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Delineating anthropogenic hydric soils on mine tailing in the Copper Basin, Tennessee for classification and use

Vanessa Catherine Stevens

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To the Graduate Council:

I am submitting herewith a thesis written by Vanessa Catherine Stevens entitled "Delineating anthropogenic hydric soils on mine tailing in the Copper Basin, Tennessee for classification and use." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant, Soil and Environmental Sciences.

J.T. Ammons, Major Professor

We have read this thesis and recommend its acceptance:

Ronald E. Yoder, Darwin Newton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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Dr. J.T. Ammons, Major Professor

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and recommend its acceptance:

Ronald E. Yoder
Dr. Ronald E. Yoder

Darwin Newton
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Accepted for the Council:

Associate Vice Chancellor and
Dean of The Graduate School

DELINEATING ANTHROPOGENIC HYDRIC SOILS ON MINE TAILINGS IN THE COPPER BASIN, TENNESSEE FOR CLASSIFICATION AND USE

A Thesis
Presented for the
Master of Science Degree
The University of Tennessee, Knoxville

Vanessa Catherine Stevens

August 2000

DEDICATION

This thesis is dedicated to everyone in Lab 315, my colleagues and friends, Danny Inman and Tommy Cook, and student workers, Zack Parham and Ryan Noble. All of your support and guidance throughout the years made graduate school the most enjoyable experience I have had.

Also, this thesis is dedicated to my father, I will always remember how you told me to live each day to the fullest and always strive to be my best.

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Zack Parham and Ryan Noble, thank you for doing all the dirty work, including endless days of dish washing, AA running, and soil weighing;

Finally, thanks to my mother, Valerie, for letting me be what I wanted to be, even though you still can't believe your daughter plays with dirt; to my sister Berna, for giving me hope to pursue my Ph.D and teach, like she is doing; to my brother Thomas, for

providing a babysitting service for my ferrets for the countless number of soil field trips; and finally, to my nephew Tyler, for never letting me forget, that it isn't so bad after all.

ABSTRACT

The location and extent of hydric soils are of interest to land managers. A soil investigation on a copper mine tailings pond in the Copper Basin, Tennessee, presented an opportunity to study the formation of anthropogenic or disturbed hydric soils. Hydric soils are important because they are one of three parameters critical in delineating wetlands. The objectives of this study were to: 1) conduct complete soil morphological, chemical, and physical characterization to identify the soils on the mine tailings pond; 2) classify the soils to the family level of soil taxonomy; and 3) use the data obtained in objectives 1 and 2 to delineate the hydric soil fringe around anthropogenic wetlands.

A total of ten pedons were described and sampled according to standard soil survey manual methods. Selected points were sampled with an auger to determine depth to the gleyed layer, color, and depth to the water table. These were used to delineate the hydric soil fringe. Particle size analysis, free iron, hydroxylamine manganese, organic carbon, total elemental analysis, pH, exchangeable bases, cation exchange capacity, KCl exchangeable acidity, neutralization potential, total sulfur, nitrogen, and carbon were the laboratory procedures performed.

Differences in depth to the water table, proximity to wetlands, location on the mine tailings pond, and landscape position accounted for the chemical, physical, and morphological differences in each profile. Depth to the gleyed layer ranged from 8 to 43 cm. Textures ranged from fine sands to silts. Because of the sand textures, cation exchange capacities (CEC) were low (<4) in all soil profiles except for soil profile #20. All horizons had a high base saturation (>100%) due to the high calcium concentrations as a result of the calcium carbonate added during the mining process.

Redoximorphic features corresponded to the changing depth to water table. Iron and manganese concentrations corresponded to the fluctuating water table, depth to the water table, and the proximity of soil profiles to wetlands. Tests for ferrous iron reacted positively to alpha, alpha-dipyridyl in horizons above gleyed layers and negatively in gleyed layers indicating ferrous iron was low or removed, especially in those profiles with shallow water tables.

Sites #5, #6, and #7 were classified as Psammaquents. Sites #8, #12, #13, #14, #15, and #16 were classified as Endoaquents. Site #20 was classified as an Epiaquent. ArcView, selected sampling points, and soil physical, chemical, and morphological characterization were successful in delineating the 15.4 ha (38 ac) of hydric soils around anthropogenic wetlands for future land use management.

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CHAPTER 1

INTRODUCTION

DESCRIPTION OF THE COPPER BASIN, TENNESSEE

The Copper Basin in Southeast Tennessee, near Ducktown, consists of about 60,000 acres surrounded by the Appalachian (or Blue Ridge) Mountains of Tennessee, Georgia, and North Carolina (Fig. 1). The physiographic region of this basin is in the Unaka Mountains, east of the Valley and Ridge physiographic region (Fig. 2). The site is N 35°02' 57.4" latitude and W 84°21' 14.4" longitude in the Isabella Quadrangle.

The 86-ha (212-ac) mine tailings pond is located north of the London Flotation Plant at an elevation of 1720 ft above sea level. Mines located in the area include the Isabella, Calloway, Hancock, Hiwassee, Cocheco, Cherokee, Eureka, East Tennessee, London, Culchute, United States, Biggs-Boyd, Tennessee, Mary, and Polk County Mines (Fig. 3) (Copper Basin Museum, 1999).

HISTORY OF THE COPPER MINING INDUSTRY

Copper was first discovered in the Copper Basin in 1843. The first shipment of copper ore was made in 1847 to a smelter in Boston. In 1850, the first mines opened in Ducktown named the Hiwassee and Cocheco, followed by the Polk County Mine in 1852. The Copper Basin is the only known location in Tennessee where copper bearing ores occur in a commercial amount and grade (Maher, 1966).

Past mining practices of open pit smelting of raw ore released sulfur dioxide into

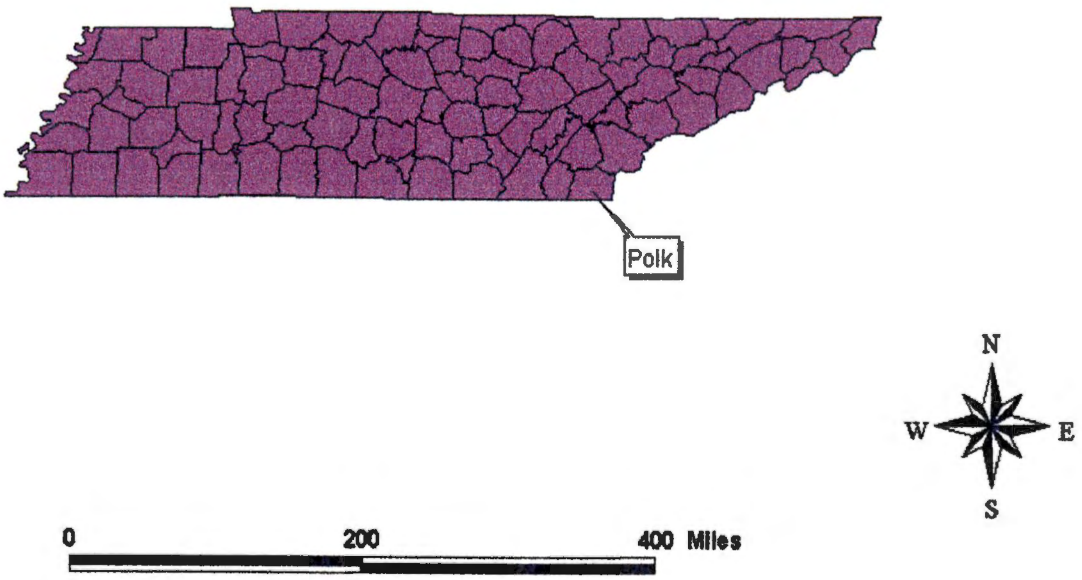

Figure 1. Location map of Polk County, Tennessee

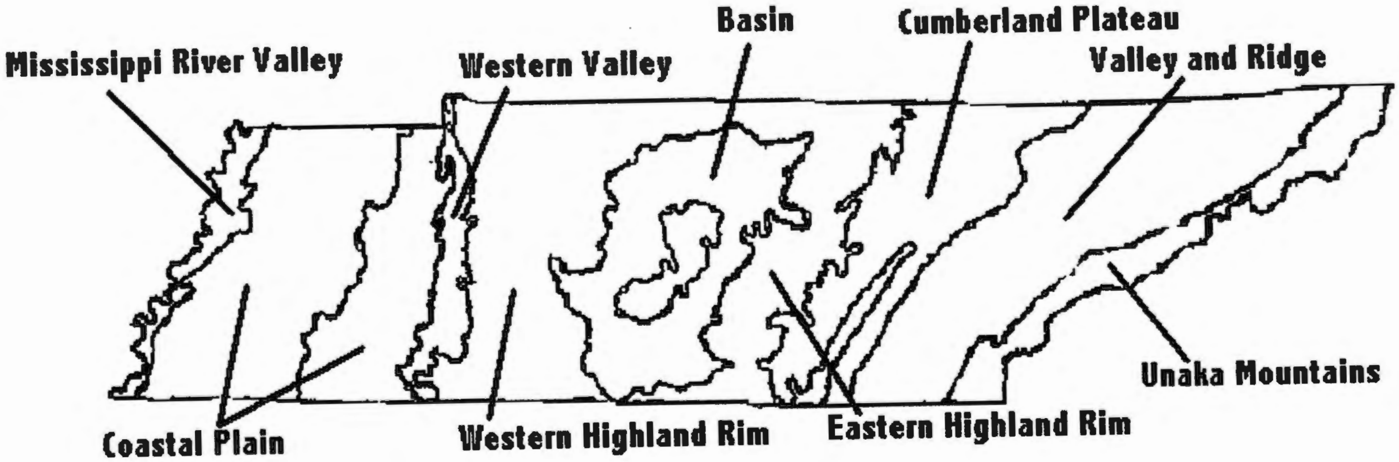

Figure 2. Physiographic regions of Tennessee.

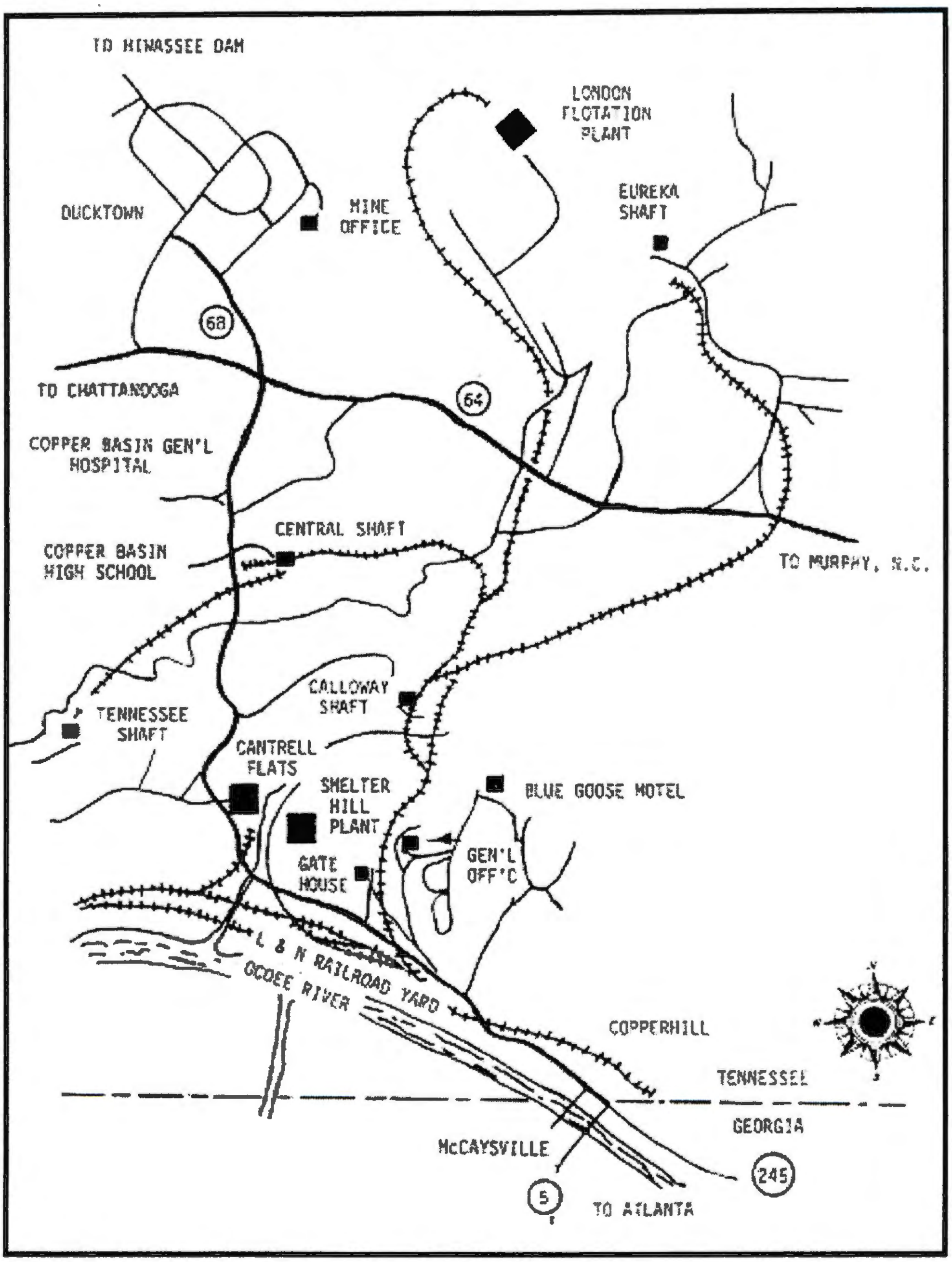

Figure 3. Map of Copper Basin's mines (Cities Service Company, 1974).

the air. During open pit smelting, masses of ore were put on top of piles of wood. Trees were harvested from area forests and used as fuel to roast the ore. These acres of roast heaps were a major factor in the Basins environmental degradation. High concentrations of sulfur dioxide released from the burning caused acid conditions. As a result, vegetation began to die and with the loss of vegetation, erosion occurred (Quinn, 1988).

Copper mining grew with the addition of the North Georgia Railway in 1891. This railroad allowed faster shipment of supplies for smelting (Muncy, 1991). As more ore was mined and processed, more sulfur dioxide was released into the air. The impact of sulfur dioxide on the land reached its peak in 1907 (Quinn, 1988). After 1907, open air roasting of ores stopped. Acid capture and processing plants were built where sulfur dioxide was captured and transformed to sulfuric acid and used for other purposes such as for the fertilizer industry. Smelting operations in the Copper Basin finally began to control the sulfur dioxide emission and as a result, air quality improved. However, because of earlier practices, 23,000 acres of land in the Copper Basin were left barren (TVA, 1945; Allen, 1950; Muncy, 1991).

In the 1930s, reclamation studies and revegetation programs began, including work by the Tennessee Valley Authority (TVA) (Quinn, 1988). The TVA became involved with the Tennessee Copper Company by implementing a revegetation plan for the Copper Basin (Muncy, 1991). The revegetation plan included planting Virginia Pine (*P. virginiana Mill*), Shortleaf Pine (*P. echinata Mill*), Loblolly Pine (*Pinus taeda L.*), and Pitch Pine (*P. rigida Mill*) trees to control erosion (Muncy, 1986).

In 1963, Cities Service Corporation took over the mining operations from the

Tennessee Copper Company who first started the company in 1899 (Quinn, 1988). The Cities Service Corporation continued the revegetation plans (Cities Service Company, 1975). The Soil Conservation Service (SCS), now the Natural Resources Conservation Service (NRCS), began research and surveys in the area in the 1970s. By the late 1970s, many of the sites were successfully revegetated with Loblolly, Shortleaf, and Virginia Pine, and grass-legume mixtures, including Sericea Lespedeza (*Lespedeza cuneata*). Cities Service Corporation was acquired by Tennessee Chemical Company in 1982 (Quinn, 1988). In 1983, more Loblolly Pine seedlings were hand planted (Tyre and Barton, 1986). By 1987, TVA, SCS (NRCS), and the Tennessee Chemical Company made plans to revegetate the areas that were still barren (Quinn, 1988). Plans included continued erosion control and reducing deposition and sedimentation of metal-rich and acid soils into the Ocoee River which is the main drainage for the Copper Basin. Earlier sedimentation and acidic runoff killed much of the fish and aquatic life in the Ocoee River (Quinn, 1988).

Finally, in July of 1987, the Copper Basin's mines closed (Quinn, 1988). Tennessee Chemical Company went bankrupt in 1987. BIT Manufacturing, Inc. took a piece of Tennessee Chemical Company after they went bankrupt (Muncy, 1991). Presently, Occidental Petroleum Company owns the land where the London Flotation Plant is located including the land surrounding the plant.

The Copper Basin is slowly recovering from the devastation that began over a century ago. Revegetation and reclamation efforts are ongoing. Occidental Petroleum Company, Tennessee Department of Environment and Conservation, and The University of Tennessee are actively working on research projects to revegetate areas around the London Flotation Plant and in the mine tailings pond.

COPPER MINING PROCESS AND ORIGIN OF TAILINGS

The copper mining process involved many steps to access, mine, and ship the final ore products to areas across the United States. This process involved mining the ore, extracting the metal, and depositing the waste (Cities Service Company, 1974). The mining process involved five stages. These included excavating, drilling and blasting, loading, hauling, and crushing the ore. The ore produced copper, copper sulfate, iron sinter, sulfuric acid, zinc concentrate, ferric sulfate, slag, liquid sulfur dioxide, sodium hydrosulfite, and organic chemicals (Tennessee Copper Company, 1960).

First, the ore was mined or blasted underground using an ammonium nitrate-fuel oil mixture. After the ore was mined, it was separated from the waste rock, crushed, and carried out of the shaft for treatment at the London Flotation Plant (Cities Service Company, 1974). In the London Flotation Plant, the ore was processed by flotation which separated the copper, iron, and zinc from unwanted rock. First, the ore was ground to a to a fine powder. The fine powder was put through the flotation process. Components of copper, iron, and zinc were separated into a bulk concentrate. Calcium carbonate ($CaCO_3$) was added during the flotation process to aid in the separation. The iron, copper, and zinc minerals attached to bubbles and floated to the surface as froth. These minerals were skimmed off and separated. Products that were captured went to smelters for further processing. The flotation plant also separated sulfur dioxide gas which was a product of the milling process. The sulfur dioxide gas was sent to the acid plant and converted to sulfuric acid (H_2SO_4) (Cities Service Company, 1974). The sulfuric acid was used in fertilizers, iron and steel, petroleum products, textiles, and explosives (Maher, 1966).

Copper was extracted after the minerals were separated in the flotation process. In the copper extraction process, the ore was heated and melted in the smelter. Any iron in the sample reacted with the silica to form slag which floated to the surface. The slag was sent to the pellet plant where it was reheated and melted a second time to recover additional copper. The additional copper was in the form of molten cuprous sulfide. Sulfur was also removed so only the copper metal remained. Finally, the copper metal was ready for sale (Cities Service Company, 1974).

To extract the iron, iron sulfide was heated in roasters. Intense heat in the roasters produced iron sinter which is a high-grade iron oxide product used to produce iron and steel products. The iron concentrates that were burned in these roasters produced the iron pellets which also went to the pellet plant (Cities Service Company, 1974).

The zinc was extracted during a recovery process which involved two circuits. The S circuit was the first circuit which recovered magnetite from zinc. During this process, zinc sulfides were produced. The R circuit was the second circuit which received tailings from the copper recovery process. These tailings were treated with copper sulfate. After treatment, zinc floated to the surface and was recovered. Each circuit produced zinc concentrates for sale. (Cities Service Company, 1974).

Unwanted materials (tailings) from these copper mining processes were released into the 86-ha (212-ac) mine tailings pond located North of the London Flotation Plant. Tailings are waste materials generated by the mining and processing of ores (Hossner and Hons, 1992). The water in the tailings pond eventually evaporated and/or drained. The unwanted materials that were released settled according to the size of particles. Sand particles settled first, usually near the outlet. Finer clay and silt size particles settled at a slower rate and were deposited farther from the outlet at lower landscape positions.

During the 1970s, when the tailings were released into the mine tailings pond and after the water was drained, water naturally began to collect and impound in low landscape positions such as depressions. Naturally, wetlands began to form because of the constant saturation and impoundment of water. Two large wetlands and several smaller wetlands have formed on the tailings pond. These wetlands have not been altered or dredged since their formation. The water level in the wetlands is not artificially controlled, but controlled by seasonal fluctuations and changes in the water table. Future plans include building a dam and flooding the lower landscape to expand the wetland area and continue to support wetland species while reclaiming the upper areas of the mine tailings pond.

GEOLOGY OF THE COPPER BASIN

The Copper Basin is located in the Unaka Mountain chain, also called the Blue Ridge Mountains, and is part of the Appalachian Mountains (Miller, 1974). The Great Smoky Mountains are included in the Blue Ridge/Unakas. These mountains formed approximately 250 million years ago as a result of the east coast of North America colliding with the west coast of Africa. These mountains have steep rugged terrain which formed as a result of millions of years of erosion and intense deformation also known as the Allegheny orogeny (Moore, 1994).

Geology of the Copper Basin consists of many geologic formations. These formations range in age from the Late Proterozoic Era to the Upper Ordovician Period (800 to 435 million years before present) (USGS, 1993). One formation apparent in the Copper Basin is the Copperhill Formation (Precambrian in age or 600,000,000 years old) (Fig. 4). The Copperhill Formation is part of the Great Smoky Group (Precambrian in age) (Miller, 1974). Both the Great Smoky Group and the Copperhill Formation are part of the Ocoee Supergroup.

The Great Smoky Group contains massive layers of saprolite, schist, arkose, graywacke, shale, conglomerate, phyllite, quartzite, gneiss, granite, and mica. Granite and gneiss are located in the northern part of the Unaka Mountains. Phyllite, slate, schist, and quartzite are located in the southern portion of the mountains (Moore, 1994). Much of this bedrock, mostly schist, is at the surface because of erosion. Many places also show saprolite as the major bedrock with layers of mica in the soil (Springer and Elder, 1980).

The rocks in the Great Smoky Group include metamorphic, igneous, and sedimentary rocks (Fig. 5). Metamorphosed rocks have been tilted, tumbled, turned, and folded because of the uprising and formation of the Appalachian Mountains. Metamorphism involves multiple stages of deformation (Slater, 1982). Metamorphic rocks have formed from preexisting sedimentary or igneous rocks, due to alteration by

ERA	PERIOD	YEARS BEFORE PRESENT
CENOZOIC	QUATERNARY	2,500,000
	TERTIARY	68,000,000
	CRETACEOUS	140,000,000
MESOZOIC	JURASSIC	205,000,000
	TRIASSIC	230,000,000
	PERMIAN	285,000,000
	PENNSYLVANIAN	325,000,000
	MISSISSIPPIAN	350,000,000
	DEVONIAN	410,000,000
PALEOZOIC	SILURIAN	430,000,000
	ORDOVICIAN	500,000,000
	CAMBRIAN	600,000,000
PRECAMBRIAN		

Figure 4. Geologic time scale showing age of Precambrian period.

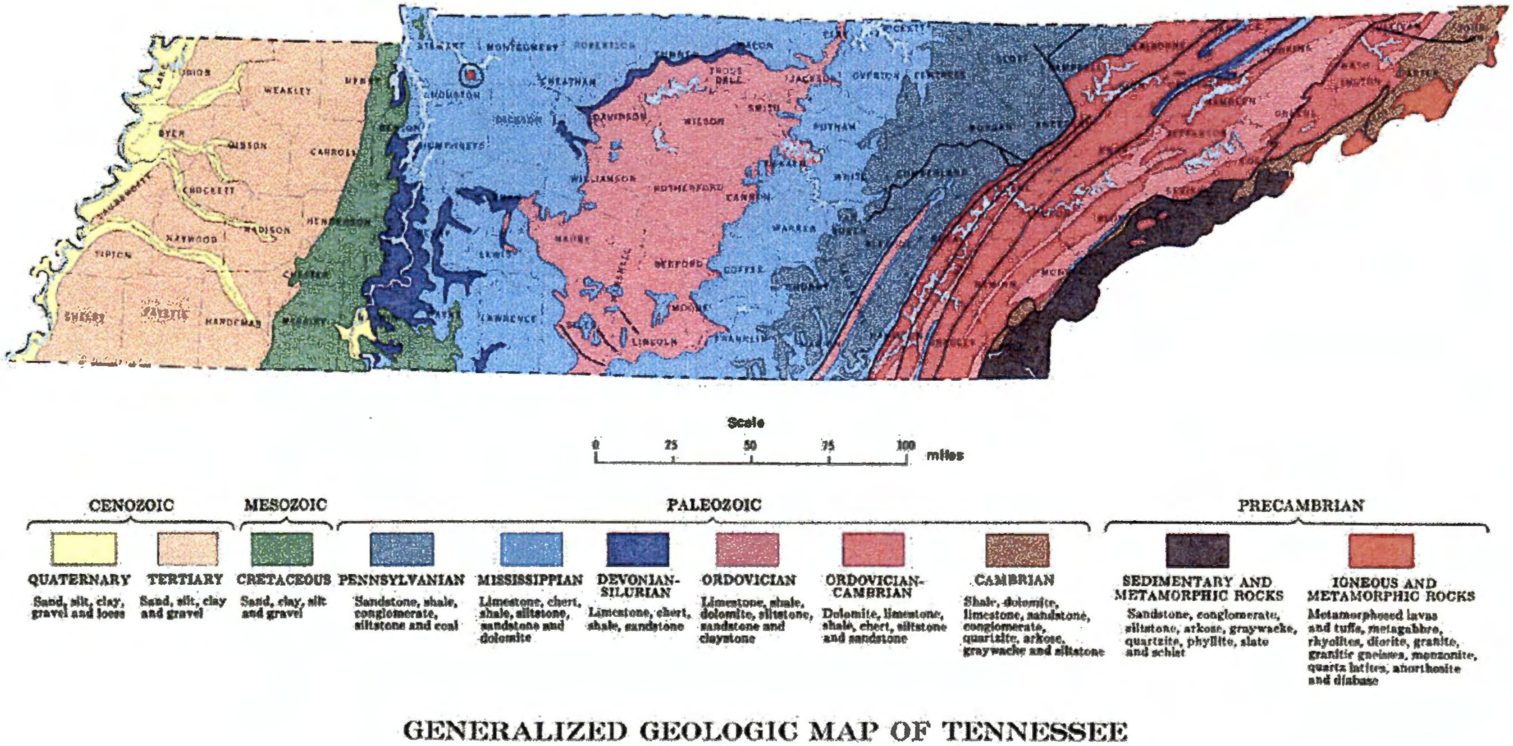

Figure 5. Geologic map of Tennessee.

heat, pressure, and/or chemical change (Moore, 1994).

The metamophosed rocks produced highly mineralized zones. These mineralized zones were sulfide-rich and were mined to obtain small quantities of gold and pyrite (FeS_2). These altered rocks also contained the copper ore deposits that were mined many years ago and gave the Copper Basin its name (Moore, 1994). Iron oxides, magnetite, gold, and silver were also found in these deposits.

The copper ore deposits mined included high-grade "black ores" or chalcocite which contained the purest and most natural form of copper. Because they were high grade, they were the first ores mined (Maher, 1966). Black ores were located between 5 and 20 feet below the surface. The gossan ores were the next ores mined. They were located between 5 and 100 feet below the surface. These gossan ores were weathered, oxidized, and enriched zones. Once the gossan ores were depleted, the sulfide ores were mined. Sulfide ores contained the lowest grade of copper. But, they contained the most abundant copper and pyrite (FeS_2). Some of these lower grade sulfide ores are still present today (Copper Basin Museum, 1999).

CHAPTER 2

SOIL GENESIS AND CLASSIFICATION OF DISTURBED HYDRIC SOILS

INTRODUCTION

Anthropogenic or disturbed soils such as those formed on mined areas have unique properties compared to undisturbed soils. When a soil has been disturbed, the five soil forming factors (climate, organisms, relief, parent material, and time) are interrupted. Commonly, these soils have not been exposed to the soil forming factors for long enough periods of time to develop properties such as structure, horizonization, and profile development. Therefore, their development and formation give them unique characteristics unlike any other soil (Indorante and Jansen, 1984).

Disturbed soils are difficult to define and classify using the current *Keys to Soil Taxonomy*. Therefore, it is critical to understand the soil classification system and to develop a minesoil classification system that can be used to classify disturbed soils. A new minesoil classification system, such as the West Virginia University Minesoil Classification System (Ammons and Sencindiver, 1990), could help reduce interpretation problems associated with minesoils and better understand disturbed soils for future land use and development.

The objectives of this chapter were to: 1) identify the disturbed hydric and non-hydric soils on the mine tailings pond using standard soil survey methods such as complete soil morphological, chemical, and physical characterization and 2) classify both hydric and non-hydric soils to the family level using the *Keys to Soil Taxonomy*.

LITERATURE REVIEW

Definition and Importance of Soil

Soil is defined as "as natural body of mineral and organic matter that changes, or has changed, in response to climate and organisms" (Buol et al., 1989). According to Hilgard (1906), soil is "loose and friable material in which, by means of their roots, plants may or do find a foothold and nourishment, as well as other conditions of growth." Nevertheless, soils are a very important natural resource and are essential to our existence, whether the soil is considered a medium for plant growth (Buol, et al., 1989) or interpreted for physical and chemical properties including soil profile development. The study of the soils development and formation is termed the study of pedology. Pedology is used to refer to the combination of two phases- soil genesis and classification. It is also used to refer to the entire field of soil genesis and classification, including morphology, survey, and interpretation (Buol et al., 1989).

Five Soil Forming Factors

Hans Jenny and his publication of *Factors of Soil Formation* in 1941, introduced five important concepts critical in how soil scientists understand soil development today. According to Jenny (1941), soil is a natural body of mineral and organic material formed from the action and interactions of the climate, organisms, parent material, relief, and time. These are best remembered as s = cl, o, r, p, t. All of these factors, together, are very critical in soil formation.

Time

The amount of time a soil has been exposed to the other soil forming factors and weathering processes is indicative of how it develops. Time starts at point zero or what the soil was like in its original state. This is the point at which a new cycle of soil development begins (Buol et al., 1989). Time zero indicates the moment that parent material is first exposed to the factors of soil formation (Joffe, 1949). Time zero can be considered a catastrophic event, such as a volcanic eruption, earthquake, disturbance by man, or landslide. Many older soils, such as those on uplands, have been forming for thousands of years (Springer and Elder, 1980). Other soils, such as alluvial soils, or soils deposited by water, are much younger. They have not had the time to form compared to upland soils (Brady, 1974).

Relief

Relief is defined as "the configuration of inequalities of a land surface with which natural and anthropic features are combined on topographic maps" (Buol et al., 1989). Attributes of relief include elevation, slope, natural soil drainage condition, aspect (degrees off North), slope configurations, and positions (such as upland or toeslope positions) (Buol et al., 1989). A flat landscape is less likely to be exposed to erosional processes as compared to hilly or mountainous terrain. As a result, the rate of soil formation and type of soils formed differ in different areas (Brady, 1974). Relief can be also be described by the physiographic region or topography of an area. For example, Ducktown, Tennessee is located between the Unaka Mountains and Valley and Ridge physiographic regions.

Climate

Climate depends on the location and elevation of a specific area (Buol et al., 1989). Factors critical in climate determination include temperature, precipitation amount, rainfall intensity, wind, humidity, and clouds, storms, microclimate or local climate condition, and water balance (Springer and Elder, 1980). Microclimate and macroclimate must both be considered. The microclimate or local climatic conditions is the first few feet above the soil surface. Slope aspect, wind, and shading of vegetation are attributes of a microclimate. Precipitation, light, and temperature influence soil formation in a macroclimate (Buol et al., 1989).

Temperature and precipitation are two critical components of climate which vary depending on a specific area. They are both involved in the chemical and physical processes that affect soil formation (Brady, 1974). Soil reactions depend on temperature in the soil. As the temperature increases 10 C °, chemical reaction rates double (Jenny, 1941). Temperature also affects the type and amount of vegetation. Temperature is controlled by the amount of water found in the soil profile (Buol et al., 1989).

Parent Material

Parent material is the initial material which has not yet been influenced by climate, organisms, relief, and time. It is the material at time zero or from which the soil originally formed (Buol et al., 1989). The texture, structure, chemical, and mineralogical composition of the soil are determined largely by parent material (Brady, 1974). This initial material can be approximated by looking at the C horizon of a soil profile. This material has not had time to change and lies deep within the Earth so that it is not affected by organisms (Buol et al., 1989).

