age of the project were used to provide insight into why some projects were more successful than others; and
4. The average annual change in farm characteristics representing an incremental change for each project situation regardless of the age of the project as a comparable basis for comparison.

The results of this analysis follow the next two paragraphs.

The second model, Model II, is referred to as an exploratory model. No attempt was made to compare the two types of drainage projects using the same variables. The elimination of non-relevant variables was accomplished using the method described in the Spearman Rank Correlation Coefficient section. The result of the exploratory approach would be the best possible equation for each type of drainage system, without the restriction of having the same variables appear in both equations.

In all equations the dependent variable containing a one and the dependent variable containing a two are to be associated with surface and subsurface drainage respectively. The standard errors are shown in round brackets and the t-statistics are shown in square brackets.

The R^2 and the F statistic are also given. A list of the chosen variables considered in the comparative model can be found in Appendix H, and a list of variables considered in the exploratory model can be found in Appendix I.

H. Model I: Strictly Comparative Behavior

Assumption I - Viability explained by farm characteristics before drainage

When the chosen variables for Assumption I were regressed against the IRR for surface and subsurface drainage projects, no significant relationships were established. Using this model it is not possible to predict project viability for either type of drainage before the drainage system is installed.

Assumption II - Viability explained by farm characteristics in 1985, after drainage

It is not possible using Model I to establish a comparative relationship to significantly predict project viability for both the surface and subsurface drainage projects.

Assumption III - Viability explained by absolute change in farm characteristics since drainage

The variables measured in terms of their absolute change between 1985 and the year before drainage for surface drainage are:

1. AAUCH, the change in the number of animal units on the farm; and
2. PRAGE, the age of the project in years,

and for subsurface drainage they are:

1. AEICH, the change in capital investment in equipment;
2. DUM1, the change in land use factor.

Transformations of the dependents used in this section are as follows:

$$IRR1 = (IRR + 13)^{0.2858}$$

$$IRR2 = (IRR + 13)^{0.5957}$$

The relationship for the surface drainage projects is as follows:

IRR1 =	2.629 +	0.006 AAUCH +	0.088 PRAGE1
	(0.288)	(0.0026)	(0.045)
	[.000]	[.03]	[.08]
	R^2 = .40		sig F = .05

There is a positive relationship between the IRR and the animal unit change over the life of the project and the age of the project(i.e., the older the project the higher the IRR). This is not unexpected because there is a negative relationship between the costs per acre gained and improved and the age of the project. The older the project the less the costs per acre gained and improved, in real dollars. These costs per acre gained and improved have a reasonably strong positive correlation with the IRR. It is interesting to note that this is not the same cost-age relationship that is found with subsurface drainage projects, where the drainage costs per acre gained and improved are higher the older the project. The maximum age of subsurface drainage projects in this study was seven years, reflecting a time of higher land prices and increased economic activity. During this period the demand for drainage installation from landowners wishing to increase their land base was probably high, causing inflated prices from drainage contractors. The above relationship was significant at the 5% level and explains 40% of the variation in the IRR. The animal unit variable's coefficient was significant at the 3% level and the project age variable's coefficient was significant at the 8% level.

The absolute change relationship for the subsurface projects was as follows:

IRR2 =	3.383 +	0.0005 AEICH +	3.833 DUM1
	(1.47)	(.00014)	(1.59)
	[.04]	[.008]	[.03]
	R^2 = .66		sig F = .003

There is a positive relationship between the IRR and the absolute change in capital expenditure on equipment and the dummy variable representing the change in land use. Both variables' coefficients, the constant and the equation are significant at the 5% level. The equation explains 66% of the variation in the IRR.

For comparison purposes the IRR was related to all four variables mentioned in the opening paragraph for each type of drainage. The equation for the surface drainage is as follows:

$$
\begin{array}{llll}
IRR1 = & 2.672 + & 0.0075\ AAUCH + & 0.105\ PRAGE \\
 & (.335) & (.003) & (.061) \\
 & [.0000] & [.05] & [.12] \\
 & & -\ 0.239\ DUM1 + & 0.000002\ AEICH1 \\
 & & (.433) & (.0000055) \\
 & & [.59] & [.70] \\
 & & R^2 = .42 & sig\ F = .20
\end{array}
$$

There is a positive relationship between the IRR and the animal unit change, the age of the project and the change in capital expenditure on equipment but a negative relationship between the IRR and the dummy variable representing land use change, and this is opposite to what is expected. Only the animal unit change variable's coefficient and the constant are significant at the 5% level. The equation is not significant and therefore not able to predict surface drainage viability.

The comparitive equation for the subsurface drainage is as follows:

$$
\begin{array}{llll}
IRR2 = & 5.036 + & 0.00005\ AEICH + & 3.000\ DUM1 \\
 & (2.567) & (.000016) & (1.942) \\
 & [.08] & [.01] & [.16] \\
 & & -\ 0.303\ PRAGE + & 0.007\ AAUCH \\
 & & (.354) & (.0159) \\
 & & [.41] & [.66] \\
 & & R^2 = .69 & sig\ F = .02
\end{array}
$$

There is a positive relationship between the IRR and the change in capital expenditure on equipment(the higher the capital expenditure on equipment the greater the project viability) and the dummy variable representing the change in land use and a negative relationship between the project age as expected but a sign opposite to that expected is found on the animal unit change. It was expected, that since the subsurface drainage farms had a higher emphasis on seeded acreage, the animal units would have a negative relationship with the IRR. Only the capital expenditure variable's coefficient is significant at the 5% level. The equation is significant at the 5% level and explains 69% of the variation in the IRR.

When all the variables were included in both equations, only the absolute animal unit change variable's coefficient and the constant remained significant at the 5% level in the surface drainage equation, but the equation itself was not significant and thus not able to predict project viability. In the subsurface drainage relationship the equation is significant at the 1% level and the variables are able to explain 72% of the variation in the IRR, but only the absolute change in capital expenditure on equipment variable's coefficient remained significant. The subsurface drainage equation is a better explanator of project viability than is the surface drainage equation.

Assumption IV - Viability explained by the average annual rate of change

Three variables were thought to be important in explaining the expected IRR in terms of the average annual changes in the farms or farm management between the time the drainage was installed and 1985. These variables were:

1. AUCHYR, the change per year in the animal units on the farm;
2. DUM1, the variable representing the change in land use; and
3. Z16, the change in the capital expenditure on equipment per year since the drainage took place.

The transformed dependents used in the average annual change analysis follows:

$$IRR1 = (IRR + 13)^{0.2858}$$

$$IRR2 = (IRR + 13)^{0.5957}$$

For the surface drainage project the following equation was established:

IRR1 =	3.146 +	0.011 AUCHYR
	(.148)	(.006)
	[.000]	[.13]
	R^2 = .17	sig F = .13

There is a positive relationship between the annual change in animal units and the expected IRR but neither the annual change in animal units coefficient nor the equation are significant at the 5% level of significance.

The relationship for the subsurface drainage projects was as follows:

IRR2 =	2.814 +	0.00011 Z16 +	4.683 DUM1
	(1.414)	(.000033)	(1.522)
	[.07]	[.006]	[.01]
	R^2 = .67		sig F = .002

There is a positive relationship between the IRR and the change per year in equipment capital expenditure and the dummy variable representing land use change. Both variables' coefficients and the equation are significant at the 5% level and together explain 67% of the variation in the IRR. The constant term is only significant at the 7% level.

For comparison purposes all three variables were related to the IRR for both types of projects. For surface projects the following relationship was established:

IRR1 =	3.142 +	0.0088 AUCHYR +	0.110 DUM1 +	.000015 Z16
	(.406)	(.0077)	(.420)	(.000019)
	[.0000]	[.28]	[.80]	[.45]
	R^2 = .25		sig F = .35	

None of the variables' coefficients nor the equation are significant at the 5% level. The constant is significant at the 5% level.

For the subsurface drainage projects the following equation was established:

IRR2 =	2.78 +	.00011 Z16 +	4.615 DUM1 +	.0155 AUCHYR
	(1.467)	(.00003)	(1.584)	(.032)
	[.09]	[.008]	[.02]	[.64]
	R^2 = .68		sig F = .008	

The addition of the animal unit change per year variable increased the R^2 by an insignificant amount(.007), reduced the F-statistic and was not a significant variable in the relationship. The other variables except for the constant remain significant.

When all the relevant variables were forced into the equation for the surface drainage system, the equation and all the variables' coefficients proved to be not significant and therefore unable to predict project viability. On the other hand the subsurface drainage equation was successful in explaining 68% of the variation on project viability. The equation, the land use factor variable's coefficient and the annual change in capital expenditure on equipment variable's coefficient were significant at the 5% level. In both equations inclusion of the additional [illegible] necessary to make both equations the same, was detrimental to the overall relationship.

In all of the above mentioned relationships, only the land use factor variable's coefficient(sig at 5%), the absolute change in capital investment in equipment variable's coefficient(sig at 5%) and the annual change in capital investment on equipment variable's coefficient(sig at 5%) proved significant for the subsurface drainage projects. For the surface drainage projects only the absolute change in animal units variable's coefficient(sig at 5%) proved to be significant. Combinations of the best explanators from each type of drainage, failed to provide significant relationships.

I. Model II: Exploratory Model

As stated earlier the second model was a exploratory model that allowed for a greater diversity of variables. No attempt was made to compare the two types of drainage projects using the same variables. A list of variables used in the exploratory model can be found in Appendix K. Six assumptions within Model II were considered:

1. The IRR was related to information about the farm and farmer in the year before drainage;
2. The IRR was related to information about the farm, farmer and drainage project in 1985;
3. The IRR was related to the absolute change in the characteristics between 1985 and the year before drainage;
4. The IRR was related to the average annual change in characteristics[141];

[141] The possibility of negative changes exist. Some good managers may have noticed a nonoptimal use of inputs over the years. This analysis is not capable of determining if the manager was or is operating in the stage II portion of the

5. The IRR was related to a land use change factor, the size of project and estimated CLI land classification; and
6. A repeat of 5 above, but including the previously omitted outlier.

Assumption I - Viability explained by farm characteristics before drainage

No significant relationships were found for either the surface or subsurface projects using variables relating to before drainage characteristics. Therefore it is not possible to predict project viability by measures of management intensity prior to the drainage project being installed.

Assumption II - Viability explained by farm characteristics in 1985, after drainage

The variables identified as being important in explaining project viability for the surface drainage projects were:

1. AUA, the number of animal units on the farm in 1985; and
2. PRAGE, the age of the project in years, in 1985.

The transformation of the dependent variable follows:

$$IRR1 = (IRR + 13)^{0.2858}$$

The following relationship between the IRR and the explanatory variables was established for the surface drainage projects:

IRR1 =	2.168 +	0.004 AUA +	0.124 PRAGE
	(.329)	(.001)	(.044)
	[.000]	[.008]	[.02]
	R^2 = .52		sig F = .01

The IRR is expected to increase as the number of animal units and the age of the project increase. The equation, the number of animal units in 1985 variable's coefficient, the age of the project variable's coefficient and the constant were all significant at the 5% level. The variables and the constant were able to explain 52% of the variation in surface project

[141](cont'd) classic production function.

viability.

The variables identified as being important in explaining project viability for the subsurface drainage projects were:

1. DUM1, the change in land use factor;
2. CRINA, the cropping intensity in 1985; and
3. Z13, the capital to labor ratio in 1985.

The transformation of the dependent variables was as follows:

$$IRR2 = (IRR + 13)^{0.5957}$$

For the subsurface drainage projects the following relationship was established:

IRR2 =	-26.59 +	.0093 Z13 +	28.468 CRINA +	4.428 DUM1
	(7.479)	(.0035)	(7.411)	(1.333)
	[.005]	[.026]	[.003]	[.008]
	R^2 = .81		sig F = .0007	

This relationship was able to explain 81% of the variation in the IRR. The equation, all explanatory variables' coefficients and the constant, were significant at the 5% level. The positive relationship between Z13, DUM1, CRINA and the IRR2 indicates that landowners with a higher capital to labor ratio and higher cropping intensities that drain land never used before, are more likely to have viable projects.

