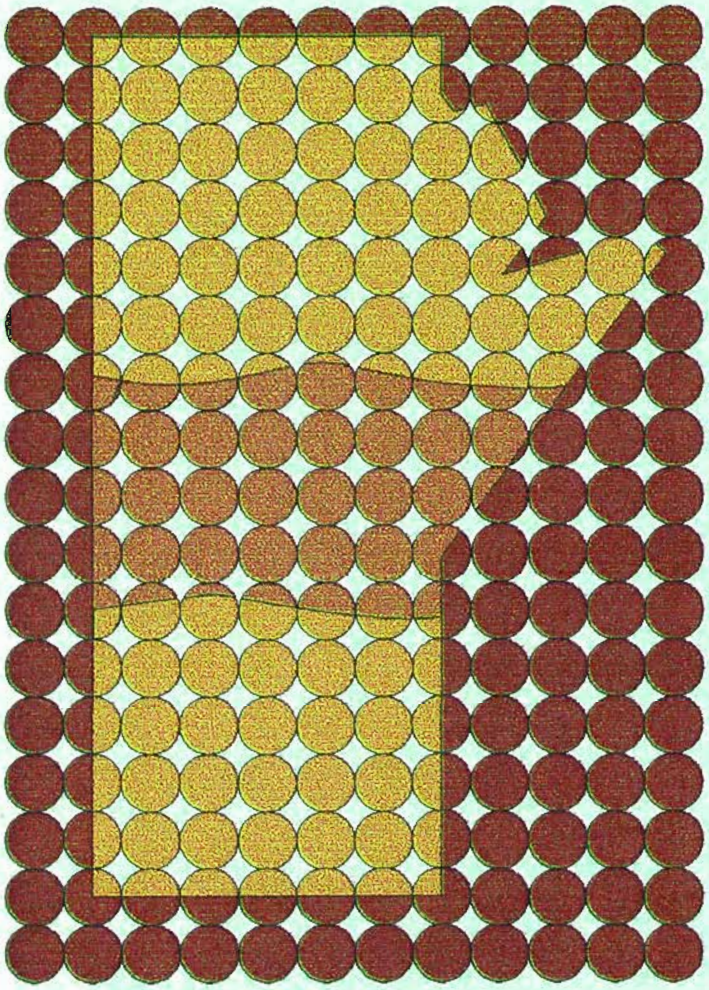

MANITOBA
Soil Resource

Soils of the Roblin Effluent Irrigation Site

Special Report Series 96-1

Agriculture and Agri-Food Canada

Manitoba Agriculture

SOILS OF THE ROBLIN EFFLUENT IRRIGATION SITE

NE 1/4 Section 20-25-28 W

by

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SOIL RESOURCE SECTION
MANITOBA AGRICULTURE

in cooperation with

MANITOBA LAND RESOURCE UNIT
AGRICULTURE AND AGRI-FOOD CANADA

and

DEPARTMENT OF SOIL SCIENCE, UNIVERSITY OF MANITOBA

PREFACE

The detailed soil survey of the Roblin Effluent Irrigation Site was carried out by staff of the Manitoba Soil Resource Section, Soils and Crops Branch, Manitoba Agriculture and the Manitoba Land Resource Unit, Centre for Land Resource and Biological Resource Research, Agriculture and Agrifood Canada. The soil map at a scale of 1:5 000 and the accompanying report provides detailed soil resource information designed to facilitate the management of the land base for disposal of treated municipal effluent from the Town of Roblin lagoon system. The soil map and accompanying data will also assist in the planning and layout of research and demonstration plots and instrumentation and detailed monitoring related to evaluation of environmental impact.

This report contains descriptive information for the major soils that occur on the Effluent Irrigation Site, as well as interpretations for dryland and irrigation agriculture. A brief discussion of soil properties and management relationships is included.

During the course of this survey, a significant volume of site specific information was gathered that for practical reasons cannot be included in this report. The Manitoba Soil Resource Section and the Manitoba Land Resource Unit jointly maintain data files for automated manipulation and analysis for soil characterization and interpretation. Several interpretive maps showing properties such as pH, organic matter, drainage, risk of erosion, and risk for subsoil and/or groundwater contamination have been derived from digital GIS databases. Additional requests for such data should be directed to: Manitoba Soil Resource Section, Department of Soil Science, 362 Ellis Building, University of Manitoba, Winnipeg, Manitoba, R3T 2N2.

ACKNOWLEDGEMENTS

The report on the Soils of the Roblin Effuent Irrigation Site was conducted as a joint project of the Manitoba Department of Agriculture, Agriculture and Agri-Food Canada and the Soil Science Department, University of Manitoba.

The soils were mapped in the fall of 1994 by G. F. Mills assisted by E. Gauer and J. Thiele. The detailed soil characterization and moisture studies were carried out by P. Haluschak.

Laboratory analysis and data were provided by R. Mirza, J. Madden and E. St. Jacques under the direction of P. Haluschak.

Map compilation and digitization, generation of interpretative maps and preparation for publication was provided by J. Griffiths.

Computer processing and programming was provided by C. L. Aglugub.

Report formatting was provided by Mrs. M. Chabbert and Mr. C.L. Aglugub.

R. G. Eilers for reviewing the manuscript.

HOW TO USE THIS SOIL REPORT

This soils report contains considerable information about the soils, their origin and formation, their classification and their potential for various uses such as dryland agriculture and irrigation. The report is divided into five parts: Part 1 provides a general description of the area; Part 2 describes the methodology used in the study; Part 3 discusses the development, scientific classification and morphological characteristics of the soils in the study area; Part 4 provides an interpretation of soil properties and associated landscape features as they affect soil capability or suitability for various agricultural uses and Part 5 includes a discussion of environmental issues and considerations, particularly with reference to sustainable effluent irrigation on agricultural land. Baseline data regarding soil quality on the Site is provided in summaries of key soil properties characterized during the course of the survey.

The accompanying soil map is presented at a 1:5 000 scale on an air photo base to assist the user in locating the soil areas in relation to landscape features, roads and field boundaries. The following steps are suggested to assist the user in retrieving soil information from the map and report:

STEP 1 - Consult the soil map in pocket of report folder. Locate the area(s) of interest on the map and identify the pertinent map unit symbols. Arabic numerals placed as superscripts following map symbols indicate the approximate proportion of each soil type within the map unit.

STEP 2 - Consult the extended legend accompanying the soil map for an alphabetical listing of soil symbols giving the soil name, surface texture, drainage, related information concerning landform and stratigraphy of the soil materials and soil classification.

STEP 3 - For interpretive information about soil capability for dryland agriculture and soil suitability for irrigation, consult the appropriate section in Part 4. Criteria utilized as guidelines in making these interpretations are provided in Appendix A. A discussion of environmental issues and interpretation of the soils for suitability for effluent irrigation is included in Part 5.

STEP 4 - Further information concerning the morphological properties and extent of the soils is presented in Part 3 where the soils are described alphabetically according to soil name.

STEP 5 - Additional site specific information not contained in this report is available on request from the Manitoba Soil Resource Section, Manitoba Agriculture, Ellis Bldg., University of Manitoba.

SUMMARY

The Roblin Effuent Irrigation Site is located 3.2 km south of Roblin, Manitoba at the junction of Provincial Trunk Highway 83 and Provincial Road 583. The Site covers the entire northeast quarter of section 20-25-28 W and consists of dominantly well drained, fine loamy, moderately to strongly calcareous glacial till. The area is underlain by discontinuous sand and gravel strata at depths between 2.4 and 15 metres. In the southwest portion of the Site, localized areas of the till are mantled by thin veneers of fine loamy lacustrine sediments. The landscape is dominantly hummocky with topography ranging from level to very gently and gently sloping. The irregular topography of the Site lacks a well developed drainage network and numerous, shallow undrained depressions occur throughout the landscape.

The climate is cool subhumid. Long term climatic records from 6 weather stations in the area indicate total precipitation ranges from 385 to 495 mm. Approximately 75 percent of the precipitation occurs as rain during the period of April to October. Growing season precipitation is variable due to the local occurrence of storm events which account for much of the summer rainfall. Mean annual air temperature at the climatic stations ranges from 0.2 to 1.4^{0}C, while the average length of the frost-free season in the area varies from 96 to 108 days.

The soils on the Effluent Irrigation Site are dominantly well drained Chernozemic Dark Gray soils (56%) developed on fine loamy glacial till. Approximately 32 percent of the soils are imperfectly drained Dark Gray soils and about 0.8 percent of the area consists of poorly drained Rego Humic Gleysols. Humic Luvic Gleysols associated with the shallow depressions throughout the Site are leached with imperfect to poor drainage and account for 11 percent of the area. All the soils have a moderate organic matter content and good moisture holding capacity. The pH values range from 5.2 to 7.5.

Very slight erosion is observed on the shallow soils on the crests and upper slopes of the ridges and knolls and a corresponding thickening of the surface horizons occurs on the soils of the lower slopes. Approximately 16 percent of soils are at slight risk of erosion by water. Slightly stony conditions affect about 78 percent of the Site. The soils are nonsaline. Surface drainage is quite variable, ranging from well to rapid on the upper slopes to slow and very slow in the poorly drained depressions subject to periodic inundation.

The agricultural capability of the soils on the Site ranges from Class 2T for the Erickson soil to 6W for the local areas of Sinnott soil in which drainage has not been improved. Topography, drainage, surface ponding and erosion are the major conditions affecting capability and land management for dryland agriculture in the area. The majority of the near level, well drained and imperfectly drained soils on the Site are rated in Class 2 and 3 for irrigation. However, local occurrences of poorly drained soils are rated in Class 4 for Irrigation suitability. Limitations for sprinkler irrigation result from the reduced permeability associated with the more compact subsurface horizons underlying most of the well drained soils. Topography results in a slight limitation to irrigation but the surface ponding resulting from repeated irrigation applications imposes additional management considerations for the irrigation system.

The soil and climatic conditions on the Site constitute a window of information for the Erickson soil association in west-central Manitoba. The results gained from monitoring sprinkler application of wastewater on these soils and evaluation of the impacts on the soil, crop yield and quality and the environment can be extrapolated to other areas of similar soil and climatic conditions in western Canada.

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PART 1

GENERAL DESCRIPTION OF STUDY AREA

1.1 INTRODUCTION

The detailed soil inventory of the soils of the Roblin Effluent Irrigation Site was conducted by staff of the Soil Resource Section, Soils and Crops Branch, Manitoba Department of Agriculture in cooperation with the Manitoba Land Resource Unit of Agriculture and Agrifood Canada. The survey was in responce to a request from Ms. E. Gauer, Soil Conservation Specialist, Northwest Region, Manitoba Agriculture on behalf of the Town of Roblin. This site, located on the NE 1/4 Section 20, Township 25, Range 28W, is to be used by the Town of Roblin for the disposal of treated sewage effluent from the town sewage lagoon (Figure 1).

1.2 RELIEF AND DRAINAGE

Elevations on the Site range from less than 542 metres (1778 ft) in the southwest corner to 546 metres (1791 ft) in the northeast portion of the Site. The topography of the area is subdued hummocky with local relief being generally less than 2 metres. Slopes are dominantly less than 5 percent ranging from about 15 to 40 metres in length. Approximately 16 percent of the area is nearly level to level (< 0.5 %), about 68 percent is nearly level (0.5 to 2.0 %) and 16 percent is very gently sloping with slopes ranging up to 5 percent (Figure 2).

Surface drainage of the Site varies from well to poor and very poor. Extensive areas of low relief hummocky terrain are moderately well to well drained with inclusions of low lying imperfectly to poorly drained depressional sites. Surface drainage in this low-relief hummocky terrain is poorly developed although the land surface slopes very gently from the northeast to the southwest. Surface drainage has been somewhat improved on the Site through clearing of the natural mixed woods vegetation and construction of a local network of drains and ditches associated with road construction in the region.

1.3 PHYSIOGRAPHY AND SURFACE DEPOSITS

The Effluent Irrigation Site is situated within the Newdale Plain subsection (Ehrlich et al., 1959) of the Assiniboine River Plain (Klassen, 1979). This landscape consists dominantly of undulating to hummocky till moraine and rolling morainal veneers overlying shale bedrock. The glacial till surface deposits are comprised of moderately to strongly calcareous loamy till of mixed shale, limestone and igneous origin.

The landscape on the Effluent Irrigation Site is gently undulating, low relief hummocky terrain characterized by level to nearly level (0 to 2 percent slopes) and very gently sloping (2 to 5 percent slopes) topography. The topography of the study site is irregular and lacks a well developed drainage network. Numerous, shallow undrained depressions occur throughout the landscape.

The dominant surface deposit on the Site consists of moderately to strongly calcareous, loam to clay loam textured till. The subsoil is moderately alkaline (pH values ranging from 7.8 to 8.3) with electrical conductivities typically less than 0.5 dS/m.

Soil investigations derived from a detailed grid inspection to a depth of 1.5 m indicated that local areas of the upper till deposit have been modified by post-glacial waters resulting in occurrences of shallow lacustrine deposition. These water-modified areas are characterized by thin deposits of loamy lacustrine sediments overlying the loamy till. The presence of pebble lines and thin lenses of fine gravel separating a pebble-free surface from more compact, slightly stony morainal till is a common marker for these modified surface layers.

A series of shallow drill logs to a depth of 4.5 m confirmed that the near-surface material consists dominantly of uniform loam to clay loam

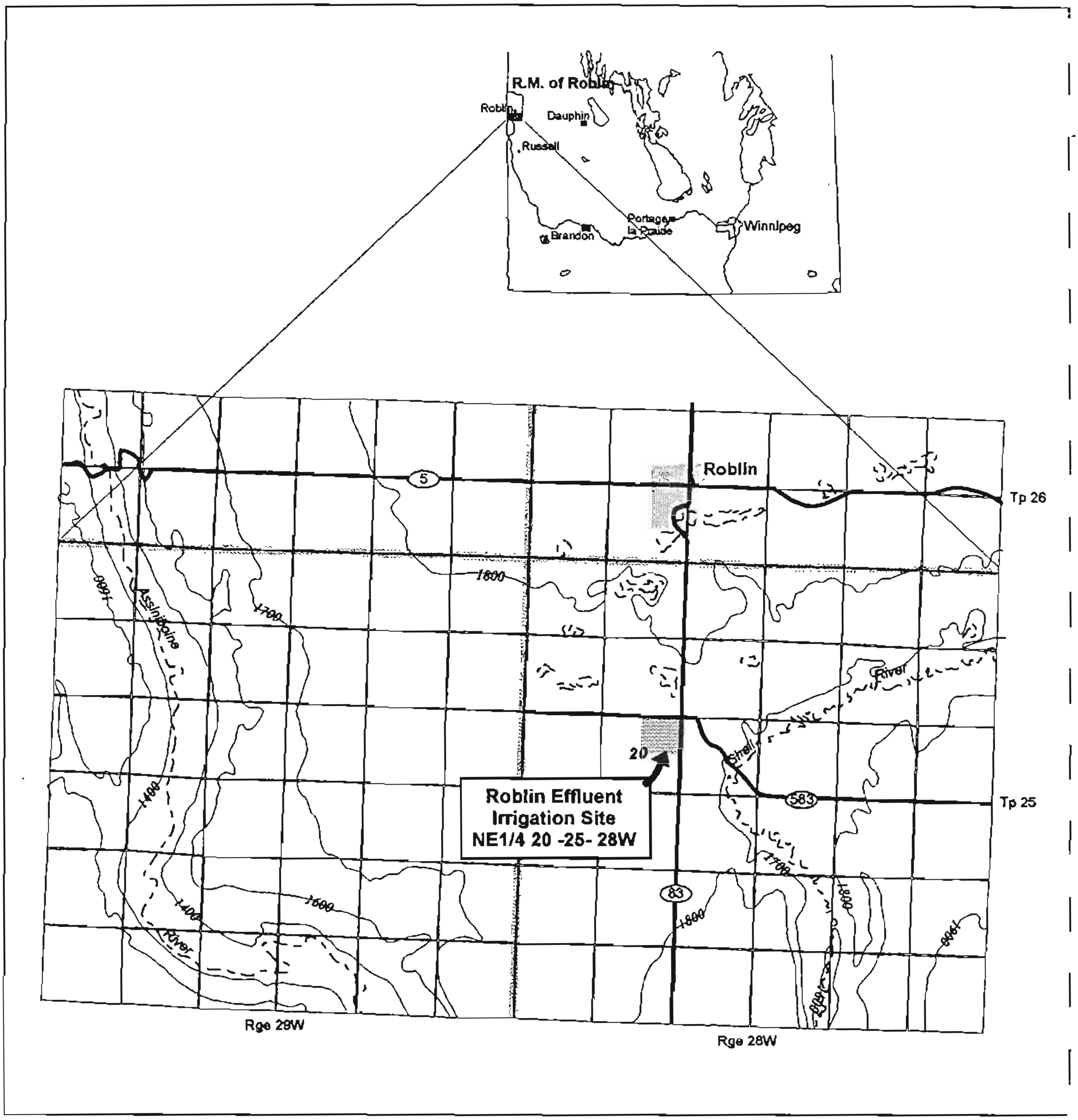
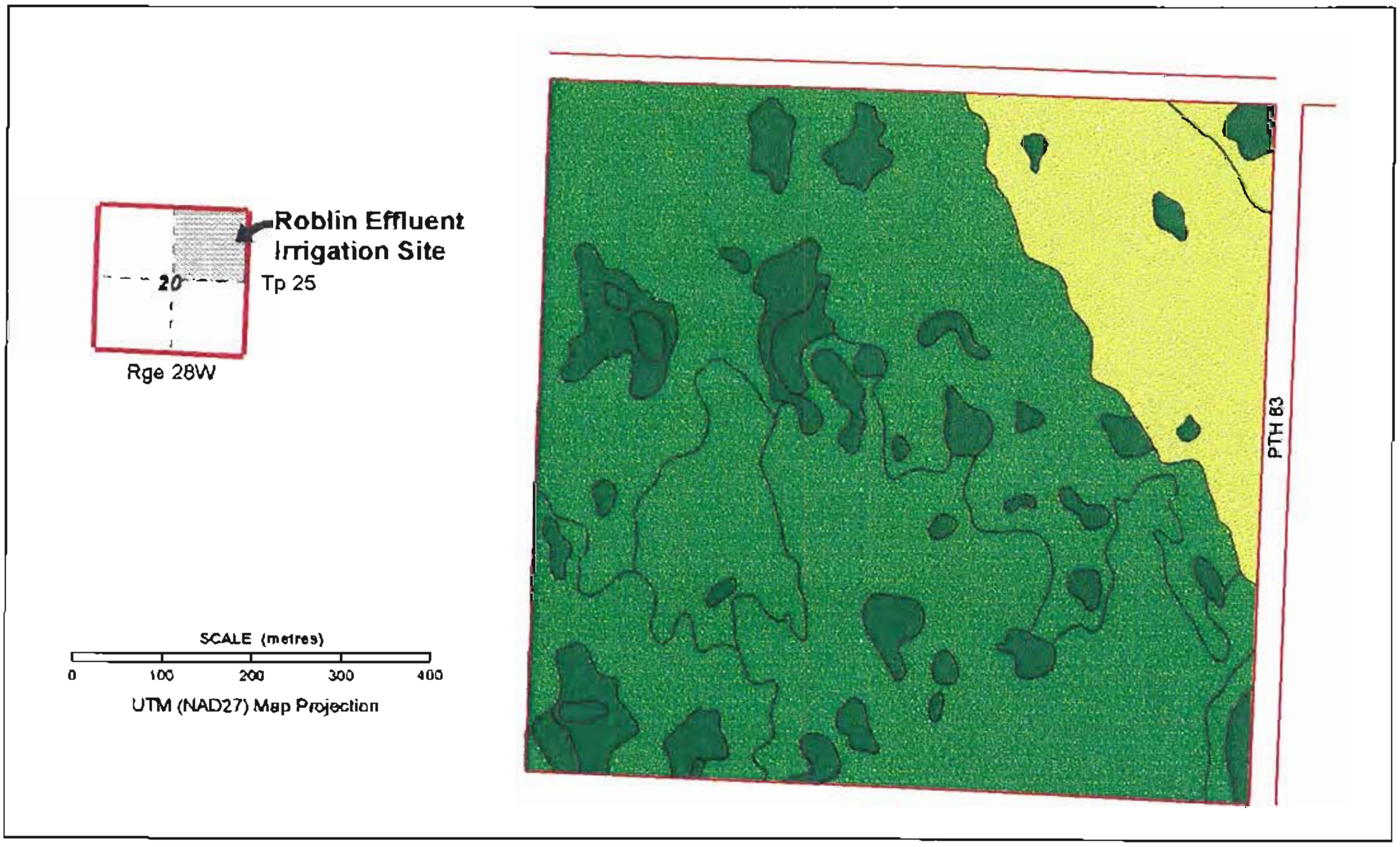


Figure 1 Location of Study Area.

Figure 2 **Topography**

Slope describes the steepness of the landscape surface. The slope classes shown on this map are delineated from the dominant slope measurements taken during the course of the detailed soil survey. At the local level, slopes are more variable and are related to soil type. Specific colours are used to indicate the most significant, limiting slope class for each polygon.

Steepness and length of the slope are important topographic factors affecting the potential for surface runoff and infiltration of precipitation. Limitations to cultivation and kind of land use also increase with increasing steepness of slope.



Slope Classes	Area, ha	Percent of Total
level to nearly level (0-0.5%)	18.48	13.03%
nearly level (0.5-2.0%)	46.48	71.42%
very gently sloping (2-5%)	10.12	15.55%

textured till (information from 3 topographic transects provided by Prairie Farm Rehabilitation Administration, personal communication). However, till deposits in the area are commonly interbedded with layers of sand and gravel occurring at depths ranging from 2 metres to more than 65 metres. Drill logs compiled during the installation of five observation wells on the Site indicate that well- to poorly-sorted sand and gravel occurs at depths between 2.4 to 15 metres (Figure 3). These sandy layers range from thin lenses of less than 1 m to layers in excess of 10 metres in thickness (Prairie Farm Rehabilitaion Administration, personal communication). The presence of these coarse textured layers promotes drainage and leaching and may contribute to local groundwater recharge.

1.4 HYDROLOGY

Regionally, the Roblin area is located in a groundwater recharge area. The occurrence of a few deep depressions containing permanent water bodies surrounded by poorly drained, carbonated soils indicates that some minor local discharge of freshwater occurs to these lakes (Eilers, 1983). The Shell River valley, located about 1 km to the east of the Site and incised some 37 m (125 feet) below the till plain, would be expected to cause local drawdown of the regional watertable and increase the potential for groundwater recharge.

There is no well developed pattern of natural surface drains on the study site. The drainage of surface water is largely internal; that is, most of the precipitation either infiltrates directly into the soil or moves off into depressions in the landscape from where it moves down through the soil to recharge the groundwater or evaporates into the atmosphere.

1.5 CLIMATE

The climate of the Roblin area is characterized by short, cool summers and long cold winters. Frequent changes in the major air masses affecting the area contribute to extreme variability of weather patterns in each season.

Because weather data from the climate station at Roblin are from a relatively short time period, it is useful to utilize meteorological data from 5 additional weather stations within the area; namely Kamsack to the west, Grandview and Gilbert Plains to the east and Russell to the south. Data from Dauphin is included for comparison with conditions at lower elevations to the east.