Parent material is separated into two groups, sedentary or transported. Sedentary parent material develops in place and is in its original state (also called residual). Transported parent material has been moved by gravity, water, ice, or wind. Transported parent material includes colluvial (deposited by gravity), alluvial, marine, or lacustrine (deposited by water), glacial (deposited by ice), and aeolian (deposited by wind). Colluvium, consists of rock fragments which have become unattached and deposited by gravity. These stony rock fragments have not been altered or weathered significantly. Alluvial, marine, and lacustrine parent materials have been deposited by water movement. Alluvial deposits include floodplains, alluvial fans, and deltas. Glacial till consists of small stones or large boulders deposited by ice. Soils formed from glacial till are heterogeneous. Aeolian deposits are deposited by wind erosion. Loess (a fine-silty textured soil) is an example of an aeolian deposit found especially in the Midwest. Volcanic ash and sand dunes are also considered aeolian deposits (Brady, 1974).

Organisms

Organisms play a critical role in soil formation. Soil is a mixture of life involving plants, animals, macroorganisms such as earthworms, and microorganisms such as bacteria and fungi. These organisms mix and loosen the soil, help to redistribute nutrients, and break down organic matter (Buol et al., 1989). Larger animals such as moles and gophers initiate soil mixing and granulation (Brady, 1974). They aid in root penetration as well as moisture conservation (Hilgard, 1906). Organisms can actually protect soils from erosion by stabilizing them and reducing the impact of water and wind

(Buol et al., 1989).

Soil Classification

Soil taxonomy is a system of classification of soils developed by the USDA Soil Survey Staff. This system of classification organizes different soils from lower to higher categories for identification and use. Soil classification began in 1883, when the Russian soil scientist, V.V. Dokuchaev, founder of pedology, first developed the concept of soils as natural bodies that needed to be classified. He produced the first scientific classification of soils and developed soil mapping methods. Dokuchaev laid the foundation for the science of soil genesis (Buol et al., 1989). In 1927, and then in 1936, C.F. Marbut, director of the U.S. Soil Survey Division, devised a soil classification scheme based on soils being natural bodies. In 1938, Marbut's classification system was revised by Kellogg and Thorp, to produce a classification system of all the soils in the United States (Soil Survey Staff, 1993). In 1975, Guy Smith, director of Soil Survey Investigations for USDA-SCS, developed the soil classification system which is much like the soil classification system used today (Buol, et al., 1989).

Today's soil classification system is based on six categories: order, suborder, great group, subgroup, family, and series (lowest category in the classification system). Soil orders are based on the presence or absence of major diagnostic horizons. Diagnostic horizons have specific soil characteristics that are indicative of certain classes of soils (Miller and Donahue, 1990). Currently, there are twelve soil orders in the United States (Soil Survey Staff, 1998).

The suborder is the next category which subdivides the orders based on the presence or absence of characteristics such as soil wetness, soil moisture regimes, major parent material, and vegetation; the suborder is also a subdivision based on genetic homogeneity. Suborders are further divided into great groups depending on the degree of horizonization, arrangement of horizons, and presence or absence of certain diagnostic horizons. Great groups are divided into subgroups which are based on the central concept of that great group (Buol et al., 1989). A family is separated based on soil particle size, mineralogy, reaction classes (pH), and soil temperature classes (Springer and Elder, 1980). A family can also be separated based on plant growth characteristics; a family is further divided into the lowest category, soil series. The soils in a series have similar profile characteristics (Brady, 1974). These characteristics include the arrangement of horizons, texture, structure, consistence, and reaction. A soil series is named from where that soil was originally described (Buol et al., 1989).

Significance of Disturbed Soils and Their Formation

Disturbed soils are unique and have to be studied in detail to achieve valid interpretations (Ammons and Sencindiver, 1990). Defining, classifying, mapping, and characterizing these disturbed soils are difficult. Only recently has there been a demand for soil maps on disturbed soils. Pedologists have been slow to separate and define different soils in disturbed areas because of their high variability (Indorante and Jansen, 1984).

Disturbed soils are so variable because each disturbance produces a different effect on that soil. For example, soils disturbed by mining practices will differ from those soils disturbed by landfilling. Soils with only a surface horizon disturbance, such as plowing or moderate erosion are not included in this range because the *Keys to Soil Taxonomy* already describe those soils (Soil Survey Staff, 1994). Currently, *Keys to Soil Taxonomy* offers no classification scheme to account for disturbed soils. The dissimilarities inherent in disturbed soils presents the problem when classifying (Indorante and Jansen, 1984).

Prior to the 1980s, surface mined lands were classified as Orthents and delineated on soil maps as mine dumps or strip mines (Indorante and Jansen, 1984). In the 1980s, most of the mined land in the Eastern U.S. was mapped as Udorthents or families of Typic Udorthents (Ammons and Sencindiver, 1990). Problems arose because there were no interpretative data given to identify the soil and determine previous practices to that soil (Indorante and Jansen, 1984).

Today, disturbed soils are mapped by defining soil units (separating the soils into like and unlike categories) and delineating corresponding bodies in the landscape. Important aspects to consider include what the soil was like before mining, method of mining and type of equipment used, original geologic formation, and reclamation practices initiated after mining. This gives soil scientists an idea of the disturbed soils' characteristics. Aerial photographs, mining histories, field notes, and reclamation notes are also important for delineation. Once the soil unit is defined and soils are separated into like and unlike categories, field notes, soil morphology of pedons, and lab analyses are done on the selected profiles. Finally, the soil units are used as a basis to propose a new soil series (Indorante and Jansen, 1984).

Because many of the minesoils do not fit into any of the classes in *Keys to Soil Taxonomy*, a new minesoil suborder termed Spolent was proposed by researchers in the 1970s at West Virginia University. At least three of the following criteria must be met in order for the Spolent suborder to be used: 1) Disordered coarse fragments, 2) Color mottling not associated with horizonization, 3) Sharp edges on coarse fragments, 4) Bridging voids between coarse fragments created when rock and fine materials are deposited together by a dragline or other machine, 5) Thin surface horizon higher in fines, 6) Pockets of contrasting materials, 7) Artifacts, 8) Carbolithic coarse fragments, or 9) Irregular distribution of oxidizable carbon (Ammons and Sencindiver, 1990).

MATERIALS AND METHODS

Site Selection

The study sites are located on a mine tailings pond in Polk County, Tennessee. The mine tailings pond is located north of the London Flotation Plant at N 35°02' 59.4" latitude and W 84°21'11.0" longitude on the 7.5-minute Isabella Quadrangle (Isabella Quadrangle, USGS, 1978).

An initial site investigation of the wetlands surrounding the mine tailings pond was performed using USGS topographic maps (Isabella Quadrangle; USGS, 1978) to identify contour lines, slope, and drainage patterns. Aerial photographs were used to identify the hydric soil fringe.

After the initial site investigation, an onsite physical investigation was performed using a soil probe to locate the hydric soil fringe. All of the soil profiles were selected based on where the hydric soil fringe might be located as determined from the aerial map, observations from the onsite physical investigation, and areas that had characteristics of wetlands as described by the Wetland Training Institute Inc., (1995). All site positions were recorded using a GPS unit. Later, laboratory analysis and chemical characterization of samples were completed on the samples collected. An aerial map of the mine tailings pond shows where the cores were pulled and their relation to the wetlands (Fig. 6).

Field Methods

A total of nine soil pits were excavated with shovels to the water table and each horizon was described and sampled. One profile, #16, was sampled using a Giddings Hydraulic Probe to a depth of 110 cm. Table 1 outlines the latitude and longitude of the ten soil profiles on the mine tailings pond.

Field descriptions included horizon designation, lower depth, soil color (moist and dry), texture, structure, and alpha, alpha, dipyridyl reaction (Childs, 1981). Redoximorphic features such as iron depletions, manganese and iron concentrations, and/or a gleyed matrix were noted. Other characteristics noted included depth to the water table, depth to the gleyed layer, slope percent, types and density of hydrophytic vegetation, slope aspect, soil drainage class, and parent material. Each profile was classified to the family level using the *Keys to Soil Taxonomy* (Soil Survey Staff, 1998).

All profiles were described and sampled according to National Cooperative Soil Survey Standards (Soil Survey Staff, 1998).

Figure 6. Aerial map of mine tailings pond showing location of cores in relation to wetlands.

Table 1. Latitude and Longitude of Ten Soil Profiles on Mine Tailings Pond.

Site	North Latitude	West Longitude
5	N 35°02'59.4"	W 84°21'25.6"
6	N 35°02'58.0"	W 84°21'24.8"
7	N 35°02'58.6"	W 84°20'42.8"
8	N 35°03'03.2"	W 84°21'06.0"
12	N 35°03'00.3"	W 84°21'32.1"
13	N 35°03'04.8"	W 84°21'13.8"
14	N 35°03'04.6"	W 84°21'05.0"
15	N 35°03'09.7"	W 84°21'02.6"
16	N 35°02'59.6"	W 84°21'40.6"
20	N 35°02'55.3"	W 84°21'02.2"

Laboratory Methods

Each soil sample was air-dried and crushed to pass a 2-mm diameter sieve. A fraction of the 2-mm sieved sample was then separated and passed through a 60-mesh screen (Soil Survey Staff, 1996). Moist and dry weight (oven-dried at 105°C for 12 hours) were recorded and percent moisture content was calculated.

Particle size distribution of clay, silt, and sand fractions were determined using the pipette method (Kilmer and Alexander, 1949). Sand fractions were separated into very coarse, coarse, medium, fine, and very fine sand (Gee and Bauder, 1986). Textures of each horizon were determined using the USDA textural classification system.

Because these samples were high in free carbonates, pH 5.0 sodium acetate buffer was used to remove carbonates (Gee and Bauder, 1986) before particle size separation. The low amount of carbon content in the soil precluded pretreatment and removal of organic matter.

An Orion Research analog pH meter (model 301) was used to determine the pH of each sample using a 1:1 soil-water solution (Olsen and Ellis, 1982a) and a 2:1 soil solution in 0.02 N calcium chloride.

A fizz test using 2 N HCl was performed initially to determine if free carbonates were present. Neutralization potential (Sobek et al., 1978), a part of acid-base accounting, was used on the 60-mesh samples to determine the amount of neutralizing bases or free carbonates present in the soil.

Exchangeable bases were extracted by saturation with 1 N ammonium acetate at pH 7 (Hammer and Lewis, 1987) and analyzed on a Perkin-Elmer 5000 Atomic

Absorption Spectrophotometer. Cation exchange capacity was determined using an acidified sodium chloride solution and distilled in a Lab Conco Rapid Distillation Unit to determine cmol (+)/kg for cation exchange capacity (Chapman, 1965).

Total acidity was determined using the KCl extraction method using 1 N potassium chloride (Thomas, 1982). The KCl extract was analyzed on the atomic absorption spectrophotometer to determine exchangeable aluminum. The exchangeable aluminum was used to determine the effective cation exchange capacity of the soil.

Manganese oxides were extracted using an acidified hydroxylamine hydrochloride method (Chao, 1972; Gambrell and Patrick, 1982). The extract was analyzed on the atomic absorption spectrophotometer to determine the amount of easily reducible manganese in each horizon.

Free iron oxides were extracted using the citrate-dithionite method (Olsen and Ellis, 1982b) on 60-mesh soil samples. After the iron was extracted, the iron content (in ppm of Fe^{2+}) was determined on the atomic absorption spectrophotometer.

Alpha, alpha,-dipyridyl (Childs, 1981) was used to determine the presence of ferrous iron (Fe^{2+}) in each horizon. If ferrous iron was present, a light pink to a deep red color formed.

Total elemental concentrations were determined using a modified microwave digestion technique using hydrofluoric acid and aqua-regia (Ammons et al., 1995). After the samples were digested, the extract was analyzed on the ICP Model, ICAPES (inductively coupled argon plasma emission spectrometer) for 24 elements; these included (Al, As, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, S, Se, Si, Sr, Ti, Zn, and Zr).

The Walkley-Black method (Jackson, 1958) was used to determine the amount of oxidizable organic carbon and percent organic matter.

Total sulfur was determined by leaching a sample with hydrochloric and nitric acid. This was necessary to remove chlorides and nitrates. This gave HCl extractable sulfur which contains mostly sulfates and HNO_3-extractable sulfur which contains mostly pyritic sulfur. The non-extractable sulfur contains mostly organic sulfur. Total carbon, nitrogen, and sulfur percentages were determined on the Leco-CNS 2000 (Sobek et al., 1978).

The Mehlich I (Dilute-Double-Acid) method was used to assess soil fertility levels (Mehlich, 1953). The major plant nutrients extracted using dilute hydrochloric and sulfuric acid were Ca, K, Mg, Na, Cu, Zn, Fe, and Mn. This extract was analyzed on the atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Hydric Soil Profile #5

Soil profile #5 was located at N 35° 02'59.4" and W 84°21'25.6" west on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had hydrophytic vegetation dominated by some scarce brown sedges and cattails. Surface water was apparent from the adjacent wetland. Soil samples were collected and morphology was described to a depth of 55 cm (this was the initial water table depth). The parent material was alluvium.

Soil profile #5 showed evidence of gleying at 9 cm (Fig.7). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 5GY 4/1 to N4 and N3 (Table 2). Redoximorphic features such as iron and manganese concentrations in the C horizon and iron depletions in Cg1 were noted, indicating anoxic conditions; a fluctuating water table and repeated soil saturation were apparent. Water drives the development of redoximorphic features by assisting in additions, removal, transfers, and transformations of substances in the soil (Mausbach and Richardson, 1994). Horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl indicating there was enough ferrous iron (Fe^{2+}) to react with the dye. Gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 3). Consequently, ferrous iron was low or removed from these horizons. This indicates that these soils were subjected to constant saturation and have been waterlogged for some time, not only due to seasonal differences, but also due to a constant high water table. The soil drainage class was very poorly drained meaning that water is removed from the soil very slowly and free water remains at or near the surface during much of the growing season (Soil Survey Staff, 1993). Depth to the water table was 42 cm.

Total sand percentages ranged from 94.0% in the uppermost horizon (8-20 cm) to 90.35% as the lowest percentage which occurred in the Cg4 horizon (42-50 cm) (Table 4). Fine sand percentages (of total sand) ranged from 43.7% in the Cg5 horizon (50-55 cm) to 55.9% in the Cg3 horizon (27-42 cm). Fine sand percentage made up the majority of the distribution of sand size fractions (Table 5). This site was located closer to the outlet where the tailings were released into the tailings pond, therefore the larger sized

Figure 7. Hydric Soil Profile #5.

Table 2. Morphology of Hydric Soil Profile #5.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	8	5G 4/1 5YR 5/8 5GY 5/1	10YR 4/6 10YR 4/4	fS	sls sg	abrupt	loose	Very Strong	Fe and Mn Concentrations
Cg1	20	5Y 4/2	10YR 4/4 2.5Y 4/4 5GY 4/1 N4	fS	sls sg	clear	loose	Very Strong	Fe Depletions
Cg2	27	5GY 4/1	5Y 4/3 2.5 Y 4/4	fS	sls sg	clear	loose	Very Strong	
Cg3	42	5GY 4/1	2.5Y 4/4 5Y 4/3	fS	sls sg	clear	loose	Very Strong	Fe Depletions
Cg4	50	N3	N4	fS	sls sg	clear	loose	Very Strong	
Cg5	55+		N4	fS	sls sg	-	loose	Very Strong	

*Abbreviations for morphology designations are given in Appendix A.

Table 3. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl for Hydric Soil Profile #5.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C	8	20.84	6.6	2.11	0.2448	0	0	0
Cg1	20	19.79	6.2	2.66	0.2844	0.23	0	0.23
Cg2	27	20.89	6.3	1.87	0.3152	0.08	0	0.08
Cg3	42	20.64	6.0	1.61	0.3244	0.08	0	0.08
Cg4	50	20.49	6.8	0.76	0.3457	0.04	0	0.04
Cg5	55+	22.48	6.9	0.95	0.3237	0.04	0	0.04

Horizon	Lower Depth (cm)	CEC			Bases		Base Saturation (%)	alpha,alpha dipyridyl
		cmol+ kg^{-1}	Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}		
C	8	1.20	113.30	0.53	0.05	0.08	>100	Positive
Cg1	20	0.85	69.60	0.91	0.09	0.05	>100	Negative
Cg2	27	1.07	85.10	1.17	0.22	0.05	>100	Negative
Cg3	42	0.67	37.80	1.20	0.15	0.04	>100	Negative
Cg4	50	0.62	19	1.18	0.12	0.03	>100	Negative
Cg5	55+	0.49	18.30	1.09	0.09	0.03	>100	Negative

Table 4. Particle Size Distribution for Hydric Soil Profile #5.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	8	94.00	2.87	3.13
Cg1	20	93.19	3.66	3.15
Cg2	27	91.84	4.91	3.25
Cg3	42	90.50	5.31	4.19
Cg4	50	90.35	6.60	3.05
Cg5	55+	92.19	5.22	2.59

Table 5. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #5.

Horizon	Lower Depth (cm)			SAND			SILT	SILT
		VCOS %	COS %	MS %	FS %	VFS %	COSi %	F Si %
C	8	1.17	13.19	15.34	46.71	17.49	1.23	1.64
Cg1	20	0.76	9.69	11.78	48.64	22.23	1.8	1.86
Cg2	27	0.65	8.49	12.97	48.81	20.63	2.79	2.13
Cg3	42	0	2.52	7.01	55.91	24.87	3.44	1.87
Cg4	50	0.09	3.96	6.53	49.04	30.18	4.58	2.02
Cg5	55+	1.19	11.31	13.50	43.68	22.43	3.84	1.39

particles (sands) settled out first. Finer particles such as silts settled farther from the outlet. The total clay percentages in all horizons ranged from 2.59% to 4.19% indicating that there was little pedogenic development (Table 4).

This soil profile had a weak iron pan above the gleyed layers. This site had a shallow water table and was located closer to the wetland than the other sites. Manganese concentrations corresponded to the fluctuating water table. Manganese concentrations (hydroxylamine manganese which accounts for Mn^{2+}, a reducible form) were lowest (0.2448 g kg^{-1}) in the horizon preceding the gleyed layers (Table 3). Higher manganese concentrations (0.2844 g kg^{-1}) in the Cg1 horizon can be attributed to the increased ability of anaerobic microorganisms to actively reduce Mn^{4+} to a more usable form. As oxygen becomes limited in the gleyed layers, the anaerobic organisms use manganese oxides and iron oxides and convert them to these reduced forms (Mausbach and Richardson, 1994). Manganese concentrations were slightly higher in the gleyed layers because, although the water table was shallow, it may have not been shallow enough to leach the manganese from the gleyed layers. Reduced manganese is also very mobile. Hydroxylamine manganese concentrations were much lower than total manganese concentrations (total manganese includes Mn^{2+} and Mn^{4+}) (Fig. 8). Low cation exchange capacities and sandy textures did not allow the Mn^{2+} to bind and attach to the exchange sites, therefore it was readily leached from the soil profile.

Free iron and total iron (Fe^{3+} and Fe^{2+}) concentrations also fluctuated with the fluctuating water table. In those profiles with shallower water tables, iron concentrations decreased with depth because ferrous iron (Fe^{2+}) is very mobile and moved with the

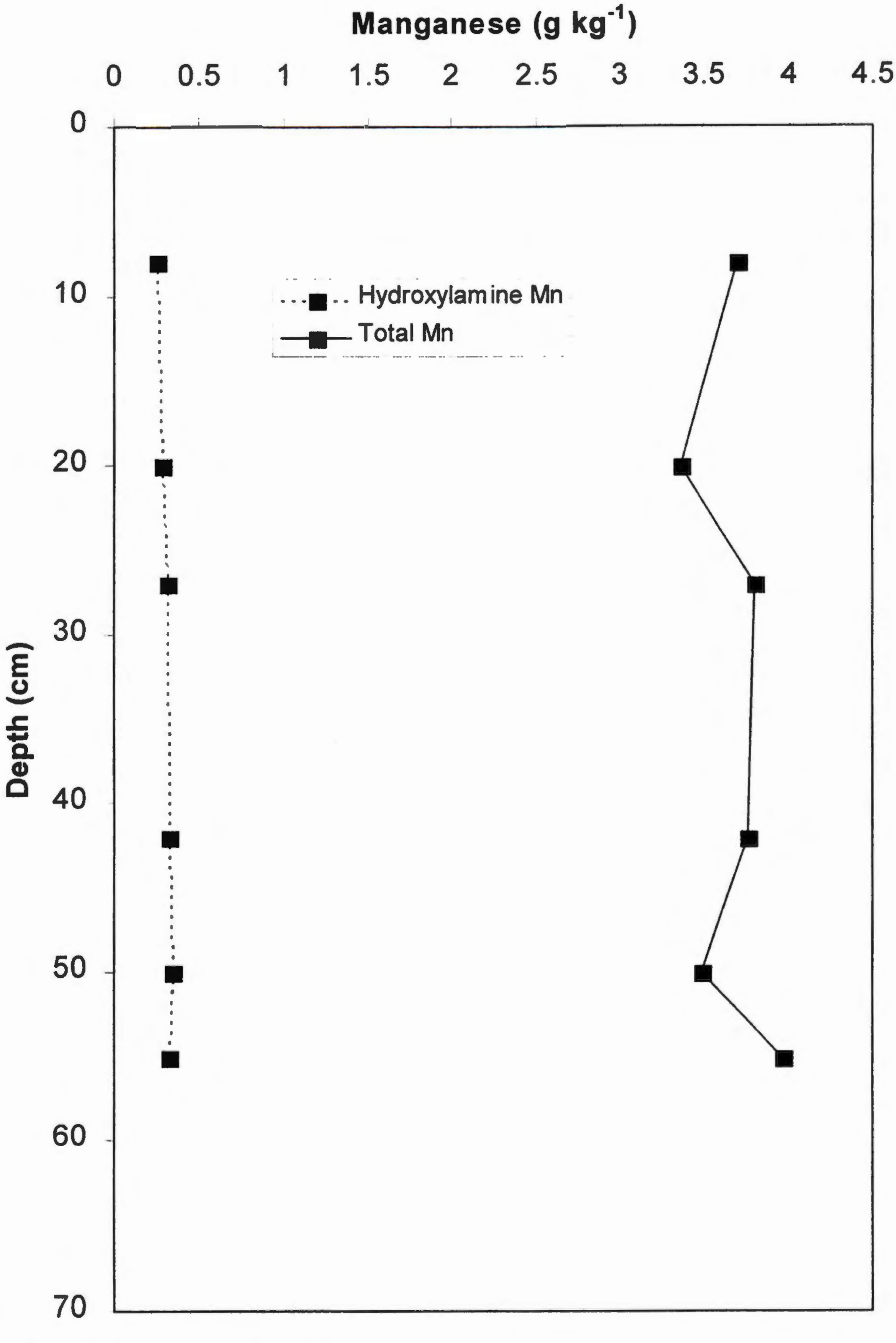

Figure 8. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #5.

fluctuating water table. Free iron (%) was lower in the C horizon (2.11%) compared to Cg1 in which the free iron was slightly higher (2.66%), but compared to the other gleyed layers, decreased (Table 3). Free iron and total iron concentrations increased with depth to the Cg1 horizon (8-20 cm) before decreasing in the Cg2 horizon (27-55 cm), illustrating typical development of the gleyed layers and active conversion of Fe^{3+} to Fe^{2+} by microorganisms (Fig. 9). As iron is reduced, the typical gray color of a hydric soil develops. High total and free iron concentrations in Cg1 can be attributed to anaerobic microorganisms actively converting Fe^{3+} to a more usable form of Fe^{2+}. In addition, these higher iron concentrations may be related to and increase in Fe^{3+}. Fe^{3+} and sulfur are products of pyrite oxidation. Pyritic oxidation also produces sulfuric acid (H_2SO_4) (Sparks, 1995). An increase in Fe^{3+} corresponded to a slight decrease in pH for Cg1 and a higher total sulfur percent (Table 6). Free iron simulated the same pattern as total iron and was lower than total iron throughout the soil profile. Iron concentrations decreased in Cg2 and at lower depths because it leaches easily in sandy textures and will not bind well. A decrease in fine sand should correspond to an increase in free iron oxide concentration (8-20 cm), which was not apparent in this profile (Fig. 9). A free iron oxide bulge should be apparent with an increase in total clay percent and a decrease in fine sand (Tables 4, 5). This was significant because a decrease in fine sand would mean an increase in other soil particle sizes such as clay, therefore increasing the ability for free iron oxides to be retained in the soil.

Low cation exchange capacity (CEC) throughout the profile can be attributed to low clay percent (Table 3). Clays have the exchange sites which are responsible for

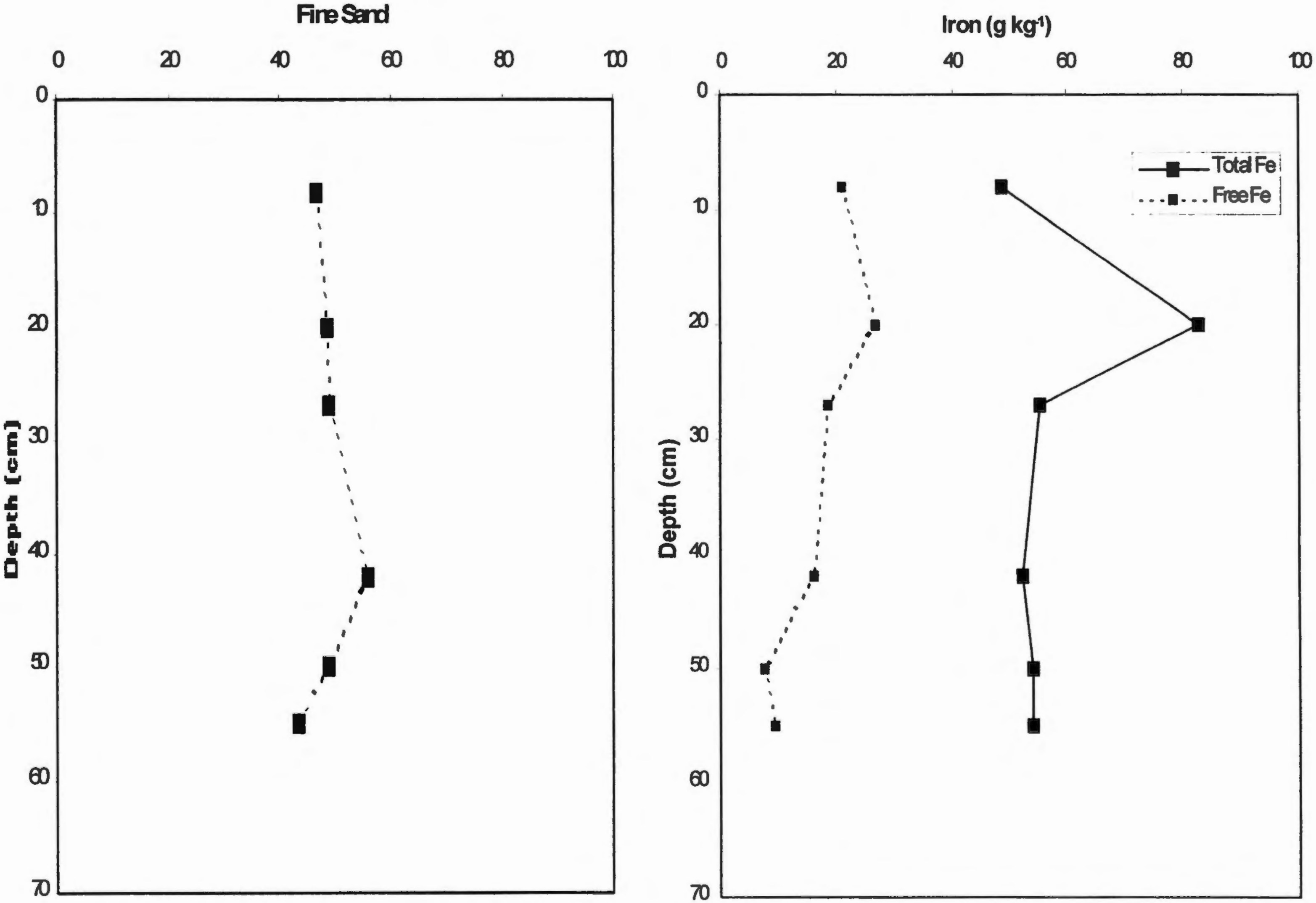

Figure 9. Fine sand, total iron, and free iron for Hydric Soil Profile #5.

Table 6. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #5.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	8	2.33	0.05	2.21	0.32
Cg1	20	1.91	0.05	5.59	0.09
Cg2	27	2.14	0.05	2.46	0.07
Cg3	42	2.12	0.06	2.22	0.02
Cg4	50	2.11	0.06	2.32	0.05
Cg5	55+	2.25	0.05	2.84	0.02

cations (Ca^{2+}, K^+, Na^+, Mg^{2+}) to be held or exchanged on a site (Miller and Donahue, 1990). Because of the low clay percentage, there was little to no exchange. Cation exchange capacity was highest in the surface (1.20 cmol+ kg^{-1}), decreased to 0.85 cmol+ kg^{-1} in Cg1, increased again to 1.07 cmol+ kg^{-1} in Cg2, and steadily decreased to a depth of 55 cm. Organic carbon content could be attributed to the higher CEC in the surface horizon. Organic carbon had a regular decrease with depth to the Cg5 horizon with the exception of Cg4 (50 cm) (Fig. 10). A surface high in organic matter is one characteristic of a hydric soil. The higher organic carbon content above the gleyed layers supplied the energy for anaerobic microorganisms and initiated the action of oxidation and reduction processes throughout the soil profile. The lower organic carbon content in the gleyed layers could be attributed to low decay rates and a decrease in plant roots because of the very poor drainage. In addition, the wetter conditions in the gleyed layers may have restricted organic matter oxidation (Brady and Weil, 1996). In general, soils high in clay and silt textures generally have higher organic matter content than sandy soils. This is related to nutrient and water holding capacities (Brady and Weil, 1996).

High base saturation (>100%) was observed in all horizons (Table 3). This can be attributed to the high calcium concentrations in each horizon. Greater calcium concentrations in horizons can be associated with the high amounts of calcium carbonate ($CaCO_3$) used during the mining process. As $CaCO_3$ dissolves, it releases calcium (Ca^{2+}) and carbonic acid (H_2CO_3) (Miller and Donahue, 1990).

The calcium carbonate equivalent (CCE%) was determined by neutralizing potential, a part of acid-base accounting. CCE determines the amount of readily available

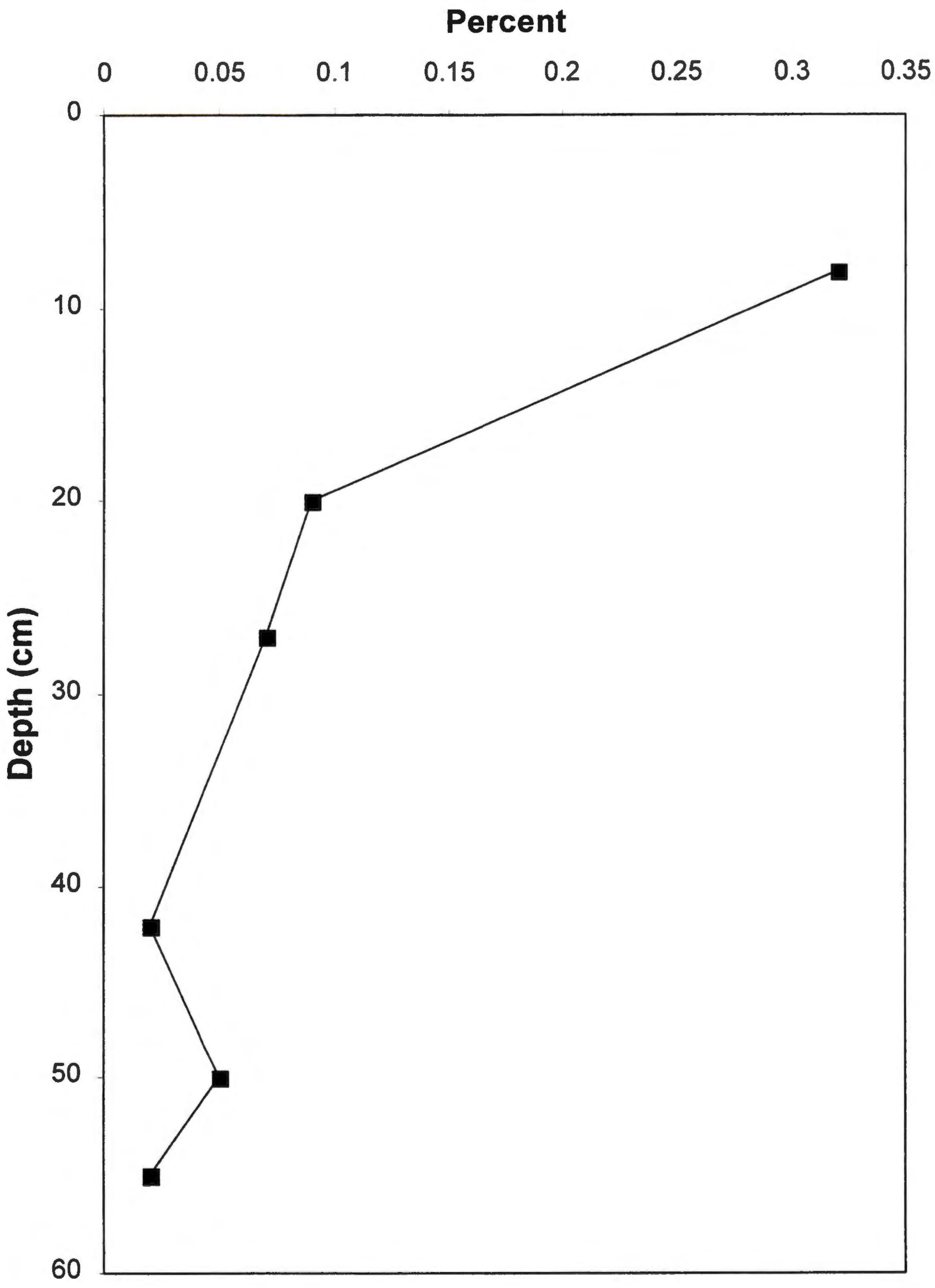

Figure 10. Organic carbon distribution for Hydric Soil Profile #5.

neutralizing bases in the soil (Jackson, 1958). The pH is usually dependent on CCE but because these soils have been disturbed, a normal pattern may not be followed. As CCE increases, pH should also increase, because this increases the potential for base cations to form. This is related to the buffering capacity of the soil. Buffering capacity is the ability of a soil to resist changes in pH. An increase in buffering capacity can be attributed to an increase in CEC which is related to an increase in clay. As the buffering capacity increases, it is more difficult to change the pH. Because these soils were so sandy with low clay percentages, buffering capacity was also lower. The added calcium carbonate used during the mining process removes acid formers. Hydrogen ions do not form and pH does not decrease (Miller and Donahue, 1990). The CCE remained nearly constant throughout the profile regardless of pH, with a slight increase in the lowest horizon (Cg5) (Table 3). In this horizon, the CCE was the highest (22.48%) which corresponded to the high pH (6.9). A very strong effervescent reaction to 10% HCl was noted in each horizon indicating that free carbonates were abundant (Table 2).

