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An Evaluation of Water Management Initiatives Undertaken by the Deerwood Soil & Water Management Association

By

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A Practicum Submitted
in Partial Fulfillment of
the Requirements for the Degree
Master of Natural Resources Management

Natural Resources Institute
University of Manitoba
Winnipeg, Manitoba, Canada

May, 1995

ISBN 0-612-13413-X

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AN EVALUATION OF WATER MANAGEMENT INITIATIVES UNDERTAKEN BY THE DEERWOOD SOIL & WATER MANAGEMENT ASSOCIATION

BY

BRYAN OBORNE

A Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

Acknowledgements

I wish to extend my deepest gratitude to the many, many individuals whose assistance and support made this research project, and completion of my degree, a tangible reality.

Firstly, I must thank my partner, Gail, whose understanding and support during this trying experience was the foundation which carried our relationship, particularly during the last several months. I am truly fortunate and blessed. Thank you H.B.

I am grateful to my parents and mother-in-law who have contributed in ways too numerous to mention.

My Practicum research committee was committed throughout the process, and I am especially indebted to Dr. Gary Johnson for his patience, guidance, and rigorous training.

I must also thank Geordie Jackson, Les McEwan, Gordon Orchard, Bill Turner, and the rest of the Deerwood Executive for their guided tours, informative discussions, and warm hospitality. I wish to highlight the support of Don and Thelma Alexander who made us feel at home in the hills.

I also extend my gratitude to the Reeves, Councillors, and staff from the Rural Municipalities of Lorne, Thompson, and Roland; without their contributions, this study would not have been feasible.

I received ongoing technical assistance from a number of experts at the Prairie Farm Rehabilitation Administration offices in Morden and Winnipeg, and from several departments of the Manitoba Government, particularly the Water Resources Branch. The Sustainable Development Committee of Cabinet provided the research opportunity to The International Coalition. Thank you very much.

Finally, I would not have survived without great help from the staff and faculty of the Natural Resources Institute, and the Faculty of Graduate Studies office of the University of Manitoba.

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Abstract

Increasingly, government decision-makers are demanding clear and concise economic rationalisations of all publicly-financed expenditures, including the provision of conservation programmes. The Deerwood Soil and Water Management Association has worked to coordinate multi-agency assistance with member farmers' soil, water, and habitat conservation/management activities within three sub-watersheds along a portion of the Manitoba Escarpment in South-Central Manitoba. This study sought to analyse the success of the Deerwood model and to provide policy recommendations which may be applicable elsewhere in agricultural regions of Manitoba where severe soil erosion and flooding are common.

Evidence supporting the causality and effectiveness of Deerwood's small dam network was collected via a comparative study approach involving the adjacent North and South Tobacco Creek Watersheds. After comparing historic streamflows, major runoff events, agricultural conservation practices, soil types, and vegetation cover, a control scenario was assumed to exist with the South Tobacco Creek under a management regime involving 30 strategically placed headwater retention structures (Deerwood's small dam network). Survey data collected from watershed landowners appeared to indicate: significant reductions in downstream erosion and flooding damage; lengthened runoff periods, and reduced creek turbidity. These trends were supported by recent Prairie Farm Rehabilitation Administration hydrology modeling which has proven the effectiveness of Deerwood's dam's in reducing peak runoff rates following Spring snowmelt and Summer rainstorm events.

Two Rural Municipalities lying within this drainage area were contacted for cost information relating to the maintenance of ditches, roads, and stream crossings within the region. Defensible estimates of cost reductions attributable to Deerwood's dams were received from the R.M.'s of Thompson and Roland.

Economic analysis was carried out based a framework focussing on the tangible benefits of Deerwood's small dam network (Krutilla and Fisher, 1975). Municipal cost reductions (tangible economic benefits) attributable to Deerwood's dams were both deflated to 1986 dollars and discounted to 1986 as the initial project year. Economic Payback Period Analysis (Johnson, 1995 and Gittinger, 1994) was used to assess these benefits and costs. Intangible Deerwood dam benefits reported within the landowner survey were also discussed; as were some potential intangible costs. The overall impact of the Deerwood dams was then considered in environmental, economic, and social terms.

It was found that a network of small dams built and operated by and organisation of volunteer landowners can be an effective and efficient system of land and water management. Substantial municipal benefits may be attributed to the headwater storage activities of the Deerwood Soil and Water Management Association. Based on municipal cost savings alone, it was determined the Deerwood small dam network can be expected to have a financial payback period of approximately 16 years (undiscounted) and an economic payback period of 25 years (discounted at 5%). At the 8% discount rate Deerwood's dams nearly pay back capital costs after their 50 year lifespan. Individual landowner benefits can realistically be expected to generate enough value to make the Deerwood dam network economically viable at the 8% rate. Operating & maintenance costs associated with Deerwood dams are typically a landowner responsibility and have been minimal.

Substantial Provincial benefits of Deerwood's small dam network may also exist but; these cannot be measured at this time due to a lack of information. Given the range of wildlife, educational, recreational, esthetic, spiritual, and quality of life values reportedly provided to damowners, it is realistic to assume substantial societal benefits may be generated by Deerwood's dams. Given the importance attached to wildlife habitat by Canadians and the proven benefits of stored water, it is quite possible that Deerwood's dams may be economically viable at the 15% discount rate. Further research in this regard is warranted.

1. INTRODUCTION

"Efficient Use of Resources" is a fundamental guideline highlighted in Manitoba's strategic planning document for achieving sustainable development in the Province (Manitoba Government, 1990)[1]. Sustainable development is both desirable and necessary. Manitobans have come to expect the range of environmental, economic, and social qualities, amenities, and opportunities associated with residency in the Province. Any public investments made in support of projects designed to fulfill these goals will continually be compared with their associated positive and negative results.

Accurate and applicable tools for the evaluation of such projects are required if efficient resource use is to be incorporated into development project planning. Assuming "development projects" may occur in support of conservation-related goals, there is an opportunity to apply the *efficient use of resources* guideline within a natural resources management and public policy context applicable to Manitoba.

Severe flooding (Figure 1a), soil erosion (Figure 1b), and degraded water quality have arisen as issues of concern due in part to natural conditions and, from the inappropriate application of conventional farming practices during the last century. Historically, extensive cultivation, summerfallowing, land clearing, and widespread drainage have caused environmental concerns in many agricultural areas of Manitoba, particularly along the Manitoba (or Pembina) Escarpment (MEHSSC, 1988; Carlyle, 1980) (Figure 1c, Plate 1a).

[1] The Province of Manitoba and The Manitoba Round Table have formulated a Provincial Sustainable Development Strategy based on ten Principles and six Fundamental Guidelines.

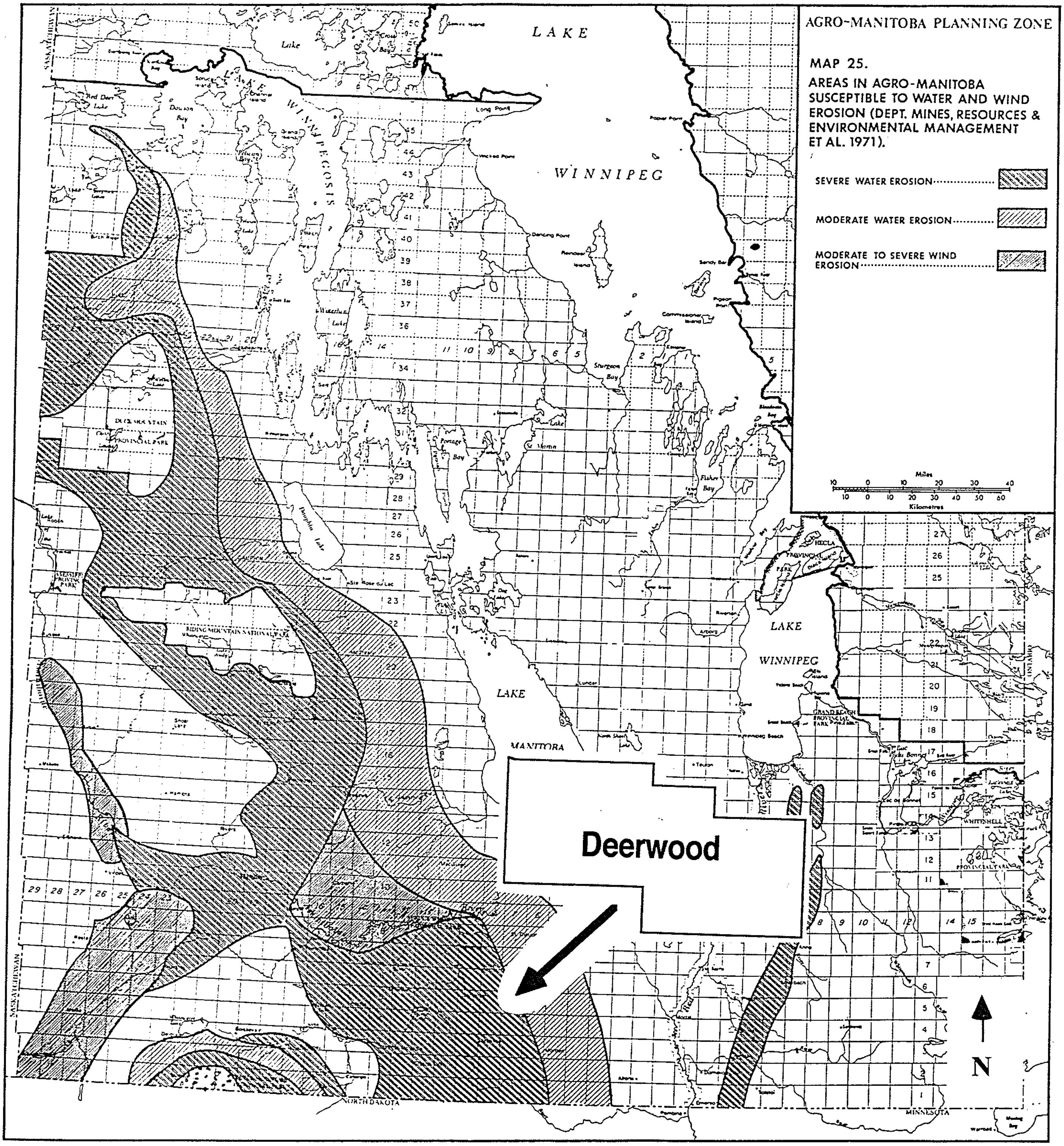

Figure 1a
Areas in Agro-Manitoba Susceptible to Water and Wind Erosion
Source: Adapted from W.P. Barto & C.G. Vogel, *Agro-Manitoba Information Package* (Winnipeg: Department of Mines, Natural Resources, and Environment, 1978), Map #25

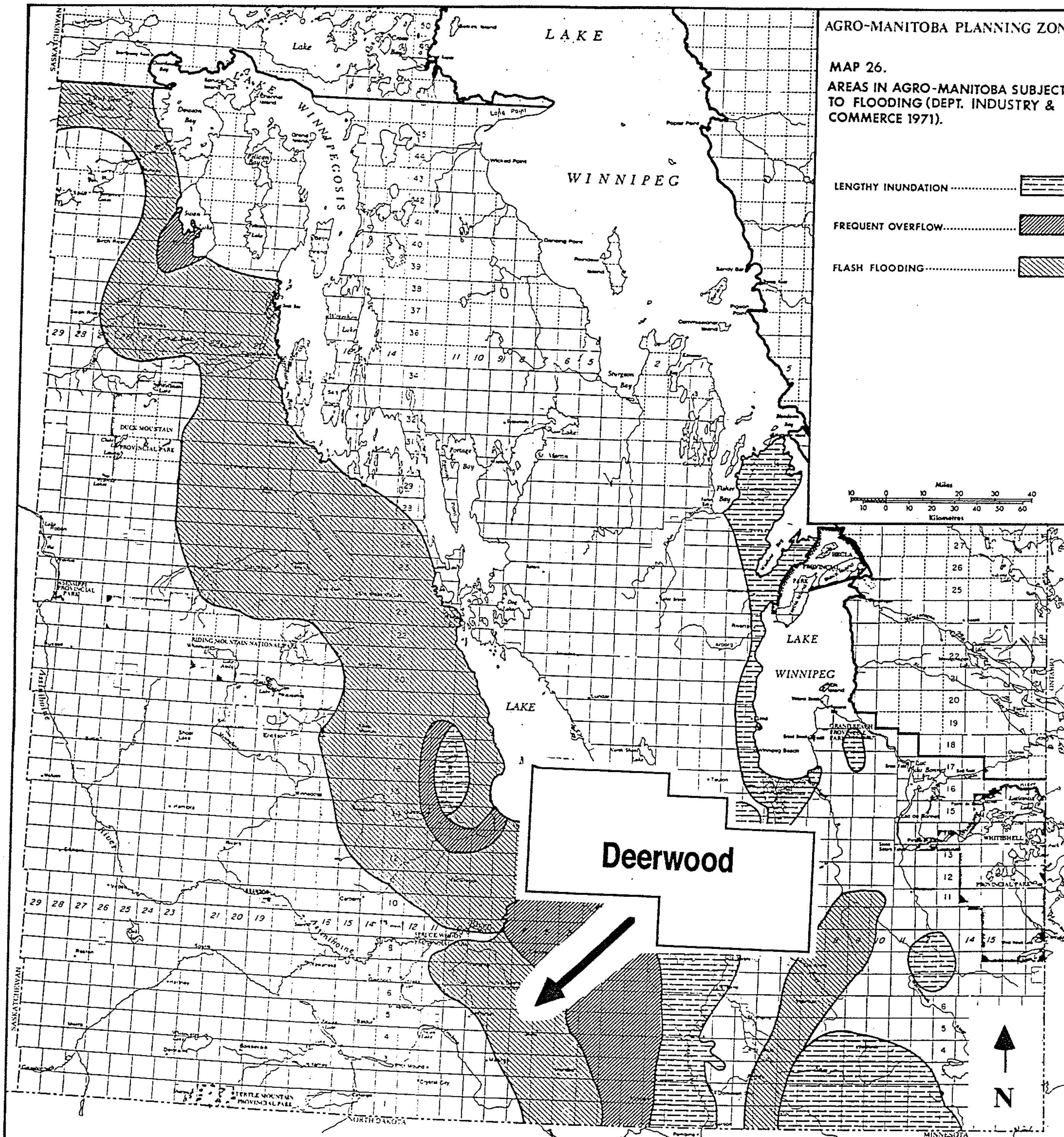

Figure 1b
Areas in Agro-Manitoba Subject to Flooding
Source: Adapted from W.P. Barto & C.G. Vogel, *Agro-Manitoba Information Package* (Winnipeg: Department of Mines, Natural Resources, and Environment, 1978), Map #26

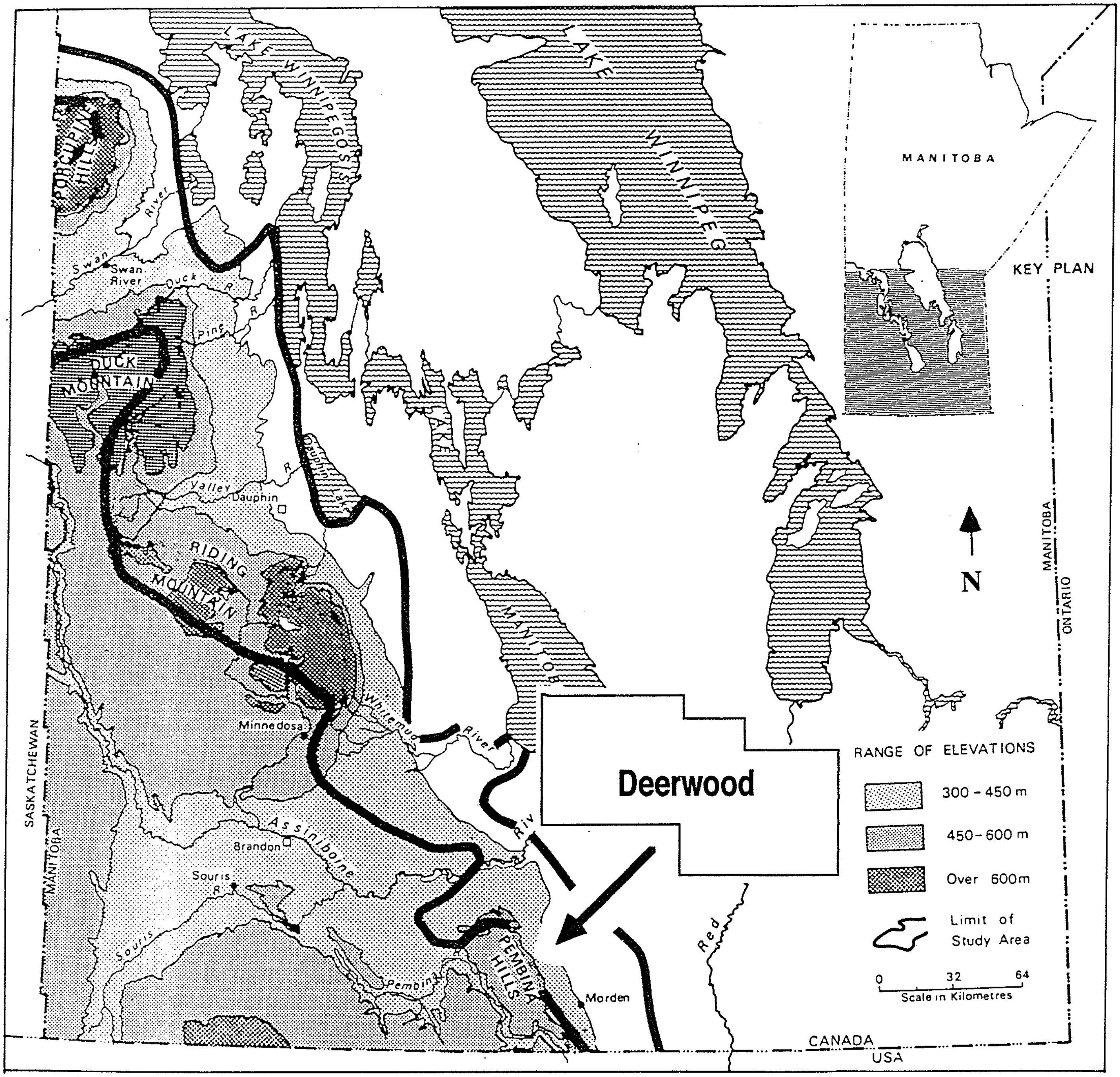

Figure 1c
The "Manitoba" or "Pembina" Escarpment Physiography
Source: Manitoba Escarpment Headwater Storage Steering Committee
Manitoba Escarpment Headwater Storage Study: Main Report,
(Winnipeg, Manitoba Natural Resources/Agriculture Canada-PFRA, p.2)

Various problems associated with these farming practices, as with many other environmental concerns, may be characterised as "externalities[2];" as they have not been "internalised" within any economic markets, within the accounts of individual landowners, or within the natural resources accounts of society at large (Friend, 1991; Randall, 1987; Batie, 1986; and Coote, 1983). Such environmental externality problems are often chronic effects; and comprehensive solutions have typically been slow to emerge from the public policy realm.

Rural Municipalities and Local Government Districts are responsible for planning and administration activities within several dozen local political jurisdictions of Agro-Manitoba (Manitoba Planning Act, 1992). These administrative bodies undertake numerous natural resources management initiatives including drainage ditch, road, and bridge construction & maintenance. Other public agencies including Conservation Districts (Figure 1d) and federal & provincial departments are also responsible for land & water conservation, management, and development activities. Such responsibilities are typically carried out through infrastructure funding and maintenance, the offering of various programmes, and the administration of policies. Finally, non-profit/non-government organisations and local landowners can play a critical role in land & water management at the individual farm or regional level.

It may be assumed that land & water management efforts of these various groups may result in a number of positive impacts which may be characterised as environmental, economic, and/or social. Benefits achieved through improved land & water management may include: reduced peak runoff flows which lessen downstream flooding and erosion damage; improved farm productivity; increased groundwater re-charge; stabilised water supply; wildlife habitat; esthetic, recreational, and spiritual values to local residents and visitors; and reduced maintenance/repair costs for municipal infrastructure (Goldman et al., 1986; USFWS, 1982; and FAO, 1977a). Optimally, benefits will accrue within a coordinated river basin management system (Lundqvist et al., 1985).

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[2] Externalities have been defined by Randall (1987), p.182 as : "a source of market failure which may have beneficial or adverse effects. The most common form, *external diseconomy*, refers to situations in which one party creates an annoyance for others and does not take account of that annoyance."

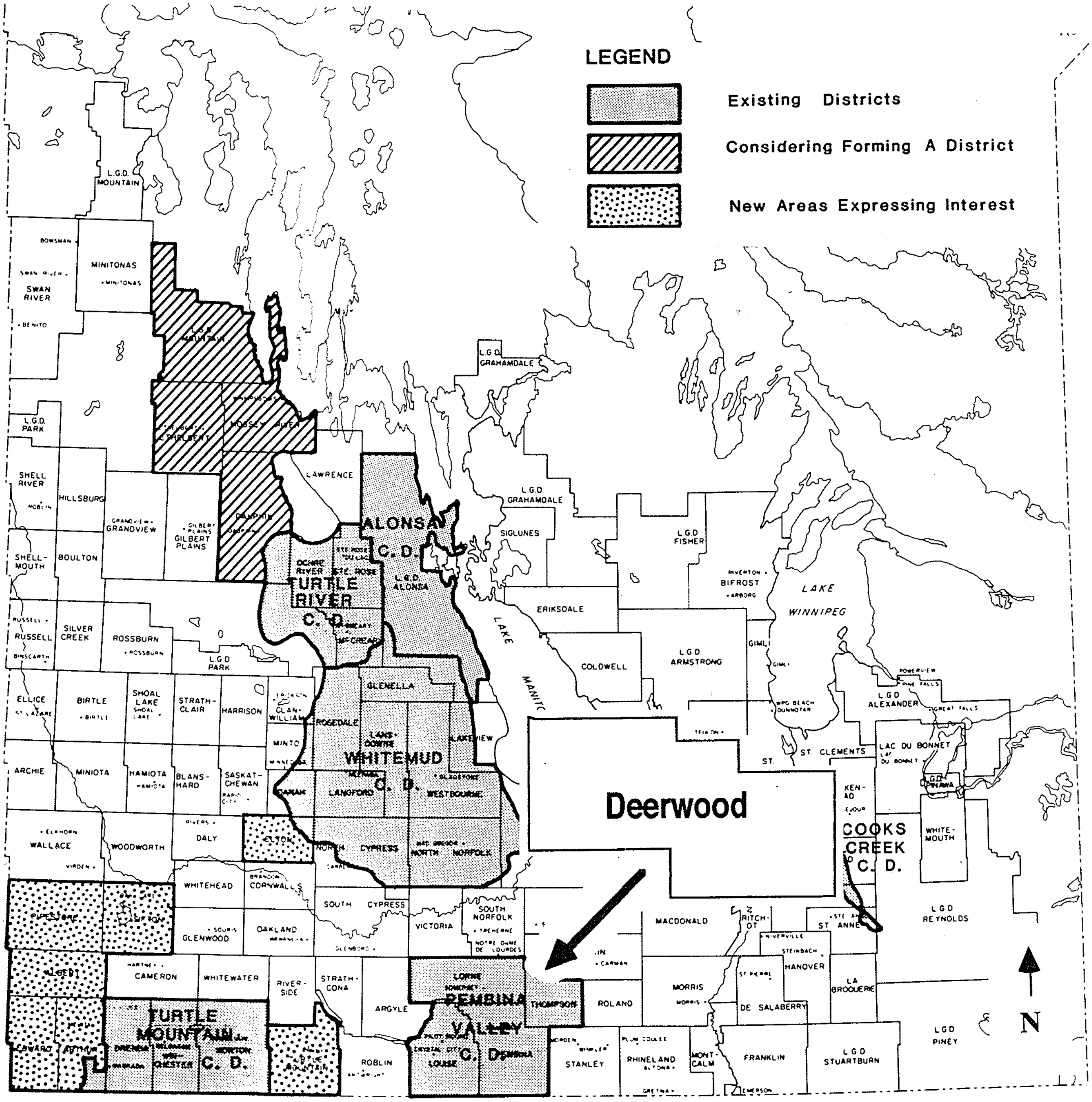

Figure 1d
Rural Municipalities, Local Government, and Conservation Districts in Manitoba
Source: 1994 Municipal Officials Directory, MB Rural Development

Traditionally, larger-scale, capital-intensive water management projects, such as flood-damage-reduction dams and water storage reservoir impoundments have been considered to provide the most significant contributions to land & water conservation, management, and community development. It is often due to the apparent multiplicity of these efforts that impressive cost-benefit rationalisations can be demonstrated prior to public investment and project completion (Newson, 1992; Shabman, 1988; Smith, 1974; and Laycock, 1970). Significant efforts have been undertaken to evaluate the effectiveness of programmes and policies designed to enhance the sustainability of land & water management of agricultural regions (Tyrchniewicz & Wilson, 1994; Prairie Research Associates, 1992: and Josephson, 1992). It is apparent that the costs and benefits associated with such efforts require further study and evaluation; the policy implications could be significant.

The Deerwood Soil and Water Management Association coordinates and initiates multi-agency assistance with farmers' soil, water, and habitat conservation and management activities within three sub-watersheds along a portion of the Manitoba Escarpment in South-Central Manitoba (Figure 1e). Much of this organisation's work involves the building of small headwater retention structures, or "small dams"[3] which appear to have significant environmental, economic, and social benefits (O'Grady, 1990) (Plate 1b).

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[3] Small dams refer to structures approximately 4m high, with approximately 40 acre feet of storage, and built for approximately $10.0 K or less.

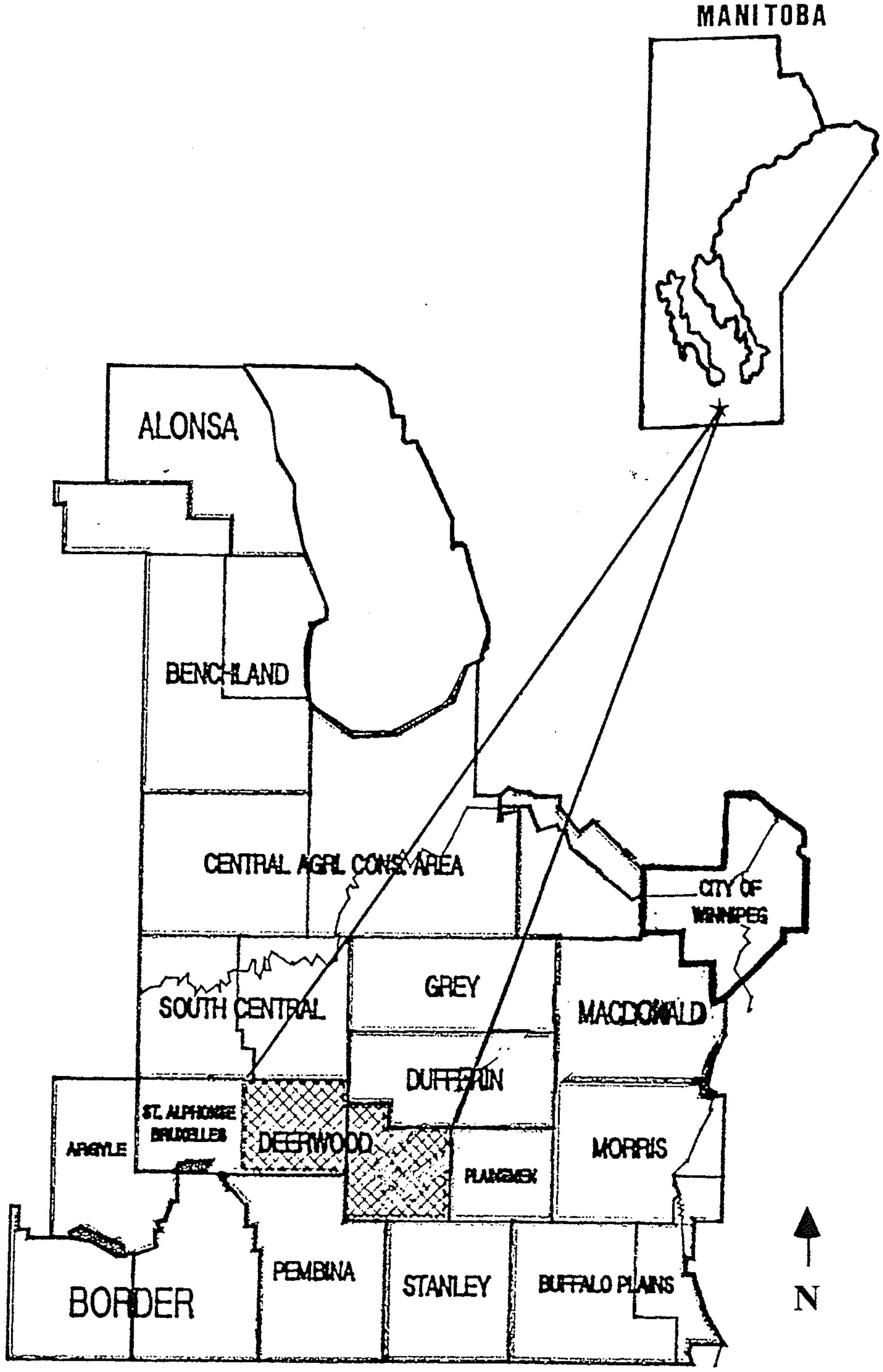

Figure 1e
Project Area of the Deerwood Soil & Water Management Association
Source: Agriculture Canada - Prairie Farm Rehabilitation Administration
(Winnipeg, PFRA, 1993)

Plate 1a
The Moreau Gulley: A Severe Case of Erosion on the Manitoba Escarpment

Plate 1b
A Typical Small Dam in the Deerwood Region

Problem Statement

Aside from programme delivery reviews, little evaluation work has been done regarding the physical and socio-economic effectiveness of integrated land & water conservation, management, and development initiatives (Biwas, 1985). However, there is an emerging body of literature which suggests that small, well organised groups of landowners can work together to deliver efficient and effective soil and water conservation programming on the local landscape (Curtis & DeLacy, 1995 and Sampson, 1992). In addition, fiscal difficulties currently being experienced within Canada, Manitoba, and many other jurisdictions are causing government decision-makers to increasingly demand clear and concise rationalisations of all publicly financed expenditures, including the provision of conservation related programmes.

It has become apparent that various impacts of small-scale, sub-watershed land & water management initiatives may result in positive and significant physical benefits (PFRA, 1994; STCPPSC, 1992). It has also been suggested privately initiated efforts to address environmental problems related to agricultural practices provide benefits which are likely undervalued at this time (Curtis & DeLacy, 1995 and Sampson, 1992).

The quantification of values external to applicable markets has long been a difficult barrier in the formulation of all public policy aimed at maximising societal welfare[4]. No widely accepted evaluation framework exists to assess the environmental, economic, and social effects of local land & water management efforts. Without proper evaluation however, the effectiveness and efficiency of many land & water improvement efforts may continue to be questioned, further delaying the resolution of many management problems within many agricultural regions, including Agro-Manitoba.

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[4] Theories of Welfare Economics, particularly the optimisation of individual utility, economically efficient allocation, and distribution of resourcess and income are the very core of public policy (Randall, 1987, p.51-198).

The Province of Manitoba's *Sustainable Development Committee of Cabinet* [5] is seeking to determine if the efficiency and effectiveness of land & water management programmes within Manitoba may be quantified. The SDCC is particularly interested in the economic value of programmes aimed at addressing land & water concerns which have traditionally been experienced along the Manitoba Escarpment, such as erosion and flooding. The SDCC has provided funding to The International Coalition for Land & Water Stewardship in the Red River Basin to undertake a research project related to these interests.

An excellent case study is now available. A majority of small dams built by the Deerwood Soil & Water Management Association to address severe flooding and erosion along a South-Central Manitoba portion of the Escarpment have been in place for several years. Additionally, the presence of similar conditions in a watershed adjacent Deerwood's most intensive region of activity appears to allow for the establishment of a control scenario; ideal conditions exist for a comparative study to be undertaken.

The following questions serve to clarify the problem statement, bringing its components into sharper focus:

How May the Land & Water Management Efforts of an Organisation of Agricultural Landowners be Evaluated within a Public Policy Context?

Do the Benefits of Deerwood's Efforts Exceed their Costs?

Do Appropriate Methods Exist to Quantify these Benefits and Costs?

What Relationship Exists Between Deerwood's Water Management Efforts, and the Solution to Similar Land & Water Problems Experienced Elsewhere on the Manitoba Landscape?

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[5] The SDCC is comprised of Manitoba's Ministers of Education, Environment, Natural Resources, Agriculture, Rural Development, and Energy and Mines. The SDCC makes recommendations to Cabinet regarding sustainable development.

Research Objectives

In order to effectively research the problem identified above, the following objectives were established to frame the study within suitable terms of reference. Specifically, in order to administer *An Economic Evaluation of Water Management Efforts Undertaken by the Deerwood Soil & Water Management Association*, this study proposed:

1) To become familiar with the historic and current activities of the Deerwood Soil & Water Management Association (DSWMA);
2) To review the literature pertinent to watershed management and evaluation;
3) To review the range of water management projects undertaken by the DSWMA;
4) To develop a suitable framework for the economic evaluation of Deerwood's water management projects;
5) To assess if the economic benefits of Deerwood's water management efforts exceed the costs experienced for their construction, operating and, maintenance;
6) To provide analysis and discussion regarding economic evaluation data and;
7) To make recommendations regarding the efficiency and effectiveness of the Deerwood water management programme, and its relationship to the solution of similar land & water concerns experienced in other areas of Manitoba.

Summary of Research Methods and Process

In order to address the proposed research objectives, the methods utilised to undertake this study included: a review of related literature; a detailed background study of the Deerwood region and the DSWMA; a comparative study of two adjacent watersheds; collection of survey data from local municipalities and landowners and; the establishment of an appropriate evaluation framework. A thorough analysis of the data facilitated the formulation of conclusions and recommendations.

Assumptions and Limitations

It has been assumed that a high degree of local support for land & water conservation and the efforts of the Deerwood organisation generally exists within the project area. Every effort has been made to ensure that this support did not serve to bias the research through the exaggeration of benefits or the minimisation of costs related to Deerwood's water management efforts. Landowner survey data was generated from a relatively small sample size, and results must be considered within this context. In addition, a number of assumptions were made in support of the establishment of a control scenario between the North and South Tobacco Creek Watersheds. While many efforts were made to confirm the existence of a control situation, there are surely errors in this regard. Soil types, climatic conditions, and natural vegetation were all considered. In addition, some human induced variables such as farm type, application of conservation methods, and clearing of land prior were considered prior to making the assumption of control.

2. RESEARCH METHODS

Length of Study

The study was conducted over a period of 12 months between June 1993 and June 1994 during which the researcher relocated to the study area. It was believed that better understanding of environmental conditions and management approaches could be obtained by living in the Deerwood region. It was anticipated much local assistance would be required during the study. Residing within a small community in close proximity permitted the researcher to act as an onlooker making naturalistic observations of the Deerwood Soil & Water Management Association and its activities. The utility of personalised and humanised evaluation has been extensively documented. Patton (1990) has provided guidelines regarding the "Known Sponsor Approach." Discussions with the DSWMA President, Executive, and Technician were easily facilitated due to relocation; regular access to a local member of The International Coalition Board was of immeasurable value.

Research Subjects

While Deerwood's network of small dams was the primary focus of the study, the following subjects were all considered pertinent: The Province of Manitoba was included due to its responsibility for most waterways designated third order and above (Figure 2i). The Rural Municipalities of Lorne, Roland, and Thompson were also considered given their responsibility for the administration and management of numerous local roads, bridges, and ditches within and downstream of the Deerwood region. In addition, the Pembina Valley Conservation District (PVCD) was included in the research given its complementary role to several municipalities in the areas of soil and water management. The PVCD also has specific responsibilities for the building of some headwater retention structures in the vicinity of the Deerwood project area (PVCD, 1992). Finally, all residents living within the Deerwood project region whose land is drained by tributaries of the North and South Tobacco Creeks were subjected to research.

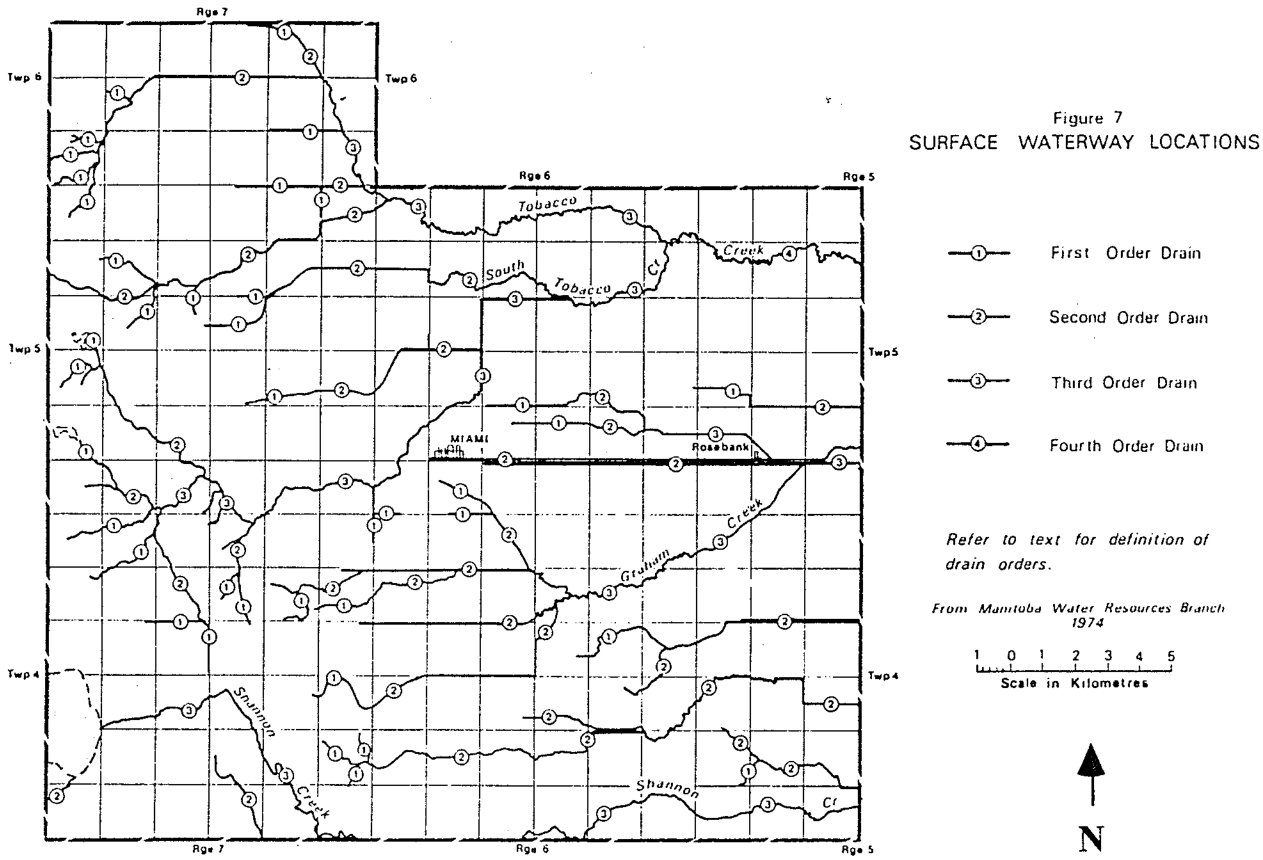

Figure 2a
Provincial Drains (3rd Order and Above)
Source: Madison, 1983, *Tobacco Creek Watershed Land and Water Management Study*
Tobacco Creek Steering Committee, p. 22

Procedure

Literature Review

An extensive literature review was employed to assist in establishing the utility of the study within the historical context of watershed planning and management. Additionally, it was anticipated new ideas and previous data germane to the study would be revealed. It was hoped current theoretical frameworks and practical applications of project evaluation would be available for consideration. Literature reviews are typically valuable for this range of purposes (Leedy, 1974).

Background Research

A thorough background review of the Deerwood project area including physiography, soils, climate, previous research, and management history was undertaken. A detailed description of the origins and activities of the Deerwood Soil and Water Management Association was undertaken. This information proved extremely useful throughout the study.