Assumption III - Viability explained by the absolute change in farm characteristics since drainage

For the surface drainage projects the relationship between the absolute change variables and the internal rate of return in Model II was identical to the relationship established under Model I, before the addition of the land use factor variable and the absolute change in capital expenditure on equipment. See Model I, Assumption III, Viability explained by absolute change in farm characteristics since drainage.

For the subsurface drainage projects, under Model II, there was no change in the form of the equation as established in Model I, Assumption III, Viability explained by absolute change.

Assumption IV - Viability explained by the average annual rate of change

No significant relationships were found for the surface drainage projects at the 5% level of significance. The best relationship is described in Model I, Assumption IV, Viability explained by the average annual rate of change.

The variables identified as being important for explaining project viability for the subsurface drainage projects were:

1. Z16, the annual change in capital expenditure on equipment;
2. DUM1, the land use factor; and
3. FCHYR, the annual change in fertilizer used per acre.

The transformed dependent variable is as follows:

$$IRR2 = (IRR + 13)^{0.5957}$$

The relationship between the IRR and the annual change variables for the subsurface drainage projects were as follows:

IRR2 =	3.013 +	.0009 Z16 +	4.885 DUM1 -	0.278 FCHYR
	(1.219)	(.00003)	(1.311)	(.126)
	[.03]	[.009]	[.004]	[.05]
	R^2 = .78		sig F = .001	

There is a positive relationship between the IRR and the annual change in capital expenditure on equipment indicating the greater the change in capital expenditure the more likely the project will be viable, and the IRR and the dummy variable representing the change in land use. This particular relationship was explained earlier. There is a negative relationship between the IRR and the annual change in fertilizer use per acre(the sign is not as expected)[149]. The elimination of the annual change in fertilizer use per acre, reduces the

[149]One explanation of the negative relationship between the average annual change in fertilizer use per acre and the internal rate of return is the possibility that landowners easily identify chemical fertilizer use as an input that can be cutback in tougher economic times. Ten of fourteen landowners used in the subsurface behavioral analysis had viable projects and of these ten, two reduced their use of chemical fertilizer per acre and four did not change the quantity of chemical

R^2 to .67 and the significance of the equation to .002.

Assumption V - Land Use Change, Soil and Project Size, Outlier Excluded

The size of project, CLI land classification and land use factor variables were regressed against the internal rate of return to establish if they had any predictive ability in estimating project viability. No significant relationships were established for the surface drainage projects.

In the relationship between the IRR and the above variables only the land use factor variable proved to be significant at the 5% level for the subsurface projects.

The transformed dependent variable is as follows:

$$IRR2 = (IRR + 13)^{0.5957}$$

The following equation was established:

IRR2 =	2.284 +	5.063 DUM1
	(1.916)	(2.069)
	[.26]	[.03]
	R^2 = .33	sig F = .03 .

The relationship explains 33% of the variation in the IRR. The coefficient of variable DUM1 and the equation are significant at the 3% level but the constant term is not significant at the 5% level. The conclusion is that even if the outlier(the landowner who installed subsurface drainage but showed no change in land use on the drained area and therefore no cash benefits) is excluded, the land use factor is an important predictor of project viability.

Assumption VI - Land Use Change, Soil and Project Size, Outlier Included

The relationship examined in this section is identical to the one above, but includes the previously omitted outlier and increases the number of cases considered for the subsurface drainage projects to fifteen. This inclusion of the outlier caused changes in the transformations of the dependent variable, but no change in the significance of the

[149](cont'd) fertilizer used per acre over the life of the project.

relationship between the IRR, the dummy variable, the soil or size of the project for the surface drainage projects.

For the subsurface drainage projects the relationship improved to the point where the dummy variable was able to explain 47% of the variation in the IRR. None of the other two variables' coefficients proved to be significant.

The newly transformed dependent variable is:

$$IRR2 = (IRR + 101)^{1.5307}$$

The resulting relationship is as follows:

IRR2 =	676.228 +	833.673 DUM1
	(220.098)	(246.673)
	[.009]	[.005]
	R^2 = .47	sig F = .005

The improvements over the situation where the outlier was omitted, besides the improvement to the R^2, included the significance of the constant term to the 1% level as compared to the 26% level, the improvement in the significance of the coefficient of variable DUM1 from 3% to less than 1% and the improvement in the equation F-statistic from a significance at the 3% level to significance at the 1% level.

As explained earlier, the outlier was the result of a landowner draining land for the sole purpose of being able to get on that land earlier in the spring. There were no cash benefits associated with this land improvement, therefore the land use factor was zero and the IRR was -100%. The strengthened relationship between the poor IRR and the land use factor(taking on a value of zero) is a result of the inclusion of the strong positive relationship between the no change in the land use factor corresponding to no incremental gain. Also contributing to a better fit was the increase in the number of cases being considered.

The behavioral analysis failed to identify important management intensity characteristics that would aid in predicting project viability prior to the installation of the drainage system. The behavioral analysis did substantiate the original hypothesis that management intensity influences project viability after the drainage project has been installed.

Surface drainage viability is related to the number of animal units on the farm in 1985 and the absolute change in animal units on the farm between 1985 and the year prior to drainage. The higher the number of animal units or the greater the absolute change in the animal units the more viable the project. The project age variable is important in confirming that the lower the original costs of the system, the greater the viability. Older surface projects had lower per acre costs in real terms.

The behavioral analysis of subsurface drainage projects also substantiates the original hypothesis. The land use factor is important in predicting project viability. If the area being considered for drainage has been producing at least part of the time the chances are not very good that the subsurface drainage project will be economically viable. In addition to the land use factor, the capital-labor ratio and the cropping intensity variables in 1985 and the variables relating to changes in expenditure on equipment were important in explaining project viability. The positive relationship between the previously mentioned variables and the project viability confirms that farms that are more capital intensive or have a higher cropping intensity are more likely to have a viable project.

V. SUMMARY, RESULTS and CONCLUSIONS

A. Purpose and Method

The purpose of this research was to provide some answers to economic questions regarding the economic viability of drainage from a private enterprise point of view. The desired results are decision making criteria to promote rational economic decisions regarding anticipated drainage projects prior to actually undertaking the project.

The objectives of this study were: 1) to explore an effective method of assessing the economic worthiness of alternative drainage designs in Alberta; 2) to establish whether an increase in management intensity proxied by changes in land use, capital, and input use since the drainage installation, influences the economic worthiness criteria and to determine why some drainage projects are more successful than others; and 3) to determine the extent of consistency between landowners' expectations from drainage and benefits actually received.

Two types of drainage design were examined, surface and subsurface. Fifteen pairs of structurally similar farms in east central Alberta differing only in the type of drainage design used, were randomly selected for analysis. Similarity of the farms allowed differences in economic viability of drainage to be attributed to the type of drainage design. Standard project appraisal techniques were employed to determine the economic viability of the drainage systems.

The influences of management intensity on project viability were explored with two behavioral models. The first was a strictly comparative model which examined the viability of each drainage system using the same explanatory variables.The second was an exploratory model with no *a priori* specification of the explanatory variables.

The Kolmogorov-Smirnov two sample test and the Wilcoxon matched-paired analysis test were applied to confirm that the pairs of farms were structurally similar. Differences existed at the 5% level of significance for seeded acreage and cropping intensity characteristics only. These differences were not significant at the 1% level. Only the CLI land classification was different at both the 5% and 1% levels of significance, principally due to the arbitrary classification of drained organic soils.

B. Limitations of Study

The results found and the conclusions drawn in this research are based on a sample size of fifteen for each type of drainage. The small sample size reflects the small number of drainage projects officially recorded. The lack of generally available government support for drainage combined with onerous licensing procedures either limit the number of drainage projects or impede public knowledge of drainage work.

Two basic problems exist with a small sample size. The first is a reduced number of degrees of freedom for statistical tests and regression analysis. The second is that the probability of committing a Type II error (to accept the null hypothesis when it is false) increases as N decreases. Interpretations, conclusions and recommendations must be drawn carefully.

Throughout the study the assumption has been made that good managers use more of an input than do poor managers. Measurements of inputs have been used as a proxy for management intensity but there is no way ~~of knowing~~ in which stage of the classical production function a particular manager is operating. A good manager, over the life of the project, may have reduced the use of some input if he discovered its' use to be nonoptimal. Throughout this research the assumption has been that a good manager will always have increased his use of inputs relative to the land base over time.

The market values for greenfeed and native hay were estimated on the basis of the ratio of their nutritional value to the nutritional value of tame hay multiplied by the market value of tame hay. This procedure presumes there is a market for native hay and greenfeed, where none normally exists.

1985 market prices for grains, oilseeds and hay were based on Alberta Agriculture's preliminary 1984-85 prices and these prices were projected until the end of the project life. An updated version of the above price information indicated that preliminary 1985 grain and oilseed prices may actually be lower than the ones used in the study but tame hay prices may be higher. This means that based on cash benefits, the viability of surface drainage projects may be underestimated while that of subsurface drainage projects may be somewhat overestimated.

C. Results

The drainage systems had different characteristics. The construction costs of subsurface drainage were higher than construction costs for surface drainage. The total acreage gained[150] from surface systems was higher than the total acreage gained from subsurface systems. Consequently the costs per total acre gained were higher for subsurface systems. Rehabilitation time, the length of time required before the drained land became productive, was greater for surface drained land.

Similarities between drainage systems are total costs[151], and costs for rehabilitation, maintenence and operation. The acres improved by drainage were similar for both systems. Measurements of project worth were examined under four scenarios distinguishing between reported maintenance and a theoretical yearly maintenance based on 3% of the original construction cost. Comparisons are made against a 5% opportunity cost of capital benchmark.

1. Scenario I considered all costs associated with the project, all benefits(cash and non-cash) and the appropriate taxes.
2. Scenario II considered all costs and taxes as in Scenario I above but did not include any non-cash benefits.
3. Scenario III considered all the costs, cash benefits and taxes as in Scenario II but examines the effect of a cash grant equivalent to 50% of the construction costs.
4. Scenario IV considered all costs, taxes and the effect of a 25% reduction in cash benefits on the project viability.

Using the 5% opportunity cost of capital benchmark and reported maintenance costs, surface drainage was not viable in only one of fifteen cases in Scenario I, which included all farm costs, all farm benefits and taxes and in Scenario II which included all farm costs, cash benefits and taxes. If a 50% grant was applied toward the construction costs as in Scenario III, all projects were viable. When the cash benefits were reduced by 25%, Scenario IV, two of fifteen projects were not viable. The mean IRRs were 63.1% in Scenario I, 55.3% in Scenario

[150]The total acres gained from drainage include the acres gained directly from the drainage system and the acres surrounding the gained area that were improved ~~by~~ the drainage system.

[151]Total costs include costs of the system/construction plus any rehabilitation, maintenance and operating costs.

II, 74.3% in Scenario III and 39.2% in Scenario IV. The inclusion of the 3% yearly maintenance costs did not alter the mean IRRs significantly but did increase the number of nonviable projects in Scenario IV to two.

Four of fifteen subsurface drainage projects were not viable in Scenario I, with all farm costs, all farm benefits and taxes and in Scenario III, all farm costs, cash benefits, taxes and a 50% grant. In Scenario II, where all farm costs, cash benefits and taxes are represented, five of fifteen projects were not viable. When cash benefits were reduced by 25%, nine of fifteen projects were not viable and one was marginally viable. The mean IRRs were 20.1% in Scenario I, 6.3% in Scenario II, 18.3% in Scenario III and -2.1% in Scenario IV. Inclusion of the 3% yearly maintenance costs increased the number of nonviable projects to seven in Scenario II and to eleven in Scenario IV and reduced the mean IRRs substantially in all Scenarios.

In the behavioral analysis Model I was unsuccessful in establishing strictly comparable explanations for economic viability. Variables significant in explaining project viability for one type of drainage project were never significant for the other.

