ENVIRONMENTAL AND SOCIO-ECONOMIC IMPLICATIONS OF LAND AND WATER RESOURCES PLANNING IN EDEN CREEK WATERSHED

By

Randolph Seecharan

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

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ABSTRACT

Planning of land and water related activities on a watershed basis has become an extremely complex task in Canada. With present concern about the physical degradation of the environment and growing demand for agricultural commodities, it is essential that watershed planning be an orderly process so that the quality of the environment is maintained and adequate levels of production are achieved.

This study analyzes rainstorm runoff, soil erosion, associated water problems and the socio-economic conditions of residents of Eden Creek watershed in Manitoba. In examining these problems the study assessed relationships between the welfare of residents and their methods of resource management. Age of the farm operator and the level of education appear to affect the way in which the operator manages farm resources. Older operators with low education levels lack the incentives and skills to make appropriate use of their farms. Over time, this has resulted in excessive soil erosion and low farm incomes. Limited opportunities for entry into agricultural and other forms of employment have also resulted in migration of watershed residents.

Farm budgets were prepared to determine if rearrangement of farm resources on three hypothetical farms was economically viable. The study showed that, in all three cases, rearrangement increased net farm returns.

Recommendations are proposed which would improve farm income. These also indicate the need for further hydrological information and changes in land-use patterns to reduce runoff and soil erosion.

ACKNOWLEDGEMENTS

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Finally, for my wife, Sandra Taylor, I reserve a special thank you,for her unfailing encouragement and endurance, I will forever be grateful.

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ac	acres
ac ft	acre feet
cfs	cubic feet per second
csm	cubic feet per second per square mile
ha	hectares
kg	kilograms
m	metres
mi	miles
m^3	cubic metres
m^3/s	cubic metres per second
mm	millimetres
q/p	peak discharge
t	tonnes
T_b	time to base
T_p	time to peak

Glossary of Terms

Antecedent Moisture Condition - the soil moisture condition created by a specified amount of rainfall in five days preceding a flood event. The initially dry condition is AMC I, average condition is AMC II, and initially wet conditions is AMC III.

Curve Number (CN) - a number between 0 and 100 which indicates the runoff producing potential of a soil/land use combination when the ground is not frozen.

Design Storm - a specified amount of storm rainfall.

Direct Runoff - runoff which enters a stream channel during or soon after a storm as a result of surface or rapid sub-surface flow.

HU - acronym for Hydrological Unit.

Hydrological Soil Group - a classification of a soil on the basis of its permeability after prior wetting and swelling of the soil.

SCS - acronym for Soil Conservation Service.

Time to Base - the time from the start to the end of runoff from a storm event.

Time of Concentration (Tc) - the time taken for storm runoff to travel from the farthest point of the basin to the site in question, the farthest point being determined on the basis of travel time and not necessarily distance.

USLE - acronym for Universal Soil Loss Equation.

Watershed - the area of land drained above a given point on a stream, also termed drainage basin or catchment area.

CHAPTER 1

INTRODUCTION

1.1 Study Area

The Eden Creek watershed is located on the northwestern edge of the Whitemud River Watershed Conservation District, in townships 16 and 17, ranges 15 and 16 W (Fig. 1-1). The watershed is approximately 4575 ha (11,300 ac) in size,with headwaters in and adjacent to the Riding Mountain National Park.[1]

The watershed lies in a region characterized by high summer temperatures and low winter temperatures. Approximately 80 percent of the precipitation falls as rain during April to October and about 20 percent as snow from November to March. The average length of frost-free period ranges from 95 to 130 days. Natural vegetation in the watershed is mostly coniferous-mixed wood, broad-leaf forest with some interspersion of aspen groves and grassland.

Most of Eden Creek watershed is occupied by Gray Luvisol soils, developed from shaley parent material during the Upper Cretaceous period (Fig. 1-2). The land is predominantly used for agriculture with over 75 percent of the land under cultivation (Fig. 1-3). The main crops include small grains (wheat, oats, barley and rye), alfalfa and tame hay.

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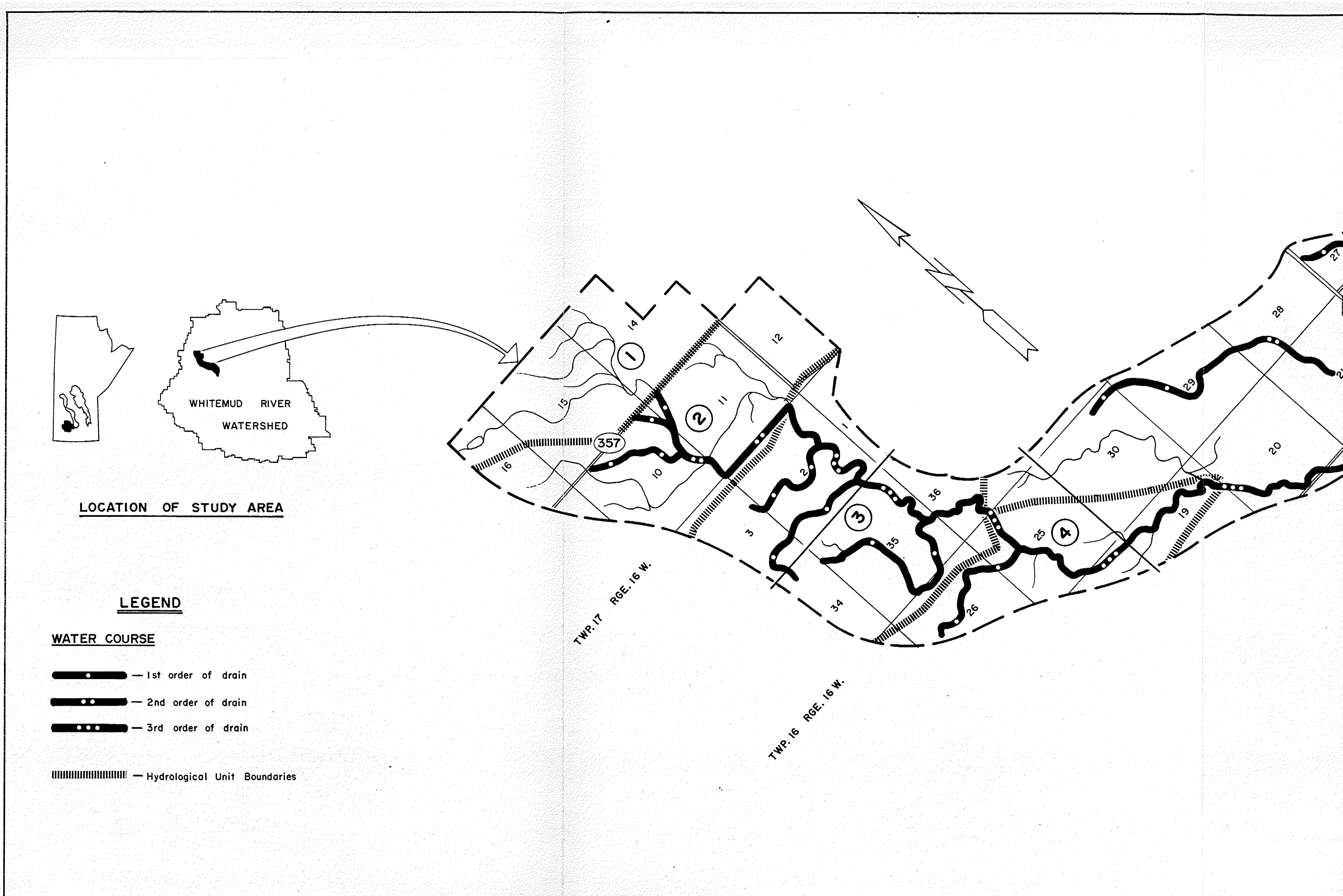
[1]Wherever appropriate, measurements will be given in both metric and British units.


WHITEMUD RIVER WATERSHED
LOCATION OF STUDY AREA
LEGEND
WATER COURSE
— 1st order of drain
— 2nd order of drain
— 3rd order of drain
— Hydrological Unit Boundaries
357
TWP.17 RGE.16 W.
TWP.16 RGE.16 W.

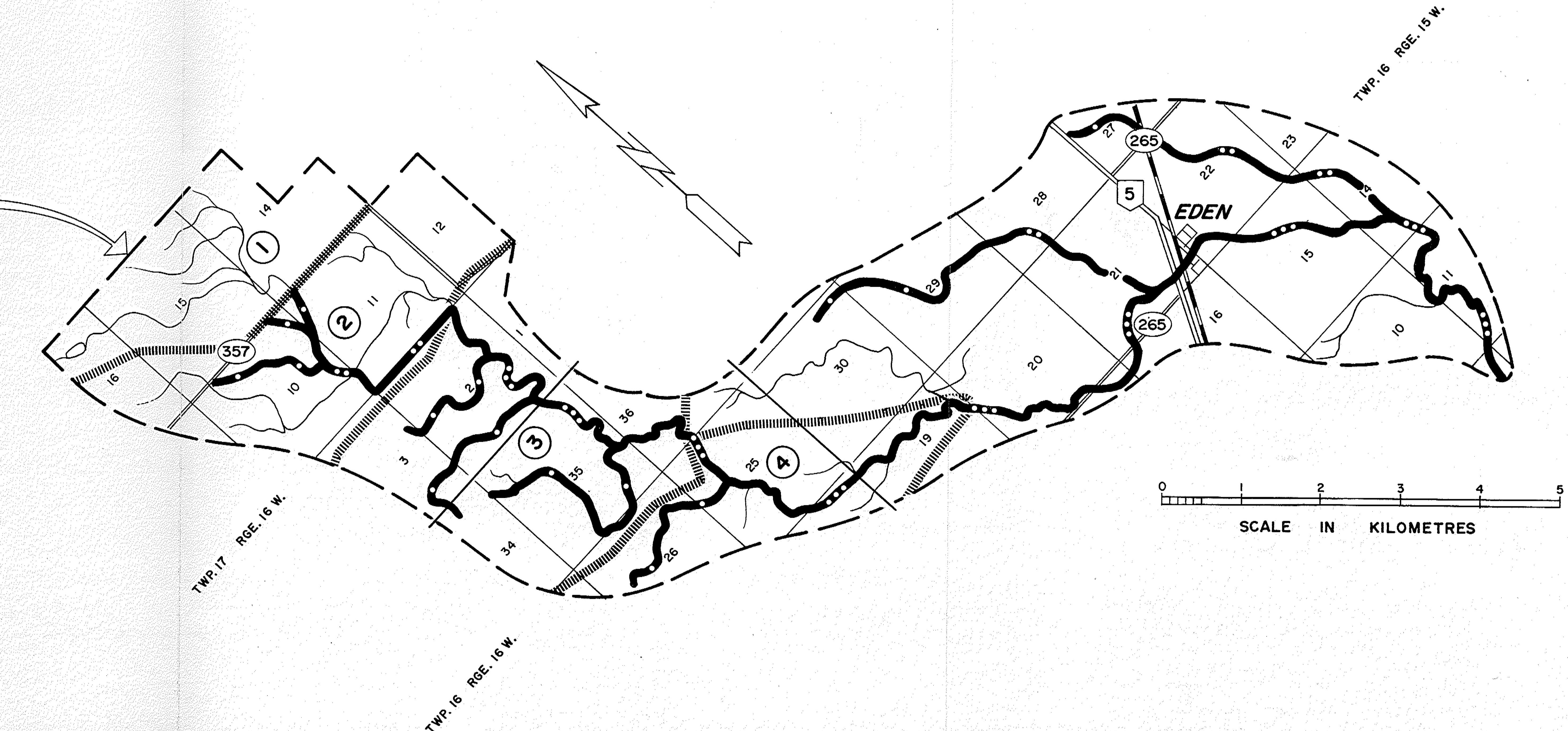


FIGURE 1-1

EDEN CREEK STUDY AREA

DESIGNATION OF DRAINS AND HYDROLOGICAL UNIT BOUNDARIES

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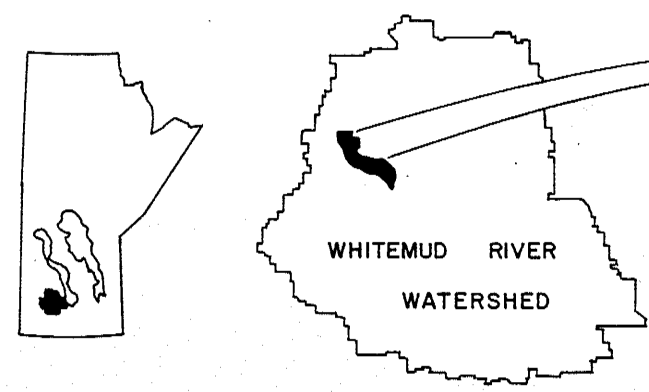
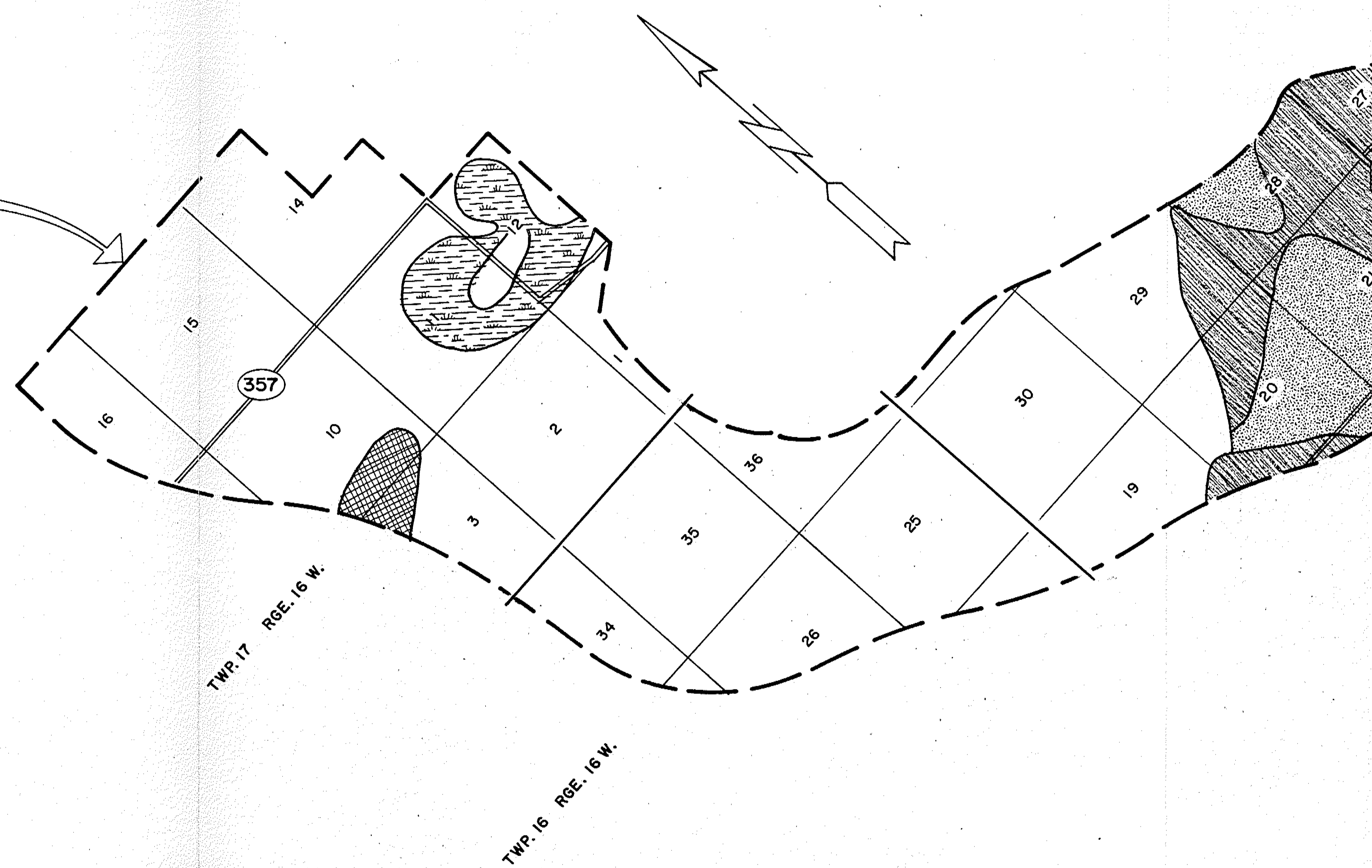


LOCATION OF STUDY AREA



LEGEND

- Chernozemic black soils
- Chernozemic dark grey soils
- Chernozemic black soils (high lime)
- Gray Luvisol soils
- Marsh, deep to shallow organic soils

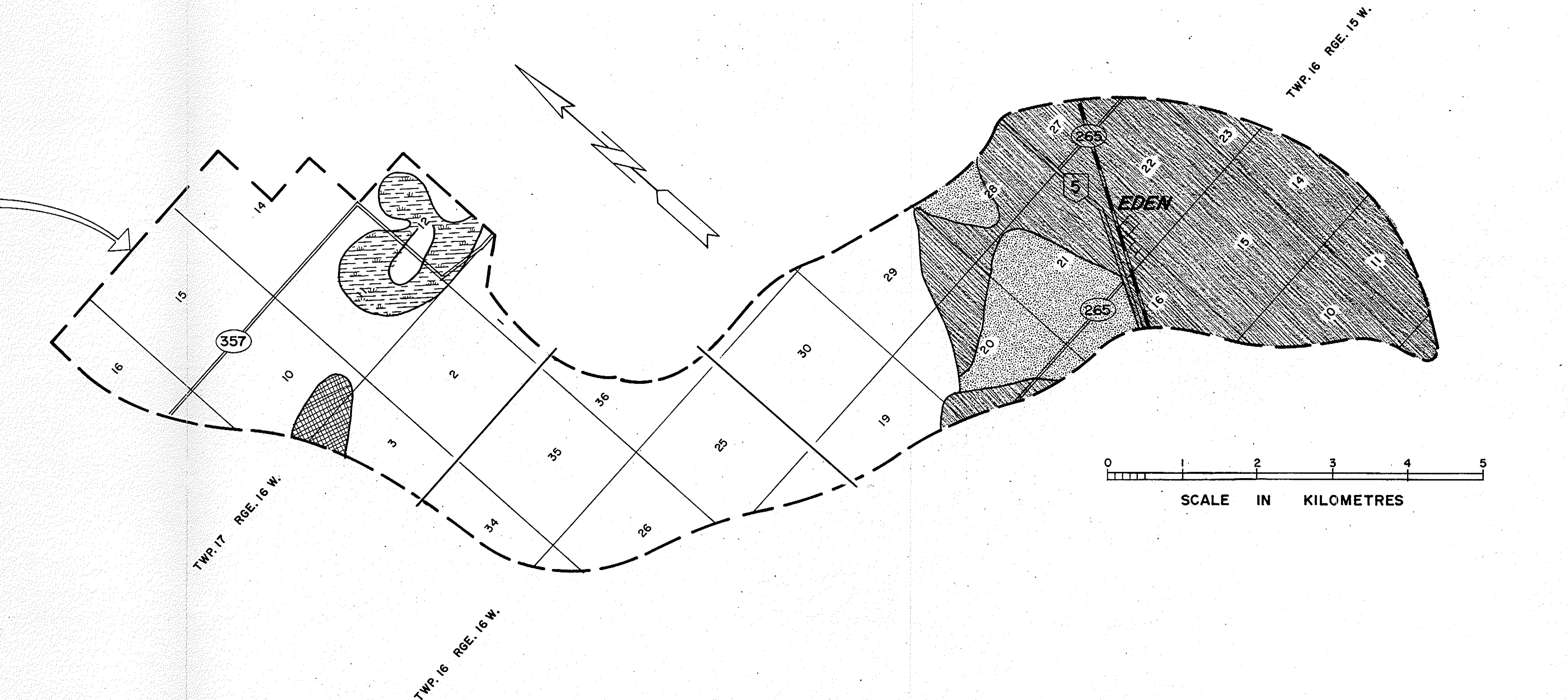


FIGURE I-2

EDEN CREEK STUDY AREA

SOIL ASSOCIATION

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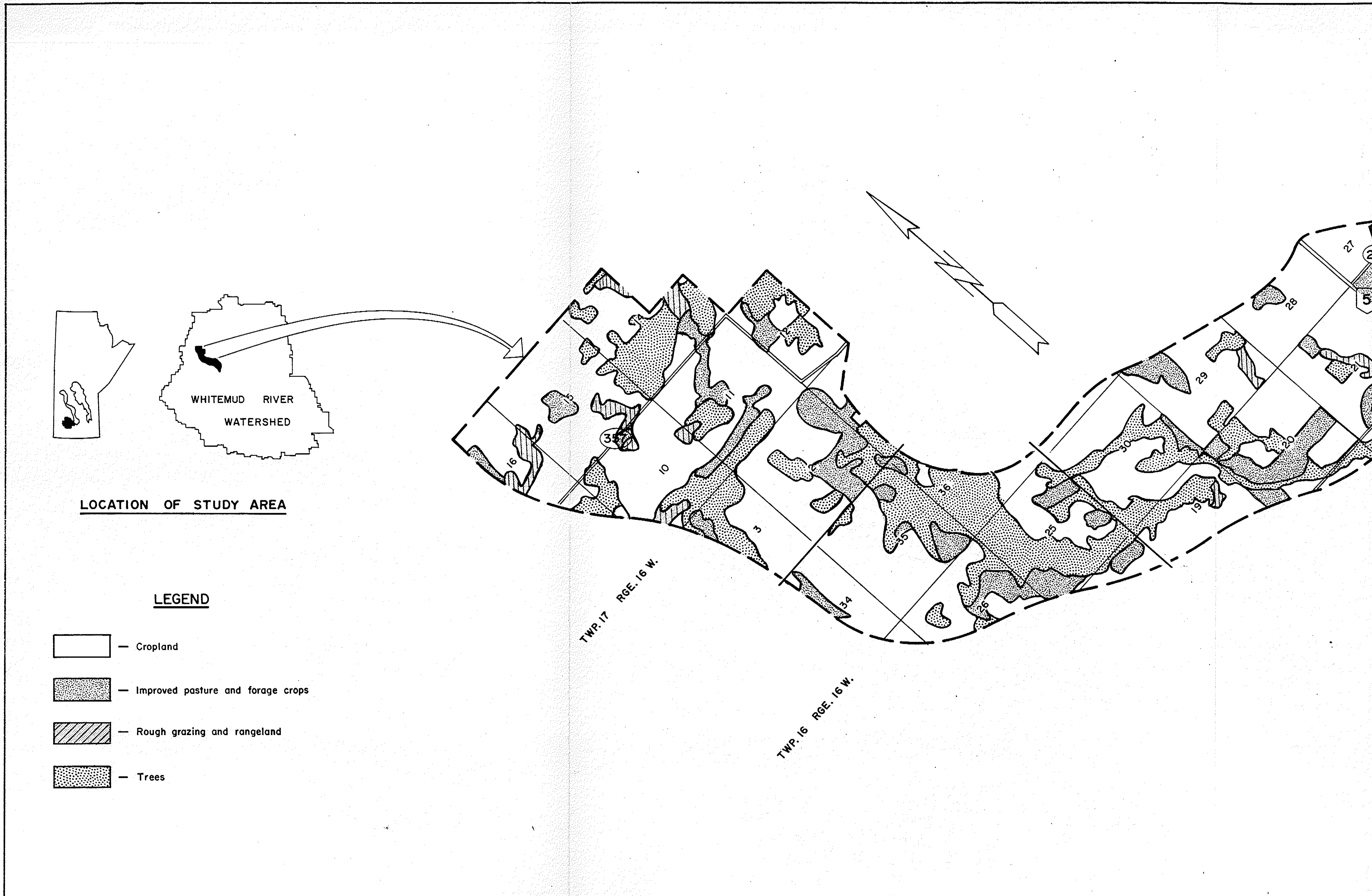
WHITEMUD RIVER
WATERSHED
LOCATION OF STUDY AREA
LEGEND
— Cropland
— Improved pasture and forage crops
— Rough grazing and rangeland
— Trees
TWP.17 RGE. 16 W.
TWP. 16 RGE. 16 W.
16
10
3
34
35
26
25
36
19
20
30
29
28
27

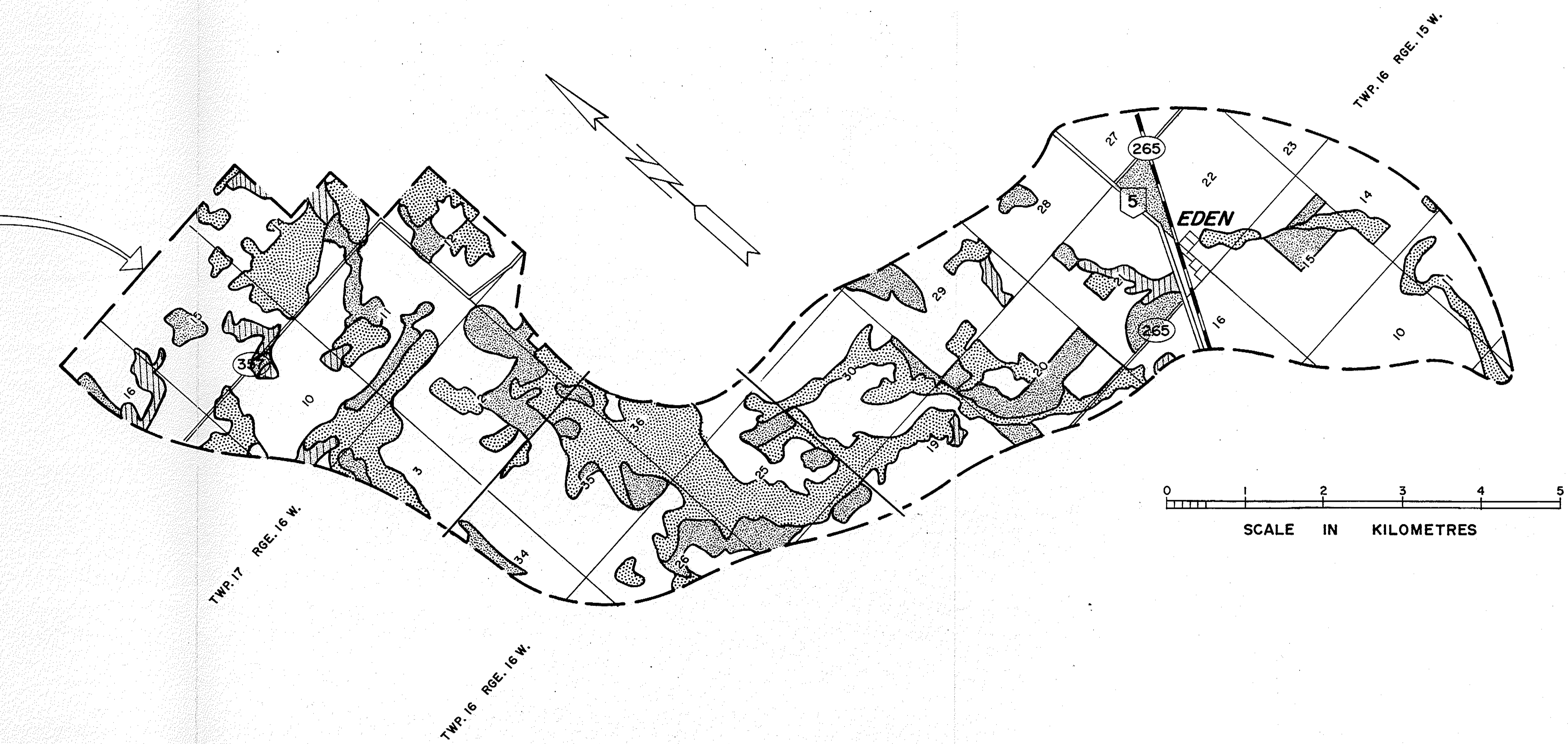

FIGURE 1-3

EDEN CREEK STUDY AREA	
1970 LAND USE	
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1.2 Problem Statement

Loss of vegetation and the increase in runoff resulting in erosion, gullying, sedimentation and flash flooding are serious management problems in watersheds. These problems are especially common in agricultural areas, both within and outside the Whitemud River Watershed Conservation District where there is no adequate protection of soil from erosion (Fig. 1-4). In the Eden Creek watershed, only 15 percent of the land is in brush or unimproved state. As a result of the removal of vegetation, soil erosion by uncontrolled runoff has had a serious effect on productivity of the land base with subsequent deposition and siltation in channels within the watershed.