The Deerwood Executive Committee

The Deerwood Soil & Water Management Association Executive served as a local "sounding board" for questions and ideas of the researcher. Meetings, at the call of the President, also contributed to a clearer understand the Deerwood region, its people, and its soil & water issues. As details regarding the research methodology largely evolved during the study, the DSWMA Executive was an invaluable resource.

Documentation of Provincial Costs

Discussions took place with Manitoba Government officials in an attempt to estimate historical and current damage repair and maintenance costs associated with the operation of provincial waterways (third to seventh order drainage ditches) downstream of the Deerwood project area.

Documentation of Municipal Costs

Introductory presentations to the Rural Municipalities of Lorne, Thompson, and Roland occurred, while occasional contact with the Pembina Valley Conservation District was also maintained. These entities were informed of plans and requirements associated with the study, while their assistance was often solicited. Much valuable data was collected.

Once municipal interest in the study had been confirmed, a descriptive survey was distributed employing the general interview guide approach (Patton, 1990). Each Reeve and municipal council, and the PVCD received the list of general questions which outlined issues requiring exploration (Appendix 1); follow-up meetings were scheduled as necessary to further address the questions. The interview was comprised of questions relating to each municipality's historical costs of water-related problems including road, bridge, and ditch maintenance and/or damage costs; temporal questions regarding these costs during the period between 1989 and 1993, and the municipality's awareness of local social or environmental changes attributable to the construction of dams by Deerwood. Affected waterways included the Graham Creek, and both branches of the Tobacco Creek.

Documentation of Dam Costs and Landowner Costs, Benefits, and Values

An analytical survey was conducted using a standardised, open-ended questionnaire (Leedy, 1974; Patton, 1990). All landowners whose property was bisected by, or adjacent to, either the North Tobacco or South Tobacco Creeks (or its tributaries) upstream from their confluence were contacted. Through the mail, these landowners each received identical questionnaires, with an explanatory cover letter from the municipality in which they paid taxes and a self-addressed stamped envelope (Appendix 2). The North Tobacco Creek was identified as a control scenario because only five dams (one multi-purpose, one dry, and three backfloods[6]) have been constructed within its watershed. Conversely, the South Tobacco, with 30 dams in total, was logically selected as the managed environment.

All questionnaires were inconspicuously codified, as some follow-up was anticipated. The questionnaire was structured with guidance from Patton (1990), and assistance from the researcher's NRI Practicum Committee. It was comprised of 32 questions, some incorporating illustrative examples for clarity. No respondent would be required to complete the entire questionnaire. Respondents were asked to indicate first, whether or not a dam existed upon their property (i.e. dam ownership). Subsequent instructions directed the respondent to continue the questionnaire in sequence or, to move to another section of the survey.

Damowners were asked to indicate and describe their use of the dam, associated costs, and general value perception questions (Patton, 1990). Additionally, all respondents were asked to indicate and describe flooding and erosion damages which may have occurred during the past five years (1989-1993). Non-damowners were asked to indicate and describe their use of the North Tobacco or South Tobacco Creeks, as applicable. Finally, several general information and value perception questions were posed.

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[6] While 9 Deerwood dams within the natural drainage area of the North Tobacco Creek, only 5 exist within the current North Tobacco watershed, due to the Roseile diversion noted earlier.

Reporting, Analysis, and Discussion of Results

Survey data derived from Provincial, municipal, and individual landowner contacts were reported, tabulated, and basic trends identified. It was anticipated the individual landowner questionnaire would elicit the majority of data requiring analysis. An analysis framework developed by Krutilla and Fisher (1975) was employed towards the evaluation of Deerwood dam benefits and costs via Economic Payback Period Analysis. Discussion focussed on the implications of tangible municipal benefits and apparent environmental and social values associated with the Deerwood dams.

Conclusions and Recommendations

Conclusions were provided in response to each research objective outlined in Chapter One. Finally, a set of recommendations arising from the research were prepared. The International Coalition will incorporate these findings within a widely circulated discussion paper prior to its final project report to the Province of Manitoba.

3. REVIEW OF RELATED LITERATURE

The Evolution of River Basin Management

Small Scale Prehistoric Contributions

Bennett (1974) has outlined the importance of analysing prehistoric cultures to learn lessons relevant to present-day watershed management. Planners and decision-makers often fail to use such data. Ironically, it has been due to the construction of large scale water management project such as the Tennessee Valley Authority works and the Aswan High Dam that archeologists have been able to trace the early establishment of dams, fishing technology, and other riverine uses. Along the Negev and Sinai Peninsulas, modern agricultural water development has emulated ancient management efforts in Israel. In some instances erosion check dams, old terrace systems, and directed runoff have simply been restored. Ancient systems in Meso America appear to demonstrate a sound understanding of the natural and managed interrelationships between water flow and soil fertility, often on a sub-watershed or catchment basis. These examples also highlight the potential for archaeologists to become more involved in the long-term feasibility of alternative water management systems. A variety of water management works have been identified to have existed within numerous low-energy agricultural societies of the prehistoric world (Table 3a) (Bennett, 1974)

Table 3a: Prehistoric Water Management Works
Source: Bennett, 1974, p. 34-81

1.	Diversions of running streams into nearby fields;
2.	Ponds to hold water for later use;
3.	Catchment basins for rainfall;
4.	Slope development to increase aquifer recharge by holding water in silted terraces;
5.	Dams for diverting streamflow into ditches for domestic and agricultural use;
6.	Large canal and distribution systems carrying river water to agricultural regions;
7.	Large reservoirs for long term storage;
8.	Devices to tap groundwater at water table levels;
9.	Artificial islands used for agriculture in permanent, shallow lakes;
10.	A large variety of wheels, levers, and bucket systems for lifting water and;
11.	A variety of drainage schemes.

It is noted that few water management opportunities appear to have been missed by prehistoric peoples; the variety of these schemes arising because of necessary adjustments to compensate for local environmental conditions. These management systems were effective and efficient in supporting small local populations due in large part to their simple, flexible, ecosystem-based designs managed by a devoted community labour force. (Bennett, 1974). The Anasazi of Chaco Canyon, New Mexico ingeniously controlled and distributed sporadic rainfall runoff within a system of ditches and diversion dams, eventually channeling water to small agricultural plots around 900 a.d. The Anasazi communities thrived for 250 years, until a drought, followed by climatic cooling, appears to have caused their demise after 1150 a.d. (Canby, 1982).

> Formerly slaves to a fickle environment, by the 900's the Anasazi began to assent control. They did it by manipulating water. In addition to their pueblos, the Chacoans built and maintained a vast array of water control devices. They also built check dams that collected eroding soil and held the water that carried it. Though individually small, these devices sometimes numbered in the hundreds within a single community.
>
> (Canby, 1982, p. 565, 568)

Large Scale Hydraulic Civilisations

The centrally controlled civilisations which arose at other periods in history were often dependent on large, brittle, complex, labour intensive systems. However, significant advances in engineering technology and irrigated crop production developed due to these efforts. Centralised political control was a key factor during this period (Bennett,1974). Newson (1992) categorises the hydraulic cultures as "management in advance of science." Toynbee (1976) has deduced that a high degree of social organisation was required for the hydraulic civilisations to function effectively during their existence. The scope and magnitude of these projects required foresight and coordinated planning, even without the support of science.

As early as 6000 b.c. various forms of water manipulation were occurring in order to sustain settled agricultural communities. Irrigation and elementary flood control were practised in the Indus region, China, Egypt, and Mesopotamia. (Newson, 1992). Major flood damage reduction initiatives were undertaken to protect the city of Mohenjodaro on the Indus River, while the residents of the city itself enjoyed a well established sewage system some 2500 years b.c. (Hamblin, 1973). The Romans are recognised for their hydraulic contributions in Europe. The Nile River was managed to a great degree, both in its headwaters and downstream, for flood protection and irrigation, and land drainage activities were carefully planned to prevent erosion (Bennett, 1974). Sennacherib the Assyrian built a dam to destroy the city of Babylon in 689 b.c., later surveying and designing numerous dam construction and irrigation schemes (Smith, 1972). Biswas (1967) has tabulated the development of the early hydraulic civilisations (Table 3b). The magnificent growth of these hydraulic civilisations were often followed by equally spectacular declines. After the fall of the Roman Empire, a dark period begins for water management and hydraulics (Newson, 1992). Flood-proofing works for the ancient city of Mohenjodaro on the Indus River did not address headwater management whatsoever, and eventually failed without upstream controls. The Roman systems failed after losing control of large slave populations and through resource exhaustion. Sumerian efforts on the Tigris-Euphrates system eventually failed because of poor information transmission created by the fragmentation of their society into smaller city-states (Toynbee, 1976).

Table 3b: Key Dates in the Development of Hydraulic Civilisations
Source: Biswas, 1967, in Newson, 1992, p. 3

3000 b.c.	King Menes dams the Nile and diverts its course;
3000 b.c.	Nilometres used to record rising levels of Nile River;
2800 b.c.	Failure of Sadd el-Kafara dam on Nile;
2750 b.c.	Origin of the Indus Valley water supply and drainage systems;
2200 b.c.	Various waterworks on the "Great Yu" River in China;
1850 b.c.	Lake Moeris and other works of Pharaoh Amenmhet III in Egypt;
1750 b.c.	Codification of Sumerian and Babylonian water law by King Hammurbi;
1050 b.c.	Water metres used at Gadames Oasis in North Africa;
714 b.c.	Destruction of qanat systems at Ulhu (Armenia) by King Saragon II;
700 b.c	Qanat systems gradually spreading to Persia, Egypt, and India and;
690 b.c.	Construction of Sennacherib the Assyrian's channel.

The Catchment Concept

Although knowledge of various aspects of the hydrologic cycle appeared to be evident since antiquity; it was not until the 1500's that a comprehensive understanding of the entire process began to emerge. da Vinci's 1502 sketch of the Arno River Basin is the first recorded image of a watershed system; it depicts how slopes and channels influence the headwater sources of the Arno's tributaries (Popham, 1946). In 1580, Palissy provided the first accurate description of the runoff process (Ward, 1982). Finally, in 1799, John Dalton quantitatively linked the processes of rainfall and runoff (Dooge, 1974). Unfortunately, human understanding of the interrelationships between soil type and land use is relatively recent (Newson, 1992).

Smith (1969) has offered several reasons why attention gradually began to be paid to the "catchment" or "basin." He suggests river networks served to integrate societies sharing the same drainage area through the provision of water power, irrigation, domestic & agricultural water supply, fish & game supplies, and accessibility - either by valley floor or the river itself. More specifically, Pereira (1973) maintains that above all else, irrigation has been the driving force behind historical efforts to manage and/or develop the resources of a watershed region. Additionally, he adds, the flourishing of irrigation agriculture has gone hand in hand with the existence of a stable and vigorous central government.

Newson (1992) suggests the first region to adopt an institutional approach to watershed management was Southern England. The emergence of problematic land and water concerns created by intensive population growth and industrial development necessitated coordinated action. Parker's account (1976) documents serious flooding and erosion issues within the catchment of the River Rhee in Cambridgeshire, the cause being upland forest-clearing. As early as the 1300's local manorial courts began to enforce laws to prevent the pollution of important small streams (for community health purposes). The development of sewers in England can be traced to the 1400's. Intensive land drainage and irrigated agriculture became widespread after the 1600's. The first modern dams were used for collecting fish (weirs) and for milling power, as evident by the 1700's.

A number of conflicting and competing uses for water resources in England were evident by this point. This trend lead to the entrenchment of the legal concept of Riparian Rights in 1859 (Wisdom, 1979).

> Whatever the purpose of river regulation, no scheme could fulfill its potential without the cooperation of all interests involved. A balance had to be struck between the protection of individual rights and the furtherance of the common good.
>
> (Sheail, 1988, p. 222)

Modern River Basin Management

Wengart (1980) describes three distinct eras of river basin management in the United States. The "Preparatory Period" may be traced to the late 19th Century, with John Wesley Powell's 1879 report on the development potential of the Western U.S. "Arid Lands." The Preparatory Period was characterised by the urgency of immediate development and simplistic project rationalisation.

The "Development Period" occurred from approximately 1933 to 1965. During this era, the US Federal Government gradually took responsibility for the nation's water resources and their management. Goals for regional socio-economic development were added to multi-purpose planning; and federal investments provided benefits including: flood plain protection, free navigation, irrigation water, and hydroelectric power generation (Wengart, 1980; Allee, 1987). The early Development Period was characterised by the creation of the Tennessee Valley Authority in 1935 which opened the way for a basin-wide experiment in multipurpose water development. The TVA was established with the objective of stimulating an underdeveloped section of the country from the depths of the depression; flooding and erosion damage had severely undermined the ability of the region's residents to earn a living (Galloway, 1987). Restoration of a complete watershed (41,000 mi^2) was the goal which led to the establishment of nine multi-purpose reservoirs, backed by many smaller dams. Permanent forest cover was also re-established on approximately half of all highly erodible land (Pereira, 1973).

With the passing of the US Flood Control Act of 1936 by Congress, water project evaluation criteria were established and; attention began to be paid to the costs of river basin management. At this time, it was declared that federal support would be available only for projects in which "the benefits to whomsoever they accrue are in excess of estimated costs" (Galloway, 1987). This marked the beginning of a long history of project evaluation which, in time, would include concepts of: national efficiency, regional development economics, environmental quality, and social well-being.

The late Development Period can be characterised by the drafting in 1965 of the Water Resources Planning Act (WRPA) (by the Presidentially appointed US Water Resources Council) which, among other recommendations, called for the establishment of a four objective water project evaluation system (Wengart, 1980; Allee, 1987). A strong emphasis was placed upon basin-wide planning. While #3, was later not accepted by Congress, the following recommendations definitely encompassed a new policy approach:

1) To enhance national economic development;
2) To enhance the quality of the environment;
3) To enhance social well-being and;
4) To enhance regional development.

(Dawes, 1972)

Wengart's final era of U.S. river basin management is defined as the "Environmental Transition Period," occurring from 1965 to 1987. Initially, the impact of the 1965 WRPA recommendations ran against the agency and institutional view of maximised hydrologic engineering and development. Traditional dam and channel work slowed considerably as public investment was expanded in other important areas such as wastewater treatment and chemical contamination of water supplies. Unfortunately, the basin concepts embodied within the 1965 act became fragmented and disintegrated in the 1980's. The Reagan administration dismantled the WRPA in 1981; and the Water Resources Council came under critical review. While many environmental programmes have been initiated and are continuing; it appears coordinated river basin management will only come about if identified as a political goal serving the wishes of well-organised interests (Allee, 1987; Wengart, 1980). Fortunately, science seems to have responded to the challenge created by this policy gap.

The Emergence of a Watershed Discipline

Heindl (1972) suggests scientific study of the watershed concept arose with the rise in public concern relating to environmental degradation. Scientists recognised "the watershed" during the early 1960's as a sensible framework within which to address interrelated problems such as water quality and contamination. As any investigations aimed at addressing such chronic concerns would be both expensive and long-lasting, the approach of "taking the whole watershed into account" emerged as an efficient and practical means of tackling these issues with the support of science. Two pervasive concepts founded the discipline:

> 1) The watershed is a closed-system which integrates the physical forces which act upon it and;
>
> 2) The knowledge and experience gained through the study of one watershed is transferable and thus, may be applied extensively elsewhere (also: concentrated, small basin study is applicable to larger ones).
>
> (Heindl, 1972, p. 3)

Allee (1987) points to Gilbert White's 1957 paper as the first "pure doctrine" of watershed planning, management, and development, citing three ideas and two concepts which characterise a watershed approach. Ideally, any initiative would incorporate multi-purpose storage projects, basin-wide programming, and comprehensive regional development. Conceptually, articulated land & water programmes (including irrigation, drainage, flood plain management, and erosion control) would be provided through unified administration. It was later accepted: that more information pertaining to physical processes was required and; that larger watersheds may well have characteristics which differ from the smaller ones of which they are comprised. Consequently, great efforts were then made to increase the quantitative understanding of catchment hydrology. Two types of research became common: experimental (cause & effect) and representative (basins typical of larger areas were studied) (Heindl, 1972).

Heindl (1972) identified the following specific watershed research needs applicable as of the mid-1960's:

1) Economic impact studies;
2) Non-dollar evaluations;
3) Multi-purpose vs. single-purpose structures/approaches;
4) Modification of research priorities and;
5) Enlargement of scope.

Heindl also believed watershed research had not progressed satisfactorily; most relevant findings had not yet been presented in forms useful for watershed managers. He considered this unfortunate, as many of society's most pressing problems were related to land and water management (Heindl, 1972).

Agricultural Catchment Management: Issues, Trends, and Research

Direct Problems and Externality Issues in Agriculture

Pereira (1973) outlines the relationship between croplands and water resources.

> The main hydrological effect of arable cropping is on the reception of rainfall and its partition between overland flow and infiltration into the soil. By the exposure of bare soil to rain, sun, and wind, the capacity to absorb heavy rainfall is reduced, so that immediate overland runoff can produce sharp peaks of streamflow which may combine, in a large watershed, into floods. Cultivation without adequate precautions to prevent surface runoff from reaching erosive velocities can result in transport of surface soil. This produces sheet and gulley erosion of the farmlands with consequent deposition of sediment in channels and storage reservoirs lower in the watershed. Soil in suspension represents a deterioration in water quality.
>
> (Pereira, 1973, p.167)

Coote (1983) and Batie (1986) provide a comprehensive review of the relationship between conventional agriculture and the external environmental costs associated with conventional field management techniques. The root cause of human-induced (as opposed to natural) erosion is the application of inappropriate field methods in soil regions where any cultivated agriculture is sustainably questionable (Goldman et al., 1986). For example, Carlyle (1980) describes the long-time practice, and inappropriateness, of summerfallowing on the Canadian prairie, a practice which became increasingly popular after the turn of the century. In summerfallow, a field is cultivated in the Spring to minimise weed growth, then left uncropped for a season. The goal is to increase soil moisture and nutrients via organic matter oxidation. Ironically, on prairie soils, summerfallowing is incredibly destructive; as fragile soils are left open to the eroding forces of water and wind. Organic material breakdown occurs, resulting in lost nutrients and soil matter itself (Coote, 1983). Coupled with widespread drainage of natural wetlands and denudation of natural vegetation, soil erosion increased dramatically during the past century. This was particularly evident as cultivation became more intensive after World War II with the widespread availability of highly efficient, mechanised farm equipment (Shepherd, 1986). Intensive, inappropriate agricultural development is, in many cases, partially the result of numerous macro-economic forces such as transportation policy and international trade (Sopuck, 1988).

Meanwhile, damage resulting from soil erosion occurs in two forms: a) direct on-farm losses in soil productivity through lost water retention ability, deterioration of soil structure, loss & division of cropland by gullies, salinisation, lost organic matter, and acidification which all serve to cause decreasing yields, crop quality and eventually, decreasing land values and; b) indirect off-farm air and water pollution whereby eroding soil particles can carry soil nutrients, dissolved minerals, animal wastes, and may or may not contain pesticide residues (Isensee & Sadeghi, 1993) to create the single greatest non-point source of water pollution (Batie 1986; Madison, 1983; and; Coote, 1983).

Natural wetlands have been another specific on-farm casualty of agricultural development. Wetlands often represent significant unvalued externality benefits including: groundwater recharge, climate stabilisation, erosion control, improved water quality, waste management, wildlife habitat, food production (e.g. waterfowl, wild rice), species protection, education, esthetics, and recreation. In addition there are numerous direct economic benefits such as flood damage reduction, which are likely also undervalued (TIC, 1992; Usher & Scarth, 1990). Both on-farm and off-farm damages may be treated as external diseconomies. In fact, it is the on-farm losses of soil and wetlands which may hold the key to identifying and accounting for many unvalued benefits and costs associated with land & water management and development.

Related to soil erosion and wetland loss through agricultural development, flooding damage has been described by Pereira (1973) as "the most dramatic symptom of land misuse." One can trace the roots of flooding damage from antiquity to the present day.

> Failure to maintain irrigation channels of sediment eventually destroyed thirty centuries of Tigris and Euphrates irrigation agriculture and; continued erosion of the headwaters today has been known to carry up to 14 million tons of soil and rock debris past Baghdad in a single day.
>
> (Pereira, 1973, p. 23)

Similar externality problems currently exist within the Mississippi River Basin, problems which became very apparent during the summer floods of 1993. The cumulative effect of levees built to prevent natural flooding along the river since 1837 have served to increase the capacity of the river channel to contain floodwater. This increased capacity reduces floodflow velocity, thus disallowing a process of natural erosion to occur along its bottom and banks. Flood discharges in both 1973 and 1993 occurred at similar volumes to historical large events, but crested at much higher levels, causing greater damage (through breached levees) than would have occurred naturally. Also, as natural headwater retention has been dramatically reduced with the loss of original wetlands (Iowa 89%, Illinois 85%, and Missouri 87% respectively), the natural ability of the river basin system to accommodate flooding has be undermined significantly through human settlement and agricultural development of the floodplain (Common Ground, 1993).

Public Values and Private Land Ownership

The on-farm and off-farm degradation effects of conventional agricultural practices give rise to a controversial but necessary debate which may well be at the heart of the land & water management externality case. A clear understanding of the negative environmental effects of conventional agriculture seem to have been understood by legislators and even many farmers since the dust storms of the 1930s. This was evidenced by the creation of a prairie conservation agency under the Prairie Farm Rehabilitation Act of 1935 (Coote, 1987).

Farmer acceptance for various types of soil conservation appears to have generally increased since the 1980's; although widespread improvements in agricultural practice have been slower to materialise (Padgitt & Lasley, 1993; Esseks & Kraft, 1993; and Poor, 1987). Virtually all agricultural land is privately held, and landowners have traditionally retained all rights to its management. Sampson (1992) however, explains the historical dilemma of attempting to achieve public or social values on private land. The key element is time; conservation practices typically do not immediately provide measurable returns. When considered over a longer timeframe -a minimum of 5-10 years has been suggested (Johnson, 1994), practices such as conservation tillage, shelterbelt planting, and maintenance of wetlands may become directly profitable to individual landowners. The problem is that immediate on-farm costs can result in externality benefits both on and off the farmland (i.e. wildlife users, downstream property owners, and society at large), while returns to the individual farmer only come much later.

There has been much debate regarding the pivotal role of property rights in natural resources management. Pearse (1988) has documented the evolution of this concept, suggesting the human understanding of ownership is entrenched within Western thought. The goal for progressive natural resources planning and management should be an effective, organised relationship between publicly valued resources, (such as soil, water, and wildlife) and, their maintenance by the private individuals owning the land on which they are located. Pearse does not offer any workable models for implementation.

Chan (1989) notes the rights associated with the ownership of property have changed over time in the United States. The "frontier" or resource exploitation mentality has gradually begun to disappear as a "stewardship" or caring ethic has become more common among property owners. This argument is also supported by Mulvihill's analysis (1991) which comments that the entrenchment of property rights within the Canadian constitution may not be an inhibition to environmental protection.

Much work has been undertaken by researchers and conservation farming organisations alike to compare the on-farms costs of conventional versus conservation agriculture in North America (MNDZTFA,1992). There is now substantial agreement that the total farmer costs of conservation tillage are fairly similar and, in some cases, comparatively less than conventional methods of agriculture. Capital and variable costs per acre/hectare are higher for most forms of conservation tillage due to required investments in equipment and higher herbicide treatment costs. However, these costs are substantially offset by lower production costs stemming from fewer tillage operations. Labour costs may be reduced by up to 61% annually when compared to conventional systems. On some soils, fertiliser costs may be reduced because of a higher concentration of organic matter (Weersink et al.,1992).

Randall (1987) addresses the existence and nature of market failure whereby the outcomes of free market activity result in an inefficient use of resources. "Non-exclusive" goods and services (i.e. many resources) are characterised by "attenuated" (weakened) property rights. Largely due to the characteristics of the goods themselves appropriate pricing does not occur because it is impossible to collect prices for resource use. Such resources may include: migratory birds, fish, and wildlife; ambient air; soil, and; water in streams, lakes, and oceans. Without a price, these resources cannot be rationed among users (resulting in overexploitation - "Tragedy of the Commons") and thus; revenue cannot be raised to pay for necessary maintenance and conservation. Johnson (1993b) also articulates the view that environmental goods and services are indeed public goods susceptible to overexploitation through market failure.

There are emerging natural resources management systems which recognise the importance and changing views of private ownership (Scarth, 1984). One method concerns the contracted payment to individual landowners in exchange for management practices which result in immediate off-farm environmental and social externality benefits. Direct benefits on the farm are also possible in the longer term. Such is the case with the North American Waterfowl Management Plan (NAWMP), which appears to be proving effective and efficient.

Contracted payments delivered by a consortium of continental waterfowl and wildlife interests provide a return to the landowner at rates commensurate or above those which could be achieved directly through agriculture (Josephson, 1992; MHHC, 1992). This is but one management regime which addresses the important role of private property rights in achieving environmental and social externality goals. Under the NAWMP, the monetary prices for avoiding social and environmental externality costs associated with conventional agriculture (i.e. poor soil management and wetland drainage) have been paid directly to landowners in return for improved land & water management practices which they provide to external societal benefactors.

There are numerous examples which provide an alternative, workable method of natural resources management in certain situations. Berkes et al. (1989) have noted the potential for cooperative community-based management of "common property resources." An ethic of shared responsibility for resources which are easily exhausted/degraded without cooperation is a common characteristic in such cases.

Axelrod and Hamilton (1981) outline principles for the evolution of human cooperation. It is conceivable that individual landowners working together within a community may cooperate towards their mutual benefit, as in the avoidance of external diseconomies in agriculture. Johnson (1993a) notes the connections between externality problems and common property resources are complex and very difficult to quantify.

Natural Resources Accounting, Ecological Economics, and Economic Value

For most nations of the world, the commercial value of the natural resources with which they are endowed have been catalogued, either by the country itself, or by an external body such as an international agency or bank. In terms of agriculture, the amount of arable land within a country is indicative of its potential for food or cash crop production. Relative to this research, Canada utilises a land quality rating system to account for its productive capacity. The *Canada Land Inventory* has been supplemented by various newer documents which highlight regions where soil salinity, water erosion, and wind erosion are likely to be limiting production factors.

While not yet standard practice, the loss and degradation of natural resources capital within nations has been the focus of intensive research (World Resources Institute, 1991; Repetto et al., 1989).

A new discipline has emerged in recent years which attempts to address the "values" provided by earth's natural systems. Gallon (1993) describes ecological economics as a means of acknowledging and measuring society's use of natural capital. d'Arge (1990) traces the origins of the development of ecological economics as a response to traditional macroeconomic models which were unable to provide a framework to define ultimate resource constraints to economic growth. Ecological economics is rooted in the classical writings of Malthus, Ricardo, Mill, and Darwin; the first to debate issues of population, living standards, and resource quality.

> Most macroeconomic models do not recognise the existence of a natural environment or a set of productive ecosystems. Few consider the availability of exhaustible resources, and none of the models embodied in textbooks or used by Washington D.C. policymakers is consistent with the principles of physics, chemistry, or biology. This has led to growing discontent: the macroeconomic paradigms are almost valueless in giving any rational or complete evaluation of U.S. policies, especially in the long run.
>
> (d'Arge, 1990, p. 430)

Gowdy (1993) has addressed biodiversity as one important indicator of natural capital which must be quantified. Meanwhile, Friend (1991), proposes a more complete nationwide natural resources accounting approach. Raven (1993) supports this view by suggesting an even more holistic method. Finally, Burgenmeier (1993) suggests we must look far beyond environmental accounting to a method which addresses social and economic effects simultaneously.

Individual consumer preferences are expressed in terms of monetary values. While some believe the concept of "monetising" environmental benefits or certain damages to be inappropriate, at present it is the best method by which gains or losses in societal welfare or utility may be uniformly represented. While the use of alternative measurement units such as energy and time have been attempted; they fail in the indication of consumer preferences (Pearce & Turner, 1990).

An important use for economic value measurements is to demonstrate the effectiveness of environmental policy decisions. The gains of sound environmental policy do not become evident in the form of immediate monetary gain, such as within the national accounts of a country. They typically emerge gradually through increases in overall quality of life for a nation's residents. As environmental benefits "tend to be less concrete" than marketable benefits, there is a tendency for underestimation (Pearce & Turner, 1990).

Pearce & Turner (1990) have described the taxonomy of economic values as they relate to the study and management of natural systems and policy. **Total Economic Value** equals the sum of the following:

1) Actual Use Value;
2) Option Value and;
3) Existence Value

(Pearce & Turner, 1990, p.131)

Actual use of the environment quantifies readily measurable benefits which accrue to the user(s). Option value is a more complex measure relating to the individual preferences of consumers in relation to risk. Gross Willingness to Pay (WTP) for an environmental good is comprised of the actual cost of acquiring the good and the expected consumer surplus the individual expects to receive from the good (i.e. improved water quality). The net WTP (net benefit) is equal to the consumer surplus expected by the individual (the cost of not using it).

However, due to risk and uncertainty, consumers are often willing to pay an additional amount above their expected consumer surplus in order to ensure their future use of a specific environmental good. This total WTP is called *Option Price* and is comprised of consumer surplus and option value to the individual. Ignorance of option values typically underestimates the true value of environmental goods (Pearce & Turner, 1990). Existence value is unrelated to any actual or potential use of an environmental good. This range of values is generally supported through various motive of altruism, (i.e. concern for future generations, animal welfare); although increasing attention is being paid to the concept of stewardship (Pearce & Turner, 1990).

The Role of Economics in Water Policy Evaluation

Economic analysis contributes to the establishment or revision of policy in four ways:

1) It may legitimise prior decisions of the policy client;
2) It may increase a client's understanding of the policy;
3) It may lead to a decision changing the allocation of budget funds or regulatory procedures or;
4) It may result in a programme change (budget or regulatory) which improves the welfare of the intended beneficiaries.

(Shabman, 1988, p.113)

The concept of economic justification for projects has been viewed as an important function of economic analysis. Too often, the employees of water resource related agencies are given to understand all evaluation efforts should be bent toward supporting decisions which have already been made. Additionally, economic analysis and economists have frequently raised "annoying" questions which eventually led to a re-thinking of development policies and organisational objectives through the generation of project alternatives. Finally, economists have contributed to water resource management and development by being internal and external critics working to generally expand awareness of alternative policy opportunities (Smith, 1974).

Economics has been used to logically tie policy decisions to a general theory of production, capital growth, and overall value determination. In terms of water management, economics has been employed at both the micro level, through the analysis of biological or engineering production and; at the macro level, with the emergence of "basin analysis," where the watershed is treated as a "firm" with the goal of more accurately estimating regional or national incomes. Economists have typically been confounded by the necessity of assigning economic values to the various non-marketed products and services derived from water. Much discussion has occurred regarding appropriate methods for comparing values occurring at different points in time (Smith, 1974).

Addressing Agricultural Land & Water Management Problems

The causes of land & water management problems are diverse and complex. Long-term solutions require coordinated approaches comprising a broad range of disciplines and interests. Newson (1992) concludes, "it is likely that *technocratic* solutions will remain influential, if not dominant in a world of teeming population and widespread famine and disease. But, "the *people* issues are never far behind the technical ones." With regard to water management problems, Newson points to the two technical issues requiring attention:

1) Controlling soil loss by erosion and salinisation and;

2) Storing water properly.

A variety of computer models have emerged to estimate the volumes of soil which will erode off various soil types under different land management techniques (Cameron et al., 1992). These models are being applied within small agricultural watershed areas with increasing degrees of accuracy; the most prevalent being the Universal Soil Loss Equation (Mellerowicz et al., 1994). A wide variety of land management techniques may be utilised to minimise soil loss. These include appropriate land use planning, terracing & contour cultivation, reduced tillage methods, crop residue management, grassed waterways, gulley stabilisation, and rotational grazing. (Newson, 1992; FAO, 1977b; Pereira, 1973). Proper water conveyance, storage, or energy dissipation may be achieved through the use of natural upland or re-created wetlands, various methods of cropland management designed to retain water on or within agricultural land, and methods of impounding various quantities of runoff behind engineered structures such as berms, road gradings, check dams, and sediment traps (TIC, 1993; Goldman et al., 1986; Pereira, 1973). The range of possible land treatment measures which may be utilised to combat soil erosion are outlined in Table 3c.

Table 3c: Land & Water Management Techniques for the Prevention of Soil Erosion
Source: FAO, 1977b, in Newson, 1992, p. 193

PRINCIPLE OF LAND TREATMENT	TREATMENT MEASURE	TREATMENT GROUPING
Soil Selection	• Selective land management according to soil type	**Land Management Practices**
Soil Management (Soil Cover)	• Cover crop • Shorter fallow period • Optimum planting time • Adequate fertiliser • Crop residue incorporation • Improved tillage practices	**Land Management Practices**
Soil Management (Soil Condition) **Water Management (Retention)**	• Crop residue incorporation • Improved tillage practices • Soil amendments • Improved rotation • Strip cropping	**Land Management Practices**
Water Management (Retention)	• Contour cultivation	**Erosion Control Works**
Water Management (Disposal)	• Grassed waterways • Gulley stabilisation	**Erosion Control Works**

Goldman et al. (1986) have reviewed the range of structural controls which reduce water erosion and retain sediment. They fall into three categories:

1) Conveyance facilities which are designed to carry runoff in a non-erosive manner into a natural stream or a permanent storm drainage system;

2) Energy dissipation structures which reduce flow velocities to non-erosive rates and;

3) Sediment retention structures which are designed to remove sediment carried in runoff.

(Goldman et al., 1986, p.7.1-8.71)

Headwater retention is typically associated with small watersheds as a method for flood damage reduction and/or water supply augmentation for domestic or livestock usage. Recreational and wildlife benefits may also be seen if water is impounded on a year-round basis (Madison, 1983). Specifically, three types of water retention structures exist:

1) Flood Retarding (Detention) Structures may be installed in the headwaters of small watersheds in order to reduce the downstream impacts of flood flow peaks by temporarily holding back floodwaters. Little or no water is stored as they are designed to slowly release floodwaters over a period of several hours or days;

2) Water Retention Structures are designed to impound water within a reservoir for recreational or water supply use and;

3) Multi-Purpose Structures typically provide some degree of flood damage reduction and water supply benefits; while recreation and wildlife benefits may also be realised. A standing impoundment represents only a portion of the total storage capacity of the reservoir. The remaining portion is reserved for temporary storage of floodwater, which is slowly released.

(adapted from Madison, 1983, p. 102-103)

Community Involvement in Watershed Management

Local involvement in water resources and land management planning has been an increasingly prevalent since the early 1980's. Priscoli (1989) points to the need for engineers planning watershed management to invite expanded public participation:

> Frequently, the major problems faced by engineers and scientists are not technical. They are problems of reaching agreement on facts, alternatives, and solutions. The engineer, trained and regarded for technical excellence is frequently frustrated by what are perceived as extra social or environmental design constraints. However, far from constraints, broadening the social objectives of engineering presents new opportunities for engineering service if one makes the effort to look.
>
> (Priscoli, 1989 in Newson, 1992, p.274)

A number of modern entities designed to improve and coordinate local river basin management have been established. The Tennessee Valley Authority (TVA) is perhaps the most important because:

1) It was formed to ameliorate existing environmental and regional economic problems;
2) It has been influential across the world in promoting successor organisations and;
3) It has been the subject of studies which reveal, by some definitions, it was largely unsuccessful.

(Newson, 1992, p.246)

Newson (1992) criticises the TVA as being too dependent on the building of large dams with the goal of regional economic restoration. A lack of attention was paid to land & water system energetics and interactions, change, and the influential role of human decisions.

While a variety of river basin organisations exists, Newson (1992) suggests they all "face profound problems of scale;" in that land and water issues are widespread, but the means by which to address them are less pervasive (i.e. funding). Newson says river basin organisations will operate best by owning land and/or influencing area landowners to concur with their wishes for improved watershed management. These efforts must be undertaken at the small "catchment" level. In support of this thesis, Konrad et al. (1986) suggests "an essential feature of large basin management is to set goals for the small (priority) areas first.

In an early study, Kaynor (1972) analysed the range, interests, and effectiveness of citizen input in watershed management. He concluded local interest and participation was limited, being constrained by fragmentation in local decision-making and a lack of basin/region-wide approaches. While there was indeed influence at the local level; it appeared to include elected officials only. Grassroots citizens could only become involved by becoming local elected officials or "quasi-officials" through appointment. This fact is largely the case today in many jurisdictions with land & water management responsibility, such as conservation districts in Manitoba, conservation authorities in Ontario, and soil conservation districts & water resource districts in most U.S. states (TIC, 1993; Powell, 1983 and; Elliott,1978).

Hoban (1992) suggests any organised group of individuals with an interest in improved watershed management can work cooperatively. He cites the following strategies for building the right conservation team:

1) Involve the right people;
2) Build a common purpose;
3) Establish attainable goals;
4) Develop shared leadership;
5) Set up a flexible organisation;
6) Make best use of available talents;
7) Understand success and failure and;
8) Know when teamwork is appropriate.

(Hoban, 1992, p. 294-297)

Several successful land & water resource management initiatives undertaken by organised individuals have been reported in the literature. One notable example includes a number of Remedial Action Plans (RAPs) carried out by residents in the Great Lakes area, with the support of the International Joint Commission.

The RAP process applies an ecosystem approach toward the remediation of past and present damage around the lakes; and attempts to harmonise environmental, economic, and community goals (Hartig & Zarull, 1992). Several "keystones for success" have been identified including:

1) Continued public involvement of stakeholder groups;
2) Effective communication & cooperation;
3) Ongoing availability of human and financial resources;
4) Strong attention to resource needs and;
5) A track record of success.

(Hartig & Zarull, 1992, p. 263-273)

Similarly, organisations of community interests have existed in a variety of areas to improve watershed management including: the Red River Basin, Laos, the Illinois River Basin and, India (Krenz & Leitch, 1993; Sharma, 1992; Holling, 1989 and; Singh, 1977). A particularly intriguing example involves the network of volunteer "landcare" groups which have emerged across Agro-Australia since 1986. These organisations have been found to be highly efficient and effective at mobilising community cooperation to achieve sustainable resource use at the catchment or watershed level. Landcare groups have facilitated partnerships between agencies, community groups, and researchers (Curtis & DeLacy, 1995).

Research Relevant to Small Agricultural Watersheds

In the early 1950's the U.S. Congress approved the *Watershed Protection and Flood Prevention Act (PL - 566)*. This legislation made it possible for soil and water conservation districts, counties, municipalities, or other local & state organisations to obtain technical and/or financial assistance from the Federal Government in the preparation of soil and water projects which would provide for flood prevention and related water management goals. As of November, 1971, the U.S. Secretary of Agriculture had received applications for assistance covering 2,935 small watersheds[7] containing 226 million acres. Some 60% of these applications received assistance through the programme (Trock, 1972).

Jennings et al. (1972) provide some detail regarding the *PL-566* programme as it related to the building of headwater retention structures. Several thousand floodwater retarding structures were constructed on upstream tributary watersheds by the U.S. Soil Conservation Service during the life of the programme. A heavy concentration of projects occurred in the Southwestern U.S., with some 1500 water storage structures built in Texas alone. Typically, these floodwater retarding structures were developed as small reservoirs with uncontrolled outlets and emergency overflow spillways. They were designed to control flood runoff over some 50% of small watersheds. One prominently featured project area was the Honey Creek Study Area in Texas, a 39 square mile watershed in which twelve structures were built with a combined storage of 7,857 acre feet. Floodwater control was achieved on approximately 20.9 square miles of this area (Jennings et al., 1972).

[7] These "small watersheds" averaged 77,000 acres or 120 square miles each. Water storage projects developed under the PL-566 programme, were also labelled "small" at approximately 1000 acre feet in size. These projects are still much larger than those located within the Deerwood project area which average less than 100 acre feet in storage.

Roger Trancik (1986) cites Eaton Centre, Toronto, as a downtown centre that is fairly successful in integrating with the existing downtown streets. While the centre is primarily ordered around a central mall, it also has some small shops located along the outside edge, facing Yonge street. This externally-oriented configuration retains the physical continuity of the city grid and contributes to the pedestrian environment along the street (Figure 2.3).