Model II, the exploratory model, failed to uncover any significant relationships between project viability and the characteristics of the farm operation in the year preceding drainage. Viability was related however, to aspects of the farm operation prevailing in 1985, after drainage. The number of animal units on the farm in 1985 combined with the age of the project explained 52% of the variation in project viability. The combination of the 1985 capital-labor ratio, cropping intensity and land use factor explained 81% of the variation in subsurface project viability. Put another way, viability of subsurface drainage is better under conditions of mechanization, more intensive cropping and higher value crops over the whole farm.

The absolute change in animal units over the life of the project and project age explained 40% of the variation in surface project viability. For the subsurface projects the combination of the absolute change in capital expenditure on equipment and land use factor explained 66% of the variation in project viability.

Average annual changes in measures of intensification exhibited no significant relationships with viability for the surface drainage projects. For subsurface projects the combination of average annual change in capital expenditure on equipment, annual change in fertilizer use per acre and land use factor explained 79% of the variation in subsurface project viability. Neither land capability classification nor project size were significant in explaining project viability.

Landowners seem satisfied with the realized benefits from drainage. Only two of fifteen surface drainers felt their system had not worked as expected. Four of fifteen subsurface drainers felt their system had not worked as expected. Fourteen of fifteen surface drainers would drain land again. Thirteen of fifteen subsurface drainers would drain land again.

D. Interpretive Conclusions

A list of interpretive conclusions based on the results of this research follows:

1. Landowners contemplating drainage should consider both surface and subsurface drainage designs. Surface drainage projects are more viable than subsurface projects and their viability is not particularly sensitive to reductions in the benefit stream;
2. Landowners contemplating subsurface drainage and expecting an economically viable project must be prepared to substantially intensify their use of the drained area;
3. Landowners contemplating drainage by subsurface means must be aware that the economic viability of the project is likely to be higher under conditions of higher mechanization and more intensive cropping over the whole farm;
4. Landowners contemplating drainage by subsurface means should be aware that the viability is sensitive to reductions in the benefit stream;
5. Public agencies promoting land expansion through drainage should consider price stabilization policies or insurance policies to protect the landowners against reductions in the benefit stream;
6. Public funding by means of cash grants is not justifiable for surface drainage projects. These projects are viable under normal conditions; and

7. Before public funding in the form of cash grants is provided for a subsurface project, the potential for a change in intensity, in both the whole farm operation and the drained area, should be examined.

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APPENDIX A: The Canadian Land Inventory: Soil Capability for Agriculture

The CLI soil capability for agriculture is an interpretive classification which groups mineral soils in seven classes according to their potentialities and limitations for agricultural use. Organic soils are not placed in a capability class. The CLI classes are an assessment of the degree of intensity of limitations on the uses of the land for agricultural purposes.

The first three CLI classes are capable of sustained production of common cultivated crops. They are described as follows:

CLI Class 1 - these soils have no significant limitations to use for crops.

CLI Class 2 - these soils have moderate limitations that restrict the range of crops or require moderate conservation practices.

CLI Class 3 - these soils have moderately severe limitations that restrict the range of crops or require special conservation practices.

The fourth class is considered marginal for arable agriculture.

CLI Class 4 - these soils have severe limitations that restrict the range of crops that can be grown or require special conservation practices to overcome both.

The fifth class is capable of use only for permanent pasture or hay.

CLI CLass 5 - these soils have very severe limitations that restrict their capability for producing perennial forage crops and improvement practices are feasible.

Agriculture capability of the sixth class is limited to use for native grazing.

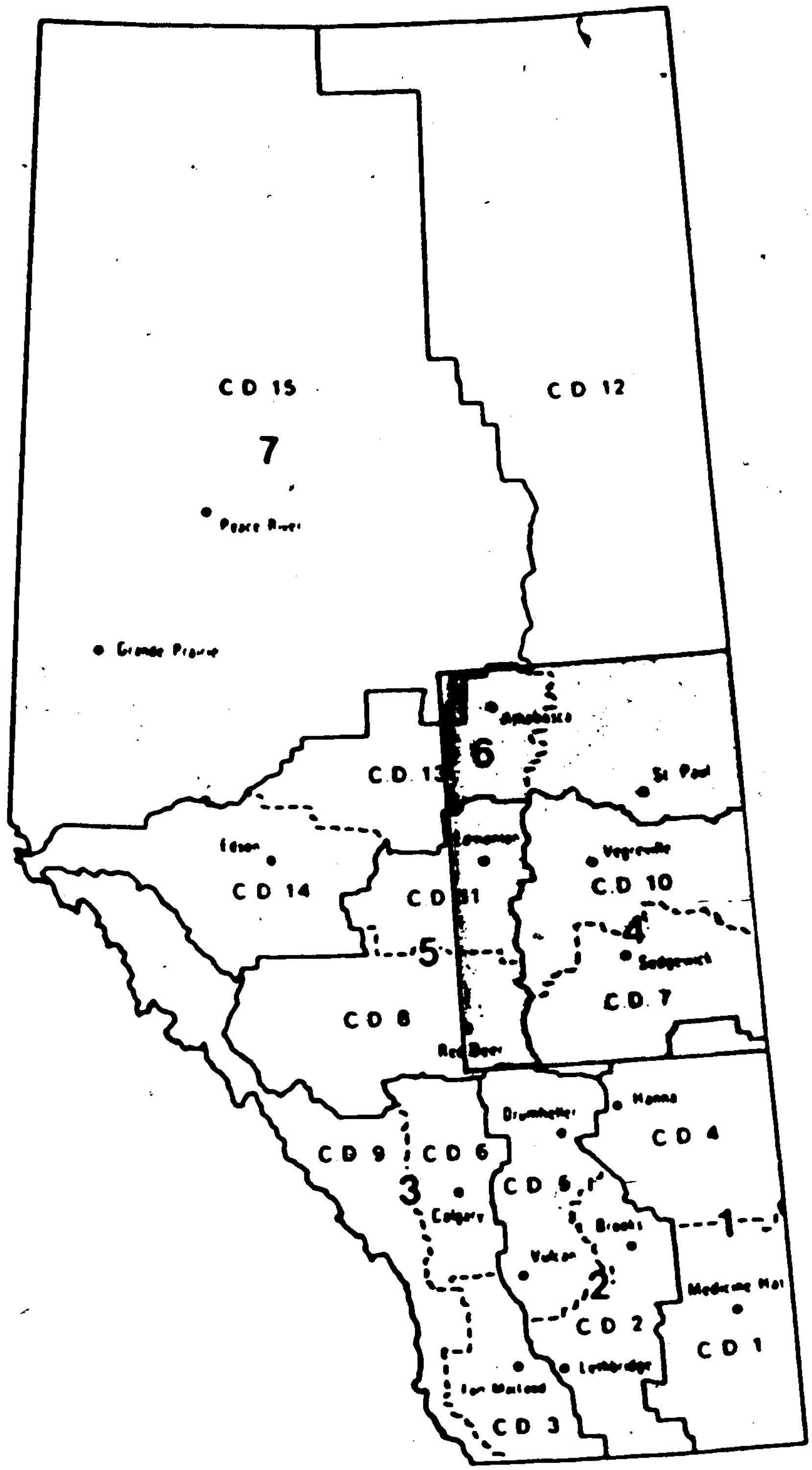
CLI Class 6 - these soils are capable only of producing perennial forage and improvement practices are not feasible.

CLI Class 7 - these soils have no capability or potential for arable agriculture or pasture.

O - Organic soils(not placed in capability classes).

Source: International Society of Soil Science, page 96 and Canada Land Inventory Soil Capability for Agriculture - Alberta Map.

APPENDIX B: Map Showing Census Divisions and Area Under Study



Source: Alberta Agriculture, *Agriculture Statistics Yearbook, 1983*. Agdex No. 853-10.

APPENDIX C: A Summary of Cost Sharing Policy on Water Management Projects

Alberta Environment[152] has recognized the need for an equitable, practical and easily applied policy in financial assistance for cost-sharing on water resource projects including drainage projects. Under the statement of policy, the province is prepared to cost-share with local authorities on water resource management projects from which direct public benefits accrue. "Local Authority" means a city, town, new town, village, municipal district, county or the Ministry of Municipal Affairs in the case of an improvement district. The province will provide a grant equal to 75% of the eligible cost of a project[153]. Eligible costs are engineering costs related to project design and construction and capital costs associated with construction.

Projects eligible for assistance are:

1. Flood Control and Drainage;
2. Flow Regulation;
3. Erosion Control;
4. Water Based Recreation;
5. Fish, Waterfowl and Wildlife Enhancement; and
6. Source of Water Supply,

provided that:

1. The project is initiated by a local authority;
2. There is a demonstrated need for the project; and
3. The project is in the public interest.

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[152]Alberta Environment. *Cost Sharing on Water Management Projects, Position Paper No. 5, Revised 1980*. Edmonton. Alberta Environment, Water Resources Administration Division. 1980.

[153]In a news release dated April 25, 1986, Fred Bradley, Minister of the Environment, announced a change in the funding formula from 75% provincial - 25% local government to 86% provincial - 14% local government for drainage and erosion control projects undertaken under the Alberta Water Resources Grant Program.

Procedure for Obtaining Assistance

The procedure for obtaining assistance is divided into four phases, the first being the eligibility phase in which the local authority identifies a particular water resource problem and the department of the environment carries out an inspection and determines whether or not it is eligible for assistance under the program. The second involves a feasibility study that investigates alternative solutions to the water problem and reports on estimated costs and an assessment of the engineering, sociological and biological aspects of the solution and recommends whether or not it should be implemented. Upon submission of this report for approval, the local authority officially requests financial assistance from the department for implementation of the project. If the project is approved the project proceeds to the construction phase and a cost sharing agreement, between the local authority and the department, is signed. The third phase involves obtaining licenses or permits and right-of-ways and easements and the local authority proceeds with construction. After completion the department inspects the project to ensure it has been constructed as planned. The fourth phase involves submitting the as constructed plans and the itemized account of actual costs, issuing a final license or permit and the forwarding of the grant to the local authority. The grant is equal to 75% of the constuction and engineering costs of the project.

Not all projects proposed by local authorities are guaranteed financial assistance. It will depend on the water management priorities established by the provincial government and the availability of funding.

APPENDIX D: Average Farm Value for Major Crops in Alberta

YEAR	Wheat	Oats	Barley	Rye	Canola	Tame Hay	Native Hay	Greenfeed
1971	4.29	1.65	2.21	2.71	7.13	70.96	76.83	63.14
1972	5.66	2.58	3.88	4.74	9.72	65.54	70.95	58.34
1973	11.19	4.25	4.74	6.89	15.09	94.99	102.82	61.06
1974	8.98	3.45	4.99	5.06	16.01	93.27	100.98	82.99
1975	7.05	2.85	4.64	5.30	10.22	85.34	92.39	75.94
1976	5.23	2.11	3.51	4.06	11.35	85.51	92.58	76.09
1977	5.00	1.73	2.91	4.18	11.62	86.36	93.49	76.85
1978	5.91	1.65	2.78	4.12	10.27	75.12	81.32	66.85
1979	6.73	1.97	3.20	5.21	8.50	83.80	90.72	74.57
1980	6.75	2.25	3.82	5.69	8.04	93.12	100.82	82.87
1981	5.47	1.73	2.72	3.95	6.88	68.08	73.70	60.59
1982	4.77	1.23	2.06	2.29	6.62	75.71	81.97	67.37
1983	4.94	1.64	2.65	2.93	9.02	76.60	82.93	68.16
1984	4.62	1.53	2.56	2.56	8.07	82.57	90.72	74.57
1985	4.53	1.50	2.51	2.51	7.92	81.00	87.69	72.08

Source: Alberta Agriculture. Statistics Branch. All values in 1985 dollars. 1985 prices based on 1984 prices.

APPENDIX E: Table of Farm Input Price Indices Using 1985 as a Base Year

YEAR	FARM INPUT PRICE INDEX
1971	30.3
1972	32.5
1973	37.9
1974	44.1
1975	49.8
1976	53.5
1977	55.0
1978	61.9
1979	72.2
1980	79.4
1981	92.0
1982	95.1
1983	95.3
1984	98.1
1985	100.0

Source: Statistics Canada. *Farm Input Price Index*. Catalogue 62-004. Quarterly. Statistics Canada. 1971-1985.