Growing season characteristics (heat units and frost-free period) are relatively uniform across the region. Maximum temperatures and precipitation occur during summer. Mean daily air temperatures from stations around Roblin indicate that July is the warmest month with average temperatures in excess of 18°C. The average frost-free period is 100 days ranging from 96 days in the Kamsack area to 96 days at Gilbert Plains and 105 days around Dauphin at lower elevations to the east. Length of period free of a killing frost (base -2.21°C) ranges from 113 at Kamsack to 131 at Dauphin. Growing degree days above 5.5°C in the area range from about 1490 at Gilbert Plains to 1580 at lower elevations to the east. Both frost-free season and GDD's decrease at higher elevation and on north-facing aspects in the landscape.

The average total precipitation in the area is 457 mm with approximately 70 percent of the total annual precipitation falling as rain during the period of April to October. Mean growing season rainfall (May to September) is 283 mm. Moisture distribution during the growing season may vary widely from location to location, as much of the precipitation is received during summer storm events. Climatological data from the six stations is summarized in Tables 1, 2 and 3.

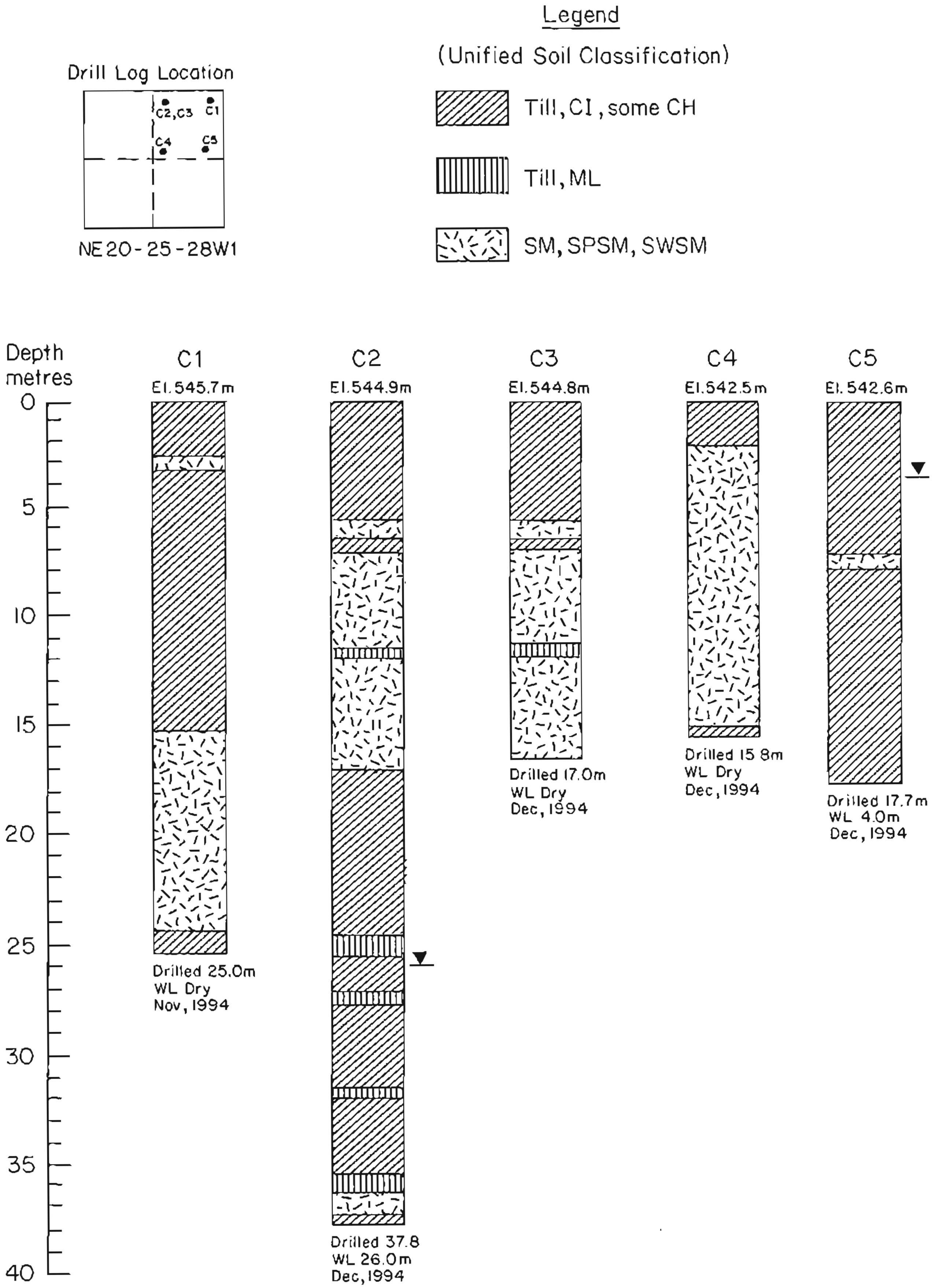


Figure 3 Generalized Stratigraphy from Deep Drill Logs (PFRA Geotechnical Division)

Table 1 Climatic Parameters at Selected Climate Stations in West Central Manitoba (Atmospheric Environment Service, 1982)

Climatic Parameter	Climate Station					
	Kamsack	Roblin	Grandview	Gilbert Plains	Dauphin	Russell
Elevation m.a.s.l	433.2	529	465	404	305	567
Temperature, °C:						
mean annual	0.9	0.2		0.8	1.4	0.8
mean maximum	7.0	6.8		7.0	7.4	6.4
mean minimum	-5.2	-6.4		-5.5	-4.6	-4.7
Precipitation:						
mean annual, mm	385.7	476.7	460.4	476.6	495.8	451.2
rainfall, mm	285.8	351.1	328.3	335.5	354.7	314.3
Mean Monthly rainfall, mm						
• May	36.0	43.7	40.1	39.9	43.0	37.9
• June	72.6	79.4	71.5	71.2	86.3	71.3
• July	54.2	65.8	70.3	70.0	64.1	58.9
• August	54.6	52.0	58.8	57.5	62.2	60.5
• September	40.7	65.3	53.4	57.9	57.7	49.0

Table 2 Climatic Parameters Relevant to Crop Growth at Selected Climate Stations in West Central Manitoba (Ash, 1991)

Climatic Parameter	Probability Level[1]	Climate Station				
		Kamsack	Gilbert Plains	Dauphin A	Russell	Roblin [2]
Corn Heat Units	50	2157.0	2239.5	2390.7	2166.1	
	25	2010.3	2117.7	2231.9	2023.6	
	10	1077.7	2005.2	2086.9	1894.7	
Growing Degree-Days (base 5°C)	50	1502.2	1491.1	1580.0	1450.3	1443.3
	25	1428.0	1422.6	1484.8	1372.7	
	10	1362.4	1359.5	1398.6	1302.6	
Frost-free (mean) period days (base -2.2°C)	50	113.3	125.5	130.8	125.1	
	25	101.0	112.3	122.2	113.5	
	10	89.9	100.1	114.4	103.0	

[1] Probability levels indicate the percent of time that minimum values for each parometer are less than the mean, ie., 50% probability.

[2] Atmospheric Environment Service, 1982

Table 3 Frost Data and Probability for Last Freezing Temperature, Spring and First Freezing Temperature, Fall at Selected Climate stations in West Central Manitoba (Atmospheric Environment Service, 1982)

Station Location	Probability Level*						
	10% (1 in 10)	25% (1 in 4)	33% (1 in 3)	50% (1 in 2)	66% (2 in 3)	75% (3 in 4)	90% (9 in 10)
Spring Frost on or after							
Kamsack	June 25	June 16	June 12	June 7	May 31	May 28	May 21
Gilbert Plains	June 18	June 12	June 7	June 2	May 29	May 27	May 20
Dauphin A	June 16	June 7	June 3	May 30	May 25	May 23	May 18
Russell	June 7	June 1	May 29	May 26	May 20	May 18	May 9
Fall Frost on or before							
Kamsack	August 14	August 25	August 26	September 6	September 9	September 14	September 21
Gilbert Plains	August 21	September 1	September 4	September 11	September 14	September 15	September 18
Dauphin A	September 1	September 9	September 10	September 16	September 21	September 22	September 29
Russell	September 4	September 7	September 10	September 14	September 17	September 19	September 29
(0°C) Frost free period (days) equal to or less than							
Kamsack	48	72	77	96	102	103	107
Gilbert Plains	68	87	88	96	105	108	111
Dauphin A	85	93	95	105	111	118	130
Russell	94	100	103	108	115	122	136

* Probability levels indicate the percentage of the time (number of years) that the spring and fall frost dates and frost free period deviate from the mean value (50% probability) by the amount indicated, ie., Dauphin frost free period at 10% probability will be 85 days or less 1 year in 10. The date of the last spring frost at the 10% probability level at Dauphin will be on June 16 or later 1 year in 10.

PART 2

METHODOLOGY

2.1 INTRODUCTION

The detailed study of soil conditions on the Effluent Irrigation Site was carried out in 1994 and involved various field activities. The field investigation included the following:

a) A detailed soil survey (1:5 000 scale) was conducted utilizing routine procedures for inspecting, describing, and sampling soils along a grid system (Figure 4). Approximately every second site was sampled for characterization of particle size, electrical conductivity, organic matter and pH.

b) All sites were examined by means of a spade and hand auger to determine the uniformity of the till subsoil and the occurrence of buried sand and gravel strata.

c) Field sampling and testing of soils for hydraulic conductivity properties (6 sites) and bulk density and moisture retention was determined at 7 sites representative of dominant topographic and drainage positions in the landscape.

d) Nine sites were investigated and sampled to a depth of approximately 4.5 meters. These sites were part of an initial investigation conducted by PFRA in 1994. Five deep drill sites for installation of observation wells were logged to depths ranging from 15 m to 38 m. An electromagnetic terrain survey was completed using an electrical conductivity (EM38) meter to characterize background levels of salinity to a depth of 60 and 120 cm along a 50 meter grid. The drill logs and the salinity grid were located on a topographic survey of the site completed by PFRA staff.

The grid inspection sites and the drill sites were sampled to determine selected chemical and physical properties of the soils. Although no detailed soil sample sites were obtained from the study area, several sites representative of the major soils on the Effluent Irrigation Site were sampled and characterized from the SW 1/4 of section 20-25-28W, immediately to the southwest of the study site (Eilers, 1983).

2.2 SOIL SURVEY AND MAPPING

In the mapping process soils were inspected along a 200 meter grid across the study area. Additional inspection sites were selected to refine the location of soil boundaries and to determine the local variability of soils in the study area. Soil inspections were made by hand spade to a depth of 75 to 100 cm and a hand auger was utilized to verify the nature of the underlying soil material to a depth of about 1.5 meters. The surface plow layer (upper 15 to 20 cm) was sampled at every second site in the grid and subsoil samples were taken on a random basis to characterize the parent material. A total of 65 soil inspection sites were described giving an average soil inspection density of 1 site per 0.98 hectares. Soil and site characteristics were recorded and each profile was classified according to standard survey procedures (Agriculture Canada, 1987). Survey grid points, drill sites, and location of detailed characterization sites are shown in Figure 4.

2.3 THE SOIL MAP

The soils of the Effluent Irrigation Site were mapped on a 1:15 840 scale black and white aerial photograph which was subsequently enlarged to a scale of 1:5 000 for production of the final map manuscript. Six soil series with various phases of topography and stoniness were identified on the soil map for a total of 46 polygons.

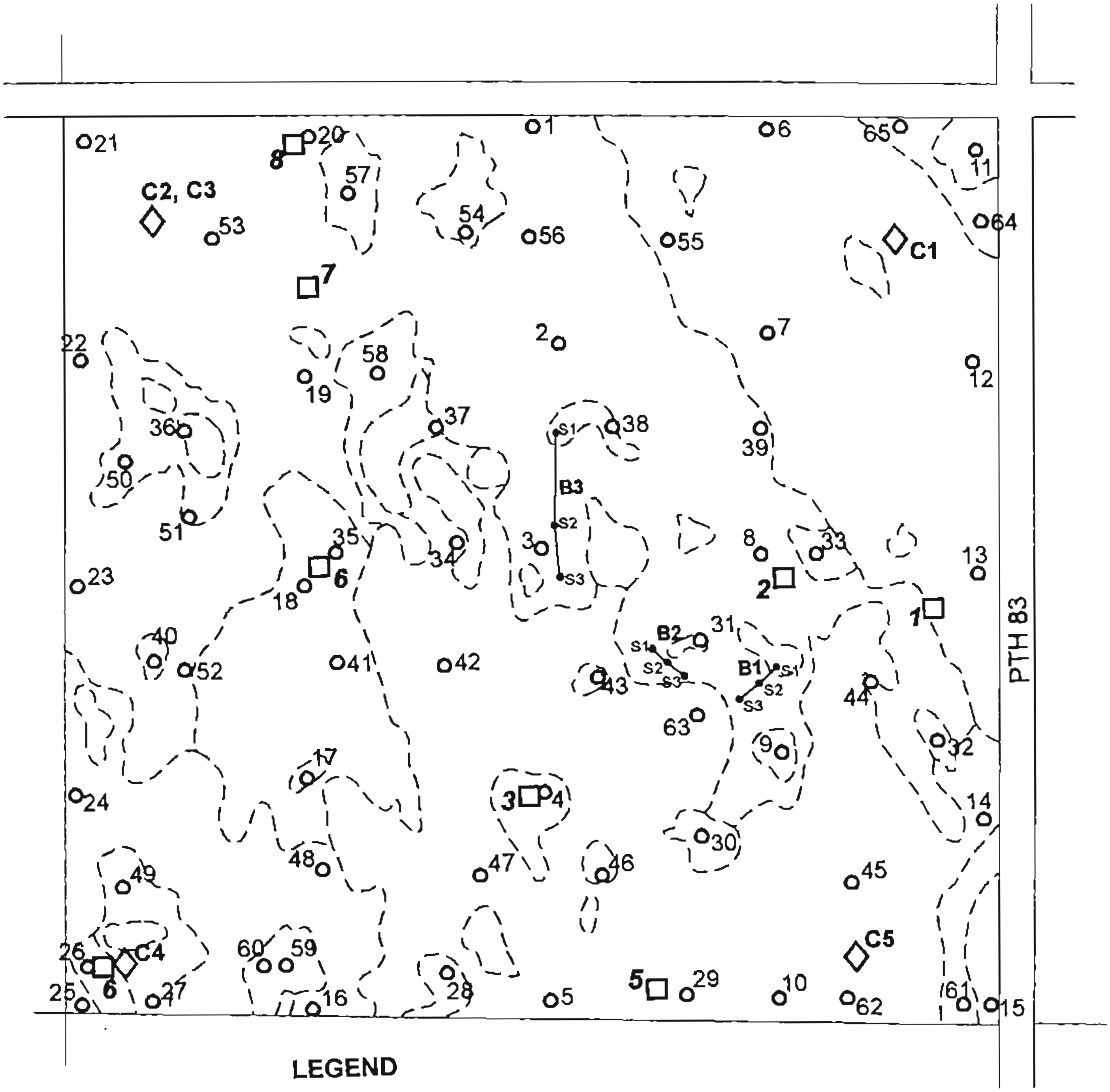
The basic soil map and supporting data may be used to generate a number of derived and interpretive maps. The range of map products includes: topography, stoniness, surface pH, organic carbon, agricultural capability, irrigation suitability and potential environmental impact from irrigation, risk for subsoil and/or groundwater contamination and water erosion risk.

2.4 DEEP DRILLING PROGRAM

Initial evaluation of the land on the study site took place in early summer of 1994 when three transects consisting of 3 drill logs each were sampled and described to 4.5 meters (PFRA, pers. communication). During the winter of 1994, five deep well sites (Sites C1 to C5) were installed and logged to depths from 15.8 m to 37.8 m. The deep stratigraphy compiled from information supplied by CPFRA is summarized in Figure 3.

2.5 SALINITY SAMPLING

All samples from the inspection sites were analyzed for electrical conductivity. Data from the surface soils are summarized in Table 9. Electrical conductivity values for all sites are included in Tables 24 and 25 (Appendix B). Soluble salt analysis from deep drill transects are presented in Table 26. The data from separate EM38 transects run on a 50 meter grid resulted in 270 grid point readings for 0-60 cm (horizontal reading) and 1-120 cm (vertical reading) depths. These readings are presented in Figures 14 and 15 (Appendix B).



LEGEND

soil inspection site, 1 - 65

detail soil sample site, ***1 - 8***

deep drill transect, **B1 - B3**

test holes, **C1 - C5**

Figure 4 Location of Groundtruth and Sampling Sites

PART 3

DEVELOPMENT, CLASSIFICATION AND DESCRIPTION OF SOILS

3.1 INTRODUCTION

This section of the report describes the main characteristics of the soils and their realationship to the factors of soil devolpment. It also provides a description of the classification and morphology of the soils in the study. The soils of the study site were initially mapped at a reconnaissance scale of 1:125 000 as the Erickson Association which commonly was comprised of up to nine member soil types or associates (Grandview Map Sheet Area, Ehrlich et al., 1959).

The present detailed survey at a 1:5 000 scale recognizes six soil series to characterize the soil variability on the Effluent Irrigation Site. Four of the soils are developed on moderately to strongly calcareous fine loamy (clay loam) glacial till deposits and two soil types are developed on a variable thickness of fine loamy lacustrine sediments. The soils are dominantly well drained Dark Gray Chernozems (56.4 percent) and imperfectly drained Gleyed Dark Gray Chernozems (31.9 percent). Local areas of poorly drained soils are classified as Rego Humic Gleysols (0.8 percent) and Humic Luvic Gleysols (10.9 percent).

3.2 SOIL DESCRIPTIONS

A general description of each soil series mapped on the Site is given in this section. The area in hectares and percent of total area for each soil series is included with the description. A convenient key to the classification of soils in the study in relation to parent material and drainage is shown in Table 4. The areal extent of each soil and phase mapped on the Site is summarized in Tables 5 and 6.

Generalized descriptions for each soil series are presented in alphabetical order and include genetic profile type, texture, calcareous class, parent material, topography, drainage and other chemical and physical properties. The charactertistics and properties are based on summaries and averages of soil data systematically documented and recorded during the course of the soil survey. The description of those soils which are of very limited occurrence on the study site is supplemented by samples collected over a larger area. Chemical and physical analysis from samples taken at grid points during the survey are presented in Tables 24 and 25.

3.2.1 Banks Series (BAX) (3.8 ha., 5.9 %)

The Banks series consists of well drained Orthic Dark Gray soils developed on strongly to very strongly calcareous, shallow (20 to 100 cm), uniform, fine loamy glaciolacustrine sediments overlying very strongly calcareous, loamy morainal deposits. These soils occur on crest and upper slope positions of level to very gently sloping lacustrine veneer deposits and have moderate permeability, slow surface runoff and a moderately low water table during the growing season. Banks soils are slightly stony. The majority of these soils are currently used for crop production although native vegetation was usually comprised of mixedwood forest of aspen and white spruce with occasional oak.

In a representative profile of Banks soil, the solum is generally about 66 cm thick. The profile is characterized by a dark gray, loam to clay loam textured Ap horizon overlying a dark brown to brown clay loam textured Bt; horizon, and a grayish brown clay to silty clay loam Ck horizon. The parent material is typically light brownish gray in

Table 4 Classification of Soil Series in Relation to Drainage and Parent Material[1]

Soil Drainage	Soil Subgroup[2]	Parent Material		
		Fine Loamy (L, CL, SiCL) moderately to strongly calcareous glacial till	Fine loamy (L, CL, SiCL) moderately to strongly calcareous lacustrine sediments underlain by fine loamy glacial till:	
			at depths > 1 m	at depths < 1 m
Well to moderately well	Orthic Dark Gray	Erickson (ECK) 32.9 ha, 50.5%		Banks (BAX) 3.9 ha, 5.9 %
Imperfect	Gleyed Dark Gray	Petlura (PTU) 20.8 ha, 31.9%		
Poor	Rego Humic Gleysol		Proven Lake (PVK) 0.2 ha, 0.3%	
	Humic Luvic Gleysol	Roblin (RBN) 7.1 ha, 10.9%		
Very Poor	Rego Humic Gleysol	Sinnott (SNT) 0.3 ha, 0.4%		

[1] Dominant soils describing map units with estimated areal extent in hectares
[2] The Canadian System of Soil Classification, 2nd Ed., Agriculture Canada Publication 1646, 164pp.

Table 5 Areal Extent of Soil Series*

Map Symbol	Soil Name	Areal Extent	
		Hectares	Percent
BAX	Banks	3.8	5.9
ECK	Erickson	32.9	50.5
PUT	Petlura	20.8	31.9
PVK	Proven Lake	0.2	0.3
RBN	Roblin	7.1	10.9
SNT	Sinnott	0.3	0.5
Total		65.1	100.0

Table 6 Areal Extent of Soil Phases*

Map Symbol	Soil Name	Soil Phase	Areal Extent	
			Hectares	Percent
BAX/xbxx	Banks	nearly level	3.8	5.9
ECK/xxxx	Erickson		3.1	4.7
ECK/xb1x	Erickson	nearly level, slightly stony	20.1	30.9
ECK/xc1x	Erickson	very gently sloping, slightly stony	9.7	14.9
PUT/xxxx	Petlura		0.1	0.2
PTU/xb1x	Petlura	nearly level, slightly stony	20.2	31.0
PTU/xc1x	Petlura	very gently sloping, slightly stony	0.5	0.7
PVK/xxxx	Proven Lake		0.2	0.3
RBN/xxxx	Roblin		7.1	10.9
SNT/xxxx	Sinnott		0.3	0.5
Total			65.1	100.0

*Areal extent summarized in these tables includes minor inclusions from all map units, so may differ slightly from summaries derived from interpretive maps.

colour and is underlain by compact, light gray, loam to clay loam, strongly calcareous till.

Banks soils occur in close association with Erickson soils. They are similar to Erickson soils in having similar horizon development, but differ inhaving slightly deeper profiles and lower amounts of stones and cobbles on the surface. Banks soils have medium available water holding capacity, medium surface organic matter levels, and high natural fertility. Banks soils correlate with Onanole till substrate phase soils previously published in the West Lake soil report (Soil Report No. 8) and the Grandview soil report (Soil Report No. 9).

3.2.2 Erickson Series (ECK) (32.9 ha., 50.5 %)

The Erickson series consists of moderately well to well drained Orthic Dark Gray soils developed on moderately to strongly calcareous, fine loamy (loam to clay loam) glacial till derived from shale, limestone and granitic rock materials. These soils occur on crests and upper slope positions of very gently undulating and hummocky morainic landscapes. Surface runoff is moderately rapid from the steeper slopes and moderate from lower slopes. Permeability is moderately slow. The Erickson soils have a low water table during the growing season. Erickson soils may be slightly eroded and are non-stony to moderately stony, and non-saline. They have a medium available water holding capacity, medium organic matter content and high natural fertility. The majority of these soils are currently cultivated for crop production.

In a representative profile of Erickson soil the solum is approximately 40 cm thick. The soil is characterized by a dark gray loam to clay loam textured A horizon (Ah and Ahe horizons) about 25 cm thick (ranging in thickness from 8 to 45 cm) and a dark brown to brown clay loam to clay textured Bt or weakly developed Btj horizon 7 to 45 cm thick. The depth of the profile varies with the slope of the landscape, deeper profiles occurring in areas characterized by lower slopes. A thin BC horizon and a well developed horizon of lime accumulation (Cca horizon) may occur below the B horizon. The underlying parent material is typically light gray to white coloured, strongly calcareous, loam to clay loam and silty clay loam textured material which is slightly to moderately stony and cobbly.

