THE BEHAVIOUR OF IRON AND TRACE ELEMENTS DOWN CATENARY SEQUENCES IN WEST CENTRAL SASKATCHEWAN

by

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ABSTRACT

Doyle (1977, 1979), working on the Southern Canadian Interior Plain evaluated regional geochemical patterns based on parent material. He found that regional variation in the total concentration of copper, iron, manganese and zinc arose largely from differences among parent materials, rather than from more local (within parent material) differences caused by pedological factors.

To extend Doyle's work, a more detailed local investigation of the within parent material variation of copper, iron, manganese and zinc on four parent materials was carried out in the Rosetown area, Saskatchewan. Principal objectives of this study were to find the causes and magnitude of downslope catenary changes in the geochemical pattern on each of four soil parent materials, utilizing DTPA extraction to indicate the availability of these micronutrients to crops.

Soil samples were collected from soils developed on lacustrine clay (Regina Soil Series), lacustrine silt (Elstow Soil Series), glacial till (Weyburn Soil Series) and aeolian sand (Dune Sand Soil Series). Five sites were selected for each parent material and at each site, five pits were dug at intervals downslope. Laboratory analysis for the entire sample set included the determination of pH, organic matter, copper, iron, manganese and zinc concentrations for soil digested with 4:1 $HNO_3/HClO_4$ mixture and the same metals extracted with DTPA solution. Further analysis comprised sequential extraction of copper, iron, manganese and zinc, particle size separation and X-ray diffraction.

Highest total elemental concentrations are found in the Ap horizon of the Rego Dark Brown Chernozems developed on lacustrine clay, followed by lacustrine silt and glacial till soils, with soils on aeolian sands having the lowest values. The A horizons of lacustrine silt soils contain the highest DTPA extractable concentrations of iron, manganese and zinc, whereas, maximum extractable concentrations in the C horizons are associated with lacustrine clays. DTPA extractable copper in both A and C horizons is at a maximum in lacustrine clay soils.

For the majority of sites, the highest total and DTPA elemental concentrations occur at the base of the slope, this being most marked for lacustrine silt soils. Total elemental concentrations for the four parent materials exhibit a relatively greater uniformity when considering both trends downslope and down profile than DTPA concentrations. A much greater proportion of DTPA extractable manganese and zinc occurs in the organic rich surface horizons compared to the more alkaline C horizons. This is also found for copper and iron but to a lesser extent.

Analysis of variance shows that the compositional variation among parent materials for total elemental data, accounts for well over 50% of the overall data variability. Duncan's New Multiple Range test results further substantiate these textural groupings into lacustrine clay, lacustrine silt and glacial till and aeolian sand. Results are less conclusive for DTPA elemental data.

However, even though soil copper, iron, manganese and zinc are influenced by many pediological factors operating separately and jointly, a large percentage of the total variability when predicting DTPA elemental concentrations can be accounted for by the variables included in the regression equations. The Index of Determination (I^2) shows that the variability in DTPA elemental concentrations is best accounted for by the regression equations for the lacustrine clay soils with 93-98% of the total variability explained.

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CHAPTER I

INTRODUCTION

I.1 Statement of Problem

In the early seventies increasing interest in the geochemistry of the natural environment as it may affect human and animal health, prompted the U.S. Geological Survey to begin a wide ranging programme of geochemical studies in the state of Missouri. The prime objective was to determine regional variations in the chemical characteristics of the rocks, waters, soils and vegetation.

As part of this programme, Miesch (1976), described a sampling strategy based on analysis of variance to evaluate regional geochemical patterns. Sampling design was based on broad categories within each of the major natural sampling media, each category being chosen so that its components would exhibit as much geochemical uniformity as possible, in comparison to differences among categories (Connor et al. 1972). Utilizing this approach, Tidball (1976), found the variance between trace element concentrations in soil series in Missouri amounted to about 80% of total variance.

Doyle (1977, 1979), applied the same techniques to the Southern Canadian Interior Plain, and produced regional geochemical maps for copper, iron, manganese and zinc using soil parent material as the prime category. This was effective in so far as the quaternary parent materials are few, readily defined, relatively homogenous and cover large areas. Also, because of rather weak pedological development, parent materials are a major factor determining trace element content in both the A and C horizons. Consequently, regional variation in total concentration of the elements studied, arise largely from differences among parent materials rather than from more local (within parent material) differences caused by pedological factors. Furthermore, these differences were found to be broadly consistent with soil texture and mineralogy. Thus, quartz rich aeolian sands are found to be impoverished in all four elements whereas lacustrine clays are relatively enriched. However Doyle (1977, 1979) essentially compared differences among parent material groups and all samples were taken from mid catena positions to minimise within group variance.

To extend Doyle's work to within parent material variations, a more detailed local investigation of the variation of copper, iron, manganese and zinc on four parent materials has been carried out in the Rosetown area, Saskatchewan. Principal objectives of this study were to find the causes and magnitude of downslope catenary changes in the geochemical patterns on each of four soil parent materials, utilizing DTPA extraction to relate results to availability of these micronutrients to crops.

I.2 Previous Work

Many workers have found that the geographical distribution of micronutrients in soils appears to be more closely related to the composition of parent materials than to any other single factor. (Mitchell, 1972; Nair and Cottenie, 1971; Follett and Lindsay, 1970; Archer, 1963; Swaine and Mitchell, 1960). For example, Berrow and Mitchell (1980), working on soil developed on glacial till in

Scotland, concluded that total trace element contents of the soil were related primarily to the nature of the source rocks. Similarly on the Canadian Prairies, Bayrock and Pawluk (1966), also working on soils developed on glacial till, found that the distribution of trace elements could be related to bedrock subcrop patterns.

Nevertheless, despite the importance of the soil parent material, trace element composition of a soil is also influenced by pedogenic processes which may result in removal or redistribution of trace elements in the soil (Hodgson, 1963). Thus, besides the mineralogical composition of the parent material, total amounts of trace elements present in soils depend on the type and intensity of weathering and on the climatic and other factors predominating during the process of soil formation (Sillanpää, 1978). Factors that operate separately and jointly include weathering and leaching of soluble constituents; movements related to gleying and its associated oxidation and reduction effects; biogenic cycling and surface enrichment; size sorting with clay movement down profile; and possibly effects resulting from microbial activity (Mitchell, 1955). However, a high degree of profile development or an advanced stage of weathering is necessary before marked variation in micronutrient patterns is evident. (Follett and Lindsay, 1970). Nair and Cottenie (1971) working on brown earths, found that the relationship between parent material and total trace element content in the soil can be close enough to permit predictions of one while knowing the other. Ultimately, however as in Austalian soils that have undergone several cycles of weathering, over a long period, there may be little correlation between composition of the solum and its parent material (Oertel, 1961).

Availability of soil trace elements to crops depends not only on its total content but also on the forms in which it occurs (Berrow and Mitchell, 1980). For example, Viets (1962), views groups of individual forms in terms of 'pools'. Successive pools represent varying degrees of availability from ions in the soil solution to those remaining in the primary minerals. Each pool, except for the most unavailable corresponds to the forms of an element which are subject to removal by different types of extractants.

Various studies have shown that soil texture (Mitchell, 1955; Nair and Cottenie, 1971); pH (Hodgson, 1963); organic matter accumulation (Hodgson, 1963; Fleming et al, 1968) and drainage impedance (Swaine and Mitchell, 1960; Hodgson, 1963; Berrow and Mitchell, 1980) are major influences on the distribution of extractable trace elements. Nair and Cottenie (1971) obtained poor results when predicting available trace element concentrations from parent material content because of the varying influences of the above factors.

Berrow and Mitchell (1980), working on four soil types in Scotland, found the total content of a soil to be relatively constant throughout the profiles, and concluded that total content does not therefore provide a reliable indication of the availability of trace elements in soil. Furthermore, Sillanpää (1978) observed that the amounts of trace elements removed yearly with normal crop yields, represent only a very small proportion, generally less than 1% of the total amounts of the various trace elements present in soils. Thus, it is clear that total micronutrient concentration even in the most deficient case will generally far exceed requirements of the crop, although in some extreme cases when the parent material has an abnormally low micronutrient content, for example, granite, this will not be so. Consequently, total concentrations are not necessarily a reliable index of availability of micronutrients to the plant (Sillanpää, 1978) except perhaps where the total content is very low (Viets, 1962).

In an attempt to overcome these problems and predict micronutrient status of soils, many extractants have been used to evaluate availability. These have included 0.1N HCl, 1N NH_4OAc, EDTA - $(NH_4)CO_3$, DTPA (Stewart and Tahir, 1971); 0.01 M $CaCl_2$ 2N $MgCl_2$, NH_4OAc, 0.05 HCl: 0.025 H_2SO_4, DTPA (John, 1971); N NH_4OAc, 1.5 M NH_4 H_2PO_4, 2N $MgCl_2$, DTPA (Khan et al, 1978); M NH_4Ox, 2.5% HOAc, 0.05 M EDTA (Berrow and Mitchell, 1980).

In North America, DTPA is probably the most frequently used extractant because it offers the most favarouble combination of stability constants for the simultaneous complexing of iron, zinc, copper and manganese. Norvell, (1972) found that although a number of chelating agents can effectively complex copper and zinc in soils, DTPA was exceptional in that it was also among the best for iron and manganese. Since iron and zinc deficiencies are most prevalent on calcareous soils which cover large areas in North America, the extractant was designed specifically to avoid excessive dissolution of $CaCO_3$ with the release of occluded micronutrients which are normally not available for absorption by roots. Follett and Lindsay (1970), working on Colorado soils with serious micronutrient deficiencies of zinc and iron, found that it provides a reasonably satisfactory index of their availability. Other examples, include de Boer and Reisenauer (1973), working on Californian soils, who conducted experiments to evaluate DTPA as an extractant of available soil iron, established guides for fertilization. Similarly, Haby and Sims (1979), in Montana suggested that DTPA soil analysis of copper, iron, manganese and zinc should be carried out before forecasting fertilizer applications. Also Gough et al (1980), working on plants and soils of the Northern Great Plains found that DTPA results for copper, iron, manganese and zinc lead to better correlations than EDTA results.

Studies on the distribution of both total and available trace elements down catenary segnences are very limited. However, Yaalon et al. (1971), working on the distribution of manganese in three catenas on Mediterranean soils found that total manganese increased down slope by 50-80% for all three slopes. Fortescue (1974b) working in Ontario noted that the topographic setting of particular sampling pits modified the characteristic vertical distribution of trace elements in soil.

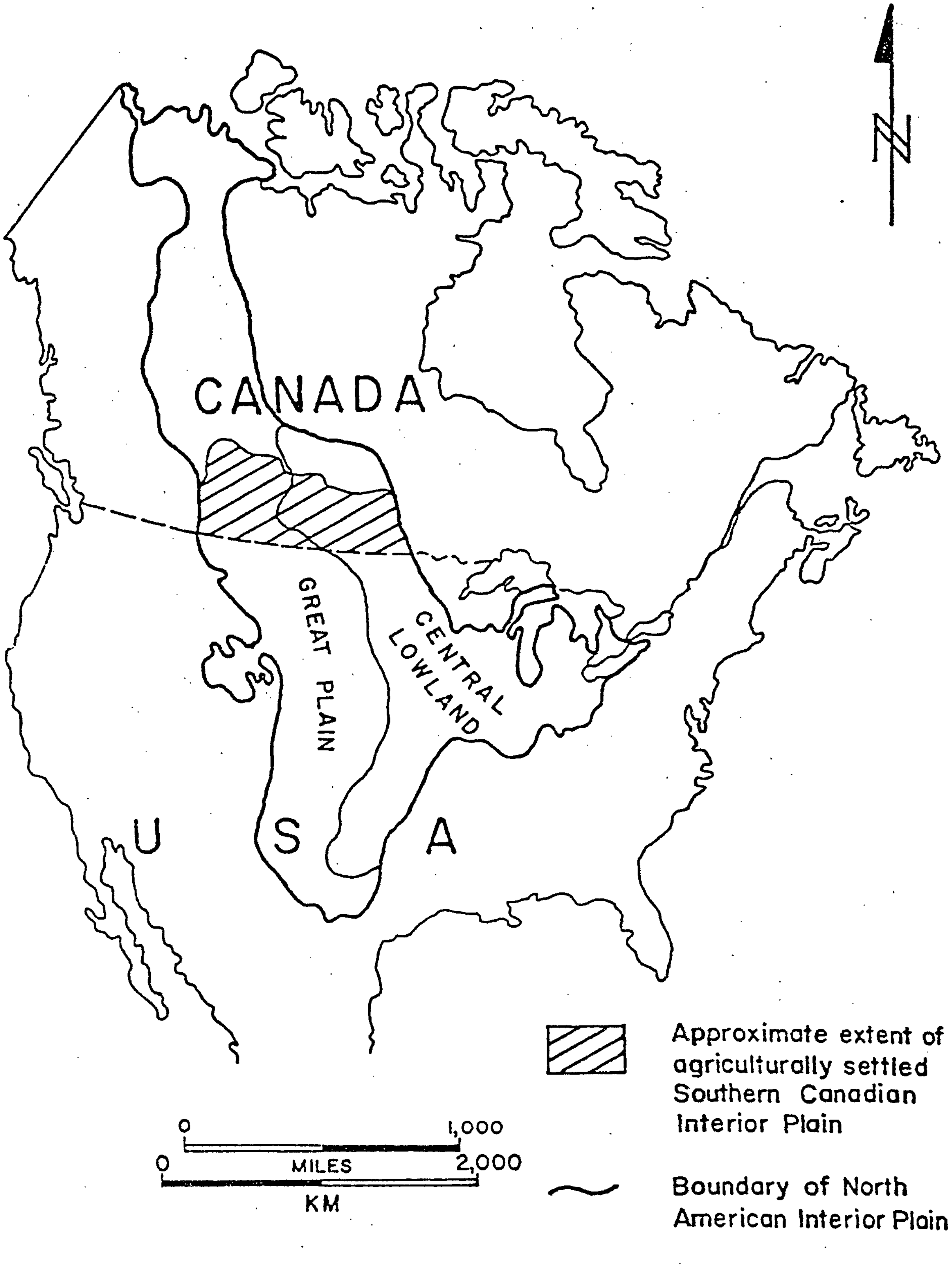


FIGURE 1 Location of Agriculturally Settled Southern Canadian Interior Plain (Doyle, 1977)

CHAPTER II

THE STUDY AREA

II.1 General Geographical Description

The study area comprises approximately 9900 km^2 in West Central Saskatchewan, (Fig. 2), Rosetown itself lying about 80 km. South West of Saskatoon, and lies within the physiographic region known as the Great Plains Province of the Interior Plains of North America (Fig. 1). There are two major physiographic subdivisions, the Saskatchewan Plain Region, or second Prairie step and the Alberta High Plain Region or third Prairie step (Acton and Ellis, 1978). The study area includes the Saskatchewan River Plain and the Howarden Hill Uplands (Fig. 3). The former occupies the central lowland area and is generally flat to gently rolling, ranging in elevation from 600 m. adjacent to the upland to 500 m. in the north east. The Howarden Hill Uplands in the east rises to a maximum elevation of about 615 m., and are characterized by an undulating to rolling surface. Considerably higher elevation (up to 750 m.) and more rugged relief occur on the Missouri Coteau Upland, which forms part of the Alberta High Plain. (Fig 3).

II.2 Climate

The climate is semi arid with short warm summers and cold long winters. Mean July and January temperatures are 19°C and 16°C respectively. Forty to fifty percent of the total precipitation (35 cm.) falls in the growing season, from May to September, with the bulk of the rainfall falling in June (8 cm.). Loss of soil moisture by

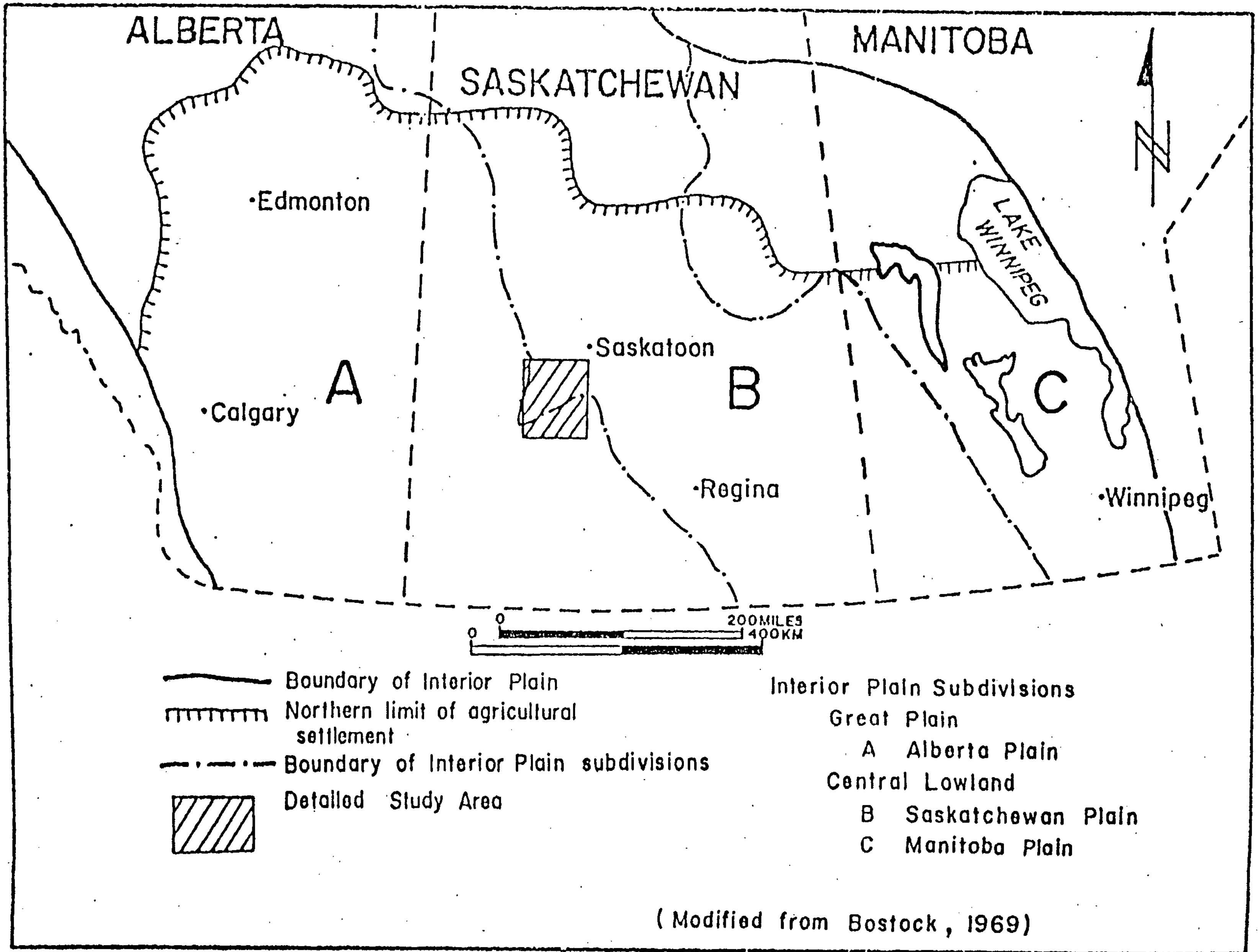


FIGURE 2 Major Physiographic Subdivisions of the Southern Canadian Interior Plain

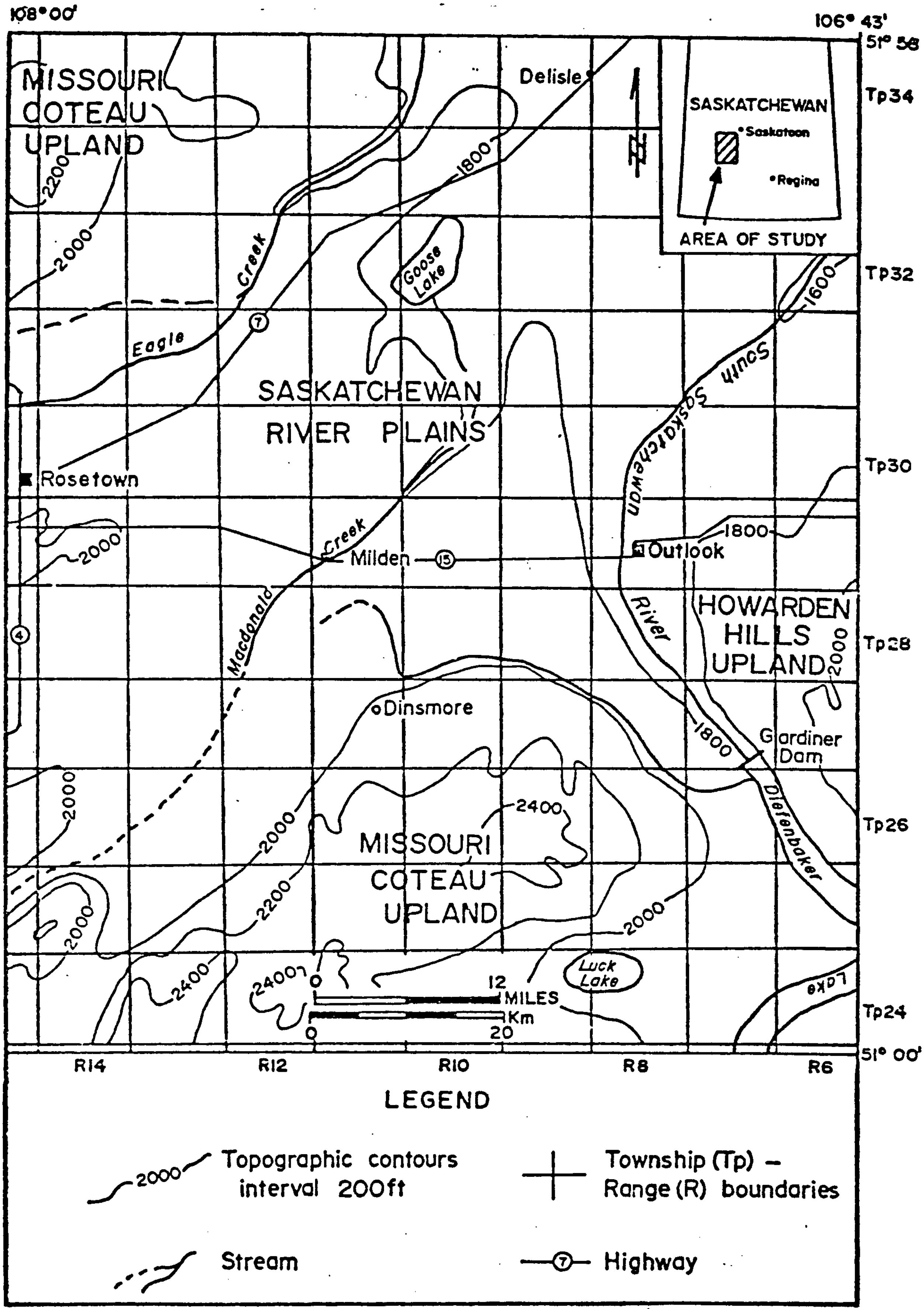


FIGURE 3. Topography and drainage, Rosetown area (Doyle, 1977)

evaporation and transpiration by plants results in a moisture deficency of 17-23 cms.

II.3 Geology (Fig. 4)

The Geology consists of flat lying sequences of clays, silts and gravels, ranging in age from the Upper Cretaceous Lea Park Formation to Pleistocene glacial and fluvio-glacial deposits, resulting from at least four glaciations (Christiansen, 1979). However, with the exception of exposures of silty clays and sands of the Bearpaw Formation at various locations along the South Saskatchewan River and in the Coteau Uplands (Scott, 1971), the only widespread deposits are Tertiary and Quaternary sands and gravels (Christiansen and Meneley, 1971).

Bedrock units are typically overlain by from 30 to 150 metres of Pleistocene Drift (Scott 1971), that form the soil parent materials of the region (Fig. 5), and prevent the underlying bedrock from having much direct influence on soils. However, the bedrock formations did serve as a source of materials for the glacial drift (Acton and Ellis, 1978) and composition and mode of deposition of the glacial materials greatly affects texture of the soils and the nature of the soil landscapes.

Predominent glacial materials include glacial till (materials deposited directly from ice), glacio-fluvial (deposited by water flowing from the ice) and glacio-lacustrine sediments (deposited in still waters of glacial lakes). Tills generally comprise a mixture of particle sizes ranging from clays to abundant pebbles and cobbles of

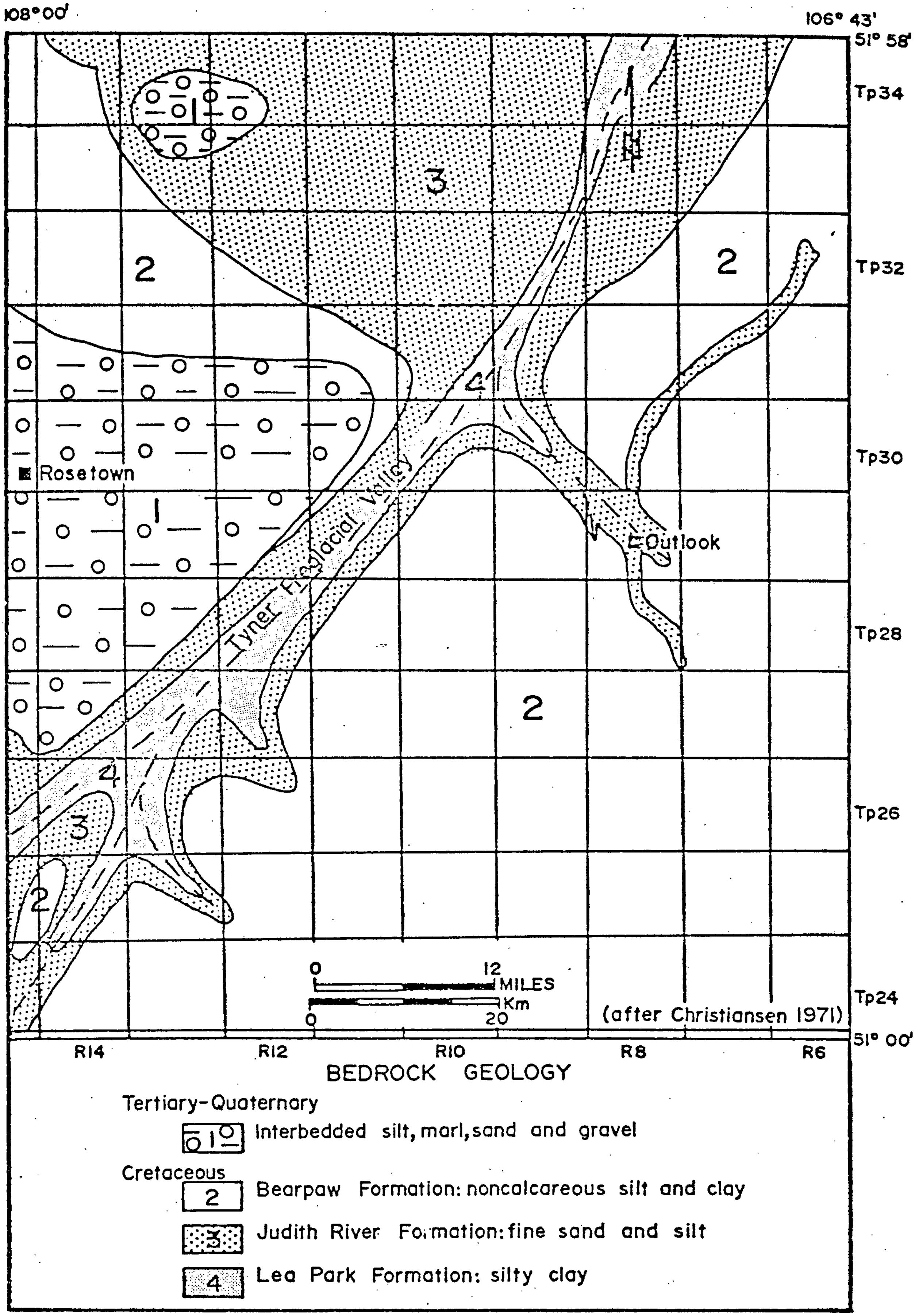


FIGURE 4 Bedrock geology, Rosetown area (Doyle, 1977)

igneous, metamorphic and carbonate rocks. Ablation tills containing a considerable amount of coarse englacial debris, result in landscapes of high relief with knoll and kettle patterns. In contrast, the finer textured ground moraine gives rise to smoother landscapes and till plains. Calcareous deposits underlie both the Missouri Coteau and the Howarden Hill Uplands and in many areas the drift is mantled by discontinuous ablation deposits, varying from 1 to 5 metres thick.

Glacio-fluvial and lacustine sediments are characterized by sorting of the materials resulting in a predominence of sands, silts or clays. Thick deposits of lacustrine and associated deltaic sediments produce nearly level landscapes. However, when the glacio-fluvial or lacustrine deposits are thin the resulting land form usually reflects the underlying material. All the lowland areas are underlain by lake deposits, with their maximum elevations decreasing from south to north reflecting the decreasing elevation of the glacial lakes in that direction.

Glacio-fluvial and glacio-lacustrine deposits have been modified and redistributed by wind (aeolian) action forming elongate blowout or parabolic dunes, these are especially notable, south of Delisle. Most dunes have been stabilized by vegetation, but in some localities dune migration is occurring (Scott, 1971).

The youngest soil parent materials are the alluvial flood plain deposits of rivers. These are most extensive along the South Saskatchewan River but in all amount to only a small percentage of the region as a whole.

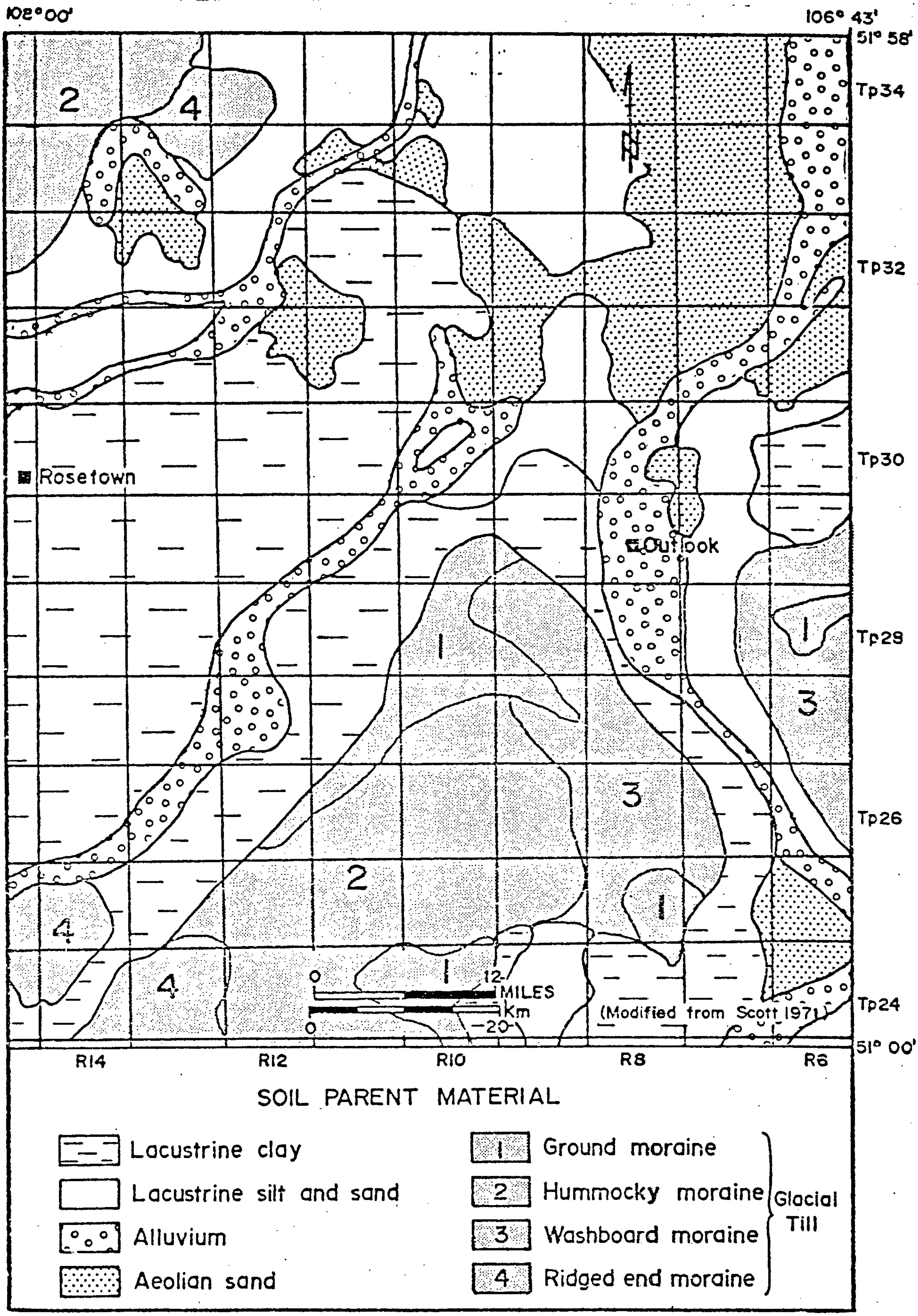


FIGURE 5 Soil Parent Materials, Rosetown Area (Doyle, 1977)

Table 1 - Description of the Regina, Elstow, Weyburn and Dune Sand Soil Series

SOIL TYPES: DOMINANTLY DARK BROWN CHERNOZEMS			
Soil Series	Dominant	Significant	Parent Material
REGINA	Rego Dark Brown	Orthic Dark Brown	Fine textured, moderately calcareous clayey glacio-lacustrine deposit
ELSTOW	1. Orthic Dark Brown 2. Calcareous Dark Brown 3. Rego dark Brown	1. Calcareous Dark Brown 2. Eluviated Dark Brown 3. Orthic Dark Brown	Medium to moderate fine textured, moderately calcareous silty glacio-lacustrine deposits
WEYBURN	1. Orthic Dark Brown 2. Calcareous Dark Brown	1. Calcareous Dark Brown 2. Eluviated Dark Brown 3. Gleysolic	Medium to moderate fine textured, moderately calcareous unsorted glacial till
DUNE SAND	Orthic Regosol	Carbonated +/ or Salinized Regosolics	Coarse to moderate coarse aeolian or wind-worked sandy glacio fluvial and lacustrine deposit

(Ellis et al. 1970)

II.4 Soil Types

Chernozemic soils occupy over ninty percent of the area, although Regosols, Solonetzic and Gleysolic soils are also present (Ellis et al, 1970). Profile development is generally weak, due in part to the relatively young age of the surficial deposits as well as the comparatively low precipitation. Thus, pedogenic processes have had little effect on the non calcareous aeolian sands where Orthic Regosols predominate (Table 1). Similarly on the moderately calcareous lacustrine clays, Rego Dark Brown and Rego Brown Chernozems predominate (Table 1).

Horizon differentiation is more advanced on the lacustrine silts and sands, and glacial tills which are characterized by Orthic and to a lesser extent Calcareous, Eluviated Brown and Dark Brown Chernozems (Table 1). Bm and Bt horizons in these soils, which range in thickness from a few centimetres on tills and lacustrine silts to over thirty eight centimetres on lacustrine sands, are commonly underlain by carbonate enriched Cca horizons. Four soil series associations, selected for sample collection on the the basis of their importance and wide distribution, (Figs. 6,7) will be described in detail.

II.4.1 Regina Association

The Regina Association consists chiefly of Chernozemic Dark Brown soils developed on uniform, clayey, glacio-lacustrine deposits (Table 1). Its parent material is a dark greyish brown, moderately calcareous, heavy clay. Stones are virtually absent except where the

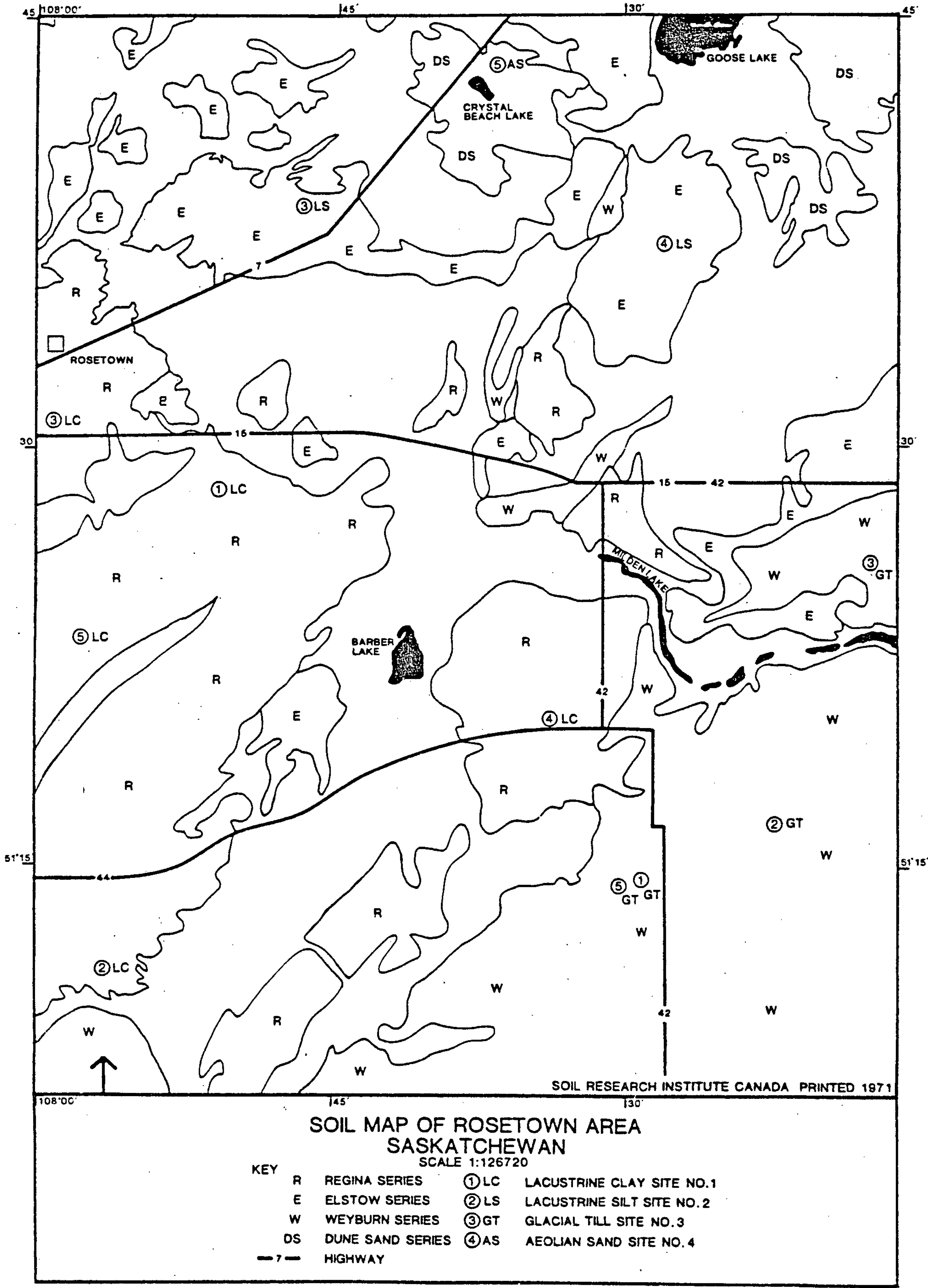


FIGURE 6 Location of Sites, Rosetown Area

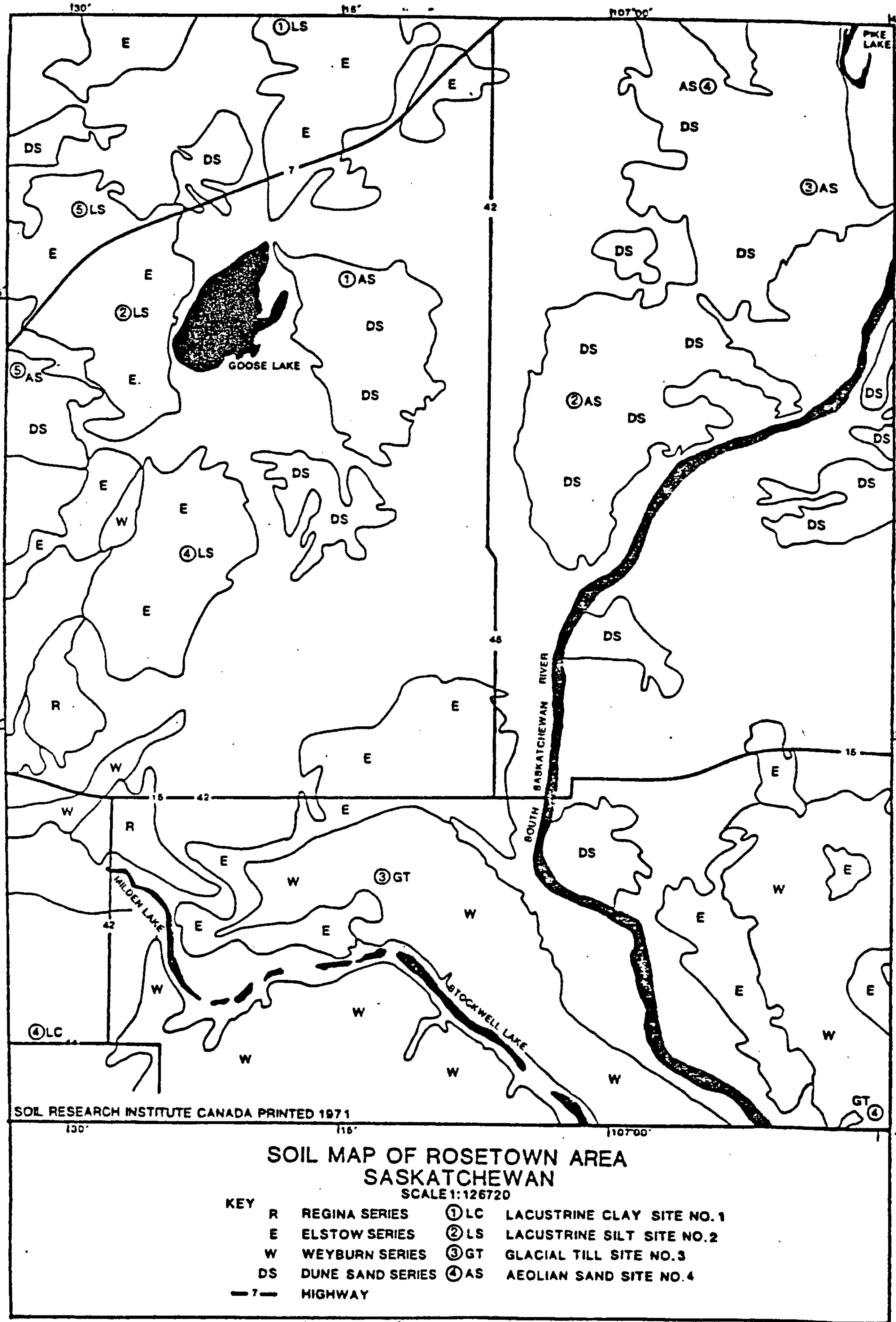


FIGURE 7 Location of Sites, North East of Rosetown Area

parent material is thin over the underlying glacial till. Regina soils occur mainly on very gently sloping or undulating topography as seen in the area due south of Rosetown. The dominant series is a Rego Dark Brown occurring on higher sites. An Orthic Dark Brown series often develops an slightly flatter and lower sites. This series can occupy depressions in the microrelief (Ellis et al, 1970). Gleysols occupy lower moderately to poorly drained sites down slope from the Orthic and Rego Series.