APPENDIX F: Questionnaire Used in this Study

ECONOMIC APPRAISAL OF FARM DRAINAGE QUESTIONNAIRE

ALL INFORMATION WILL BE KEPT STRICTLY CONFIDENTIAL

1. Legal Location of Drained Land: ______________________________

   ____
2. Owners Name: ______________________________
3. Address: ______________________________
4. Telephone No.: ______________________________
5. Type of Drainage: ______________________________
6. P.S.U. Number: ______________________________
7. Date of Interview: ______________________________

NOTES: ____

RESEARCH FUNDING PROVIDED BY FARMING FOR THE FUTURE

ECONOMIC APPRAISAL OF FARM DRAINAGE

SECTION A: HISTORY OF DRAINAGE

1. What was the one primary reason for draining?

    ____ To remove a wet area or standing water

    ____ To facilitate the removal of spring runoff

    ____ To control salinity

    ____ Other (please specify) ____

2. What benefits did you feel would be achieved by drainage?

    ____ increased crop land and returns

    ____ remove nuisance factor

    ____ eliminate wasted inputs

    ____ control weed problems

    ____ control wasted outputs

    ____ eliminate hunter trespassing

    ____ consolidate fields

    ____ facilitate larger machinery

    ____ aesthetics

    ____ other

3. What induced you to drain the land in the first place?

    ____ literature ____ neighbors

    ____ yourself ____ contractors sales pitch

    ____ annoyance ____ previous drainage experience, where ____________________

4. When was the drainage system installed?

    ________ years installed: month ________ year ________

5. How has the land been used since draining?

    ________ years of no use whatsoever

    ________ years used as hay/pasture

    ________ years cropped for cereal/oilseeds

________ total years since draining

6. What year after drainage did you get the first crop off?

________ year

7. How would you classify the drained area?

____ temporary slough or pothole ___ wet 0-3 mo. ___ wet 0-6 mo.

____ permanent slough or pothole wet all year

____ temporary wetland used for pasture or hay

____ permanent wetland marsh, not suitable for forage

____ bush or tree land

8. In the following diagram of your quarter section, sketch the drained area showing the approximate number of sloughs, potholes or wet areas, their distribution, and location in the quarter. Estimate the cultivated acres before drainage and after drainage. Sketch one diagram for each quarter drained.

Legal Location: ________	Legal Location: ________	Legal Location: ________
Cultiv. Ac. Before ________	Cultiv. Ac. Before ________	Cultiv. Ac. Before ________
Cultivated Ac. After ______	Cultivated Ac. After ______	Cultivated Ac. After ______

9. Was there any other problem associated with the drained area such as:

____ salinity

____ alkalinity

____ other

10. The system works as well as you expected it to work?

Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

11. If the system doesn't work as well as you expect it should, rank what you perceive to be the main problem.

____ design	____ surveying
____ installation and construction	____ engineering
____ soil testing	____ other

12. Were the design characteristics of the system the direct result of you having a certain cropping objective in mind?

____ Yes What Crop? ________________

____ No

13. What specific varieties of crops have you tried to grow on the drained field and which have been successful?

Crop	Successful Yes	No
________	___	___
________	___	___
________	___	___

14. Given the information you now know, would you drain land again?

____ Yes ____ No ____ Not Sure

15. If literature had been available regarding the economics of drainage, it would have helped influence your decision?

Strongly Agree Agree Neutral Disagree Strongly Disagree

SECTION B: BIOGRAPHICS

1. How long have you farmed this property?

   ________ Years

2. What are the total acres of your farm?

   ________ Total ________ Owned ________ Rented

3. How many acres are cultivated?

   ________ Acres

4. How many acres are?

   ________ seeded ________ houseplot

   ________ Fallow ________ bush

   ________ pasture ________ sloughs & wetland

   ________ forage land

5. How many people are in your family household?

   1 2 3 4 5 6 7 8

6. How many people are involved in farm labor on your farm?

   Family members 1 2 3 4

   Hired help 1 2

7. How many hours per week does each member contribute?

Total Hours	Member	No. of weeks at hours per week								
________	Family 1	___ wks at	0	10	20	30	40	50	60	hrs/wk
		___ wks at	0	10	20	30	40	50	60	hrs/wk
		___ wks at	0	10	20	30	40	50	60	hrs/wk
		___ wks at	0	10	20	30	40	50	60	hrs/wk
		___ total weeks								

________	Family 2	____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ total weeks							
________	Family 3	____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ total weeks							
________	Family 4	____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ total weeks							
________	Hired 1	____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ total weeks							
________	Hired 2	____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ wks at 0	10	20	30	40	50	60	hrs/wk
		____ total weeks							

8. How would you classify your farm?

____ Cash crop

____ Dairy

____ Mixed Livestock

____ Other

____ Cash Crops & Livestock

____ Beef

____ Swine

SECTION C: CAPITAL COST, OPERATION, MAINTENANCE & REHABILITATION

1. What was the total cost of the drainage?

	WHO PAID Self	Other
System Costs: Year ________		
________ survey	________	________
________ design	________	________
________ installation & construction	________	________
________ special equipment (pumps etc.)	________	________
________ other	________	________
Rehabilitation Costs: (brushing, rocks, etc.) Year ________		
________ hired equipment	________	________
________ labor hours (+ self)	________	________
________ machinery hours (own)	________	________
________ herbicides	________	________
________ other	________	________
Operation Costs:		
________ yearly operating costs	________	________
Maintenance:		
________ maintenance costs ________ year	________	________

2. Is your drainage system a tile (plastic pipe) or ditch system?

____ pipe ____ ditch

SECTION D: DIMENSIONS OF THE DRAINAGE

1. How many feet of pipe were installed, what were the diameters of this pipe and was the pipe filtered?

   ________ feet of ________ diameter, filtered ____ yes ____ no

   ________ feet of ________ diameter, filtered ____ yes ____ no

   ________ feet of ________ diameter, filtered ____ yes ____ no

   ________ total length

2. What is the planned life of the project?

   ________ years

3. How many ditches were dug? ____________ ditches

4. What was the total length of ditch? ____________ feet

5. What was the average width? ____________ feet

6. What was the average depth? ____________ feet

7. How much land did you lose to the ditches of this drainage system? ____________ acres

8. What is the planned (expected) life of the ditches ________ years

9. After a heavy rain or in early spring how many days does it take to remove all of the water?

   ________ days

SECTION E: BENEFITS

1. At the time you drained your land what was the price of farm land in your area?

   ________ $/acre

2. What is farm land selling for now in your area?

   ________ $/acre

3. What would be the price of a quarter with drainage?

   ________ $/acre

4. Before draining you were under the impression that this investment would pay (i.e. be economic)

   Strongly Agree   Agree   Neutral   Disagree   Strongly Disagree

5. Has your impression of the benefits of the drainage system changed since installation? What did you think the major benefit would be before drainage and after?

   Before ____

   After ____

6. How much would someone have to pay you per acre NOT to drain land?

   ________ $/acre

7. Did you use the cost of the project as a tax deduction in the year the system was installed?

   ____ Yes   ____ No   ____ Didn't know it could be done

   If yes, did you still pay income tax that year?

   ____ yes   ____ no

   If yes, how much income tax money did the drainage system save you **OR** what is your marginal income tax rate?

   ________ dollars **OR**

   ________ $ = drainage cost ________ x tax rate ________

   If no, how much of the drainage expense was needed to bring your taxable income into the zero tax payable range?

   ________ dollars or ____ %

   ________ tax saving = ________ expense x tax rate ________

8. How many acres were gained, directly and indirectly, by the drainage system? (i.e. how much land is now being used that wasn't usable before, based on a 5 to 10 year average, keeping in mind that some years have been wetter than others?)

_________ acres gained

_________ acres indirectly gained

9. What crops were grown on the drained quarter(s) the year before drainage, what were the average yields and how many acres were seeded to each crop? Include forage (tons, bales) and pasture (animals/acre) values.

Year	Quarter	Crop	Yields	Acres

10. What crops were grown on the drained quarter(s) the year(s) after drainage? What were the average yields on the undrained portion and on the drained portion? Include forage (tons, bales) and pasture (animals/acre) value.

Year	Quarter	Crop	Yield UnDrained	Yield Drained

11. What is the productive capacity of the ditch area for hay production?

_________ bales/tons on whole ditch system.

12. Prior to drainage what was the frequency of harvest from the drained land?

_____ Never harvested

_____ Used as pasture (native)

_____ Harvested occasionally (1-4/10)

_____ Harvested every second year (5/10)

_____ Harvested in most years (6-9/10)

_____ Every year, with losses

____ Every year, with difficulty

13. Since drainage what has been the frequency of harvest from this land?

____ Never harvested

____ Used as pasture (native)

____ Harvested occasionally (1-4/10)

____ Harvested every second year (5/10)

____ Harvested in most years (6-9/10)

____ Every year, with losses

____ Every year, with difficulty

____ Every year

14. Has there been a difference in the grain grade and dockage on the drained quarter since drainage?

Crop	Dockage Before %	Dockage After %	% Graded Before	% Graded After
Wheat	___	___	__1 __2 __3 __Feed	__1 __2 __3 __Feed
Barley	___	___	__ Malting __ Feed	__ Malting __ Feed
Canola	___	___	__1 __2 __3	__1 __2 __3

____ no difference

____ not sold

____ don't know

~~15. The germination~~ rate since drainage is higher than before drainage.

Agree Same Disagree Don't Know

16. If you had a salinity problem, the drainage system has controlled or reversed this salinity problem.

Agree Same Disagree Don't Know

17. The drainage system has controlled or reduced plant diseases or parasites.

Agree Same Disagree Don't Know

18. The drainage system has increased the drought resistance of the plants.

Agree Same Disagree Don't Know

19. There has been an improvement in soil structure.

___

Agree Same Disagree Don't Know

20. What has been the difference in all risk crop insurance rates?

____ increased ____ same ____ decreased ____ doesn't use

21. Has the removal of the wet area reduced any wasted input costs and what was the value of these wasted inputs? (do not include labor and machinery)

____ no saving ____ seed value

____ fertilizer value ____ herbicide value

____ other ______________________________

22. Has there been any advancement of the seeding time after drainage?

____ Yes ________ days

____ No

23. Has there been an extension of the harvest season?

____ Yes ________ days

____ No

24. Have you been able to change species of crops due to a longer growing season?

____ Yes ____ No

25. Is there any noticeable difference in the evenness of the maturation of the crops?

____ Yes ____ No

26. Is there any difference in the length of time it takes the field to become workable after a heavy rainfall compared to when it was not drained?

____ Yes ________ days ____ No

27. Have you noticed a difference in the amount of grain lost or damaged due to birds or waterfowl?

____ Yes ____ No

28. If yes, what is the approximate value of this difference?

________ Value of crops lost

________ Value of crops gained

29. How long did it take you to perform each operation, before and after drainage and how many operations did you perform or how much time did you save on each field operation?

Operation	# of Operations	Hours Saved
Disc	________	________
Cultivate	________	________
Fertilize	________	________
Spraying	________	________
Harrowing	________	________
Seeding	________	________
Harvesting	________	________
Haying	________	________
Other	________	________

30. Labor requirements have decreased since drainage.

Strongly Agree Agree Neutral Disagree Strongly Disagree

31. If you agree, approximately how many hours are saved?

________ hours of labor

32. For your particular situation, how would you rank the removal of the following inconveniences as a result of drainage? (1 = most important)

____ Machinery not stuck as often

____ Less wasted inputs

____ Combine not plugging up

____ Other benefits ________________________________

SECTION F: INTENSITY OF FARMING

1. What type of equipment did you own the year prior to drainage? (Please specify only the largest of each).

________ Tractor value	Model ________	Year _____	HP ________
________ Combine value	Model ________	Year _____	Cyl. width _____
________ Cultivator value	Model ________	Year _____	Width ________
________ Sprayer value	Model ________	Year _____	Width ________

2. What equipment do you own today? (Please specify only the largest of each).

________ Tractor value	Model ________	Year _____	HP ________
________ Combine value	Model ________	Year _____	Cyl. width _____
________ Cultivator value	Model ________	Year _____	Width ________
________ Sprayer value	Model ________	Year _____	Width ________

3. How much livestock did you own before drainage?

________ Brood Cows ________ Bulls

________ Other Cattle ________ Sheep

________ Swine

4. How much livestock do you own now?

________ Brood Cows ________ Bulls

________ Other Cattle ________ Sheep

________ Swine

5. How much land did you farm prior to drainage?

________ total acres ________ owned ________ rented

SECTION G: MANAGEMENT INTENSITY

1. In the last year prior to drainage, what area of crops were grown (acres) over the whole farm?

________	Winter Wheat	________	Spring Wheat
________	Oats	________	Barley
________	Flax	________	Canola
________	Fall Rye	________	Spring Rye
________	Mustard	________	Buckwheat
________	Canary Seed	________	Field Beans
________	Summerfallow	________	Tame Hay
________	Native Hay	________	Pasture
________	Wasteland	________	Other

________ Total Acres

2. What were the yields of these crops, on average for the whole farm over the two years prior to drainage, in bushels per acre, tons/acre or acres per animal unit month?