Erickson soils are dominant in gently sloping areas and occur in close association with imperfectly drained Petlura soils on mid to lower slope positions and poorly drained Roblin and Sinnott soils in depressional sites in gently undulating to hummocky landscapes. The Erickson soil may be associated with local occurrences of soils in which the B horizon is absent (Rego Dark Gray soils) or in which the B horizon is carbonated (Calcareous Dark Gray soils).

3.2.3 Petlura Series (PTU) (20.8 ha., 31.9 %)

The Petlura series consists of Gleyed Dark Gray soils developed under imperfect drainage on moderately to strongly calcareous, fine loamy (loam to clay loam) glacial till derived from shale, limestone, and granitic rocks. The surface texture is dominantly clay loam; surface runoff is moderate to slow. Typically, Petlura soils are slightly stony, slightly eroded and occur in lower slope positions of complex topography with slopes in the range of 2 to 5 percent. The majority of these soils are cultivated for crop production. Native vegetation, where it exists, consists of aspen, balsam poplar, some willow, herbaceous plants and grasses.

A typical cultivated soil profile consists of a dark gray, granular Ap-Ahe horizon (average 32 cm thick), a dark grayish-brown to olive-brown Bt or Btgj horizon (average 57 cm thick), with a thin transitional BC horizon or a zone of lime accumulation (Cca horizon) between the Bt horizon and the underlying strongly calcareous parent material. The Ckgj horizon is light gray to white coloured, slightly to moderately cobbly and mottled with iron staining.

Iron mottling was observed in 14 percent of the A horizons, 65 percent of the B horizons, and 85 percent of the C horizons described during the course of this survey. The presence of iron mottling in the soil profile is indicative of the soil water regimes that have a higher, more persistant moistu re status than the associated well drained Erickson soils. On the other hand, these soils have a lower moisture status than the associated poorer drained Roblin and Sinnott soils. Petlura soils were previously mapped as the imperfectly drained Gray Wooded associate of the Erickson Association in the Westlake (1958) soil reports and the Gleyed Dark Gray Wooded associate of the Erickson association in the Grandview map area (Soil Report No. 9).

3.2.4 Proven Lake Series (PVK) (0.2 ha., 0.3 %)

The Proven Lake series consists of Rego Humic Gleysol soils developed under poorly to very poorly drained conditions on deep, moderately calcareous, loam to silt loam textured glaciolacustrine sediments. The topography is generally depressional or gently sloping with poorly drained conditions due to seepage. The surface texture is dominantly loam; surface runoff is very slow to absent. Proven Lake soils are of very limited extent in the map area, occurring in one small poorly drained map unit in which the underlying till substrate is just beyond the 1 m depth. Although the Proven Lake soils in the study area are cultivated, native vegetation consists of either stands of black spruce with an understory of mixed mosses, or sedges and meadow grasses with willow and occasional balsam poplar.

A typical cultivated soil profile consists of a thin mesic peat or mucky loam surface layer, a thin dark gray to black Ah horizon, grading through a thin transitional AC horizon to a strongly mottled, light colored Ckg horizon. In some sites, the peaty layer may be thicker, ranging from 15 to 40 cm, and is designated as a peaty phase. The Proven Lake soils on the study site are strongly leached and classified as Humic Luvic Gleysols. This classification variant differs from normal Proven Lake soils by strongly leached Ahe and Aeg horizons between the dark coloured, humus-rich surface horizon and the strongly developed Bt horizon. The B horizon is strongly developed, dark grayish brown silty clay to clay, massive to angular blocky aggregates which are are strongly mottled with reddish and yellowish brown iron staining.

The Proven Lake soils are the poorly drained Meadow associate of the Proven Lake association as mapped in the Rossburn-Virden (Soil Report No 6) and the Westlake (Soil Report No. 8) map areas.

3.2.5 Roblin Series (RBN)
(7.1 ha., 10 9 %)

The Roblin series consists of poorly drained Humic Luvic Gleysols developed on moderately to strongly calcareous, loam to clay loam textured till derived from shales, limestone, and granitic rock origin. Roblin soils occur in depressional areas of the landscape and because of this, the soil profile contains sediments and materials deposited by surface waters. Coarse textured gravely layers are common at the contact with the underlying morainal till. Roblin soils have a loamy surface texture, a clayey Bt and a clay loam parent material. The water table in the Roblin soils is commonly at the surface in the spring, decreasing well below rooting depth during the growing season. The Roblin soils are slightly cobbly. Roblin soils have very slow surface runoff and moderate to slow permeability. Although most of the Roblin soils on the study site are cultivated, native vegetation where it exists, consists of grasses and sedges.

A typical cultivated soil profile consists of a gray to dark gray loam to clay loam textured Ap-Aheg-Aeg horizon (average 28 cm thick), a dark brown clay to clay loam textured Btg horizon (average 48 cm thick), and an underlying light gray, mottled clay loam to silty clay loam Cg or Ckg horizon. The high clay content in the B horizon is largely pedogenic, having been translocated from the strongly leached and eluviated surface horizon. Iron mottling was observed in 88 percent of the A horizons and 100 percent of the B and C horizons described in this project. The abundance of mottles throughout these soils is an indication of their persistant high moisture status and reflects the seasonal lowering of the water table permitting periods of aeration.

Roblin soils are easily identified in the landscape by their light gray surface colours. This feature is particularly noticeable in cultivated fields where the strongly eluviated Aeg horizon has been disturbed amd brought to the surface by cultivation. Roblin soils occur in depressional areas, and therefore, receive runoff waters from adjacent soils. The deeply eluviated profile of the Roblin soils indicate that much of this ponded water moves down through the soil profile, and is probably added to the groundwater zone. For these reasons, Roblin soils are interpreted as local sites of rapid groundwater recharge. Most Roblin soils are dry by early to mid summer.

The Roblin soils were previously described as the Gray Wooded Gley associate of the Erickson association in the Soil Report of the Grandview area (Soil Report No. 9).

3.2.6 Sinnott Series (SNT)
(0.3 ha., 0.4 %)

The Sinnott series consists of Rego Humic Gleysol soils developed in moderately to very strongly calcareous, fine loamy textured morainal till derived from shale, limestone, and granitic rocks. Sinnott soils are nonstony, level to depressional, and very poorly drained. The soils are slowly permeable with a water table often ponded at or above the soil surface. Surface runoff is very slow to absent. Sinnott soils commonly occur in the lowest depressions in the landscape. Although some are used for crops, land use is primarily as marsh habitat and natural grazing. Vegetation often consists of cattails, bullrushes, and slough grass.

Uncultivated Sinnott soils are characterized by thin (less than 40 cm) surface layers of mesic to humic organic materials. These soils are mapped as Sinnott peaty phase. Cultivated Sinnott soils have a mucky loam textured Ap horizon (average 22 cm thick) overlying a clay loam textured Ckg horizon. Many Sinnott soils contain free lime carbonates at the soil surface which indicates a lack of leaching. Infilration is very slow in these soils. The lack of leaching, dull matrix colours of the soil material, high water table, abundance of mottling and the location of Sinnott soils in deep depressions are indicative of local groundwater discharge conditions. Sinnott soils are closely associated with Petlura, Roblin and Cayer soils and semi-permanent and permanent water bodies. They differ significantly from the Roblin soils in being less leached and having shallower soil profiles. The Sinnott soils were previously described as the Meadow associate of the Erickson association in the Grandview soil report (Soil Report No. 9).

PART 4

AGRICULTURAL USE AND MANAGEMENT INTERPRETATIONS

4.1 INTRODUCTION

This section provides predictions of performance or soil suitability ratings for agricultural land use based on soil and landscape characteristics, laboratory data and soil behaviour under specified conditions of land use and management. Soil capability and suitability ratings are interpretations of basic soil resource information and are intended to serve as guides for planners and managers.

4.1.1 Single Factor, Derived and Interpretive Maps

Evaluation of soil resource information (soil properties) is most appropriate in relation to the landscape and environment in which the soil occurs. Management of soil and landscape data using Geographic Information System (GIS) technology enables rapid and more quantitative analysis of natural soil variability than is possible using manual techniques. The areal distribution of various soil components and properties that occur in complex landscapes can be highlighted in map form and so assist in planning and managing the soil resource. This information can be shown as single factor maps and interpretive maps which highlight the distribution of individual soil properties. Interpretive maps may indicate the degree of soil limitation or potential for selected agricultural uses and environmental issues.

GIS techniques can help the land manager in understanding soil and landscape relations and in implementing research and demonstration activities. In addition, use of the GIS can assist in the design, sampling and instrumentation of sites for monitoring soil quality and assessing environmental impact.

A series of derived and interpretive maps at an approximate scale of 1:8 000 are included in this section to assist in the interpretation of the soil resource information for the Roblin Effluent Irrigation Site. These colour thematic maps were generated by the PAMAP Geographic Information System from the 1:5 000 scale soil map and related soil analysis and landscape information. The maps portray a selection of individual soil properties or landscape conditions for each map unit delineation. Combinations of soil properties or landscape features affecting land use and management are derived as specific interpretations.

Soil properties determine to a great extent the potential and limitations for both dryland and irrigation agriculture as well as suitability for meeting the requirements of specific crops. In this section, interpretive soil information is provided for agricultural land use evaluations such as:

a) soil capability for agriculture
b) irrigation suitability
c) soil suitability for forage production, and
d) risk of water erosion.

A general overview of the soil and landscape characteristics on the Site is given in Table 7. A summary of the soils showing their areal extent and their interpretive classification for agricultural capability and irrigation suitability is provided in Table 12.

It is important to note that the derived maps portraying specific interpretations are based on the dominant condition in each map unit. For this reason slight differences may occur between estimates of areal extent

Table 7 Summary of Land Resource Characteristics

Characteristic	Areal Extent		
	Hectares	Acres	% of Area
Soil Drainage Classes			
Well	36.7	90.7	56.4
Imperfect	20.8	51.4	31.9
Poor	7.3	18.0	11.2
Very Poor	0.3	0.7	0.5
Topography (slope) classes			
x level to nearly level (0-0.5%)	10.8	26.7	16.5
b nearly level (0.5 to 2.0%)	44.2	109.2	67.9
c very gently sloping (2.0 - 5.0%)	10.1	25.0	15.6
Erosion Classes	Erosion slight to very slight, no erosion mapped		
Agricultural Capability classes			
Class 1	-	-	-
Class 2	57.5	142.1	88.3
Class 3	-	-	-
Class 4	-	-	-
Class 5	7.1	17.5	10.9
Class 6	0.5	1.2	0.8
Class 7	-	-	-
Irrigation Suitability Rating			
Excellent	-	-	-
Good	36.7	90.7	56.4
Fair	20.8	51.4	31.9
Poor	7.6	18.8	11.7
Potential Environmental Impact Under Irrigation			
Negligible	-	-	-
Low	57.5	142.1	88.3
Moderate	-	-	-
High	7.6	18.8	11.7

derived from the interpretive maps and the summary of areal extent provided from the soil map.

4.2 SOIL PROPERTIES AFFECTING CROP MANAGEMENT

This section of the report examines specific soil properties that affect various management and associated tillage activities for crop production. The areal distribution of selected soil and landscape properties is shown in a series of single factor and interpretive maps (Figures 5 to 7). Selected chemical and physical characteristics of the surface horizons of representative soils are summarized in Table 8. Analytical data from the inspection sites are presented in Appendix B, Tables 24 and 25 in which the data are organized by site number and soil series respectively.

4.2.1 Soil Texture

The proportion of individual mineral particles (sand, silt, clay) present in a soil is referred to as texture. Soil texture, or particle size distribution, strongly influences the soil's ability to retain moisture, its general level of fertility, the ease or difficulty of cultivation, permeability and susceptibility to erosion. The dominant surface texture on the Site is loam to clay loam which contributes to good available water holding capacity, moderate to moderately slow permeability and good soil aggregation (structure) to aid in resistance against erosion. The average particle size distribution of surface soils on the Site is sand, 36%; silt, 37%; and clay 27% (Table 8).

All soils are subject to erosion if the soil surface is not covered by vegetation or crop residues. The gently sloping areas of the Erickson and Petlura soils are subject to erosion by water. All soils on the Site are subject to wind erosion if the soil surface is exposed. Continuous cropping and minimum or zero tillage to maximize residue cover will minimize the risk of erosion. If row crops or crops such as canola that produce low amounts of residue are in the crop rotation, practices such as seeding annual crops like fall rye and winter wheat will help protect the soil surface during the critical post-harvest period until the establishment of groundcover the following spring. These practices also help to maintain organic matter in the soil for improved water retention, structure and fertility.

4.2.2 Soil pH

Soil pH values express the degree of acidity and alkalinity. A summary of pH values is shown in Table 8 and the distribution of surface soil pH conditions are shown in Figure 5. Individual site data are presented in Appendix B, Tables 24 and 25. The pH values of surface soils on the Site range from 5.2 to 7.5 with a mean pH of 6.3. This range of pH from strongly acid to mildly alkaline is fairly large for a small area. The more acid values occur in depressional sites characterized by the strongly leached soils of the Roblin (RBN) series whereas neutral pH soil is more common on the freely drained upper and mid slopes of the Erickson (ECK) and Banks (BAX) soils and mid to lower slopes of the imperfectly drained Petlura (PTU) soils. Lower slopes and nearly level areas of Petlura soils are under the periodic influence of capillary rise from a water table resulting in mildly alkaline soil conditions.

4.2.3 Organic Matter

Soil organic matter is important to the health and productive capacity of the soil. The organic matter content of the surface soil on the Site ranges from a low of 3.8 percent to a high of 10.5 percent (Table 8, organic carbon % X 1.72 = organic matter %). The average organic matter content of the soils on the Site is 6.3 percent. These values are well within the mid to upper range for loam to clay loam textured soils in the Dark Gray zone in Manitoba. The overall level of soil organic matter on the Site is satisfactory but cultural practices to maintain or increase the organic matter content are required to ensure good structure, fertility and tilth. The distribution of surface organic matter in the soils is shown on Figure 6.

Soil carbon serves as an important indicator of the status of several major processes in the environment which are sensitive to change. Environmental change caused by cultivation, forest fires, and changes in hydrology and climate, can alter soil moisture, soil temperature and organic matter content and result in an increase or decrease in soil carbon. Change in the carbon content of soil organic matter affects the atmosphere as well as the soil system.

Soil organic carbon content varies with drainage and position in the landscape. Well drained Erickson soils on the Site average about 3.6 percent organic carbon, imperfectly drained Petlura soils about 4.1 percent and poorly drained Roblin soils about 3.5 percent (Table 8). Highest average organic carbon content occurs in the lower slopes of the imperfectly drained Petlura soils which receive runoff containing sediment from adjacent upper slopes in the landscape. The average organic carbon content of the well drained Erickson soils varies somewhat with topographic position ranging

Table 8 Summary of Surface Soil Properties For All Series

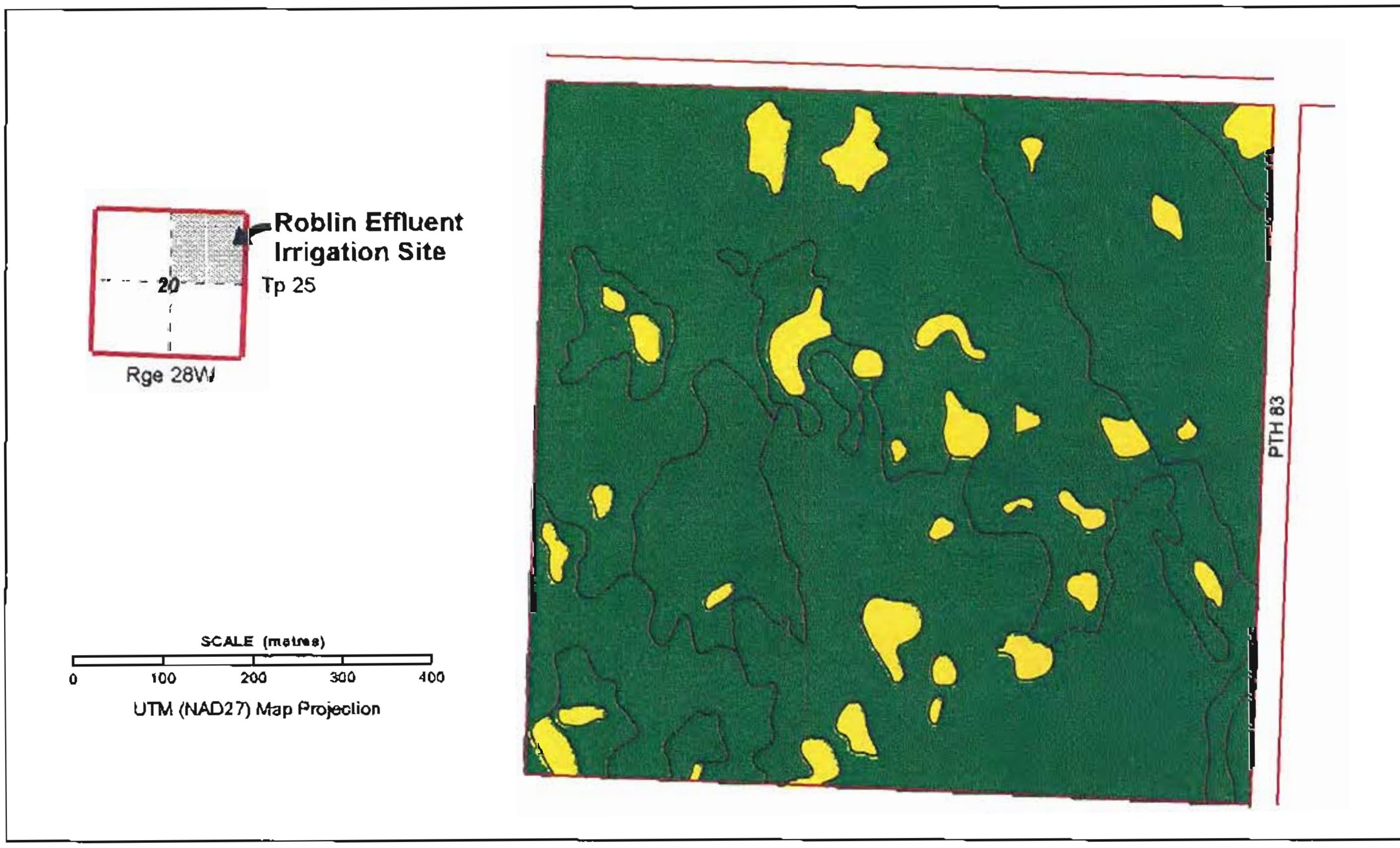
Soil Code	Soil Name	Number of Samples	Organic Carbon * %		pH		Electrical Conductivity mS/cm		Particle Size						Texture Class
									% Sand		% Silt		% Clay		
			Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
BAX	Banks	3	4.39	.12	6.57	.55	.37	.15	36.00	3.61	35.67	4.04	28.34	.58	Clay Loam
ECK	Erickson	9	3.59	.84	6.58	.60	.40	.07	39.56	5.22	31.78	3.19	28.67	2.74	Clay Loam
PTU	Petlura	7	4.08	.73	6.94	.43	.40	.15	38.00	3.96	31.86	3.29	30.14	2.34	Clay Loam
PVK	Proven Lake	1	2.73	.00	5.60	.00	.20	.00	37.00	.00	.42.00	.00	21.00	.00	Loam
RBN	Roblin	9	3.45	1.22	5.92	.45	.32	.12	31.44	4.95	44.56	4.45	24.00	5.22	Loam

* Organic Carbon % x 1.72 = Organic Matter %
SD = Standard Deviation

Figure 5 **Surface Soil pH**

Soil reaction or pH is a measure of the degree of acidity or alkalinity of a soil. The solubility and availability of nutrients to plants is closely related to the pH of the soil. In acid soils some nutrients may be found in such quantities to become toxic to plants whereas in soils with neutral pH, the solubility is decreased to the point at which the toxicity is corrected. In soils with alkaline pH, the solubility of certain nutrients is further decreased to the point where deficiencies of some nutrients may occur. Optimum plant growth is generally in the range of pH of 6.1 to 7.8 but many plants grow very well outside this range.

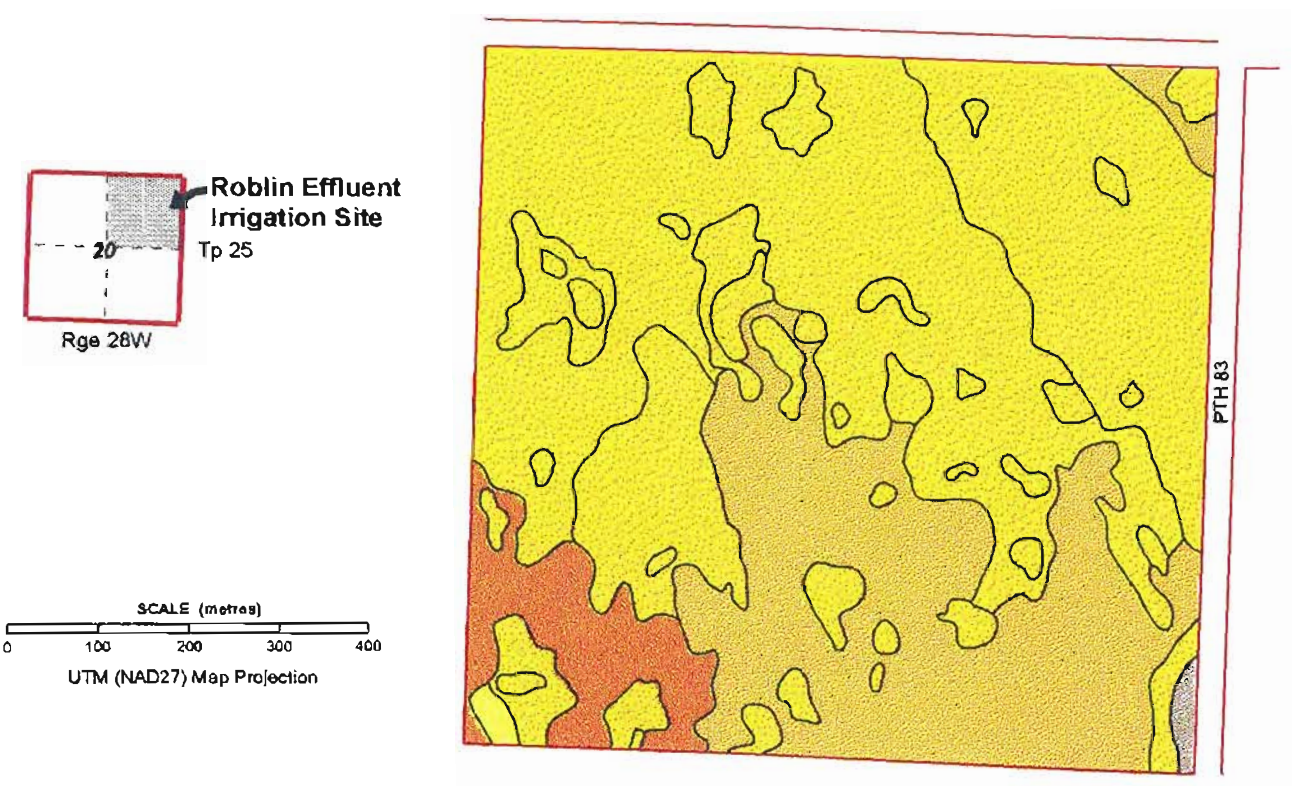
The inherent sensitivity of the soil to acidification is related to pH level and the occurrence of carbonates in surface horizons and the subsoil. Soil ecosystems containing calcareous materials have sufficient buffering capacity to neutralize incoming acidity without appreciably changing its own pH. Soils with surface pH levels of 4.6 to 6.0 and low subsoil carbonates are considered to be moderately sensitive to acidification.



pH Class	Area, ha	Percent of Area
strongly acid (5.1-5.5)	-	-
medium acid (5.6-6.0)	60.08	92.31%
slightly acid (6.1-6.5)	-	-
neutral (6.6-7.3)	5.00	7.69%
mildly alkaline (7.4-7.8)	-	-

Figure 6 **Soil Organic Matter**

Soil organic matter plays a key role in soil quality. It is a source of, and a sink for plant nutrients and is important in maintaining soil tilth, aiding the infiltration of air and water, promoting water retention, reducing erosion and controlling the efficacy and fate of applied pesticides. The status of soil organic matter is important to the health and productive capacity of the soil. The concept of sustainable agriculture implies that a soil must sustain its ability to produce crops over an extended period of time. Therefore, assessment of changes in soil organic matter is important in evaluating soil quality. The level of organic matter in the soils on the Crop Diversification Centre falls well within the upper range for loam to clay loam textured soils in the Chernozemic Black zone of southern Manitoba.