The particle size control section had >90% sand ranging in the highest percentage of sand as fine sand (Fig. 11). Horizons in the control section had a texture of loamy fine sand or coarser putting it in the Psammaquent great group. This soil had no evidence of pedogenic development, no diagnostic horizons, and had stratification making it an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. The mineralogy class was mixed. This site was classified as a mixed, mesic Typic Psammaquent. Sandy was not used because it is considered redundant.

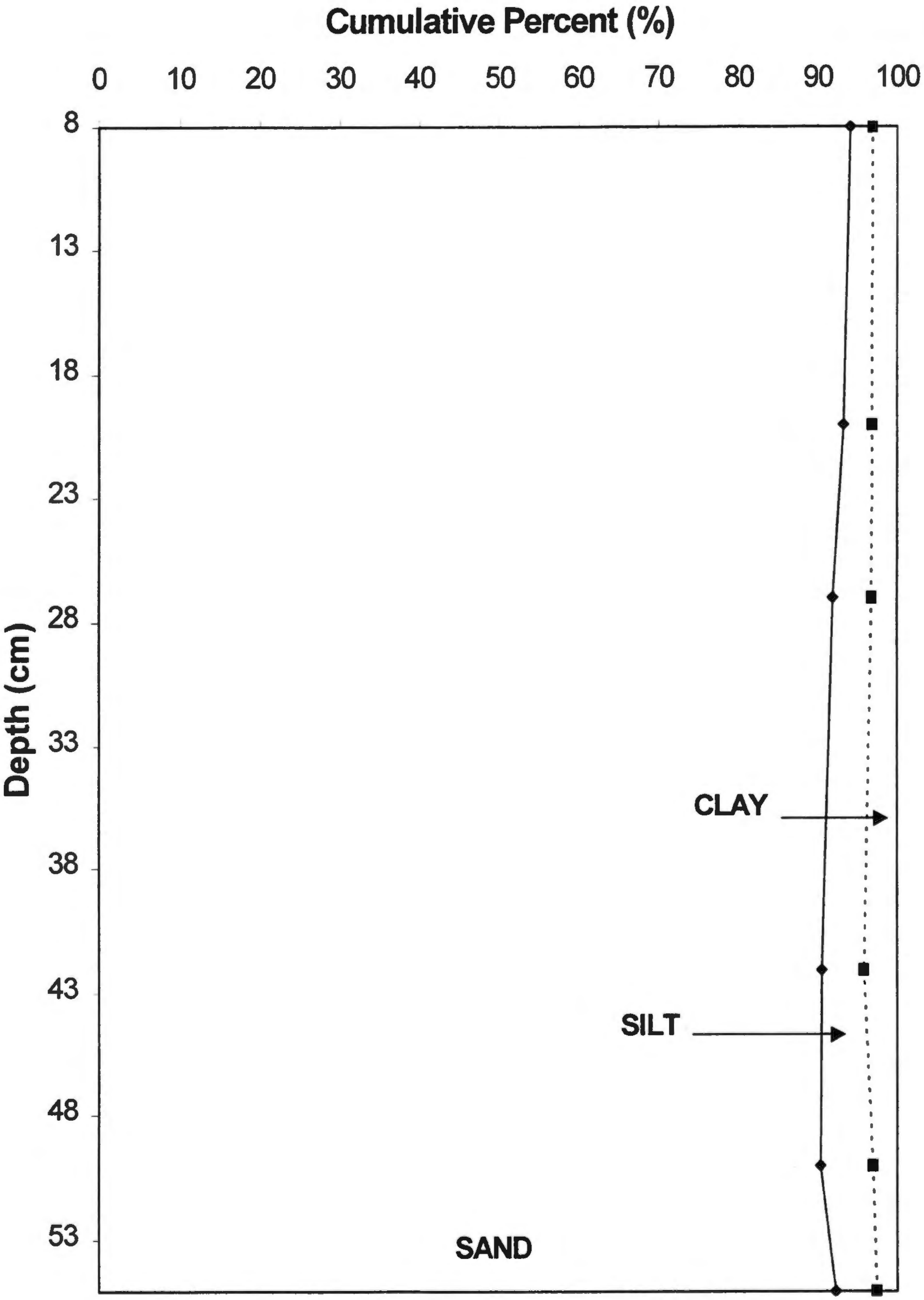

Figure 11. Particle size plot for Hydric Soil Profile #5.

Non-Hydric Soil Profile #6

Non-hydric soil profile #6 was located at N 35°02'58.0" and W 84°21'24.8" west on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had less hydrophytic vegetation than soil profile #5 including few scarce brown sedges. Surface water was also apparent from the adjacent wetland. Soil samples were collected and morphology was described to a depth of 66 cm. The parent material was alluvium.

Soil profile #6 showed evidence of gleying at 29 cm (Fig.12). This profile was non-hydric because colors recorded did not reach chroma ≤2 until 29 cm. Colors in the first three horizons (C1, C2, and C3) ranged from 10YR 4/6, 7.5YR 4/4, 5YR 3/4, and 2.5YR 4/4. Gleyed horizon colors ranged from 2.5YR 3/2 (moist) to 5GY 4/1 (moist) and 5Y 4/2 (dry) (Table 7). Redoximorphic features such as iron and manganese concentrations were noted in the top four horizons. As in soil profile #5, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl indicating there was enough ferrous iron to react with the dye. In addition, the gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 8). Here, ferrous iron was either very low or leached from these horizons. This profile had been saturated for some time to remove the ferrous iron. Although this profile was non-hydric, the soil drainage class was also very poorly drained because of its location near the wetland and the abundance of surface water located around the site. Depth to the water table (49 cm) was not as high as soil profile #5 because this site was located farther upland. As a result, this site did not support as much hydrophytic vegetation.

Figure 12. Non-Hydric Soil Profile #6.

Table 7. Morphology of Non-Hydric Soil Profile #6.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C1	10	10YR 4/6 7.5YR 4/6	10YR 4/6	fS	sls sg	clear	loose	Very Strong	Fe and Mn Concentrations
C2	17	10YR 4/4 2.5Y 5/4	10YR 4/6 7.5YR 4/4 10YR 4/4	fS	sls sg	clear	loose	Very Strong	Fe and Mn Concentrations
C3	28	5YR 3/4 7.5YR 5/6	10YR 3/3 2.5YR 4/4	fS	sls sg	abrupt	loose	Very Strong	Mn Concentrations
Cg1	43	2.5YR 3/2	5Y 4/3	fS	sls sg	clear	loose	Very Strong	Mn Concentrations
Cg2	56	5GY 4/1	5Y 4/3 5Y 4/2	fS	sls sg	clear	loose	Very Strong	
Cg3	66+		5GY 5/1	fS	sls sg	-	loose	Very Strong	

*Abbreviations for morphology designations are given in Appendix A.

Table 8. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Non-Hydric Soil Profile #6.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_20)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C1	10	16.53	7.1	3.79	0.2795	0.04	0	0.04
C2	17	20.74	7.1	3.17	0.2737	0.04	0	0.04
C3	28	18.15	6.9	4.22	0.2894	0.08	0	0.08
Cg1	43	21.42	6.5	1.92	0.3156	0.08	0	0.08
Cg2	56	20.29	6.4	1.71	0.3163	0.08	0	0.08
Cg3	66+	22.49	6.6	1.17	0.3281	0.04	0	0.04

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Bases Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}	Base Saturation (%)	alpha,alpha dipyridyl
C1	10	1.15	127.70	0.30	0.03	0.04	>100	Positive
C2	17	0.98	155.43	0.30	0.03	0.04	>100	Positive
C3	28	0.96	103.48	0.56	0.04	0.03	>100	Positive
Cg1	43	0.83	48.99	0.68	0.08	0.04	>100	Negative
Cg2	56	0.81	47.33	0.74	0.09	0.04	>100	Negative
Cg3	66+	0.75	22.99	1.01	0.08	0.04	>100	Negative

Total sand percentages ranged from 94.2% in C2 (10-17cm) to 89.9% in C3 (17-28 cm) (Table 9). Fine sand percentages (of total sand) ranged from 39.9% in the C2 horizon (10-17 cm) to 57.5% in the Cg2 horizon (43-56 cm). As in soil profile #5, fine sand percentage made up the majority of the distribution of sand size fractions (Table 10). Total clay percentages in all horizons ranged from 2.64% to 3.39% indicating there was little pedogenic development (Table 9).

Soil profile #6 did not have a weak iron pan above the gleyed layers. This site was located slightly farther upland from the wetland than soil profile #5, but still had a shallow water table. As in soil profile #5, easily reducible manganese concentrations were lowest (0.2795 g kg^{-1} in C1, 0.2737 g kg^{-1} in C2, and 0.2894 g kg^{-1} in C3) in the horizons preceding the gleyed layers (Table 8). Higher easily reducible manganese concentrations were present in the gleyed layers. Manganese seemed to move with the fluctuating water table. In addition, hydroxylamine manganese concentrations were much lower than total manganese concentrations (Fig. 13). Low cation exchange capacities and sandy textures did not allow the Mn^{2+} to attach to the exchange sites, therefore manganese leached easily from the soil profile.

Free iron was higher in the horizons preceding the gleyed layers. Gleyed layers had the lowest free iron concentrations. Unlike soil profile #5, where the highest free iron concentration was in the first gleyed layer, in profile #6, the highest free iron concentration was in C3 (4.22%) which was the layer located directly above the gleyed layers. The lowest free iron concentration was in the bottom gleyed horizon, Cg3 (1.17%) (Table 8). Free iron concentrations decreased in C2 (10-17 cm) but increased

Table 9. Particle Size Distribution for Non-Hydric Soil Profile #6.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C1	10	91.28	5.78	2.93
C2	17	94.17	2.44	3.39
C3	28	89.87	7.03	3.10
Cg1	43	94.12	3.24	2.64
Cg2	56	94.09	2.85	3.05
Cg3	66+	93.05	3.71	3.24

Table 10. Distribution of Sand and Silt Particle Size Fractions for Non-Hydric Soil Profile #6.

Horizon	Lower Depth (cm)	SAND					SILT	SILT
		VCOS %	COS %	MS %	FS %	VFS %	COSi %	F Si %
C1	10	1.13	10.25	13.35	44.75	21.25	2.36	3.42
C2	17	0.80	16.24	22.42	39.96	14.65	0.29	2.15
C3	28	1.53	13.38	14.05	41.49	19.03	3.55	3.48
Cg1	43	1.70	14.98	15.07	45.32	16.77	0.79	2.45
Cg2	56	0.28	3.77	8.58	57.51	23.95	1.72	1.13
Cg3	66+	0.28	5.84	8.57	53.87	24.67	2.28	1.43

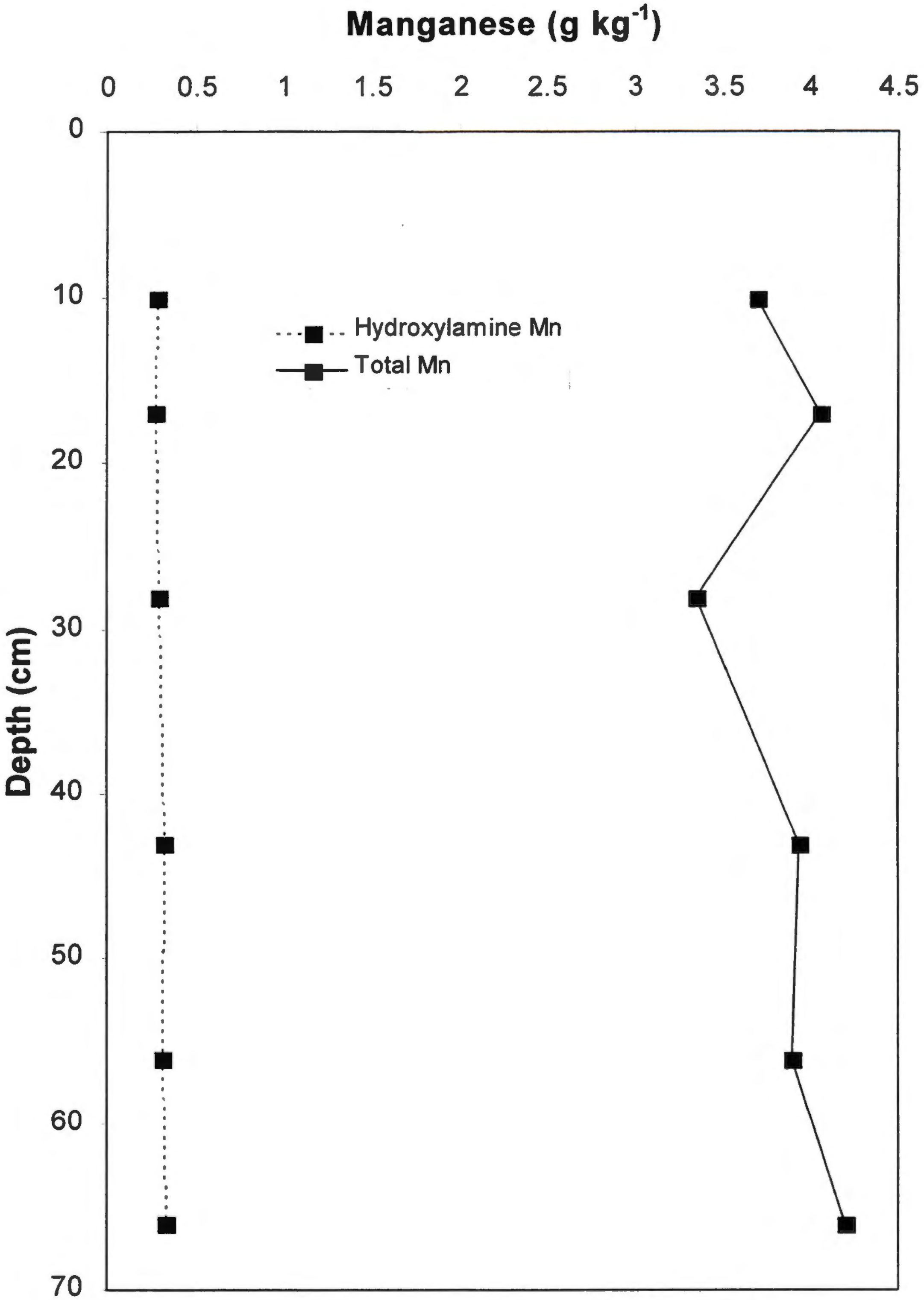

Figure 13. Total manganese and HCL-hydroxylamine manganese for Non-Hydric Soil Profile #6.

once again in C3 (17-28 cm) before decreasing in the gleyed layers (Fig. 14). The decrease in free iron could be attributed to the sandy textures and its high potential to leach from the soil profile. Total iron concentrations increased with depth to C3 (17-28 cm) and then steadily decreased to Cg2 (43-56 cm) but slightly increased again in Cg3 (56-66 cm). The higher total iron concentrations in C3 and Cg3 could be attributed to an increase in Fe^{3+} and total sulfur percent as a result of pyrite oxidation (Table 11). Free iron concentrations were lower than total iron but did not follow the same pattern as total iron. A decrease in fine sand corresponded to an increase in free iron oxide concentration which was apparent in this profile (Fig.14). A free iron oxide bulge corresponded to an increase in total clay percent and a decrease in fine sand (Tables 9,10).

Cation exchange capacity (CEC) decreased steadily throughout the soil profile (Table 8). This can be attributed to the low clay percentage and the low exchange on the sites. Cation exchange capacity was highest in the surface horizon (1.15 cmol+ kg^{-1}), decreased to 0.98 cmol+ kg^{-1} in C2 and continued to decrease down to a depth of 66 cm. Unlike soil profile #5, organic carbon can not be attributed to the high CEC in the surface horizon. Organic carbon was 0% throughout the soil profile to a depth of 66 cm except for C3 in which it increased to 0.03% (Fig. 15). The slight increase in organic carbon percent is negligible and is not related to a change in texture.

High base saturation (>100%) was observed in all horizons (Table 8). This can be attributed to the high calcium concentrations in each horizon. As in soil profile #5, the horizons above the gleyed layers showed higher calcium concentrations (Table 8). Calcium carbonate equivalent (CCE) was lowest in the surface horizon (16.53%) (Table

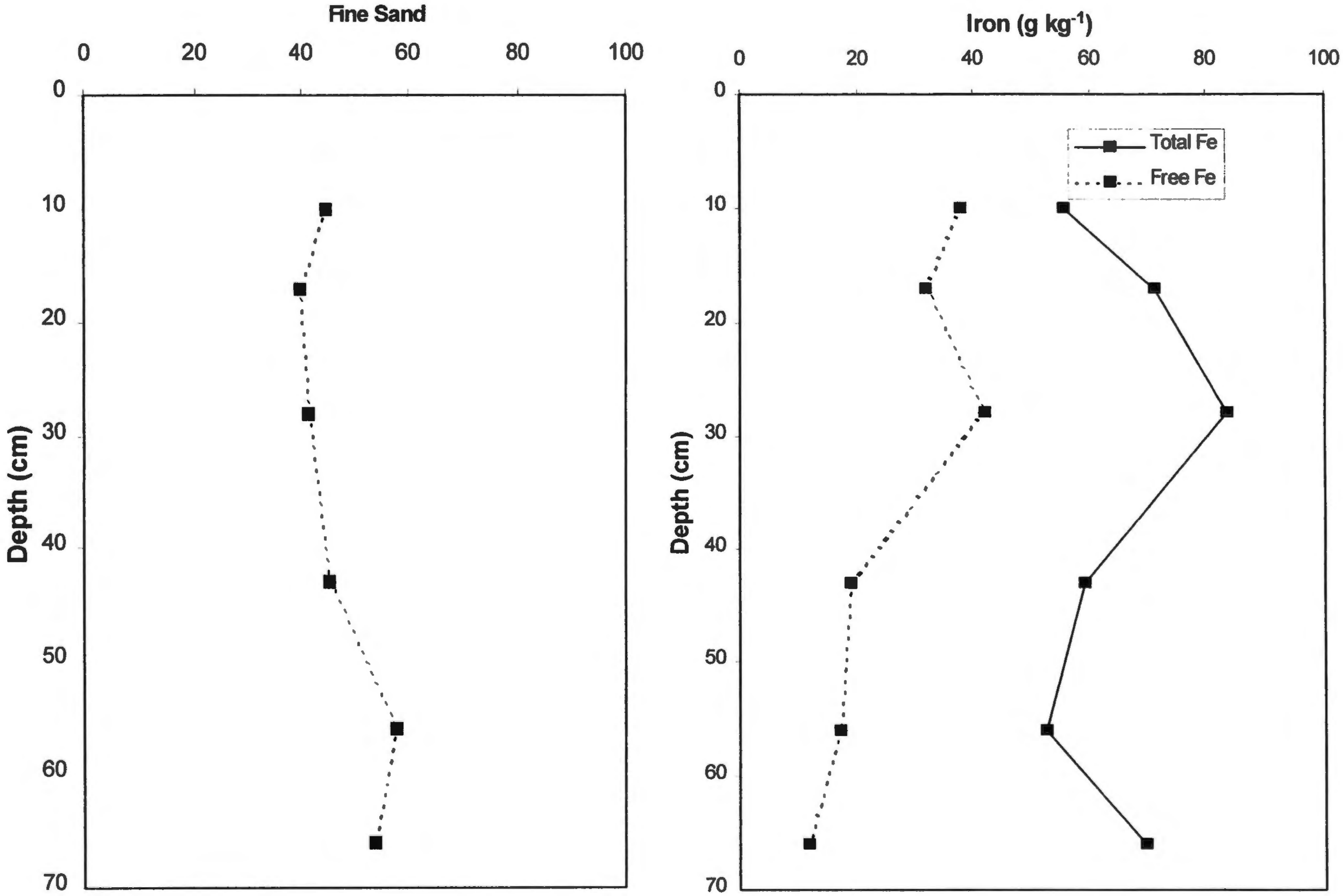

Figure 14. Fine sand, total iron, and free iron for Non-Hydric Soil Profile #6.

Table 11. Total carbon, nitrogen, sulfur, and organic carbon percent for Non-Hydric Soil Profile #6.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C1	10	1.73	0.06	2.10	0
C2	17	2.27	0.06	2.15	0
C3	28	1.63	0.06	5.46	0.03
Cg1	43	2.27	0.07	2.47	0
Cg2	56	2.10	0.05	1.51	0
Cg3	66+	2.35	0.05	3.79	0

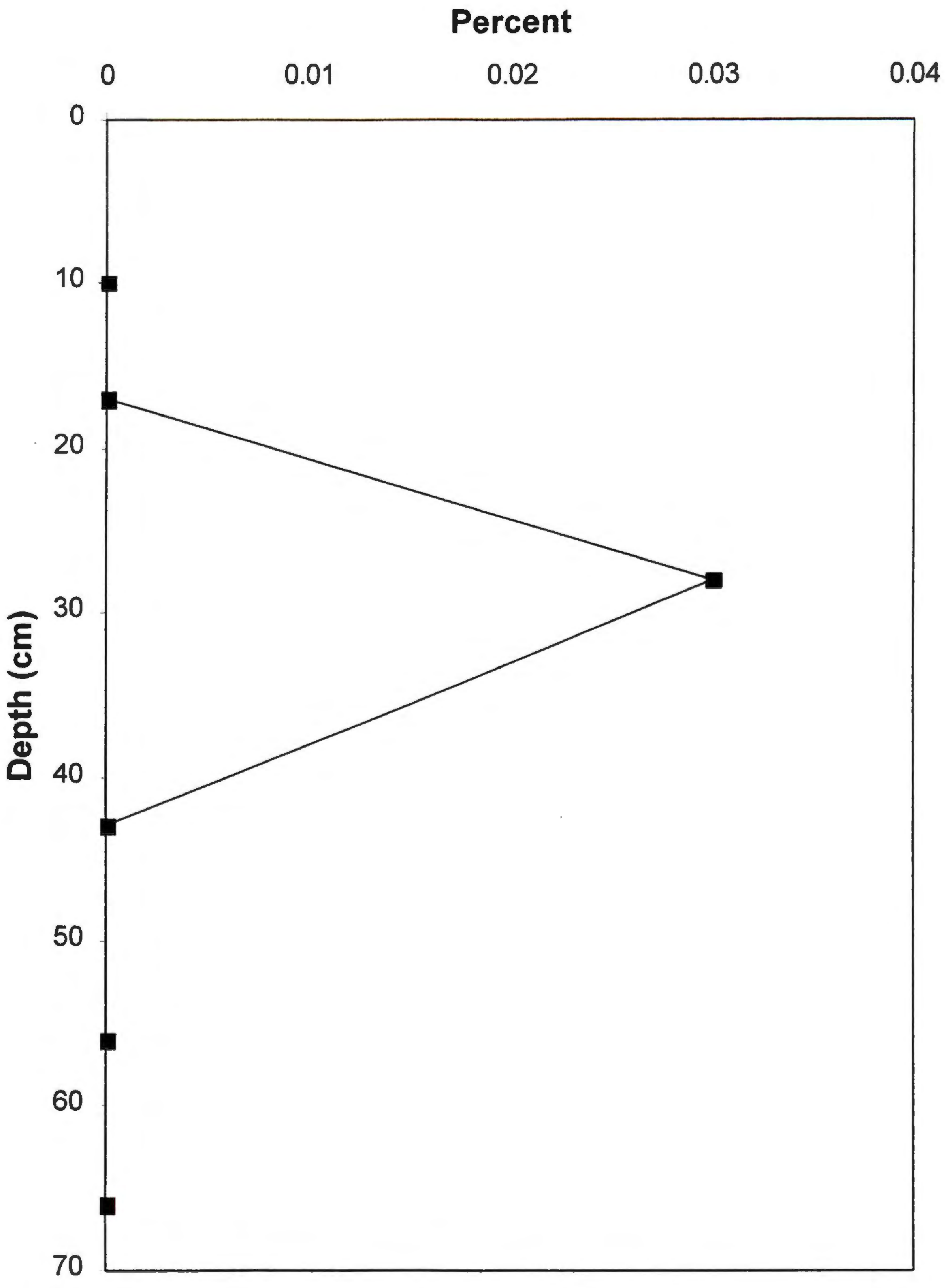

Figure 15. Organic carbon distribution for Non-Hydric Soil Profile #6.

8). This did not correspond to the high pH of 7.1. The highest CCE was recorded in the Cg3 horizon. However, this did not correspond to a high pH value which was 6.6 (Table 8). All horizons had a very strong reaction to 10% HCl indicating free carbonates were abundant (Table 7).

The particle size control section had >89% sand with the highest percentage of total sand as fine sand (Fig. 16). Textures in all horizons in the control section were loamy fine sand or coarser putting it in the Psammaquent great group. The order was also Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix below 29 cm. In addition, between 40 and 50 cm below the soil surface, this soil had aquic conditions and a texture of loamy fine sand or coarser, and a hue of 5GY, and enough active ferrous iron to give a positive reaction to alpha, alpha-dipyridyl to put it in the aquent suborder. Mineralogy class was mixed. This site was classified as a mixed, mesic Typic Psammaquent.

Hydric Soil Profile #7

Hydric soil profile #7 was located at N 35°02'58.6" and W 84°20'42.8" east on the mine tailings pond in between two vegetated areas. This site was one of the sites farthest from the outlet where the tailings were released. This site was located on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had scarce hydrophytic vegetation such as sedges, rushes, and reeds. There was not any surface water apparent because this site was far from any of the wetlands on the tailings pond. Soil samples were collected and morphology was described to a depth

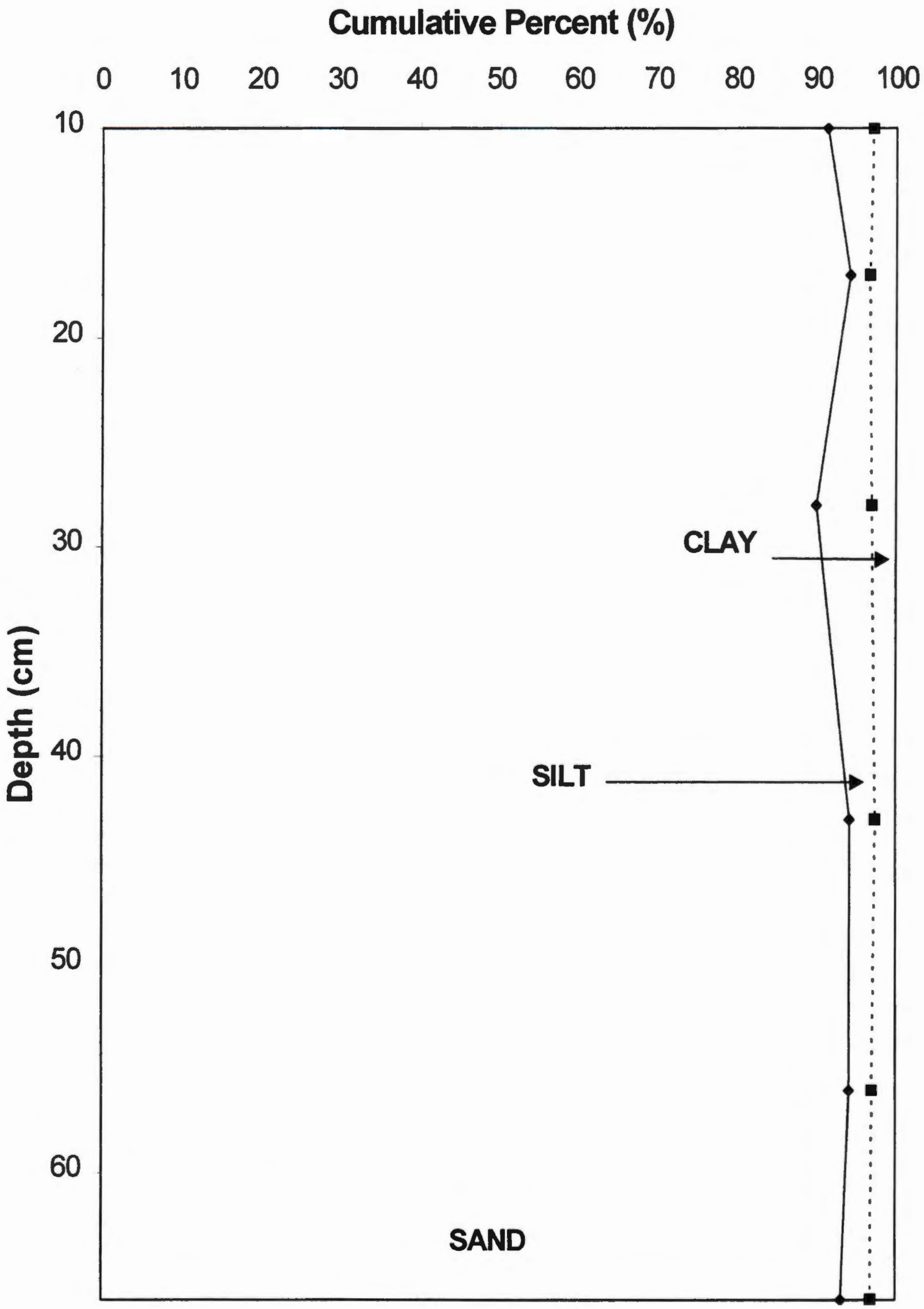

Figure 16. Particle size plot for Non-Hydric Soil Profile #6

of 43 cm. The parent material was alluvium.

This profile showed evidence of gleying at 18 cm (Fig. 17). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 10YR 4/2, 2.5Y 4/2, 5GY 4/1, and N3 (Table 12). Redoximorphic features such as iron and manganese concentrations and some iron depletions were noted in C1 and C2 horizons. Iron concentrations and depletions were also present in both gleyed layers. As noted in soil profiles #5 and #6, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl indicating there was abundant ferrous iron. In addition, gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 13). Ferrous iron was low or leached from these horizons. This profile had been saturated for some time to remove the ferrous iron. Unlike profiles #5 and #6, the soil drainage class was poorly drained meaning water is removed slowly from the soil and the soil is wet at shallow depths periodically during the growing season (Soil Survey Staff, 1993). Depth to the water table was shallower than profiles #5 and #6 at 30 cm. This site was located at a lower landscape position than the other sites.