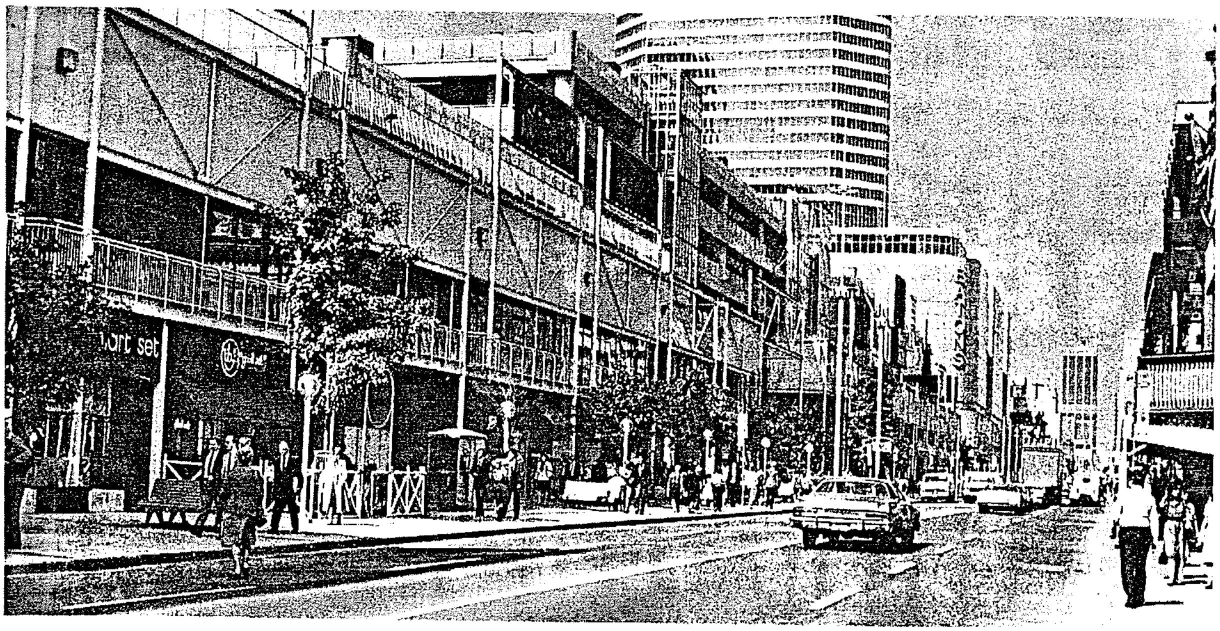


Figure 2.3. Eaton Centre retains the continuity of, and activity along, Yonge Street.[19]

[19] Trancik, Roger, *Finding Lost Space* (New York: Van Nostrand Reinhold, 1986), page 50.

Trock suggested some reasons for the variety of findings in his analysis. He noted the workplans prepared by project sponsors anticipated benefits from land treatment, flood control, and channel improvements which would include: erosion control; reduction of damages from inundation during floods; and reduction of damage from silt deposition and channel erosion. However, other benefits were realised from watershed developments which were not counted or even anticipated. While careful calculation of costs for land treatment measures was evident in the workplans for all three watershed projects, determination of associated benefits was quite superficial. The following were highlighted as possible reasons for these variances:

1) When a project watershed is located within an active soil & water conservation district, it is difficult to separate those land treatment measures carried out because of either programme.

2) No research data was available to allow project planners to predict the effects of various land treatments on reductions in peak runoff flows. As such, it was impossible to calculate land treatment costs and benefits attributable to the project, or in terms of reduced flood damage.

3) In the three project watersheds, flood control benefits were attributable to both land treatment and structural measures. Implied was an equality of benefits and costs from land treatment and water control structures.

4) Installation costs of flood detention structures in all three watersheds were underestimated, largely due to design modifications and delays caused by an inability to acquire storage sites. Total site costs were then calculated as the sum of discounted net returns foregone during the lifetime of the dam or project.

5) Operating and maintenance costs were generally lower than estimated by planners. This was not a surprise due to the short lifetime of the projects to that point. It was anticipated that long-run maintenance and operating costs would be accurate.

6) Considerable differences existed between planners' estimates of flood control benefits (attributable to land treatment and flood detention structures), and those found in the analysis. Some may have been due to the limited observations of hydrological events during the short period of evaluation. These differences were expected to disappear as years are added to the project and the anticipated distribution of flood producing storms is reached.

7) The benefits from altered land use and the restoration of former land productivity were mis-calculated in that: no significant restoration of previously unusable land actually occurred and; such land use changes were not planned with the possibility of the shift which occurred (in regional comparative advantage) with the ability to grow new crop types such as forages.

8) Some significant benefits accrued, due to the use of stored water behind flood detention structures, which were not counted in the workplans. For example, flood water was used for irrigation of cash crops, recreational uses of the water became available, and a town was supplied with additional water for domestic and industrial use.

(Trock, 1972, p. 68-69)

In 1972, Heindl noted a major concern regarding watershed research in that research data collected thusfar had not been practically applied to improve watershed management elsewhere beyond the research site. He deemed this to be unfortunate because of the relevance of watershed research to vast numbers and types of land & water resource management problems.

> Most work today continues to be concerned with locally oriented interests which are determined by the geographical preferences of a large group of individuals, and the parochial pressures exerted by the institutions which employ them.
>
> (Heindl, 1972, p. 5)

Heindl also noted, until the watershed concept becomes widely accepted and used in planning, the value of small watershed or sub-basin research will remain untenable as a unit or closed system. He suggests data derived from research within small watersheds should be taken at face value. While it may have been imperfectly measured, imperfectly defined, and imperfectly understood, such studies often provide the best available valid data. As such, through "intelligent interpretation" it is possible to glean useful information, even without more detailed studies. A classification system which codifies and quantifies the existing body of knowledge was called for (Heindl, 1972).

Newson (1992) points to some attempts by watershed research pioneers in the early twentieth century.

> Although the river and the hillside do not resemble each other at first sight, one may fairly extend the river all over its basin and up to its very divides.
>
> W.M. Davis, 1899 in Newson, 1992, p.281)

Paired catchment studies were occurring as early as 1900 in Switzerland in order to investigate the impacts of forest cover on runoff, strongly concluding the beneficial effects of tree cover. Then, from 1912 to the early 1960's the results of 39 similar paired catchment studies in the U.S. revealed virtually the same results (Newson, 1992). During the International Hydrological Decade (1965-1974), catchment research continued.

Ward (1971) highlighted the pitfalls associated with catchment research, and its wider applicability throughout larger watershed or river basin regions including:

1) Lack of control concerns;
2) Representativeness problems;
3) Accuracy of data questions;
4) Relative ease of data manipulation and;
5) High costs.

(Ward, 1971 in Newson, 1992, p.289)

While there are many problems with the use of small/sub-watershed/catchment data to make inferences regarding a much larger watershed/basin system, 20 years after Heindl, with much frustration, Newson (1992) also acknowledges catchment level data could be better but, it cannot be ignored. It is still the best available

Hillslope Hydrology

Due to forced rising, approaching airstreams undergo adiabatic cooling, subsequently condensing their water vapour into rain. As such, projecting features of a landscape, whether mountains, hill ranges, escarpments, or plateaus are often source areas for streamflow (Strahler, 1987 and Pereira, 1973).

As summarised by Chorley (1978), Horton's "infiltration - based" theory has remained the classical hillslope hydrological cycle model, with some variations, since 1933. In simplest form, Horton's *Infiltration Theory of Runoff* predicts prolonged rain falling on the slopes of a drainage basin having a uniform initial infiltration capacity will ultimately produce "Hortonian overland flow" more or less simultaneously throughout the basin. This assumes runoff intensity greater than the threshold infiltration capacity/rate, and accounting for surface storage capacity.

Horton extended his hillslope infiltration theory to include the mechanics of surface erosion in addition to runoff. In the same way Horton believed overland flow was the cause for hydrograph storm peaks; he also assumed it to be the sole "motor" of surface fluvial erosion. He predicted a shear stress strong enough to separate soil particles would develop at a critical distance downslope from the landform divide. Erosion would occur first as sheet erosion, then in the form of rills, which might subsequently coalesce to form new stream channels/gullies. Overland flow rates have been estimated at speeds of up to 10,000 feet per day (Chorley, 1978; Emmett,1978).

There are four components to Horton's intricate and composite view of the hillslope hydrological cycle. As described by Chorley, these include: infiltration, interception of rainfall (depending on vegetative cover), evapotranspiration, and depression storage & surface detention (Chorley, 1978). The last two factors require specific definition:

> 1) Depression storage relates to the amount of water held in surface depressions on the landscape (natural or agricultural cover), none of which runs off and;
>
> 2) Surface detention is that part of the rainfall which remains on the ground surface during a storm, gradually moving downslope via overland flow, and either runs off or is absorbed by infiltration after the rain ends.
>
> (Chorley, 978, p.8)

Chorley also translates Kirkby's qualifier that Hortonian overland flow will only occur instantaneously within a watershed if the basin is small and has relatively homogeneous soil, soil moisture, interception rates, depression storage, and infiltration conditions. Although Hortonian overland flow is quite common where vegetation is sparse and soils are thin, it is rare where there is substantial cover. This may vary dramatically within a growing year (Chorley, 1978).

History of Water Management Policy in the Lower Red River Basin

A number of water problems have existed in the Lower Red River Basin since the settlement of agricultural families in the region. After a period of extreme flooding and drought from 1965 - 1980, water management in the region was again on the minds of residents and local government officials. The *Lower Red River Valley Water Commission* attempted to develop and implement a comprehensive water plan to replace traditional ad hoc approaches. The envisioned approach would incorporate dams, drains, diversions, and numerous non-structural approaches such as zoning and land use planning to achieve a variety of objectives desired by area residents (O'grodnik, 1984). The research provided by O'grodnik offers a useful history and policy review.

In addition to records provided by Palliser (Ball, 1995), the roots of water management problems in the lower Red River Valley may be traced to the establishment of a system which, from 1895 to 1935, brought about the drainage of two million acres of inherently wet but extremely fertile land for agricultural development. Three long-standing concerns have existed because of the expensive process of drainage :

1) "Foreign water" has regularly plagued the owners of lowland agricultural areas;
2) Strong perceptions exist that foreign water problems occur and have become worse because of upland drainage, land use changes, and road construction etc. and;
3) Owners of upstream land should be made to pay a portion of lowland drainage costs.

(O'grodnik, 1984, p. 15)

Through decades of study and several Provincially appointed commissions, various aspects of the problem gradually became more clearly defined. The Sullivan Commission (1918-1921) addressed the physical design of the agricultural drainage system; it was felt a watershed-based drainage system should have been used versus a gridiron approach. Also, Sullivan suggested upland contributors of foreign water should be paying for the opportunity to dump water on those downstream.

The Finlayson Commission (1935-1936) determined downstream flows of runoff were accelerated because of associated land clearing and road & ditch construction which comprised the upland drainage process. However, as Finlayson determined, it was impossible to ascertain the relevant proportions of additional water flows due to upland development. As there were discrepancies in the amount of total damage, upland areas could not reasonably be expected to contribute financially (O'grodnik, 1984).

For whatever reason, rapid and high volume runoff had resulted in erosion and silt deposition in lowland areas downstream. Due to this extra water, local maintenance districts were forced to install more drains, with costs borne by Rural Municipalities (ultimately local taxpayers). Rising construction costs augmented these problems and; as the costs increased, the proportion of Provincial contributions for required drain maintenance decreased (O'grodnik, 1984).

The Lyons Commission (1947-1949) determined upstream land use and road & ditch work had definitely affected water flow in two ways: increasing total runoff and increasing the "order of runoff" or peak flow during runoff events. However, similar to non-point source pollution, specific liability for foreign water problems could not be proven and; it was recommended that the Province become responsible for two thirds of all future maintenance and construction of drains which intercept, collect, and carry foreign water together with local water (O'grodnik, 1984).

To address problems of water management in the Lower Red River Basin, two dominant policy themes emerged over time, resulting in:

1) The transfer of much financial responsibility from rural municipalities to the Province and;
2) The enactment of legislation which permitted a more holistic approach to land & water management (embodied within the Watershed Conservation Districts Act of 1959, and the later Conservation Districts Act of 1976).

(O'grodnik, 1984, p.16)

While the affected municipalities eagerly accepted financial relief, O'grodnik suggests the establishment of conservation districts has been a frustratingly slow process. As of 1995, seven districts exist. O'grodnik's suggestions regarding the reasoning for this delayed process are:

1) A lack of initiative at all levels;
2) A belief long term benefits and savings of coordinated land & water management are nonexistent;
3) An inability among Rural Municipalities to cooperate;
4) The fear of a shift in financial responsibility from the Province back to local government or local landowners and;
5) A lingering parochialism between Rural Municipalities and the Province: fearing the offloading or loss of administrative and legislative rights (respectively)

(O'grodnik, 1984, p.16)

Manitoba/Pembina Escarpment Problems: Research and Management

Carlyle's Research

Carlyle (1980) provides a general overview of environmental problems experienced in Manitoba along the Manitoba Escarpment; in which he includes the Porcupine Hills, Duck Mountain, Riding Mountain, the Pembina Hills, and Turtle Mountain. Water and land management concerns combine to create severe conditions of erosion, silt deposition, and downstream flooding, particularly along the Eastern faces in the Northwest and South-central regions. Interestingly, MacKenzie's travels to the region noted serious erosion problems much earlier (Ball, 1995).

Carlyle points to relief and its subsequent impact on climate which typically results in higher areas of Manitoba receiving more precipitation; some regions receive as much as 40% more rainfall than nearby lower plains.

The following can result:

> Meltwater flowing eastward from the higher parts of the escarpment, which form a major watershed divide, frequently cause spring flooding of good agricultural land east of the scarp face and in the valleys separating the main upland masses. Flash flooding, which occurs later in the season after heavy rainstorms on the escarpment, is even more serious. Gulleying and erosion by water also detract from the agricultural potential of land along the escarpment.
>
> (Carlyle, 1980, p.257)

In addition to steep slopes and heavy runoff, erosion and sedimentation problems are compounded by the fact much of the escarpment, particularly in the Northwest region, is comprised of shale. Carlyle also cites discussions with Thomlinson (1977) and Shortinghuis (1953) which document the process whereby shale carried downstream during spring runoff or summer rain events serve to clog ditches and streams, destroy crops, and render some land unusable for agriculture (Carlyle, 1980).

Inappropriate land use, government policy, and water drainage projects have all contributed to the Escarpment's erosion and flooding problems. The frequency and amount of downstream flooding, in addition to the problems of shale deposition in the lowlands were thus compounded. Escarpment slopes were also seen to be wholly unsuitable for cultivation and the sowing of cereal crops, the actual and dominant land use of most escarpmental areas in Manitoba. Additionally, overgrazing by cattle generated increased runoff, erosion, and flooding in other regions of the escarpment, particularly in the extreme Northwest and on the Turtle Mountain (Ellis, 1962-1963 in Carlyle, 1980).

Finally, Canadian government immigration policy also assisted in the creation of most land and water problems in the Northwest escarpment region and; the subsequent drainage of land to expand agricultural potential merely intensified erosion, flooding, and sedimentation on slopes and downstream lowlands on all Eastward draining Escarpment faces in the agricultural areas of Manitoba (Carlyle, 1980).

The Wilson Creek Watershed Study

In 1957, a joint Federal-Provincial *Committee on Headwater Flood and Erosion Control* was struck to analyse land & water management problems along the Manitoba Escarpment and; to collect long-term precipitation and hydrological data which was known to be lacking prior to the study. The Wilson Creek watershed, on the Eastern slope of Riding Mountain was selected as a long-term study area. During the study, the natural processes at work in the watershed came to be quite well understood. It was confirmed floods may result from rapid snowmelt and from intense rainstorms; the latter being the most serious because they alter channel flows, fill drainage ditches with sediment, and damage crops. The mere presence of the escarpment appears to enhance precipitation. The volume of flood flows is highly variable and; higher runoff values occur when the soil is near saturation (CHFEC, 1983). After 25 years of research, the committee also concluded:

> 1) The majority of the problem of flooding and erosion originates in the headwaters of the escarpmental area of the watershed; while the majority of shale sediment which periodically clogs downstream drains originates in the alluvial fan (of Wilson Creek) at the immediate base of the escarpment;
>
> 2) There is no evidence to suggest any significant deterioration of the natural (parkland) environment in the headwaters (of Wilson Creek) has taken place which would result in a negative impact on natural water storage or erosion and;
>
> 3) It has been demonstrated that artificial storage of floodwaters can be achieved by the construction of detention basins. However, the economic viability of these basins has not been proven as their beneficial effects on flood damage reduction have not been fully evaluated.
>
> (CHFEC,1983, p.11)

A number of land & water management methods were tested at Wilson Creek. Two headwater reservoirs constructed in the upper reaches of the watershed are of particular interest. It was determined, with a headwater dam and detention basin controlling 11% of the total watershed, peak flood flows could be reduced by up to 25% (a 310 acre foot reservoir was used to control a 320 acre drainage area). However, because stable dam/reservoir sites exist only in the glacial tills which exist at the top of the Escarpment, only a small portion of the total drainage area could ever be managed (CHFEC, 1983).

The Committee appeared to have been disappointed or unimpressed by these findings as determined by one analysis carried out as a component of the Wilson Creek work:

> The consequent reduction in sediment loading to the agricultural drainage network would not reduce the costs of channel maintenance sufficiently to offset the costs of headwater reservoir construction based on costs and damages of the 1940-69 period.
>
> (MacKay, 1969 in CHFEC, 1983, p.6)

However, after discussions with local Wilson Creek resident and study participant, J.E. Thomlinson, Carlyle views the impact of headwater storage as very significant:

> Structures designed to reduce runoff and erosion were put to the test in 1975, when the heaviest and most intense rainstorm ever recorded in Manitoba was centred on Wilson Creek. Analysis of the storm's effects revealed that the headwater dam was the best, indeed the only, method to significantly reduce runoff and erosion.
>
> (Carlyle, 1980, p.260)

During the Wilson Creek research there was much discussion regarding the similar relationship between headwater storage structures and naturally created beaver ponds (Ball, 1995).

The Dauphin Lake Enhancement Project

In 1989, the Dauphin Lake Advisory Board, comprising area landowners, local government officials, and interest groups was struck to develop a management plan to address key issues affecting this drainage basin of the Northwest Manitoba Escarpment (Manitoba Government, 1989). After reaching consensus on many of the problem areas, the Board has recommended a variety of management initiatives to address lake regulation problems, siltation damage, decreased water quality, and a declining local fishery. It is clear the most critical and relevant factor leading to any progress has been the ability of a diverse set of area interests to agree on common goals (Towle, 1994).

The Tongue River Pilot Watershed Project

In the late 1940's, residents living within the Tongue River watershed in North Dakota began to address frustrating land and water management problems along the Escarpment which bisects the Northeast corner of the state. In 1953, three soil conservation districts and two water district boards within Cavalier and Pembina Counties sponsored initiation of the Tongue River Pilot Watershed Project, one of 50 similar pilot watershed efforts nationwide under the PL-566 appropriation. These projects were 75% supported by the US Congress with the goal of demonstrating opportunities for soil protection and flood damage reduction on a regional scale. Between 1955 and 1961 a total of ten sizable dams averaging some 2300 acre feet were built within the tributaries of the Tongue in order to reduce peak stream flows through water retention. Meanwhile, local landowners had stepped up their own conservation work within the fields, pastures, and remaining woodlands of the watershed. Altogether the community and sponsors contributed about 25% of the total project cost of $4.0 million (1960$) (Askew, 1994; USDA-SCS, ca. 1958).

According to local residents, downstream flooding is a now distant memory (Goodman, 1994). Additional benefits include community water supply and recreation opportunities from the largest dams. Icelandic State Park along the Renwick Dam upstream from Cavalier is said to be the most heavily visited park in the state. Interestingly, it is because of the additional recreation and water supply benefits of the Tongue River Project dams that local agricultural conservation efforts today are focussed on the improvement of water quality. Major efforts by the Pembina County Soil Conservation District involve the promotion of conservation tillage and reduced chemical usage. Sedimentation of the Tongue River Project dams results as eroding soil and fertilizer particles attached to the soil are carried downstream within drainage water. Sedimentation reduces the useful life of a dam, while fertilizer concentrations in stored water behind a dam promote the growth of algae, reducing the usefulness of this water for recreation or domestic consumption (Askew, 1994).

The Manitoba Escarpment Headwater Storage Steering Committee

Following the Wilson Creek report, and likely because of its findings, another committee was struck to formulate applicable recommendations to the Manitoba Government. The *Manitoba Escarpment Headwater Storage Steering Committee* was charged with the task of reviewing escarpmental erosion and flooding problem areas of Agro-Manitoba; investigating headwater storage and alternative measures to address these problems and; to present recommendations regarding management options.

The Headwater Storage Report defined the Manitoba Escarpment as a "major influence on land & water management decisions in Manitoba" and:

> Once the Western shore of Lake Agassiz, the Manitoba Escarpment extends about 500 kilometres Northwesterly through Manitoba from the Canada-US border at Morden to the Manitoba-Saskatchewan border between Swan River and The Pas. Due to its steep slope and consequent rapid runoff, the escarpment has a profound effect on the water regime and the land-shaping processes associated with the many streams which flow across it.
>
> (MEHSSC, 1988, p.1)

The Steering Committee saw the Escarpment to be comprised of four major sections: the Pembina Hills, Riding Mountain, Duck Mountain, and the Porcupine Hills; all of which have basically similar topographic features (Figure 3a):

1) A rolling upper region;
2) A steep escarpment face;
3) An abrupt decrease in slope at the base;
4) A relatively flat area to the East and;
5) Flatter sections (terraces, benches) mantled by recent alluvial deposits (i.e. beach ridges of Lake Agassiz).

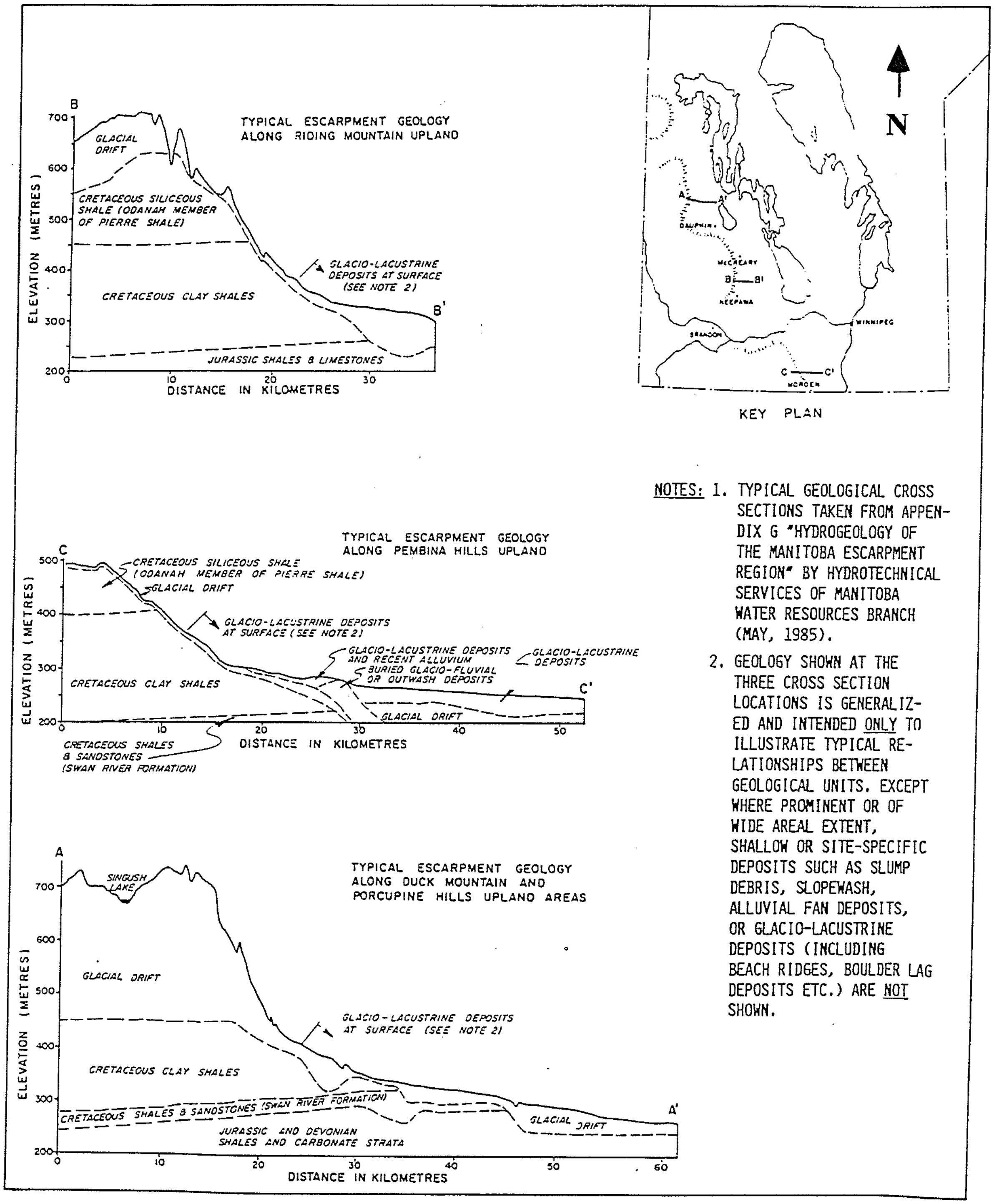


Figure 3a
Typical Landforms in Various Areas of the Manitoba Escarpment
Source: MEHSSC, *Manitoba Escarpment Headwater Storage Study: Main Report* (Winnipeg: MEHSSC, 1988, p. 10

The MEHSSC also summarised the creation of land & water problems along the Escarpment:

> Prior to settlement, runoff from the Escarpment was detained by the beach ridges and alluvial deposits forming an area of bogs and swamps. As lands were cleared for agriculture, drains were extended through the swampy areas and up the lower slopes of the escarpment. Water that was formerly detained there flowed unimpeded into the flat areas of cultivated land. During periods of high runoff, the channels often overflowed and either caused erosion of farmland of deposited silt, shale, and debris onto the fields. In addition to agricultural land, municipal works such as roads and stream crossings have also been damaged extensively.
>
> (MEHSSC, 1988, p. 3)

Additionally, the Steering Committee traced the research and policy recommendations presented by the Drainage Commissions and more recent studies (see review of O'grodnik above) and concludes:

> Despite all those initiatives, flooding ad erosion problems along the Escarpment were not adequately solved. One solution frequently recommended by farmers, municipal councillors, and others concerned with water management along the Escarpment is the construction of headwater dams to reduce flood peaks on the streams through agricultural lands at the base. It is commonly believed that changes in land use in the headwaters are at least partially responsible for the loss of natural headwater storage, and the increase in frequency of damaging floods and; this loss can be offset by constructing headwater retention reservoirs.
>
> (MEHSSC, 1988, p.4-5)

The MEHSSC undertook a comprehensive review of potential headwater retention sites. Of 123 sites considered for headwater storage on the Escarpment, twelve were seen to be effective in solving downstream erosion and flooding problems. Subsequent engineering surveys, designs and economic analysis showed only four sites warranting further consideration. Finally, only one site was recommended "to be considered for construction;" with three others recommended for "further study because of uncertainties in the analysis." Costs for these promising projects ranged from approximately $500.0 K to $1.0 M, with storage capacities of approximately 1000 dam^3 to 1800 dam^3.

Finally, a number of suggestions for management alternatives to headwater storage were collected (but not analysed) at public meetings comprising part of the study. Common ideas included:

1) Re-foresting or planting grass of lower class escarpment lands;
2) The installation of energy-dissipation weirs in problematic waterways;
3) Improved stubble management and;
4) Changes in cropping patterns.

(MEHSSC, 1988, p. 8)

Evaluating Land & Water Management Projects

Public Policy Evaluation Frameworks

Pal (1987) defines policy analysis "as the disciplined application of intellect to public problems." In terms of programme evaluation, policy analysis seeks to answer the core questions: Does the programme do what is supposed to do?; If not, why not? and; What should be done? Empirical evaluation incorporates quantitative or rational techniques for analysis. The Rational Evaluation Approach necessarily involving three characteristics: demonstrable cause-effect relationships, empirical data, and replicable findings. Given this approach, a Rational evaluation may typically be comprised of five steps including:

1) Determination of objectives;
2) Consideration of alternatives;
3) Comparison of positive and negative impacts and;
4) Ranking of alternatives based on established criteria.

(Pal, 1987, p. 44)

Numerous criticisms of the Rational relate to its apparent overemphasis on technical solutions, the flow of information, and the assumption of a single decision-making unit. Many theorists have also argued that the Rational model does not represent an adequate representation of public decision-making. An alternative option, the Incremental Model, attempts to describe the modern governmental decision-making process. Pal describes how governments maintain coordinated policies and decisions, apparently without an organised policy evaluation and formulation structure:

> Modern governments have extraordinarily complex bureaucratic structures with overlapping mandates and few clear centres of control. Moreover, policy making is often distinguished by crisis response, short time horizons, and uncertainty, rather than the leisurely pace of dispassionate assessment implied by the Rational Model. Nonetheless, things still get done.
>
> (Pal, 1987, p.45)

However, the Rational approach remains a good guide. Its worthwhile contributions include: systematic problem identification and assessment; the provision of valuable, factual information which holds decision-makers accountable and limits uninformed debate and; the enforced consideration of benefits and costs (as opposed to the rhetoric of powerful interests) (Pal, 1987).

Pal differentiates between two types of evaluation processes, *summative* and *formative*. A summative approach is a comprehensive assessment of each of four possible evaluation categories. Summative programme evaluation is a final assessment to aid decisions regarding the continuation, termination, adoption, or rejection of particular programmes. It does not show means of improving programme performance (Pal, 1987). The range of categories required for summative evaluation, and their assessment components, are listed in Table 3d. A formative approach is designed to isolate and assess particular aspects of a programme in relation to overall impact. Consequently, only the necessary categories listed on Table 3d would be applicable.

Table 3d: Categories of Empirical Evaluation and their Assessment Components
Source: Pal, 1987, p. 48

Planning Evaluation	Process Evaluation	Impact Evaluation	Efficiency Evaluation
target population	staff effort	desired results	benefit - cost ratio
current/future needs	delivery mechanisms	unintended results	cost effectiveness
resource requirements	information systems	explanation of results	

Impact evaluation seeks to determine if a programme is successful or not in terms of intended effects. As such, causality must be determined (i.e. the programme must be identified as the cause of the observed effects - the programme is the independent variable). Determining causality is often difficult however, due to numerous possible interrelated effects. Statistical techniques may be employed to neutralise extraneous causal variables. The *classic experimental design* is the ideal method for determining causality. Using a randomly selected group of individuals, the policy is engaged via a programme or other intervention to an experimental group. Meanwhile a control group is used to determine of changes arising because of the intervention are statistically significant. However, experimental designs are rarely used in the process of policy evaluation, due in large part to their high costs and time requirements.

Another method of experimental design is the *single observation* or *pre-experimental design*. With this method, policy outcomes are measured at some period after implementation. Comparisons between programme recipients and non-recipients are useful in determining causality. While analytically weaker, it avoids many cost or time constraints characterising the classical approach (Pal, 1987).

Two techniques are useful in Efficiency evaluation: *benefit - cost analysis* and *cost - effectiveness analysis.* These methods are employed to help weigh and compare costs and impacts among all available alternatives in order to ensure each dollar spent achieves the maximum possible effect. Cost - effectiveness analysis is designed to assist decision-makers in the comparison of different programme alternatives for achieving a given set of goals. Without addressing monetary values, cost - effectiveness analysis assumes given programme goals are valid and assumes the least-cost strategy which will achieve these goals (Pal, 1987).

Krutilla and Fisher (1975) offer a unique evaluation method which suggests the "ostensible" or tangible benefits and costs of publicly funded projects should be considered prior to attempting detailed quantification of the intangibles. This approach should remove many borderline projects from analysis as; more economically viable projects will be able to withstand scrutiny. Every reasonable effort should be made to consider tangible benefits and costs. Gittinger (1994) provides an excellent guide for the economic analysis of agricultural projects. Benefit-cost analysis is discussed in the following sections.

Overview of Benefit-Cost-Analysis

The Benefit-Cost-Analysis (BCA) procedure has evolved since the U.S Flood Control Act of 1936 (see "Modern River Basin Management" above) where Congress declared federal support would only be provided for flood damage reduction projects where:

> The benefits to whomsover they accrue are in excess of estimated costs and; the lives and social security of people are enhanced.
>
> (Galloway, 1987, p. 311; James, 1974, p. 8)

There were three aspects to the relevant 1936 supporting legislation - U.S. Statutes #1570:

1) Benefits and costs must express the desirable and undesirable effects of a water project in commensurable (equal, usually monetary) units in that:
   Benefits/Consequences may be positive or negative and;
   Costs relate to all aspects of construction and operating the project;

2) "Whomsoever" was deemed to be "in the best interests of humanity," meaning *Pareto-Optimum Welfare,* defined as any change/improvement which harms no one and which makes some people better off and;

3) "Social security" recognises the impossibility of expressing all values in monetary units. Social security was taken to mean "one's perception of their own quality of life." The social security concept was meant to transcend the project effects which can be assigned a monetary value, in order to incorporate values traditionally called "intangible."

(James, 1974, p. 10-12)

For over forty years since its initial usage, the BCA procedure has undergone numerous reviews. However, beginning in 1968, some particularly relevant modifications begin to emerge. At that time The Special Task Force of the U.S. Water Resources Council, a Presidentially appointed policy advisory committee recommended revisions to the formula for determining the appropriate discount rate on large water projects. It was recommended, the rate should be increased to the point where costs and benefits are discounted to present-day-values (Dawes, 1972). In 1971, another Special Task Force provided recommendations aimed at addressing a lack of criteria regarding the intangible effects of water management and development. They suggested the traditional process of estimating tangible economic effects, accompanied with a description of intangible effects should be replaced.

In its place, it was recommended all effects should be accounted for in the BCA ledgers based upon four separate, but not necessarily equal objectives/accounts being:

1) *To enhance national economic development* (including all project effects measurable in monetary units);

2) *To enhance the quality of the environment* (restoration, conservation, and improvement in the quality of natural and cultural resources and ecological systems in ways beyond those which can be expressed in monetary units. Due to the diversity of units involved, project desirability in relation to this account cannot be expressed within a single index. Trade-offs among gains and losses must be made by politically chosen leaders or due public process);

3) *To enhance social well-being* (enhancing the lives of people in ways which cannot be measured in monetary units or through quantitative measurement of environmental quality. This could include: changes in population patterns, security from hazards, economic stability, and educational or cultural opportunities) and;

4) *To enhance regional development* (fairly distributing the benefits from achieving the above three objectives.

(James, 1974, p.18-22)

Upon reviewing the 1971 recommendations of the Water Resources Council, the U.S. Federal Office of Management and the Budget (OMB) did not accept the aspects of social well-being as contained within Objective #3 (above) and; the OMB would not accept a $5^3/_8$% discount rate (discussed below) recommended for federally supported water projects, opting instead for 7% for the first five years, and 10% afterward. These actions would serve to ignore social benefits whatsoever and minimise long-term economic benefits of water management projects (Dawes, 1972).

This effect is also noted by Pal (1987) who points to BCA's tendency to highly rank the most apparently efficient projects, even if associated benefits may numerically be quite small or of a short-term nature. Significantly larger benefits may be delivered with other projects which, according to the BCA formula, are less efficient. Choosing between Pareto Optimality and issues of equity and distribution proves to be extremely difficult for decision-makers, and BCA does not provide clear answers in this regard (Pal, 1987).

Benefit-Cost-Analysis may be used for a wide variety of applications in addition to its long-time application for legislative approval of water management projects. Consequently, BCA findings are both useful and influential. In fact, it is due to the construction of large-scale public waterworks projects that the concept of benefit-cost analysis was derived during the early decades of the twentieth century (Galloway, 1988). Three common uses of BCA are as: a filter; a ranking device and; a contribution toward an informal, multi-dimensional information system. The use of BCA carries an "imperative, suggestive force" which contributes greatly toward gathering support for specific projects (Randall, 1987). The following five statements help to clarify the concept of Benefit-Cost-Analysis:

1) An existing environment may be viewed as an asset, producing services which people value;
2) A proposed project or programme is an attempt to modify the existing environment at some cost, changing the services it produces;
3) BCA compares a) the value of the environment changed by the project minus the costs associated with its development with b) the value of the unchanged environment prior to project development;
4) The complex relationships among natural systems inputs, human controlled inputs, environmental attributes, and the services provided, must be understood and quantified if the results of BCA are to be complete and reliable and;
5) The value of an environment-changing project depends on two things: a) the net value of services it produces within given time periods and; b) the rate at which future benefits and costs are discounted.

(adapted from Randall, 1987, p.237-238)

Practically, Pal (1987) notes two process problems arising with the determination and quantification of costs and benefits: the selection of an appropriate accounting unit (whose costs and benefits should be measured?) and, the issue of intangibles (problems with placing monetary values on costs and benefits) and/or externalities (benefits or costs occurring to third parties without compensation). In terms of accounting units relevant to public policy, three basic choices are: the individual; the government and; society at large. In terms of quantifying intangibles (e.g. people's value of leisure time), benefit-cost calculations usually mention their possible existence, and the probability of their occurrence (Pal, 1987).

Central to the BCA process is the concept of *opportunity cost* whereby the forfeiture of public expenditure alternatives is compared to the project or programme under study. Additionally, *external* vs. *internal* costs and benefits must be identified (external costs and benefits are unintended effects occurring outside the project area). *Incremental* vs. *sunk* costs are also important in that sunk costs have occurred in the past while incremental costs would be incurred if the programme were to be established or continued. Finally, *total* costs of a programme include the proportion of all operating and overhead costs which could be attributed to its provision. As total costs would be occurring anyway, *marginal* costs refer to any additional resources required for its specific delivery (Pal, 1987).

Numerous authors such as VanDeVeer & Pierce (1986) and Kelman (1986) have intellectually dismantled Benefit-Cost-Analysis, mainly on ethical grounds. However, these papers are critiquing BCA based upon its long-time application in the construction of massive water and other development projects. Such articulated shortcomings of BCA are not germane to this study, given its focus of measuring the values related to small scale water management and conservation initiatives.

While Haimes (1988) maintains faulty BCA can occur because there are certain "noncommensurable attributes" of project development which cannot be factored into the Benefit-Cost ratio; Randall (1987) acknowledges the externality problems (see review of "Agricultural Externalities in Agriculture" above) which arise with BCA because of the absence of direct markets for many beneficial and adverse impacts of projects. For these cases, several methods of non-market evaluation have been developed.

The Discount Rate

Discount rates are used in Benefit-Cost-Analysis to account for the values of future benefits and costs. The *present values* of future benefits and costs are determined with the use of discount factor ($^1/_{(1+i)^j}$) where i is the social discount rate per year and j is the index of the year in which the cost or benefit will occur. As j gets larger (future benefits and costs are more remote), the discount factor becomes smaller, as do the present value of benefits and costs. A larger discount rate (i) results in a smaller present value for benefits and costs occurring in the future (Treasury Board, 1989; Russell, 1988). Additionally, selection of the rate of discount is critical to the results of BCA because. Higher rates will result in a) fewer project proposals passing a BCA filter and; b) higher rankings for projects which generate substantial benefits in early years, with the major costs coming later in time (Randall, 1987).

Discount rates are particularly important where government expenditures are concerned because the benefits and costs of government expenditures are often realised over different time periods. As such, temporal differences may serve to affect the desirability of development projects. Distant benefits are often deemed less valuable by society because they are not available for immediate consumption. The discount rate is itself the price paid for the use of public funds which would otherwise be available for other purposes such as reinvestment (Treasury Board, 1989; Randall, 1987).

In 1971, the Special Task Force of the U.S. Water Council (discussed above) recommended a discount rate of $5^3/_8$% for federally supported projects and; a requirement that sensitivity analyses be carried out for all projects (comparisons using several discount rates). The U.S. Federal Office of Management and the Budget (OMB) instead opted for 7% for the first five years, and 10% afterward (Dawes, 1972).

The Canadian Treasury Board has sought to enforce a 10% discount rate in the application of benefit-cost analysis. Many practitioners however, have recommended a rate closer to 7% (Pal, 1987).

Quantifying Externalities

A systematic method for assessing the management of resources with environmental, economic, or social externality values requires a standardised method to quantify externalities. There are several means by which valuation may occur.