Under the A.R.D.A. (Agricultural Rehabilitation and Development Act) Soil Capability Classification, the Regina Rego and Orthic series of the upland are placed at the top of class 2 (ie. good arable land) and represent the best agricultural soils of the Dark Brown Zone. They are particularly suited to large scale wheat farming. This high agricultural rating results from a combination of their high water holding capacity, good fertility and favourable topography. (Ellis et al, 1970). The Gleysols are placed in class 3 (i.e. fair, arable land).

II.4.2 Elstow Association

The Elstow Association comprises a group of Chernozemic Dark Brown soils developed on medium to moderately fine textured silty glacio-lacustrine deposits (Table 1). Their parent materal is greyish brown to light olive brown, moderately calcareous loam, silt loam, clay loam and silty clay loam. Surface stones are absent to few except where the Elstow deposit is thin (less than four feet) (Ellis et al, 1970) and underlain by glacial till. The soils occur mainly on very gently sloping to roughly, undulating topography. An Orthic Dark Brown soil is dominant in the association and occupies nearby all positions in landscapes of low relief, as well as the well drained mid slope position in landscapes of rougher relief.

Under the A.R.D.A. Soil Capability Classification, Elstow soils are placed in class 3 (ie. fair arable land). Their limited water holding capacity and inability to support good plant growth during periods of drought are their major deficiencies.

II.4.3 Weyburn Association

The Weyburn Association consists mainly of Chernozemic Dark Brown soils of medium to fine texture, developed on unsorted glacial till (Table 1). Their parent materials are pale brown, light yellowish brown or greyish brown (marked with whitish spots and streaks of calcium carbonate), sandy clay loams. Glacial stones are common and can be a serious handicap to cultivation. The Association occurs on a wide range of topographical sites, in deposits from gently undulating to strongly rolling moraine. Weyburn landscapes have the sinuous appearance typical of glacial till areas characterized by a succession of knolls or ridges forming the highest land and separated by lowland depressions.

Nearly all the Weyburn sites have been mapped as loams. An Orthic Dark Brown is the dominated series of the Association. This occupies well drained, intermediate slopes with Eluviated Dark Brown soils on lower and more gentle slopes. Calcareous Dark Browns occur on the upper slopes and crests of knolls and ridges. However, an Orthic Regosol, which is usually the eroded phase of the Calcareous or

Orthic Dark Brown Series, occurs on eroded knolls and ridges. Gleysols occupy undrained depressions and flat, poorly drained, lower lands.

Under the A.R.D.A. Classification, the best Weyburn soils are placed in class 3 (ie. fair arable land). These soils include Weyburn loams in undulating to gently rolling topography. Soils on rougher relief are placed in clased 4 to 5 (ie. poor to unsuitable land) depending on the severity of the topography. Local areas of Gleysolic soils are placed in class 5 (ie. unsuitable for cultivation).

II.4.4 Dune Sand Association

This association consists mainly of coarse to moderately coarse textured Regosolic soils developed on aeolian or wind worked, sandy glacio-fluvial and lacustrine deposits (Table 1). The parent material is a yellowish brown to greyish brown sand. It is generally lime free except when underlain by heavier textured subsoils (Ellis et al, 1970).

The Association occurs on a wide range of topography from undulating sand plains to hilly duned areas. Surface and internal drainage is excessive due to the very high permeability of these sandy deposits. More pronounced dune areas usually contain a higher proportion of fine sands whereas, the more subdued landscapes are composed of mixed fine and coarse sands. On the wide range of topography associated with Dune Sands, Orthic Regosols occur in all positions except depressions where carbonated or saline Regosol Series and occasionally Gleysolic soils are developed.

Under the A.R.D.A. classification, most Dune Sand Soils are placed in class 6, and are considered suitable only for native pasture. However, Dune Sand on smoother topography may be considered as class 5. Efforts have been made in some cases, and are required in others, to stabilize the shifting sand and thus control its encroachment on to the adjoining arable lands.

II.5 Variation in Soil Morphology Downslope (Fig. 8)

It was evident from field studies, that shallower soils tend to be associated with convex, upper slopes, and deeper soils with concave, lower slopes. Furthermore, for the sites investigated there is generally (regardless of parent materal type) a rapid increase in depth of soil profile once a certain lower slope position is reached and gleysols occupy the depressions. However, of the four soil series studied only the Weyburn and Elstow Associations have moderately well developed soil profiles (Table 1), with Orthic Dark Brown Chernozems as the predominant soil series. Moss (1972), working in Saskatchewan recognizes three types of Orthic Dark Brown Chernozems. Orthic soils with a lime layer (Cca horizon) between 7-12 inches and those with this layer below 12 inches, classified respectively, as shallow orthic and deep orthic soils. AB Orthics with an AB horizon between the Ap and B horizons are the third type. In the field, this is designated as a break down of structure rather than on a textural basis.

The Deep Orthic soils perhaps, represent the classic orthic profile and are found almost exclusively in the classic orthic slope position - the midslope (King, 1976). King (1976) suggests that this

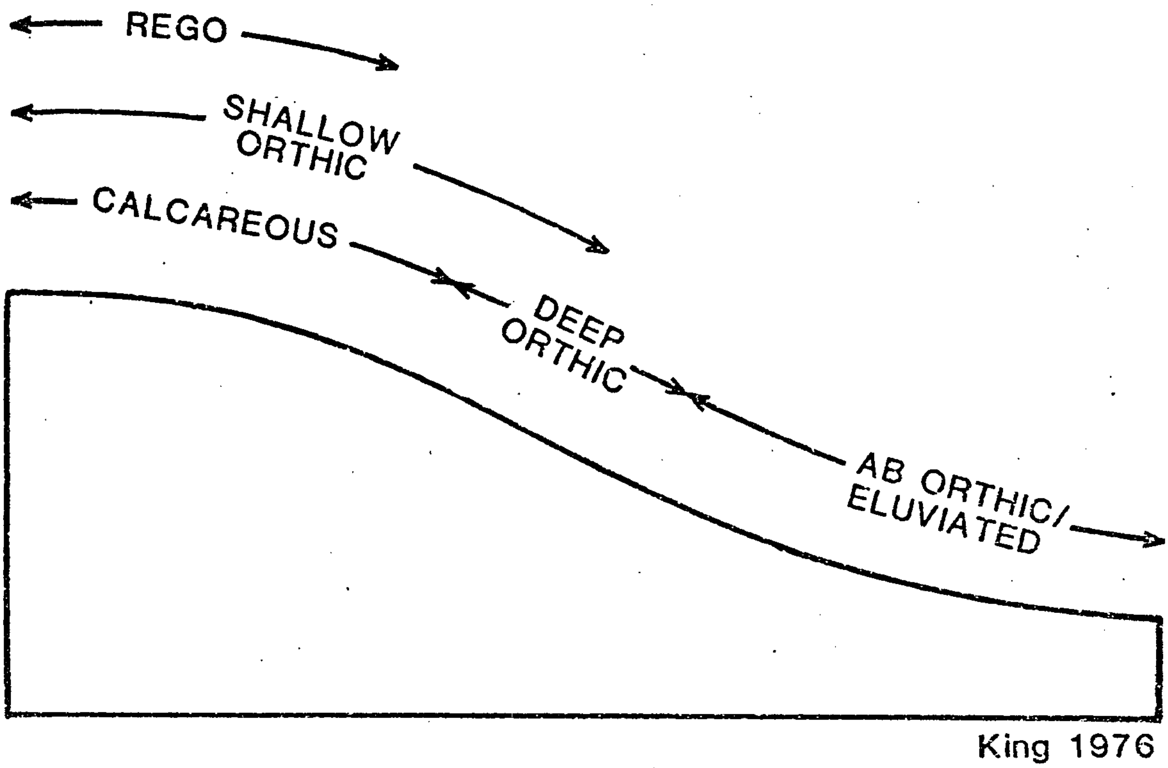


FIGURE 8 General Variations in Soil Morphology Downslope

marks some critical juncture between situations of moisture deficiency and moisture excess. In contrast, shallow orthic soils have a wider distribution and can occur everywhere except in toe slope position (King 1976). AB Orthics occur in footslope positions which they share with the eluviated soils (Figure 8). However, the latter also extend onto the toe slope positions. Gleyed Eluviated soils occupy the toe slope positions almost exclusively whereas Rego soils tend to be found on the crest and shoulder slope positions. Calcareous soils can occur anywhere from crest to midslope positions.

In this manner, distribution of soils downslope support the traditional concepts of catenary sequences. Most exceptions are due to slope variations which overide the general slope positions. It is noted that depth of the solum seems to respond to the land surface form, even down to minor irregularities. So that soil development is seen to mirror even small changes in form. Hence, although the classical model comprises upslope convexity (leading to shallower sola), rectlinear midslope and concave lower slope (leading to deeper sola), it is found to be the exception and soil development at a site is related to more local factors.

King (1976), found that given a uniform slope, moisture accumulations and associated depth of leaching will decrease as distance from the moisture source increases. He also observed that thickness of the Ap horizon does not appear to follow any particular pattern, although overdeepening is apparent at the footslope positions. This is also found to be the case in this study.

II.6 Agricultural Land Use

The main agricultural activity on lacustrine clay, silt and sand deposits is wheat production. Other cereals include, barley, rye, flax, oats and rapeseed. Owing to low rainfall, annual yields on clay soils are at least twice that on sands. Mixed farming is practiced on the glacial till areas, and regions underlain by aeolian sand are used for pasture and occasionally as wild game reserves.

CHAPTER III

METHODS

A List of the Abbreviations used in the text is given in Table 2.

III.1 Sample Collection

Soil samples were collected from soils developed on four different parent materials, lacustrine clay (Regina Soil Series), lacustrine silt (Elstow Soil Series), glacial till (Weyburn Soil Series) and aeolian sand (Dune Sand Soil Series). Five sites were selected for each parent material and at each site five pits were dug at intervals, down the slope, pit no. 1 is at the crest position running at intervals downslope to pit no. 5. All horizons were sampled in duplicate and a composite sample comprising five subsamples, collected from the surface horizon within a 3 metre radius about each pit.

Each pit was photographed and a description of site and soil characteristics entered on standard sheets (Description of Ecosystems in the Field, Ministry of the Environment, Research Analysis Branch, Technical paper 2). Slope was measured using a Brunton compass and distances between the pits were measured using a calibrated length of rope. All samples were numbered randomly. Coordinates were recorded using the (one thousand metre) Universal Transverse Mercator Grid. Pit locations are summarized in Figures 6 and 7.

III.3 Sample Preparation

Soils were oven dried at 80°C and then gently disaggregated, using a porcelain pestle and mortar, prior to sieving through a

Table 2 - Abbreviations List

LIST OF ABBREVIATIONS		
	LC	Lacustrine Clay
	LS	Lacustrine Silt
	GT	Glacial Till
	AS	Aeolian Sand
	OM	Organic Matter
(*CUT)	Cu_T	Copper in Soil Digested With 4:1 HNO_3 /$HClO_4$ Mixture (i.e. Total Soil Copper)
(*CUD)	Cu_D	Copper Extracted With DTPA Solution
	Cu_O	Copper Extracted With NaOCl Solution (i.e. Copper Associated with Organic Matter)
	Cu_C	Copper Extracted With 5% HCl Solution (i.e. Copper Associated with Soil Carbonates)
	Cu_A	Copper Extracted With NH_4Ox Solution (i.e. Copper Associated with Amorphous Iron Oxides)
	Cu_R	Copper Extracted With 4:1 HNO_3 /$HClO_4$ (i.e. Residual Soil Copper, final extraction in the sequential extraction procedure)

*Used in computer printout.

(minus 10-mesh) nylon sieve. A quarter split was ground in a ring mill to minus 80-mesh. The affects of grinding on soil samples are summarized by Fletcher (1981).

III.3 Methods of Sample Analysis

All soils were analyzed for the following:

III.3.1 pH

pH was determined by the standard method used in the Geochemistry Labaratory, U.B.C. whereby 10 g. of a minus 10-mesh (2 mm) soil is added to 10 ml. of distilled water. The slurry is stirred four times at 10 minute intervals and then allowed to settle for 30 minutes, pH is then determined using a glass and calomel reference electrode pair with an Orion Model 404 pH meter.

III.3.2 Organic Matter

Organic carbon was determined by the Walkley Black titrimetric method (Black et al, 1965).

1N K_2CrO_7 is added to lg. soil (minus 80-mesh) to oxidise organic matter. Ferroin (phenanthroline ferrous sulphate) is added as indicator and changes from green through blue to red brown on the complete reduction of excess K_2 CrO_7 by 0.5 N $FeSO_4$. A blank determination was carried out for each batch of forty samples. A duplication of 1 sample in 10 was taken.

III.3.3 Trace Metals

Table 3 - Instrumental Settings for Techtron Atomic Absorption-IV Spectrophotometer

Element	Wavelength (A°)	Air Pressure (psi)	Fuel Gauge Setting	Slit Width (μ)	Camp Current (MA)
Cu	3247.5	20	2.5	50	3
Fe	*2488.3	20	2.5	50	5
Mn	2794.8	20	2.5	50	5
Zn	2138.6	20	2.5	100	6

* 2483.3 Used For DTPA Solutions
** Acetylene

III.3.3.1 Nitric Acid / Perchloric Acid Digestion

Samples were digested using 4:1 $HNO_3/HClO_4$ mixture (Fletcher, 1971) in batches of twenty four. Each batch included one U.B.C. standard rock, one blank and one duplicate. Solutions were analysed on the Techtron IV Atomic Absorption Unit for copper, iron, manganese and zinc. Operating conditions are summarized in Table 3.

This digestion is referred to as 'total' in the text, however it is not a complete digestion and some of the more resistant material will remain as residue.

III.3.3.2 DTPA Extraction

DTPA extractions were carried out according to Lindsay and Norvell (1978). These authors developed this test to identify deficiencies of Cu, Fe, Mn and Zn in calcareous soils. The extractant consists of 0.005 M DTPA (diethylene triamine penta acetic acid), 0.1 M triethanolamine and 0.01 M $CaCl_2$ at a pH of 7.3. The extractant is buffered at pH of 7.3 and contains $CaCl_2$ so that equilibrium with $CaCO_3$ is established at a CO_2 level about 10 times that of the atmosphere. Thus, the extractant precludes dissolution of $CaCO_3$ and the release of occluded nutrients which are normally not available to plants. Samples are run in batches of 24 which includes one soil standard, one blank and two duplicates. Copper, iron, manganese and zinc concentrations were then measured on the Techtron IV Atomic Absorption Unit (Table 3).

III.3.4 Sequential Extraction Analysis

First, catenas were selected on the basis of the change in A/C ratios; when these change significantly down a catena, while the C horizon value remains fairly constant, it indicates development of catenary trends on a uniform parent material. Second, catenas with consistent patterns were selected for sequential extraction to estimate proportions of copper, iron, manganese and zinc fixed in specific fractions of the soil. (Refer to Table 4 for list of samples selected). Four reagents were chosen to extract the five elements in a stepwise manner, each extractant drawing from a different 'pool'. The method used is a modified version of the procedure suggested by Hoffman and Fletcher (1979). A flow chart is shown in Figure 9. Solutions were analysed by atomic absorption spectrophotometry (Techtron IV Atomic Absorption unit) for copper, iron, manganese and zinc concentrations. (Table 3).

III.3.5 Particle Size Analysis

Further selection of two pits (Table 4) per catena was carried out for each parent material, one from an upper slope position and one from a lower slope position. The pits were chosen to manifest the maximum variation between upslope and downslope positions. Greater variation is shown throughout the pits for DTPA elemental values than for total elemental values. Therefore, DTPA concentrations were studied more closely when selecting the pits. Textural analysis was undertaken according to the Methods Manual, Pedology Laboratory U.B.C. (1981). Pretreatment of soil includes addition of a 5% sodium hypochlorite solution (destruction of organic matter) and a citrate buffer/sodium dithionite mixture (removal of free iron oxides) prior to hydrometer analysis.

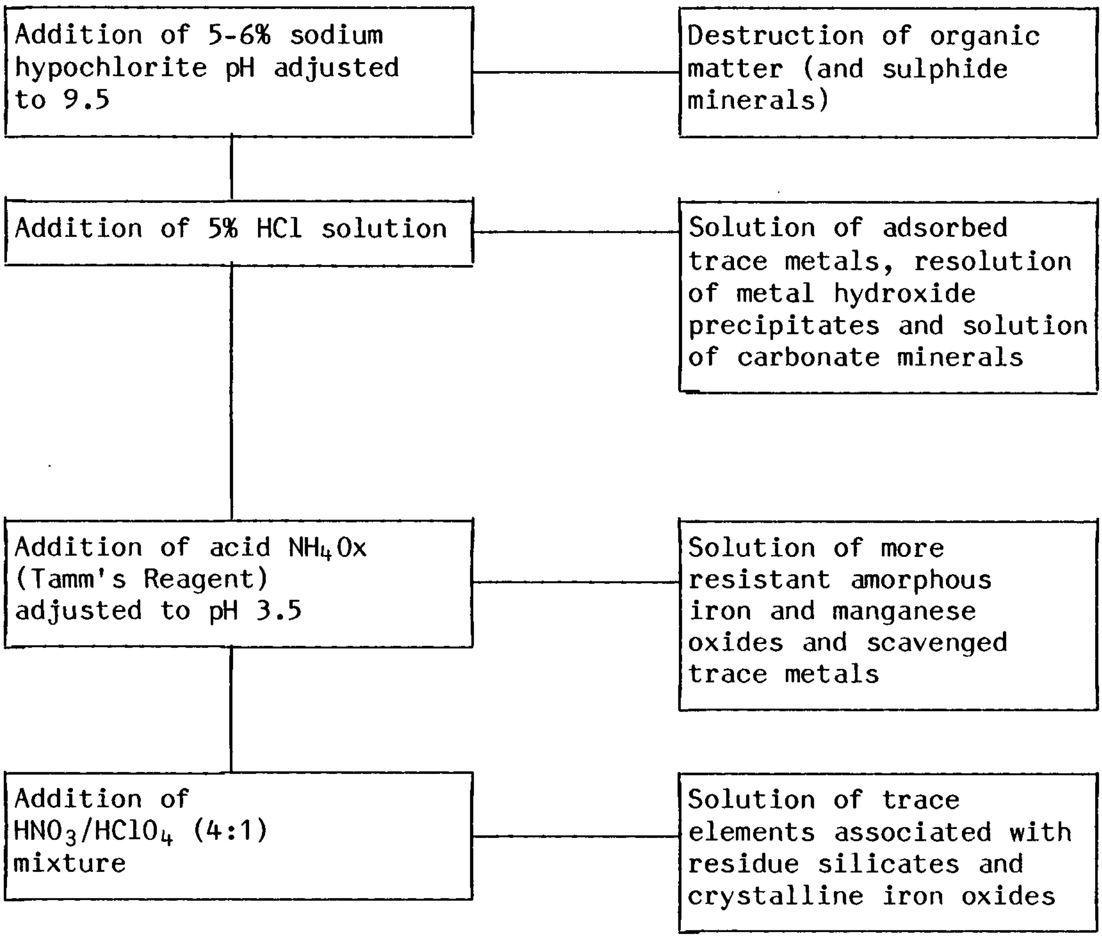
Table 4 List of Samples Analysed For Sequential Extraction, Particle Size Analysis and XRD

P.M.	LACUSTRINE CLAY					LACUSTRINE SILT					GLACIAL TILL					AEOLIAN SAND				
SITE NO.	SITE 3					SITE 5					SITE 3					SITE 3				
PIT NO.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	6	280	357	358	169	37	572	116	528	506	211	461	368	464	294	390	144	206	243	548
SEQUENTIAL	354	54	141	284	39	35	117	535	226	512	210	133	466	462	52	491	443	580	238	382
EXTRACTION	140	420	108	51	70	34	119	167	225	307	428	370	465	351	136	529	49	571	578	530
	473	227	474	391	373	576	118	299	555	204	372	369	-	345	341	158	-	543	375	383
	33	472	32	-	-	-	-	7	531	540	371	-	-	-	342	2	523	-	-	-
		280			169	37				506		461		464			144			548
PARTICLE		54			39	35				512		133		462			443			382
SIZE		420			70	34				307		370		351			49			530
ANALYSIS		227								204				345			523			383
		472			373	576				540		369								
														464						
X-RAY					39	35								*463c			*442c			
DEFRACTION														462						
														351						
														345						

*Composite Samples

Sample Nos. See Appendix A for details of the samples.

Figure 9 - Outline of Sequential Extraction Procedure



III.3.6 X-Ray Diffraction Technique

Eight samples (Table 4) (minus 10-mesh) were pre-treated with a 10% sodium acetate solution (removal of carbonates and soluble salts) followed by a 5% sodium hypochlorite solution (oxidation of organic matter). Samples were then separated by centrifuging into two size fractions 0.2-2μ and 2-5μ at speeds of 750 rpm and 300 rpm respectively. Each fraction was placed in a litre cylinder, distilled water added and allowed to settle. Slides were prepared and saturated with either 1N potassium chloride solution or 1N magnesium acetate and 1N magnesium chloride solution. Samples were run through the X-ray diffractometer and treated according to the procedure outlined in the Methods Manual, Pedology Labaratory U.B.C. 1981). X-ray conversion tables were used to diagnose X-ray diffraction spacings for minerals present. (Table 5).

III.4 Quality Control (Table 6)

Random errors are assumed to follow a normal Gaussian distribution about their mean concentration (c). Analytical precision is then specified as the percent relative variation at the two standard deviation (95%) confidence level.

Precision control charts were plotted using the method described by Thompson and Howarth (1978). This method utilizes a graphical plot of $(X_1 - X_2)$ versus $(X_1 + X_2)/2$ where X_1 and X_2 are pairs of duplicates. The absolute difference $(X_1 - X_2)$ being an estimator of the standard deviation (δc) and the mean value $(X_1 + X_2)/2$ being an estimator of average concentration. The spread of data

Table 5 - Principal Minerals and Their d/n SPACING (A°) (JACKSON, 1956)

CLAY MINERAL	d/n SPACING (A°)
Illite	10.0
Montmorillonite	17.7
Kaolinite	7.2
Quartz	3.35
Plagioclase Feldspar	3.12-3.23
Potassium Feldspar	3.21-3.28
Vermiculite	14.2
Chlorite	14.2
Amphibole	8.40-8.48

Note: d/n Spacings Given Are The First Order Peaks

Table 6 - Precision at the 95% Confidence Level for Total and DTPA Elemental Concentrations

Element	Total	No. Of Duplicates Pairs	DTPA	No. Of Duplicate Pairs
Cu	17%	33	30%	65
Fe	15%	33	15%	63
Mn	10%	34	10%	65
Zn	15%	33	30%	65
Organic Matter	10%	23		
pH	10%	30		

points is then compared to theoretically derived distributions against which precision may be compared.

Precision at the 95% confidence level ranged from within 10-30% for copper, iron, manganese and zinc extracted with DTPA solution and from within 10-17% for the same elements digested with $HNO_3/HClO_4$. (4:1) mixture. Precision for both pH and organic matter was within 10% precision at the 95% confidence level.

III.5 Statistical Methods

The following section gives a general overview of the various statistical methods used in evaluating the total (Cu_T, Fe_T, Mn_T, Zn_T) and DTPA (Cu_D, Fe_D, Mn_D, Zn_D) extraction data. Calculations were carried out for the most part on an Amdahl-470-V8 computer, using programs supplied by both the University of British Columbia Computing Centre and by the Statistical Research Laboratory, University of Michigan.

Many statistical methods assume that the data are normally distributed with equal sample variance (homogeneity of variance). However, several authors have suggested that the distributions of trace elements in geochemical materials approximate log normality (Ahrens, 1954; Hawkes and Webb, 1962, Miesch, 1967). Histograms and descriptive statistics (Appendix B) indicated that this was the case with the present data which was therefore transformed ($\log_{10}$) prior to running statistical tests.

The various statistical methods used are:-

III.5.1 Analysis of Variance

This is a method of estimating the amount of total variation in a data set that can be attributed to assignable causes of variation and how much can be attributed to chance (random error) (Harnett, 1970). A nested (hierarchical) classification model is set up -

$$Y_{ijk} = u + M_{(i)} + C_{j(i)} + \varepsilon_{k(i,j)}$$

where Y_{ijk} is the observed value for the kth replication of the jth level of C nested in the ith level of M.

u is the mean for the entire population.

M (i) are main groups where i = 1,p. (There are four parent materials so p=4).

$C_{j(i)}$ are subgroups where j=1,5. (There are five catenas per parent material so s=5).

$\varepsilon_{k(ij)}$ is the random error term.

Thus the total data variability is partitioned into within and among group components with the main groups being based on soil/parent material type. Data was divided by horizon that is, into A horizon and C horizon data and by depth from 0-30 cm. For the latter, data were weighted according to the depth of each horizon using the formula presented by Kloosterman and Lavkulich (1973).

$$VA_j = 1 / \Sigma h_i \sum_{j=1}^{N} (h_j \times V_j).$$

where VA_j is the average value of variable j; V_j is the thickness of horizon i and h_j is the variable j value of horizon i.

The assumption of this data set was that the expression of a soil may be considered as the average of the variable values over the depth of the profile (Kloosterman and Lavkulich, 1973).

The analysis of variance (ANOVAR) has been documented for general use on the Amdahl -470-V8 computer by M. Greig and D. Osterlin (1978).

III.5.2 Duncans New Multiple Range Test

This test was used to evaluate the significance of differences among means for various groups of data defined on the basis of soil parent material. It has been described in detail by Duncan (1955). This test has been documented for general use on the U.B.C. Amdahl -470-V8 computer.

III.5.3 Correlation and Regression

The linear correlation coefficient r was computed to measure the strength of relationships between data for different parent materials and between data for the different horizons, within each parent material.

A backwards stepwise Multiple Curvilinear regression model was then used, to predict the dependent variables, Cu_D, Fe_D, Mn_D and Zn_D. A Curvilinear model, incorporating the square, $\log_{10}$, and reciprocal of the independant variables was used; as in many cases, it is not reasonable to assume a linear relationship between the dependent variable and the independent variable. The independent variables for the regression analysis are Cu_T, Fe_T, Mn_T, Zn_T, pH and OM.

The coefficient of Multiple Regression R, is a common measure of the adequacy of a regression, when squared it is designated by R^2 and called the Coefficient of Determination. When applying a curvilinear model rather than a linear model, the Index of Multiple correlation I must be used (Ezekiel and Fox, 1961). The Index of Correlation has a meaning exactly corresponding to that of the coefficient of Correlation R but applies to Curvilinear regression and not linear.

CHAPTER IV

RESULTS

IV.1 Raw Data

IV.1.1 Total and DTPA Elemental Data

Highest total elemental concentrations are found in the Ap horizon of the Rego Dark Brown Chernozems developed on lacustrine clay, followed by lacustrine silt and glacial till soils with soils on aeolian sands having the lowest values (Table 7). There is a tendency especially in the organic rich surface plough layer, for total concentrations to increase downslope. These increases are relatively more pronounced for DTPA compared to total metal concentrations and are most apparent for lacustrine silt soils (Figs. 15 to 19). The A horizons of these soils also contain the highest DTPA extractable concentrations of iron, manganese and zinc whereas, maximum extractable concentrations in the C horizon are associated with lacustrine clays. DTPA extractable copper in both A and C horizons is at a maximum in lacustrine clay soils (Table 8). Proportionally, DTPA extractable metal concentrations range from less than 1% in the case of iron up to 12% of the total content for copper (Table 9).

IV.1.1.1 Lacustrine Clay Catenas (Figs. 10 to 14)

Soils are highly calcareous and increase in alkalinity down profile to maximum pH values of about 8.0 in the C horizon. Organic matter content decreases with depth from the surface but remains fairly constant downslope except at site 3 (Fig. 12), where there is a

Table 7 - Geometric Means and Standard Deviations (in parenthesis) for Cu, Fe, Mn and Zn in Soils Digested with HNO_3 /$HClO_4$

A Horizon	Cu_T(ppm)	Fe_T(%)	Mn_T(ppm)	Zn_T(ppm)	No. Of Samples
LC	24.8 (1.1)	2.5 (1.2)	309.0 (3.3)	85.7 (1.1)	25
LS	14.5 (1.2)	1.5 (1.2)	317.2 (1.2)	70.7 (1.1)	25
GT	12.8 (1.2)	1.3 (1.1)	285.0 (1.2)	52.5 (1.3)	25
AS	3.8 (1.5)	0.7 (0.8)	123.6 (1.5)	31.1 (1.5)	25

C Horizon	Cu_T(ppm)	Fe_T(%)	Mn_T(ppm)	Zn_T(ppm)	No. Of Samples
LC	24.6 (1.1)	2.2 (1.2)	291.7 (1.1)	79.3 (1.1)	25
LS	18.0 (2.4)	1.2 (1.2)	283.8 (1.7)	53.6 (1.3)	25
GT	13.4 (1.2)	1.3 (1.2)	268.2 (1.2)	45.9 (1.4)	25
AS	3.6 (1.4)	0.6 (0.8)	99.1 (1.5)	21.7 (1.3)	25

Table 8 - Geometric Means and Standard Deviations (in parenthesis) for Cu, Fe, Mn and Zn Extracted from Soils with DTPA

A Horizon	Cu_D(ppm)	Fe_D(ppm)	Mn_D(ppm)	Zn_D(ppm)	No. Of Samples
LC	2.8 (1.2)	10.2 (1.5)	8.0 (1.3)	0.6 (0.7)	25
LS	1.4 (1.3)	36.9 (2.0)	24.1 (1.4)	1.7 (1.5)	25
GT	1.4 (1.2)	18.6 (2.8)	10.0 (1.7)	2.6 (1.8)	25
AS	0.4 (0.5)	20.1 (1.6)	6.1 (1.6)	1.8 (1.9)	25
C Horizon	Cu_D(ppm)	Fe_D(ppm)	Mn_D(ppm)	Zn_D(ppm)	No. Of Samples
LC	3.0 (1.2)	13.5 (1.2)	5.0 (1.4)	0.4 (0.7)	25
LS	1.7 (1.3)	10.1 (1.4)	2.9 (1.4)	0.2 (0.6)	25
GT	1.6 (1.3)	10.2 (1.9)	3.1 (1.6)	0.2 (0.6)	25
AS	0.3 (0.6)	9.4 (1.4)	2.7 (1.6)	0.2 (0.5)	25

Table 9 - Percentage of DTPA Extractable Cu, Fe, Mn and Zn to Total Cu, Fe, Mn and Zn Concentrations (A and C Horizons) in Lacustrine Clay, Lacustrine Silt, Glacial Till and Aeolian Sand

		Cu(%)	Fe(%)	Mn(%)	Zn(%)
A Horizon					
	LC	11	0.04	3	1
	LS	10	0.2	8	2
	GT	11	0.1	4	5
	AS	11	0.3	5	6
C Horizon					
	LC	12	0.1	2	0.5
	LS	9	0.1	1	0.4
	GT	12	0.1	1	0.4
	AS	8	0.2	3	0.9

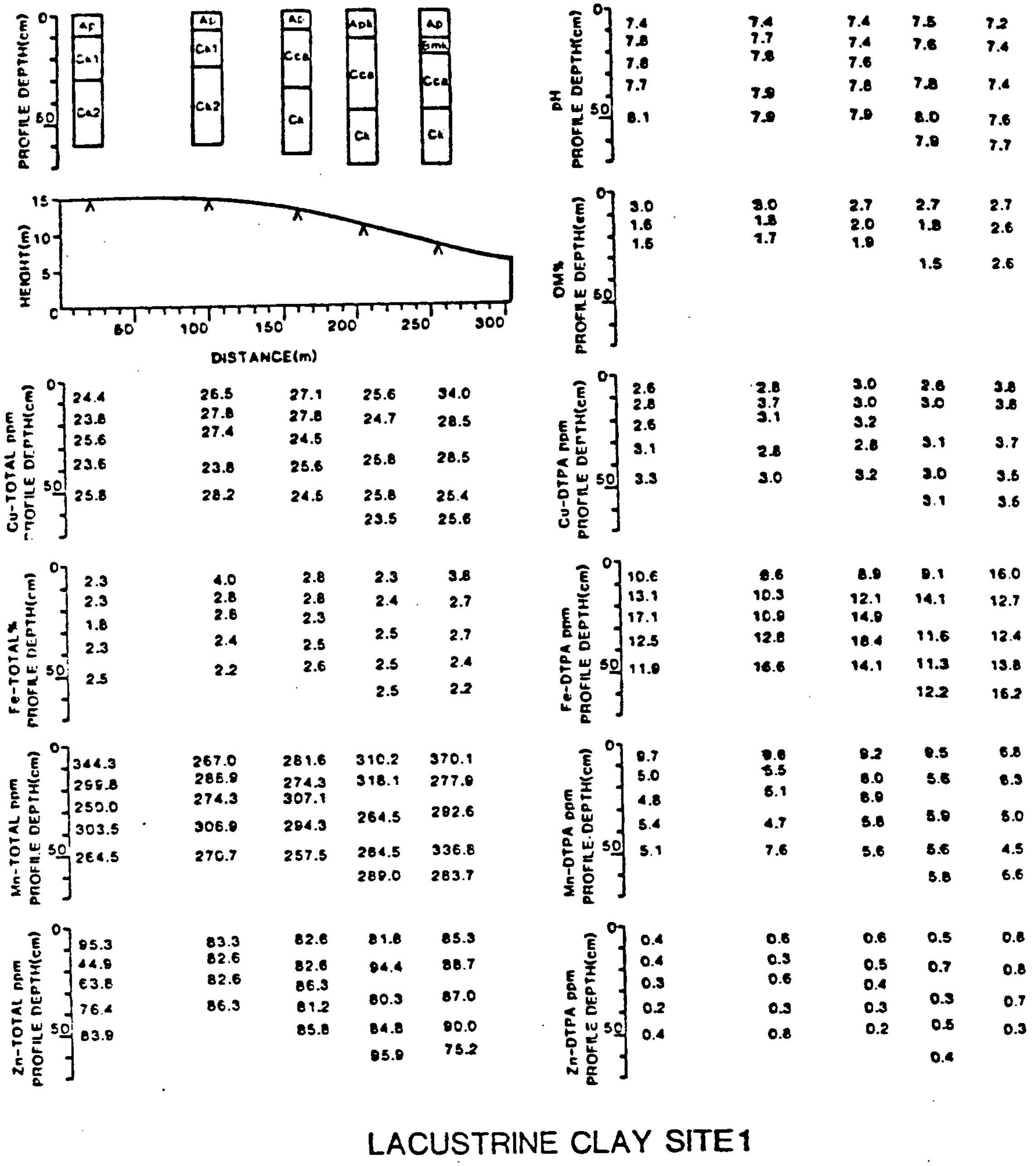
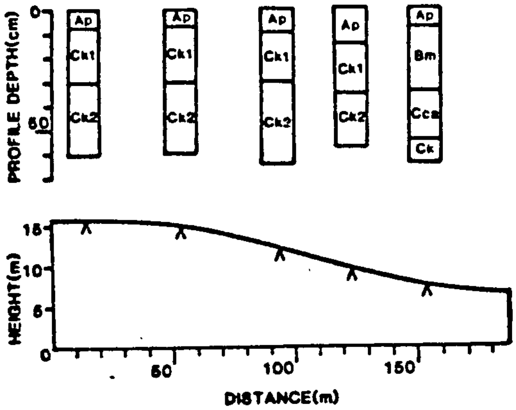


FIGURE 10 Total and DTPA Elemental Data, pH and Organic matter Content, down Catena, for Lacustrine Clay Soils - Site 1



pH (PROFILE DEPTH(cm), 0–50)

7.7	7.7	7.7	7.5	7.4
7.7	7.7	7.7	7.5	7.3
8.0	7.7	7.8	7.5	7.5
7.9	7.9	7.8	7.5	7.5
8.0	8.1	7.7	7.7	7.6

OM% (PROFILE DEPTH(cm), 0–50)

1.9	1.9	1.9	2.0	2.0
1.8	1.8	1.7	1.9	2.3
1.8	1.6	1.6	2.0	2.1

Cu-TOTAL ppm (PROFILE DEPTH(cm), 0–50)

23.9	25.8	25.1	28.5	27.3
23.6	25.8	25.8	25.8	25.3
26.1	25.9	27.7	25.8	23.7
27.1	27.4	27.4	25.9	22.1
25.8	25.8	26.9	25.8	19.4

Cu-DTPA ppm (PROFILE DEPTH(cm), 0–50)

2.8	3.0	3.1	2.5	2.8
2.8	2.8	3.2	2.8	2.4
3.1	3.1	3.2	2.6	2.1
3.3	3.1	3.2	3.0	2.1
3.0	1.7	3.1	2.6	1.6

Fe-TOTAL % (PROFILE DEPTH(cm), 0–50)

3.1	2.7	2.4	3.0	2.5
2.4	2.0	2.3	1.6	2.3
2.9	2.1	3.2	1.8	2.5
3.0	2.9	2.5	2.9	2.4
2.5	2.3	2.1	2.2	2.0