Total sand percentages ranged from 59.1% in Cg2B (33-43cm) to 90.8% in C2 (8-17 cm) (Table 14). Fine sand percentages (of total sand) ranged from 14.0% in the Cg2B horizon (33-43 cm) to 49.1% in the C2 horizon (8-17 cm). Here, the higher fine sand percent corresponded to the higher total sand percent. Fine sand percentage made up the majority of the distribution of sand size fractions in all horizons except for Cg2B in which very fine sand (39.6%) made up the majority of the distribution of sand size particles (Table 15). Total clay percentages ranged from 2.08% in the Cg1 horizon to

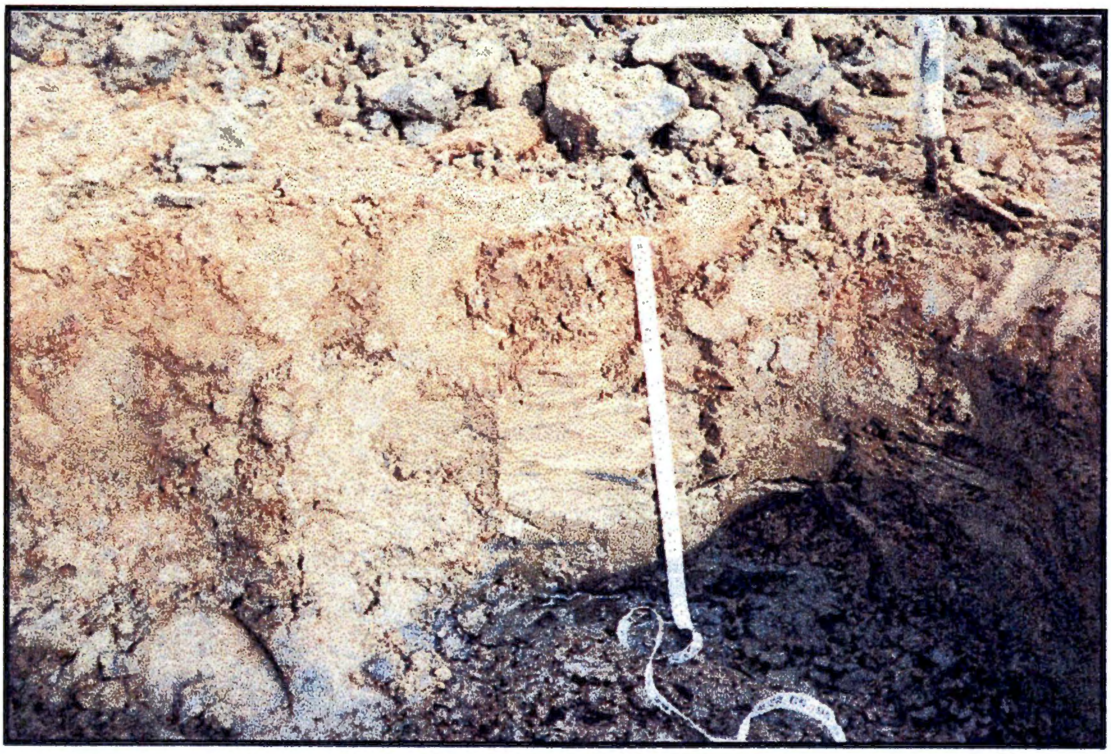

Figure 17. Hydric Soil Profile #7.

Table 12. Morphology of Hydric Soil Profile #7.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C1	8	5YR 4/4	10YR 4/6 7.5YR 4/4	fS	sls sg	clear	loose	Slight	Fe and Mn Concentrations
C2	17	7.5YR 4/4 10YR 4/4	2.5Y 5/6	fS	sls sg	abrupt	loose	Very Strong	Fe and Mn Concentrations Fe Depletions
Cg1	33	10YR 4/2 2.5Y 4/2	2.5Y 6/4	LfS	sls sg	clear	loose	Very Strong	Fe Depletions & Concentrations
Cg2	43+	5GY 4/1 N3	5Y 4/4 N5	S/LfS/VfSL	sls sg	-	loose	Very Strong	Fe Depletions & Concentrations

*Abbreviations for morphology designations are given in Appendix A.

Table 13. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl for Hydric Soil Profile #7.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C1	8	6.51	6.5	5.84	0.5241	0.04	0	0.04
C2	17	10.13	6.8	4.68	0.4596	0.04	0	0.04
Cg1	33	13.72	6.8	3.38	0.3368	0.04	0	0.04
Cg2A	43+	21.63	6.4	2.17	0.3643	0.04	0	0.04
Cg2B	43+	17.64	6.8	2.93	0.3877	0.04	0	0.04

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Bases				Base Saturation (%)	alpha,alpha dipyridyl
			Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}		
C1	8	1.68	177.10	0.26	0.03	0.04	>100	Positive
C2	17	1.20	138.90	0.32	0.02	0.04	>100	Positive
Cg1	33	1.22	121.40	1.05	0.04	0.04	>100	Negative
Cg2A	43+	0.73	44.47	1.31	0.08	1.26	>100	Negative
Cg2B	43+	1.08	38.80	2.25	0.13	0.04	>100	Negative

Table 14. Particle Size Distribution for Hydric Soil Profile #7.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C1	8	89.75	5.76	4.49
C2	17	90.83	4.77	4.40
Cg1	33	85.09	12.83	2.08
Cg2A	43+	86.39	9.09	4.52
Cg2B	43+	59.05	33.92	7.03

Table 15. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #7.

Horizon	Lower Depth (cm)	VCOS %	COS %	SAND MS %	FS %	VFS %	SILT COSi %	SILT F Si %
C1	8	0.47	7.64	9.53	47.85	23.69	2.21	3.55
C2	17	0.75	8.86	9.70	49.05	21.45	2.87	1.90
Cg1	33	0.49	3.82	3.73	46.37	29.90	5.22	7.61
Cg2A	43+	0.28	2.73	3.77	43.52	35.14	5.78	3.32
Cg2B	43+	0	0.27	0.55	14.03	39.55	18.90	15.02

7.03% in the Cg2B horizon (Table 14). Cg2 was divided into A and B because of the difference in colors. Cg2A was dark gray and Cg2B was a blue-gray color.

In the C2 horizon, there was a hard restrictive layer somewhat resembling an iron pan directly above the gleyed layers. This layer restricted some of the water flow and perched water above this layer. Unlike soil profiles #5 and #6, easily reducible manganese concentrations were substantially higher (0.5241 g kg^{-1} in C1 and 0.460 g kg^{-1} in C2) in the horizons preceding the gleyed layers (Table 13). Lower manganese concentrations were noted in the gleyed layers. Lower manganese concentrations may be due to the shallower water table leaching the manganese from the soil profile because manganese, in the reduced form, is very mobile. This profile also had low cation exchange capacities and sandy textures which did not allow the Mn^{2+} to attach to the exchange sites. Total manganese increased throughout the profile, especially in Cg2A (3.920 g kg^{-1}). In addition, hydroxylamine manganese concentrations were much lower than total manganese concentrations (Fig. 18).

The highest free iron concentration was in C1 (5.84%). The lowest free iron concentration was in the bottom gleyed horizon, Cg2A (2.17%) (Table 13). Free iron concentrations decreased with depth throughout the soil profile (Fig. 19). The substantial decrease in free iron could be attributed to the sandy textures and its ability to leach more easily and apparently move with the shallower water table. Free iron concentrations were lower than total iron but did not follow the same pattern as total iron. Total iron concentrations increased with depth to the first gleyed layer, Cg1 (17-33 cm), decreased in Cg1, then steadily increased in Cg2 (33-43 cm). There was not a substantial decrease

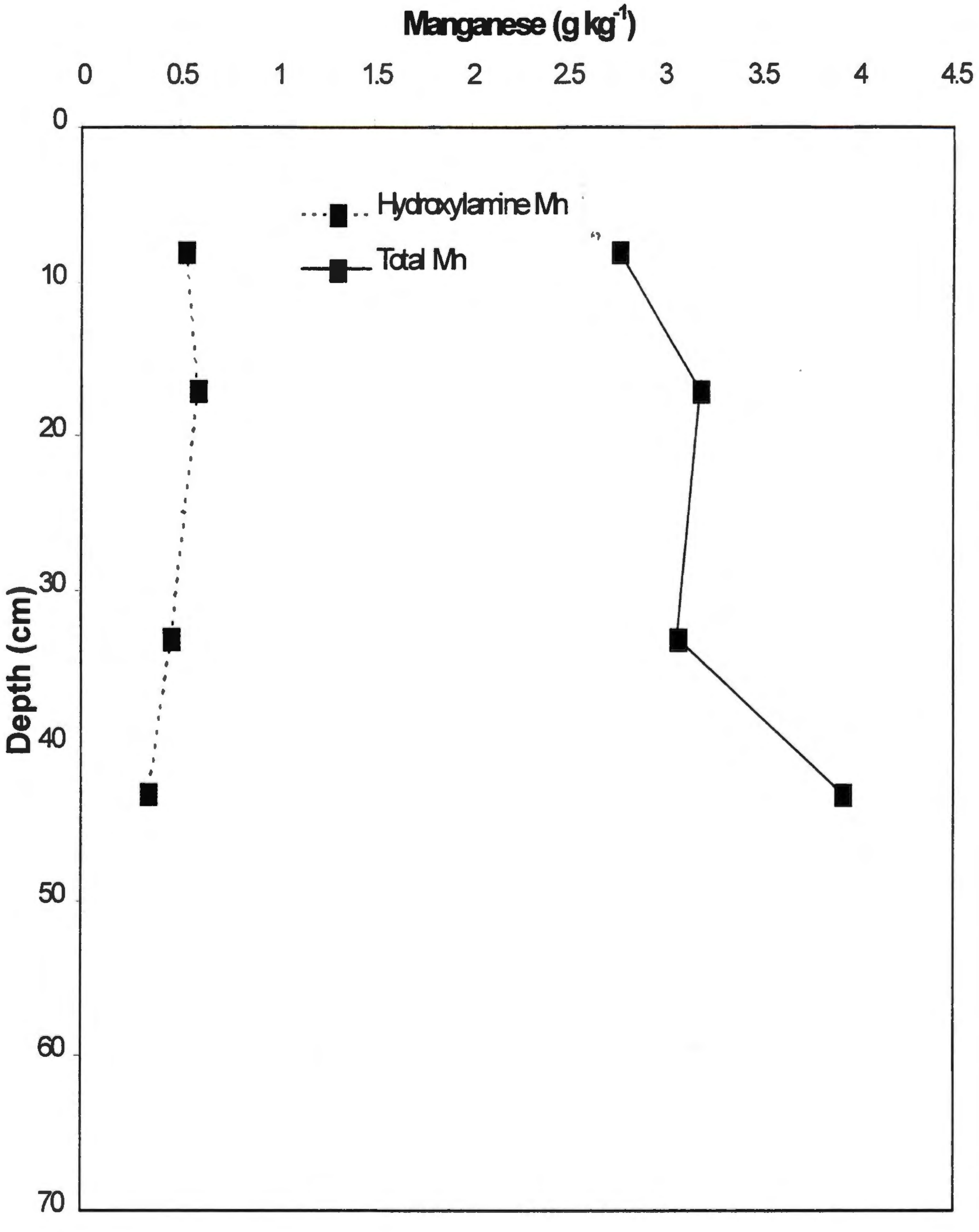

Figure 18. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #7.

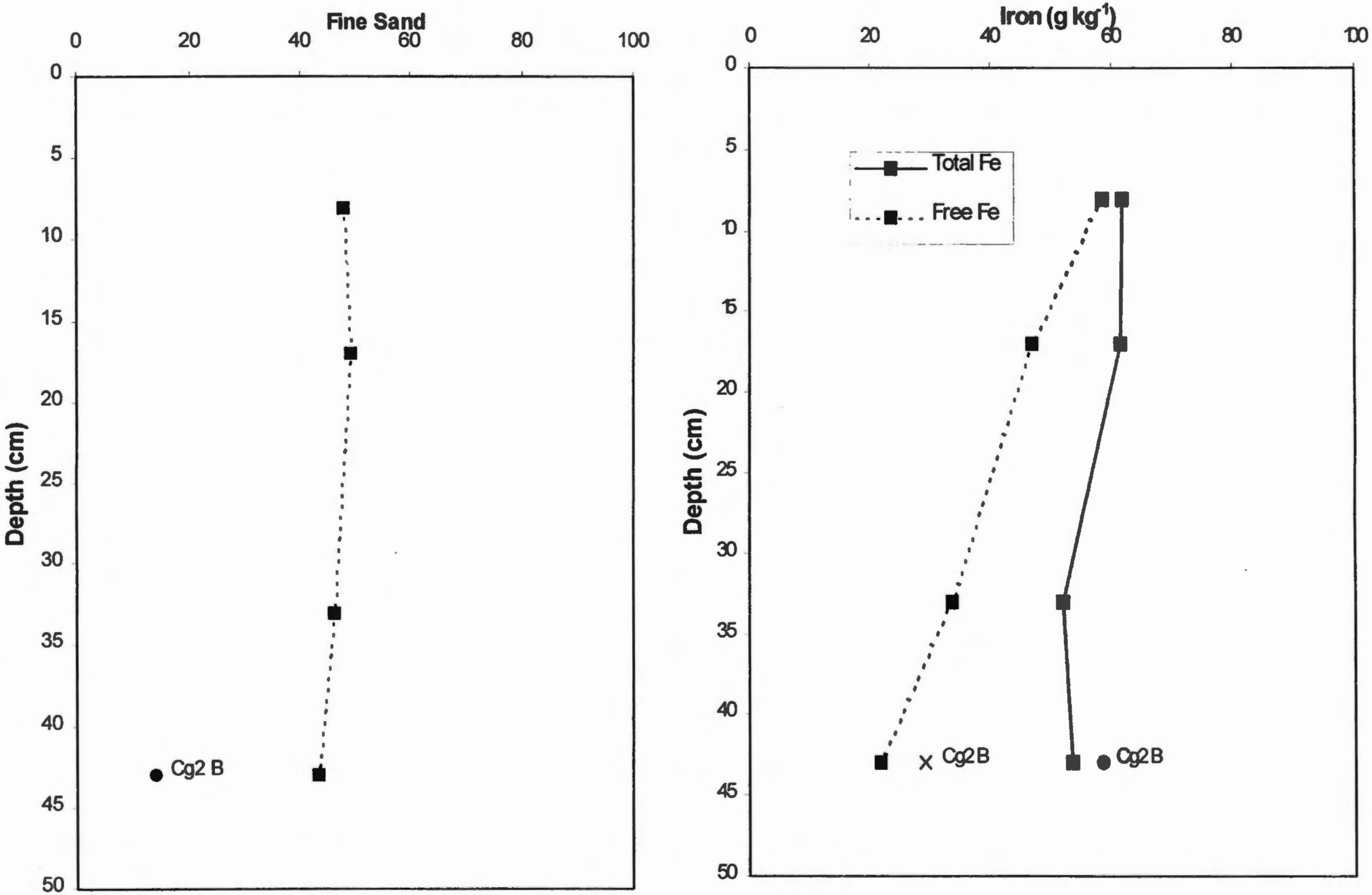

Figure 19. Fine sand, total iron, and free iron for Hydric Soil Profile #7.

or increase in any one horizon which could be attributed to an increase in total sulfur percent and a decrease in pH as a result of pyrite oxidation (Table 16). A decrease in fine sand should correspond to an increase in free iron oxide concentration, which was not apparent in this profile except for the bottom horizon (33-43 cm) (Fig. 19). A free iron oxide bulge should be apparent with an increase in total clay percent and a decrease in fine sand.

Cation exchange capacity (CEC) steadily decreased throughout the soil profile, except for Cg2B in which it increased to 1.08 cmol+ kg^{-1} (Table 13). Although this was not a substantial increase, the increase was related to an increase in total clay percentage and a decrease in total sand percentage (Table 14). Like soil profiles #5 and #6, CEC was highest in the surface horizon (1.68 cmol+ kg^{-1}) (Table 13). Organic carbon cannot be attributed to the higher CEC in the surface horizon. Organic carbon was 0% throughout the soil profile to a depth of 33 cm. In Cg2A and Cg2B, organic carbon increased slightly to 0.14% and 0.45%, respectively (Fig. 20). This was almost negligible, but this slight increase could be related to an increase in finer textures to a very fine sandy loam.

High base saturation (>100%) was observed in all horizons (Table 13). This can be attributed to the high calcium concentrations in each horizon. Horizons above the gleyed layers showed higher calcium concentrations, however, the Cg1 horizon also showed a high calcium concentration (Table 13). Both Cg2A and Cg2B showed low calcium concentrations. Calcium carbonate equivalent (CCE) increased with increasing pH, except for Cg2A which had the highest CCE (21.63%) corresponding to the lowest pH (6.4) (Table 13). As stated before, as CCE increases, so should pH, because this

Table 16. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #7.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C1	8	0.72	0.06	1.16	0
C2	17	1.08	0.06	1.18	0
Cg1	33	1.34	0.05	1.31	0
Cg2A	43+	2.21	0.05	1.90	0.14
Cg2B	43+	1.47	0.05	2.10	0.45

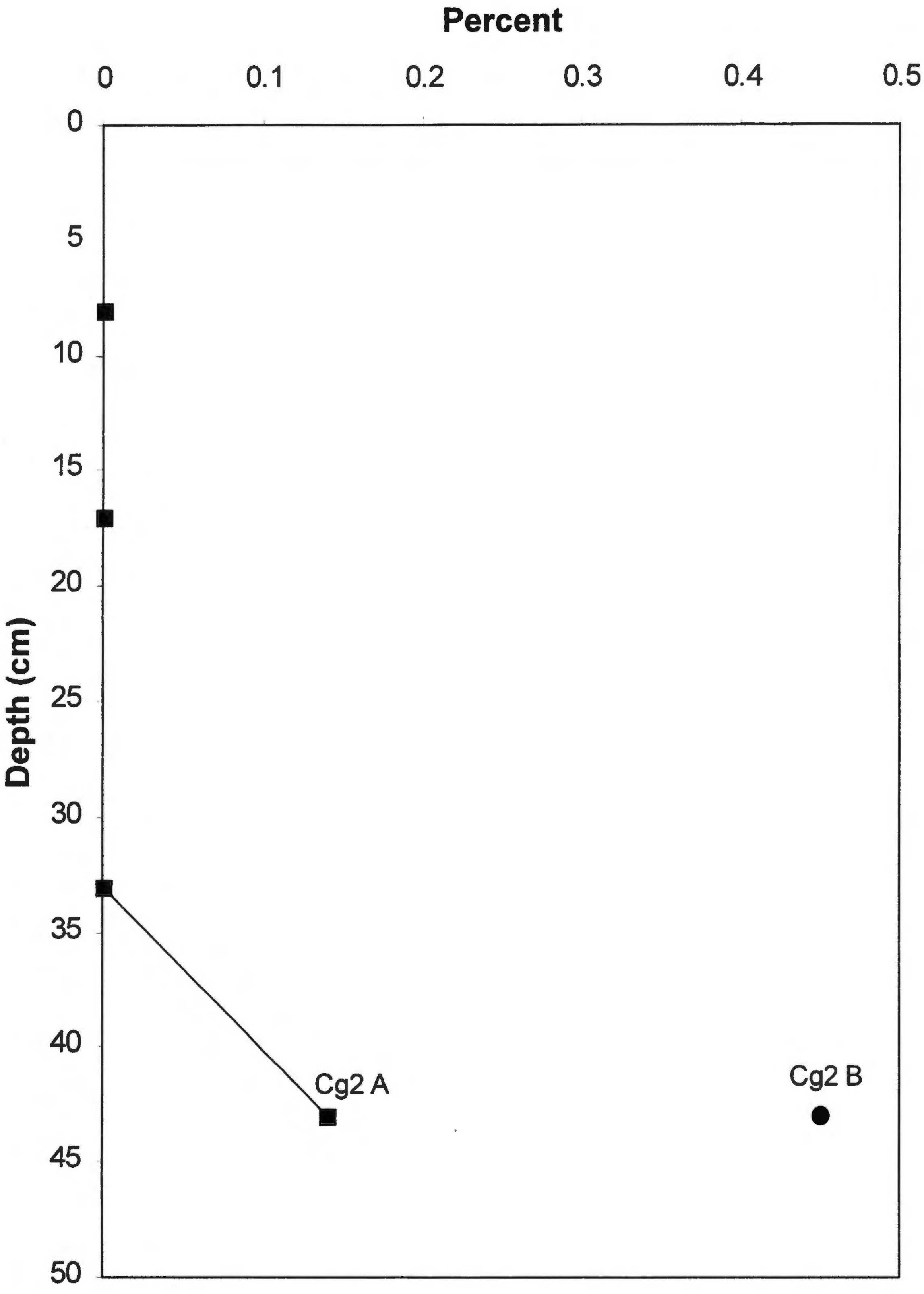

Figure 20. Organic carbon distribution for Hydric Soil Profile #7.

increases the potential for base cations to form. The lower pH in the surface horizon corresponded to the lower CCE. This was a similar trend noted with the other soil profiles located on the east side of the mine tailings pond. In addition, unlike soil profiles #5 and #6, the surface horizon only had a slight reaction to 10% HCl, while the other horizons reacted very strongly indicating free carbonates were abundant (Table 12). The slight reaction to HCl also corresponded to the slightly lower pH and lower CCE.

The particle size control section had less than 35% rock fragments and a texture of loamy fine sand or coarser in all layers within the particle size control section putting it in a Psammaquent great group (Fig. 21). The order was Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. Mineralogy class was mixed. This site was classified as a mixed, mesic Typic Psammaquent.

Hydric Soil Profile #8

Hydric soil profile #8 was located at N 35°03'03.2" and W 84°21'06.0" east on the mine tailings pond. This site was close to soil profile #7. This site was located on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had scarce hydrophytic vegetation such as sedges and rushes. There was not any surface water evident at this site. Soil samples were collected and morphology was described to a depth of 33 cm. The parent material was alluvium.

This profile showed evidence of gleying at 11 cm (Fig. 22). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in).

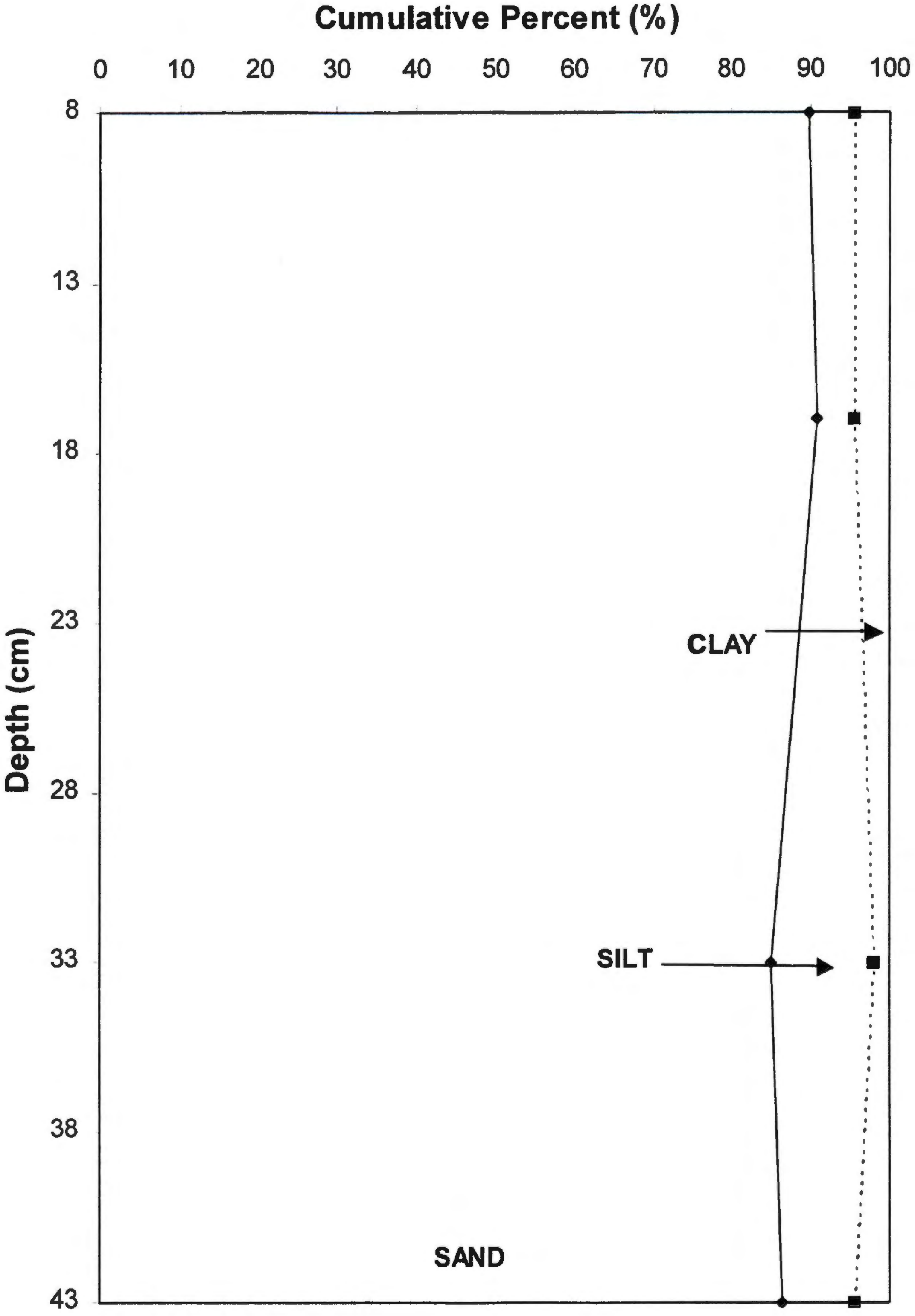

Figure 21. Particle size plot for Hydric Soil Profile #7.

Figure 22. Hydric Soil Profile #8.

Gleyed horizon colors (moist) ranged from 5GY 4/1 to N3 (Table 17). Redoximorphic features such as iron concentrations and depletions were present in the C horizon. Iron depletions were present in the Cg1 horizon. The horizon above the gleyed layers tested positive for the presence of ferrous iron. In addition, the gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 18). Like profile #7, the soil drainage class was poorly drained. Depth to the water table was shallower than profile #7 at 28 cm. This site was also located at a lower landscape position than the other sites.

Total sand percentages ranged from 81.1% in the Cg2 horizon (15-33 cm) to 92.8% in Cg1 (10-15 cm) (Table 19). Fine sand percentages ranged from 27.8% in Cg2 (15-33cm) to 51.9% in Cg1 (10-15 cm). Higher fine sand percentages corresponded to higher total sand percentages. Fine sand percentage made up the majority of the distribution of sand size fractions in all horizons except for Cg2 in which very fine sand (49.9%) made up the majority of the distribution of sand size particles (Table 20). Total clay percentages ranged from 2.85% in the Cg1 horizon to 4.77% in the C horizon (Table 19).

Like soil profile #7, there was a hard restrictive layer directly above the gleyed layers. Easily reducible (hydroxylamine) manganese concentrations were substantially higher (0.4741 g kg^{-1} in C) in the horizon preceding the gleyed layers. Lower easily reducible manganese concentrations (0.3108 g kg^{-1} in Cg1 and 0.3354 g kg^{-1} in Cg2) were noted in the gleyed layers (Table 18). Because of the high mobility of manganese, it was likely the constant fluctuating shallower water table leached the manganese from the gleyed layers. This profile also had low cation exchange capacities and sandy textures

Table 17. Morphology of Hydric Soil Profile #8.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	10	7.5YR 4/4 5YR 3/4	5YR 3/4 10YR 4/6	LfS	sls sg	abrupt	loose	None	Fe Concentrations & Depletions
Cg1	15	5GY 4/1	N4 2.5Y 5/4	fS	sls sg	clear	loose	Very Strong	Fe Depletions
Cg2	33+	N3	N5	LvfS	sls sg	-	loose	Very Strong	

*Abbreviations for morphology designations are given in Appendix A.

Table 18. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Hydric Soil Profile #8.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_20)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C	10	3.68	5.7	7.04	0.4741	0.04	0	0.04
Cg1	15	18.69	6.6	2.13	0.3108	0.04	0	0.04
Cg2	33+	20.19	7.0	1.34	0.3354	0.04	0	0.04

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}			Bases		Base Saturation (%)	alpha,alpha dipyridyl
			Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}		
C	10	2.30	170.12	0.80	0.09	0.06	>100	Positive
Cg1	15	0.60	42.90	2.91	0.21	1.59	>100	Negative
Cg2	33+	0.66	17.40	2.57	0.19	0.80	>100	Negative

Table 19. Particle Size Distribution for Hydric Soil Profile #8.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	10	84.26	10.97	4.77
Cg1	15	92.84	4.31	2.85
Cg2	33+	81.14	15.38	3.48

Table 20. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #8.

Horizon	Lower Depth (cm)	VCOS %	COS %	SAND MS %	FS %	VFS %	SILT COSi %	SILT F Si %
C	10	1.25	3.94	6.05	50.54	22.10	5.82	5.15
Cg1	15	0	0.82	1.92	51.99	37.46	3.00	1.32
Cg2	33+	0	0.72	1.35	27.82	49.99	12.47	2.91

which did not allow the Mn^{2+} to attach to the exchange sites. In addition, hydroxylamine manganese concentrations were much lower than total manganese concentrations, especially in the gleyed layers. Total manganese concentrations increased in the gleyed layers (Fig. 23).

The highest free iron concentration was in the C horizon (7.04%). The lowest free iron concentration was in the bottom gleyed horizon, Cg2 (1.34%) (Table 18). Free iron concentrations decreased with depth to 33 cm throughout the soil profile (Fig. 24). The substantial decrease in free iron could be attributed to the sandy textures and its ability to leach more easily and move with the shallower water table. Free iron concentrations were lower than total iron and followed the same pattern as total iron. Total iron concentrations were highest in the C horizon (0-10 cm), decreased in Cg1 (10-15 cm), and increased again in Cg2 (15-33 cm). The increase in total iron the C and Cg2 horizons could be attributed to an increase in Fe^{3+}, total sulfur percent, and a decrease in pH only in the C horizon (Table 21). A decrease in fine sand corresponded to an increase in free iron oxide concentrations in all horizons (Fig. 24). As free iron increased, and fine sand decreased, total clay percent increased (Tables 19, 20).

Cation exchange capacity (CEC) decreased from 2.30 cmol+ kg^{-1} in the surface horizon (Table 18). The higher CEC was related to an increase in total clay percentage (Table 19). Organic carbon was 0% from the surface to a depth of 15 cm. Organic carbon increased to 0.30% in Cg2 (15-33 cm) (Fig. 25). The slight increase in organic carbon percent could be attributed to the finer texture of a loamy very fine sand.

High base saturation (>100%) was observed in all horizons (Table 18). This was

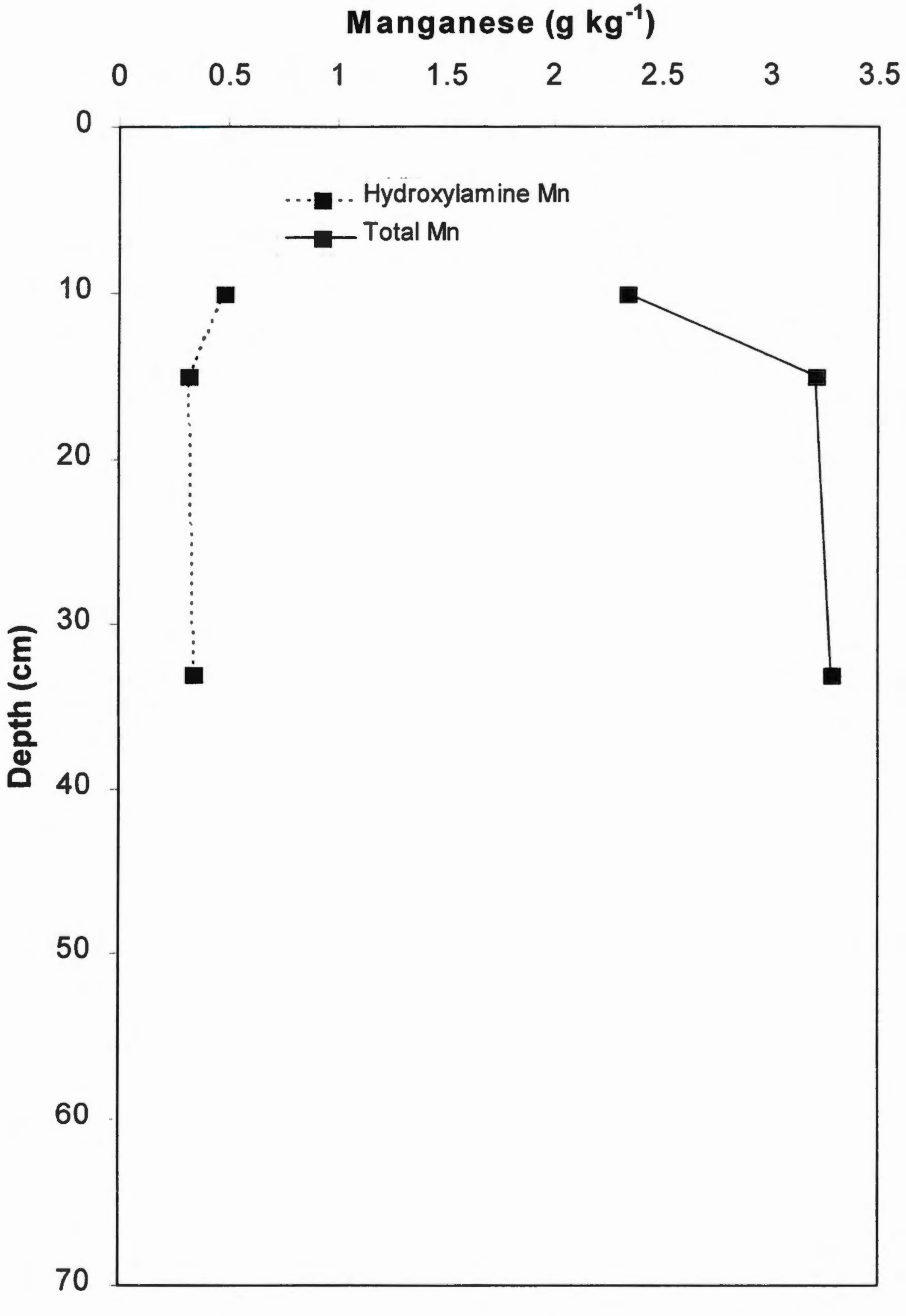

Figure 23. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #8.