Surface water problems such as erosion, flash flooding and water ponding on poorly drained land have occured regularly whenever there are large summer rainstorms (Manitoba Department of Mines, Resources and Environmental Management, 1974).[2] These problems seem to be influenced by:

(1) Topography - In general there is a wide range of elevation over a relatively short distance (Fig. 1-5). At the highest point of the watershed, elevation is 671 m (2200 ft) above sea level, whereas 5 km (3 mi) to the east it declines to about 610 m (2,000 ft). At the lower end of the watershed elevation is further reduced to 381 m (1,250 ft) above sea level.

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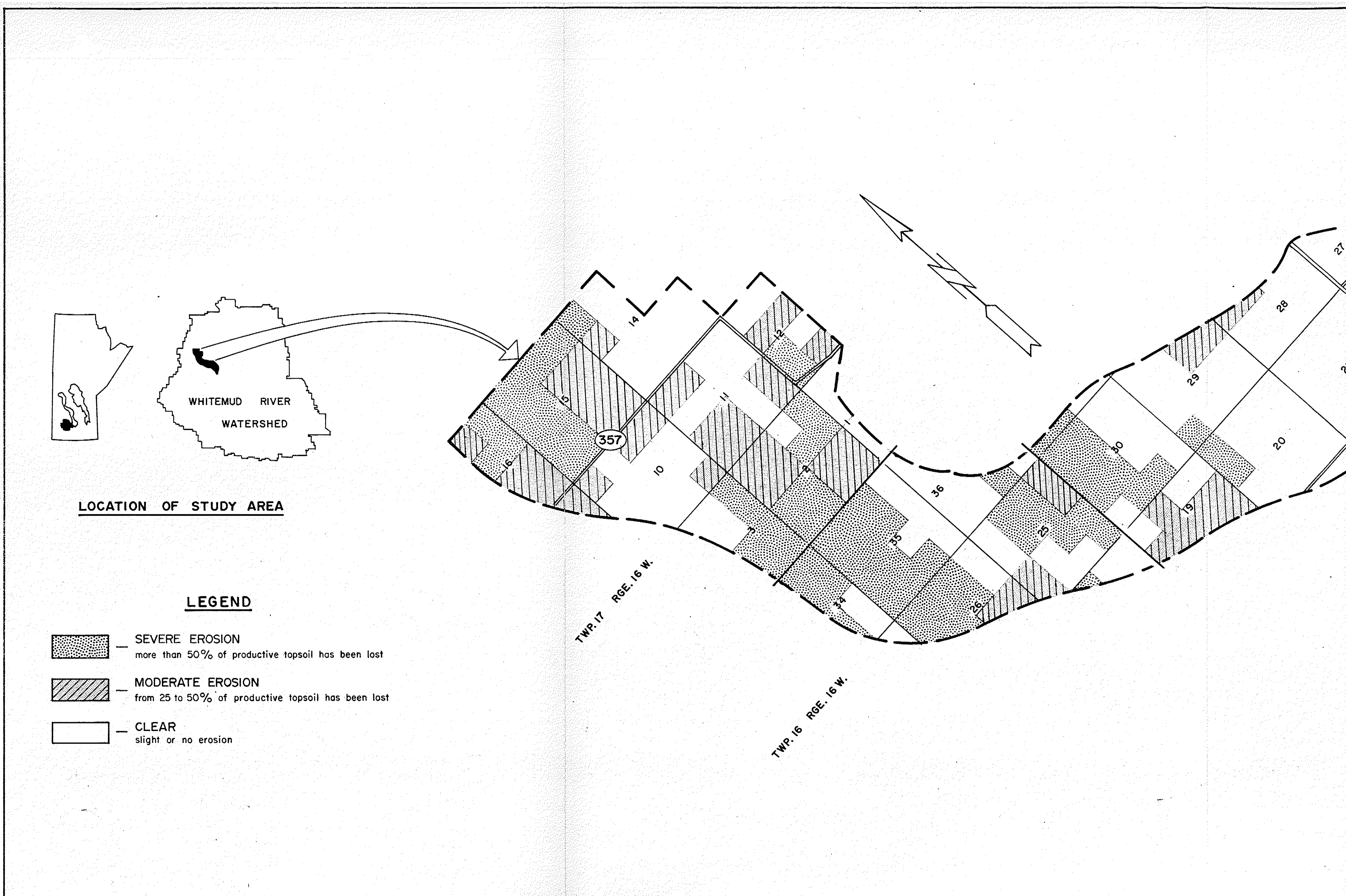
[2]The department name was changed to Department of Natural Resources as of January, 1980.


WHITEMUD RIVER WATERSHED
LOCATION OF STUDY AREA
LEGEND
SEVERE EROSION
more than 50% of productive topsoil has been lost
MODERATE EROSION
from 25 to 50% of productive topsoil has been lost
CLEAR
slight or no erosion
357
TWP. 17 RGE. 16 W.
TWP. 16 RGE. 16 W.
14
12
15
11
1
16
10
2
36
3
35
34
26
25
30
19
29
28
27
20

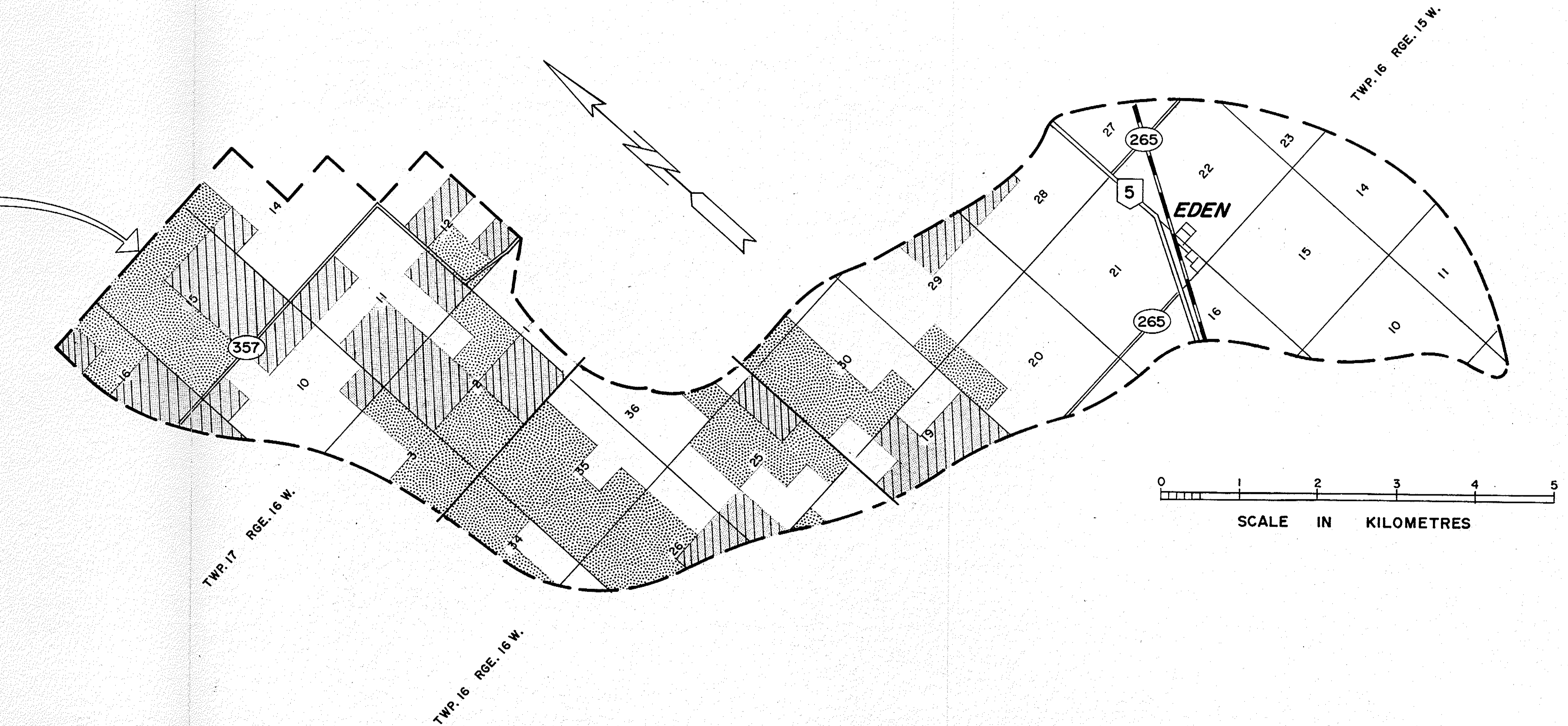


FIGURE 1-4

EDEN CREEK STUDY AREA

SOIL EROSION

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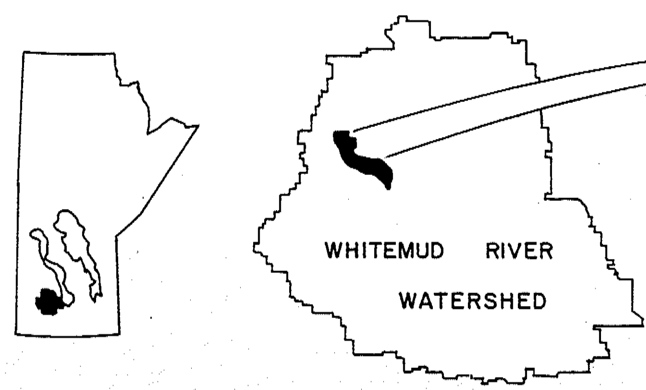
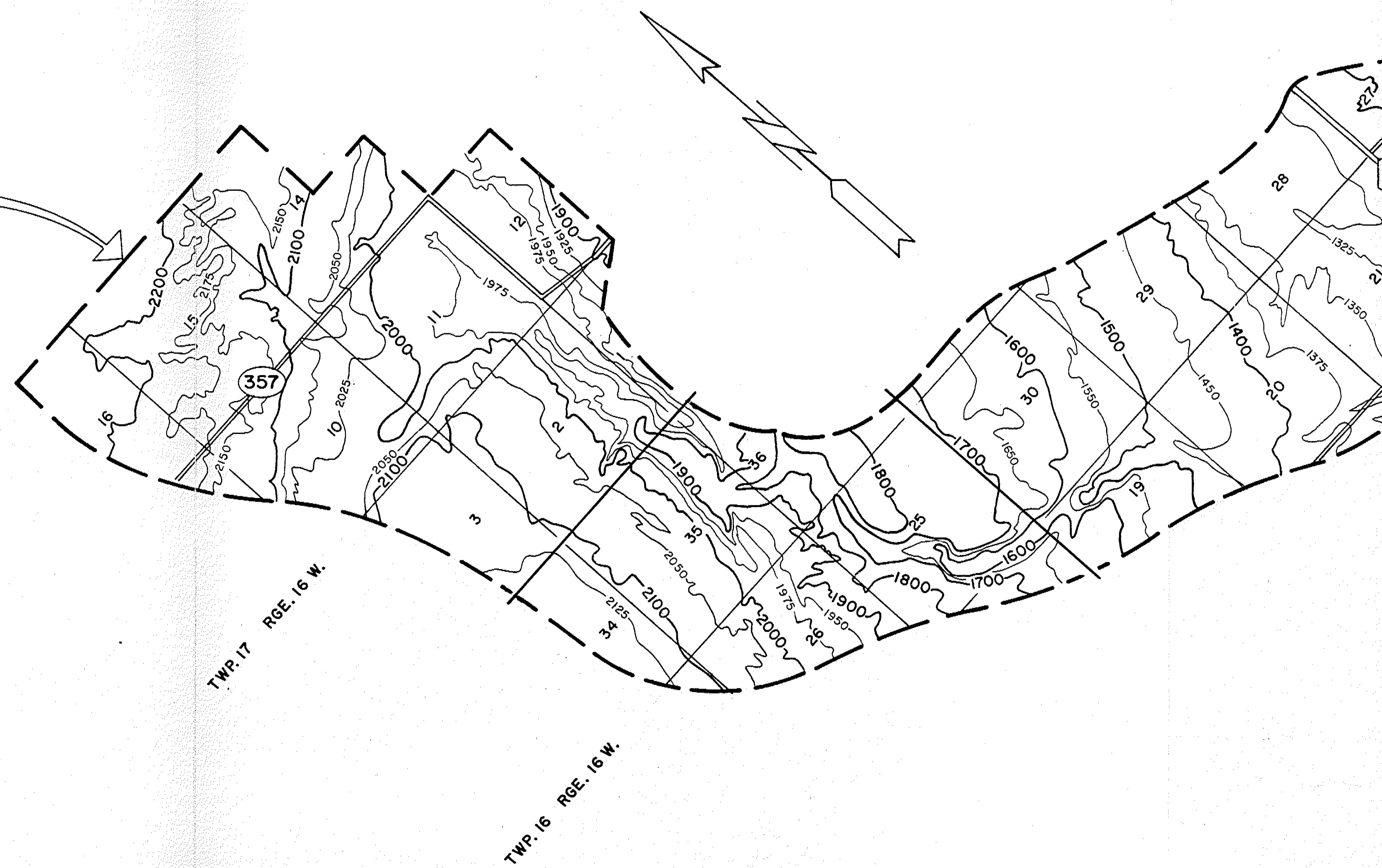


LOCATION OF STUDY AREA



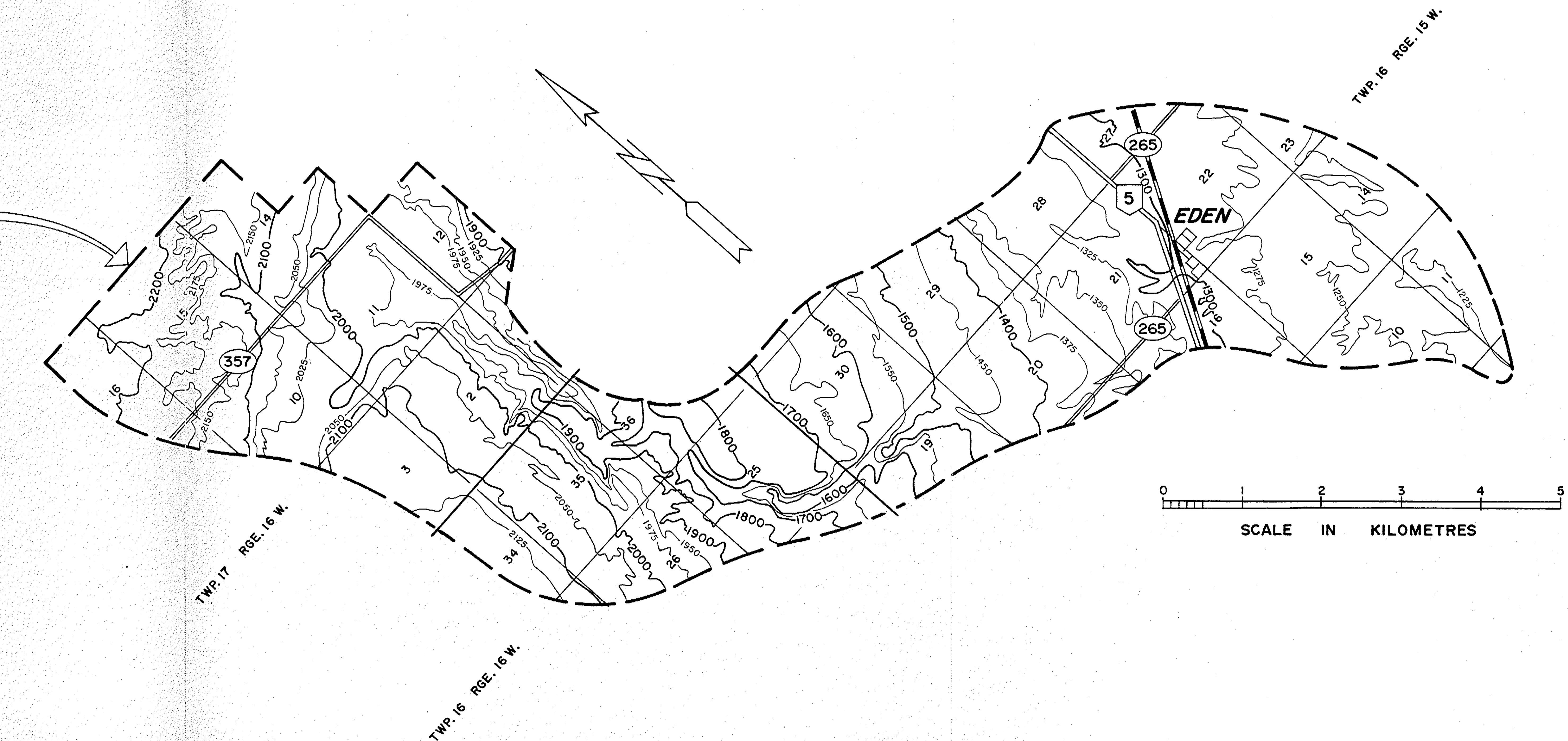


FIGURE 1-5

EDEN CREEK STUDY AREA

CONTOUR MAP

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(2) Precipitation - Annual precipitation in the 10th percentile ranges is estimated from 381 to 406 mm (15 to 16 in) in Eden Creek Watershed, whereas elsewhere in the Whitemud River Watershed Conservation District it varies from 330 to 356 mm (13 to 14 in). Annual precipitation in the 90th percentile ranges is estimated at 635 to 660 mm (25 to 26 in) in Eden Creek watershed compared to a range of 538 to 635 (21 to 25 in) for the rest of the Whitemud River Watershed Conservation District (Fig. 1-6).

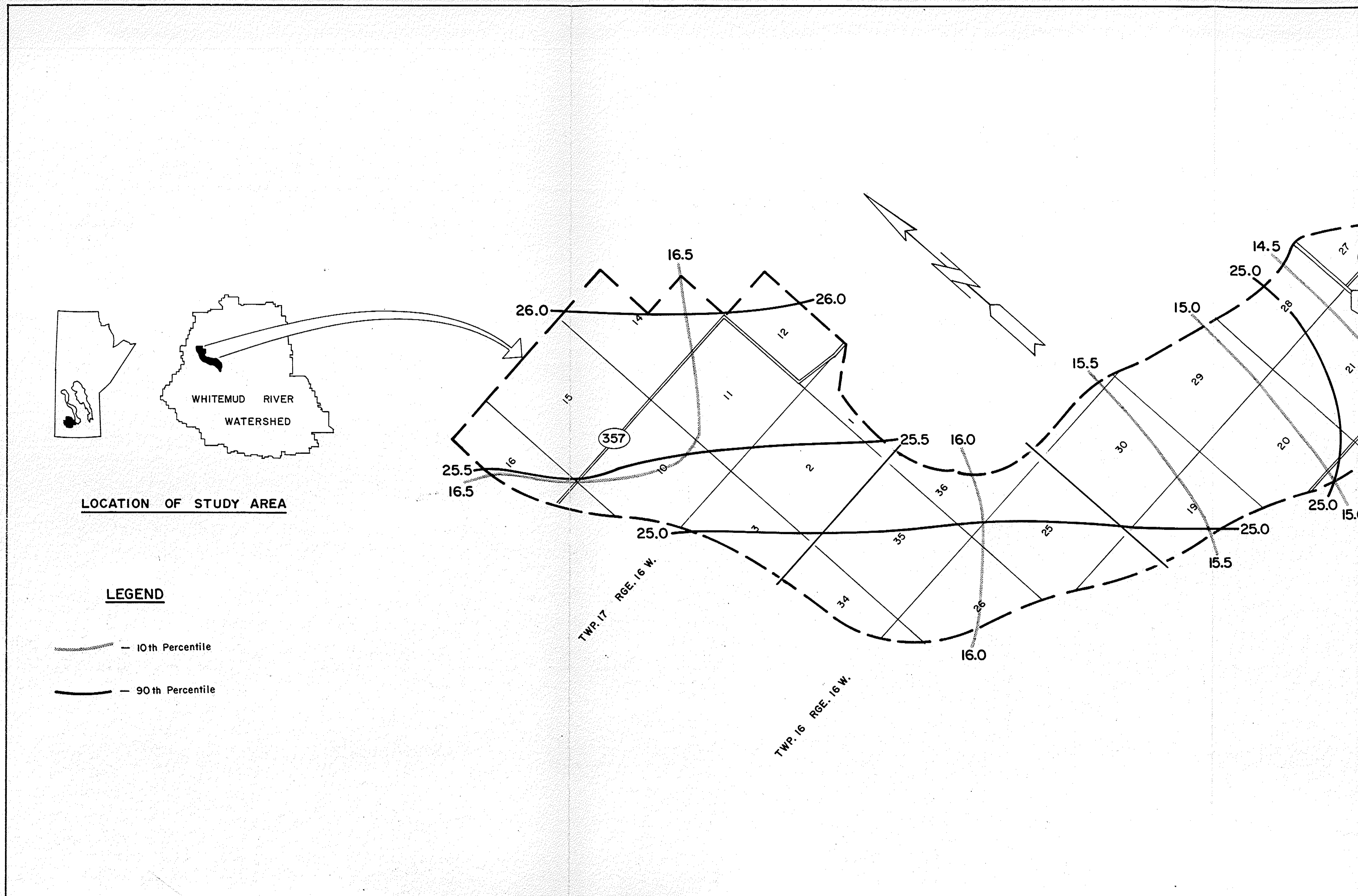
(3) Runoff - Compared with basin situations runoff within Eden Creek Watershed is much more intense.

Directly related to the physical environmental problems are the socio-economic conditions of Eden Creek residents. Generally, development of services in rural Manitoba are of a substantially lower quality when compared to urban areas. Migration of population from rural areas to large urban centres where there are more jobs and education opportunities has largely contributed to reduction of tax revenues and consequently the reduction of rural services (Province of Manitoba, 1973).

In Eden Creek watershed the lack of a comprehensive development plan has resulted in a steady decline of watershed population. In 1974, the Department of Mines, Resources and Environmental Management identified the following trends within the watershed:

(1) Watershed depopulation - Since 1971, there has been a steady decline in population. From 1971 to 1976, the watershed population has declined by 16 percent (Statistics Canada, 1976, unpublished data).

(2) Age of watershed population - A large proportion of families have a household head


WHITEMUD RIVER WATERSHED
LOCATION OF STUDY AREA
LEGEND
— 10th Percentile
— 90th Percentile
357
TWP. 17 RGE. 16 W.
TWP. 16 RGE. 16 W.
26.0
26.0
16.5
25.5
16.5
25.5
16.0
25.0
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25.0

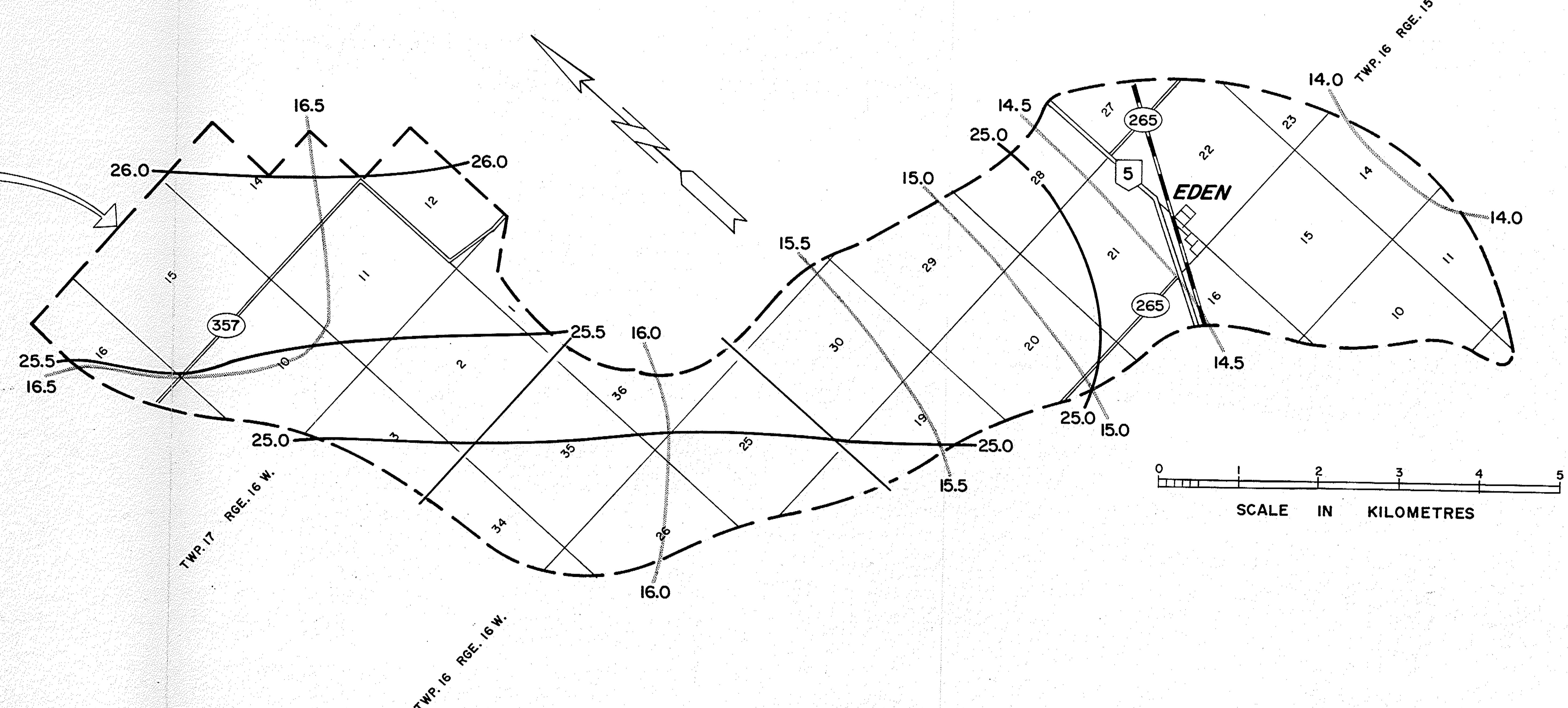

FIGURE 1-6

EDEN CREEK STUDY AREA

ESTIMATED ANNUAL PRECIPITATION

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in the older age group, over 55 years of age.