Pearce & Turner (1990) classify techniques used to economically measure externalities as either *direct* or *indirect*. Using a direct approach, monetary value for the effect is determined via consideration of a *surrogate market*, where environmental benefits are quantified by examining their importance to other goods or services which are marketed or; through *experimental techniques* in which a market is simulated and survey respondents place hypothetical valuations on real environmental improvements.

Indirect valuation methods are merely an assessment of individual consumer preferences for certain scenarios. They do not provide a means by which to determine an individual's willingness to pay for environmental benefits which may be provided by a project or programme (Pearce & Turner, 1990).

If information limitations are severe and Benefit-Cost Analysis is impossible, value estimates may occur through other types of analysis such as: proving the existence (without values) of positive environmental goods and services. Such methods include: sensitivity analysis, cost-effectiveness, and risk-benefit analysis (Randall, 1987).

According to Cherick & Caverhill (1991) and Dixon et al. (1986) three general methods exist to quantify externalities. The first, polling or contingent valuation can be employed if "the polling instrument is designed carefully and qualified respondents are utilised, and advised of the intended use of results." Monetary values for externalities may be determined with a representative sample through a consensus or Delphi response questionnaire technique, or through surveys regarding trade-off options or willingness to pay/accept questions. (Pearce & Turner, 1990)

Randall provides a more detailed definition:

> Contingent valuation attempts to determine the amount of compensation paid (or received), that will restore the initial utility level of an individual (or society) who experiences an increase or decrease in the quantity of a non-market good (externality).
>
> (Randall, 1987, p.260)

Grosclaude (1993) has outlined the applicability of estimating externality effects through contingent valuation. In particular, he offers means by which to identify various sources of potential bias during willingness to pay studies. They include: strategic bias (in which respondents do not reveal their true preferences); design bias (in which respondent preferences may be influenced by the nature of questions asked); hypothetical bias (respondents, as hypothetical purchasers, will not suffer any costs for poor decisions) and; operational bias (the degree to which the hypothetical market actually simulates a realistic scenario). CVM results are most useful for indicating a respondent's total economic valuation of an environmental good or service, encompassing actual use, option, and existence values (Pearce & Turner, 1990).

Randall also outlines several conditions which must be accomplished for successful contingent valuation:

> 1) Baseline conditions must be established with respect to the physical availability of non-marketed goods (externalities) and the institutions which may attempt to regulate access;
>
> 2) Changes which would result from the proposed project or policy must be defined and described;
>
> 3) The context of contingent choices must be made available to the participants (i.e. would they possibly be paying for some options?) and;
>
> 4) Participants must provide statements regarding their maximum willingness to pay and minimum willingness to accept various options.
>
> (Randall, 1987, p. 261)

The second method of implied evaluation or shadow pricing relies on costs of required or anticipated measures to address or mitigate environmental, economic, or social externality effects. Property or the measurement of other land values are one comparison which may be used (Cherick & Caverhill, 1991; Dixon et al.,1986). Randall (1987) calls this method "implicit" or "Hedonic pricing," which Pearce & Turner (1990) define as:

> Using appropriate statistical techniques, the Hedonic approach attempts to a) identify how much of a property value differential is due to a particular environmental difference between properties and b) infer how much people are willing to pay for an improvement in the environmental quality that they face and what the social value of improvement is.
>
> (Pearce & Turner, 1990, p.143)

Randall (1987) also offers additional implied evaluation/shadow pricing approaches including: the travel-cost method (Hotelling) and the use of labour market observations to estimate the value of human health and safety.

The last externality quantification method outlined by Cherick & Caverhill (1991), direct estimation, attempts to identify all quantifiable effects of an externality as incremental unit values. The sum of individually measured positive and negative externality effects reflects total value. This process may become highly judgmental and subjective. Benheim (1993) has raised a new issue for externalities accounting, measuring decreased quality of life due to environmental degradation.

This would add another element to externalities quantification and may prove useful in identifying the effects of externalities on both individuals and society at large. Time consumption is also a concern. Opportunity cost, loss of earnings, or changes in production measurements may be used with this method (Cherick & Caverhill; 1991; Dixon et al., 1986). Shabman (1988) has noted the wide support among economists for the use of opportunity cost in Benefit-Cost-Analysis.

Valuing Environmental and Social Benefits

Hovde & Leitch (1994) have reviewed the available literature regarding means by which to determine the total economic value of wetlands, then applying a valuation model at five sites within the State of North Dakota. User, owner, regional, and social values were estimated. Annual per acre values ranged from US$4.00 to a landowners to US$373 on a regional basis. Hovde (1994) has also offered that most wetland valuation estimates, while attracting considerable attention, are not well suited to policy-making because:

1) Economic principles are not strictly adhered to;
2) Studies are limited by not valuing all compatible functions or outputs;
3) Studies are highly site specific and;
4) Studies use uncommon denominators

(Hovde, 1994 in Hovde & Leitch, 1994, p.2)

The maintenance of abundant wildlife populations through habitat preservation has traditionally been a high priority for Canadians. Typically, some 80% of residents voice their support for responsible habitat management (Environment Canada, 1993). The State of Minnesota (1991) has placed restitution dollar values on various wildlife species as compensation for hunting infractions. Values start at US$20 for small non-threatened mammals and US$50 for small non-threatened gamebirds and ducks. Values rise steeply according to wildlife size, rarity, and endangeredness. Dubos (1986) and Taylor (1986) have outlined many of the inherent and human spiritual values associated with nature experiences.

4. PROJECT BACKGROUND

Context

This study was commissioned as the principal research component of a project undertaken by The International Coalition for Land & Water Stewardship in the Red River Basin (TIC). TIC received project funding from the Manitoba Government Sustainable Development Innovations Fund in order to complete A Financial Analysis of Small Headwater Retention Structures within the Southeastern Region of the Manitoba Escarpment. TIC's project objective was "to quantify in financial[8] terms the environmental, economic, and social values of water management activities," as undertaken by the Deerwood Soil and Water Management Association. It is anticipated the project will be useful in shaping Red River Basin-wide policy through consideration of the Deerwood model (TIC, 1992).

Site Description: People and Landscape

The Deerwood Soil and Water Management Association

The Deerwood Soil and Water Management Association (DSWMA) is an organisation of some 150 landowners who farm within an 875 square kilometre area (342 square miles) along the Manitoba Escarpment within the Rural Municipalities of Thompson and one half of the R.M. of Lorne in South-central Manitoba (Figure 1e). An Executive Committee directs the affairs of the organisation including administration, communication, and negotiations with governments and agencies. A salaried Technician is active in the delivery of all programmes, providing support to the volunteer Executive and its active President.

8 Financial: Monetary values or costs, measured in $CDN.

Deerwood was formally established in 1984 under the *Agri-Food Programme*, an initiative of the *Canada-Manitoba Economic and Regional Development Agreement* (ERDA). The five year ERDA programme funded a number of research, evaluation, and demonstration projects throughout Manitoba (O'Grady, 1990). In 1989, the *Agri-Food Programme* was replaced by the *Canada-Manitoba Soil Conservation Agreement* under which the DSWMA was maintained as one of 44 "Local Organisations" of Manitoba producers to control and coordinate local programme delivery. Numerous L.O.'s cover South-Central Manitoba (Figure 4a). Local Organisations (L.O.'s) are incorporated and can legally receive and disburse funds (Prairie Research Associates-PRA, 1992). Upon completion of the 1989 agreement in 1994, the *Canada-Manitoba Agreement on Agricultural Sustainability* was established under the Federal Green Plan. The role of Local Organisations changed somewhat in that these groups now present annual priorities on a project-by-project basis. L.O.'s now compete for funds with other conservation entities sponsoring land & water sustainability projects throughout Agro-Manitoba.

The DSWMA has, since its formal inception in 1984, worked to coordinate and initiate multi-agency assistance with farmers' soil, water, and habitat conservation and management activities. O'Grady provides a description of Deerwood which is especially germane to this study:

> The Deerwood project is a prototype of progressive soil and water conservation activities. Deerwood's activities are integrated into the individual farm management plans of the members to address soil and water management problems where they originate. The DSWMA has the potential, as a prototype of soil and water conservation practices, to demonstrate to other interest groups the means to ensure the agricultural land base is sustained. The practical experience of the DSWMA members may be used to improve these techniques and extend their application to other farm groups.
>
> (O'Grady, 1990, p. 5)

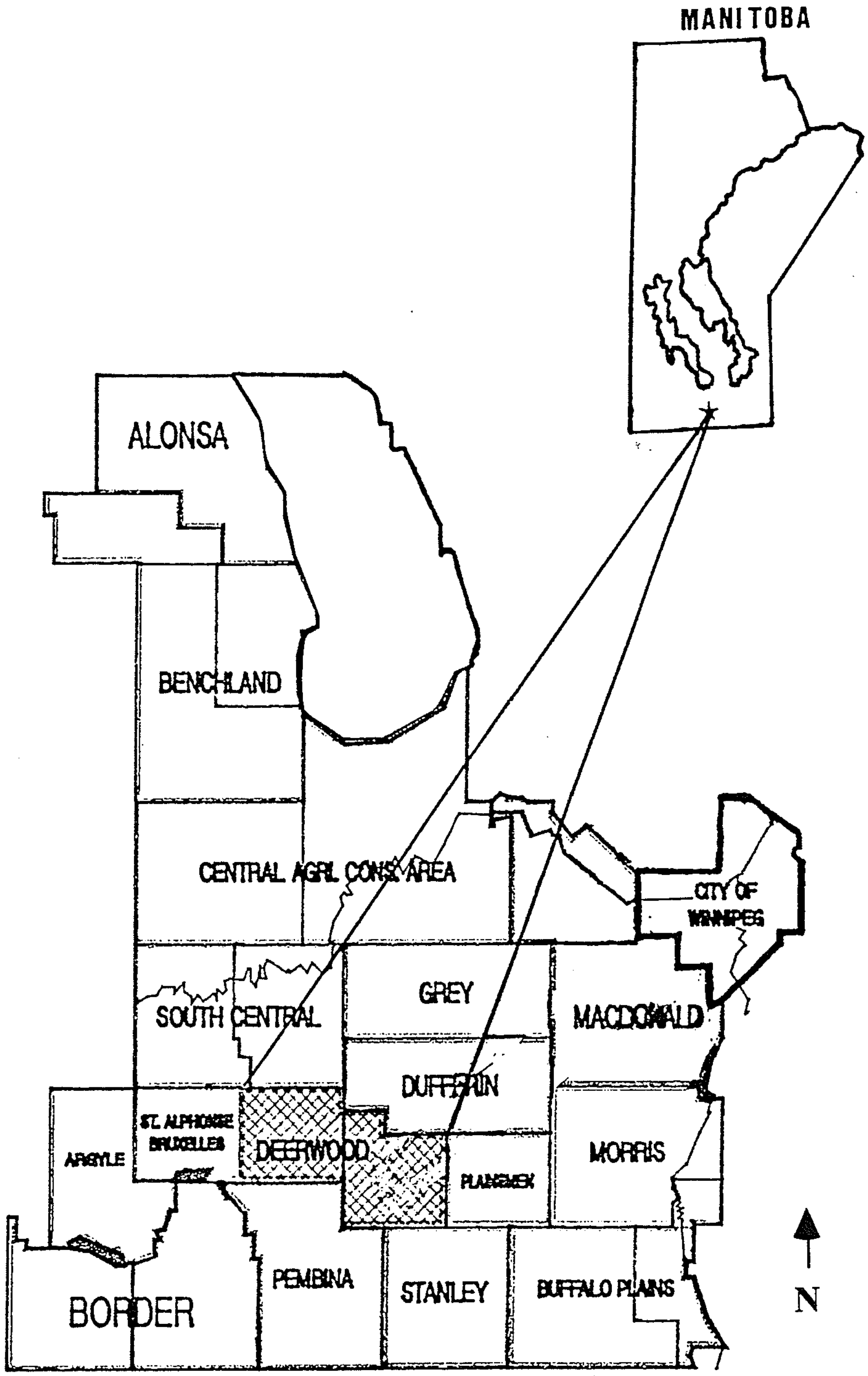


Figure 4a
Local Organisations in South-Central Manitoba
Source: Agriculture Canada - Prairie Farm Rehabilitation Administration
(Winnipeg, PFRA, 1993)

While DSWMA has delivered many land-related programmes, the organisation's focus has been on addressing the related concerns of erosion by water and flood prevention within three sub-watersheds draining the Manitoba Escarpment. O'Grady (1990) has documented the experience and attitudes held by Deerwood's membership regarding soil & water conservation. He found the Deerwood approach to be effective at integrating and coordinating resource management planning at the local level. These findings were supported by PRA (1992) in their recommending of numerous means by which to enhance the effectiveness of Local Organisations.

The Deerwood Project Region: Geography, Problems, and Management

Physiography

The DSWMA project area is typical of many locations along the Manitoba/Pembina Escarpment where serious erosion and flooding problems exist. Since the early 1960s, the area has been studied intensively by Federal and Provincial government departments and agencies. Madison (1983) has provided the most comprehensive assessment of the region's landscape.

Three distinct physiographic units exist in the Deerwood region: a) the Upland/Pembina Hills unit; b) the Escarpment and Lake Agassiz beach ridges unit and; c) the Lowland/Lake Agassiz basin unit (Figure 4b). The rapid change in elevation is due to the underlying rock formations of the Escarpment and geological processes before and after glaciation (Madison, 1983).

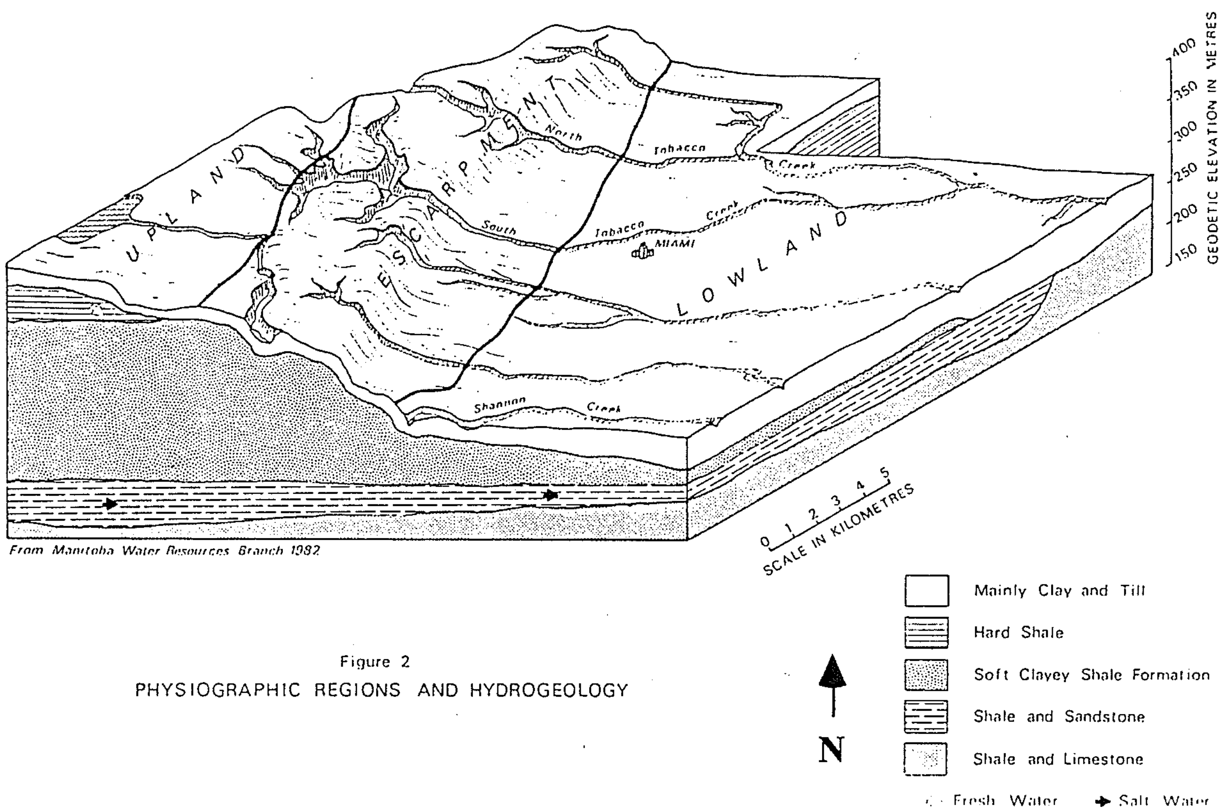


Figure 4b
Physiographic Units of the Manitoba Escarpment Near the Deerwood Region
Source: Madison, 1983, *Tobacco Creek Watershed Land and Water Management Study*
Tobacco Creek Steering Committee, p.12

Climate

The climate is classified by Koppen as Dfb, continental sub-humid with a summer precipitation maximum. Microclimatic variations exist due to terrain and elevational differences (i.e. faster snowmelt on Escarpment face and base, retention of snow in tree-covered coulees and valleys). Average annual precipitation is 530mm (21 in.) with 75% (410mm, 16 in.) of this falling as rain between April and October (25%: 120mm, 5 in. as snow). However, there is a high degree of variability in precipitation within a given year, and from year-to-year. Annual temperatures range from a mean daily minimum of -2°C (27°F) to a mean daily maximum of 8°C (47°F). The average frost-free period is 120 days (frost season is from September 4 to May 5) (Madison, 1983).

Soils and Agricultural Capability

A gradually declining number of landowners operate mixed farms throughout the area (Madison, 1983). Much of the native vegetation cover of the region has been removed, replaced, or modified in some way since the settlement period. In terms of agricultural capability, three distinct land resource units exist within the Deerwood project area. The following descriptions provided by Manitoba Escarpment Headwater Storage Steering Committee (1988) seem to confirm the widely held perceptions of local residents (Alexander, 1995 and McEwan, 1995) and Madison's findings (1983). Figure 4c indicates the potential for agriculture on the soils in the Deerwood region.

In the Northwestern portion of the Deerwood region, the Black, but lighter (more erosive), sandy to sandy loam soils of the Almasippi Land Resource Unit are most common. Soil drifting and low water retention ability limit Canada Land Inventory (CLI) agricultural capability to 3w and 4em (crop range is restricted, and special conservation practices are required). With proper conservation , grains, oilseeds, and special crops may be farmed. However, the lower classes will be limited to mixed farming with livestock forages (Madison, 1983).

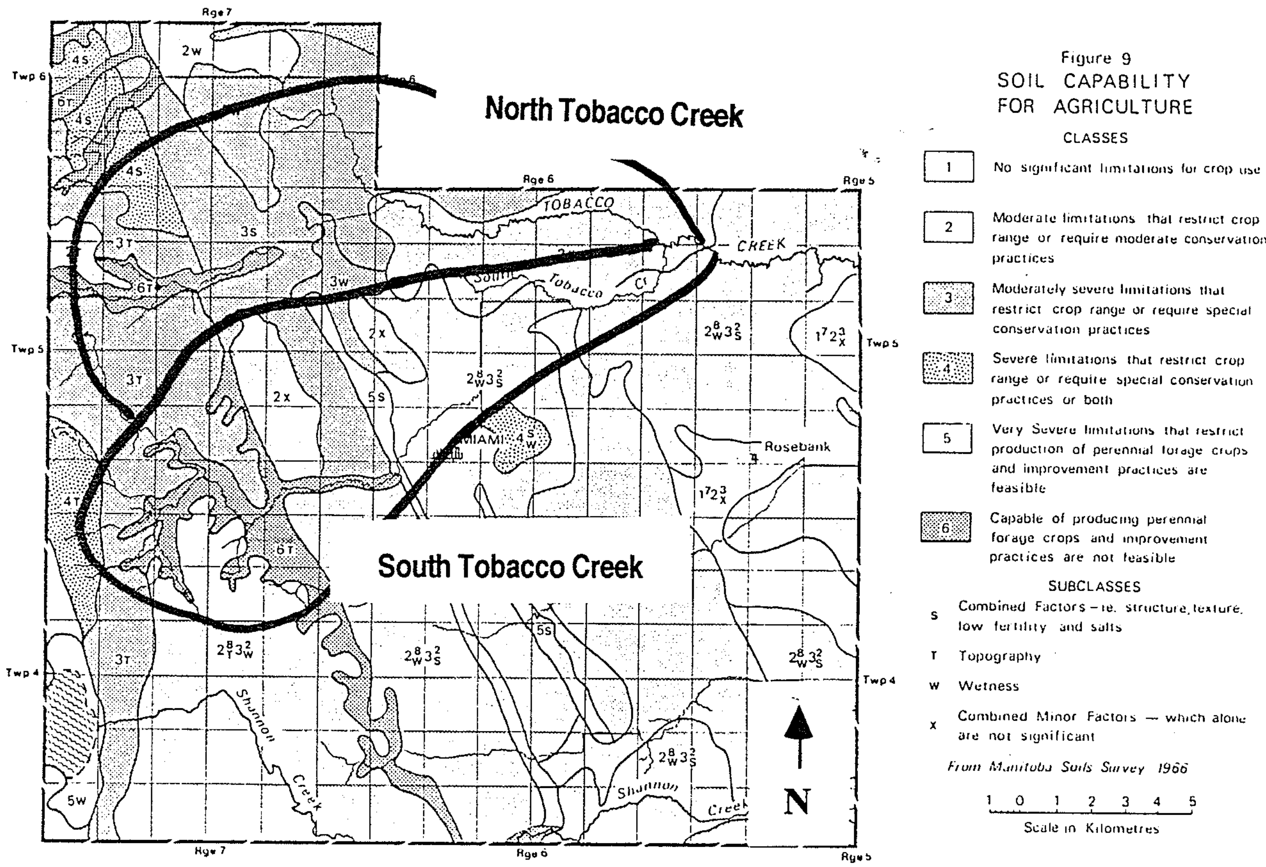


Figure 4c
Soil Capability for Agriculture in the Deerwood Region
Source: Madison, 1983, *Tobacco Creek Watershed Land and Water Management Study*
Tobacco Creek Steering Committee, p.33

In the Southwestern component of the Deerwood region, the Pembina-Altamont Unit may be found. Black Soils are widely present, with the other major soils in the unit being the Dark Greys. Loam to clay loam is the unit texture. Canada Land Inventory soil capability classes range from 4t to 2t, with topography being a major limitation on agricultural land use (erosion problems). Grains, mixed farming, and livestock forages are recommended (Madison, 1983).

Finally, in the Eastern half of the Deerwood region, the Portage-Altona Land Resource Unit, with its dominant Black Soils and flat topography result in 1 and 2w capability classes (wetness problems). Grains, oilseeds, and special crops are recommended for production (Madison, 1983).

Surface Drainage Regime

Four waterways drain the Deerwood project region: the Graham Creek, the Shannon Creek, and the North & South Branches of the Tobacco Creek (Figure 4b). Natural drainage flow is primarily from West to East, towards the Red River. These streams, for the most part, have their origins on the Upland Plateau and within the many gullies and ravines of the Escarpment. One permanent water body exists within the Deerwood region. Lizard Lake lies eight miles Southwest of Miami, is supplied by local drainage, and drains via Shannon Creek to the East and Lyle Creek to the Northwest in Lorne Municipality (Madison, 1983).

The Graham Creek Watershed

The Graham Creek Watershed lies South of Miami between the Shannon and Tobacco Creek drainage areas. It drains approximately 130 square kilometres (51 square miles) of the Deerwood project region.

The Tobacco Creek Watersheds

The majority of Upland tributaries draining gullies and ravines of the Escarpment converge to form the North and South Branches of Tobacco Creek, with their confluence approximately nine kilometres (six miles) Northeast of the Village of Miami. At the confluence, the Tobacco Creek drainage area comprises some 308 square kilometres (120 square miles[9]) of the entire 875 square kilometre Deerwood project area (342 square miles). At some points along the Escarpment, these tributaries may descend in elevation as much as 130 m (430') over eight km (5 miles). The North Tobacco[10] drains approximately 174 square kilometres (68 square miles), with the South Tobacco Creek draining approximately 134 square kilometres (52 square miles) (MEHSSC, 1988) (Plate 4a).

Comparable streamflow data for the North and South Tobacco Creek Watersheds is available between 1965 and 1970. Environment Canada monitoring stations (#050F018 and #050F019) existed on each tributary just above the confluence during this period. This data assumed the drainage areas discussed above: 174 km^2 and 134 km^2 for the North and South Tobacco respectively. It is possible the North Tobacco diversion occurred before 1965 as; the date of diversion construction could not be ascertained from government officials, local municipalities, or area landowners. As evidenced by the six year period denoted by Table 4a, it is clear the North and South branches of Tobacco Creek each experienced similar runoff events, either due to Spring snowmelt or Summer storm runoff. The two creeks also had similar flow capacities.

[9] While the combined natural drainage area of the North and South Tobacco Creeks is approximately 120 square miles (308 square kilometres) above their confluence, a diversion Southwest of Roseile, MB transfers a Northwest portion of the North Tobacco drainage into the Roseile Creek.

[10] As noted above, the current North Tobacco drainage area is somewhat smaller by approximately 31 square kilometres (12 square miles) due to the diversion to Roseile Creek.

Table 4a: North(#050F018) and South(050F019) Tobacco Creek Streamflow Discharges (m^3/s): 1965 - 1970
Source: Yarotski, 1995: Environment Canada Streamflow Monitoring and Deerwood Rainfall Station (5020720) Records

Year and Type	North Tobacco Maximum Daily Discharges	North Tobacco Maximum Peak Discharges	South Tobacco Maximum Daily Discharges	South Tobacco Maximum Peak Discharges
1965 Melt	12.7 (April 13)		13.8 (April 13)	
1966 Melt	6.34 (May 5)	12.7 (7:00am, May 5)	12.0 (May 5)	16.6 (4:30am, May 5)
1967 Rain	11.9 (April 21)		17.4 (April 21)	
1968 Rain	10.1 (Aug. 25)	23.2 (7:30pm, Aug. 24)	19.1 (Aug. 25)	
1969 Melt	19.4 (April 10)	22.7 April 10)	20.0 (April 11)	
1970 Melt	17.1 (April 30)	18.5 (7:35am, April 30)	21.1 (April 26)	26.6 (5:20am, April 26)

While monitoring at the South Tobacco site #050F019 did continue past 1970, the North Tobacco site #050F018 was monitored until 1992. Also, an upstream South Tobacco monitoring site near Miami (#050F017) has been in operation since 1963. Comparison of #050F017 and #050F018 data between 1965 and 1992 proved useful (Table 4b). Even with the smaller South Tobacco Creek drainage area above #050F017 (76.9 km^2) being some 40% to 50% smaller than the monitored North Tobacco drainage[11], similar flow trends were observed at both stations until 1979, when severe flooding exceeded monitoring ability.

Peak flows in the North Tobacco virtually disappeared between 1980 and 1982, although comparable maximum daily discharges were noted. From 1983 onward, North Tobacco peak flows remained low relative to the South Tobacco, and beginning in 1984 and 1985, dramatic reductions in maximum North Tobacco daily discharges occurred until the end of the 1992 monitoring period. It seems unlikely that localised storms and rapid runoff periods were concentrated only in the South Tobacco Watershed.

[11] Depending on whether the diversion to Roseile Creek is considered or not.

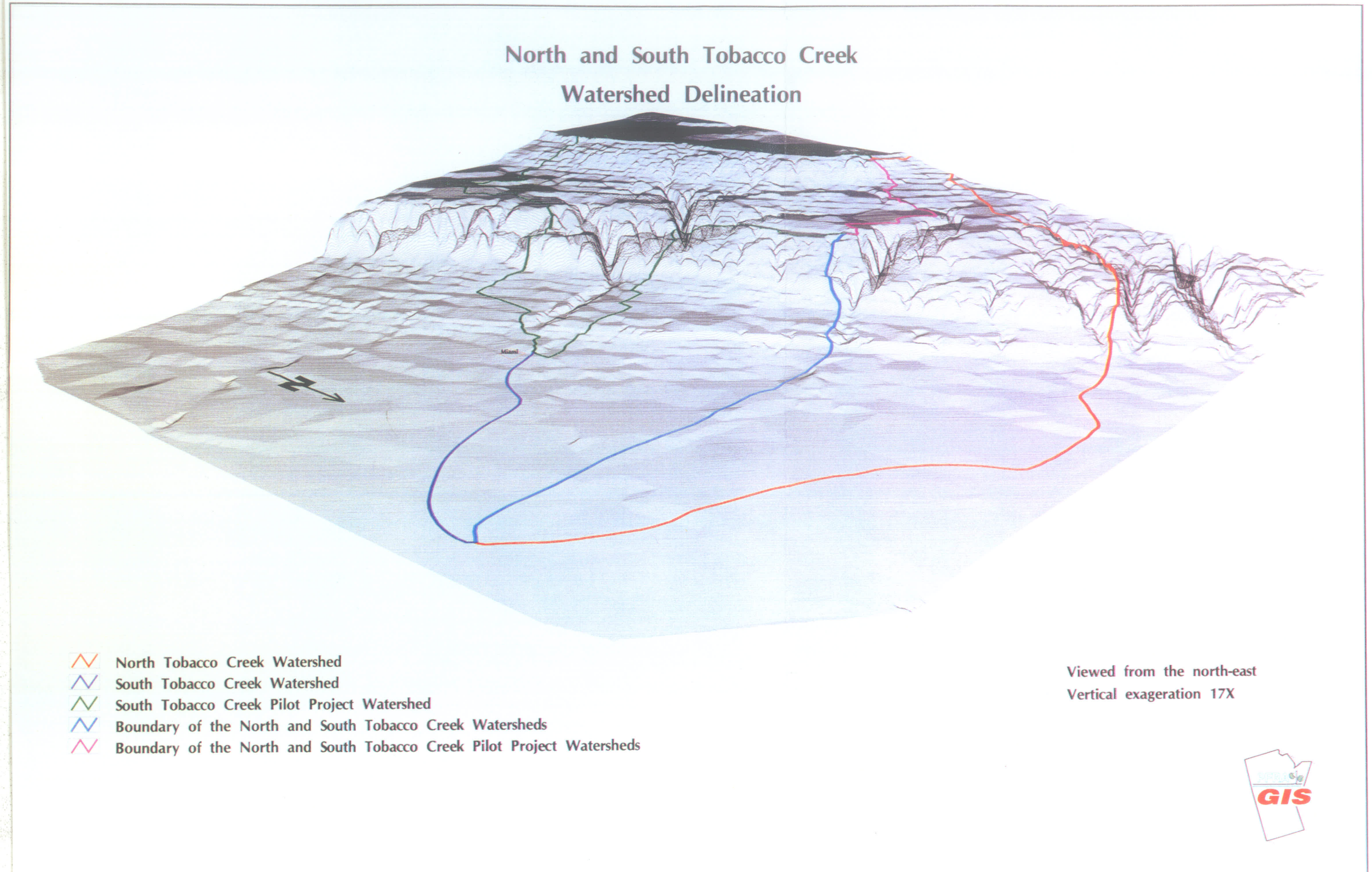


Plate 4a
North and South Tobacco Creek Watershed Delineation
Source: PFRA/MRSC, 1994
(Agriculture Canada/Manitoba Natural Resources)

Table 4b: North(#050F018) and South(050F017) Tobacco Creek Streamflow Discharges (m^3/s): 1965-1992
Source: Yarotski, 1995: Environment Canada Streamflow Monitoring and Deerwood Rainfall Station (5020720) Records

Year and Type	North Tobacco Maximum Daily Discharges	North Tobacco Maximum Peak Discharges	South Tobacco Maximum Daily Discharges	South Tobacco Maximum Peak Discharges
1965 Melt	12.7 (April 13)		7.93 (April 13)	
1966 Melt	6.34 (May 5)	12.7 (7:00am, May 5)	8.35 (May 5)	14.8 (1:30am, May 5)
1967 Rain	11.9 (April 21)		15.0 (April 20)	24.4(3:00pm, Apr. 20)
1968 **Rain**	10.1 (Aug. 25)	23.2 (7:30pm, Aug. 24)	18.6 (Aug. 24)	24.6 (7:30am, Aug. 24)
1969 Melt	19.4 (April 10)	22.7 April 10)	10.3 (April 12)	
1970 Melt	17.1 (April 30)	·18.5 (7:35am, April 30)	12.8 (April 29)	13.4 (3:50am, April 29)
1971 Melt	9.71 (April 9)	13.4 (1:00pm, April 9)	11.4 (April 8)	
1972 Melt	4.16 (March 19)		6.06 (April 9)	
1973 Melt	.436 (March 14)	.518 (5:10pm, Mar. 15)	.255 (March 11)	
1974 Rain	19.3 (April 21)	22.1 (11:20am, Apr. 21)	14.9 (April 17)	17.9 (1:12am, May 21)
1975 Rain	3.96 (June 29)	4.50 (1:13am, June 29)	4.11 (June 28)	14.2 (2:20pm, June 28)
1976 Melt	4.45 (April 3)	7.82 (2:41pm, Apr. 3)	6.20 (April 5)	9.94 (11:27pm, Apr. 4)
1977 Rain	.773 (Sept. 26)	.869 (11:56am, Sept 29)	.923 (May 18)	1.70 (6:05am, May 18)
1978 Rain	3.43 (May 26)	5.18 (11:59am, May 26)	8.55 (April 6,)	11.6 (2:25am, May 26)
1979 Melt	26.8 (April 20)	Maximum Record	28.0 (April 19)	Maximum Record
1980 Melt	1.46 (April 7)		1.50 (April 5)	2.05 (11:39, Apr. 6)
1981 Melt	.339 (March 16)		.267 (March 15)	1.30 (6:45am, June 24)
1982 Rain	1.16 (April 14)		2.43 (April 12)	3.62 (11:07pm, Apr. 11)
1983 Melt	3.71 (April 1)	4.75 (3:22pm, Apr. 7)	4.46 (April 7)	11.2 (8:57pm, Mar. 30)
1984 M/R	.290 (May 6)	.714 (10:17pm, Mar. 27)	1.09 (June 22, Rain)	3.60 (3:30am, June 22)
1985 Rain	4.05 (Aug. 18)	4.96 (3:45am, Aug. 18)	15.0 (Aug. 17)	23.5 (8:05am, Aug. 17)
1986 M/R	7.65 (March 24)	8.45 (4:45pm, Mar. 24)	16.9 (May 5, Rain)	28.5 (4:08am, May 5)
1987 Melt	3.20 (April 6)	3.43 (8:49am, Apr. 6)	5.39 (April 5)	6.66 (10:00pm, Apr. 5)
1988 Melt	.475 (April 3)	.931 (8:02am, Apr. 5)	.375 (April 3)	
1989 Melt	.894 (April 17)	1.18 (10:30pm, Apr. 17)	1.44 (April 14)	2.54 (11:52pm, Apr. 15)
1990 M/R	2.74 (April 1)	3.17 (6:40am, Apr. 2)	4.56 (June 12, Rain)	18.3 (1:16am, June 12)
1991 Rain	2.24 (July 13)	2.87 (2:00pm, July 13)	2.94 (July 12)	10.5 (3:28pm, June 13)
1992 Melt	2.30 (March 7)		4.76 (March 7)	8.52 (9:15pm, Mar. 7)

It is possible the upstream diversion of the North Tobacco occurred at some point after 1979. Assuming this to be the case, it was important to note that substantial Summer storm and Spring runoff events influenced the Tobacco Creek Watershed from 1979 to 1988. Additionally, between 1989 and 1992, three sizable runoff events occurred on: June 12, 1990; June 13, 1991 and; March 7, 1992.

Further review of Tobacco Creek area rainfall intensity data between 1979 and 1991 was carried out (Table 4c). A one inch (25.4 mm) rainfall occurring over a six hour period may be described as intense for the Tobacco Creek region (Harden, 1995). Ten of twelve years contained storm events of this intensity. Both 1989 and 1990 also contained substantial sizable Summer storm events. 1991 to 1994 storm intensities were also significant and are discussed and the end of this chapter and in Chapter Six. Runoff and storm event trends were considered important to the establishment of a control scenario between the North and South Tobacco Creeks over time.

Table 4c: Tobacco Creek Watershed Six Hour Rainfall Intensity (mm): 1979-1991
Source: Yarotski, 1995: Environment Canada Deerwood Rainfall Station (5020720) Records

Year	1979	1980	1981	1982	1983	1984	1985	1986	1988	1989	1990	1991
Rainfall	37.4	33.1	44.2	39.8	42.2	39.9	64.5	32.4	trace	21.7	26.4	33.7

Tobacco Creek Soils

As commonly perceived by local residents (McEwan, 1995 and Orchard, 1995), erosion and natural water retention ability of soils appear to differ between the two sub-catchments of the Tobacco Creek watershed. The soils of the North Tobacco Creek are represented for the most part by the sandy characteristics of the Almasippi Unit, with the Pembina-Altamont Unit most common within the South Tobacco (Fraser, 1994; MEHSSC, 1988). Somewhat greater erosivity in the North Tobacco is also represented by Figure 4d, which indicates the potential for wind erosion in the area, a key indicator of lighter/sandier soil texture.

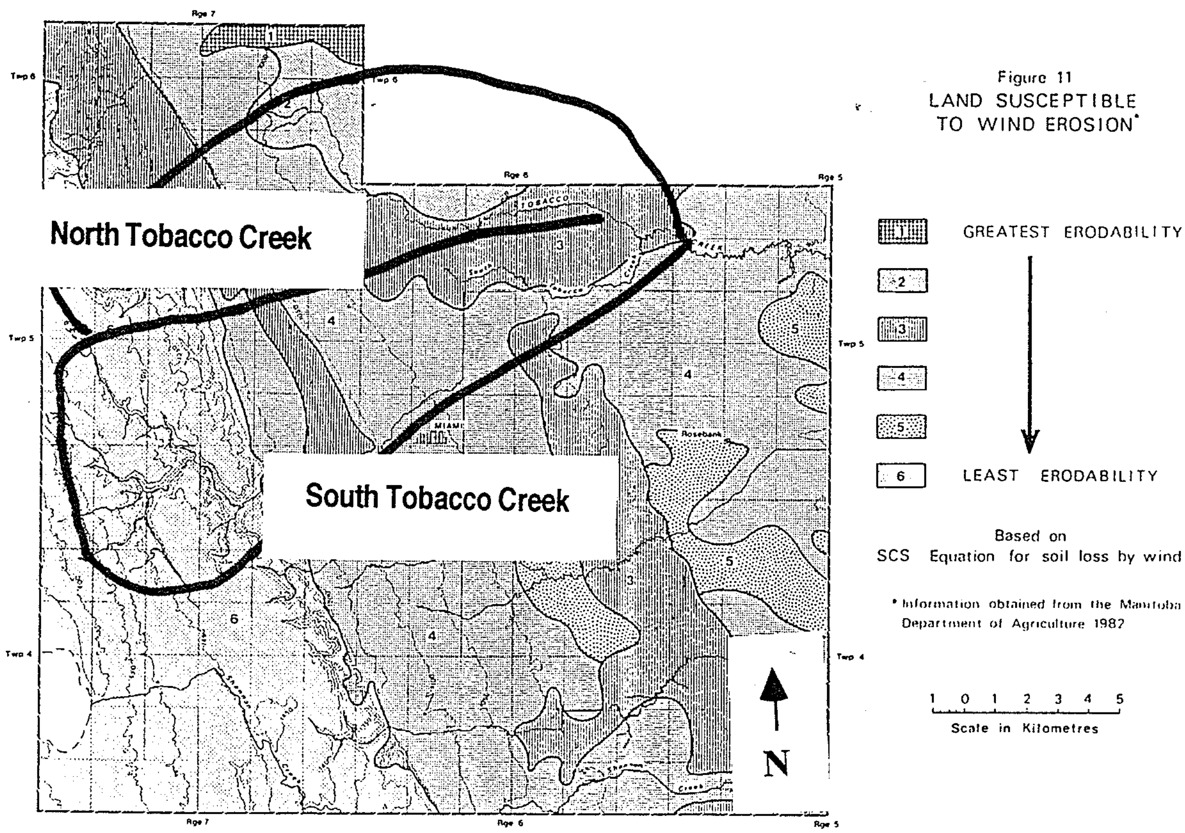


Figure 4d
Potential for Wind Erosion in the Deerwood Region
Source: Madison, 1983, *Tobacco Creek Watershed Land and Water Management Study*
Tobacco Creek Steering Committee, p. 41

The significance of soil differences may well be offset however, given a marked natural vegetation cover differential between the two catchments. Table 4d shows greater relative forest cover reduction in the South Tobacco since the introduction of the bulldozer after World War II (Madison, 1983). As discussed earlier the elevation of 1125' (375m) separates the Lowland from the Escarpmental physiographic unit in this region of the Manitoba Escarpment. Much of the North and South Tobacco drainage areas lie above this elevation in the form of Upland and Escarpment physiographic terrain. After 1948, a dramatic reduction in the percentage of natural vegetation cover above this elevation occurred within both watersheds. However, denudation was much more prominent in the South Tobacco as evidenced by the percentages of remaining critical cover in 1980. Current estimates of remaining vegetation cover are provided in Chapter Six.

