MANITOBA
Soil Resources

Soils of the Manitoba Zero Tillage Research Association Research Farm

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SOILS OF THE MANITOBA ZERO TILLAGE RESEARCH ASSOCIATION RESEARCH FARM

Section 31-12-18 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 Manitoba Zero Tillage Research Association Research Farm 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 Canada at the request of the Manitoba Zero Tillage Research Association. The soil map at a scale of 1:5 000 and the accompanying report provides detailed soil resource information required for planning and managing the soils on the farm to support field scale zero tillage research in Manitoba.

This report contains descriptive information for the major soils that occur on the Manitoba Zero Tillage Research Farm (MZTRF), 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 interpretative maps (Figure 3 to 12) showing properties such as erosion, drainage, salinity and organic matter content 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

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The soils were mapped in the fall of 1993 by G. P. Podolsky assisted by D. Schindler.

Detailed soil characterization and moisture studies were carried out by P. Haluschak and E. St. Jacques.

Deep drilling was completed by D. Swidinsky assisted by D. Schindler.

Laboratory analysis and data were provided by R. Mirza, D. Schindler 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 and K. Gehman.

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

Report formatting was provided by C.L. Aglugub and D. Schindler.

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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 four 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, and Part 4 provides an interpretation of soil properties and associated landscape features as they affect soil capability or suitability for various uses. Baseline data regarding soil quality on the farm 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 the soils capability for dryland agriculture and suitability for irrigation, consult the appropriate section in Part 4. Criteria utilized as guidelines in making these interpretations are provided in Appendix A.

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 Manitoba Zero Tillage Research Association Research Farm is located 17.6 kilometers north of Brandon on Section 31-12-18 W. The Farm covers the entire section of land and consists of well to poorly drained, fine loamy, moderately to strongly calcareous, glacial till. The topography ranges from level to very gently sloping.

The climate is cool to moderately cool subhumid. Long term climatic records from four weather stations in the area indicate total precipitation ranges from 426 to 490 mm. 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 four climatic stations ranges from .8 to 1.7 °C, while the average length of the frost-free season varies from 90 to 115 days.

The soils on the research farm are dominantly well and imperfectly drained Chernozemic Black soils (68 %) developed on fine loamy, till deposits. Poorly to very poorly drained Gleysols account for the remaining 32 percent. All the soils have high organic matter content and good moisture holding capacity. The pH values range from 7.1 to 8.3.

Slight erosion has occurred on approximately 3.3 percent of soils. Slightly stony conditions affect about 55 percent of the farm acres. Weakly saline soil conditions occur on 22 percent of the farm area. Surface drainage on the farm is quite variable, ranging from well to rapid on the upper slopes to prolonged inundation of the poorly drained pothole areas.

The soil and climatic conditions on the research farm constitute a window of information which may apply to much of the Newdale Till Plain and similar areas.

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PART 1

GENERAL DESCRIPTION OF STUDY AREA

1.1 INTRODUCTION

The "Parkland Agricultural Research Initiative" (PARI) demonstration farm was conceived by Agriculture Canada in 1992 to address concerns about soil degradation on prairie Parkland acres. Ducks Unlimited Canada agreed to secure the land for projects in each of the prairie provinces and the Manitoba Zero Tillage Research Association (MZTRA) was considered the logical choice to manage the Manitoba farm. The major farm partners represent a mix of producers, conservation organizations, government, private industry and other parties reflecting local needs. The program will concentrate on solving production problems and help meet the challenges of further development within the zero tillage system. The increased interest in zero tillage, as an alternative to conventional practises, must also address the need to demonstrate environmental sustainability.

The Manitoba Zero Tillage Research Farm is located on Section 31-12-18 W.P.M. about 17.6 kilometres north of Brandon, at the northeast corner of the junction of Highway 10 and Provincial Road 353 (Figure 1). The section was originally mapped as the Newdale (clay loam) Association in the Carberry Map Sheet (Ehrlich et al, 1957) and is representative of large areas of Newdale soils in the Parkland landscape. Approximately two-thirds of the farm will be allocated to cropland while the remainder is to be protected as habitat with a combination of native grass, bush and wetland.

In order to assess the impact of agricultural practices on the environment, a detailed study of the initial conditions, areal extent and characteristics of the soil, water and ecological resources of the management area are required. However, since it is no longer possible to document the initial, undisturbed quality of these resources, the alternative is to document the current status of the resource quality. This documentation may be used as baseline data to monitor future resource assessments and changes using Geographic Information System (GIS) technology.

Sustainable economical agricultural production is fundamentally dependent on the climate and quality of the soil resource. Soil quality must be maintained in support of sustainable economic farming systems. In order to facilitate sustainable land management under a zero tillage system it is essential to have a detailed understanding of the soil resource quality. To provide a detailed inventory and characterization of the soil quality and variability on the MZTRF, a soil survey was initiated and completed in the fall of 1993.

1.2 RELIEF AND DRAINAGE

Elevations on the farm range from 1625 ft., (495 m) in the southeast corner to 1675 ft. (510 m.) in the northwest corner. The general topographic gradient on the farm is about 6 meters per kilometer. Approximately half of the project area has a very gently sloping (2-5%) topography with the remainder being level to nearly level (0-2%).

As a result of the irregular undulating to hummocky relief pattern on the farm, surface drainage is quite variable, ranging from well to rapid on the upper slopes to very poor in the depressed pothole areas subject to prolonged inundation. General overall drainage is toward the southeast with local variation. Well drained soils extend over 52% of the project, while imperfectly drained areas cover 16% and poorly drained to very poorly drained soils are distributed over 32% of the farm area.

1.3 PHYSIOGRAPHY AND SURFACE DEPOSITS

The research farm is situated within the Newdale Plain subsection of the Assiniboine River Plain. The area consists dominantly of undulating to hummocky ground moraine characterized by numerous potholes, sloughs and intermittent lakes. This physiographic subsection ranges in elevation from 390 to 600 m a.s.l. and forms a broad gently sloping plain between Riding Mountain and the Assiniboine River valley.

The surface deposits in the study area consist of boulder till of mixed materials derived from shale, limestone and granitic origin. The soils of the Newdale association are moderately to strongly calcareous and belong to the fine loamy particle size class. The dominant soil texture on the farm is clay loam. Hard siliceous shale and soft bentonitic shale of the Riding Mountain Formation underlie the 75 meter thick surface deposits.

1.4 CLIMATE

The climate of the study 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.

Climatic conditions for the farm are best represented by long term meteorological data from four weather stations within the area; namely, Brandon airport, Hamiota, Minnedosa, and the Rivers airport. Growing season characteristics (heat units and frost free period) are fairly uniform, varying mainly with elevation and latitude. However, moisture distribution during the growing season may vary greatly, as much of the precipitation is received during summer storm events. Averaging the data from the four sites results in a mean annual temperature of 1.4 °C. The total precipitation is 459 mm with 340 mm of mean annual rainfall. The average frost free period is 106 days. Climatological data from the four stations is summarized in Tables 1 to 3.

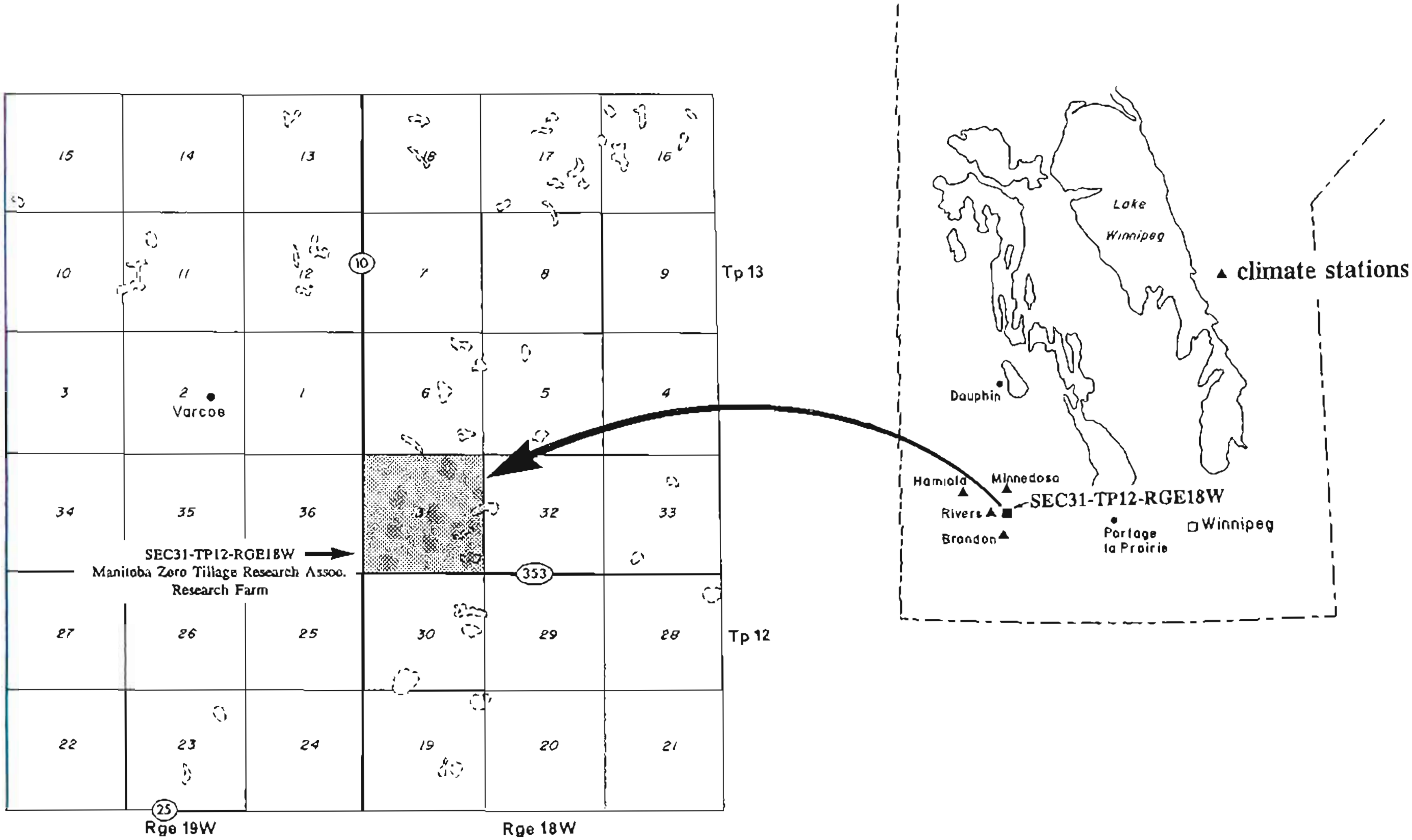


Figure 1. Location of Study Area

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

Climatic Parameter	Climate Station			
	Brandon	**Hamiota**	**Minnedosa**	**Rivers**
Elevation m.a.s.l	409.	518.	518.	473.
Temperature, °C:				
mean annual	1.5	1.6	.8	1.7
mean maximum	7.8	7.4	7.0	7.3
mean minimum	-4.7	-4.3	-5.4	-3.9
Precipitation:				
mean annual, mm	450	426	490	472
rainfall, mm	339	322	360	344
Mean Monthly rainfall, mm				
• May	45.2	36.2	49.0	38.7
• June	77.1	74.5	81.3	74.2
• July	66.6	62.1	73.4	77.1
• August	64.6	61.3	62.5	64.9
• September	44.0	47.4	48.2	45.8

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

Climatic Parameter	Probability Level	Climate Station			
		Brandon	**Hamiota**	**Minnedosa**	**Rivers**
Corn Heat Units	50	2334	2305	2130	2401
	25	2211	2135	1993	2256
	10	2100	1981	1869	2125
Growing	50	1595	1553	1442	1571
Degree-Days	25	1514	1468	1349	1494
(base 5°C)	10	1441	1392	1266	1423
Frost-free (mean)	50	127	126	122	134
period days	25	119	117	113	126
(base -2.2°C)	10	111	108	104	119

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							
Brandon	June 9	June 3	May 31	May 27	May 20	May 17	May 8
Hamiota	June 12	May 29	May 27	May 24	May 15	May 13	May 7
Minnedosa	June 22	June 11	June 8	June 7	June 1	May 20	May 17
Rivers	June 11	May 31	May 27	May 24	May 17	May 15	May 8
Fall Frost on or before							
Brandon	August 31	Sept 8	Sept 10	Sept 14	Sept 16	Sept 18	Sept 21
Hamiota	August 17	Sept 6	Sept 10	Sept 13	Sept 15	Sept 18	Sept 22
Minnedosa	August 14	August 19	Sept 18	Sept 8	Sept 13	Sept 14	Sept 17
Rivers	Sept 4	Sept 10	Sept 1	Sept 17	Sept 21	Sept 25	Sept 26
(0°C) Frost free period (days) equal to or less than							
Brandon	94	97	99	107	116	119	128
Hamiota	85	101	105	110	113	122	132
Minnedosa	65	79	82	90	100	101	109
Rivers	97	104	108	115	124	127	134

PART 2

METHODOLOGY

The detailed study of soil conditions on the research farm was carried out in the fall of 1993 and involved various field activities. The investigations 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 2).

b) A drilling program was conducted to investigate and sample soils (14 sites) to a depth of approximately 3 meters.

c) Field sampling and testing of soils for bulk density (24 sites) and moisture retention (4 sites).

d) Slope transects were carried out in order to characterize the sequence and distribution of soils along three toposequences.

e) A salinity survey was undertaken using an EM 38 electromagnetic induction instrument to assess the presence and levels of salinity to 120 cm. EM 38 transects were carried out at five wetland sites (Figure 2) in addition to readings at the regular soil inspection sites.

The grid inspection sites, drill sites and slope transects were sampled to determine selected chemical and physical properties of the soils.

2.1 SOIL SURVEY AND MAPPING

In the mapping process soils were inspected along 6 east-west transects across the farm at intervals of 320 meters. Two additional north-south transects were placed at each end of the section. Site inspections were recorded and sampled every 160 meters along each transect. Soil inspections were made by hand spade and auger to a depth of 120 cm. Surface samples at 0 to 20 cm. and subsurface samples at 50 to 70 cm were taken at each site. The grid survey on the research farm resulted in an average soil inspection density of 1 site per 2.5 hectares. Soil characterizations were recorded and each profile was classified according to standard survey procedures (Agriculture Canada, 1987). Survey grid points, drill sites, slope transects and EM 38 wetland sites are shown in Figure 2.

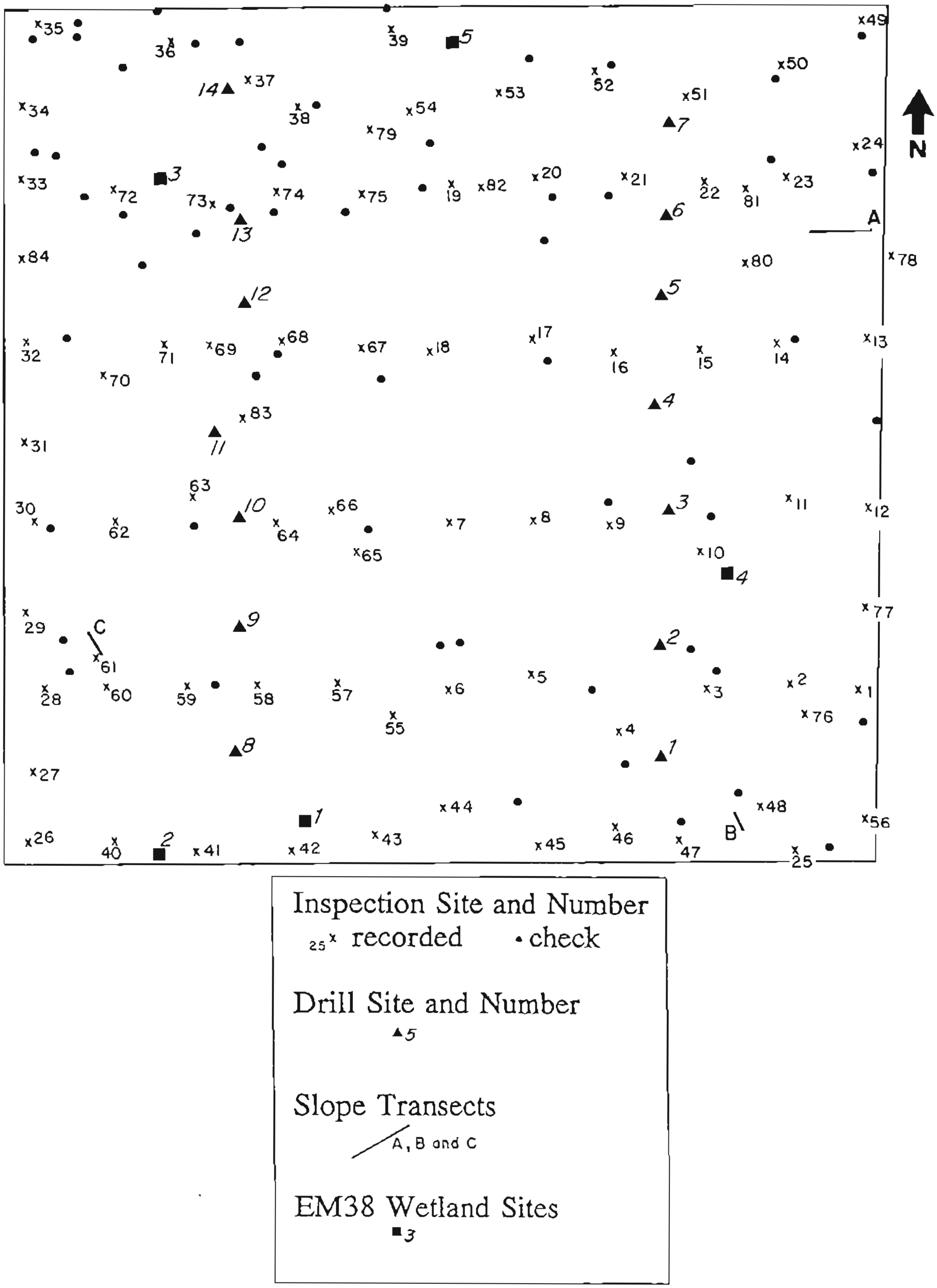
2.2 THE SOIL MAP

The soils of the research farm were mapped on a 1:20 000 black and white aerial photograph which was enlarged to a scale of 1:5 000. Eight soil series with various phases of erosion, topography, stoniness and salinity were identified on the soil map for a total of 226 polygons. The basic soil map and supporting data may be used to generate a number of derived and interpretive maps. A range of map products may include: erosion, topography, stoniness, salinity, agricultural capability, irrigation suitability, drainage, pH, and organic carbon.

2.3 SALINITY SAMPLING

All samples from the grid inspection sites and drill sites were analyzed for electrical conductivity (Table 21). Additional samples were collected from the EM 38 wetland transects. Five wetlands, with a total of 18 transects, were characterized using an EM 38 conductivity instrument. The wetland EM 38 survey resulted in approximately 420 grid point readings for 0-60 cm (horizontal) and 0-120 cm (vertical) depths. The resulting data and graphs are presented in Appendix B and C.

Figure 2. Grid Map and Location of Inspection 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 relationship to the factors of soil development. It also provides a description of the classification and morphology of soils in the study. The soils of the research farm were originally mapped (1:125,000 scale) as the Newdale Association (smooth phase) which commonly had up to five member soil types or associates (Carberry Map Sheet Report, 1957).

The present detailed survey at a 1:5 000 scale recognizes eight soil series to characterize the soil variability on the farm, all developed on the same parent material. The soils are dominantly well to imperfectly drained Black Chernozems (68% of the area) while the remaining 32% is comprised of Humic and Luvic Gleysols. All the soils are developed on moderately to strongly calcareous fine loamy (clay loam) glacial till of mixed limestone, shale and granitic rock origin.

3.2 SOIL DESCRIPTIONS

A general description of each soil series mapped on the research farm is given in this section. The area in hectares and percent of total for each soil series is included with the description. A brief 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 farm is summarized in Tables 5 and 6. Three cross sections along slope transects, indicating the relative position of the various soils in the landscape, are shown in Figures 14, 15, 16.