________	Winter Wheat	________	Spring Wheat
________	Oats	________	Barley
________	Flax	________	Canola
________	Fall Rye	________	Spring Rye
________	Mustard	________	Buckwheat
________	Canary Seed	________	Field Beans
________	Summerfallow	________	Tame Hay
________	Native Hay	________	Pasture
________	Wasteland	________	Other

3. This year, what area of crops are grown (acres) over the whole farm?

________ Winter Wheat	________ Spring Wheat
________ Oats	________ Barley
________ Flax	________ Canola
________ Fall Rye	________ Spring Rye
________ Mustard	________ Buckwheat
________ Canary Seed	________ Field Beans
________ Summerfallow	________ Tame Hay
________ Native Hay	________ Pasture
________ Wasteland	________ Other ________ Total Acres

4. What are the yields of these crops, based on an average for the whole farm over the past two years, in bu./ac., tons/ac., or acres per animal unit month.

________ Winter Wheat	________ Spring Wheat
________ Oats	________ Barley
________ Flax	________ Canola
________ Fall Rye	________ Spring Rye
________ Mustard	________ Buckwheat
________ Canary Seed	________ Field Beans
________ Summerfallow	________ Tame Hay
________ Native Hay	________ Pasture
________ Wasteland	________ Other

5. What weed problems did you try and control the year before drainage?

____ Quack grass	____ Sow thistle
____ Canada thistle	____ Foxtail
____ Wild oats	____ Other

6. What weed problems did you try and control the first crop year after drainage?

____ Quack grass ____ Sow thistle

____ Canada thistle ____ Foxtail

____ Wild oats ____ Other

7. Which herbicides did you use in the year before drainage and at what rate per cultivated acre?

	Chemical	Acres	Recommended Rate	Other Rate
Wild oats				
Broadleaf				
Special purpose				

8. Which of the herbicides did you use this year and at what rates?

	Chemical	Acres	Recommended Rate	Other Rate
Wild oats				
Broadleaf				
Special purpose				

9. What fungicide did you use the year before drainage, what proportion of your seed was treated, at what rates, and what were the costs per acre?

	Chemical	% of Seed Treated	Rate	$/Acre

10. What fungicide did you use this year, what proportion of your seed was treated, at what rates, and what were the costs per acre?

	Chemical	% of Seed Treated	Rate	$/Acre

11. What proportion (%) of seeded acres was seeded with certified or registered seed or better seed on the whole farm the year before drainage?

_________ % of acres

12. What proportion (%) of seeded acres was seeded with certified or registered seed or better seed on the whole farm this year?

_________ % of acres

13. What fertilizer did you use and at what rates did you apply it the year before drainage on the whole farm on stubble? Specify the pounds per acre of each fertilizer, the proportionality of each fertilizer in a blend or the actual N, P_2O_5 or K applied.

	N/ac.	P_2O_5/ac.	Other Blends
Barley	________	________	________
Wheat	________	________	________
Canola	________	________	________
Oats	________	________	________

14. What fertilizer did you use and at what rates did you apply it the year after drainage on the whole farm on stubble? Specify the pounds per acre of each fertilizer, the proportionality of each fertilizer in a blend or the actual N, P_2O_5 or K applied.

	N/ac.	P_2O_5/ac.	Other Blends
Barley	________	________	________
Wheat	________	________	________
Canola	________	________	________
Oats	________	________	________

15. Did you make other improvements to the drained field as a direct result of the drainage? such as:

____ Brushcutting

____ Fence removal

____ Field enlargement

____ Combinations of the above

APPENDIX G: Peripheral Results

A: Characteristics of Drained Area-History of Drainage

Primary Reason for Draining

Participants in the survey were asked what the main reason for draining the land was? Of fifteen surface drainage respondents fourteen drained to remove a wet area or standing water and one drained in order to facilitate the removal of spring run-off.

Twelve of fifteen subsurface drainers, drained to remove a wet area or standing water, two of fifteen drained to remove a wet area or standing water that was causing salinity problems and one of fifteen drained to remove a wet area or standing water, facilitate the removal of spring runoff and to control salinity.

Classification of the Wet Area

Of fifteen surface drainers, one drained an area that was wet between 0 and 6 months, seven drained a permanent slough or pothole that was wet all year, one drained a temporary wetland that was used at times for hay or pasture, six drained a permanent wet marsh that was not suitable for pasture and none drained an area wet between 0 and 3 months or bush or treed land.

Of fifteen subsurface drainers, three drained an area that was wet between 0 and 3 months per year, four drained an area that was wet between 0 and 6 months per year, seven drained a permanent slough or pothole that was wet all year long, one drained a permanent wet marsh not suitable for pasture and none drained a temporary wet area occasionally used for hay or pasture or bush or treed land.

Other Problems Associated with the Wet Area

Landowners were asked if there were any other problems associated with the wet area in addition to the obvious excess water problem. Of the surface drainers, fourteen of fifteen reported no other problems with the wet area and one of fifteen reported the problem of peat(organic soils).

Of the subsurface drainers, eight of fifteen reported no other problems, six of fifteen reported salinity problems and one of fifteen reported an alkilinity problem.

Perceived Benefits of Drainage

Participants were asked what they felt, prior to drainage, would be the benefits achieved by drainage. All fifteen of the surface drainers felt that one of the benefits would be increased cropland and returns, eight of fifteen thought a benefit would be the removal of the nuisance factor caused by the wet area, three of fifteen thought the benefit would be the elimination of wasted inputs, control of weed problems or control of wasted outputs(product loss). Two of fifteen felt it would eliminate hunter trespassers, none felt field consolidation would be a benefit, one of fifteen felt the drainage would help facilitate the use of large machinery and none considered that the drainage would contribute to aesthetics(beautify the land).

Of the subsurface drainers, twelve of fifteen felt that one of the benefits would be increased cropland and returns, ten of fifteen felt a benefit would be the removal of a nuisance factor, seven of fifteen felt they would eliminate input waste, three of fifteen thought drainage would help control weed problems, two of fifteen felt it would help control wasted outputs, none were concerned with hunter trespassers, six of fifteen thought they would be able to consolidate fields, four of fifteen thought it would facilitate the use of large machinery and none considered aesthetics to be important.

Does the drainage system work?

When asked whether the drainage system worked as well as they expected it to work, three of fifteen surface drainers strongly agreed that it did, ten of fifteen agreed it did and two of fifteen disagreed the system worked up to their expectations.

One of fifteen subsurface drainers strongly agreed and nine of fifteen agreed the system worked as expected, one of fifteen remained neutral and four of fifteen disagreed that the system worked as expected.

System Problems

When asked what they thought the major problem of the system was, one of fifteen surface drainers thought it was related to installation and construction and one of fifteen reported problems not related to the system itself and thirteen of fifteen reported no problem.

Of the subsurface drainers two of fifteen thought there were design problems, one of fifteen thought the problems were combinations of design, installation and construction, one of fifteen reported combinations of design and surveying, one of fifteen thought it was combinations of design and engineering and ten of fifteen reported no problems.

Harvest Frequency - Before and After

Prior to drainage twelve of fifteen surface drainers never harvested from this drained land, two of fifteen used the wet area as native pasture and one of fifteen was able to make use of the land on between one and four years out of ten. After drainage, three of fifteen surface drainers used the drained area as native pasture, one of fifteen was able to harvest in between six and nine years out of ten, one of fifteen was able to harvest every year with losses and nine of fifteen were able to harvest every year.

Of the subsurface drainers, ten of fifteen were never able to harvest prior to drainage, one of fifteen was able to harvest in between one and four years out of ten, one of fifteen was able to harvest every second year(i.e., five out of ten years), two of fifteen were able to harvest every year with losses and one of fifteen were able to harvest every year prior to drainage. After drainage one of fifteen was able to harvest every second year, one of fifteen was able to harvest every year with difficulty and thirteen of fifteen were able to harvest every year.

Drain Land Again?

Of the surface drainers, fourteen of fifteen would drain land again and one of fifteen would not. Of the subsurface drainers thirteen of fifteen would drain land again, one of fifteen would not and one of fifteen was not sure.

Influence of Literature

Landowners were asked whether or not they perceived that available literature information on the economics of drainage would have influenced their decision to drain. Of the surface drainers, none strongly agreed that it would have made a difference, eight of fifteen agreed, four of fifteen were neutral, two of fifteen disagreed and one of fifteen strongly disagreed that the information would have an effect on their decision to drain.

None of the subsurface drainers strongly agreed, nine of fifteen agreed, four of fifteen were neutral, two of fifteen disagreed and none strongly disagreed that the literature would have made a difference.

Compensation not to drain

Landowners were asked how much someone would have to pay or compensate them per acre not to drain land. Of the surface drainers two of fifteen would accept yearly compensation of between $0 and $50 per acre, six of fifteen said between $51 and $100 per acre, one of fifteen each said between $101 and $200, $201 and $500 and $1001 and $5000 per acre, two of fifteen of the landowners indicated that those wishing to have the wet areas remain would have to purchase the land(quarter) and relocate them, one of fifteen said it depended on the situation(i.e., he gave permission to develop wetlands on another area of his farm) and one of fifteen couldn't place a value on it. Of the eleven that would accept compensation, the range of this compensation was between a minimum of $30 per acre and a maximum of $2000 per acre per year with a mean value of $307.30 per acre per year.

Of the subsurface drainers, two of fifteen wanted yearly compensation of between $0 and $50 per acre, one of fifteen of between $51 and $100 per acre; two of fifteen each between $101 and $200 and $201 and $500 per acre, four of fifteen between $501 and $1000 per acre and $1001 and $5000 per acre. None would demand purchase and relocation, one of fifteen said it would depend on the situation and two of fifteen could not place a value on not being able to drain. Of the 12 that would accept compensation, the range of this compensation was between a minimum of $50 per acre and a maximum of $5000 per acre with a mean value of $785.00 per acre per year.

B. Drainage System Specifics

Size of the drained area

Surface drainers reported total gains in land area of between 15 and 450 acres, with a mean gain of 94.0 acres. This total acreage gained included the acreage gained directly from the drainage system, which varied between 15 and 300 acres, with a mean of 79.7 acres plus the acreage gained indirectly(the subsequent improvement of the area surrounding the area that was specifically drained), which varied between 0 and 150 acres with a mean of 14.3 acres.

Subsurface drainers reported total gains in land area of between 10 and 50 [illegible] with a mean of 28.0 acres. Directly gained acreage ranged from 0 to 50 acres [illegible] of 21.0 acres. Indirectly gained acreage varied between 0 and 50 acres with a m[illegible]7.0 acres.

Costs associated with drainage

Four categories of drainage costs were identified(Chapter III, Investment). The first set of costs identified were costs of the drainage system itself. These system costs include costs for surveying and design, installation and construction, costs of special equipment and other costs applicable to the system. System costs for surface drainage ranged between $9.78 and $485.66 per acre with a mean cost of $162.27 per total acre gained. System costs for subsurface drainage varied between $121.15 and $1373.20 per acre, with the mean cost of $525.77 per total acre gained.