(3) Farm size and crop yields - Farms are smaller between 65 and 130 ha (160 to 320 ac) when compared to the rest of Agro-Manitoba. In 1977 average yield for wheat was 1485 kg/ha within the watershed as compared to 2123 kg/ha for Agro-Manitoba.

(4) Income and education levels - Family incomes are much lower ($5,534) when compared with the rest of Agro-Manitoba ($8,786). About 49 percent of the population 15 years and over had less than grade 9, including some with no kindergarten or no school.

1.3 Objectives

The means by which continuing development of resources could be reconciled with the need to sustain the physical environmental integrity of the resource base is important in watershed planning. The primary objective of the study then, is to explore how present and alternative land-use practices could be balanced with the maintenance of long term soil productivity and farming income, while reducing runoff.

The sub-objectives of the study are:

(1) To estimate the amount of runoff and soil erosion from summer rainstorms under existing and proposed land-use practices.

(2) To determine how socio-economic characteristics of Eden Creek watershed residents affect resource use.

(3) To develop a hypothetical farm plan to enhance the development of Eden Creek's land and water resources.

1.4 Research Methods

A combination of methods was applied to achieve the objectives of this study. The Soil Conservation Service (SCS) procedure and the Universal Soil Loss Equation (USLE) were used to estimate runoff and soil loss respectively.[3] Detailed information concerning land use, cultivation practices, crop rotation system, soil properties and slope/length required for the application of both methods were obtained by a combination of on-site evaluation, laboratory analysis and aerial photographic interpretation.

The SCS equation is expressed as follows:

$$R = \frac{(P - Ia)^2}{(PIa - S)}$$

Where:

R = estimated runoff

Ia = initial abstraction of moisture by soil

S = potential maximum moisture of soil

P = precipitation of storm

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[3] For a more detailed explanation of the SCS procedure and the USLE, see Appendix A and B.

The USLE is given as:

$$A = RKLSCP$$

Where:

A = average annual soil loss

R = rainfall factor

K = soil erodibility factor

L = slope gradient factor

C = cropping and management factor

P = conservation practices

Statistics Canada provided most of the information for income and demographic analysis. Most was in the form of unpublished data on the basis of enumeration areas. For comparative purposes the Eden Creek data was compared with Manitoba averages.

To develop a hypothetical farm plan for Eden Creek watershed, three different farm sizes were analyzed under various farm management practices using a budget simulation model designed for Agro-Manitoba by the Department of Agricultural Economics and Farm Management, University of Manitoba. This particular model employs a producer's physical input data, that is, land inventory, machinery inventory and management practices together with average pricing techniques to arrive at a cost and return account for each crop produced. A total cost/return summary is computed and a total cost per ha summary is also printed.

1.5 Limitations

As a result of time constraints, the problems specified in section 1.2 will only be quantified for those areas as outlined by the four hydrological boundaries (Fig. 1-1).

During the field season runoff gauges were placed at two locations to record actual runoff so that a comparison could be made with the results obtained by the application of the estimated runoff procedure. Since a storm event of sufficient magnitude did not occur, the runoff analysis was based on the estimated procedure only.

Due to limited hydrological records for Eden Creek, much of the information was extrapolated from Wilson Creek watershed. The two watersheds are similar in size, relief and geology and are approximately 25 km (16 mi) apart.

The information obtained from statistics Canada for socio-economic analysis was based on enumeration boundaries as defined by Census Canada and these boundaries are not the same as those for Eden Creek. However, the information does not invalidate the results of the study.

Although the appropriate application of farm budgets used in this study is for static and short term problems, the results can still be useful to farm operators if farm inputs and outputs are adjusted to reflect changing physical and economic conditions.

Despite the limitations noted, the methods and data used were sufficiently accurate to enable formulation and analysis of various trends within the watershed and the preparation of development plans.

1.6 Organization of the Study

The examination of the environmental and socio-economic problems within Eden Creek watershed are presented in the following sections. Chapters 2 and 3 present results and general background information regarding runoff, erosion and socio-economic characteristics.

Chapter 4 analyzes and integrates the results presented in Chapters 2 and 3.

Chapter 5 discusses alternative solutions. This chapter consists of two parts: (1) an overview of land-use changes in the United States and its effects on runoff, erosion and farm income, (2) the effects of land-use changes within Eden Creek watershed on runoff, erosion and farm income.

Chapter 6 provides the summary, findings and recommendations of the study.

CHAPTER 2

RUNOFF, SOIL LOSS AND ASSOCIATED PROBLEMS IN EDEN CREEK WATERSHED

In the Eden Creek watershed, lack of natural vegetative cover and intense summer rainstorms are conducive to rapid runoff, resulting in peak discharges in excess of natural channel capacity. As a result, water related land-use problems are common.

Soils within the watershed are particularly susceptible to erosion by water due to the sloping and irregular topography (Appendix C). Loss of soil through sheet and gully erosion are major problems and an estimated soil loss of 20 t/ha/yr is not uncommon. This excessive erosion results in sediment deposition in drainage channels necessitating a costly dredging and maintenance program. Generally, other potential effects of soil loss by erosion are:

(1) Loss in crop production potential.

(2) Loss of nutrients needed for crop production.

(3) Reduction in quality of crop produced.

(4) Reduction of the infiltration rate and waterholding capacity of the soil.

(5) Deterioration in soil structure.

(6) Loss of cropland by gullies and stream bank erosion.

(7) Division of fields by gullies.

(8) Reduced income from the land which in turn results in decreased land values.

2.1 Watershed Precipitation

In order to estimate runoff, precipitation records for a long period of time are necessary. Since precipitation records for Eden Creek watershed were limited to two years and were insufficient to carry out any hydrological analysis, precipitation data from Wilson Creek watershed were used to estimate runoff. The two watersheds are similar in topographic and geologic features. The only major difference between the two watersheds is that Wilson Creek is covered by virgin forest, whereas most of the natural vegetation has been removed from Eden Creek to accommodate the expansion of agriculture.

Table 2-1 indicates that precipitation at Eden Creek for 1978 and 1979 is similar to that of Wilson Creek for the same period. This does not prove that the two watersheds have similar rainfall distribution. A longer period of precipitation records is necessary to establish that point. However, all evidence seems to indicate that this may be the case.[1]

The topographic anomaly of Riding Mountain escarpment, along which Eden Creek watershed is located causes radical changes in precipitation patterns. Generally, combined effects of orographic lifting of moist air and strong frontal lifting result in a significantly greater number of severe

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[1]Personal communication, J. Thomlinson, Manager, Wilson Creek Watershed Project, Department of Mines, Resources and Environment, 1979.

Table 2-1

Comparison of Precipitation at
Eden Creek and Wilson Creek
During Summers, 1978 and 1979
mm (in)

	May		June		July		August		September		Total	
Year	Eden	Wilson Creek	Eden	Wilson Creek	Eden	Wilson Creek	Eden	Wilson Creek	Eden	Wilson Creek	Eden	Wilson Creek
1978	95 (3.75)	43 (1.68)	37 (1.44)	59 (2.31)	61 (2.40)	65 (2.57)	33 (1.31)	34 (1.35)	1.26 (4.97)	1.61 (6.35)	352 (13.87)	362 (14.28)
1979	74 (2.92)	79 (3.10)	24 (0.95)	40 (1.58)	35 (1.39)	47 (1.85)	19 (0.73)	37 (1.45)	46 (1.81)	50 (1.98)	198 (7.80)	253 (9.96)

Source: Department of Mines, Resources and Environment 1978 to 1979 (unpublished data).

thunderstorms and also prolonged heavy precipitation (Gray 1973). As a result, these storms are expected to be more vigorous and intense than in other locations in Manitoba.

2.2 Runoff

Rainfall runoff can be divided into three major components. Surface runoff includes that part of runoff which travels over the soil surface to the nearest channel. Storm seepage or interflow is that part of runoff which infiltrates into the soil to a relatively impermeable layer and as a result, spreads out and flows laterally a short distance below the soil surface towards a stream. Ground water runoff is runoff that percolates through the soil mantle to the ground water table and is eventually discharged in a stream.

2.2.1 Estimated Runoff Measurements

The SCS procedure was used to estimate runoff and peak discharges in Eden Creek Watershed.[2] As required by the SCS method, it was assumed that 127 mm (5.01 in) of precipitation fell in 24 hours with a return period of 10 years (P_{10} - 24 hrs/127 mm). The hydrological soil group was assumed to belong to the C classification, that is, the soils of Eden Creek were characterized as having slow infiltration

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[2]Described in more detail in Appendix A.

and transmission rates.

Weighted curve numbers (CN) required as input to the SCS model were calculated for each HU under the existing land-use pattern. The antecedent moisture condition prior to the storm was assumed to be moderately wet (varies from 3.55 cm to 5.33 cm).

Peak discharges for the four HU's were estimated at 21 m^3/s (740 cfs), 28 m^3/s (1000 cfs), 31 m^3/s (1080 cfs), and 24 m^3/s (850 cfs), respectively (Table 2-2). Weighted runoff for the HU's combined is equivalent to 78 mm (3.08 in).

2.3 Erosion

Soil erosion as a process involves detachment of soil particles from soil structure and transport of particles to another location. Energy for this process is provided by runoff as it flows over the land surface. Erosion within Eden Creek watershed may be classified as sheet and rill erosion of cultivated and pasturelands, gully erosion in upland drainage ways and channel erosion of the main stream.

Sheet erosion on cropland is primarily due to improper methods of cultivation. This type of erosion process results in uniform removal of soil particles, organic matter and soluble nutrients from the land, as a result of raindrop splash and surface runoff. Thus, this process is a serious detriment to maintenance of soil fertility and productivity. Impact of raindrops breaks the soil into smaller particles and the splash action may carry these particles some distance away from the initial point of impact. As rainfall rate

Table 2-2

Runoff and Peak Discharge Estimates
for Eden Creek Watershed, 1979

HU	Drainage Area ha (ac)	CN	Time of Concentration hr	Largest Flow Length Eden Creek m (ft)	Average Slope %	Runoff mm (in)	Peak Discharge m^3/s (cfs)	Time to Peak hr	Time to Base hr
1	502 (1,241)	81	1.9	4,528 (14,856)	6	78 (3.07)	21 (740)	3.78	10.09
2	755 (1,856)	80	2.3	9,938 (16,192)	5	76 (2.98)	28 (1,000)	4.48	11.96
3	866 (2,139)	81	2.8	7,628 (25,025)	8	78 (3.07)	31 (1,080)	4.94	13.19
4	427 (1,056)	82	1.8	6,643 (21,795)	10	81 (3.17)	24 (850)	3.84	10.25

exceeds infiltration rate, surface runoff begins. Detachment and transport by raindrop impact and surface runoff constitute sheet erosion. Since soil loss is uniform, sheet erosion may go unnoticed.

Rill erosion occurs when runoff begins to concentrate along paths of least resistance. The erosive force of flow exceeds the resistance of soil structure and results in formation of small shallow channels or rills. Since these rills are obliterated with normal tillage operations, this type of erosion may go unnoticed until serious damage to productivity has resulted.

As rill erosion progresses, it can turn into gully erosion. In Eden Creek Watershed, gully erosion is one of the most severe land management problems. Soil loss associated with an advancing gully can be due to scouring by flowing water and wet-dry and/or freeze-thaw cycles, which then results in sloughing of gully banks. Within the watershed, gullies often vary from 3 m (10 ft) to 6 m (20 ft) in depth and 63.7 m (70 yds) to 91 m (100 yds) in length. As a result of gullying, considerable land is lost from production. Moreover, large gullies prevent farmers from gaining access to their fields and in some cases, can result in damage to farm equipment.

Erosion on the main stream results primarily in channel deepening and widening. This is especially prominent along lower reaches of Eden Creek. Channel erosion is similar to gully erosion except the flow of water persists longer in the channel following a rainfall. Flowing water usually cuts into the bank below the water level over a period of time and finally undermining it to the extent that it will cave in or slide into the stream bed. The tendency of streams to meander increases stream channel erosion and results in some cases in appreciable loss of land.

2.3.1 Soil Loss Estimates

Estimation of soil loss from water erosion for Eden Creek watershed was determined by the use of the Universal Soil Loss Equation (Appendix B). Soil loss tolerance levels within Eden Creek watershed were assumed to be 0.9 t/ha for soils of the Granville Association and 1.8 t/ha for the Clarksville and Wapus Associations.[3] Establishment of tolerance levels within the watershed were based upon soil properties, soil depth, topography and prior erosion. The difference in tolerance levels for soils within the Eden Creek watershed is due to the high shale content found in the soil profile for the Wapus and Clarksville Associations.

The gross annual soil loss for Eden Creek watershed was estimated at 483,288 t (Table 2-3). Approximately 40 percent of the total area cultivated within the watershed was above the maximum soil loss tolerance level under 1979 land-use conditions. The annual soil loss from these fields was estimated at 138,189 t and the average soil loss per hectare was estimated at 3.08 t.

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[3]Soil loss tolerance is the amount of soil that can be lost from a field (in t/ha/yr) so that a high level of productivity can still be maintained over a long period of time.

Table 2-3

Estimated Annual Soil Loss For Eden Creek Watershed, 1979[1]

Total Area in Cultivated Fields ha (ac)	Total Area in Cultivated Fields Above the Maximum Soil Loss Tolerance Level ha (ac)	Total Average Soil Loss t/yr For Cultivated Fields	Average Soil Loss t/yr For Fields Above Maximum Soil Loss Tolerance Level
1,549	631	483,288	138,189
(3,828)	(1,559)		

[1]The calculations used to derive the estimated soil loss for Eden Creek were based on the English system of weights and measures. Values for A and T were then converted to metric equivalents.

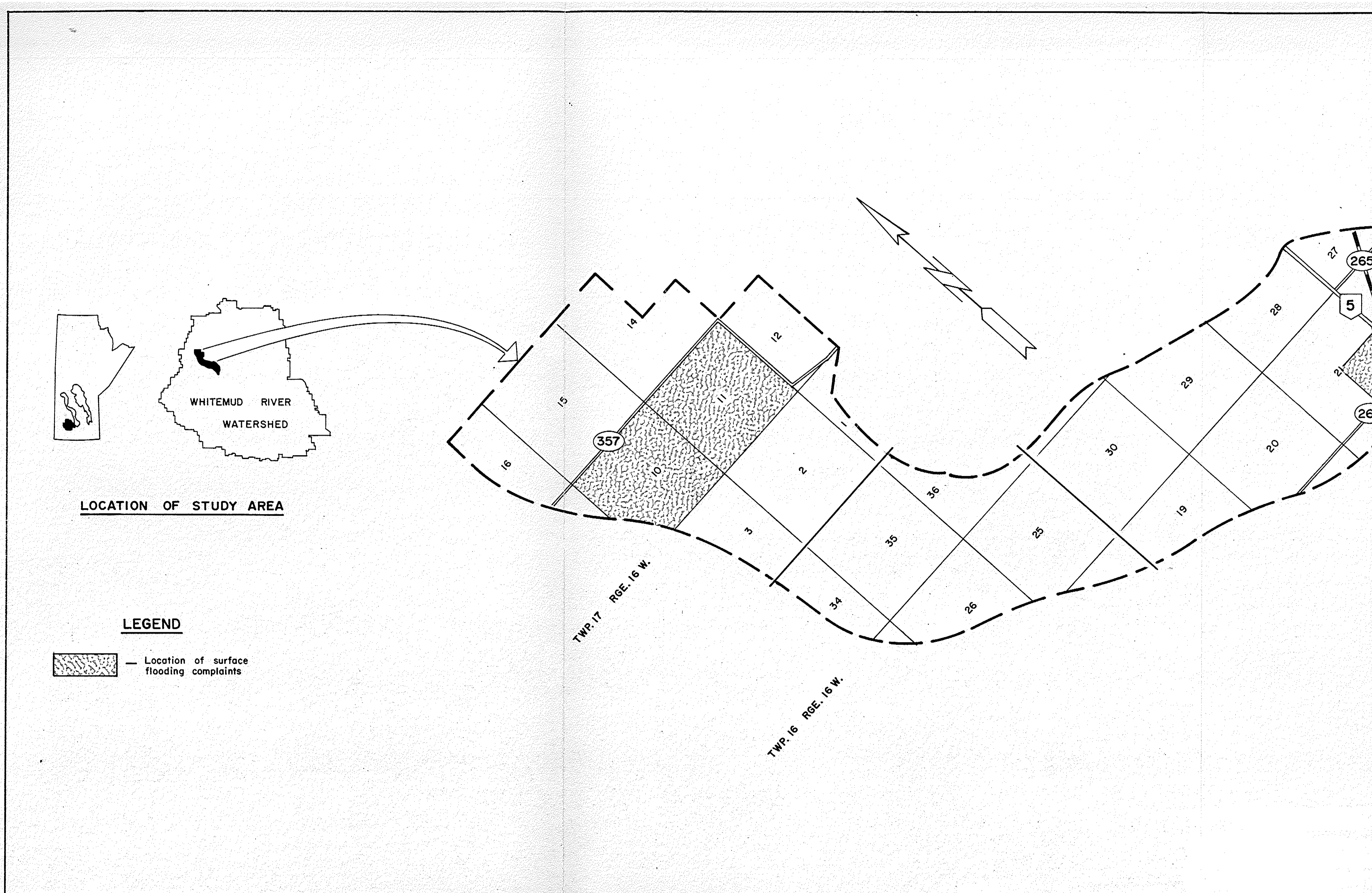
2.4 Flooding

Figure 2-1, indicates areas within the watershed that have been subjected to flooding. Most of the flooding occurs around the village of Eden at the lower end of the watershed. Although there are no quantifiable cost estimates for flood damages, local residents had reported that flash floods, which usually occur after a heavy rainstorm, result in crop damage, make it impossible to operate farm equipment on the land, destroy roads and bridges and cause loss of soil. All of these effects lead to inconvenience and loss of income for area residents.

2.5 Sedimentation

Sedimentation in the watershed involves two basic processes; movement of shale downstream by water action and carrying of silt suspended in water. Most of the sediment is deposited in drainage channels and along edges of cultivated fields. Sediment deposition in channels often compounds flood problems by blocking water flow, therefore causing flood water to spread across fields more than it normally would.

While effects of sedimentation have not been thoroughly investigated within the Eden Creek watershed some of the problems are obvious. Following a heavy storm runoff, stream channels are often filled with mud which smothers vegetation and is aesthetically unpleasing. Sediment deposits in fields adjacent to main channels alter soil structure and nutrient content, causing deterioration of crops and increasing harvesting and equipment maintenance costs. Sedimentation of


WHITEMUD RIVER
WATERSHED
LOCATION OF STUDY AREA
LEGEND
Location of surface flooding complaints
357
5
265
TWP.17 RGE.16 W.
TWP.16 RGE.16 W.
14
12
15
11
16
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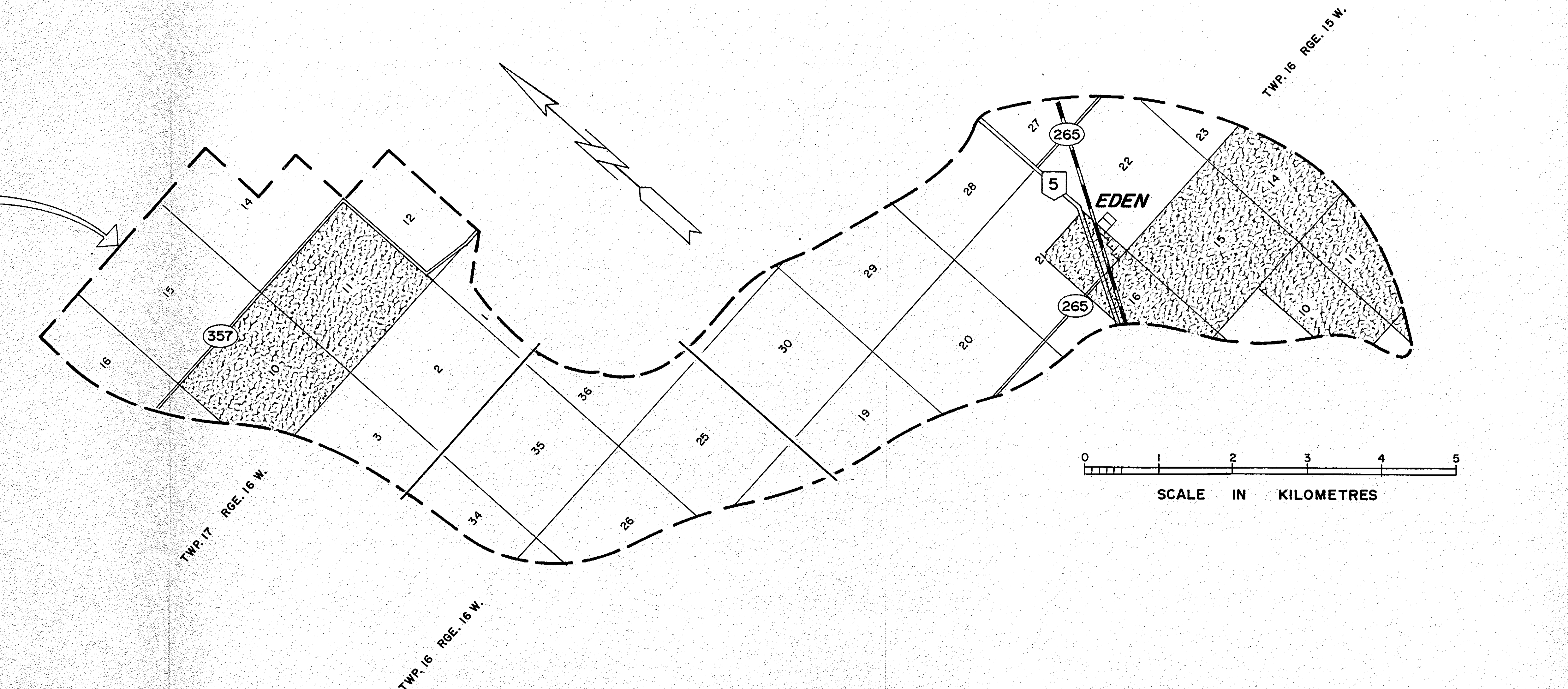

FIGURE 2-1

EDEN CREEK STUDY AREA

WATER COMPLAINTS

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natural field drains inhibits surface water runoff from cultivated fields and results in costly dredging operations.

In the Wilson Creek Watershed, analysis has shown that an average of 1,530 m^3 of material is moved annually (Canada Department of Fisheries and Environment, 1976). Average annual suspended sediment yield for the same watershed between 1962 and 1975 was estimated to be just over 10,000 t.

CHAPTER 3

SOCIO-ECONOMIC CHARACTERISTICS OF EDEN CREEK WATERSHED

Settlement within Eden Creek watershed by farmers was influenced by the availability of wood on the slopes of the Riding Mountain escarpment. As well, most of the fertile land elsewhere in Manitoba had already been claimed by earlier settlers.

Agriculture is the primary economic activity within Eden Creek watershed. Generally, crop yields and farming income are low as compared with the rest of Agro-Manitoba. As a result, many farmers seek off-farm work to supplement their income.

The reduction of the watershed population within Eden Creek watershed became significant after 1961. Similar trends were also reported for other farming communities in Manitoba. Approximately 1,000 families leave farming each year in search of better jobs and educational opportunities (Province of Manitoba, 1973). In addition, most of the population that migrate from these communities are younger and better educated, thus leaving a large proportion of the remaining population in the older age group classifications.

3.1 Demographic Characteristics

Since 1961, except for the period between 1966 and 1971, there has been steady decline in population in the Eden Creek watershed (Table 3-1). Since 1971, population has declined by 16 percent. This is approximately comparable to provincial averages, as the Manitoba farm population declined by 22 percent from 1971 to 1976.

Table 3-1

Population of Eden Creek Watershed (1961 - 1976)

Year	Male	Female	Total	Percentage Change from Previous Census
1961	475	406	881	-
1966	380	437	817	- 7
1971	540	460	1,000	18
1976	455	390	845	- 16

Source: Statistics Canada 1961 to 1976 (unpublished data). Based upon enumeration areas approximating watershed boundaries. Enumeration areas for 1971 and 1976 were different from those of 1961 and 1966.

It was not possible to obtain precise population estimates for Eden Creek watershed. Population data in Table 3-1 was based upon enumeration areas, the smallest geographical units employed by Statistics Canada. The increase in population between 1966 and 1971 was most likely due to changes in enumeration boundaries. Therefore, the changes in population numbers over the years are not directly comparable, however, general depopulation trends within the watershed can still be observed.