Organic Matter Content 0-20 cm, %	Area ha	Percent of Area
4.6 - 5.5	0.22	0.34%
5.6 - 6.5	44.47	68.33%
6.6 - 7.5	16.09	24.73%
7.6 - 8.5	3.86	5.93%
no data	0.44	0.67%

from a low of 2.4 percent on a slightly eroded crest to a high of 4.7 percent in an upper to mid slope position on long, gentle slopes. The organic carbon content of the Roblin soils found in depressions in the landscape varies considerably because of runoff and sediment received from soils on adjacent upper slopes. This surface runoff also increases the net inflow of surface water through the Roblin soil resulting in development of a strongly leached surface horizon and reduced levels of organic matter. The average organic carbon content of the Roblin soils is 3.5 percent, ranging from a low of 2.2 percent to a high of 6.1 percent.

4.2.4 Soil Moisture Properties

Soil texture strongly influences important properties of the soil water regime such as available water holding capacity, hydraulic conductivity and infiltration rate. The dominant surface soil texture on the Effluent Irrigation Site is loam to clay loam. As soils of the Erickson series represent about 50 percent of the soils on the Site, physical properties and moisture characteristics from two Erickson soils sampled in the vicinity are used to characterize soil moisture properties on the Site (Table 9). Additional measurement of bulk density (Table 10) and saturated hydraulic conductivity (Table 11) was obtained from soils on the Site. Definitions for the soil physical and moisture properties measured follow:

<u>Available water holding capacity (AWHC)</u> is the amount of water held in the soil that plants can use. The maximum amount of available water held in the soil is the difference between the field capacity and permanent wilting point, expressed in centimeters of water per unit depth of soil.

<u>Bulk Density</u> refers to the mass of dry soil per unit bulk volume.

<u>Field capacity (FC)</u> is the maximum amount of water held in a soil, measured a few days after it has been thoroughly saturated and allowed to drain freely. This is the optimum moisture condition for plant growth.

<u>Infiltration or intake rate</u> refers to the movement of water from the soil surface into and through the soil. It is commonly expressed as distance per unit of time, eg. cm/hr or volume per unit area per unit time, eg. liters per hectare per minute.

<u>Permanent wilting point (PWP)</u> is the water content at which plants cannot extract sufficient water to meet their requirement and therefore begin to wilt. As the moisture content of the soil declines, it becomes increasingly difficult for plants to use the remaining soil water.

<u>Saturation Percentage</u> is the moisture percentage of a saturated soil paste, expressed on an oven dry weight basis. It is a measure of the total water holding capacity of a soil.

<u>Saturated hydraulic conductivity (Ksat)</u> refers to the effective flow velocity in soil at unit hydraulic gradient. It is an approximation of the permeability of soil and is expressed in cm per hour.

Available water holding capacity is used as a guide for scheduling irrigation. The amount of water held in the soil is expressed as a percent of AWHC. AWHC influences the amount of water that can be applied at one time. Irrigation is usually applied when about half the available water has been used by the crop. If a soil such as Erickson has a water holding capacity of 258 mm, and irrigation was applied at 50 percent AWHC, up to 130 mm could be added without losing any water to deep drainage. Extra care must be taken when irrigating soils of the Roblin series. These soils located in depressional areas of the landscape receive runoff from soils on adjacent upper slopes and as a result are subject to ponding. The deeply eluviated profile of the Roblin soils indicates that much of this ponded water moves down through the soil profile and is probably added to the groundwater zone. The Roblin soils are interpreted as local sites of fast groundwater recharge. Irrigation may extend the period of surface ponding, and with it, the potential for

Table 9 Physical, Chemical and Moisture Retention Properties of the Erickson Soil

Soil Series	Horizon	Depth cm	OM %	CaCo2 %	Sand %	Silt %	Clay %	Texture Class	BD g/cc	FC %	PWP %	AW mm	AW cc/cc
Erickson SE14-21-28W	Ap	0-15	2.75	0.0	45	33	22	Loam	1.51	19.2	6.1	30	0.20
	Bt	15-35	1.10	0.0	38	28	34	Clay Loam	1.49	19.9	7.1	38	0.19
	BC	35-53	1.01	17.8	38	35	27	Loam	1.44	20.3	5.8	38	0.21
	Cca	53-74	0.0	20.1	38	38	24	Loam	1.65	20.3	6.0	50	0.24
	Ck_1	74-100	0.0	21.8	91	37	22	Loam	1.66	20.2	7.1	57	0.22
	Ck_2	100-120	0.0	18.9	42	37	21	Loam	1.62	20.9	7.0	45	0.23
Total Available Water												**258**	
Erickson NE01-28-28A	Ap	0-22	7.74	0.0	20	46	34	Clay Loam	0.90	37.3	9.6	55	0.25
	Bmk	22-35	1.20	3.4	24	44	32	Clay Loam	1.20	27.0	7.1	31	0.24
	BC	35-70	0.00	12.8	29	41	30	Clay Loam	1.30	24.1	6.7	79	0.23
	Ckg_1	70-100	0.00	18.8	32	43	25	Loam	1.39	21.7	6.9	62	0.21
	Ckg_2	100-120	0.00	12.1	28	45	23	Loam	1.41	20.3	9.6	30	0.15
Total Available Water												**258**	

OM = Organic Matter; BD = Bulk Density; FC = Field Capacity; PWP = Permanent Wilting Point; AW = Available Water

Table 10 Soil Bulk Density and Saturation Percentage

Site No.	Soil Series (Symbol)	Horizon	Depth cm	Texture Class	Bulk Density g/cc	Saturation %
2	Erickson (ECK)	Ap Ahe Btj Ck	0-10 10-32 32-60 60-77	CL CL C CL-SiCL	1.19 1.30 1.37 1.37	55.1 50.9 48.3 48.3
3	Roblin (RBN)	Ap Ae Btg_1 Btg_2 Ckg	0-16 16-34 34-64 64-90 90-114	CL L C C-CL CL-SiCL	1.15 1.59 1.48 1.70 1.75	56.6 40.0 44.2 35.9 34.0
4	Roblin (RBN)	Ap Ahe, Ae Btg_1 Btg_2	0-16 16-33 33-62 62-77	L L SiC C	1.31 1.40 1.43 1.51	50.6 47.2 46.0 43.0
5	Petlura (PTU)	Ap Ahe Btjq	0-13 13-28 28-53	CL CL C	1.04 1.27 1.34	60.8 52.1 49.4
6	Erickson (ECK)	Ap, Ahe Btj BC Ck_1 Ck_2	0-18 18-41 41-64 64-85 85-97	CL CL CL L CL-SiCL	1.17 1.40 1.37 1.39 1.65	55.9 47.2 48.3 47.6 37.7
7	Erickson (ECK)	Ap Btj Ck	0-10 10-39 39-55	L-CL CL CL-SiCL	1.32 1.63 1.47	50.2 38.5 44.5
8	Erickson (ECK)	Ap, Ahe Btj Ck_1 Ck_2	0-18 18-40 40-66 66-86	L CL L L	1.32 1.42 1.45 1.45	50.2 46.4 45.3 45.3

Summary of Average Bulk Density by Horizon

Horizon	Number of Samples	Average Bulk Density gm/cc
Ap	7	1.21
Ahe	4	1.39
Btjg,Btg, BC	10	1.47
Ck	7	1.50

Table 11 Saturated Hydraulic Conductivity (Ksat cm/hr)

Site No.	Soil Series (Symbol)	Horizon	Depth cm	Ksat cm/hr	
				Low	High
1	Erickson (ECK)	Ap Btj Ck1	6-17 18-28 51-70	0.75 1.99 0.85	0.82 2.24 2.18
2	Erickson (ECK)	Ap Ahe Btj Ck	6-18 19-30 50-60 150-160	1.37 4.37 2.54 0.18	1.92 6.98 - 0.31
3	Roblin (RBN)	Ap Ahe Btg	8-18 20-36 33-34	0.37 0.28 0.04	0.50 0.35 saturated conditions
4	Roblin (RBN)	Ap Ae Btg Ckg	6-18 18-28 36-46 152-162	0.25 0.40 0.92 0.10	0.25 0.69 - saturated conditions
5	Petlura (PTU)	Ap Ahe Btjg Ckg	7-17 19-29 32-42 55-65	1.02 3.02 1.69 1.43	1.12 - - -
6	Erickson (ECK)	Ap Btj Ck	5-16 23-33 55-65	0.56 4.04 2.19	0.87 - -

Summary of Saturated Hydraulic Conductivity by Horizon

Horizon	Number of Samples	Ksat cm/hr
Ap	14	0.88
Ahe, Ae	7	2.30
Btj,Btg	7	1.93
Ck, Ckg	8	1.02

increased movement down through the soil to the watertable. This downward moving water could carry nutrients, pesticides or other dissolved substances quickly below the rooting zone and eventually through deep drainage to the groundwater.

The soils on the Effluent Irrigation Site have moderate to moderately slow rates of infiltration. Initial infiltration into dry surface soil conditions depends on texture and is estimated to vary from 0.4 to 5 cm/hr slowing to a basic rate of 0.2 to 2 cm/hr on uniformly wetted soil up to saturation level.

Soil texture and stratigraphy influence hydraulic conductivity which governs the rate at which saturated soil transmits water. Saturated hydraulic conductivity determines the drainability of the 1.2 to 3 m zone and hence the irrigation suitability and potential for deep infiltration. Average saturated hydraulic conductivity data (Table 11) for selected soils on the Effluent Irrigation Site indicate the saturated flow is lowest in the plow layer (0.88 cm/hr), is highest in the Ahe and Ae horizons which are undisturbed by cultivation (2.3 cm/hr) and decreases with increasing depth into the B horizons (1.93 cm/hr) and the C horizons (1.02 cm/hr).

4.2.5 Soil Drainage and Groundwater Hydrology

The distribution of surface drainage on the Effluent Irrigation Site varies from well to very poor (Figure 7). Well drained soils account for 56 percent of the area, imperfectly drained soils cover 32 percent, 11 percent is poorly drained and 0.5 percent is poorly drained. Most of the precipitation and snowmelt on the site is retained in the local landscape as runoff from the knolls and upper slope positions accumulates in the intervening depressions. The depressional areas within the low-relief, hummocky topography are relatively shallow and so do not collect a large volume of water. Removal of water from these depressions is largely through evaporation and seepage. Most of the depressions are characterized by the Roblin soils which are dry by early to mid summer. Additional water applied to the landscape under irrigation tends to pond in the depressions during the growing season, causing local drowned out areas of crop and increasing the risk of deep leaching to the groundwater.

The Site is located in a regional groundwater recharge area. However, a few deep depressions containing permanent water bodies surrounded by poorly drained carbonated soils in the vicinity of the Site indicate the occurrence of some minor local freshwater discharge to these water bodies.

4.2.6 Stoniness

Approximately 51 hectares or 78% of the soils on the Site are slightly stony. This slightly stony condition occurs mainly on the Erickson and Petlura soils. The majority of coarse fragments are in the 8 to 25 cm size range and are referred to as cobbles. This degree of stoniness commonly covers only 0.01 to 0.1 percent of the soil surface and is not considered a limitation for agriculture capability since there is little or no hindrance to cultivation and clearing is not generally required. The remainder of the soils on the Site are non-stony.

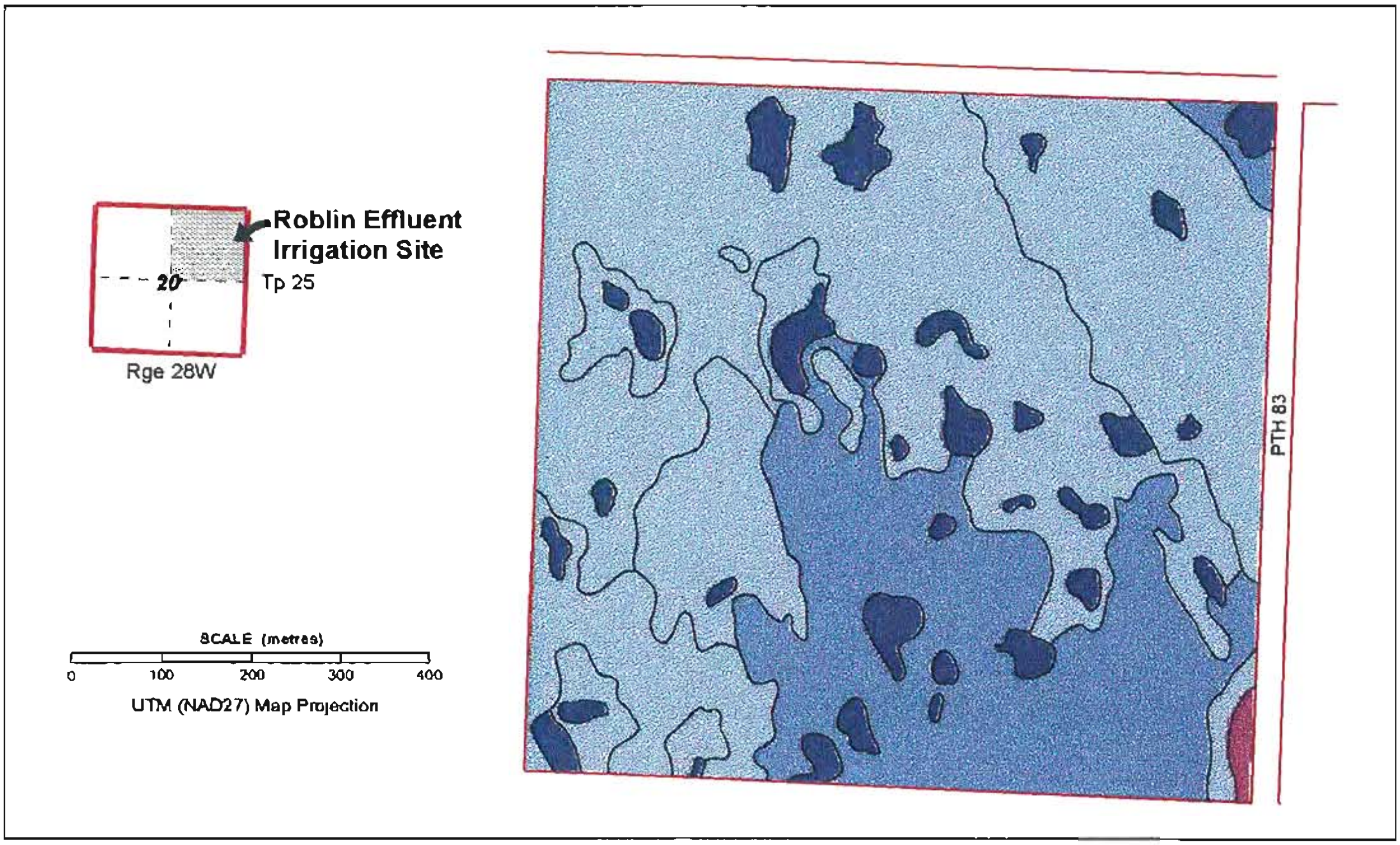
4.3 SOIL CAPABILITY FOR AGRICULTURE

The classification of soil capability for agriculture is based on an evaluation of both soil characteristics and landscape conditions that influence soil suitability and limitations for agricultural use. In this classification, mineral soils are grouped into classes of capability or general suitability; subclasses describe the type of limitation or properties that affect dryland farming. These ratings imply a risk to regional production capacity when the soils are used and the way they respond to management (Anon, 1965).

There are seven capability classes, each of which groups soils together that have the same relative degree of potential for agricultural use. Risk or hazard for use is indicated by the subclass limitation. The subclass limitation becomes progressively greater from Class 1 to Class 7.

Figure 7 **Soil Drainage**

Soil drainage refers to the frequency and duration of periods when the soil is free of saturation. Four soil drainage classes are indicated on this map: Well drained - excess water is removed from the soil, flowing downward readily into underlying pervious material or laterally as subsurface flow; Imperfectly drained - water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. The source of moisture includes precipitation and/or groundwater; Poorly drained - water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time when the soil is not frozen. The main water source is subsurface flow and/or groundwater in addition to precipitation: Very poorly drained - water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time that the soil is not frozen. Excess water is present in the soil throughout most of the year.



Soil Drainage Classes	Area ha	Percent of Area
good	43.70	67.13%
imperfect	16.09	24.73%
poor	5.00	7.69%
very poor	0.29	0.45%

4.3.1 Soil Capability Classes

The class indicates the general suitability of the soils for agriculture. The first three classes are considered capable of sustained production of common field crops, the fourth is marginal for sustained arable agriculture, the fifth is suitable only for improved permanent pasture, the sixth is capable of use only for native pasture while the seventh class is for soils and land types considered incapable of use for arable agriculture or permanent pasture. A description of the capability classes is provided in Appendix A, Table 17.

4.3.2 Soil Capability Subclasses

Soil capability subclasses identify the soil properties or landscape conditions that may limit use or be a hazard. The various kinds of limitations recognized at the subclass level are defined in Appendix A, Table 18.

4.3.3 Soil Capability Classification

The soils on the Roblin Effluent Irrigation Site range from Class 2 to Class 6 in agricultural capability. Class 2 soils account for 57.5 hectares or 88.3%, Class 5 for 7.1 hectares or 10.9%, and Class 6 soils account for 0.51 hectares or 0.8% of the land area on the Site. The agriculture capability classification of the soils on the Centre is shown in Figure 8.

Class 2 soils on the Site have level to nearly level topography (0-2% slopes), are deep and well to moderately well drained with cumulative minor adverse characteristics which singly are not serious enough to affect the class rating (2X). These soils have a moderate limitation for crop production. Class 2 soils also include imperfectly drained soils with a wetness limitation (2W) and the well drained and imperfectly drained soils having a topographic limitation (2T). The 2-5% slopes associated with the 2T soils may increase cultivation costs over that of a smooth landscape and increase the risk of water erosion. Class 5 soils on the Site have very severe limitations as a result of excess water (5W) which restricts the choice of crop to production of perennial forages that tolerate wet soil conditions. This class includes lower, undrained depressional areas of the landscape in which the excess wetness persists at or above the soil surface for significant periods of the growing season. Two areas of Class 6 soil have an extremely severe limitation due to excess wetness which restricts cropping to production of perennial forages (6W). These soils may have high capability for native vegetation species and habitat for waterfowl and wildlife if surface ponding persists throughout the growing season. A summary for agricultural capability, irrigation suitability and areal extent of soils on the Effluent Irrigation Site is provided in Table 12.

4.4 IRRIGATION SUITABILITY

The irrigation suitability classification is an interpretive assessment of land suitability for irrigated agriculture and is made from soil survey data. The irrigation rating provided in this section is an initial rating based on general information about specific soils indicated on the soil map.

It is emphasized that the decision to irrigate a parcel of land will require additional field investigation that utilizes the same criteria but will include an on-site examination of water tables, salinity and stratigraphy to a depth of 3 meters.

The rating guidelines in this section are derived from "An Irrigation Suitability Classification System for the Canadian Prairies" (ISC, 1987). This classification system takes into account recent advances in irrigation management and technology and provides general guidelines for irrigation suitability classification that are applicable to both local and regional conditions. The irrigation suitability rating of the soils is based on soil and landscape characteristics. These characteristics are ranked in terms of their sustained quality under long-term management under irrigation. It does not consider factors such as method of water application, water application, water availability, water quality or economics of this type of land use.

Soil properties considered important for evaluating irrigation suitability are: texture, soil drainage, depth to water table, salinity and

Table 12 Agricultural Capability and Irrigation Suitability Rating

Map Symbol	Soil Name	Areal Extent		Agricultural Capability Class	Irrigation Suitability Rating		
		ha	%		Class	General Rating	Potential Environmental Impact
BAX/xbxx	Banks	3.8	5.9	2X	2xA	Good	Low
ECK/xxxx	Erickson	3.1	4.7	2X	2kxA	Good	Low
ECK/xb1x	Erickson	20.1	30.9	2X	2kxA	Good	Low
ECK/xc1x	Erickson	9.7	14.9	2T	$2kxBt_2$	Good	Low
PTU/xxxx	Petlura	0.1	0.2	2W	3wA	Fair	Low
PTU/xb1x	Petlura	20.2	31.0	2W	3wA	Fair	Low
PTU/xc1x	Petlura	0.5	0.7	2W	$3wBt_2$	Fair	Low
PVK/xxxx	Proven Lake	0.2	0.3	6W	4wA	Poor	High
RBN/xxxx	Roblin	7.1	10.9	5W	4wA	Poor	High
SNT/xxxx	Sinnott	0.3	0.5	6W	4wA	Poor	High
Total Area		65.1	100.0				

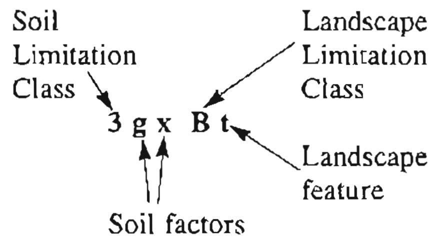
geological uniformity. **Landscape** features considered important for rating irrigation suitability relate mainly to the influence of topography and stoniness.

The irrigation suitability classification of the soil and landscape characteristics in the study area will assist in making initial irrigation plans. The decision to irrigate a parcel of land should first be based on a ranking of suitability based on information presented in this report. The next step should involve an on-site field investigation to examine the depth to water table, salinity and geological uniformity to a depth of 3 m. Drainability, drainage outlet requirement, organic matter status and potential for surface crusting are other factors to consider. This assessment should also consider potential impact of irrigation on "Non-target" non-irrigated areas as well as on the irrigated area.

4.4.1 Irrigation Suitability Rating

The most limiting soil property or landscape feature is combined to determine the placement of a land area in one of 16 classes of irrigation suitability which are grouped and described by 4 ratings of general suitability as **Excellent, Good, Fair and Poor** (Appendix A, Table 19). The guidelines utilized for evaluating the effect of soil properties and landscape features on long term irrigation are included in Appendix A, (Tables 20 and 21 respectively).