Fe-DTPA ppm (PROFILE DEPTH(cm), 0–50)

11.4	10.8	11.3	8.0	8.7
13.3	19.6	16.0	16.7	10.7
11.9	11.1	11.0	16.2	11.2
13.9	12.1	19.6	11.5	12.6
11.9	12.9	14.7	18.6	13.0

Mn-TOTAL ppm (PROFILE DEPTH(cm), 0–50)

270.3	272.0	260.7	261.0	329.1
326.0	230.5	333.9	221.6	336.5
324.0	340.0	226.7	221.6	304.2
338.0	274.3	289.0	248.4	300.5
264.5	292.3	307.2	266.0	263.0

Mn-DTPA ppm (PROFILE DEPTH(cm), 0–50)

4.9	5.9	5.9	4.6	6.5
5.0	5.8	7.2	5.6	6.6
5.9	4.7	4.3	7.1	6.8
4.7	3.8	5.1	6.5	5.8
5.2	4.7	7.1	5.6	2.3

Zn-TOTAL ppm (PROFILE DEPTH(cm), 0–50)

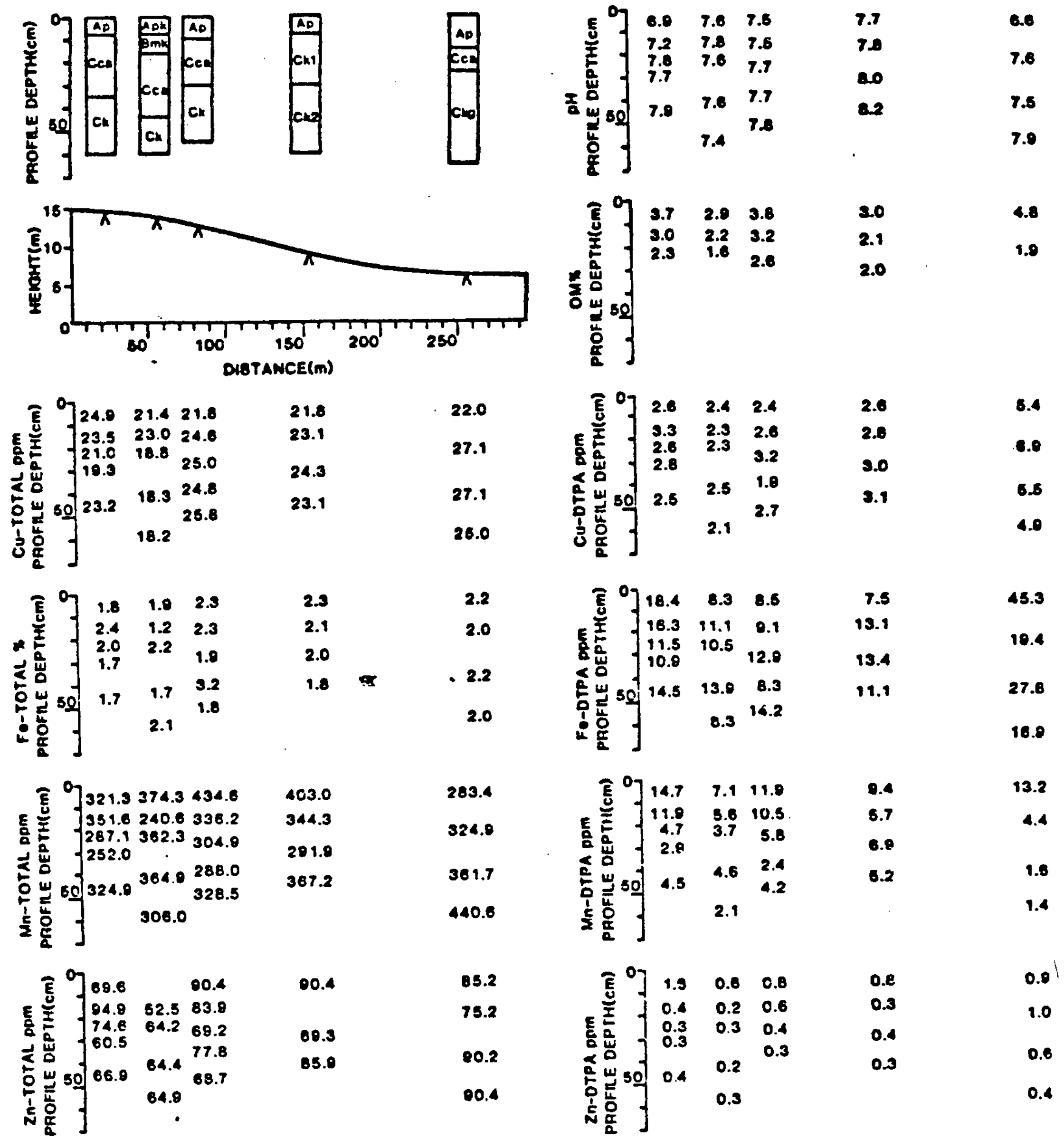
96.5	84.8	81.6	89.5	91.7
87.6	86.2	89.4	62.0	88.1
94.9	90.4	79.2	62.6	85.8
89.4	80.0	84.2	86.5	84.9
82.1	77.3		75.8	76.0

Zn-DTPA ppm (PROFILE DEPTH(cm), 0–50)

0.3	0.4	0.3	0.5	0.5
0.2	0.4	0.5	0.4	0.5
0.3	0.3	0.5	0.4	0.7
0.2	0.3	0.5	0.3	0.5
0.2	0.2	0.3	0.5	0.2

LACUSTRINE CLAY SITE2

FIGURE 11 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Lacustrine Clay Soils - Site 2



LACUSTRINE CLAY SITE3

FIGURE 12 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Lacustrine Clay Soils - Site 3

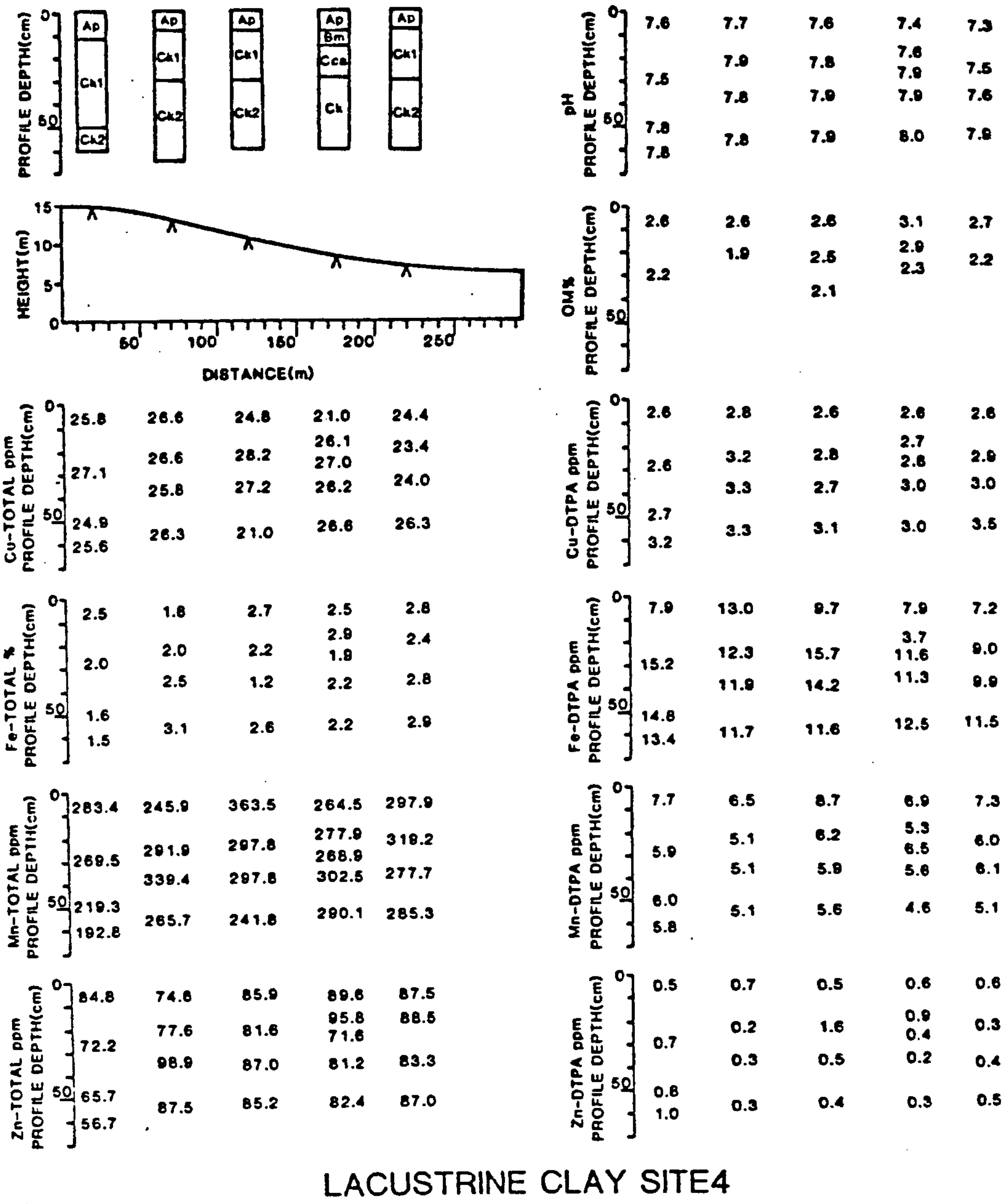
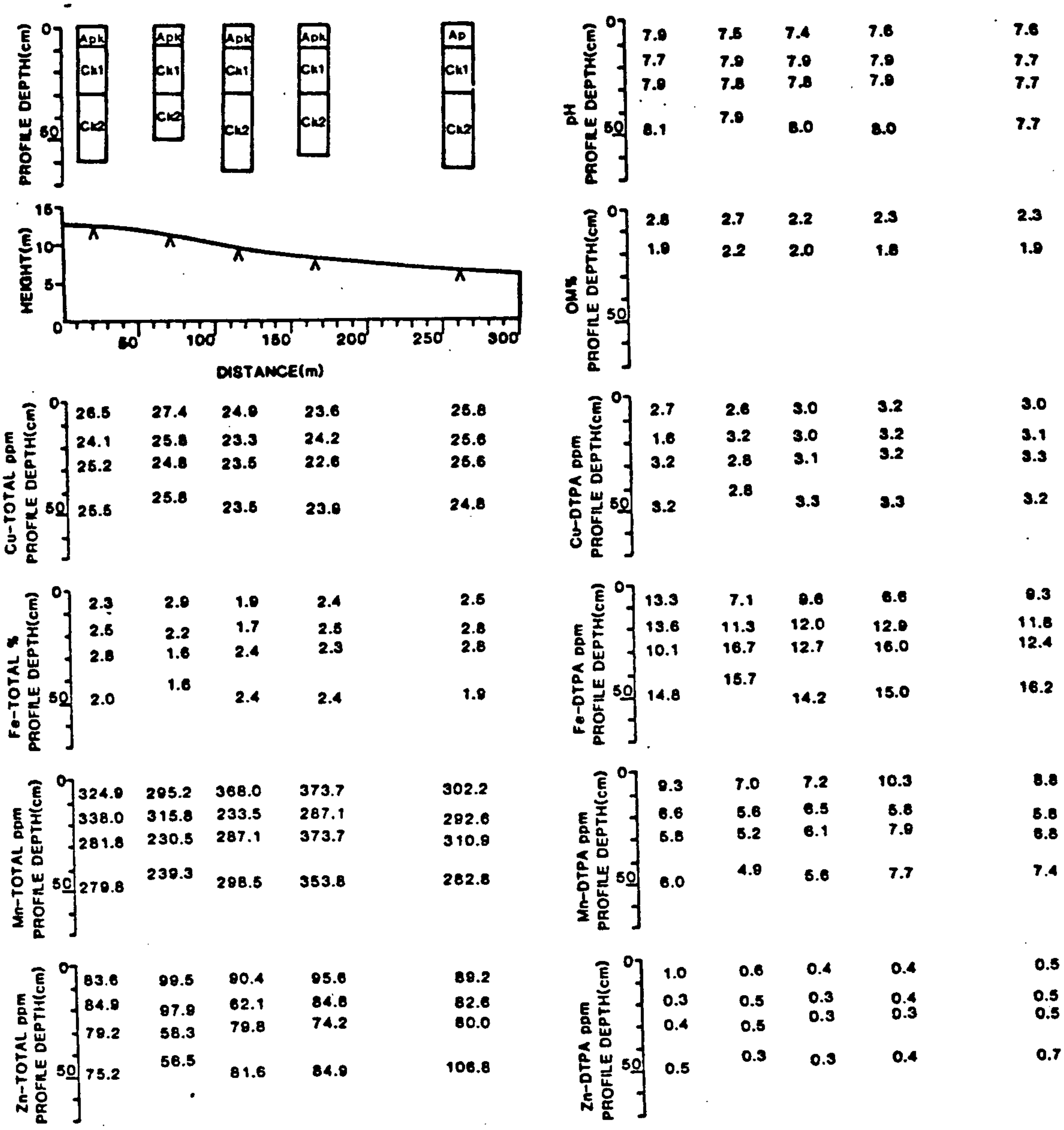


FIGURE 13 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Lacustrine Clay Soils - Site 4



LACUSTRINE CLAY SITE5

FIGURE 14 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Lacustrine Clay Soils - Site 5

30% increase in organic content up to 4.8% in the A horizon at the base of slope.

Trace element variations within profiles and down catenas are relatively subdued. Nevertheless, there is a tendency for soils at the base of the slope to show enriched total and DTPA surface values for all four elements, this is most apparent at sites 1 and 3 (Figs. 10 and 12). In the case of copper, DTPA extractable concentrations account for 11-12% of the total concentrations, much lower proportions are found for the other three elements (Table 9). Mn_D and Zn_D values decrease down most profiles whereas at all four sites Fe_D concentrations tend to increase with depth.

IV.1.1.2 Lacustrine Silt Catenas (Figs. 15 to 19)

pH increases from the moderately acidic surface horizons towards the calcareous parent material and pH values as high as 9.0 are encountered in Cca horizon. Organic matter content of surface horizons can increase substantially down catenas with maximum values up to 6.3% in the vicinity of the break in slope.

Total and DTPA elemental concentrations in the surface horizons tend to be highest at the base of catenas with DTPA extractable concentrations showing a proportionally greater range than total contents. This is especially marked for Fe_T and Fe_D (Figs. 17, 19) and least obvious for Cu_T and Cu_D concentrations (Fig. 18). DTPA, and to a lesser extent total iron, manganese and zinc show a general decrease in concentration from the surface down to the C horizon.

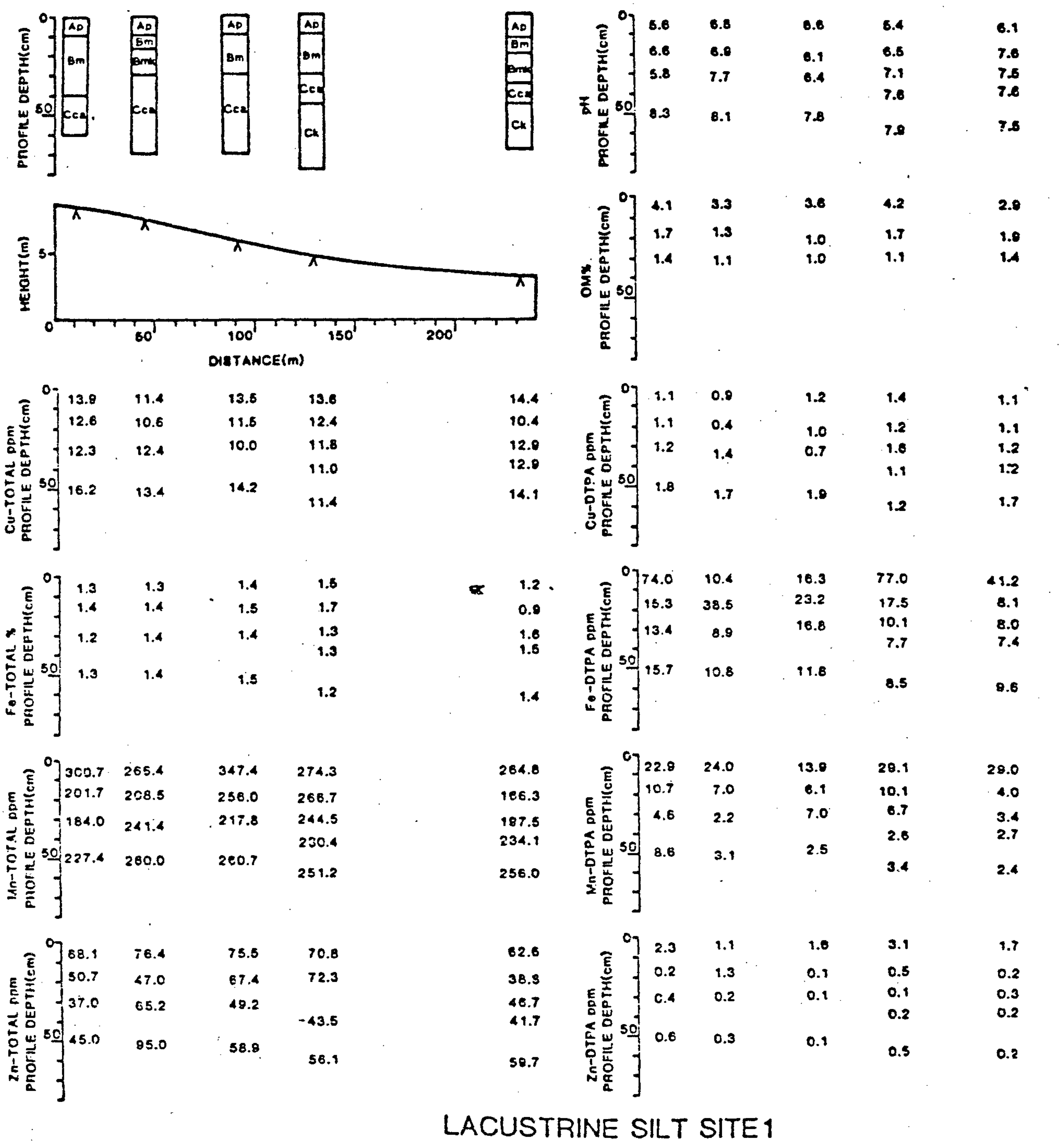
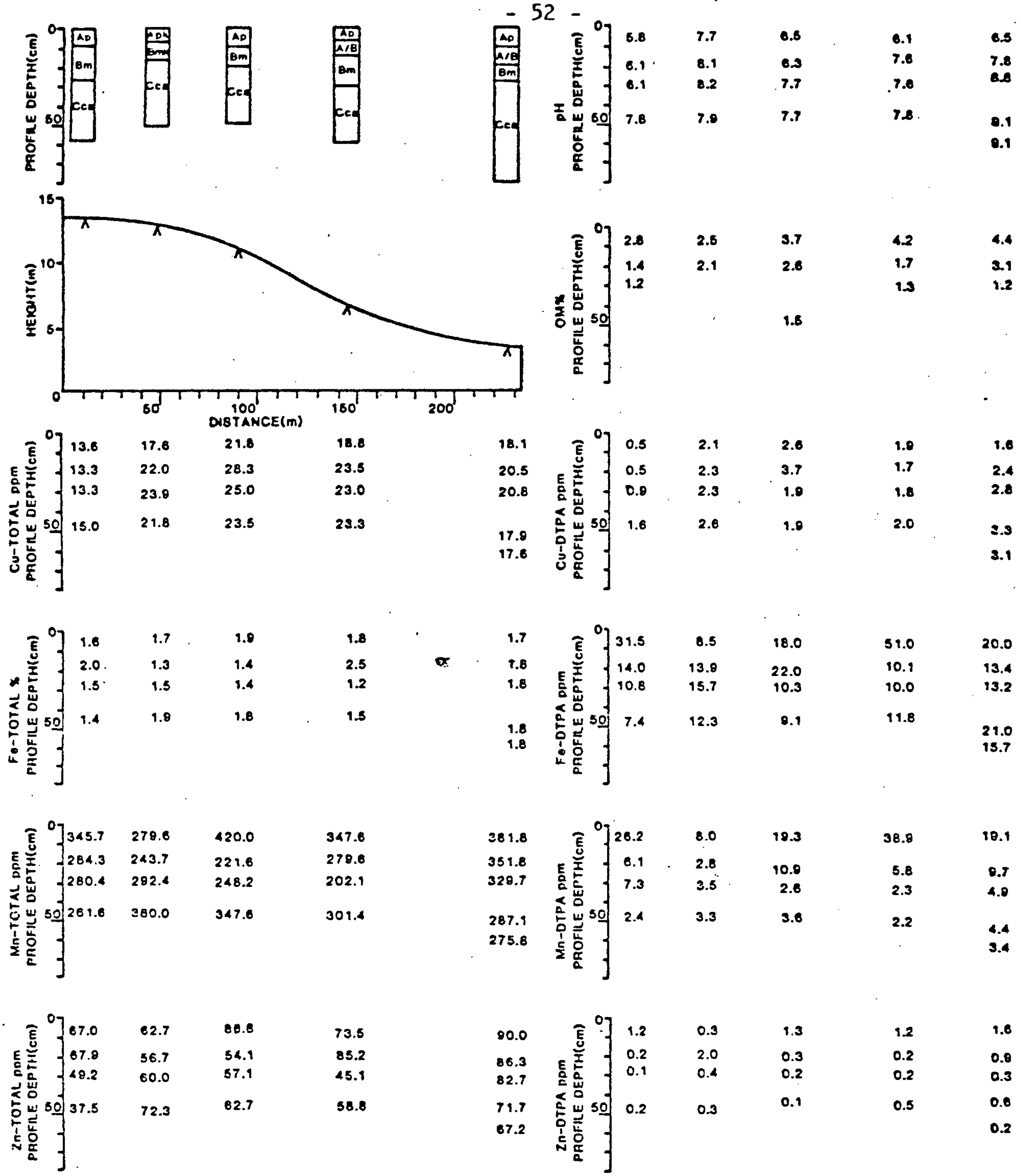


FIGURE 15 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Lacustrine Silt Soils - Site 1



LACUSTR1NE SILT SITE2

FIGURE 16 Total and DTPA Elemental Data, pH and Organic Matter content, down Catena for Lacustrine Silt Soils - Site 2

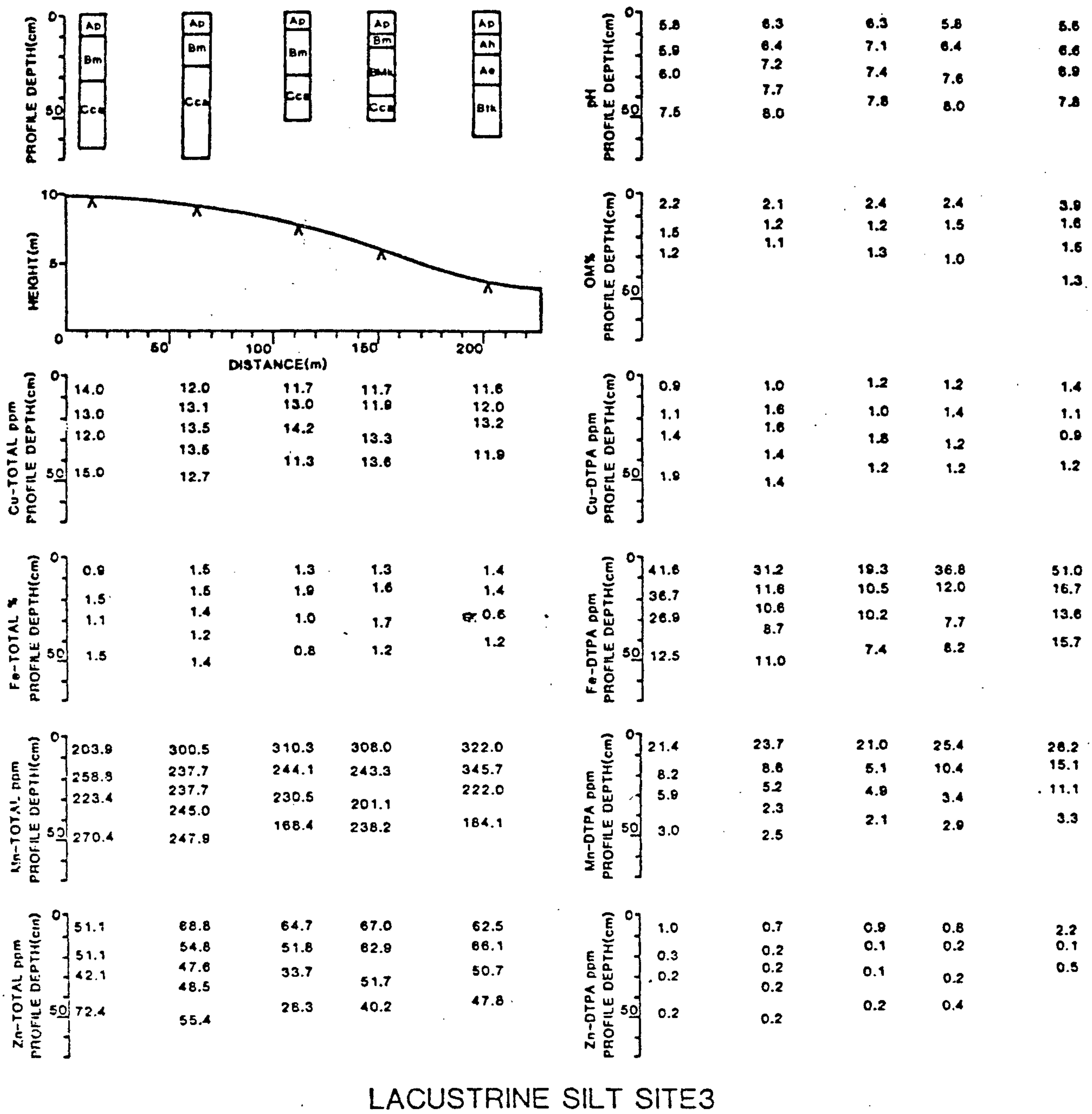


FIGURE 17 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena for Lacustrine Silt Soils - Site 3

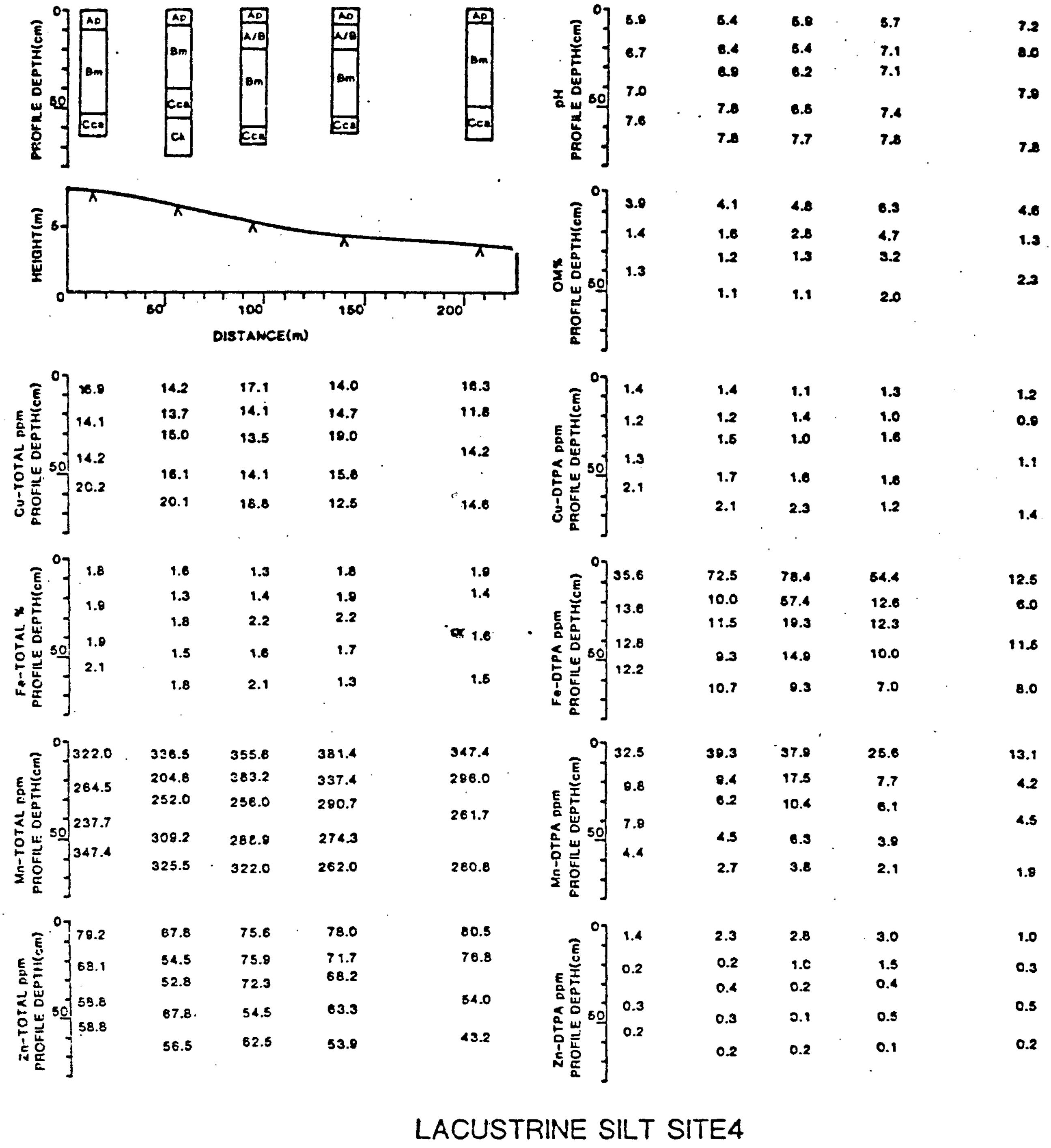
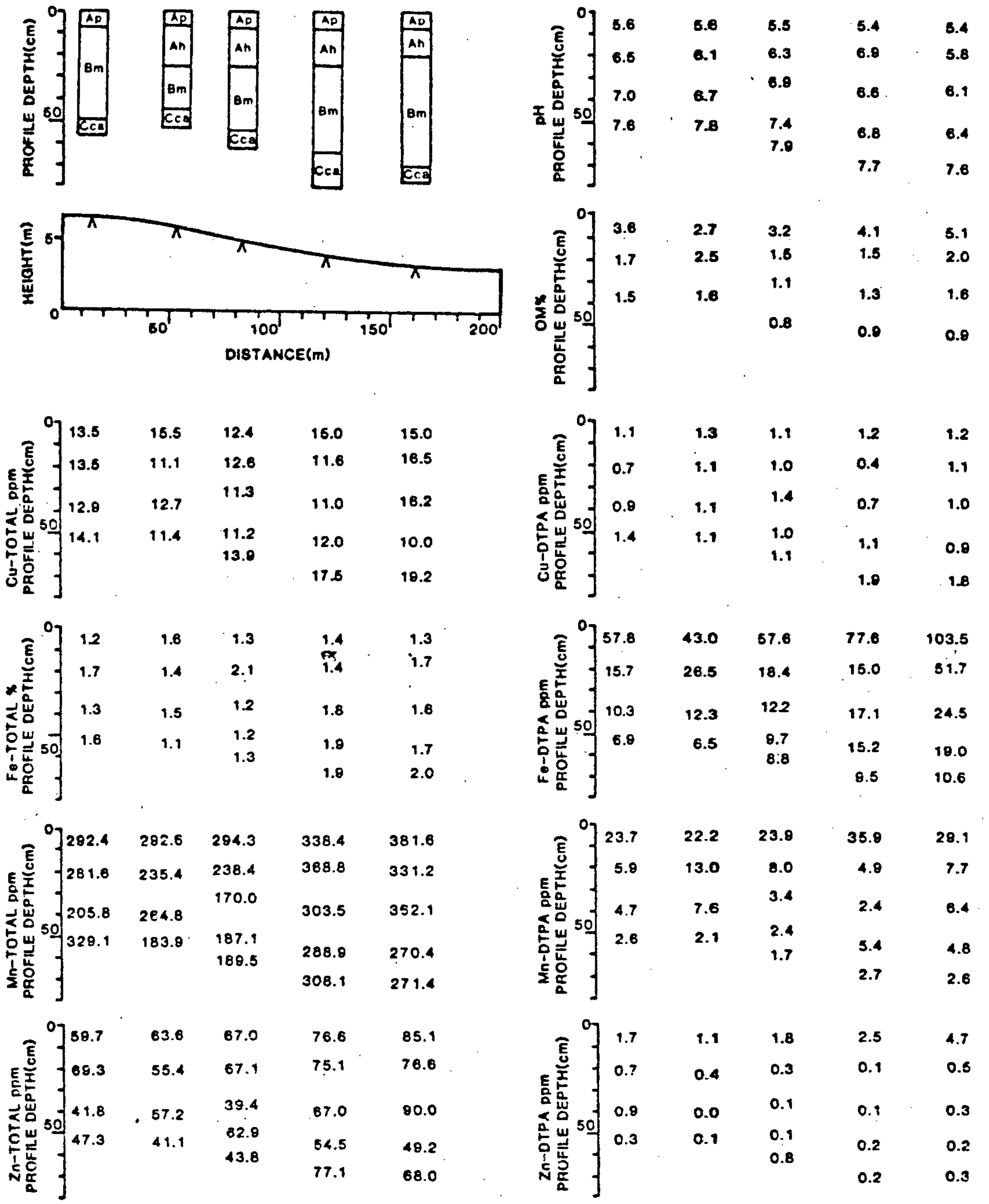


FIGURE 18 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena for Lacustrine Silt Soils - Site 4



LACUSTRINE SILT SITE5

FIGURE 19   Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena for Lacustrine Silt Soils - Site 5

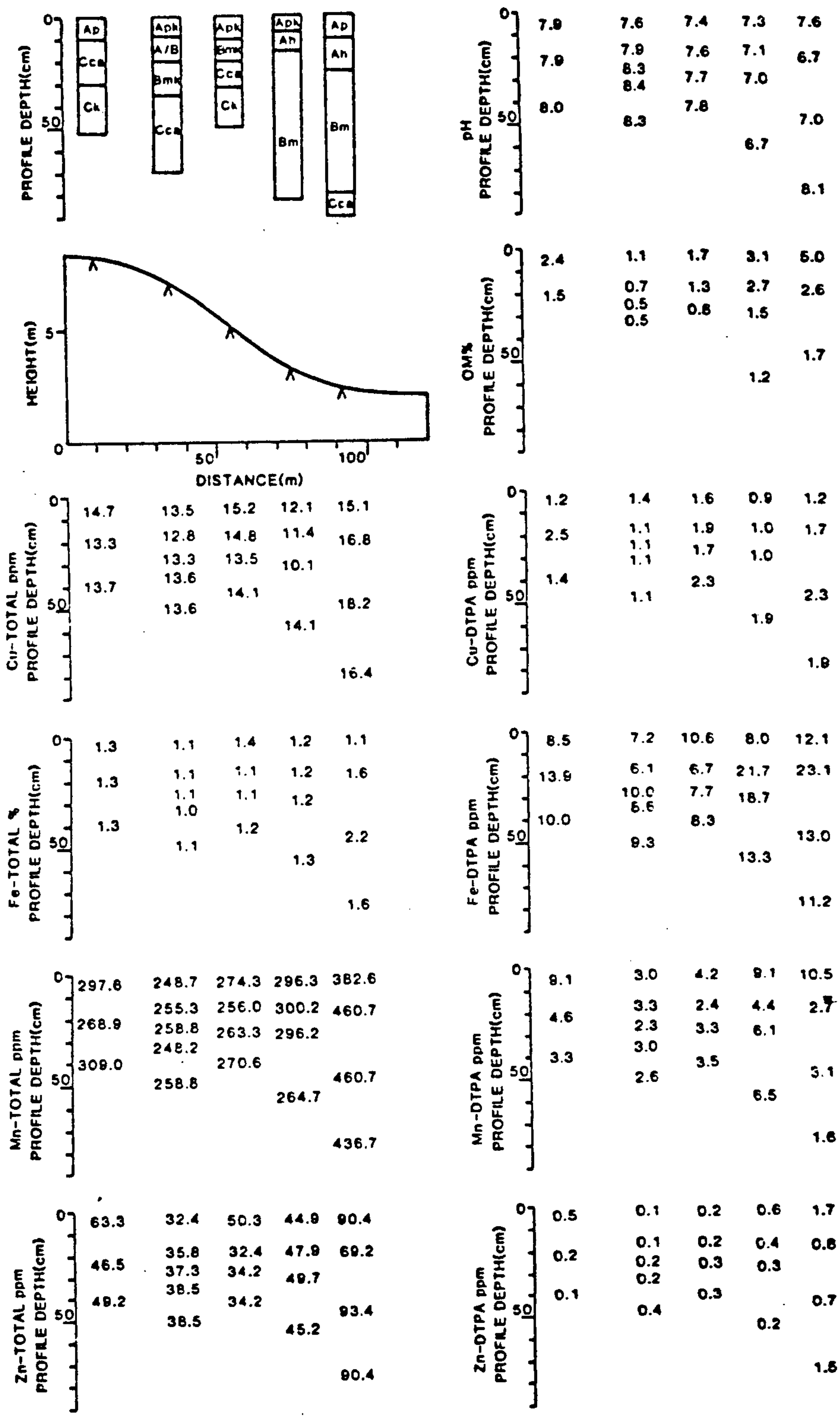
However, especially for Fe_T, this is often preceded by a slight increase in concentrations immediately below the plough layer.

DTPA extracted manganese concentration in the Ap horizon accounts for 8% of the total manganese content. This decreases to 1% in the C horizon (Table 9). The proportion of ZnD/Zn_T shows a similar decrease from 2% to 0.4% whereas Cu_D/Cu_T and Fe_D/Fe_T remain essentially constant at approximately 10% and 0.1% respectively.

IV.1.1.3 <u>Glacial Till Catenas</u> (Figs. 20 to 24)

pH generally increases with depth from the weakly acidic to weakly alkaline surface, to the calcareous C horizon. However, several pits at the base of the catenas show a decrease of pH immediately below the Ap horizon (Figs. 20, 21). Organic matter content increases downslope for all catenas with values up to 6% in depressional sites, compared to 2-3% on the crests.