Generalized descriptions for each soil series are presented in alphabetical order and include genetic profile type, texture, calcareous classes, parent material, topography, drainage and other chemical and physical properties. The characteristics and properties are based on summaries and averages of soil data systematically documented and recorded during the course of the farm survey in addition to a larger sample collected over a broader area. Chemical and physical analysis from samples taken at grid points during the survey are presented in Tables 21 and 22.

Table 4. Soil Legend - Manitoba Zero Tillage Research Farm

Parent Materials:	**Soils developed on fine loamy (L,CL,SICL), moderately to strongly calcareous glacial till**	
Drainage	**Subgroup**	**Soil Series (Symbol)**
Well	Orthic Black Calcareous Black Rego Black	Newdale (NDL) Cordova (CVA) Rufford (RUF)
Imperfect	Gleyed Rego Black Gleyed Eluviated Black	Varcoe (VRC) Angusville (ANL)
Poor	Rego Humic Gleysol Humic Luvic Gleysol Rego Humic Gleysol	Drokan (DRO) Penrith (PEN) Marsh Complex (MHC)

3.2.1 Angusville Series (ANL) (13 ha., 5% of total area)

The Angusville series is characterized by a Gleyed Eluviated Black soil profile developed on moderately to strongly calcareous, slightly stony, fine loamy (L-CL) morainal till of limestone, granitic and shale bedrock origin. These soils are imperfectly drained and occur in lower to mid slope positions of undulating to hummocky landscapes, in close association with the well drained Newdale, Rufford and Cordova soils, the imperfectly drained Varcoe series, and the poorly drained Drokan and Penrith series. Surface runoff is slow to moderately slow; permeability is moderately slow to slow within the solum and moderately slow in the subsoil. Vegetation on non-cultivated lands consists of trembling aspen.

The average thickness of the soil profile is 61 cm and varies from 45 to 85 cm. The A horizon has a mean thickness of 25 cm and ranges from 20 to 40 cm. The very dark gray to gray Ap horizon is 15 to 20 cm thick, and the dark gray to gray Ae (Ahe) horizon, 5 to 15 cm thick. The dark brown to dark yellowish brown Btgj is 25 to 35 cm thick. A lime enriched layer of 10 to 20 cm may be present. The C horizon is light olive brown with yellowish brown mottles.

The Angusville soil profile is thicker and more strongly developed and free of lime carbonate in comparison to the closely associated, shallower, carbonated Gleyed Rego Black Varcoe series. The strongly leached Angusville soils are sites of net surface water infiltration and are considered to be sites of local recharge to the groundwater.

3.2.2 Cordova Series (CVA) (7.2 ha., 2.7% of total area)

The Cordova series is characterized by a Calcareous Black solum on moderately to strongly calcareous, slightly to moderately stony, loamy (L-CL) morainal till of mixed limestone, granitic and shale rock origin. These soils are well to rapidly drained and occur in the upper slope and crest positions of undulating to hummocky landscapes, in close association with the well drained Rufford and Newdale series. Surface runoff is moderately rapid to rapid, depending on slope. Permeability is moderately slow. Native vegetation consists of mixed tall prairie grasses and herbs.

The Cordova soil profile has a thin, very dark gray Ap(k) horizon, 12 to 18 cm thick, a calcareous, yellowish brown to dark yellowish brown Bmk horizon, 5 to 15 cm thick, a thin transitional BC horizon and a light gray lime carbonate accumulation layer, 20 to 30 cm thick. Secondary carbonates may be found along vertical cracks within the underlying grayish brown (dry) or dark grayish brown (moist) Ck horizon. In areas, where these soils have been eroded by wind and water, the crest positions have lost most of the A horizon and part of the B horizon has been cultivated. In a few areas, the Cca horizon has been incorporated into the plow layer, imparting a light gray surface color.

In the study area, the A horizon is 16 cm thick and varies from 15 to 30 cm; the depth of solum is 35 cm and varies from 30 to 50 cm. The Cordova series differs from the Rufford series, with a carbonated Rego Black profile in having a Bmk horizon. Both Cordova and Rufford series differ from the Newdale series, in having free lime carbonate present in the solum, and lacking an A and B horizon free of carbonates.

3.2.3 Drokan Series (DRO) (51.2 ha., 19.3% of total area)

The Drokan series is characterized by a Rego Humic Gleysol (carbonated) solum, developed on moderately to strongly calcareous, loamy (L-CL) morainal till of limestone, granitic and shale rock origin. They are poorly to very poorly drained and occur in depressional positions of the undulating to hummocky morainal landscape. Surface runoff is negligible and the soils remain in a ponded condition unless drainage has been improved. Permeability is moderately slow to slow. In most landscapes, these soils are influenced by seepage from the slough, and may have a considerable content of soluble salts. Native vegetation consists of sedges, cattails, rushes and willows. Saline areas have baltic rush, wild barley and saline goosefoot. These soils are best retained in their natural state.

The Drokan soil profile has a moderately decomposed organic layer, 5 to 10 cm thick, a very dark gray Ah horizon, 10 to 18 cm thick, a mottled transitional AC horizon, 4 to 8 cm thick and a lime accumulation layer, 8 to 12 cm thick. The C horizon is olive gray to olive with yellowish brown mottles. Gypsum crystals are common in the lime accumulation layer and C horizon. In saline areas, white flecks of salt and gypsum are present above the lime accumulation layer in the Ah and AC horizons; soils with appreciable soluble salt are delineated as Drokan saline phase.

In this study area, the average A horizon is 25 cm thick and varies from 10 to 50 cm; the average depth of its solum is 38 cm and varies from 20 to 60 cm. It differs from the closely related Penrith soil series in being carbonated and having shallower, less distinct horizons.

3.2.4 Marsh Complex (MHC) (18.5 ha., 7.0% of total area)

The Marsh complex consists of very poorly drained, Rego Humic Gleysol soils developed on mucky loam deposits over moderately to strongly calcareous till. These soils occur on level to depressional areas that are covered with water and are usually saturated for most of the year. The native vegetation consists entirely of reeds and sedges.

These soils have a surface layer of either muck or mineral material high in organic matter content and are underlain by strongly gleyed, olive gray mineral materials. An Ahg horizon, up to 15 cm thick, may be present below the muck surface layer.

Marsh soils are undifferentiated with respect to texture and composition of their parent material. They also are much more poorly drained than other Gleysolic (Drokan) soils.

3.2.5 Newdale Series (NDL) (79 ha., 29.8% of total area)

The Newdale series is characterized by an Orthic Black solum developed on moderately to strongly calcareous, loamy (CL) morainal till of limestone, granitic and shale origin.These soils are well drained and occur in mid to upper slope positions of undulating to hummocky landscapes. Surface runoff is moderate to moderately rapid; permeability is moderately slow. Most of these soils are presently cultivated; they have formed under intermixed aspen grove and grassland vegetation.

The Newdale solum has a black to very dark gray Ah horizon, commonly 20 cm thick and ranging from 15 to 40 cm, a dark brown Bm horizon, 10 to 30 cm thick, and a transitional BC horizon, 3 to 15 cm thick. A lime carbonate horizon, 10 to 15 cm thick may be present in shallower soils but is not evident in deeper profiles. Its solum depth averages 40 cm and ranges from 25 to 60 cm. Minor amounts of well drained Eluviated Black soils occur within the Newdale mapping units. These eluviated soils range from 75 cm to greater than 1 m in depth. They have thick A (combined Ah, Ahe) horizons, 30 to 60 cm and Bt horizons that are 40 cm thick.

The Newdale soils in the study area differ from the very similar Rufford and Cordova soils in being more strongly leached, thicker and free of lime carbonate in the A and B horizons.

3.2.6 Penrith Series (PEN) (15.8 ha., 6% of total area)

The Penrith series is characterized by a Humic Luvic Gleysol solum developed on moderately to strongly calcareous, loamy (L, CL) morainal till of limestone, granitic and shale rock origin. These soils are poorly drained and occur in depressional positions which may be at slightly elevated portions of undulating to hummocky landscapes. These soils are subject to ponding for a variable period in the spring and early summer but usually are free of water in the summer and fall, unless replenished by heavy rains and runoff. Permeability is very slow within the solum and moderately slow in the subsoil. Vegetation consists of sedge and ringed with willow.

The solum of the Penrith series commonly has a moderately to strongly decomposed organic surface layer, 4 to 8 cm thick, a dark gray to gray Ahe horizon, 6 to 10 cm thick, a light gray, platy structured Aeg horizon, 6 to 10 cm thick, a dark gray to gray Btg horizon, 35 to 45 cm thick, and a gray transitional BC horizon, 15 to 25 cm thick. In the study area, the A horizon thickness averages 35 cm and ranges from 15 to 45 cm; the average solum depth is 65 cm and ranges from 30 to 75 cm.

The Penrith soils differ from the Drokan soils in being more strongly leached and having more distinct and thicker horizons. Penrith soils usually occur at sites of local infiltration where there is a net downward movement of water in the soil. These soils are affected by ponding of surface water for a shorter time than Drokan soils. Penrith soils are sometimes cultivated, but surface ponding after heavy rains may result in drown out of crops.

3.2.7 Rufford Series (RUF)
(51.3 ha., 19.4% of total area)

The Rufford series is characterized by a thin Rego Black solum developed on moderately to strongly calcareous, loamy (L,CL) morainal till of limestone, granitic and shale origin. These soils are moderately well to well drained and occur on the upper slopes and knoll positions in undulating to hummocky landscapes in close association with Cordova and Newdale soils. Runoff is moderately rapid to rapid; permeability is moderately slow.

Rufford profiles commonly have a very dark gray to very dark grayish brown Ah horizon, 12 to 18 cm thick and a thin AC horizon, 6 to 10 cm thick. A lime accumulation layer, 5 to 15 cm thick, is usually present. In the study area, the A horizon averages 25 cm and ranges from 15 to 40 cm; the solum depth averages 27 cm and ranges from 15 to 40 cm.

Rufford soils differ from Cordova soils in being less leached and having thinner, less distinct horizons. Both Rufford and Cordova soils differ from the Newdale soils in being less leached and having free lime carbonate in their A and B horizons.

3.2.8 Varcoe Series (VRC)
(28.8 ha., 10.9% of total area)

The Varcoe series is characterized by a Gleyed Rego Black (carbonated) solum on moderately to strongly calcareous, loamy (L, CL) morainal till of limestone, granitic and shale origin. These soils are imperfectly drained and occur in the lower slope positions of undulating to hummocky landscapes in close association with Angusville soils. They receive runoff from the upper slopes, and in some landscapes, may be influenced by seepage. Permeability is slow and may be restricted during periods of subsoil saturation. In areas where seepage waters contain appreciable salts, accumulation of salts may occur within the soil.

Varcoe profiles average 42 cm in thickness and range from 20 to 60 cm. The A horizon is usually 25 cm thick and ranges from 20 to 50 cm; very dark gray in color and is underlain by a dark gray transitional AC horizon, 4 to 8 cm thick. A lime accumulation horizon may be present, but is thin and discontinuous. Gypsum crystals are present within the C horizon. Varcoe soils containing significant soluble salts in the A horizon as well as gypsum, have been identified as the saline phase of the series.

Table 5. Area by Soil Series

Soil	Area (ha)	Percent
Marsh	18.55	7.00
Angusville	13.12	4.95
Cordova	7.20	2.75
Drokan	51.20	19.33
Newdale	79.05	29.84
Penrith	15.76	5.95
Rufford	51.28	19.38
Varcoe	28.76	10.86

Table 6. Area by Soil Phases

Soil	Phase	Area (ha)	Percent
Marsh	xxxx	18.55	7.00
Angusville	xbxx	6.71	2.53
Angusville	xxxx	6.40	2.42
Cordova	xc1x	7.20	2.72
Drokan	xxxx	6.66	2.51
Drokan(s)	xxxs	44.54	16.81
Newdale	xc1x	79.05	29.84
Penrith	xxxx	15.76	5.95
Rufford	xc1x	42.23	16.02
Rufford	1c1x	8.85	3.34
Varcoe	xb1x	1.27	.48
Varcoe	xbxx	10.19	3.85
Varcoe	xxxx	2.9	1.09
Varcoe(s)	xb1s	6.9	2.60
Varcoe(s)	xbxs	5.77	2.18
Varcoe(s)	xx1s	.36	.14
Varcoe(s)	xxxs	1.35	.51

PART 4

USE AND MANAGEMENT INTERPRETATIONS OF SOILS

4.1 INTRODUCTION

This section provides predictions of performance or soil suitability ratings for various land uses based on soil and landscape characteristics, laboratory data and on soil behaviour under specified conditions of land use and management. Suitability ratings or interpretations are intended to serve as guides for planners and managers. A general acreage overview of the farm is given in Table 7.

Soil properties determine to a great extent the potential and limitations for both dryland and irrigation agriculture. In this section, interpretive soil information is provided for the following agricultural land use evaluations:

a) soil capability for agriculture
b) irrigation suitability

A summary of the soils on the farm showing their areal extent and their interpretive classification for agricultural capability and irrigation suitability is provided in Table 8.

4.2 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.

4.2.1 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 15.

4.2.2 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 16.

4.2.3 Soil Capability

The soils on the research farm range from Class 2 to Class 7 in agricultural capability. Class 2 soils account for 62% or 159 hectares, Class 3 for 6% or 15 hectares, Class 5 for 25% or 64 hectares and Class 7 soils account for 7% or 18 hectares of the farm.

Class 2 soils include the imperfectly drained soils with a wetness limitation (2W) and the well drained soils having a topographic limitation (2T). The 2-5% slopes associated with the 2T soils may increase farming costs over that of a smooth landscape and increase the risk of water erosion. The Class 3 soils have a moderately severe limitation resulting from the presence of soluble salts (3N). The salts may affect crop growth, restrict crop growth or the range of crops grown. Class 5 soils on the farm have very severe limitations as a result of excess water (5W) and salinity. This class includes all the poorly drained soils. The Marsh Complex (7W) constitutes the Class 7 soils which have no capability for arable culture, however have

Table 7. Summary of Land Resource Characteristics

Summary Class	Hectares	Acres	% of Area
Soil Drainage			
Well	133	333	52
Imperfect	41	102	16
Poor	64	160	25
Very Poor (MHC)	18	45	7
Agricultural Capability Classes			
Class 2	159	397	62
Class 3	15	38	6
Class 5	64	160	25
Class 7	18	45	7
Irrigation Suitability			
Good	136	339	53
Fair	38	96	15
Poor	82	205	32
Erosion Classes			
Erosion 1 (slight)	8.5	21.1	3.3
Slope Classes			
x level to nearly level (0-.5%	92	230	36
b nearly level (.5-2%)	31	77	12
c very gently sloping (2-5%)	133	333	52
Stoniness Classes			
1 slightly stony	141.3	353.3	55.2
Salinity Classes			
s slightly saline	56.8	142	22.2

Mean Organic Matter	8.0 %
Mean pH Value	7.6

Table 8. Agricultural Capability and Irrigation Suitability Rating

Map Symbol	Soil Name	Areal Extent		Agricultural Capability Class	Irrigation Suitability		
		ha	%		Class	General Rating	Potential Environmental Impact
ANL/xxxx	Angusville	6.4	2.4	2W	3k A	Fair	Low
ANL/xbxx	Angusville	6.71	2.5	2W	3k A	Fair	Low
CVA/xc1x	Cordova	7.20	2.7	2T	2k Bt2	Good	Low
DRO/xxxx	Drokan	6.66	2.51	5W	4w A	Poor	High
DRO/xxxs	Drokan	44.5	16.8	5W	4w A	Poor	High
MHC/xxxx	Marsh	18.6	7.00	7W	4w A	Poor	High
NDL/xc1x	Newdale	79.1	29.8	2T	2k Bt2	Good	Low
PEN/xxxx	Penrith	15.8	5.95	5W	4w A	Poor	High
RUF/xc1x	Rufford	42.2	16.0	2T	2k Bt2	Good	Low
RUF/1c1x	Rufford	8.85	3.34	2T	2k Bt2	Good	Low
VRC/xxxx	Varcoe	2.9	1.09	2W	3w A	Fair	Low
VRC/xbxx	Varcoe	10.2	3.85	2W	3w A	Fair	Low
VRC/xb1x	Varcoe	1.3	0.48	2W	3w A	Fair	Low
VRC/xbxs	Varcoe	5.8	2.18	3N	3wsA	Fair	Low
VRC/xb1s	Varcoe	6.9	2.6	3N	3wsA	Fair	Low
VRC/xx1s	Varcoe	.4	0.14	3N	3wsA	Fair	Low
VRC/xxxs	Varcoe	1.4	0.51	3N	3wsA	Fair	Low
Total Area		**265.0**	**100.0**				

Agricultural Capability by Series and Area			
2W	VRC, ANL	27.3 ha.	10.3 %
2T	CVA, NDL, RUF	137.3 ha.	51.8 %
3N	VRC Saline	14.3 ha.	5.4 %
5W	DRO, PEN	66.8 ha.	25.2 %
7W	MHC	18.5 ha.	7.0 %

high capability for native vegetation species, habitat for waterfowl and wildlife. A summary for agriculutural capability, irrigation suitability and areal extent of soils on the MZTRF is presented in Table 8.

4.3 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. **The decision to irrigate a parcel of land will require additional field investigation that utilizes the same criteria but will include 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 availability, water quality or economics of this type of land use.

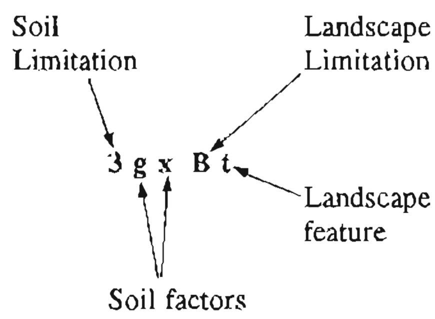
Soil properties considered important for evaluating irrigation suitability are: texture, soil drainage, depth to water table, salinity and geological uniformity. **Landscape features** considered important for rating irrigation suitability relate mainly to the influence of topography and stoniness.

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 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.

4.3.1 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 17). The guidelines utilized for evaluating the effect of soil properties and landscape features on long term irrigation are included in Appendix A, (Tables 18 and 19 respectively).

An example of an irrigation suitability class rating is shown below:



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).

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 irrigation suitability ratings in Table 8 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.

4.3.2 Environmental Impact

An assessment of potential environmental impact from irrigation is provided in Table 8. 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 ranging from "**none to low, moderate and high**" (Table 20). 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

4.4 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 3 to 12). Selected chemical and physical characteristics of the soils for surface and subsurface depths are summarized in Table 9. Additional data on bulk density and soil moisture retention properties for specific sites are provided in Tables 10 and 11. Analytical data from the grid sites and slope transects are presented in Appendix C, Tables 21 and 22 in which the data are organized by site number and series respectively.

4.4.1 Soil Texture

The proportion of individual mineral particles (sand, silt, clay) present in a soil is referred to as texture. Soil texture strongly influences the soil's ability to retain moisture, its general level of fertility, the ease or difficulty of cultivation, permeability and erosion potential. The dominant texture on the farm is clay loam which contributes to good available water holding capacity and moderate to moderately slow permeability.

The soils on the farm, particularly those on steeper slopes, are subject to erosion if the soil surface is not covered by vegetation or crop residue. Continuous cropping and minimum or zero tillage to maximize residue cover will minimize the risk of erosion. These practices will also maintain organic matter in the soil for improved water retention, structure and fertility.

4.4.2 Soil pH

Soil pH values express the degree of acidity and alkalinity. The surface values on the farm range from 7.1 to 8.3 with a mean of 7.6. This range of values is characterized as neutral to moderately alkaline. Generally the range in pH values is fairly narrow with the lower values on the leached (ANL, PEN) soils and the higher values in the poorly drained (DRO, MHC) soils. A summary of pH values is shown in Table 9 and individual site data are presented in Appendix C, Tables 21 and 22.

4.4.3 Organic Matter

The status of soil organic matter is important to the health and productive capacity of the soil at both the provincial and national level but it's most important at the local farm scale. Of all the soil properties affected by environmental change, the carbon content of soil organic matter is probably the only one that affects the atmosphere as well as the soil system. Environmental change caused by cultivation, forest fires, and changes in hydrology and climate, can alter soil moisture, temperature and organic matter content and result in an increase or decrease in soil carbon. Soil carbon serves as an important indicator of the status of several major processes in the Biosphere which are sensitive to environmental change and related to the health of the environment.