An example of an irrigation suitability class rating is shown:

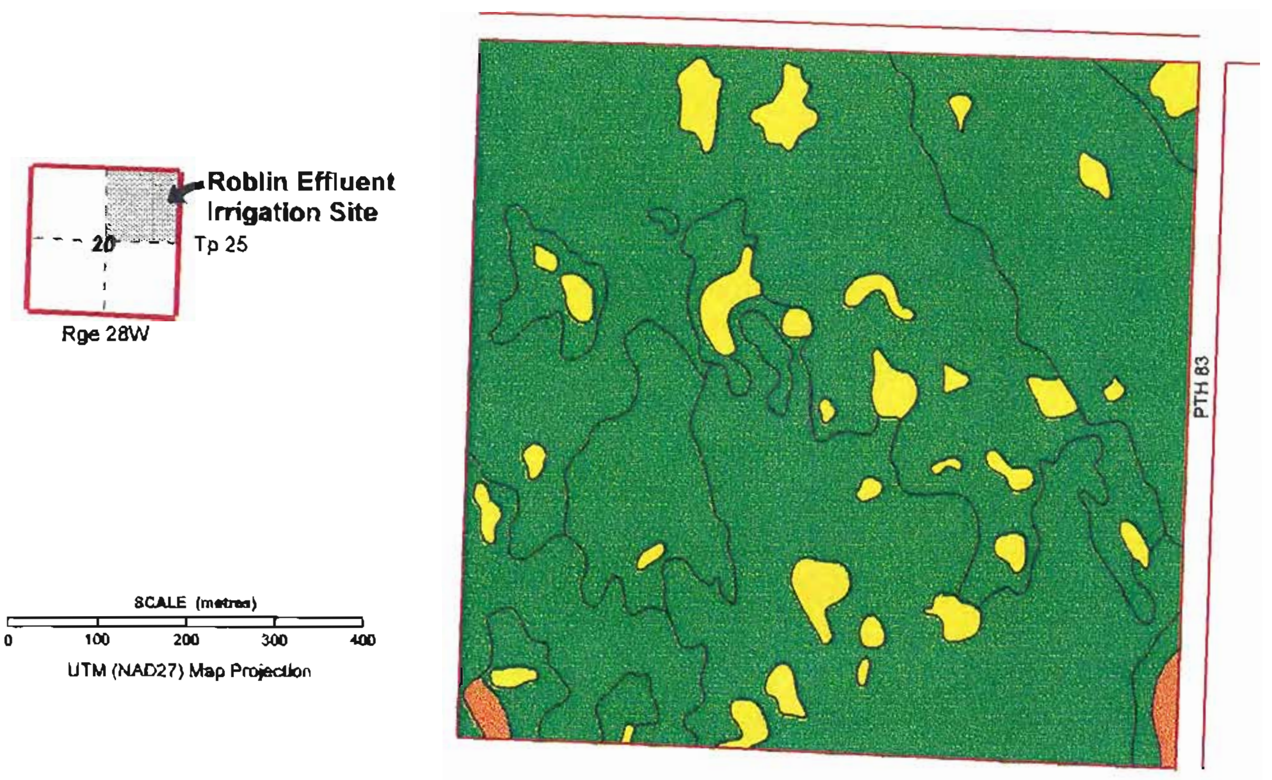


A maximum of 3 codes is used to identify the subclass rating. Geological uniformity (g) and drainability (x) are soil factors contributing to the soil rating of Class 3, Moderate. Complex topography is the limiting landscape characteristic of the area for rating irrigation suitability. As the soil factor (Class 3, Moderate) is more limiting than the landscape feature (Class B, Slight) the general rating for this land area is Fair (Table 17).

Figure 8 **Agricultural Capability**

This evaluation utilizes the 7 class Canada Land Inventory (CLI, 1965) Soil Capability for Agriculture System. Classes 1 to 3 represent land which is capable of sustained arable culture, soils in class 4 are marginal for sustained arable culture, the fifth is capable of use as improvable permanent pasture and hay, the sixth is capable of use only for native pasture while soils in class 7 are are unsuitable for arable culture or permanent pasture.

This generalized interpretive map is based on rating the dominant soil type in each map unit. The classification of the subdominant soil components and the nature of the subclass limitations are indicated in the soil report.

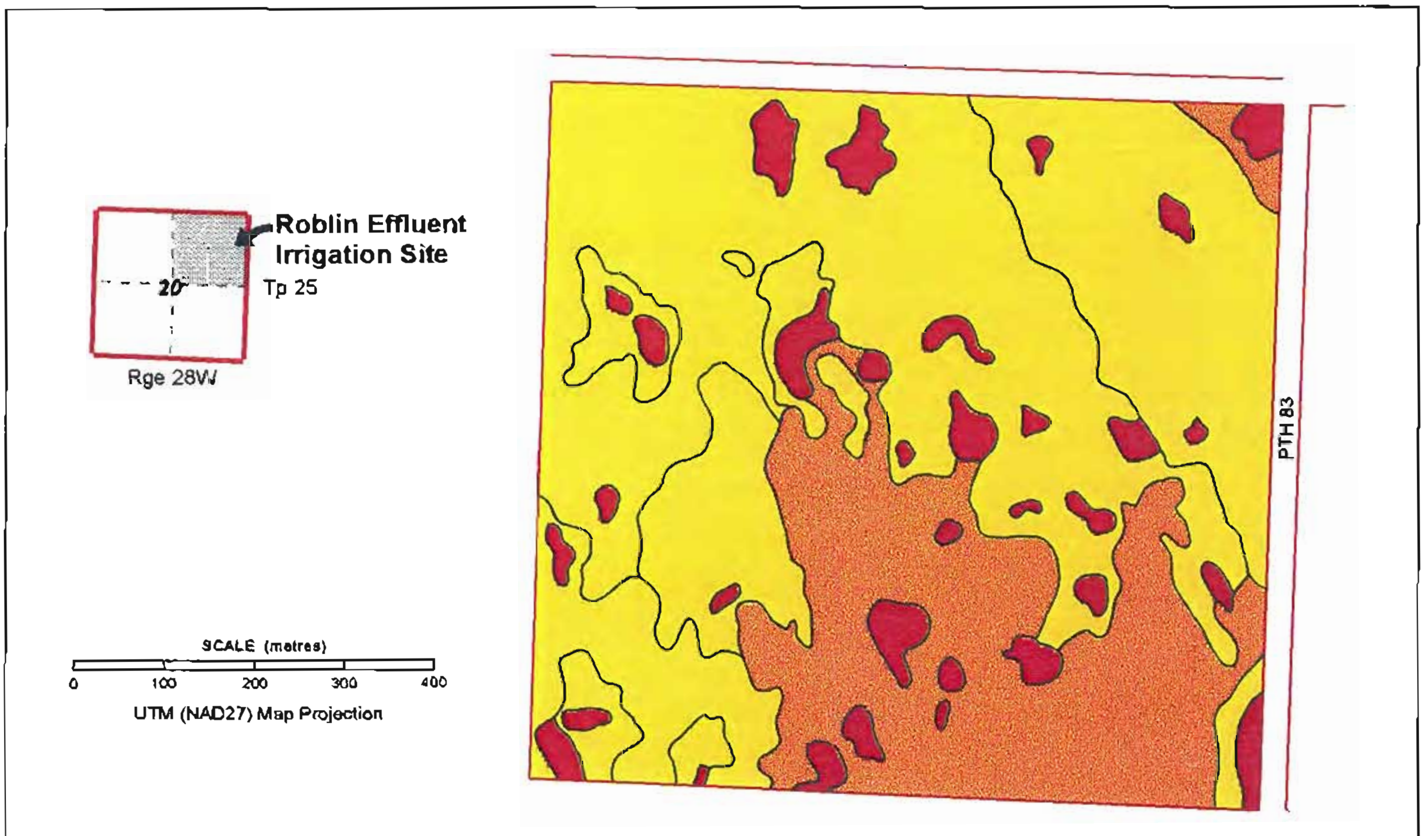


Agricutural Capability Classes	Area ha	Percent of Area	Agricutural Capability Classes	Area ha	Percent of Area
Class 1	-	-	Class 5	4.78	7.34%
Class 2	59.78	91.87%	Class 6	0.52	0.79%
Class 3	-	-	Class 7	-	-
Class 4	-	-			

Figure 9 **Irrigation Suitability**

Irrigation suitability is evaluated using a four class system: Classes are **Excellent, Good, Fair and Poor**. Irrigation ratings are based on an assessment of the most limiting combination of soil and landscape conditions. Soils and landscapes in the same class have a similar relative suitability or degree of limitation for irrigation use, although the specific limiting factors may differ.

This generalized interpretive map is based on the properties of the dominant soil type and landscape feature in each polygon. The classification of the subdominant soil and landscape components and the relevant subclass limitations are indicated in the soil report. The irrigation rating does not consider water availability, water quality or economics of irrigated land use.



Irrigation Suitability Classes		Area ha	Percent of Area
	excellent	-	-
	good	43.69	67.13%
	fair	16.09	24.74%
	poor	5.30	8.13%

An ideal soil area to be used for irrigation will have the following characteristics:

- loam texture
- uniform texture both vertically and horizontally
- uniformly well drained
- non saline
- permeable
- nearly level
- non stony

Any departure from these characteristics, ie sandy and clayey soils, presence of contrasting textural layers vertically in the soil, horizontal variation in soil texture within the landscape, imperfect and poor drainage, salinity, reduced soil permeability, undulating and hummocky topography and surface stoniness will lower the irrigation suitability. These factors may not only influence the sustainability of irrigation but can also affect the type of irrigation system that can be used and the type of management needed.

Areas with no or slight soil and/or landscape limitations are rated **Excellent** to **Good** and can usually be considered irrigable. Areas with moderate soil and/or landscape limitations are rated as **Fair** and considered marginal for irrigation providing adequate management exists so that the soil and adjacent areas are not adversely affected by water application. Soil and landscape areas rated as **Poor** have severe limitations for irrigation.

The soils on the Site range from Good to Poor in suitability for irrigation (Figure 9). Soils rated Good for irrigation occupy 36.7 hectares or 56.4% of the land area whereas soils rated as being Fair for irrigation cover 20.8 hectares or 31.9%. Soils rated as Poor suitability cover 7.6 hectares (11.7%) of the land area.

The irrigation suitability ratings in Table 12 are based largely on soil characteristics in the upper 1.2 m and the main landscape features for each soil series and phase. Limited information available to the 3 m depth was used to characterize the geological uniformity of major soil types. Following the initial ranking of irrigation suitability, a more detailed investigation may indicate that portions of the area are significantly better or poorer than the general rating indicated.

4.4.2 Environmental Impact

The environmental impact from irrigation on either the irrigated land or on "non-target", non irrigated areas and crops is an important aspect to consider prior to irrigation development. The guidelines for environmental impact assessment provide a general assessment of relative ratings a **"negligible, low, moderate and high"** (Table 22). This rating recognizes soil and/or landscape conditions which under irrigation could impact on the irrigated area as well as a "non-target" non-irrigated area. Examples of adverse environmental impact are higher water tables, more persistent soil saturation, increased soil salinity and contamination of groundwater or surface water.

Use of this rating is intended to serve as a warning of possible environmental impact but it is not part of the initial irrigation suitability classification. The evaluation of potential environmental impact has been separated from the initial irrigation suitability rating provided in the ISC system (1987) since it may be possible to design and manage the irrigation system to overcome these limitations. The irrigator must determine the nature or cause of a specific environmental concern and then give special consideration to soil-water-crop management practices that will mitigate the possibility for any adverse impact.

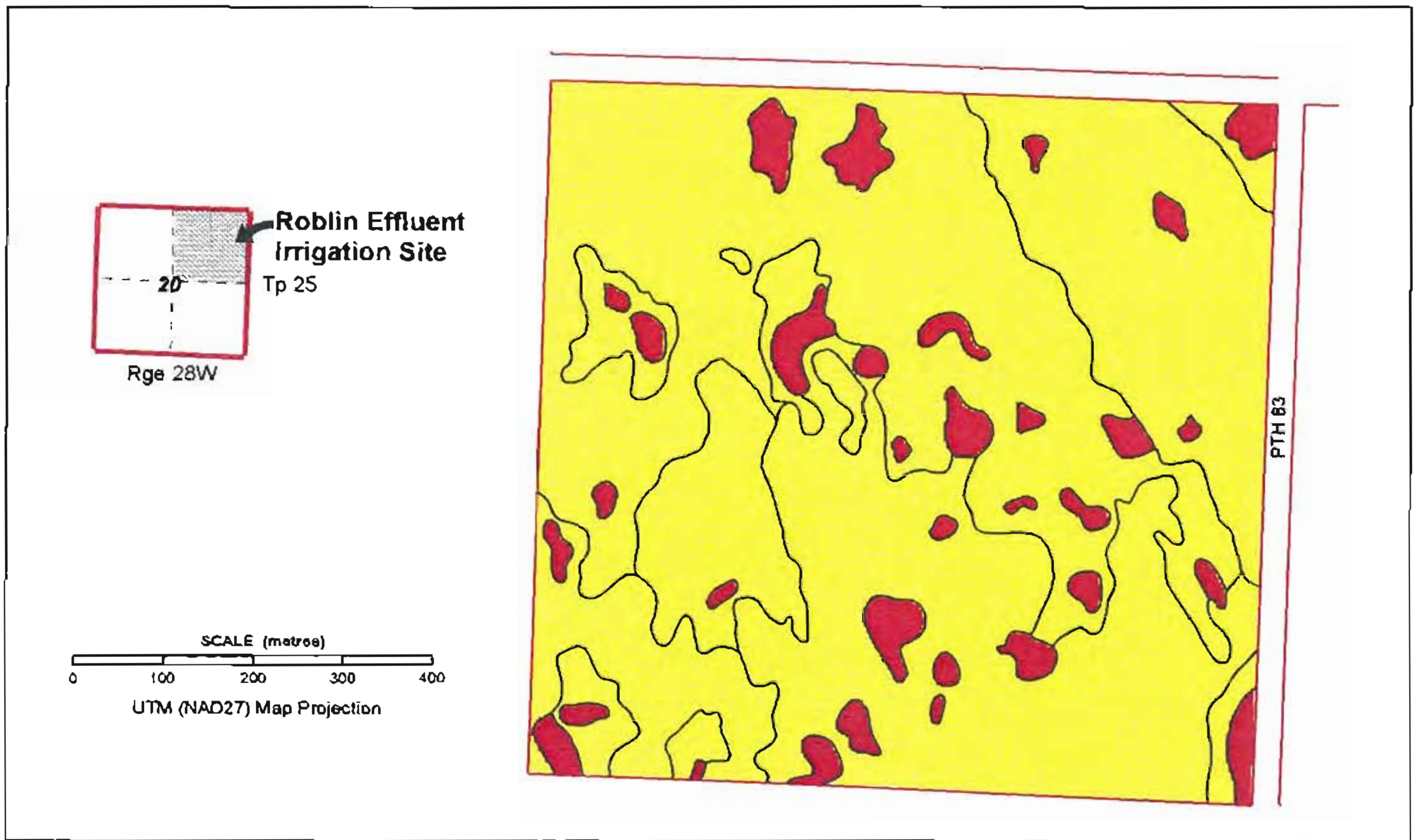
Soil factors and landscape features considered in providing a potential environmental impact evaluation are:

1. Soil Texture
2. Geological Uniformity
3. Hydraulic Conductivity
4. Depth to Water Table
5. Salinity
6. Topography

Soil characteristics and landscape features on the Site result in potential environmental impact ratings ranging from Low

Figure 10 **Potential Environmental Impact Under Irrigation**

The sensitivity or susceptibility of soils and landscapes to change resulting from irrigation should be assessed on both the irrigated land and "non target", non-irrigated areas and crops. This evaluation is intended to serve as a warning of possible change in the soil which may impact on adjacent crops or the environment. The rating provides a general assessment of relative sensitivity to change of **Negligible, Low, Moderate and High.** Examples of possible change to the environment are higher water tables, more persistent soil saturation, increased soil salinity and contamination of groundwater or surface water. Evaluation of soil and landscape sensitivity to potential environmental impact is separate from the initial irrigation suitability rating since it may be possible to design and manage the irrigation system to overcome these limitations.



Potential Impact	Area ha	Percent of Area
negligible	-	-
low	59.78	91.87%
moderate	-	-
high	5.30	8.13%

to High (Table 17 and Figure 10). Irrigation of the major area of soils on the site (59.8 hectares or 91.9%) is estimated to result in a low potential for impact on the environment. Soil and landscape conditions resulting in a High potential environmental impact cover 7.6 hectares or 11.7% of the land on the Site.

The initial evaluation of environmental impact is based on information on soil characteristics within the upper 1.2 m. Additional investigation to 3 m is required to verify the subsoil stratigraphy and to confirm the initial rating.

Three deep-drill transects to 4.5 m indicate that the stratigraphy to this depth consisted of uniform clay loam till deposits. However, five test holes on the Site indicate that well- to poorly-sorted sand and gravel occurs at depths between 2.4 to 15 metres (Figure 3). These sandy layers range from thin lenses of less than 1 m to layers in excess of 10 metres in thickness. The presence of these coarse textured layers promotes drainage and leaching and may contribute to local groundwater recharge.

4.5 SOIL SUITABILITY FOR FORAGE CROPS

Forage crops are commonly produced on a wide range of soil and landscape conditions. The best soils for production of common field crops also have the potential to produce high yields of forage crops. Soil requirements for various forage species differ so that matching soil and field conditions to those requirements is important in order to optimize forage production. Soil properties such as texture, pH, salinity, drainage and rooting depth and landscape features such as surface stoniness, topography (slope range and pattern as it influences the distribution of locally arid sites and areas affected by excess moisture in the landscape) and flood hazard are the criteria used to rate soils for production of domestic grasses and legumes. This generalized rating is modified from that used by the United States Department of Agriculture for domestic grasses and legumes for wildlife (Table 23 in Appendix A). Although this generalized rating can be applied to a range of forage species, the establishment and management of specific grass and legume crops must consider the requirements of the individual crop.

The evaluation of soils on the Effluent Irrigation Site for suitability to produce forage crops is based on soil and landscape conditions necessary for successful long term management of the forage stand. Well drained Erickson and Banks soils and imperfectly drained Tee Lake soils are rated as Good for forage production with no significant limitation. The poorly drained Roblin soils are rated Fair whereas the poorly drained Proven Lake soils are rated Poor and the very poorly drained Sinnott soils are rated Very Poor (Figure 11).

4.6 EROSION STATUS AND RISK OF EROSION

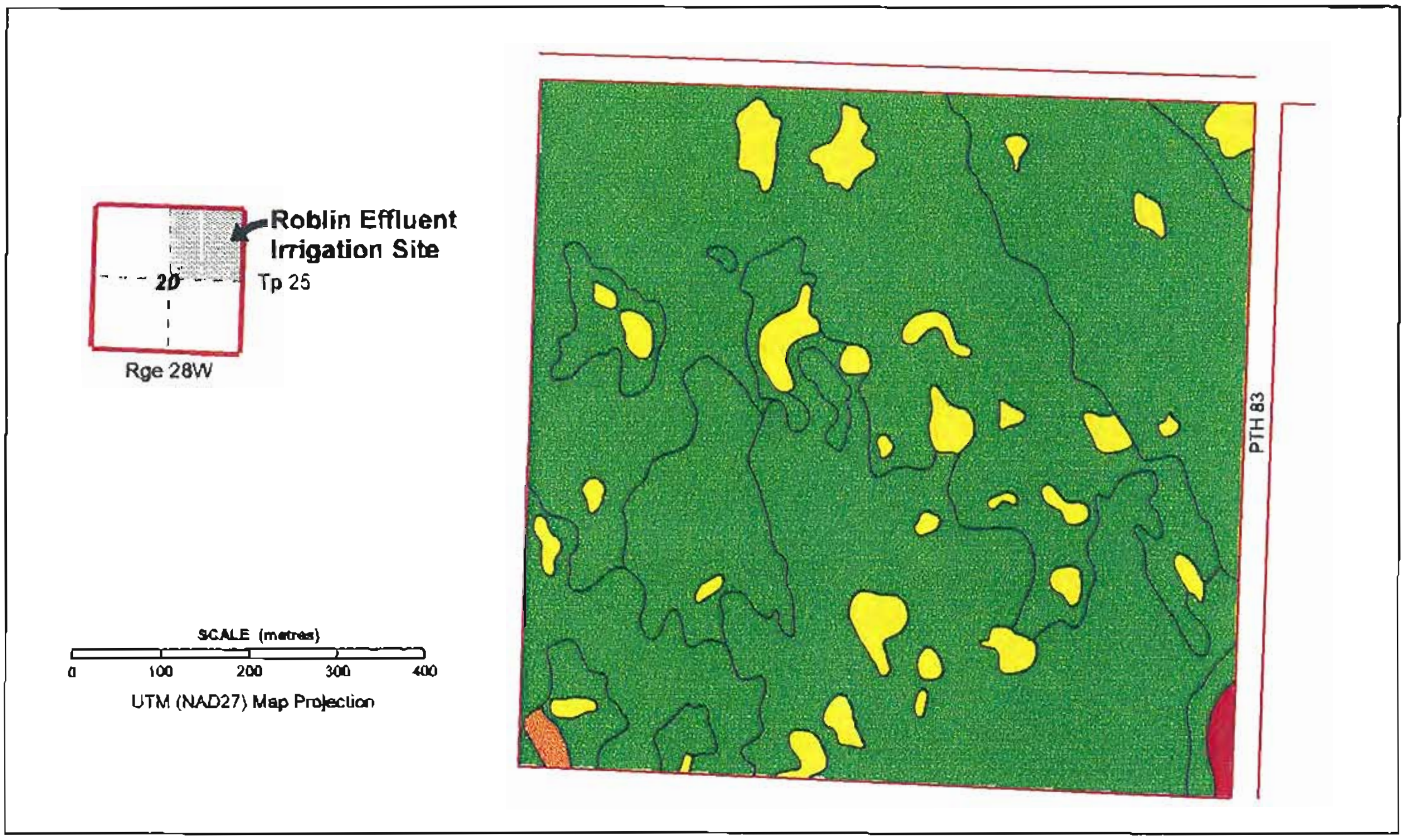
The risk of soil erosion by water is greatest in sloping landscapes and on soils in which permeability restricts infiltration and contributes to runoff of precipitation and snowmelt. The observed extent and severity of water erosion on the Effluent Irrigation Site is minimal because of the dominance of undulating and nearly level to level terrain with low local relief. Approximately 84 percent of the Site is characterized by level and nearly level topography with the remainder of the area consisting of very gently sloping terrain (Figure 2).

The risk of water erosion can be estimated using the Universal Soil Loss Equation (Wischmeier and Smith, 1965). The Universal Soil Loss Equation (USLE), **A=KRLSCP** expresses average annual soil loss as a function of rainfall erosivity (R), soil erodibility (K), length of slope (L) and slope percent (S), soil cover with vegetation and/or crop residue (C) and erosion control practices (P). Although soil and crop management practices are the only practical way to control sediment loss, the inherent susceptibility of the soil to particle detachment and transport is a major factor in the soil loss equation. Research shows that soil erosion due to rainfall and runoff may vary more than tenfold just because of basic soil differences (Wischmeier et al., 1971).

Figure 11 **Soil Suitability for Forage Crops**

This evaluation utilizes a four class system: Classes are **Good, Fair, Poor and Very Poor**. Soil properties such as texture, pH, salinity, drainage and rooting depth and landscape features such as surface stoniness, topography (slope range and pattern as it influences the distribution of locally arid sites and areas affected by excess moisture in the landscape) and flood hazard are the criteria used to rate soils for production of domestic grasses and legumes.