The second type of cost associated with the drained land were rehabilitation costs(costs associated with brushing, breaking, rock picking, extra weed control and extra seed bed preparation). Rehabilitation costs for surface drainage systems ranged between

$0 and $225.29 per acre with a mean cost per total acre gained of $58.11. Subsurface drainage rehabilitation costs varied between $0 and $289.33 per acre with a mean cost per total acre gained of $76.30.

The third type of cost associated with drainage, operating costs, were not encountered by any surface or subsurface drainers and are thus $0 per total acre gained for both.

The final costs considered were maintenance costs, which involve any repairs or general upkeep necessary to keep the system functional. Surface drainers reported maintenance costs ranging from $0 to $9.88 per acre with a mean maintenance cost of $1.49 per total acre gained. Subsurface drainers reported maintenance costs ranging between $0 and $8.32 per acre with a mean maintenace cost of $1.00 per acre.

Costs per total acre gained and improved

The costs of draining land by surface drainage methods, based only on system costs ranged between $9.78 and $485.66 per acre with a mean cost of $162.27 per acre. When all costs are considered(the summation of system costs, rehabilitation costs, operating costs and maintenance costs) the costs per total acre gained varied between $18.88 and $631.62 with a mean cost of $221.87 per acre.

The costs of subsurface drainage, when only system costs were considered, ranged between $121.15 and $1373.20 per acre, with a mean of $525.77 per total acre gained. When all costs were considered the costs per acre ranged between $121.15 and $1373.20 per acre with a mean cost per total acre gained of $603.06.

Costs per acre gained only

If one considers only the acres gained from drainage, costs per acre are higher. Based on system costs only, surface drainers costs per acre gained, ranged between $9.78 and $485.66 with a mean cost of $179.35. When all project costs were considered, costs per acre gained ranged between $22.72 and $631.62 per acre with a mean cost per acre gained of $249.03.

of fifteen landownwers reported gained acreage and amongst these landowners, the meai acres gained were 28.6 with a range between 10 and 50 acres. The system costs per acre gained ranged from $157.95 to $1087.00 per acre with a mean system cost per acre gaine of $544.38. When all project costs are considered, the costs per acre gained ranged from $298.00 to $1245.70, with a mean total cost per acre gained of $663.06.

Costs per acre improved only

There are no landowners using surface drainage means that reported only improved acreage. Of the fifteen landowners using subsurface drainage four reported on improved acreage and the mean size of this improved acreage was 22.5 acres, ranging between 10 and 50 acres. The system costs of these improved acres ranged between $121.15 and $1373.20 with mean system cost per improved acre of $676.18. When all costs are considered, the costs per improved acreage ranged between $121.15 and $1373.2 with a mean total cost per improved acre of $677.91.

The mean total costs per acre only gained or only improved were similar($663.06 vs. $677.91), but a difference exists when only the system costs are considered. The mea system costs per acre gained are less than the mean system costs per acre improved($544.38 vs. $676.18). There is a substantiation that other costs(i.e., rehabilitation, maintenance and operating costs) are higher for the gained acreage versus the improved acreage(i.e., a mean of $118.68 per acre vs. $1.73 per acre).

Project age and maintenace costs

The assumed project life was taken as fifteen years. It may be reasonable to expect that maintenance costs may be encountered as the project increases in age. Leitch[154] stated that according to the U.S. SCS, 1978, maintenance costs ranged from about 3% of the initial project cost per year to about one-third of the original cost every

[154]Leitch, Jay A. *Economics of Prairie Wetland Drainage.* 1982 Winter Meeting. American Society of Agricultural Engineers

seven years. The surface projects in this study had a mean age of 5.3 years(range one to thirteen years) and the subsurface projects had a mean age of 3.7 years(range two to seven years).

The effects of a 3% maintenance cost per year are discussed in the measurements of project viability section.

C. Benefits Associated with Drainage

There are three basic benefits associated with drainage. The first are cash benefits from the increased production on the gained land. The second benefits are non-cash benefits for which values can easily be imputed(i.e., estimates of machinery time and labor time savings, input savings(i.e., the non waste of fertilizers, etc. because of either overlapping or loss that occurs after an area has been fertilized and is later under water) and the savings because of the elimination of waterfowl damage. The third type of benefits are non-cash benefits for which it would be difficult to assign a value. These include improvements that may be provided because of the drainage, such as improvements to grain grade(reduced dockage), higher germination rates, controlled or reduced salinity problems, reduced parasites, improved soil structure, improved plant drought resistance, changes in crop insurance rates, advancements in seeding time, extension of the harvest season, ability to work the land sooner after a heavy rain and the ability to change crop species.

Cash Benefits

The calculation of value of cash benefits associated with drainage are outlined in Chapter III, Farm Production and Valuation. The landowners, during the interviews provided information on the particular crop they grew on the drained land each year since the land was drained and the yields of these crops. These qualities were multiplied by their value per bushel etc. for the particular year, in 1985 dollars, to estimate the total cash benefit attributable to the drained land. The cash values were then entered in the cash flows as cash benefits.

Non-cash Benefits – Value Imputed

Non-cash benefits for which values could be imputed, included the value of machinery time savings, the value of labor time savings, the estimate of input savings and the value of grain lost or damaged by waterfowl.

Regarding the machinery time savings, surface drainers reported a mean time savings of 10.4 hours per year(range 0 to 50 hours) for an estimated mean dollar value of $157.20(range $0 to $972) per year. Subsurface drainers reported a mean machinery time savings of 15.7(range 0 to 76) hours per year for a mean estimated dollar value of $276.80(range $0 to $1408) per year.

Yearly labor time savings reported by the surface drainers were a mean of 9.2(range 0 to 60) hours per year for an estimated mean dollar value of $113.07(range $0 to $450) per year. Individuals draining by subsurface means reported a mean labor time savings of 19.1(range 0 to 84) hours for a mean estimated dollar value of $143.53(range $0 to $630) per year.

Estimated input savings reported by those draining by surface drainage systems ranged between $0 and $865 per year with a mean value of $130.00 per year. Subsurface drainers reported input savings of between $0 and $1650 per year with a mean yearly value of $346.70 per year.

Of the surface drainers, ten of fifteen reported no difference in the grain lost or damaged by waterfowl. Of the five that reported differences, the mean difference was $327.02 per year(over the life of the project). Of the subsurface drainers, thirteen of fifteen reported no difference, one of fifteen reported a difference but couldn't value it and one of fifteen reported a mean difference of $265.49 per year.

Non-cash Benefits - No imputed value

Participants in the survey were asked whether or not they noticed or experienced other non-cash benefits associated with the drainage project. No attempt was made to estimate a dollar value for these non-cash benefits.

Regarding a noticeable difference in grain grade and dockage, only one surface drainage landowner noticed a difference, nine of fifteen did not notice a difference, two of fifteen did not sell their grain and three of fifteen did not know. Of the subsurface landowners, one of fifteen noticed a difference, nine of fifteen did not notice a difference, one of fifteen did not sell his grain and four of fifteen did not know.

Regarding an improved germination rate, two of the fifteen participants using surface drainage methods gave no response, four ageed that the germination rate had improved and nine noticed no change. Six of fifteen subsurface drainers greed there was an improvement in germination rate, four thought it was the same, four disagreed there was a difference and one didn't know.

Regarding salinity problems, five of fifteen landowners draining by surface means did not respond, nine of fifteen thought there was no change and one of fifteen didn't know. Five of fifteen subsurface drainers did not respond, five of fifteen agreed that the salinity problem was controlled or reversed, one of fifteen thought there was no change and four of fifteen didn't know.

Regarding the theory that improved drainage increases the drought resistance of plants, one of fifteen surface drainers did not respond, three of fifteen agreed that drought resistance was improved, ten of fifteen thought it was the same and one of fifteen disagreed. Five of fifteen subsurface drainers agreed it was improved, four of fifteen thought it was the same, two of fifteen disagreed and four of fifteen did not know.

Twelve of fifteen landowners using surface drainage methods agreed there was improvements in the soil structure and the remaining three of fifteen thought it was the same. Of the landowners using subsurface drainage methods, thirteen of fifteen noticed an improvement in soil structure, one of fifteen disagreed and one of fifteen didn't know.

Five of fifteen surface drainers reported no change in crop insurance rates, one of fifteen did not respond and nine of fifteen do not use crop insurance. Ten of fifteen subsurface drainers noticed no change and five of fifteen did not use crop insurance.

Ten of fifteen surface drainers reported an advancement in seeding time and five of fifteen did not. Among those that did report an advancement in seeding time, the mean number of days was 5.2(range 0 to 15 days). Eleven of fifteen subsurface drainers noted an advancement in seeding time with a mean of 5.9days(range 0 to 21 days). Four of fifteen reported no change.

An extension of the harvesting season was reported by seven of fifteen of the surface drainers with a mean extension of 2.1 days(range 0 to 12 days), seven of fifteen reported no change and one of fifteen did not respond. Eight of fifteen subsurface drainers reported an extension of the harvest season, with a mean extension of 5.0 days(range 0 to 21 days) and seven of fifteen noticed no change.

An earlier seeding date and extended harvest date, lengthen the growing season and the flexibility in the choice of crop species. Landowners were asked if they were able to change crop species because of the drainage. Only two of fifteen surface drainers said they were and thirteen of fifteen said they were not or did not. Of the subsurface drainers, three of fifteen answered yes to the question and twelve of fifteen answered no.

Good drainage has the ability to allow the landowner to work a field sooner after a heavy rain. One of fifteen surface drainers did not respond, three of fifteen noticed no change and eleven of fifteen said there was a difference and this difference amounted to a mean of 3.7 days(range 0 to 10 days). Two of fifteen subsurface drainers responded no to the question, thirteen of fifteen said there was a difference and the mean difference was 9.3 days(range 0 to 30 days).

Regarding the evenness in crop maturity, both the surface and subsurface drainers did not respond one of fifteen times, said there was a difference nine of fifteen times and noticed no difference five of fifteen times.

D. Removal of Inconveniences

Landowners were asked to rate the four most important inconvenience removals that occurred because of the drainage. Of the inconveniences reported first important, two of fifteen surface drainers reported none, nine of fifteen reported that machinery was not stuck as often, three of fifteen stated less inputs were wasted and one of fifteen said it was that cows were not getting stuck as often. Of the second most important inconveniences removed eight of fifteen reported none, three of fifteen said it was that machinery was not stuck as often, two of fifteen reported it was less wasted inputs, one of fifteen reported production on unusable land and one of fifteen reported improved weed control. For the third most important inconvenience removed, eleven of fifteen reported none, three of fifteen said it was the elimination of the combine plugging up and one of fifteen said it was the elimination of extra operations and time because of overlapping. No one reported a removal of a fourth inconvenience.

One of fifteen subsurface drainers reported no first important inconvenience removed, six of fifteen said it was the elimination of the machinery being stuck as often, five of fifteen said it was the elimination of wasted inputs, one of fifteen said it was the consolidation of fields and the enjoyment of a larger field, one of fifteen said it was the elimination of extra operations and time because of overlapping and one of fifteen said it was not having to go around a wet area. One of fifteen reported no second most important inconvenience removed, six of fifteen thought it was machinery not being stuck as often, three of fifteen said it was the removal of wasted inputs and one of fifteen said it was the removal of production loss because of tramping swaths(i.e., with a combine). Nine of fifteen reported no third most important inconvenience removed, two of fifteen said it was the removal of wasted inputs, two of fifteen said it was the combine not plugging up as often, one of fifteen said it was field consolidation and the enjoyment of a larger field and one of fifteen said it was the improved weed control. For the fourth most important inconvenience, thirteen of fifteen reported none and two of fifteen said it was the combine not plugging up as often.

E. **Impression of Drainage Benefits Before and After**

Landowners were asked what they thought the major benefits from drainage would be before they installed the drainage and now that the drainage was installed, what they felt the major benefits were. There was an allowance for up to four benefits for each situation, before and after.