Surface organic matter content of the soils on the Zero Till Research Farm ranges from 6.4 to 13.6 percent, well within the mid to upper range for loam textured soils in the Chernozemic Black zone of southern Manitoba. The well drained soils average about 6.8 percent organic matter whereas the imperfectly drained soils average 8.1 percent and the poorly drained areas about 12 percent. There is a general increase in organic matter content from the upper to lower slope positions in the landscape. The overall level of soil organic matter on the farm is satisfactory but cultural practices to maintain or increase the organic matter content are required to ensure good structure, fertility and tilth. The organic matter content of the surface soil on the Zero Till Farm is summarized in Table 9 and the areal distribution is shown on Figure 5.

The total organic carbon content (organic matter percent $\div$ 1.72 = organic carbon) has been measured for the soils of the Zero Till Research Farm, calculated to a depth of 1 m and summarized in Table 12. Total organic carbon content ranges from 154 to 165 tonnes per hectare (t/ha) in the well drained soils, 175 to 200 t/ha for the imperfectly drained soils and 232 to 254 t/ha in the poorly drained soils. The very poorly drained soils in the Marsh complex contain 214 t/ha. The total soil organic carbon to 1 m depth for the entire Farm (256 ha) is estimated at 49,377 tonnes. This data provides a detailed look at the variability and distribution of organic matter and total soil organic carbon content of Black Chernozemic soils developed on loamy glacial till landscapes in the Parkland Region of Manitoba. The carbon content of the soils on the Farm falls within the range indicated for similar soil landscapes in Western Canada (Soil Carbon Data Base Working Group, Interim Report, January, 1993. CLBRR Cont. No. 92-179).

4.4.4 Soil Drainage and Groundwater Hydrology

The distribution of surface drainage on the Zero Till Farm varies from excessive runoff on the steeper slopes to prolonged inundation of the depressional areas (Figure 6). Well drained soils account for 52 percent of the area, imperfectly drained soils cover 16 percent and the remaining 32 percent is poorly to very poorly drained. Most of the precipitation and snowmelt on the Farm is retained in the local landscape as runoff from the knolls and upper slope positions accumulates in the intervening depressions to form sloughs and marshes. Portions of most of the larger sloughs and marshes are characterized by areas of shallow open water in most years. Removal of water from these potholes or depressions is largely through evaporation and seepage.

The farm is located in a regional groundwater recharge area. Pedologic and hydrologic processes interact in the environment to influence soil profile characteristics and soil distribution. Water movement in and through the soil is directly related to two distinct features of hydrology; gradient and hydraulic conductivity. Soil profile characteristics can be used to infer the local water regimes in the landscape. The depth and degree of leaching as indicated by the type and sequence of profile horizons help to interpret local shallow groundwater activity. For example, leached and eluviated profiles result from infiltration and downward water flow through the soil. In contrast, non-leached profiles, that is soils which contain lime carbonate and soluble salts generally indicate relatively little infiltration.

Approximately 63 percent of the soils on the Zero Till Farm are characterized by net infiltration of water. Soils included in this group are the well drained Cordova, Rufford and Newdale soils and the leached Angusville and Penrith soils. These soils reflect removal of soluble constituents from the soil profile and represent sites of potential groundwater recharge. In contrast, exfiltration, that is, upward water movement and evaporation from the soil surface is characteristic of 37 percent of the soils on the farm. These profiles are non-leached, often developing in areas where much of the precipitation and snow melt runs off, such as the crest of slopes and knolls, or in areas which have relatively persistent high water tables and moisture status such as adjacent to water-filled depressions. Diagnostic features of these areas include imperfectly and poorly to very poorly drained soils which are carbonated and often weakly to moderately saline. Imperfectly drained Varcoe soils, poorly drained Drokan soils and very poorly drained soils of the Marsh complex are in this group. These soils are associated with persistent high water tables resulting from very low groundwater gradients and slow infiltration due to relatively low hydraulic conductivity and high moisture status.

4.4.5 Risk for Subsoil and/or Groundwater Contamination

The kind and degree of soil profile development is a function of the 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 a soils 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.

Hydrologically, the entire landscape on the farm is described as a groundwater recharge area characterized by slow downward hydraulic gradients. The risk to subsoil contamination by infiltration of surface waters varies with soil conditions and position in the landscape. Based on these assumptions, the relative risk for subsoil contamination is estimated in Table 13 and the areal extent of the soil conditions affecting this risk is shown in Figure 7.

Upper and mid slope positions in the landscape are characterized by runoff which usually accumulates in adjacent lower slope and depressional areas. Leached soils in these lower slopes and depressions occupy 10.9 percent of the area and present the highest risk for infiltration of chemical and/or fertilizer to the subsoil and the groundwater. A moderate risk of infiltration occurs at crest and upper slope positions where the runoff potential is greater and the soils are moderately to weakly leached (52.0 percent of area). Non-leached, carbonated soils represent a low risk (15.0 percent of area) and moist areas of both carbonated and salinized soils represent a very low risk (22.2 percent of area) for infiltration to occur to the subsoil.

The potential for infiltration and leaching to occur in this landscape is estimated in terms of **relative risk**. Evaluation of the potential for subsoil and/or groundwater contamination requires careful

Table 9. Summary of Soil Properties For All Series

Soil Series	Horizon	n	OM %	pH	EC mS/cm	n	Particle Size			Texture Class
							Sand %	Silt %	Clay %	
Newdale	A	30	6.67	7.5	0.5	14	34	32	34	CL
	C	30		7.8	0.9	14	35	33	32	CL
Rufford	A	14	6.47	7.6	0.5	8	33	31	36	CL
	C	14		7.9	0.4	8	30	33	37	CL
Cordova	A	8	7.45	7.5	0.7	4	36	31	33	CL
	C	8		7.9	1.1	4	33	35	32	CL
Angusville	A	4	8.27	7.3	0.5	2	27	38	35	CL
	C	4		8.0	0.2	1	32	34	34	CL
Varcoe	A	19	8.00	7.6	1.1	10	31	33	36	CL
	C	19		7.9	3.3	9	30	35	35	CL
Penrith	A	3	13.66	7.1	0.9	3	21	47	32	CL
	C	2		8.2	0.4	1	33	35	32	CL
Drokan	A	12	10.44	8.0	3.3	7	30	34	36	CL
	C	12		8.0	4.9	7	31	32	37	CL
Marsh	A	1	4.20	8.3	6.6					
	C	2		7.9	4.8	1	38	26	36	CL

n = Number of samples; OM = Organic Matter; EC = Electrical Conductivity (mS/cm)

Table 10. Summary of Soil Properties From 24 Sites

Soil Series	N	Depth cm	B.D. g/cm^3	O.M. %	N	Ksat cm/hr
Newdale	10	0-12	0.99	7.60		
(NDL)	8	12-20	1.42	3.72	13	1.3
	9	20-30	1.44	2.00		
Rufford	7	0-11	1.08	6.72		
(RUF)	6	11-19	1.37	3.74	4	1.2
	7	19-31	1.43	2.40		
Angusville	2	0-11	1.03	6.59		
(ANL)	2	11-17	1.45	3.60	2	0.1
	2	17-36	1.48	0.55		
Varcoe	5	0-11	1.07	6.72		
(VRC)	4	11-19	1.30	5.57	4	0.4
	5	19-30	1.38	2.84		

N = Number of Samples; B.D. = Bulk Density; O.M. = Organic Matter;
Ksat = Saturated Hydraulic Conductivity

Table 11. Summary of Physical, Chemical and Moisture Properties of Soils

Soil Series	Horizon	Depth cm	OC %	Texture	BD g/cc	FC %	PWP %	AW mm	AW % vol
Newdale	Ap	0- 14	4.87	CL	0.91	34.5	13.2	27	19
(NDL)	Ah	14- 27	2.72	CL	1.40	25.4	12.0	24	19
	Bm	27- 42	1.07	CL	1.67	20.6	9.9	27	18
	BC	42- 60	0.49	CL	1.57	20.3	9.1	32	18
	Ck1	60- 84	0.39	CL	1.49	20.5	10.7	35	15
	Ck2	84-120	0.25	CL	1.50	21.2	10.2	59	17
								204	
Newdale	Ap	0- 15	4.79	SIL	1.07	32.4	12.5	32	21
(NDL)	Ah	15- 30	0.99	SICL	1.40	23.3	12.5	23	15
	Btj	30- 54	1.05	SIC	1.42	26.4	12.1	49	20
	Ck1	54- 78	0.35	CL	1.55	23.0	10.9	43	19
	Ck2	78-120	0.16	L	1.59	20.2	10.2	67	16
								214	
Rufford	Ap	0- 12	4.86	CL	1.04	33.0	14.3	23	19
(RUF)	AC	12- 29	1.73	CL	1.36	25.3	12.3	30	18
	Ck1	29- 59	0.91	SICL	1.32	26.8	13.7	52	17
	Ck2	59- 86	0.35	SIL	1.37	23.2	10.1	48	18
	Ck3	86-120	0.15	CL	1.52	21.0	8.4	65	19
								218	
Varcoe	Apk	0- 13	3.29	C	1.13	28.5	13.9	21	17
(VRC)	AC	13- 27	1.43	C	1.36	27.9	14.7	25	18
	Ckgj1	27- 60	0.59	SICL	1.31	30.1	13.7	71	21
	Ckgj2	60- 89	0.15	SCL	1.65	19.9	7.1	61	21
	Ckgj3	89-120	0.06	L	1.65	20.2	9.6	54	17
								232	

OC= Organic Carbon, BD= Bulk Density, FC= Field Capacity, PWP= Permanent Wilting Point, AW= Available Water

Table 12. Zero Till Farm Organic Carbon Content

Drainage	Soil Series	Organic Carbon Content to 1 m depth(t/ha)	Area (hectares)	Total Organic Carbon to 1 m depth (tonnes)
Well	Newdale (NDL)	156.74	79.05	12,390.30
	Cordova (CVA)	164.70	7.20	1,185.84
	Rufford (RUF)	154.32	51.28	7,913.53
Imperfect	Varcoe (VRC)	199.11	28.76	5,726.40
	Angusville (ANL)	175.75	13.12	2,305.84
Poor	Penrith (PEN)	253.16	15.76	3,989.80
	Drokan (DRO)	232.20	51.20	11,888.64
Very Poor	Marsh (MHC)	214.40	18.55	3,977.12
Total Organic Carbon on Farm to 1 m depth				49,377.47

Table 13. Relative Risk for Subsoil and/or Groundwater Contamination

Soil Conditions	Risk	Extent	
		Hectares	%
Leached and eluviated,lower slope and depressions Angusville (ANL), Penrith (PEN)	High	28.89	10.9
Moderately to weakly leached, upper slopes and knolls Newdale (NDL), Cordova (CVA), Rufford (RUF)	Moderate	137.53	51.97
Non-leached, carbonated, lower slopes and depressions Varcoe (VRC), Drokan (DRO), Marsh (MHC)	Low	39.37	14.93
Non-leached, carbonated and salinized, lower slopes and depressions Drokan saline phase (DRO s), Varcoe saline phase (VRC s)	Very Low	58.92	22.24

interpretation. The possibility for leaching of chemicals and fertilizer 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 accumlulate in the soil environment. Pedologic and hydrologic processes influence the impact that different kinds of land use may have on the environment. The degree of difficulty or feasibility of protecting the soil and groundwater or of applying remedial measures to reclaim contaminated soil is related to the degree of risk, ie., greatest on the high risk areas in the landscape. Given this scenario, the high risk soils could serve as potential sites for monitoring the impact of land use on the subsoil and/or groundwater environment.

4.4.6 Soil Moisture Properties

Soil moisture properties were measured at four sites on the research farm (Table 11). Various physical properties including organic carbon, carbonates, particle size and bulk density were analyzed on soil horizons to a depth of 1.2 meters. Soil moisture content at field capacity, permanent wilting point and available water holding capacity were determined for each soil to a depth of 1.2 meters.

Field capacity (FC) 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.

Permanent wilting point (PWP) 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.

Available water holding capacity (AWHC) 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 centimetres of water per unit depth of soil.

4.4.7 Soil Salinity

Salinity levels for soils sampled on the research farm are shown in Tables 21 and 22, Appendix C. The areal extent and level of salinity across the farm is also presented in a derived map format shown in Figure 8. Generally the average surface (0-15 cm) electrical conductivity levels range from .5 to 3.3 mS/cm while the subsurface levels (50-70 cm) range from .2 to 4.9 mS/cm (Table 9). Weakly saline soils affect 57 hectares or 22 percent of the farm area. The Drokan saline phase soils account for 16.8 %, while Varcoe saline phase soils make up the remaining 5.4 percent. Approximately 50 % of all Varcoe soils are saline and 90 % of the Drokan soils are saline.

The origin and accumulation of soluble salts in soil is from continual evaporation of soil water and the subsequent concentration of accumulation of salt at the soil surface. The salinity in these soils results from seepage and evaporation from a saturated soil or from soil adjacent to semi-permanent sloughs and water bodies. These sites are often referred to and described mistakenly as local groundwater discharge areas.

The EM 38 grid point and wetland transect readings assisted in the calibration and extrapolation of limited electrical conductivity data available from soil analyses. The calibration procedure included sampling for lab analysis to 120 cm at a number of sites where EM 38 readings were taken in order to establish a general relationship between the EM 38 readings and the actual electrical conductivity levels. The resulting regression curve showed that EM 38 readings of approximately 85 to 150 mS/m^{-1} correspond to electrical conductivities of 4 to 8 mS/cm. It should be noted that EM 38 readings primarily reflect soil salinity levels, but are also affected by texture, moisture content, temperature or any combination of these factors. Extrapolation of the EM 38 data assisted in the delineation of saline map units. Five wetland transect graphs are shown in Figures 17 to 21. These graphs show the general trend of salinity levels in a landscape going from the depression or pothole to a middle or upper slope position. Highest levels of salinity typically occur in the grassed depressional (poorly drained) areas up to the grass-cultivated boundary. Frequently there is a narrow band of saline cultivated soils bordering the grassed depressions. A summary of the EM 38 wetland transect data is presented in Table 23 Appendix C.

4.4.8 Stoniness

Approximately 55 % of the zero till farm or 141 hectares are slightly stony (Figure 9). The stony condition occurs dominantly on the Newdale, Rufford, Cordova and Varcoe soils. Under a slightly stony condition, only 0.01 to 0.1 % of the land surface is occupied by stones. Class 1 stoniness is not considered a limitation for soil capability since there is little or no hinderance to cultivation and clearing is generally not required. The majority of the coarse fragments are in the 8-25 cm. range and are referred to as cobbly.

4.4.9 Erosion Status and Risk Assessment

Erosion is defined as the detachment and movement of soil particles by water, wind, ice or gravity. Soil erosion by water is the main concern on undulating and hummocky soil landscapes in the agricultural region of Manitoba. Soil loss resulting from rainfall-runoff is usually due to combinations of raindrop splash, and sheet, rill, gully and channel bank erosion. Sheet and rill erosion are usually least apparent in the landscape, but often the most damaging as it causes gradual thinning of the soil profile over the entire slope. Sheet erosion tends to occur on upper slopes and ridges whereas the more visible rills form in the area of concentrated runoff on mid and lower slopes. The deposition of eroded soil at the base of slopes or in ditches constitutes additional losses and costs attributed to erosion.

The observed extent and severity of erosion on the Zero Till Farm is minimal (Figure 11). Approximately 9 hectares or only 3 percent of the soils are characterized by slight erosion (up to 25 percent of the original A horizon may have been removed). Most soils with this degree of erosion are not significantly different in use capabilities and management requirements from noneroded soil.

Evaluating the risk of water erosion is an important management activity which serves to identify the relative susceptibility of various soil landscapes. This information can then be used to design effective conservation practices for susceptible areas. The higher the risk, the more critical becomes the requirement for protective measures.

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 intensity, soil erosivity, topography, cover and conservation practices. Although soil and crop management practices are the only practical way to control sediment loss, the inherent susceptibility of a soil to particle detachment and transport is a major factor in the soil loss equation. Soil erosion due to rainfall and runoff may vary more than tenfold just because of basic soil differences (Wischmeier et al, 1971).

Soil properties which affect infiltration rate, permeability and total water holding capacity and those that affect dispersion, splashing, abrasion and transportation of soil particles by runoff are relatively uniform on the Zero Till Farm and are not expected to cause any significant differences in soil loss from water erosion. Application of the USLE parameters to conditions on the Farm indicates the estimated soil loss would differ according to differences in slope length and steepness.

Topographic characteristics on the Farm are shown in Figure 10. Slope steepness in the hummocky landscapes ranges from 2 to 5 percent. Slope length in these landscapes varies from 25 to 50 m with mean slope lengths being about 40 m. Soils in landscapes characterized by steeper slopes and greater lengths are more susceptible to water erosion. Soils in nearly level areas (0.5 to 2 percent slopes) and level to depressional areas (0 to 0.5 percent slopes) are less susceptible to water erosion. These low relief areas however, generally receive sediment removed from adjacent upper slopes and knolls (Table 14).

Soil loss from a bare, unprotected soil surface (no soil protection from crop cover or management) is considered a worst case scenario. Soil loss decreases dramatically however, if the soil is managed under a minimum till system . The protection to the soil surface provided by crop residue results in a four to five fold reduction in estimated soil loss (Table 14).

The rate of soil loss is usually expressed in terms of average soil loss per hectare per year. Estimation of potential soil loss on this farm ranged from 0 to 14.5 tonnes. A negligible risk of water erosion would apply to a major portion of the farm 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 most soils on the Farm. It is preferable to use the lower limits of tolerable soil loss under Manitoba conditions because the soils are frozen and snow-covered for the winter period.

4.4.10 Single Factor and Derived 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. Such single factor maps and interpretative maps show the distribution of individual soil properties and indicate the degree of soil limitation or potential for selected agricultural uses and environmental applications.

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 of sampling and instrumentation sites for monitoring soil quality and assessing environmental impact.

A series of derived and interpretive maps at a 1:16 000 scale for the Zero Till Farm are provided in Figures 3 to 12. These colour thematic maps are generated by the PAMAP Geographic Information System from the 1:5000 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.

The interpretive and single factor themes generated for the Zero Till Farm are:

- Interpretive Map for Agricultural Capability . . . . Figure 3
- Interpretive Map for Irrigation . . . . Figure 4
- Derived Map for Organic Matter . . Figure 5
- Derived Map for Drainage . . . . . . Figure 6
- Derived Map for Relative Risk for Subsoil and/or Groundwater Contamination Figure 7
- Derived Map for Salinity . . . . Figure 8
- Derived Map for Stoniness . . . . . . Figure 9
- Derived Map for Topography . . . . Figure 10
- Derived Map for Erosion . . . . Figure 11
- Derived Map for Erosion Risk . . . . Figure 12

Table 14. Estimated Risk of Soil Losses From Water Erosion

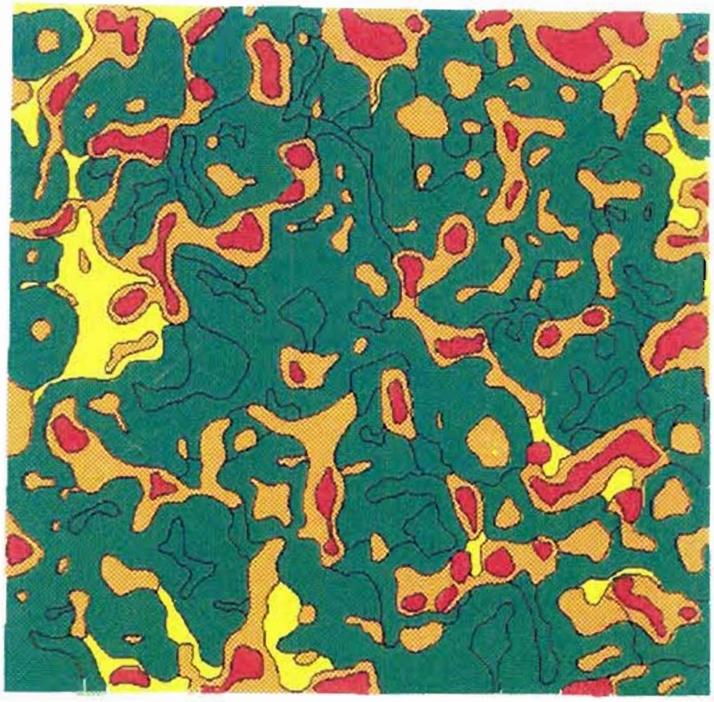
Risk Class[1]	Topographic Class and Associated Soils	Slope Characteristics		Estimated Soil Loss, t/ha/yr	
		Steepness %	Length m	Bare Soil	Minimum Till
Negligible <6.0 tonnes/ha/year	Level to depressional Drokan (DRO) Penrith (PEN) Marsh (MHC) Angusville (ANL) Varcoe (VRC)	0-0.5	20-50	0-2.5	0-0.5
		Potential Sediment Gain			
	Undulating, nearly level Angusville (ANL) Varcoe (VRC)	0.5-2	30-50	1.9-5.0	0.4-1.0
		Potential Sediment Gain			
Low to Moderate 6.0-21.9 tonnes/ha/year	Undulating to hummocky, very gently sloping Newdale (NDL) Rufford (RUF) Cordova (CVA)	2-5	25-50	4-14.5	0.8-2.9

[1] Risk classes of High and Severe do not occur.