This generalized interpretive map is based on rating the dominant soil type in each map unit. The classification of the subdominant soil components are indicated in the soil report.



Forage Suitability Classes	Area ha	Percent of Area
good	59.78	91.87%
fair	4.78	7.34%
poor	0.22	0.34%
very poor	0.29	0.45%

Soil loss from a bare, unprotected soil surface is considered a worst case scenario. The actual erosion risk will decrease markedly according to cropping and tillage practices, type of crops grown and how residues from the previous crop are managed. Assuming that the soils on the Site are bare (without vegetation and crop residue) and that they are not under conservation practices, approximately 84 percent of the soils are at negligible risk of water erosion (potential soil loss of less than 6 tonnes/hectare/year). A low to moderate risk of water erosion resulting in potential soil loss of 6.0 to 21.9 tonnes/hectare/year is estimated for about 16% of the soils on the Site (Table 13 and Figure 12). Some 43 percent of the soils on the Site occur in depressions and on gently sloping lower positions in the landscape and are subject to potential sediment gain during water erosion events on adjacent upper slope positions. Calculated soil loss values for more steeply sloping Erickson soils in the Roblin area ranged from 5.22 T/ha on 6 percent slopes to 37.5 T/ha on a 15 percent slope (Eilers, 1983).

Soil losses due to water erosion are most likely to occur during a brief "window" of time in the spring following snowmelt. The risk is greatest following seeding and prior to germination of the crop. Soils growing low residue-producing crops such as potatoes are at much greater risk to water erosion than soils under cereal and oilseed production. Conservation measures with fall seeded cover crops, shelterbelt planting, strip cropping and crop residue management all help to protect the soil surface and reduce the potential for soil loss. The protection to the soil surface provided by crop residues results in a four to five fold reduction in estimated soil loss (Table 13).

Such estimates, however do not indicate what is tolerable soil loss and what is excessive soil loss. Annual limits of soil loss tolerance vary with individual soils and their properties. Soil loss tolerance is the maximum allowable soil loss that can occur and still maintain the long term productivity of the soil. Calculation of an annual soil loss tolerance must consider soil properties, soil depth, topography and prior erosion. The annual soil loss should recognize management concerns for the long term sustained use of the soil resource and the environment. A negligible risk of water erosion would apply to all soils on the Irrigation Site if tolerable soil loss limits were selected at the upper end of the range. If lower limits of tolerable soil-loss are selected, a low to moderate risk of water erosion would apply to a greater portion of soils on the Site. Under Manitoba conditions it is preferable to utilize the lower limits of tolerable soil-loss because the soils are frozen and snow covered for the winter period.

Table 13 Estimated Risk of Soil Loss from Water Erosion[1]

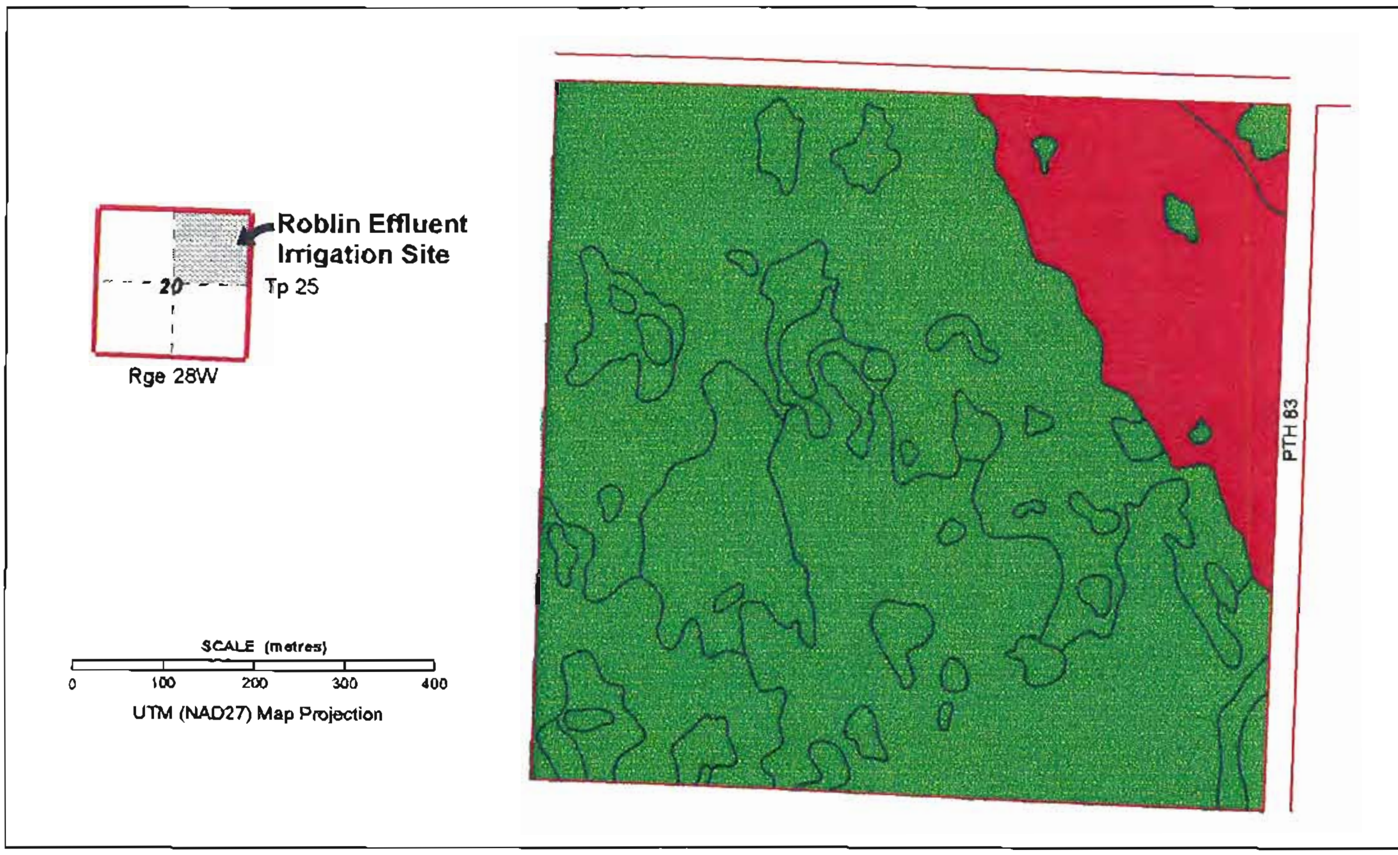
Risk Class	Topographic Class and Associated Soils	Slop characteristics		Estimated Soil Loss, T/ha/yr	
		Steepness %	Length, m	Bare Soil	Minimum Till
Negligible Potential soil loss of <6 tonnes/ha/yr)	Level to depressional Erickson, (ECK) Petlura, (PTU) Proven Lake, (PVK)	0-0.5	20-50	0-2.5	0-0.5
	Roblin, (RBN) Sinnott, (SNT)	Potential Sediment Gain			
	Undulating, nearly level Erickson, (ECK) Banks, (BAX)	0.5-2	30-50	1.9-5.0	0.4-1.0
	Petlura/xb1x	Potential Sediment Gain			
Low to Moderate (Potential soil loss of 6.0 - 21.9 tonnes/ha/yr)	Undulating to hummocky, very gently sloping: Erickson, (ECK) Petlura, (PTU)	2-5	25-50	4-14.5	0.8-2.9

[1] Risk and severity of soil loss estimated from soil-losses measured under similar topographic conditions on the Manitoba Zero Till Research Farm (Podolsky and Schindler, 1994).

Figure 12 **Risk of Water Erosion**

Water erosion is the process by which soil is moved from one area and deposited in another. Erosion occurs naturally in all landscapes but can be accelerated by human activity such as agriculture, forestry and urban development to levels that cause environmental and economic problems. Although soil and crop management practices are the only practical way to control sediment loss, the inherent susceptibility of the soil to particle detachment and transport is affected by surface soil properties such as texture, organic matter content and soil structure.

The risk of soil erosion by water is greatest in sloping landscapes and on soils in which permeability restricts infiltration and contributes to runoff of precipitation and snowmelt. Assessment of water erosion risk assumes that the soils are bare (without vegetation of crop residue) and not under conservation practices. Rainfall and runoff events during the critical spring period must be considered in assessing soil erosion risk. Cropping and tillage practices will significantly reduce this risk depending on soil type, crop rotation and soil conservation practices.



Water Erosion Risk Classes	Area ha	Percent of Area
negligible	54.96	84.45%
low to moderate	10.12	15.55%

PART 5

ENVIRONMENTAL ISSUES AND CONSIDERATIONS

5.1 INTRODUCTION

The health and quality of the soil is a major factor in sustaining the wide range of land use activities on which modern society depends for sustenance. Common environmental concerns focus on the health of the soil and water resource and its sustainable use. This section provides an evaluation of the soil resource on the Site in terms of performance or soil suitability rating for effluent irrigation and the potential impact on sustaining soil and water quality. The risk of subsoil and/or groundwater contamination is assessed and potential impact on soil properties such as pH, heavy metal status and soil structure are evaluated.

5.2 EFFLUENT IRRIGATION

Increased interest in recycling municipal wastewater on land is the result of general public awareness of growing water pollution problems (Sopper, 1979). Planning for the efficient and economical utilization of waste products is becoming an essential part of successful community management (Van Volk and Landa, 1979). Use of land to manage wastes from municipal wastewater treatment plants is an attractive alternative to their discharge into lakes and streams. Evaluation of the impact of using lagoon-treated municipal sewage effluent upon the crops, the soil and the groundwater was initially studied in the Roblin area by Penkava and Murray, (1985). Current emphasis on environmental quality applies to the recycling of potential sewage pollutants through the production of agricultural products.

5.2.1 Quality of Effluent Waters

Municipal sewage commonly is subjected to three levels of treatment; primary, consisting mainly of physical processes to remove solids; secondary, consisting of biological processes to remove most of the remaining suspended solids and organic matter; and tertiary, consisting of additional processes to achieve greater removal of materials that might pollute the receiving water course. Land application of wastewater after secondary treatment can be used to replace tertiary treatment processes. Treatment of wastewater using this approach considers the wastewater and the nutrients that it contains as a **resource** rather than as a product for treatment and disposal. Treatment of the wastewater is provided by natural biological and chemical processes as it moves through the "living filter" provided by the soil, plants, microorganisms and related ecosystems (Sopper, 1979).

The Roblin Effluent Irrigation Study (Penkava and Murray, 1985) included a monitoring component of the systems being put in place to apply treated municipal effluent as a source of irrigation for agricultural land. Results of the monitoring program during the 1982 to 1984 growing seasons indicated that use of treated sewage effluent from the Town of Roblin was not associated with any health hazards during that time.

Analysis of the treated effluent used for irrigation found that all chemical properties with the exception of Ph, chloride and manganese were within recommended admissible levels (Irrigation Water Quality Standards, Klassen, 1983). Although the electrical conductivity of the effluent was within the safe range for many crops including alfalfa, sensitive crops could be damaged.

5.2.2 Soil and Landscape Quality

The system selected for applying effluent to land should recognize inherent limitations of the soil-landscape and the objectives to be achieved in utilizing the wastewater. The effluent is applied by sprinkler irrigation to the land for treatment and for meeting the nutritional needs of vegetation. Application rates for effluent water are usually based on the nutrient and water requirements of the vegetative cover.

Suitability of a soil for disposing of municipal waste waters depends upon properties related to soil profile and landscape characteristics. Soil physical properties include texture, structure, hydraulic conductivity, infiltration rate, drainage and slope. Chemical properties include cation exchange capacity, organic matter content, exchangeable bases, heavy metal content, electrical conductivity and soil Ph. Criteria for site selection for sewage sludge and wastewater application on agricultural lands have been outlined by Hall et al., (1976).

Soil conditions (soil texture, drainage and topography) on the Effluent Irrigation Site are dominantly Good and Fair for irrigation with several local areas rated as Poor suitability (Figure 9). The potential environmental impact rating (Figure 10) assumes that high quality water is utilized for irrigation. A Negligible impact is indicated on 92 percent of the Site with a High potential for environmental impact occurring on 8 percent of the Site (areas rated as having Poor irrigation suitability in Figure 9).

5.2.3 Heavy Metals

The presence of certain heavy metals in sewage effluent and sludge is one of the major limitations to its long-term application to land. Many of these metals remain bound in the soil so that any problems that they might create in the future could be difficult to correct. Baseline characterization of the landscape and monitoring is required to identify any changes in the heavy metal status of soil and water. Predictions of the long-range effect of certain heavy metals on plants and animals consuming plants grown on soils irrigated with treated effluent may be required to insure the sustainability of the effluent management system.

Background level and distribution of heavy metal and trace element content in soils is required for evaluation of soil quality for crop growth, forage and livestock production and for the safe application of sewage sludge and effluent on agricultural land (Haluschak et al., 1994). The total heavy metal content of the Erickson and Petlura soils sampled from the Effluent Irrigation Site (Table 14) falls generally in the range obtained for Erickson soils in Manitoba (Haluschak et al., 1984) with the exception of a higher iron content and a lower content of cobalt and lead. In contrast, the Roblin soil contained lower amounts of manganese, zinc, cobalt, lead and nickel than concentrations observed for surface horizons of clay loam textured soils throughout Agro-Manitoba (Haluschak et al., 1994). The lower concentrations in the Roblin soil may result from long periods of saturation and leaching related to its location in depressions in the landscape.

Almost any element is toxic to plants when present in abnormally high concentrations. Sewage sludge and effluent often have high concentrations of some heavy metals and other elements required by plants in trace amounts. If plants accumulate the elements in high concentrations, then livestock feeding on them may be poisoned. Heavy metals and trace elements that commonly occur in sewage effluent may accumulate to toxic levels in the soil and affect plant growth and animal nutrition or move to the groundwater.

The available heavy metal content of the soils on the Site (Table 15) provides an indication of the amount of each element that is available for plant uptake. Plant available trace elements in these soils are generally adequate for good plant growth. At these concentrations, the potential for accumulation of toxic levels in the soil is minimal providing the effluent irrigation meets recommended standards for water quality.

5.3 POTENTIAL IMPACT ON SUSTAINING SOIL AND WATER QUALITY

Assessment of potential impact on sustaining soil and water quality under irrigation with treated effluent must consider the chemical and microbiological characteristics of the effluent as well as the soil-landscape properties of the area to be irrigated. Results obtained by Penkava and Murray (1985) from monitoring the impact of effluent irrigation on similar soil types in the Roblin area (SW 20-25-28W) during 1982 to 1984 indicate that soil Ph, electrical conductivity, sodium, calcium, magnesium and sodium adsorption ratio tended to increase slightly during a three year monitoring period. There was no marked increase or decrease in the concentration of manganese, copper, zinc, iron and boron. During the period of study the use of effluent irrigation was not associated with any health hazard.

Table 14 Total Minor Element Content of Soils in the Erickson Association

Horizon	Depth cm	Texture	Fe %	Mn ppm	Zn ppm	Cu ppm	Co ppm	Pb ppm	Ni ppm	Cd ppm	Mo ppm	Ag ppm	V ppm	Hg ppb	Se ppm	As ppm	Cr ppm
Erickson Series (well drained, upper slope)																	
Ap	0-15	CL	2.7	1570	76	25	12	13	27	0.2	3	0.2	96	70	0.6	-	-
CK	60-110	CL	2.9	716	71	26	15	11	33	0.1	4	0.1	106	90	0.3	9	49
Petlura Series (imperfectly drained, mid to lower slope)																	
Ap	0-15	CL	2.3	750	72	24	13	5	27	0.2	2	0.1	90	30	0.5	-	-
Ckgj	85-150	CL	2.3	535	62	23	10	7	24	0.2	5	0.2	92	80	0.3	12	55
Roblin Series (poorly drained, depressional)																	
Ap	0-18	CL	1.9	220	59	22	9	11	14	0.1	4	0.2	71	100	0.7	-	-
Ckg	65-100	L	2.2	473	50	20	10	9	21	0.1	4	0.1	90	110	0.1	8	45

Table 15 Available Minor Element Content of Soils in the Erickson Association[1]

Horizon	Depth cm	O.M. %	Fe ppm	Cu ppm	Zn ppm	B ppm	Mn ppm	SO_4-S ppm
				Benchmark 1 Site 1 (Depression)				
Ap	0-15	4.1	170	0.9	2.1	2.1	31.4	4
Ah	15-70	4.3	199	1.0	4.2	2.0	20.7	2
				Benchmark 1 Site 2 (Mid Slope)				
Ap	0-15	5.1	53	0.6	1.2	1.9	28.3	6
Bm	15-36	1.9	51	0.8	0.4	0.6	19.5	4
				Benchmark 1 Site 3 (Upper Slope)				
Ap	0-10	4.5	23	0.5	0.4	1.3	9.1	5
Ck	10-100	<1.0	32	0.9	0.2	0.9	6.4	4
				Benchmark 2 Site 1 (Depression)				
Ahe	0-43	4.7	263	0.8	3.1	2.0	24.7	4
				Benchmark 2 Site 2 (Mid Slope)				
Ap	0-10	4.5	55	0.3	1.5	2.0	21.2	4
Bm	10-15	3.5	45	0.4	1.7	2.0	16.3	4
Ckg	15-450	<1.0	34	1.3	0.4	0.5	7.5	3
				Benchmark 2 Site 3 (Upper Slope)				
Ap	0-5	4.8	40	0.5	0.8	1.8	18.0	3
Bm	5-18	4.8	43	0.7	0.8	2.1	17.6	3
Ck	18-38	<1.0	77	1.1	0.2	0.4	24.9	>20
				Benchmark 3 Site 1 (Lower Slope)				
Ap	0-25	6.3	165	0.8	2.1	2.3	8.7	5
Ae	25-33	1.0	104	0.9	0.1	1.4	5.5	4
				Benchmark 3 Site 2 (Mid to Lower Slope)				
Ap	0-8	5.4	38	0.7	0.9	2.5	5.9	8
Ae	8-20	4.5	29	0.6	0.8	1.3	5.1	5
Bt	20-25	4.7	39	0.4	1.0	1.9	4.3	5
Cg	25-69	1.0	76	2.0	0.8	3.9	1.0	7
				Benchmark 3 Site 3 (Upper Slope)				
Ap	0-5	4.9	26	0.7	0.7	2.2	9.1	12
Ae	5-10	5.1	23	0.5	0.6	2.1	8.4	6
Ck	10-38	<1.0	34	1.1	0.2	0.9	7.5	7

[1] Data from analysis of benchmark sampling by PFRA, Earth Sciences Division, June 1 and 2, 1994

5.3.1 Risk for Subsoil and/or Groundwater Contamination

The potential for infiltration and leaching to occur in a landscape is estimated in terms of **relative risk**. The possibility for leaching of chemicals and nutrients to the subsoil and groundwater should be considered in the context of proximity to a potable aquifer and the feasibility for remediation if excess chemicals accumulate in the soil environment.

Pedologic and hydrologic processes influence the degree of risk that different kinds of land use may impose on the environment. The degree of difficulty of protecting the soil and groundwater or of applying remedial measures to reclaim contaminated soil is related to these same pedologic and hydrologic processes in the landscape. Soils identified as a high risk for subsoil and/or groundwater contamination are potential sites for monitoring the impact of land use on soil and water in the environment.

The landscape on the Effluent Irrigation Site is described hydrologically as a groundwater recharge area characterized by slow downward hydraulic gradients. The sensitivity or risk for subsoil contamination by infiltration of surface waters varies with soil conditions and position in the landscape. The risk of leaching from the soil surface to depths below the rooting zone is a function of soil texture and stratigraphy of the subsoil materials. A greater degree of protection against deep leaching is provided by soils with a large water-holding capacityand slow infiltration rate increasing the time for dissolved substances in the soil water to remain near the surface where they can be utilized by vegetation and soil microorganisms.

The kind and degree of soil profile development is a function of local gradients in the landscape and the hydraulic conductivity of the soil parent material. Using the relative degree of leaching in the soil profile as an indicator of soil susceptibility to surface water infiltration, it is possible to estimate the effective area of local recharge to the groundwater. Research has shown that in loamy textured hummocky glacial landscapes, eluviated soils are the most likely sites for local groundwater recharge whereas leached and weakly leached soils are primarily sites of soil water replenishment. Moist, non-leached, salinized and carbonated profiles are typical of soils where evaporation exceeds infiltration. Based on these assumptions, the relative risk for subsoil contamination is estimated in Table 16 and the distribution of soil conditions affecting this risk is shown in Figure 13.

Level and very gently sloping positions of the landscape are characterized by little or no runoff with most of the incoming precipitation infiltrating the soil. Approximately 99 percent of the soils on

Table 16 Relative Sensitivity for Subsoil and/or Groundwater Contamination

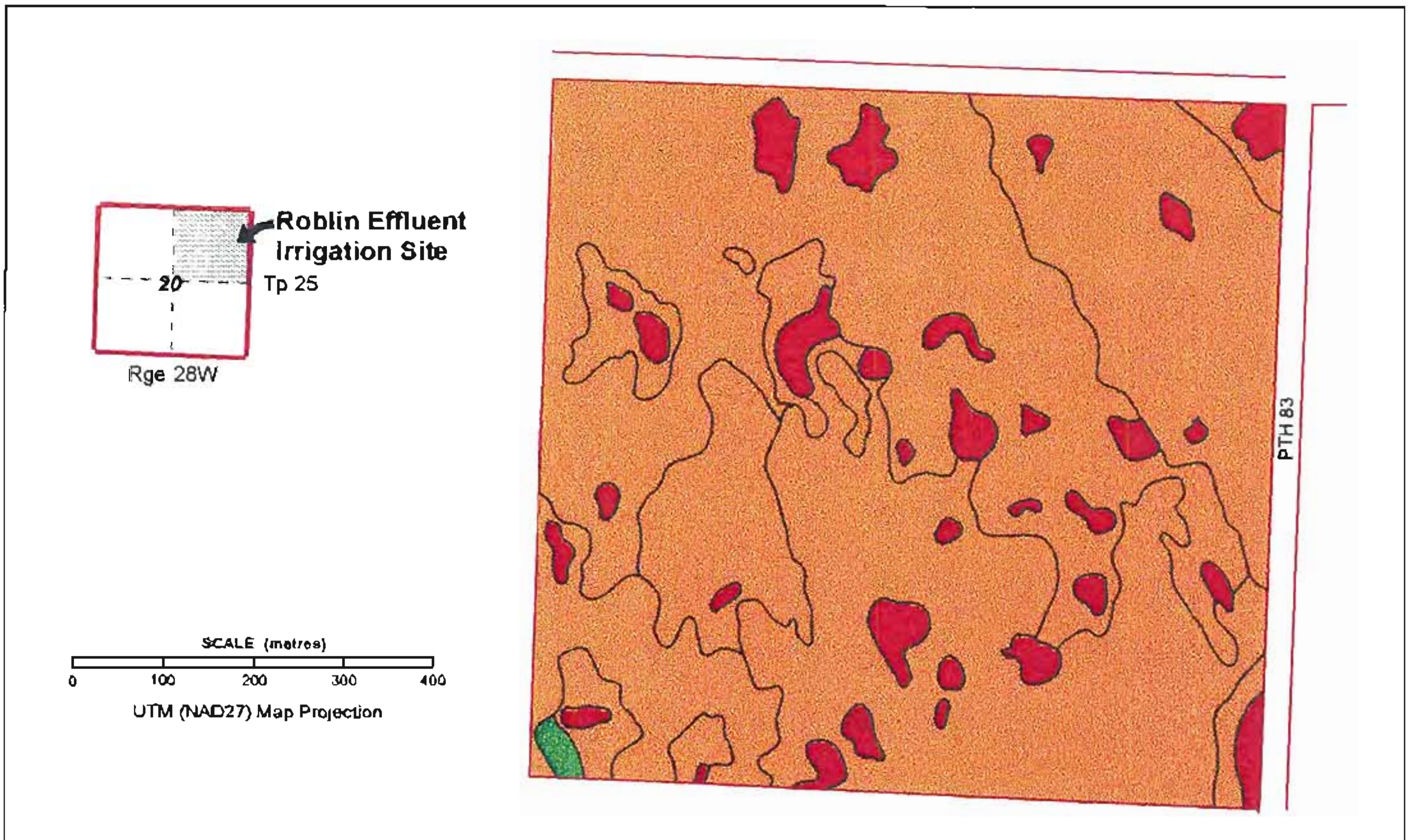
Soil Conditions and Soils	Relative Sensitivity	Areal Extent	
		Hectares	%
Leached and Eluviated soils; lower slopes and depressions: Roblin (RBN) Sinnott (SNT)	High	7.4	11.3
Moderately to weakly leached, upper slopes and knolls: Erickson (ECK), Petlura (PTU) Banks (BAX)	Moderate	57.6	88.3
Non-leached, carbonated lower slopes and depressions: Proven Lake (PVK)	Very low	0.2	0.3

Figure 13 Sensitivity for Subsoil and/or Groundwater Contamination

Evaluation of the soils ability to regulate water movement and retention in the environment must consider soil characteristics as well as regional and local hydrology.