Table 4d: Natural Vegetation Cover Reduction in the Deerwood Region 1948 - 1980
Source: Modified from Madison, 1983, p. 59

Catchment	Drainage Area Above 1125'	Forested Area 1948	Forested Area 1980	Reduction of Drainage Area	Reduction of 1948 Extent	Critical Cover as of 1980
North Tobacco	11,520 acres	5,155 ac	4,215 ac	8.2%	18.2%	**36.6%**
South Tobacco	17,280 acres	5,294 ac	3,040 ac	13.1%	42.6%	**17.6%**

Water Problems and Damage Costs

Madison describes the precipitation regime of the area as characterised by winter snowfall; long, low intensity rains in the Spring; short high intensity thunderstorms in the Summer and; long, low intensity general rains in the Fall. Surface runoff is highest in periods of snowmelt and early Spring rains, moderate during the Fall, and very high during extreme Summer storm events. Two significant effects result from the region's runoff regime:

1) High velocity streamflow in the Upland and steeply sloping Escarpment regions which has resulted in erosion of drainage channels, roads and farm property, washouts of municipal stream crossings and;

2) Reduced velocity of streamflow in the Lowland regions which, coupled with the reduced capacities of drainage channels, may result in widespread flooding of farm property (with sediment damage or weed contamination), and clogging of municipal culverts.

(adapted from Madison, 1983, p.44-47)

Topography of the area, denudation of natural bush cover, and inappropriate field management techniques such as summerfallowing have combined to produced sever sheet, rill, and gulley erosion problems on agricultural lands the Deerwood region. While soil conservation measures have gradually improved, water management has been of longstanding concern to area landowners. Channel erosion of natural and artificial drainage systems in the Escarpment region has also arisen as a major concern for the Rural Municipality of Thompson. Water erosion problems have been well documented in the region (Figure 4e) (Madison, 1983).

The Lowland region of the Deerwood project area contains the most areas prone to flooding. Prior to agricultural development and artificial drainage, the Lowlands were typically represented by a series of "flat, marsh-like areas which acted as temporary storage reservoirs retarding the speed of surface runoff." Madison paints a clear picture of the flooding problem in Deerwood.

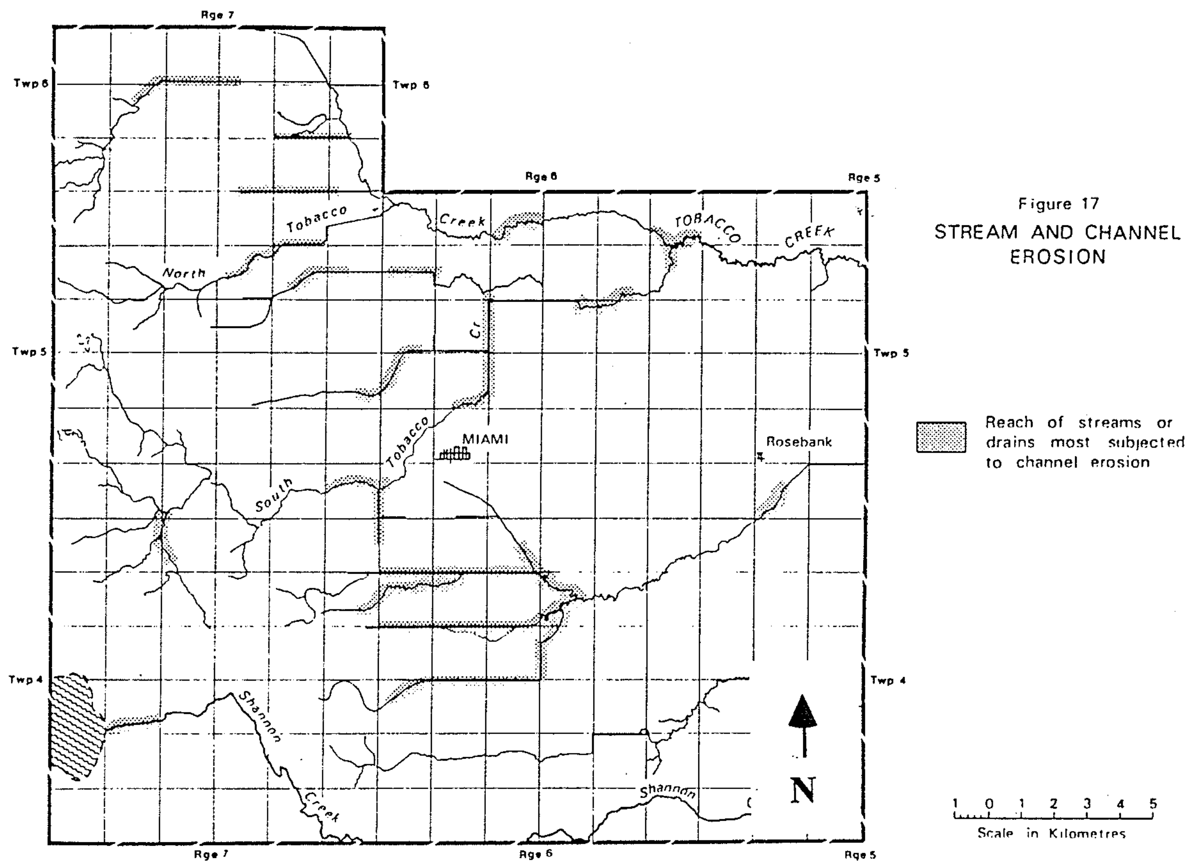


Figure 4e
Stream and Channel Erosion in the Deerwood Region
Source: Madison, 1983, *Tobacco Creek Watershed Land and Water Management Study*
Tobacco Creek Steering Committee, p.88

> Until recently (early 1980's), drainage channels and ditches along road allowances to facilitate land drainage and to speed up the downstream passage of water was the prime concern of the Municipal Government. Little thought or consideration was given to the side effects such undertakings might have, for example, increased erosion or the impact on water supply. Farmers worked individually in efforts to drain their own land without consideration of how their drainage systems would affect their downstream neighbours. Many of the channels and ditches were designed to facilitate land drainage and so do not have the capacities to convey floods. To compound this problem further, spring snowmelt and its accompanying runoff often occur when downstream channels are not clear of snow and ice. Under such conditions, these snow and ice accumulations often cause blockages which result in channel overflows.
>
> (Madison, 1983, p. 86)

Specific instances of flooding and erosion damage within the Deerwood region have also been well documented financially. In 1979, a 50 year Spring runoff resulted in the Municipality of Thompson claiming damages under the Manitoba Flood Damage Assistance Plan totaling $24,850. While area producers claimed only $12,900, it has been noted many other farmers may have been eligible to claim, but were unaware of the programme. Actual productivity losses to erosion in 1979 are not known. However, it has been estimated municipal claims accounted for only 3% of total damages (MEHSSC, 1988). Silt and debris deposition problems have also been extensively chronicled in the Lowlands. (Madison, 1983).

Erosion and flooding problems have been well documented within each branch of the Tobacco Creek. At one site on the North Tobacco, total damages for the 1979 event have officially been estimated to have occurred over 580 ha. (1440 ac.), with associated total costs of $320,000. Additionally, a second site on the South Tobacco experienced flooding and erosion over 3000 ha. (7500 ac.) with damages estimated at $1,200,000. This site also experienced a severe thunderstorm event in 1986, affecting 1800 ha (4500 ac) and costing $340,000. Total average annual damages in 1986 dollars were: $55,000 on the North Tobacco and $210,000 on the South Tobacco (MEHSSC, 1988) (Figures 4f, 4g).

Planning and Management History

The extent of severe erosion and flooding damage in the North and South Tobacco Creek Watersheds has given rise to a variety of research and management initiatives carried out in the Deerwood region.

Public sector entities such as Manitoba Agriculture, the Prairie Farm Rehabilitation Administration of Agriculture Canada, Ducks Unlimited Canada, the Manitoba Habitat Heritage Corporation, and the Pembina Valley Conservation District have promoted soil conservation and water management through information extension, funding programmes, and long-term habitat lease agreements with private landowners.

Construction of headwater storage structures in the Upland and Escarpment Units has long been viewed by area residents as the only permanent solution for erosion and flooding problems along the Manitoba Escarpment (Madison, 1983). Consequently, the Deerwood region has been intensively studied by both PFRA and the Water Resources Branch of Manitoba Natural Resources. In 1971, PFRA carried out engineering feasibility, effectiveness, and cost analysis studies in the identification of 15 potential sites on Tobacco Creek for headwater storage reservoirs, each designed to hold several thousand acre feet of water. While this large-scale approach was found to be feasible, costs could not be reconciled with anticipated benefits (Madison, 1983).

In 1981 the R.M. of Thompson requested the Province of Manitoba to establish a Demonstration Soil & Water Management Project in the Tobacco Creek Watershed which would include a headwater storage pilot project. The Tobacco Creek Steering Committee, comprised of Federal and Provincial officials and one local elected official, was subsequently struck to initiate a resource study of the area. After reviewing several sites identified in the 1971 PFRA study, the Steering Committee determined that three Upland sites on the Graham Creek should be ruled out because of limited storage capacities and small drainage areas (Madison,1983).

After careful analysis of aerial photographs, three "headwater storage concepts" on the South Tobacco Creek were selected for further study. Due to geotechnical and hydrological characteristics of the watershed, the ratio between flood runoff and drainage area is large, resulting in high costs for dam construction (Madison, 1983). The three headwater storage concepts were:

1) A Combined road/dam structure on P.R. #240 which would have a height of 20 m (65'), storing 2200 dam^3 (1820 a.f.), flooding 85 acres at full supply level, with a total cost of $1.5 G (1982);

2) A 9 m (30') high dam located 1.5 k (1 mile) downstream from P.R. #240, with 985 dam^3 (815 a.f.) of storage, flooding 64 acres at a cost of $730.0 K (1982) and;

3) A network of Upland sites located upstream from P.R. #240 with a combined storage capacity of 1200 dam^3 (992 a.f.), and costing $850.0K (1982).

(Madison, 1983, p.105-106)

Similar to the Graham Creek sites ruled out earlier, the South Tobacco network of smaller dams was not considered in further detail. Interestingly, the Steering Committee determined, the largest and most costly of the three concepts, the P.R. #240 structure, would be the most cost-effective in reducing downstream flooding and erosion damages. However, as project benefits could not be comprehensively quantified, this large project could not be rationalized (Madison, 1983).

In 1988, another review panel, the Manitoba Escarpment Headwater Storage Steering Committee, reported on their analysis of two possible storage sites in the Tobacco Creek Watershed. A 28 m (90') dam was considered for the North Tobacco (Figure 4f) and preliminary designs were carried out for a reservoir storing 940 dam^3 (760 a.f.), flooding 72 acres. At a cost of $1.42 G (1988), the dam could not pass the benefit cost analysis (BCA) filter. A site on the South Tobacco was also considered, with a ten m (33') dam designed to impound 1100 dam^3 (910 a.f.) at a total cost of $980.0 K (1988). This is the identical site 1.5 km downstream from P.R. #240, which PFRA had reviewed in 1981 (Figure 4g). According to economic analysis, this site passed the BCA test. However, the MEHSSC apparently had concerns with the data, and only recommended further study (MEHSSC, 1988). No further actions have been undertaken with regard to this site.

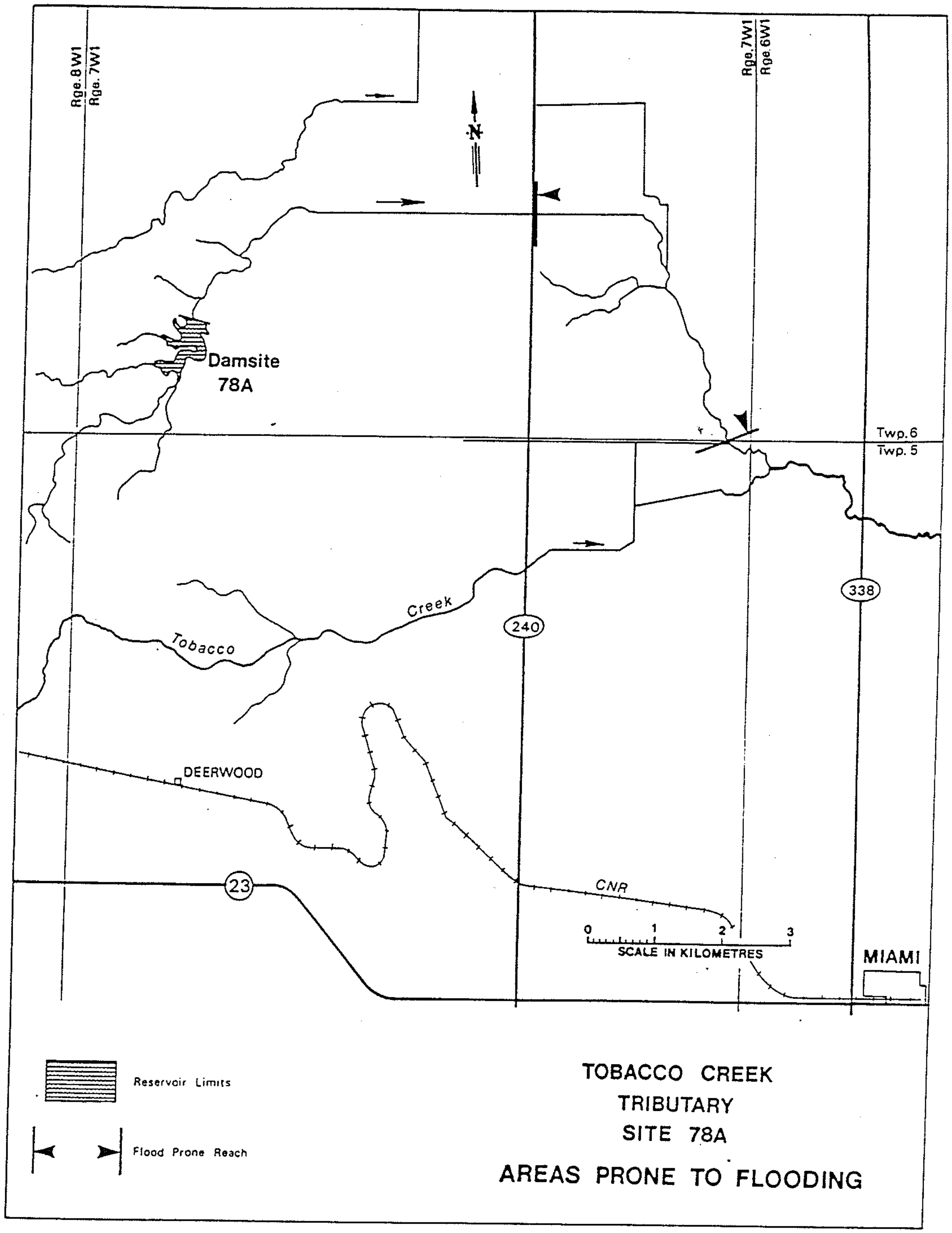


Figure 4f
1979 Flooding and Erosion on the North Tobacco Creek
North Tobacco Dam Site Considered by the MEHSSC
Source: MEHSSC, 1988, *Manitoba Escarpment Headwater Storage Study*
PFRA/Manitoba Natural Resources, p. 49

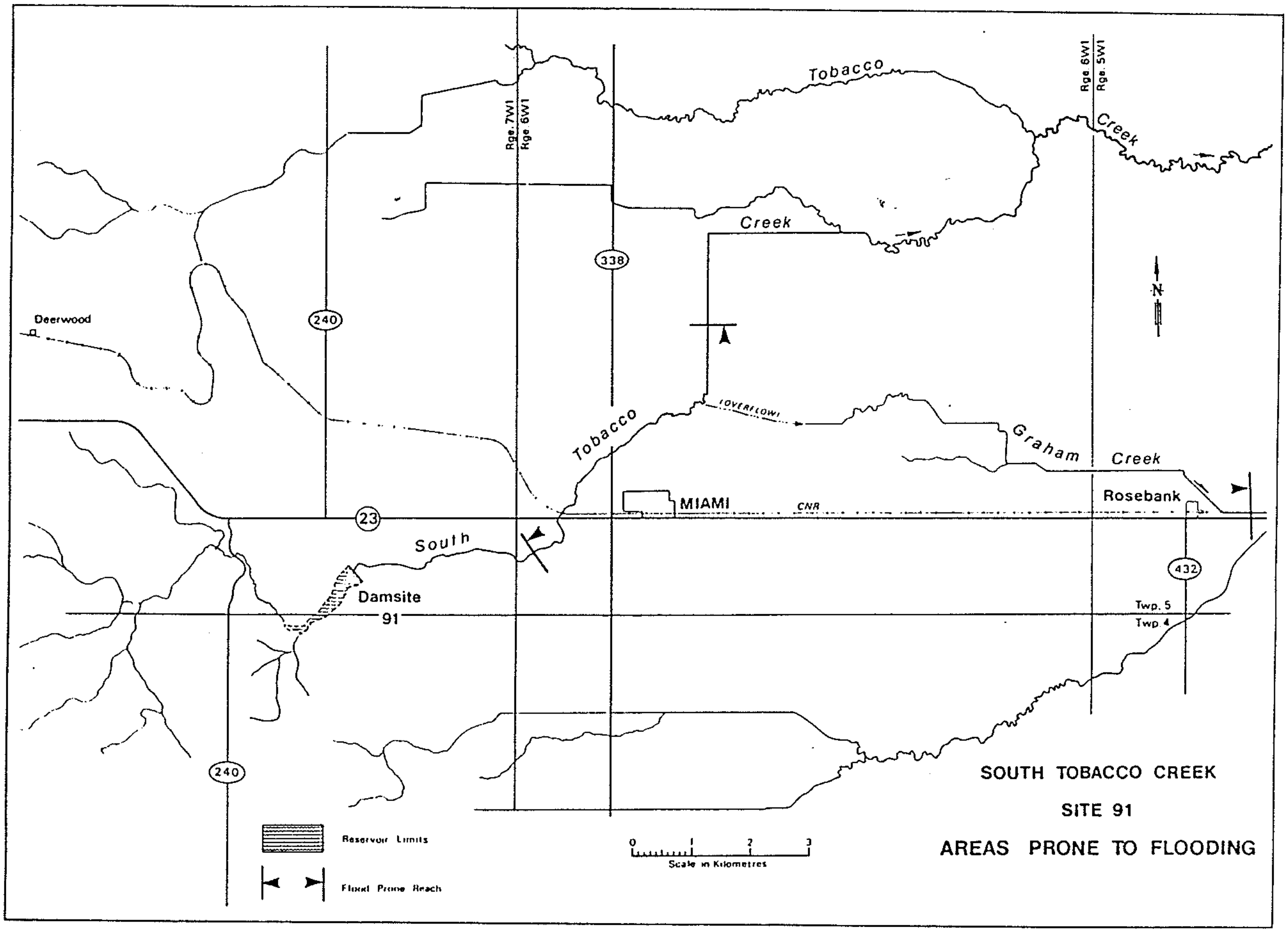


Figure 4g
1979 Flooding and Erosion on the South Tobacco Creek
South Tobacco Dam Site Considered by the MEHSSC
Source: MEHSSC, 1988, *Manitoba Escarpment Headwater Storage Study*
PFRA/Manitoba Natural Resources, p. 52

The Deerwood Soil & Water Management Association began establishing partnerships and delivering conservation programs in 1984. Between 1985 and 1992, 45 small headwater retention structures (small dams) were constructed, primarily on the Upland tributaries of the Graham and South Tobacco Creeks (Plate 4a). 30 dams are located in the South Tobacco Creek Watershed, with five dispersed sites in the North Tobacco, four in the Roseile Creek watershed[12], and six strategically placed on tributaries of the Graham Creek. A total of 42 Deerwood dams have management impacts on the Graham, North Tobacco, and South Tobacco Creeks, although efforts have largely focussed on the Graham and South Tobacco. After the 1988 construction season, 22 (52%) of these were completed. Three basic designs exist (Plates 4b-4e):

1) Multi-Purpose Dams hold water for various seasonal, domestic, and irrigation uses. Each is designed with a 300 mm (12") drain pipe, gate, and stand pipe. The stand pipe is used to regulate seasonal storage, to control spring flood water, to release excess slowly, and to store water for summer use. Stockwatering, wildlife habitat, and fish rearing are other common uses. The dams are totally drained in the Fall to prepare for full flood control potential in the Spring. The average construction cost is $8527 (ranging from $3826 to $22,783), with an average capacity of 12.54 a.f. (10.36 dam^3);

2) Dry Dam/Flood Control Structures serve to decrease peak flows during Spring runoff and Summer rainstorm events by retaining water for a short period of time, and reducing flow rates. Costs range from $2536 to $23,083 ($11,770 average) and; have an average capacity of 17.4 a.f (14.38 dam^3).

3) Backflood Dams retain water at a shallow depth over large acreages of cropped or pastured lands. Water is retained for at least two weeks before being released, thereby greatly increasing soil moisture in the flooded area to the benefit of crops and wildlife. There are several backflood projects, ranging in cost from $1044 to $10,362 ($5103 average) and; hold an average of 36.79 a.f. (30.4 dam^3).

(O'Grady, 1990, p. 22-23; STCPPSC, 1992, p. 3[13,14]

12 While these dams exist within the natural hydrological boundaries of the North Tobacco Creek drainage, a diversion built several years ago now carries water from the Northwest portion of the watershed into the Roseile Creek.

13 Costs deflated to 1986$.

14 1 dam^3 = 1.21 acre feet.

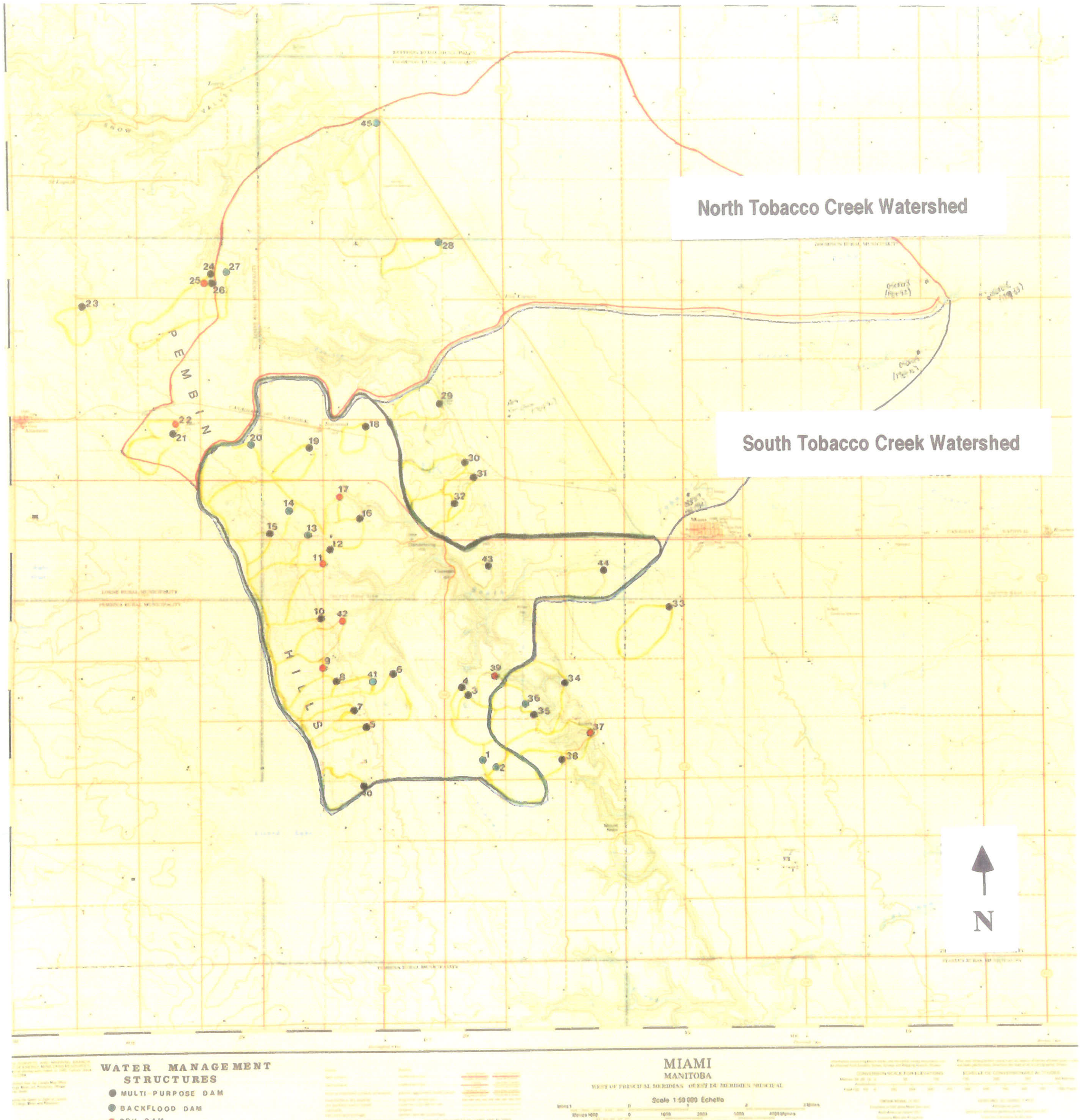


Plate 4b
Participating Landowners' Dam Sites in Deerwood
Source: Bill Turner, DSWMA Technician

Plate 4c
Typical Dry Dam Under Construction in Deerwood Region
Source: Bryan Oborne

Plate 4d
Typical Backflood Dam in Deerwood Region
Source: Bryan Oborne

Plate 4e
Typical Multi-Purpose Dam in Deerwood
Source: Bill Turner, DSWMA Technician

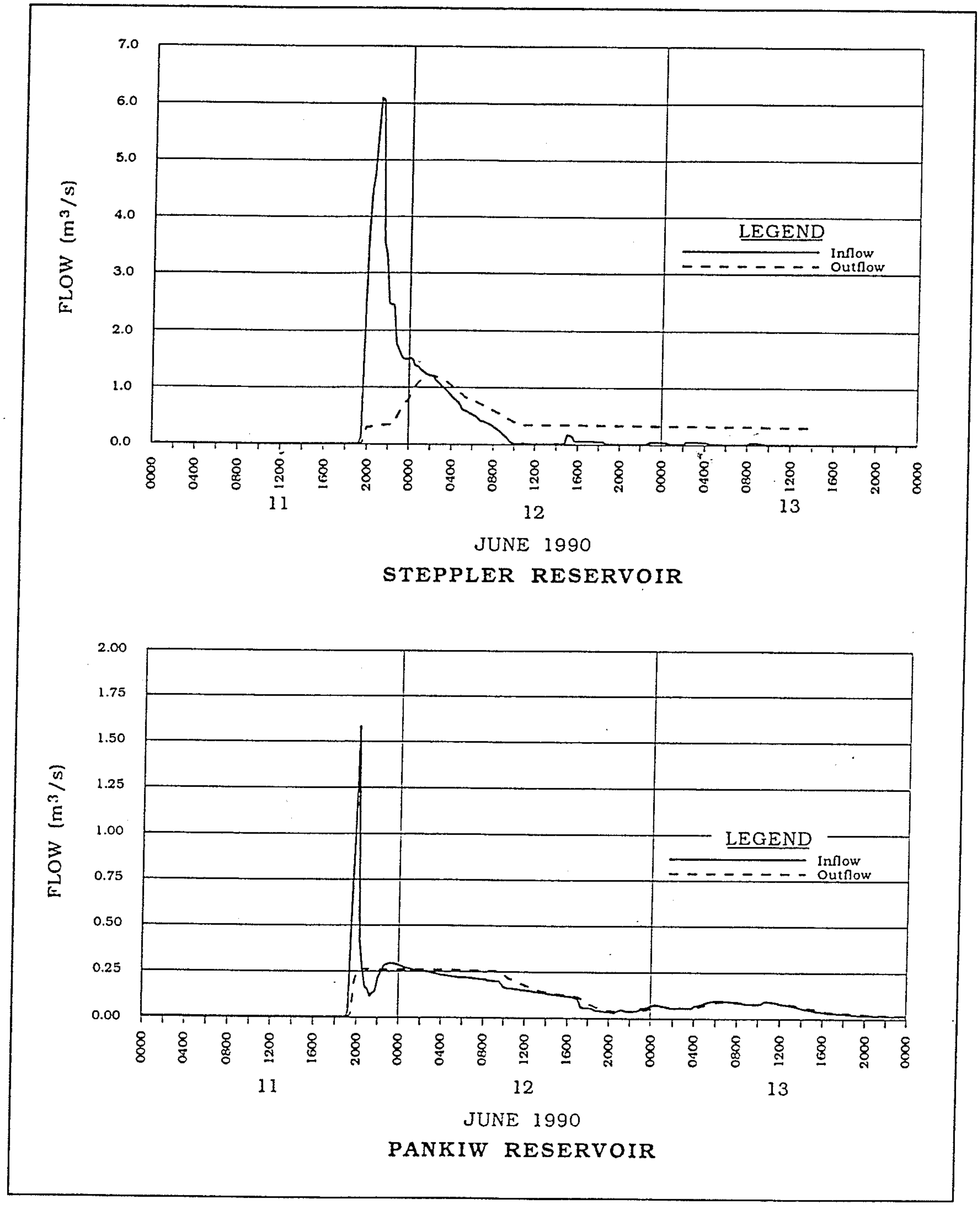
Plate 4f
Typical Multi-Purpose Dam in Deerwood Region
Source: Bill Turner, DSWMA Technician

The 1988 report of the Manitoba Escarpment Headwater Storage Steering Committee recommended the establishment of representative pilot watershed projects whereby:

> The interest and initiative of local conservation groups and the potential of the watershed for developing solutions which could be transferred to neighbouring basins. Once implemented, these pilot projects should be monitored on a continuing basis and periodically evaluated to establish the effectiveness of the measures under consideration.
>
> The South Tobacco Creek is one area recommended for a pilot project. The watershed is physically representative of the Manitoba/Pembina Escarpment and; there is great local interest in soil & water conservation. The Deerwood Soil & Water Management Association and PFRA have already undertaken an integrated land & water management programme in this area including the construction of several dozen very small headwater storage dams. An evaluation of the effectiveness of these dams should be included as part of the pilot project.
>
> (MEHSSC, 1988, p.77)

In 1991, the South Tobacco Creek Pilot Project was established through a consortium of government agencies to improve the understanding of runoff characteristics of small watersheds and the physical processes which cause flooding and runoff erosion along the Manitoba Escarpment (STCPPSC, 1992). The pilot project is also providing critical precipitation and streamflow data which has been historically poor.

Numerous methods to address Manitoba Escarpment erosion and flooding problems are being assessed through innovative testing and monitoring studies. A major emphasis has been on chemical and nutrient migration via water under various land treatments. While South Tobacco Pilot Project activities are ongoing, preliminary analysis of the hydrologic effectiveness of four of Deerwood's dams has taken place. Major Summer storm events occurring in June 1990, June 1991, and July 1991 tested the effectiveness of these structures. Peak flow reductions ranging from 60% to 90% were observed (PFRA, 1992, 1991). Figure 4h shows two dams which are representative of these significant peak flow reductions.



INFLOW AND OUTFLOW HYDROGRAPHS

June 11, 1990 Rainstorm

Figure 4h
June 11, 1990 Peak Flow Reductions at Two Monitored Deerwood Dams
Source: PFRA, 1992, *Annual Report: South Tobacco Creek Pilot Project*
STCPPSC, Winnipeg, Figure 2

5. RESULTS

Documentation of Provincial Costs

Through discussions with Provincial officials it was discovered that records relating to the costs of maintaining specific drainage waterways in the Deerwood region were not feasibly obtainable. Additionally, understanding the local drainage regime from a Provincial perspective would require solid historical flow data from several watersheds (Barlishen, 1994). As these issues were deemed to be beyond the established terms of reference, it was decided to abandon this aspect of the study. Additionally, as there are very few kilometres of Provincial waterway in the Deerwood project area (third order and above).

Documentation of Municipal Costs

Rural Municipality of Lorne

This R.M. is largely represented by an Upland physiographical landscape. While the municipality has experienced significant flooding and erosion-related problems elsewhere within their jurisdiction, only a very small portion of the North and South Tobacco Creek watersheds drain from Lorne R.M. As Deerwood's dams are located primarily along the Eastern edge of the municipality, the municipal council did not believe flooding and erosion-related costs would be affected by dam construction. Further study was not relevant.

Rural Municipality of Thompson

Although cost estimates could not be derived directly from the R.M. of Thompson accounts, the municipal council was "confident and conservative" with the figures provided. The R.M. strongly believed Deerwood's dams serve to significantly slow streamflows, reducing erosion and flooding within much of the municipality. The R.M. of Thompson has contributed $10.0K each year in backhoe/grader & operator time towards Deerwood's construction of multi-purpose or dry headwater storage dams. These costs were factored into Deerwood's total dam construction costs in Chapter Six.

The descriptive municipal survey gleaned data fairly specific to actual dam sites (Plate 4a):

North Tobacco Creek

One dam (#28) was deemed by the municipality to provide some cost savings in the form of reduced flooding and erosion to a downstream road, but an actual figure was impossible to determine.

South Tobacco Creek

On one tributary of the creek, three dams (#30, #31, #32) have resulted in reduced flooding and erosive damage to an R.M. road. Operating & Maintenance cost savings to the municipality have been $2000 to $2500 per year over the past five years (1989-1993) in the form of:

- Reduced backhoe/grader & operator time spent repairing and maintaining the road;
- Downsizing of culvert pipes (as less flow capacity is required) and;
- Less money spent to purchase gravel for road repairs and maintenance.

In the past five years, no culvert replacements and only one bridge structure were required within the South Tobacco Creek Watershed upstream from Miami. It is the R.M.'s view, the upstream Deerwood dams (#3-#20, #29, #39, #40, #41, #42, and #44) have extended the lifespans of many stream crossings by five to ten years, depending upon initial size and cost. Apparently due to reduced flooding and erosion, the one bridge which was replaced, was permitted to be reduced in size by 50%, and as some components of the original structure were salvageable, a net capital cost savings of $5500 (1992) was realised.

Graham Creek

Serious erosion of the municipal drainage ditch downstream of dam #37 occurred prior to its construction in 1989. The following is a poignant description of the problem and its apparent solution:

> Erosion was eating away the road North of the ditch along NE 24-4-7W. This dam created enough flood control allowing us to reconstruct the ditch, thus saving the road. While it cost us $5000 to rebuild the ditch, our cost of re-building the road would have been $30,000. We saved $25,000 (1990) because of this dam.
>
> (R.M. of Thompson, April, 1994)

Deerwood dams #33, #34, #35, and #36 have combined to reportedly prevent much flooding downstream. Based on the experience with Deerwood dam #37, the R.M. views these dams as a capital investment. Major flooding and culvert & bridge damage, which occurred during a previous summer storm has not been repeated, even within similar sized rainfall events. The cost savings have thus been considerable and were reported to be $25,000 (1991) by the municipality. These benefits are summarised in Table 5a.

Table 5a: R.M. of Thompson Reported Cost Savings Attributed to Deerwood's Dams: 1989-1993

R.M. Infrastructure Item	Dam No. (see Plate 4a)	Cost Savings
Reduced road damage	#30, #31, #32	$2000-$2500 per year (1989-93)
Extended lifespans of several stream crossings by 5 - 10 years and reduced required bridge size	#3 - #20, #29, #39, #40 - #42, #44	Extended capital value and $5500 for bridge reduction (1992$)
Preservation of ditch	#37	$25,000 (1990$)
Estimated benefits based on proven experience with #37	#33 - #36	$25,000 (1991$)

Rural Municipality of Roland

In response to the descriptive survey, the R.M. reviewed its works budget over two time periods: 1979-88 and 1989-93. As with the R.M. of Thompson, the municipal council was "confident and conservative" in the presentation of these numbers and; there was concern that figures not be exaggerated in any way. Additionally, there was a strong belief that Deerwood's dams were responsible for the cost reductions. Estimates for replacing bridges & culverts and dredging & maintaining ditches & stream crossings are summarised in Table 5b.

Table 5b: R.M. of Roland Reported Cost Savings Attributed to Deerwood's Dams: 1989-93

Budget Items	**1979 - 1988**	**1989 - 1993**
Crawler & Scraper includes: machine, operator, fuel	800 hours @ $80/hr. = $64,000/year	562 hours @ $80/hr. = $44,960/year
Materials includes: culverts, couplers, gravel, concrete, etc.	= $40,000/year	= $25,000/year
Tractor/Backhoe/Truck includes: machines, additional operator, etc.	= $7000/year	= $4900/year
Total	**$111,000/yr**	**$74,860/yr**

The R.M. of Roland attributed this dramatic decrease in operating and maintenance costs largely to Deerwood's work on the Tobacco and Graham Creeks, and two or three relatively large reservoirs on the Shannon Creek further South. Roland also contributes approximately $10.0K/year in backhoe/grader & operator time towards Deerwood's management efforts, and these costs were factored into Deerwood's total dam construction costs in Chapter Six. There was no doubt in the Council's view that Deerwood's dams are responsible for approximately 45% of this budget reduction. The Tobacco and Graham Creek Watersheds account for some 82 of the R.M.'s 180 square miles (45.6%) and; this is where most cost reductions have been experienced.

$111,000 - $74,860 = $36,140 @ 45.6% of municipality = $16,479.84 cost savings/year.

The municipality was able to cite several examples of reduced flooding damage. It was also reported that a general perception exists among many residents in the area that flow rates of both the Graham and Tobacco Creeks have slowed down considerably:

- "We no longer have flooding in the lower, Eastern part of the municipality"
- "Up to 1989-90, washouts have been a major problem; during 1980 and 1981, we replaced several culverts each year, at $10.0K to $12.0K per year"
- "We sincerely believe the water has slowed down; there is now less stress on culverts/bridges"
- "We would like to see Deerwood finish the job up there. It's really only 50% completed".

(R.M. of Roland, April, 1994)

Documentation of Individual Landowner Costs, Benefits, and Values

Response rates differed for North Tobacco and South Tobacco Creek landowners participating in the analytical survey. In the North Tobacco, 48 questionnaires were distributed with 17 respondents, for an overall response rate of 35.42%; while 55 South Tobacco residents received the questionnaire with 28 respondents, for an overall response rate of 50.91%. Raw data results were spreadsheet-tabulated (Tables 6a, 6b) on a question-by-question basis (columns), with the questionnaire number of each respondent listed (rows). Responses were grouped according to physiographic unit within each respective watershed (i.e. Upland, Escarpment, and Lowland). Response rates for each "a" (yes/no) question were determined in terms of physiographic unit, and cumulatively. Finally, the presence of additional comments was also noted on the spreadsheets.

Questionnaire structure was also reflected on the raw data spreadsheets. Three groups of respondents completed specific components of the questionnaire:

Damowner Respondents: completed questions regarding Dam Uses, Dam Costs, and Dam Importance & Value;

All Respondents: completed General questions regarding Flood Problems in Last Five Years, Erosion Problems in Last Five Years, Runoff Rate Changes in Last Five Years, Water Quality Changes in Last Five Years, Conservation Methods, and Farm Information and;

Non-Damowner Respondents: completed the initial dam ownership question which resulted in respondents' routing to either a) continue to question #2, or to skip to #17. Dam owners did not complete questions #29 - #32 (questions regarding Importance and Value of Creek).

The following landowner questionnaire template summarises responses received within each watershed. The number of respondents to each question is noted, in addition to particularly relevant respondent comments.

North Tobacco Creek

17 of 48 questionnaires returned (35.42%)

Survey Question Responses

1. a) *Is a small dam used to store water anywhere on your property which borders the North Tobacco Creek or the South Tobacco Creek (or upstream channels/tributaries)?* *Yes:* ☐ *No:* ☐
If yes, please continue below. If no, please go to question 17.

A total of 4 respondents had dams.