Table 3-2, shows the watershed population by age and sex for 1971 and 1976.[1] In 1971, 49 percent of the population were between the ages of 15 and 54. In 1976, the population within this age group was 46 percent, a reduction of 3 percent.

The village of Eden, the main trading centre in the watershed, has shown a significant reduction in population (Table 3-3) from 181 in 1951 to 106 in 1976. Over the years, some of its commercial enterprises have been closed, including its only grain elevator.

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[1] "All figures from Statistics Canada have been subjected to a confidentiality procedure to prevent the possibility of associating small figures with an identifiable individual. The particular technique used is known as "random rounding". Under this method, all last or "unit" digits in a table (including all totals) are randomly rounded (either up or down) to "0" or "5". This technique provides the strongest possible protection against direct, residual or negative disclosures without adding any significant error to the census data. However, since totals are independently rounded they do not necessarily equal the sum of individual rounded figures in distributions. Also, minor differences can be expected for corresponding totals and cell values in various tabulations". (Statistics Canada, 1976, unpublished data).

Table 3-2

Eden Creek Watershed Population by Age and Sex (1971 - 1976)

Year 1971	0-4	5-9	10-14	15-19	20-24	25-34	35-44	45-54	55-64	65-70	70+
Male	45	55	65	60	25	45	50	65	60	25	45
Female	25	30	60	50	20	45	55	55	60	25	35
Total	65	80	125	110	45	95	110	125	120	45	75
Year 1976											
Male	35	35	70	45	25	50	50	45	50	20	30
Female	30	35	60	40	20	40	40	55	40	15	15
Total	65	70	130	80	35	85	95	95	95	35	45

Source: Statistics Canada 1971 and 1976 (unpublished data).

Table 3-3

Population of the Village of Eden (1941 - 1976)

Year	Total	Percentage Change (from 1951)
1941	147	-
1951	188	22
1961	146	-22
1966	140	- 4
1971	108	-23
1976	106	- 2

Source: Statistics Canada 1941 to 1976 (unpublished data).

3.1.1 Age of Family Head

The watershed population has a large proportion of families with a head in the older age group classifications (Table 3-4). In 1976, of the total household heads, 67 percent were over 45 years old and 47 percent were over 55 years.

Although it was not possible to compare age of family head with the rest of Agro-Manitoba, Swanson (1974) reported that the proportion of families with a head over 55 years in the Whitemud River Conservation District was much higher than the rest of Manitoba.

3.1.2 Education

The level of education of Eden Creek watershed residents is relatively low compared with the rest of the province. Table 3-5 shows that 49 percent of the population 15 years and over had less than grade 9 including no kindergarten or no school. This level compares with 35 percent for the rest of Manitoba as a whole (Statistics Canada, 1976, unpublished data).

In 1976, 10 percent of the population had attended post-secondary schools, including non-university schools. Approximately 69 percent of those attending post-secondary schools graduated with a diploma or degree.

Table 3-6 indicates that the levels of education for husbands and wives in a household are low. About 53 percent had less than grade 9 including no kindergarten or no school, and very few had any advanced education.

Table 3-4

Household Heads by Age and Sex (1971 - 1976), Eden Creek Watershed

Year 1971	15-24	25-34	35-44	45-54	55-64	65+
Male	5	30	45	65	60	50
Female	-	-	-	-	10	20
Total	5	30	45	65	70	70
Year 1976						
Male	15	35	35	50	55	45
Female	-	-	5	5	5	25
Total	15	35	40	55	60	70

Source: Statistics Canada 1971 and 1976 (unpublished data).

Table 3-5

Population 15 Years and Over by Level of Schooling and Sex (1976), Eden Creek Watershed

	Less than Grade 9 Including No Kindergarten or No School	9-10	11-12 Without School Certificate	11-12 With School Certificate	Post-Secondary non-University without Certificate or Diploma	Post-Secondary non-University with Certificate or Diploma	University Without Degree	University With Certificate or Diploma	University with Degree
Male	170	70	50	20	10	20	10	5	5
Female	150	75	50	10	0	10	0	5	0
Total	320	145	100	30	10	30	10	10	5

Source: Statistics Canada (unpublished data).

Table 3-6

Levels of Education of Husbands and Wives in a Household by Level of Schooling and Sex (1976), Eden Creek Watershed

	Les than Grade 9 Including No Kinder-garten or No School	9-10	11-12 Without School Certi-ficate	11-12 With School Certi-ficate	Post-Second-ary non-Uni-versity without Certifi-cate or Diploma	Post-Second-ary non-Uni-versity with Certificate or Diploma	Uni-versity Without Degree	University with Certi-ficate or Diploma	Uni-versity with Degree
Male	95	30	30	10	10	20	10	5	5
Female	120	35	25	5	0	10	0	5	0
Total	215	65	55	15	10	30	10	10	5

Source: Statistics Canada 1976, (unpublished data).

3.2 Economic Characteristics

The major source of income for Eden Creek residents is from agriculture. Presently, the land is used primarily for crop production. The major crops produced are rapeseed, wheat, oats, barley and tame hay. Figure 3-1 outlines present land-use on the basis of four categories, namely: cropland, improved pasture, rough grazing and rangeland and woodlands.

Soils within the watershed have moderate to moderately severe limitations that restrict the range of crops that can be grown, unless special conservation practices are undertaken (Figure 3-2).

3.2.1 Incomes

Average total income for farmers in Eden Creek watershed and vicinity is much lower than the Manitoba average (Table 3-7).[2] For instance in 1977, the average total net income from farm and off-farm sources for area farmers was $5,534 compared with $8,768 for Manitoba as a whole. From 1971 to 1977, incomes in the Eden Creek watershed and vicinity have averaged 60 percent of provincial values. These lower incomes could be indicative of the poorer soil base in the area.

Off-farm work is a greater source of income than net farm sources for Eden Creek residents, averaging 61 percent

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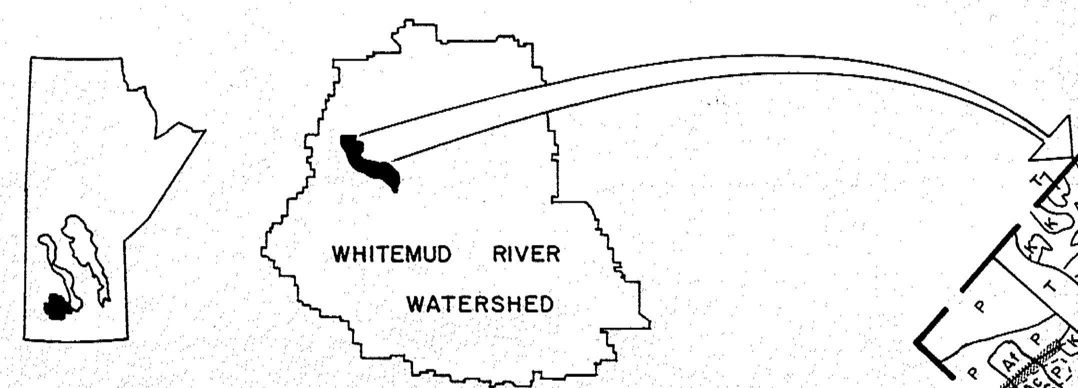
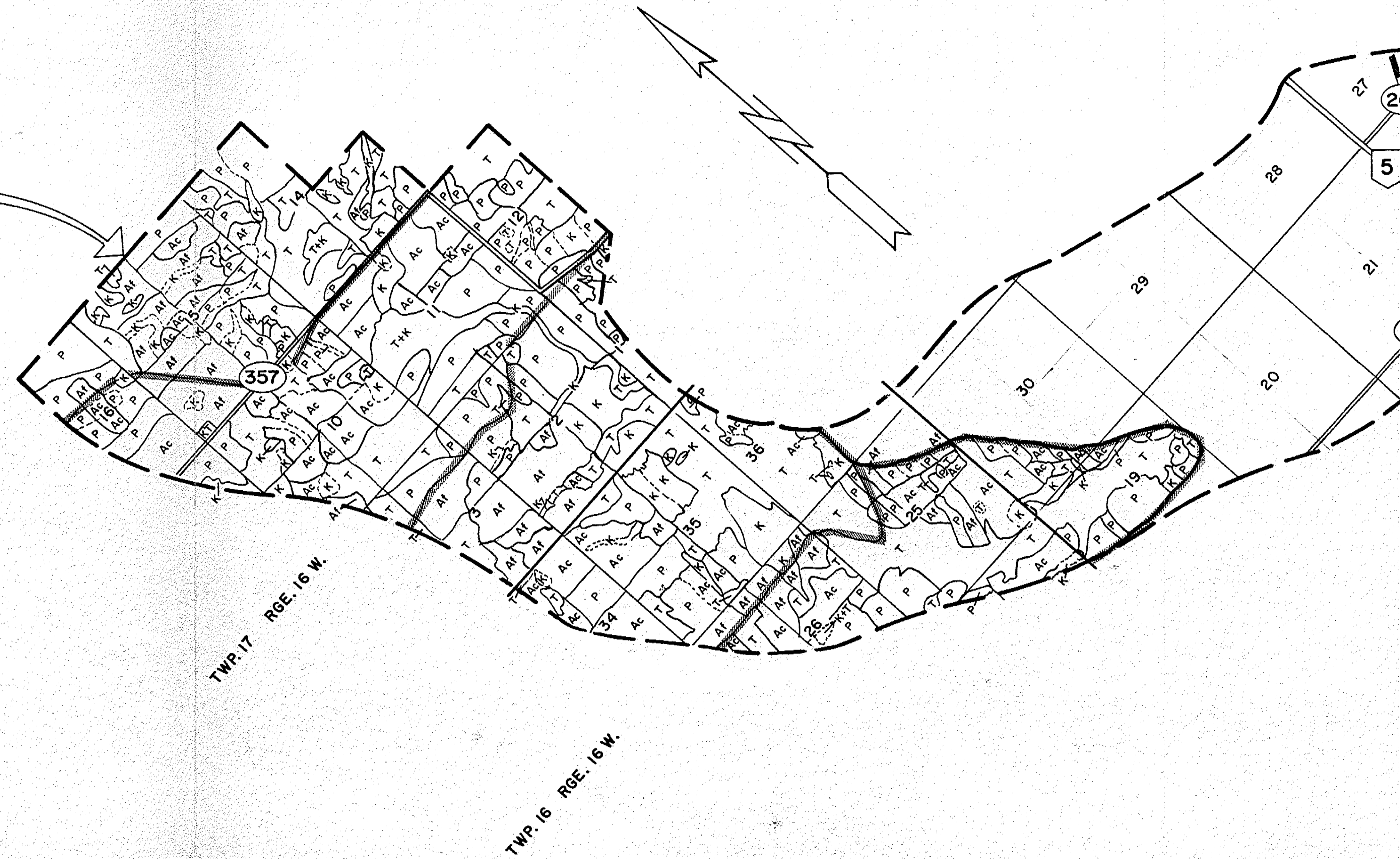
[2] Income estimates were obtained from Statistics Canada, based upon personal income tax files for farmers who gave their address as Eden and seven other post offices in the near vicinity.



LOCATION OF STUDY AREA



LEGEND

A- CROPLAND
c-crop f-fallow

P- Improved PASTURE and FORAGE

T- TREES

K- Rough GRAZING and RANGELAND

-HYDROLOGICAL UNIT boundary

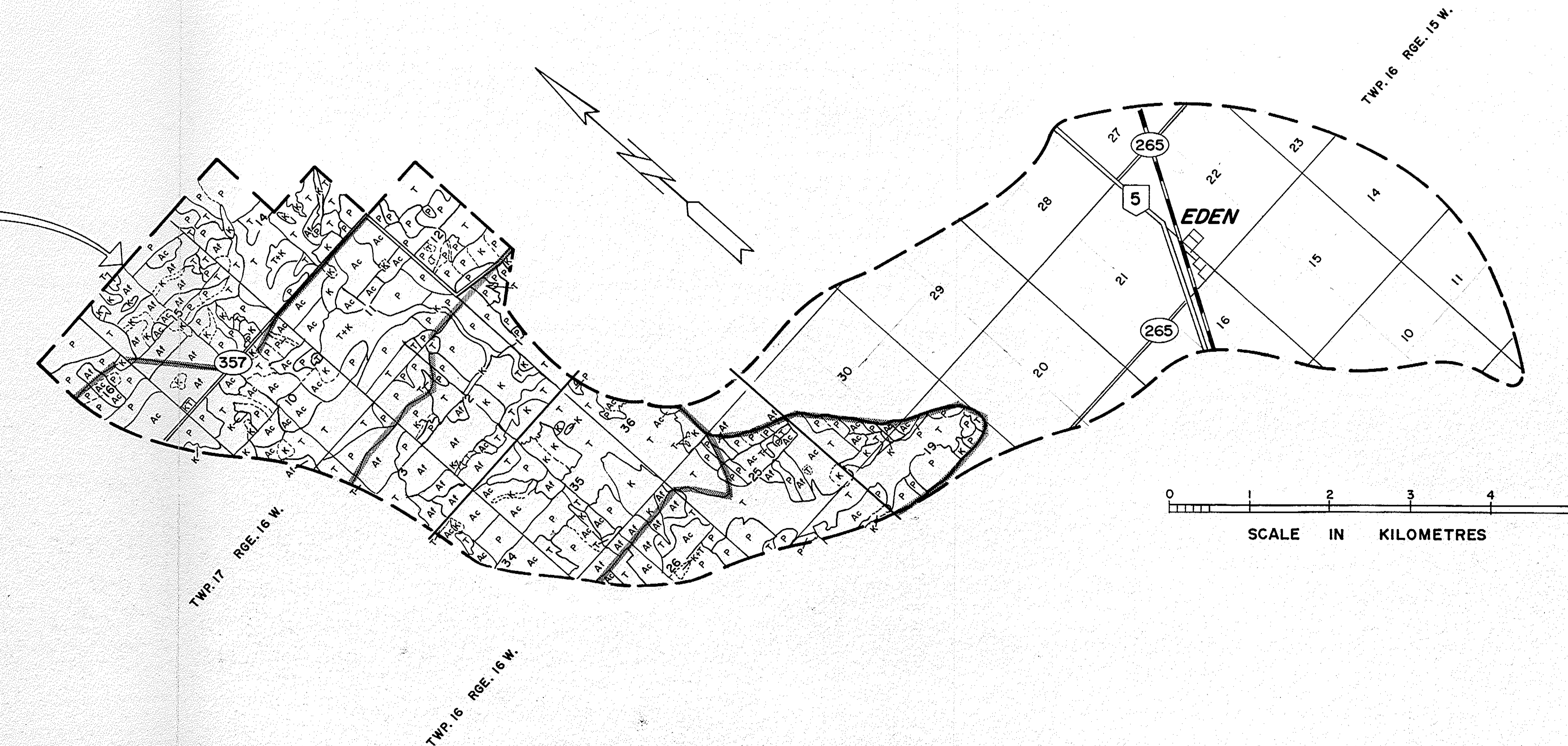


FIGURE 3-1

EDEN CREEK STUDY AREA

1979 LAND USE

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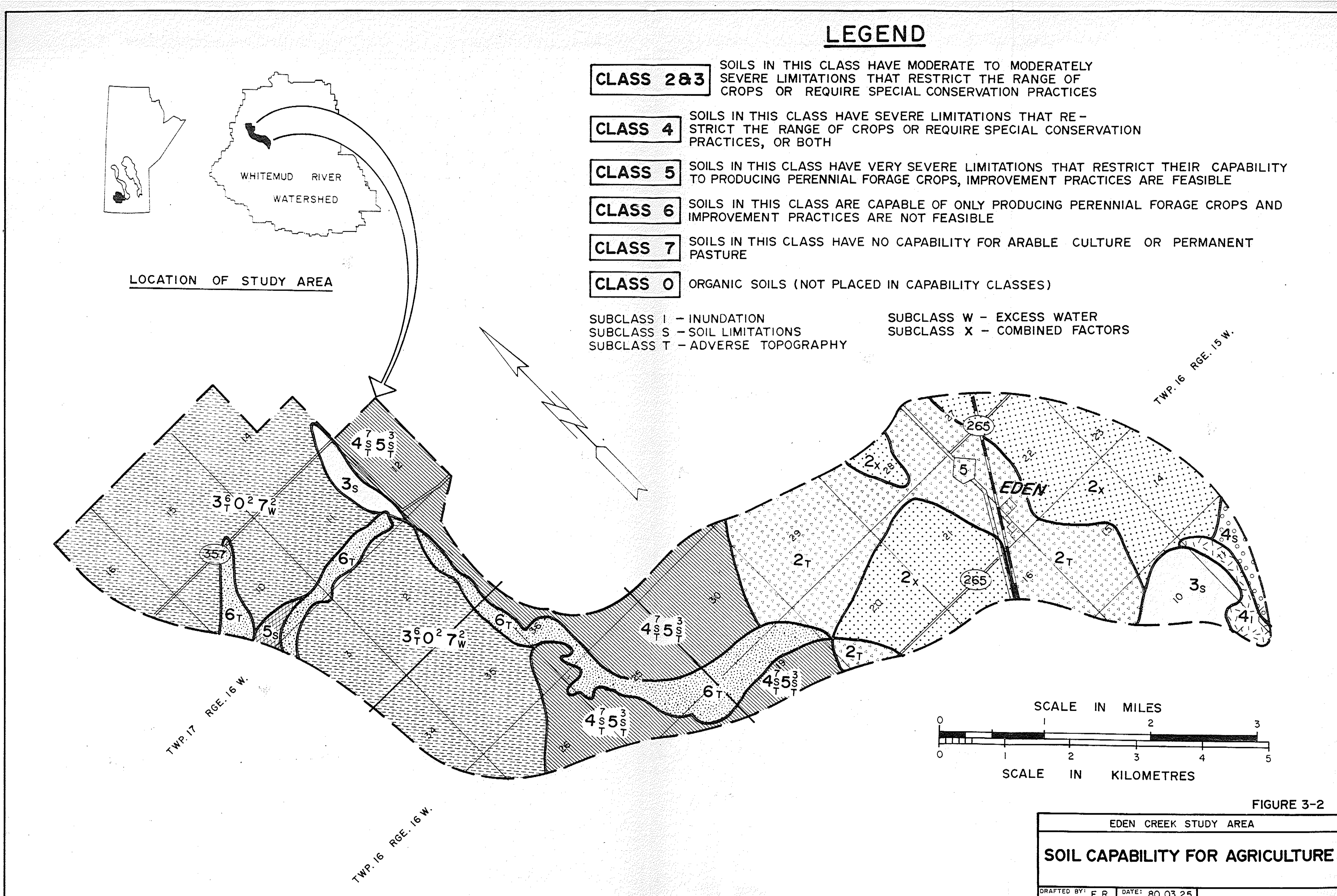

FIGURE 3-2

EDEN CREEK STUDY AREA

SOIL CAPABILITY FOR AGRICULTURE

Table 3-7

Average Farm Income for the Eden Creek Vicinity[1] and Manitoba (1971 to 1977)

Year	Number of Farms		Average Farm Gross ($)		Average Farm Net ($)		Average Off-Farm Income ($)		Average Total Income ($)	
	Eden Creek Vicinity	Manitoba	Eden Creek Vicinity	Manitoba	Eden Creek Vicinity	Manitoba	Eden Creek Vicinity	Manitoba	Eden Creek Vicinity	Manitoba
1971	330	38,720	7,449	12,681	472	931	1,315	2,212	1,788	3,143
1972	335	39,250	9,085	15,930	713	1,800	1,676	2,536	2,389	4,338
1973	335	40,070	11,848	33,545	1,947	3,737	1,773	3,028	3,720	6,768
1974	320	40,230	14,103	39,737	2,845	4,823	2,582	4,078	5,427	8,904
1975	335	41,395	16,880	42,582	2,959	4,597	3,179	4,832	6,138	9,427
1976	325	41,395	16,794	44,857	1,828	3,517	3,657	5,541	5,484	9,038
1977	315	41,355	17,381	23,282	1,584	2,716	3,949	6,063	5,534	8,768

Source: Statistics Canada 1971 to 1977 (unpublished data).

[1] "Eden Creek Vicinity" is comprised of that area served by the rural post offices of Eden, Birnie, Elk Ranch, Franklin, Kelwood, Mountain Road, Polonia and Riding Mountain.

from 1971 to 1977. The provincial average for off-farm income was 57 percent over the same period.

3.2.2. Crop Yields

Average crop yields within the Eden Creek watershed are lower than the rest of Manitoba. Table 3-8 compares provincial average yields from 1975 to 1978 for wheat, oats, barley, and tame hay with those for Eden Creek watershed. Watershed yields were estimated using Manitoba Crop Insurance Corporation data and the yields given are the averages between F- and H- rated soils.[3]

3.2.3 Farm Size

Although there are no specific data on farm sizes, most of the farms within the Eden Creek watershed are between 65 and 130 ha (160 to 320 ac) with many less than 65 ha (Swanson (1974). There are, however, a few larger units over 195 ha (480 ac) in size.

Table 3-7 shows that the number of farms in the vicinity of Eden Creek watershed has been declining over the years. In 1975, there were 335 farms compared with 315 in 1977.

3.2.4 Land Tenure

The most common form of tenure within Eden Creek watershed is private ownership. In 1979, approximately 20 percent

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[3]F- rated soils are located on the lower reaches of Eden Creek watershed. H- rated soils, which are considered to be of a poorer type of soil, are located along the upper reaches of the watershed.

Table 3-8

Average Crop Yields for Eden Creek Watershed
and Manitoba for 1975 to 1977 in Kg/ha

	Wheat		Barley		Oats		Tame Hay	
Year	Eden	Manitoba	Eden	Manitoba	Eden	Manitoba	Eden	Manitoba
1975	1,485	1,691	1,717	1,829	1,495	1,733	3,180	4,454
1976	1,485	1,823	1,717	2,257	1,495	1,859	3,180	4,142
1977	1,485	2,123	1,717	2,661	1,495	2,105	3,180	4,142

Source: (1) Manitoba Department of Agriculture 1975, 1976 and 1977.

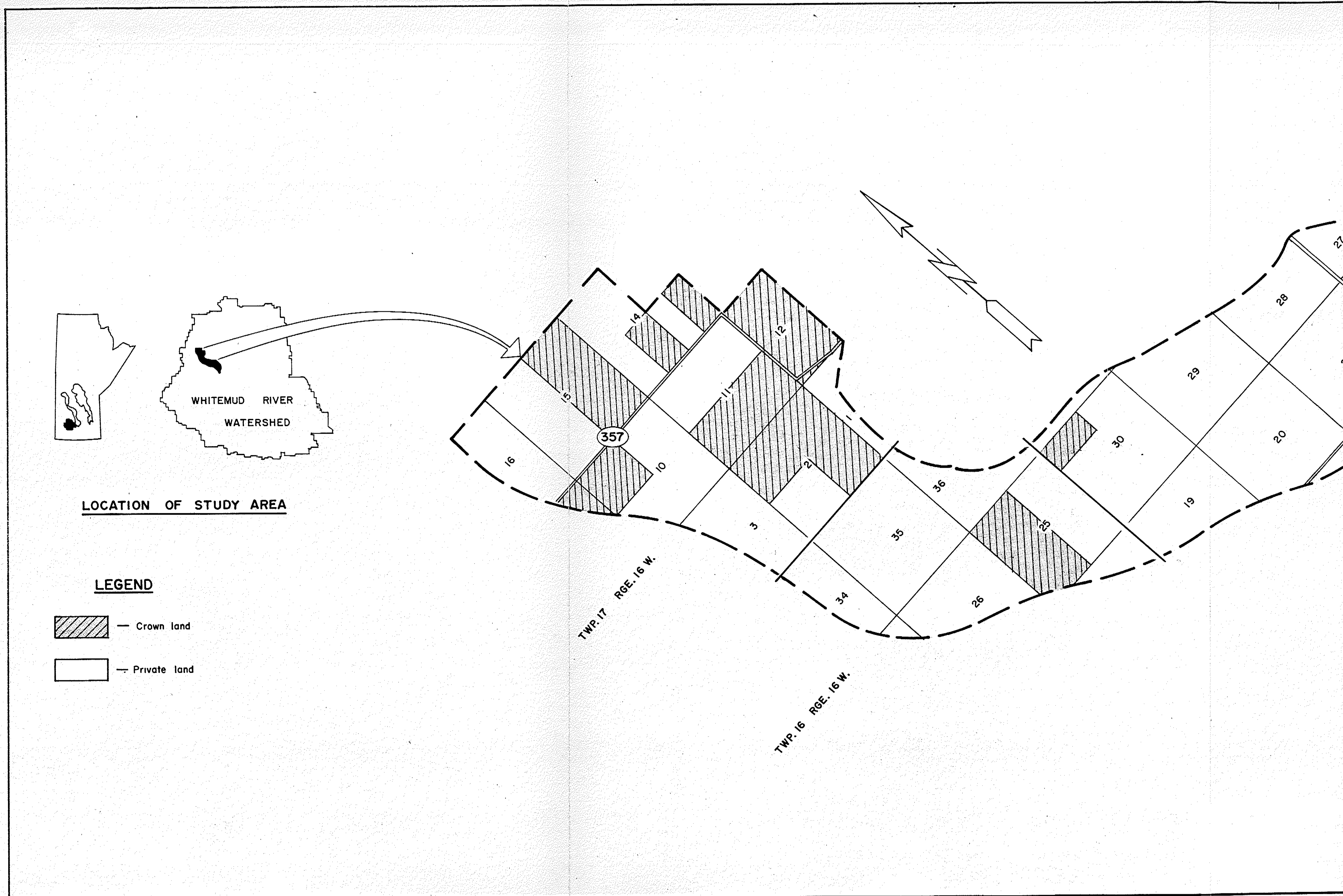
(2) Manitoba Crop Insurance Corporation, 1978.

of the land was owned by the provincial government (Fig. 3-3). It was not possible to obtain figures of actual parcels of land rented by farmers.

3.2.5 Labour Force Activity

In 1976, total labour force population in Eden Creek watershed was estimated at 510, with 20 percent unemployed (Table 3-9). Of the total number of persons unemployed, 70 percent were between the ages of 15 and 54 and 30 percent over 55 years.

Of the total employed, 72 percent were between the ages of 15 and 54, whereas 28 percent were over 55 years.