Landscapes characterized by regional groundwater recharge have increased potential for water movement down through the soil to the groundwater. Leached soil profiles resulting from net infiltration and occurring in landscapes characterized by groundwater recharge are most sensitive to deep infiltration of water and potential for movement to the groundwater.

Because agriculture is carried out on large areas of land, often situated over groundwater aquifers, there is a risk for agrochemicals to enter the groundwater. The potential for agrochemicals (e.g., nutrients, pesticides) to enter the groundwater is greater on soil types where intensive cropping results in substantial use of chemicals and where concentrated production of livestock results in high rates of manure being applied to the soil.



Soil Sensitivity Classes	Area ha	Percent of Area
very low	0.22	0.34%
low	-	-
moderate	59.77	91.86%
high	5.07	7.80%

the Site are characterized by net infiltration of water. A moderate risk of infiltration occurs on knolls and mid to upper slopes characterized by the well drained Erickson soils and level to very gently sloping areas characterized by the imperfectly drained Petlura soils. Non-leached and carbonated soils in lower slopes around depressions characterized by Sinnott soils and Proven Lake soils represent a relatively low risk for infiltration to occur to the subsoil.

Portions of the landscape where carbonates are removed to lower depths indicate a greater potential for leaching to occur. Accumulation of excess water in the depressions occupied by the Roblin soils and the Sinnott soils results in greater leaching potential. Leached soils in these depressions occupy 7.1 ha or 10.9 percent of the area and present the highest risk for infiltration of chemical and/or nutrients to the subsoil and the groundwater.

5.3.2 Soil Suitability for Effluent Irrigation

Evaluation of soil suitability for effluent irrigation must consider the overall suitability for irrigation (Figure 9) as well as the potential for adverse environmental impact resulting from irrigation (Figure 10). Such impact assessment commonly includes the potential for change to the environment such as high water tables, more persistent soil saturation, increased salinity and contamination of groundwater or surface water. Soils rated Good for irrigation (Erickson soils) and Fair for irrigation (Petlura soils) generally experience Negligible impact from good irrigation management. In contrast, the Roblin soils on the Site have Poor suitability for irrigation and also have a High potential impact on the environment. The Roblin soils are also rated as having a High relative risk for subsoil and groundwater contamination (Table 16).

If deep percolation of irrigation effluent occurs, it is most likely to take place through the Roblin soils due to their location in depressional portions of the landscape and their high leaching potential. In addition, because they are focal points for hydrologic activity in the landscape, they also have a High relative risk for contamination of the subsoil and/or groundwater. Although the Roblin soils occupy only about 11 percent of the area, their distribution in small, localized depressions throughout the landscape may affect the sustainability of long-term effluent irrigation for the entire Site.

5.3.3 Potential Impacts: Beneficial and Degradative

Land application of municipal waste water can result in multiple benefits provided there are not adverse impacts resulting from the effluent quality or from the soil-landscape conditions. Wastewater can provide the necessary moisture and plant nutrients to help maximize crop production. At the same time the soil-plant-microorganism ecosystem can adequately accept these waste products and alter them to an environmentally acceptable state.

The natural moisture status of the soils on the Site and the potential for surface ponding and saturation of the subsoil are key factors affecting the sustainability of effluent irrigation. Water in excess of field capacity, whether derived from precipitation or irrigation of effluent or a combination of the two will result in surface ponding. The frequency of occurrence of surface ponding on the Roblin soils is increased under irrigation. Surface ponding can restrict the growth of the agricultural crop, reduce trafficability and result in deep percolation of excess surface water into the subsoil and potentially to an underlying aquifer.

The potential for salinization exists where the salt content of the effluent is high. Reduced crop yield may result in portions of the landscape where a buildup of salt occurs. This may occur over time in the lower slope areas adjacent to the strongly leached Roblin soils.

Criteria for crop selection and management for effluent irrigation have been described by Sopper (1979). The "living filter" concept of land application of wastewater has potential to provide for the sustained uptake and removal of nutrients in the wastewater.

5.4 MONITORING OF SOIL AND WATER QUALITY

In almost all cases, the application of waste water to land will result in some changes in the characteristics of the soil. Consequently, some level of monitoring is recommended to insure the sustainability of the effluent management system.

Initially, an annual sampling should be maintained to obtain baseline levels of key soil properties. Soil characteristics commonly monitored are salinity, pH and potential toxic metal concentrations. Elements which can be toxic to plants and the animals consuming the plants should be monitored. These include heavy metals and trace elements required for plant growth but which are toxic in excess amounts such as selenium (Se), arsenic (As), nickel (Ni), lead (Pb), cadmium (Cd), chromium (Cr), mercury (Hg), silver (Ag), iron (Fe), manganese (Mn), cobalt (Co), and vanadium (V).

Monitoring on the Site should also study the buildup of soil salinity. The effluent has elevated levels of both sodium and chloride. Ponded irrigation water that occurs in depressional areas of the landscape could contribute to a buildup in salinity. However, as the Roblin soils in these sites are leached, the salinity may move through the soil without affecting the soil or vegetation.

Evaluation of the soils on the Site indicates that the majority of the area provides the soil conditions required for the sustainable application of treated municipal sewage effluent (Table 16). Poorly drained soils occupying low-lying depressions in the landscape are deeply leached and constitute a potential hazard for movement of dissolved nutrients and other constituents in the sewage effluent to the subsoil and/or the groundwater (Figure 13).

The importance of continuous and thorough monitoring practices cannot be overemphasized. Guidelines for agricultural irrigation using treated municipal wastewater should be followed (Technical Advisory Committee, 1990). Monitoring guidelines recommend scheduled testing of soil conditions and wastewater quality. In addition, water quality in water wells in or adjacent to an irrigation area should be analyzed for the same parameters as the wastewater.

APPENDIX A

GUIDES FOR EVALUATING AGRICULTURAL CAPABILITY,

IRRIGATION SUITABILITY,

SOIL SUITABILITY FOR GRASSES AND LEGUMES

Table 17 Description of the Agricultural Capability Classes

Class 1

Soils in this class have no important limitations for crop use. The soils have level or gently sloping topography; they are deep, well to imperfectly drained and have moderate water holding capacity. The soils are naturally well supplied with plant nutrients, easily maintained in good tilth and fertility; soils are moderately high to high in productivity for a wide range of cereal and special crops.

Class 2

Soils in this class have moderate limitations that reduce the choice of crops or require moderate conservation practices. The soils have good water holding capacity and are either naturally well supplied with plant nutrients or are highly responsive to inputs of fertilizer. They are moderate to high in productivity for a fairly wide range of crops. The limitations are not severe and good soil management and cropping practices can be applied without serious difficulty.

Class 3

Soils in this class have moderate limitations that restrict the range of crops or require moderate conservation practices. The limitations in Class 3 are more severe than those in Class 2 and conservation practices are more difficult to apply and maintain. The limitations affect the timing and ease of tillage, planting and harvesting, the choice of crops and maintenance of conservation practices. The limitations include one or more of the following: moderate climatic limitation, erosion, structure or permeability, low fertility, topography, overflow, wetness, low water holding capacity or slowness in release of water to plants, stoniness and depth of soil to consolidated bedrock. Under good management, these soils are fair to moderately high in productivity for a fairly wide range of field crops.

Class 4

Soils in this class have severe limitations that restrict the choice of crops or require special conservation practices or both. These soils have such limitations that they are only suited for a few crops, or the yield for a range of crops may be low, or the risk of crop failure is high. The limitations may seriously affect such farm practices as the timing and ease of tillage, planting and harvesting, and the application and maintenance of conservation practices. These soils are low to medium in productivity for a narrow range of crops but may have higher productivity for a specially adapted crop. The limitations include the adverse effects of one or more of the following: climate, accumulative undesirable soil characteristics, low fertility, deficiencies in the storage capacity or release of soil moisture to plants, structure or permeability, salinity, erosion, topography, overflow, wetness, stoniness, and depth of soil to consolidated bedrock.

Class 5

Soils in this class have very severe limitations that restrict their capability to producing perennial forage crops, and improvement practices are feasible. These soils have such serious soil, climatic or other limitations that they are not capable of use for sustained production of annual field crops. However, they may be improved by the use of farm machinery for the production of native or tame species of perennial forage plants. Feasible improvement practices include clearing of bush, cultivation, seeding, fertilizing and water control.

Some soils in Class 5 can be used for cultivated field crops provided unusually intensive management is used. Some of these soils are also adapted to special crops requiring soil conditions unlike those needed by the common crops.

Class 6

Soils in this class are capable only of producing perennial forage crops and improvement practices are not feasible. Class 6 soils have some natural sustained grazing capacity for farm animals, but have such serious soil, climatic or other limitations as to make impractical the application of improvement practices that can be carried out on Class 5 soils. Soils may be placed in this class because their physical nature prevents the use of farm machinery, or because the soils are not responsive to improvement practices, or because stock watering facilities are inadequate.

Class 7

Soils in this class have no capability for arable culture or permanent pasture because of extremely severe limitations. Bodies of water too small to delineate on the map are included in this class. These soils may or may not have a high capability for forestry, wildlife and recreation.

Table 18 Agricultural Capability Subclass Limitations

C - **Adverse climate**: This subclass denotes a significant adverse climate for crop production as compared to the "median" climate which is defined as one with sufficiently high growing season temperatures to bring field crops to maturity, and with sufficient precipitation to permit crops to be grown each year on the same land without a serious risk of partial or total crop failures.

D - **Undesirable soil structure and/or low permeability**: This subclass is used for soils difficult to till, or which absorb water very slowly or in which the depth of rooting zone is restricted by conditions other than a high water table or consolidated bedrock.

E - **Erosion**: Subclass E includes soils where damage from erosion is a limitation to agricultural use. Damage is assessed on the loss of productivity and on the difficulties in farming land with gullies.

F - **Low fertility**: This subclass is made up of soils having low fertility that either is correctable with careful management in the use of fertilizers and soil amendments or is difficult to correct in a feasible way. The limitation may be due to lack of available plant nutrients, high acidity or alkalinity, low exchange capacity, high levels of carbonates or presence of toxic compounds.

I - **Inundation by streams or lakes**: This subclass includes soils subjected to inundation causing crop damage or restricting agricultural use.

L - **Coarse wood fragments**: In the rating of organic soils, woody inclusions in the form of trunks, stumps and branches (> 10 cm diameter) in sufficient quantity to significantly hinder tillage, planting and harvesting operations.

M - **Moisture limitation**: This subclass consists of soils where crops are adversely affected by doughtiness owing to inherent soil characteristics. They are usually soils with low water-holding capacity.

N - **Salinity**: Designates soils which are adversely affected by the presence of soluble salts.

P - **Stoniness**: This subclass is made up of soils sufficiently stony to significantly hinder tillage, planting, and harvesting operations. Stony soils are usually less productive than comparable non-stony soils.

R - **Consolidated bedrock**: This subclass includes soils where the presence of bedrock near the surface restricts their agricultural use. Consolidated bedrock at depths greater than 1 meter from the surface is not considered as a limitation, except on irrigated lands where a greater depth of soil is desirable.

T - **Topography**: This subclass is made up of soils where topography is a limitation. Both the percent of slope and the pattern or frequency of slopes in different directions are important factors in increasing the cost of farming over that of smooth land, in decreasing the uniformity of growth and maturity of crops, and in increasing the hazard of water erosion.

W - **Excess water**: Subclass W is made up of soils where excess water other than that brought about by inundation is a limitation to their use for agriculture. Excess water may result from inadequate soil drainage, a high water table, seepage or runoff from surrounding areas.

X - **Cumulative minor adverse characteristics**: This subclass is made up of soils having a moderate limitation caused by the cumulative effect of two or more adverse characteristics which singly are not serious enough to affect the class rating.

Table 19 Description of Irrigation Suitability Classes

General Rating	Class	Degree of Limitation	Description
Excellent	1A	No soil or landscape limitations	These soils are medium textured, well drained and hold adequate available moisture. Topography is level to nearly level. Gravity irrigation methods may be feasible.
Good	2A 2B 1B	Slight soil and/or landscape limitations	The range of crops that can be grown may be limited. as well, higher development inputs and management skills are required. Sprinkler irrigation is usually the only feasible method of water application.
Fair	3A 3B 3C 1C 2C	Moderate soil and/ or landscape limitations	Limitations reduce the range of crops that may be grown and increase development and improvement costs. Management may include special conservation techniques to minimize soil erosion, limit salt movement, limit water table build-up or flooding of depressional areas. Sprinkler irrigation is usually the only feasible method of water application.
Poor	4A 4B 4C 4D 1D 2D 3D	Severe soil and/ or landscape limitations	Limitations generally result in a soil that is unsuitable for sustained irrigation. Some lands may have limited potential when special crops, irrigation systems, and soil and water conservation techniques are used.

Table 20 Soil Features Affecting Irrigation Suitability

Symbol	Soil Feature	Degree of Limitation			
		None(1)	Slight(2)	Moderate(3)	Severe(4)
d	Structure	Granular, Single Grained, Prismatic, Blocky, Subangular Blocky	Columnar Platy	Massive	Massive
k	Ksat (mm/hr) (0 - 1.2m)	>50	50 - 15	15 - 1.5	<1.5
x	Drainability (1.2 - 3m) (mm/hr)	>15	5 - 15	0.5 - 5	<0.5
m	AWHC subhumid mm/1.2m (% vol.) subarid	>120 (>10) >150 (>12)	120 - 100 (8 - 10) 120 - 150 (12 - 10)	100 - 75 (6 - 8) 100 -120 (10 - 8)	<75 (<6) <100 (<8)
q	Intake Rate (mm/hr)	>15	1.5 - 15	1.5 - 15	<1.5
s	Salinity depth(m) (dS/m) 0 - .6 .6 - 1.2 1.2 - 3	<2 <4 <8	2 - 4 4 - 8 8 - 16	4 - 8 8 - 16 >16	>8 >16 >16
n	Sodicity (m) (SAR) 0 - 1.2 1.2 - 3	<6 <6	6 - 9 6 - 9	9 - 12 9 - 12	>12 >12
g	Geological 0 - 1.2m Uniformity 1.2 - 3m	1 Textural Group 2 Textural Groups	2 Textural Groups, Coarser Below 3 Textural Groups Coarser Below	2 Textural Groups Finer Below 3 Textural Groups Coarser Below 3 Textural Groups Finer Below	3 Textural Groups Finer Below
r	Depth to Bedrock (m)	>3	3 - 2	2 - 1	<1
h	Depth to Watertable (m)	>2	2 - 1.2 (if salinity is a problem)	2 - 1.2 (if salinity is a problem)	<1.2
w	Drainage Class	Well, Moderately Well, Rapid, Excessive	Imperfect	Imperfect	Poor, Very Poor
	*Texture (Classes) 0 - 1.2m	L, SiL, VFSL, FSL	CL, SiCL, SCL, FSCL, SL, LVFS	C, SC, SiC VFS, LS, CoSL	HvC GR, CoS, LCoS, S
	*Organic Matter %	>2	1 - 2	1 - 2	<1
	*Surface Crusting Potential	Slight	Low	Low	Moderate

* Other important factors used to interpret type and degree of limitation but which do not present a limitation to irrigation themselves. No symbol is proposed for these factors since they will not be identified as subclass limitations.

Table 21 Landscape Features Affecting Irrigation Suitability

Symbol	Landscape Features	Degree of Limitation			
		None (A)	Slight (B)	Moderate (C)	Severe (D)
t1	Slope - Simple %	<2	2 - 10	10 - 20	>20
t2	- Complex %	<5		5 - 15	>15
e	Relief m (Average Local)	<1	1 - 3	3 - 5	>5
p	Stoniness -Classes -Cover (%)	0, 1 & 2 (0-3%)	3 (3-15%)	4 (15-50%)	5 (>50)
i	Inundation -Frequency of Flooding (period)	1:10 (yr)	1:5 (yr)	1:1 (annual-spring)	1:<1 (seasonal)

Table 22 Soil and Landscape Conditions Affecting Environmental Impact Rating

Soil Property and Landscape Feature	Potential Degree of Impact			
	Negligible	Low	Moderate	High
Textural Groups[1] (Classes[2]) Surface Strata (1.2 m)	MF (SCL,CL,SiCL) F (SC,SiC,C)	M (Si,VFSL,L,SiL)	MCo (CoSL,SL, FSL,VFS, LVFS)	VCo (VCoS,CoS); Co (LCoS,LS, FS,LFS)
Geological Uniformity Weighted textural groupings[3] Surface Strata (1.2 m) / Substrata (1.2-3.0 m)	MF to VF / M to VF; M / MF to VF	MF / MCo to Co; F / Co; MCo to Co / MF to VF	M / MCo to Co; Co / M; MF / VCo	VCo to Co / VCo to Co; MCo / Co to VCo; Co / VCo to MCo; M / VCo
Hydraulic Cond Ksat (mm/hr)	< 1.5	1.5 - 15	15 - 50	>50
Depth to Water Table (m)	> 2 m	(2 m --------------------- 1 m)		<1 m
Salinity (dS/m)	0 - 4	4 - 8	8 - 15	>15
Topography (% Slope)	0 - 2	2 - 5	5 - 9	> 9

[1]Textural Groups: VF=Very Fine, F=Fine, MF=Moderately Fine, M=Medium, MCo=Moderately Coarse, Co=Coarse, VCo=Very Coarse

[2]Texture Classes:

Very Coarse - VCo
- VCoS -Very Coarse Sand
- CoS -Coarse Sand
- S -Sand

Coarse - Co
- LCoS -Loamy Coarse Sand
- LS -Loamy Sand
- FS -Fine Sand
- LFS -Loamy Fine Sand

Moderately Coarse - MCo
- CoSL -Coarse Sandy Loam
- SL -Sandy Loam
- FSL -Fine Sandy Loam
- VFS -Very Fine Sand
- LVFS -Loamy Very Fine Sand

Medium - M
- Si -Silt
- VFSL -Very Fine Sandy Loam
- L -Loam
- SiL -Silt Loam

Moderately Fine - MF
- SCL -Sandy Clay Loam
- SiCL -Silty Clay Loam
- CL -Clay Loam

Fine - F
- SC -Sandy Clay
- SiC -Silty Clay
- C -Clay

Very Fine - VF
- HC -Heavy Clay

[3]Slash indicates surface strata (1.2 m) overlying substrata (1.2-3.0 m), ie: MF to VF / M to VF

Notes for Table 22

1. Guidelines developed for making this impact rating employ four relative degrees of risk of degradation: **None, Low, Moderate and High.** This rating is not part of the irrigation suitability classification, but rather is intended to serve as a warning of possible adverse impact on the soil, adjacent crops or the environment. Since all situations cannot be completely covered by general guidelines, an on-site inspection is recommended for the evaluation of potential adverse environmental impact.

2. A major concern for land under irrigation is the possibility of adverse impact on the groundwater and surface water quality in and adjacent to the irrigated area. The soil factors selected for impact evaluation include those properties that determine water retention and movement through the soil and topographic characteristics that affect runoff and redistribution of moisture in the landscape. The risk of altering the soil drainage regime and soil salinity or the potential for runoff, erosion or flooding is determined by the detailed criteria for each property. Soil factors and landscape features considered in determining an environmental impact evaluation are:

    1. Soil Texture
    2. Geological Uniformity
    3. Hydraulic Conductivity
    4. Depth to Water Table
    5. Salinity
    6. Topography

3. **Soil texture** and the **thickness and uniformity of geological deposits** (assessed by weighing textures in surface strata and subsurface strata) combine to affect the soil's water holding capacity and **hydraulic conductivity** (ability to transmit water and leachate either vertically or laterally in the soil). The presence and sequence of strongly contrasting soil textures within 3 m of the surface (**geological uniformity**) are used to determine the potential for downward movement (moderately coarse to fine materials underlain by coarse materials) or lateral movement (very coarse and coarse materials underlain by fine materials) of water and leachate. Uniform, highly permeable materials with low water holding capacity present the highest potential for adverse impact on groundwater quality. Uniform materials of low permeability provide the best buffer against impact on groundwater quality.

    A shallow **depth (< 1 m) to water table** has a higher risk for contamination than soils with a deep water table. Soils with high levels of **salinity** may adversely impact on groundwater quality due to the leaching associated with irrigation practices (ie: applied leaching fraction).

    Topographic patterns with slopes in excess of 2 percent require special consideration for soil and water management to reduce the potential for runoff and erosion. The risk of runoff and potential for local flooding, build-up of water tables and soil erosion increases with slope gradient. Soil erosion results in loss of topsoil and transport of nutrients and pesticides to non-target areas.

Table 23 Guide for rating soil suitability for domestic grasses and legumes

This guide applies to soils to be used for production of domestic perennial grasses and legumes planted for forage, pasture and soil amendment crops. Soil properties and landscape conditions that affect stand establishment, renovation and long term maintenance and sustainability are required.

G - Good: Soil conditions are favourable for establishing a wide variety of climatically adapted species and for maintaining adequate stands with good growth rates.

F - Fair: Soil conditions are suitable for establishing a wide variety of climatically adapted species, but require good management to maintain adequate stands with good growth rates.

P - Poor: Soil conditions include severe limitations that make renovation difficult or that may limit successful establishment to a few species.

V - Very Poor: Soil conditions preclude the establishment of any but very sparse stands, or make seeding, fertilization or renovation impossible or impractical.