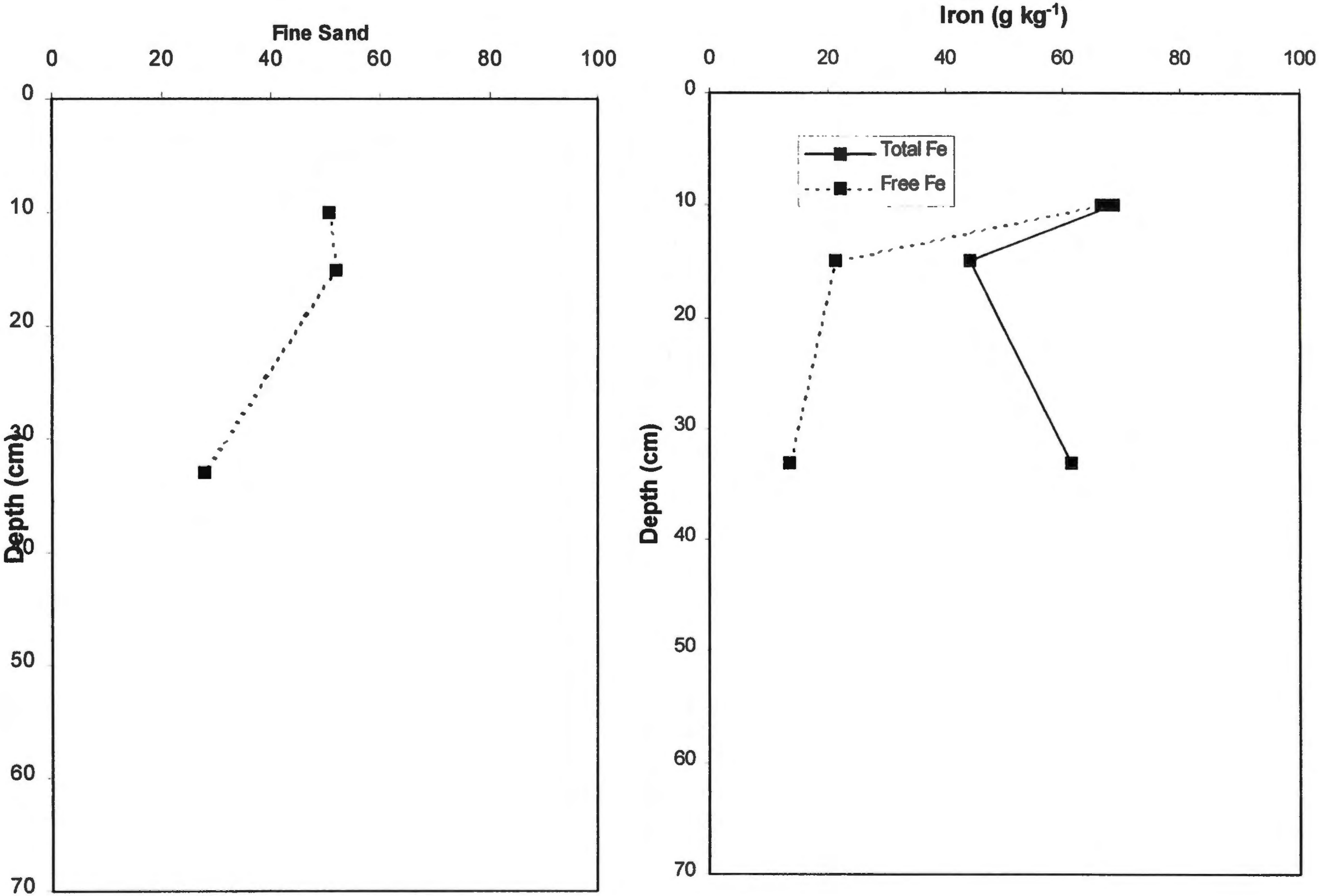

Figure 24. Fine sand, total iron, and free iron for Hydric Soil Profile #8.

Table 21. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #8.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	10	0.42	0.06	1.54	0
Cg1	15	1.93	0.04	1.87	0
Cg2	33+	2.00	0.04	2.97	0.30

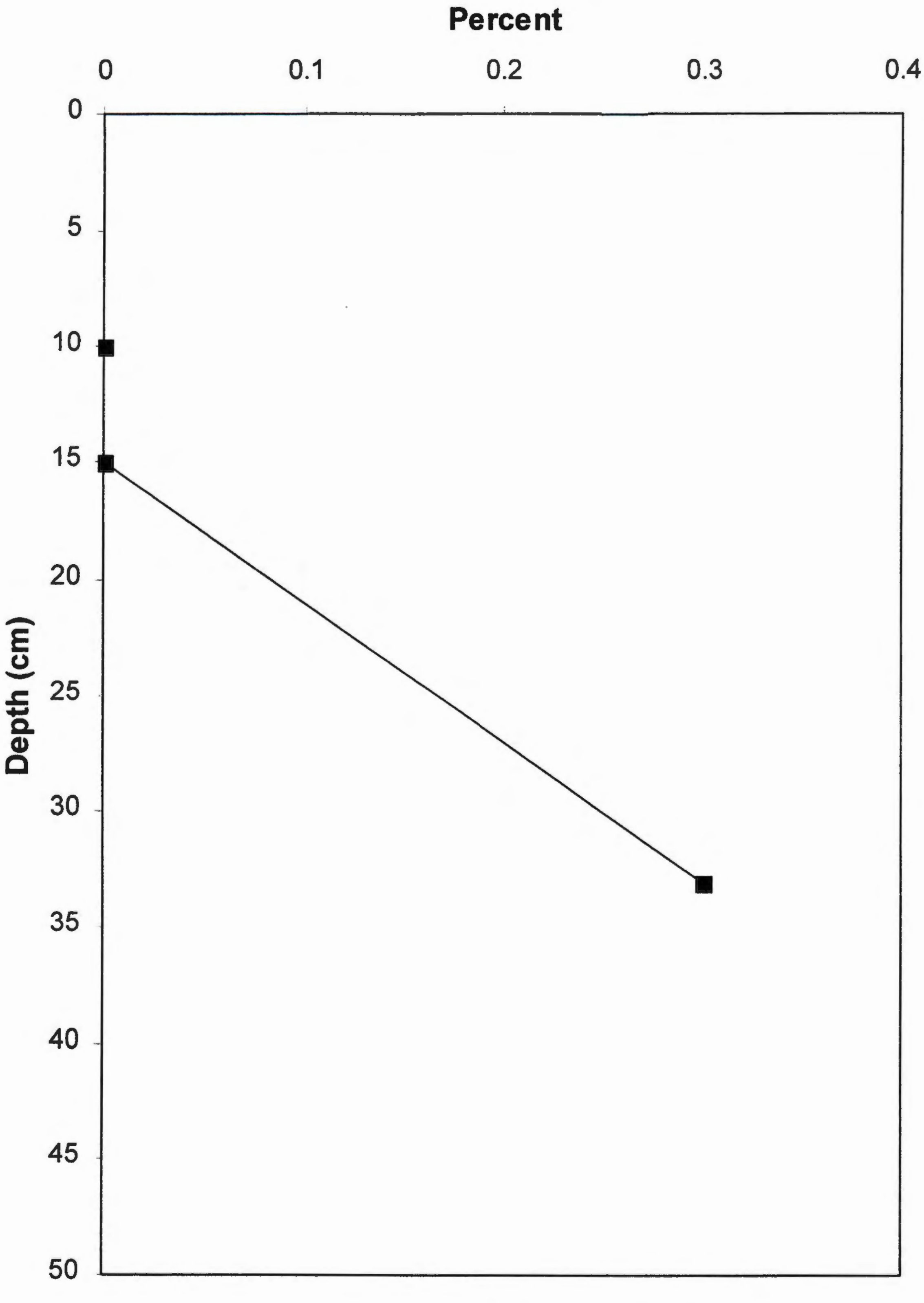

Figure 25. Organic carbon distribution for Hydric Soil Profile #8.

related to the high calcium concentrations in each horizon. The C horizon above the gleyed layers showed a higher calcium concentration than the gleyed layers (Table 18). Calcium carbonate equivalent (CCE) increased with increasing pH and depth throughout the soil profile. The highest CCE (20.19%) was in Cg2 and corresponded to the highest pH of 7.0. The lowest CCE (3.68%) was in C and corresponded to the lowest pH of 5.7 (Table 18). The lower pH could be attributed to the production of sulfuric acid (H_2SO_4), a product of pyrite oxidation. The surface horizon also had no reaction to 10% HCl, while the other horizons reacted very strongly indicating free carbonates were abundant (Table 17). This no reaction to HCl corresponded to the lower CCE and lower pH.

The particle size control section had >81% sand putting it in a sandy particle size class (Fig. 26). Mineralogy class was mixed. This soil had no evidence of pedogenic development, no diagnostic horizons, and had stratification making it an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. This site was classified as a sandy, mixed, mesic Typic Endoaquent.

Hydric Soil Profile #12

Hydric soil profile #12 was located at N 35° 03'00.3" and W 84°21'32.1" west on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had hydrophytic vegetation dominated by sedges, rushes, reeds, and cattails. Some surface water was visible. Soil samples were collected and morphology was described to a depth of 70 cm. The parent material was alluvium.

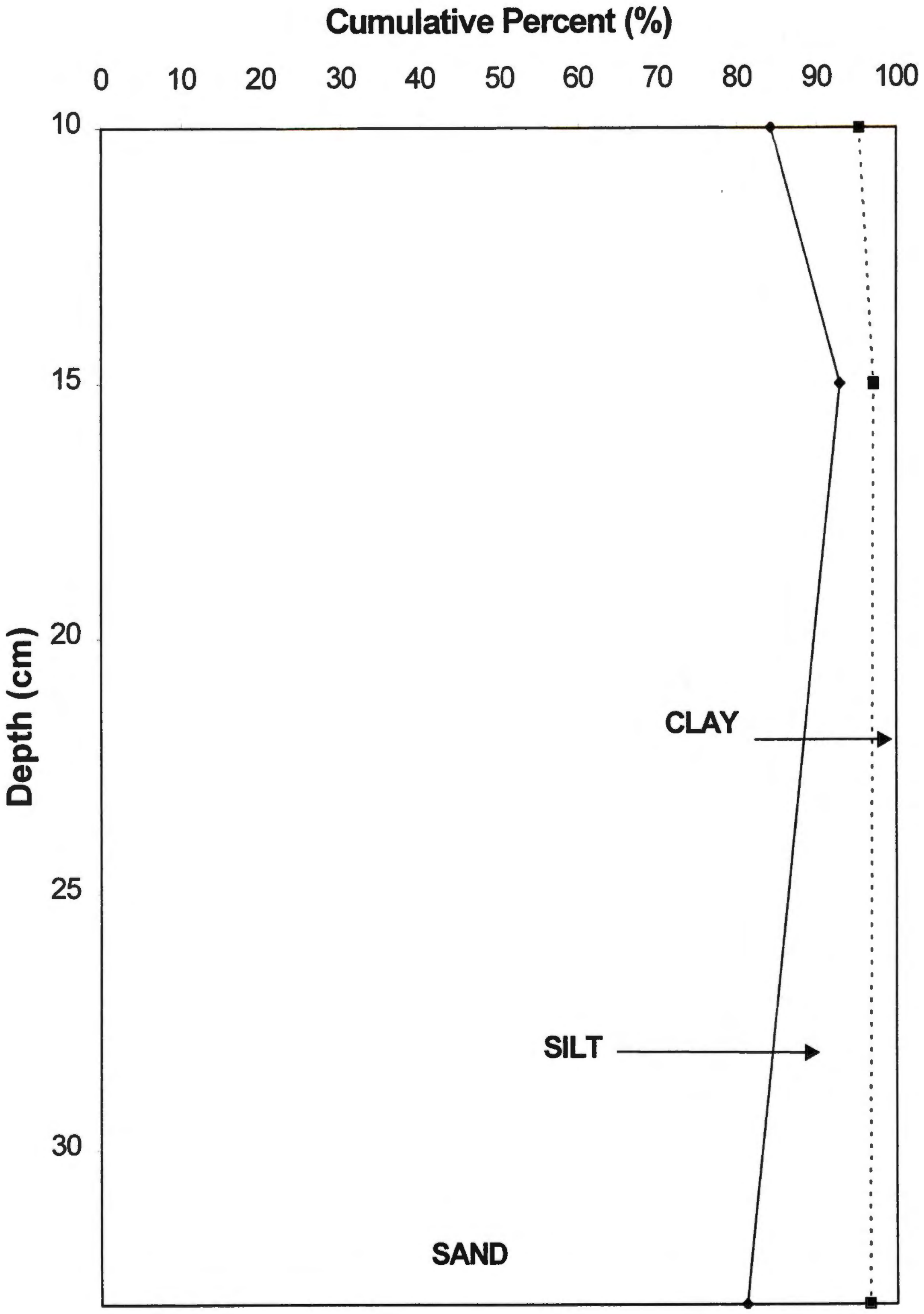

Figure 26. Particle size plot for Hydric Soil Profile #8.

Soil profile #12 showed evidence of gleying at 13 cm (Fig. 27). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 5G 2.5/1, 5G 3/1, N2.5, 5GY 3/1, to 5BG 2.5/1 (Table 22). Redoximorphic features such as iron concentrations and iron depletions in the C horizon and iron concentrations in Cg2 were noted indicating anoxic conditions, a fluctuating water table, and repeated soil saturation were apparent. As in the other sites, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl indicating there was enough ferrous iron (Fe^{2+}) to react with the dye. Gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 23). The soil drainage class was very poorly drained. This site had a deeper water table than the other sites at 67 cm.

Total sand percentages ranged from 27.6% in the bottom horizon (Cg 5) (60-70 cm) to 91.8% in the Cg2 horizon (23-32 cm) (Table 24). Fine sand percentages (of total sand) ranged from 7.46% in Cg5 (60-70 cm) to 61.4% in Cg2 (23-32 cm). Fine sand percentage made up the majority of the distribution of sand size fractions, except for the bottom Cg5 horizon in which very fine sand made up the majority (Table 25). Silt percentage, especially fine silt, increased in the bottom horizon. In this site, finer particles began to settle out at later times farther from the outlet. In addition, total clay percentages increased. Total clay ranged from 1.47% in Cg1 to 5.61% in Cg5 (Table 24).

Easily reducible (hydroxylamine) manganese concentrations were lowest (0.6544 g kg^{-1}) in the horizon preceding the gleyed layers (Table 23). However, easily reducible manganese concentrations were higher throughout the profile compared to the other sites. It is likely that the deeper water table, which did not fluctuate as often, did not leach the

Figure 27. Hydric Soil Profile #12.

Table 22. Morphology of Hydric Soil Profile #12.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	12	10YR 3/4	10YR 4/6 10YR 5/4	fS	sls sg	abrupt	loose	Very Strong	Fe Concentrations & Depletions
Cg1	23	5G 2.5/1	10Y 5/1	LfS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg2	32	5G 3/1	10Y 5/1	fS	sls sg	clear	loose	Very Strong	Gleyed Matrix Fe Concentrations
Cg3	47	N2.5	10Y 5/1	LfS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg4	60	5GY 3/1	10Y 5/1	LfS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg5	70+	5BG 2.5/1	10Y 5/1	SiL	sls sg	-	loose	Very Strong	Gleyed Matrix

*Abbreviations for morphology designations are given in Appendix A.

Table 23. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Hydric Soil Profile #12.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C	12	14.03	6.6	3.83	0.6544	0.04	0	0.04
Cg1	23	17.58	6.8	1.90	1.2220	0.04	0	0.04
Cg2	32	15.01	7.05	0.77	0.8616	0.04	0	0.04
Cg3	47	13.14	6.7	1.81	0.8473	0.04	0	0.04
Cg4	60	12.86	6.7	2.45	0.8089	0.04	0	0.04
Cg5	70+	8.15	6.1	7.34	0.7723	0.42	0	0.42

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Bases Ca^{2+} cmol+ kg^{-1}	Bases Mg^{2+} cmol+ kg^{-1}	Bases K^+ cmol+ kg^{-1}	Bases Na^+ cmol+ kg^{-1}	Base Saturation (%)	alpha,alpha dipyridyl
C	12	1.45	61.30	1.06	0.12	0.12	>100	Positive
Cg1	23	0.65	26.33	0.75	0.06	0.06	>100	Negative
Cg2	32	0.55	20.09	0.65	0.05	0.05	>100	Negative
Cg3	47	0.98	18.95	1.07	0.07	0.06	>100	Negative
Cg4	60	0.96	18.33	1.52	0.07	0.07	>100	Negative
Cg5	70+	2.98	57.96	5.70	0.07	0.05	>100	Negative

Table 24. Particle Size Distribution for Hydric Soil Profile #12.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	12	88.42	9.48	2.11
Cg1	23	86.06	12.47	1.47
Cg2	32	91.82	5.42	2.77
Cg3	47	82.24	12.51	5.25
Cg4	60	81.73	14.86	3.40
Cg5	70+	27.57	66.82	5.61

Table 25. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #12.

Horizon	Lower Depth (cm)			SAND			SILT	SILT
		VCOS %	COS %	MS %	FS %	VFS %	COSi %	F Si %
C	12	3.08	5.36	3.28	46.10	29.60	6.06	3.42
Cg1	23	0	1.39	2.69	46.62	34.56	9.36	3.11
Cg2	32	0	2.14	3.60	61.44	23.86	4.56	0.86
Cg3	47	0.69	1.97	2.76	44.38	31.66	10.34	2.17
Cg4	60	0.19	1.64	3.10	43.72	32.31	9.25	5.61
Cg5	70+	0.98	3.14	1.47	7.46	12.85	15.42	51.40

manganese from the soil profile. Higher easily reducible manganese concentrations (1.2220 g kg^{-1}) in the Cg1 horizon can be attributed to the increased ability of anaerobic microorganisms to actively convert and reduce Mn^{4+} to Mn^{2+}. Manganese concentrations decreased with depth in the gleyed layers, especially approaching the water table. Hydroxylamine manganese was much lower than total manganese but followed the same trend as total manganese. Total manganese increased in Cg1 (12-23 cm), decreased in Cg2 (23-32 cm), increased again in Cg3 (32-47 cm), and finally decreased with depth to 70 cm, following no specific pattern (Fig. 28).

Unlike the other soil profiles, free iron did not follow any trend. In the C horizon, free iron decreased with depth to Cg4 in which it increased to 2.45%. In Cg5, free iron increased again to 7.34% (Table 23). This increase could be attributed to anaerobic microorganisms actively converting Fe^{3+} to Fe^{2+}. An increase in both free iron and total iron in Cg5 could be attributed to increases in both cation exchange capacity and clay percent (Tables 23, 24). Total iron concentrations (Fe^{3+} and Fe^{2+}) increased in the Cg1 horizon (12-23 cm), decreased in the Cg2 horizon (23-32 cm), and increased again with depth to Cg5 (60-70 cm) (Fig. 29). A decrease in fine sand corresponded to an increase in free iron oxide concentration, which was apparent in this profile (Fig. 29). The total iron curve is opposite the fine sand curve, especially in Cg5 in which the texture has changed. Clay percent increased and fine sand decreased, therefore increasing the ability of free iron oxides to be retained in the soil.

Cation exchange capacity (CEC) was highest in Cg5 (2.98 cmol+kg^{-1}). This can be attributed to the higher clay percent. CEC in the C horizon was 1.45 cmol+ kg^{-1},

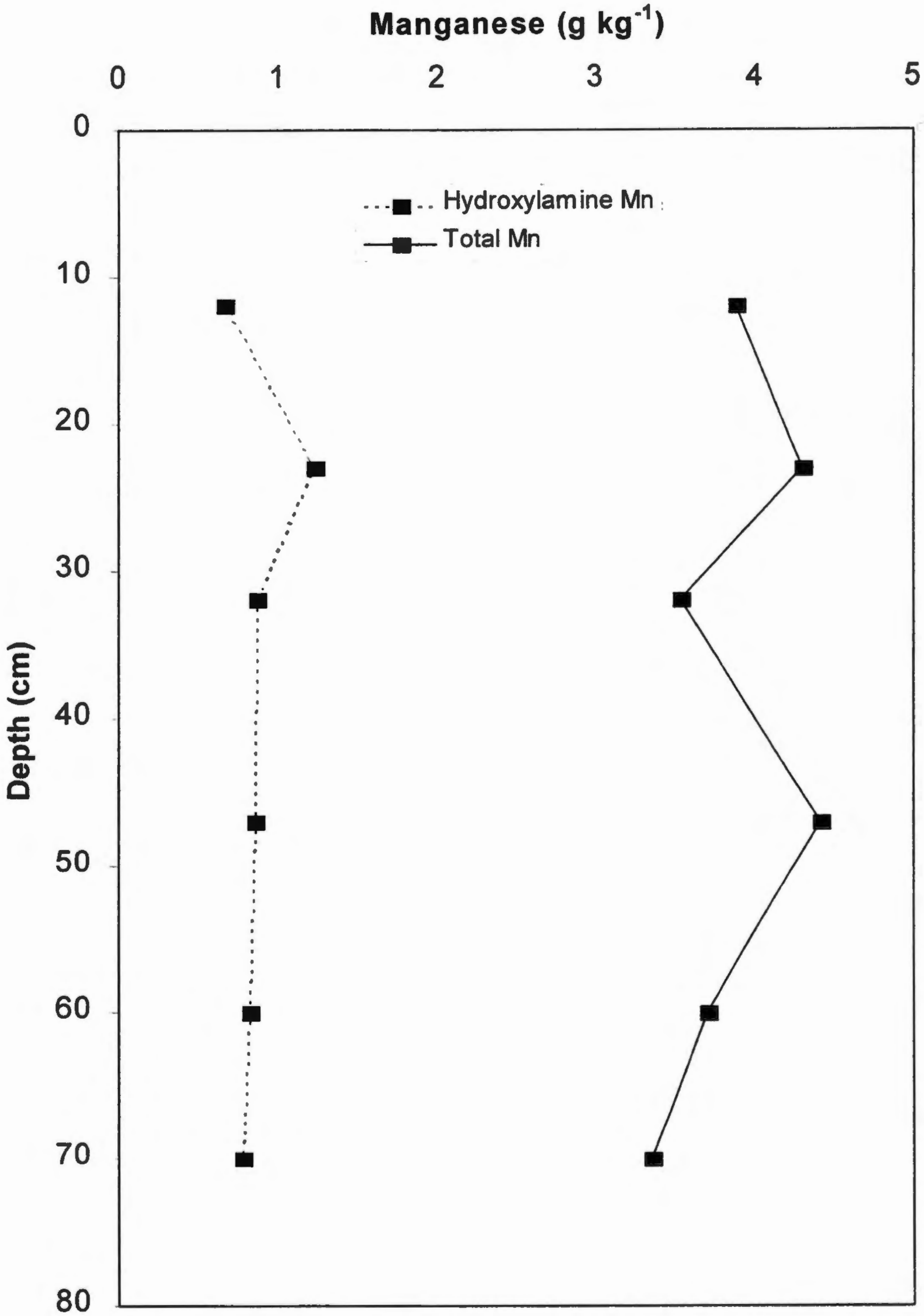

Figure 28. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #12.

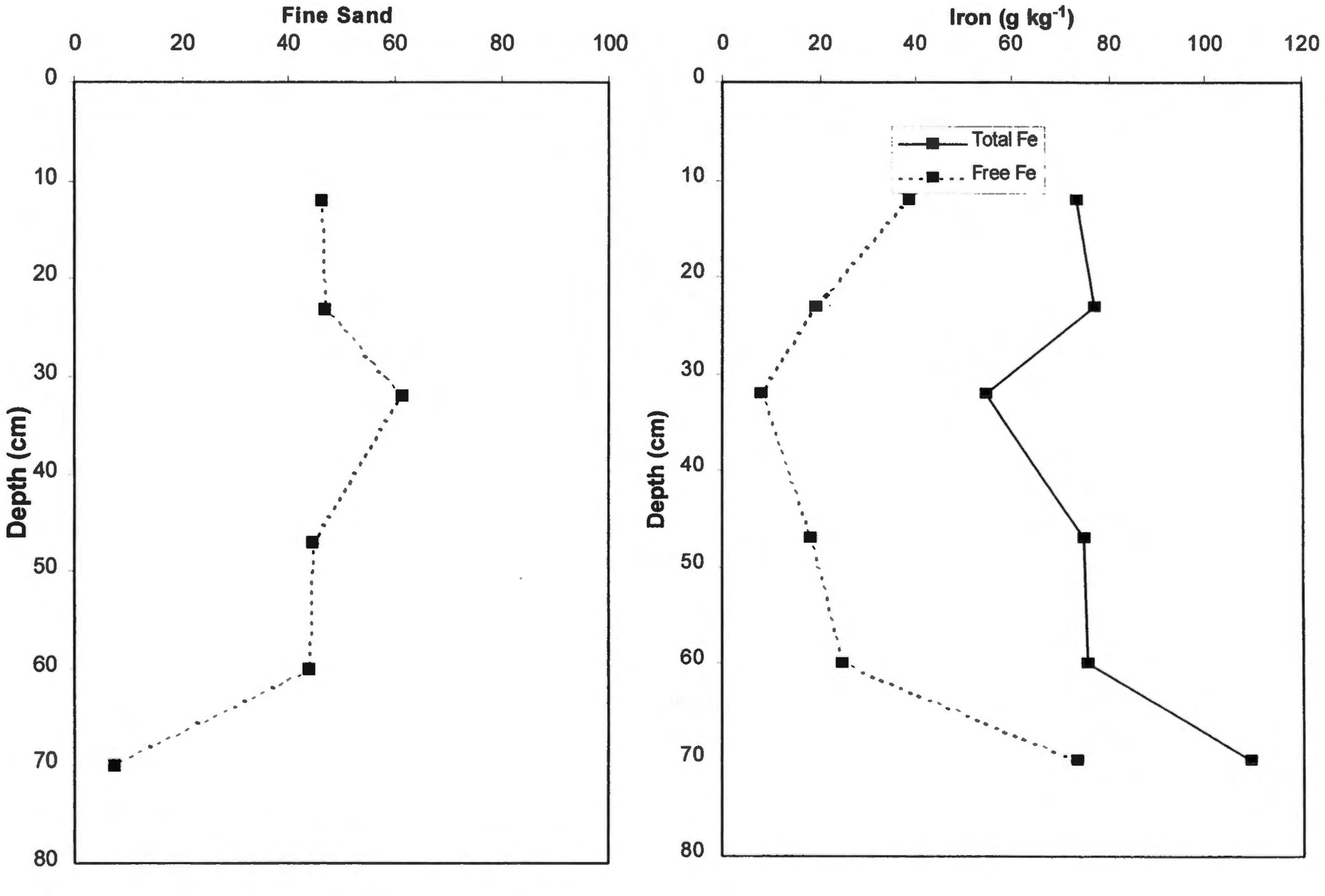

Figure 29. Fine sand, total iron, and free iron for Hydric Soil Profile #12.

decreased in Cg1 and Cg2, and increased again slightly in Cg3 and Cg4 (Table 23). Organic carbon percentages fluctuated with depth to 70 cm. The lowest organic carbon percent was in the surface horizon (0.04%). There was an increase in organic carbon percent in Cg4 (0.40%) and Cg5 (0.46%) (Fig. 30). This slight increase could be attributed to the fine texture increase to a silt loam. Finer textures have better water holding and nutrient holding capacities.

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 23). This can be attributed to the high calcium concentrations in each horizon. Greater calcium concentrations were observed in the horizon preceding the gleyed layers, except for Cg5, which also had a high calcium concentration (Table 23). Calcium carbonate equivalent (CCE) increased to Cg1 and decreased steadily to a depth of 70 cm (Table 23). pH values fluctuated with changes in CCE and did not necessarily increase with an increase in CCE although the lowest pH (6.1) corresponded to the lowest CCE (8.15%) in the bottom horizon. This low pH corresponded to a high total sulfur percent (Table 26). As pyrite is oxidized, sulfur and sulfuric acid form. The production of sulfuric acid may be attributed to the lower pH. A very strong effervescent reaction to 10% HCl was noted in each horizon indicating that free carbonates were abundant (Table 22).

The particle size control section had in the fraction less than 75 mm in diameter, 15% or more fine sand or coarser particles and less than 18% clay making it coarse-loamy (Fig. 31). Mineralogy class was mixed. The CEC/clay ratio in the control section (25-100 cm) was semiactive (0.38). This soil was in the calcareous reaction class because in

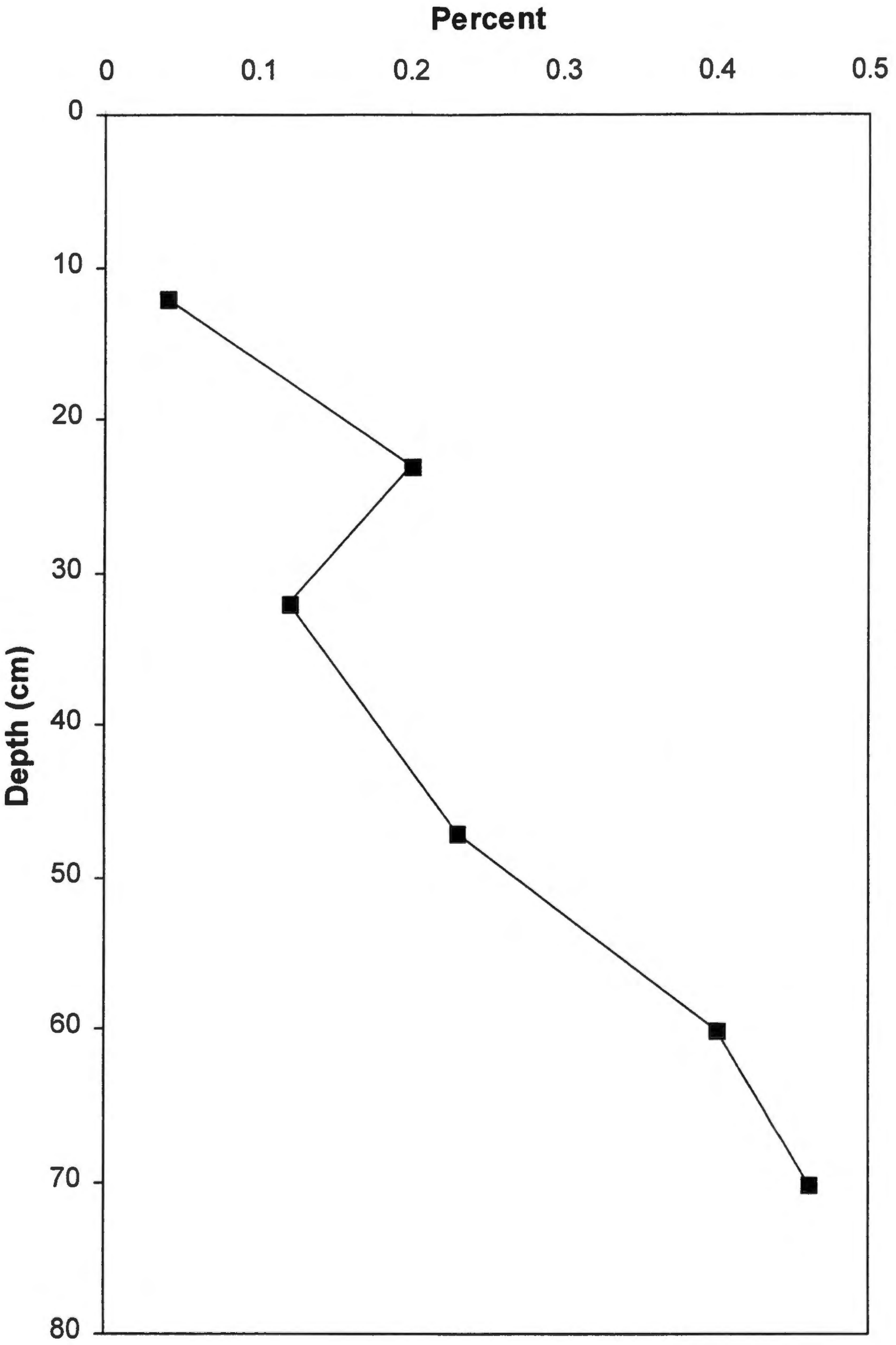

Figure 30. Organic carbon distribution for Hydric Soil Profile #12.