Of the landowners using surface drainage means, nine of fifteen said the first perceived major benefit would be increased cropland and returns, four of fifteen thought it would be increased pasture, one of fifteen thought it would be expanded cultivated acres at a minimum cost and one of fifteen thought it would be increased pasture and hay land. Eight of fifteen did not state a second major perceived benefit, five of fifteen stated they thought it would be the removal of a nuisance, one of fifteen thought it would be the elimination of wasted inputs and one of fifteen thought it would help control wasted output. Eleven of fifteen did not mention a third major perceived benefit, one of fifteen thought it would be the elimination of wasted inputs, one of fifteen thought it would help control weed problems, one of fifteen thought it would help control wasted output and one of fifteen thought it would help eliminate hunter trespassers. No respondents mentioned a fourth major perceived benefit before drainage.

After the drainage had been installed eight of fifteen surface drainers said the frst major benefit was increased cropland and returns, three of fifteen stated it was increased pasture, one of fifteen received what they expected, one of fifteen thought he upgraded the value of his farm, one of fifteen thought it worked better than expected and planned to crop the drained area and one of fifteen thought it worked better than expected. Eight of fifteen did not state a second perceived major after drainage benefit, five of fifteen stated it was the removal of the nuisance factor, one of fifteen said it was the elimination of input waste and one of fifteen said it was the control of wasted output. For the third major benefit after drainage, eleven of fifteen did not give one, one of fifteen stated it was the elimination of input waste, one of fifteen said it was the control of weed problems, one of fifteen stated it was the control of wasted output and one of fifteen stated it was the elimination of hunter trespassing. Fourteen of fifteen did not report a fourth major benefit and one of fifteen stated he had less expense now.

Of the landowners using subsurface drainage methods, one of fifteen reported no first perceived major benefit, ten of fifteen stated they thought it would be increased cropland and returns, one of fifteen thought it would be the full removal of a nuisance factor, one of fifteen thought there would be increased convenience, one of fifteen thought there would be easier access to the land and one of fifteen thought it would remove the water. Six of fifteen did not give a second major pecceived benefit, five of fifteen thought it would be the removal of a nuisance factor, one of fifteen thought it would eliminate wasted inputs, one of fifteen thought it would help control the weed problems and two of fifteen thought they would consolidated their fields. Nine of fifteen did not report a third perceived major benefit, five of fifteen thought they would eliminate input waste and one of fifteen thought he would eliminate hunter trespassing. Twelve of fifteen of the landowners gave no fourth [illegible] benefit before drainage, two of fifteen thought it would help control weeds and one of fifteen thought it would help facilitate larger machinery.

After the drainage had been installed, one of fifteen reported no first major benefit from drainage, eight of fifteen reported increased croplands and returns, one of fifteen reported a consolidation of fields, one of fifteen reported only a partial removal of a nuisance factor, one of fifteen reported the removal of the water, one of fifteen stated that he would have received what he expected before drainage if the system worked properly and two of fifteen stated they received what they expected. Seven of fifteen did not report a second major benefit after drainage, five of fifteen reported a removal of a nuisance factor, one of fifteen reported an elimination of input waste, one of fifteen reported controlled weed problems and one of fifteen reported a consolidation of fields. For a third major benefit after drainage, nine of fifteen reported none, five of fifteen reported the elimination of wasted inputs and one of fifteen reported the elimination of hunter trespassing. For the fourth major benefit, twelve of fifteen reported none, two of fifteen reported the control of weed problems and one of fifteen reported the ability to facilitate large machinery.

F. Other Improvements

Landowners were asked if they made any other improvements to the drained field after the drainage was completed. Two of fifteen landowners draining by surface means did some brush cutting, eight of fifteen did a combination of brushcutting, fence removal and field enlargement, three of fifteen did nothing extra, one of fifteen fenced and seeded the area and one of fifteen brushed, fenced and seeded the area. one of fifteen of the landownwers using subsurface drainage did some brushcutting, three of fifteen enlarged the field, seven of fifteen did a combination of brushcutting, fence removal and field enlargement and four of fifteen made no extra improvements.

G. Comparisons of Farms Before and After Drainage and the Basis for Management Intensity

As a basis for management intensities and the hypothesis that the landowners that manage more intensely are more likely to have a positive net present value or an internal rate of return greater than zero, the landowners were asked questions regarding land and input use before and after the drainage project. These values were used later in various combinations in the behavioral analysis that related the IRR to management intensity values.

H. Farm Size, Before and After

Landowners were asked about the size of the farm before and after the drainage system was installed. Farms with surface drainage systems varied in size from 323 to 1600 acres with a mean size of 764.3 acres before drainage was installed and varied in size from 316 to 1600 acres with a mean of 828.3 acres after drainage. The subsurface drainage farms ranged in size from 200 to 1760 acres with a mean size of 744.3 acres before drainage and ranged in size from 270 to 1920 acres with a mean size of 847.3 acres after.

I. Acres Improved

Surface drained farms had an improved acreage(cultivated land including summerfallow) ranging from 100 to 1400 acres with a mean of 487.4 acres before drainage and a range of 120 to 1450 acres with a mean of 558.0 acres after drainage. Subsurface drained farms had improved acreage ranging from 170 to 1600 acres with a mean of 576.8 acres before drainage and ranged from 205 to 1750 acres with a mean of 667.2 acres after drainage.

J. Acres Fallow

Surface drained farms had a mean of 55.3 acres of fallow with a range of 0 to 240 acres before drainage and a mean of 47.7 acres with a range of 0 to [illegible] acres after drainage. Subsurface drained farms had a mean of 43.0 acres of fallow before drainage with a range of 0 to 500 acres and a mean of 29.0 acres after drainage with a range of 0 to 400 acres.

K. Capital Investment

Landowners were questioned about four major pieces of equipment: the year, model and horse power of their largest tractor, the year, model and cylinder width of their combine, the model, year and width of their cultivator and model, year and width of their sprayer. Values were obtained for the tractor and combine using Official Guide: Tractors and Farm Equipment[155], converted to 1985 Canadian dollars and assumed to be representative of the capital investment on the farm.

The surface drained farms had a capital investment ranging from $0 to $114,551 with a mean of $39,253 the year before drainage and a range of $8,685 to $132,271 with a mean of $54,961 in 1985. The subsurface drained farms had a capital investment ranging

[155]National Farm and Power Equipment Dealers Association. *Official Guide: Tractors and Farm Equipment*. St. Louis. National Farm and Power Equipment Dealers Association. ISSN 0162-6809. 1972-1985.

from $6,300 to $219,137 with a mean of $67,670 the year before drainage and a range of $4,685 to $160,616 with a mean of $68,658 in 1985.

L. Machinery Complement

The largest tractor horse power was assumed to be representative of the rest of the farm machinery complement. The surface drainers had a mean tractor horsepower of 120.1(ranging from 60 to 150 H.P.) the year before drainage and a mean tractor horsepower of 143.9 (ranging from 75 to 250 H.P.) in 1985. The subsurface drainers had a mean tractor horsepower of 140.3(ranging from 82 to 230 H.P.) before drainage and a mean tractor horsepower of 168.9(ranging 90 to 300 H.P.) in 1985. The tractor horsepower value was instrumental in establishing the appropriate machinery complement and capacities and the machinery costs used in the calculation of the values of the monetary savings(because of the reduction in the time required for a field operation after the wet area had been removed) associated with the drained land.

M. Livestock

Landowners were asked about the numbers of livestock on their farm the year before drainage and in 1985. Surface drainers reported a mean of 32.1 brood cows, 1.1 bulls, 32.5 other cattle(i.e., replacements), 0 sheep, 9.6 dairy cows and 3.5 swine before drainage and 39.4 brood cows, 1.3 bulls, 46.4 other cattle, 0 sheep, 9.4 dairy cows and 3.9 swine in 1985. Subsurface drainers reported a mean of 16.9 brood cows, 0.7 bulls, 41.2 other cattle, 7.1 sheep, 3.0 dairy cows and 235.4 swine before drainage and 19.1 brood cows, 0.7 bulls, 55.1 other cattle, 7.1 sheep, 3.0 dairy cows and 100 swine in 1985.

For comparison purposes all animals except swine were converted to animal units. Surface drainers had a mean animal unit equivalent of 75.9(range 0 to 181) before drainage and 97.2(range 0 to 307.5) animal units in 1985. Subsurface drainers had a mean animal unit equivalent of 63.6(range 0 to 316.5) before drainage and 79.7(range 0 to

454.0) animal units in 1985.

N. **Herbicide Use**

Surface drainers applied herbicides on a mean of 329.0(ranging from 0 to 1400) acres and at a mean cost of $12.00(ranging from $0 to $58.75) per acre the year before drainage and on a mean of 360.0(ranging from 0 to 1100) acres at a mean cost of $13.69(ranging from $0 to $58.75) per acre in 1985. Subsurface drainers applied herbicides on a mean of 471.5(ranging from 50 to 1155)acres at a mean cost of $17.28(ranging from $1.72 to $49.88) per acre the year before drainage and on a mean of 547.9(ranging from 0 to 1350) acres at a mean cost of $20.24(ranging from $0 to $80.53) per acre in 1985.

O. **Fungicide Use**

Surface drainers used fungicides on 6.7% of their seed at a mean cost of $0.19 per acre before drainage and on a mean of 16.2% of their seed at a mean cost of $0.54 per acre in 1985. Subsurface drainers used fungicides on a mean of 48.5% of their seed at a cost of $1.43 per acre the year before drainage and on a mean of 48.5% at a meam cost of $1.63 per acre in 1985.

P. **Proportion of Better, Certified or Registered Seed**

Surface drainers used a mean of 37.9% better seed the year before drainage and a mean of 60.3% in 1985. Subsurface drainers used better seed a mean of 68.3% of the time before drainage and a mean of 65.7% of the time in 1985.

Q. Fertilizer Use

Surface drainers fertilized a mean of 343.3 acres the year before drainage and applied a mean of 10,352 lbs(30.15 lbs/ac) of actual nitrogen, 7,972 lbs(23.22 lbs/ac) of actual phosphorous, 535 lbs(1.56 lbs/ac) of actual potassium and no sulfur. In 1985 they fertilized a mean of 382.7 acres and applied a mean of 17,952 lbs(46.91 lbs/ac) of actual nitrogen, 8,902 lbs(23.26 lbs/ac) of actual phosphorous, 1,127 lbs(2.94 lbs/ac) of actual potassium and 1,176 lbs(3.07 lbs/ac) of actual sulfur.

Subsurface drainers fertilized a mean of 494.8 acres the year before drainage and applied a mean of 31,047 lbs(62.75 lbs/ac) of actual nitrogen, 13,157 lbs(26.59 lbs/ac) of actual phosphorous, 1,277 lbs(2.58 lbs/ac) of actual potassium and no actual sulfur. In 1985 they fertilized a mean of 588.2 acres and applied a mean of 37,624 lbs(63.96 lbs/ac) of actual nitrogen, 15,902 lbs(27.04 lbs/ac) of actual phosphorous, 3,642 lbs(6.19 lbs/ac) of actual potassium and 967 lbs(1.64 lbs/ac) of actual sulfur.

APPENDIX H: List of Variables Considered in Model I

The following variables were used as a proxy for management intensity when relating the internal rate of return to the before drainage characteristics in Assumption I, Model I.

CRINB - the cropping intensity on the farm the year before drainage i.e., the ratio of all cultivated land, including that sown to tame hay, minus the summerfallow area to the total amount of cultivated land.

AUB - the number of animal units on the farm the year before drainage.

EQINVB - the 1985 equivalent value of the largest tractor and combine used as a proxy for the capital expenditure in equipment in the year before drainage.

INPEXB - the capital expenditure on herbicides, fungicides and fertilizers the year before drainage.

PRLDB - the price of land in the area the year before drainage.

The following variables were used as a proxy for management intensity when relating the internal rate of return to the after drainage(1985) characteristics in Assumption II, Model I.

CRINA - cropping intensity in 1985, same formula as described above.

AUA - the number of animal units on the farm in 1985.

DUM1 - the land use factor, equal to one if the land was never used before, zero otherwise.

V170 - the size of the drainage project which includes all acres gained and improved.

The following variables were used as a proxy for management intensity when relating the internal rate of return to the absolute change characteristics in Assumption III, Model I.