LEGEND Water Erosion Risk

Class		Soil Loss tonnes/ha/year
	Negligible	<6.0
	Low	6.0-10.9
	Moderate	11.0-21.9
NA	High	22.0-32.9
NA	Severe	>33.0

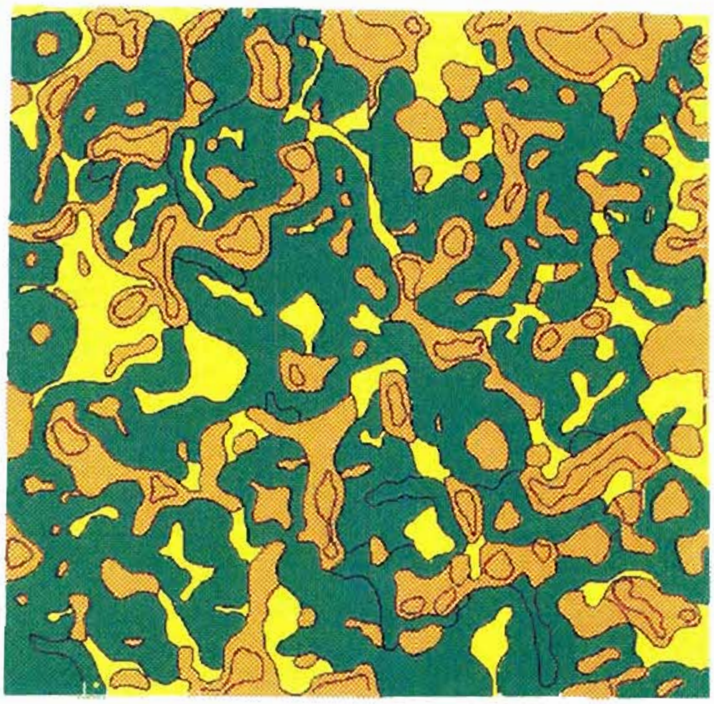
N



Agricutural Capability

Class	Area ha	% Area
2	159	62
3	15	6
5	64	25
7	18	7

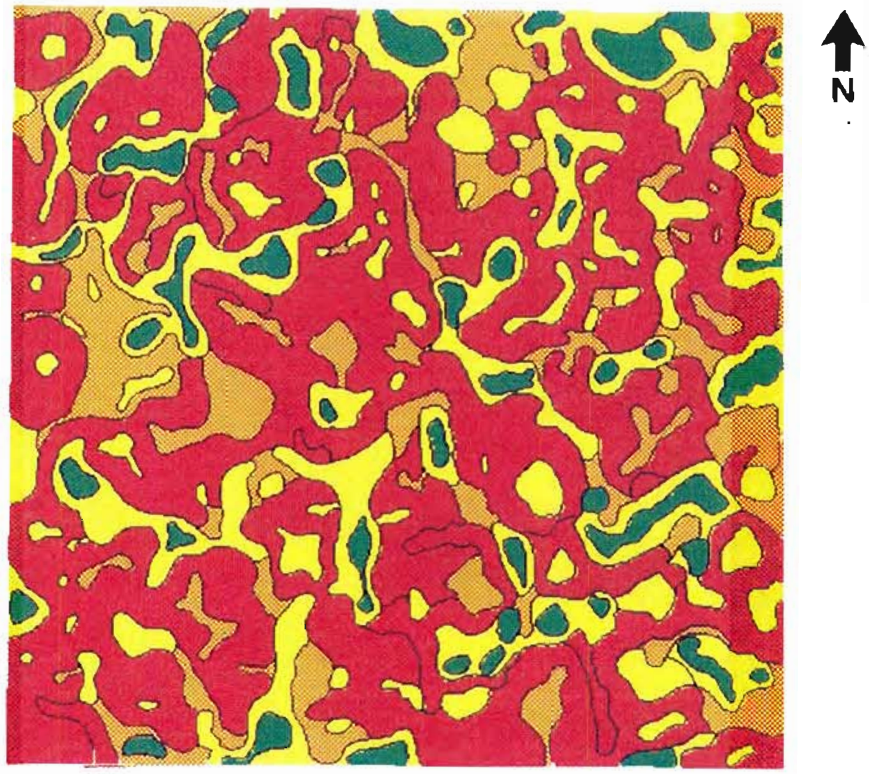
Figure 3



Irrigation Suitability

Class	Area ha	% Area
Good	136	53
Fair	38	15
Poor	82	32

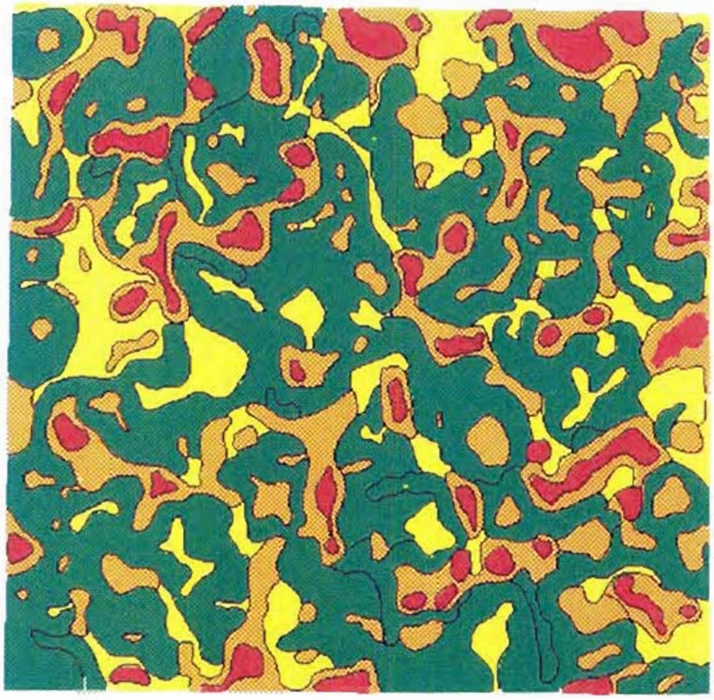
Figure 4



Organic Matter and Organic Carbon Levels

	Surface (0-20cm) Organic Matter (%)	Organic Carbon (tonnes/ha)	Area ha	% Area
Red	6.4 - 7.5	154 - 165	137	52
Orange	8.0 - 8.3	172 - 200	41	16
Yellow	10.4 - 14	232 - 253	67	25
Green	>14	214	18	7

Figure 5



Drainage

Class	Area ha	% Area
Well	133	52
Imperfect	41	16
Poor	64	25
Very Poor	18	7

Figure 6

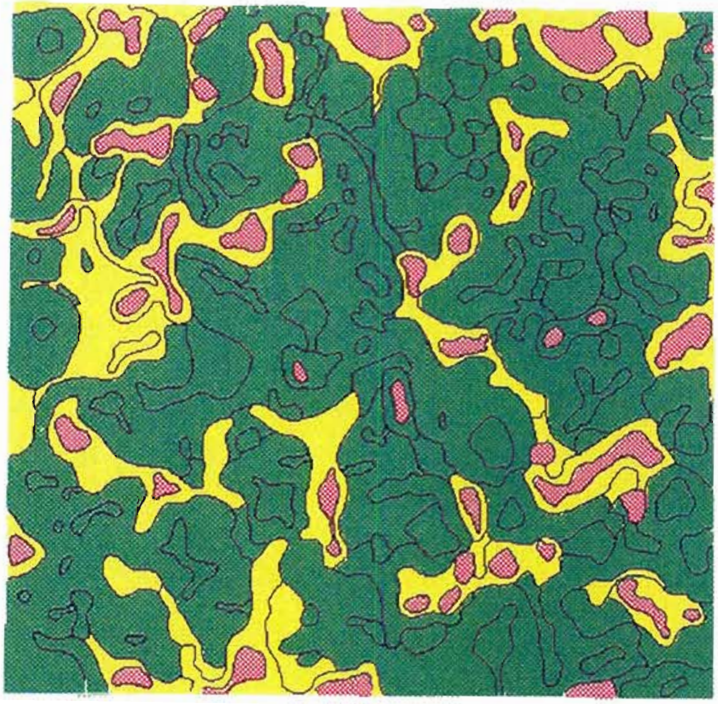
N

Risk for Subsoil and/or Groundwater Contamination

Risk	Area ha	% Area
High	28.9	10.9
Moderate	137.5	52.0
Low	39.4	14.9
Very Low	58.9	22.2

Figure 7

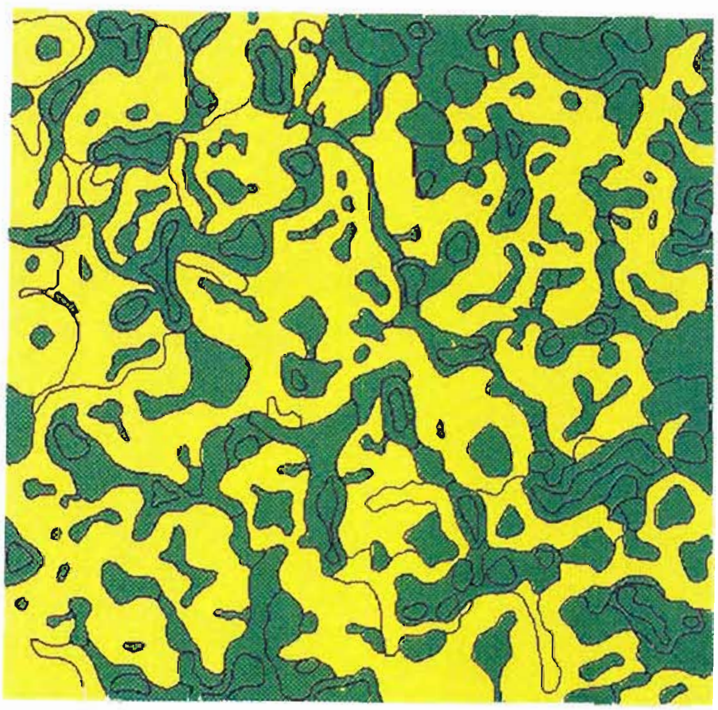
N



Salinity

Class (mS/cm)	Area ha	% Area
nonsaline (0 - 4)	181	71
weakly saline (4 - 8)	57	22
Marsh	18	7

Figure 8



Stoniness

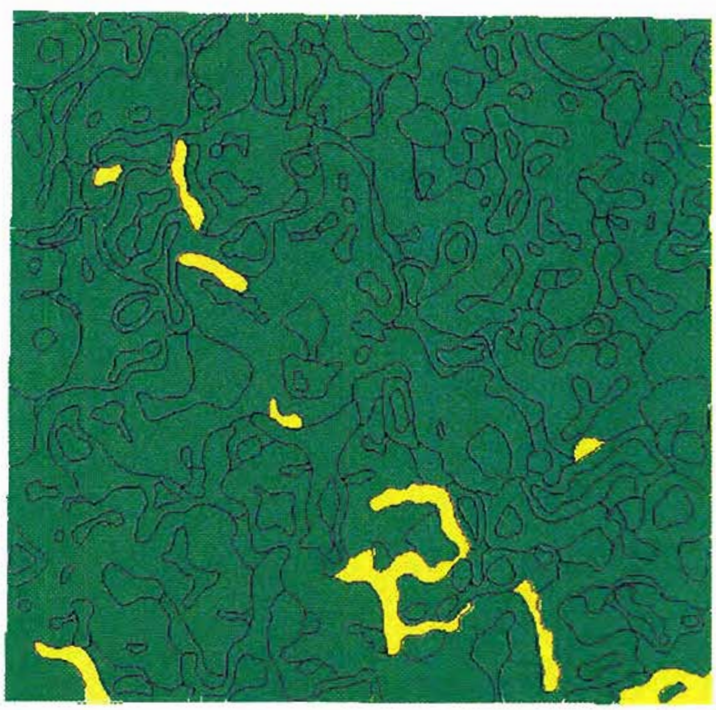
Class	Area ha	% Area
nonstony	115	45
slightly	141	55

Figure 9

Topography

Class	Area ha	% Area
a (0-0.5%)	92	36
b (0.5-2%)	31	12
c (2-5%)	133	52

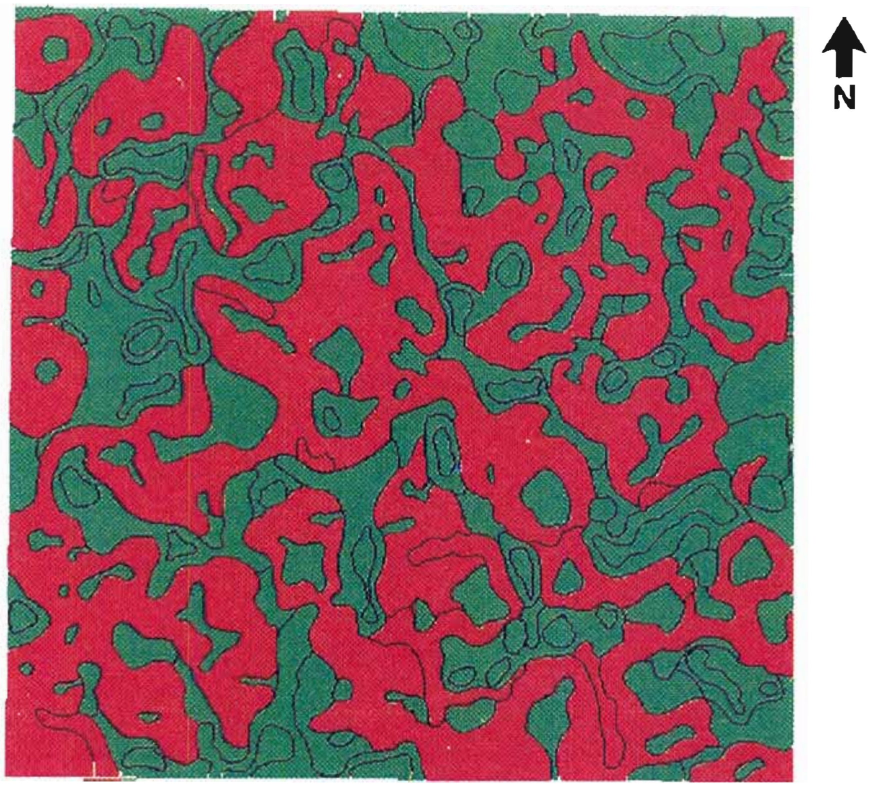
Figure 10



Erosion

Class	Area ha	% Area
noneroded	247	97
slightly eroded	9	3

Figure 11



Water Erosion Risk

	Slope Class	Risk Class	Erosion Rate (t/ha/yr)
Green	a & b (0-2%)	negligible	<6
Red	c (2 - 5%)	low to moderate	6 - 22

Figure 12

APPENDIX A

GUIDES FOR EVALUATING AGRICULTURAL CAPABILITY AND IRRIGATION SUITABILITY

Table 15. 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 16. 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 droughtiness 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 17. 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 18. 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 19. 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 20. Soil and Landscape Conditions Affecting Environmental Impact Rating

Soil Property and Landscape Feature	Potential Degree of Impact			
	None	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 20.

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 weighting 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.

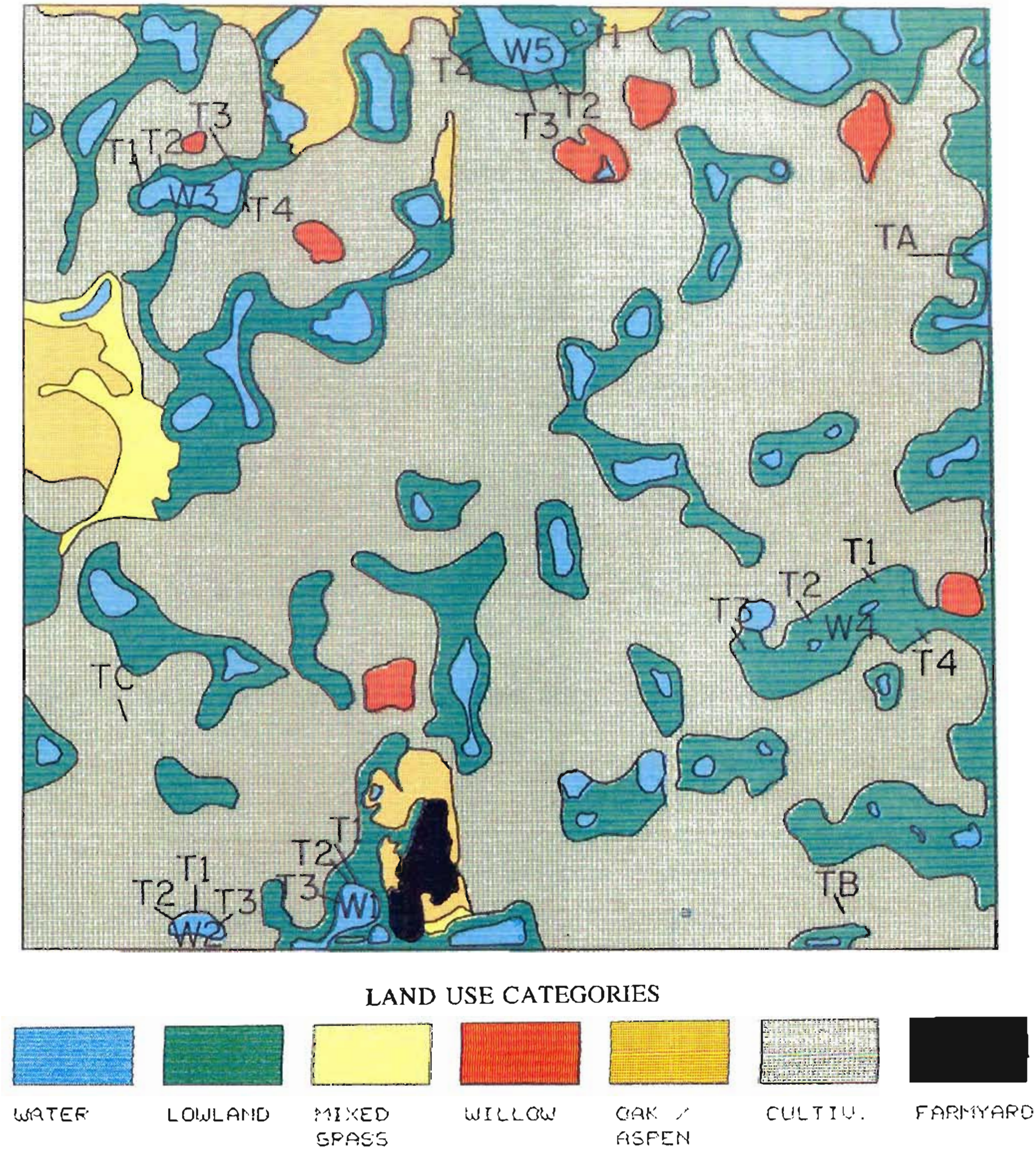
    A shallow **depth (< 1 m) to water table** has a higher risk for contamination than soils with a deep water table. Soils with high levels of **salinity** may adversely impact on groundwater quality due to the leaching associated with irrigation practices (ie: applied leaching fraction).

    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.