Dam Uses: (Completed by Damowners Only) ***Total Damowners: 4***

Is your dam used for the following purposes?

2. a) *Flood Damage Reduction:* *Yes:* ☐ *No:* ☐
b) *If yes, please describe how flooding is reduced with your dam:*

All 4 damowners reported the use of their dam(s) for flood damage reduction.

Summary Comments:

- **"Noticeable stream bed containment during heavy rains reported by downstream landowner"**
- **"It (dam) is used to lessen damage on downstream roads"**

3. a) *Soil Erosion Prevention:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how erosion is prevented with your dam:*

All 4 damowners reported the use of their dam(s) for soil erosion prevention.
Summary Comments:

- "(the dam) limits overflow (of water)."
- "Stream bed erosion is non-existent below dam."
- "Previous to dam construction, grassed waterways were being eroded. They are now stabilized."

4. a) *Stock Watering:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how cattle are watered using your dam.*

2 damowners reported the use of the dam(s) for stock-watering.
Summary Comments:

- "Extension of water flow through downstream pasture - more continuous supply."
- "Indirectly, the retained water is used to re-charge a well which is directed into a hog barn."

5. a) *Irrigation (e.g. backflood, traveling gun):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how you irrigate with water stored by your dam.*

3 damowners reported the use of their dam(s) for irrigation (all backflood[15]).
Summary Comments:

- "(I have) future plans to irrigate sub-soil with my second dam, it's installed on cultivated land."

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[15] Backfloods constitute a low earthen dam which impounds a low level of water over a relatively large area, typically for the irrigation of forage crops or pasture.

6. a) *Domestic Water Supply:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe your system.*

2 damowners reported the use of their dam(s) for domestic water supply.
Summary Comments:

- "Since dam construction, my well has never gone dry. Previously experienced seasonal deficiencies almost every winter."
- "Indirectly, the retained water is used to re-charge a well which is directly into my home."

7. a) *Waterfowl Habitat (e.g. ducks, geese):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how waterfowl habitat is created or maintained.*

3 damowners reported the use of their dam(s) for waterfowl habitat.
Summary Comments:

- "Some ducks staying all summer long."
- "We notice ducks, mostly mallards, but also some red-heads and wood ducks. They use the pond area during early season breeding when most larger water bodies are still frozen."

8. a) *Fish Pond (e.g. trout):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe, indicating type of fish stocked.*

0 damowners reported the use of their dam(s) for fish rearing.

9. a) *Other Wildlife Habitat (e.g. deer, songbirds):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how other wildlife habitat is created/maintained.*

2 damowners reported the use of their dam for other wildlife habitat.
Summary Comments:

- "Deer and moose regularly visiting the dam site."
- "Deer, moose, prairie chickens, and rabbits regularly visit the water source; as well as living in nearby bush and grassland."

10. a) Other Purposes: *Yes:* ☐ *No:* ☐

b) If yes, please explain the role of your dam.

0 damowners reported any other uses for their dam(s).

Dam Costs: (Completed by Damowners only) *Total Damowners: 4*

11. a) Have you experienced dam operating or maintenance costs? *Yes:* ☐ *No:* ☐

If yes:

b) Are these costs experienced annually or sporadically?

c) Please describe these costs.

0 damowners reported any operating or maintenance costs experienced with their dam(s).

12. a) Have you experienced unforeseen problems with your dam? *Yes:* ☐ *No:* ☐

b) If yes, please describe the nature of these problems

1 dam owner reported experiencing unforeseen problems with their dam(s).

Summary Comments:

- "Some repairs needed to stabilize shut-off control."

Dam Importance and Value: (Completed by Damowners Only) *Total Damowners: 4*

13. a) Do you believe this dam has caused groundwater levels to rise? *Yes:* ☐ *No:* ☐

b) If yes, please describe how you know

3 damowners believed groundwater levels have risen because of their dam(s).

Summary Comments:

- 1) "Well water has remained stable and,
  2) improved forage production on elevations below dam downstream."
- "In 1988, a nearby well went dry. As long as the dam is full, this well stays within 3' from the surface."

14. a) Do you believe this dam has improved the esthetic value of the landscape?

Yes: ☐ *No:* ☐

b) If yes, please explain.

1 dam owner believed their dam(s) improved the esthetic value of the landscape.
Summary Comments:

- **"We see more wildlife and waterfowl in the yard than before."**

1 dam owner believed their dam(s) had <u>both</u> a positive and negative esthetic value. No comments were provided.

15. a) Do you believe this dam has improved your family's quality of life? Yes: ☐ *No:* ☐

b) If yes, please explain.

1 dam owner believed their dam(s) improved their family's general quality of life.
Summary Comments:

- **"Marginally, It (the dam) is another source of entertainment and education for our children, in teaching them that water can be managed instead of just drained."**

16. a) Do you believe this dam has increased the value of your property? Yes: ☐ *No:* ☐

b) If yes, by what percentage since dam installation?_%

2 damowners believed their dam(s) increased the value of their property.
Summary Comments:

- **"Livestock security by 50% - no market value."**
- **"5%"**

Flooding Damage: (Completed by All Respondents) *Respondents: 17*

In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following flooding problems for you?

17. a) Seeding Problems (e.g. delays, poor germination): *Yes:* ☐ *No:* ☐
b) If yes, please describe the nature of these problems.

3 landowners reported experiencing seeding problems attributable to flooding damage.
Summary Comments:

- "Some small problems with beaver dams.
- "Floods about 7 acres in two places on my quarter section - delays seeding, washes crops out, some erosion, requires re-seeding."
- "Creek drowned out Canola seeded in June 1993."

18. a) Standing Crop Damage (e.g. sedimentation, summer flooding): *Yes:* ☐ *No:* ☐
b) If yes, please describe the nature of this damage.

5 landowners reported experiencing standing crop damage.
Summary Comments:

- "(Creek) overflow flooded most of my East quarter."
- "(Water) comes quickly out of hill after rain, jumps out of creek, thus crop damage!"
- "(Damaged) Canola (1993) and Wheat (1992)."
- "5 acres were flooded in 1993 - delayed swathing until ground dried."
- "(Water) covered small seedlings with soil."

19. a) Introduction of Weeds: *Yes:* ☐ *No:* ☐
b) If yes, please explain this problem further.

2 landowners reported experiencing the introduction of weeds via creek flooding.
Summary Comments:

- **"More milkweed and leafy spurge every year."**
- **"Milkweed."**

20. a) Property Damage (buildings, equipment, stored crops/feed): *Yes:* ☐ *No:* ☐
b) If yes, please describe this damage.

1 landowner reported experiencing property damage caused by flooding.
Summary Comment:

- **"Before construction of dam, some deepening of gulley at edge of cultivated field."**

21. a) Other: *Yes:* ☐ *No:* ☐
b) If yes, please explain.

2 landowners reported experiencing other flooding-related problems.
Summary Comments:

- **"Over the years, land which is regularly covered with water does not grow as well."**
- **"Erosion of side hill."**

Soil Erosion: (Completed by All Respondents): ***Respondents: 17***

In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following soil erosion problems for you?

22. a) Gulley Erosion (water creates a well defined channel in field): Yes: ☐ No: ☐
b) If yes, please describe the nature of this problem.

6 landowners reported experiencing gulley erosion.
Summary Comments:
- "(Water) dug channel in field in June 1993."
- "Gulley forming from runoff.
- "Annual erosion from steeper slopes - problem corrected with grassed waterways and alfalfa on higher slopes."
- "Water jumping the bank and running across the field parallel to the creek, causing washouts for a quarter mile."

23. a) Sheet Erosion (loss of soil over a wide span on field)?: Yes: ☐ No: ☐
b) If yes, please describe the nature of this problem.

4 landowners reported experiencing sheet erosion.
Summary Comments:
- "In places, water is flowing very fast. Saline areas are increasing."
- "Not over a wide span, but some areas had to filled in with a front-end loader."
- "Limited damage."
- "In the Spring of 1990, Tobacco Creek rose high enough to go out over a 30 acre field - we lost a fair bit of topsoil."

24. a) *Extensive RM ditch damage occurred near your property?:* *Yes:* ☐ *No:* ☐
    b) *If yes, please describe if/how your land or other property was affected.*

3 landowners reported extensive ditch damage near their property.
Summary Comment:

- 2 or 3 miles West, the R.M.'s road was nearly washed out; a very deep ditch cut into the shoulder.

1 landowner reported serious damage further downstream. The comments are most poignant.
Summary Comment:

- "In the 1950's the creek running East from the Five Corners was no deeper than a man's height. Now it is unsafe to drive alongside. Many other drains in the area have experienced the same effect."

25. a) *Other:* *Yes:* ☐ *No:* ☐
    b) *If yes, please explain.*

2 landowners reported other effects of erosion.
Summary Comments:

- "Control dams are great but; beavers are causing alot of damage to standing trees, with more lost every year. Trappers should be compensated to trap beavers."
- "Need more dams upstream, ditch gradually getting worse."

General: (Completed by all Respondents): ***Respondents: 17***

26. During the last five years, have you noticed changes in the following?

a) The length of Spring runoff in the creek draining your land? *Yes:* ☐ *No:* ☐

b) If yes, please explain.

5 landowners reported noticing changes in the length of Spring runoff in the creek.
Summary Comments:

- "Spring runoff has been very short and small."
- "No snow."
- "In general, a shorter period of time."
- "Water drains slowly all summer. Before, the creek stopped running in July." (dam owner)
- "Dam on the creek extends the runoff period well into late June." (dam owner)

c) The quality of water within the creek after a Summer storm? *Yes:* ☐ *No:* ☐

d) If yes, please describe.

3 landowners reported noticing changes in creek water quality after a summer storm.
Summary Comments:

- "(Creek) contains more soil."
- "Very muddy."
- "Observed water from my drainage basin compared to Boyne Creek West of Roseile
  - very different in colour (respondent's drainage much clearer) after a major rain." (dam owner).

27. a) Do you practice any methods of land and water conservation? *Yes:* ☐ *No:* ☐

b) If so, please describe which types, and for how long?

12 landowners reported their practice of land and water conservation.
Summary Comments:

- "Reduced tillage - try to leave more straw on field."
- "Built a small dam myself - but it is hard to maintain."
- "Minimum tillage."
- "Everything I do."
- "Forage on steeper land; shelterbelts; grassed waterways; minimum tillage; want to do contours."

28. a) *Please indicate the type of farm you operate.*
Cash Crops: ☐ *Livestock:* ☐ *Dairy:* ☐ *Mixed:* ☐
b) *If Mixed, please indicate which areas.* _____

An even mix of landowners reported operating cash crops or mixed (cattle/hogs & grains/oilseeds).

Creek Importance and Value: (Completed by Non-Dam Owners Only)

Total Non-Damowners: 13

If you own a dam, and have completed questions 1-28, please ignore the following. All others, please continue.

29. a) *Is the creek important to your farming operation?* *Yes:* ☐ *No:* ☐
b) *If yes, please explain how.*

6 landowners reported the creek was important to their farming operations.
Summary Comments:

- **"The potential exists to irrigate crops; raise the water level and slow down flooding."**
- **"I would like to start a small amount of Saskatoons - interested in selling garden vegetables and waterfowl."**
- **"Drainage."**
- **"Water for cattle." (3)**

30. a) *Do you believe the creek improves the overall esthetic value of the local landscape?*
Yes: ☐ *No:* ☐
b) *If yes, please describe.*

8 landowners reported their belief the creek improves esthetic value.
Summary Comments:

- **"The original plan was not far off. We should quit tampering with it."**
- **"Water, plant life, water for wildlife."**
- **"Beauty."**

31. a) Do you believe the creek improves the general quality of life for you and your family?

Yes: ☐ *No:* ☐

b) If yes, please explain.

8 landowners reported believing the creek improves general quality of life.

Summary Comments:

- "Water recharge - can't live without water."
- "I enjoy walking in the bush, seeing various wildlife. Windbreak effect of trees is great."
- "Enjoyment of creek presence, wildlife etc."
- "Beauty."

32. a) Do you believe the creek increases the value of your property? *Yes:* ☐ *No:* ☐

b) If yes, by what percentage if compared to similar land without a creek? ______ %

2 landowners reported believing their property values are increased by the creek's presence.

Summary Comments:

- "20%"
- "25%"

Additional Comments (Completed by All Respondents) *Respondents: 17*

5 respondents provided additional comments.

Summary Comments:

- "Land with no creek is worth more (easier to farm). Owners should be helped to keep creek functional.
- "I think Deerwood SWMA should build a few more dams upstream. They seem to be cost-efficient."
- "A small dam would improve our stock watering capacity. In dry years, our water flow is reduced to springs, especially during July and August."
- "Our land is all bush and rolling hills. It pleases me to have a creek nearby."

South Tobacco Creek

28 of 55 questionnaires returned (50.91%)

Survey Question Responses

1. a) *Is a small dam used to store water anywhere on your property which borders the North Tobacco Creek or the South Tobacco Creek (or upstream channels/tributaries)?* *Yes:* ☐ *No:* ☐
If yes, please continue below. If no, please go to question 17.

A total of 15 respondents had dams.

Dam Uses: (Completed by Dam Owners Only) *Total Damowners: 15*

Is your dam used for the following purposes?

2. a) *Flood Damage Reduction:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how flooding is reduced with your dam:*

All 15 damowners reported the use of their dam(s) for flood damage reduction.

Summary Comments:

- **"Slowed flow of water into South Tobacco Creek which helps reduced flooding downstream."**
- **"(Dam is) used as a flow inhibitor. Water is stored and released over a period of several days."**
- **"Runoff is controlled in proper channel. Water walks, does not run off."**
- **"It reduces the flow rate at the bottom end."**
- **"Volume of water flow is significantly reduced."**
- **"It (dam) slows down water that enters the main Tobacco Creek vein."**
- **"(Dam) slows water up."**
- **"The dam is above a field road; the pipe doesn't wash out."**
- **"The flow is reduced, or limited to a 12" flow."**
- **"Dam controls Spring runoff - keeps drainage from an 80 acre bush in stabilised gulley."**
- **"Dam stores runoff for release later in Spring."**

3. a) *Soil Erosion Prevention:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how erosion is prevented with your dam:*

12 damowners reported the use of their dam(s) for soil erosion prevention.
Summary Comments:

- "Dam slows down runoff of water."
- "Downstream erosion prevented by allowing a smaller volume of water instead of a larger volume all at one time."
- "Water is controlled. Prevents flash flooding."
- "It (dam) reduces the flow of water at the bottom end."
- "(Dam) controls stream bank erosion downstream."
- "Downstream erosion along the watershed is reduced."
- "(Dam) slows the speed of water to the main Tobacco vein."
- "Slows water up."

"Prevents creek bank erosion."

"(Dam) reduces runoff through 12" pipe so runoff stays in stabilized gulley or drain that crosses rest of quarter section.

4. a) *Stock Watering:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how cattle are watered using your dam.*

9 damowners reported the use of their dam(s) for stock-watering.
Summary Comments:

- "Pump water out of dam to watering trough."
- "Mostly direct watering. A pump-out would be better."
- "They (cattle) help themselves."
- "Cattle have free access to water in dams. Fencing and water troughs are planned for the future."
- "Solar-powered pump and trough."
- "Cattle water directly at dam - part of a rotational pasture system. Dam is only source of water."

5. a) *Irrigation (e.g. backflood, traveling gun):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how you irrigate with water stored by your dam.*

3 damowners reported the use of their dam(s) for irrigation (all backflood[16]).
Summary Comments:

- **"Some backflood on pasture."**
- **"Backflood on pasture."**
- **"Pasture backflood recharges subsoil with Spring runoff."**

6. a) *Domestic Water Supply:* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe your system.*

0 damowners reported the use of their dam(s) for domestic water supply.

7. a) *Waterfowl Habitat (e.g. ducks, geese):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how waterfowl habitat is created or maintained.*

11 damowners reported the use of their dam(s) for waterfowl habitat.
Summary Comments:

- **"Grass and rushes grow around dam for shelter and nesting ground."**
- **"(Dam) replaces prairie slough which have been drained."**
- **"Nesting area - water available for a longer period."**
- **"Notice more ducks and geese - mallards, Canadas, wood ducks etc."**
- **"Water is stored and plant life is maintained around pond for cover."**
- **"Dam creates a pond. The pond has been habitat for waterfowl."**
- **"Ducks and geese nest there."**
- **"Wood ducks attracted to nest boxes."**
- **"Two wood ducks maintain a nest each year. All sorts of wildlife around dams."**
- **"Dam creates a slough. Water levels are maintained year-round - cattle are fenced out."**

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[16] Backfloods constitute a low earthen dam which impounds a low level of water over a relatively large area, typically for the irrigation of forage crops or pasture.

8. a) *Fish Pond (e.g. trout):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe, indicating type of fish stocked.*

5 damowners reported the use of their dam(s) for fish rearing.
Summary Comments:

- "Presently have minnows. May stock with fingerlings in future."
- "Rainbow trout. Have harvested trout in the Fall for two years."
- "Will stock the dam this year with trout."
- "Tried trout for two years, but harvest was unsuccessful."

9. a) *Other Wildlife Habitat (e.g. deer, songbirds):* *Yes:* ☐ *No:* ☐
   b) *If yes, please describe how other wildlife habitat is created/maintained.*

11 damowners reported the use of their dam for other wildlife habitat.
Summary Comments:

- "There are deer in this area. Dam will be a water source if South Tobacco Creek fails to flow."
- "Enhances wildlife habitat somewhat comparable to what beaver dams did in the past."
- "More shorebirds etc."
- "Excellent water source for deer, raccoons, etc."
- "Deer water and have their young nearby. Great watering hole for all birds and animals."
- "Fenced wildlife slough area around dam."

10. a) *Other Purposes:* *Yes:* ☐ *No:* ☐
    b) *If yes, please explain the role of your dam.*

3 damowners reported any other uses for their dam(s).
Summary Comments:

- "Earth dam provides access to fields isolated by steep terrain."
- "It beautifies the valley and surroundings."
- "It has improved our house water well level."

Dam Costs: (Completed by Damowners Only) ***Total Damowners: 15***

11. a) Have you experienced dam operating or maintenance costs? *Yes:* ☐ *No:* ☐

If yes:

b) Are these costs experienced annually or sporadically?

c) Please describe these costs.

3 damowners reported operating or maintenance costs experienced with their dam(s).

Summary Comments:

- **"Old dams built in the 1950's were repaired by the Conservation District in 1992 @ $5.0K each. Were repaired again by Deerwood in 1993 @ $5.0K total (paid by PVCD)**[17]
- **"Overflow culvert was too small and washed out in 1992. I replace @ $500. I would like to install another but cannot afford it. Deerwood would not fund this dam**[18]**, and I made a mistake installing too small of a culvert and no spillway, for complete water storage. I guess Deerwood was right and; they can go to hell."**
- **"Once in 8 years, Spring ice bent the gate inlet."**

12. a) Have you experienced unforeseen problems with your dam? *Yes:* ☐ *No:* ☐

b) If yes, please describe the nature of these problems

5 damowners reported experiencing unforeseen problems with their dam(s).

Summary Comments:

- **"Outlet gate is leaking."**
- **"Culvert has broken apart, and dam cannot hold water (for a long period of time)."**
- **"Improper repairs by PVCD required additional repairs, which Deerwood carried out. Dams appear to be holding well now**[19]
- **"Overflow is too small and in the wrong place**[20]

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[17] Although they now form part of the Deerwood network, these dams were not built by Deerwood (likely by the R.M. of Thompson in the 1950's). Consequently, its costs are relevant to this study.

[18] This is another dam which contributes somewhat to headwater storage in the South Tobacco Creek watershed. It however, was not funded by Deerwood, and its costs are not relevant to this study.

[19] These are the same dams referenced in footnote #12.

[20] This is the same dam referenced in #12.

Dam Importance and Value: (Completed by Damowners Only) ***Total Damowners: 15***

13. a) Do you believe this dam has caused groundwater levels to rise? *Yes:* ☐ *No:* ☐

b) If yes, please describe how you know

9 damowners believed groundwater levels have risen because of their dam(s).
Summary Comments:

- "Water table seems to be higher."
  "Springs have appeared downstream."
- "Water (in dam) is soaking away."
- "Nothing obvious with my dam, but I have seen my neighbour's well rise with his dam."
- "The levels are higher. We now have plenty of water for garden etc."
- "In dry years, our well supplies adequate water, because of a dam which backfloods our pasture, which is a 1/2 mile away."

14. a) Do you believe this dam has improved the esthetic value of the landscape?

Yes: ☐ *No:* ☐

b) If yes, please explain.

11 damowners believed their dam(s) improved the esthetic value of the landscape.
Summary Comments:

- "Water is our life blood for farming."
- "Greater abundance of birds and animals in the vicinity."
- "Increased wildlife populations - ability to increase vegetative growth adjacent to dams and downstream."
- "Permanent water where water normally is not."
- "Seeing stored water in the Spring makes you appreciate water as a resource, not as a drainage problem."

15. a) *Do you believe this dam has improved your family's quality of life?* *Yes:* ☐ *No:* ☐
    b) *If yes, please explain.*

8 damowners believed their dam(s) improved their family's general quality of life.
Summary Comments:

- "We look forward to Canada geese nesting and watch them daily."
- "We hope!!"
- "Dams have increased our pasture carrying capacity. Therefore, increased net income."
- "Having fish in the dam, and knowing ducks are using it."
- "We made a campsite down at our dam, and visit it often.
- "We go row boating on one dam, or just visit them (dams) for an outing."
- "Having more wildlife around."
- "Every Spring we tour the dam as a family to do bird counts. We do alot of wildlife watching in the Summer; and the kids keep bird nesting boxes."

16. a) *Do you believe this dam has increased the value of your property?* *Yes:* ☐ *No:* ☐
    b) *If yes, by what percentage since dam installation? _%*

8 damowners believed them dam(s) increased the value of their property.
Summary Comments:

- "20%"
- "1-2%"
- "5"
- "10"
- "20"

Flooding Damage: (Completed by All Respondents) **Respondents: 28**

In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following flooding problems for you?

17. a) Seeding Problems (e.g.. delays, poor germination): *Yes:* ☐ *No:* ☐
b) If yes, please describe the nature of these problems.

3 landowners reported experiencing seeding problems attributable to flooding damage.
Summary Comment:

- "Creek banks are higher than the fields. When it spills over the banks, water runs across the field."

18. a) Standing Crop Damage (e.g. sedimentation, summer flooding): *Yes:* ☐ *No:* ☐
b) If yes, please describe the nature of this damage.

5 landowners reported experiencing standing crop damage.
Summary Comments:

- "Gate on culvert lets water out of R.M. ditch and on to field."
- "Gulleying and siltation were the major result of Summer flooding from South Tobacco Creek overtopping its channel (and from local flooding - highway and R.M. ditches.)
- "Trees and sticks along with sediment on a few acres of grassland."
- "Runs have been cut in field which causes sedimentation in lower areas."

19. a) Introduction of Weeds: *Yes:* ☐ *No:* ☐
b) If yes, please explain this problem further.

4 landowners reported experiencing the introduction of weeds via creek flooding.
Summary Comments:

- "Very little."
- "Milkweed."
- "Leafy spurge showing up near creek in pasture, presumably brought in by creek water."

20. a) *Property Damage (buildings, equipment, stored crops/feed):* *Yes:* ☐ *No:* ☐
    b) *If yes, please describe this damage.*

2 landowners reported experiencing property damage caused by flooding.
Summary Comments:

- "Flooded my machine shed and some grain (500 bu.)"
- "(Lost land due to) stream bank erosion."

21. a) *Other:* *Yes:* ☐ *No:* ☐
    b) *If yes, please explain.*

4 landowners reported experiencing other flooding-related problems.
Summary Comments:

- "field siltation from R.M. ditch flooding onto filed left a layer of silt up to 3" deep on 5 acres. Lost productivity for two years."
- "Beavers have dammed up a considerable amount of water. However, no farmland damage yet."
- "Field near road culvert was partially washed out."

  "The usual pot-hole flooding etc."

Soil Erosion: (Completed by All Respondents): *Respondents: 28*

In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following soil erosion problems for you?

22. a) *Gulley Erosion (water creates a well defined channel in field):* *Yes:* ☐ *No:* ☐
    b) *If yes, please describe the nature of this problem.*

4 landowners reported experiencing gulley erosion.
Summary Comments:

- "Where trees have been cut, it has washed."
- "Water spills over the banks and runs down the field."
- "Mainly Spring flooding from South Tobacco Creek cut a 3' deep gulley across field.
- "Runs have been cut in field which cause sedimentation in lower areas."

23. a) *Sheet Erosion (loss of soil over a wide span on field)?:* *Yes:* ☐ *No:* ☐
 b) *If yes, please describe the nature of this problem.*

5 landowners reported experiencing sheet erosion.
Summary Comments:

- "Heavy rains in short time. I doubt if these dams will help. Hard to defend against a cloudburst."
- "Heavy Spring rain after seeding in 1991 caused significant sheet erosion."
- "Mostly hill areas in field have had the most soil loss."

24. a) *Extensive RM ditch damage occurred near your property?:* *Yes:* ☐ *No:* ☐
 b) *If yes, please describe if/how your land or other property was affected.*

4 landowners reported extensive ditch damage near their property.
Summary Comment:

- "Silt settles along the ditch."
- "R.M. is changing water from natural water channels across private property into ditches -sending too much water where it was not intended to go.
- "Water leaves highway #23 ditch and crosses field, resulted in siltation twice in 1991. Dam since built should prevent problem."
- "Water is running from ditch across a field and washing out topsoil into another ditch."

25. a) Other: *Yes:* ☐ *No:* ☐

b) If yes, please explain.

1 landowner reported other effects of erosion.

Summary Comment:

- "We try to keep the creek as is with trees etc., but on some curves (meanders) there is wash."

General: (Completed by all Respondents): *Respondents: 28*

26. During the last five years, have you noticed changes in the following?

a) The length of Spring runoff in the creek draining your land? *Yes:* ☐ *No:* ☐

b) If yes, please explain.

14 landowners reported noticing changes in the length of Spring runoff in the creek.

Summary Comments:

- "The water takes long to get here."
- "Creek does not get as high and runoff lasts longer."
- "Creek runs for a longer period of time."
- "Seems to me, creek flooding is reduced and creek flows for longer time at reduced flows. Keeping creek running helps keep creek clean."
- "Slight lengthening of runoff."
- "The water is holding in dam."
- "Beaver dam hold water back."
- "Water takes longer to move. It does not <u>run</u>, it <u>walks</u>."
- "Creeks are running longer through season due to controlled release from dam."
- "The dams slow the flow of water."
- "Dam slows Spring runoff."
- "The creeks have run longer, but as a result of more snow and slower melt."
- "It runs longer because of the control pipe (12")."

c) The quality of water within the creek after a Summer storm? *Yes:* ☐ *No:* ☐

d) If yes, please describe.

8 landowners reported noticing positive changes in creek water quality after a summer storm. Two landowners noticed negative changes in creek water quality

Summary Comments:

- "The water still has silt in it, but has improved some."
- "I am sure creek water is clearer than in the past."
- "Still significant streambank erosion - hides benefits of reduced tillage/trash management in rest of watershed."
- "The water is cleaner."
- "It's clearer."
- "Any improvement in water quality would be directly attributable to upstream farming practices."
- "Had dam only two years, but water flow looks clean and blue."
- "Usually quite dirty - silt from upstream."
- "Alot more sediment, such as dirt and shale in creek bed."

27. a) Do you practice any methods of land and water conservation? *Yes:* ☐ *No:* ☐

b) If so, please describe which types, and for how long?

22 landowners reported their practice of land and water conservation.

Summary Comments:

- "We seeded the grass by the creek and; we don't cut any trees in the creek."
- "Planted saline-tolerant grasses and legumes in saline areas."
- "Leave grass in small water runs in field."
- "We have always used grass in our cropping programme. We also built the dam to slow water down and help groundwater."
- "Conservation tillage, no stubble burning, continuous cropping etc. -15 years."
- "Reduced tillage, sewed forages, shelterbelts, stabilized gulley -10 years."
- "Minimum till, straw management, grassed waterways etc. -30 years"
- "Increased surface residue on crop land -3 years. Working toward No-Till."
- "Trees. Nobody cuts live trees on my land. I cut only dead ones."
- "Land is in hay meadow or forages."
- "Continuous cropping and no stubble-burning. -20 years, it works well!"

28. a) *Please indicate the type of farm you operate.*
Cash Crops: ☐ *Livestock:* ☐ *Dairy:* ☐ *Mixed:* ☐
b) *If Mixed, please indicate which areas.* _____

An even mix of landowners reported operating cash crops or mixed (cattle/hogs & grains/oilseeds).

Creek Importance and Value: (Completed by Non-Dam Owners Only)

Respondents: 13

If you own a dam, and have completed questions 1-28, please ignore the following. All others, please continue.

29. a) *Is the creek important to your farming operation?* *Yes:* ☐ *No:* ☐
b) *If yes, please explain how.*

3 landowners reported the creek was important to their farming operations.
Summary Comments:

- "Water for livestock in Summer."
- "Livestock and; I also use it to water garden in the Summer."
- "Irrigating the garden."
- "Supports hardwoods that supply fuel."

30. a) *Do you believe the creek improves the overall esthetic value of the local landscape?*
Yes: ☐ *No:* ☐
b) *If yes, please describe.*

7 landowners reported their belief the creek improves esthetic value.
Summary Comments:

- "As compared to flat prairie land, it is mostly tree-lined and pleasant to look at."
- "Wildlife mainly."
- "Attracts wildlife."

31. a) *Do you believe the creek improves the general quality of life for you and your family?* *Yes:* ☐ *No:* ☐

b) *If yes, please explain.*

7 landowners reported believing the creek improves general quality of life.

Summary Comments:

- "Spiritually."
- "Esthetics."
- "Wildlife such as ducks, deer, beavers etc. can be seen regularly."
- "Place to go on hikes, nature walks."

32. a) *Do you believe the creek increases the value of your property?* *Yes:* ☐ *No:* ☐

b) *If yes, by what percentage if compared to similar land without a creek?* ______ *%*

4 landowners reported believing their property values are increased by the creek's presence.

Summary Comments:

- "5%"
- "20%"

Additional Comments (Completed by All Respondents) *Respondents: 28*

10 respondents provided additional comments.

Summary Comments:

- "I would like to see more small dams in our area. Since the dams have been put in. In the last two years, our creek ran all Summer. We also have had more rain."
- "In the 1950's the creek was a small runway that was in grass. The R.M. has straightened it, pushed up its banks, and has to be cleaned out with a dragline.
  This happens every few years."
- "I think all dams should have a holding area in front of them, in order to get the most use.
- "Small dams, although important, are a small part of the overall farming practices necessary for soil conservation or the "buzz words" today - *sustainable development.*

6. ANALYSIS AND DISCUSSION

Analysis Framework

As discussed in Chapter Three, Krutilla and Fisher's review of commodity and amenity resource valuation (1975) provided an excellent framework for the analysis of small scale headwater storage initiatives of the Deerwood Soil and Water Management Association. This model recommended comprehensive analysis of the "ostensible" or "true" costs and the apparent (readily measurable) benefits of resource management and development projects which are dependent upon public capital. Krutilla and Fisher also noted, professionally competent analysis of tangible costs and benefits can make the task of analysing environmental and social values unnecessary; these values are often intangible.

The evaluation process was designed to build a rational case in support of Deerwood's small scale headwater retention model of watershed management. If the existence of such tangible benefits could be proven to exceed actual small dam costs, detailed estimates of environmental and social benefits would not be required to prove overall project worth. However, noting and describing the presence of intangible benefits and costs would serve to strengthen the analysis.

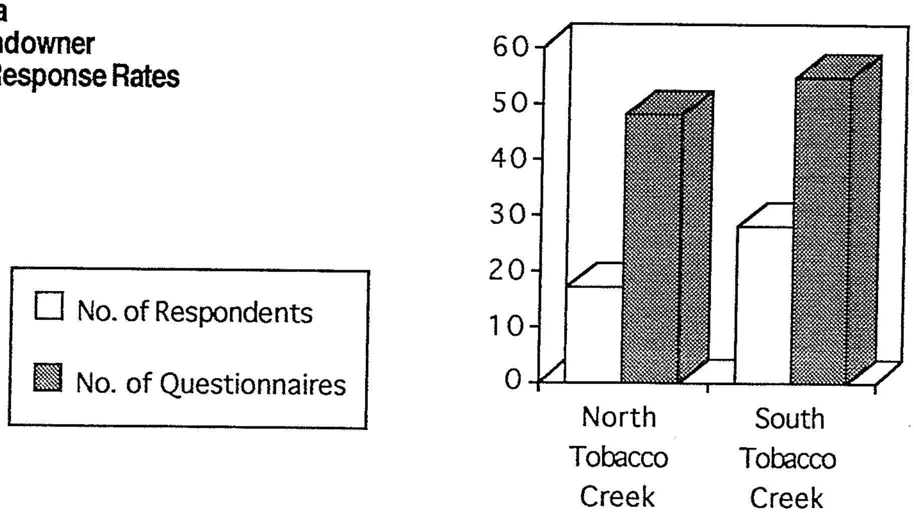
An overview of data generated via the landowner survey provided evidence in support of a control scenario between the North and South Tobacco Creek Watersheds. After a review of each landowner survey question, the tangible benefits and costs of Deerwood's dams were analysed using municipal data and Deerwood dam cost information. Generally intangible, the perceived environmental and social benefits of these structures were then discussed according to information gleaned from the landowner survey and case study information. Finally, a review of potential intangible costs was provided.

Small Dam Impacts Reported Via Landowner Survey

Tables 6a and 6b represent landowner responses to survey questions from the North and South Tobacco Creek Watersheds. Figure 6a indicates questionnaire response rates within both watersheds; rates of 35.42% and 50.91% were seen for the North and South Tobacco respectively. While difficult to substantiate, the author perceived a certain degree of animosity toward and/or disinterest regarding Deerwood's activities among landowners in the North Tobacco. This may partially account for the difference in survey response rates. There are a similar number of absentee landowners within each watershed area, nullifying the potential response rate impacts of non-residency. The following comments covered the range of reasons for non-response to the landowner survey, as determined through random follow-up telephone contact:

- "I didn't have time - too busy."
- "I didn't understand why it was relevant to my situation."
- "I solved my water problems a long time ago. I drained my land and filled the potholes as best I could in order to get the water off as fast as possible."

Figure 6a
Dam/Landowner
Survey Response Rates



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
55			IF DAM OWNERS, USES OF DAM																		
1	Num	Physiography	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b
2	201	Lowland																			
3	204	Lowland	1	1	1	1	1			1	1			1							
4	205	Lowland																			
5	207	Lowland																			
6	209	Lowland																			
7	211	Lowland																			
8	212	Lowland																			
9	213	Lowland		1																	
10	223	Lowland																			
11		Subtotal	1	2		1				1				1							
12		Resp's	17	4		4				4				4							
13		Approx %	6	50		25				25				25							
14	242	Escarpment																			
15	243	Escarpment																			
16	215	Escarpment	1			1				1	1										
17	219	Escarpment																			
18	235	Escarpment																			
19	221	Escarpment	1	1	1	1	1	1	1	1	1	1	1	1	1			1	1		
20		Subtotal	2	1		2		1		2		1		1				1			
21		Resp's	17	4		4		4		4		4		4				4			
22		Approx %	12	25		50		25		50		25		25				25			
23																					
24																					
25	222	Upland																			
26	246	Upland	1	1	1	1	1	1	1			1	1	1	1			1	1		
27		Subtotal	1	1		1		1		1		1		1				1			
28		Resp's	17	4		4		4		4		4		4				4			
29		Approx %	6	25		25		25		25		25		25				25			
30																					
31																					
32		Total	4	4		4		2		4		2		3				2			
33		Tot Resp's	17	4		4		4		4		4		4				4			
34		Approx %	24	##		##		50		##		50		75				50			
35																					
36																					
37																					
38																					
39																					
40																					
41																					
42																					
43																					
44																					
45																					
46																					
47	n = 48																				
48	RESP = 17																				
49	RR = 17/48 *100 = 35.42%																				
50																					
51																					
52																					
53																					

	A	B	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
55			DAM COSTS				DAM BENEFITS								FLOODING DAMAGE/ 5 YEARS									
1	Num	Physiography	11a	11b	12a	12b	13a	13b	14a	14b	15a	15b	16a	16b	17a	17b	18a	18b	19a	19b	20a	20b	21a	21b
2	201	Lowland													1	1								
3	204	Lowland															1	1						
4	205	Lowland													1	1	1	1	1	1			1	1
5	207	Lowland													1	1	1	1	1	1				
6	209	Lowland															1	1						
7	211	Lowland																						
8	212	Lowland																						
9	213	Lowland																						
10	223	Lowland																						
11		Subtotal													3		4		2				1	
12		Resp's													17		17		17				17	
13		Approx %													18		24		12				6	
14	242	Escarpment																						
15	243	Escarpment															1	1					1	1
16	215	Escarpment					1		1															
17	219	Escarpment																						
18	235	Escarpment																						
19	221	Escarpment			1	1	1	1					1	1							1	1		
20		Subtotal			1		2		1				1				1				1		1	
21		Resp's			4		4		4				4				17				17		17	
22		Approx %			25		50		25				25				6				6		6	
23																								
24																								
25	222	Upland																						
26	246	Upland					1	1	1	1	1	1	1	1										
27		Subtotal					1		1		1		1											
28		Resp's					4		4		4		4											
29		Approx %					25		25		25		25											
30																								
31																								
32		Total			1		3		2		1		2		3		5		2		1		2	
33		Tot Resp's			4		4		4		4		4		17		17		17		17		17	
34		Approx %			25		75		50		25		50		18		29		12		6		12	

	A	B	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP
55			EROSION DAMAGE/5 YEARS								RUN t, H2O QI				CONS		FARM		NO-DAM CREEK BENEFITS								AD
1	Num	Physiography	22a	22b	23a	23b	24a	24b	25a	25b	26a	26b	26c	26d	27a	27b	28a	28b	29a	29b	30a	30b	31a	31b	32a	32b	ADD
2	201	Lowland													1		CA										
3	204	Lowland			1	1							-1	1			CA		1	1	1		1		1	1	
4	205	Lowland			1	1	1	1	1	1					1	1	CA		1	1	1	1	1	1			1
5	207	Lowland	1	1											1	1	CA		1	1	1		1				
6	209	Lowland									-1	1			1	1	CA				1	1	1	1			
7	211	Lowland									-1	1					MI1	1									
8	212	Lowland					1	1									MI1	1	1	1							
9	213	Lowland	1	1			1	1	1	1			-1	1	1	1	MI1	1	1	1	1		1	1			1
10	223	Lowland			1	1																					
11		Subtotal	2		3		3		2		2		2		5				5		5		5		1		2
12		Resp's	17		17		17		17		17		17		17				13		13		13		13		17
13		Approx %	12		18		18		12		12		12		29				38		38		46		8		12
14	242	Escarpment																			1	1	1	1	1	1	1
15	243	Escarpment	1	1											1	1	CA				1	1	1	1			
16	215	Escarpment	1												1		CA										
17	219	Escarpment													1	1	CA				1		1				
18	235	Escarpment	1	1							-1	1			1	1	MI1	1	1	1							1
19	221	Escarpment	1	1	1	1	SEE ADD COMMENT				1	1	1	1	1	1	MI1	1									1
20		Subtotal	4		1						2		1		5				3		4		4		1		4
21		Resp's	17		17						17		17		17				13		13		13		13		17
22		Approx %	24		6						12		6		29				23		31		31		8		24
23																											
24																											
25	222	Upland													1	1	MI1	1									
26	246	Upland									1				1	1	MI1	1									
27		Subtotal									1				2												
28		Resp's									17				17												
29		Approx %									6				12												
30																											
31																											
32		Total	6		4		3		2		5		3		12				6		8		8		2		5
33		Tot Resp's	17		17		17		17		17		17		17				13		13		13		13		17
34		Approx %	35		24		18		12		29		18		71				46		62		62		15		29