Table 26. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #12.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	12	1.55	0.09	1.79	0.04
Cg1	23	2.57	0.08	2.57	0.20
Cg2	32	1.65	0.06	1.15	0.12
Cg3	47	1.39	0.06	1.71	0.23
Cg4	60	1.31	0.06	2.58	0.40
Cg5	70+	0.61	0.07	4.17	0.46

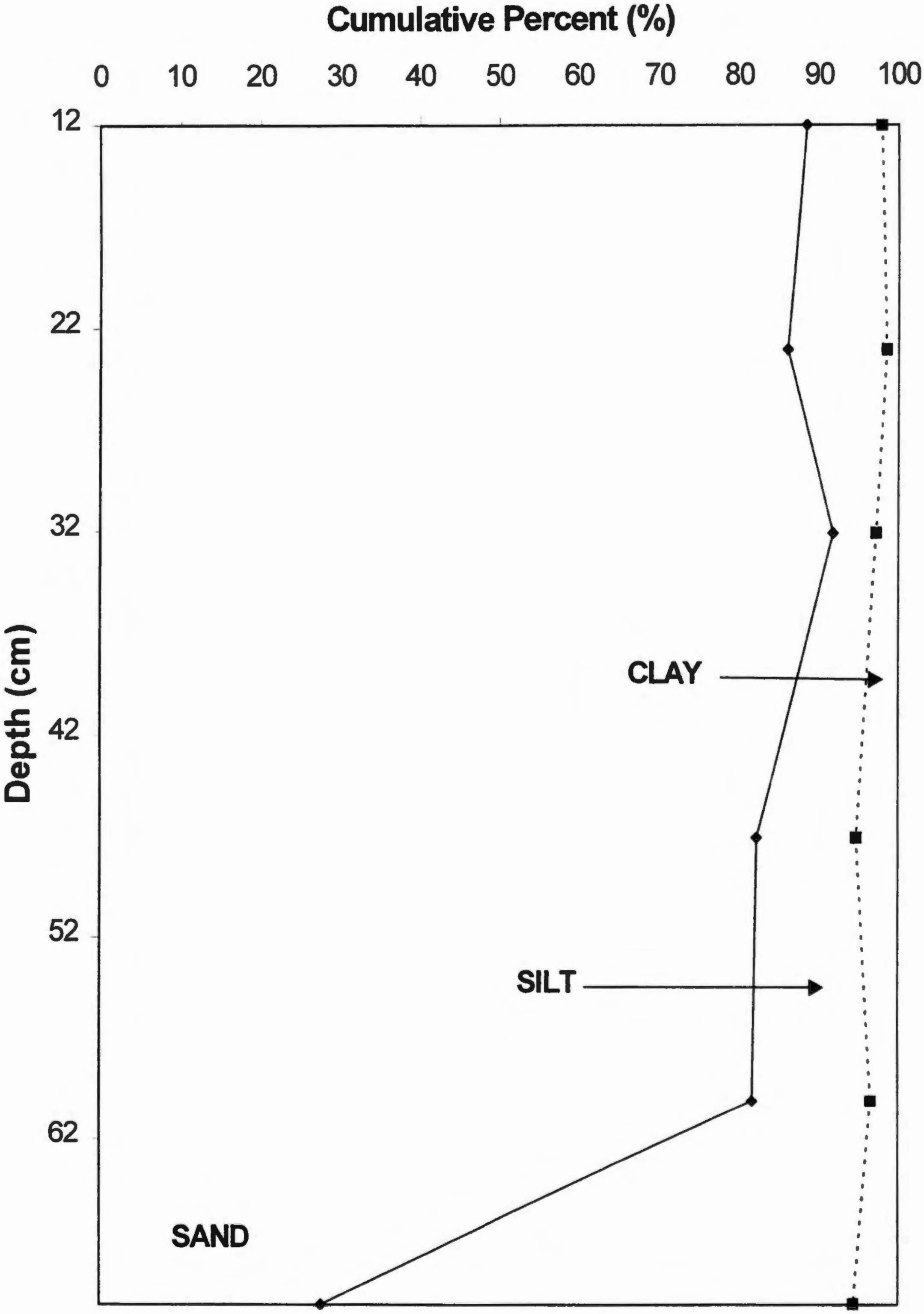

Figure 31. Particle size plot for Hydric Soil Profile #12.

the fine-earth fraction, there was effervescence in all parts of the control section. This soil was an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. This site was classified as a coarse-loamy, mixed, semiactive, calcareous, mesic Typic Endoaquent.

Hydric Soil Profile #13

Hydric soil profile #13 was located at N 35° 03'04.8" and W 84°21'13.8" east on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. From profile #13, there was a small drainageway leading to the wetland. The slope was at 1%. This site had hydrophytic vegetation dominated by some sedges and rushes. Cattails were visible from the adjacent wetland. There was also surface water evident from an adjacent wetland. Soil samples were collected and morphology was described to a depth of 61 cm. The parent material was alluvium.

Soil profile #13 showed evidence of gleying at 11 cm (Fig. 32). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 10Y 2.5/1, to 5GY 2.5/1, and N2.5 (Table 27). Redoximorphic features such as iron concentrations and depletions were evident in the C horizon indicating anoxic conditions, a fluctuating water table, and repeated soil

saturation were apparent. As in the other sites, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl. In addition, gleyed layers showed no reaction to alpha, alpha-dipyridyl (Table 28). The soil drainage class was very poorly drained. As

Figure 32. Hydric Soil Profile #13.

Table 27. Morphology of Hydric Soil Profile #13.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	10		10YR 5/6 10YR 4/6	VfSL	sls sg	abrupt	loose	Very Strong	Fe Concentrations & Depletions
Cg1	20	10Y 2.5/1	10Y 4/1	VfSL	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg2	33	5GY 2.5/1	10Y 5/1	L	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg3	51	10Y 2.5/1	10Y 5/1	SiL	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg4	61+	N2.5	10Y 5/1	VfSL	sls sg	-	loose	Very Strong	Gleyed Matrix

*Abbreviations for morphology designations are given in Appendix A.

Table 28. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Hydric Soil Profile #13.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_20)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C	10	10.20	6.7	2.77	0.6948	0.08	0	0.08
Cg1	20	17.58	6.6	7.51	1.2068	0.08	0	0.08
Cg2	33	16.79	6.2	7.25	1.1837	0.07	0	0.07
Cg3	51	19.99	7.1	4.01	1.2887	0.04	0	0.04
Cg4	61+	19.08	7.3	3.40	1.1547	0.04	0	0.04

Horizon	Lower	CEC			Bases		Base	alpha,alpha
	Depth		Ca^{2+}	Mg^{2+}	K^+	Na^+	Saturation	dipyridyl
	(cm)	cmol+ kg^{-1}	cmol+ kg^{-1}	cmol+ kg^{-1}	cmol+ kg^{-1}	cmol+ kg^{-1}	(%)	
C	10	1.42	80.91	1.08	0.26	0.07	>100	Positive
Cg1	20	1.88	37.68	4.63	0.11	0.06	>100	Negative
Cg2	33	1.91	32.53	5.66	0.12	0.05	>100	Negative
Cg3	51	1.01	28.08	1.88	0.16	0.09	>100	Negative
Cg4	61+	0.67	22.25	1.23	0.14	0.05	>100	Negative

in soil profile #12, this site had a deeper water table measured at 61 cm.

Total sand percentages ranged from 36.9% in Cg3 (33-51 cm) to 70.3% in the C horizon (0-10 cm) (Table 29). Fine sand percentages were lower than very fine sand percentages in all horizons. In Cg2 (20-33 cm) and Cg3 (33-51), total clay and total silt percentages increased (Table 29). According to the particle size data, Cg2 was a loam and Cg3 was a silt loam. Coarse and fine silt percentages also increased (Table 30).

As in soil profile #12, easily reducible (hydroxylamine) manganese concentrations were lowest (0.6948 g kg^{-1}) in the horizon preceding the gleyed layers (Table 28). However, easily reducible manganese concentrations were also higher throughout the gleyed layers. As stated in soil profile #12, this can be attributed to the deeper water table which did not fluctuate as often to leach manganese from the soil profile. Hydroxylamine manganese was much lower than total manganese but did not follow the same pattern as total manganese. Total manganese concentrations decreased with depth to Cg1. In the gleyed layers, total manganese concentrations increased to Cg3 than decreased in Cg4. This slight decrease in Cg4 for both total and hydroxylamine manganese can be attributed to the water table which was recorded at 61 cm and leached manganese from the profile (Fig. 33).

Free iron was lowest in the C horizon (2.77%). The highest free iron percentages were in Cg1 (7.51%) and Cg2 (7.25%). This corresponded to the highest clay percentages and cation exchange capacities (Table 28). In Cg3 and Cg4, free iron decreased to 61 cm. Total iron concentrations (Fe^{3+} and Fe^{2+}) were lowest in C, increased in the Cg1 horizon (10-20 cm) and Cg2 horizon (20-33 cm), and decreased again with

Table 29. Particle Size Distribution for Hydric Soil Profile #13.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	10	70.34	27.29	2.37
Cg1	20	47.34	47.71	4.95
Cg2	33	49.87	39.42	10.71
Cg3	51	36.97	59.17	3.86
Cg4	61+	68.39	24.53	7.08

Table 30. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #13.

Horizon	Lower Depth (cm)	VCOS %	COS %	SAND MS %	FS %	VFS %	SILT COSi %	SILT F Si %
C	10	0.50	4.92	2.21	23.51	36.17	20.22	7.07
Cg1	20	0.59	3.63	1.18	8.35	29.96	37.22	10.49
Cg2	33	3.88	1.99	0.40	9.46	31.65	33.45	5.97
Cg3	51	0.19	0.10	0	4.01	26.66	35.93	23.24
Cg4	61+	0	0.20	0.90	24.80	40.40	20.65	3.88

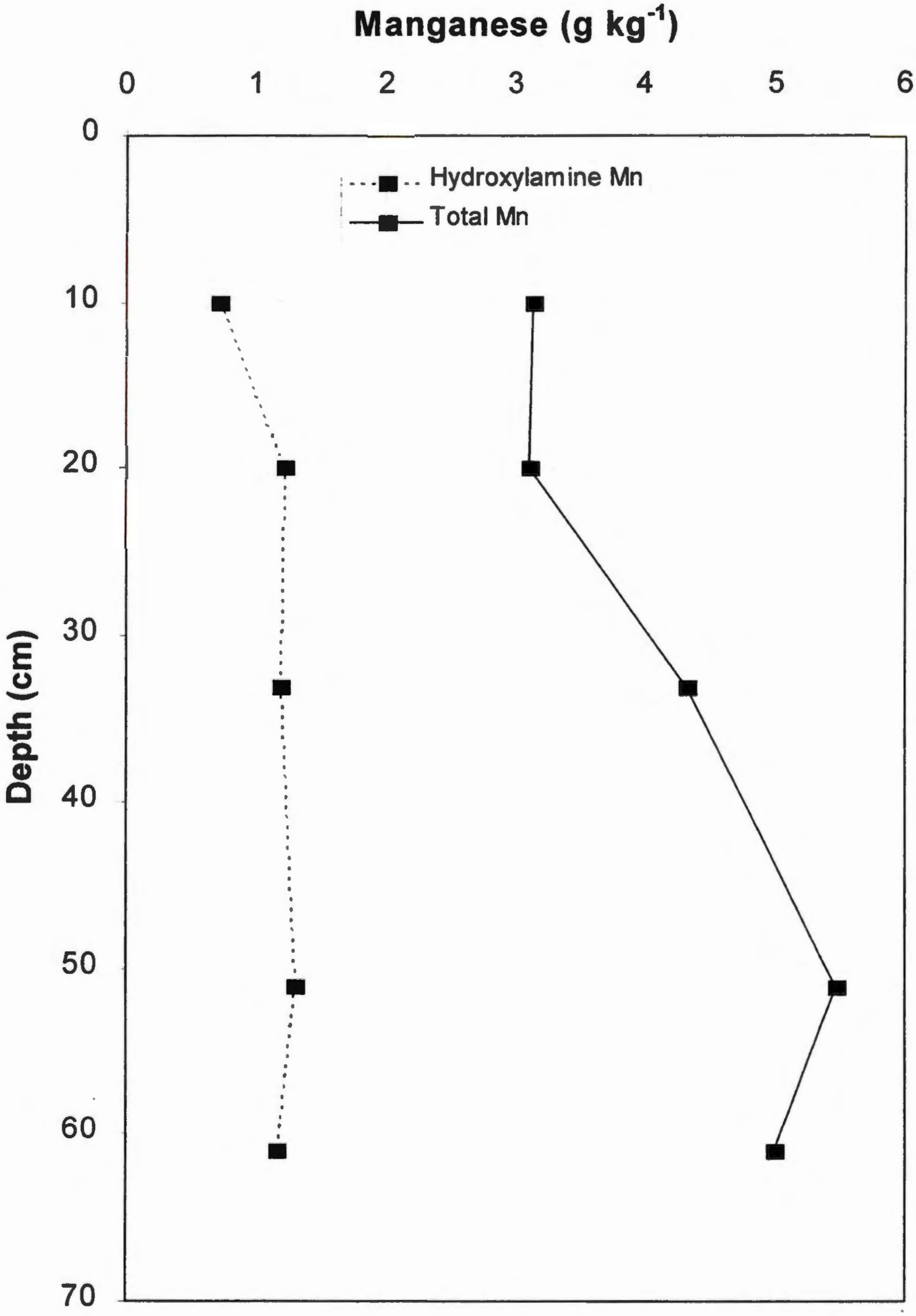

Figure 33. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #13.

depth to Cg4 (51-61 cm) (Fig. 34). The increase in total iron in Cg1 and Cg2 can be attributed to an increase in Fe^{2+} from anaerobic microorganisms. In addition, these higher iron concentrations may be related to an increase in Fe^{3+}. This increase corresponded to a slight decrease in pH (Table 28) and an increase in total sulfur percent for both horizons (Table 31) as a result of pyrite oxidation. Because of the deeper water table, these horizons were exposed to oxidation. A decrease in fine sand corresponded to an increase in free iron oxide concentration, except in Cg3 for the total iron curve (Fig. 34). Throughout the soil profile, as total clay percent increased and fine sand decreased, the ability of free iron oxides to be retained in the soil increased, except in Cg3.

Cation exchange capacity (CEC) was highest in Cg1 (1.88 cmol+kg^{-1}) and Cg2 (1.91 cmol+kg^{-1}) (Table 28). This can be attributed to an increase in total clay percent. CEC was 1.42 cmol+ kg^{-1} in the surface horizon, increased in Cg1 and Cg2, and decreased with depth to Cg4 (61 cm). In addition to the total clay percent, high organic carbon content (1.11% and 1.16% respectively) could be attributed to the high CEC in Cg1 and Cg2. Finer textures also increased in these horizons. Cg1 was a very fine sandy loam and Cg2 had a loam texture. The organic carbon curve followed the same pattern as the CEC curve (Fig. 35).

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 28). This can be attributed to the high calcium concentrations in each horizon. As in the other profiles, greater calcium concentrations were observed in the horizon preceding the gleyed layers and decreased steadily with depth throughout the soil profile (Table 28). Calcium carbonate equivalent (CCE) increased to Cg1, decreased

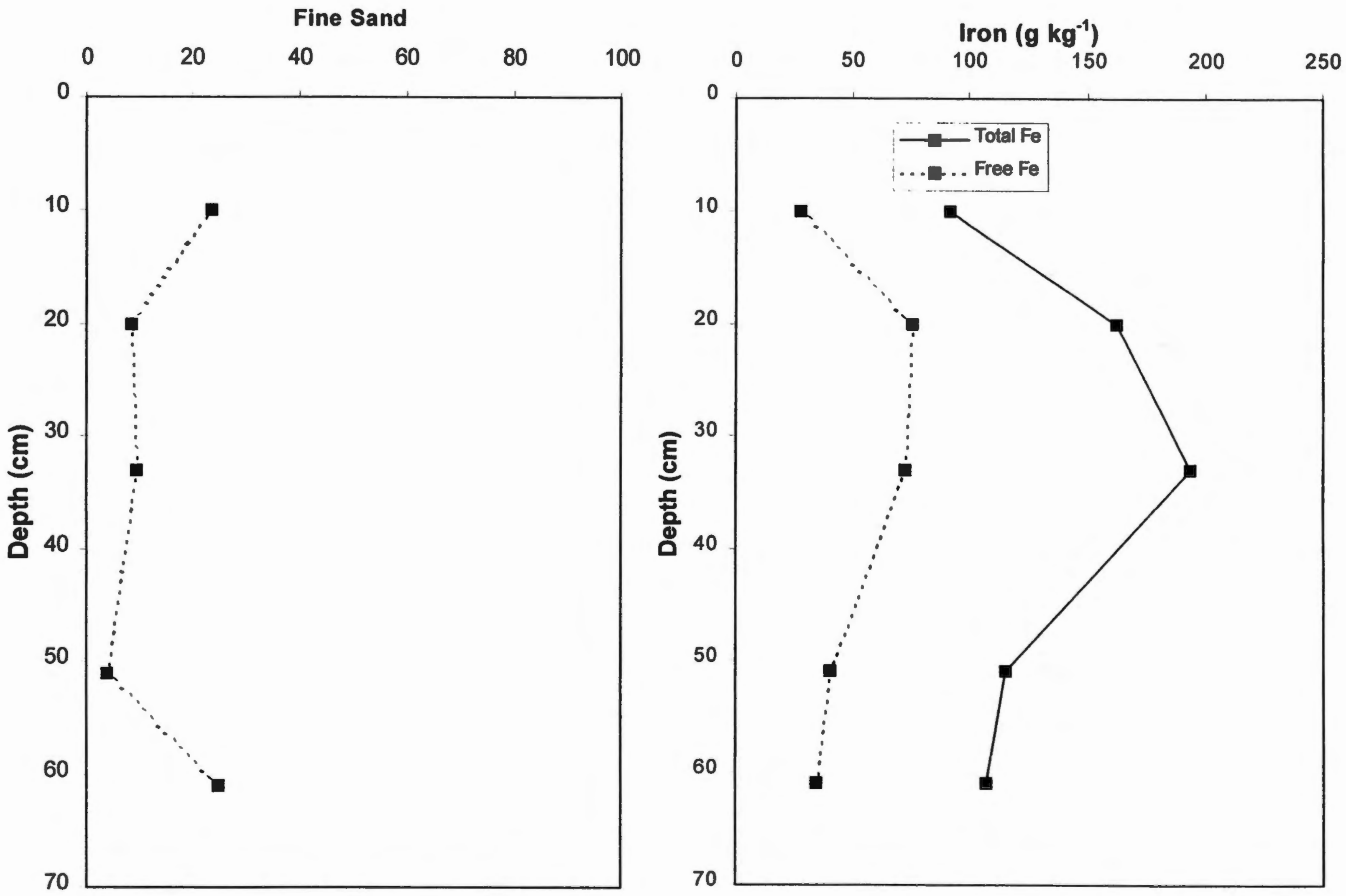

Figure 34. Fine sand, total iron, and free iron for Hydric Soil Profile #13.

Table 31. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #13.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	10	1.03	0.07	3.15	0.18
Cg1	20	1.71	0.06	10.94	1.11
Cg2	33	1.56	0.06	8.67	1.16
Cg3	51	2.05	0.06	3.47	0.80
Cg4	61+	2.01	0.06	3.57	0.72

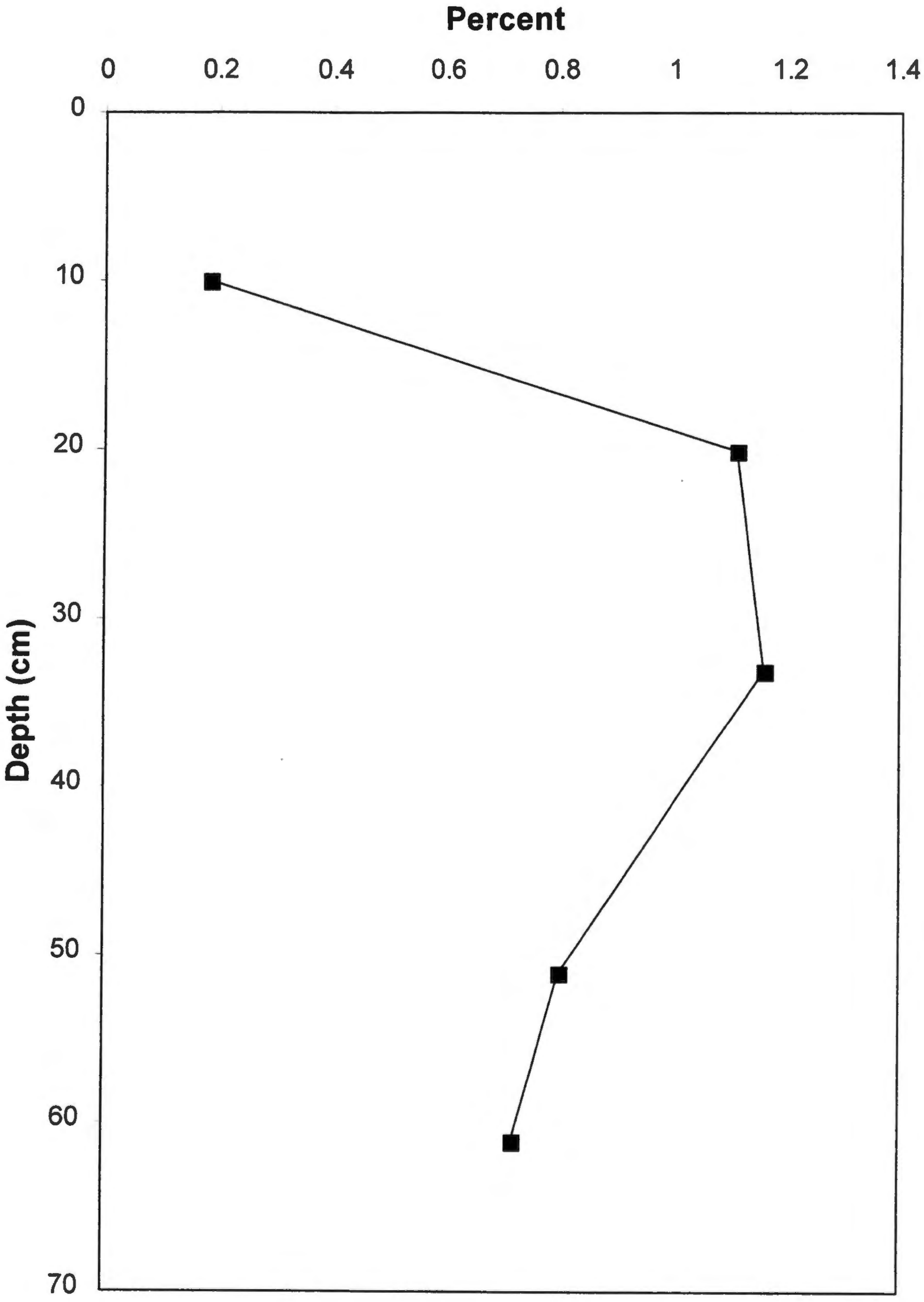

Figure 35. Organic carbon distribution for Hydric Soil Profile #13.

slightly in Cg2, and then increased in Cg3 and Cg4 (Table 28). pH values fluctuated with changes in CCE and did not necessarily increase with an increase in CCE. However, the high CCE in Cg3 (19.9%) and Cg4 (19.1%) corresponded to the highest pH values (7.1 and 7.3 respectively). As stated above, the lower pH values in Cg1 and Cg2 can be attributed to sulfuric acid, a product of pyrite oxidation. A very strong effervescent reaction to 10% HCl was noted in each horizon indicating that free carbonates were abundant (Table 27).

The particle size control section had in the fraction less than 75 mm in diameter, less than 15% fine sand or coarser particles and less than 18% clay making it coarse-silty (Fig. 36). Mineralogy class was mixed. The CEC/clay ratio in the control section (25-100 cm) was subactive (0.14). This soil was in the calcareous reaction class because in the fine-earth fraction, there was effervescence in all parts of the control section. This soil was an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. This site was classified as a coarse-silty, mixed, subactive, calcareous, mesic Typic Endoaquent.

Hydric Soil Profile #14

Hydric soil profile #14 was located at N 35° 03'04.6" and W 84°21'05.0" east on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. This site was west of a drainageway. The slope was at 1%. This site had hydrophytic vegetation dominated by some sedges and rushes. There was not any surface

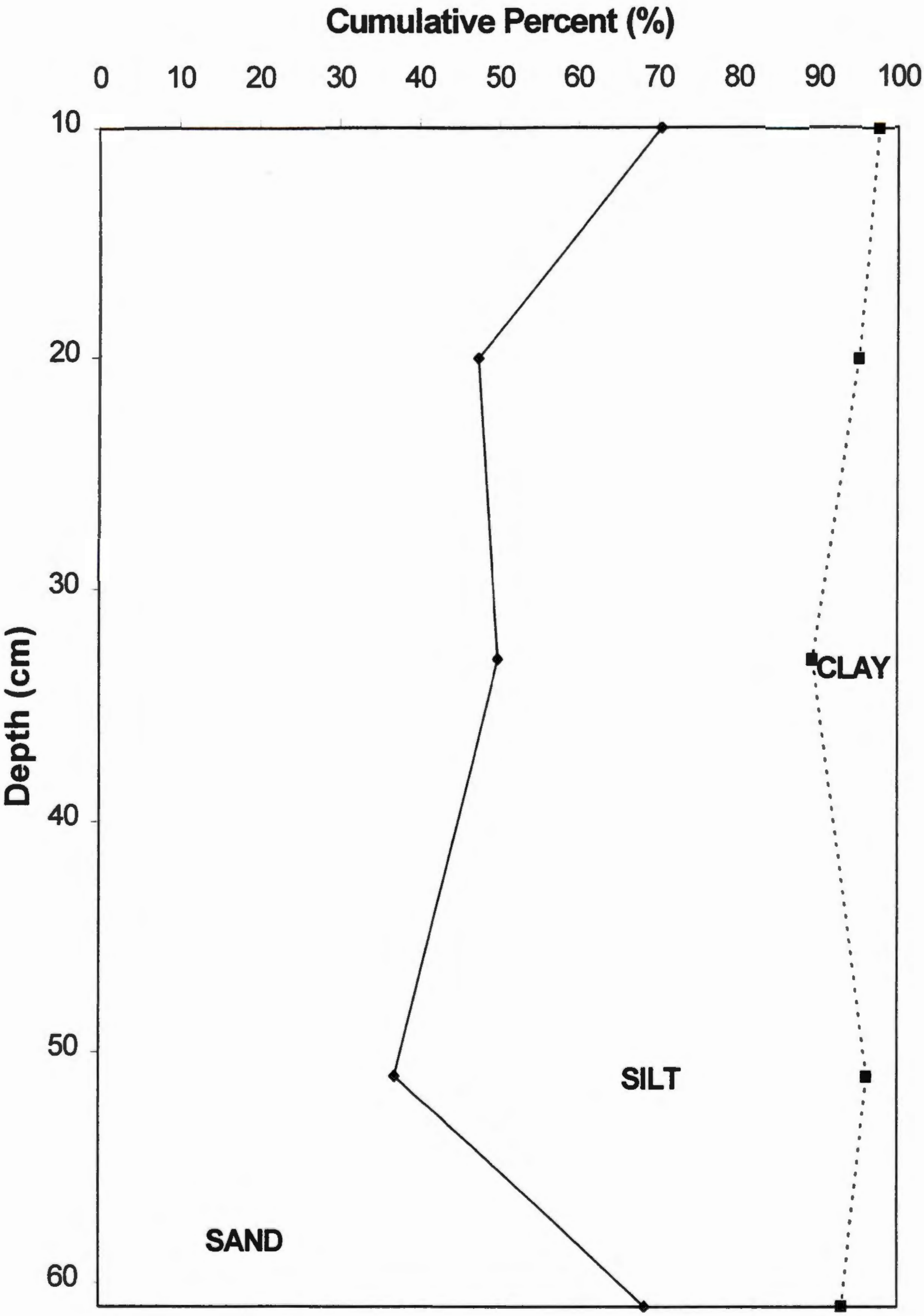

Figure 36. Particle size plot for Hydric Soil Profile #13.

water visible. Soil samples were collected and morphology was described to a depth of 79 cm. The parent material was alluvium.

As in soil profile #13, evidence of gleying was at 11 cm (Fig. 37). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 10Y 3/1, to 5GY 2.5/1, 10Y 2.5/1, and N2.5 (Table 32). Redoximorphic features such as iron concentrations and depletions were evident in the C horizon indicating anoxic conditions, a fluctuating water table, and repeated soil saturation were apparent. In dry samples, few iron concentrations and depletions were also apparent throughout the gleyed layers. As in the other sites, horizons above the gleyed layers tested positive for alpha, alpha-dipyridyl indicating that ferrous iron was present. All gleyed layers showed no reaction to alpha, alpha-dipyridyl, except for Cg3 (30-44 cm) which showed a positive reaction to the dye (Table 33). This indicates that there was an abundant amount of ferrous iron in the sample. The soil drainage class was poorly drained. As in soil profile #13, this site had a deeper water table than the other sites at 76 cm.

Total sand percentages ranged from 45.4% in the Cg3 horizon (30-44 cm) to 80.5% in the Cg2 horizon (18-30 cm) (Table 34). As in soil profile #13, fine sand percentages were lower than very fine sand percentages in all horizons. Very fine sand percentages made up the majority of sand size particles in this profile (Table 35). Total clay percentages ranged from 1.5% in Cg2 to 8.1% in Cg4 (Table 34). In addition, this profile had low total clay percentages indicating little pedogenic development.

As in soil profiles #12 and #13, easily reducible (hydroxylamine) manganese

Figure 37. Hydric Soil Profile #14.

Table 32. Morphology of Hydric Soil Profile #14.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	10	10YR 3/6 10YR 4/6	10YR 4/4	VfSL	sls sg	abrupt	loose	Very Strong	Fe Concentrations & Depletions
Cg1	18	10Y 3/1	10Y 5/1	VfSL	sls sg	clear	loose	Very Strong	Few Fe Concentrations
Cg2	30	5GY 2.5/1	10Y 5/1	LvfS	sls sg	clear	loose	Very Strong	Few Fe Concentrations & Depletions
Cg3	44	N2.5	10Y 4/1	VfSL	sls sg	clear	loose	Very Strong	Very few Fe Concentrations
Cg4	56	10Y 2.5/1	10Y 5/1	L	sls sg	clear	loose	Very Strong	Very few Fe Concentrations
Cg5	76+	5GY 2.5/1	10Y 5/1	VfSL	sls sg	-	loose	Very Strong	Few Fe Depletions

*Abbreviations for morphology designations are given in Appendix A.

Table 33. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Hydric Soil Profile #14.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^{+} cmol+ kg^{-1}
C	10	7.23	6.4	5.96	0.8872	0.11	0	0.11
Cg1	18	15.98	6.9	5.50	1.1670	0.07	0	0.07
Cg2	30	15.48	7.0	4.08	1.0820	0.04	0	0.04
Cg3	44	17.57	6.7	7.23	1.1378	0.04	0	0.04
Cg4	56	17.35	6.8	6.24	1.2538	0.08	0	0.08
Cg5	76+	17.72	6.9	3.65	1.1590	0.04	0	0.04

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Bases Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^{+} cmol+ kg^{-1}	Na^{+} cmol+ kg^{-1}	Base Saturation (%)	alpha,alpha dipyridyl
C	10	2.90	61.09	9.08	0.59	0.44	>100	Positive
Cg1	18	1.58	40.56	3.34	0.19	0.10	>100	Negative
Cg2	30	0.78	19.99	0.75	0.08	0.08	>100	Negative
Cg3	44	1.72	29.10	1.99	0.14	0.08	>100	Positive
Cg4	56	1.26	44.63	2.06	0.19	0.06	>100	Negative
Cg5	76+	0.79	24.22	1.03	0.10	0.09	>100	Negative

Table 34. Particle Size Distribution for Hydric Soil Profile #14.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	10	60.20	35.32	4.48
Cg1	18	50.56	45.17	4.28
Cg2	30	80.46	18.01	1.53
Cg3	44	45.42	48.00	6.59
Cg4	56	46.41	45.51	8.08
Cg5	76+	69.90	24.01	6.10

Table 35. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #14.