Although there are exceptions, highest surface concentrations of all four elements tend to be found at the base of the catenas. At site 5 and to a lesser extent site 4 (Figs. 24, 23) this trend is present throughout the profile. Similarly, Cu_D, Fe_D, Mn_D and Zn_D also manifest relatively high surface concentrations in the depressional sites. This is especially true of Fe_D which shows a twenty fold increase in concentration from the ridge crest to the base of slope. Fe_D also increases down catena at each of the other sites as does Mn_D. (Figs 21, 24). The only consistent trend for total elemental



GLACIAL TILL SITE 1

FIGURE 20 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena for Glacial Till Soils - Site 1

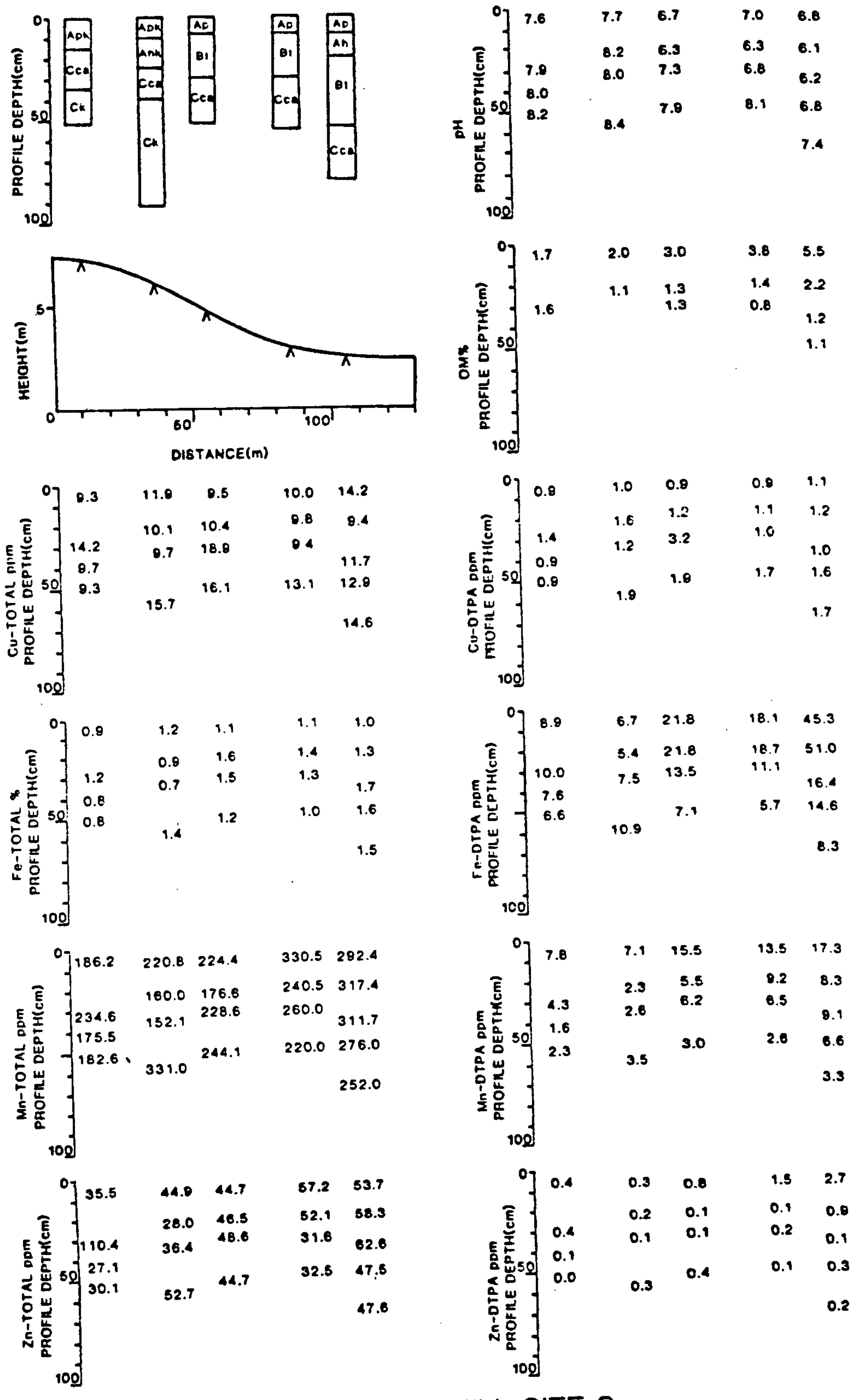


FIGURE 21 TOTAL AND DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Glacial Till Soils - Site 2

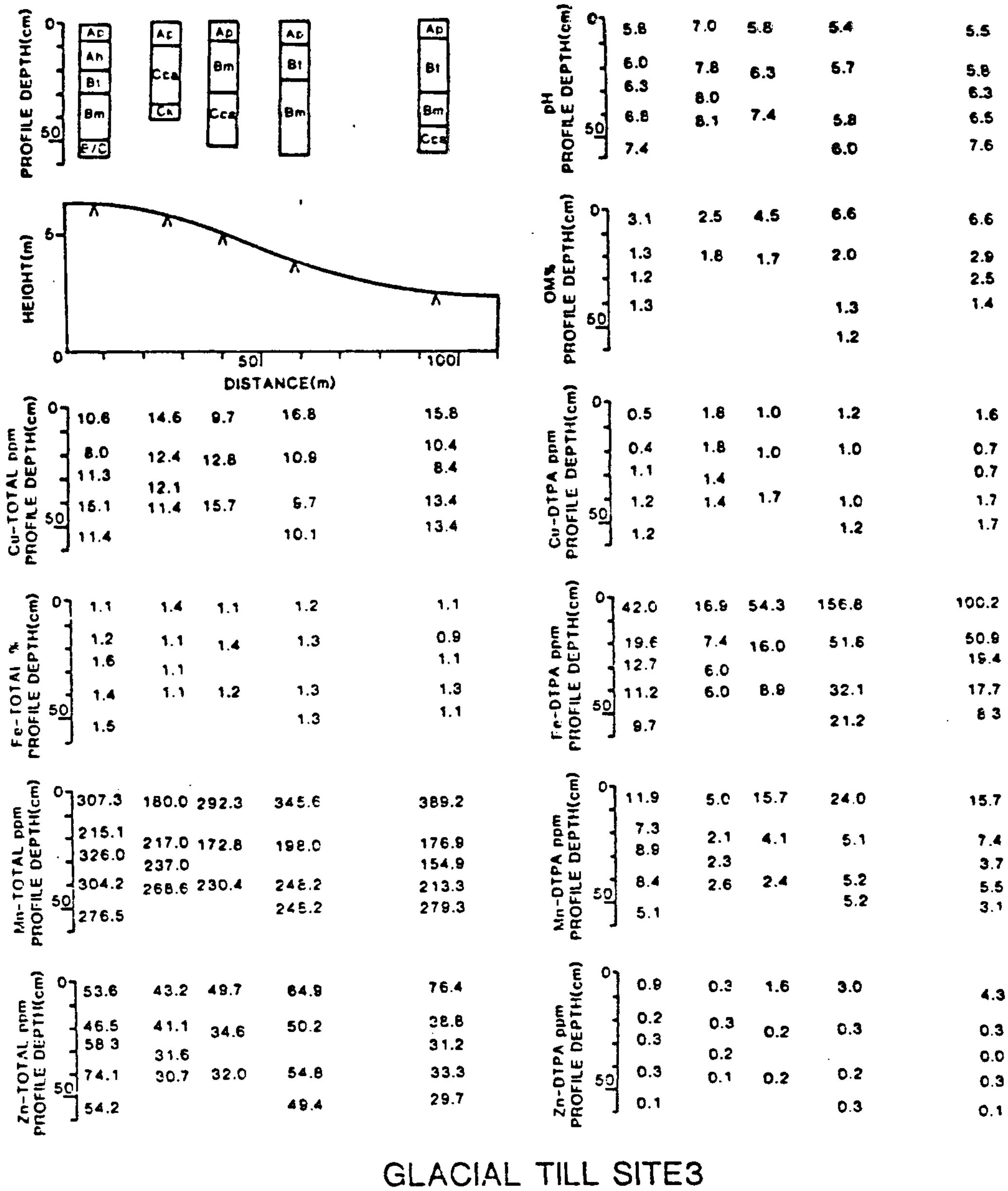


FIGURE 22 Total and DTPA Elemental Data, pH and Organic Matter content, down Catena, for Glacial Till Soils - Site 3

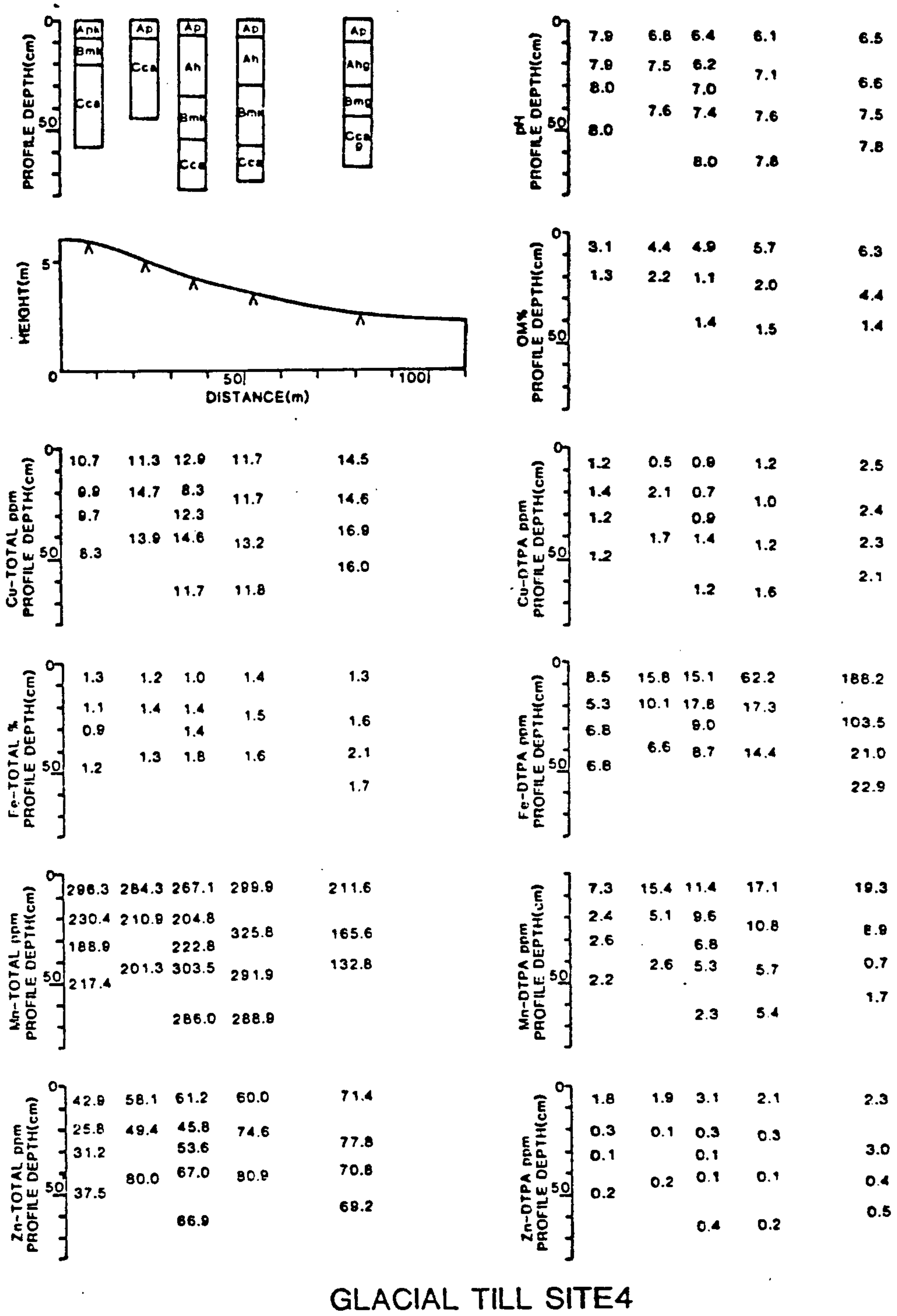


FIGURE 23 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Glacial Till Soils - Site 4

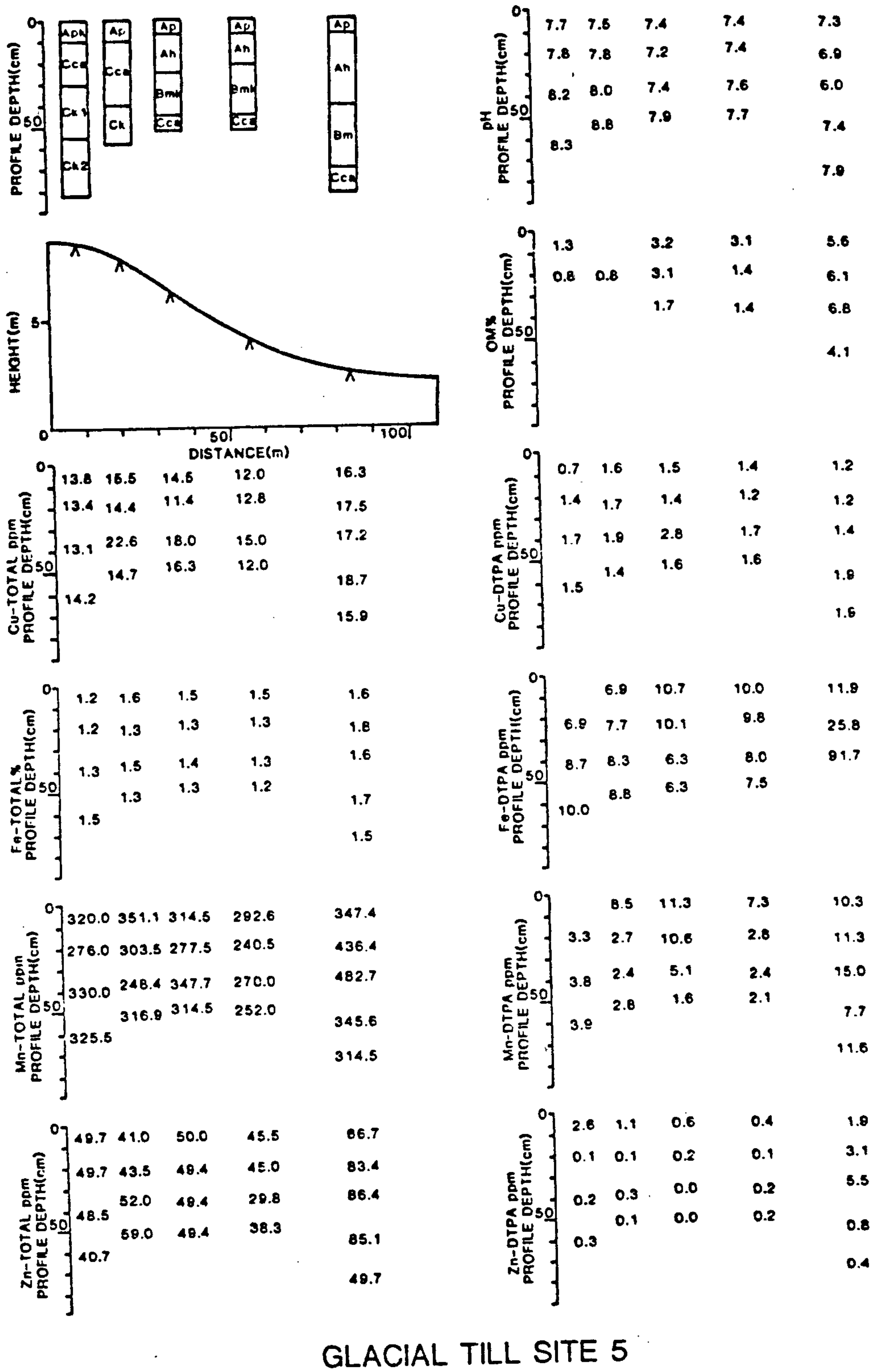


FIGURE 24 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Glacial Till Soils - Site 5

concentrations is for Zn_T values which generally decrease with depth down profile. This decrease is most apparent for the profile at the base of slope, of site 3, with 76 ppm and 29 ppm for the A and C horizons respectively (Fig. 22).

Copper DTPA concentrations account for 11-12% of total soil copper, and iron DTPA for 0.1% of total soil iron. The proportion Zn_D/Zn_T is 5% in the surface horizons decreasing to 0.4% in the C horizon (Table 9).

IV.1.1.4 Aeolian Sand Catenas (Figs. 25 to 29)

pH increases with depth to parent material but unlike those on other parent materials, soils are generally weakly acidic to neutral. Organic matter content of surface horizons generally increases from the crest to the base of the catena.

The majority of catenas reveal increasing surface values for all four elements, extracted with $HNO_3/HClO_4$, downslope, this is especially pronounced at site 2 (Fig. 26). Fe_D, Mn_D and Zn_D also tend to increase downslope (Figs. 27, 28, 29).

Cu_T and Zn_T values generally decrease with depth down profiles whereas total iron content is fairly consistent occasionally revealing a slight decrease with depth (Fig. 26). Total manganese values, however, show an increase just below the plough layer and then decrease with depth. This is especially pronounced for pits at the base of slope (Fig. 26).

Most pits show a decrease in concentrations of Fe_D, Mn_D and Zn_D

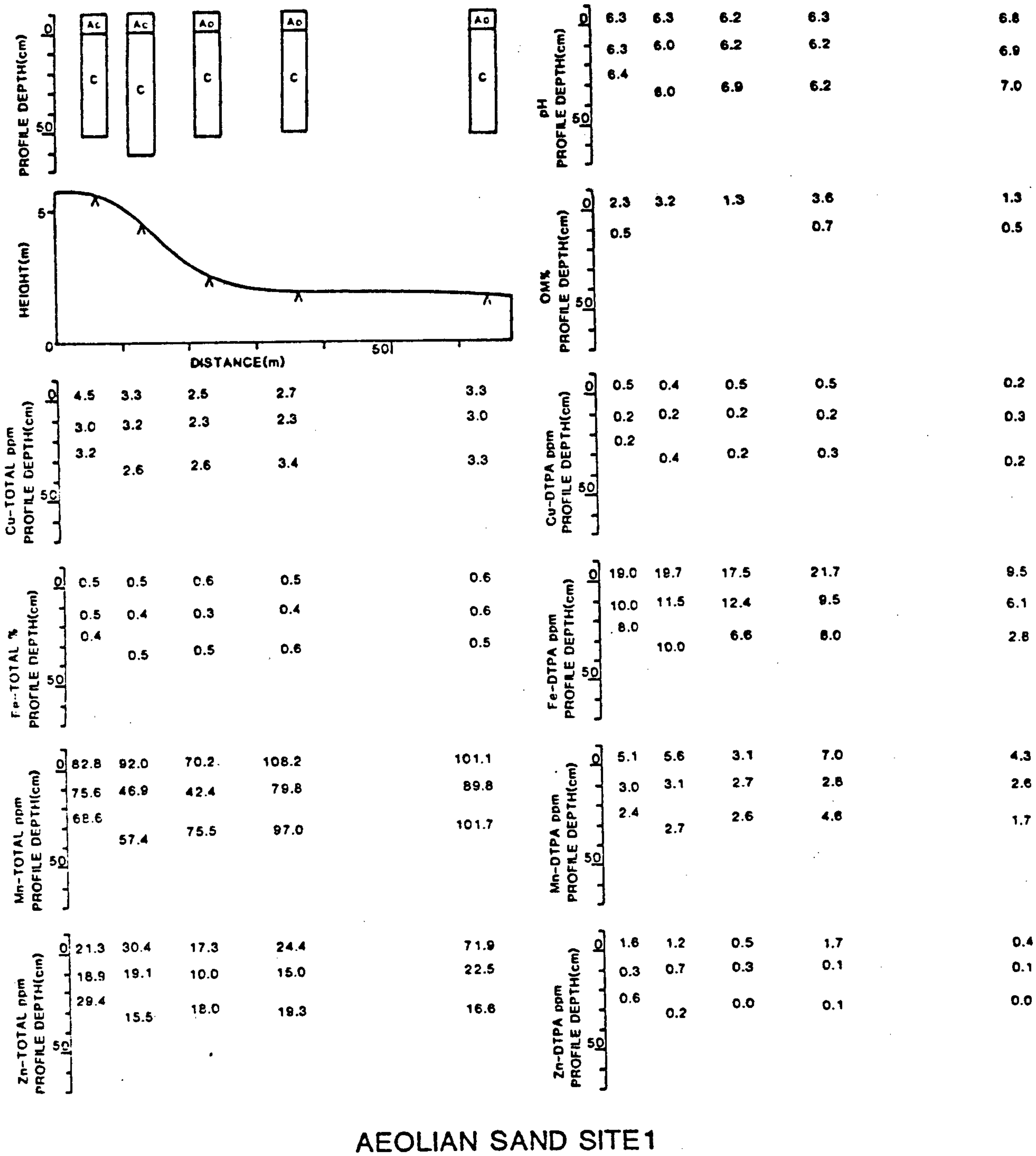
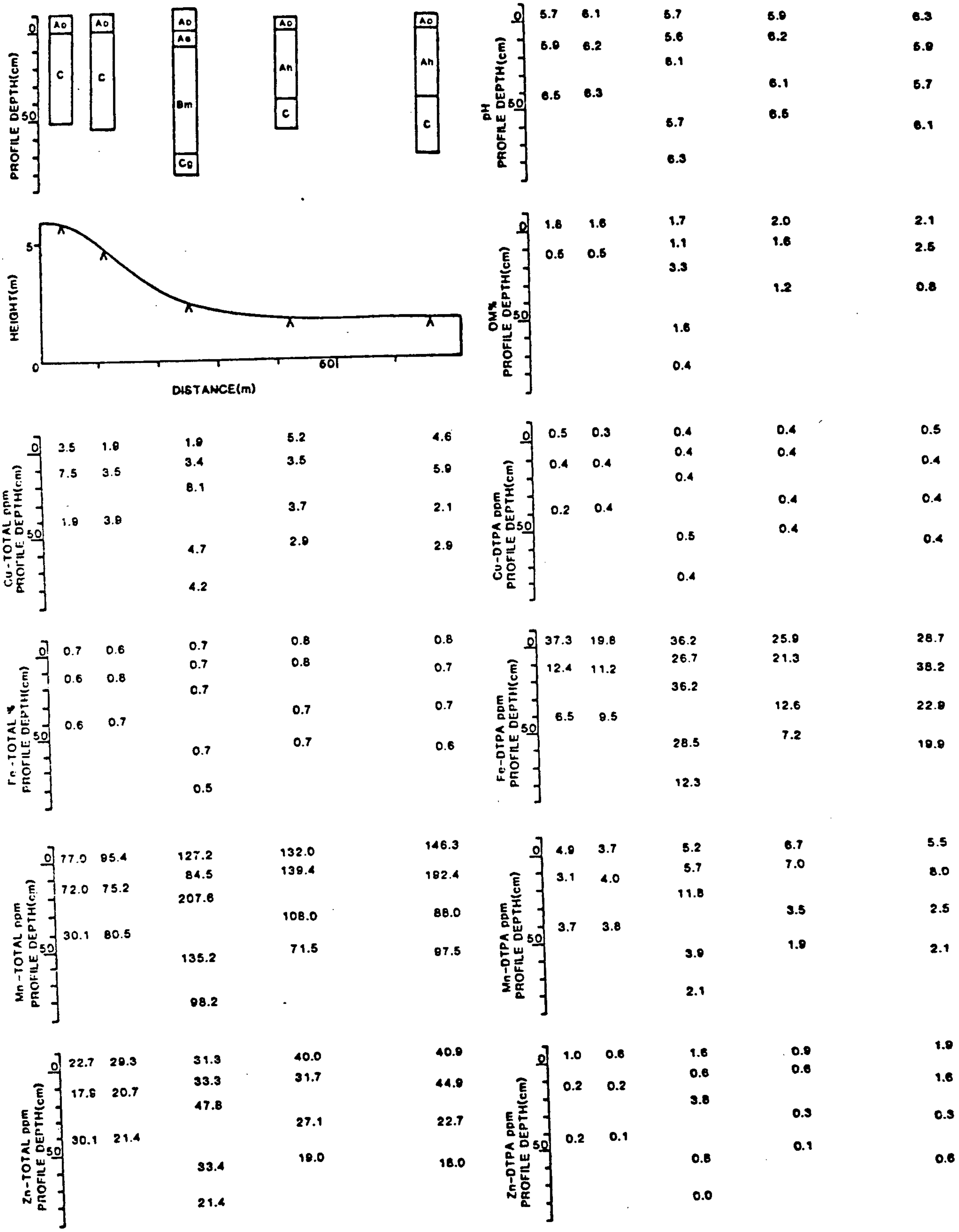
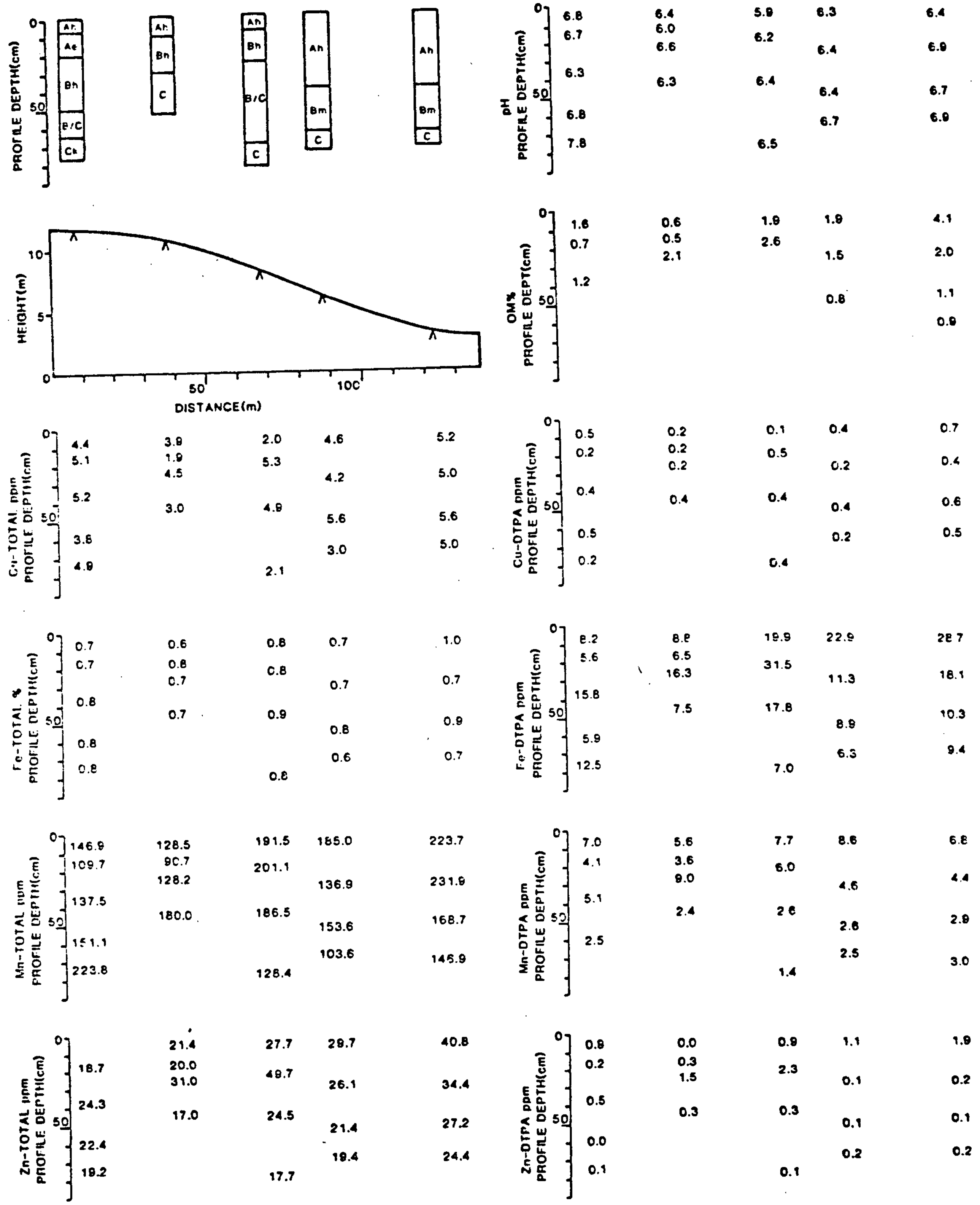


FIGURE 25 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Aeolian Sand Soils - Site 1



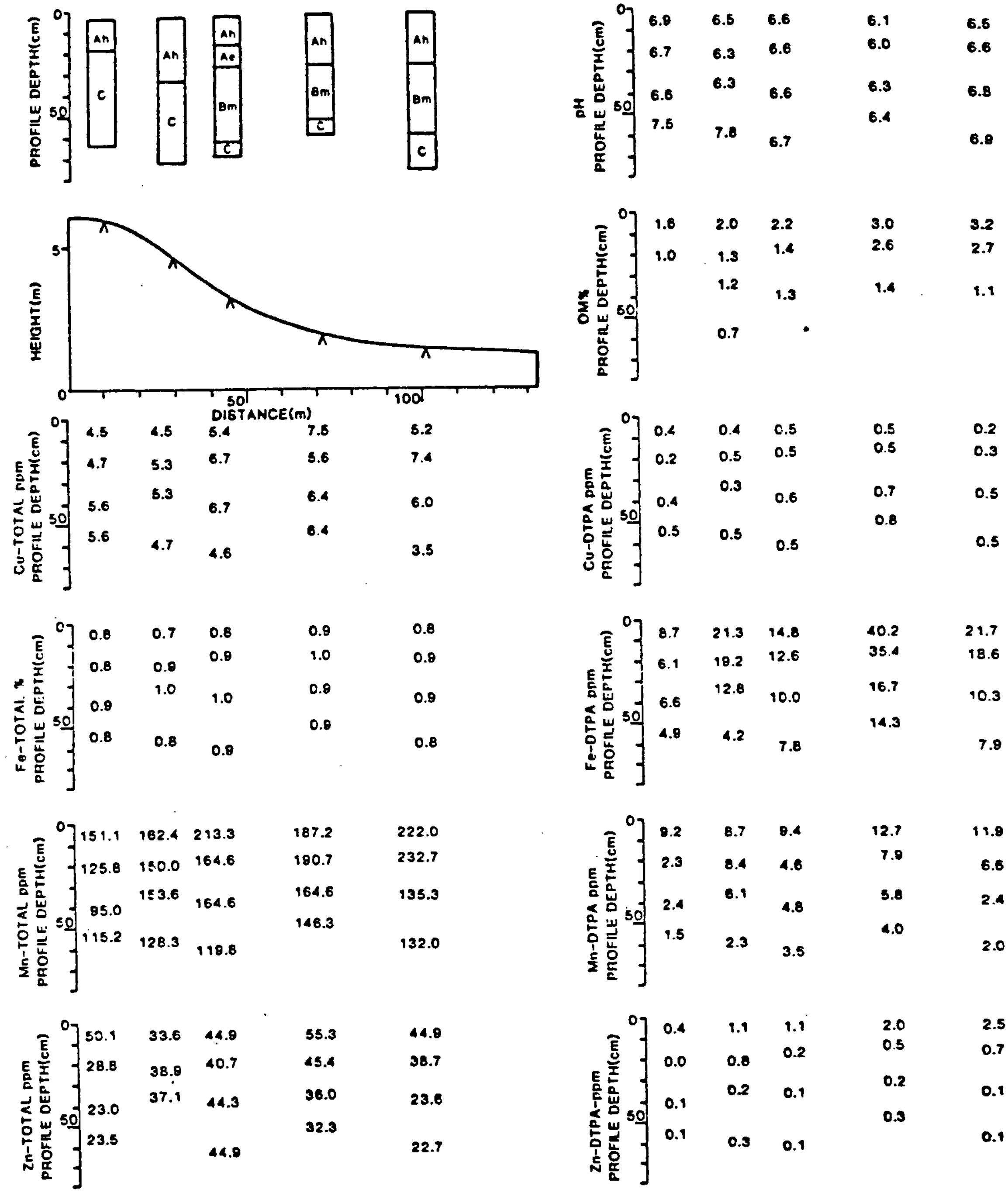
AEOLIAN SAND SITE 2

FIGURE 26 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Aeolian Sand Soils - Site 2



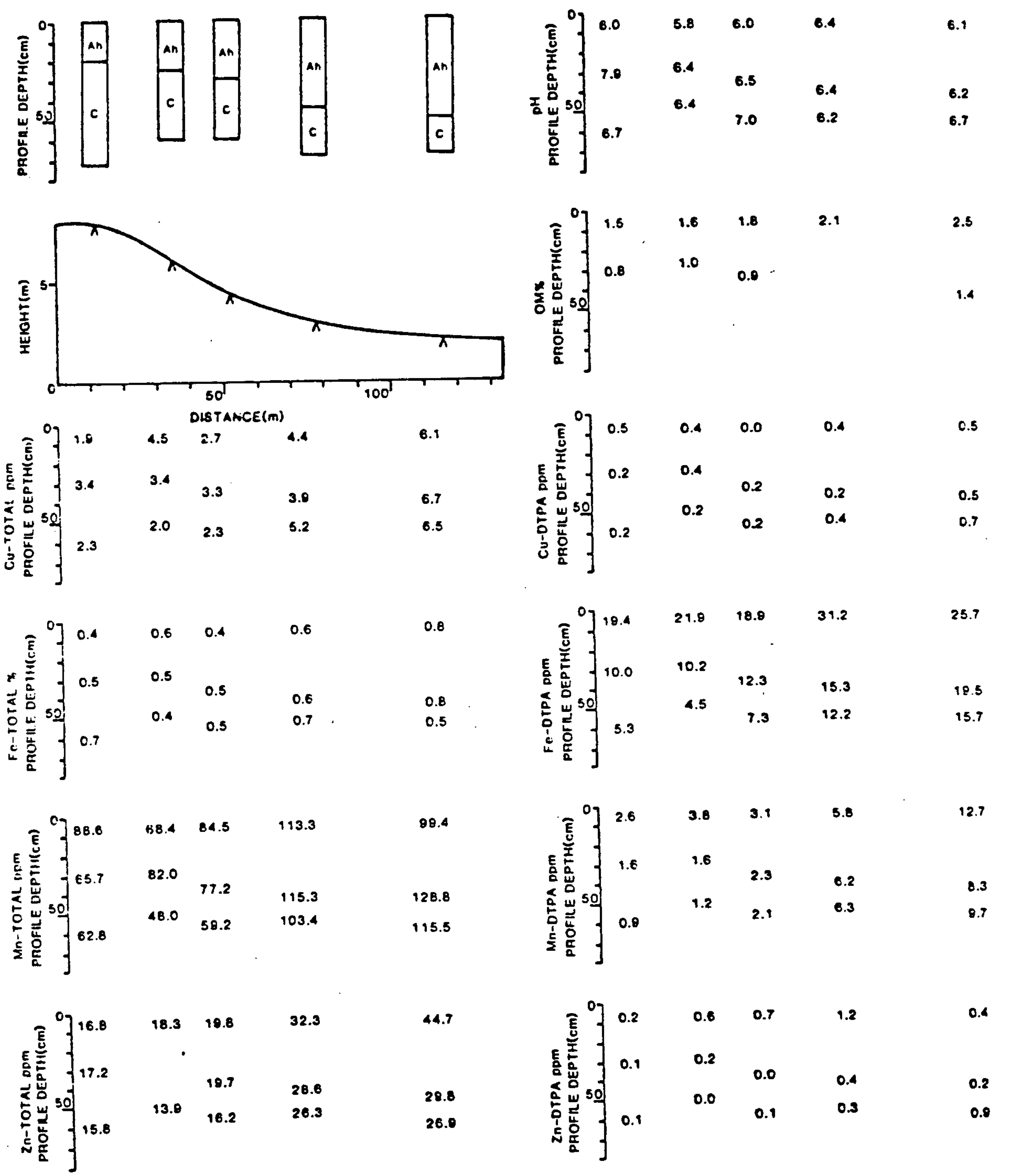
AEOLIAN SAND SITE3

FIGURE 27 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Aeolian Sand Soils - Site 3



AEOLIAN SAND SITE4

FIGURE 28 Total and DTPA Elemental Data pH and Organic Matter Content, down Datena, for Aeolian Sand Soils - Site 4



AEOLIAN SAND SITE5

FIGURE 29 Total and DTPA Elemental Data, pH and Organic Matter Content, down Catena, for Aeolian Sand Soils - Site 5

down profile. Proportions of Cu_D/Cu_T range from 8-11% whereas other DTPA elemental concentrations account for a lower proportion of the total content. The proportion of Zn_D/Zn_T is greater in the surface horizon (6%) than in the C horizon (0.9%).

IV.1.1.5 Summary

Organic matter increases down the catena for most sites whereas pH decreases. This is especially pronounced in glacial till and lacustrine silt soils.

For 18 sites, the highest total and DTPA elemental concentrations occur at the base of the slope. This being most marked for lacustrine silt soils. Total elemental concentrations for the four parent materials exhibit a relatively greater uniformity when considering both trends downslope and down profile than DTPA concentrations. A much greater proportion of DTPA extractable Mn and Zn occurs in the organic rich surface horizons compared to the more alkaline C horizons. This is also found for copper and iron but to a lesser extent (Table 9). An enrichment of Mn_D and Fe_D is seen in the Bm and/or Bt horizon for lacustrine silt and glacial till soils, with a subsequent decrease in values at greater depths.

IV.1.2 Sequential Extraction

Samples analysed are listed in Table 4.

IV.1.2.1 Lacustrine Clay Catena (Table 10)

Copper extracted with 5% HCl amounts to approximately half of

Table 10 - Arithmetic Means and Ranges for Cu, Fe, Mn and Zn Extracted Sequentially from Lacustrine Clay Soils (A and C Horizons)

A Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. Of Samples
Cu ppm	10.4 (8.1-11.4)	17 (13.1-19.1)	-	8.2 (7.3-9.1)	5
Fe ppm	241.4 (192.5-288.7)	354.7 (275.9-433.5)	3165 (2796-3573)	2.1% (1.6-2.5%)	5
Mn ppm	11.5 (7.2-15.7)	95.6 (32.5-149.1)	182.5 (152.5-206.1)	70.9 (63.4-81.5)	5
Zn ppm	-	7.1 (6.8-7.6)	14.2 (13.9-14.9)	61.5 (57.5-65.0)	5

C Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. Of Samples
Cu ppm	8.0 (6.2-10.8)	16.3 (11.7-31.0)	-	6.7 (5.0-8.0)	9
Fe ppm	151.7 (111.2-256.7)	468.5 (275.9-433.5)	4294 (2718-7378)	2.2% (1.6-3.9%)	9
Mn ppm	10.0 (5.7-13.1)	28.1 (21.7-65.4)	179.0 (107.0-224.9)	77.0 (41.2-105.2)	9
Zn ppm	-	6.5 (4.1-9.0)	15.2 (9.6-26.1)	50.6 (32.6-66.2)	9

total soil copper, lower proportions are found for Cu_O, Cu_R, the lowest being for Cu_A. However, more than 85% of the iron and 74% of the zinc requires a strong extraction ($HNO_3/HClO_4$) for its release. Most of the remaining iron and zinc is associated with the free iron oxides released by ammonium oxalate. Highest manganese concentrations, 56% of total soil manganese, are liberated when extracted with ammonium oxalate, the lowest proportion (4%) is given by Mn_O.

Iron extracted with 5% HCl increases by 25% from the A to the C horizon, however Mn_C shows a corresponding decrease of 70%. Fe_C also shows a two fold increase downslope from crest to base and there is a marked decrease in the amount of iron associated with organic matter, with depth down profile.

IV.1.2.2 Lacustrine Silt Catena (Table 11)

Maximum extraction for copper occurs with Cu_C, (just less than half of total soil copper) followed by Cu_O and CU_R. CU_A concentrations fell below the detection level. Highest values for iron and zinc are associated with the $HNO_3/HClO_4$ digestion with approximately 81% and 63% of the total contents being extracted, respectively. The bulk of the remaining iron and zinc is contained in the free iron oxide fraction with the lowest concentrations in the organic matter fraction. Approximately 63% of total soil manganese is associated with the amorphous iron oxides. Lowest manganese concentrations are found in the organic matter fraction.

Table 11 - Arithmetic Means and Ranges for Cu, Fe, Mn and Zn Extracted Sequentially from Lacusticine Silt Soils (A, B and C Horizons).

A Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	6.4 (5.6-8.6)	11.1 (7.1-13.4)	-	6.5 (4.8-8.3)	7
Fe ppm	120.5 (105.4-233.0)	291.2 (230.8-354.7)	2676 (2220-3106)	1.5% (1.0-1.8%)	7
Mn ppm	13.2 (11.5-15.7)	38.6 (13.9-90.8)	209.4 (173.2-267.6)	49.7 (39.5-58.0)	7
Zn ppm	-	7.7 (4.3-12.2)	11.5 (9.9-15.8)	43.7 (30.6-61.3)	7
B Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	7.7 (6.1-10.7)	8.9 (4.3-14.1)	-	5.5 (3.3-7.3)	9
Fe ppm	199.8 (99.5-233.0)	340.7 (236.5-394.1)	3072 (2641-3573)	1.5% (0.7-2.0%)	9
Mn ppm	10.2 (6.8-13.1)	11.5 (7.0-14.8)	170.7 (123.7-236.4)	42.9 (32.5-52.9)	9
Zn ppm	-	11.5 (4.3-7.2)	11.4 (9.1-17.3)	30.8 (17.3-62.4)	9
C Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	6.8 (5.6-8.4)	11.9 (7.1-16.8)	-	4.6 (3.2-6.6)	5
Fe ppm	141.3 (93.7-203.9)	434.4 (346.2-576.9)	2499 (2297-7656)	1.4% (1.0-1.7%)	5
Mn ppm	-	27.2 (15.4-39.1)	135.2 (95.7-183.1)	64.9 (45.7-77.9)	5
Zn ppm	-	5.0 (4.3-5.8)	13.9 (9.9-19.7)	24.6 (21.8-28.4)	5

Iron associated with organic matter increases by up to 40% from the Ap to the Bm horizons, a decrease of 30% then occurs from the Bm to the Cca horizons. Iron extracted with 5% HCl increased by one third with depth down profile to the Cca horizon. In contrast, Mn_C decreasd by 70% from the Ap to the Bm horizon and increased by just over a half from the Bm to the Cca horizon. An increase of 13% occurs from the Ap to the Bm horizons for Fe_A with a decrease of 19% from the Cca horizons.