WHITEMUD RIVER WATERSHED
LOCATION OF STUDY AREA
LEGEND
— Crown land
— Private land
357
TWP. 17 RGE. 16 W.
TWP. 16 RGE. 16 W.
16
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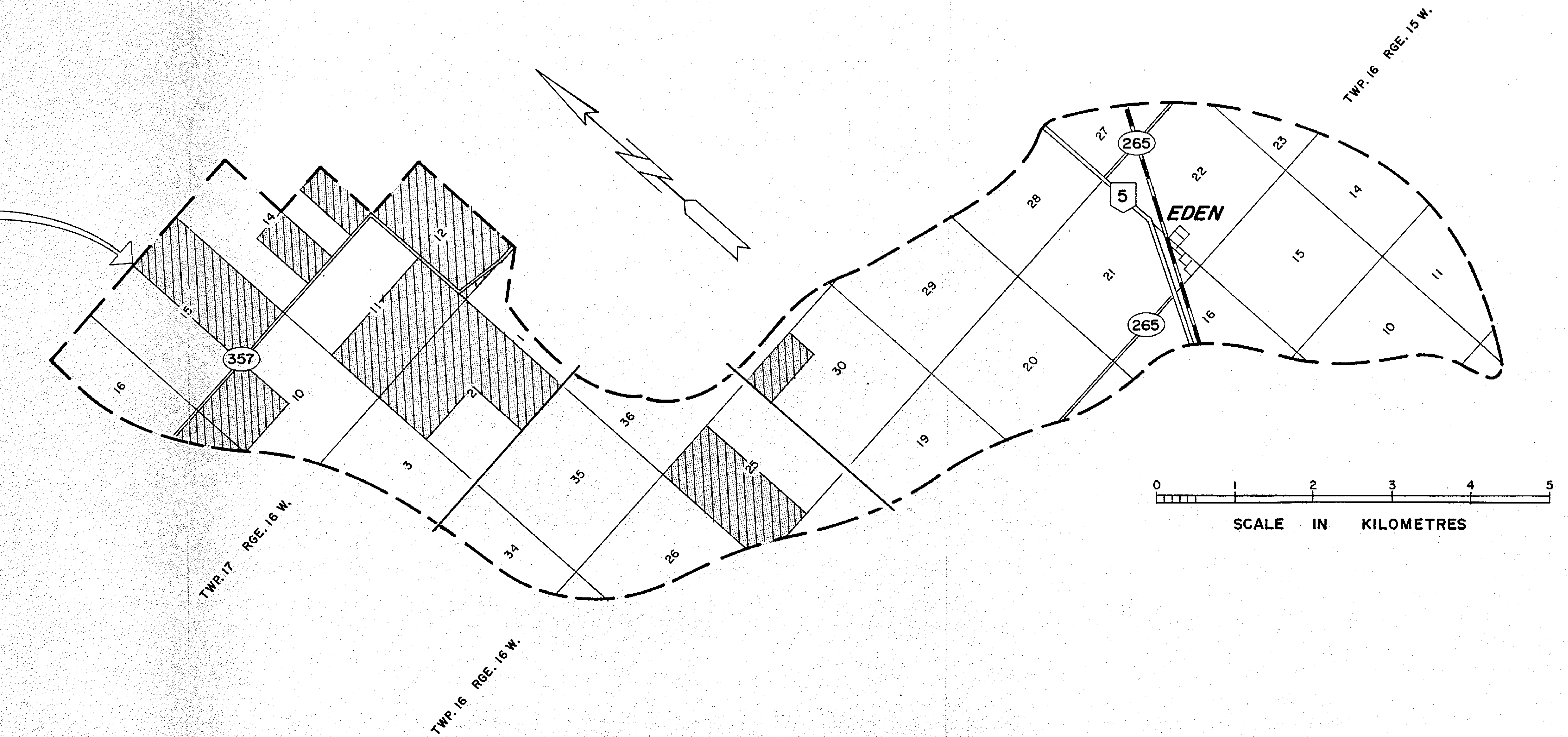

FIGURE 3-3

EDEN CREEK STUDY AREA

LAND TENURE

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Table 3-9

Population 15 Years and Over by Labour Force Activity and Age (1976), Eden Creek Watershed

	15-24	25-44	45-54	55-64	65+
Employed	85	150	60	75	40
Unemployed	35	30	5	15	15
Total	120	180	65	90	55

Source: Statistics Canada 1976 (unpublished data).

CHAPTER 4

INTEGRATION AND ANALYSIS OF PHYSICAL AND SOCIO-ECONOMIC DATA

The objective of this chapter is to integrate and analyze the data presented in Chapters 2 and 3 and to determine if a relationship exists between the socio-economic welfare of Eden Creek watershed residents and resource utilization.

4.1 Rainfall Runoff

The sloping and irregular topography combined with frequent summer rainstorms within the Eden Creek watershed result in excessive runoff and high peak discharges of relatively short duration (Table 2-2). The time to peak is relatively short averaging about four hours for each sub-watershed. Whenever these peak responses exceed the natural channel capacity, flash flooding results. This type of flooding is especially prominent along the upper and lower reaches of Eden Creek watershed following a heavy rainstorm (Fig. 2-1).

Table 2-2 indicates that approximately 61 percent of the total rainfall over the watershed results in runoff. However, the SCS procedure includes only surface and subsurface runoff. The percentage of runoff from rainfall would therefore be much greater if ground water runoff was also included.

In analyzing the hydrological data for Eden Creek watershed, the following combination of factors were also found to influence the volume of runoff and peaks associated with a storm.

(1) Antecedent moisture conditions - If watershed soils are dry, runoff potential will be low. If the soils are saturated from antecedent rains prior to a heavy rainstorm, runoff potential is high.

(2) Rainfall intensity - Heavy rainfall in excess of infiltration capacity of soil will contribute largely to runoff.

(3) Duration of rainfall - Rainfall of longer duration will increase the amount of water that would be available for runoff.

(4) Basin characteristics - The higher elevation and orientation of slopes towards the main channel results in rapid runoff and peak responses.

(5) Land-use cover - By exposing bare soil to precipitation, the capacity to absorb prolonged precipitation is greatly reduced.

Hydrological data from Wilson Creek watershed were used in the SCS procedure to estimate runoff for Eden Creek watershed. In computing the runoff values, an assumption was required about the AMC prior to the design 24 hours rainstorm. AMC was assumed to be moderate (AMC = II), because of the hydrological conditions at Wilson Creek where summer precipitation is relatively frequent. Given the proximity and similar topography of Wilson and Eden Creek watershed, it is reasonable to assume that on most occasions, the AMC prior to a summer rainstorm will also be moderate for Eden Creek watershed. This assumption would have a direct bearing on the amount of rainfall that would result in runoff for Eden Creek watershed. If AMC I was assumed for the Eden Creek watershed, the volume of runoff and peak discharges would have been lower than the estimated values in Table 2-2. Likewise if the AMC III was assumed, the volume of runoff and peak discharges would have been much greater.

4.2 Erosion

Clearing the land exposes the soil to the direct impact of high intensity rainstorms. As a result, the capacity of the soil to absorb heavy storm precipitation is reduced. Without adequate vegetative cover or structural measures to control runoff, surface runoff reaches erosive velocities and results in soil detachment, transport and deposition.

Within Eden Creek, the erosion process is hastened by the following combination of factors:

(1) Soil erodibility - Because the soils are loose and granular they are readily susceptible to erosion by water.

(2) Slope length - As slope length increases, soil loss is greater due to increased runoff velocity.

(3) Summer fallow and frequent tillage - Such practices expose much soil to the direct impact of rainfall.

(4) Rainfall intensity and duration - Since the rainfall provides the energy for the erosion process to begin, it follows that the greater the intensity and duration of rainfall, the greater the erosive action.

Table 2-3 and Appendix B indicates that approximately 40 percent of the total area in cultivated fields in Eden Creek watershed was above the maximum soil loss tolerance level in 1979. If the present cropping practices continue within the watershed, the percentage can be expected to be greater, since many fields are just below the tolerable soil loss level of 0.9 and 1.8 t/ha.

In analyzing the soil loss results for Eden Creek watershed, significant factors that contribute to soil erosion by water seem to be the sloping topography characterized by compound slopes[1] and the amount of land which is exposed to the direct impact of rainfall.

4.3 Farming Practices

In recent years, researchers both in Canada and the United States have questioned certain agricultural practices such as tillage and summer fallow, Stone et al. (1973); Lal and Stepphun (1977). Besides being costly, these practices enhance the erosion process, thus contributing to the degradation of the physical environment. In Eden Creek watershed, both practices are quite common.

4.3.1 Summer Fallow

The U.S. Department of Agriculture (1971) has identified the runoff potential of various types of land-use practices. The practice of summer fallow was noted as the greatest contributor to runoff potential followed by row crops, small grains, tame forage, grassland, meadow and woods respectively. In the Eden Creek watershed, approximately 24 percent of the land is in summer fallow during any crop growing period. The common farming practice is a three-year crop rotation pattern, two years of crop followed by one year of summer

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[1] The occurrence of multiple slopes within an overall single slope.

fallow. This type of practice exposes much of the soil to the runoff/erosion process.

Spratt *et al.* (1975) reported that the reasons given by farmers for summer fallowing the land are to improve soil nutrients and to control weeds. Spratt *et al.* further noted that such practices should only be undertaken in regions receiving less than 406 mm (16 in) of rainfall. Furthermore, Stone (1973) indicated that only 16 percent of the available moisture is stored by fallowed soil. Stone, concluded that such practices are inefficient and should be eliminated except where moisture availability is a serious limiting factor to crop production.

Fallowing enhances the breakdown of organic matter and the conversion of organic nitrogen to nitrate which can be used by plants. However, repeated fallowing will deplete the organic matter content to a level that, even after fallowing, nitrogen supplies are inadequate to meet the needs of the crop, thus resulting in reduced yields.

The use of chemicals if applied properly is a much superior means of weed control. Although the use of chemicals involves a substantial cash outlay, the benefits from the increased crop yields is likely to more than compensate for this additional cost.

4.3.2 Tillage

Tillage practices as carried out by farmers within Eden Creek watershed result in the mechanical breakdown of soil and the turning over and exposure of new soil material to the influence of weathering. With the passing of time, the finer more erodible particles are easily removed by agents of erosion.

Tillage is viewed by farmers as a method of incorporating and dispersing crop residues, promoting the over-winter of precipitation and facilitating the application of soil-incorporated herbicides. However, several studies have shown that tillage may not be necessary since there are other ways of achieving the same objectives.

Lal and Stepphun (1979) reported that adequate fertilization lessens the need for fall tillage. To eliminate problems of excessive crop residues which make seeding a second crop difficult, use of commercial drills for use under no till conditions is recommended. The use of chemicals during the spring to control weeds may be more important than tillage operations.

Lal and Stepphun (1979) also noted that fall tillage for the production of spring seeded crops does not appear to be necessary nor of sufficient value to warrant expenditure on fuel, equipment wear or time.

Bowren and Dryden (1971), reported that fall tillage does not contribute to increased yields. Although it saves time during the busy planting period, it results in greater soil loss since the soil lies fallow over the winter without adequate protection. Depending on the soil type, the use of the conventional moldboard plough by farmers produces a very cloddy soil surface. As a result, the rough surface is conducive to ponding which holds runoff after a storm.

However, the soil clods provide a poor seedbed requiring disking and harrowing after ploughing.[2] These secondary tillage operations while essential for adequate seedbed preparation reduce ponding and contribute to surface sealing. Thus runoff and soil losses are usually high.

4.4 Demographic Influences

Examination of the demographic characteristics of Eden Creek watershed indicates that the level of education and the age of the farm operator may be partially responsible for problems in resource mismanagement.

Between 1961 and 1966, the population of Eden Creek watershed declined by 7 percent whereas between 1971 and 1976, the decline was 16 percent (Table 3-1). The reasons for out migration may be related to low farm incomes and lack of alternative opportunities within the Eden Creek watershed.

Sharp and Kristjanson (1966) found that young adults in rural Manitoba who are better educated tend to migrate. Swanson (1974) also noted the same trend within the Whitemud River Watershed Conservation District. In the Eden Creek watershed between 1971 and 1976, the population between the ages of 15 and 54 declined by 3 percent (Table 3-2).

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[2]Disking is used to turn and loosen the soil, whereas harrowing is used to pulverize and smooth the soil.

Because of the lack of data, it was not possible to prove that those who migrate from Eden Creek watershed are better educated. However, there are no reasons why there should be any differences between the young adult group that are migrating from Eden Creek watershed and those of other farming communities in Manitoba. The relatively high proportion of watershed residents with a low level of education support this assumption (Table 3-5 and 3-6).

Although the migration of the young adult group may not appear to be significant in numbers, the relative degree of migration within the Eden Creek watershed in terms of total population is quite substantial.

The reasons for migration by Eden Creek residents may also be related to the difficulty of farmers in obtaining loans in order to improve their farming operations. Few farmers within the watershed have ever qualified for Provincial government loans. The reason given is that the farm operations are not economically viable and as such, do not meet the loan requirements of the Manitoba Agriculture Credit Corporation.[3]

In 1976, approximately 21 percent of the population of Eden Creek was over 55 years. However Table 3-5 indicates that the proportion of families with a head over 55 years was much greater (47%). Heady (1965) argues that older farmers

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[3] Personal communication, D. Johnson, Credit Officer, Manitoba Agriculture Credit Corporation, 1979.

are less likely to accept the burden of additional debt necessary to efficiently manage a farm in order for it to be economically self-sustaining. Furthermore, it would be more difficult for the older farmers to give up farming and find a job elsewhere. Thus, the older farm operators are more likely to accept lower income and avoid additional risks associated with improving a farm operation. To change the present mode of operation would require a substantial capital investment and, since the farmers' desire may be to maximize short-term profits, it follows that to undertake such changes would not be advantageous.

Generally, the level of education within the Eden Creek watershed is similar to that found elsewhere in rural Manitoba. Approximately 49 percent of the population 15 years and over had little or no schooling (Table 3-5). Three percent of the population 15 years and over attended university compared with one percent for the Whitemud River Watershed Conservation District, Swanson (1974). About 53 percent of husbands and wives in a household had less than grade 9 education including no schooling. Although no specific figures are available, it is likely that most residents with a low level of education are of the older age group, and many may in fact be heads of households.

Denison (1964) originally suggested that the level of educational achievement by an individual affects his performance in his chosen occupation. Denison hypothesized that an individual having more education is more efficient and productive in a given occupation. Assuming this hypothesis is correct, the lower level of education in Eden Creek watershed would likely be responsible for poor management practices that result in low crop yields, low farm incomes and types of measures undertaken to control runoff, erosion and associated land and water related problems.

4.5 Economic

Compared with the rest of Agro-Manitoba, average farm incomes are lower for Eden Creek residents, and many farmers have to supplement their incomes by working off the farm. However, average incomes from off-farm work by Eden Creek residents are also much lower than the average off-farm income for the rest of Agro-Manitoba. In 1977, the average off-farm income for Eden Creek residents was $3,949 compared with $6,063 for the rest of Agro-Manitoba (Table 3-7). This suggests that off-farm employment opportunities are limited in the vicinity of Eden Creek. As well, the possibility exists that non-farm employment skills for watershed residents are relatively low, resulting in poor off-farm earnings.

Many farms within the Eden Creek watershed are less than 65 ha (160 ac) in size. Although no specific figures were available, Swanson (1974) pointed out that many of these farms are situated between Neepawa and Riding Mountain National Park. Swanson concluded that a typical farm, in order to provide an adequate net income, should be between 129 to 194 ha (320 to 480 ac) in size.

Thus, it is likely that one of the reasons for low farm incomes within the Eden Creek watershed is the small size of many farms.

Analysis of the labour force data for Eden Creek watershed shows that 65 percent of the total unemployed were between the ages of 15 and 44 (Table 3-9). These age groups are likely better educated and include individuals that would probably migrate from the watershed.

The average income of watershed residents may be a function of other variables. The relatively low level of education and large proportion of population in the upper age groups may not be conducive to efficient use of resources. Swanson (1974) noted that when incomes are low, the efficient use of resources is unlikely, because it does not allows for capital accumulation. Low income offers less opportunity to save, therefore, less capital is accumulated and it follows that without capital, the farmer does not have the resources to re-invest in his farm. What little capital is saved is likely to be kept for retirement rather than for reinvestment in the farm business. The farming units found within the Eden Creek watershed may be too small to be economically viable and this may affect the amount of income a farmer receives from his investment. Moreover, since the farmer has to seek off-farm work, less attention may be directed to conservation practices, since benefits from such measures accrue only in the long term. On the other hand, it could be argued that off-farm work may have kept area farmers in the agricultural business, thus reducing watershed migration.

4.6 Implications

The preceding analysis has indicated that a relationship exists between the socio-economic welfare of Eden Creek watershed residents and the way the resources are being utilized. The amount of uncontrolled runoff and soil erosion, low crop yields and farm incomes, the age and level of education of the farm operator and no observable signs of conservation practices within the watershed support the above assertion.

If present farm practices within Eden Creek watershed continue unchanged, this may eventually result in economic exhaustion of the soil for agriculture. Furthermore, if runoff and the rate of erosion are not controlled, increased sedimentation, gullying and flash floods can also be expected to continue within the watershed.

It is also likely that agricultural service industries which are a major source of employment in the vicinity of Eden Creek watershed, could be reduced due to continued migration of watershed residents. Moreover, because of the declining watershed population and low farm incomes, future investment in the community might be precluded.

Improved land-use practices must be accompanied by effective runoff and erosion control measures. At the same time, such practices should be economically viable. Stabilization of the land base might subsequently result in reducing watershed depopulation, increasing farm incomes and stimulating investment in the local community.

CHAPTER 5

ALTERNATIVE LAND-USE CHANGES

The need for coordinating soil and water management on a watershed basis to maintain the resource base and enhance the standard of living for residents provides challenges and opportunities for improved economic analysis of resource development. More attention,especially in the United States, is being directed to the water-related aspects of land-use planning. Questions are being raised regarding the effect of erosion control and land-use practices on runoff and peak discharges. Can these practices, under certain land and climatic conditions, sharply reduce runoff and peak flows, and will these changes be measureable?

Besides environmental problems, researchers are also seeking ways in which selected conservation practices can prevent watershed deterioration and at the same time be economically viable so as to provide a better quality of life for watershed residents. The aim of these research programs is to help prevent the decline of watershed populations, particularly the young and better educated, whose loss weakens the socio-economic and cultural fabric of these regions.

5.1 Effects of Conservation Practices

Conservation practices for runoff and erosion control have been developed through the U.S. Department of Agriculture. In the early 1950's, farming practices such as contour tillage, strip cropping and crop rotations were tested by researchers for erosion control and found to be so effective that these practices were widely recommended as major items in the controlling of erosion and excess runoff, Harrold and Dragoun (1969). Reforestation on fields and use of deeper rooted crops were also found to reduce the runoff and erosion process.

Harrold and Dragoun (1969) studied the effect of land-use treatment on flow from agricultural lands in Hastings, Nebraska where detailed data on rainfall, runoff, soils and land use were available. Results showed that these treatments reduced peak rates of storm flow by about 50 percent, water yields by 30 percent and sediment yield by 50 percent. Results also indicated that seeding of eroded cultivated cropland with adapted perennial grasses had by far the greatest effect on erosion control and surface runoff. After three years, these seeded areas performed the same hydrologically as native meadows with very little surface runoff and no measurable erosion. Similar results were also obtained by the same researchers in Treynor, Iowa.

5.2 Economic Benefits from Conservation Practices

Benefits from conservation practices can result not only in increased crop yields but also in increased incomes.

Pavelis and Timmons (1960) examined the economic benefits of comprehensive watershed planning. The Neeper Watershed in Iowa was affected by problems similar to those of Eden Creek watershed. Increased runoff, erosion, gullying, sedimentation and flooding along sections of the stream were common. To help alleviate or reduce these problems and at the same time to make it economically viable for watershed farmers to secure a reasonable economic return from conservation practices, the following proposals were made:

(1) Changes in farmland use including a 35 percent reduction in row crops, a 52 percent reduction in small grains such as oats, and a 182 percent increase in forage crops.

(2) Supplementary practices such as 53,000 km of terracing and 226,632 ha of contouring.

(3) Reforestation of specified areas that were severely eroded.

(4) Structural measures to control flooding.

By adopting these measures, it was estimated that the benefit/cost ratio of the land treatment alone would be 2.22, based on average annual benefits of $2,689,707 and annual costs of $1,208,302, Pavelis and Timmons (1966). Estimates of annual structural costs alone would total $177,200 and estimated annual benefits equalled $191,652 indicating a benefit/cost ratio of 1.08. Considering both land treatment and structural measures, the overall estimated benefit/cost ratio was 2.08.

Similar results were obtained from a study of Hound Dog Creek Watershed, Iowa, by Cormack and Timmons (1968). By re-organization of resources, a profit-maximizing farm could increase average farm net revenue by 18 percent from pre-development conditions. A second plan, which would require the use of additional capital and labour,could increase average farm net revenue by an additional 21 percent.

5.3 Effects of Land-Use Changes on Runoff and Soil Erosion in the Eden Creek Watershed

The previous sections (5.1 and 5.2) presented research evidence from the United States indicating the benefits that could be obtained from land-use changes. Such changes not only resulted in protection of the physical resource base but provided opportunities for farm operators to increase net income.

This section analyzes land-use changes in Eden Creek watershed to determine the effectiveness in controlling erosion and runoff. To assess such changes, the cropping management factor (C) was modified in the USLE for each field. To justify the changes, the present crop rotations within Eden Creek watershed were determined as follows:[1]

(1) A three year crop rotation, C-C-SF with 91 kg of residue prior to seeding.[2]

(2) If the land was privately owned and the field crop was alfalfa, it was assumed that the cropping pattern was 3 years C-C-C, 5 years A-A-A-A-A and 1 year SF.

(3) If the land was owned by the Crown and the field crop was alfalfa, it was assumed that the crop rotation was 3 years C-C-C, 8 years A-A-A-A-A-A-A-A and 1 year SF.

Given these crop rotations for Eden Creek watershed and the amount of soil loss for each field (see Appendix B), alternative

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[1]Crop Rotations were determined by L. Slevinsky, Water Resources Branch, Dept. of Mines, Natural Resources and Environment.

[2]C refers to crop, SF refers to summer fallow and A refers to alfalfa.

C values were computed for these fields based on the procedure developed by Wischmeier and Smith (1965).

Appendix B indicates the maximum permissible C values and proposed land-use options that are necessary to be within the tolerable soil loss level of 0.9 and 1.8 t/ha. Land-use options that are required to reduce the soil losses to tolerable level for Eden Creek watershed are as follows (Fig. 5-1):

(1) Option A: If the C value is .05 or less, fields should be re-planted with native vegetation or trees.

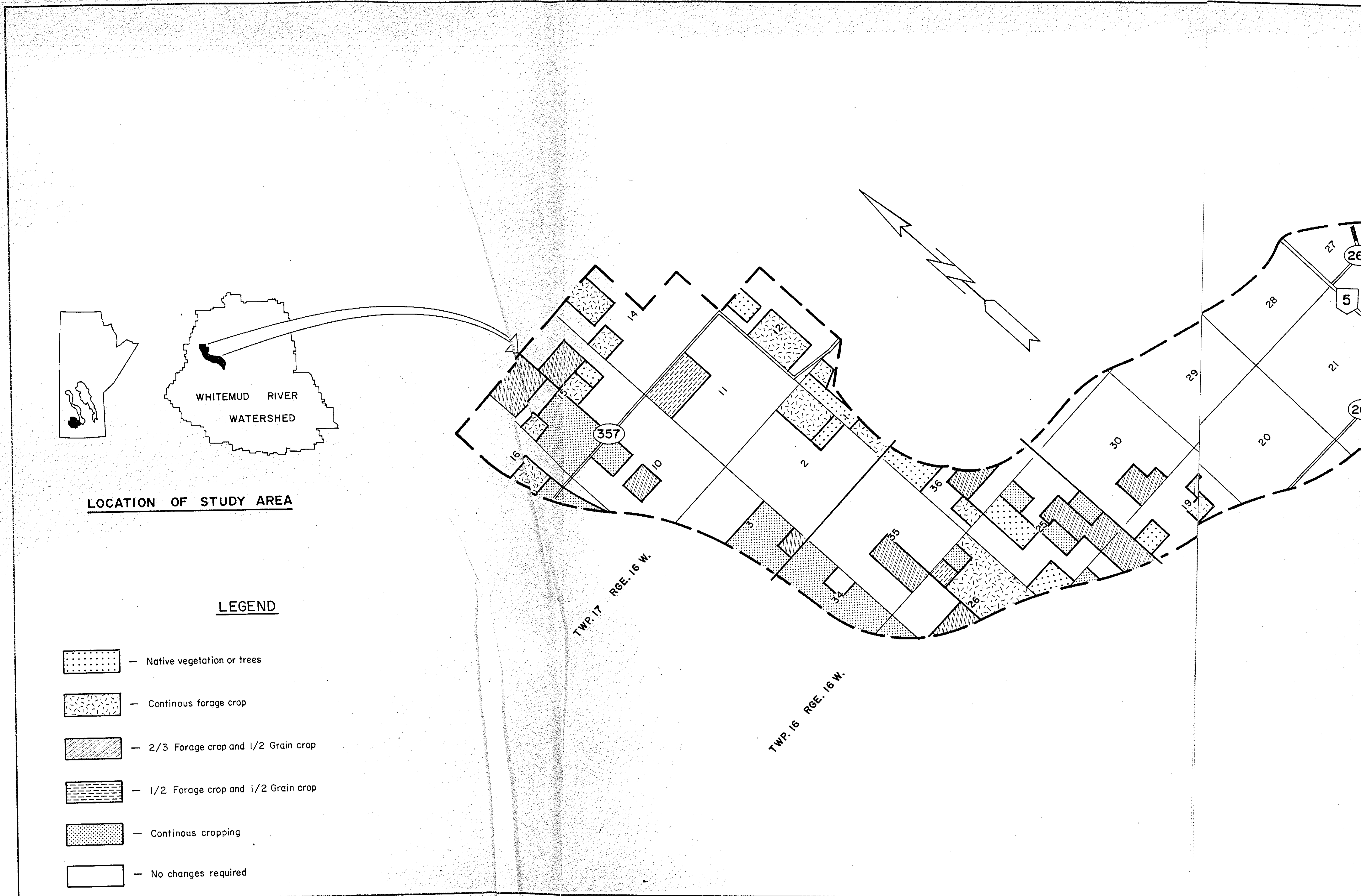
(2) Option B: If the C value is between .06 and .1, fields should be changed to a continuous forage rotation.