Horizon	Lower Depth (cm)	VCOS %	COS %	SAND MS %	FS %	VFS %	SILT COSi %	SILT F Si %
C	10	2.02	7.97	3.03	13.51	30.25	20.27	15.05
Cg1	18	1.00	1.20	0.50	10.39	32.07	22.55	22.62
Cg2	30	0.20	1.18	1.47	24.07	51.28	16.32	1.69
Cg3	44	0.40	2.20	0.60	9.28	29.55	30.67	17.33
Cg4	56	0.20	1.28	0.39	8.67	30.94	23.68	21.83
Cg5	76+	0.20	0.39	0.69	22.81	44.04	16.26	7.75

concentrations were lowest (0.8872 g kg^{-1}) in the horizon preceding the gleyed layers (Table 33). Manganese concentrations were higher in the gleyed layers. This can be attributed to the anaerobic microorganisms actively converting manganese to a more usable form of Mn^{2+}. Higher manganese concentrations can also be attributed to the deeper water table which did not fluctuate as often to leach manganese from the soil profile. Hydroxylamine manganese concentrations increased to Cg1, then fluctuated with depth throughout the profile, but eventually decreased in Cg5 at a depth close to where the water level was recorded. Hydroxylamine manganese was much lower than total manganese concentrations. Total manganese concentrations increased steadily throughout the soil profile to a depth of 56 cm, then slightly decreased in Cg5 (Fig. 38), again, most likely due to the depth to the water table.

Free iron was lowest in the Cg 5 horizon (3.65%). The highest free iron percentages were in Cg3 (7.23%) and Cg4 (6.24%). The high free iron percent in both Cg3 and Cg4 can be attributed to an increase in total clay (Table 34) and cation exchange capacities in both horizons (Table 33). However, Cg5 also had an increase in clay, but free iron was lowest in this horizon (3.65%). Both free and total iron concentrations were lowest in Cg5, most likely due to the water table which was recorded at this depth, leaching the iron from this horizon. Total iron showed a substantial increase in Cg3, almost as high as in the C horizon. This could be attributed to an increase in Fe^{3+}. These higher total iron values corresponded to higher total sulfur percentages (Table 36) and lower pH values (Table 33) as a result of pyrite oxidation. These gleyed layers were not affected by the deeper water table, therefore, oxidation occurred. Free iron and total iron

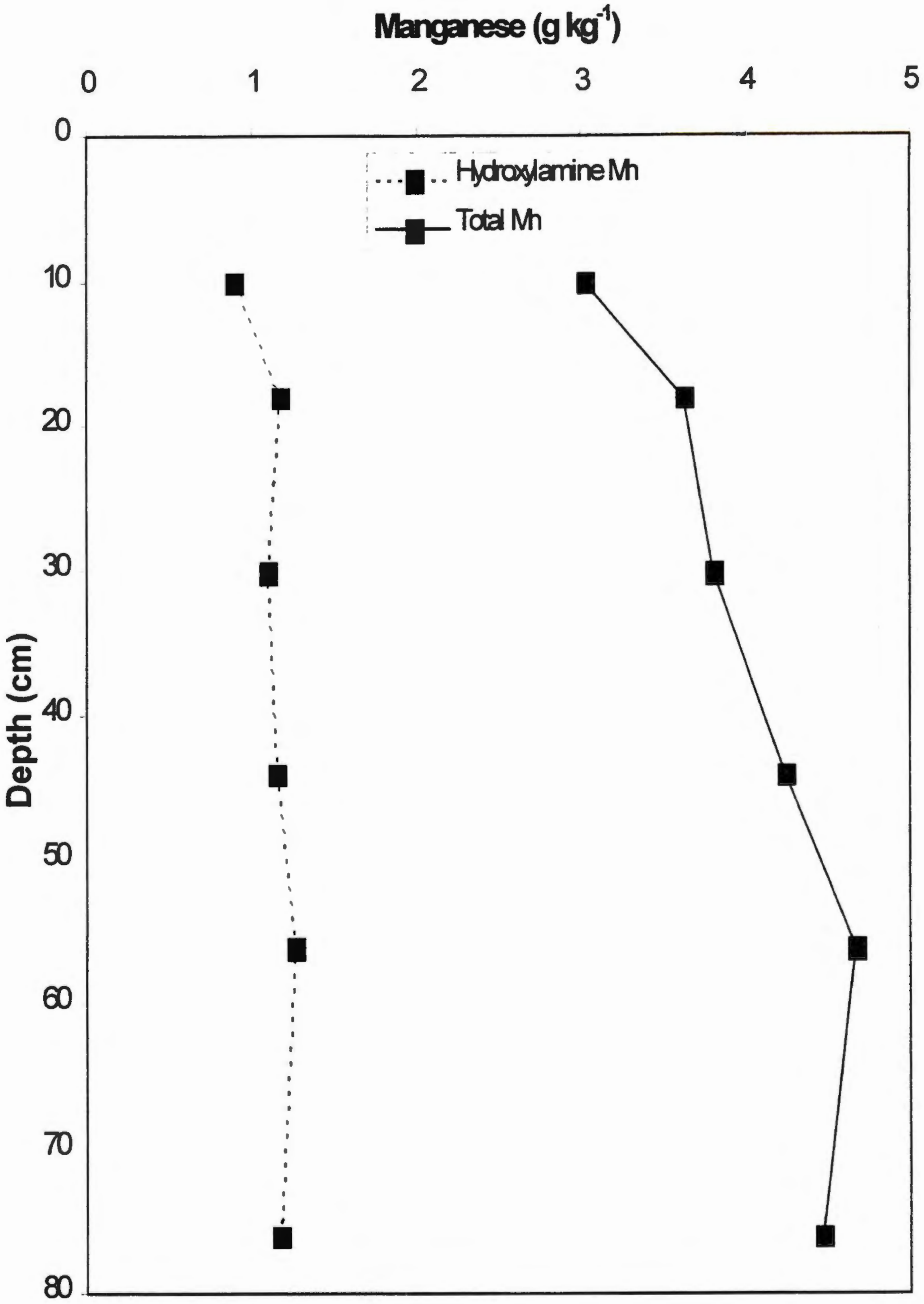

Figure 38. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #14.

Table 36. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #14.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	10	0.65	0.07	7.42	0.50
Cg1	18	1.46	0.06	5.12	1.23
Cg2	30	1.53	0.06	4.99	0.55
Cg3	44	1.74	0.06	8.09	1.57
Cg4	56	1.84	0.05	5.18	1.12
Cg5	76+	1.94	0.05	4.12	0.89

curves followed similar patterns (Fig. 39). A decrease in fine sand corresponded to an increase in free iron oxide concentration, except in the surface horizon (Fig. 39). Throughout the soil profile, as total clay percent increased and fine sand decreased, the ability of free iron oxides to be retained in the soil increased.

Cation exchange capacity (CEC) was highest in the surface horizon (2.90 cmol+kg^{-1}). CEC increased in Cg1 (1.58 cmol+kg^{-1}), Cg3 (1.72 cmol+kg^{-1}), and Cg4 (1.26 cmol+kg^{-1}) (Table 33). This can be attributed to an increase in total clay percent, but only in Cg3 and Cg4. CEC decreased in Cg2, most likely due to a decrease in clay percent. Although, there was also a decrease in CEC in Cg5, however, it is likely this was not related to a decrease in clay percent. In addition to higher total clay percentages, relatively high organic carbon percentages (1.23%, 1.57%, and 1.12%) could be attributed to the higher CEC's in Cg1, Cg3, and Cg4, respecitvely (Fig. 40). Higher organic carbon content in these horizons may also be attributed to the finer textures which have better nutrient and water holding capacities.

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 33). This can be attributed to the high calcium concentrations in each horizon. As in the other profiles, the greatest calcium concentration was observed in the horizon above the gleyed layers. Lower calcium concentrations were recorded in the gleyed layers (Table 33). Calcium carbonate equivalent (CCE) increased throughout the profile to a depth of 76 cm (Table 33). The lowest CCE was recorded in the surface horizon (7.23%). This corresponded to the lowest pH value. pH values increased from the surface horizon (6.4) to Cg1 (6.9) and fluctuated within the gleyed layers (Table 33).

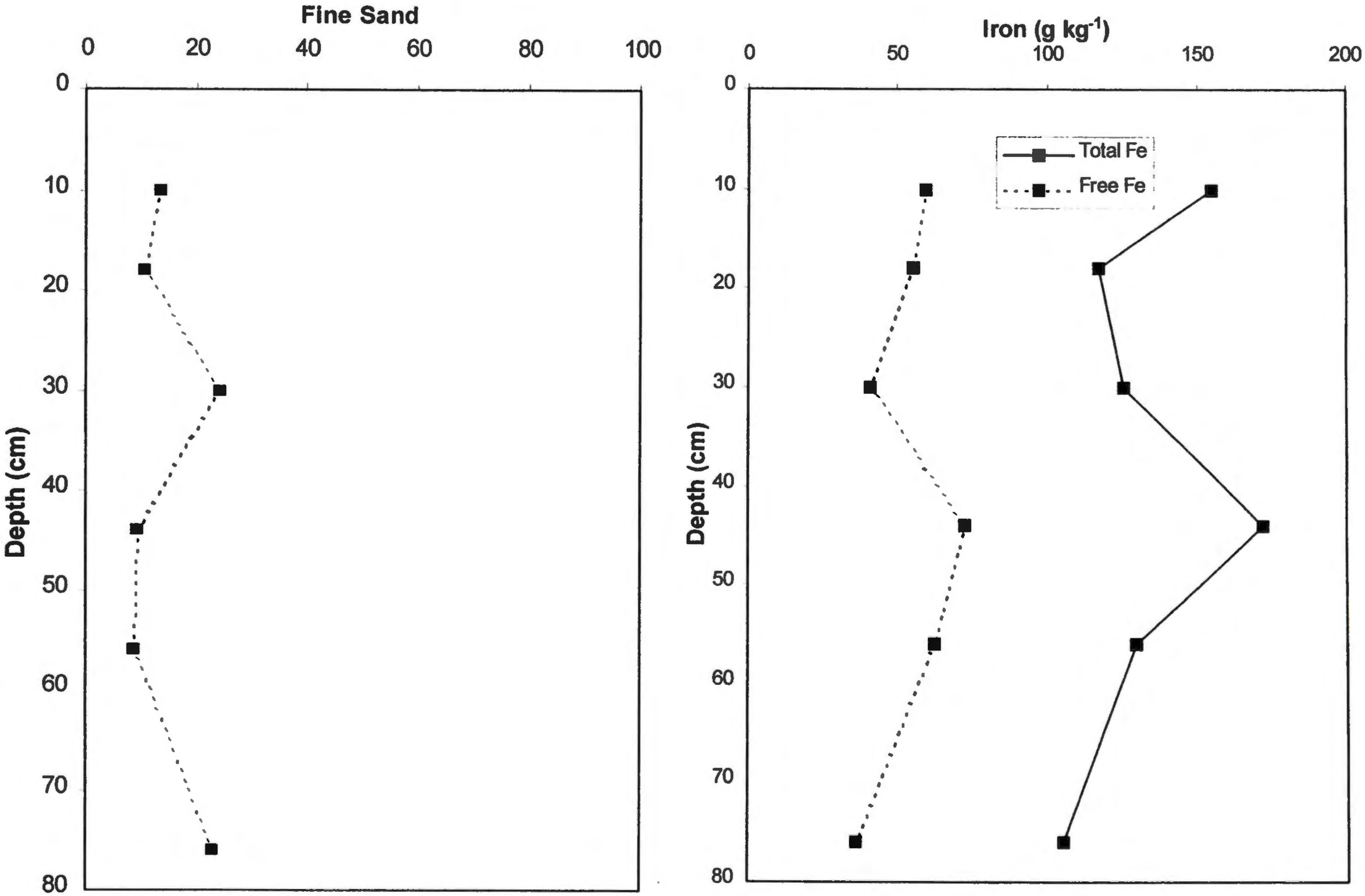

Figure 39. Fine sand, total iron, and free iron for Hydric Soil Profile #14.

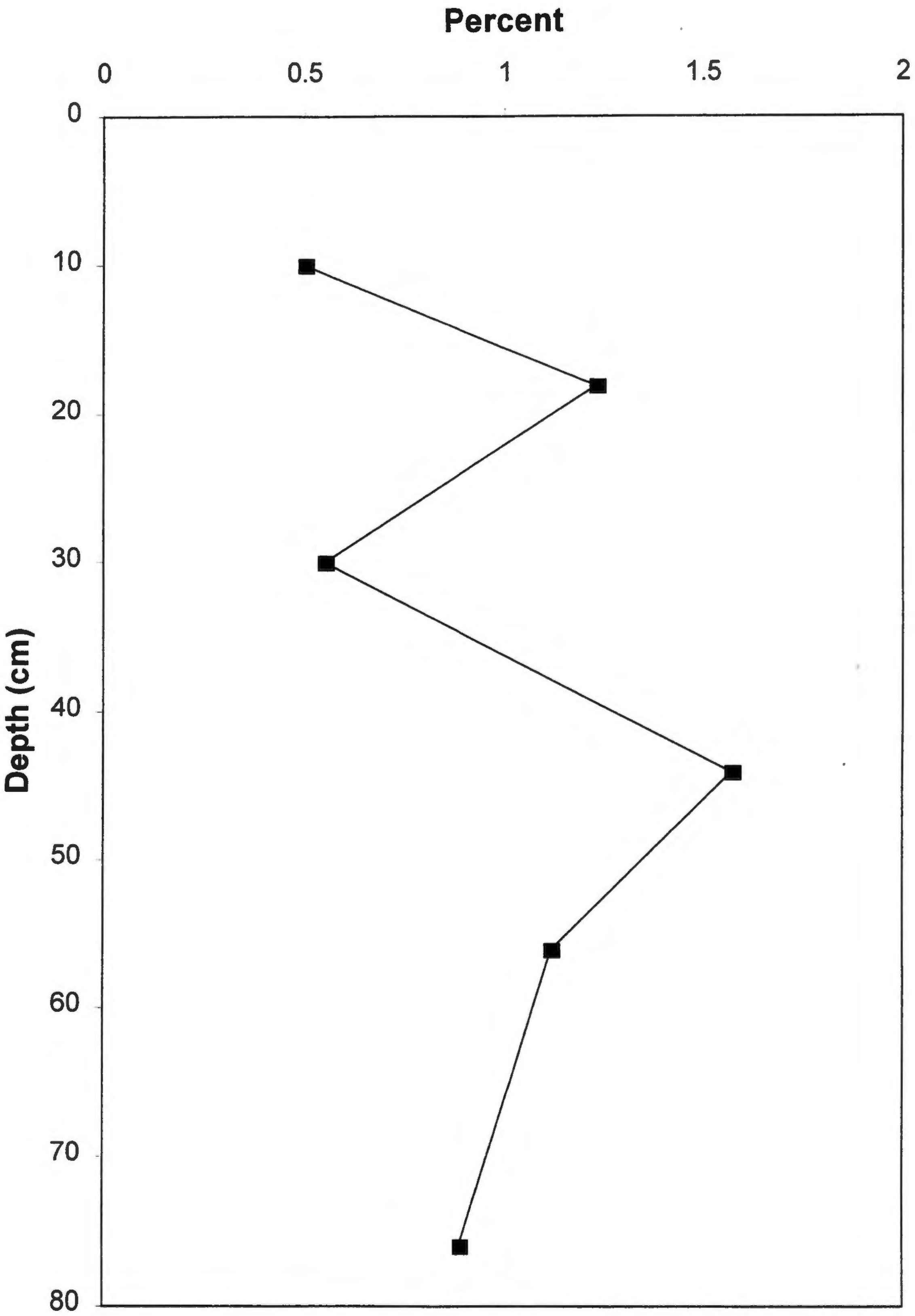

Figure 40. Organic carbon distribution for Hydric Soil Profile #14.

As stated above, lower pH values in C and Cg3 may be due to sulfuric acid, a product of pyrite oxidation. A very strong effervescent reaction to 10% HCl was noted in each horizon indicating that free carbonates were abundant (Table 32).

As in soil profile #13, the particle size control section had in the fraction less than 75 mm in diameter, less than 15% fine sand or coarser particles and less than 18% clay making it coarse-silty (Fig. 41). Mineralogy class was mixed. The CEC/clay ratio in the control section (25-100 cm) was subactive (0.18). This soil was in the calcareous reaction class because in the fine-earth fraction, there was effervescence in all parts of the control section. This soil was an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. This site was classified as a coarse-silty, mixed, subactive, calcareous, mesic Typic Endoaquent.

Hydric Soil Profile #15

Hydric soil profile #15 was located at N 35° 03'09.7" and W 84°21'02.6" east on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. The slope was at 1%. This site had hydrophytic vegetation dominated by some sedges and rushes. There was not any surface water visible. Soil samples were collected and morphology was described to a depth of 67 cm. The parent material was alluvium.

In this profile, evidence of gleying began at 9 cm (Fig. 42). This profile was hydric because at least 50% of the matrix had a chroma ≤2 at a depth of 25 cm (10 in). Gleyed horizon colors (moist) ranged from 5GY 3/1, to 5GY 2.5/1, 10GY 2.5/1, and 5PB

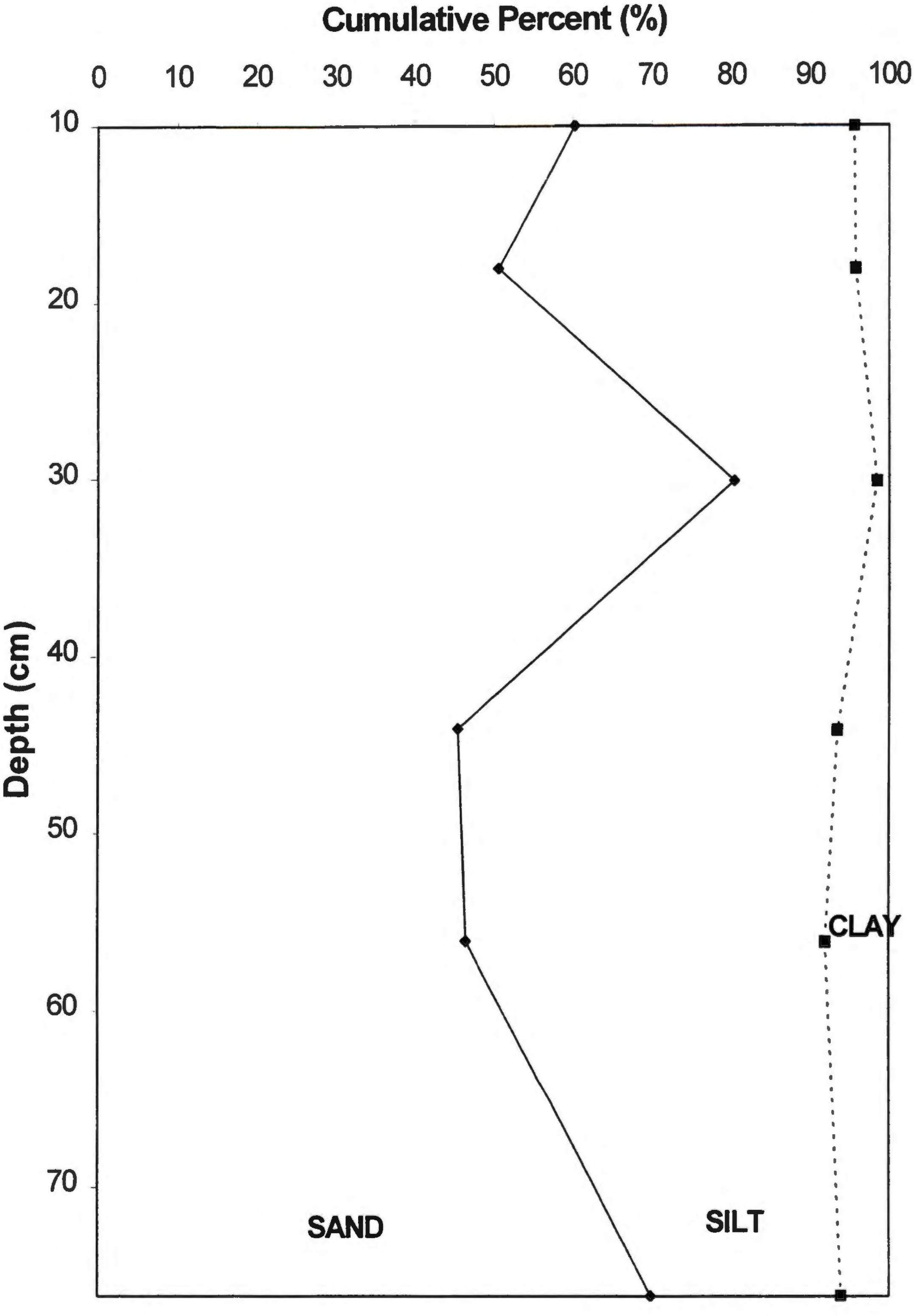

Figure 41. Particle size plot for Hydric Soil Profile #14.

Figure 42. Hydric Soil Profile #15.

2.5/1 (Table 37). Redoximorphic features such as iron concentrations and depletions were evident in the C and Cg1 horizons indicating anoxic conditions, a fluctuating water table, and repeated soil saturation were apparent. Few iron concentrations were noted in the Cg2 and Cg4 horizons. In the C, Cg1, and Cg4 horizons, a positive test for ferrous iron using alpha, alpha-dipyridyl was recorded. This indicates that ferrous iron was present in the sample. The Cg2 and Cg3 horizons showed no reaction to alpha, alpha-dipyridyl (Table 38). The soil drainage class was poorly drained. The water table was recorded at 82 cm.

This profile was located farthest east on the mine tailings pond than any other profile. In addition, it was also farthest from the outlet where the tailings were released. As a result, and by looking at the textures in Table 37 and cumulative particle size percent in Figure 43, total silt percentages were very high resulting in silt and silt loam textures. Total sand percentages decreased especially in the bottom horizon where it was only 7.75%. Total silt percentages ranged from 35.4% in the surface horizon to 86.3% in the bottom horizon (Table 39). Coarse and fine silt percentages increased, especially fine silt percentages (Table 40). Total clay percentages did not increase substantially and ranged from 2.99% in Cg2 to 7.24% in the C horizon (Table 39).

As in soil profiles #12, #13, and #14, easily reducible manganese concentrations were lowest (0.3300 g kg^{-1}) in the horizon preceding the gleyed layers (Table 38). In addition, easily reducible manganese concentrations were higher in the gleyed layers. The highest easily reducible manganese concentration was recorded in the bottom Cg4 horizon (1.418 g kg^{-1}). This was the highest concentration recorded in any of the soil

Table 37. Morphology of Hydric Soil Profile #15.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C	8	10YR 3/4 10YR 5/6	10YR 6/3 10YR 5/6	VfSL	sls sg	abrupt	loose	None/Slight	Fe Concentrations & Depletions
Cg1	24	5GY 3/1 5GY 2.5/1	10Y 4/1	SiL	sls sg	clear	loose	Very Strong	Fe Concentrations & Depletions
Cg2	41	5GY 2.5/1	10Y 4/1	SiL	sls sg	clear	loose	Very Strong	Very few Fe Concentrations
Cg3	57	10GY 2.5/1	10Y 5/1	SiL	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg4	67+	5PB 2.5/1	10Y 4/1	Si	sls sg	-	loose	Very Strong	Few Fe Concentrations

*Abbreviations for morphology designations are given in Appendix A.

Table 38. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Hydric Soil Profile #15.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C	8	2.28	5.8	1.65	0.3300	0.27	0	0.27
Cg1	24	14.43	6.6	9.20	1.1229	0.11	0	0.11
Cg2	41	12.71	6.5	15.15	1.1868	0.11	0	0.11
Cg3	57	17.20	7.0	5.65	1.2732	0.03	0	0.03
Cg4	67+	17.17	7.0	9.07	1.4180	0.03	0	0.03

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}			Bases		Base Saturation (%)	alpha,alpha dipyridyl
			Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}		
C	8	4.82	104.83	22.37	0.34	0.31	>100	Positive
Cg1	24	1.99	75.19	3.55	0.15	0.18	>100	Positive
Cg2	41	3.80	70.40	6.38	0.23	0.07	>100	Negative
Cg3	57	1.43	44.20	2.28	0.21	0.08	>100	Negative
Cg4	67+	3.52	85.26	4.72	0.33	0.06	>100	Positive

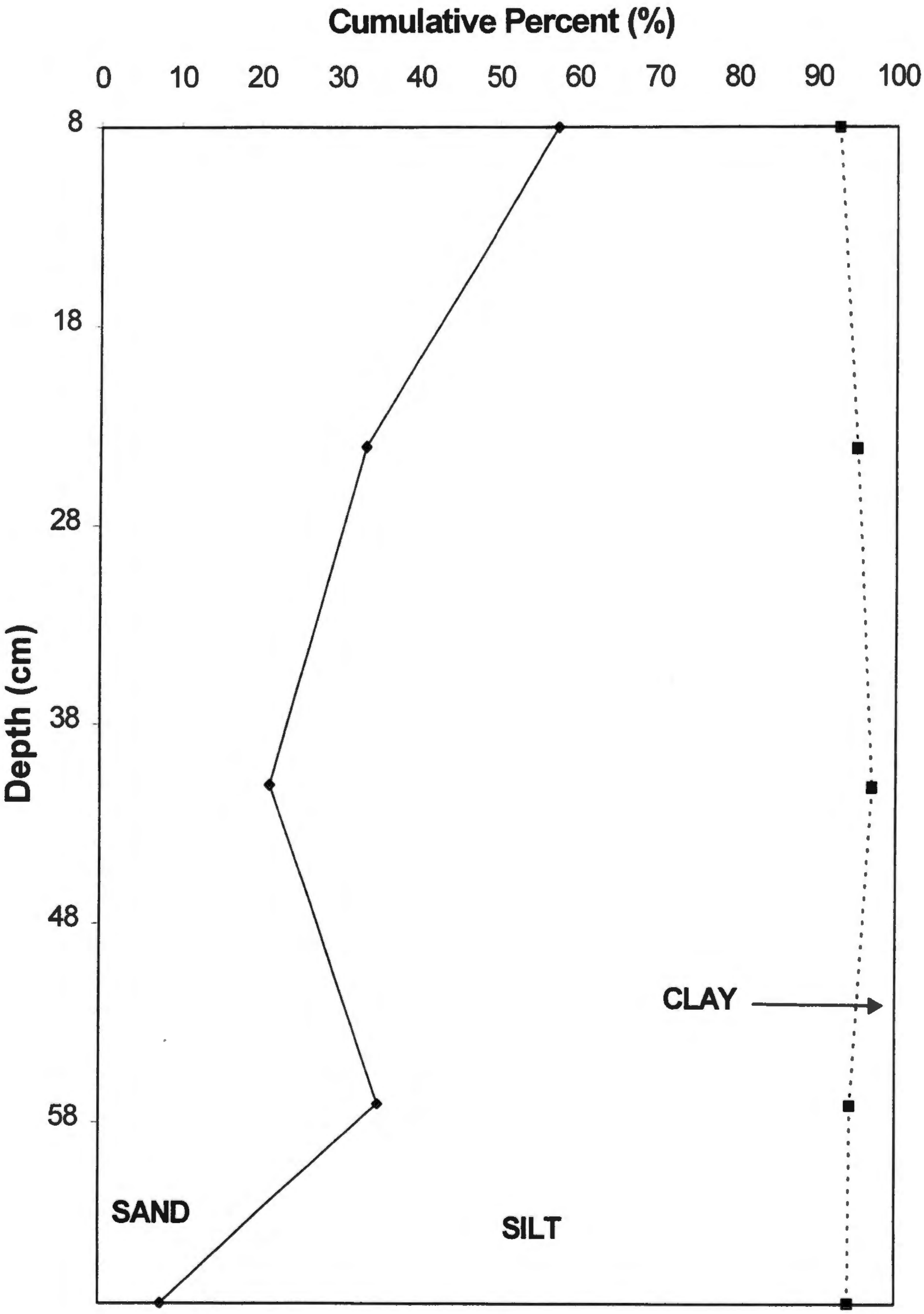

Figure 43. Particle size plot for Hydric Soil Profile #15.

Table 39. Particle Size Distribution for Hydric Soil Profile #15.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C	8	57.36	35.40	7.24
Cg1	24	33.25	61.81	4.94
Cg2	41	21.22	75.79	2.99
Cg3	57	34.94	59.35	5.71
Cg4	67+	7.75	86.33	5.92

Table 40. Distribution of Sand and Silt Particle Size Fractions for Hydric Soil Profile #15.

Horizon	Lower Depth (cm)	VCOS %	COS %	SAND MS %	FS %	VFS %	SILT COSi %	SILT F Si %
C	8	4.92	7.95	2.30	9.84	27.32	18.11	17.29
Cg1	24	3.79	3.89	1.46	3.89	16.72	32.10	29.71
Cg2	41	5.12	4.00	0.92	2.15	6.97	10.07	65.72
Cg3	57	0	0.20	0.20	4.29	24.06	27.49	31.86
Cg4	67+	0	0.20	0.20	0.50	4.23	11.51	74.82

profiles on the east side of the mine tailings pond. Both hydroxylamine manganese and total manganese concentrations increased steadily throughout the profile. A substantial increase was recorded from C to Cg1 which indicated that anaerobic microorganisms were converting Mn^{4+} to Mn^{2+} (Fig. 44). It was likely that manganese concentrations never decreased in the gleyed layers because the water table was so deep and probably did not fluctuate as often to leach the manganese from the profile.

Free iron percent was lowest in the layer preceding the gleyed layers (1.65%). Free iron percentages fluctuated throughout the gleyed layers with the highest free iron percent in the Cg2 horizon (15.15%) (Table 38). However, the high free iron percent did not correspond to a high clay percent in this horizon. In fact, this horizon had the lowest total clay percent in the profile (Table 39). Free iron and total iron curves followed the same pattern and increased in Cg1 and Cg2, decreased in Cg3, and increased again in Cg4 (Fig. 45). The increase in iron concentrations in Cg1, Cg2, and Cg4 could be attributed to an increase in Fe^{3+}. These horizons also have high total sulfur percentages (Table 41) and lower pH's, only in Cg1 and Cg2 (Table 38). It is likely the deeper water table, did not leach the iron from the bottom horizon. Fine sand was very low throughout the profile because of the increase in the silt and clay percent. This corresponded to a higher free iron oxide concentration (Fig. 45).