Table 6a
North Tobacco Creek Survey Responses

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
55			IF DAM OWNERS, USES OF DAM																		
1	NUM	Physiography	1	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b	10a	10b
2	101	Lowland																			
3	103	Lowland	1	1		1		1						1	1			1			
4	104	Lowland																			
5	105	Lowland																			
6	109	Lowland																			
7	114	Lowland																			
8	115	Lowland	1	1	1	1	1	1	1					1	1			1	1		
9	123	Lowland																			
10	124	Lowland																			
11		Subtotal	2	2		2		2						2				2			
12		Resp's	28	15		15		15						15				15			
13		Approx %	7	13		13		13						13				13			
14																					
15	125	Escarpment	1	1	1	1	1														
16	129	Escarpment																			
17	130	Escarpment																			
18	132	Escarpment																			
19	133	Escarpment	1	1	1		1		1						1				1		
20	136	Escarpment	1	1	1	1	1	1	1	1	1			1	1			1	1		
21	138	Escarpment	1	1	1	1	1	1	1												
22	139	Escarpment	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1
23	141	Escarpment	1	1	1			1	1	1	1			1	1						
24	145	Escarpment	1	1	1	1	1							1	1	1	1	1	1		
25	146	Escarpment																			
26	147	Escarpment	1	1	1	1	1	1	1					1	1	1	1	1	1	1	1
27	157	Escarpment	1	1	1	1	1	1	1	1	1			1	1			1	1		
28	148	Escarpment																			
29	150	Escarpment	1	1	1	1	1									1	1	1			
30		Subtotal	10	10		8		6		3				6		4		6		2	
31		Resp's	28	15		15		15		15				15		15		15		15	
32		Approx %	36	67		53		40		20				40		27		40		13	
33	134	Upland	1	1	1	1	1							1	1			1	1		
34	153	Upland																			
35	155	Upland	1	1	1	1	1	1	1					1	1	1	1	1	1		
36	156	Upland	1	1	1									1	1			1		1 PE	1
37																					
38		Subtotal	3	3		2		1						3		1		3		1	
39		Resp's	28	15		15		15						15		15		15		15	
40		Approx %	11	20		13		7						20		7		20		7	
41																					
42		Total	15	15		12		9		3				11		5		11		3	
43		Tot Resp's	28	15		15		15		15				15		15		15		15	
44		Approx %	54	##		80		60		20				73		33		73		20	
45																					
46																					
47																					
48																					
49																					
50																					
51	n = 56-2+1=55																				
52	Respondents = 28																				
53	RR = 28/55 * 100 = 50.91%																				

	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
55	DAM COSTS				DAM BENEFITS								FLOODING DAMAGE/ 5 YEARS									
1	11a	11b	12a	12b	13a	13b	14a	14b	15a	15b	16a	16b	17a	17b	18a	18b	19a	19b	20a	20b	21a	21b
2																	ADD	ADD				
3									1	1							1	1				
4																						
5													1	1	1	1	1	1				
6																						
7																						
8						1	1	1														1
9																	1	1				
10													1	1	1	1	1	1			1	1
11							1		1				2		2		4				1	
12							15		15				28		28		28				28	
13							7		7				7		7		14				4	
14																						
15			1	1			1	1			1	1							1	1		
16															1	1						
17																					1	1
18																						
19																						
20					1	1	1		1	1	1											
21			1	1																		
22	1	ND	1	ND	1	1	1	1	1	1	1	1							1	1		
23					1	1																
24							1		1	1	1	1										
25																						
26	1	ND	1	ND	1	1	1	1	1	1	1	1										
27			1	1	1	1	1	1	1	1	1	1										
28													1		1							
29					1		1															
30	2		5		6		7		5		6		1		2				2		1	
31	15		15		15		15		15		15		28		28				28		28	
32	0		33		40		47		33		40		4		7				7		4	
33					1	1	1	1														
34																					1	1
35	1	1			1	1	1	1	1	1	1	1			1	1						
36					1	1	1		1	1	1										1	1
37																						
38	1				3		3		2		2				1						2	
39	15				15		15		15		15				28						28	
40	7				20		20		13		13				4						7	
41																						
42	3		5		9		11		8		8		3		5		4		2		4	
43	15		15		15		15		15		15		28		28		28		28		28	
44	20		33		60		73		53		53		11		18		14		7		14	
45																						
46																						
47																						
48																						
49																						
50																						
51																						
52																						
53																						

	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO	BP
55	EROSION DAMAGE/5 YEARS								RUN t, H2O QI				CONS		FARM		NO-DAM CREEK BENEFITS								AD
1	22a	22b	23a	23b	24a	24b	25a	25b	26a	26b	26c	26d	27a	27b	28a	28b	29a	29b	30a	30b	31a	31b	32a	32b	ADD
2	1	1	ADD	ADD			1	1	1	1	1	1	1	1	MI1	1			1		1				1
3									1				1		CA						1	1			
4															CA										
5	1	1			1	1					-1	1	1	1	CA										1
6									1	1					CA				1		1		1		
7									1	1			1	1	MI1	1	1	1							
8			1	1	1	1					-1	1	1	1	MI1	1									1
9									1	1	1	1	1	1	MI1	1	1	1	1	1	1	1	1	1	1
10	1	1			1	1			1	1			1	1	MI1										
11	3		1		3		1		6		4		7				2		3		4		2		4
12	28		28		28		28		28		28		28				13		13		13		13		28
13	11		4		11		4		21		14		25				15		23		31		15		14
14																									
15									1	1	1	1	1	1	CA										
16			1	1									1	1	CA				1	1	1	1			
17									1	1			1	1		1									
18					1	1							1	1	MI1		1	1	1	1					
19																									
20	ADD								1	1	1		1	1	MI1	1									1
21													1	1	MI1	1									
22	ADD								1	1	1	1	1	1	MI1										1
23									1	1			1	1	LIV										
24									1	1			1	1	CA										
25																			1		1		1		1
26											1	1	1	1	CA	ADD									1
27																									
28			1												CA										
29			1										1		MI1	1									
30			3		1				6		4		11				1		3		2		1		4
31			28		28				28		28		28				13		13		13		13		28
32			11		4				21		14		39				8		23		15		8		14
33												ADD	1	1	MI1										1
34									1	1			1	1		ADD			1	1	1	1	1	1	1
35	1	1	1	1							1	1	1	1	MI1	1									
36									1	1	1	1	1	1	CA										
37																									
38	1		1						2		2		4						1		1		1		2
39	28		28						28		28		28						13		13		13		28
40	4		4						7		7		14						8		8		8		7
41																									
42	4		5		4		1		14		10		22				3		7		7		4		10
43	28		28		28		28		28		28		28				13		13		13		13		28
44	14		18		14		4		50		36		79				23		54		54		31		36
45																									
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Table 6b
South Tobacco Creek Survey Responses

Physiographic Representation of Manitoba Escarpment Units in Landowner Surveys

Figures 6b and 6c indicate the distribution of survey respondents according to local Manitoba Escarpment physiography[21]. As noted in Chapters Three and Four, physiography is a critical factor for understanding and managing land & water problems in escarpmental areas. As the Manitoba Escarpment is Northwest - Southeast oriented, a larger proportion of the North Tobacco Creek watershed lies within the Lowland unit relative to the South Tobacco[22]. The survey sample captured this fact, with more Lowland and less Escarpment physiography represented within the North and South Tobacco surveys respectively.

Figure 6b
North Tobacco Creek
Physiographic Units
Represented in Survey

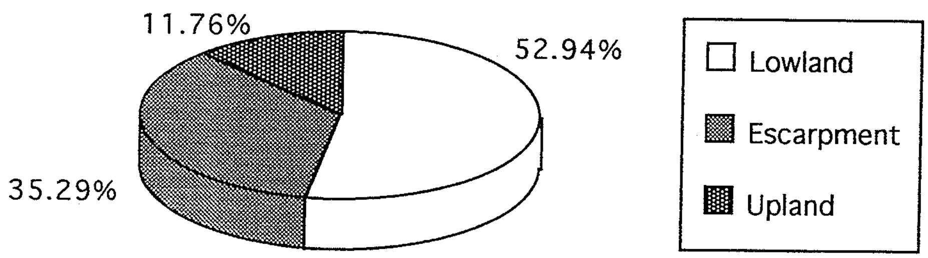
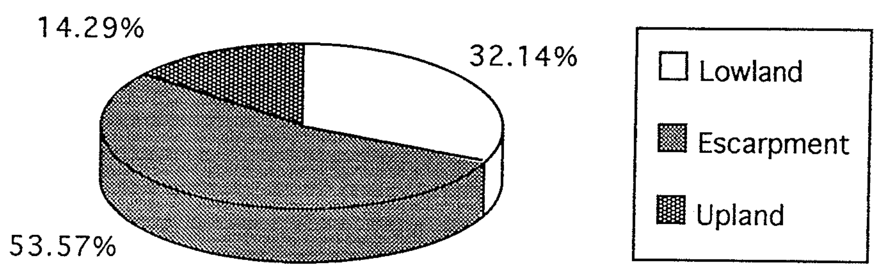


Figure 6c
South Tobacco Creek
Physiographic Units
Repesented in Survey



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21 While no official definition of the Manitoba Escarpment's three physiographic units exists, it may generally be determined on a site-specific basis based on landscape slope. For the purposes of this study, geodetic elevations at or below 375m (1125') were used to mark the beginning of the Lowland region, with 500m (1500') as the Upland - Escarpment boundary.

22 Estimating the relative number of sections (1 square mile) within each physiographic region, the North Tobacco Creek is naturally comprised of 63.3% Lowland, 32.6% Escarpment, and 4.1% Upland. The South Tobacco watershed is comprised of 45.1% Lowland, 41.2% Escarpment, and 13.7% Upland.

Confirmation of Control Scenario between Watersheds

As discussed in Chapter Four, similar environmental and climatic conditions were assumed exist within the North and South Tobacco Creek Watersheds. While it was established that soils in the North Tobacco may be somewhat more erosive, a relatively greater abundance of natural vegetation found within the elevated portions of the North Tobacco Watershed was presumed to reduce potential erosion impacts (Table 4d). Vegetative cover was re-estimated for analysis purposes using a 1994 satellite land use map to confirm if similar cover ratios currently exist (Plate 6a). It was revealed that additional bush clearing had occurred since 1980. Accounting for the adjustment in the North Tobacco Creek's drainage area, 1994 vegetation cover above 1125' was approximately 3520 acres in the North Tobacco and 2560 acres in the South Tobacco.

A substantially greater proportion of the North Tobacco Creek Watershed was found to be remaining in natural cover relative to the South Tobacco. As discussed in Chapter Four, in 1980, natural vegetation covered 36.6% and 17.6% of critical Upland and Escarpment physiography in the North and South Tobacco Creek Watersheds respectively. By 1994, natural cover areas had dropped to 30.6% and 14.8%. The vegetative cover assumption of was thus still assumed to be reasonable.

Survey question #28 (type of farm operation) was used to determine if significant differences existed between the types of farms operated by landowners in the North and South Tobacco Creek Watersheds. The survey revealed approximately equal distributions of farming operation types. This trend seemed to indicate similar amounts of forage cover within each watershed, a possible factor affecting erosivity . The 1994 satellite land use map (Plate 6a) confirmed this hypothesis. Farm operation type was thus not assumed to be a factor affecting the control scenario assumption.

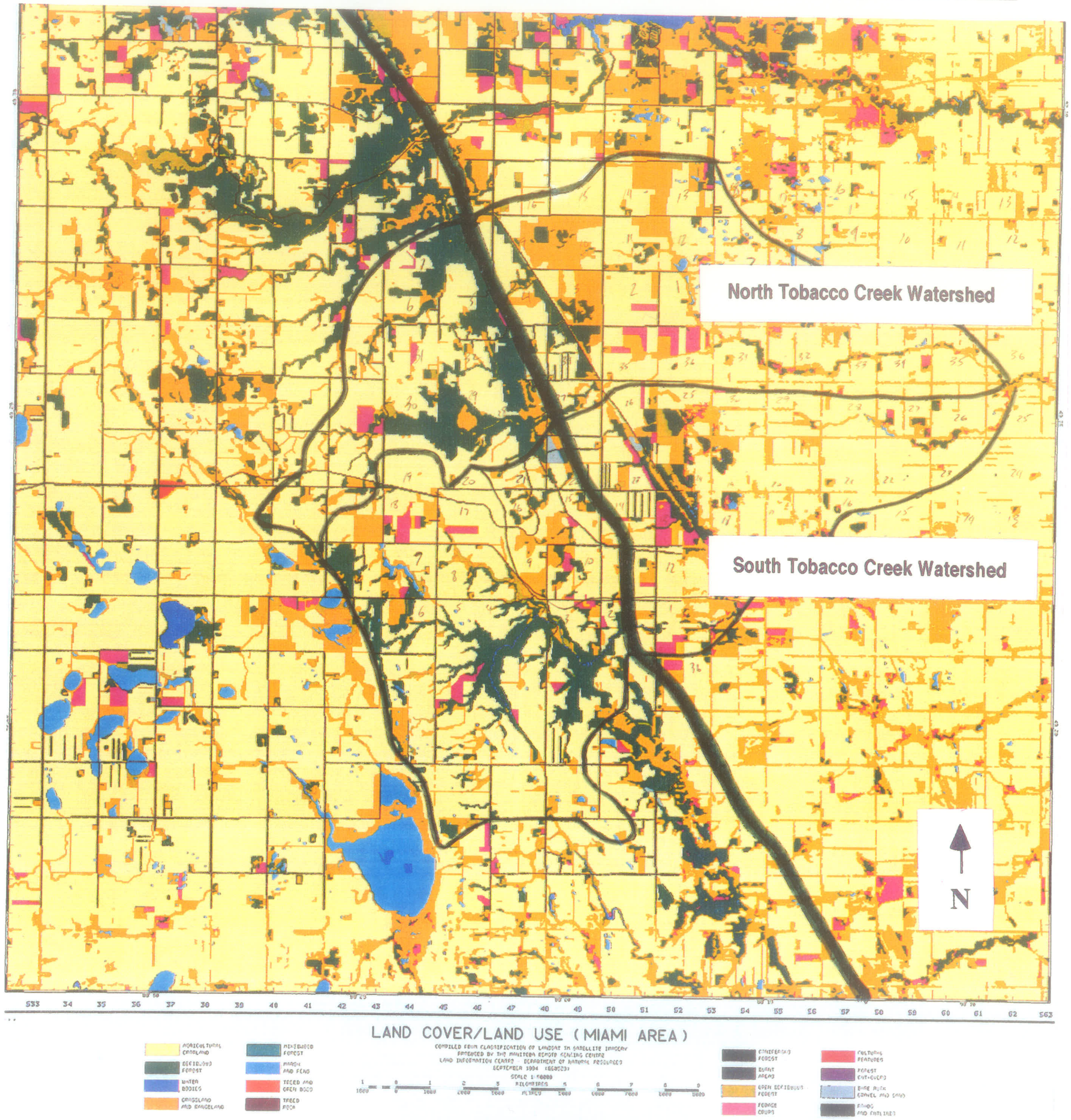

Plate 6a
1994 Land Cover/ Land Use (Miami Area)
Source: Manitoba Remote Sensing Centre, MNR[23].

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[23] Green areas refer to natural vegetation cover while the dark black line denotes the Lowland/Escarpment boundary elevation of 1125' or 375m.

Survey question #27 (land and water conservation practices) was employed to identify differences in the type and degree of agricultural conservation practiced within each watershed. Survey respondents reported a variety of conservation methods employed. According to respondents, a slightly higher degree of land and water conservation was found to occur in the South Tobacco Creek Watershed; reported rates of conservation application were relatively high at 71% in the North and 79% in the South. The application of on-farm conservation measures was not considered to be a factor influencing the establishment of a control scenario.

Causality: Determination of Deerwood Dam Impacts

Questions #17 - #26 (flooding, soil erosion, water quality, and runoff period) assisted in determining whether evidence of reduced erosion and flood reduction impacts of Deerwood's small dam network could be elucidated from survey respondents. It was anticipated that comparison of this data to the PFRA hydrology model discussed in Chapter Four would prove useful in analysis.

Perceived Water Quality Changes

Question #26c and #26d (post-Summer storm water quality) asked dam/landowners if they noticed water quality changes in the North or South Tobacco Creeks during the past five years[24]. Of three respondents in the North Tobacco who noticed water quality (turbidity) changes (18%), only one (6%), a dam owner,[25] reported an increase in water quality (reduced turbidity). Conversely, in the South Tobacco Watershed, eight respondents (29%) reported noticing improved water quality in the creek after Summer storms during the past five years (Figure 6d). Two South Tobacco landowners (17%) reported decreased water quality in the Lowland region.

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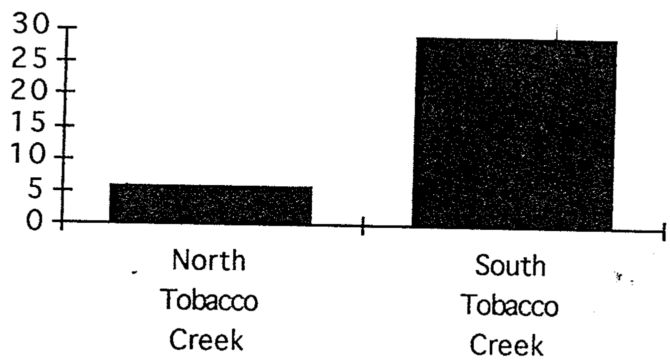
[24] As noted in Chapter 3, most of Deerwood's dams were built during the Summer/Fall of 1988.

[25] See notes # 9 and #12 regarding the dams which lie within the Northwest portion of the North Tobacco Creek Watershed and subsequently, do not influence North Tobacco Creek Watershed management.

Figure 6d:
Percentage of Respondents Noticing Improved Creek Water Quality

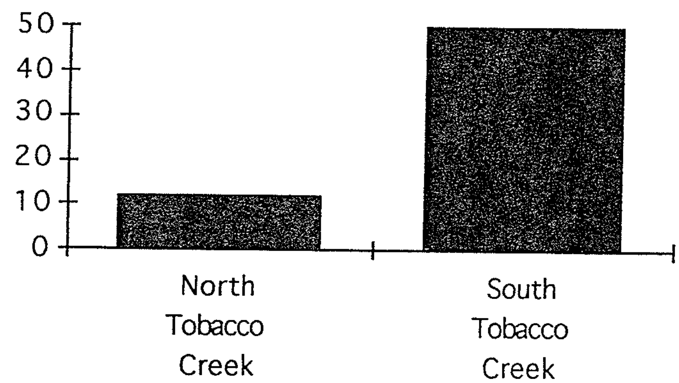


According to the landowner survey, substantially more South Tobacco Creek Watershed respondents noticed increased water quality (reduced turbidity) during the past five years. Far fewer North Tobacco Creek Watershed respondents noticed water quality changes at all. The only North Tobacco respondent reporting reduced turbidity was a damowner whose land is longer part of the North Tobacco drainage area.

Perceived Runoff Period Changes

Questions #26a and #26b (Spring runoff period) asked survey respondents if they noticed changes in the period of creek runoff during the past five years. In the North Tobacco Creek Watershed, two landowners (12%) (both were damowners)[26] reported runoff period increases, and three other landowners reported shorter runoff periods. *One respondent (6%) suggested the reason for shorter runoff is due to less winter precipitation in recent years.* Conversely, in the South Tobacco, 14 respondents (50%) reported increased runoff periods (Figure 6e). Most were damowners (i.e. four of these were non-damowners located in the Lowland region) *One respondent (3.6%) suggested the increase was due to "more snow and slower melt" in recent years.* Many South Tobacco respondents directly mentioned the dams as the reason for the increased runoff period.

Figure 6e:
Percentage of Respondents
Noticing Lengthened Creek Runoff



Substantially more South Tobacco Creek Watershed respondents noticed increased periods of Spring creek flow (lengthened runoff) during the past five years. Far fewer North Tobacco respondents noticed creek flow changes. Two North Tobacco Creek Watershed respondents who noticed increased runoff periods were damowners; one of these owned land now outside the hydrological boundary.

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[26] One of these dams in lies in the Northwest portion of the watershed.

Reported Incidences of Erosion

Questions #22- #25 (soil erosion during past five years) were designed to elicit responses regarding instances of erosion occurrence on land owned by survey respondents in the North and South Tobacco Creek Watersheds. Erosion instances could include: gulley erosion, sheet erosion, R.M. drainage ditch damage, or other damage. It is possible individual respondents may have "double counted" individual erosion events. Consequently, the presence of one erosion event (i.e. one landowner) was tabulated if respondents reported one, two, three, or four individual incidences.

Several interesting trends are evident. Table 6c represents the number of landowners reporting erosion problems according to physiographic unit. With less responses, more erosion incidences were reported in the North Tobacco Watershed relative to the South. Both Lowland and Escarpmental erosion within the South Tobacco Creek Watershed is reported at much lower rates than within the North Tobacco.

Table 6c: Number & Frequency of Landowners Reporting Erosion Problems by Physiographic Unit

Physiographic Area of Erosion Occurrence	North Tobacco Creek (17 Respondents)	South Tobacco Creek (28 Respondents)
Lowland	10 (58.8%)	8 (28.6%)
Escarpment	5 (29.4%)	2 (7.1%)
Upland	0 (0%)	2 (7.1%)
Total Reported Erosion	**15 (88.2%)**	**12 (42.9%)**

In both watersheds, the majority of reported erosion occurred within the Lowland physiographic unit, with South Tobacco erosion reportedly occurring at less than half the rate as within the North Tobacco. A more significant trend relates to a comparison of Escarpmental erosion, which was reported to occur in the South Tobacco at less than one quarter of the North Tobacco rate. Due to the North-South orientation of the Manitoba Escarpment, the North Tobacco survey sample is over-represented in terms of the Lowland physiographic unit, and the South Tobacco is over-represented by the Escarpment unit. This fact particularly strengthens the Escarpment data, while the Lowland difference is also substantial. Overall, South Tobacco erosion appears to be occurring at less than one half the rate as in the North Tobacco according to landowners surveyed (42.9% vs. 88.2%).

Incidences of Flooding

Questions #17 - #21 (flooding during past five years) were designed to elicit responses related to the occurrence of flooding. Flooding instances could include: seeding problems (i.e. delays, poor germination), standing crop damage, introduction of weeds, property damage, and other damage. Again, given the possibility of "double counting" by respondents, the presence of one flooding case (i.e. one landowner) was tabulated if respondents reported one, two, three, or four individual incidences.

One notable trend is apparent. While slightly less overall flooding appears to be occurring within the South Tobacco relative to the North Tobacco (64.3% vs. 76.5% of survey respondents); there is a very significant reported reduction of flooding within the Lowland unit of the South Tobacco compared to the North Tobacco (32.1% vs. 58.8% of respondents) (Table 6d).

Table 6d: Number & Frequency of Landowners Reporting Flooding Problems by Physiographic Unit

Physiographic Area of Erosion Occurrence	North Tobacco Creek (17 Respondents)	South Tobacco Creek (28 Respondents)
Lowland	10 (58.8%)	9 (32.1%)
Escarpment	3 (17.6%)	6 (21.4%)
Upland	0 (0%)	3 (10.7%)
Total Reported Flooding	**13 (76.5%)**	**18 (64.3%)**

Again due to the geographical orientation of the Manitoba Escarpment, survey results over-represented Lowland physiography in the North Tobacco and the Escarpment unit of the South Tobacco. While the results bore out the expectation of a high number of flooding reports in the Lowland, a substantial difference between the two watersheds exists in terms of reported rates. A similar rate of reported flooding occurrence was seen on the Escarpment units of each watershed, and Upland data was inconclusive.

Correlation with PFRA Flood Modeling Research

The results of survey questions #17 - #26 (flooding, soil erosion, water quality, and runoff period) appeared to support PFRA peak flow reduction studies on several Deerwood dams as discussed in Chapter Four. A substantial number of South Tobacco Creek Watershed landowners noticed: reduced flooding and soil erosion, improved water quality (less turbidity), and lengthened creek runoff periods during the past five years.

PFRA (1994) has completed a preliminary analysis of the effectiveness of Deerwood's small dam network within the South Tobacco Creek Watershed (Table 6e). At various rainfall runoff intensities, the modeled effect of Deerwood's dams have been compared with those estimated for a larger structure (option #2 - Figure 4g). Projected peak flow impacts indicate comparable effects, particularly with more common runoff intensities (i.e. 1:2 - 1:50 events). Trends of: reduced flooding and soil erosion, improved water quality, and lengthened runoff periods would be expected according to the PFRA model, which predicts Deerwood's dams to be effective in reducing peak flows by 25% and 15% in Summer storms and Spring snowmelts respectively (PFRA, 1995).

Table 6e: Instantaneous Rainfall Runoff Peaks at the South Tobacco Creek Hydrometric Station
Source: PFRA, 1994, Table 1.

		Modeling Results for Small Dams[27]		Modeling Results for One Large Dam[28]	
Runoff Event	Estimated from Freq. Analysis[29]	Instantaneous Peak (m^3/s)	Percent Peak Reduction	Instantaneous Peak (m^3/s)	Percent Peak Reduction
1:2	7.0	6.1	13	6.4	9
1:5	17	14	18	15	12
1:10	26	21	20	19	27
1:20	36	28	22	26	28
1:50	51	38	25	34	33
1:100	64	48	25	40	38
1:200	79	61	23	55	30
1:500	100	78	22	82	18

27 All the small reservoirs with conservation pools were started at full supply level, while all other reservoirs were started empty in the modeling exercise.

28 The reservoir was started empty in the modeling exercise.

29 Estimated from frequency analysis of instantaneous peaks recorded and estimated at the South Tobacco Creek near Miami WSC hydrometric station (050F017).

As the landowner survey data supported PFRA's peak flow reduction data (1995, 1994, 1992, 1991), a causal relationship was reasonably assumed to exist between Deerwood's dams and the reduction of peak flows during Spring runoff and major Summer storm events, the primary causes of erosion and flooding damage in the Deerwood region.

Damowner Survey Questions

Questions #1 - #16 (damowner information) focussed on the range of perceived benefits and costs, and dam uses and values reported by individual landowners participating in Deerwood's small dam projects. Only damowners in the North and South Tobacco Creek Watersheds were required to complete this portion of the survey. The majority of respondents owned dams built by the Deerwood Soil and Water Management Association. A small number of respondents reported building dams on their own. Four North Tobacco Creek damowners and 15 South Tobacco Creek damowners responded to the survey. For an accurate representation of damowner data, analysis was based upon the number of damowners responding to the survey.

Damowner Benefits

Questions #13 - #16 (dam benefits) were designed to indicate damowners' perceptions of the benefits associated with their dams. Respondents were asked to comment on the impact of their dam on local groundwater levels, esthetic values, quality of life for their families, and property values.

South Tobacco Creek

Nine of 15 South Tobacco damowners (60%) believed local groundwater levels have risen because of their dams or those owned by neighbours. This trend was viewed positively (vs. negative effects of groundwater rising, i.e. salinity). Several damowners reported increased well levels since dam installation, while one noted a stabilised effect of groundwater supplies in dry years, and one noted the appearance of springs downstream.

Eleven of 15 South Tobacco damowners (73%) believed their dams have contributed to the esthetic value of the surrounding landscape. Three respondents cited the general importance of stored water as a resource, and two others reported increased wildlife presence due to their dam.

Eight of 15 South Tobacco damowners (53%) believed their dams have improved the overall quality of life for their families. A variety of reasons ranging from increased cattle carrying capacity and income to recreation to wildlife habitat were noted. A theme of *quality family time* was strongly and directly associated with dams and their water storage benefits.

Finally, eight of 15 damowners (53%) in the South Tobacco Creek Watershed believed their dams have increased the value of their property. Property increases of 1% to 20% were reported.

North Tobacco Creek

Three of four North Tobacco Creek Watershed damowners (75%) believed local groundwater levels have risen because of their dams or those owned by a neighbour. Stabilised well levels and improved downstream forage production were cited.

One of four North Tobacco damowners (25%) reported improved esthetic values associated with their dam. A second respondent (25%) noted both positive and negative esthetic impacts.

One of four North Tobacco damowners (25%) indicated their dam marginally served to improve the quality of life for their family, specifically as a source of water management education.

Finally, two of four damowners (50%) indicated their dams increased farmland property values. Livestock security was specifically mentioned by one respondent.

Damowner Costs

Questions #11 and #12 (dam costs and problems) were included in the survey in order to get an indication of operating and maintenance costs associated with Deerwood's dams. Additionally, it was hoped any unforeseen problems experienced by damowners would be reported.

South Tobacco Creek

While three of 15 South Tobacco damowners (20%) reported operating and maintenance costs, two of these owned dams not built by Deerwood. The one Deerwood damowner experienced very minor costs associated with culvert damage caused by Spring ice[30]. Five of 15 damowners in total (33%) reported unforeseen problems. While some minor culvert leakage and drainage problems were experienced by Deerwood damowners, the survey captured problems experienced by two damowners not associated with Deerwood.

North Tobacco Creek

Of four North Tobacco damowners, zero reported any operating or maintenance costs. One of four damowners (25%) reported minor culvert problems.

Damowner Uses

Questions #2 - #10 (dam information) were intended to capture the full range of dam uses reported by respondents. Respondents were asked to indicate and describe the uses of their dam(s). Flood damage reduction, soil erosion prevention, stock watering, irrigation, waterfowl habitat, fish pond (fish rearing), other wildlife habitat, and other purposes were provided as survey options.

30 It should be noted there is one Deerwood dam not captured by the survey which required repair costs of $5000.

South Tobacco Creek

All 15 South Tobacco damowners (100%) reported using their dam for flood control, and numerous examples were provided regarding damage reduction effectiveness throughout the watershed.

Twelve of 15 (80%) reported the use of their dam for erosion control. Again, numerous examples were provided to explain how water flows are slowed considerably because of dams.

Nine of 15 (60%) used their dams for stockwatering. A variety of systems were reported to be in use, ranging from direct watering to solar powered pumping of water to a trough. Current or planned rotational grazing systems were mentioned by some respondents.

Three of 15 South Tobacco respondents (20%) used their dams for backflood irrigation.

No South Tobacco damowners reported directly using dams for domestic water supply.

Eleven of 15 South Tobacco damowners (73%) reported the use of their dams for both waterfowl and other wildlife habitat. A variety of species were mentioned and, numerous comments were provided to explain exactly how the dam serves to provide waterfowl habitat.

Five of 15 damowners (33%) reported the use of their dam for stocking fish (e.g. trout) as an economic enterprise. Of these, one indicated their past success with stocking, two indicated their plans to stock in the near future, and one indicated a lack of stocking success during the past two years.

Three of 15 damowners (20%) reported other purposes for their dams including: access of fields isolated by step terrain; esthetics and; improved well water levels.

North Tobacco Creek

Four of four North Tobacco damowners (100%) reported using their dams for flood damage reduction. Positive impacts on downstream landowners and roads were mentioned specifically.

Four of four damowners (100%) reported the use of their dams for soil erosion prevention. Descriptive examples were provided by three respondents.

Two of four damowners (50%) reported using their dams for stockwatering. One indicated their dam recharges groundwater to keep well water levels high enough to water cattle.

Three of four North Tobacco damowners (75%) used their dams for backflood irrigation of pasture lands. One of these respondents indicated future plans to irrigate cultivated land in the future.

Two of four damowners (50%) reported using their dams for domestic water supply. Both indicated an indirect relationship; groundwater levels had apparently been recharged by the dams in order to provide a constant supply of domestic water in the home.

Three of four North Tobacco damowners (75%) reported the use of their dams for waterfowl habitat. Several duck species were mentioned. Two damowners (50%) indicated the use of their dams for other types of wildlife habitat including deer, moose, grouse, and rabbits.

No North Tobacco damowners reported using dams for fish rearing.

General Perceptions of Non-Damowners Regarding Creek Importance and Value

Survey questions #29 - #32 (creek importance to farming operation, esthetic value, quality of life, value of property) were utilised in the survey to indicate general uses and values attached to the North and South Tobacco Creek by area landowners not owning small dams. Respondents from each watershed viewed the creeks in their area similarly. Several respondents in each watershed cited the importance of the creek as a source of water for cattle watering and garden-sized irrigation. Esthetics were highly valued by respondents in both watersheds. Beauty, wildlife, spirituality, and recreation were mentioned by a number of North and South Tobacco landowners. Property values attributable to the North or South Tobacco Creeks ranged from 5% to 25%. Several additional comments by survey respondents indicated general support for the concept of small scale headwater storage.

Analysis of Tangible Costs and Benefits

Economic Payback Period Analysis was employed to analyse tangible benefits and costs associated with Deerwood's small dam network (Johnson, 1995, Gittinger, 1994).

Dam Costs

Capital costs for each dam built by Deerwood were provided by Deerwood's Technician (Turner, 1993) and verified by a Federal engineer (Zyla, 1993). Engineering design costs for all Deerwood dams were provided by the Prairie Farm Rehabilitation Administration as "in-kind" contributions. While design costs reportedly declined as more Deerwood's dams were built, it is important to note that new dams built in different environments may require significant design costs (Alexander, 1995). As noted by the landowner survey, Deerwood's dams appear to have very low operating and maintenance costs; this has also been confirmed by discussions with the Deerwood Technician (Turner, 1994). The short lifespan of the dams is most likely a factor. The expected life of Deerwood's dams has been accepted to be at least 50 years (Samp, 1994). No distinctions were made between the three types of dam construction: dry; backflood; and multi-purpose. All dams built by Deerwood which exist within the North Tobacco, South Tobacco, and Graham Creeks were included in the analysis[31]. Dams situated within the Roseile Creek Watershed were excluded. Table 6f outlines the type, size, and costs of all dams. 1986 was selected as the base year for dam capital cost deflation[32]. Table 6g represents Deerwood dam capital costs discounted at 0%, 5%, 8%, and 15% over 50 years since 1986 or "project year zero." Sensitivity analysis resulted in present values (1986$) for Deerwood's small dam network of: $346, 607; $303, 983; $282, 970 and; $243, 791 respectively. All financial contributions toward Deerwood's dam costs (Federal, Provincial, Municipal, private conservation agencies, and private landowners) were included in costs.

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31 This figure includes all direct construction costs as paid out by all involved agencies, local governments, and individual landowners.

32 Deflation was used to standardize all dam costs and benefits to 1986 dollars. Otherwise, differential year-dollar values would distort the analysis. This is effect is distinct from discounting, as discussed in Chapter Three.

	A	B	C	D	E	F	G
1	Number	Dam Type	Storage	Acres	Year	Capital Cost	DeFlated Cost
2			(a.f. @ FSL)	Controlled			(1986$)
3	1	backflood	40.5	95.3	1989	5341	4648.39
4	2	backflood	20.3	317.1	1989	1200	1044.39
5	3	multi-purpose	22	263.8	1986	16629	16629.00
6	4	multi-purpose	2.8	27.6	1987	5816	5554.92
7	5	multi-purpose	5.7	63.2	1989	7512	6537.86
8	6	multi-purpose	49	431.3	1989	15178	13209.75
9	7	multi-purpose	2.4	101.3	1986	4505	4505.00
10	8	multi-purpose	5.7	89.7	1988	6252	5704.38
11	9	dry	20.3	353.5	1989	22966	19987.82
12	10	multi-purpose	12.2	210	1989	11802	10271.54
13	11	dry	32.4	450	1988	25299	23083.03
14	12	multi-purpose	8.9	153.9	1988	8948	8164.23
15	13	backflood	11.4	249.2	1987	6557	6262.66
16	14	backflood	135.3	701.3	1987	8446	8066.86
17	15	multi-purpose	1.5	102.9	1986	5792	5792.00
18	16	multi-purpose	3.3	194.2	1986	6334	6334.00
19	17	dry	4.1	101.3	1987	4865	4646.61
20	18	multi-purpose	7.3	167.5	1988	5581	5092.15
21	19	multi-purpose	1.4	167.1	1985	3738	3826.00
22	20	backflood	48.6	438	1988	5242	4782.85
23	21	multi-purpose	2.5	179.3	1985	5421	5548.62
24	22	dry	1.2	63.7	1985	2478	2536.34
25	23	multi-purpose	15.4	177	1988	5526	5041.97
26	27	backflood	10.5	100.3	1986	4135	4135.00
27	28	backflood	31.6	238.3	1988	6383	5823.91
28	29	multi-purpose	10.5	182.9	1988	7873	7183.39
29	30	multi-purpose	20.3	250.1	1988	9885	9019.16
30	31	multi-purpose	11.4	117.3	1990	19773	16686.08
31	32	multi-purpose	4.5	200.3	1986	4873	4873.00
32	33	multi-purpose	12	389.6	1988	4587	4185.22
33	34	multi-purpose	49	464.4	1990	26998	22783.12
34	35	multi-purpose	14.6	162.4	1989	10433	9080.07
35	36	backflood	18	120.3	1990	5076	4283.54
36	37	dry	40.5	325.2	1989	13927	12120.97
37	38	multi-purpose	15.4	155	1988	6324	5770.07
38	39	dry	11.1	124	1992	7694	6240.06
39	40	multi-purpose	12.2	185	1992	15799	12813.46
40	41	backflood	23.3	166	1992	12776	10361.72
41	42	dry	12.2	205	1992	16986	13776.16
42	43	multi-purpose	11.2	74	1992	15569	12626.93
43	44	multi-purpose	12.2	185	1992	7336	5949.72
44	45	backflood	28.4	234	1991	1976	1625.00
45	Total 42		803.1	8977.3		$389,831	346606.93
46	Averages		19.12143	213.745238		$9,282	8252.55

Table 6f
Deerwood Dam Types, Sizes, and Capital Costs
Source: Turner/Zyla, 1994

	H	I	J	K	L
1	Year	Discounted @ 0%	Discounted @ 5%	Discounted @ 8%	Discounted @ 15%
2		1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project
3	1989	4648.39	4015.45	3690.04	3056.39
4	1989	1044.39	902.18	829.07	686.70
5	1986	16629.00	16629.00	16629.00	16629.00
6	1987	5554.92	5290.40	5143.44	4830.36
7	1989	6537.86	5647.65	5189.96	4298.75
8	1989	13209.75	11411.08	10486.32	8685.62
9	1986	4505.00	4505.00	4505.00	4505.00
10	1988	5704.38	5174.04	4890.59	4313.33
11	1989	19987.82	17266.23	15866.97	13142.31
12	1989	10271.54	8872.94	8153.88	6753.70
13	1988	23083.03	20936.99	19789.98	17454.09
14	1988	8164.23	7405.20	6999.51	6173.33
15	1987	6262.66	5964.43	5798.75	5445.79
16	1987	8066.86	7682.72	7469.31	7014.66
17	1986	5792.00	5792.00	5792.00	5792.00
18	1986	6334.00	6334.00	6334.00	6334.00
19	1987	4646.61	4425.34	4302.42	4040.53
20	1988	5092.15	4618.73	4365.70	3850.40
21	1985	3826.00	4017.30	4132.08	4399.90
22	1988	4782.85	4338.18	4100.52	3616.52
23	1985	5548.62	5826.05	5992.51	6380.91
24	1985	2536.34	2663.15	2739.24	2916.79
25	1988	5041.97	4573.22	4322.68	3812.45
26	1986	4135.00	4135.00	4135.00	4135.00
27	1988	5823.91	5282.45	4993.06	4403.71
28	1988	7183.39	6515.55	6158.60	5431.68
29	1988	9019.16	8180.64	7732.48	6819.78
30	1990	16686.08	13727.68	12264.76	9540.32
31	1986	4873.00	4873.00	4873.00	4873.00
32	1988	4185.22	3796.12	3588.15	3164.63
33	1990	22783.12	18743.73	16746.28	13026.32
34	1989	9080.07	7843.71	7208.05	5970.29
35	1990	4283.54	3524.08	3148.53	2449.13
36	1989	12120.97	10470.55	9622.02	7969.74
37	1988	5770.07	5233.63	4946.91	4363.00
38	1992	6240.06	4656.43	3932.30	2697.75
39	1992	12813.46	9561.60	8074.66	5539.61
40	1992	10361.72	7732.07	6529.64	4479.66
41	1992	13776.16	10279.98	8681.31	5955.81
42	1992	12626.93	9422.41	7957.11	5458.97
43	1992	5949.72	4439.77	3749.33	2572.23
44	1991	1625.00	1273.23	1105.95	807.91
45		346606.93	303982.92	282970.11	243791.09
46					

Table 6g
Discounted Dam Costs (1986$)

Municipal Benefits

As reported via the municipal survey, Tables 6h and 6i indicate total estimated benefits arising because of avoided road, bridge, and ditch damage and maintenance costs in the Rural Municipalities of Thompson and Roland from 1989 to 1993. All three sub-watersheds in which Deerwood dams exist were included in the analysis. The South Tobacco, the North Tobacco, and the Graham Creeks were discussed in Chapter Four.