Symbol[1]	Property Affecting Use	Degree of Soil Suitability			
		Good - G	Fair - F	Poor - P	Very Poor - V
w	Wetness[2]	Well, moderately well and imperfect drained soils with no ponding	Poorly drained Rapidly drained	Very poorly drained, Very rapidly drained	---
s	Soil Texture (surface layers)[2 3]	SL, FSL, VFSL, L, SiL, SiCL, SCL, CL	LS, LFS, SiC, C, SC	S, FGr, Peat	—
m	Available water capacity to 1m[4]	>15 cm and/or moderate rainfall and/or moderate evapotranspiration	7.5 - 15 cm and/or moderate rainfall and/or moderate evapotranspiration	<7.5 cm and/or low rainfall and/or high evapotranspiration	—
d	Thickness of soil (useful to crops)	over 50 cm	over 50 cm	25-50 cm	<25 cm
i	Flooding	None to occasional (none to 1 in 10 years)	Frequent (1 in 5 years)	Very frequent (1 in 3 years) Grazing >10 weeks	Very frequent (1 in 3 years) Grazing 5 to 10 weeks
p	Surface Stoniness[2]	None to slight	Moderately stony	Very stony	Exceedingly and excessively stony
t	Slope	0-15%	15-35%	>35%	---
n	Salinity	non saline to slightly saline (<4d S/m)	Moderately saline (5 - 10 dS/m)	Very saline (11-15 dS/m)	Extremely saline (>16 dS/m)

1 The symbols are used to indicate the nature of the limitation

2 See also definitions for texture, stoniness and soil drainage classes in the Manual for Describing Soils in the Field (Canada Soil Survey Committee, 1982).

3 Surface soil texture influences soil rating as it affects water holding capacity and seedbed preparation.

4 This property evaluates the adaquacy of moisture for vegetative growth. It incorparates the concept of supply through rainfall, less through evapotranspiration and storage within the rooting zone. In soils where the water table is within rooting depth for a significant portion of the year, water storage capacity may not significantly influence vegetative growth.

APPENDIX B

SOIL ANALYTICAL DATA

Table 24 (1 of 2) Soil Analytical Data by Site Number

Site Number	Soil Code/Var*	Horizon	Depth (cm)	VCS %	CS %	MS %	FS %	VFS %	Total Sand %	Total Silt %	Total Clay %	Organic Carbon %	pH	CaCO3 Equiv. %	Elec. Cond. (mS/cm)	% Water at Saturation
2	PTU	Ap	0- 14	2	4	11	9	10	36	34	30	4.43	6.8		0.5	55.9
		Ck	55-120	2	5	12	13	10	42	33	25	0.21	8.0	19.5	0.8	41.9
4	RBN	Ap	0- 18	2	3	8	8	9	30	42	28	6.08	6.0		0.4	76.9
		Ckg	65-100	3	5	13	13	11	45	31	24	0.15	7.6	17.4	0.4	40.7
6	ECK	Ap	0- 15	2	4	16	10	9	41	29	30	2.55	7.5		0.4	47.8
		Ck1	40-120	1	2	7	8	7	25	39	36	0.31	8.1	24.0	1.0	52.9
		Ck2	120-200	2	3	13	9	12	40	36	24	0.12	8.0	16.4	0.7	42.9
8	ECK	Ap	0- 15	1	3	7	9	11	31	37	32	3.58	6.9		0.4	53.9
		Ck1	60-110	4	4	9	8	10	35	33	32	0.34	8.1	18.4	0.3	45.8
		Ck2	110-200	3	5	11	13	11	43	32	25	0.19	7.9	16.9	0.4	42.5
10	PTUc	Ap	0- 15	3	5	13	10	11	42	26	32	3.18	7.5		0.3	52.1
		Ckgj3	85-150	3	5	11	13	8	40	32	28	0.17	8.0	18.6	0.5	45.3
13	ECK	Ap	0- 20	2	4	12	9	11	38	31	31	4.65	7.2		0.3	49.9
		Ck	75-150	3	4	10	13	10	40	32	28	0.20	7.8	15.4	0.4	44.2
14	PTUc	Ap	0- 20	2	4	11	10	12	39	31	30	4.47	7.3		0.4	54.0
		Ckg3	60-130	1	2	5	8	13	29	37	34	0.19	7.9	17.7	0.2	59.8
16	BAX	Ap	0- 20	2	4	12	11	10	39	32	29	4.52	6.6		0.2	48.8
		Ck	70-120	0	1	5	8	13	27	45	28	0.46	7.9	21.2	0.2	46.4
		2Ck	120 160	4	5	14	13	14	50	29	21	0.11	7.9	19.9	0.2	41.1
18	ECK	Ap	0- 10	2	5	11	12	10	40	31	29	37.40	6.5		0.4	50.2
		Ck	25-100	5	7	13	11	9	45	29	26	0.21	7.9	22.3	0.3	41.3
20	ECK	Ap	0- 12	3	5	13	11	13	45	28	27	2.78	6 8		0.5	44.2
		Ck	25-100	3	5	14	11	10	43	32	25	0.47	8.0	18.3	0.2	41.0
22	ECK	Ap	0- 12	2	4	11	13	10	40	34	26	4.32	5.9		0.4	50.3
		Ck1	80-150	4	6	16	11	10	47	29	24	0.17	7.8	19.5	0.3	38.8
		Ck2	150-200	3	5	11	11	9	39	34	27	0.12	7.7	15.4	0.3	42.0

* c = Classification variant
x = parent material and classification variant

Table 24 (2 of 2) Soil Analytical Data by Site Number

Site Number	Soil Code/Var*	Horizon	Depth (cm)	VCS %	CS %	MS %	FS %	VFS %	Total Sand %	Total Silt %	Total Clay %	Organic Carbon %	pH	CaCO3 Equiv. %	Elec. Cond. (mS/cm)	% Water at Saturation
24	BAX	Ap	0- 20	2	3	9	8	10	32	40	28	4.29	6.0		0.5	52.1
		Ck	65- 75	0	1	2	4	17	24	46	30	0.49	7.5	14.7	0.4	46.4
		2Ck	75-150	2	3	7	7	10	29	34	37	0.32	7.7	16.0	0.2	50.9
		2Ck2	150-160	3	4	11	10	10	38	33	29	0.43	7.8	15.1	0.3	42.9
26	PVKx	Ap	0- 18	3	5	10	8	11	37	42	21	2.73	5.6		0.2	40.9
		Btg	35- 75	0	0	0		8	8	42	50	0.43	5.7		0.1	55.1
		BC	75-100	0	0	0	0	6	6	39	55	0.48	5.4		0.1	67.6
		2Ckg	100-160	3	5	11	11	10	40	34	26	0.17	7.6	20.2	0.3	43.0
28	RBNp	Ap	0- 14	2	3	10	9	15	39	37	24	3.06	6.3		0.6	52.1
29	PTUc	Ap	0- 18	2	3	7	9	9	30	36	34	4.99	6.8		0.3	55.3
32	RBN	Ap	0- 25	1	2	6	5	8	22	47	31	4.24	5.9		0.3	53.7
34	PTUc	Apk	0- 20	3	5	11	11	10	40	32	28	3.38	7.3		0.7	54.9
36	RBN	Ap	0- 26	1	3	8	6	10	28	50	22	2.65	5.5		0.2	47.5
37	RBN	Ap	0- 20	2	4	8	9	10	33	50	17	2.20	5.7		0.3	44.0
38	RBNd	Ap	0- 14	2	2	8	6	11	29	40	31	4.06	6.5		0.3	55.9
40	RBN	Ap	0- 20	3	5	9	9	10	36	47	17	2.49	5.2		0.2	44.7
42	PTU	Ap	0- 12	2	4	14	8	11	39	34	27	3.40	6.5		0.3	52.8
		Btgj	12- 30	1	3	8	8	9	29	31	40	0.54	7.0		0.2	53.1
44	ECK	Ap	0- 15	1	3	9	8	11	32	36	32	4.50	6.6		0.3	55.5
46	RBN	Ap	0- 15	2	3	9	7	13	34	43	23	3.66	6.5		0.3	53.2
48	BAXc	Ap	0- 20	2	4	10	11	10	37	35	28	4.35	7.1		0.4	55.1
50	ECK	Ap	0- 10	2	5	14	11	11	43	31	26	2.41	6.1		0.4	45.1
52	ECK	Ap	0- 10	4	6	14	13	9	46	29	25	3.74	5.7		0.5	47.3
54	RBN	Ap	0- 15	2	3	9	7	11	32	45	23	2.58	5.7		0.3	48.0
56	PTUc	Ap	0- 15	2	3	12	13	10	40	30	30	4.69	6.4		0.3	55.3

* c = Classification variant
x = parent material and classification variant

Table 25 (1 of 2) Soil Analytical Data by Soil Series

Site Number	Soil Code/Var.	Horizon	Depth (cm)	VCS %	CS %	MS %	FS %	VFS %	Total Sand %	Total Silt %	Total Clay %	Organic Carbon %	pH	CaCO 3 Equi. %	Elec. Cond. mS/cm	% Water at Saturation
16	BAX	Ap	0- 20	2	4	12	11	10	39	32	29	4.52	6.6		0.2	48.8
		Ck	70-120	0	1	5	8	13	27	45	28	0.46	7.9	21.2	0.2	46.4
		2Ck	120-160	4	5	14	13	14	50	29	21	0.11	7.9	19.9	0.2	41.1
24	BAX	Ap	0- 20	2	3	9	8	10	32	40	28	4.29	6.0		0.5	52.1
		Ck	65- 75	0	1	2	4	17	24	46	30	0.49	7.5	14.7	0.4	46.4
		2Ck	75-150	2	3	7	7	10	29	34	37	0.32	7.7	16.0	0.2	50.9
		2Ck2	150-160	3	4	11	10	10	38	33	29	0.43	7.8	15.1	0.3	42.9
48	BAXc	Ap	0- 20	2	4	10	11	10	37	35	28	4.35	7.1		0.4	55.1
06	ECK	Ap	0- 15	2	4	16	10	9	41	29	30	2.55	7.5		0.4	47.8
		Ck1	40-120	1	2	7	8	7	25	39	36	0.31	8.1	24.0	1.0	52.9
		Ck2	120-200	2	3	13	9	12	40	36	24	0.12	8.0	16.4	0.7	42.9
08	ECK	Ap	0- 15	1	3	7	9	11	31	37	32	3.58	6.9		0.4	53.9
		Ck1	60-110	4	4	9	8	10	35	33	32	0.34	8.1	18.4	0.3	45.8
		Ck2	110-200	3	5	11	13	11	43	32	25	0.19	7.9	16.9	0.4	42.5
13	ECK	Ap	0- 20	2	4	12	9	11	38	31	31	4.65	7.2		0.3	49.9
		Ck	75-150	3	4	10	13	10	40	32	28	0.20	7.8	15.4	0.4	44.2
18	ECK	Ap	0- 10	2	5	11	12	10	40	31	29	37.40	6.5		0.4	50.2
		Ck	25-100	5	7	13	11	9	45	29	26	0.21	7.9	22.3	0.3	41.3
20	ECK	Ap	0- 12	3	5	13	11	13	45	28	27	2.78	6.8		0.5	44.2
		Ck	25-100	3	5	14	11	10	43	32	25	0.47	8.0	18.3	0.2	41.0
22	ECK	Ap	0- 12	2	4	11	13	10	40	34	26	4.32	5.9		0.4	50.3
		Ck1	80-150	4	6	16	11	10	47	29	24	0.17	7.8	19.5	0.3	38.8
		Ck2	150-200	3	5	11	11	9	39	34	27	0.12	7.7	15.4	0.3	42.0
44	ECK	Ap	0- 15	1	3	9	8	11	32	36	32	4.50	6.6		0.3	55.5
50	ECK	Ap	0- 10	2	5	14	11	11	43	31	26	2.41	6.1		0.4	45.1
52	ECK	Ap	0- 10	4	6	14	13	9	46	29	25	3.74	5.7		0.5	47.3
02	PTU	Ap	0- 14	2	4	11	9	10	36	34	30	4.43	6.8		0.5	55.9
		Ck	55-120	2	5	12	13	10	42	33	25	0.21	8.0	19.5	0.8	41.9
10	PTUc	Ap	0- 15	3	5	13	10	11	42	26	32	3.18	7.5		0.3	52.1
		Ckgj3	85-150	3	5	11	13	8	40	32	28	0.17	8.0	18.6	0.5	45.3

Table 25 (2 of 2) Soil Analytical Data by Soil Series

Site Number	Soil Code/Var.	Horizon	Depth (cm)	VCS %	CS %	MS %	FS %	VFS %	Total Sand %	Total Silt %	Total Clay %	Organic Carbon %	pH	CaCO 3 Equi. %	Elec. Cond.	% Water at Saturation
14	PTUc	Ap	0- 20	2	4	11	10	12	39	31	30	4.47	7.3		0.4	54.0
		Ckg3	60-130	1	2	5	8	13	29	37	34	0.19	7.9	17.7	0.2	59.8
29	PTUc	Ap	0- 18	2	3	7	9	9	30	36	34	4.99	6.8		0.3	55.3
34	PTUc	Apk	0- 20	3	5	11	11	10	40	32	28	3.38	7.3		0.7	54.9
42	PTU	Ap	0- 12	2	4	14	8	11	39	34	27	3.40	6.5		0.3	52.8
		Btgj	12- 30	1	3	8	8	9	29	31	40	0.54	7.0		0.2	53.1
56	PTUc	Ap	0- 15	2	3	12	13	10	40	30	30	4.69	6.4		0.3	55.3
26	PVKx	Ap	0- 18	3	5	10	8	11	37	42	21	2.73	5.6		0.2	40.9
		Btg	35- 75	0	0	0		8	8	42	50	0.43	5.7		0.1	55.1
		BC	75-100	0	0	0	0	6	6	39	55	0.48	5.4		0.1	67.6
		2Ckg	100-160	3	5	11	11	10	40	34	26	0.17	7.6	20.2	0.3	43.0
04	RBN	Ap	0- 18	2	3	8	8	9	30	42	28	6.08	6.0		0.4	76.9
		Ckg	65-100	3	5	13	13	11	45	31	24	0.15	7.6	17.4	0.4	40.7
28	RBNp	Ap	0- 14	2	3	10	9	15	39	37	24	3.06	6.3		0.6	52.1
32	RBN	Ap	0- 25	1	2	6	5	8	22	47	31	4.24	5.9		0.3	53.7
36	RBN	Ap	0- 26	1	3	8	6	10	28	50	22	2.65	5.5		0.2	47.5
37	RBN	Ap	0- 20	2	4	8	9	10	33	50	17	2.20	5.7		0.3	44.0
38	RBNd	Ap	0- 14	2	2	8	6	11	29	40	31	4.06	6.5		0.3	55.9
40	RBN	Ap	0- 20	3	5	9	9	10	36	47	17	2.49	5.2		0.2	44.7
46	RBN	Ap	0- 15	2	3	9	7	13	34	43	23	3.66	6.5		0.3	53.2
54	RBN	Ap	0- 15	2	3	9	7	11	32	45	23	2.58	5.7		0.3	48.0

Table 26 Soluble Salt Analysis from Transects B1, B2, and B3 (Benchmark samples from PFRA, June 1 and 2, 1994, see Figure 4 for location of transects)

Transect/Site No.	Slope Position	Depth cm	pH	EC dS/m	Sodium Adsorption Ratio	Soluble Salts, mg/L			
						Ca	Mg	Na	Cl
B1S1	Depression	0-15	8.2	0.43	0.3	2.71	0.94	0.34	0.62
		15-70	8.2	0.28	0.3	1.71	0.55	0.34	0.34
		70-110	7.7	0.25	0.3	1.49	0.46	0.31	-
		110-450	7.9	0.31	0.3	1.79	0.84	0.33	-
B1S2	Mid Slope	0-15	7.8	0.32	0.2	2.52	0.77	0.25	0.33
		15-35	8.2	0.37	0.2	3.11	1.00	0.32	0.26
		35-127	7.9	0.38	0.3	2.92	1.12	0.41	-
		127-250	8.0	0.35	0.3	2.04	1.27	0.37	-
		250-450	8.0	0.28	0.3	1.60	1.08	0.33	-
B1S3	Upper Slope	0-10	8.2	0.44	0.2	3.88	0.88	0.33	0.39
		10-100	8.3	0.31	0.3	2.41	0.82	0.41	0.38
		100-450	8.2	2.50	0.2	22.30	13.7	0.66	-
B2S1	Depression	0-43	7.6	0.28	0.3	1.62	0.64	0.35	0.41
		43-55	7.6	0.46	0.2	2.78	1.13	0.26	-
		55-450	8.2	0.32	0.2	2.13	0.99	0.30	-
B2S2	Mid Slope	0-10	7.9	0.46	0.2	3.42	1.21	0.23	0.44
		10-15	8.0	0.38	0.2	2.27	0.80	0.27	0.28
		15-450	8.1	0.32	0.3	1.99	1.06	0.34	0.55
B2S3	Upper Slope	0-5	8.3	0.45	0.1	3.66	1.21	0.23	0.72
		5-18	8.3	0.37	0.2	3.45	1.07	0.28	0.34
		18-450	8.1	0.50	0.3	3.42	2.03	0.42	0.54
B3S1	Lower Slope	0-25	8.2	0.36	0.2	2.78	1.50	0.28	0.27
		25-33	7.9	0.28	0.3	1.77	1.12	0.42	0.34
		33-70	7.7	0.21	0.4	1.29	0.79	0.44	-
		70-150	8.0	0.37	0.4	2.43	1.30	0.49	-
		150-450	8.1	0.42	0.4	2.56	1.26	0.58	-
B3S2	Mid to Lower Slope	0-8	8.3	0.46	0.2	3.51	1.67	0.35	0.66
		8-20	8.2	0.37	0.3	2.65	1.39	0.46	0.38
		20-25	8.2	0.45	0.3	3.39	1.80	0.53	1.26
		25-93	8.2	0.36	0.4	2.07	1.67	0.49	0.78
		93-150	8.1	0.40	0.5	2.31	1.45	0.65	-
		150-450	8.1	0.33	0.4	2.30	1.69	0.59	-
B3S3	Upper Slope	0-5	8.4	0.72	0.1	5.09	2.46	0.28	1.30
		5-13	8.4	0.51	0.2	4.23	1.95	0.29	0.70
		13-450	8.3	0.59	0.4	1.15	4.89	0.68	0.90

Figure 14 Background EM38 Data, 50 metre grid 0-60 cm depth, May 27 and 28, 1994

30	30	22	30	30	32	48	42	40	21	37	26	28	28	42	30	36
24	24	24	22	22	26	40	36	38	33	31	20	27	28	30	20	30
23	20	22	22	26	24	34	31	25	30	23	32	28	24	27	26	24
19	23	28	27	24	30	23	36	37	30	38	22	24	23	20	20	20
23	33	22	28	31	30	26	30	38	22	30	24	20	28	22	30	22
23	25	22	20	28	22	27	32	24	36	21	22	22	30	22	31	20
34	22	23	26	28	37	40	28	24	37	21	31	28	22	24	30	23
27	22	20	22	28	25	31	27	23	37	26	30	20	37	30	28	28
30	22	24	28	22	28	32	37	29	35	29	28	28	31	25	40	24
27	30	30	27	30	20	28	38	40	32	37	32	24	24	27	28	23
24	24	22	30	30	21	30	30	34	30	33	29	30	22	32	24	20
23	20	23	30	22	34	30	30	34	30	35	30	22	27	32	20	27
23	20	30	27	28	30	34	28	34	30	34	32	20	22	20	24	32
24	24	22	23	30	23	30	29	32	30	32	30	28	22	34	22	32
30	28	28	21	30	34	40	28	33	32	27	32	23	21	30	30	
30	18	28	22	32	36	40	20	30	40	38	36	27	28	33	30	

Note: Horizontal scale is exaggerated.

Figure 15 Background EM38 Data, 50 metre grid 0-120 cm depth, May 27 and 28, 1994

30	30	28	36	40	35	40	42	38	28	44	31	30	32	34	36	37
28	25	30	24	30	28	48	40	40	41	37	25	23	30	34	41	38
25	23	28	27	32	26	34	37	38	26	36	41	33	27	26	28	39
22	30	30	30	32	30	40	41	44	26	38	25	26	26	28	26	26
31	30	40	30	26	38	34	32	44	30	32	27	26	32	32	38	25
34	30	28	24	38	38	34	34	40	38	43	25	38	27	36	40	30
30	26	26	26	38	42	34	33	44	42	44	34	28	38	25	28	26
25	24	28	26	28	30	37	31	34	42	32	37	34	28	44	28	28
30	24	24	28	30	30	33	37	28	41	30	30	24	44	36	46	28
32	31	32	33	30	30	44	46	28	34	26	36	32	30	38	28	30
24	30	22	32	26	27	34	34	30	39	26	37	26	29	24	26	30
30	24	26	34	32	34	30	39	63	36	37	35	24	25	32	26	33
25	24	30	33	26	33	28	34	38	38	44	36	30	28	26	25	29
25	30	25	30	28	28	40	37	30	34	36	46	34	28	36	24	40
25	30	25	30	28	28	40	37	30	34	36	46	34	28	36	24	40
34	34	26	26	25	34	40	33	34	34	38	37	33	36	26	28	
30	13	30	28	32	44	46	48	34	40	42	40	34	38	33	50	

Note: Horizontal scale is exaggerated.

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MAP UNIT SYMBOLOGY

Simple Map Units

Series Symbol

$$\frac{\text{ECK}}{\text{xc1x}}$$

Degree of Erosion(none)

Degree of Salinity(none)

Topography (very gently sloping)

Degree of stoniness (slightly)

RBN

Series with no phases

Compound Map Units

Series Symbol

Percentile of Map Unit

$$\frac{\text{ECK}^{7} - \text{PTR}^{2} - \text{RBN}^{1}}{\text{xb1x}}$$

Degree of Salinity (none)

Degree of Erosion (none)

Topography (nearly level)

Degree of Stoniness (slightly stony)

In a compound unit where two series share the same denominator, the phases apply to both series accordingly.

Phases

Degree of Erosion

x	noneroded or minimal
1	slightly eroded
2	moderately eroded
3	severely eroded
o	overblown

Stoniness

		(Surface covered)
x	nonstony	<.01 %
1	slightly stony	.01-.1 %
2	moderately stony	.1-3 %
3	very stony	3-15 %
4	exceedingly stony	15-50 %
5	excessively stony	>50 %

Slope Class

x	0-.5 %	level to nearly level
b	.5-2 %	nearly level
c	2-5 %	very gently sloping
d	5-9 %	gently sloping
e	9-15 %	moderately sloping
f	15-30%	strongly sloping
g	30-45%	very strongly sloping
h	45-70%	extremely sloping

Degree of Salinity Cond. (mS/cm)

x	nonsaline	0-4
s	weakly saline	4-8
t	moderately saline	8-15
u	strongly saline	15+

SOIL LEGEND

Soil Symbol	Soil Name	Surface Texture	Soil Drainage	Mode of Deposition	Family Particle Size	Soil Subgroup
BAX	Banks	Clay Loam	Well	Lacustrine/Till (Morainal)	Coarse Loamy/Loamy	Orthic Dark Gray
ECK	Erickson	Clay Loam	Well	Till (Morainal)	Fine Loamy	Orthic Dark Gray
PTU	Petlura	Clay Loam	Imperfect	Till (Morainal)	Fine Loamy	Gleyed Dark Gray
PVK	Proven Lake	Clay Loam	Poor	Lacustrine	Fine Loamy	Rego Humic Gleysol
RBN	Roblin	Loam	Poor	Till (Morainal)	Fine Loamy	Humic Luvic Gleysol
SNT	Sinnott	Clay Loam	Poor	Till (Morainal)	Fine Loamy	Rego Humic Gleysol