In the surface horizon, Cu_C, Mn_C and Zn_C show marked decreases down catena of 47%, 59%, and 37% respectively whereas Cu_R, Fe_R and Zn_R exhibited increases down slope of between 30-40%.

IV.1.2.3 Glacial Till Catena (Table 12)

Highest copper concentrations are found for the sodium hypochlorite and 5% HCl extractions amounting to 46% and 32%, respectively, of total soil copper. Iron and zinc extracted with $HNO_3/HClO_4$ exhibit the highest concentrations with successivley lower concentrations in the free iron oxide, carbonate and organic fractions. Zn_O concentrations are below the detection level. High manganese concentrations, 67% of the total, are associated with the free iron oxides.

In surface horizons copper and iron content associated with the organic matter fraction increases downslope by 36% and 27%, respectively. Copper extracted with 5% HCl shows a two fold increase from surface horizon to Cca horizon whereas Mn_C shows a two fold decrease. However, Cu_C, Mn_C and Zn_C all exhibit marked increases, of 60%, 80% and 48% respectively, in the plough layer downslope. Manganese associated with the free iron oxides decreases by 26%, with depth down profile, whereas Mn_R shows an increase of 23%. A 36% decrease occurs for zinc digested with HNO_3 /$HClO_4$ with depth down profile.

IV.1.2.4 Aeolian Sand Catena (Table 13)

Copper concentrations are highest in the organic matter fraction taking up to 46% of total soil copper, copper extracted with 5% HCl accounts for 39% of the total contents and the lowest values are found for Cu_A. Maximum iron and zinc concentrations are again given by the HNO_3 / $HClO_4$ digestion followed by Fe_A, Zn_A, Fe_C, Zn_C and Fe_O in that order. Zn_O concentrations are below the detection level. Manganese associated with the amorphous iron oxide fraction exhibits the highest concentrations amounting to 67% of total soil manganese.

Iron associated with organic matter exhibits a 23% decrease down profile. Manganese extracted with ammonium oxalate shows a 23% decrease with depth from the Ah to the Cca horizon, and both Mn_A and Zn_A increase two fold downslope in the surface horizons. Mn_C and Zn_C also show a marked increase in the surface horizons downslope. Zinc liberated with HNO_3/$HClO_4$ decreases by 35% down profile but shows a two fold increase in the surface horizon from the crest to the base of the slope.

Table 12 - Arithmetic Means and Ranges for Cu, Fe, Mn and Zn Extracted Sequentially from Glacial Till Soils. (A and C Horizons).

A Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	10.9 (8.6-13.3)	7.6 (3.5-10.6)	-	5.1 (4.0-6.5)	5
Fe ppm	193.2 (105.4-288.8)	289.4 (192.3-354.7)	2223 (1942-2373)	1.5% (1.2-1.7%)	5
Mn ppm	8.4 (7.3-13.1)	55.3 (20.9-105.3)	165.3 (126.3-208.2)	35.9 (26.1-39.0)	5
Zn ppm	-	6.0 (4.1-8.1)	9.6 (8.1-13.7)	30.3 (24.2-36.8)	5
C Horizon	**NaOCl**	**HCl**	**NH_4Ox**	**HNO_3 / $HClO_4$**	**No. of Samples**
Cu ppm	9.8 (8.6-10.1)	14.7 (10.6-21.4)	-	3.9 (3.3-4.4)	6
Fe ppm	200.6 (64.4-288.8)	303.5 (12.2-27.1)	2239 (956.9-3029)	1.2% (0.6-1.8%)	6
Mn ppm	7.8 (5.7-9.8)	21.8 (12.2-27.1)	122.3 (77.7-182.1)	46.7 (26.4-56.2)	6
Zn ppm	-	5.2 (3.7-5.9)	7.2 (5.1-9.5)	19.3 (8.2-29.4)	6

Table 13 - Arithmetic Means and Ranges for Cu, Fe, Mn and Zn Extracted Sequentially from Aeolian Sand Soils. (A and C Horizons)

A Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	8.3 (5.7-11.1)	6.2 (2.8-11.3)	-	2.2 (1.8-2.9)	7
Fe ppm	169.6 (99.5-288.8)	245.3 (192.3-275.9)	1896 (1631-2097)	7796 (5572-8936)	7
Mn ppm	7.5 (4.2-9.5)	14.6 (3.5-41.9)	123.4 (68.2-200.4)	31.0 (26.8-35.5)	7
Zn ppm	-	5.5 (2.2-6.8)	6.5 (3.3-9.9)	13.9 (9.2-18.7)	7
C Horizon	NaOCl	HCl	NH_4Ox	HNO_3 / $HClO_4$	No. of Samples
Cu ppm	6.2 (5.0-6.7)	5.9 (3.5-8.6)	-	2.5 (2.2-3.9)	6
Fe ppm	131.3 (99.5-174.8)	233.1 (153.9-307.7)	1795 (1455-2097)	6982 (4172-9154)	6
Mn ppm	7.7 (5.2-7.8)	12.1 (7.0-22.2)	94.7 (60.6-124.8)	32.0 (22.8-49.7)	6
Zn ppm	-	4.2 (3.1-5.0)	5.1 (2.5-6.5)	9.1 (6.8-10.6)	6

IV.1.2.5 Summary

Generally, elemental concentrations for each extraction procedure are found to be highest in the lacustrine clay soils, lacustrine silt and glacial till show similar values and the aeolian sand soils exhibiting the lowest concentrations.

Copper is strongly associated with both the organic matter and carbonate fractions. Manganese extracted with 5% HCl is concentrated in the surface horizons decreasing markedly to the C horizons, this is especially pronounced for the lacustrine clay soils. However, manganese is most abundant in the amorphous iron oxide fraction. Iron and zinc are principally associated with the more cystalline oxides and silicates. However, iron and zinc extracted with ammonium oxalate show marked trends with high iron concentrations encountered in the lower horizons and high zinc concentrations in the plough layer.

IV.1.3 Particle Size Analysis (Table 14)

Samples analysed are listed in Table 4.
The highest clay content (53%), occurs in lacustrine clay soils, the highest silt content (62%), in lacustrine silt soils and similarly the highest sand content in aeolian sand soils (71%) (Table 15).

From Table 14, it is seen that an increase in the amount of clay and a decrease in the amount of sand occurs for all four parent materials down the catenas. This trend in most pronounced in surface horizons. An increase in silt content is also shown for lacustrine silt soils. Overall, results are more consistent for lacustrine clay, lacustrine silt and glacial till than for aeolian sand soils.

Table 14 - Particle Size Separation for Lacustrine Clay, Lacustrine Silt, Glacial Till and Aeolian Sand Soils

Parent Material	Pit No.	Horizon Type	Clay%	Silt%	Sand%
LC	2	Apk	47	43	10
		Bmk	54	44	2
		Cca	49	50	2
		Ck	36	45	19
LC	5	Ap	57	43	0
		Cca	58	42	0
		Ck	66	34	0
LS	1	Ap	29	56	15
		Bm	30	60	11
		Cca	27	56	17
LS	5	Ap	32	66	2
		Ah	32	67	1
		Bm	36	64	1
		Cca	38	58	4
GT	2	Ap	29	48	23
		Cca	35	39	27
		Ck	33	56	11
GT	4	Ap	29	57	14
		Bt	27	51	22
		Bm	27	41	33
AS	2	Ah	2	6	92
		Bh	0	5	95
		C	4	19	78
AS	5	Ah	8	43	50
		Bm	7	49	44
		C	15	6	79

Table 15 - Mean Values of Percent Clay, Silt and Sand for LC, LS, GT and AS Soils and Their U.S.D.A. Textural Classification

Parent Material	Mean Values % Clay	Silt	Sand	USDA Classification Of Texture
LC	53.0	43.2	3.7	Silty Clay
LS	32.1	61.6	6.3	Silty Clay Loam
GT	29.8	45.5	24.7	Silty Loam
AS	6.4	23.1	70.5	Loamy Sand

U.S.D.A. textural classifications of the soils are given in Table 15.

IV.1.4 X Ray Diffraction

Samples analysed are listed in Table 4.

The prominant clay mineral in the five till samples is illite, accompanied by kaolinite, quartz and feldspars; traces of chlorite, montmorillonite and vermiculite are evident. There is little variation in the clay mineralogy between each horizon although the Bm and C horizons reveal high peak intensities for montmorillonite. The 2-5μ size fraction tend to have greater peak intensities for quartz, amphibole and feldspars than the 0.2-2μ size fraction.

Lacustrine silt soil (Bm horizon) has a high peak intensity for illite and montmorillonite with lower peak intensities for kaolinite, amphibole, the feldspars and quartz; chlorite and vermiculite appear in trace amounts. In lacustrine clay soils, the Cca horizon gives high peak intensities for illite with trace amounts of quartz, the feldspars, chlorite, vermiculite and montmorillonite, both size fractions show the intensity of the plagioclase feldspar peak to be more pronounced than the potassium feldspar peak. This is also the case for the aeolian sand soil (Ap horizon) with illite again being the main mineral.

IV.2 Statistical Test Results

Analysis of Variance, Duncan's New Multiple Range Test, Correlation and Regression analysis were computed for total and DTPA elemental data, pH and organic matter. All data was $\log_{10}$ transformed. (pH was not transformed for the Analysis of Variance and Duncan's New Multiple Range test).

IV.2.1 Analysis of Variance (Table 16)

pH has a high component for among compared to within parent material variance for all horizons. Organic matter shows similar percentages for the surface horizons. The compositional variation among the parent materials accounts for 74-98% of the total data variability for Cu, Fe and Mn in soil digested with $HNO_3/HClO_4$, horizon C data revealing the highest percentages.

DTPA elemental data show a compositional variation between parent materials of 52-97%, the highest percentages occurring in the surface horizons. Variables not included in the table are not significant at the 0.05 level. This is more frequent in the C horizon.

IV.2.2 Duncan's New Multiple Range Test (Tables 17 to 19)

Glacial till and lacustrine silt data exhibit similar mean values and therefore tend to be grouped together, this is especially so for the total elemental data. Zn_T did not show significant differences between mean concentrations for the four parent materials (at the 0.05 level), in any horizon.

The mean elemental concentrations for the DTPA extractions give varied groupings. However, glacial till and lacustrine silt soils are generally found within the same group. The more developed lacustrine silt soils exhibit the highest mean concentrations for surface horizons, whereas the lacustrine clay soils reveal the highest mean concentrations for C horizons. A far greater number of variables show significant differences between the mean concentrations for the four

Table 16 - Comparison of Logarithmic Within and Among Sample Site Variance Components for A Horizon, 0-30 cm Depth and C Horizon Soil (Significant at P = 0.05).

Soil	Variables	Estimated Total Log_{10} Variance	Partitioned Variance: Among Parent Material Component	Among Parent Material % of Total	Within Parent Material Component	Within Parent Material % of Total
A Horizon	*pH	0.3644	0.2664	73	0.0980	27
	Cu_T	0.1544	0.1144	74	0.0400	26
	Fe_T	0.0188	0.0158	84	0.0300	16
	Mn_T	0.040	0.0350	88	0.0500	12
	Mn_D	0.0592	0.0572	97	0.0020	3
	Zn_D	0.040	0.021	52	0.0190	48
	OM	0.0168	0.0128	76	0.0040	24
0-30 cm.	*pH	0.4881	0.4171	85	0.0710	15
	Fe_T	0.0508	0.0472	93	0.0036	7
	Mn_T	0.0367	0.0317	86	0.0050	14
	Fe_D	0.0424	0.0284	67	0.0140	33
	Mn_D	0.0653	0.0573	88	0.0080	12
	OM	0.0109	0.0088	81	0.0021	19
C Horizon	*pH	0.3047	0.2984	98	0.0063	2
	Cu_T	0.1365	0.1340	98	0.0025	2
	Fe_T	0.0626	0.0580	93	0.0046	7
	Mn_T	0.0625	0.0623	99	0.0002	1

* Estimated Total Variance

Table 17 - Results of Application of Duncan's New Multiple Range Test to Log_{10}, A Horizon Soil Data for Individual Parent Materials

Soil	Variable	Geometric Mean Concentrations* (ppm)			
A Horizon	**pH	6.1	6.2	6.9	7.5
		LS	AS	GT	LC
	OM	2.0	2.5	3.2	3.2
		AS	LC	LS	GT
	Cu_T	3.9	12.6	15.9	25.1
		AS	GT	LS	LC
	***Fe_T	0.6	1.3	1.6	2.5
		AS	GT	LS	LC
	Mn_T	125.9	251.1	316.2	316.2
		AS	GT	LC	LS
	Cu_D	0.6	1.0	1.3	3.2
		AS	GT	LS	LC
	Fe_D	10.0	20.0	31.6	31.6
		LC	AS	GT	LS
	Mn_D	6.3	7.9	15.9	20.0
		AS	LC	GT	LS
	Zn_D	0.6	0.6	0.8	1.3
		AS	LC	GT	LS

* Means not underscored by the same overlapping line are significantly different at P = 0.05. each forming a separate group.

** pH is not log_{10} transformed.

*** Fe_T data are in percent.

Table 18 - Results of Application of Duncan's New Multiple Range Test to Log_{10}, 0-30 cm Depth Soil Data for Parent Materials

Soil	Variable	Geometric Mean Concentrations* (ppm)			
0-30 cm	**pH	6.2	6.3	7.0	7.6
		LS	AS	GT	LC
	OM	1.6	2.0	2.5	3.2
		AS	LC	GT	LS
	Cu_T	3.9	12.6	15.9	25.1
		AS	GT	LS	LC
	***Fe_T	0.6	1.3	1.6	2.5
		AS	GT	LS	LC
	Mn_T	125.9	251.1	316.2	316.2
		AS	GT	LS	LC
	Fe_D	12.6	15.9	15.9	31.6
		LC	GT	AS	LS
	Mn_D	5.0	6.3	7.9	20.0
		AS	LC	GT	LS

* Means not underscored by the same overlapping line are significantly different at P = 0.05, each forming a separate group.

** pH is not log_{10} transformed.

*** Fe_T Data are in percent

Table 19 - Results of Application of Duncan's New Multiple Range Test to Log_{10}, C Horizon Soil Data for Parent Materials

Soil	Variable	Geometric Mean Concentrations* (ppm)			
C Horizon	**pH	6.7	7.7	7.8	7.8
		AS	GT	LS	LC
	OM	0.3	0.5	0.6	0.9
		GT	AS	LS	LC
	Cu_T	3.2	12.6	15.9	25.1
		AS	GT	LS	LC
	***Fe_T	0.6	1.3	1.6	2.0
		AS	GT	LS	LC
	Mn_T	100.0	316.2	316.2	398.1
		AS	LS	LC	GT
	Cu_D	0.3	1.6	3.2	3.2
		AS	LS	GT	LC
	Fe_D	7.9	10.0	10.0	12.6
		AS	LS	GT	LC

*Means not underscored by the same overlapping line are significantly different at P = 0.05, each forming a separate group.

**pH is not log_{10} tranformed.

***Fe_T Data are in percent.

parent materials in the upper plough layer compared to lower horizons.

IV.2.3 Correlation (Tables 20 to 27)

The highest correlation coefficients (at a significance level of 0.05) are most frequently found for lacustrine silt and glacial till data, where pH is negatively associated with Fe_D, Mn_D and Zn_D. High positive correlations are also found between Zn_D, Fe_D and Mn_D in both these soils and furthermore, DTPA elemental data are positively linked to organic matter, especially in surface horizons. (Tables 23, 25).

Relationships between variables for lacustrine clay soils tend to be more subdued than for the other three parent materials. However, lacustrine clay data for the A horizon (Table 21) show positive correlations for iron and copper, both total and DTPA extractable. Glacial till and aeolian sand data exhibit strong positive relationships between Cu_T, Fe_T, Mn_T and Zn_T, in comparison to lacustrine clay and lacustrine silt data.

IV.2.4 Regression (Tables 28 to 33)

A Backwards Stepwise Multiple Curvilinear Regression Analysis was carried out on A horizon data for all parent materials combined and for individual parent materials, as most variation occurs in this horizon. Regression equations were determined (Tables 29 to 33). The Index of Determination (I^2) was calculated (Table 28).

For the four parent materials combined (Table 29), 68-85% of the variation in DTPA elemental concentrations can be accounted for by

TABLE 20

Correlation Coefficients Relating $\log_{10}$ Total and DTPA Elemental Data, pH and Organic Matter for Lacustrine Clay Soils (A, B and C Horizons).

N= 62 DF= 60 R@ .0500= .2500 R@ .0100= .3248

VARIABLE										
LGPH	1.0000									
LGDCU	-.2278	1.0000								
LGDFE	-.2552	.4536	1.0000							
LGDMN	-.5415	-.0631	-.0061	1.0000						
LGDZN	-.4284	.1689	.1526	.4377	1.0000					
LGTCU	.0373	.2960	.1013	-.1593	.2222	1.0000				
LGTMN	-.1286	-.0796	-.2578	.3626	.1723	-.2883	1.0000			
LGTZN	-.1633	.0548	-.3370	.2570	.1342	.1128	.4182	1.0000		
LGTFE	-.1888	.0741	-.3184	.0086	.0649	.2854	.0556	.4293	1.0000	
LGOM	-.6379	.0385	-.0328	.7867	.5840	-.1547	.3304	.2646	.0291	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 21

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Lacustrine Clay Soils (A Horizon)

N= 25 DF= 23 R= .0500= .3961 R= .0100= .5052

VARIABLE	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM
LGPH	1.0000									
LGDCU	-.5853	1.0000								
LGDFE	-.6704	.7514	1.0000							
LGDMN	-.4901	.1839	.3434	1.0000						
LGDZN	-.4408	.0524	.4076	.5694	1.0000					
LGTCU	.0510	.1260	.0294	-.3275	-.0346	1.0000				
LGTMN	.0076	-.1454	-.1554	.4275	.2293	-.2192	1.0000			
LGTZN	.1917	-.0094	-.3822	-.2534	-.4843	-.0556	.1862	1.0000		
LGTFE	.0488	.1325	-.1779	-.3283	-.2548	.5158	-.2488	.3971	1.0000	
LGOM	-.6312	.2324	.4626	.7959	.7171	-.3882	.2709	-.2605	-.2350	1.0000

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 22

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Lacustrine Silt Soils (A, B and C Horizons)

N= 32 DF= 30 R@ .0500= .3494 R@ .0100= .4487

VARIABLE										
LGPH	1.0000									
LGDCU	.1831	1.0000								
LGDFE	-.9410	-.0868	1.0000							
LGDMN	-.7436	.0300	.7212	1.0000						
LGDZN	-.7134	.1129	.7359	.8426	1.0000					
LGTCU	.2999	.6294	-.1309	-.1733	-.0481	1.0000				
LGTMN	.0760	.1779	.0213	.0362	.1329	.4264	1.0000			
LGTZN	.0458	.1586	.0178	.1259	.2940	.3555	.7530	1.0000		
LGTFE	.3376	.4003	-.3381	-.2873	-.2810	.4844	.4087	.4788	1.0000	
LGOM	-.5247	.2114	.5754	.7501	.8806	.1334	.3439	.4536	-.0373	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 23

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Lacustrine Silt Soils (A Horizon)

N= 30 DF= 28 R@ .0500= .3610 R@ .0100= .4629

VARIABLE										
LGPH	1.0000									
LGDCU	.0217	1.0000								
LGDFE	-.9328	.0533	1.0000							
LGDMN	-.6150	.2913	.6372	1.0000						
LGDZN	-.6196	.3280	.6736	.7880	1.0000					
LGTCU	.1041	.5968	.0654	.1371	.2620	1.0000				
LGTMN	.0484	.1633	.0577	.1062	.2134	.4310	1.0000			
LGTZN	.1500	.2165	-.0508	.0444	.2510	.5025	.7856	1.0000		
LGTFE	.2951	.3681	-.2949	-.2236	-.2103	.4481	.3979	.5311	1.0000	
LGOM	-.3393	.4417	.4578	.6549	.8766	.4267	.4345	.4591	.0526	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 24

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Glacial Till Soils (A, B and C Horizons)

N= 43 DF= 41 R® .0500= .3008 R® .0100= .3887

VARIABLE	50. LGPH	51. LGDCU	52. LGDFE	53. LGDMN	54. LGDZN	55. LGTCU	56. LGTMN	57. LGTZN	58. LGTFE	59. LGOM
LGPH	1.0000									
LGDCU	.3195	1.0000								
LGDFE	-.8510	.0563	1.0000							
LGDMN	-.6292	-.2950	.6522	1.0000						
LGDZN	-.5525	-.0233	.6821	.7507	1.0000					
LGTCU	.0773	.6241	.1485	-.0170	.2412	1.0000				
LGTMN	-.2389	.0135	.2100	.3183	.4851	.4256	1.0000			
LGTZN	-.3156	.1205	.4796	.4760	.6006	.5021	.5306	1.0000		
LGTFE	.0099	.3982	.1389	.0699	.1274	.5533	.4085	.5020	1.0000	
LGOM	-.5795	-.0279	.6883	.8140	.8833	.2699	.4260	.5756	.2093	1.0000

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 25

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Glacial Till Soils (A Horizon)

N= 36 DF= 34 R@ .0500= .3291 R@ .0100= .4238

VARIABLE										
LGPH	1.0000									
LGDCU	.1839	1.0000								
LGDFE	-.8373	.2178	1.0000							
LGDMN	-.5336	-.1267	.5868	1.0000						
LGDZN	-.4694	.1932	.6457	.7260	1.0000					
LGTCU	.0043	.6326	.2262	.0777	.3675	1.0000				
LGTMN	-.2097	.0852	.1807	.3100	.4974	.4719	1.0000			
LGTZN	-.3643	.2585	.5303	.5343	.6788	.5885	.6414	1.0000		
LGTFE	.0321	.4534	.1274	.0313	.1601	.5658	.4257	.5586	1.0000	
LGOM	-.4777	.2261	.6533	.7747	.9225	.4624	.5083	.6870	.2213	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 26

Correlation Coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Aeolian Sand Soils (A, B and C Horizons)

N= 35 DF= 33 R@ .0500= .3338 R@ .0100= .4296

VARIABLE										
LGPH	1.0000									
LGDCU	-.0190	1.0000								
LGDFE	-.5245	.4370	1.0000							
LGDMN	.1603	.0360	.3358	1.0000						
LGDZN	-.0794	.3419	.6005	.4637	1.0000					
LGTCU	.4011	.3293	.2118	.6055	.2516	1.0000				
LGTMN	.4222	-.0486	.1479	.5988	.2540	.5544	1.0000			
LGTZN	.3519	.0308	.1991	.6678	.3512	.5708	.6078	1.0000		
LGTFE	.0593	.0664	.1295	.4603	.1274	.4942	.6554	.5602	1.0000	
LGOM	.0455	.3651	.6537	.5786	.6659	.4429	.4038	.4483	.1122	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

TABLE 27

Correlation coefficients Relating Log_{10} Total and DTPA Elemental Data, pH and Organic Matter for Aeolian Sand Soils (A Horizon)

N= 34 DF= 32 R@ .0500= .3388 R@ .0100= .4357

VARIABLE										
LGPH	1.0000									
LGDCU	-.0747	1.0000								
LGDFE	-.4768	.5054	1.0000							
LGDMN	.2747	.0811	.2817	1.0000						
LGDZN	-.0990	.3397	.6383	.4937	1.0000					
LGTCU	.3886	.3180	.2544	.6640	.2487	1.0000				
LGTMN	.4290	-.0577	.1700	.6379	.2523	.5526	1.0000			
LGTZN	.4215	.0514	.1714	.6631	.3599	.5935	.6208	1.0000		
LGTFE	.0494	.0614	.1460	.4890	.1260	.4933	.6547	.5702	1.0000	
LGOM	.1415	.4221	.6277	.5479	.6998	.4896	.4321	.4334	.1260	1.0000
	LGPH	LGDCU	LGDFE	LGDMN	LGDZN	LGTCU	LGTMN	LGTZN	LGTFE	LGOM

N = No. of Samples
DF = Degrees of Freedom
R .0500 = Correlation Coefficient (Significant at P = 0.05 level)
R .0100 = Correlation Coefficient (Significant at P = 0.01 level)

Coefficients underlined are significantly >0 at P = 0.01

the independent variables presented in the respective regression equations (at a significance level of 0.05%).

Lacustrine clay soils show the highest percentages (Table 30), 90-98% of the variability in Cu_D, Fe_D, Mn_D and Zn_D alone being explained, three variables alone pH, pH^2 and Cu_T, accounting for 96% of the variation in Fe_D. Lacustrine silt soils show a wider range of I^2 values, however, a large amount of the variation in Fe_D (96.9%) and Z_D (95.8%) is accounted for by 9 and 12 independent variables respectively. Glacial till soils exhibit a lower Index of Determination (I^2) for Fe_D than lacustrine silt soils, but a higher percentage of the variability in Mn_D can be accounted for in the till. Only, 54%, of the variation in Cu_D is explained in these soils, furthermore the corresponding percentage is even less (35%) in the aeolian sand soils. (Table 33). However, in the latter, 63-68% of the variation in Fe_D, Mn_D and Zn_D concentrations can be accounted for by the regression equations. Predictions for Cu_D, Fe_D, Mn_D and Zn_D can be computed from the regression equations (Tables 29-33) as follows. For example, for lacustrine clay soils,

$$\mathrm{Log}_{10}\ Fe_D = 53 - 15.8\ pH + 14346\ Cu_T + 1.1\ pH^2$$

$$Fe_D = 10^{(53 - 15.8\ pH + 14346\ Cu_T + 1.1\ pH^2)}$$

(Fe_D is given as a fraction, which is then converted to parts per million).

Table 28 - Index of Determination (I^2) for the Dependent Variables Log_{10}, Cu_D, Fe_D, Mn_D and Zn_D for All Parent Materials (A Horizon Data) and Individual Parent Materials (A Horizon Data)

Dependent Variable	All Data	LC	LS	GT	AS
$I^2(Log_{10}\ Cu_D)$	0.847	0.925	0.669	0.542	0.352
S(Y,X) Est.	0.387	0.210×10^{-6}	0.344×10^{-6}	0.133×10^{-6}	0.133×10^{-6}
D.F.	117	15	23	30	26
$I^2(Log_{10}\ Fe_D)$	0.739	0.967	0.969	0.762	0.636
S(Y,X) Est.	0.154×10^{-4}	0.147×10^{-5}	0.525×10^{-5}	0.237×10^{-4}	0.538×10^{-5}
D.F.	114	21	20	31	32
$I^2(Log_{10}\ Mn_D)$	0.727	0.908	0.561	0.758	0.640
S(Y,X) Est.	0.455×10^{-5}	0.905×10^{-6}	0.642×10^{-5}	0.277×10^{-5}	0.182×10^{-5}
D.F.	116	16	27	29	27
$I^2(Log_{10}\ Zn_D)$	0.684	0.981	0.958	0.689	0.679
S(Y,X) Est.	0.575×10^{-6}	0.583×10^{-7}	0.276×10^{-6}	0.749×10^{-6}	0.480×10^{-6}
D.F.	119	10	17	35	19

I^2 = Index of Determination (Significant at the 0.05 level)
S(Y,X) Est.= Estimated Standard Error of Estimate (Dependent variable = Y, Independent variables = $X_1, X_2, \ldots X_n$
D.F. = Degrees of freedom.

Table 29 - Multiple Curvilinear Regression Equations for Log_{10}, Cu_D, Fe_D, Mn_D And Zn_D for all Parent Materials (A Horizon Data) (At a Significance Level of 0.05)

$$Log_{10}\ Cu_D = 3.3 + \frac{0.16 \times 10^{-5}}{Cu_T} - \frac{0.27 \times 10^{-2}}{OM} - 3443\ Mn_T - 22\ Fe_T + 0.472 \times 10^{7}\ Mn_T{}^2 + 1.6\ Log_{10}\ Cu_T$$

$$- 0.45\ Log_{10}\ Zn_T + 1.3\ Log_{10}\ Fe_T$$

$$Log_{10}\ Fe_D = - 3296 + \frac{5187}{pH} - 374\ pH + 11359\ Cu_T - 739\ Mn_T - 27.5\ Fe_T - 52.8\ OM + 9.6\ pH^2$$

$$+ 486\ OM^2 + 5568\ log_{10}\ (pH) + 0.93\ log_{10}\ Fe_T + log_{10}\ OM.$$

$$Log_{10}\ Mn_D = 0.94 \times 10^{-1} - \frac{0.46 \times 10^{-6}}{Cu_T} + \frac{0.64 \times 10^{-2}}{OM} - 0.19\ pH + 3351\ Mn_T - 0.57 \times 10^{7}\ Mn_T{}^2$$

$$- 1.7\ OM^2 + 0.61\ log_{10}\ Zn_T - 0.36\ log_{10}\ Fe_T + 1.6\ log_{10}\ OM$$

$$Log_{10}\ Zn_D = -3.8 - \frac{0.12 \times 10^{-4}}{Zn_T} - 1.7pH + 29388\ Cu_T + 0.12\ pH^2 - .88\ log_{10}\ Cu_T - 0.67\ log_{10}\ Fe_T$$

$$+ 1.5\ log_{10}\ OM.$$

Table 30 - Multiple Curvilinear Regression Equations for Log_{10}, Cu_D, Fe_D, Mn_D and Zn_D for Lacustrine Clay Soils (A Horizon Data). (At a Significance Level of 0.05)

$$\log_{10} Cu_D = 2815 + \frac{5240}{pH} - 92.9\ pH + 86428\ Cu_T - 427.4\ Fe_T + 3908\ {Fe_T}^2 - 117.4\ OM^2 + 3214 \log_{10} pH - 4.8 \log_{10} Cu_T + 12.9 \log_{10} Fe_T$$

$$\log_{10} Fe_D = 53 - 15.8\ pH + 14346\ Cu_T + 1.1\ pH^2$$

$$\log_{10} Mn_D = 1087 - \frac{0.10 \times 10^{-3}}{Cu_T} + \frac{2.3}{Fe_T} + 1045\ Mn_T - 10441\ Fe_T + 15\ OM + 65177\ {Fe_T}^2 - 8.7 \log_{10} Cu_T + 624.2 \log_{10} Fe_T$$

$$\log_{10} Zn_D = 2891 + \frac{0.28 \times 10^{-2}}{Cu_T} - \frac{0.19 \times 10^{-1}}{Mn_T} - \frac{3.4}{Fe_T} - 28.7\ pH - 0.38 \times 10^{7}\ Cu_T + 0.20 \times 10^{6}\ Mn_T - 14167\ Fe_T - 187\ OM + 1.9\ pH^2 + 84335\ {Fe_T}^2 + 479 \log_{10} Cu_T - 289 \log_{10} Mn_T + 892 \log_{10} Fe_T + 11 \log_{10} OM.$$

Table 31 - Multiple Curvilinear Regression Equations for Log_{10}, Cu_D, Fe_D, Mn_D and Zn_D for Lacustrine Silt Soils (A Horizon Data).
(At a Significance Level of 0.05)

$$Log_{10}\ Cu_D = -10684 + \frac{16683}{pH} - \frac{0.45 \times 10^{-2}}{OM} - 1261\ pH + 22450\ Cu_T + 33\ pH^2 + 18342\ log_{10}\ pH.$$

$$Log_{10}\ Fe_D = -72.3 - \frac{0.61 \times 10^{-5}}{Cu_T} - \frac{0.28}{OM} - 0.42\ pH - 71756\ Zn_T + 968\ OM - 4714\ OM^2$$

$$+ 10.9\ log_{10}\ Zn_T - 0.62\ log_{10}\ Fe_T - 68.6\ log_{10}\ OM.$$

$$Log_{10}\ Mn_D = -3.4 - \frac{0.91 \times 10^{-2}}{OM} - 0.17\ pH$$

$$Log_{10}\ Zn_D = 3229 - \frac{1.8 \times 10^{-1}}{Mn_T} + \frac{4.2}{Fe_T} - \frac{0.26 \times 10^{-1}}{OM} - 1.7\ pH - 0.26 \times 10^6\ Cu_T + 0.18 \times 10^6\ Mn_T$$

$$- 59602\ Fe_T + 0.67 \times 10^6\ Fe_T^2 + 23\ log_{10}\ pH + 9\ log_{10}\ Cu_T - 266\ log_{10}\ Mn_T$$

$$+ 2006\ log_{10}\ Fe_T$$

Table 32 - Multiple Curvilinear Regression Equations for Log_{10}, Cu_D, Fe_D, Mn_D and Zn_D for Glacial Till Soils (A Horizon Data). (At a Significance Level of 0.05)

$$Log_{10}\ Cu_D = 5.88 - \frac{0.42 \times 10^{-5}}{Cu_T} + \frac{0.93 \times 10^{-4}}{Zn_T} + 283\ Fe_T - 9454\ Fe_T^{\ 2} + 3.5\ \log_{10} Zn_T + 0.27\ \log_{10} OM$$

$$Log_{10}\ Fe_D = 2.98 + \frac{0.11 \times 10^{-3}}{Mn_T} + 99\ OM^2 - 5.6\ \log_{10} pH + 0.84\ \log_{10} Zn_T$$

$$Log_{10}\ Mn_D = -20.5 - \frac{0.44 \times 10^{-3}}{Mn_T} + 83\ OM^2 - 1.2\ \log_{10} Cu_T - 4.2\ \log_{10} Mn_T + 0.67\ \log_{10} Zn_T + 0.47\ \log_{10} OM.$$

$$Log_{10}\ Zn_D = -\ 7.0 \times 24.3\ OM.$$

Table 33 - Multiple Curvilinear Regression Equations for Log_{10}, Cu_D, Fe_D, Mn_D and Zn_D for Aeolian Sand Soils (A Horizon Data). (At a Significance Level of 0.05)

$$\mathrm{Log}_{10}\ Cu_D = -0.20 \times 10^6 + \frac{0.32 \times 10^6}{pH} + \frac{0.18 \times 10^{-3}}{Zn_T} - 24273\ pH - 0.14 \times 10^6\ Zn_T + 642\ pH^2 + 0.35 \times 10^6\ pH + 24.6\ \log_{10} Zn_T$$

$$\mathrm{Log}_{10}\ Fe_D = -5.7 + \frac{13.3}{pH} + 0.67\ \log_{10} OM$$

Log_{10}

$$\mathrm{Log}_{10}\ Mn_D = 74.5 + \frac{0.53 \times 10^{-3}}{Mn_T} - \frac{0.64 \times 10^{-5}}{Zn_T} - 36643\ Mn_T + 104.6\ OM - 1218\ OM^2 + 21.5\ \log_{10} Mn_T - 1.8\ \log_{10} OM$$

$$\mathrm{Log}_{10}\ Zn_D = -0.32 \times 10^6 + \frac{0.50 \times 10^6}{pH} + \frac{0.34 \times 10^{-3}}{Mn_T} - \frac{0.35 \times 10^{-4}}{Zn_T} - \frac{1.3}{Fe_T} + \frac{0.78 \times 10^{-1}}{OM} - 37475\ pH + 87988\ Fe_T - 1043\ OM + 989.4\ pH^2 - 0.21 \times 10^7\ Fe_T^{\ 2} + 8955\ OM^2 + 0.54 \times 10^6\ \log_{10} pH + 7.2\ \log_{10} Mn_T - 1384\ \log_{10} Fe_T + 40\ \log_{10} OM.$$

CHAPTER V

DISCUSSION

V.1 General Discussion

Total elemental concentrations vary with the changing texture of the parent materials. Lacustrine clay with the highest clay content shows the greatest concentrations of copper, iron, manganese and zinc owing to the ability of clays, in particular illite and montmorillonite to adsorb and occlude trace elements onto and within their structure. In contrast, the aeolian sands with their high quartz content, have little capacity for either structural inclusion or surface adsorption; lacustrine silt and glacial till soils reveal total elemental values that lie within these extremes.

Analysis of variance supports this with a compositional variation among parent materials accounting for well over 50% of the total data variability (Table 16). Also, Duncan's New Multiple Range Test results, further substantiate textural groupings, into lacustrine clay, lacustrine silt and glacial till and aeolian sand (Tables 17 to 19). Similar textural groups were found by Doyle (1977, 1979) in the Rosetown region, Haluschak and Russell (1971) in Manitoba and Pawluk and Bayrock (1969) in Alberta.

Although, total elemental concentrations between parent materials differ, generally similar catenary trends are exhibited on all four parent materials. Thus surface elemental values increase downslope, (this being notable for aeolian sand, lacustrine silt and glacial till) with a concomitant increase in both clay and organic matter content. Variation of total metal concentrations both within and between soil parent materials can therefore be related to textural changes.

Accumulation of clays in depressions results from high winds (120 km./hr.), during the summer months when the soil is often moisture deficient and dust storms are prevalent. The wind blown material accumulates in the depressions. Lateral translocation possibly plays a secondary role owing to lack of moisture. Also, deeper profiles and resulting thicker horizons in the depressions, must be related to the deposition of wind blown material. Increased organic matter content of soils in the depressions is probably due to the wetter horizon producing greater crop yields, hence a more lush vegetation occurs in the depressions. Also, wind blown material deposited here contains large amounts of cut wheat.

DTPA elemental concentrations vary with parent material type. Fe_D, Mn_D and Zn_D concentrations are highest in A horizons of the more developed lacustrine silt soils of the Elstow series. Cu_D concentrations are highest on the Rego Dark Brown Chernozems of the lacustrine clay soils. Regosols on the aeolian sand have the lowest values as is the case for total elemental concentrations.

Analysis of variance shows that for Fe_D, Mn_D and Zn_D, the compositional variation among parent material accounts for between 50-90% of the total data variability. Duncan's New Multiple Range test results for DTPA metal concentrations do not show the distinctive groupings detectable for total elemental values. However, it is found that lacustrine silt soils always lie within the group with the highest elemental mean concentrations and in contrast, aeolian sand soils are for the most part found in the group with the lowest elemental mean values. Glacial till soils most commonly occur in the same grouping as the lacustrine silt soils (Tables 17 to 19).

Lacustrine silt soils are more permeable than their lacustrine clay counterparts. Their higher infiltration rate results in greater profile development, with the appearance of a Bm horizon and a wider pH range. This increased development and increased weathering presumably accounts for their increased DTPA extractable iron, manganese and zinc contents in the A horizons, despite their lower total contents than the lacustrine clay. As a result, these elements show little correlation between DTPA and corresponding total contents. This lack of correlation confirms that totals are not a reliable indicator of available trace elements. In contrast, copper is the only element studied showing positive correlations between Cu_D and Cu_T for both lacustrine silt and glacial till soils (Tables 22 to 25).

DTPA metal concentrations increase downslope in the surface horizons for the majority of sites. These increases downslope are most marked for Fe_D and Mn_D on lacustrine silt soils (Figs. 15-19) and probably respond, as suggested for total elemental concentrations, to the accumulation of clays and organic matter in the depressions. Furthermore, DTPA extractable metal values are generally less uniform than total values possibly reflecting differences in amounts and type of clay minerals (XRD shows evidence of translocation down profile of montmorillonite clays in preference to illite types) and their greater susceptibility to influences of pedological factors.

Thus, relatively high DTPA extractable values are generally greatest in surface horizons, possibly related to high organic matter content, to the removal of elements from subsurface horizons by successive generations of crops and their subsequent immobilization in surface layers and to a higher intensity of weathering than in the subsurface horizons. Both lacustrine clay and aeolian sand soils show high positive correlations between Cu_D and Fe_D in A horizons (Tables 21, 27). This possibly occurs as the less developed lacustrine clay soils have a large proportion of their available copper and iron still remaining in the surface horizons having undergone little translocation down profile, a high percentage of which is probably complexed by organic matter. Whereas for the aeolian sand soils which have a very low clay content, high percentages of copper and iron are likely to be associated with organic matter, which is present in relatively large amounts.