(3) Option C: If the C value is between .1 and .15, fields should be changed to 2/3 forage and 1/3 crop rotation.

(4) Option D: If the C value is between .16 and .18, fields should be changed to 1/2 forage and 1/2 crop rotation.

(5) Option E: If the C value is ≥ .19, fields should be changed to a continuous cropping rotation.

To illustrate land-use changes in order to control erosion, a 16 ha field located in the southeast quarter, section 34, township, 16, and range 16 in Eden Creek watershed has a soil loss of 3 t/ha under present cropping practices (Appendix B). The tolerable soil loss level for this field was determined to be 1.8 t/ha. To be within the tolerable soil loss level, a maximum permissible C value of .22 was computed. Substituting the C value of .22 for the existing value of .35 in the USLE, soil loss could be reduced to 1.78 t/ha, which is within the tolerable soil loss level. All other factors in the USLE


WHITEMUD RIVER WATERSHED
LOCATION OF STUDY AREA
LEGEND
— Native vegetation or trees
— Continous forage crop
— 2/3 Forage crop and 1/2 Grain crop
— 1/2 Forage crop and 1/2 Grain crop
— Continous cropping
— No changes required
TWP. 17 RGE. 16 W.
TWP. 16 RGE. 16 W.
357
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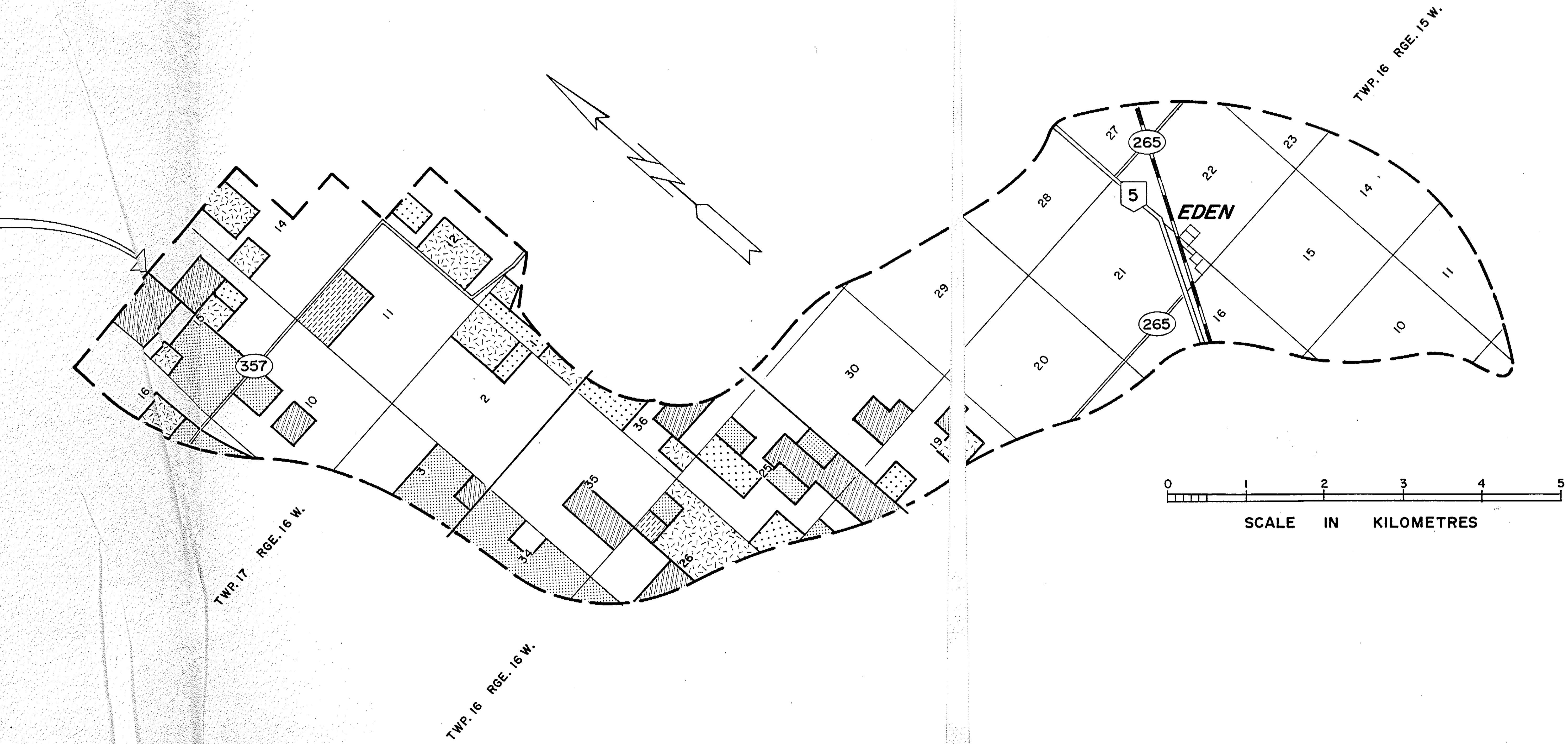

FIGURE 5-1

EDEN CREEK STUDY AREA

LAND USE OPTIONS

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remained unchanged. The crop rotation that would therefore be required for this 16 ha field is continuous cropping, Option E.

Based on the analysis for the entire Eden Creek watershed, the following changes in total are necessary to maintain soil losses within tolerable levels:

(1) 57 ha (141 ac) should be changed to option A.

(2) 137 ha (334 ac) should be changed to option B.

(3) 153 ha (390 ac) should be changed to option C.

(4) 27 ha (67 ac) should be changed to option D.

(5) 254 ha (628 ac) should be changed to option E.

The rest of the cultivated fields required no land-use changes.

Although the land-use changes suggested will control soil erosion to the tolerable levels, such changes will not significantly reduce the estimated volume of runoff or peak discharge resulting from rainfall runoff. Application of the SCS procedure to accommodate these land-use changes,within Eden Creek watershed showed that the volume of runoff for each HU was reduced only by 6 percent, 13 percent, 9 percent, and 3 percent respectively (Table 5-1). The percentage reduction in peak discharge for each HU was 11 percent, 21 percent, 15 percent, and 5 percent respectively (Table 5-2 and Fig. 5-2 to 5-5).

Since the changes in land-use to control soil erosion did not reduce runoff and peak discharge significantly, further land-use changes are recommended and assessed. These are as follows:

Table 5-1

Effects of Land Use Changes on Runoff Volumes,
Eden Creek Watershed
m^3 (ac ft)

Hydrological Units	Existing	Alternate C-Value Changes	Alternate Recommended Changes	% Reduction C-Value Changes	% Reduction Recommended Changes
HU-1	390,861 (317)	367,434 (298)	332,910 (270)	6	15
HU-2	570,879 (463)	498,132 (404)	483,336 (392)	13	16
HU-3	674,451 (547)	616,500 (500)	575,811 (467)	9	15
HU-4	344,007 (279)	332,910 (270)	292,221 (237)	3	15

Table 5-2

Effects of Land Use Changes on Peak Discharges, Eden Creek Watershed

m^3/s (cfs)

Hydrological Unit	Existing	Alternate C-Value Changes	Alternate Recommended Changes	% Reduction C-Value Changes	% Reduction Recommended Changes
HU-1	21.00 (740)	18.73 (660)	14.13 (498)	11	33
HU-2	28.37 (1,000)	22.41 (790)	19.86 (700)	21	30
HU-3	30.64 (1,080)	26.10 (920)	21.14 (745)	15	31
HU-4	18.44 (650)	17.45 (615)	12.63 (445)	5	32

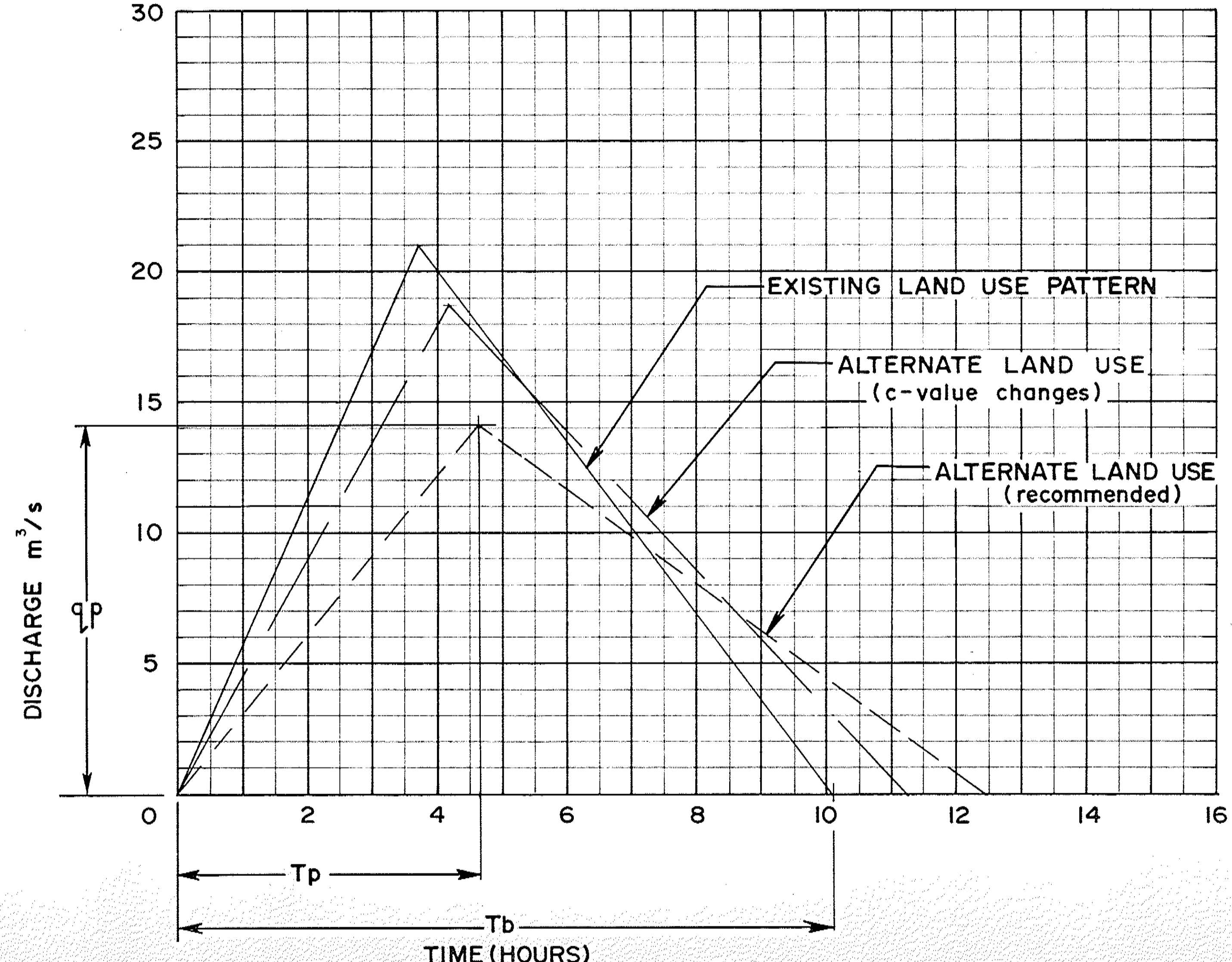

FIGURE 5-2

EDEN CREEK STUDY AREA

HYDROLOGICAL UNIT I

PEAK DISCHARGE
UNDER EXISTING AND ALTERNATE LAND USE

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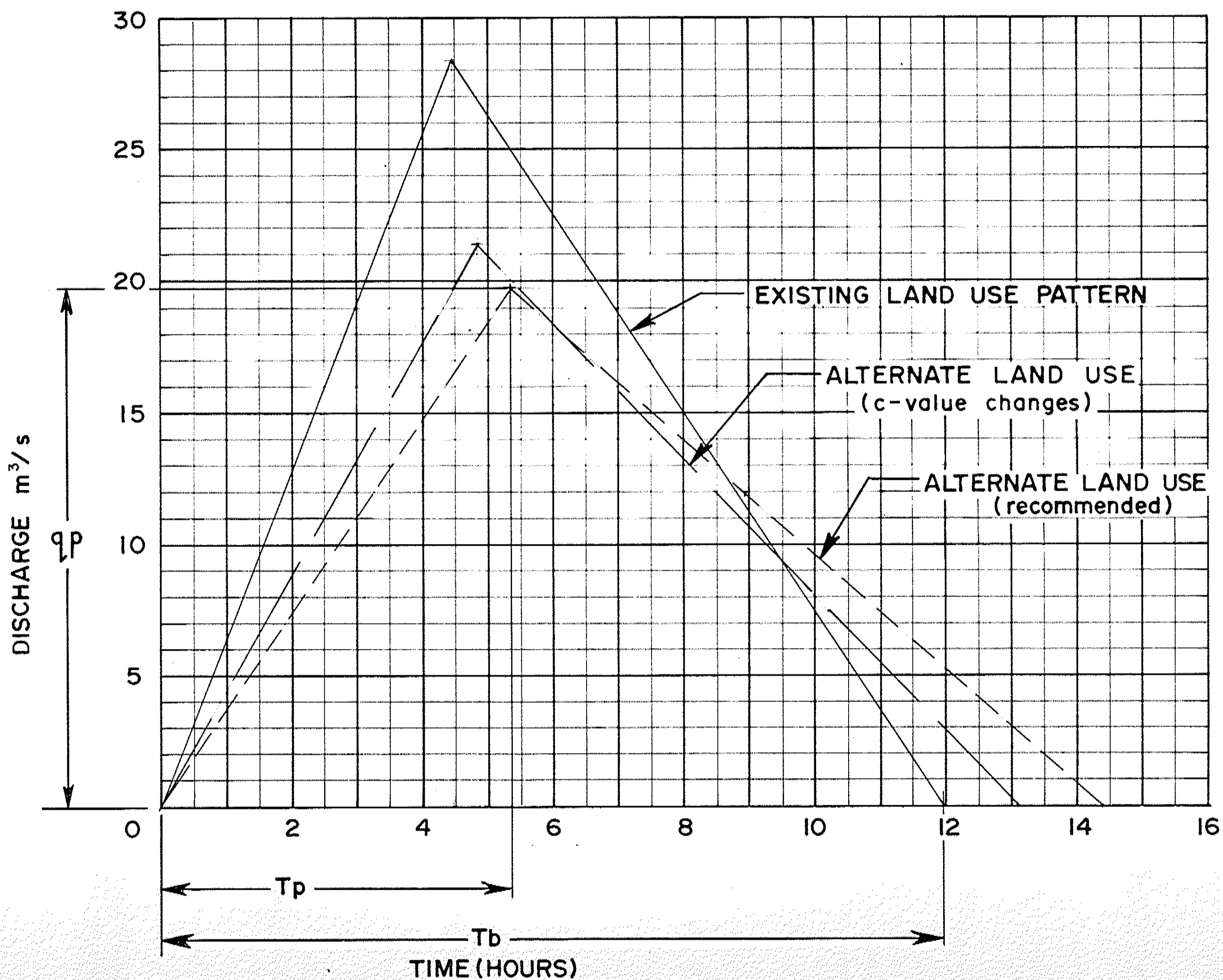

FIGURE 5-3

EDEN CREEK STUDY AREA

HYDROLOGICAL UNIT 2

PEAK DISCHARGE

UNDER EXISTING AND ALTERNATE LAND USE

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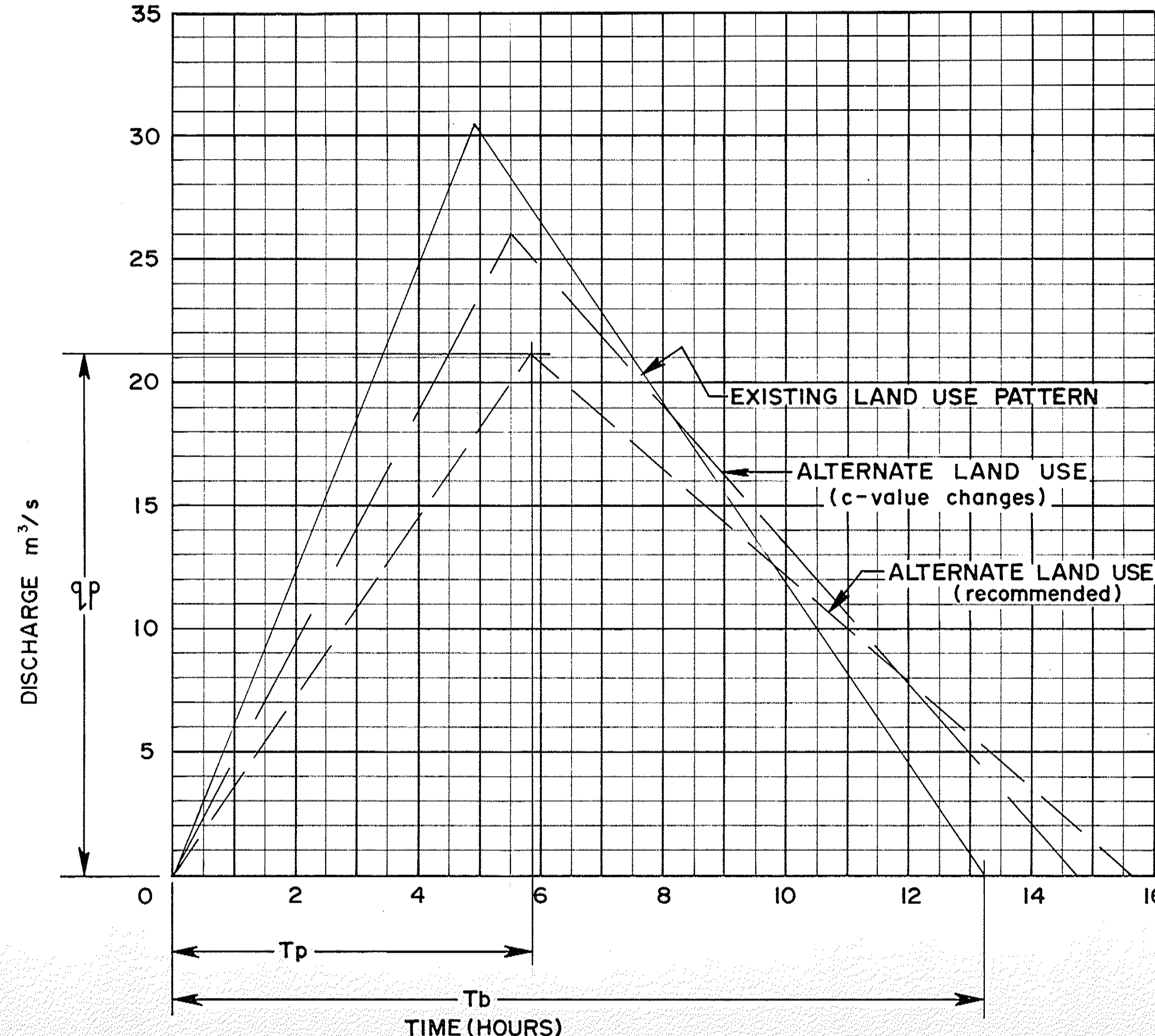

FIGURE 5-4

EDEN CREEK STUDY AREA

HYDROLOGICAL UNIT 3

PEAK DISCHARGE

UNDER EXISTING AND ALTERNATE LAND USE

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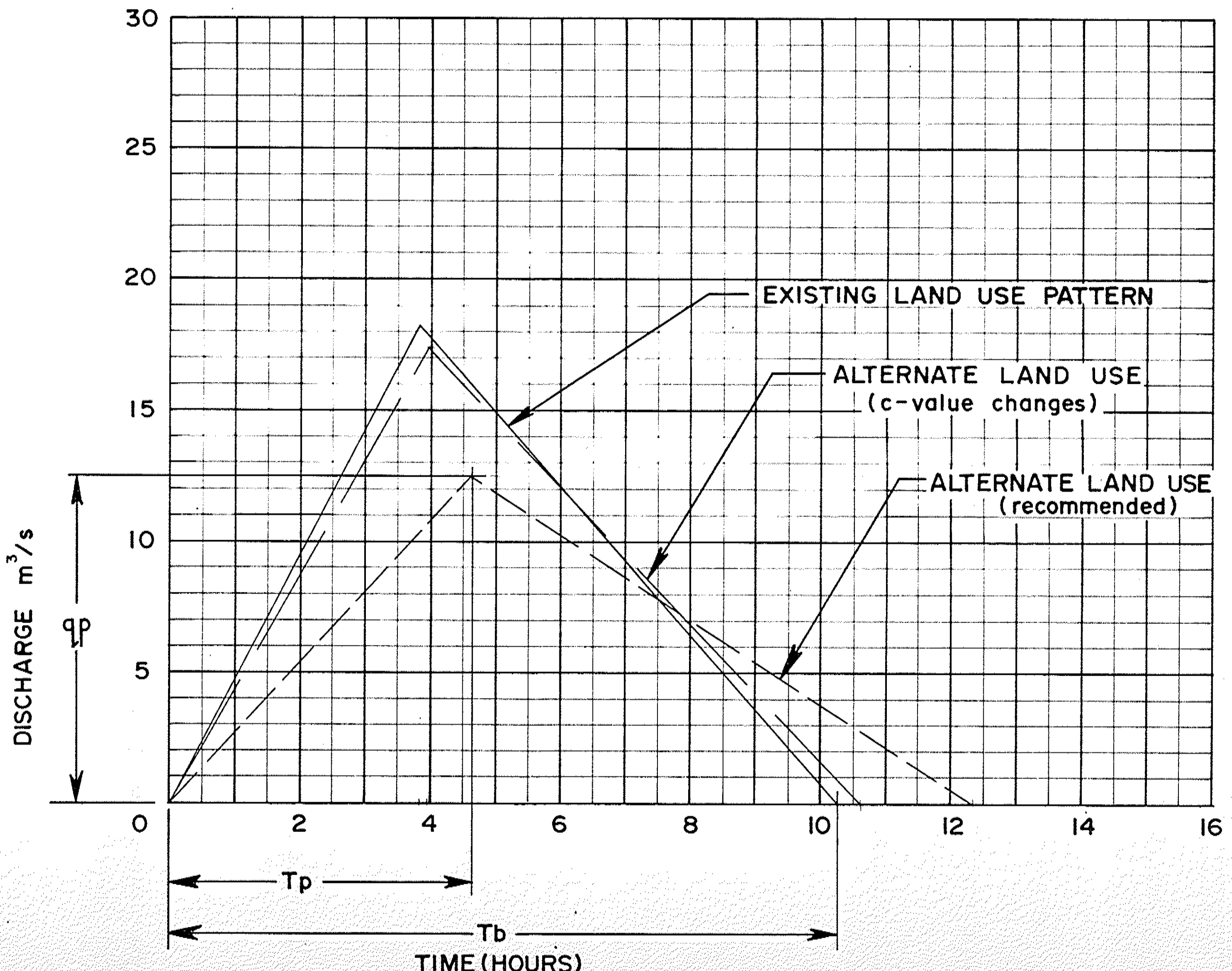

FIGURE 5-5

EDEN CREEK STUDY AREA

HYDROLOGICAL UNIT 4

PEAK DISCHARGE

UNDER EXISTING AND ALTERNATE LAND USE

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(1) Complete elimination of summer fallow within the watershed.

(2) Limited contouring.

(3) Cultivated fields that are currently above the tolerable soil loss level should be changed entirely to forage crop production.

Under these possibilities, the percentage reduction in runoff volumes were 15 percent, 16 percent, 15 percent, and 15 percent respectively for each HU (Table 5-1). Reduction in peak discharges for each HU was 33, 31, 31, and 32 percent respectively. As well, the time to peak increased by approximately one hour for each HU (Table 5-2 and Fig. 5-2 to 5-5). Table 5-1 indicates that the percentage reduction in the volumes of runoff were not that significant, however, the percentage reduction in peak discharges was greater. This is much more important in the case of flash floods, since any significant reduction in peak discharges will ultimately result in reduced flooding along the length of the channel. The time of concentration and time to base increased in all four HU's. Time to base increased by approximately two hours for each HU (Fig. 5-2 to 5-5). Time of concentration increased from 1.9 to 2.4 hours for HU-1; 2.3 to 2.8 hours for HU-2; 2.8 to 3.3 hours for HU-3; and 1.8 to 2.4 hours for HU-4. Any increase in time of concentration would reduce the rate of rainfall runoff and this implies that the erosive action of rainfall would likely be reduced.

Although soil loss under these recommended changes were not quantified, it follows from the previous analysis that these land-use changes would further reduce soil losses within the watershed.

Further land-use changes of fields to achieve greater reduction in runoff and peak flows would not be advisable, since this would require that the entire Eden Creek watershed be reforested. Complete reforestation would not likely be an economical and socially viable alternative for watershed residents.

Besides the above land-use changes, additional conservation measures could be undertaken to further reduce runoff and peak discharge. The following additional measures are suggested:

(1) Installation of grassed waterways which will reduce the velocity of runoff and resist the soil cutting action of water.

(2) Retaining crop residues on fields to reduce the removal of soil by rainfall runoff.

(3) Reduced tillage practices to control the amount of erosion and runoff.

The use of structural measures such as retention basins to control runoff could be effective, however, such measures would likely be too costly. Dearman (1980), studying the effects of erosion on the main channel within Eden Creek watershed, suggested that retention basins to control runoff would be too expensive. Dearman further suggested, that in places where the main channel is severely eroded, armouring the banks with rip-rap would be more effective in stabililizing eroded channel banks.

It is likely that once runoff and soil erosion problems are controlled by changing the land-use practices other land and water related problems such as gullying, sedimentation, and flash floods would also be reduced.

Existing gullies within the Eden Creek watershed could be filled, levelled and grassed where feasible.

5.4 Estimation of Economic Benefits from Land-use Changes in Eden Creek Watershed

To determine the costs and benefits of land-use changes, farm budgets were prepared for three hypothetical farms of various sizes under present and alternate land-use changes. As input to the budgetary simulation model, producer physical data were supplied by the Manitoba Department of Agriculture, the Department of Agricultural Economics and Farm Management, University of Manitoba, and resource planners familiar with the study area. Based on the input data, the following parameters were assumed under existing farm practices:

(1) Farm sizes of 65 ha (160 ac), 129 ha (320 ac), and 194 ha (480 ac).