AAUCH - the absolute change in animal units on the farm(the difference between the animal units on the farm in the year before drainage and the animal units on the farm in 1985).

PRAGE - the age of the project in years.

DUM1 - the land use factor, defined above.

AEICH - the absolute change in value of equipment between 1985 and the year before drainage.

The following variables were used as a proxy for management intensity when relating the internal rate of return to the annual change characteristics in Assumption IV, Model I.

Z16 - the annual change in capital expenditure on equipment over the life of the project.

DUM1 - the land use factor, defined previously.

V170 - the size of the drainage project, defined earlier.

AUCHYR - the annual change in animal units over the life of the project.

APPENDIX I: List of Variables Considered in Model II

The following variables were used as a proxy for management intensity when relating the internal rate of return to the before drainage characteristics in Assumption I, Model II.

CRINB - the cropping intensity on the farm the year before drainage i.e., the ratio of all cultivated land, including that sown to tame hay, minus the summerfallow area to the total amount of cultivated land.

AUB - the number of animal units on the farm the year before drainage.

EQINVB - the 1985 equivalent value of the largest tractor and combine used as a proxy for the capital expenditure in equipment in the year before drainage.

INPEXB - the capital expenditure on herbicides, fungicides and fertilizers the year before drainage.

PRLDB - the price of land in the area the year before drainage.

YRSFMB - the number of years farming the property when the drainage was installed.

TOTACB - total acreage of the farm the year before drainage.

FERTB - fertilizer use per acre the year before drainage.

HERBB - herbicide expenditure in $/acre the year before drainage.

FUNGB - fungicide expenditure in $/acre the year before drainage.

BETSDB - the percentage of seeded acres seeded with certified, registered or better seed the year before drainage.

SEEDACB - all acres cultivated minus the summerfallow acreage the year before drainage.

TRHPB - the horsepower of the largest tractor the year before drainage.

Z1 - the ratio of the owned to total acres before.

Z5 - the ratio of the improved acres to the total acres before.

Z10 - the ratio of the labor to improved acres before.

Z12 - the ratio of the capital to labor use before.

Z14 - the ratio of the capital to total land before.

Z17 - the ratio of the animal units to improved acres before.

The following variables were used as a proxy for management intensity when relating the internal rate of return to the after drainage(1985) characteristics in Assumption II, Model II.

CRINA - cropping intensity in 1985, same formula as described above.

AUA - the number of animal units on the farm in 1985.

DUM1 - the land use factor, equal to one if the land was never used before, zero otherwise.

Z7 - the number of person days labor used on the farm in 1985.

V170 - the size of the drainage project which includes all acres gained and improved.

INPEXA - the expenditure per acre on fungicides, herbicides and fertilizer in 1985.

EQINVA - capital value of the largest tractor and the combine in 1985.

PRAGE - the age of the drainage project in 1985.

PRLDA - the price of land in the area in 1985.

YRSFMA - the number of years farming the property in 1985.

TOTACA - the total acres of the farm in 1985.

FERTA - fertilizer use per acre in 1985.

HERBA - herbicide expenditure in $/acre in 1985.

FUNGA - fungicide expenditure in $/acre in 1985.

BETSDA - the percentage of seeded acres seeded with certified, registered or better seed in 1985.

RHABTM - the number of years of rehabilitation time.

Z16 - the annual change in capital expenditure on equipment.

Z19 - ratio of years since draining to the total years farming the property.

V168 - acres gained from drainage.

V169 - acres improved by drainage.

Z2 - the ratio of the owned to total acres after.

Z6 - the ratio of the improved acres to the total

Z11 - the ratio of the labor to improved acres

Z13 - the ratio of the capital to labor use af

Z15 - the ratio of the capital to total land aft

Z18 -the ratio of the animal units to improved acres after.

V170 - total increase in acres because of drainage(the summation of the acres gained and the acres improved).

The following variables were used as a proxy for management intensity when relating the internal rate of return to the absolute change characteristics in Assumption III, Model II. The absolute change relates to the difference between 1985 and the year before drainage.

AAUCH - the absolute change in animal units on the farm.

PRAGE - the age of the project in years.

DUM1 - the land use factor, defined above.

AEICH - the absolute change in value of equipment.

ACIBCH - the absolute change in the cropping intensity.

AFERCH - the absolute change in the fertilizer use per acre.

AHERCH - the absolute change in herbicide expenditure per acre.

AFUNCH - the absolute change in fungicide expenditure per acre.

ABSDCH - the absolute change in the percentage of better seed use.

ATACCH - the absolute change in the total acres farmed.

The following variables were used as a proxy for management intensity when relating the internal rate of return to the annual change characteristics in Assumption IV, Model II. These variables represent the average yearly changes that occurred over the age of the project.

Z16 - the annual change in capital expenditure on equipment.

DUM1 - the land use factor, defined previously.

V170 - the size of the drainage project, defined earlier.

B5AA - the annual change in animal units.

B1 - the annual change in total acres.

B2 - the annual change in owned acres.

B3 - the annual change in rented acres.

B4 - the annual change in tractor horsepower.

B6 - the annual change in cultivated acres including summerfallow.

B7 - the annual change in cultivated acres excluding summerfallow.

B8 - the annual change in herbicide expenditure per acre.

B9 - the annual change in fungicide expenditure per acre.

B10 - the annual change in the percentage of acres seeded to better seed.

B13 - the annual change in the owned to total acreage ratio.

B14 - the annual change in the seeded to total acreage ratio.

B15 - the annual change in the improved to total acreage ratio.

B16 - the annual change in the capital to person days labor ratio.

B17 - the annual change in the capital to total land ratio.

B18 - the annual change in the animal units to improved acres ratio.

B19 - the annual change in the horsepower to inproved acres ratio.

B20 - the annual change in the cropping intensity ratio.

FCHYR - the annual change in fertilizer use per acre.

AINPCH - the annual change in expenditures on herbicides, fungicides and fertilizer.

AUCHYR - the annual change in animal units.

The following variables were used in Assumption V and IV in Model II. was:

V763 - the CLI land classification rating.

V170 - size of the drainage system, acres gained plus improved.

DUM1 - land use factor.

APPENDIX J: Comments Made by Landowners Regarding Drainage

The following comments were made voluntarily by landowners either during the preliminary telephone contact or during the in-person interviews. The comments are in no particular order and no reference is made to the type of drainage system although in some cases the type of system referred to is obvious.

-drained land for convenience

-grows greenfeed - barley and oats won't ripen - cattle won't eat native stuff

-muskeg was in production at one time - flooded during the 70's - 1985 will be a test year

-this land was totally covered in water - up to 3 feet at some times - since drainage it has been used as pasture and this year plans to cut hay - grass is higher than animals in some places - foresees crop production in future - in 1966 owner grew rape - became wet during wet years - definitely worthwhile

-broke some during a dry year when it became wet couldn't do anything with it

-doesn't pay - that is Canada doesn't pay - Europe does

-really helped - controls flooded area

-couldn't walk across - now can drive a vehicle on - very helpful

-affected quite a bit of his pasture - some years would work and seed and fertilize, then have a wet summer and not get a kernel off - cattle in pasture always crossing wet area and having dirty udders - feels when hay was high it was worthwhile - area affected ranged from 0 to 50 acres

-very happy to have drained - land useless before

-had a 40 acre field and a 90 acre field - now has one good field about 180 acres

-before-cattle couldn't get on - now using it for grazing - but feels he could grow a hay crop

-potholes and sloughs would seep from one low spot to another - cows had chapped udders - oats would grow, barley wouldn't - weed problem - quack grass dragged all over - now work entire field at the same time instead of going around it

-the benefit is not having to go around

-didn't do it right - need to remove the water more quickly - system capacity too small

-cost lots of money - won't get money back but convenience - last 2-3 years can't even tell if the system is working

-worthwhile at the time because the price of land was high - but he'd still do it again - better than buying high priced land

-makes a difference depending on year - for getting stuck

-system wasn't installed properly initially but after corrections it works OK - feels contractor made some mistakes

-had been using the land - seeded later but during a wet year crops would get drowned out - did help

-benefit not having to go around - soil probably no. 3 but guesses the wet area is probably no. 1

-gained ability to farm land sooner - on way earlier - always seeded but now sooner - relatively happy - not happy with outlets

-always seeded the area but usually later - now earlier in the spring - in wet year didn't do any good - last 2 years OK but feels because of dry years

-some wet areas in everyone of all 10 quarters - land was low and muddy before

-on land sooner

-convenience more important - don't have to go around

-water ran onto land and no place to go - 60 acres covered with water and rest was low - only good for cattle

-very worthwhile - cattle stuck before - but still need water for cattle - fully aware of fact that permanent sloughs may be source of recharge

-will crop eventually - good soil

-backhoe in one month ago in 1/4 foot of water - finished seeding today June 05, 1985 - most land took one year

-was always cultivated - usually seeded but if had a wet summer land would flood - crop ruined

-happy - best land - good soil

-worthwhile - land useless before

-weeds - slough grass - hard to value nuisance factor - encourages ducks to nest where sloughs are permanent - by the time ducklings hatch areas are dry

-slough still there - not drained completely

-works terrific

-probably really benefitted 300 to 400 acres but neighbors don't realize it - ditch only on his place - some places ditch is 56 feet wide - lost 10 to 15 acres to ditch - gained about 70

-worthwhile - convenience - estimates 10 to 20 year payback - expensive undertaking but on a 50 acre field that took 8 hours to work it now takes 6 hours - knocked off 2 hours plus got rid of nuisance - real convenience - preserves sanity

-water encroachment now controlled

-worked the first year but since then have had dry years

-couldn't get to land

-cleared tamarack and willow - seeded to pasture

-worthwhile

-land not really gained - always cropped but got on sooner

-helps if you don't like corners

-upset because risers not finished

-well worth it - used to farm in circles

-not installed properly - pipe not located properly

-biggest problem company more concerned with outlet - didn't really identify recharge area - example, sand lens seems to be source - need better engineering - better soil testing

-straight economics can't value the inconveniences like the 4 below - can't plug into a computer - 1) how do you put a dollar value on getting stuck and having to get the neighbor to pull you out - burn out clutch from slamming and jerking machinery, 2) combine plugs up and burns out belts - crop heavy because of double application of seed, 3) waste anhydrous doubling up, 4) going around sloughs full of weeds - cultivator picks them up and drags them all over the field

-convenience is tremendous - uses a 45 foot cultivator and 80 foot sprayer - just go over the hill and straight through - can't believe the difference in crop yield in former sloughs

-now square fields

-notice a difference every year - germination even - no bare spots until roots hit salinity

-convenience to go through sloughs - yields 3 to 4 times surrounding land last year - expects payback 5 to 6 years on continuous cropping

-looks good - works well - total production - input saved

-best soil

-didn't work too well this spring

-works well - good crops lately - may not work well on heavy soil - need a lot more pipe - expensive but worth it - feels government should help out with high costs because high water table coming from other places

-got to have money to play - $40,000 to $50,000 - at first didn't think it was worth it but savings mainly chemicals and fertilizer - had about 50 potholes - now work a 1/2 section in the same time as it took to work a quarter before - cut the time in half - pulls large anhydrous tank and go through about $1000 worth every 3 hours - save 3 hours, save $1000 - convenience - saves time, fuel, chemicals and fertilizer

-slough was about 10 acres but the alkali problem was spreading

-25 to 30 year payback - convenient - pleased

-terrible - doesn't work - feels everything was installed wrong inlets - outlets and levels improperly done didn't supervise because he had good luck in Ontario with a contractor that did everything right - has faith that the system could work if done right - here it cost $1 per foot - in Ontario only $0.39 per foot

-doesn't work - husband drained opposite to natural flow needs more work

-situation different from southern farmers - here drain peat land - takes several years to dry out and before full utilization is realized

-helps sleep - not worried about cows

-major savings did not come from the large drained slough but rather from the numerous potholes that were removed when the major slough was drained

-doesn't work as well as expected - has had freezing problems

-disappointed in quality of work

-did smallest possible area as a trial - wasn't satisfied with quality of work and had personality conflict with contractor - he felt they weren't prepared to do the job - lacked proper tools - won't hire the same people again