APPENDIX B

LAND USE MAP, SLOPE TRANSECTS AND EM38 TRANSECTS

Figure 13. Land Use Map



Slope Transects	**TA, TB, TC**
Wetland Sites	W1 - W5
Salinity Transects	**T1, T2, etc**

Figure 14. Slope Transect A

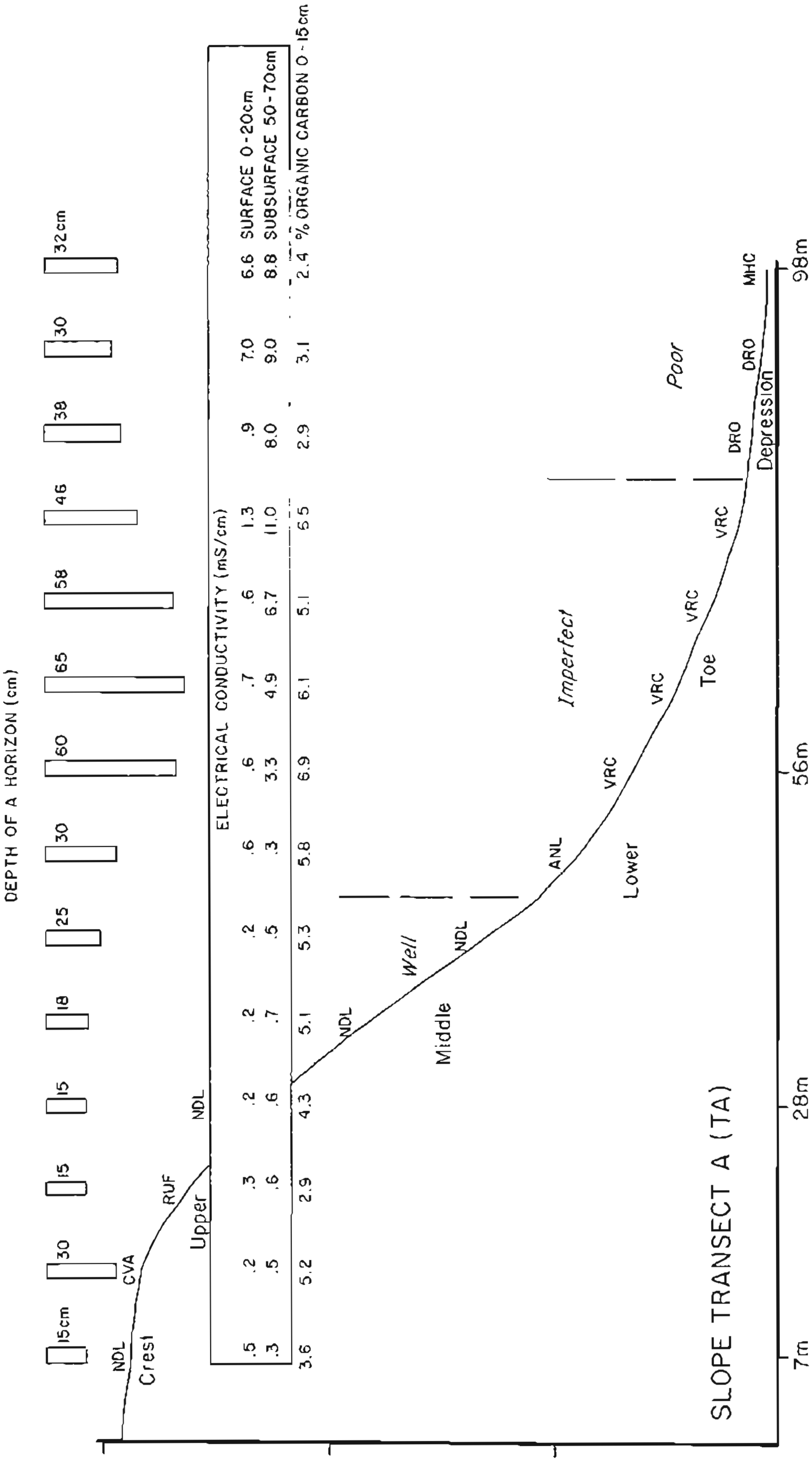


Figure 15. Slope Transect B

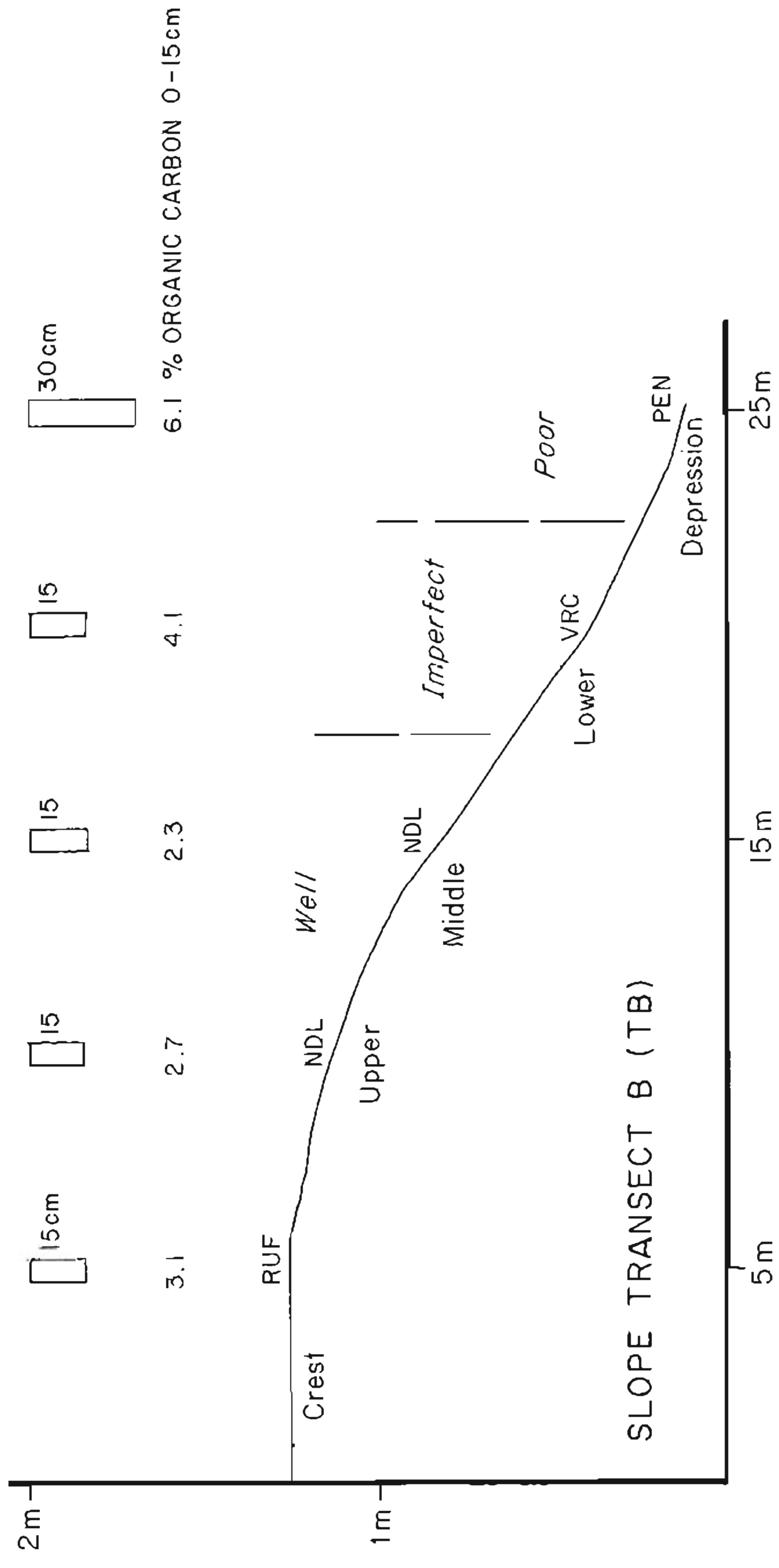


Figure 16. Slope Transect C

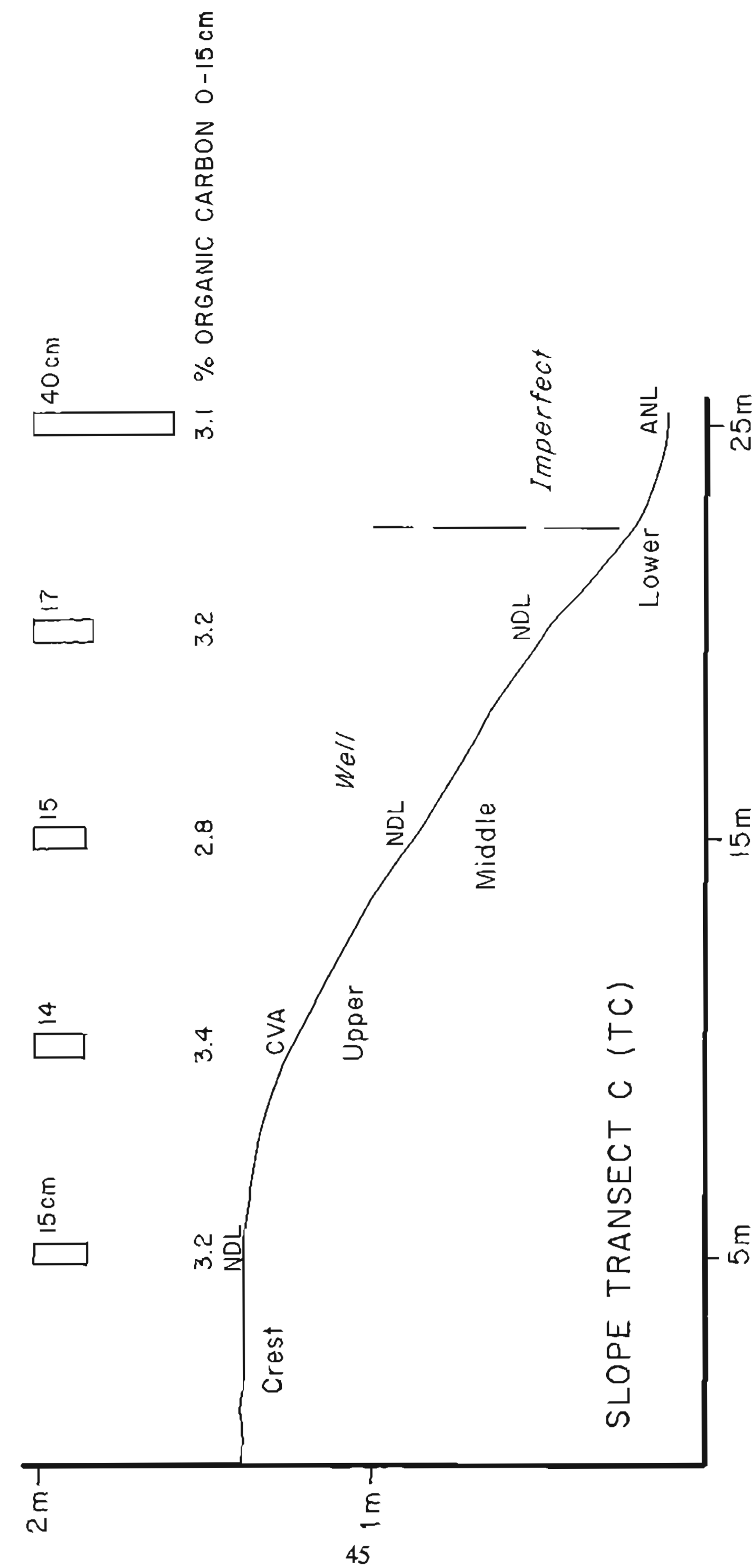


Figure 17. Salinity Characterization Wetland 1 - Transect 2

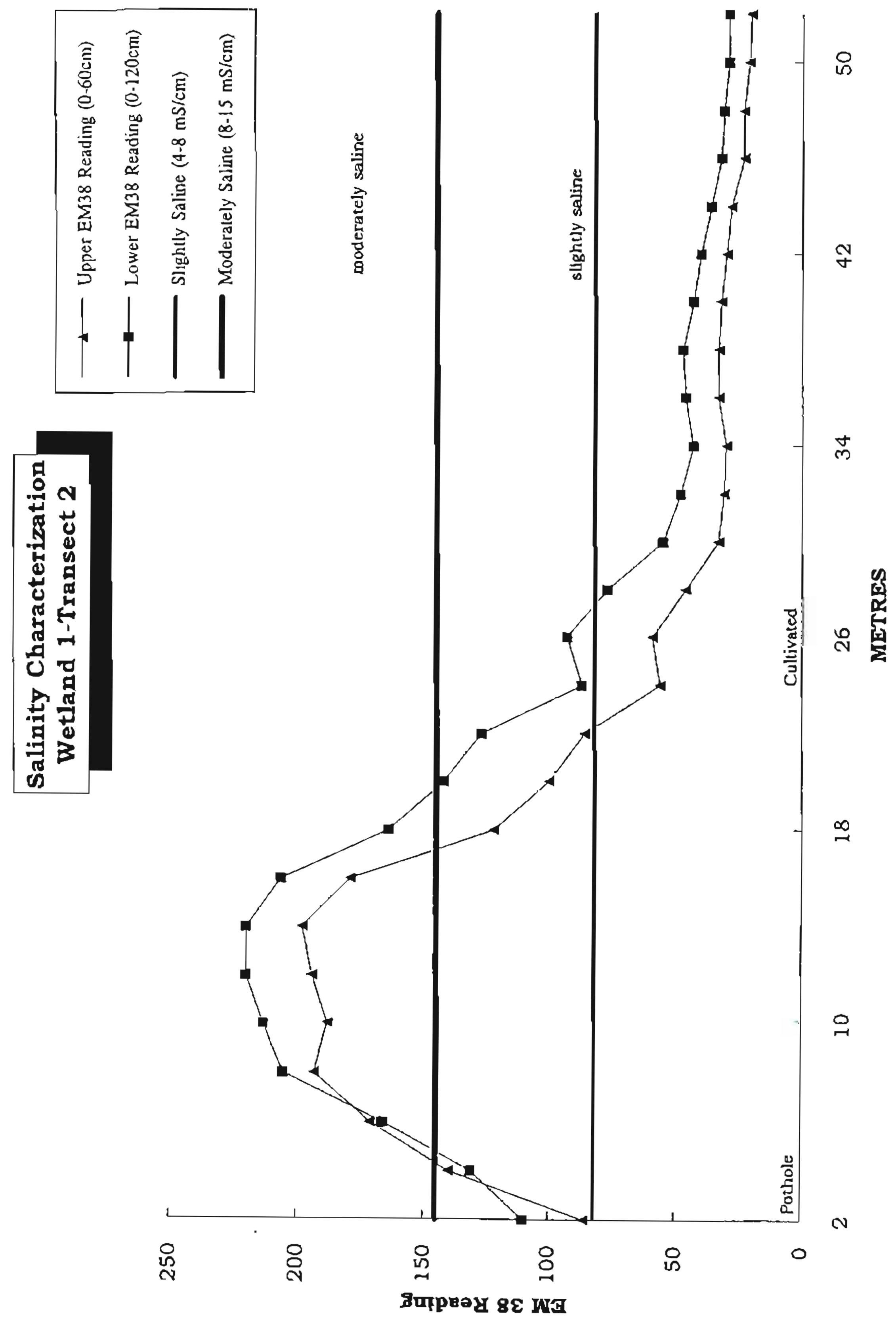


Figure 18. Salinity Characterization Wetland 2 - Transect 2

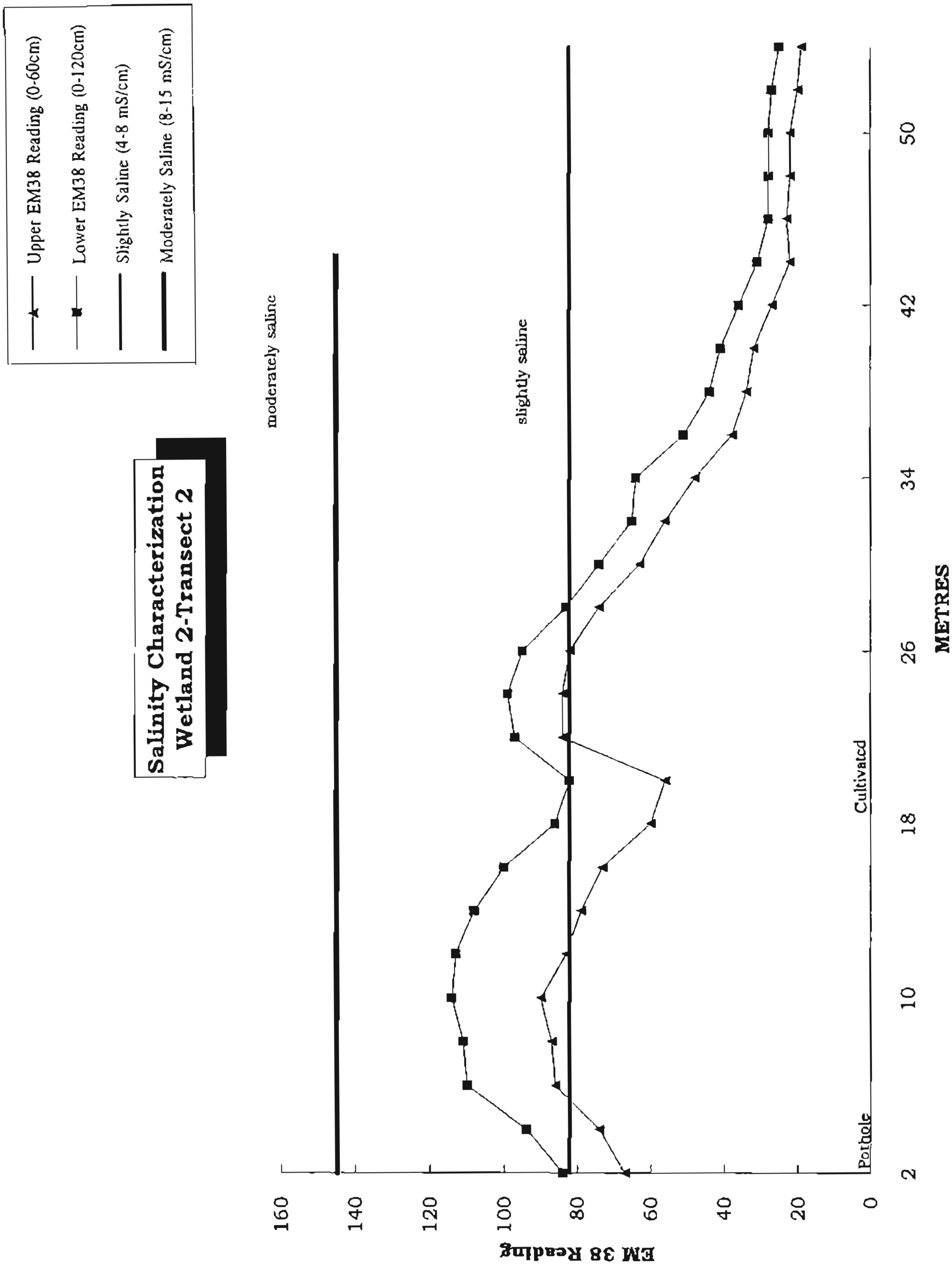


Figure 19. Salinity Characterization Wetland 3 - Transect 2

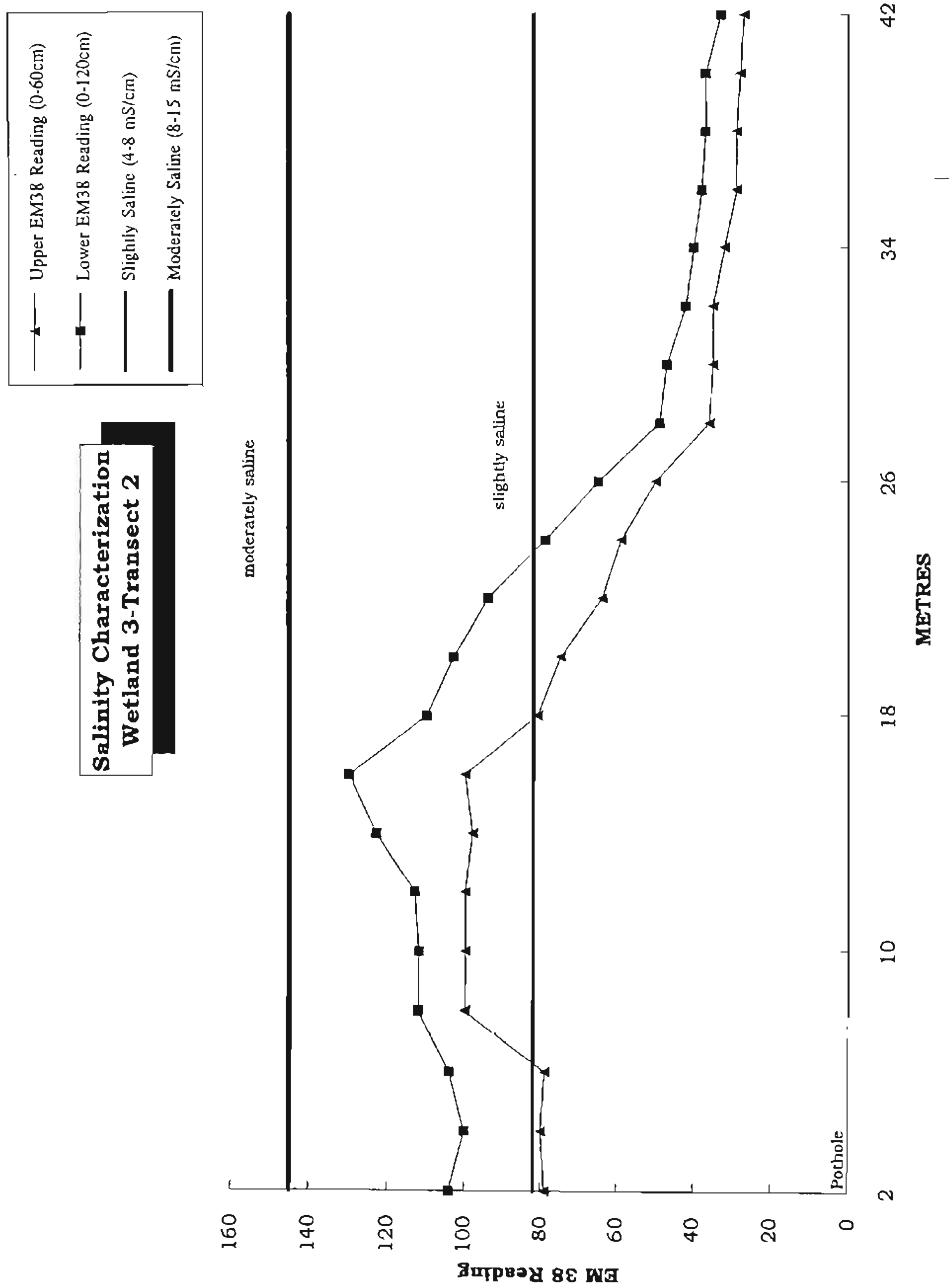


Figure 20. Salinity Characterization Wetland 4 - Transect 2

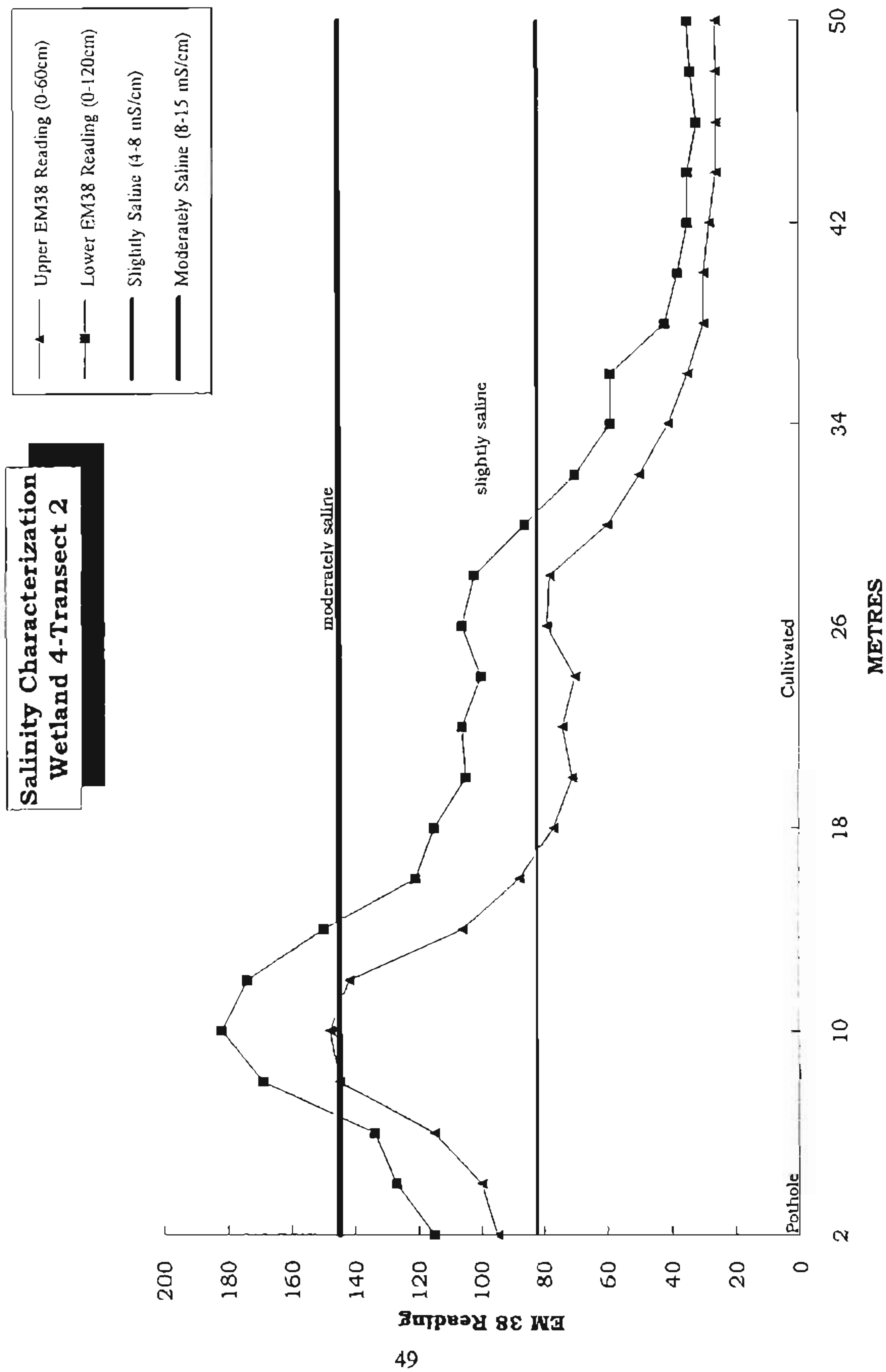
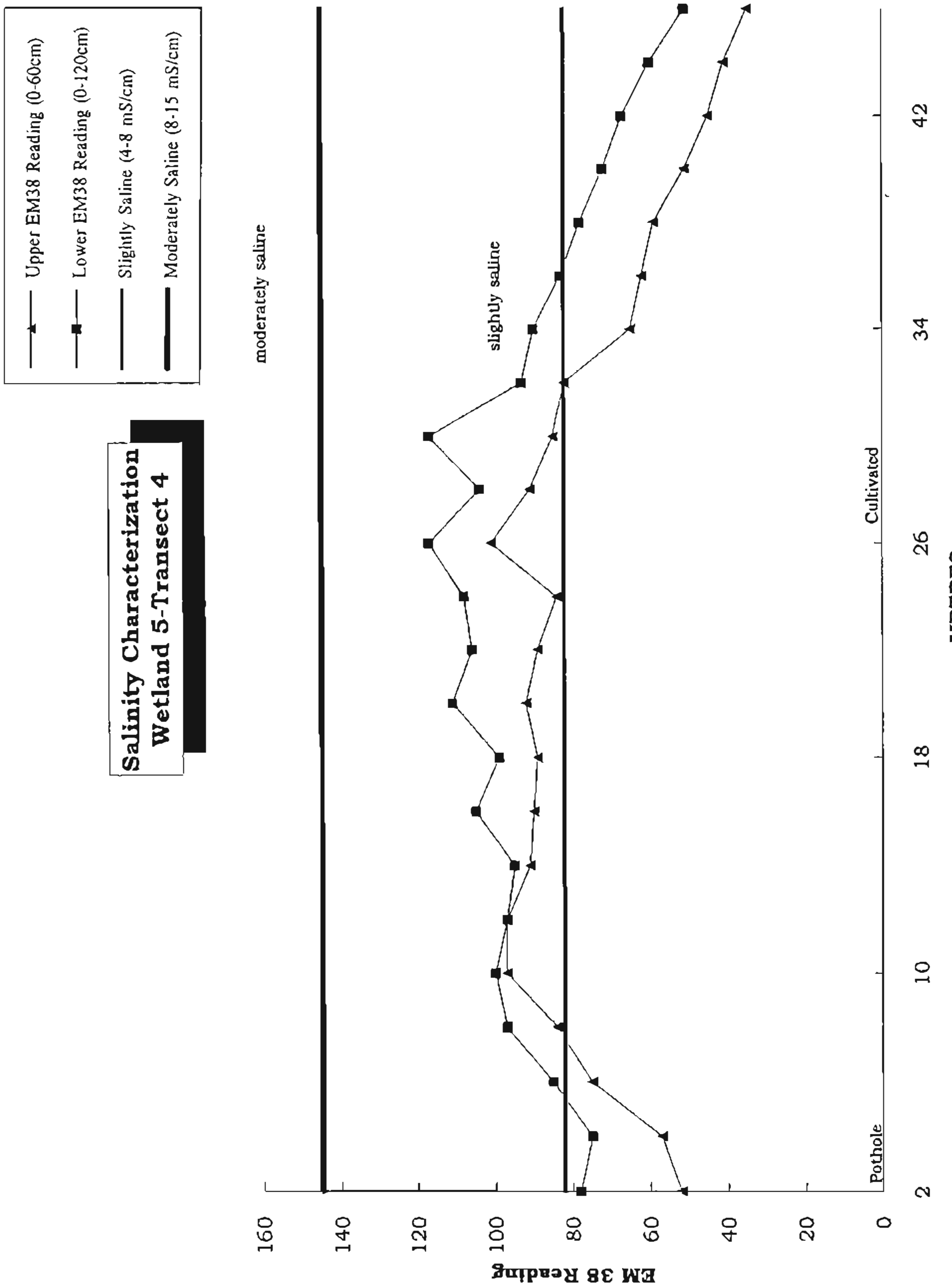


Figure 21. Salinity Characterization Wetland 5 - Transect 4



APPENDIX C

SOIL ANALYTICAL DATA AND EM38 DATA

Table 21. Soil Analytical Data at Survey Grid Points and Slope Transects

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
2	CVA	Ap	0	15	CL	4	5	7	11	7	34	30	36	5.3	7.5	3.78	0.9	53.3
2	CVA	Ck	50	75	CL	4	4	7	9	7	31	36	33	42.0	7.9	0.37	0.2	49.9
3	RUF	Ap	0	15	CL	1	3	5	8	7	24	38	38	4.3	7.6	4.40	0.5	55.7
3	RUF	Ck	25	50	SIC	0	1	3	6	4	14	42	44	25.9	7.9	0.84	0.5	54.5
4	NDL	Ap	0	20	CL	3	5	8	12	8	36	30	34	0.4	7.1	4.42	0.8	60.5
4	NDL	Cks	60	75	L	3	5	8	18	13	47	29	24	22.4	8.1	0.39	5.2	39.6
5	VRC	Ap	0	25	SIC	0	1	3	5	3	12	47	41	0.0	6.7	3.77	0.5	63.6
5	VRC	Ckgj	40	60	CL	4	4	5	7	6	26	41	33	29.1	7.7	0.43	0.3	38.3
6	CVA	Ap	0	15	CL	3	6	9	13	9	40	28	32	7.0	7.5	3.20	0.7	51.0
6	CVA	Ck	40	60	L	4	6	10	18	12	50	28	22	29.5	8.0	0.28	0.3	34.8
7	NDL	Ap	0	20	CL	3	5	8	12	8	36	32	32	1.4	7.4	2.38	0.7	46.8
7	NDL	Btj	20	35	CL	2	5	9	12	8	36	25	39	0.6	7.5	1.50	0.2	44.8
7	NDL	Ck	50	60	CL	4	5	8	12	8	37	35	28	22.5	7.7	0.45	0.3	39.3
8	CVA	Apk	0	20										2.9	7.4	4.27	0.4	55.8
8	CVA	Ck	50	60										23.5	7.8	0.38	0.2	48.2
9	PEN	Ap	0	20	SICL	1	1	3	6	5	16	48	36	0.0	6.3	8.32	0.8	88.1
9	PEN	Btg	35	50	SIC	0	0	2	5	4	11	40	49	0.0	6.8	0.41	0.3	60.4
10	VRC	Aps	0	25	SCL	14	10	11	8	5	48	27	25	0.0	7.7	3.80	5.5	59.8
10	VRC	Ckgjs	50	75	CL	3	7	11	13	7	41	25	34	28.6	8.0	0.17	6.4	34.1
11	NDL	Ap	0	20										1.7	7.4	5.46	0.9	58.5
11	NDL	Ck	40	60										26.7	7.9	0.38	0.3	47.8
12	VRC	Ap	0	20	CL	3	4	7	10	7	31	33	36	0.0	7.0	4.63	0.6	50.1
13	CVA	Ap	0	20	CL	3	4	6	10	8	31	35	34	2.6	7.4	6.29	1.1	66.1
13	CVA	Cks	50	65	C	0	0	2	7	10	19	38	43	35.1	7.9	0.41	6.4	51.9
14	NDL	Ap	0	20										0.6	7.0	2.64	0.5	49.7
15	CVA	Ap	0	18										4.5	7.5	4.62	0.8	56.5