Most of the DTPA elemental concentrations have negative correlations with pH and decrease as pH increases, down profile. However, Cu_D concentrations do show slight increases down several profiles (Figs. 10-14) on strongly calcareous lacustrine clay soils. In this case, sequential analysis revealed high copper concentrations (25% of total soil copper) with sodium hypochlorite extractions for the A horizon (Table 10) whereas copper extracted with 5% HCl was a greater proportion (48%) of total soil copper in the C horizon. This suggests that adsorption of copper by clays is playing a greater role lower in the profile than is complexing by organic matter.

Sequential analysis, also shows that for glacial till and aeolian sand soils which have relatively low clay and silt contents, approximately half of the copper in the A horizon is associated with the organic matter fraction. This is appreciably more than for lacustrine clay and lacustrine silt soils suggesting that in soils low in clay and silt, organic matter plays a more significant role in the scavenging of copper. Similarly, Apostolatris and Douka (1970) working in Greece found that an increase in extracted copper occurs with an increase in organic matter content in soils having organic matter contents greater than 1%. Further evidence of the important role of organic matter in lacustrine silt, glacial till and aeolian sand soils are the high correlation of Fe_D, Mn_D and Z_D with organic matter (Tables 20 to 27).

Sequential analysis also reveal high proportions of Fe, Mn and Zn for the ammonium oxalate extraction suggesting that amorphous iron oxides play an influential role governing the availability of zinc and possibly manganese. This is especially pronounced for lacustrine silt and glacial till soils.

In support of the above results, Shuman (1979) found that there was nearly as much zinc in the iron oxide fractions as in the clay fraction. Several workers have positively associated zinc with clay content and Kalbasi and Racz (1978), working on Manitoba soils, suggested this correlation resulted from amorphous iron oxides being clay sized.

Oxalate values are high in the surface as well as the Bm horizons. Moore (1973), working on Scottish soils also found that iron extracted with oxalate gave high surface values. This was attributed to more intense weathering of minerals at the surface and retardation of aging of iron oxides in the presence of organic matter (Schwertmann et al, 1968).

From sequential analysis results, (Tables 8-11) manganese extracted with 5% HCl is shown to play an important role accounting for up to 27% of total soil manganese. Berrow and Mitchell (1980), working with well drained soils found similar results, with more acid soluble manganese than EDTA extractable. This was explained by the manganese being fixed in an oxide form, rather than as an organic form, as is the case with poorly drained soils. Sequential analysis shows that about half the total manganese is extracted by oxalate from the lacustrine clay soils (A horizon) compared to 70% for aeolian sand soils (A horizon). This suggests that the lower clay content, the more important the amorphous iron oxide fraction becomes in fixing manganese.

For zinc, sequential analysis results show that for aeolian sand soils (A horizon) the amount of zinc extracted with 5% HCl averages about 21%, whereas, with the other parent materials corresponding values ranged from 9 to 13%. Zinc is often found to be deficient in calcareous, high pH soils, aeolian sands have a pH range of 5-7 rendering zinc to be more available. However, this is not the case for DTPA results, where the extracting solution is buffered at pH 7.3.

Deficiencies of iron as well as zinc are well known to occur on calcareous soils. Hodgson et al (1966), found zinc deficiencies to be more widespread than copper deficiencies due to the relatively low level of zinc present as organic complexes (60% compared to 98% for copper) (Hodgson et al, 1966). From Table 34 and 35, assembled by Follett and Lindsay (1970), all soils are found to be amply supplied with available (DTPA extractable) iron and manganese. Lacustrine clay, glacial till and aeolian sand soils show low to marginal DTPA extractable zinc levels, and aeolian sand soils also, show low corresponding copper levels, hence crops grown might respond favourably to treatment with greater yields and improved quality.

V.2 Predictions

Analysis of variance has shown that the amount of compositional variation between parent materials account for well over 50% of the total data variability for both totals and DTPA elemental concentrations. These differences previously discussed, are probably mainly due to textural and mineralogical variations. Duncan's New Multiple Range test results, also, substantiate these textural groupings. On the basis of similar results, Doyle (1977) suggested that 10 samples per parent material, sampled at the midslope position, are adequate to produce stable geochemical maps. However, he used total elemental concentrations rather than available (DTPA extractable) metal concentrations. It is probable, that considerably

Table 34 - Critical Iron and Zinc DTPA Soil Test Value (Follett and Lindsay, 1970)

Level	Fe ppm	Zn ppm
low	0.0 - 2.0	0.0 - 0.5
marginal	2.0 - 4.5	0.5 - 1.0
adequate	>4.5	>1.0

Table 35 - Estimated Critical Copper and Manganese DTPA Soil Test Value (Follett and Lindsay, 1970)

Level	Cu ppm	Mn ppm
may require treatment	0.0 - 0.2	0.0 - 0.1
adequate	>0.2	>0.1

more than 10 samples per parent material be needed to produce reliable maps showing the availability of trace elements in an area, as DTPA elmental concentrations are not as consistent as total elemental concentrations. It is apparent from results that the midslope position provides a reliable mean concentration for the overall slope, for total elemental data in the surface horizons, however it is less reliable for DTPA elemental values as relatively greater increases occur at the base of the slope.

When considering all the parent materials together, 73-85% of the total variability in DTPA elemental concentrations can be accounted for by 8-11 independent variables in the respective regression equations (Tables 28, 29) the highest percentage being for Cu_D. However, the Index of Determination (I^2) (Table 28) shows that the variability in DTPA elemental concentrations is best explained for the less developed lacustrine clay soils, with 96.7% of the total variation in Fe_D accounted for by three variables, pH, pH^2 and Cu_T. Regression equations for Cu_D and Zn_D for these soils, include pH and organic matter coefficients (significant at the 0.05 level) whereas for Mn_D, total elemental data alone explains 72.7% of the variation, suggesting that pH and organic matter content probably exert a greater influence on the availability of Cu_D and Zn_D compared to Mn_D.

The more well developed enriched surface horizons of the lacustrine silt soils which show strong trends in DTPA elemental concentrations, reveal that a large amount (96-97%) of the variation in Fe_D and Zn_D can be accounted for. The regression equation for Zn_D comprises coefficients for pH, organic matter and Fe_T, suggesting that iron, as well as, pH and organic matter content, plays an important role possibly influencing the availability of zinc.

Variations in iron, extracted with DTPA, are generally, well explained by a relatively low number of variables, this is especially so for lacustrine clay soils where three variables, as mentioned above, account for a large amount of the total variation. Glacial till and aeolian sand soils show lower I^2 values (Table 28) and therefore, less of the variation in DTPA elemental concentrations is explained, in comparison to the more fertile lacustrine clay and lacustrine silt soils.

However, the amount of total variation in DTPA elemental concentrations accounted for in many of the regression equations is generally found to be high (80-90%). Hence, the independent variables selected appear to answer for a large part of the variation and should lead to reliable prediction as to the availability of these trace metals.

CHAPTER VI

CONCLUSION

1. Highest total elemental concentrations are found in the Ap horizon of the Rego Dark Brown Chernozems, developed on lacustrine clay soils, followed by lacustrine silt and glacial till soils, with soils on aeolian sand exhibiting the lowest values. The A horizons of lacustrine silt soils contain the highest amounts of DTPA extractable Fe, Mn and Zn, whereas, maximum extractable concentrations in the C horizon are associated with lacustrine clays. DTPA extractable Cu values in both the A and C horizons are at a maximum in lacustrine clay soils.
2. Analysis of variance shows that the compositional variation among parent materials, for total elemental data, accounts for well over 50% of the overall data variability. Duncan's New Multiple Range Test results, further substantiate these textural groupings into lacustrine clay, lacustrine silt and glacial till and aeolian sand. Results are less conclusive for DTPA elemental data.
3. Total elemental concentrations display a relatively greater uniformity when considering both trends downslope and down profile. However, at most sites, highest total and available elemental concentrations occur in the surface horizons at the base of the slope, being most pronounced for Fe_D and Mn_D in lacustrine silt soils. Furthermore, similar increases occur for clay and organic matter down catenas.

4. A quarter of total soil copper is associated with the organic matter fraction, in surface horizons for lacustrine clay soils, whereas approximately half of total copper in the C horizon is associated with soil clays and carbonates. For soils low in clay and silt, for example, glacial till and aeolian sand soils, the organic matter fraction plays a more significant role in scavenging soil copper.
5. High correlations are found between Fe_D, Mn_D, Zn_D and organic matter, this is especially marked for lacustrine silt and glacial till soils. Furthermore, a much greater proportion of DTPA extractable Mn and Zn occurs in the organic rich surface, compared to the more alkaline C horizon, this is also true for iron but to a lesser extent.
6. 50% of total soil manganese is found to be associated with the amorphous iron oxide fraction in lacustrine clay soils, whereas, in aeolian sand soils the corresponding percentage is 70%, suggesting that for soils low in clay, the amorphous iron oxides play a more significant role in fixing manganese. Furthermore, an enrichment of Mn_D and Fe_D occurs in the Bm and/or Bt horizons for lacustrine silt and glacial till soils which suggests that amorphous iron oxides possibly influence available soil manganese. These soils also exhibit high proportions of zinc extracted with ammonium oxalate in the plough layer. However, iron and zinc are principally found in the more crystalline oxides and silicates, which contain high percentages of total soil iron and zinc.

7. Thus, even though soil copper, iron, manganese and zinc are influenced by many pedological factors, operating separately and jointly, a large percentage of the total variability, when predicting DTPA elemental concentrations, can be accounted for by the variables included in the regression equations (Tables 28-33). The Index of Determination (I^2) shows that the variability in DTPA elemental concentrations, is best accounted for by the regression equations for the lacustrine clay soils, with 93-98% of the total variability explained. The more weathered lacustrine silt soils, reveal that a large amount of the variation in Fe_D and Zn_D, (96-97%), can be accounted for by the respective regression equations, but for Cu_D and Mn_D, less of the total variability can be explained.

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APPENDIX A

DATA LIST

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LC	1	017061	1	0	10	AP	280	24.41 2.62	2.29 10.57	344.33 9.74	95.28 0.34	7.35	2.95
LC	1	017061	1	0	0	AP	105	25.29 2.46	2.38 14.69	306.70 9.24	84.21 0.58	7.40	2.80
LC	1	017061	1	10	30	CK1	291	23.75 2.80	2.26 13.08	299.77 5.04	44.94 0.39	7.80	1.63
LC	1	017061	1	10	30	CK1	104	25.62 2.64	1.81 17.14	249.97 4.78	63.76 0.32	7.80	1.52
LC	1	017061	1	30	60	CK2	326	23.58 3.13	2.28 12.52	303.54 5.42	76.40 0.21	7.65	
LC	1	017061	1	30	60	CK2	151	25.85 3.32	2.50 11.89	264.46 5.08	83.88 0.37	8.05	
LC	1	017061	2	0	8	AP	456	26.53 2.81	3.99 8.59	266.97 9.58	83.33 0.56	7.40	3.00
LC	1	017061	2	0	0	AP	050	26.88 2.49	1.81 10.41	251.19 10.90	77.61 0.53	7.60	3.20
LC	1	017061	2	8	25	CK1	499	27.79 3.15	2.76 10.35	288.91 5.48	82.61 0.34	7.70	1.81
LC	1	017061	2	8	25	CK1	500	27.43 3.15	2.76 10.92	274.29 5.13	82.61 0.60	7.80	1.67
LC	1	017061	2	25	60	CK2	293	23.75 2.80	2.42 12.80	306.90 4.70	86.29 0.34	7.90	
LC	1	017061	2	25	60	CK2	003	28.15 3.02	2.15 16.60	270.23 7.61	 0.77	7.90	
LC	1	017061	3	0	8	AP	498	27.06 2.97	2.81 8.91	281.60 9.24	82.61 0.60	7.40	2.75
LC	1	017061	3	0	0	AP	497	28.89 2.80	2.98 9.49	274.29 9.24	86.96 0.60	7.35	2.78
LC	1	017061	3	8	35	CK1	496	27.79 2.97	2.81 12.13	274.29 5.99	82.61 0.46	7.35	1.98
LC	1	017061	3	8	35	CK1	255	24.49 3.17	2.32 14.93	307.05 8.90	86.29 0.40	7.60	1.90
LC	1	017061	3	35	65	CK2	106	25.63 2.81	2.47 18.37	294.29 5.77	81.20 0.32	7.80	
LC	1	017061	3	35	65	CK2	123	24.49 3.17	2.64 14.11	257.47 5.63	85.81 0.23	7.90	
LC	1	017061	4	0	12	APK	102	25.63 2.64	2.35 9.12	310.25 9.50	81.80 0.45	7.50	2.75
LC	1	017061	4	0	0	APK	274	23.58 2.62	3.23 10.30	337.89 8.52	89.39 0.39	7.60	2.71
LC	1	017061	4	12	45	CK1	298	24.74 2.97	2.39 14.12	318.13 5.57	94.38 0.69	7.60	1.81
LC	1	017601	4	12	45	CK1	153	25.85 3.15	2.53 11.61	264.46 5.93	80.31 0.25	7.75	1.52
LC	1	017601	4	45	70	CK2	152	25.85 2.97	2.53 11.33	264.46 5.59	84.77 0.54	7.95	
LC	1	017601	4	45	70	CK2	156	23.53 3.15	2.51 12.18	289.02 5.76	95.91 0.29	7.90	
LC	1	017601	5	0	12	AP	495	34.00 3.85	3.80 15.98	370.07 6.85	85.29 0.76	7.20	2.75
LC	1	017601	5	0	0	AP	494	29.26 3.50	2.81 13.90	292.57 9.58	117.39 0.72	7.20	3.61
LC	1	017601	5	12	20	BMK	493	28.53 3.85	2.72 12.72	277.94 6.33	88.70 0.76	7.35	2.57
LC	1	017601	5	20	45	CK1	492	28.53 3.67	2.72 12.43	292.57 4.96	86.96 0.67	7.35	2.64
LC	1	017061	5	45	70	CK2	297	25.40 3.50	2.42 13.80	336.84 4.52	89.89 0.30	7.60	
LC	1	017061	5	45	70	CK2	103	25.63 3.52	2.17 16.16	283.66 6.60	75.18 1.93	7.70	
LC	2	935743	1	0	7	AP	272	23.91 2.80	3.07 11.41	270.31 4.87	96.54 0.34	7.70	1.93
LC	2	935743	1	0	0	AP	082	24.16 2.64	1.93 12.25	239.34 7.42	65.56 0.49	7.60	2.36
LC	2	935743	1	7	30	CK1	273	23.58 2.80	2.39 13.26	325.96 5.04	87.60 0.22	7.70	1.76
LC	2	935743	1	7	30	CK1	352	26.14 3.13	2.90 11.88	323.95 5.95	94.92 0.34	8.00	1.83
LC	2	935743	1	30	60	CK2	202	27.09 3.32	2.99 13.88	338.03 4.74	89.39 0.21	7.90	
LC	2	935743	1	30	60	CK2	155	25.85 2.97	2.53 11.89	264.46 5.25	82.10 0.21	7.95	
LC	2	935743	2	0	8	AP	154	25.85 2.97	2.69 10.76	272.02 5.93	84.77 0.41	7.65	1.90
LC	2	935743	2	0	0	AP	457	27.66 2.64	2.98 7.70	266.87 5.31	76.67 0.64	7.60	2.22
LC	2	935743	2	8	30	CK1	084	25.77 2.81	1.96 19.59	230.47 5.77	66.17 0.36	7.65	1.77
LC	2	935743	2	8	30	CK1	411	25.87 3.15	2.07 11.10	340.00 4.72	90.40 0.29	7.70	1.59
LC	2	935743	2	30	60	CK2	484	27.43 3.15	2.93 12.13	274.29 3.77	80.00 0.34	7.85	
LC	2	935743	2	30	60	CK2	244	25.80 1.75	2.29 12.94	292.25 4.74	77.30 0.22	8.05	
LC	2	935743	3	0	10	AP	161	25.10 3.15	2.44 11.33	260.69 5.93	81.57 0.25	7.65	1.90
LC	2	935743	3	0	0	AP	162	25.10 2.80	1.83 9.63	253.13 5.59	64.54 0.50	7.65	2.04
LC	2	935743	3	10	30	CK1	271	25.85 3.17	2.32 15.79	333.91 7.19	89.39 0.45	7.70	1.72
LC	2	935743	3	10	30	CK1	445	27.66 3.17	3.19 10.96	226.74 4.28	79.17 0.51	7.80	1.55
LC	2	935743	3	30	65	CK2	083	27.38 3.17	2.50 19.59	288.98 5.11	84.21 0.49	7.80	
LC	2	935743	3	30	65	CK2	303	26.95 3.15	2.06 14.75	307.20 7.13	106.97 0.30	7.70	

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm)	DTPA Cu (ppm)	TOTAL Fe (%)	DTPA Fe (ppm)	TOTAL Mn (ppm)	DTPA Mn (ppm)	TOTAL Zn (ppm)	DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LC	2	935743	4	0	15	AP	458	28.46	2.46	3.04	8.00	260.87	4.62	89.51	0.51	7.50	2.02
LC	2	935743	4	0	0	AP	079	26.41	2.64	1.86	13.71	230.47	6.76	65.56	0.63	7.50	2.40
LC	2	935743	4	15	35	CK1	085	25.77	2.81	1.84	16.66	221.61	5.61	61.95	0.40	7.45	1.81
LC	2	935743	4	15	35	CK1	080	25.77	2.64	1.84	16.16	221.61	7.09	62.56	0.40	7.50	1.98
LC	2	935743	4	35	58	CK2	471	25.91	2.97	2.93	11.54	248.37	6.51	86.49	0.30	7.50	
LC	2	935743	4	35	58	CK2	081	25.77	2.64	2.23	18.61	265.93	5.61	75.79	0.45	7.70	
LC	2	935743	5	0	8	AP	327	27.28	2.78	2.50	8.67	329.14	6.47	91.69	0.51	7.40	1.98
LC	2	935743	5	0	0	APO	382	68.12	2.96	.74	9.31	329.70	6.12	89.89	0.55	7.40	1.90
LC	2	935742	5	8	20	BM	305	25.26	2.44	2.34	10.67	336.46	5.57	88.09	0.47	7.25	2.29
LC	2	935742	5	20	55	CCA	195	23.74	2.10	2.49	11.19	304.23	6.82	85.81	0.65	7.50	2.07
LC	2	935742	5	20	55	CCA	196	22.07	2.10	2.39	12.59	300.47	5.77	84.92	0.47	7.50	
LC	2	935742	5	55	65	CK	197	19.39	1.57	2.02	12.94	262.91	2.27	75.98	0.17	7.60	
LC	3	918113	1	0	8	AP	006	24.91	2.58	1.76	18.42	321.26	14.70	69.62	1.63	6.90	3.72
LC	3	918113	1	0	0	AP	031	24.19	0.36	1.65	25.45	296.00	21.10	66.87	0.69	7.00	4.07
LC	3	918113	1	8	20	CCA1	354	23.46	3.32	2.36	16.30	351.61	11.89	94.92	0.44	7.15	2.87
LC	3	918113	1	8	20	CCA1	140	21.00	2.64	1.96	11.47	287.13	4.75	74.96	0.27	7.80	2.31
LC	3	918113	1	20	35	CCA2	473	19.34	2.80	1.72	10.95	251.97	2.91	60.54	0.25	7.70	
LC	3	918113	1	35	60	CK	033	23.23	2.49	1.74	14.49	324.87	4.50	66.87	0.43	7.90	
LC	3	918113	2	0	8	APK	280	21.44	2.45	1.86	8.35	374.27	7.13	76.76	0.65	7.60	2.82
LC	3	918113	2	0	0	APK	183	22.07	1.40	1.88	9.44	394.37	8.04	75.98	0.43	7.55	3.07
LC	3	918113	2	8	16	BMK	054	23.00	2.31	1.16	11.10	240.58	5.63	52.54	0.24	7.75	2.25
LC	3	918113	2	16	25	CCA1	420	18.77	2.27	2.21	10.50	362.26	3.67	64.17	0.25	7.60	1.59
LC	3	918113	2	25	45	CCA2	227	18.29	2.46	1.69	13.89	364.95	4.62	64.36	0.20	7.60	
LC	3	918113	2	45	60	CK	472	18.24	2.10	2.13	8.28	305.96	2.05	64.87	0.25	7.35	
LC	3	918113	3	0	10	AP	357	21.78	2.36	2.26	8.45	434.57	11.89	90.40	0.79	7.50	3.80
LC	3	918113	3	0	0	AP	353	23.46	1.91	2.42	8.67	434.57	13.99	94.92	0.76	7.40	3.97
LC	3	918113	3	10	30	CCA	141	24.55	2.64	2.31	9.12	336.25	10.55	83.88	0.62	7.50	3.25
LC	3	918113	3	10	30	CCA	108	24.96	3.17	1.88	12.94	304.93	5.80	69.17	0.36	7.70	2.55
LC	3	918113	3	30	55	CK	474	24.81	1.92	3.19	8.28	287.96	2.40	77.84	0.25	7.70	
LC	3	918113	3	30	55	CK	032	25.81	2.67	1.81	14.19	328.48	4.15	68.66	0.95	7.80	
LC	3	918113	4	0	8	AP	358	21.78	2.62	2.26	7.55	402.96	9.44	90.40	0.79	7.65	3.04
LC	3	918113	4	0	0	AP	025	26.77	1.96	1.71	9.06	261.70	6.05	62.69	1.33	7.85	2.68
LC	3	918113	4	8	30	CK1	284	23.09	2.80	2.07	13.08	344.33	5.74		0.34	7.80	2.05
LC	3	918113	4	8	30	CK1	051	24.29	3.02	1.96	13.42	291.87	6.86	69.25	0.44	8.00	2.03
LC	3	918113	4	30	60	CK2	391	23.12	3.15	1.76	11.10	367.15	5.25	85.88	0.34	8.20	
LC	3	918113	5	0	15	AP	169	21.96	5.42	2.25	45.31	283.35	13.21	85.15	0.91	6.60	4.80
LC	3	918113	5	0	0	AP	270	23.26	5.98	2.19	45.14	333.91	15.74	98.32	1.03	6.40	4.35
LC	3	918113	5	15	25	CCAG	038	27.10	6.93	2.05	19.43	324.87	4.40	75.22	1.01	7.55	1.90
LC	3	918113	5	25	65	CKG	070	27.06	5.51	2.17	27.76	361.66	1.58	90.23	0.57	7.50	
LC	3	918113	5	25	65	CKG	373	24.96	4.90	1.85	16.91	440.58	1.40	90.40	0.40	7.90	
LC	4	221894	1	0	12	AP	143	25.85	2.64	2.50	7.94	283.35	7.74	84.77	0.54	7.60	2.62
LC	4	221894	1	0	0	AP	282	24.74	2.62	2.55	10.02	306.90	6.26	116.85	0.64	7.45	2.57
LC	4	221894	1	12	50	CK1	076	27.06	2.64	1.86	15.18	269.47	5.94	72.18	0.72	7.50	2.15
LC	4	221894	1	12	50	CK1	047	24.94	2.67	1.59	14.81	219.35	5.98	65.67	0.81	7.80	
LC	4	221894	1	50	60	CK2	046	25.59	3.20	1.50	13.42	192.81	5.80	56.72	1.01	7.80	
LC	4	221894	2	0	8	AP	043	26.56	2.84	1.81	12.95	245.88	6.51	74.63	0.69	7.70	2.55
LC	4	221894	2	0	0	AP	415	24.77	2.80	2.98	7.20	265.66	6.65	100.00	0.71	7.50	2.45
LC	4	221894	2	8	30	CK1	062	26.56	3.20	2.05	12.26	291.87	5.10	77.61	0.16	7.90	1.90

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LC	4	221894	2	30	65	CK2	328	25.80 3.30	2.50 11.88	339.39 5.07	98.88 0.30	7.80	
LC	4	221894	2	30	65	CK2	416	26.28 3.32	3.06 11.70	265.66 5.07	87.50 0.29	7.80	
LC	4	221894	3	0	8	AP	362	24.80 2.62	2.68 9.66	363.46 8.74	85.88 0.53	7.60	2.59
LC	4	221894	3	0	0	AP	361	25.13 2.62	2.42 9.06	371.36 9.79	88.59 0.53	7.55	2.80
LC	4	221894	3	8	30	CK1	012	28.15 2.84	2.24 15.70	297.80 6.23	81.62 1.59	7.80	2.46
LC	4	221894	3	30	60	CK2	011	27.18 2.67	1.16 14.19	297.80 5.88	87.02 0.52	7.90	2.12
LC	4	221894	3	30	60	CK2	173	21.02 3.15	2.59 11.61	241.80 5.59	85.15 0.41	7.85	
LC	4	221894	4	0	8	AP	172	21.02 2.62	2.53 7.93	264.46 6.94	89.64 0.58	7.40	3.11
LC	4	221894	4	0	0	AP	436	26.90 2.64	2.93 5.04	265.14 6.33	93.75 0.77	7.50	3.34
LC	4	221894	4	8	12	B_	437	26.15 2.73	2.89 3.70	277.94 5.31	95.83 0.92	7.60	2.92
LC	4	221894	4	12	30	CCA	058	27.21 2.84	1.87 11.57	268.88 6.51	71.64 0.36	7.85	2.34
LC	4	221894	4	30	60	CK	060	26.24 3.02	2.17 11.34	302.49 5.63	81.19 0.24	7.90	
LC	4	221894	4	30	60	CK	059	26.56 3.02	2.23 12.49	290.11 4.57	82.39 0.28	8.00	
LC	4	221894	5	0	8	AP	423	24.40 2.62	2.81 7.80	297.86 7.34	.87.50 0.59	7.30	2.73
LC	4	221894	5	0	0	AP	422	24.77 2.80	2.76 7.50	289.81 8.74	83.33 0.67	7.40	2.69
LC	4	221894	5	8	30	CK1	182	23.41 2.90	2.36 9.00	319.25 6.00	88.49 0.30	7.50	2.17
LC	4	221894	5	30	60	CK2	421	24.02 2.97	2.85 8.90	277.74 6.12	83.33 0.38	7.60	
LC	4	221894	5	30	60	CK2	482	26.33 3.50	2.89 11.54	285.26 5.13	86.96 0.46	7.90	
LC	5	933967	1	0	8	APK	030	26.45 2.67	2.32 13.28	324.87 8.34	83.58 0.95	7.90	2.77
LC	5	933967	1	0	0	AP	113	24.16 2.64	2.58 15.18	301.61 7.42	89.39 0.49	7.60	2.04
LC	5	933967	1	8	30	CK1	186	24.08 1.57	2.52 13.64	338.03 6.65	84.92 0.34	7.70	1.90
LC	5	933967	1	8	30	CK1	434	25.15 3.17	2.76 10.07	281.76 5.82	79.17 0.39	7.85	
LC	5	933967	1	30	60	CK2	040	25.48 3.20	2.02 14.81	279.75 5.98	75.22 0.53	8.05	
LC	5	933967	2	0	8	APK	459	27.37 2.64	2.89 7.11	295.16 7.02	99.46 0.60	7.50	2.75
LC	5	933967	2	0	0	AP	001	28.47 2.67	1.85 12.08	301.41 8.48	109.23 0.69	7.60	
LC	5	933967	2	8	30	CK1	041	25.81 3.20	2.17 11.34	315.85 5.63	97.91 0.49	7.90	2.16
LC	5	933967	2	8	30	CK1	078	24.80 2.81	1.63 16.65	230.47 5.20	58.35 0.52	7.80	
LC	5	933967	2	30	50	CK2	077	25.77 2.81	1.64 15.67	239.34 4.95	56.54 0.32	7.90	
LC	5	933967	3	0	10	APK	412	24.86 2.97	1.90 9.60	368.00 7.17	90.40 0.42	7.40	2.21
LC	5	933967	3	0	0	AP	444	26.53 2.64	3.10 7.70	270.63 6.16	87.50 0.47	7.50	2.22
LC	5	933967	3	10	30	CK1	055	23.32 3.02	1.65 12.03	233.50 6.51	62.10 0.32	7.85	1.99
LC	5	933967	3	10	30	CK1	159	23.53 3.15	2.40 12.74	287.13 6.10	79.78 0.25	7.80	
LC	5	933967	3	30	65	CK2	170	23.53 3.32	2.44 14.16	298.47 5.59	81.57 0.25	8.00	
LC	5	933967	4	0	10	APK	268	23.58 3.17	2.42 6.60	373.67 10.27	95.64 0.40	7.60	2.31
LC	5	933967	4	0	0	AP	267	22.62 2.99	2.29 12.50	365.71 9.24	89.39 0.40	7.65	2.24
LC	5	933967	4	10	30	CK1	139	24.23 3.17	2.53 12.94	287.13 5.80	84.77 0.36	7.85	1.76
LC	5	933967	4	10	30	CK1	265	22.62 3.17	2.32 15.97	373.67 7.87	74.19 0.27	7.90	
LC	5	933967	4	30	58	CK2	266	23.91 3.34	2.42 14.93	353.79 7.70	84.92 0.36	8.00	
LC	5	933967	5	0	10	AP	150	25.85 2.97	2.53 9.35	302.24 8.80	89.24 0.50	7.60	2.35
LC	5	933967	5	0	0	AP	451	26.53 2.99	2.98 9.19	292.57 7.36	81.67 0.47	7.50	2.47
LC	5	933967	5	10	30	CK1	487	25.60 3.15	2.76 11.83	292.57 5.82	82.61 0.51	7.70	1.88
LC	5	933967	5	10	30	CK1	488	25.60 3.32	2.76 12.43	310.86 6.85	80.00 0.51	7.70	
LC	5	933967	5	30	62	CK2	067	24.80 3.20	1.89 16.19	282.77 7.39	106.77 0.65	7.70	
AS	1	430383	1	8	0	AO	516	4.49 0.53	0.53 18.97	82.79 5.13	21.28 1.63	6.30	2.33
AS	1	430383	1	0	0	AO	121	3.92 0.35	0.55 21.17	150.81 6.68	35.75 2.22	6.30	2.59
AS	1	430383	1	0	20	AC	335	3.02 0.17	0.49 9.95	75.64 2.97	18.88 0.25	6.25	0.52
AS	1	430383	1	20	52	C_	004	3.24 0.18	0.24 7.55	68.58 2.42	29.41 0.60	6.40	
AS	1	430383	2	8	0	AO	115	3.27 0.35	0.50 19.70	91.85 5.63	30.39 1.20	6.30	3.18

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
AS	1	430383	2	0	0	AO	114	3.27 0.18	0.46 17.63	84.60 6.27	26.82 0.94	6.25	2.24
AS	1	430382	2	0	20	AC	024	3.23 0.18	0.40 11.47	46.83 3.11	18.10 0.69	5.95	
AS	1	430382	2	20	62	C_	505	2.62 0.35	0.49 9.77	57.35 2.74	15.49 0.17	6.00	
AS	1	430382	3	10	0	AO	562	2.46 0.53	0.57 17.48	70.22 3.14	17.27 0.46	6.20	1.32
AS	1	430382	3	0	0	AO	508	4.87 0.35	0.66 13.51	117.71 8.04	28.94 1.54	7.40	3.75
AS	1	430382	3	0	40	AC	438	2.27 0.18	0.34 12.44	42.42 2.74	10.00 0.30	6.20	
AS	1	430382	3	40	53	C_	242	2.61 0.18	0.53 6.65	75.54 2.62	17.98 0.04	6.90	
AS	1	430382	4	10	0	AO	374	2.68 0.53	0.50 21.74	108.21 7.00	24.41 1.67	6.25	3.59
AS	1	430382	4	0	0	AO	127	4.25 0.18	0.54 29.40	117.70 8.26	26.82 3.16	6.60	4.01
AS	1	430382	4	0	30	AC	075	2.26 0.18	0.40 9.48	79.78 2.81	15.04 0.12	6.20	0.67
AS	1	430383	4	30	50	C_	348	3.35 0.35	0.60 8.03	96.97 4.63	19.33 0.13	6.20	
AS	1	430383	5.	10	0	AO	281	3.30 0.18	0.60 9.46	101.05 4.35	71.91 0.39	6.75	1.25
AS	1	430383	5	0	0	AO	038	3.23 0.20	0.54 6.00	119.12 2.00	26.87 0.10	6.45	2.12
AS	1	430383	5	0	25	AC	300	2.87 0.26	0.58 6.12	89.83 2.61	22.47 0.07	6.85	0.49
AS	1	430383	5	25	53	C_	247	3.27 0.18	0.49 2.80	101.73 1.75	16.63 0.00	7.00	
AS	2	575304	1	10	0	AO	552	3.50 0.53	0.66 37.25	77.02 4.95	22.68 0.97	5.70	1.84
AS	2	575304	1	0	0	AO	279	2.91 0.35	0.68 19.48	 5.39	 1.42	6.00	1.74
AS	2	575304	1	0	20	AC	521	7.49 0.35	0.57 12.36	71.99 3.08	17.87 0.17	5.90	0.52
AS	2	575304	1	20.	52	C_	069	1.93 0.18	0.60 6.48	30.08 3.69	30.08 0.16	6.50	
AS	2	575304	2	10	0	AO	275	1.94 0.26	0.65 19.76	95.40 3.65	29.32 0.60	6.10	1.56
AS	2	575304	2	0	0	AO	524	3.74 0.35	0.68 21.84	93.59 5.13	26.81 1.07	6.10	1.91
AS	2	575304	2	0	40	AC	536	3.50 0.44	0.76 11.21	75.19 3.94	20.68 0.21	6.20	0.45
AS	2	575304	2	40	54	C_	556	3.87 0.35	0.67 9.46	80.46 3.76	21.36 0.13	6.30	
AS	2	575304	3	12	0	AO	276	1.94 0.35	0.66 36.17	127.21 5.22	31.29 1.63	5.70	1.70
AS	2	575304	3	0	0	AO	569	3.52 0.53	0.76 37.25	91.79 6.14	28.18 1.39	5.60	1.81
AS	2	575304	3	0	8	AE	425	3.37 0.35	0.75 26.67	84.53 5.73	33.33 0.60	5.55	1.10
AS	2	575304	3	8	70	BMG	023	8.07 0.36	0.69 36.23	207.56 11.76	47.76 3.79	6.10	3.30
AS	2	575304	3	8	70	BMG	404	4.70 0.53	0.74 28.50	135.00 3.94	33.45 0.75	5.70	1.55
AS	2	575304	3	70	83	CG	145	4.20 0.35	0.53 12.35	98.23 2.11	21.42 0.00	6.25	0.44
AS	2	575304	4	6	0	AO	532	5.25 0.35	0.83 25.87	132.03 6.67	39.91 0.86	5.90	1.98
AS	2	575304	4	0	0	AO	405	4.70 0.70	0.74 39.00	154.00 19.24	49.72 2.60	5.60	3.38
AS	2	575304	4	0	8	AH1	543	3.50 0.35	0.79 21.27	139.37 6.93	31.75 0.60	6.20	1.60
AS	2	575304	4	8	40	AH2	406	3.70 0.35	0.66 12.60	108.00 3.50	27.12 0.25	6.10	1.24
AS	2	575304	4	40	57	C_	551	2.91 0.35	0.70 7.61	71.52 1.88	19.05 0.13	6.50	
AS	2	575304	5	4	0	AO	560	4.57 0.53	0.76 28.66	146.29 5.46	40.91 1.89	6.30	2.12
AS	2	575304	5	0	0	AO	246	4.25 0.53	0.66 18.05	133.18 7.70	38.65 2.16	6.60	2.62
AS	2	575304	5	0	40	AH	241	5.88 0.35	0.73 38.19	192.37 8.04	44.94 1.57	5.90	2.52
AS	2	575304	5	0	40	AH	553	2.09 0.39	0.72 22.93	88.02 2.48	22.68 0.27	5.70	0.77
AS	2	575304	5	40	72	C_	015	2.91 0.36	0.55 19.93	97.46 2.08	18.00 0.60	6.10	
AS	3	733442	1	0	6	AH	390	4.36 0.53	0.68 8.15	146.86 7.00	 0.92	6.80	1.55
AS	3	733442	1	0	0	A_	377	3.02 0.18	0.67 6.04	114.01 6.12	27.12 0.57	7.20	0.96
AS	3	733442	1	6	20	AE	491	5.12 0.18	0.74 5.62	109.71 4.11	18.70 0.17	6.70	0.66
AS	3	733442	1	20	50	BH	529	5.24 0.35	0.82 15.81	137.50 5.13	24.26 0.47	6.30	1.18
AS	3	733442	1	50	65	BC	158	3.77 0.53	0.78 5.95	151.12 2.54	22.41 0.04	6.80	
AS	3	733442	1	65	78	CK	002	4.85 0.18	0.81 12.48	223.80 	18.21 0.08	7.80	
AS	3	733442	2	0	10	AH	144	3.88 0.18	0.63 8.82	128.45 5.63	21.42 0.05	6.40	0.58
AS	3	733442	2	0	10	AH	443	1.80 0.18	0.81 6.52	90.70 3.59	20.00 0.26	6.00	0.45
AS	3	733442	2	0	0	A_	442	2.65 0.35	0.82 8.52	124.34 6.16	23.33 0.68	6.60	1.18