(2) A cropping system of C-C-SF.

(3) Crops consisting of wheat, barley and tame hay.

(4) Application of little or no fertilizer.

(5) Two fall tillage and two spring tillage operations.

(6) The farmer owns the land and equipment.

(7) Average crop yields as based on Manitoba Crop Insurance ratings.

Under proposed land-use changes, the following were assumed:

(1) Farm sizes would remain the same.

(2) One-half of the fields would be placed into production of tame hay.

(3) Application of fertilizers would be increased.

(4) Crops would be the same as under existing conditions but with higher yields.

(5) Summer fallowing would be eliminated.

(6) Tillage practices would be reduced.

Farm budgets, prepared to reflect the above assumptions, showed that under present farming practices, the net returns to management were negative under all three farm plans (Table 5-3 and Appendix D).[1] By re-arranging the farm resources to maximize returns, and at the same time, to reflect land-use changes discussed in section 5.3, (i.e. reduction of erosion and runoff) the farm budgets indicated net returns to management were positive under alternative farm plans. Table 5-4 shows the total costs and total gross returns for the three hypothetical farms under alternative farm arrangements. Compared with the results obtained for present farm practices, the net returns to management under the alternative farm plans are considerably greater. Not only were returns positive for the entire farm operations but individual field crops also showed a positive net return to management. For instance, under present farm practices, total costs for growing 16 ha of

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[1]Mr. L. Longmuir, Programmer, Dept. of Agricultural Economics, University of Manitoba, assisted in preparing the computer program for the farm budget analysis.

Table 5-3

Total Cost/Return for Hypothetical Farms Under Present Farm Plans, Eden Creek Watershed

Farm Size ha	Total Cost $	Total Gross Returns $	Net Returns to Management $
65	8,541.77	8,174.74	- 366.94
129	17,493.58	16,349.68	- 1,143.91
194	26,897.84	24,524.52	- 2,373.33

Table 5-4

Total Cost/Return for Hypothetical
Farms Under Alternative
Farm Plans, Eden Creek Watershed

Farm Size ha	Total Cost $	Total Gross Returns $	Net Returns to Management $
65	11,728.31	16,416.99	4,688.68
129	24,205.41	32,833.99	8,628.58
194	37,297.47	49,250.99	11,953.52

wheat were $3,159.33. Total gross returns were $3,301.40 thus leaving a net return to management of $142.07. Under alternative farm plans for the same field, total costs were $3,597.46 and total gross returns were $5,137.00, leaving a net return of $1,539.53.

One of the main reasons for increased farm income under alternate conditions was the elimination of summer fallow. There are many reasons why this practice should be eliminated. It is the single largest contributor to runoff. This practice enhances the soil erosion process. Its elimination would allow for additional acreage to be cropped and would provide for the more efficient use of labour and capital. Moreover, evidence has been presented that in areas receiving 406 mm (16 in) of rainfall, summer fallow is not needed for moisture conservation.

It should be noted, that the elimination of summer fallow would mean higher expenditure for fertilizer and herbicides. Since cash flow is a problem for farmers in the Eden Creek watershed, initial funding will have to be provided through existing government farm programs or through the creation of special funding.

Under alternate farm plans, crop yields were also increased (Appendix D). For instance, wheat yields were assumed to increase from 1,479 to 2,354 kg/ha and barley from 1,453 to 2,690 kg/ha. These higher yields represent yields attainable under good management practices in Manitoba.

To summarize, the farm budget analysis shows that there is a positive relationship between higher farming income and changes in land-use practices to control runoff and soil erosion.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary and Conclusions

The study indicates that the degration of the physical environment is related to the socio-economic conditions that exist within the Eden Creek Watershed. The watershed is characterized by small farms, an older population, low income levels, low education levels, intense storm runoff, soil erosion and associated water related problems. It is an area where conservation measures are necessary to protect the physical resource base from further deterioration. However, implementation of such measures may be difficult, since the farm operators lack the necessary capital to make the required adjustments. In addition, they may lack the managerial ability to undertake such programs.

If existing problems are allowed to continue within Eden Creek watershed, it can be expected that this may result in further rural de-population. To some extent, migration has been encouraged, based on the belief that low income and low crop yields indicate a misallocation of resources and that the reallocation of resources is the solution to income disparities. While this may be true, such solutions may not be the answer to the problems experienced by Eden Creek residents. Given that in Manitoba migration off the farm has been taking place at the rate of 1,000 families per year and that agriculture is one of the dominant industries in the province, it follows that re-organization of farm resources to increase farm incomes may be a feasible solution to help maintain Eden Creek's long term agricultural productivity and population.

Evidence presented indicates that farming practices such as tillage and summerfallow should be reduced or eliminated. Both practices are conducive to the runoff/erosion process, and economically both practices are an added cost with no real visible benefits. Lower crop yields within Eden Creek area relative to the rest of Manitoba supports this assumption.

Application of the SCS procedure to estimate runoff and peak flows under alternate land-use changes, although encouraging, requires further investigation to compare estimated with actual runoff and peak flow values. Results obtained showed that the volumes of runoff were not reduced significantly, however, peak flows were reduced by approximately 30 percent in all four HU's. This reduction in peak flows, resulted in a longer time of concentration and time to base for the design storm analyzed for Eden Creek watershed. These hydrological changes could result in the reduction of flash floods and erosion within the watershed. Other conservation practices, such as grassed waterways and retention of crop residues could further serve to reduce runoff and soil erosion by water.

The preparation of farm budgets was based on the assumption that the prime objective of the farm operation is to maximize net returns. Results obtained showed that by rearrangement of farm resources, the farm operator could increase income above current levels. It should be noted that the appropriate use of farm budget analysis is for static and short term problems, and that prices of farm inputs and outputs change over time. However, the results can still be useful to farm operators as a guide to decide on the optimal farm organization if all prices exhibit similar movement over time.

The increased profits obtained from rearrangement of farm resources will allow for capital accumulation and re-investment in farm operations, and at the same time, the physical resource base will be protected from further deterioration. This enables the farm operator to plan ahead and formulate plans for re-investment. With stabilized income, the farmer should also find it easier to secure farm loans from credit corporations and other financial institutions.

In terms of cost, additional inputs of land, labour and capital will be required. Since the farm operator lacks the capital to undertake such projects, financial assistance from government agencies should be made available for re-training farmers as to the use of the best conservation practices and the initial re-organization of farm resources. The results of this research justify such an approach since it has shown that additional inputs of production contribute more to management returns.

Although the possibility of livestock production was not investigated in the analysis of this study, it is felt that this activity should be researched. The climatic conditions of the watershed are suitable for growing forage crops and such a farming activity may further enhance the economic viability of a farm operation.

Resource planners should seek the assistance of farm operators whenever making any plans to re-organize farm resources, since the farmer may have different values attached to the land which may not be based solely on economic criteria. To convince farmers to change their operations may be difficult. Economic incentives, regulations or interaction between local residents and resource planners are different means of achieving this goal and should be fully explored.

Despite limitations noted, land-use adjustments and conservation practices accompanying the introduction of profit-maximizing farm plans could reduce runoff, soil erosion, and provide an economic incentive for farmers to remain within the watershed. In this case,the objectives of watershed development would be achieved through farm planning. Net revenues to farm operators would increase and the physical resource base protected in the long run. This does not mean that the damages will be reduced to zero, but they would be of such magnitude that it would not be feasible to introduce other measures.

Although the success of farm planning will depend on many variables, such as farm size and available capital, this study illustrates the effectiveness of changing land-use to accomodate the physical capabilities of the resource base in meeting stated objectives of watershed planning and development.

6.2 Recommendations

Based on the foregoing analysis the following recommendations are made:

(1) Further in-depth studies are required to compare actual flow measurements with the results obtained by the application of the SCS procedure. This would require continued monitoring of gauges already installed within the watershed.

(2) Soil tillage practices should be reduced to the minimum for erosion control.

(3) Summer fallow should be completely eliminated.

(4) Forage production should be increased in the watershed especially in areas that are severely eroded.

(5) Contour farming, which includes tilling of the soil and growing crops in strips across slopes, should be encouraged.

(6) Drainage channels should be grassed and present or potential gully sites seeded to forages within the watershed.

(7) Crop residues should be retained on the fields after harvesting.

(8) Establishment of trees or shrub cover should be encouraged on severely eroded areas.

(9) Financial assistance should be made available to farmers to enable them to reorganize farming operations so as to meet conservation requirements. The extent of this type of assistance will have to be determined by further studies.

(10) Retraining programs to assist farmers as to the use of the best management practices should be implemented.

(11) Further research should be undertaken to study the feasibility of expanding livestock production in Eden Creek watershed. Studies are also needed to

determine other types of economic opportunities which would provide alternative job opportunities for watershed residents.

Implementation of these recommendations would improve farm incomes for Eden Creek residents and at the same time, improve the quality of the resource base for the benefit of present and future generations in the area.

BIBLIOGRAPHY

Beasley, R. P. Erosion and Sediment Pollution Control. Iowa State University Press. Ames, Iowa, 1972.

Bowren, K. E. and R. D. Dryden. Field Crops. Canadex v. 110, No. 22 Agricultural Canada, 1971.

Canada Department of Fisheries and Environment. Sediment Data: Canadian Rivers, Water Resources Branch, Ottawa, 1976.

Cormack, M. and J. F. Timmons. Integrating Farm and Watershed Planning in Soil and Water Resource Management. J. of Soil and Water Conservation. v. 23, No. 3, p. 84 - 88, 1968.

Dearman, R. Eden Creek Erosion Control Study. Department of Natural Resources, Manitoba, 1980.

Denison, E. E. Measuring the Contribution of Educational to Economic Growth, in The Residual Factor and Economic Growth. Paris: OECD Study Group in the Economics of Education, 1964.

Elrhich, W., L. Pratt, A. Poiser and F. Leclaire. Reconnaisance Soil Survey of West Lake Map Area Report No. 8, Canada Dept. of Agriculture and Soils Dept., University of Manitoba, 1958.

Gray, D. M. Handbook on the Principles of Hydrology. National Research Council of Canada. Ottawa, 1970.

Harrold, L. and F. Dragoun. Effect of Erosion-Control Land Treatment on Flow from Agriculture Watersheds. ASAE v. 12, No. 6, p. 857 - 861, 1969.

Haythorne, G. V. Labour in Canadian Agriculture. Harvard University Press, Cambridge, 1960.

Heady, E. O. Economics of Agriculture Production and Resource Uses. Prentice-Hall, N. J., 1965.

James, L. D. and R. Lee. Economics of Water Resources Planning. McGraw-Hill Book Company. New York, 1971.

Jenkins, G. C. An Inventory of the Agricultural Capability, Productivity and Eroded State of Soils, Whitemud River Watershed Resource Study, Phase 1. Dept. of Mines, Resources and Environmental Management. Manitoba, 1972.

Lal, R. and H. Stepphun. Fall Tillage on the Canadian Prairies. ASAE and CSAE, University of Manitoba, 1979.

Lassey, W. R. Planning in the Rural Environment. McGraw Hill, N. Y., 1977.

Longmuir, C. N., M. Senkiw, A. Pokrant, and C. Framingham. Crop Production Simulator. Res. Bulletin No. 78-2. Dept. of Agricultural Economics and Farm Management. University of Manitoba, Winnipeg, 1978.

Manitoba Crop Insurance Corporation, Rates and Coverage, 1978.

Manitoba Department of Agriculture. Agriculture Yearbook, Manitoba Government, Winnipeg, 1975, 1976, and 1977.

Manitoba Department of Mines, Resources and Environmental Management. Whitemud River Watershed Resources Study. Winnipeg, Manitoba, 1974.

______. Proposal to Establish a Pilot Project in the Eden Creek Watershed. Winnipeg, Manitoba, 1974.

Osborn, H. B. and L. Lane. Precipitation-Runoff Relations for Very Small Semi-arid Rangeland Watersheds, Water Resources Research, v. 5, No. 2, p. 419 - 429, 1969.

Pavelis, A. P. and J. F. Timmons. Programming Small Watershed Development. J. of Farm Economics, v. 42, No. 2, 1960.

Province of Manitoba. Regional Perspectives, Manitoba Government, Winnipeg, 1973.

Ricca, V. T., P. Simmons, J. McGuinness and E. Taiganides. "Influences of Land Use on Runoff from Agricultural Watersheds", Trans. ASAE No. 2, p. 187 - 199, 1970.

Robillard, P. D. and M. F. Walter. Field and Practice Priorities for Sediment Control, Trans. ASAE No. 79, 1979.

SCSA. Soil Erosion: Prediction and Control. The Proceedings of a National Conference on Soil Erosion. May 24 - 26, 1976. Purdue University, W. Lafayette, Indiana, 1977.

Sharp, E. F. and G. A. Kristjanson. The People of Manitoba, 1951 - 1961. AROA, Project No. 7030. Department of Forestry and Rural Development, Ottawa, 1966.

Spratt, E. D., J. H. Strain and B. J. Corby. Summer Fallow Substitutes for Western Manitoba. Can. J. Plant Sci. v. 55, No. 2, p. 477 - 484, 1975.

Stone, L. R., T. C. Olson, and M. L. Horton. Water Loss Estimates from Fallow Soil. J. of Soil and Water Conservation. v. 23, No. 2, p. 122 - 124, 1973.

Swanson, W. Socio-Economic Input, Whitemud River Watershed Resource Study Phase 1. Land-Use Planning Branch, Environment Canada, Ottawa, 1974.

Tolley, G. S. and F. E. Riggs. Economics of Watershed Planning. Iowa State University, Ames, Iowa, 1971.

Tyler, E. J. An Exploratory Study of Factors Related to Population Migration in the Rural Municipality of Rosedale. Brandon College, Brandon, Manitoba, 1964.

U. S. Department of Agriculture. Soil Conservation Service. Supplement to Engineering Field Manual, Sec. 4 Hydrology. N. Dakota, U. S. A., 1971.

______. National Engineering Handbook. Sec. 4, Hydrology. Washington, U. S. A., 1971.

Walter, D. J. An Economic Analysis of an Alternative Environmental and Resource Policies for Controlling Soil Loss and Sedimentation from Agriculture. Unpublished Ph. D. Thesis, Iowa State University, Ames, Iowa, 1977.

Wischmeier, W. H. A Rainfall Erosion Index for a Universal Soil Loss Equation. Soil Science Soc. Amer. Proc. v. 23, p. 246 - 249, 1959.

______ and D. D. Smith. Rainfall Energy and its Relationship to Soil. Trans America, Geophics Union, v. 39, No. 2, p. 285 - 291, 1958.

______. Predicting Rainfall - Erosion Losses from Cropland East of the Rocky Mountains. U. S. Department of Agriculture, Washington, No. 282, 1965.

APPENDIX A

SOIL CONSERVATION SERVICE MODEL

(SCS)

The SCS method estimates surface and sub-surface runoff only, and since the procedure is based on precipitation occuring on one calendar day, rainfall intensity is ignored since nothing is known about time distributions.

The equation is expressed as follows:

$$R = \frac{(P - Ia)^2}{(P\ Ia - S)} \qquad (1)$$

Where:

- R = estimated runoff
- Ia = initial abstraction of moisture by soil
- S = potential maximum moisture of soil
- P = precipitation of storm

The relationship between the initial abstraction of moisture at the beginning of the storm and the potential moisture retention of the soil can be approximated by a simple linear relationship and this is assumed to be 0.25, and is based on studies carried out in the United States (U.S. Dept. of Agriculture, 1971). Using this relationship in equation (2), the expression for the runoff prediction is now reduced to:

$$R = \frac{(P - 0.25)^2}{(P + 0.8S)} \qquad (2)$$

S in equation (2) is defined by the hydrological soil type and surface conditions in the watershed. Soils are classified into four hydrologic types depending on their infiltration and transmission characteristics. These soil groups are defined as follows:

A = low runoff potential and high infiltration and transmission rates.

B = moderate infiltration and transmission rates.

C = slow infiltration and transmission rates.

D = high runoff potential and slow infiltration and transmission rates.

Surface conditions are classified according to land cover which includes woods, meadow, pature and cultivated fields. Fields are further classified according to type of crop and land use practices employed. Using data obtained from watersheds in the United States, SCS hydrologists assigned values called soil-cover complex numbers (CN) to several combinations of soil type and surface conditions.

Since S varies with the antecedent moisture condition (AMC) of a watershed, CN's have been estimated for various AMC's. The SCS hydrologist has defined AMC on a particular day as the total rainfall occuring in the five preceeding days. Three levels of conditions have been estimated:

(1) dry, varies from 0 to 3.55 cm (1.4 in).

(2) moderately wet, varies from 3.55 cm (1.4 in)to 5.33 cm (2.1 in).

(3) saturated, over 5.33 cm (2.1 in).

S of a particular watershed is then calculated using the relation:

$$S = \frac{1000}{CN} - 10 \qquad (3)$$

The AMC for the study area was assumed to be moderately wet and was divided up into four sub-watersheds or hydrological units (HU's) and the study was conducted on the basis of these units. Each HU is the drainage area of a minor tributary flowing into the main stream (Fig. 1-1).

To illustrate the SCS procedure to estimate runoff and peak discharge, the characteristics for HU-1 within the Eden Creek will be used. These characteristics are as follows:

(1) DA = 502 ha (1,241 ac)

(2) Average CN = 81

(3) Largest flow length = 14,856 m (4,528 ft)

(4) Average slope = 6%

(5) Design precipitation = P_{10} - 24 hr/127 mm (5.01 in)

Given these watershed characteristics, runoff is estimated directly from charts developed by the SCS for estimating runoff rates. Each graph of these charts relates peak discharge to the watershed area and rainfall depth for a given set of watershed characteristics and slopes.[1] Runoff for HU-1 is estimated at 79 mm (3.07 in).

Peak discharge (Q) is determined by the equation:

$$Q_{cfs} = Q_{csm} / \text{in} \times \frac{DA}{640} \times R_o \text{ in}$$

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[1]See U.S. Dept. of Agriculture. National Engineering Handbook, Sec. 4, Hydrology. Washington, U.S.A., 1974.

The steps in determining Q are:

(1) $\left(\frac{200}{CN} - 2\right) / P_{24} = \left(\frac{200}{81} - 2\right) / 5.01 = 0.09$

(2) $Q_{10} = 124(1241/640)3.07$

$= 740$ cfs (21 m^3/s)

The unit peak is computed from the formulas:

$T_p = \frac{484}{q/p}$ and

$T_b = 2.67\ T_p$

The steps in determining T_p and T_b are:

(1) 128 X 3.07 X 1.94 = (762.34)

(2) $T_p = \frac{484 \times 1.94 \times 3.07}{762.34} = 3.78$ hr

(3) $T_b = 2.67 \times 3.78 = 10.09$ hr

APPENDIX B

USLE AND ESTIMATED SOIL LOSS
BY FIELDS AND MANAGEMENT
OPTIONS FOR EDEN CREEK WATERSHED

(Fields identified by section,
township and range)

The USLE equation can be expressed as follows:

$$A = R\ K\ L\ S\ C\ P \qquad (1)$$

Where:

A = average annual soil loss

R = rainfall factor

K = soil erodibility factor

L = slope length factor

S = slope gradient factor

C = cropping and management factor and,

P = conservation practices.

The rainfall factor (R) is a measure of the erosiveness of the average annual pattern of rainfall in an area. This single rainstorm parameter is actually and interaction term which is equal to the value of the product of two rainstorms characteristics, the total kinetic energy of the rainstorm and its maximum 30 minute intensity and can be expressed as follows:

R = El/100 where E is the storm energy and l is the maximum 30 minute intensity. (2)

Values for this study were derived from long-term rainfall records available for the Wilson Creek Watershed, and the R value was determined to be 51.

Soil erodibility values K for soil materials were determined on soil samples (AP or AL + AE horizons) by use of the soil erodibility monograph (Wishmeier and Smith, 1965).

The topographic factors, slope length (L) and slope gradient (S) has been combined into one term (LS) in the

USLE.

$$LS = 1\frac{1}{2} (0.0076 + 0.053 S + 0.00076 S^2) \quad (3)$$

Where L is the slope length and S is the slope in percentage. Land use on individual fields within the watershed was mapped by field observation and average slope/length per quarter section was calculated. Regional soils and crop specialists including farmers within the watershed were contacted to establish the most common crop rotations. Yield levels were obtained from crop insurance data for computation of (C) factors.

Erosion control practices (P) in the form of strip-cropping or contour ploughing were not observed, therefore the erosion control factor P in the USLE was given a value of 1.

Average soil loss within Eden Creek watershed was computed for all cultivated fields and the following management options were suggested to reduce soil loss to a tolerable level.[1]

A = Native vegetation or trees

B = Continuous forage crop

C = 2/3 forage crop and 1/3 grain crop

D = ½ forage crop and ½ grain crop

E = Continuous cropping

F = No changes required.

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[1]As previously mentioned on page 21, calculations used to derive the estimated soil loss for Eden Creek were based on the English system of weights and measures. Values for A and T were converted to metric equivalents.

The remainder of this section deals with soil loss computations and options for each field within Eden Creek watershed.[1]

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[1]Mr. L. Slevinsky, Water Resources Branch, assisted with the soil loss computations for Eden Creek watershed.

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
NE-16-17-16	1	1.8	51	.26	2.40	.12	1.7	.13	28	F
	1	1.8	51	.26	2.25	.12	1.6	.16	18	F
	1	1.8	51	.26	2.25	.35	4.6	.16	4	E
	1	1.8	51	.26	6.00	.12	4.2	.06	7	B
	1	1.8	51	.26	6.00	.35	12.5	.06	3	B
	1	1.8	51	.26	1.55	.12	1.1	.19	7	F
SE-16-17-16	1	1.8	51	.26	1.55	.12	1.1	.19	12	F
	1	1.8	51	.26	1.55	.35	3.1	.19	3	E
	1	1.8	51	.26	1.78	.12	1.3	.23	15	F
	1	1.8	51	.26	1.78	.35	3.7	.23	21	E
NW-15-17-16	1	1.8	51	.26	2.40	.35	5.0	.13	15	C
	1	1.8	51	.26	.70	.35	1.5	.44	13	F
	1	1.8	51	.26	3.60	.35	7.5	.082	9	B
	1	1.8	51	.26	1.45	.35	3.0	.21	6	E
NE-15-17-16	1	1.8	51	.26	.85	.12	0.6	.35	11	F
	1	1.8	51	.26	.86	.35	1.7	.35	7	F
	1	1.8	51	.26	2.15	.35	4.5	.14	13	C
	1	1.8	51	.26	2.85	.35	5.9	.11	16	C
	1	1.8	51	.26	2.40	.35	5.0	.13	9	C
	1	1.8	51	.26	1.70	.12	1.2	.17	3	F

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
SE-15-17-16	1	1.8	51	.26	3.65	.09	2.0	.081	3	B
	1	1.8	51	.26	5.80	.09	3.0	.052	5	A
	1	1.8	51	.26	1.40	.09	0.7	.21	4	F
	1	1.8	51	.26	2.60	.09	1.4	.21	9	F
	1	1.8	51	.26	2.15	.09	1.1	.14	6	F
	1	1.8	51	.26	2.00	.09	1.0	.15	9	F
	1	1.8	51	.26	1.20	.09	0.6	.25	2	F
SW-15-17-16	1	1.8	51	.26	1.78	.35	3.7	.23	15	E
	1	1.8	51	.26	1.78	.35	3.7	.23	53	E
NE-9-17-16	1	1.8	51	.26	1.78	.12	1.2	.23	11	F
NW-10-17-16	1	1.8	51	.26	1.08	.09	0.6	.28	12	F
	1	1.8	51	.26	1.70	.35	3.5	.19	7	E
	1	1.8	51	.26	.70	.09	0.4	.44	8	F
	1	1.8	51	.26	.70	.35	1.5	.44	4	F
NE-10-17-16	1	1.8	51	.26	.70	.35	1.5	.44	10	F
	1	1.8	51	.18	2.00	.12	1.0	.22	6	F
	1	1.8	51	.18	1.10	.35	1.6	.40	5	F
	1	1.8	51	.18	.38	.35	0.5	1.00	13	F
	1	1.8	51	.18	.38	.12	0.2	1.00	5	F
SE-10-17-16	1	1.8	51	.26	.38	.35	0.8	.70	16	F
	1	1.8	51	.26	.38	.35	0.8	.70	16	F

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
SW-10-17-16	1	1.8	51	.26	.70	.35	1.5	.42	17	F
	1	1.8	51	.26	1.40	.35	3.0	.22	10	E
	1	1.8	51	.26	.38	.35	0.8	.70	6	F
NW-14-17-16	1	1.8	51	.26	1.40	.12	1.0	.21	3	F
	1	1.8	51	.26	4.00	.12	2.9	.092	6	B
	1	1.8	51	.26	2.40	.12	1.7	.12	9	F
	1	1.8	51	.26	3.10	.35	6.4	.096	7	B
	1	1.8	51	.26	.58	.12	0.4	.51	27	F
SW-14-17-16	1	1.8	51	.26	.56	.12	0.4	.56	3	F
SE-14-17-16	1	1.8	51	.26	.55	.35	1.1	.56	8	F
	1	1.8	51	.26	.55	.12	0.4	.56	2	F
	1	1.8	51	.26	.40	.12	0.3	.63	7	F
NW-11-17-16	1	1.8	51	.26	1.70	.35	3.5	.18	14	D
	1	1.8	51	.26	.60	.35	1.2	.48	13	F
	1	1.8	51	.26	.45	.35	0.9	.59	6	F
NE-11-17-16	1	1.8	51	.20	.30	.35	0.5	1.00	6	F
	1	1.8	51	.20	.45	.12	0.3	.90	6	F
	1	1.8	51	.20	.45	.35	0.3	.90	5	F
SE-11-17-16	1	1.8	51	.20	1.70	.09	0.7	.23	13	F
	1	1.8	51	.20	.70	.09	0.3	.58	12	F
	1	1.8	51	.20	.40	.09	0.2	1.00	5	F
	1	1.8	51	.26	.70	.09	0.4	.44	9	F
	1	1.8	51	.26	2.35	.09	1.3	.13	16	F