15	CVA	Ck	50	100										28.2	7.6	0.26	0.3	45.1
16	PEN	Ap	0	25	SICL	0	2	5	7	3	17	51	32	0.0	7.1	9.42	1.0	95.0
16	PEN	Ahe	25	45	SICL	1	2	3	5	4	15	51	34	0.0	7.0	2.33	0.3	47.8
16	PEN	Btg	45	75	C	0	1	2	4	3	10	35	55	0.4	7.3	0.85	0.4	66.1
17	DRO	Ahk	0	40	C	3	4	6	8	6	27	30	43	10.2	7.8	6.08	1.2	90.4
17	DRO	Ckgs	55	75	C	3	4	6	8	6	27	30	43	22.9	7.9	0.69	5.3	62.1
18	NDL	Ap	0	20											7.4	3.12	0.6	50.2
18	NDL	Ck	50	65											7.8	0.50	0.2	49.0

Site No's 1 - 84 Field Inspection Sites, 101 - 114 Slope Transect A, 121 - 125 Slope Transect B, 131 - 135 Slope Transect C

Table 21. Soil Analytical Data at Survey Grid Points and Slope Transects (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
19	VRC	Apk	0	20	CL	2	4	6	9	7	28	37	35	2.7	7.6	2.70	0.5	58.0
19	VRC	Ckgjs	60	100	SIC	1	1	2	3	1	8	44	48	0.7	7.8	1.01	4.2	82.4
20	VRC	Ap	0	20											7.4	5.58	0.7	55.8
20	VRC	Ckgj	40	65											7.9	0.89	0.3	46.8
21	DRO	Ahks	0	50											8.0	4.11	3.7	80.9
22	NDL	Ap	0	20	CL	3	5	7	11	8	34	33	33	2.7	7.6	5.76	0.7	61.3
22	NDL	Ck	40	60	CL	3	5	7	10	7	32	33	35	29.1	7.9	0.71	0.4	45.2
23	NDL	Ap	0	15											7.2	4.14	0.8	56.9
23	NDL	Ck	50	60											7.9	0.55	0.2	42.7
24	DRO	Ah	0	25	CL	3	3	6	9	6	27	41	32	0.0	7.6	7.44	0.8	82.0
24	DRO	Ckg	45	60	CL	4	5	7	9	6	31	34	35	15.2	7.8	0.38	0.7	47.3
25	RUF	Ap	0	15											7.6	3.24	0.6	68.1
25	RUF	Ck	50	75											7.9	0.24	0.9	51.8
26	NDL	Ap	0	20	SIC	1	2	3	5	5	16	42	42	0.0	7.3	4.24	0.4	25.9
26	NDL	Cks	45	70	SCL	13	10	9	10	6	48	27	25	25.9	8.2	0.55	6.9	25.9
27	RUF	Ap	0	30											7.6	4.00	0.5	53.6
27	RUF	Ck	30	50											7.9	0.82	0.2	56.2
28	DRO	Ahk	0	30	CL	1	2	5	8	6	22	38	40	1.4	8.0	3.51	0.4	47.3
28	DRO	Ckgs	50	70	C	3	4	6	9	7	29	30	41	24.7	8.1	0.50	4.1	71.4
29	NDL	Ap	0	20											7.7	3.36	0.2	40.4
29	NDL	Cks	40	50											7.7	0.80	4.8	95.6
30	DRO	Apks	0	40											7.9	2.89	3.6	58.5
30	DRO	Ckgs	55	70											7.9	0.44	4.3	52.9
31	NDL	Ap	0	30	CL	3	4	7	10	7	31	36	33	5.3	7.6	6.40	0.4	39.0
31	NDL	Ck	55	70	SICL	2	1	3	6	6	18	42	40	27.9	8.4	0.54	1.3	76.3
32	NDL	Ah	0	40	CL	5	5	8	12	8	38	27	35	0.0	7.4	4.02	0.2	58.3
32	NDL	Ck	70	85	CL	4	5	7	11	7	34	31	35	19.1	7.7	1.14	0.2	30.1
33	VRC	Apk	0	20	C	6	4	5	7	4	26	31	43	6.1	8.2	3.68	1.5	51.2
33	VRC	Ckgj	50	75	CL	4	4	6	10	7	31	34	35	31.3	7.7	0.55	0.6	65.3
34	DRO	Oh	40	0											7.5	9.29	2.4	128.8
34	DRO	Ckgs	15	50											8.1	0.30	4.5	62.8
35	RUF	Ap	0	15	CL	3	4	7	10	8	32	32	36	6.0	7.6	3.73	0.8	49.1
35	RUF	Ck	35	40	CL	4	5	6	10	7	32	28	40	31.8	7.9	0.67	0.6	51.4
36	DRO	Ahk	0	15	CL	2	3	5	7	6	23	38	39	7.4	8.2	5.79	2.6	94.6
36	DRO	Ckgs	50	75	C	3	4	6	8	7	28	28	44	38.7	8.6	0.37	6.9	56.6