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
AS	3	733442	2	10	30	BH	049	4.63 0.18	0.66 16.30	182.20 9.00	31.05 1.51	6.60	2.12
AS	3	733442	2	30	52	C_	523	2.89 0.35	0.68 7.47	179.98 2.40	17.02 0.26	6.30	
AS	3	733442	3	0	8.	AH	206	2.01 0.09	0.76 19.94	191.55 7.69	27.71 0.90	5.90	1.90
AS	3	733422	3	0	0	A_	579	5.28 0.43	0.86 31.52	182.86 8.88	30.46 1.47	5.80	2.85
AS	3	733422	3	8	25	BH	580	5.31 0.53	0.80 31.52	201.14 5.97	49.72 2.27	6.20	2.61
AS	3	733442	3	25	70	BC	571	4.92 0.35	0.89 17.77	186.51 2.56	24.55 0.34	6.40	
AS	3	733442	3	70	81	C_	547	2.10 0.37	0.79 7.02	128.37 1.37	17.69 0.13	6.50	
AS	3	733442	4	0	40	AH	243	4.57 0.35	0.66 22.92	184.97 8.56	29.66 1.08	6.30	1.86
AS	3	733442	4	0	40	AH	238	4.25 0.18	0.72 11.28	136.88 4.62	26.07 0.11	6.40	1.52
AS	3	733442	4	0	0	A_	355	4.02 0.87	0.73 30.19	197.53 9.09	29.83 0.97	5.75	1.97
AS	3	733442	4	40	65	BM	578	5.63 0.35	0.82 8.88	153.60 2.56	21.36 0.08	6.40	0.80
AS	3	733442	4	65	75	C_	375	3.02 0.18	0.62 6.34	103.58 2.54	19.44 0.18	6.70	
AS	3	733442	5	0	40	AH	548	5.25 0.71	0.99 28.66	223.73 6.83	40.82 1.93	6.40	4.13
AS	3	733442	5	0	40	AH	382	5.03 0.35	0.73 18.11	231.88 4.37	34.35 0.18	6.85	1.97
AS	3	733442	5	0	0	A_	538	6.00 0.53	0.92 29.89	220.06 9.58	45.35 2.40	6.20	3.72
AS	3	733442	5	40	65	BM	530	5.60 0.57	0.93 10.32	168.71 2.90	27.21 0.15	6.70	1.11
AS	3	733442	5	65	72	C_	383	5.03 0.53	0.73 9.36	146.86 2.97	24.41 0.81	6.90	0.86
AS	4	663500	1	0	15	AH	258	4.52 0.35	0.80 8.68	151.06 9.24	50.06 0.40	6.90	1.56
AS	4	663500	1	0	0	A_	550	4.20 0.53	0.87 10.32	146.71 7.68	28.12 0.46	6.90	1.53
AS	4	663500	1	15	40	AC	208	4.66 0.18	0.77 6.12	125.81 2.27	28.83 0.04	6.70	1.03
AS	4	663500	1	40	61	C_	514	5.61 0.35	0.88 6.61	95.03 2.40	22.98 0.13	6.60	
AS	4	663500	1	40	61	C_	526	5.61 0.53	0.82 4.89	115.19 1.54	23.49 0.13	7.50	
AS	4	663500	2	0	30	AH	010	4.53 0.45	0.66 21.28	162.44 8.74	33.61 1.12	6.50	1.99
AS	4	663500	2	0	30	AH	585	5.31 0.53	0.91 19.20	149.94 8.43	38.87 0.84	6.30	1.25
AS	4	663500	2	0	0	A_	574	5.87 0.53	0.90 14.04	160.91 5.46	38.18 0.21	6.25	1.74
AS	4	663500	2	30	55	AC	586	5.31 0.35	0.96 12.80	153.60 6.14	37.06 0.17	6.30	1.22
AS	4	663500	2	55	69	C_	392	4.69 0.53	0.76 4.20	128.31 2.27	 0.25	7.80	0.72
AS	4	663500	3	0	15	AH	334	5.36 0.52	0.78 14.77	213.33 9.44	44.94 1.10	6.60	2.15
AS	4	663500	3	0	0	A_	515	6.36 0.53	0.85 28.74	187.18 9.24	59.57 0.94	6.10	2.19
AS	4	663500	3	15	25	AE	581	6.73 0.53	0.91 12.61	164.57 4.61	40.68 0.21	6.60	1.39
AS	4	663500	3	25	60	BM	582	6.73 0.64	1.03 10.03	164.57 4.78	44.29 0.13	6.60	1.32
AS	4	663500	3	60	66	C_	292	4.62 0.53	0.89 7.84	119.77 3.57	44.94 0.11	6.70	
AS	4	663500	4	0	25	AH	501	7.49 0.53	0.91 40.24	187.18 12.66	55.32 2.01	6.10	2.92
AS	4	663500	4	0	25	AH	537	5.60 0.53	1.04 35.35	190.72 7.87	45.35 0.47	6.00	2.57
AS	4	663500	4	0	0	A_	264	6.46 0.53	0.90 27.78	242.48 15.06	53.63 2.20	6.10	3.52
AS	4	663500	4	25	50	BM	325	6.40 0.70	0.92 16.70	164.57 5.77	35.96 0.21	6.30	1.42
AS	4	663500	4	50	56	C_	324	6.40 0.78	0.94 14.29	146.29 4.02	32.36 0.34	6.40	
AS	4	663500	5	0	25	AH	245	5.22 0.18	0.78 21.68	221.97 11.89	44.94 2.50	6.45	3.25
AS	4	663500	5	0	25	AH	343	7.37 0.35	0.89 18.62	232.73 6.65	38.65 0.68	6.60	2.75
AS	4	663500	5	0	0	A_	344	5.36 0.70	0.81 23.76	267.64 9.79	49.44 2.37	6.30	3.49
AS	4	663500	5	25	60	BM	570	5.98 0.53	0.82 10.32	135.31 2.39	23.64 0.13	6.80	1.11
AS	4	663500	5	60	75	C_	542	3.50 0.53	0.88 7.90	132.03 2.00	22.68 0.13	6.90	
AS	5	223327	1	0	20	AH	072	1.93 0.53	0.45 19.43	88.64 2.64	16.84 0.16	6.00	1.51
AS	5	223327	1	0	0	A_	061	2.92 0.75	0.44 20.36	91.99 3.87	16.72 1.01	6.20	1.95
AS	5	223327	1	20	60	AC	380	3.35 0.18	0.51 9.96	65.70 1.57	17.18 0.13	7.85	0.85
AS	5	223327	1	60	72	C_	430	2.25 0.18	0.66 5.33	62.79 0.86	15.83 0.11	6.65	
AS	5	223327	2	0	25	AH	429	4.50 0.35	0.58 21.93	68.43 3.77	18.25 0.60	5.75	1.56
AS	5	223327	2	0	0	A_	489	4.39 0.35	0.52 38.46	82.29 7.02	20.87 1.31	5.50	1.60

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm)	DTPA Cu (ppm)	TOTAL Fe (%)	DTPA Fe (ppm)	TOTAL Mn (ppm)	DTPA Mn (ppm)	TOTAL Zn (ppm)	DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
AS	5	223327	2	25	50	AC	413	3.36	0.35	0.52	10.20	82.00	1.57		0.17	6.40	0.89
AS	5	223327	2	50	60	C_	223	2.00	0.18	0.43	4.55	48.02	1.22	13.86	0.04	6.40	
AS	5	223327	3	0	30	AH	224	2.66	0.00	0.45	18.89	84.51	3.15	19.84	0.70	5.95	1.79
AS	5	223327	3	0	0	A_	258	2.91	0.18	0.46	20.83		6.33	44.69	2.16	6.15	1.89
AS	5	223327	3	30	45	AC	128	3.27	0.18	0.45	12.35	77.24	2.29	19.67	0.00	6.50	0.89
AS	5	223327	3	45	60	C_	248	2.29	0.18	0.46	7.29	59.19	2.05	16.18	0.07	7.00	
AS	5	223327	4	0	45	AH	174	4.39	0.35	0.56	31.15	113.34	5.76	32.27	1.24	6.40	1.86
AS	5	223327	4	0	45	AH	269	3.88	0.18	0.60	15.28	115.28	6.16	28.61	0.40	6.40	1.20
AS	5	223327	4	0	0	A_	260	3.23	0.35	0.50	18.05	99.38	9.93	27.71	1.89	6.10	2.07
AS	5	223327	4	45	69	C_	261	5.17	0.35	0.17	12.15	103.35	6.33	26.37	0.32	6.20	
AS	5	223327	5	0	40	AH	262	6.14	0.53	0.78	25.69	99.38	12.66	44.69	0.40	6.05	2.45
AS	5	223327	5	0	0	A_	349	8.04	0.70	0.80	25.69	131.88	11.19	30.88	0.42	6.10	2.35
AS	5	223327	5	40	50	AC	350	6.70	0.53	0.79	19.45	128.78	8.35	29.84	0.22	6.15	1.45
AS	5	223327	5	50	68	C_	027	6.45	0.71	0.46	15.70	115.51	9.69	26.87	0.90	6.70	
LS	1	396549	1	0	10	AP	065	13.93	1.07	1.13	74.02	300.72	22.86	68.06	2.34	5.60	4.11
LS	1	396549	1	0	0	A_	022	14.84	1.07	1.06	72.45	279.75	25.95	63.88	2.58	6.10	3.85
LS	1	396549	1	10	21	BM1	064	12.63	1.07	1.38	15.27	201.66	10.73	50.75	0.18	6.60	1.69
LS	1	396549	1	21	40	BM2	066	12.31	1.24	1.16	13.42	183.97	4.57	37.12	0.36	5.80	1.38
LS	1	396549	1	40	60	CCA	021	16.18	1.78	1.25	15.70	227.41	8.65	45.01	0.60	8.25	
LS	1	396549	2	0	10	AP	249	11.43	0.88	1.34	10.42	266.36	23.96	76.40	1.08	6.80	3.28
LS	1	396549	2	0	0	A_	250	11.10	0.53	1.27	12.94	270.06	33.22	59.33	0.95	6.65	3.18
LS	1	396549	2	10	15	BM	486	10.61	0.35	1.40	38.46	208.46	7.02	46.96	1.31	6.90	1.29
LS	1	396549	2	15	30	BMK	485	12.43	1.40	1.37	8.88	241.37	2.23	65.22	0.21	7.65	1.11
LS	1	396549	2	30	70	CCA	396	13.44	1.66	1.35	10.80	260.00	3.06	94.92	0.27	8.10	
LS	1	396549	3	0	10	AP	306	13.47	1.22	1.36	16.31	347.43	13.91	75.51	1.63	6.60	3.63
LS	1	396549	3	0	0	A_	146	12.92	1.06	1.34	26.46	294.69	24.62	72.28	1.76	6.65	3.49
LS	1	396549	3	10	20	BM1	304	11.45	1.05	1.53	23.22	256.00	6.09	67.42	0.13	6.05	1.01
LS	1	396549	3	20	30	BM2	194	10.03	0.70	1.41	16.79	217.84	7.00	49.16	0.09	6.35	1.00
LS	1	396549	3	30	70	CCA	149	14.22	1.93	1.49	11.76	260.69	2.46	58.90	0.09	7.75	
LS	1	396549	4	0	10	AP	455	13.64	1.41	1.45	77.04	274.29	29.09	70.83	3.08	5.40	4.20
LS	1	396549	4	0	0	A_	424	12.01	1.06	1.47	71.11	317.99	32.51	70.83	2.65	5.40	4.28
LS	1	396549	4	10	20	BM1	384	12.40	1.22	1.72	17.51	266.67	10.14	72.32	0.53	6.45	1.69
LS	1	396549	4	20	30	BM2	257	11.79	1.58	1.27	10.07	244.47	6.67	46.06	0.09	7.10	1.14
LS	1	396549	4	30	45	CCA	483	10.97	1.12	1.25	7.69	230.40	2.57	43.48	0.17	7.55	
LS	1	396549	4	45	68	CK	381	11.39	1.22	1.20	8.45	251.21	3.15	56.05	0.48	7.85	
LS	1	396549	5	0	12	AP	111	14.37	1.06	1.18	41.16	264.83	29.01	62.57	1.74	6.10	2.93
LS	1	396549	5	0	0	A_	056	15.55	0.89	1.03	18.87	240.58	20.76	53.73	1.51	6.70	3.42
LS	1	396549	5	12	20	BM	057	10.36	1.07	0.89	8.10	166.28	4.04	38.81	0.24	7.60	1.90
LS	1	396549	5	20	35	BMK	453	12.88	1.23	1.56	8.00	197.49	3.42	46.67	0.26	7.50	1.39
LS	1	396549	5	35	45	CCA	454	12.88	1.23	1.49	7.41	234.06	2.74	41.67	0.17	7.55	
LS	1	396549	5	45	68	CK	408	14.11	1.75	1.41	9.60	256.00	2.45	59.66	0.21	7.50	
LS	2	294368	1	0	8	AP	215	13.63	0.53	1.57	31.48	345.74	26.23	67.04	1.20	5.80	2.80
LS	2	294368	1	0	0	A_	216	13.63	0.53	1.54	25.88	326.53	34.97	66.15	0.99	5.90	2.80
LS	2	294368	1	8	20	BM1	217	13.30	0.53	1.97	13.99	284.27	6.12	67.93	0.17	6.05	1.45
LS	2	294368	1	20	25	BM2	218	13.30	0.87	1.54	108.47	280.43	.34	49.16	0.09	6.65	1.20
LS	2	294368	1	25	58	C_	433	15.02	1.58	1.45	7.41	261.64	2.40	37.50	0.21	7.80	
LS	2	294368	2	0	6	APK	168	17.57	2.10	1.66	9.50	279.58	7.96	62.75	0.33	7.70	2.45
LS	2	294368	2	0	0	A_	018	20.06	1.60	1.55	9.06	333.90	11.24	93.62	1.20	7.90	3.01

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LS	2	294368	2	6	16	BMK	020	22.00 2.31	1.26 13.89	243.66 2.77	56.66 1.98	8.10	2.12
LS	2	294368	2	16	30	CCA1	019	23.94 2.31	1.49 15.70	292.39 3.46	60.02 0.43	8.20	
LS	2	294368	2	30	52	CCA2	409	21.84 2.62	1.90 12.30	380.00 3.32	72.32 0.29	7.90	
LS	2	294368	3	0	10	AP	410	21.84 2.62	1.90 18.00	420.00 19.24	86.78 1.30	6.50	3.70
LS	2	294368	3	0	0	A_	230	19.28 2.11	1.82 17.36	403.36 25.67	80.45 1.98	6.80	3.63
LS	2	294368	3	10	20	BM	091	28.29 3.69	1.43 22.04	221.61 10.89	54.14 0.32	6.25	2.57
LS	2	294368	3	20	35	CCA1	090	24.96 1.93	1.38 10.29	248.20 2.64	57.14 0.23	7.65	
LS	2	294368	3	35	50	CCA2	166	23.53 1.92	1.80 9.07	347.58 3.56	62.75 0.08	7.65	1.52
LS	2	294368	4	0	6	AP	165	18.82 1.92	1.82 50.97	347.58 38.94	73.50 1.16	6.10	4.18
LS	2	294368	4	0	0	A_	164	19.45 2.10	1.77 53.81	321.13 55.87	75.29 1.53	5.90	4.49
LS	2	294368	4	6	15	AB	163	23.53 1.75	2.47 10.14	279.58 5.77	85.15 0.22	7.55	1.65
LS	2	294368	4	15	30	BM	092	22.96 1.85	1.18 10.04	202.11 2.31	45.11 0.20	7.60	1.29
LS	2	294368	4	30	60	CCA	005	23.30 1.96	1.49 11.77	301.41 2.25	58.82 0.52	7.80	
LS	2	294368	5	0	10	AP	287	18.14 1.57	1.71 20.04	381.75 19.13	89.89 1.59	6.50	4.41
LS	2	294368	5	0	0	A_	288	18.14 1.57	1.71 20.87	381.75 16.52	85.39 1.66	6.60	4.93
LS	2	294368	5	10	20	ABI	892	04.51 2.45	.81 13.36	351.81 9.74	86.29 0.86	7.80	3.06
LS	2	294368	5	20.	28	BM	346	20.78 2.78	1.81 13.16	329.70 4.90	82.70 0.34	8.75	1.24
LS	2	294368	5	28	70	CCA1	175	17.88 3.32	1.80 20.96	287.13 4.40	71.71 0.58	9.10	
LS	2	294368	5	70	80	CCA2	176	17.57 3.06	1.76 15.72	275.80 3.39	67.23 0.21	9.10	
LS	3	093257	1	0	10	AP	094	13.98 0.88	0.94 41.63	203.88 21.44	51.13 0.99	5.75	2.15
LS	3	093257	1	0	0	A_	095	13.98 0.88	1.17 39.18	265.93 23.09	60.15 0.94	5.80	2.36
LS	3	093257	1	10	25	BM1	096	12.98 1.06	1.49 36.74	258.84 8.25	51.13 0.32	5.86	1.46
LS	3	093257	1	25	30	BM2	093	11.98 1.41	1.14 26.94	223.38 5.94	42.11 0.23	6.00	1.18
LS	3	093257	1	30	65	CCA	177	15.05 1.92	1.47 12.46	270.42 3.05	72.40 0.15	7.50	
LS	3	093257	2	0	10	AP	178	12.04 1.05	1.48 31.15	300.47 23.70	68.83 0.74	6.30	2.14
LS	3	093257	2	0	0	A_	439	11.75 1.06	1.49 23.70	234.06 18.82	54.17 0.94	6.00	2.36
LS	3	093257	2	10	17	BM1	323	13.14 1.57	1.47 11.56	237.71 8.57	54.83 0.21	6.40	1.22
LS	3	093257	2	17	25	BM2	322	13.47 1.57	1.36 10.60	237.71 5.25	47.64 0.21	7.15	1.08
LS	3	093257	2	25	40	CCA1	321	13.47 1.39	1.23 8.67	245.03 2.27	48.54 0.21	7.70	
LS	3	093257	2	40	70	CCA2	179	12.71 1.40	1.43 11.04	247.89 2.54	55.42 0.17	8.00	
LS	3	093257	3	0	8	AP	333	11.73 1.22	1.25 19.26	310.30 20.98	64.74 0.93	6.30	2.43
LS	3	093257	3	0	0	A_	101	11.65 1.06	1.01 29.40	235.79 32.53	45.11 0.99	6.15	2.68
LS	3	093257	3	8	20	BM1	203	13.04 1.05	1.85 10.49	244.13 5.07	51.84 0.13	7.10	1.20
LS	3	093257	3	20	30	BM2	073	14.17 1.78	1.01 10.18	230.47 4.92	33.68 0.12	7.40	1.30
LS	3	093257	3	30	52	CCA	074	11.27 1.24	0.82 7.40	168.42 2.11	28.27 0.24	7.80	
LS	3	093257	4	0	10	AP	180	11.70 1.22	1.35 36.81	307.98 25.40	67.04 0.83	5.80	2.38
LS	3	093257	4	0	0	A_	205	10.03 0.35	1.35 23.78	307.98 18.36	62.57 0.93	5.80	2.52
LS	3	093257	4	10	15	BM	295	11.88 1.40	1.58 11.97	243.28 10.44	62.92 0.17	6.35	1.49
LS	3	093257	4	15	40	BMK	448	13.26 1.23	1.72 7.70	201.14 3.42	51.67 0.21	7.60	0.97
LS	3	093257	4	40	52	CCA	013	13.59 1.24	1.18 8.15	238.24 2.94	40.21 0.43	8.00	
LS	3	093257	5	0	10	AP	419	11.64 1.40	1.36 51.00	322.01 26.23	62.50 2.18	5.60	3.94
LS	3	093257	5	0	0	A_	418	11.26 1.22	1.45 48.00	301.89 29.73	75.00 1.68	5.60	3.73
LS	3	093257	5	10	20	AH	235	11.97 1.06	1.43 16.67	345.74 15.06	66.15 0.14	6.60	1.62
LS	3	093257	5	20	35	AE	028	13.23 0.89	0.56 13.59	221.99 11.07	50.75 0.52	6.90	1.51
LS	3	093257	5	35	60	BT	029	11.84 1.24	1.19 15.70	184.10 3.29	47.76 1.72	7.75	1.34
LS	4	329211	1	0	10	AP	435	16.89 1.41	1.83 35.56	322.01 32.51	79.17 1.41	5.90	3.86
LS	4	329211	1	0	0	A_	564	15.82 1.50	1.69 31.52	365.71 25.60	66.18 1.13	6.00	3.96
LS	4	329211	1	10	30	BM1	157	14.12 1.22	1.87 13.59	264.46 9.82	68.12 0.17	6.70	1.41

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LS	4	329211	1	30	52	BM2	596	14.16 1.29	1.94 12.80	237.71 7.85	58.76 0.25	7.00	1.25
LS	4	329211	1	52	62	CCA	593	20.18 2.12	2.11 12.23	347.43 4.35	58.76 0.17	7.60	
LS	4	329211	2	0	8	AP	594	14.16 1.39	1.60 72.53	336.46 39.25	67.80 2.26	5.40	4.13
LS	4	329211	2	0	0	A_	511	16.84 1.57	1.57 57.49	341.96 41.07	76.60 2.31	5.40	3.82
LS	4	329211	2	8	20	BM1	565	13.71 1.24	1.31 10.03	204.80 9.39	54.55 0.17	6.40	1.56
LS	4	329211	2	20	40	BM2	507	14.97 1.47	1.81 11.50	251.97 6.16	52.77 0.39	6.90	1.18
LS	4	329211	2	40	55	CCA	388	16.08 1.75	1.55 9.30	309.18 4.55	67.80 0.27	7.75	1.14
LS	4	328211	2	55	73	CK	481	20.11 2.10	1.76 10.65	325.49 2.74	56.52 0.21	7.80	
LS	4	329211	3	0	6	AP	016	17.15 1.06	1.28 78.37	355.56 37.94	75.62 2.83	5.85	4.76
LS	4	329211	3	0	0	A_	592	15.93 1.36	1.65 71.11	402.29 31.57	74.12 3.10	5.30	1.01
LS	4	329211	3	6	20	AB	363	14.07 1.40	1.43 57.36	383.21 17.49	75.93 0.97	5.40	2.76
LS	4	329211	3	20	35	BM1	595	13.45 1.04	2.24 19.34	256.00 10.41	72.32 0.21	6.20	1.32
LS	4	329211	3	35	60	BM2	563	14.07 1.59	1.61 14.90	288.91 6.32	54.55 0.13	6.50	1.15
LS	4	328211	3	60	68	CCA	417	18.77 2.27	2.13 9.30	322.01 3.85	62.50 0.17	7.65	
LS	4	329211	4	0	8	AP	541	13.99 1.35	1.76 54.45	381.43 25.60	78.01 3.02	5.70	6.25
LS	4	329211	4	0	0	A_	407	15.45 1.22	1.55 54.00	436.00 34.97	90.40 3.18	5.60	6.25
LS	4	329211	4	8	21	AB	534	14.69 1.05	1.87 12.65	337.42 7.70	71.66 1.46	7.05	4.79
LS	4	328211	4	21	35	BM1	554	18.99 1.59	2.20 12.32	290.74 6.14	68.18 0.42	7.10	3.20
LS	4	329211	4	35	55	BM2	598	15.58 1.57	1.67 9.96	274.29 3.93	63.28 0.46	7.40	1.98
LS	4	328211	4	55	62	CCA	286	12.54 1.22	1.32 6.96	261.99 2.09	53.93 0.09	7.75	
LS	4	329211	5	0	8	AP	597	16.28 1.22	1.86 12.52	347.43 13.14	80.45 0.96	7.20	4.59
LS	4	329211	5	0	0	A_	389	16.75 1.22	1.46 21.00	425.12 19.24	95.63 1.51	7.00	5.05
LS	4	329211	5	8	25	BM1K	401	11.76 0.88	1.41 6.00	296.00 4.20	76.84 0.29	8.00	1.31
LS	4	328211	5	25	50	BM2K	014	14.24 1.07	1.58 11.47	261.70 4.50	54.01 0.52	7.90	2.30
LS	4	329211	5	50	68	CCA	468	14.60 1.40	1.51 7.99	280.77 1.88	43.24 0.21	7.75	
LS	5	264427	1	0	8	AP	037	13.55 1.07	1.18 57.83	292.39 23.74	59.70 1.74	5.55	3.59
LS	5	264427	1	0	0	A_	036	13.55 0.98	1.10 57.83	267.12 27.25	54.83 1.64	5.60	3.68
LS	5	264427	1	8	25	BM1	035	13.55 0.71	1.74 15.70	281.56 5.88	69.25 0.65	6.50	1.73
LS	5	264427	1	25	50	BM2	034	12.90 0.89	1.31 10.26	205.75 4.67	41.79 0.86	7.00	1.51
LS	5	264427	1	50	56	CCA	576	14.07 1.42	1.58 6.88	329.14 2.56	47.27 0.29	7.60	
LS	5	264427	2	0	6	AP	572	15.47 1.35	1.63 42.99	292.57 22.19	63.64 1.09	5.60	2.71
LS	5	264427	2	0	0	A_	120	13.06 1.23	1.45 46.53	272.18 26.39	64.36 1.39	5.90	3.18
LS	5	264427	2	6	25	AH	117	11.10 1.06	1.38 26.46	235.40 13.01	55.42 0.41	6.10	2.45
LS	5	264427	2	25	45	BM	119	12.74 1.06	1.49 12.35	264.83 7.56	57.21 0.05	6.65	1.59
LS	5	264427	2	45	52	CCA	118	11.43 1.06	1.10 6.47	183.91 2.11	41.12 0.14	7.80	
LS	5	264427	3	0	7	AP	116	12.41 1.06	1.32 57.55	294.25 23.92	67.04 1.84	5.50	3.28
LS	5	264427	3	0	0	A_	561	12.31 1.24	1.64 60.18	314.51 27.31	77.27 1.56	5.50	3.60
LS	5	264427	3	7	25	AH	535	12.59 1.05	2.12 18.40	238.40 8.04	67.12 0.26	6.30	1.49
LS	5	264427	3	25	40	BM1	167	11.28 1.40	1.25 12.18	170.01 3.39	39.44 0.08	6.90	1.14
LS	5	264427	3	40	55	BM2	299	11.22 1.05	1.21 9.73	187.14 2.44	62.92 0.13	7.40	0.75
LS	5	264427	3	55	62	CCA	007	13.81 1.07	1.31 8.76	189.51 1.73	43.81 0.77	7.90	
LS	5	264427	4	0	8	AP	528	14.97 1.22	1.45 77.61	338.36 35.94	76.60 2.48	5.35	4.10
LS	5	264427	4	0	0	A_	237	14.69 1.06	1.38 55.55	355.15 39.36	77.75 2.70	5.40	4.18
LS	5	264427	4	8	25	AH	226	11.64 0.35	1.42 15.04	368.79 4.90	75.08 0.13	6.85	1.52
LS	5	264427	4	25	45	BM1	225	10.97 0.70	1.82 17.14	303.48 2.45	67.04 0.09	6.60	1.34
LS	5	264427	4	45	65	BM2	555	11.96 1.06	1.94 15.19	288.92 5.38	54.55 0.17	6.80	0.87
LS	5	264427	4	65	80	CCA	531	17.49 1.92	1.87 9.49	308.08 2.74	77.10 0.21	7.70	
LS	5	264427	5	0	6	AP	506	14.97 1.22	1.32 103.47	381.55 29.10	85.11 4.71	5.40	5.14

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm)	DTPA Cu (ppm)	TOTAL Fe (%)	DTPA Fe (ppm)	TOTAL Mn (ppm)	DTPA Mn (ppm)	TOTAL Zn (ppm)	DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
LS	5	264427	5	0	0	A_	533	15.74	1.05	1.58	91.98	377.77	34.23	86.17	4.71	5.45	5.48
LS	5	264427	5	6	20	AH	512	16.46	1.12	1.67	51.74	331.16	7.70	76.60	0.47	5.75	1.98
LS	5	264427	5	20	45	BM1	307	16.17	1.05	1.56	24.47	362.06	6.44	89.89	0.26	6.10	1.59
LS	5	264427	5	45	70	BM2	204	10.03	0.87	1.68	18.97	270.42	4.83	49.16	0.19	6.40	0.83
LS	5	264427	5	70	75	CCA	540	19.24	1.84	2.00	10.60	271.40	2.56	68.03	0.25	7.55	
GT	1	297792	1	0	10	AP	379	14.74	1.22	1.27	8.45	297.59	9.09	63.28	0.48	7.85	2.42
GT	1	297792	1	0	0	A_	378	14.41	1.22	1.30	8.15	309.18	9.44	67.80	0.44	7.80	2.49
GT	1	297792	1	10	30	CCA	233	13.30	2.46	1.29	13.89	268.91	4.62	46.48	0.18	7.90	1.52
GT	1	297792	1	30	52	CK	126	13.71	1.41	1.34	9.99	308.97	3.34	49.16	0.09	8.00	
GT	1	297792	2	0	8	APK	308	13.47	1.39	1.14	7.22	248.69	2.96	32.36	0.09	7.60	1.07
GT	1	297792	2	0	0	A_	087	13.53	1.76	0.75	4.16	180.83	5.44	28.27	0.27	7.85	1.32
GT	1	297792	2	8	20	AB	100	12.81	1.06	1.09	6.12	255.29	3.30	35.79	0.14	7.90	0.70
GT	1	297792	2	20	35	BMK1	099	13.31	1.06	1.05	10.04	258.84	2.31	37.29	0.18	8.30	0.52
GT	1	297792	2	20	35	BMK2	098	13.65	1.06	0.99	8.57	248.20	2.97	38.50	0.18	8.40	0.52
GT	1	297792	2	35	70	CCA	097	13.65	1.06	1.09	9.31	258.84	2.64	38.50	0.36	8.30	
GT	1	297792	3	0	10	APK	320	15.16	1.57	1.42	10.60	274.29	4.20	50.34	0.17	7.35	1.74
GT	1	297792	3	0	0	A_	319	13.47	1.57	1.22	9.31	252.34	5.60	36.85	0.30	7.50	2.12
GT	1	297792	3	10	20	BMK	318	14.82	1.91	1.09	6.74	256.00	2.45	32.36	0.17	7.55	1.34
GT	1	297792	3	20	32	CCA	317	13.47	1.74	1.10	7.71	263.31	3.32	34.16	0.30	7.65	0.79
GT	1	297792	3	32	50	CK	316	14.15	2.26	1.17	8.35	270.63	3.50	34.16	0.34	7.80	
GT	1	297792	4	0	6	APK	315	12.13	0.87	1.17	8.03	296.23	9.09	44.94	0.64	7.30	3.07
GT	1	297792	4	0	0	A_	367	11.39	1.22	1.11	8.15	316.05	8.57	47.01	0.66	7.80	2.97
GT	1	297792	4	6	16	AH	366	11.39	1.02	1.16	21.74	300.25	4.37	47.91	0.35	7.10	2.66
GT	1	297792	4	16	40	AB	365	10.05	1.05	1.21	18.72	296.30	6.12	49.72	0.26	7.00	1.48
GT	1	297792	4	40	82	BM	364	14.07	1.92	1.29	13.28	264.69	6.47	45.20	0.22	6.70	1.24
GT	1	297792	5	0	10	AP	376	15.08	1.22	1.11	12.08	382.61	10.50	80.40	1.71	7.60	5.05
GT	1	297792	5	0	0	A_	339	14.74	1.39	1.37	9.63	372.36	11.19	65.62	1.14	7.25	4.22
GT	1	297792	5	10	25	AH	469	16.78	1.75	1.59	23.08	460.74	2.74	69.19	0.84	6.70	2.61
GT	1	297792	5	25	80	BM	470	18.24	2.27	2.21	13.02	460.74	3.08	93.41	0.67	7.00	1.74
GT	1	297792	5	80	90	CCA	386	16.42	1.92	1.56	11.17	436.72	1.57	90.40	1.54	8.10	
GT	2	382825	1	0	15	APK	089	9.34	0.88	0.93	8.94	186.15	7.75	35.49	0.36	7.60	1.67
GT	2	382825	1	0	0	A_	088	8.70	0.88	0.78	7.10	163.10	6.60	36.09	0.36	7.70	1.60
GT	2	382825	1	15	35	CCA	017	14.24	1.42	1.24	9.96	234.63	4.32	110.43	0.43	7.90	1.57
GT	2	382825	1	35	52	CK	109	9.65	0.88	0.78	7.59	175.51	1.65	27.07	0.14	8.00	
GT	2	382825	1	35	52	CK	107	9.32	0.88	0.85	6.47	182.60	2.29	30.08	0.00	8.20	
GT	2	382825	2	0	10	APK	296	11.88	1.05	1.16	6.68	220.82	7.13	44.94	0.34	7.65	1.98
GT	2	382825	2	0	0	A_	397	11.42	1.22	1.19	6.30	240.00	7.34	41.58	0.34	7.90	1.93
GT	2	382825	2	10	25	AHK	398	10.08	1.57	0.90	5.40	160.00	2.27	28.02	0.17	8.20	1.07
GT	2	382825	2	25	40	CCA	042	8.72	1.16	0.74	7.52	152.13	2.55	36.42	0.14	8.00	
GT	2	382825	2	40	82	CK	132	15.67	1.93	1.41	10.88	331.03	3.52	52.74	0.27	8.40	
GT	2	382825	3	0	9	AP	131	9.47	0.88	1.13	21.76	224.37	15.47	44.69	0.81	6.70	2.97
GT	2	382825	3	0	0	A_	129	9.47	0.88	1.21	14.70	220.69	11.96	50.06	0.50	6.90	2.55
GT	2	382825	3	9	20	BT1	130	10.45	1.23	1.57	21.76	176.55	5.45	46.48	0.09	6.25	1.31
GT	2	382825	3	20	30	BT2	134	18.90	3.17	1.53	13.53	228.57	6.15	48.63	0.14	7.30	1.31
GT	2	382825	3	30	52	CCA	189	16.05	1.92	1.16	7.08	244.13	3.05	44.69	0.41	7.85	
GT	2	382825	4	0	8	AP	188	9.70	0.87	1.13	18.12	330.52	13.55	57.21	1.49	6.95	3.77
GT	2	382825	4	0	0	A_	187	10.70	0.53	1.15	18.19	356.81	15.74	67.04	1.63	6.70	3.80
GT	2	382825	4	8	18	BT1	256	9.80	1.06	1.42	18.75	240.46	9.24	52.14	0.14	6.30	1.38

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
GT	2	382825	4	18	30	BT2	395	9.41 1.05	1.26 11.10	260.00 6.47	31.64 0.17	6.75	0.76
GT	2	382825	4	30	56	CCA	394	13.10 1.75	1.03 5.70	220.00 2.62	32.54 0.13	8.10	
GT	2	382825	5	0	8	AP	026	14.19 1.07	0.98 45.28	292.39 17.30	53.73 2.67	6.80	5.45
GT	2	382825	5	0	0	A_	399	14.19 1.07	0.98 45.28	292.39 17.30	53.73 2.67	6.80	5.45
GT	2	382825	5	8	20	AH	171	9.41 1.22	1.31 50.97	317.36 8.30	58.26 0.95	6.05	2.17
GT	2	382825	5	20	36	BT1	207	11.70 1.05	1.75 16.44	311.74 9.09	62.57 0.13	6.20	1.17
GT	2	382825	5	36	54	BT2	393	12.93 1.57	1.55 14.55	276.00 6.65	47.46 0.27	6.80	1.07
GT	2	382825	5	54	80	CCA	476	14.60 1.75	1.53 8.28	251.97 3.25	47.57 0.21	7.40	
GT	3	443991	1	0	7	AP	211	10.64 0.53	1.13 41.97	307.32 11.89	53.63 0.90	5.75	3.14
GT	3	443991	1	0	0	A_	331	11.39 1.04	1.15 41.74	306.42 19.24	62.92 1.52	6.00	0.77
GT	3	443991	1	7	20	A_	210	7.98 0.35	1.15 19.59	215.13 7.34	46.48 0.17	6.00	1.34
GT	3	443991	1	20	30	BT	428	11.26 1.06	1.62 12.74	326.04 8.90	58.33 0.30	6.25	1.18
GT	3	443991	1	30	50	B	372	15.08 1.22	1.44 11.17	304.20 8.39	74.12 0.31	6.80	1.34
GT	3	443991	1	50	56	C_	371	11.39 1.22	1.48 9.66	276.54 5.07	54.24 0.13	7.40	
GT	3	443991	2	0	10	AP	461	14.60 1.78	1.45 16.86	179.98 5.05	43.24 0.27	7.00	2.50
GT	3	443991	2	0	0	A_	460	14.60 1.41	1.42 9.19	194.38 5.99	44.97 0.47	7.00	2.78
GT	3	443991	2	10.	35	CCA	133	12.41 1.76	1.10 7.35	217.01 2.11	41.12 0.27	7.75	1.83
GT	3	443991	2	10	35	CCA	370	12.06 1.40	1.08 6.04	237.04 2.27	31.64 0.18	8.00	
GT	3	443991	2	35	40	CK	369	11.39 1.40	1.06 6.04	268.64 2.62	30.73 0.13	8.10	
GT	3	443991	3	0	8	AP	368	9.72 1.05	1.06 54.34	292.35 15.74	49.72 1.56	5.80	4.46
GT	3	443991	3	0	0	A_	467	12.04 1.40	1.30 53.25	215.97 13.69	43.24 0.88	5.65	4.00
GT	3	443991	4	8	30	BM	466	12.77 1.05	1.41 15.98	172.78 4.11	34.60 0.21	6.30	1.70
GT	3	443991	4	30	52	CCA	465	15.69 1.75	1.23 8.88	230.37 2.40	32.00 0.17	7.40	
GT	3	443991	4	0	10	AP	464	16.78 1.22	1.24 156.79	345.56 23.96	64.87 3.01	5.40	6.64
GT	3	443991	4	0	0	A_	463	12.77 1.14	1.27 121.29	287.96 22.25	69.19 2.86	5.40	6.12
GT	3	443991	4	10	23	BT	462	10.95 1.05	1.28 51.77	197.98 5.13	50.15 0.25	5.65	1.98
GT	3	443991	4	23	50	BM1	351	9.72 0.96	1.25 32.11	248.24 5.25	54.83 0.17	5.80	1.31
GT	3	443991	4	50	56	BM2	345	10.05 1.22	1.29 21.19	248.24 5.25	49.44 0.25	6.00	1.20
GT	3	443991	5	0	8	AP	294	15.84 1.57	1.15 100.17	389.24 15.65	76.40 4.30	5.45	6.57
GT	3	443991	5	0	0	A_	135	14.54 1.23	1.21 111.73	358.91 15.82	77.64 4.07	5.50	6.81
GT	3	443991	5	8	20	A_	052	10.36 0.71	0.92 50.89	176.89 7.39	38.81 0.32	5.80	2.90
GT	3	443991	5	20	30	BT	136	8.40 0.70	1.15 19.41	154.90 3.69	31.23 0.00	6.25	2.50
GT	3	443991	5	30	45	BM	341	13.40 1.74	1.29 17.66	213.33 5.51	33.26 0.25	6.50	1.38
GT	3	443991	5	45	56	CCA	342	13.40 1.74	1.07 8.35	279.27 3.15	29.66 0.13	7.55	
GT	4	763830	1	0	8	APK	360	10.72 1.22	1.27 8.45	296.30 7.34	42.94 1.80	7.90	3.07
GT	4	763830	1	0	0	A_	359	10.05 1.22	1.11 9.66	256.79 9.79	49.72 1.10	7.90	3.11
GT	4	763830	1	8	20	BMK	440	9.85 1.41	1.10 5.33	230.40 2.40	25.83 0.30	7.85	1.25
GT	4	763830	1	20	58	CCA	138	9.69 1.23	0.87 6.76	188.90 2.64	31.23 0.14	8.00	
GT	4	763830	1	20	58	CCA	426	8.26 1.23	1.19 6.82	217.36 2.23	37.50 0.17	8.00	
GT	4	763830	2	0	8	AP	209	11.30 0.53	1.25 15.79	284.27 15.39	58.10 1.89	6.80	4.42
GT	4	763830	2	0	0	A_	214	11.30 0.35	1.26 15.04	288.12 15.39	64.36 1.94	6.90	4.60
GT	4	763830	2	8	20	CCA1	239	14.69 2.11	1.43 10.07	210.87 5.13	49.44 0.09	7.50	2.21
GT	4	763830	2	20	46	CCA	414	13.89 1.75	1.34 6.60	201.26 2.62	80.00 0.21	7.60	
GT	4	763830	3	0	6	AP	008	12.94 0.89	1.02 15.09	267.12 11.42	61.22 3.05	6.40	4.89
GT	4	763830	3	0	0	A_	452	11.37 0.88	1.47 21.93	274.29 14.03	62.50 2.65	6.60	4.66
GT	4	763830	3	6	35	AH	449	8.34 0.70	1.37 17.78	204.80 9.58	45.83 0.30	6.20	
GT	4	763830	3	6	35	AH	231	12.30 0.88	1.39 9.03	222.81 6.85	53.63 0.09	7.00	1.10
GT	4	763830	3	35	55	BMK	232	14.63 1.41	1.75 8.68	303.48 5.31	67.04 0.14	7.35	1.45