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
SW-11-17-16	1	1.8	51	.26	1.10	.09	0.6	.28	15	F
	1	1.8	51	.18	.45	.09	0.2	.90	7	F
NW-12-17-16	1	0.9	51	.20	2.00	.09	0.8	.10	3	F
	1	0.9	51	.20	5.90	.09	2.0	.03	3	A
	1	0.9	51	.20	.50	.09	0.2	.39	7	F
	1	0.9	51	.20	3.10	.09	1.3	.064	7	B
	1	0.9	51	.20	1.55	.09	0.6	.13	17	F
	1	0.9	51	.20	.57	.09	0.2	.35	2	F
SE-12-17-16	1	0.9	51	.20	1.18	.09	0.5	.17	7	F
	1	0.9	51	.20	2.75	.09	1.1	.078	3	B
	1	0.9	51	.20	1.45	.09	0.6	.14	5	F
	1	0.9	51	.20	1.45	.09	0.6	.14	6	F
	1	0.9	51	.20	2.05	.09	0.9	.10	7	F
	1	0.9	51	.20	.75	.09	0.3	.26	5	F
	1	0.9	51	.20	.45	.09	0.2	.44	3	F
NW-1-17-16	1	0.9	51	.20	7.00	.12	3.8	.028	9	A
	1	0.9	51	.20	3.60	.12	2.0	.054	9	A
	1	0.9	51	.20	2.00	.12	1.0	.10	10	B
	1	0.9	51	.20	4.60	.12	2.5	.042	8	A
	1	0.9	51	.20	2.00	.12	1.1	.10	2	B

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
NE-2-17-16	1	0.9	51	.20	2.70	.09	1.1	.075	8	B
	1	0.9	51	.20	11.50	.09	4.7	.018	2	A
	1	1.8	51	.26	2.70	.09	1.5	.11	23	F
	1	1.8	51	.26	2.05	.09	1.1	.14	13	F
NW-2-17-16	1	1.8	51	.26	1.45	.09	0.8	.21	24	F
	1	1.8	51	.26	.95	.09	0.8	.32	18	F
	1	1.8	51	.26	.40	.09	0.2	.76	3	F
SW-2-17-16	1	1.8	51	.26	.58	.35	1.2	.52	24	F
	1	1.8	51	.26	.85	.35	1.8	.35	21	F
	1	1.8	51	.26	.58	.35	1.2	.52	8	F
	1	1.8	51	.26	2.00	.35	4.2	.15	5	C
SE-3-17-16	1	1.8	51	.26	2.00	.35	4.2	.15	13	C
	1	1.8	51	.26	1.08	.35	2.3	.28	7	E
	1	1.8	51	.26	1.40	.35	2.9	.22	16	E
	1	1.8	51	.26	1.45	.35	3.0	.23	7	E
SW-3-17-16	1	1.8	51	.26	1.45	.35	3.0	.23	2	E
NW-3-17-16	1	1.8	51	.26	.45	.35	0.9	.68	8	F
NE-3-17-16	1	1.8	51	.26	.70	.12	0.5	.43	12	F
	1	1.8	51	.26	.70	.35	1.5	.43	29	F
	1	1.8	51	.26	.30	.12	0.2	1	11	F
	1	1.8	51	.26	1.90	.12	1.4	.16	3	F

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
NE-34-16-16	1	1.8	51	.26	1.45	.35	3.0	.21	16	E
	1	1.8	51	.26	1.10	.35	2.3	.28	19	E
	1	1.8	51	.26	1.10	.12	0.8	.28	17	F
SE-34-16-16	1	1.8	51	.26	1.40	.35	3.0	.22	16	E
NW-35-16-16	1	1.8	51	.26	.85	.35	1.7	.35	21	F
	1	1.8	51	.26	.85	.35	1.7	.35	12	F
	1	1.8	51	.26	.35	.12	0.3	.86	14	F
	1	1.8	51	.26	.35	.35	0.7	.86	8	F
SW-35-16-16	1	1.8	51	.26	.70	.12	0.5	.43	18	F
	1	1.8	51	.26	1.40	.12	1.0	.22	16	F
	1	1.8	51	.26	.45	.35	0.9	.68	7	F
	1	1.8	51	.26	2.00	.35	4.2	.15	5	C
NE-35-16-16	1	1.8	51	.26	.70	.12	0.5	.43	13	F
NW-36-16-16	1	0.9	51	.20	4.60	.12	2.5	.038	3	A
	1	0.9	51	.20	4.60	.35	7.3	.038	1	A
	1	0.9	51	.20	2.70	.12	1.5	.075	3	B
	1	0.9	51	.20	1.40	.35	2.3	.14	8	C
NW-26-16-16	1	1.8	51	.26	.85	.35	1.7	.35	10	F
	1	1.8	51	.26	1.55	.35	1.7	.19	5	F
	1	1.8	51	.26	.95	.35	2.0	.31	3	E
	1	1.8	51	.26	2.00	.35	4.1	.15	9	C

LOCATION	P	T (t/ha)	R	K	LS	C	A (T/ha)	MAXIMUM C	ha	OPTIONS
NE-26-16-16	1	1.8	51	.26	1.85	.35	3.8	.16	13	D
	1	0.9	51	.20	.70	.35	1.1	.29	7	E
	1	0.9	51	.20	2.40	.35	3.8	.082	6	B
	1	0.9	51	.20	2.00	.35	3.2	.10	17	B
SE-26-16-16	1	0.9	51	.20	2.00	.12	1.1	.10	5	B
	1	0.9	51	.20	3.10	.12	1.7	.064	6	B
	1	0.9	51	.20	2.00	.12	1.1	.10	14	B
NW-25-16-16	1	0.9	51	.20	3.60	.09	1.5	.055	5	A
	1	0.9	51	.20	3.60	.09	1.5	.055	5	A
	1	0.9	51	.20	1.40	.09	0.6	.15	2	F
	1	0.9	51	.20	1.40	.09	0.6	.15	3	F
SW-25-16-16	1	0.9	51	.20	1.70	.09	0.7	.125	16	F
	1	0.9	51	.20	12.00	.09	4.9	.019	3	A
	1	0.9	51	.20	.95	.09	0.4	.21	6	F
NE-25-16-16	1	0.9	51	.20	1.10	.35	1.8	.19	3	E
	1	0.9	51	.20	.45	.12	0.3	.45	5	F
	1	0.9	51	.20	1.40	.12	0.7	.17	4	F
	1	0.9	51	.20	.40	.35	0.6	.50	3	F
	1	0.9	51	.20	.45	.35	0.7	.45	9	F
	1	0.9	51	.20	1.40	.35	2.3	.15	3	C
SE-25-16-16	1	0.9	51	.20	1.10	.35	1.8	.19	4	E
	1	0.9	51	.20	1.70	.12	0.9	.125	5	C
	1	0.9	51	.20	2.20	.35	3.5	.09	9	B
	1	0.9	51	.20	1.70	.35	2.7	.125	20	C

LOCATION	P	T (t/ha)	R	K	LS	C	A (t/ha)	MAXIMUM C	ha	OPTIONS
NW-24-16-16	1	0.9	51	.20	.70	.12	0.4	.29	5	F
	1	0.9	51	.20	1.40	.12	0.7	.15	4	F
	1	0.9	51	.20	.60	.12	0.3	.32	3	F
	1	0.9	51	.20	1.40	.12	0.7	.15	2	F
NE-24-16-16	1	0.9	51	.20	1.45	.35	2.3	.14	18	C
	1	0.9	51	.20	1.45	.35	2.3	.14	5	C
NW-19-16-15	1	0.9	51	.20	4.90	.12	2.7	.04	4	A
	1	0.9	51	.20	1.57	.12	0.6	.125	9	F
	1	0.9	51	.20	.45	.12	0.2	.45	7	F
	1	0.9	51	.20	.45	.12	0.2	.45	6	F
NE-19-16-16	1	0.9	51	.20	.45	.12	0.2	.45	10	F
	1	0.9	51	.20	.40	.12	0.2	.50	2	F
	1	0.9	51	.20	4.45	.12	2.4	.093	2	B
	1	0.9	51	.20	1.65	.12	0.9	.125	2	C
	1	0.9	51	.20	1.40	.12	0.7	.14	5	F
	1	0.9	51	.20	.70	.12	0.4	.29	4	F
SE-30-16-15	1	0.9	51	.20	.45	.35	0.7	.45	3	F
	1	0.9	51	.20	1.40	.35	2.2	.14	3	C
SW-30-16-16	1	0.9	51	.20	2.50	.12	1.2	.10	3	B
	1	0.9	51	.20	2.05	.35	3.3	.10	5	B
	1	0.9	51	.20	1.70	.35	3.0	.12	4	C
	1	0.9	51	.20	1.70	.12	1.0	.12	2	C
	1	0.9	51	.20	1.70	.12	1.0	.12	3	C

APPENDIX C

Soil Characteristics of Eden Creek Watershed (Soil Association in Which the Dominant Soil is Gray Luvisol)

The discussion of the Gray Luvisol soils follow the description by Elrhich *et al*. (1958).

1. Granville Association

Gray Luvisol soils constitute the largest portion of the Granville Association. These soils are deeply leached due to the lower lime carbonate content of the parent material.

Soils of the Granville Association have developed on boulder till of mixed limestone, shale and granitic origin. The parent material is higher in shale content and slightly lower in lime carbonate. Some stoniness occurs but surface stones are not sufficiently numerous to interfere with cultivation.

The topography is gently to steeply sloping. The slopes and knolls are well drained, however, numerous depressions are occupied by sloughs and meadows. The vegetation on the well drained soils is mainly aspen and white spruce with an undergrowth of hazel, wild-rose and shrub-like species. On poorly drained areas the vegetation may be willow, reeds, sedges, and tamarack.

The Granville soils have a moderate degree of natural fertility. Moisture-retention capacity is good and the soil reaction is favorable for plant growth. Although the surface horizon is acid, lime occurs within the root depth of field crops. The organic content is low and crops respond well to nitrogen fertilizers. Soil erosion by water is the most serious problem due to sloping and irregular topography.

According to Elrhich et al. (1958) the soils are best suited to mixed farming. Crop rotations should include two to three years of grass-legume crops to provide protection of the soil from erosion by water.

2. Clarksville Association

Soils of the Clarksville Association have developed on boulder till made up predominantly of shale. The parent material of these soils contains less lime carbonate than those of the Granville soils. Surface textures vary from very fine sandy loam to loam. Some stoniness occurs but they do not interfere with cultivation.

The topography is irregular, and soils on the slopes are well drained. The native vegetation is predominantly aspen woods with an under-growth of hazel, wild-rose saskatoon and choke-cherry.

The Clarksville soils have low to moderate natural fertility. Moisture retention capacity is fair and the soil reaction is favorable to crop growth. The soils have very little organic matter and are deeply leached. Soil erosion by water is the most serious problem in soils under cultivation due to irregular topography.

Elrhich et al. (1958) suggested that the soils of the Clarksville Association are best suited to the growing of permanent forage crops to help prevent soil erosion by water.

3. Wapus

Soils of the Wapus Association have developed on medium textured, shaley till deposits. The shaley material from which these soils have developed is low in lime carbonate content. Surface textures varies from fine sandy loam to silt or clay loam. Some stoniness occurs, but generally does not interfere with cultivation.

The topography is irregular and soil drainage is good due to the high permeability of shaley till and underlying shale rock. The native vegetation is predominantly aspen with an under-growth of hazel and wild-rose.

Soils of the Wapus Association have low to moderate water retention capacity and low natural fertility. In addition, there is little or no organic reserve. These soils are very susceptible to water erosion especially on the steeper slopes.

Elrhich et al. (1958) recommended that soils of the Wapus Association should be utilized for livestock production and forestry. Trees should be planted on steep slopes under cultivation. On areas that are less steep, grass-legume crops should be grown at least three years out of six.

APPENDIX D

FARM BUDGETS - TOTAL COST/RETURN SUMMARY FOR THREE FARM SIZES UNDER PRESENT AND ALTERNATIVE FARM PRACTICES, EDEN CREEK WATERSHED

	Summerfallow	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
	Type of Enterprise					
I. Acreage By Crop(acres)	40.	40.	40.	40.	160.	1.
II. Cost of Production						
1. Fuel & Lubrication	54.12	411.36	98.77	197.96	762.21	4.76
2. Repairs	53.00	389.82	159.08	173.82	775.72	4.85
3. Fertilizer	0.0	198.00	198.00	198.00	594.00	3.71
4. Pesticides	0.0	61.78	61.78	0.0	123.56	0.77
5. Seed Clean & Treat.	0.0	16.20	21.00	0.0	37.20	0.23
6. Seed	0.0	168.00	147.00	54.80	369.80	2.31
7. Twine Costs	0.0	10.70	0.0	62.99	73.68	0.46
8. Labor	81.98	772.18	223.33	434.81	1512.30	9.45
9. Custom Charges	0.0	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	20.95	131.28	64.14	76.94	293.31	1.83
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	210.04	2159.33	973.10	1199.31	4541.78	28.39
13. Rent	0.0	0.0	0.0	0.0	0.0	0.0
14. Taxes	80.00	80.00	80.00	80.00	320.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	80.00	80.00	80.00	80.00	320.00	2.00
17. "Out of Pocket Cost"	370.04	2319.33	1133.10	1359.31	5181.78	32.39
18. Investment Land&Bldg	840.00	840.00	840.00	840.00	3360.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr. - [1]	0.0	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	1000.00	1000.00	1000.00	1000.00	4000.00	25.00
22. Total Costs	1210.04	3159.33	1973.10	2199.31	8541.77	53.39
III. Gross Returns						
23. Average Yield/Acre	0.0	22.00	27.00	1.84	0.0	0.0
24. Average Price	0.0	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	0.0	195.00	0.0	0.0	195.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	0.0	3301.40	2268.00	2605.44	8174.84	51.09
IV. Returns to Investment Labor & Management	-288.06	1754.26	1358.23	1680.94	4505.36	28.16
V. Returns to Labor & Mgmt.	-1128.06	914.26	518.23	840.94	1145.37	7.16
VI. Returns to Land & Mgmt.	-370.04	982.07	1134.90	1246.13	2993.06	18.71
VII. Net Returns to Mgmt.	-1210.04	142.07	294.90	406.13	-366.94	-2.29

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

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[1] Farm equipment used in the farm budget analysis was determined to be fully depreciated therefore no cost was allowed for depreciation.

Total Cost and Return Summary Per Crop For Record Number 4

	Type of Enterprise				
	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
I. Acreage By Crop(acres)	40.	40.	80.	160.	1.
II. Cost of Production					
1. Fuel & Lubrication	417.07	108.80	479.90	1005.78	6.29
2. Repairs	450.29	195.68	469.59	1115.56	6.97
3. Fertilizer	396.00	676.00	990.00	2062.00	12.89
4. Pesticides	193.78	193.78	0.0	387.56	2.42
5. Seed Clean & Treat.	16.20	21.00	0.0	37.20	0.23
6. Seed	168.00	147.00	109.60	424.60	2.65
7. Twine Costs	10.70	0.0	171.16	181.85	1.14
8. Labor	789.34	258.77	991.96	2040.07	12.75
9. Custom Charges	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	156.08	105.66	211.93	473.68	2.96
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	2597.46	1706.70	3424.15	7728.31	48.30
13. Rent	0.0	0.0	0.0	0.0	0.0
14. Taxes	80.00	80.00	160.00	320.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	80.00	80.00	160.00	320.00	2.00
17. "Out of Pocket Cost"	2757.46	1866.70	3744.15	8368.31	52.30
18. Investment Land&Bldg	840.00	840.00	1680.00	3360.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr.----[1]	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	1000.00	1000.00	2000.00	4000.00	25.00
22. Total Costs	3597.46	2706.70	5424.14	11728.31	73.30
III. Gross Returns					
23. Average Yield/Acre	35.00	50.00	2.50	0.0	0.0
24. Average Price	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	195.00	0.0	0.0	195.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	5137.00	4200.00	7080.00	16416.99	102.61
IV. Returns to Investment Labor & Management	3168.87	2592.07	4327.82	10088.75	63.05
V. Returns to Labor & Mgmt.	2328.87	1752.07	2647.82	6728.75	42.05
VI. Returns to Land & Mgmt.	2379.53	2333.30	3335.85	8048.68	50.30
VII. Net Returns to Mgmt.	1539.53	1493.30	1655.85	4688.68	29.30

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

[1] Farm equipment used in the farm budget analysis was determined to be fully depreciated therefore no cost was allowed for depreciation.

	Summerfallow	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
I. Acreage By Crop(acres)	80.	80.	80.	80.	320.	1.
II. Cost of Production						
1. Fuel & Lubrication	101.73	813.12	189.50	391.36	1495.72	4.67
2. Repairs	130.22	1039.42	401.28	470.64	2041.55	6.38
3. Fertilizer	0.0	396.00	396.00	396.00	1188.00	3.71
4. Pesticides	0.0	123.56	123.56	0.0	247.13	0.77
5. Seed Clean & Treat.	0.0	32.40	42.00	0.0	74.40	0.23
6. Seed	54.80	336.00	294.00	109.60	794.40	2.48
7. Twine Costs	0.0	21.39	0.0	125.97	147.37	0.46
8. Labor	154.16	1517.52	427.16	851.16	2950.01	9.22
9. Custom Charges	0.0	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	42.37	275.97	131.61	159.88	609.83	1.91
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	428.48	4555.38	2005.12	2504.62	9493.59	29.67
13. Rent	0.0	0.0	0.0	0.0	0.0	0.0
14. Taxes	160.00	160.00	160.00	160.00	640.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	160.00	160.00	160.00	160.00	640.00	2.00
17. "Out of Pocket Cost"	748.48	4875.38	2325.12	2824.62	10773.59	33.67
18. Investment Land&Bldg	1680.00	1680.00	1680.00	1680.00	6720.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr. --- [1]	0.0	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	2000.00	2000.00	2000.00	2000.00	8000.00	25.00
22. Total Costs	2428.48	6555.38	4005.12	4504.61	17493.58	54.67
III. Gross Returns						
23. Average Yield/Acre	0.0	22.00	27.00	1.84	0.0	0.0
24. Average Price	0.0	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	0.0	390.00	0.0	0.0	390.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	0.0	6602.80	4536.00	5210.88	16349.68	51.09
IV. Returns to Investment Labor & Management	-594.32	3244.94	2638.04	3237.43	8526.10	26.64
V. Returns to Labor & Mgmt.	-2274.32	1564.94	958.04	1557.43	1806.10	5.64
VI. Returns to Land & Mgmt.	-748.48	1727.42	2210.88	2386.27	5576.09	17.43
VII. Net Returns to Mgmt.	-2428.48	47.42	530.88	706.27	-1143.91	-3.57

Type of Enterprise

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

[1] Farm equipment used in the farm budget analysis was determined to be fully depreciated therefore no cost was allowed for depreciation.

Total Cost and Return Summary Per Crop For Record Number 3

	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
	Type of Enterprise				
I. Acreage By Crop(acres)	80.	80.	160.	320.	1.
II. Cost of Production					
1. Fuel & Lubrication	824.53	209.54	959.81	1993.88	6.23
2. Repairs	1206.76	494.68	1304.03	3005.47	9.39
3. Fertilizer	792.00	1352.00	1980.00	4124.00	12.89
4. Pesticides	387.56	387.56	0.0	775.13	2.42
5. Seed Clean & Treat.	32.40	42.00	0.0	74.40	0.23
6. Seed	336.00	294.00	219.20	849.20	2.65
7. Twine Costs	21.39	0.0	342.31	363.71	1.14
8. Labor	1550.68	495.30	1983.93	4029.92	12.59
9. Custom Charges	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	328.28	215.70	445.76	989.74	3.09
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	5479.61	3490.79	7235.03	16205.42	50.64
13. Rent	0.0	0.0	0.0	0.0	0.0
14. Taxes	160.00	160.00	320.00	640.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	160.00	160.00	320.00	640.00	2.00
17. "Out of Pocket Cost"	5799.61	3810.78	7875.03	17485.42	54.64
18. Investment Land&Bldg	1680.00	1680.00	3360.00	6720.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr. --- 1	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	2000.00	2000.00	4000.00	8000.00	25.00
22. Total Costs	7479.61	5490.78	11235.02	24205.41	75.64
III. Gross Returns					
23. Average Yield/Acre	35.00	50.00	2.50	0.0	0.0
24. Average Price	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	390.00	0.0	0.0	390.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	10274.00	8400.00	14160.00	32833.99	102.61
IV. Returns to Investment Labor & Management	6025.07	5084.52	8268.90	19378.49	60.56
V. Returns to Labor & Mgmt.	4345.07	3404.52	4908.90	12658.49	39.56
VI. Returns to Land & Mgmt.	4474.39	4589.22	6284.97	15348.58	47.96
VII. Net Returns to Mgmt.	2794.39	2909.22	2924.97	8628.58	26.96

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

[1] Farm equipment used in the farm budget analysis was determined to be fully depreciated therefore no cost was allowed for depreciation.

	Type of Enterprise					
	Summerfallow	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
I. Acreage By Crop(acres)	120.	120.	120.	120.	480.	1.
II. Cost of Production						
1. Fuel & Lubrication	152.60	1219.69	284.25	587.04	2243.58	4.67
2. Repairs	230.84	1880.38	714.14	857.22	3682.58	7.67
3. Fertilizer	0.0	594.00	594.00	594.00	1782.00	3.71
4. Pesticides	0.0	185.35	185.35	0.0	370.69	0.77
5. Seed Clean & Treat.	0.0	48.60	63.00	0.0	111.60	0.23
6. Seed	109.60	504.00	441.00	164.40	1219.00	2.54
7. Twine Costs	0.0	32.09	0.0	188.96	221.05	0.46
8. Labor	231.24	2276.29	640.74	1276.75	4425.01	9.22
9. Custom Charges	0.0	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	65.68	433.22	204.15	248.90	951.95	1.98
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	680.35	7173.61	3126.63	3917.26	14897.84	31.04
13. Rent	0.0	0.0	0.0	0.0	0.0	0.0
14. Taxes	240.00	240.00	240.00	240.00	960.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	240.00	240.00	240.00	240.00	960.00	2.00
17. "Out of Pocket Cost"	1160.35	7653.61	3606.63	4397.27	16817.85	35.04
18. Investment Land&Bldg	2520.00	2520.00	2520.00	2520.00	10080.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr. ---- 1	0.0	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	3000.00	3000.00	3000.00	3000.00	12000.00	25.00
22. Total Costs	3680.35	10173.61	6126.62	6917.26	26897.84	56.04
III. Gross Returns						
23. Average Yield/Acre	0.0	22.00	27.00	1.84	0.0	0.0
24. Average Price	0.0	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	0.0	585.00	0.0	0.0	585.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	0.0	9904.20	6804.00	7816.32	24524.52	51.09
IV. Returns to Investment Labor & Management	-929.11	4526.88	3838.12	4695.80	12131.68	25.27
V. Returns to Labor & Mgmt.	-3449.11	2006.88	1318.12	2175.80	2051.69	4.27
VI. Returns to Land & Mgmt.	-1160.35	2250.59	3197.37	3419.05	7706.67	16.06
VII. Net Returns to Mgmt.	-3680.35	-269.41	677.37	899.05	-2373.33	-4.94

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

[1] Farm equipment used in the farm budget analys was determined to be fully depreciated therefore no cost was allowed for depreciation.

Total Cost and Return Summary Per Crop For Record Number 3

	Wheat	Barley	Tame Hay	Total	Cost Return/Acre
	Type of Enterprise				
I. Acreage By Crop(acres)	120.	120.	240.	480.	1.
II. Cost of Production					
1. Fuel & Lubrication	1236.80	314.31	1439.71	2990.82	6.23
2. Repairs	2184.34	881.08	2376.12	5441.54	11.34
3. Fertilizer	1188.00	2028.00	2970.00	6186.00	12.89
4. Pesticides	581.35	581.35	0.0	1162.69	2.42
5. Seed Clean & Treat.	48.60	63.00	0.0	111.60	0.23
6. Seed	504.00	441.00	328.80	1273.80	2.65
7. Twine Costs	32.09	0.0	513.47	545.56	1.14
8. Labor	2326.03	742.96	2975.89	6044.88	12.59
9. Custom Charges	0.0	0.0	0.0	0.0	0.0
10. Interest Oper. Cap.	514.87	331.90	693.84	1540.61	3.21
11. Crop Insurance Prem.	0.0	0.0	0.0	0.0	0.0
12. Total Variable Cost	8616.07	5383.59	11297.83	25297.48	52.70
13. Rent	0.0	0.0	0.0	0.0	0.0
14. Taxes	240.00	240.00	480.00	960.00	2.00
15. Machinery Insurance	0.0	0.0	0.0	0.0	0.0
16. Overhead, Misc.	240.00	240.00	480.00	960.00	2.00
17. "Out of Pocket Cost"	9096.07	5863.58	12257.84	27217.48	56.70
18. Investment Land&Bldg	2520.00	2520.00	5040.00	10080.00	21.00
19. Investment in Mach.	0.0	0.0	0.0	0.0	0.0
20. Machinery Depr.---- 1	0.0	0.0	0.0	0.0	0.0
21. Total Fixed Costs	3000.00	2999.99	6000.00	11999.99	25.00
22. Total Costs	11616.06	8383.58	17297.83	37297.47	77.70
III. Gross Returns					
23. Average Yield/Acre	35.00	50.00	2.50	0.0	0.0
24. Average Price	3.53	2.10	35.40	0.0	0.0
25. Crop Insur. Revenue	0.0	0.0	0.0	0.0	0.0
26. Straw ($/Acre)	585.00	0.0	0.0	585.00	1.22
27. Grazing ($/Acre)	0.0	0.0	0.0	0.0	0.0
Total Gross Returns	15411.00	12600.00	21240.00	49250.99	102.61
IV. Returns to Investment Labor & Management	8640.96	7479.37	11958.06	28078.39	58.50
V. Returns to Labor & Mgmt.	6120.96	4959.37	6918.06	17998.39	37.50
VI. Returns to Land & Mgmt.	6314.93	6736.42	8982.16	22033.52	45.90
VII. Net Returns to Mgmt.	3794.93	4216.42	3942.16	11953.52	24.90

Total "Out of Pocket Cost" Equals the Sum of Taxes, Fuel & Lubrication, Repairs, Fertilizer, Chemicals, Seed, Seed Cleaning and Treatment, Crop and Machine Insurance, Misc. Overhead, Rent, Labor, and Twine.
Assumes 12.000 % Return on Capital.

[1] Farm equipment used in the farm budget analysis was determined to be fully depreciated therefore no cost was allowed for depreciation.