Table 6h: Thompson RM Benefits Experienced From 1989 - 1993 in 1986 Dollars
NTC (North Tobacco), STC (South Tobacco), GC (Graham Creek)

Watershed Creek Location and Type of R.M Cost Savings	Year	Reported Savings	Deflated Savings (1986$)
NTC Road Damage Reduction		could not value	
STC Bridge Replacement/Reduction	1992	5500	4460.67
STC Crossing Lifespan Extension		could not value	
STC Road/Ditch Damage Reduction	1989	2000	1740.64
	1990	2000	1740.64
	1991	2000	1740.64
	1992	2000	1740.64
	1993	2000	1740.64
GC Road/Ditch Damage Reduction	1990	25000	21097.05
GC Valued Damage Reduction	1991	25000	20559.21
Total (1986$)			**54,820.13**

As discussed in Chapter Five, the R.M. of Thompson provided several specific, but conservative examples of reduced and/or avoided maintenance costs attributable to Deerwood's headwater storage structures. The R.M. was able to identify individual sites within all three watersheds which drain the municipality. Erosion and flooding related cost savings were reportedly experienced for roads, ditches, and stream crossings (stream crossings may include bridges and/or culvert installations). As cost savings estimates were reported during different years, deflation of each figure was necessary to accurately compare all data.

1986 was selected as the base year for comparison with deflation occurring in accordance with Canadian Gross Domestic Product deflation tables (Statistics Canada, 1994). In the case of multiple-year benefits experienced, one average figure was used where savings were reported by municipal officials as "x dollars per year" (i.e. STC Road Damage Reduction). Other cost savings were experienced because of single storm or runoff events, while a value was also placed on anticipated cost savings (i.e. GC Valued Damage Reduction). Some areas of known cost savings could not be quantified by the municipality. During the period from 1989 to 1993 inclusive, the R.M. of Thompson reported cost savings or benefits totaling $54,820.13 (1986 dollars).

As discussed in Chapter Five, the R.M. of Roland compared its overall construction and maintenance budgets during the periods between 1979 - 1988 and 1989 - 1993. Municipal officials were not surprised to find a substantial reduction in these costs, given the presence of Deerwood's dams. Conservatively, the R.M. attributed 45% of this reduction to headwater retention by Deerwood, based on the combined drainage areas of the Graham and Tobacco Creeks with the municipality. An average annual R.M. cost savings of $16,479.84 was found. Again, this figure was deflated to 1986 dollars. This figure was used from 1989 - 1993 for total reported cost savings or benefits of $71,713.85 (1986$). The cumulative impact of headwater retention by Deerwood in the South Tobacco and Graham Creek Watersheds seemed to be apparent in the R.M. of Roland, where a greater amount of municipal cost savings or benefits were reported relative to the R.M. of Thompson.

Table 6i: Roland RM Benefits Experienced From 1989 - 1993 in 1986 Dollars
TC (Tobacco Creek), GC (Graham Creek)

Watershed Creek Location and Type of R.M Cost Savings	Year	Reported Savings	Deflated Savings (1986$)
Reduced Construction and Maintenance	1989	16479.84	14342.77
(TC and GC)	1990	16479.84	14342.77
	1991	16479.84	14342.77
	1992	16479.84	14342.77
	1993	16479.84	14342.77
Total (1986$)			**$71,713.85**

R.M. Benefits Summary

The expected life of Deerwood's dams has generally been accepted to be at least 50 years (Samp, 1994). It was assumed that municipal benefits attributable to Deerwood's dams would continue for this length of time. Two approaches were used to estimate total municipal benefits beginning in 1986 as "project year zero." The first approach assumed a five year rotation of the Thompson R.M. benefit stream denoted in Table 6h while Roland R.M. benefits continued annually (Table 6i). The second approach assumed average benefits to be received each year. In the R.M. of Thompson, major stream crossing repairs or replacements are typically incurred every two years (Jackson, 1995); individual structures may be expected to have useful lifespans ranging from 30 to 50 years (Alexander, 1995; Jackson, 1995; and Saltzberg, 1995). Table 6j indicates these two streams of benefits over the 50 year project life. Tables 6k and 6l indicate sensitivity analyses at 0%, 5%, 8%, and 15% discount rates for each benefit stream.

	A	B	C	D	E	F	G
1	Five Year Benefit Roation Stream				Annual R.M. Benefit Stream		
2							
3	**Year**	**Thompson**	**Roland**		**Year**	**Thompson**	**Roland**
4							
5	1986-0				1986-0		
6	1987-1				1987-1		
7	1988-2				1988-2		
8	1989-3	1740.64	14342.77		1989-3	10964.03	14342.77
9	1990-4	22837.69	14342.77		1990-4	10964.03	14342.77
10	1991-5	22299.85	14342.77		1991-5	10964.03	14342.77
11	1992-6	6201.31	14342.77		1992-6	10964.03	14342.77
12	1993-7	1740.64	14342.77		1993-7	10964.03	14342.77
13	1994-8	1740.64	14342.77		1994-8	10964.03	14342.77
14	1995-9	22837.69	14342.77		1995-9	10964.03	14342.77
15	1996-10	22299.85	14342.77		1996-10	10964.03	14342.77
16	1997-11	6201.31	14342.77		1997-11	10964.03	14342.77
17	1998-12	1740.64	14342.77		1998-12	10964.03	14342.77
18	1999-13	1740.64	14342.77		1999-13	10964.03	14342.77
19	2000-14	22837.69	14342.77		2000-14	10964.03	14342.77
20	2001-15	22299.85	14342.77		2001-15	10964.03	14342.77
21	2002-16	6201.31	14342.77		2002-16	10964.03	14342.77
22	2003-17	1740.64	14342.77		2003-17	10964.03	14342.77
23	2004-18	1740.64	14342.77		2004-18	10964.03	14342.77
24	2005-19	22837.69	14342.77		2005-19	10964.03	14342.77
25	2006-20	22299.85	14342.77		2006-20	10964.03	14342.77
26	2007-21	6201.31	14342.77		2007-21	10964.03	14342.77
27	2008-22	1740.64	14342.77		2008-22	10964.03	14342.77
28	2009-23	1740.64	14342.77		2009-23	10964.03	14342.77
29	2010-24	22837.69	14342.77		2010-24	10964.03	14342.77
30	2011-25	22299.85	14342.77		2011-25	10964.03	14342.77
31	2012-26	6201.31	14342.77		2012-26	10964.03	14342.77
32	2013-27	1740.64	14342.77		2013-27	10964.03	14342.77
33	2014-28	1740.64	14342.77		2014-28	10964.03	14342.77
34	2015-29	22837.69	14342.77		2015-29	10964.03	14342.77
35	2016-30	22299.85	14342.77		2016-30	10964.03	14342.77
36	2017-31	6201.31	14342.77		2017-31	10964.03	14342.77
37	2018-32	1740.64	14342.77		2018-32	10964.03	14342.77
38	2019-33	1740.64	14342.77		2019-33	10964.03	14342.77
39	2020-34	22837.69	14342.77		2020-34	10964.03	14342.77
40	2021-35	22299.85	14342.77		2021-35	10964.03	14342.77
41	2022-36	6201.31	14342.77		2022-36	10964.03	14342.77
42	2023-37	1740.64	14342.77		2023-37	10964.03	14342.77
43	2024-38	1740.64	14342.77		2024-38	10964.03	14342.77
44	2025-39	22837.69	14342.77		2025-39	10964.03	14342.77
45	2026-40	22299.85	14342.77		2026-40	10964.03	14342.77
46	2027-41	6201.31	14342.77		2027-41	10964.03	14342.77
47	2028-42	1740.64	14342.77		2028-42	10964.03	14342.77
48	2029-43	1740.64	14342.77		2029-43	10964.03	14342.77
49	2030-44	22837.69	14342.77		2030-44	10964.03	14342.77
50	2031-45	22299.85	14342.77		2031-45	10964.03	14342.77
51	2032-46	6201.31	14342.77		2032-46	10964.03	14342.77
52	2033-47	1740.64	14342.77		2033-47	10964.03	14342.77
53	2034-48	1740.64	14342.77		2034-48	10964.03	14342.77
54	2035-49	22837.69	14342.77		2035-49	10964.03	14342.77
55	Total	517959.50	674110.19		Total	515309.41	674110.19
56							
57							
58							
59							
60							

Table 6j
Undiscounted Benefit Streams (1986$) for the R.M.'s of Thompson and Roland

Table 6I
Discounted Annual Municipal Benefit Approach (1986$)

	H	I	J	K	L
1	Discounted Annual Benefit Stream				
2					
3	**Year**	**PV of Benefits @ 0%**	**PV of Benefits @ 5%**	**PV of Benefits @ 8%**	**PV of Benefits @ 15%**
4		1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project
5	1986-0	0.00	0	0	0
6	1987-1	0.00	0	0	0
7	1988-2	0.00	0	0	0
8	1989-3	25306.80	21860.97	20089.35	16639.63
9	1990-4	25306.80	20819.97	18601.25	14469.25
10	1991-5	25306.80	19828.54	17223.38	12581.95
11	1992-6	25306.80	18884.32	15947.58	10940.83
12	1993-7	25306.80	17985.07	14766.27	9513.76
13	1994-8	25306.80	17128.64	13672.48	8272.84
14	1995-9	25306.80	16312.99	12659.70	7193.77
15	1996-10	25306.80	15536.18	11721.94	6255.45
16	1997-11	25306.80	14796.36	10853.65	5439.53
17	1998-12	25306.80	14091.77	10049.68	4730.02
18	1999-13	25306.80	13420.74	9305.26	4113.06
19	2000-14	25306.80	12781.65	8615.98	3576.58
20	2001-15	25306.80	12173.00	7977.76	3110.07
21	2002-16	25306.80	11593.34	7386.81	2704.41
22	2003-17	25306.80	11041.27	20089.35	2351.66
23	2004-18	25306.80	10515.50	6333.00	2044.92
24	2005-19	25306.80	10014.76	5863.89	1778.19
25	2006-20	25306.80	9537.87	5429.53	1546.25
26	2007-21	25306.80	9083.68	5027.34	1344.57
27	2008-22	25306.80	8651.13	4654.95	1169.19
28	2009-23	25306.80	8239.17	4310.13	1016.69
29	2010-24	25306.80	7846.83	3990.87	884.07
30	2011-25	25306.80	7473.17	3695.25	768.76
31	2012-26	25306.80	7117.30	3421.52	668.49
32	2013-27	25306.80	6778.38	3168.08	581.29
33	2014-28	25306.80	6455.60	2933.41	505.47
34	2015-29	25306.80	6148.19	2716.12	439.54
35	2016-30	25306.80	5855.42	2514.92	382.21
36	2017-31	25306.80	5576.59	2328.63	332.36
37	2018-32	25306.80	5311.04	2156.14	289.01
38	2019-33	25306.80	5058.13	1996.43	251.31
39	2020-34	25306.80	4817.27	1848.54	218.53
40	2021-35	25306.80	4587.88	1711.61	190.03
41	2022-36	25306.80	4369.41	1584.83	165.24
42	2023-37	25306.80	4161.34	1467.43	143.69
43	2024-38	25306.80	3963.18	1358.73	124.95
44	2025-39	25306.80	3774.46	1258.09	108.65
45	2026-40	25306.80	3594.72	1164.90	94.48
46	2027-41	25306.80	3423.54	1078.61	82.15
47	2028-42	25306.80	3260.52	998.71	71.44
48	2029-43	25306.80	3105.26	924.73	62.12
49	2030-44	25306.80	2957.39	856.23	54.02
50	2031-45	25306.80	2816.56	792.81	46.97
51	2032-46	25306.80	2682.44	734.08	40.84
52	2033-47	25306.80	2554.70	679.71	35.52
53	2034-48	25306.80	2433.05	629.36	30.88
54	2035-49	25306.80	2317.19	582.74	26.86
55	Total	1189419.60	412736.48	277171.76	127391.47
56		354295.20	309616.91		
57		16 Year PP	25 Year PP	Need 6.0K	Need 116K
58					
59					
60					

	H	I	J	K	L
61	Discounted Five Year Roation Benefit Stream				
62					
63	**Year**	**PV of Benefits @ 0%**	**PV of Benefits @ 5%**	**PV of Benefits @ 8%**	**PV of Benefits @ 15%**
64		1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project	1986 = Year 0 of Project
65	1986-0	0.00	0	0	0
66	1987-1	0.00	0	0	0
67	1988-2	0.00	0	0	0
68	1989-3	16083.41	13893.45	12767.53	10575.10
69	1990-4	37180.46	30588.46	27328.75	21258.05
70	1991-5	36642.62	28710.45	24938.35	18217.86
71	1992-6	20544.08	15330.31	12946.26	8881.77
72	1993-7	16083.41	11430.18	9384.52	6046.35
73	1994-8	16083.41	10885.88	8689.37	5257.70
74	1995-9	37180.46	23966.86	18599.49	10569.01
75	1996-10	36642.62	22495.39	16972.62	9057.50
76	1997-11	20544.08	12011.70	8811.00	4415.81
77	1998-12	16083.41	8955.84	6386.94	3006.10
78	1999-13	16083.41	8529.38	5913.84	2614.00
79	2000-14	37180.46	18778.66	12658.50	5254.66
80	2001-15	36642.62	17625.73	11551.28	4503.18
81	2002-16	20544.08	9411.48	5996.62	2195.44
82	2003-17	16083.41	7017.14	12767.53	1494.57
83	2004-18	16083.41	6682.99	4024.86	1299.62
84	2005-19	37180.46	14713.57	8615.16	2612.50
85	2006-20	36642.62	13810.22	7861.61	2238.87
86	2007-21	20544.08	7374.14	4081.20	1091.52
87	2008-22	16083.41	5498.11	2958.39	743.06
88	2009-23	16083.41	5236.30	2739.25	646.14
89	2010-24	37180.46	11528.47	5863.33	1298.87
90	2011-25	36642.62	10820.67	5350.48	1113.12
91	2012-26	20544.08	5777.83	2777.60	542.68
92	2013-27	16083.41	4307.91	2013.43	369.43
93	2014-28	16083.41	4102.78	1864.29	321.25
94	2015-29	37180.46	9032.86	3990.49	645.77
95	2016-30	36642.62	8478.28	3641.45	553.42
96	2017-31	20544.08	4527.08	1890.39	269.81
97	2018-32	16083.41	3375.36	1370.31	183.67
98	2019-33	16083.41	3214.63	1268.80	159.72
99	2020-34	37180.46	7077.48	2715.86	321.06
100	2021-35	36642.62	6642.95	2478.31	275.15
101	2022-36	20544.08	3547.09	1286.56	134.14
102	2023-37	16083.41	2644.69	932.61	91.32
103	2024-38	16083.41	2518.75	863.53	79.41
104	2025-39	37180.46	5545.39	1848.37	159.62
105	2026-40	36642.62	5204.93	1686.69	136.80
106	2027-41	20544.08	2779.24	875.61	66.69
107	2028-42	16083.41	2072.18	634.72	45.40
108	2029-43	16083.41	1973.51	587.70	39.48
109	2030-44	37180.46	4344.96	1257.97	79.36
110	2031-45	36642.62	4078.20	1147.94	68.01
111	2032-46	20544.08	2177.60	595.93	33.16
112	2033-47	16083.41	1623.61	431.98	22.57
113	2034-48	16083.41	1546.29	399.98	19.63
114	2035-49	37180.46	3404.39	856.15	39.46
115	Total	1192069.69	415293.33	274623.51	129047.80
116		363518.53	304474.70		
117		**16 Year PP**	**24 Year PP**	**Need 8.0 K**	**Need 115K**

Table 6K
Discounted Five Year Municipal Benefit Rotation (1986$)

Discussion of Benefits and Costs

Tangible Benefits

At discount rates of 0% and 5%, a clear case was made for Deerwood's network of headwater retention structures. Commencing in 1986, "project year zero," the small dam network had a financial (undiscounted) payback period of only 16 years. At a 5% discount rate, the economic (discounted) payback period was between 24 and 25 years. At these rates of discount, the Deerwood dams proved their worth solely in support of avoided municipal infrastructural damages. The existence of municipal benefits is well understood by the Rural Municipalities of Thompson and Roland, given that both contribute substantial amounts of construction time to the building of Deerwood dams.

After 50 years of operation, and assuming a slightly higher discount rate (8%), the Deerwood dam network could be expected to generate nearly enough municipal benefits to pay back initial capital costs, being only $6.0K to $8.0K short. At a 15% discount rate, Deerwood's small dam network project would require between $115.0K and $116.0K of additional benefits to become economically viable.

Following the Krutilla and Fisher (1975) model it was not necessary to undertake the difficult task of quantifying environmental and social benefits in order to prove the worth of Deerwood's small dam network at 0% and 5% rates of discount. In order to enhance the analysis however, a review of other potential benefits was required.

Landowner Benefits Case Study

One landowner and his family served as a useful case study which indicated the potential value of a small dam to a landowner in the Deerwood region. During a heavy June rainstorm event prior to construction of a dam by an upstream neighbour, water overtopped several crossings before entering the South Tobacco Creek. This caused flooding over approximately five acres of the landowner's farmland, with at least two acres of crop completely lost. The remaining three acres were severely damaged by siltation. This five acre parcel was unusable for two to three years afterward.

However, due to the small size of the claim, Manitoba Crop Insurance would not cover production losses. Since construction of the neighbour's dam upstream, no subsequent damage has occurred. There have since been two major Spring storm events of similar size. According to this farmer, the upstream dam has been worth approximately five acres at $150 per acre multiplied by two major storms within five years equals $1500 in 1994$.

This same landowner also has a Deerwood dam on his property to provide flood protection. He estimated gaining production on three acres of lower quality land every year; this land which formerly was damaged by annual flooding (three acres at $100 equals $300 per year in 1994$). Finally, due to the "metering" effect of the dam on previously damaging runoff waters, this landowner has obtained approximately eight bales of hay from the waterway below the dam at $25 per bale equals $200 per year in 1994$. In normal years, the added moisture provided by this "regulated dam outflow" has been a benefit for cattle production. Otherwise, a dugout would have to be built. Without the regulated outflow of the dam, great potential for erosion and flooding damage would exist. The landowner has also seen significant irrigation benefits of forage grasses from dam water.

With one Deerwood area landowner/damowner experiencing such additional benefits over a very short period (including $500+ per year or approximately $\$4000_{1994}$ within a five year period), it is reasonable to assume other landowners/damowners may receive similar benefits. Further evidence of the value of small scale water storage was provided by the landowner survey where it was determined that two landowners had built dams on their own, without any financial assistance from Deerwood. The Deerwood small dam network project quickly becomes economically viable at the 8% discount rate, where only $6.0K to $8.0K in additional benefits over 50 years would be required to justify construction.

Intangible Benefits

Many Deerwood damowners within the South Tobacco Creek Watershed reported receiving numerous wildlife, educational, recreational, esthetic, spiritual, and quality of life values due to their dams. These values, while extremely difficult to quantify, are extremely important. Work by Dubos (1986) and Taylor (1986) has highlighted many of the spiritual and quality of life values associated with natural environments. Individual damowners and their families have experienced similar values with 73% of South Tobacco damowners reportedly believing that their dams have improved the esthetic value of the landscape; a majority also indicated the role of the dam in improving their family's quality of life. Many survey respondents eloquently described the importance of their dam in terms of recreation, inspiration, and economic security. Many downstream landowners indicated interest in wildlife and stabilised streamflows as enhancing their quality of life.

The important role of many Deerwood dams in providing wildlife habitat was prevalent within the landowner survey. Some 73% of South Tobacco damowners reported the use of their dams for both waterfowl and other wildlife habitat. Support for wildlife habitat is a common trend across Canada, with approximately 80% of Canadians typically expressing support for maintaining abundant habitat for songbirds, waterfowl, small mammals, and large mammals (Environment Canada, 1993). This indicates great potential for Deerwood's dams to provide substantial social values.

Hovde's (1994) estimation of the economic value of prairie potholes in North Dakota raises intriguing possibilities regarding similar potential values associated with Deerwood's dams. Meanwhile, the State of Minnesota's (1991) valuation of individual wildlife species could also strengthen the economic case for the Deerwood's small dam storage network as a valuable wildlife habitat area. These trends raise important considerations regarding the maintenance of ecosystem biodiversity within the Agro-Manitoba landscape. Interestingly, local residents in Deerwood have reported that many Deerwood dams are located close to the former sites of old beaver ponds. It was also well known that the Manitoba Escarpment was once dotted with marshy areas, particularly on the beach ridges of former Lake Agassiz (Orchard, 1995; McEwan, 1995).

These accounts suggest the construction of Deerwood's dams may well be assisting to re-create certain aspects of the Manitoba Escarpment's natural drainage regime, and this would have numerous wildlife and other benefits. Similarly, the benefits of increased water storage potential on the Escarpment raise exciting possibilities relating to drought mitigation. Ironically, the 1988 Assiniboine - South Hespeler Study (Canada/Manitoba, 1988) determined that a number of Escarpmental storage reservoirs could well be expected to augment municipal water supplies. However, the concept was not recommended for development consideration given its inability to cost-effectively supply irrigation water to South-Central Manitoba. A well designed network of small scale water storage reservoirs evidently has positive implications in terms of both flood and drought mitigation, the defining hydrologic characteristics of Southern Manitoba's landscape. Deerwood's dams are definitely providing drought mitigation at the farm level, as evidenced by the landowner survey reports of cattle enterprise security provided by stockwater from Deerwood dams.

Additionally, it is important to note the apparent impact of Deerwood's dams in reducing the amount of "foreign water" damage caused to the municipality of Roland. This has many positive benefits in terms of inter-municipal and community relations, not to mention the potential alleviation of burdensome cost-shared maintenance agreements. As noted by O'grodnik (1984), inappropriate land clearing and drainage by landowners and municipalities has served to compound flooding and erosion damage to downstream lands since agricultural development began in Manitoba. This phenomenon is again evident today with similar problems being experienced in the Assiniboine River Basin along the Manitoba-Saskatchewan border. The Deerwood approach could well assist in the cost-effective resolution of such contentious issues.

While detailed further research is required, it is plausible the social benefits associated with Deerwood's small dam network could well result in economic pay back at the 15% discount rate.

Intangible Costs

Some potential, but difficult to measure costs may well be associated with Deerwood's small dam network. These could include: increased salinity problems related to rising groundwater levels and the risk of simultaneous failure of all structures during a major rainfall or runoff event. Increased or stabilised groundwater levels were mentioned by several landowner survey respondents as a benefit, but widespread occurrence could well become a negative effect as natural salts common in local soils are pushed to the surface. This effect seriously degrades agricultural land.

The risk of watershed-wide structure failure seems remote. However, a majority of Deerwood's dams are multi-purpose structures, and these are designed to store a "conservation pool" of water throughout the Summer months. A rainfall event massive enough to breach all, or a substantial number, of Deerwood dams would in turn cause the release of additional water stored in the multi-purpose conservation pools. This would have the effect of exacerbating flooding and erosion damages associated with the storm.

Summary of all Benefits and Costs

Table 6m provides an overview of all tangible and intangible benefits and costs associated with Deerwood's small dam network. It is apparent that a range of environmental, economic, and social values are generated because of Deerwood's small dam network. They may be classified as either tangible or intangible.

Table 6M: Range of Benefits and Costs Associated with the Deerwood Dam Network

Type	Benefits	Costs
Tangible	• Municipal Cost Savings Associated with Reduced Flooding and Erosion (e.g. less damage and maintenance to municipal roads, bridges, and culverts. • Landowner Benefits Related to Reduced Flooding and Erosion (e.g. reduced damage and enhanced production). • Agricultural Diversification Opportunities for Landowners (e.g. trout farming, irrigation of specialty crops).	• Construction Costs. • Operating and Maintenance.
Intangible	• Waterfowl and Other Wildlife Habitat. • Water Management, Environmental, and Sustainable Development Education. • Recreational Opportunities. • Esthetic, Spiritual, Quality of Life Values. • Economic Security for Livestock Owners. • Increased Land Values. • Drought Mitigation: Stabilised/Increased Groundwater Levels and Stored Water Supplies for livestock, irrigation, and domestic consumption. • Reduced Municipal Disputes Regarding Foreign Water Damage Costs.	• Salinity due to Rising Groundwater. • Risk of Network - Wide Failure During a Massive Rainfall Event.

7. SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Research Summary

A review of related literature traced the historical roots of the watershed concept, and the evolution of policy and management planning. Various environmental, economic, and social issues pertinent to soil & water conservation were also examined. Some key themes, especially those relating to property rights questions, values, and attitudes held by owners of farmland were reviewed. Additionally, some innovative cases of community involvement in watershed management were discovered. Available research relating to soil & water management within small agricultural watersheds was reviewed, and previous work along the Manitoba/Pembina Escarpment was studied in detail. Finally, quantification of costs and benefits were identified as important and problematic factors associated with effective watershed management. Techniques were reviewed in search of an appropriate analysis framework for the study. A detailed review of the Deerwood project area included an in-depth site description, prior research on the region, and land and water management history of the North and South Tobacco Creek Watersheds..

Evidence supporting the causality and effectiveness of Deerwood's small dam network was collected via a comparative study approach involving the adjacent North and South Tobacco Creek Watersheds. After comparing historic streamflows, major runoff events, agricultural conservation practices, soil types, and vegetation cover, a control scenario was assumed to exist with the South Tobacco Creek under a management regime involving 30 strategically placed headwater retention structures (Deerwood's small dam network). Survey data collected from watershed landowners appeared to indicate: significant reductions in downstream erosion and flooding damage, lengthened runoff periods, and reduced creek turbidity. These trends supported recent Prairie Farm Rehabilitation Administration hydrology modeling which has proven the effectiveness of Deerwood's dam's in reducing peak runoff rates following Spring snowmelt and Summer rainstorm events. Damowners responding to the landowner survey were asked to indicate the range of uses, operating & maintenance costs, and benefits associated with their dams.

The two Rural Municipalities lying within the Tobacco and Graham Creek drainage area were contacted for cost information relating to the maintenance of ditches, roads, and stream crossings within the region. Cost data attributable to Deerwood's dams formed the basis of reasonable estimations received from the municipalities of Thompson and Roland.

Analysis was carried out based a framework focussing on the tangible benefits of Deerwood's small dam network (Krutilla and Fisher, 1975). Municipal cost reductions (tangible economic benefits) attributable to Deerwood's dams were both deflated to 1986 dollars and discounted to 1986 as the initial project year. Economic Payback Period Analysis (Johnson, 1995 and Gittinger, 1994) was used to assess these benefits and costs. Intangible Deerwood dam benefits reported within the landowner survey were also discussed, as were some potential intangible costs. The overall impact of the Deerwood dams was then considered in environmental, economic, and social terms.

Upon completion of *An Evaluation of Water Management Initiatives Undertaken by the Deerwood Soil and Water Management Association*, the following conclusions were determined, and a set of recommendations offered.

Conclusions

1. This evaluation has demonstrated that the benefits of Deerwood's small dam network exceed their costs at low and medium rates of discount. Local municipalities receive substantial benefits.

2. Based on municipal cost savings alone, the Deerwood small dam network has a financial payback period of 16 years (undiscounted) and an economic payback period of 25 years (discounted at 5%). Individual landowner benefits can be expected to generate enough value to make the dams viable at the 8% rate. At 15%, a substantial amount of environmental and social benefits are required to make the dams cost-effective. Benefits of this magnitude may well exist. Operating & maintenance costs associated with Deerwood dams are typically a landowner responsibility and have been minimal. Substantial Provincial benefits of Deerwood's small dam network may also exist, but these cannot be measured at this time due to a lack of information.

3. Deerwood dams are used to manage approximately 9% of the local drainage area. Three types are utilised: dry dams (seven); 25 multi-purpose dams; and backflood Dams (ten). Construction costs have averaged $\$11,396_{1986}$, $\$8527_{1986}$, and $\$5103_{1986}$ respectively. Deerwood dams have cost all project sponsors a total of \$346, 607[33] in 1986 dollars[34].

4. The Deerwood Soil and Water Management Association is a community-driven resource management model which demonstrates a coordinated and cost-effective approach to water management on the Manitoba Escarpment. Survey reports regarding the effectiveness of Deerwood's small dam network supported recent PFRA hydrology modeling research.

5. a) Watershed management has been occurring for thousands of years throughout the world. Instances still exist today whereby a "watershed community" of people work collectively to address soil erosion and flooding, and to generally improve their quality of life through sustainable agricultural production.

   b) Several excellent small agricultural watershed management case studies exist along the Manitoba/Pembina Escarpment. None however, appear to have considered the potential effectiveness and efficiency of a network of small headwater retention structures managed by an organisation of volunteer landowners.

   c) Analytical techniques exist for the economic evaluation of agricultural soil and water conservation projects. As there are often data problems associated with the quantification of many benefits and costs, analysis methods which focus upon a project's tangible economic benefits are likely to provide the most defensible and credible evidence of project worth.

6. The establishment of a control scenario/comparative study between two adjacent watersheds, municipal and landowner survey data, correlation of recent PFRA hydrology modeling research, and consideration of tangible and intangible environmental, economic, and social benefits and costs proved useful and suitable in analysis and evaluation.

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33 Not including Prairie Farm Rehabilitation Administration engineering desgin costs.

34 Capital costs were contributed by the Federal and Provincial Governments, while private conservation agencies and local Rural Municipalities have also contributed substantially. Landowners participating in Deerwood's projects contribute their land, a percentage of construction costs, and most future operating and maintenance costs.

Recommendations to the Province of Manitoba

i) Where applicable, the Province of Manitoba should strongly consider supporting the existence of local volunteer associations of agricultural landowners and other community residents who work together to collectively improve land and water management efforts within small watersheds along the Manitoba Escarpment. Similar organisations working in other areas of Agro-Manitoba may also merit Provincial support. Through sub-watershed coordination and local empowerment, the efficiency and accountability of small groups of interested and committed landowners could be harnessed for maximum conservation effectiveness and efficiency in rural Manitoba. This could contribute to the achievement of environmental, economic, and social goals on the Agro-Manitoba landscape.

ii) Based on the Deerwood Soil and Water Management Association model, "Successful Local Watershed Organisation Criteria" could be established. The Province of Manitoba should then consider undertaking a review of Agro-Manitoba to assess the existence and/or feasibility of supporting local watershed organisations along the Manitoba Escarpment or elsewhere.

iii) The Province of Manitoba should consider supporting a project to enhance and formalise the relationship between local watershed organisations and Conservation Districts (possibly through local watershed organisation assumption of sub-district Conservation District Board roles). A pilot project between Deerwood and Pembina Valley Conservation District would be logical.

iv) The Province of Manitoba should strongly consider detailed monitoring of costs associated with Third Order and above waterway damage and maintenance costs. This should be carried out according to watershed areas in order to facilitate future research related to the economic benefits of watershed management (i.e. at the Conservation District level).

v) A network of small headwater retention structures managed by an organised association of committed landowners (i.e. the Deerwood model) should be considered part of the capital stock of public infrastructure. The Province should consider working with Rural Municipalities and the Federal Government towards future infrastructure programmes focussing on small scale headwater retention and watershed management as a cost-effective means to avoid municipal infrastructural damages and costs. Conservation Districts should be involved where applicable.

vi) Given the reported number of economic opportunities related to Deerwood's dams, the Province of Manitoba should continue to monitor the potential for local economic development through improved productivity and on-farm diversification based on small scale water storage. The promotion of "watershed community development" could be an innovative approach addressing both conservation and development agendas. The Australian Landcare Group experience should be given serious consideration.

vii) Periodic review of Deerwood's small dam network should be undertaken by the Province. Additional research could occur in the areas of wildlife-related, esthetic, quality of life, recreational, spiritual and other social benefits. Future operating and maintenance costs of Deerwood's small dam network should also be monitored.

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Appendices

Appendix 1: Municipal descriptive survey.

Appendix 2: Landowner/Damowner analytical survey.

TIC Deerwood Project

General Outline of Questions for Local Rural Municipalities Regarding the Costs of <u>All</u> Water-Related Problems Associated with Waterways Draining Eastward from the Manitoba Escarpment/Pembina Hills

1. Prior to 1984, on average, how much money has been spent annually within your municipality to address the following water-related problems? (this may include Provincial waterway maintenance costs and/or Provincial contributions to your municipality). Please itemize costs if possible:

   Drainage Ditch/Streambank Erosion;

   Dredging of Soil from Drainage Ditches due to Sedimentation;

   Flooding Damages Including Road/Bridge Washouts and Landowner Compensation;

   Your Contributions for Maintenance Agreements with Municipalities Downstream;

   Community/On-Farm Water Supply Shortages due to Low Groundwater Levels

   Other

2. Can you provide a number of specific examples in which adressing the above water-related problems has been particularly costly for your municipality or the Province of Manitoba?

3. Since 1988, on average, how much money has been spent annually within your municipality to address the problems described with Question #1?

4. Can you provide a number of specific examples in which the above water-related problems have significantly improved since 1988. In your opinion, what caused for these improvements?

5. In addition the above economic questions, are you aware of any additional *social/cultural* or *environmental/ecological* changes occuring within your rural municipality since 1988, which are related to small scale water management along the Eastern side of the Manitoba Escarpment? In your view, are these changes positive?

   social/cultural:
   means changes which may be generally affecting the community or society at large.

   environmental/ecological:
   means changes which have impact on local ecosystems or the broader environment.

RURAL MUNICIPALITY OF THOMPSON
INCORPORATED
19 09
OFFICE OF THE SECRETARY-TREASURER
MIAMI, MANITOBA

March 22, 1994

Dear Ratepayer:

Mr. Bryan Oborne has been living in the area since last summer. He is undertaking an independent study to determine the financial and other benefits which may be resulting from the work of the *Deerwood Soil and Water Management Association*. Mr. Oborne represents The International Coalition (TIC), a private organization promoting sensible land and water management throughout the Red River watershed.

Our RM is a member of The International Coalition. TIC has been engaged by the Manitoba Government to undertake this research; and a portion of this study will used toward Mr. Oborne's Master's of Natural Resources Management Degree at the University of Manitoba.

All landowners and/or residents of the North Tobacco Creek or South Tobacco Creek watershed are being contacted to participate in Mr. Oborne's research. While the results of this research will be published, individual responses will be kept confidential. All questionnaire participants will receive a copy of the final report.

Please take the time to complete the short questionnaire (enclosed) which Mr. Oborne has prepared. He asks that you contact him for additional information or assistance as required (#744-2188). Please mail the questionnaire to Mr. Oborne using the enclosed stamped envelope by April 5, 1994.

You may also wish to advise Mr. Oborne if there are other people who you think should receive this questionnaire. Mr. Oborne' s research may result in significant Provincial policy directives; and your involvement is very important. Thank you for your participation.

Sincerely,

Reeve and Council
R.M. of Thompson

Mary Riddell, Secretary - Treasurer

Encls.

Questionnaire
The Value of Small Scale Water Storage in the Manitoba Escarpment

Please Note:

Please read the questions carefully, answering each to the best of your ability. Please do not hesitate to contact me for additional information or assistance if required; or if there are other people who should receive a questionnaire. Please mail the questionnaire using the enclosed self-addressed envelope by **April 5, 1994.**

Thank you, Bryan Oborne ([redacted]

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1. a) Is a small dam used to store water anywhere on your property which borders the North Tobacco Creek or the South Tobacco Creek (or its upstream channels/tributaries)?

   If yes, please continue below. If no, please go to question 17. Yes: ☐ No: ☐

Dam Information
Is your dam used for the following purposes?

2. a) Flood Damage Reduction: Yes: ☐ No: ☐
   b) If yes, please describe how flooding is reduced with your dam. ______

3. a) Soil Erosion Prevention: Yes: ☐ No: ☐
   b) If yes, please describe how erosion is prevented with your dam. ______

4. a) Stock Watering: Yes: ☐ No: ☐
   b) If yes, please describe how cattle are watered using your dam. ______

5. a) Irrigation (eg, backflood, travelling gun): Yes: ☐ No: ☐
   b) If yes, please describe how you irrigate with water stored by your dam. ______

6. a) Domestic Water Supply: Yes: ☐ No: ☐
   b) If yes, please describe your system. ______

7. a) Waterfowl Habitat (eg. ducks, geese): Yes: ☐ No: ☐
   b) If yes, please describe how waterfowl habitat is created or maintained. ______

8. a) Fish Pond (eg. trout): Yes: ☐ No: ☐
   b) If yes, please describe, indicating type of fish stocked. ______

9. a) Other Wildlife Habitat (eg. deer, songbirds): Yes: ☐ No: ☐
   b) If yes, please describe how other wildlife habitat is created/maintained. ______

10. a) Other Purposes: Yes: ☐ No: ☐
    b) If yes, please explain the role of your dam. ______

Dam Costs:

11. a) Have you experienced dam operating or maintenance costs? Yes: ☐ No: ☐

    If yes:
    b) Are these costs experienced annually or sporadically? ______
    c) Please describe these costs. ______

12. a) Have you experienced unforeseen problems associated with your dam? Yes: ☐ No: ☐
    b) If yes, please describe the nature of these problems ______

General:

13. a) Do you believe this dam has caused groundwater levels to rise? Yes: ☐ No: ☐
    b) If yes, please describe how you know ______

14. a) Do you believe this dam has improved the esthetic value of the landscape? Yes: ☐ No: ☐
    b) If yes, please explain. ______

15. a) Do you believe this dam has improved your family's general quality of life? Yes: ☐ No: ☐
    b) If yes, please explain. ______

16. a) Do you believe this dam has increased the value of your property? Yes: ☐ No: ☐
    b) If yes, by what percentage since dam installation? ______%

Flooding Damage:
In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following flooding problems for you?

17. a) Seeding Problems (eg. delays, poor germination): Yes: ☐ No: ☐
    b) If yes, please describe the nature of these problems. ______________________________

18. a) Standing Field Crop Damage (eg. sedimentation, summer flooding): Yes: ☐ No: ☐
    b) If yes, please describe the nature of this damage. ______________________________

19. a) Introduction of Weeds: Yes: ☐ No: ☐
    b) If yes, please explain this problem further. ______________________________

20. a) Property Damage (buildings, equipment, stored crops/feed): Yes: ☐ No: ☐
    b) If yes, please describe this damage. ______________________________

21. a) Other: Yes: ☐ No: ☐
    b) If yes, please explain. ______________________________

Soil Erosion:
In the last five years, has water flowing within/from the North Tobacco Creek or the South Tobacco Creek (or its smaller upstream channels/tributaries) caused any of the following soil erosion problems for you?

22. a) Gulley Erosion (water creates a well defined channel in field): Yes: ☐ No: ☐
    b) If yes, please describe the nature of this problem. ______________________________

23. a) Sheet Erosion (loss of soil over a wide span on field)?: Yes: ☐ No: ☐
    b) If yes, please describe the nature of this problem. ______________________________

24. a) Extensive RM ditch damage occurred near your property?: Yes: ☐ No: ☐
    b) If yes, please describe if/how your land or other property was affected. ______________________________

25. a) Other: Yes: ☐ No: ☐
    b) If yes, please explain. ______________________________

General:

26. During the last five years, have you noticed changes in the following?

a) The length of Spring runoff in the creek draining your land? Yes: ☐ No: ☐
b) If yes, please explain. ______________________________

c) The quality of water within the creek after a Summer storm? Yes: ☐ No: ☐
d) If yes, please describe. ______________________________

27. a) Do you practice any methods of land and water conservation? Yes: ☐ No: ☐
b) If so, please describe which types, and for how long? ______________________________

28. a) Please indicate the type of farm you operate.
Cash Crops: ☐ Livestock: ☐ Dairy: ☐ Mixed: ☐

b) If Mixed, please indicate which areas. ______________________________

If you own a dam, and have completed questions 1-28, please ignore the following. All others, please continue.

29. a) Is the creek important to your farming operation? Yes: ☐ No: ☐
b) If yes, please explain how. ______________________________

30. a) Do you believe the creek improves the overall esthetic value of the local landscape?
Yes: ☐ No: ☐
b) If yes, please describe. ______________________________

31. a) Do you believe the creek improves the general quality of life for you and your family?
Yes: ☐ No: ☐
b) If yes, please explain. ______________________________

32. a) Do you believe the creek increases the value of your property? Yes: ☐ No: ☐
b) If yes, by what percentage if compared to similar land without a creek? ______________ %

Additional Comments: ______________________________