PARENT MATERIAL	SITE NO.	LOCATION (UTM)	PIT NO.	MINIMUM HORIZON DEPTH (CM)	MAXIMUM HORIZON DEPTH (CM)	HORIZON	SAMPLE NO.	TOTAL Cu (ppm) DTPA Cu (ppm)	TOTAL Fe (%) DTPA Fe (ppm)	TOTAL Mn (ppm) DTPA Mn (ppm)	TOTAL Zn (ppm) DTPA Zn (ppm)	pH	ORGANIC MATTER (%)
GT	4	763830	3	55	79	CCA	385	11.73 1.22	1.25 7.55	285.99 2.27	66.89 0.35	7.95	
GT	4	763830	4	0	8	AP	446	11.75 1.23	1.42 62.22	299.89 17.11	60.00 2.14	6.10	5.73
GT	4	763830	4	0	0	A_	199	12.75 0.35	1.45 25.18	360.56 19.24	71.51 2.50	6.50	5.43
GT	4	763830	4	8	30	AH	347	11.73 1.04	1.53 17.34	325.82 10.84	74.61 0.30	7.10	1.97
GT	4	763830	4	30	58	BMK	301	13.20 1.22	1.60 14.43	291.93 5.74	80.90 0.13	7.60	1.46
GT	4	763830	4	58	73	CCA	302	11.79 1.59	1.63 12.86	288.91 5.39	 0.22	7.80	
GT	4	763830	5	0	10	AP	142	14.54 2.46	1.33 188.18	211.57 19.34	71.39 2.26	6.50	6.33
GT	4	763830	5	0	0	A_	236	11.97 2.29	1.35 208.32	222.81 25.67	74.19 4.94	6.30	6.81
GT	4	763830	5	10	30	AHG	475	14.60 2.45	1.62 103.54	165.58 8.90	77.84 3.03	6.60	4.41
GT	4	763830	5	30	45	BG	431	16.89 2.29	2.13 21.04	132.83 0.68	70.83 0.45	7.50	1.39
GT	4	763830	5	45	68	CCA	240	16.00 2.11	1.70 22.92	 1.71	69.21 0.54	7.75	
GT	5	292793	1	0	10	APK	402	13.77 0.70	1.22	320.00	49.72 2.60	7.70	1.31
GT	5	292793	1	0	0	A_	137	15.18 1.65	1.20 6.49	268.24 3.87	41.05 0.05	7.95	1.41
GT	5	292793	1	10	30	CCA	403	13.44 1.40	1.21 6.90	276.00 3.32	49.72 0.13	7.80	0.76
GT	5	292793	1	30	55	CK1	340	13.07 1.74	1.27 8.67	329.70 3.85	48.54 0.21	8.15	
GT	5	292793	1	55	82	CK2	589	14.16 1.46	1.49 9.96	325.49 3.93	40.68 0.25	8.30	
GT	5	292793	2	0	10	AP	573	15.47 1.59	1.60 6.88	351.09 8.53	40.91 1.09	7.50	0.00
GT	5	292793	2	0	0	A_	480	16.46 1.92	1.35 7.40	237.71 4.28	43.48 0.30	7.60	2.02
GT	5	292793	2	10	40	CCA	479	14.45 1.75	1.34 7.69	303.54 2.74	43.48 0.13	7.80	0.80
GT	5	292793	2	10	40	CCA	478	22.62 1.92	1.45 8.28	248.37 2.40	51.89 0.25	8.00	
GT	5	292793	2	40	58	CK	387	14.74 1.40	1.30 8.76	316.91 2.80	58.76 0.18	8.75	
GT	5	292793	3	0	6	AP	591	14.51 1.46	1.50 10.67	314.51 11.26	49.72 0.59	7.40	3.20
GT	5	292793	3	0	0	A_	337	13.40 1.57	1.34 7.39	306.42 11.54	50.34 0.59	7.50	2.80
GT	5	292793	3	6	25	AH	254	11.43 1.41	1.30 10.07	277.46 10.61	49.44 0.23	7.20	3.07
GT	5	292793	3	25	45	BMK	253	17.96 2.81	1.42 6.25	347.75 5.13	49.44 0.05	7.40	1.72
GT	5	292793	3	45	52	CCA	252	16.33 1.57	1.27 6.30	314.45 1.57	49.44 0.04	7.85	
GT	5	292783	4	0	6	AP	559	11.86 1.42	1.49 10.03	292.57 7.34	45.46 0.38	7.40	3.06
GT	5	292793	4	0	0	A_	110	17.96 1.14	1.35 10.14	283.22 11.25	67.04 0.66	7.50	3.49
GT	5	292793	4	6	21	AH	251	12.74 1.22	1.33 9.79	240.46 2.80	44.94 0.09	7.40	1.41
GT	5	292793	4	21	45	BMK	510	14.97 1.75	1.28 8.05	269.97 2.40	29.79 0.17	7.60	1.39
GT	5	292793	4	45	52	CCA	502	11.98 1.57	1.18 7.47	251.97 2.05	38.30 0.17	7.65	
GT	5	292793	5	0	7	AP	441	16.29 1.23	1.58 11.85	347.43 10.27	66.67 1.88	7.30	5.63
GT	5	292793	5	0	0	A_	519	16.09 1.40	1.45 14.08	413.95 12.32	76.60 2.05	7.10	5.59
GT	5	292793	5	7	40	AH	545	17.49 1.24	1.83 25.70	436.45 11.26	83.45 3.11	6.90	6.15
GT	5	292793	5	7	40	AH	575	17.23 1.92	1.65 91.70	482.74 15.02	86.36 5.46	6.00	6.81
GT	5	292793	5	40	70	BM	522	18.71 1.91	1.70 201.20	345.56 7.70	85.11 0.81	4.80	4.10
GT	5	292793	5	70	82	CCA	590	15.93	1.50 119.47	314.51 11.61	49.72 0.42	4.90	

Parent Material - Lacustrine Clay - Site 3

Pit No.	Horizon	Sample No.	NaOCl (ppm) Cu	NaOCl (ppm) Fe	NaOCl (ppm) Mn	5% HCl (ppm) Cu	5% HCl (ppm) Fe	5% HCl (ppm) Mn	5% HCl (ppm) Zn	NH_4Ox (ppm) Fe	NH_4Ox (ppm) Mn	NH_4Ox (ppm) Zn	$HNO_3/HClO_4$ (ppm) Cu	$HNO_3/HClO_4$ (ppm) Fe	$HNO_3/HClO_4$ (ppm) Mn	$HNO_3/HClO_4$ (ppm) Zn
1		*C 31	8.10	203.88	18.29	10.63	275.86	96.13	6.29	2640.	159.49	10.78	6.05	*2.6	58.74	51.01
	Ap	6	8.10	203.88	15.68	17.72	315.27	107.22	6.82	2796.	180.28	14.27	7.48	*1.6	62.64	62.64
	Cca_1	354	9.07	256.69	12.18	19.05	275.86	52.88	5.93	3107.	193.75	14.05	8.00	*2.5	74.29	60.58
		140	10.12	174.76	11.92	31.04	394.09	22.27	7.32	2796.	155.13	10.76	5.75	*2.0	60.73	39.62
	Cca_2	473	8.37	117.07	0.02	28.22	423.08	59.39	8.63	3215.	107.02	14.36	6.62	*1.9	75.61	45.10
	Ck	33	10.25	145.63	12.54	14.18	354.68	29.59	5.75	3728.	160.87	13.60	7.12	*2.0	82.31	58.17
2		*C183	9.61	233.01	13.35	6.90	433.50	25.06	5.11	2408.	172.52	8.77	5.75	*1.8	49.32	32.38
	Apk	280	11.74	192.51	9.75	19.05	433.50	32.54	7.11	3573.	206.12	14.22	7.27	*1.9	81.54	57.91
	Bmk	54	10.79	233.01	13.59	14.18	433.50	38.45	6.11	3495.	173.35	12.44	5.69	*1.8	92.10	42.95
	Cca_1	420	7.27	111.22		17.85	384.62	37.61	5.18	6124.	170.76	15.75	6.87	*2.3	75.23	37.38
	Cca_2	227	7.59	203.88	11.44	16.55	630.54	65.43	6.47	7379.	161.39	17.54	5.03	*2.0	69.93	32.55
	Ck	472	6.23	111.22	6.23	12.85	307.69	41.03	4.07	8421.	154.10	17.67	5.73	*2.3	63.85	33.75
3		*C353	10.14	256.69	12.18	15.52	315.27	146.44	6.43	3029.	155.28	13.88	8.73	*3.0	62.33	64.14
	Ap	357	10.67	288.77	12.18	16.23	275.86	149.15	6.77	3029.	152.53	13.55	9.09	*2.5	63.42	60.58
	Cca	141	9.10	203.88	12.39	11.72	355.00	34.80	3.92	2718.	125.22	9.59	5.75	*1.8	41.22	33.40
		108	10.79	203.88	10.45	14.18	512.32	31.06	6.82	3806.	187.22	16.59	7.48	*1.6	81.59	42.95
	Ck	474	6.70	111.22	0.02	23.52	423.07	36.33	7.20	6124.	163.34	16.51	6.62	*1.7	73.32	37.29
		32	7.01	174.76	12.50	14.18	433.50	26.62	5.93	3806.	166.41	15.76	5.70	*1.7	69.26	38.48
4		*C 25	9.17	203.88	14.63	12.05	630.54	34.02	6.29	3262.	187.22	14.93	7.12	*2.3	84.13	56.38
	Ap	358	10.14	288.77	12.67	19.05	394.09	93.56	7.62	3262.	191.00	14.90	9.09	*2.3	76.10	65.03
	Ck_1	284	8.54	256.69	8.77	17.64	433.50	21.70	7.11	3611.	193.75	13.88	7.64	*2.3	80.82	60.58
		51	8.10	174.76	13.07	14.18	472.91	22.18	5.75	3650.	180.28	15.26	7.84	*2.3	105.16	57.27
	Ck_2	391	6.75	105.37	5.71	16.42	346.15	23.25	7.03	3522.	174.92	15.40	6.87	*2.3	67.89	39.11
5		*C270	12.81	224.60	9.26	21.18	827.59	143.73	9.31							
	Ap	169	11.13	233.01	7.15	13.11										
	Ccag	39	9.71	174.76	13.07	17.72	1379.40	48.07	8.98	3728.	202.47	26.05	5.34	*2.0	65.27	46.53
	Ckg	70	8.09	174.76	12.02	14.88	906.40	26.62	8.08	2874.	192.76	14.10	7.12	*2.8	74.33	66.22
		373	9.87	111.22	9.34	18.56	538.46	25.98	7.40	2909.	224.90	14.35	7.64	*3.9	76.33	64.90

*C - composite sample

*Fe concentration in percent (%).

Parent Material Lacustrine Silt - Site 5

Pit No.	Horizon	Sample No.	NaOCl (ppm)			5% HCl (ppm)				NH_4Ox (ppm)			$HNO_3/HClO_4$ (ppm)			
			Cu	Fe	Mn	Cu	Fe	Mn	Zn	Fe	Mn	Zn	Cu	Fe	Mn	Zn
		*C 36	8.09	203.88	40.11	7.09	315.27	34.75	7.18	2796.	213.56	13.94	5.70	*1.3	47.50	39.82
1	Ap	37	8.63	203.88	15.68	7.09	315.27	36.97	7.72	3106.	194.15	15.43	4.99	*1.0	39.52	30.60
	Bm	35	7.55	203.88	13.07	6.38	236.45	14.79	5.39							
		34	5.93	203.88	12.02	4.25	354.68	11.09	4.31	2796.	146.9	11.61	4.63	*1.4	42.79	27.03
	Cca	576	5.58	93.66	0.02	14.11	346.15	34.94	5.04	2297.	183.06	9.87	3.68	*1.3	76.37	24.28
		*C120	9.10	233.01	19.07	7.59	197.04	20.88	3.75	1902.	119.65	6.29	3.59	0.9	22.08	22.32
2	Ap	572	5.58	93.66	0.03	13.44	230.77	30.04	8.27	2679.	173.20	12.20	4.78	*1.3	51.93	33.65
		117	8.10	203.88	11.50	8.51	354.68	36.97	6.47	2874.	174.74	11.28	6.06	*1.5	50.04	36.24
	Bm	119	6.07	233.01	11.92	11.72	394.09	13.92	7.15	2796.	173.91	10.76	6.47	*0.6	40.48	27.43
	Cca	118	7.55	203.88	7.84	7.79	394.09	23.66	5.39	3262.	95.69	11.45	3.92	*1.3	55.84	22.55
		*C561	5.58	105.37	0.03	13.44	230.77	38.43	8.99	2756.	246.43	14.63	5.88	*1.6	61.86	53.77
3	Ap	116														
	Ah	535	7.26	111.22	0.03	15.45	307.69	26.55	6.48	2986.	173.20	11.57	6.98	*1.7	58.04	45.10
	Bm	167	9.61	203.88	9.53	8.28	354.68	6.96	5.11	2641.	126.61	9.60	5.03	*1.4	35.33	20.62
		299	10.67	224.60	6.82	10.58	236.45	13.56	6.94	3029	123.67	11.51	3.64	*1.4	39.50	20.67
	Cca	7	5.93	203.88	9.41	7.09	354.68	22.92	4.31	3262.	97.08	13.27	3.21	*0.9	45.69	21.75
		*C237	9.61	203.88	13.35	9.66	354.68	38.28	8.51	2563.	239.30	11.91	7.19	*1.5	44.16	46.86
4	Ap	528	5.58	105.37	0.03	10.08	346.15	55.90	10.97	2449.	267.55	14.00	7.35	*1.4	50.02	41.63
	Ah	226	8.09	233.01	12.39	10.35	236.45	13.92	4.26	2641.	243.48	9.93	8.27	*1.8	57.04	61.34
	Bm	225	7.59	233.01	10.01	8.97	394.09	11.14	5.28	3573.	194.78	10.76	6.47	*2.1	51.52	38.77
		555	6.14	99.50	0.02	10.75	307.69	10.48	6.48	3139.	198.55	10.41	3.31	*1.1	32.46	17.34
	Cca	531	6.70	105.37	0.02	16.80	576.92	39.13	4.50	3598.	137.29	15.26	5.51	*1.5	77.90	26.02
		*C533	6.70	105.37	0.03	12.09	500.0	124.37	14.03	2526.	249.95	15.08	7.35	*1.5	58.81	52.03
5	Ap	506	7.81	111.22	0.03	12.77	307.69	90.83	12.23	2450.	232.34	15.79	6.98	*1.8	44.30	46.83
	Ah	512	5.02	105.37	0.02	11.42	230.77	17.47	5.40	2220.	216.85	11.49	6.62	*1.7	46.59	53.77
	Bm	307	8.54	192.51	7.80	14.11	315.27	11.53	7.11	3262.	236.35	17.27	7.27	*2.0	52.91	62.36
		204	7.08	203.88	10.49	4.83	472.91	9.74	4.26	3339.	166.96	9.10	7.19	*1.8	47.84	32.20
	Cca	540	8.37	99.51	0.02	13.44	500.0	15.37	5.76	7656.	163.34	19.74	6.62	*1.7	68.74	28.44

*C - composite sample

*Fe concentration in percent (%)

Parent Material - Glacial Till - Site 3

Pit No.	Horizon	Sample No.	NaOCl (ppm)			5% HCl (ppm)				NH_4Ox (ppm)			$HNO_3/HClO_4$ (ppm)			
			Cu	Fe	Mn	Cu	Fe	Mn	Zn	Fe	Mn	Zn	Cu	Fe	Mn	Zn
		*C331	8.54	256.69	8.77	10.58	275.86	48.14	5.42	2175.	162.83	8.13	5.82	*1.4	36.24	30.74
1	Ap	211	8.60	203.88	9.53	3.45	354.68	20.88	4.26	2175.	182.96	8.60	5.39	*1.4	39.01	32.80
	AB	210	8.60	233.01	10.01	6.90	354.68	10.44	3.92	1903.	147.48	6.29	4.32	*1.4	39.01	26.84
	Bt	428	7.27	111.22	7.78	8.57	192.31	10.94	4.62	2296.	151.32	8.40	5.73	*1.5	37.80	31.33
	Bm	372	10.39	117.07	10.38	12.14	153.85	10.26	3.33	1990.	154.10	10.85	5.73	*1.9	33.40	23.36
	C	371	10.14	192.51	9.75	12.70	354.68	12.20	4.74	3029	182.07	9.48	4.36	*1.8	51.46	29.40
		*C460	7.27	105.37	7.78	12.85	192.31	38.29	6.47	2220.	104.12	6.30	4.97	*1.7	35.96	21.81
2	Ap	461	8.83	105.37	7.78	7.85	192.31	23.93	4.07	2373.	126.33	8.40	5.73	*1.7	37.43	24.23
	Cca	133	9.10	233.01	9.53	13.10	354.68	24.36	5.45	2252.	91.83	7.45	3.60	*1.4	46.00	16.36
		370	8.54	256.69	7.80	11.29	236.45	20.34	3.73	1709.	90.69	6.43	3.27	*0.9	40.59	14.25
	Ck	369	9.61	288.77	7.31	13.41	275.86	27.12	5.42	2408.	111.30	7.62	3.64	*1.4	56.17	19.78
		*C467	7.79	64.39	5.71	8.57	346.15	37.61	6.29	2220.	147.85	8.75	6.11	*1.6	35.96	27.26
3	Ap	368	10.67	288.77	9.75	10.58	315.27	40.68	5.76	2252.	142.91	8.13	4.00	*1.4	26.09	26.46
	Bm	466	8.31	105.37	7.27	7.14	118.39	6.84	2.41	2220.	115.92	5.95	5.73	*1.7	31.56	21.63
	Cca	465	9.87	64.39	5.71	21.42	307.70	24.62	5.92	956.	77.74	5.07	3.82	0.6	26.42	8.22
		*C463	14.03	111.22	8.82	8.57	307.70	86.15	8.51	2488.	202.69	13.30	6.49	*1.7	40.00	36.34
4	Ap	464	12.99	111.22	7.78	7.14	269.20	85.47	7.77	2373.	208.24	13.65	6.49	*1.6	38.53	36.78
	Bt	462	9.35	105.37	6.23	8.57	153.85	8.21	3.88	2144.	176.31	8.75	5.73	*2.3	35.23	33.06
	Bm	351	8.54	192.51	7.31	8.47	197.04	8.81	5.93	2097.	158.23	8.80	4.36	*1.4	34.79	30.47
		345	9.07	256.69	7.31	10.58	275.86	8.14	3.56	2602	144.97	7.62	4.36	*1.6	37.69	30.29
		*C135	12.65	233.01	9.53	8.28	512.32	132.28	8.85	2408.	194.78	13.24	5.39	*1.5	38.28	37.91
5	Ap	294	13.34	256.69	7.31	9.17	315.27	105.27	8.13	1942.	166.27	9.14	4.00	*1.2	38.41	31.18
	AB	52	8.10	203.88	13.07	6.38	275.86	14.79	3.95	2019.	129.66	5.81	3.92	*1.1	41.34	26.13
	Bt	136	5.56	203.88	9.53	13.79	394.09	9.74	5.45	2563.	102.96	6.95	3.60	*1.5	34.96	20.45
	Bm	341	8.00	256.69	8.28	11.29	315.27	6.78	2.37	2874.	115.43	7.96	4.36	*1.4	34.43	21.65
	Cca	342	9.61	256.69	8.28	11.29	275.86	23.05	4.74	2563.	118.18	6.77	3.64	*1.1	52.55	19.60

*C - composite sample

*Fe concentration in percent (%)

Parent Material - Aeolian Sand - Site 3

Pit No.	Horizon	Sample No.	NaOCl (ppm) Cu	NaOCl (ppm) Fe	NaOCl (ppm) Mn	5% HCl (ppm) Cu	5% HCl (ppm) Fe	5% HCl (ppm) Mn	5% HCl (ppm) Zn	NH_4Ox (ppm) Fe	NH_4Ox (ppm) Mn	NH_4Ox (ppm) Zn	$HNO_3/HClO_4$ (ppm) Cu	$HNO_3/HClO_4$ (ppm) Fe	$HNO_3/HClO_4$ (ppm) Mn	$HNO_3/HClO_4$ (ppm) Zn
		*C377	7.27	117.07	2.60	7.14	153.85	13.68	4.07	1646.	84.69	4.37	1.91	5885.	23.49	6.49
1	Ah	390	9.35	105.37	4.15	7.14	192.31	13.68	5.18	1837.	88.85	5.60	2.67	7172.	26.79	9.17
	Ae	491	2.79	111.22	0.02	9.41	269.23	10.48	3.96	1914	83.08	5.03	1.84	7494	29.79	10.23
	Bh	529	3.35	105.37	0.02	8.06	307.69	8.38	6.12	2144.	107.02	6.46	2.94	8244.	35.89	11.73
	BC	158	7.59	203.88	10.01	4.83	275.86	6.26	4.43	1670.	97.39	4.14	2.16	7363.	34.23	12.78
	Ck	2	5.39	174.76	7.84	3.54	275.86	22.18	4.49	2097.	124.80	2.49	3.92	9154.	49.70	7.16
		*C442	7.79	105.37	6.23	4.99	153.85	8.89	5.18	1531.	79.83	5.60	2.29	6806.	30.09	7.62
2	Ah	144	9.10	203.89	9.53	2.76	197.04	3.48	2.23	1631.	68.17	3.31	1.80	5572.	32.75	9.63
		443	5.71	111.22	6.23	3.57	192.31	6.84	4.44	2144.	72.89	4.90	2.67	7540.	30.83	9.35
	Bh	49	8.63	174.76	10.45	3.54	315.27	13.31	5.39	1669.	114.41	5.81	1.78	4179.	29.01	10.02
	C	523	5.02	111.22	0.02	6.72	192.31	6.98	3.06	1761.	86.60	6.46	2.57	7494.	34.37	10.41
		*C579			0.98	3.20	258.33	9.13	7.85	2388.	125.68	9.94	1.93	6949.	40.75	15.61
3	Ah	206	11.13	233.01	9.03	8.28	275.86	11.14	6.81	1864.	200.35	5.96	1.80	6766.	26.87	13.12
	Bh	580				1.26	201.82	9.13	7.19	2148.	119.88	10.77	1.61	6141.	32.07	13.60
	BC	571	4.47	93.66	0.02	7.39	192.31	10.48	2.70	1569.	88.71	5.74	1.47	6183.	33.99	8.50
	C	547	6.70	99.51	0.02	8.06	153.85	6.99	3.60	1455.	60.55	3.59	2.21	5246.	22.91	6.76
		*C355	9.61	256.69	8.28	8.47	236.45	9.49	6.10	1437	84.51	6.43	1.82	6170.	26.09	10.25
4	Ah	243	9.07	288.77	7.31	11.29	236.45	10.85	6.77	2097.	115.43	8.13	2.91	8936.	35.52	15.15
		238	6.07	203.88	9.53	6.21	315.27	9.05	4.77	1941.	112.70	4.96	1.79	7761.	29.44	15.76
	Bm	578														
	C	375	5.20	117.08	7.27	8.57	153.85	8.89	3.88	2066.	90.24	5.95	2.29	8276.	33.03	9.69
		*C538	6.70	99.51	0.03	6.72	230.77	34.94	7.20	1837.	139.41	8.62	2.57	8244.	32.46	16.65
5	Ah	548	7.81	99.51	0.02	7.39	230.77	41.92	6.84	1914.	147.86	9.87	2.57	8431.	34.75	18.73
		382	5.71	111.22	4.67	6.43	269.23	12.31	5.55	1990	130.50	7.87	1.91	9931.	30.80	15.58
	Bm	530	3.91	105.37	0.02	6.72	346.15	13.97	2.88	1722.	117.58	5.74	2.21	7494.	29.79	11.71
	C	383	6.23	111.22	5.19	5.00	307.69	14.36	4.99	1722.	91.63	6.30	2.29	7540.	22.75	10.56

*C - composite sample

APPENDIX B

1. DESCRIPTIVE STATISTICS

2. HISTOGRAMS: EXAMPLES SHOWING THE EFFECT OF THE LOG_{10} TRANSFORMATION ON THE DATA DISTRIBUTION

DESCRIPTIVE MEASURES ALL DATA

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
PH	261	4.9000	9.1000	7.1594	.82238	-.560	-.655
TCU	261	.19300 -5	.34000 -4	.15249 -4	.78704 -5	.011	-1.021
TMN	260	.30080 -4	.46074 -3	.25533 -3	.87721 -4	-.567	-.233
TZN	258	.13860 -4	.11043 -3	.58695 -4	.23234 -4	-.152	-.991
DCU	260	0.	.69300 -5	.16855 -5	.10895 -5	.840	1.481
DFE	260	.28000 -5	.18818 -3	.19122 -4	.22329 -4	3.998	20.313
DMN	259	.86000 -6	.39250 -4	.76322 -5	.71437 -5	2.269	5.343
DZN	261	0.	.47100 -5	.67291 -6	.75052 -6	2.319	6.189
TFE	261	.17000 -2	.39900 -1	.15192 -1	.69113 -2	.607	.148
ORGMATR	152	0.	.66400 -1	.26352 -1	.13080 -1	1.009	.884

DESCRIPTIVE MEASURES <1> PARNTMTL:LC CHEMICAL PROPERTIES BY PARENT MATERIAL

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
PH	78	6.6000	8.2000	7.6596	.25888	-1.052	2.762
TCU	78	.18240 -4	.34000 -4	.24825 -4	.26167 -5	-.217	1.537
TMN	78	.19281 -3	.43457 -3	.29860 -3	.45830 -4	.423	.117
TZN	78	.56540 -4	.10697 -3	.81242 -4	.10843 -4	-.259	-.100
DCU	78	.15700 -5	.69300 -5	.29754 -5	.75346 -6	2.547	10.737
DFE	78	.66000 -5	.45310 -4	.12816 -4	.50662 -5	3.724	20.584
DMN	78	.15800 -5	.14700 -4	.62686 -5	.22656 -5	1.115	2.462
DZN	78	.16000 -6	.16300 -5	.48795 -6	.27251 -6	1.992	5.443
TFE	78	.15000 -1	.39900 -1	.23440 -1	.47582 -2	.820	1.281
ORGMATR	47	.15200 -1	.48000 -1	.23974 -1	.63907 -2	1.374	2.843

DESCRIPTIVE MEASURES <2> PARNTMTL:LS CHEMICAL PROPERTIES BY PARENT MATERIAL

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
PH	61	5.3500	9.1000	6.9754	1.0274	-.122	-1.191
TCU	61	.10970 -4	.24960 -4	.15365 -4	.35483 -5	1.008	.275
TMN	61	.16842 -3	.42000 -3	.29422 -3	.53665 -4	-.063	-.373
TZN	61	.28270 -4	.94920 -4	.63495 -4	.13668 -4	-.240	-.132
DCU	61	.35000 -6	.33200 -5	.15064 -5	.55749 -6	1.008	1.328
DFE	61	.64700 -5	.10347 -3	.25737 -4	.23583 -4	1.433	1.118
DMN	61	.17300 -5	.39250 -4	.12700 -4	.11867 -4	.752	-.823
DZN	61	.80000 -7	.47100 -5	.87525 -6	.95543 -6	1.744	3.152
TFE	61	.82000 -2	.21300 -1	.15021 -1	.28306 -2	.281	-.179
ORGMATR	32	.11400 -1	.62500 -1	.32144 -1	.12290 -1	.242	-.501

DESCRIPTIVE MEASURES <3> PARNTMTL:GT CHEMICAL PROPERTIES BY PARENT MATERIAL

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
PH	69	4.9000	8.7500	7.3145	.81462	-.980	.360
TCU	69	.79800 -5	.17490 -4	.13071 -4	.23313 -5	-.227	-.865
TMN	68	.15213 -3	.46074 -3	.27722 -3	.64984 -4	.393	.404
TZN	68	.27070 -4	.11043 -3	.51679 -4	.16729 -4	1.065	1.261
DCU	68	.35000 -6	.24600 -5	.13919 -5	.46108 -6	.223	-.037
DFE	68	.54000 -5	.18818 -3	.23540 -4	.34875 -4	3.070	9.464
DMN	68	.15700 -5	.23960 -4	.69238 -5	.51274 -5	1.135	.692
DZN	69	.40000 -7	.43000 -5	.79275 -6	.97329 -6	1.671	1.945
TFE	69	.74000 -2	.18300 -1	.12652 -1	.22266 -2	.056	-.186
ORGMATR	42	0.	.66400 -1	.30369 -1	.18018 -1	.521	-.762

DESCRIPTIVE MEASURES <4> PARNTMTL:AS CHEMICAL PROPERTIES BY PARENT MATERIAL

VARIABLE	N	MINIMUM	MAXIMUM	MEAN	STD DEV	SKEWNESS	KURTOSIS
PH	53	5.7000	7.8000	6.4330	.46014	1.015	1.370
TCU	53	.19300 -5	.73700 -5	.38604 -5	.13735 -5	.412	-.589
TMN	53	.30080 -4	.23273 -3	.11881 -3	.47407 -4	.671	-.058
TZN	51	.13860 -4	.71910 -4	.27826 -4	.11597 -4	1.403	2.388
DCU	53	0.	.78000 -6	.37000 -6	.16926 -6	.182	-.452
DFE	53	.28000 -5	.38190 -4	.15120 -4	.91474 -5	.924	.115
DMN	52	.86000 -6	.12660 -4	.46590 -5	.26348 -5	.781	.114
DZN	53	0.	.18300 -5	.55623 -6	.53113 -6	1.122	.295
TFE	53	.17000 -2	.10400 -1	.65566 -2	.17158 -2	-.276	.435
ORGMATR	31	.44000 -2	.41300 -1	.18535 -1	.82690 -2	.762	.698

HISTOGRAM CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT	HIST%	COUNT FOR 28.DCUF (EACH X= 1)	
0.	5.5	17	+XXXXXXXXXXXXXXXXX
.40765 -6	15.3	47	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.81529 -6	5.2	16	+XXXXXXXXXXXXXXXX
.12229 -5	20.5	63	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.16306 -5	9.4	29	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.20382 -5	7.1	22	+XXXXXXXXXXXXXXXXXXXXXX
.24459 -5	9.4	29	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.28535 -5	11.7	36	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.32612 -5	12.7	39	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.36688 -5	1.9	6	+XXXXXX
.40765 -5	0.	0	+
.44841 -5	0.	0	+
.48918 -5	.3	1	+X
.52994 -5	.3	1	+X
.57071 -5	.3	1	+X
.61147 -5	0.	0	+
.65224 -5	0.	0	+
.69300 -5	.3	1	+X

MISSING 1
TOTAL 309 (INTERVAL WIDTH= .40765 -6)

HISTOGRAM CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT	HIST%	COUNT FOR 29.DFEF (EACH X= 2)	
.28000 -5	18.5	57	+XXXXXXXXXXXXXXXXXXXXXXXXXXXX
.13705 -4	59.1	182	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.24609 -4	10.1	31	+XXXXXXXXXXXXXXX
.35514 -4	3.2	10	+XXXXX
.46419 -4	3.6	11	+XXXXXX
.57324 -4	1.6	5	+XXX
.68228 -4	.3	1	+X
.79133 -4	1.3	4	+XX
.90038 -4	.3	1	+X
.10094 -3	1.0	3	+XX
.11185 -3	0.	0	+
.12275 -3	.3	1	+X
.13366 -3	0.	0	+
.14456 -3	0.	0	+
.15547 -3	.3	1	+X
.16637 -3	0.	0	+
.17728 -3	0.	0	+
.18818 -3	.3	1	+X

MISSING 1
TOTAL 309 (INTERVAL WIDTH= .10905 -4)

HISTOGRAM CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT	HIST%	COUNT FOR 30.DMNF (EACH X= 1)	
.86000 -6	4.6	14	+XXXXXXXXXXXXXX
.31182 -5	28.3	87	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.53765 -5	28.7	88	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.76347 -5	16.0	49	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
.98929 -5	6.8	21	+XXXXXXXXXXXXXXXXXXXXX
.12151 -4	4.2	13	+XXXXXXXXXXXXX
.14409 -4	2.3	7	+XXXXXXX
.16668 -4	1.3	4	+XXXX
.18926 -4	1.0	3	+XXX
.21184 -4	1.0	3	+XXX
.23442 -4	2.0	6	+XXXXXX
.25701 -4	1.3	4	+XXXX
.27959 -4	.3	1	+X
.30217 -4	.7	2	+XX
.32475 -4	.3	1	+X
.34734 -4	0.	0	+
.36992 -4	.7	2	+XX
.39250 -4	.7	2	+XX

MISSING 2
TOTAL 309 (INTERVAL WIDTH= .22582 -5)

HISTOGRAM DISTRIBUTIONS OF LOG10 DATA

MIDPOINT	HIST%	COUNT FOR 41.LDCUF (EACH X= 1)	
-7.0458	.3	1	+X
-6.9348	0.	0	+
-6.8238	0.	0	+
-6.7128	4.8	15	+XXXXXXXXXXXXXXX
-6.6019	.3	1	+X
-6.4909	7.5	23	+XXXXXXXXXXXXXXXXXXXXXXX
-6.3799	1.0	3	+XXX
-6.2690	6.5	20	+XXXXXXXXXXXXXXXXXXXX
-6.1580	2.0	6	+XXXXXX
-6.0470	3.3	10	+XXXXXXXXXX
-5.9361	14.3	44	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.8251	10.7	33	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.7141	12.1	37	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.6031	15.0	46	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.4922	19.9	61	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.3812	1.0	3	+XXX
-5.2702	1.0	3	+XXX
-5.1593	.3	1	+X

MISSING 2
TOTAL 309 (INTERVAL WIDTH= .11097)

HISTOGRAM DISTRIBUTIONS OF LOG10 DATA

MIDPOINT	HIST%	COUNT FOR 42.LDFEF (EACH X= 1)	
-5.5528	.3	1	+X
-5.4453	0.	0	+
-5.3379	1.0	3	+XXX
-5.2304	4.9	15	+XXXXXXXXXXXXXXX
-5.1229	16.2	50	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.0154	16.6	51	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.9079	21.8	67	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.8004	13.6	42	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.6929	10.7	33	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.5854	2.6	8	+XXXXXXXX
-4.4779	2.6	8	+XXXXXXXX
-4.3704	2.6	8	+XXXXXXXX
-4.2629	2.9	9	+XXXXXXXXX
-4.1554	1.9	6	+XXXXXX
-4.0479	.6	2	+XX
-3.9404	1.0	3	+XXX
-3.8329	.3	1	+X
-3.7254	.3	1	+X

MISSING 1
TOTAL 309 (INTERVAL WIDTH= .10750)

HISTOGRAM DISTRIBUTIONS OF LOG10 DATA

MIDPOINT	HIST%	COUNT FOR 43.LDMNF (EACH X= 1)	
-6.0655	.3	1	+X
-5.9679	0.	0	+
-5.8703	1.0	3	+XXX
-5.7727	3.3	10	+XXXXXXXXXX
-5.6751	6.2	19	+XXXXXXXXXXXXXXXXXXX
-5.5775	11.4	35	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.4799	7.8	24	+XXXXXXXXXXXXXXXXXXXXXXXX
-5.3822	8.5	26	+XXXXXXXXXXXXXXXXXXXXXXXXXX
-5.2846	16.9	52	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.1870	14.3	44	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-5.0894	9.4	29	+XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.9918	5.9	18	+XXXXXXXXXXXXXXXXXX
-4.8942	4.2	13	+XXXXXXXXXXXXX
-4.7966	2.9	9	+XXXXXXXXX
-4.6990	2.0	6	+XXXXXX
-4.6014	3.3	10	+XXXXXXXXXX
-4.5038	1.3	4	+XXXX
-4.4062	1.3	4	+XXXX

MISSING 2
TOTAL 309 (INTERVAL WIDTH= .97608 -1)

```
HISTOGRAM  CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT    HISTX  COUNT FOR 31.DZNF   (EACH X= 2)

 0.          13.9    43 +XXXXXXXXXXXXXXXXXXXXXX
 .32118 -6   46.3   143 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .64235 -6   15.9    49 +XXXXXXXXXXXXXXXXXXXXXXXXX
 .96353 -6    8.7    27 +XXXXXXXXXXXXXX
 .12847 -5    1.9     6 +XXX
 .16059 -5    4.5    14 +XXXXXXX
 .19271 -5    2.6     8 +XXXX
 .22482 -5    1.6     5 +XXX
 .25694 -5    1.3     4 +XX
 .28906 -5    1.6     5 +XXX
 .32118 -5     .6     2 +X
 .35329 -5    0.      0 +
 .38541 -5    0.      0 +
 .41753 -5     .3     1 +X
 .44965 -5    0.      0 +
 .48176 -5     .3     1 +X
 .51388 -5    0.      0 +
 .54600 -5     .3     1 +X

TOTAL               309  (INTERVAL WIDTH= .32118 -6)
```

```
HISTOGRAM  CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT    HISTX  COUNT FOR 25.TCUF   (EACH X= 1)

 .19000 -5    5.2    16 +XXXXXXXXXXXXXXXX
 .37882 -5    9.1    28 +XXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .56765 -5    5.2    16 +XXXXXXXXXXXXXXXX
 .75647 -5    1.6     5 +XXXXX
 .94529 -5    3.6    11 +XXXXXXXXXXX
 .11341 -4    9.1    28 +XXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .13229 -4   11.7    36 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .15118 -4    9.1    28 +XXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .17006 -4    5.5    17 +XXXXXXXXXXXXXXXXX
 .18894 -4    2.9     9 +XXXXXXXXX
 .20782 -4    1.9     6 +XXXXXX
 .22671 -4    7.1    22 +XXXXXXXXXXXXXXXXXXXXXX
 .24559 -4    9.7    30 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .26447 -4   14.9    46 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .28335 -4    3.2    10 +XXXXXXXXXX
 .30224 -4    0.      0 +
 .32112 -4    0.      0 +
 .34000 -4     .3     1 +X

TOTAL               309  (INTERVAL WIDTH= .18882 -5)
```

```
HISTOGRAM  CHEMICAL PROPERTIES FOR ALL DATA USED

MIDPOINT    HISTX  COUNT FOR 32.TFEF   (EACH X= 1)

 .17000 -2     .6     2 +XX
 .39471 -2    2.9     9 +XXXXXXXXX
 .61941 -2    9.4    29 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .84412 -2    9.4    29 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .10688 -1   10.0    31 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .12935 -1   12.9    40 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .15182 -1   13.3    41 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
 .17429 -1    8.1    25 +XXXXXXXXXXXXXXXXXXXXXXXXX
 .19676 -1    7.1    22 +XXXXXXXXXXXXXXXXXXXXXX
 .21924 -1    6.5    20 +XXXXXXXXXXXXXXXXXXXX
 .24171 -1    8.7    27 +XXXXXXXXXXXXXXXXXXXXXXXXXXX
 .26418 -1    3.9    12 +XXXXXXXXXXXX
 .28665 -1    4.5    14 +XXXXXXXXXXXXXX
 .30912 -1    1.9     6 +XXXXXX
 .33159 -1    0.      0 +
 .35406 -1    0.      0 +
 .37653 -1     .3     1 +X
 .39900 -1     .3     1 +X

TOTAL               309  (INTERVAL WIDTH= .22471 -2)
```

```
HISTOGRAM  DISTRIBUTIONS OF LOG10 DATA

MIDPOINT    HISTX  COUNT FOR 44.LDZNF  (EACH X= 1)

-7.3979      1.0     3 +XXX
-7.2723       .3     1 +X
-7.1467      1.0     3 +XXX
-7.0212      3.3    10 +XXXXXXXXXX
-6.8956      6.2    19 +XXXXXXXXXXXXXXXXXXX
-6.7700      7.2    22 +XXXXXXXXXXXXXXXXXXXXXX
-6.6444     12.4    38 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.5188     13.4    41 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.3932     13.4    41 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.2676     12.1    37 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-6.1420      6.9    21 +XXXXXXXXXXXXXXXXXXXXX
-6.0164      7.2    22 +XXXXXXXXXXXXXXXXXXXXXX
-5.8908      2.3     7 +XXXXXXX
-5.7652      6.9    21 +XXXXXXXXXXXXXXXXXXXXX
-5.6396      2.9     9 +XXXXXXXXX
-5.5140      2.6     8 +XXXXXXXX
-5.3884       .7     2 +XX
-5.2628       .3     1 +X

 MISSING             3
 TOTAL             309  (INTERVAL WIDTH= .12560)
```

```
HISTOGRAM  DISTRIBUTIONS OF LOG10 DATA

MIDPOINT    HISTX  COUNT FOR 45.LTCUF  (EACH X= 1)

-5.7212      2.3     7 +XXXXXXX
-5.6476      1.3     4 +XXXX
-5.5739      1.6     5 +XXXXX
-5.5002      2.9     9 +XXXXXXXXX
-5.4265      2.3     7 +XXXXXXX
-5.3528      3.9    12 +XXXXXXXXXXXX
-5.2791      3.9    12 +XXXXXXXXXXXX
-5.2054      1.3     4 +XXXX
-5.1317      1.0     3 +XXX
-5.0580      1.9     6 +XXXXXX
-4.9843      3.9    12 +XXXXXXXXXXXX
-4.9107     11.3    35 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.8370     15.9    49 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.7633      8.1    25 +XXXXXXXXXXXXXXXXXXXXXXXXX
-4.6896      5.2    16 +XXXXXXXXXXXXXXXX
-4.6159     24.6    76 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-4.5422      8.4    26 +XXXXXXXXXXXXXXXXXXXXXXXXXX
-4.4685       .3     1 +X

TOTAL              309  (INTERVAL WIDTH= .73690 -1)
```

```
HISTOGRAM  DISTRIBUTIONS OF LOG10 DATA

MIDPOINT    HISTX  COUNT FOR 48.LTFEF  (EACH X= 1)

-2.7696       .3     1 +X
-2.6889      0.      0 +
-2.6083       .3     1 +X
-2.5277      0.      0 +
-2.4471      0.      0 +
-2.3665      1.6     5 +XXXXX
-2.2858      2.9     9 +XXXXXXXXX
-2.2052      5.8    18 +XXXXXXXXXXXXXXXXXX
-2.1246      6.8    21 +XXXXXXXXXXXXXXXXXXXXX
-2.0440      5.2    16 +XXXXXXXXXXXXXXXX
-1.9634      9.7    30 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.8827     15.2    47 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.8021     13.6    42 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.7215     12.3    38 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.6409     14.6    45 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.5603      9.4    29 +XXXXXXXXXXXXXXXXXXXXXXXXXXXXX
-1.4796      1.6     5 +XXXXX
-1.3990       .6     2 +XX

TOTAL              309  (INTERVAL WIDTH= .80619 -1)
```