Table 21. Soil Analytical Data at Survey Grid Points and Slope Transects (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
37	NDL	Ap	0	15	CL	3	4	7	11	8	33	33	34	0.0	7.4	4.66	0.6	56.0
37	NDL	Bm	15	35	CL	3	4	7	11	7	32	30	38	0.0	7.7	0.65	0.2	49.5
37	NDL	Ck	50	75	CL	3	5	7	10	8	33	32	35	26.7	7.7	0.30	0.2	41.2
38	RUF	Ah	0	15	C	3	4	7	12	8	34	25	41	4.7	8.0	6.08	0.3	76.4
38	RUF	Ck	46	65	C	5	3	5	8	7	28	28	44	36.4	7.6	0.82	0.3	48.3
39	ANL	Ap	0	20	CL	2	4	6	10	8	30	33	37	5.7	7.5	4.09	0.4	46.6
39	ANL	Btgj	55	70	C	4	4	8	11	6	33	19	48	0.0	7.6	0.53	0.2	56.9
40	RUF	Ap	0	15	CL	3	4	7	11	9	34	31	35	7.2	7.8	3.20	0.4	47.5
40	RUF	Ck	40	50	CL	4	4	7	10	8	33	33	34	31.7	7.8	0.63	0.2	44.0
41	VRC	Aps	0	18											8.3	3.71	4.0	59.5
41	VRC	Ckgjs	45	65											8.1	0.77	6.7	49.3
42	DRO	Obs	15	0											8.0	10.82	4.3	175.8
42	DRO	Ckgs	45	60										39.8	7.4	0.44	4.6	49.0
43	VRC	Ap	0	30	CL	0	4	6	10	8	28	33	39	4.2	7.8	7.00	0.5	76.3
43	VRC	Ckgj	50	60	CL	5	5	6	10	7	33	33	34	28.3	7.6	1.10	0.3	44.4
44	RUF	Apk	0	15	CL	4	5	8	12	8	37	26	37	10.0	7.8	2.41	0.6	49.4
44	RUF	Ck	50	65	CL	4	5	7	10	8	34	33	33	28.8	7.6	0.50	0.3	42.8
45	NDL	Ap	0	20											7.9	3.14	0.6	48.9
45	NDL	Ck	45	60											7.0	0.45	0.3	44.4
46	VRC	Ap	0	20											8.0	3.07	0.4	64.8
46	VRC	Ckgjs	50	65											7.4	0.45	3.5	61.2
47	NDL	Ap	0	18	CL	4	5	9	12	9	39	30	31	3.1	7.9	4.01	0.7	45.8
47	NDL	Ck	45	60	CL	3	4	6	10	7	30	36	34	29.7	7.3	0.60	0.2	44.4
48	PEN	Ae	20	30	SIL	2	2	4	7	8	23	52	25	0.0	7.2	1.20	0.3	40.8
48	PEN	Bg	45	60	SIC	0	1	4	5	3	13	40	47	0.0	7.5	0.63	0.2	70.7
49	VRC	Apk	0	25	CL	3	4	7	10	8	32	33	35	5.7	7.9	4.05	0.3	64.7
49	VRC	Ckgj	40	60	CL	6	4	6	9	7	32	33	35	29.1	8.0	0.73	0.3	49.2
50	DRO	Ahk	0	20	CL	3	6	9	13	8	39	28	33	2.4	8.2	2.23	2.7	59.9
50	DRO	Ckgs	50	65	CL	5	4	7	10	7	33	29	38	18.3	7.2	0.70	4.7	49.8
51	NDL	Ap	0	15	CL	4	4	7	11	8	34	30	36	1.1	7.8	3.71	0.7	53.8
51	NDL	Ck	50	75	CL	5	5	7	10	7	34	31	35	27.9	7.5	0.58	0.2	43.4
52	VRC	Ap	0	20											8.2	5.59	0.6	63.1
52	VRC	Ckgj	40	60											7.6	0.82	0.4	49.7
53	NDL	Ap	0	15											8.0	3.02	0.7	46.0
53	NDL	Ck	50	65											7.2	0.46	0.3	42.6
54	NDL	Ap	0	20	CL	3	5	8	14	11	41	29	30	1.1	7.6	4.37	0.7	48.4

Table 21. **Soil Analytical Data at Survey Grid Points and Slope Transects** (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
54	NDL	Btj	30	40	C	1	2	4	9	12	28	31	41	0.6	7.9	0.73	0.2	44.5
54	NDL	Ck	50	65	SCL	5	3	9	19	13	49	25	26	26.2	7.5	0.42	0.4	39.4
56	VRC	Apk	0	20	CL	3	4	6	9	7	29	35	36	1.6	7.9	5.93	0.4	60.9
56	VRC	Ckgj	50	75	CL	4	4	5	8	7	28	40	32	29.7	7.6	0.94	0.6	47.8
57	DRO	Ahks	0	20	CL	3	4	7	10	8	32	33	35	4.9	8.2	2.59	8.5	61.4
57	DRO	Ckgs	50	65	L	4	6	8	11	9	38	38	24	27.1	8.4	0.50	6.8	39.2
58	NDL	Ap	0	20	CL	4	4	8	12	9	37	34	29	2.2	7.4	4.37	0.5	52.0
58	NDL	Ck	50	75	L	4	6	9	12	8	39	34	27	22.7	7.8	0.38	0.2	36.0
59	NDL	Ap	0	20											7.4	4.22	0.4	46.0
59	NDL	Ck	55	75											8.0	0.47	0.3	42.0
60	CVA	Ap	0	18	CL	6	5	8	13	9	41	31	28	6.5	7.5	3.84	0.6	48.6
60	CVA	Ck	50	75	CL	3	4	6	11	9	33	39	28	37.7	7.9	0.53	0.2	36.5
63	ANL	Ap	0	20	CL	2	3	5	8	7	25	42	33	0.0	6.7	6.18	0.4	63.3
63	ANL	Ckgj	50	75	CL	3	5	6	9	9	32	34	34	14.5	7.9	0.49	0.2	49.8
65	NDL	Ap	0	20											7.0	3.07	0.4	52.9
65	NDL	Ck	50	75											7.8	0.79	0.2	42.8
66	DRO	Ckgs	45	60											8.0	1.03	5.0	70.7
67	RUF	Ap	0	20											7.5	5.07	0.4	58.7
67	RUF	Ck	50	75											7.9	1.19	0.2	46.0
68	RUF	Apk	0	20	CL	3	3	6	11	12	35	37	28	10.5	7.6	4.13	0.3	49.6
68	RUF	Ck	30	40	CL	4	4	6	10	7	31	38	31	41.6	7.8	0.84	0.2	38.0
69	DRO	Ohs	20	0											7.8	14.29	5.0	233.0
69	DRO	Ckgs	40	60											8.0	1.11	4.8	48.0
70	VRC	Ahk	0	20	CL	6	9	11	12	6	44	26	30	16.5	7.4	4.16	0.6	66.1
70	VRC	Ckgjs	50	75	CL	4	6	8	10	7	35	28	37	37.3	8.0	0.63	4.0	34.8
71	VRC	Ahk	0	15											7.8	4.97	0.4	69.5
71	VRC	Ckgjs	45	65											7.8	0.23	4.5	25.6
72	DRO	Ahks	0	15	CL	5	5	8	12	9	39	32	29	6.6	7.8	3.74	5.3	68.4
72	DRO	Ckgs	45	65	CL	3	4	6	8	7	28	36	36	7.6	8.1	0.39	3.7	48.0
73	RUF	Apk	0	15											7.4	2.60	0.5	47.1
73	RUF	Cca	15	30											7.9	0.67	0.3	44.3
73	RUF	Ck	50	75											7.7	0.47	0.3	34.7
74	RUF	Ap	0	20	CL	4	5	8	12	8	37	28	35	14.7	7.4	4.27	0.4	56.6
74	RUF	Ck	40	60	CL	7	4	7	9	7	34	33	33	28.6	8.1	0.70	0.2	44.5
75	MHC	Om	40	20											7.2	19.05	0.8	239.7

Table 21. Soil Analytical Data at Survey Grid Points and Slope Transects (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
75	MHC	Cg	10	30	CL	3	5	10	13	7	38	26	36	0.0	7.8	0.61	1.9	59.1
76	DRO	ACkgs	19	40											8.0	0.90	4.7	58.7
77	NDL	Ap	0	18	CL	3	5	8	11	8	35	28	37	0.0	7.4	2.99	0.6	57.6
77	NDL	Ck	40	60	CL	4	4	7	10	7	32	32	36	14.2	7.6	1.39	0.6	51.3
78	DRO	ACkgs	25	40											7.9	2.61	4.6	61.3
84	RUF	Ap	0	15											7.6	3.42	0.7	51.3
84	RUF	Ck	40	60											8.0	0.56	0.3	53.5
									(Slope Transect A)									
101	NDL	Ap	0	15											7.5	3.65	0.5	63.3
101	NDL	Ck	50	75											8.0		0.3	54.5
102	CVA	Ap	0	15											7.6	5.21	0.2	62.1
102	CVA	Ck	50	75											7.5		0.5	50.5
103	RUF	Ap	0	15											7.6	2.95	0.3	61.7
103	RUF	Ck	50	75											8.1		0.6	50.1
104	NDL	Ap	0	15											7.6	4.33	0.2	58.4
104	NDL	Ck	50	75											8.1		0.6	43.9
105	NDL	Ap	0	15											7.5	5.07	0.2	60.9
105	NDL	Ck	50	75											8.0		0.7	47.0
106	NDL	Ap	0	15											7.4	5.31	0.2	59.8
106	NDL	Ck	50	75											7.9		0.5	47.3
107	ANL	Ap	0	20											7.4	5.87	0.6	65.1
107	ANL	Ckgj	50	75											8.2		0.3	53.6
108	VRC	Ap	0	15											7.2	6.87	0.6	67.5
108	VRC	Ckgj	75	85											8.2		3.3	69.5
109	VRC	Ap	0	20											6.7	6.11	0.7	75.9
109	VRC	Ckgjs	75	95											8.1		4.9	60.0
110	VRC	Ap	0	15											7.6	5.14	0.6	70.3
110	VRC	Ckgjs	60	75											8.2		6.7	63.9
111	VRC	Ap	0	20											7.9	6.52	1.3	82.0
111	VRC	Ckgjs	50	75											8.6	0.34	11.4	58.2
112	DRO	Ap	0	10											8.1	2.86	0.9	75.4
112	DRO	Ckgs	50	75											8.5	0.08	8.2	57.7
113	DRO	Aps	0	20											8.2	3.04	6.9	72.1
113	DRO	Ckgs	50	75											8.2	0.23	9.0	65.6
114	MHC	Ahs	0	15											8.3	2.44	6.6	89.2
114	MHC	Ckgs	50	75											8.1		8.8	81.8

Table 21. **Soil Analytical Data at Survey Grid Points and Slope Transect** (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
									(Slope Transect B)									
121	RUF	Ap	0	15	CL	4	5	8	11	8	36	29	35		7.8	3.07	0.7	56.4
121	RUF	Ck	50	75	CL	4	5	7	10	8	34	33	33		8.1	0.34	0.4	53.7
122	NDL	Ap	0	14	CL	2	5	8	11	8	33	30	37		7.5	2.76	0.4	50.1
122	NDL	Ck	50	75	CL	4	6	7	10	8	35	35	30		8.1	0.37	0.9	53.3
123	NDL	Ap	0	15	CL	4	5	7	11	8	35	30	35		7.5	2.33	0.4	53.4
123	NDL	Ck	50	75	CL	4	4	6	10	8	32	37	31		8.2	0.25	0.6	48.0
124	VRC	Ap	0	15	CL	3	5	7	10	7	32	30	38		7.8	1.06	0.5	54.1
124	VRC	Ckgj	50	75	CL	5	5	7	10	7	34	35	31		8.1	0.16	0.5	54.6
125	PEN	Ap	0	15	CL	3	4	7	9	7	30	35	35		7.8	6.08	0.8	71.0
125	PEN	Ckg	75	85	CL	4	5	7	10	7	33	35	32		8.2	0.28	0.7	48.7
									(Slope Transect C)									
131	ANL	Ap	0	15											7.6	3.09	0.5	48.1
131	ANL	Aegj	30	40											7.6	0.14	0.2	24.0
131	ANL	Ckgj	85	100											8.5		0.1	55.7
132	NDL	Ap	0	15											7.5	3.26	0.5	48.3
132	NDL	Ck	50	75											8.1	0.28	0.4	50.5
133	NDL	Ap	0	13											7.6	2.83	0.4	47.2
133	NDL	Ck	50	75											8.2	0.43	2.4	42.0
134	CVA	Ap	0	15											7.7	3.42	0.6	46.0
134	CVA	Ck	50	75											8.1	0.66	0.8	50.7
135	NDL	Ap	0	15											7.7	3.21	0.4	48.4
135	NDL	Ck	50	75											8.1	0.54	0.3	43.9

Table 22. Soil Analytical Data by Series

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
131	ANL	Ap	0	15											7.6	3.09	0.5	48.1
107	ANL	Ap	0	20											7.4	5.87	0.6	65.1
39	ANL	Ap	0	20	CL	2	4	6	10	8	30	33	37	5.7	7.5	4.09	0.4	46.6
63	ANL	Ap	0	20	CL	2	3	5	8	7	25	42	33	0.0	6.7	6.18	0.4	63.3
131	ANL	Aegj	30	40											7.6	0.14	0.2	24.0
39	ANL	Btgj	55	70	C	4	4	8	11	6	33	19	48	0.0	7.6	0.53	0.2	56.9
63	ANL	Ckgj	50	75	CL	3	5	6	9	9	32	34	34	14.5	7.9	0.49	0.2	49.8
107	ANL	Ckgj	50	75											8.2		0.3	53.6
131	ANL	Ckgj	85	100											8.5		0.1	55.7
102	CVA	Ap	0	15											7.6	5.21	0.2	62.1
2	CVA	Ap	0	15	CL	4	5	7	11	7	34	30	36	5.3	7.5	3.78	0.9	53.3
6	CVA	Ap	0	15	CL	3	6	9	13	9	40	28	32	7.0	7.5	3.20	0.7	51.0
134	CVA	Ap	0	15											7.7	3.42	0.6	46.0
60	CVA	Ap	0	18	CL	6	5	8	13	9	41	31	28	6.5	7.5	3.84	0.6	48.6
15	CVA	Ap	0	18										4.5	7.5	4.62	0.8	56.5
13	CVA	Ap	0	20	CL	3	4	6	10	8	31	35	34	2.6	7.4	6.29	1.1	66.1
8	CVA	Apk	0	20										2.9	7.4	4.27	0.4	55.8
6	CVA	Ck	40	60	L	4	6	10	18	12	50	28	22	29.5	8.0	0.28	0.3	34.8
15	CVA	Ck	50	100										28.2	7.6	0.26	0.3	45.1
8	CVA	Ck	50	60										23.5	7.8	0.38	0.2	48.2
13	CVA	Cks	50	65	C	0	0	2	7	10	19	38	43	35.1	7.9	0.41	6.4	51.9
2	CVA	Ck	50	75	CL	4	4	7	9	7	31	36	33	42.0	7.9	0.37	0.2	49.9
102	CVA	Ck	50	75											7.5		0.5	50.5
60	CVA	Ck	50	75	CL	3	4	6	11	9	33	39	28	37.7	7.9	0.53	0.2	36.5
134	CVA	Ck	50	75											8.1	0.66	0.8	50.7

Table 22. Soil Analytical Data by Series (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
112	DRO	Ap	0	10											8.1	2.86	0.9	75.4
36	DRO	Ahk	0	15	CL	2	3	5	7	6	23	38	39	7.4	8.2	5.79	2.6	94.6
72	DRO	Ahks	0	15	CL	5	5	8	12	9	39	32	29	6.6	7.8	3.74	5.3	68.4
50	DRO	Ahk	0	20	CL	3	6	9	13	8	39	28	33	2.4	8.2	2.23	2.7	59.9
113	DRO	Aps	0	20											8.2	3.04	6.9	72.1
57	DRO	Ahks	0	20	CL	3	4	7	10	8	32	33	35	4.9	8.2	2.59	8.5	61.4
24	DRO	Ah	0	25	CL	3	3	6	9	6	27	41	32	0.0	7.6	7.44	0.8	82.0
28	DRO	Ahk	0	30	CL	1	2	5	8	6	22	38	40	1.4	8.0	3.51	0.4	47.3
17	DRO	Ahk	0	40	C	3	4	6	8	6	27	30	43	10.2	7.8	6.08	1.2	90.4
30	DRO	Apks	0	40											7.9	2.89	3.6	58.5
21	DRO	Ahks	0	50											8.0	4.11	3.7	80.9
76	DRO	ACkgs	19	40											8.0	0.90	4.7	58.7
78	DRO	ACkgs	25	40											7.9	2.61	4.6	61.3
34	DRO	Ckgs	15	50											8.1	0.30	4.5	62.8
69	DRO	Ckgs	40	60											8.0	1.11	4.8	48.0
24	DRO	Ckg	45	60	CL	4	5	7	9	6	31	34	35	15.2	7.8	0.38	0.7	47.3
66	DRO	Ckgs	45	60											8.0	1.03	5.0	70.7
42	DRO	Ckgs	45	60										39.8	7.4	0.44	4.6	49.0
72	DRO	Ckgs	45	65	CL	3	4	6	8	7	28	36	36	7.6	8.1	0.39	3.7	48.0
57	DRO	Ckgs	50	65	L	4	6	8	11	9	38	38	24	27.1	8.4	0.50	6.8	39.2
50	DRO	Ckgs	50	65	CL	5	4	7	10	7	33	29	38	18.3	7.2	0.70	4.7	49.8
28	DRO	Ckgs	50	70	C	3	4	6	9	7	29	30	41	24.7	8.1	0.50	4.1	71.4
36	DRO	Ckgs	50	75	C	3	4	6	8	7	28	28	44	38.7	8.6	0.37	6.9	56.6
112	DRO	Ckgs	50	75											8.5	0.08	8.2	57.7
113	DRO	Ckgs	50	75											8.2	0.23	9.0	65.6
30	DRO	Ckgs	55	70											7.9	0.44	4.3	52.9
17	DRO	Ckgs	55	75	C	3	4	6	8	6	27	30	43	22.9	7.9	0.69	5.3	62.1
69	DRO	Ohs	20	0											7.8	14.29	5.0	233.0
34	DRO	Oh	40	0											7.5	9.29	2.4	128.8
42	DRO	Ohs	15	0											8.0	10.82	4.3	175.8
114	MHC	Ahs	0	15											8.3	2.44	6.6	89.2
75	MHC	Cg	10	30	CL	3	5	10	13	7	38	26	36	0.0	7.8	0.61	1.9	59.1
114	MHC	Ckgs	50	75											8.1		8.8	81.8
75	MHC	Om	40	20											7.2	19.05	0.8	239.7

Table 22. Soil Analytical Data by Series (Cont'd)

Site No.	Series	Horizon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
133	NDL	Ap	0	13											7.6	2.83	0.4	47.2
122	NDL	Ap	0	14	CL	2	5	8	11	8	33	30	37		7.5	2.76	0.4	50.1
106	NDL	Ap	0	15											7.4	5.31	0.2	59.8
101	NDL	Ap	0	15											7.5	3.65	0.5	63.3
37	NDL	Ap	0	15	CL	3	4	7	11	8	33	33	34	0.0	7.4	4.66	0.6	56.0
51	NDL	Ap	0	15	CL	4	4	7	11	8	34	30	36	1.1	7.8	3.71	0.7	53.8
105	NDL	Ap	0	15											7.5	5.07	0.2	60.9
53	NDL	Ap	0	15											8.0	3.02	0.7	46.0
23	NDL	Ap	0	15											7.2	4.14	0.8	56.9
104	NDL	Ap	0	15											7.6	4.33	0.2	58.4
135	NDL	Ap	0	15											7.7	3.21	0.4	48.4
132	NDL	Ap	0	15											7.5	3.26	0.5	48.3
123	NDL	Ap	0	15	CL	4	5	7	11	8	35	30	35		7.5	2.33	0.4	53.4
77	NDL	Ap	0	18	CL	3	5	8	11	8	35	28	37	0.0	7.4	2.99	0.6	57.6
47	NDL	Ap	0	18	CL	4	5	9	12	9	39	30	31	3.1	7.9	4.01	0.7	45.8
58	NDL	Ap	0	20	CL	4	4	8	12	9	37	34	29	2.2	7.4	4.37	0.5	52.0
59	NDL	Ap	0	20											7.4	4.22	0.4	46.0
7	NDL	Ap	0	20	CL	3	5	8	12	8	36	32	32	1.4	7.4	2.38	0.7	46.8
54	NDL	Ap	0	20	CL	3	5	8	14	11	41	29	30	1.1	7.6	4.37	0.7	48.4
65	NDL	Ap	0	20											7.0	3.07	0.4	52.9
4	NDL	Ap	0	20	CL	3	5	8	12	8	36	30	34	0.4	7.1	4.42	0.8	60.5
22	NDL	Ap	0	20	CL	3	5	7	11	8	34	33	33	2.7	7.6	5.76	0.7	61.3
11	NDL	Ap	0	20										1.7	7.4	5.46	0.9	58.5
26	NDL	Ap	0	20	SIC	1	2	3	5	5	16	42	42	0.0	7.3	4.24	0.4	25.9
45	NDL	Ap	0	20											7.9	3.14	0.6	48.9
18	NDL	Ap	0	20											7.4	3.12	0.6	50.2
29	NDL	Ap	0	20											7.7	3.36	0.2	40.4
14	NDL	Ap	0	20										0.6	7.0	2.64	0.5	49.7
31	NDL	Ap	0	30	CL	3	4	7	10	7	31	36	33	5.3	7.6	6.40	0.4	39.0
32	NDL	Ah	0	40	CL	5	5	8	12	8	38	27	35	0.0	7.4	4.02	0.2	58.3
37	NDL	Bm	15	35	CL	3	4	7	11	7	32	30	38	0.0	7.7	0.65	0.2	49.5
7	NDL	Btj	20	35	CL	2	5	9	12	8	36	25	39	0.6	7.5	1.50	0.2	44.8
54	NDL	Btj	30	40	C	1	2	4	9	12	28	31	41	0.6	7.9	0.73	0.2	44.5
29	NDL	Cks	40	50											7.7	0.80	4.8	95.6
11	NDL	Ck	40	60										26.7	7.9	0.38	0.3	47.8
22	NDL	Ck	40	60	CL	3	5	7	10	7	32	33	35	29.1	7.9	0.71	0.4	45.2

Table 22. Soil Analytical Data by Series (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
77	NDL	Ck	40	60	CL	4	4	7	10	7	32	32	36	14.2	7.6	1.39	0.6	51.3
45	NDL	Ck	45	60											7.0	0.45	0.3	44.4
47	NDL	Ck	45	60	CL	3	4	6	10	7	30	36	34	29.7	7.3	0.60	0.2	44.4
26	NDL	Cks	45	70	SCL	13	10	9	10	6	48	27	25	25.9	8.2	0.55	6.9	25.9
7	NDL	Ck	50	60	CL	4	5	8	12	8	37	35	28	22.5	7.7	0.45	0.3	39.3
23	NDL	Ck	50	60											7.9	0.55	0.2	42.7
54	NDL	Ck	50	65	SCL	5	3	9	19	13	49	25	26	26.2	7.5	0.42	0.4	39.4
53	NDL	Ck	50	65											7.2	0.46	0.3	42.6
18	NDL	Ck	50	65											7.8	0.50	0.2	49.0
58	NDL	Ck	50	75	L	4	6	9	12	8	39	34	27	22.7	7.8	0.38	0.2	36.0
101	NDL	Ck	50	75											8.0		0.3	54.5
65	NDL	Ck	50	75											7.8	0.79	0.2	42.8
106	NDL	Ck	50	75											7.9		0.5	47.3
37	NDL	Ck	50	75	CL	3	5	7	10	8	33	32	35	26.7	7.7	0.30	0.2	41.2
104	NDL	Ck	50	75											8.1		0.6	43.9
105	NDL	Ck	50	75											8.0		0.7	47.0
51	NDL	Ck	50	75	CL	5	5	7	10	7	34	31	35	27.9	7.5	0.58	0.2	43.4
123	NDL	Ck	50	75	CL	4	4	6	10	8	32	37	31		8.2	0.25	0.6	48.0
133	NDL	Ck	50	75											8.2	0.43	2.4	42.0
135	NDL	Ck	50	75											8.1	0.54	0.3	43.9
122	NDL	Ck	50	75	CL	4	6	7	10	8	35	35	30		8.1	0.37	0.9	53.3
132	NDL	Ck	50	75											8.1	0.28	0.4	50.5
31	NDL	Ck	55	70	SICL	2	1	3	6	6	18	42	40	27.9	8.4	0.54	1.3	76.3
59	NDL	Ck	55	75											8.0	0.47	0.3	42.0
4	NDL	Cks	60	75	L	3	5	8	18	13	47	29	24	22.4	8.1	0.39	5.2	39.6
32	NDL	Ck	70	85	CL	4	5	7	11	7	34	31	35	19.1	7.7	1.14	0.2	30.1

Table 22. Soil Analytical Data by Series (Cont'd)

Site No.	Series	Hori-zon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
125	PEN	Ap	0	15	CL	3	4	7	9	7	30	35	35		7.8	6.08	0.8	71.0
9	PEN	Ap	0	20	SICL	1	1	3	6	5	16	48	36	0.0	6.3	8.32	0.8	88.1
16	PEN	Ap	0	25	SICL	0	2	5	7	3	17	51	32	0.0	7.1	9.42	1.0	95.0
48	PEN	Ae	20	30	SIL	2	2	4	7	8	23	52	25	0.0	7.2	1.20	0.3	40.8
16	PEN	Ahe	25	45	SICL	1	2	3	5	4	15	51	34	0.0	7.0	2.33	0.3	47.8
9	PEN	Btg	35	50	SIC	0	0	2	5	4	11	40	49	0.0	6.8	0.41	0.3	60.4
48	PEN	Bg	45	60	SIC	0	1	4	5	3	13	40	47	0.0	7.5	0.63	0.2	70.7
16	PEN	Btg	45	75	C	0	1	2	4	3	10	35	55	0.4	7.3	0.85	0.4	66.1
125	PEN	Ckg	75	85	CL	4	5	7	10	7	33	35	32		8.2	0.28	0.7	48.7
84	RUF	Ap	0	15											7.6	3.42	0.7	51.3
73	RUF	Apk	0	15											7.4	2.60	0.5	47.1
3	RUF	Ap	0	15	CL	1	3	5	8	7	24	38	38	4.3	7.6	4.40	0.5	55.7
121	RUF	Ap	0	15	CL	4	5	8	11	8	36	29	35		7.8	3.07	0.7	56.4
44	RUF	Apk	0	15	CL	4	5	8	12	8	37	26	37	10.0	7.8	2.41	0.6	49.4
35	RUF	Ap	0	15	CL	3	4	7	10	8	32	32	36	6.0	7.6	3.73	0.8	49.1
38	RUF	Ah	0	15	C	3	4	7	12	8	34	25	41	4.7	8.0	6.08	0.3	76.4
25	RUF	Ap	0	15											7.6	3.24	0.6	68.1
40	RUF	Ap	0	15	CL	3	4	7	11	9	34	31	35	7.2	7.8	3.20	0.4	47.5
103	RUF	Ap	0	15											7.6	2.95	0.3	61.7
74	RUF	Ap	0	20	CL	4	5	8	12	8	37	28	35	14.7	7.4	4.27	0.4	56.6
67	RUF	Ap	0	20											7.5	5.07	0.4	58.7
68	RUF	Apk	0	20	CL	3	3	6	11	12	35	37	28	10.5	7.6	4.13	0.3	49.6
27	RUF	Ap	0	30											7.6	4.00	0.5	53.6
73	RUF	Cca	15	30											7.9	0.67	0.3	44.3
3	RUF	Ck	25	50	SIC	0	1	3	6	4	14	42	44	25.9	7.9	0.84	0.5	54.5
68	RUF	Ck	30	40	CL	4	4	6	10	7	31	38	31	41.6	7.8	0.84	0.2	38.0
27	RUF	Ck	30	50											7.9	0.82	0.2	56.2
35	RUF	Ck	35	40	CL	4	5	6	10	7	32	28	40	31.8	7.9	0.67	0.6	51.4
40	RUF	Ck	40	50	CL	4	4	7	10	8	33	33	34	31.7	7.8	0.63	0.2	44.0
74	RUF	Ck	40	60	CL	7	4	7	9	7	34	33	33	28.6	8.1	0.70	0.2	44.5
84	RUF	Ck	40	60											8.0	0.56	0.3	53.5
38	RUF	Ck	46	65	C	5	3	5	8	7	28	28	44	36.4	7.6	0.82	0.3	48.3
44	RUF	Ck	50	65	CL	4	5	7	10	8	34	33	33	28.8	7.6	0.50	0.3	42.8
25	RUF	Ck	50	75											7.9	0.24	0.9	51.8
67	RUF	Ck	50	75											7.9	1.19	0.2	46.0
121	RUF	Ck	50	75	CL	4	5	7	10	8	34	33	33		8.1	0.34	0.4	53.7
103	RUF	Ck	50	75											8.1		0.6	50.1
73	RUF	Ck	50	75											7.7	0.47	0.3	34.7

Table 22. Soil Analytical Data by Series (Cont'd)

Site No.	Series	Horizon	Depth (cm)		Text	VC %	CS %	MS %	FS %	VF %	TS %	SI %	C %	CaCO3 %	pH	OC %	EC mS/cm	SAT %
110	VRC	Ap	0	15											7.6	5.14	0.6	70.3
108	VRC	Ap	0	15											7.2	6.87	0.6	67.5
71	VRC	Ahk	0	15											7.8	4.97	0.4	69.5
124	VRC	Ap	0	15	CL	3	5	7	10	7	32	30	38		7.8	1.06	0.5	54.1
41	VRC	Aps	0	18											8.3	3.71	4.0	59.5
46	VRC	Ap	0	20											8.0	3.07	0.4	64.8
20	VRC	Ap	0	20											7.4	5.58	0.7	55.8
111	VRC	Ap	0	20											7.9	6.52	1.3	82.0
109	VRC	Ap	0	20											6.7	6.11	0.7	75.9
12	VRC	Ap	0	20	CL	3	4	7	10	7	31	33	36	0.0	7.0	4.63	0.6	50.1
33	VRC	Apk	0	20	C	6	4	5	7	4	26	31	43	6.1	8.2	3.68	1.5	51.2
56	VRC	Apk	0	20	CL	3	4	6	9	7	29	35	36	1.6	7.9	5.93	0.4	60.9
52	VRC	Ap	0	20											8.2	5.59	0.6	63.1
19	VRC	Apk	0	20	CL	2	4	6	9	7	28	37	35	2.7	7.6	2.70	0.5	58.0
70	VRC	Ahk	0	20	CL	6	9	11	12	6	44	26	30	16.5	7.4	4.16	0.6	66.1
5	VRC	Ap	0	25	SIC	0	1	3	5	3	12	47	41	0.0	6.7	3.77	0.5	63.6
10	VRC	Aps	0	25	SCL	14	10	11	8	5	48	27	25	0.0	7.7	3.80	5.5	59.8
49	VRC	Apk	0	25	CL	3	4	7	10	8	32	33	35	5.7	7.9	4.05	0.3	64.7
43	VRC	Ap	0	30	CL	0	4	6	10	8	28	33	39	4.2	7.8	7.00	0.5	76.3
49	VRC	Ckgj	40	60	CL	6	4	6	9	7	32	33	35	29.1	8.0	0.73	0.3	49.2
52	VRC	Ckgj	40	60											7.6	0.82	0.4	49.7
5	VRC	Ckgj	40	60	CL	4	4	5	7	6	26	41	33	29.1	7.7	0.43	0.3	38.3
20	VRC	Ckgj	40	65											7.9	0.89	0.3	46.8
71	VRC	Ckgjs	45	65											7.8	0.23	4.5	25.6
41	VRC	Ckgjs	45	65											8.1	0.77	6.7	49.3
43	VRC	Ckgj	50	60	CL	5	5	6	10	7	33	33	34	28.3	7.6	1.10	0.3	44.4
46	VRC	Ckgjs	50	65											7.4	0.45	3.5	61.2
70	VRC	Ckgjs	50	75	CL	4	6	8	10	7	35	28	37	37.3	8.0	0.63	4.0	34.8
56	VRC	Ckgj	50	75	CL	4	4	5	8	7	28	40	32	29.7	7.6	0.94	0.6	47.8
10	VRC	Ckgjs	50	75	CL	3	7	11	13	7	41	25	34	28.6	8.0	0.17	6.4	34.1
111	VRC	Ckgjs	50	75											8.6	0.34	11.4	58.2
33	VRC	Ckgj	50	75	CL	4	4	6	10	7	31	34	35	31.3	7.7	0.55	0.6	65.3
124	VRC	Ckgj	50	75	CL	5	5	7	10	7	34	35	31		8.1	0.16	0.5	54.6
19	VRC	Ckgjs	60	100	SIC	1	1	2	3	1	8	44	48	0.7	7.8	1.01	4.2	82.4
110	VRC	Ckgjs	60	75											8.2		6.7	63.9
108	VRC	Ckgj	75	85											8.2		3.3	69.5
109	VRC	Ckgjs	75	95											8.1		4.9	60.0

Table 23. EM 38 Transect Data

Transect Distance from Lower to Upper Slope Position (m)	Wetland 1						Wetland 2					
	Transect 1		Transect 2		Transect 3		Transect 1		Transect 2		Transect 3	
	Upper*	Lower*	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2	100	125	86	110	100	101	70	79	67	84	67	85
4	149	136	140	131	133	115	55	72	74	94	72	92
6	181	192	171	166	144	147	56	75	86	110	86	110
8	214	227	193	205	153	152	64	89	87	111	114	117
10	224	234	188	213	106	135	81	105	90	114	85	108
12	234	278	194	220	74	106	108	111	83	113	108	130
14	206	244	198	220	58	82	101	119	79	108	128	145
16	192	236	179	206	43	67	93	105	73	100	124	141
18	154	206	122	164	38	60	71	91	60	86	113	140
20	144	193	100	142	31	49	55	79	56	82	107	129
22	158	195	86	127	33	51	43	59	84	97	87	108
24	151	189	56	87	35	51	41	53	84	99	58	82
26	144	190	59	93	27	47	30	50	82	95	43	57
28	158	193	46	77	33	50	33	46	74	83	36	44
30	151	189	33	55	32	50	32	43	63	74	27	38
32	160	190	31	48	35	44	28	35	56	65	23	31
34	159	193	30	43	35	47	22	31	48	64		
36	150	185	33	46	32	45	20	28	38	51		
38	160	185	33	47			20	26	34	44		
40	153	174	32	43			19	24	32	41		
42	109	141	30	40			21	24	27	36		
44	78	126	28	36			19	26	22	31		
46	74	96	23	32					23	28		
48	61	101	23	31					22	28		
50	58	93	21	29					22	28		
52	64	95	20	29					20	27		
54	60	91							19	25		
56	82	105										
58	88	113										
60	79	103										
62	71	95										
64	67	95										
66	66	85										
68	54	75										
70	46	64										

* Upper: 0-60 cm. EM 38 Reading, * Lower: 0-120 cm. EM 38 Reading

- EM 38 Readings of 85 to 150 correspond to an Electrical Conductivity of Approximately 4-8 ms/cm.

Table 23. EM 38 Transect Data (Cont'd)

Transect Distance from Lower to Upper Slope Position (m)	Wetland 3								Wetland 4			
	Transect 1		Transect 2		Transect 3		Transect 4		Transect 1		Transect 2	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2	76	91	79	104	34	50	67	82	79	106	95	115
4	64	76	80	100	40	51	59	77	96	114	100	127
6	61	73	79	104	46	61	68	80	115	128	115	134
8	71	77	100	112	53	78	76	84	122	133	145	169
10	63	81	100	112	69	91	78	96	116	134	148	182
12	64	86	100	113	82	102	71	93	122	148	142	174
14	58	87	98	123	74	101	68	92	118	146	106	150
16	50	76	100	130	63	99	70	93	83	113	88	121
18	43	69	81	110	76	108	83	99	59	85	77	115
20	40	65	75	103	78	111	90	102	53	81	71	105
22	42	56	64	94	75	99	78	81	59	86	74	106
24	35	49	59	79	79	100	62	75	75	100	70	100
26	30	40	50	65	84	119	45	56	83	116	79	106
28	24	34	36	49	109	132	36	48	83	111	78	102
30	24	32	35	47	111	144	28	37	72	103	60	86
32	21	30	35	42	100	136	21	31	60	92	50	70
34	22	30	32	40	86	117			58	88	41	59
36	26	34	29	38	58	88			56	85	35	59
38	30	36	29	37	58	85			48	71	30	42
40	28	35	28	37	62	93			42	51	30	38
42	30	36	27	33	63	91			39	50	28	35
44	30	35			61	89					26	35
46	31	36			62	87					26	32
48	31	39			53	75					26	34
50	33	40			40	61					26	35
52	31	39			44	60						
54	31	41			49	54						
56	36	44			45	58						
58	33	45			42	54						
60	34	45			35	47						
62					33	42						
64					29	37						
66					28	35						
68					26	34						
70					25	32						
72					26	34						
74					26	32						
76					24	31						
78					23	28						
80					23	30						
82					22	29						

Table 23. **EM 38 Transect Data** (Cont'd)

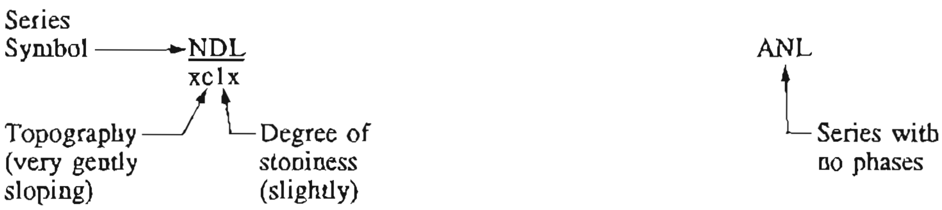
Transect Distance from Lower to Upper Slope Position (m)	Wetland 4				Wetland 5							
	Transect 3		Transect 4		Transect 1		Transect 2		Transect 3		Transect 4	
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
2	80	94	66	84	51	69	57	67	60	68	52	78
4	88	108	74	94	51	70	59	70	53	69	57	75
6	100	105	106	96	54	69	72	79	67	80	75	85
8	102	118	94	104	58	76	70	83	86	85	84	97
10	89	124	84	97	77	89	63	82	82	93	97	100
12	81	105	66	91	76	90	69	88	85	96	97	97
14	74	104	62	93	87	120	66	81	77	93	91	95
16	56	90	64	91	101	131	60	72	88	101	90	105
18	64	100	57	79	93	124	54	63	105	111	89	99
20	80	119	58	73	102	134	43	55	125	120	92	111
22	99	130	43	60	106	133	37	49	130	121	89	106
24	97	124	34	48	103	130	33	44	127	110	84	108
26	74	114	31	42	108	131	26	40	128	114	101	117
28	77	104	30	40	96	124			138	134	91	104
30	56	96	31	38	91	112			141	149	85	117
32	60	84	28	36	92	107			143	158	82	93
34	51	71			75	105			129	159	65	90
36	43	57							143	163	62	83
38	35	49							143	162	59	78
40	31	46							128	154	51	72
42	32	43							117	147	45	67
44									147	82	41	60
46									144	82	35	51
48									138	82		
50									131	82		
52									108	82		
54									89	82		
56									64	76		
58									57	71		
60									50	64		
62									45	56		

MANITOBA ZERO TILLAGE RESEARCH FARM SOIL LEGEND

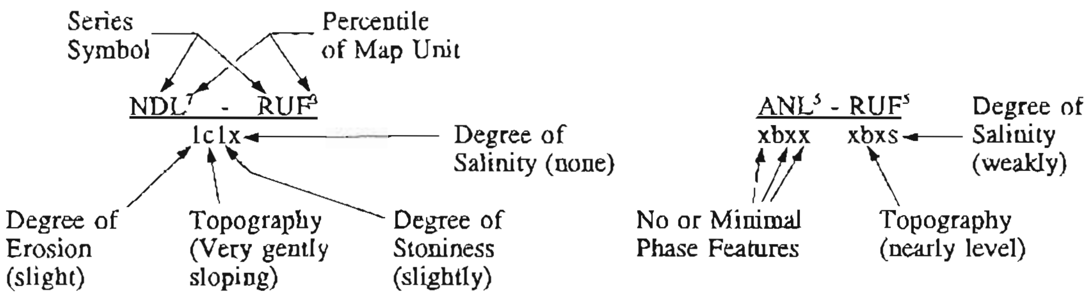
Soil Symbol	Soil Name	Surface Texture	Soil Drainage	Mode of Deposition	Family Particle Size	Subgroup
ANL	Angusville	Loam-Clay Loam	Imperfect	Till(Morainal)	Fine Loamy	Gleyed Eluviated Black
CVA	Cordova	Clay Loam	Well	Till(Morainal)	Fine Loamy	Calcareous Black
DRO	Drokan	Clay Loam	Poor	Till(Morainal)	Fine Loamy	Rego Humic Gleysol
MHC	Marsh Complex	Loam	Very Poor	Mineral, Undifferentiated	Loamy	Rego Humic Gleysol
NDL	Newdale	Clay Loam	Well	Till(Morainal)	Fine Loamy	Orthic Black
PEN	Penrith	Loam-Clay Loam	Poor	Till(Morainal)	Fine Loamy	Humic Luvic Gleysol
RUF	Rufford	Clay Loam	Well	Till(Morainal)	Fine Loamy	Rego Black
VRC	Varcoe	Clay Loam	Imperfect	Till(Morainal)	Fine Loamy	Gleyed Rego Black

MAP UNIT SYMBOLOGY

Simple Map Units



Compound Map Units



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

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

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 %

Degree of Salinity
Cond. (mS/cm)

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

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