As in soil profile #14, cation exchange capacity (CEC) was highest in the surface horizon (4.82 cmol+kg^{-1}). CEC also increased in Cg2 (3.80 cmol+kg^{-1}) and Cg4 (3.52 cmol+kg^{-1}) (Table 38). The high CEC in Cg2 cannot be attributed to the clay percent because this horizon had the lowest clay percent in the profile. Higher organic carbon

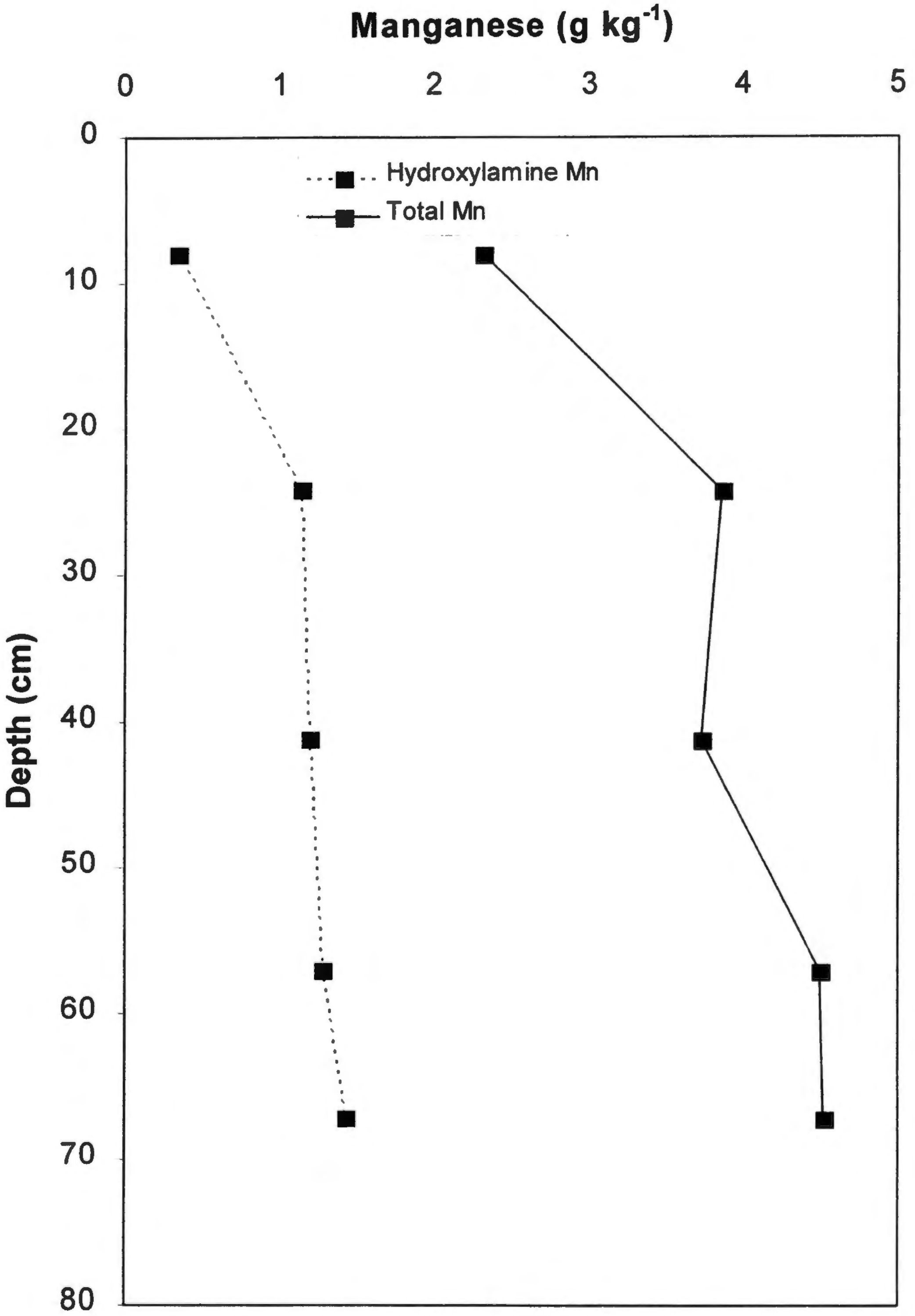

Figure 44. Total manganese and HCL-hydroxylamine manganese for Hydric Soil Profile #15.

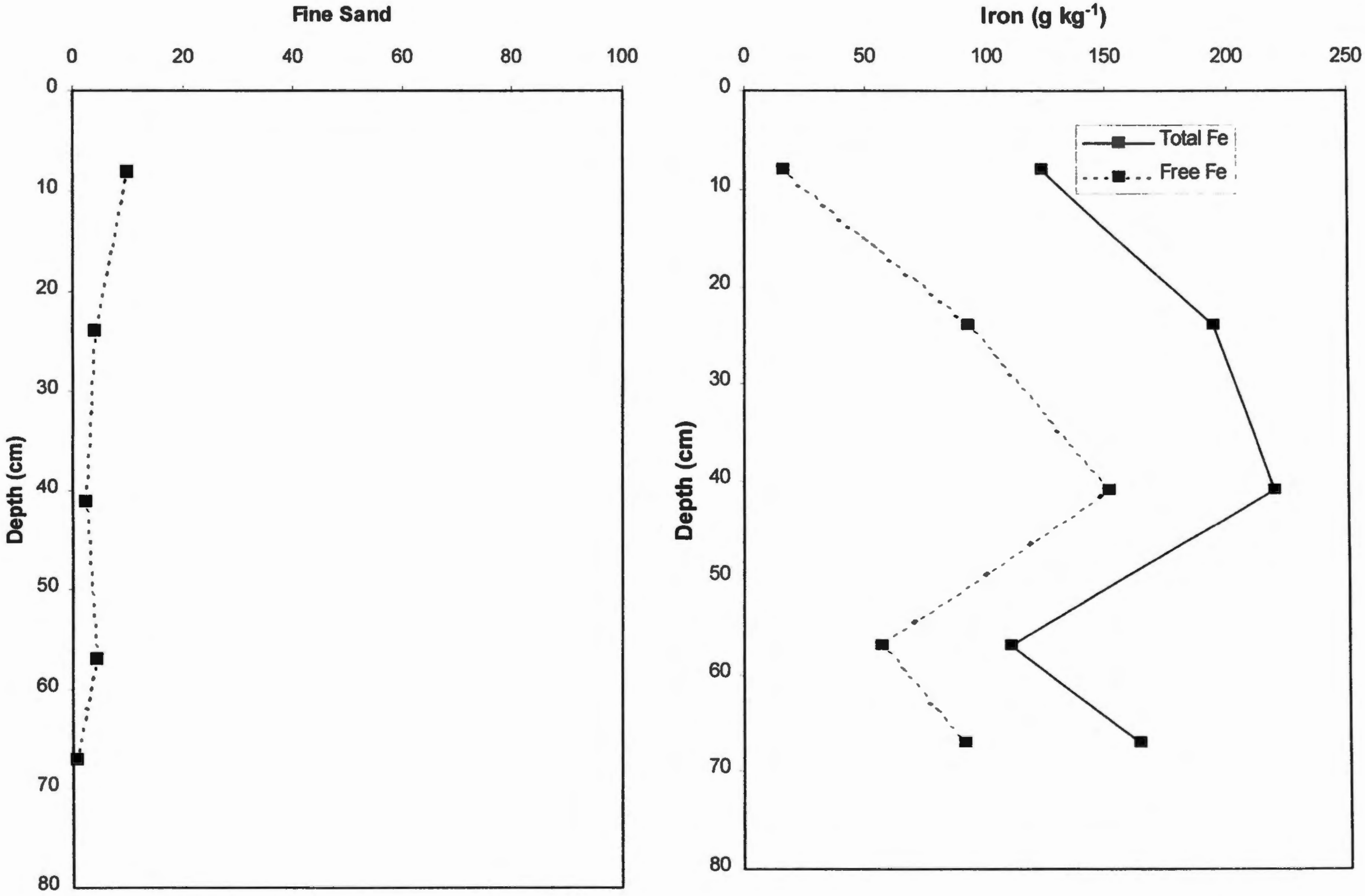

Figure 45. Fine sand, total iron, and free iron for Hydric Soil Profile #15.

Table 41. Total carbon, nitrogen, sulfur, and organic carbon percent for Hydric Soil Profile #15.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)
C	8	0.29	0.07	3.53	0.18
Cg1	24	1.27	0.06	10.39	1.10
Cg2	41	1.13	0.06	12.02	1.05
Cg3	57	1.77	0.05	4.01	1.11
Cg4	67+	1.57	0.05	7.64	1.40

percentages were recorded in the gleyed layers. These higher percentages can be attributed to an increase in finer textures, especially in the bottom horizon in which the texture was silt. Organic carbon content was lowest in the horizon preceding the gleyed layers (Fig. 46).

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 38). This can be attributed to the high calcium concentrations in each horizon. As in the other profiles, the highest calcium concentration was observed in the horizon preceding the gleyed layers. Lower calcium concentrations were recorded in the gleyed layers (Table 38). Calcium carbonate equivalent (CCE) was higher in the gleyed layers compared to the surface horizon in which it was the lowest (2.28%) (Table 38). This corresponded to the lowest pH value (5.8). pH values increased from 5.8 in the surface horizon to 6.6 in Cg1, decreased slightly to 6.5 in Cg2, and increased again to 7.0 in both Cg3 and Cg4. The low pH and CCE values in the surface horizon corresponded to the none to slight reaction to 10% HCl indicating that free carbonates were not abundant (Table 37). However, the lower pH did not correspond to a higher total sulfur percent and higher iron concentration in the surface horizon, although pyrite oxidation may be a contributing factor to the lower pH because this was the surface horizon. A very strong effervescent reaction to 10% HCl was noted in the gleyed layers and indicated that free carbonates were abundant (Table 37).

The particle size control section consisted of in the fraction less than 75 mm in diameter, less than 15% fine sand or coarser particles and, in the fine-earth fraction, less than 18% clay making it coarse-silty (Fig. 43). Mineralogy class was mixed. The

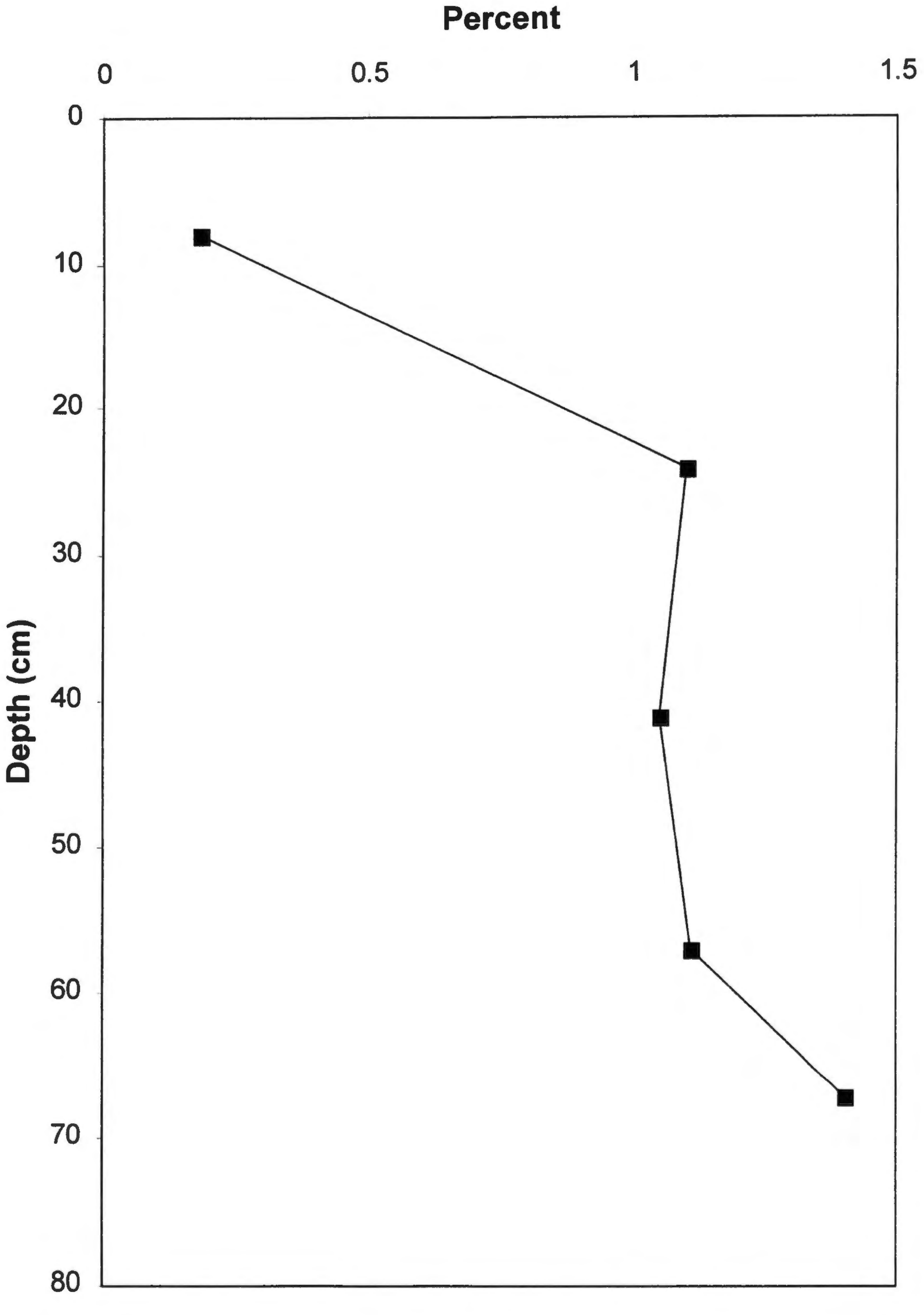

Figure 46. Organic carbon distribution for Hydric Soil Profile #15.

CEC/clay ratio in the control section (25-100 cm) was superactive (0.66). This soil was in the calcareous reaction class because in the fine-earth fraction, there was effervescence in all parts of the control section. This soil was an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 25 cm from the soil surface which put it in the aquent suborder. This site was classified as a coarse-silty, mixed, superactive, calcareous, mesic Typic Endoaquent.

Non-Hydric Soil Profile #16

Non-hydric soil profile #16 was located at N 35° 02'59.6" and W 84°21'40.6" west on the mine tailings pond on a floodplain position at an elevation of 577.9 m above mean sea level. This profile was located farthest west than any other profile on the tailings pond. The slope was at 1%. This site did not have any hydrophytic vegetation present. There was not any surface water visible. Soil samples were collected using a Giddings Hydraulic Probe to a depth of 110 cm. The parent material was alluvium.

In this profile, evidence of gleying began at 44 cm (Fig. 47). This profile was not hydric because gleying did not begin until 44 cm. Gleyed horizon colors (moist) ranged from 10Y 2.5/1, to 5GY 2.5/1, and 5GY 3/1 (Table 42). Redoximorphic features such as iron concentrations and few iron depletions were present in the surface horizon. All horizons tested positive for alpha, alpha-dipyridyl (Table 43). This indicates that ferrous iron was present throughout the soil profile. The soil drainage class was somewhat poorly drained. Depth to the water table was not reached within 110 cm.

Since this profile was located farthest west on the tailings pond and closest to the

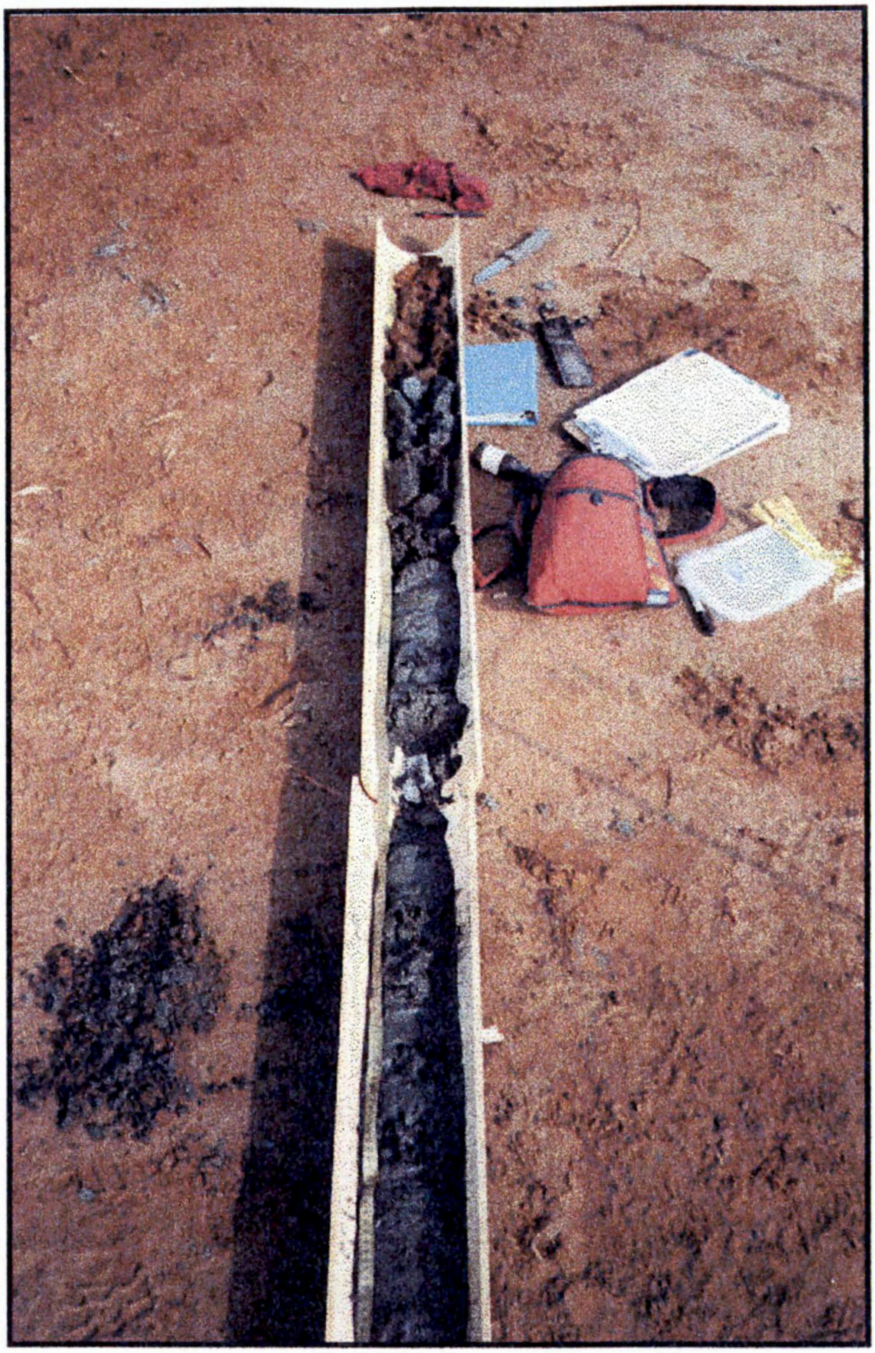

Figure 47. Non-Hydric Soil Profile #16.

Table 42. Morphology of Non-Hydric Soil Profile #16.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C1	17	7.5YR 4/6 7.5YR 3/4	10YR 4/6	LfS	sls sg	clear	loose	None	Fe Concentrations Few Fe Depletions
C2	31	7.5YR 3/4	10YR 4/6	LfS	sls sg	clear	loose	Moderate	
C3	43	10YR 3/4	10YR 4/4	fS	sls sg	abrupt	loose	Slight	
Cg1	52	10Y 2.5/1	10Y 5/1	VfSL	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg2	73	5GY 2.5/1	10Y 5/1	fS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg3	87	5GY 3/1	10Y 5/1	fS	sls sg	clear	loose	Moderate	Gleyed Matrix
Cg4	97	5GY 2.5/1	10Y 5/1	fS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg5	110+	5GY 2.5/1	10Y 5/1	fS	sls sg	-	loose	Very Strong	Gleyed Matrix

*Abbreviations for morphology designations are given in Appendix A.

Table 43. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Non-Hydric Soil Profile #16.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C1	17	0	2.8	5.62	0.0117	2.61	0.84	1.77
C2	31	6.86	6.1	0.99	1.4585	0.03	0	0.03
C3	43	8.84	6.8	1.37	0.8422	0.03	0	0.03
Cg1	52	15.78	6.5	3.68	1.3994	0.05	0	0.05
Cg2	73	15.28	6.2	2.27	0.8440	0.03	0	0.03
Cg3	87	15.40	5.8	5.41	0.6094	0.03	0	0.03
Cg4	97	18.14	6.2	2.72	0.9852	0.03	0	0.03
Cg5	110+	19.31	6.4	3.02	1.1821	0.03	0	0.03

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Bases Ca^{2+} cmol+ kg^{-1}	Bases Mg^{2+} cmol+ kg^{-1}	Bases K^+ cmol+ kg^{-1}	Bases Na^+ cmol+ kg^{-1}	Base Saturation (%)	alpha,alpha dipyridyl
C1	17	2.86	52.25	0.26	0.07	0.09	>100	Positive
C2	31	2.84	106.80	0.40	0.05	0.07	>100	Positive
C3	43	2.69	81.62	0.33	0.03	0.05	>100	Positive
Cg1	52	1.88	47.68	2.07	0.12	0.07	>100	Positive
Cg2	73	0.79	16.94	0.50	0.04	0.10	>100	Positive
Cg3	87	0.68	12.28	0.58	0.01	0.04	>100	Positive
Cg4	97	0.87	10.55	0.67	0.02	0.04	>100	Positive
Cg5	110+	1.30	10.45	0.64	0.02	0.04	>100	Positive

outlet where the tailings were released, textures ranged from loamy fine sands to fine sands, and very fine sandy loams (Table 42). Total sand percentages were high and ranged from 50.1% in Cg1 to 95.4% in Cg3. Total sand percentages increased in the bottom gleyed horizons (Cg2, Cg3, Cg4, and Cg5) (Table 44). Fine sand percentages made up the majority of the distribution of sand size fractions. Fine sand ranged from 19.38% in the Cg1 horizon to 51.04% in the Cg3 horizon (Table 45). As in the other profiles, total clay percentages remained low and ranged from 1.03% in the bottom horizon to 3.44% in C2 indicating that there was little pedogenic development (Table 44).

Unlike the other soil profiles, easily reducible (hydroxylamine) manganese concentrations fluctuated throughout the soil profile and did not reflect any pattern. The fluctuation in manganese concentrations could be attributed to the deeper water table and the inability for manganese reduction to occur, especially in the gleyed layers. The highest easily reducible manganese concentration was in C2 (1.459 g kg^{-1}). Cg1 also had a high manganese concentration (1.399 g kg^{-1}) (Table 43). Both hydroxylamine manganese and total manganese concentrations did not follow the same pattern. The highest total manganese concentration was in the Cg5 horizon (Fig. 48). It was likely that manganese concentrations never decreased substantially in the gleyed layers, especially Cg5, because the water table was so deep and probably did not fluctuate as often to leach the manganese from the profile.

Free iron percent also fluctuated throughout the soil profile. There was an increase in free iron percent from C3 (1.37%) to Cg1 (3.68%). The highest free iron percent was in the surface horizon (5.62%) (Table 43). This corresponded to the highest

Table 44. Particle Size Distribution of Non-Hydric Soil Profile #16.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C1	17	78.73	18.96	2.30
C2	31	81.46	15.11	3.44
C3	43	87.71	10.04	2.25
Cg1	52	50.10	47.25	2.65
Cg2	73	92.95	6.02	1.03
Cg3	87	95.40	1.70	2.91
Cg4	97	94.83	3.26	1.91
Cg5	110+	93.45	5.51	1.03

Table 45. Distribution of Sand and Silt Particle Size Fractions for Non-Hydric Soil Profile #16.

Horizon	Lower Depth (cm)			SAND			SILT	SILT
		VCOS %	COS %	MS %	FS %	VFS %	COSi %	F Si %
C1	17	0.89	5.75	5.65	47.30	18.64	8.49	10.47
C2	31	0.40	6.87	5.56	48.21	20.01	8.60	6.51
C3	43	0.60	13.53	12.03	48.22	12.93	2.54	7.50
Cg1	52	0.40	2.61	2.11	19.38	24.00	21.78	25.46
Cg2	73	0.57	10.13	13.09	50.72	18.15	3.16	2.87
Cg3	87	0.79	10.40	17.86	51.04	15.21	0	1.81
Cg4	97	0.88	11.99	14.13	48.93	18.42	2.63	0.62
Cg5	110+	1.09	9.92	12.70	50.20	18.95	4.2	1.31

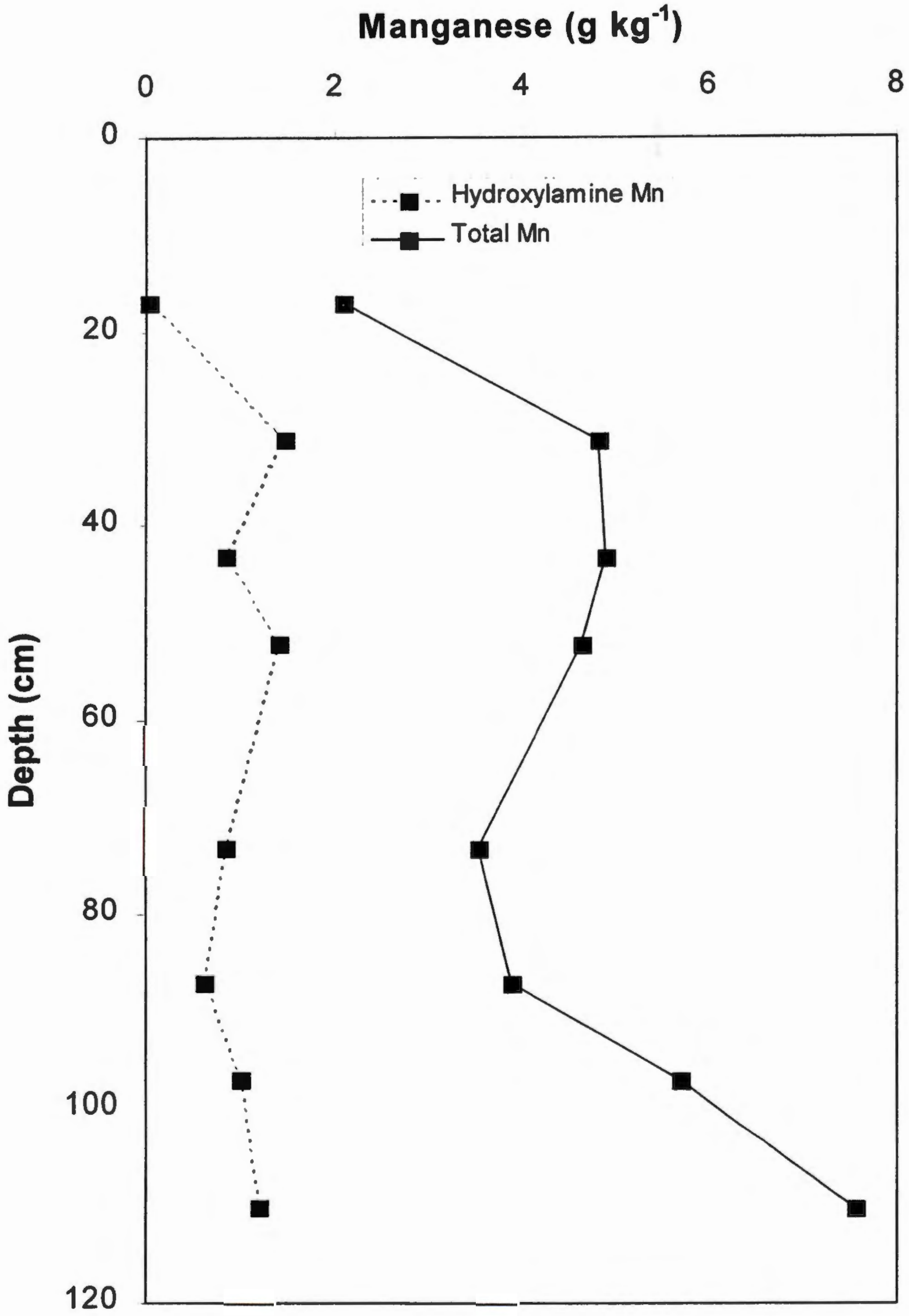

Figure 48. Total manganese and HCL-hydroxylamine manganese for Non-Hydric Soil Profile #16.

cation exchange capacity. Free iron and total iron curves followed similar patterns. Both had high iron concentrations in the surface and Cg3 horizons (Fig. 49). The substantial increase in total iron in Cg3 could be attributed to an increase in Fe^{3+}. Also, total sulfur percent (18.17%) was extremely high in Cg3 (Table 46). High iron concentrations and high total sulfur percentages corresponded to a decrease in pH in Cg3 (Table 43). Fine sand decreased substantially in Cg1. This corresponded to a decrease in total sand percent and an increase in total silt percent (Table 44). This decrease in fine sand only corresponded to a slightly higher free iron oxide concentration because clay percentages did not increase substantially in this profile (Fig. 49).

As in the other soil profiles, cation exchange capacities (CEC) were low throughout the soil profile, but highest in the surface horizon (2.86 cmol+kg^{-1}) (Table 43). CEC decreased from the surface to Cg3, and then increased with depth to Cg5. The higher CEC in C1, C2, and C3 could be attributed to slightly higher clay percentages (Table 44). Organic carbon percentages fluctuated throughout the profile. The highest organic carbon percent was in Cg1 (Fig. 50). This corresponded to the finer texture of very fine sandy loam. Organic carbon percentages did not increase substantially because this profile consisted of coarse textures of loamy sands and sands which have very little nutrient holding capacities.

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 43). This can be attributed to the high calcium concentrations in each horizon. As in the other profiles, the greatest calcium concentrations were observed in the horizons preceding the gleyed layers. Lower calcium concentrations were recorded in

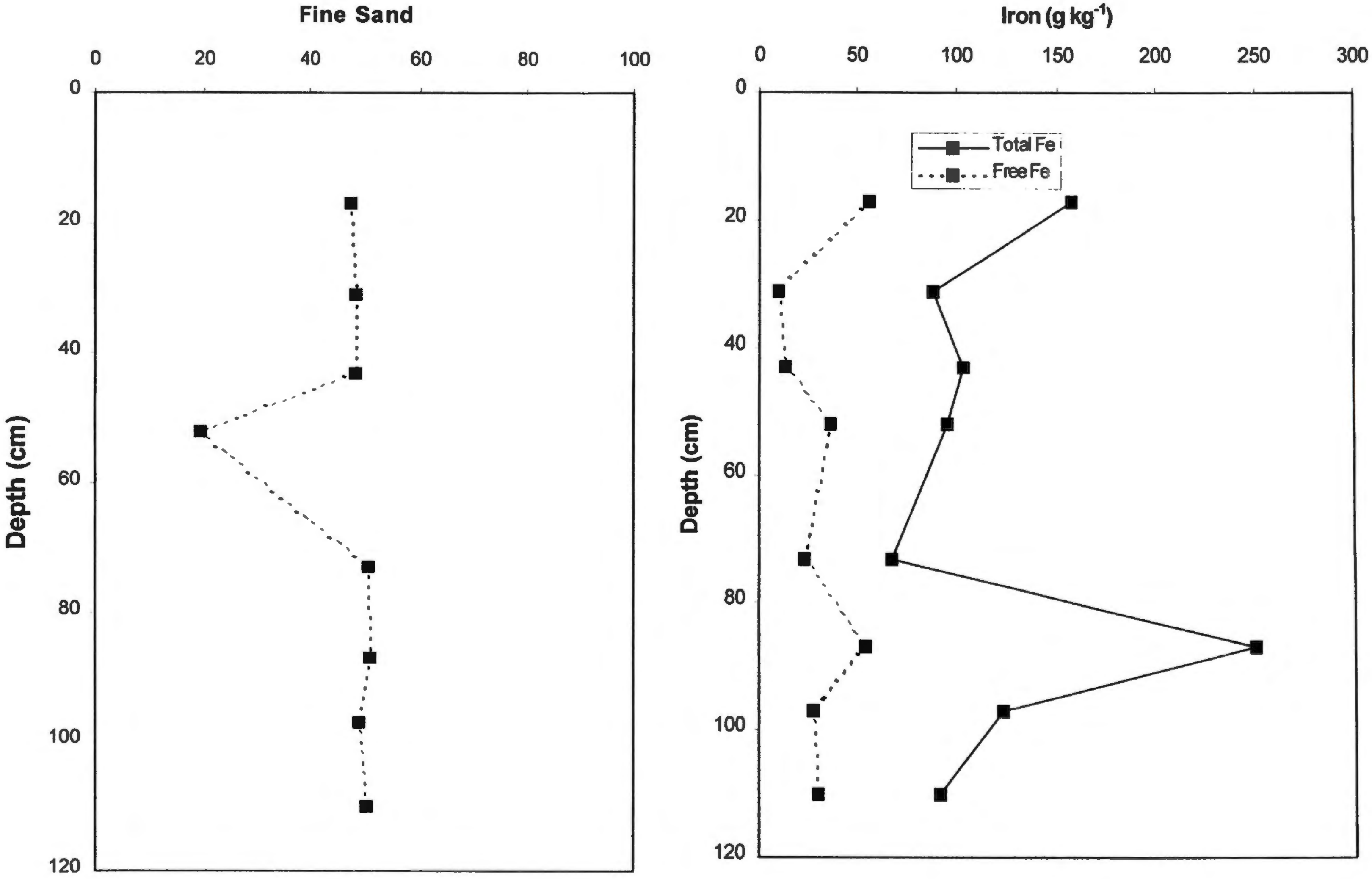

Figure 49. Fine sand, total iron, and free iron for Non-Hydric Soil Profile #16.

Table 46. Total carbon, nitrogen, sulfur, organic carbon, HCl extractable sulfur, HNO_3 extractable sulfur, and non-extractable sulfur percent for Non-Hydric Soil Profile #16.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)	HCl Extractable Sulfur (%)	HNO_3 Extractable Sulfur (%)	Non-extractable Sulfur (%)
C1	17	0.19	0.07	1.63	0.17	1.03	0	0.60
C2	31	0.82	0.06	2.89	0.09	2.26	0	0.63
C3	43	1.11	0.05	2.53	0.15	1.27	0.03	1.22
Cg1	52	1.54	0.05	4.20	1	0.69	0	3.51
Cg2	73	1.58	0.05	3.36	0.06	0.04	0.31	3
Cg3	87	1.32	0.06	18.62	0.32	0.10	0	18.52
Cg4	97	2.26	0.05	5.37	0.02	0	0	5.37
Cg5	110+	2.28	0.05	5.52	0	0	0.50	5.02

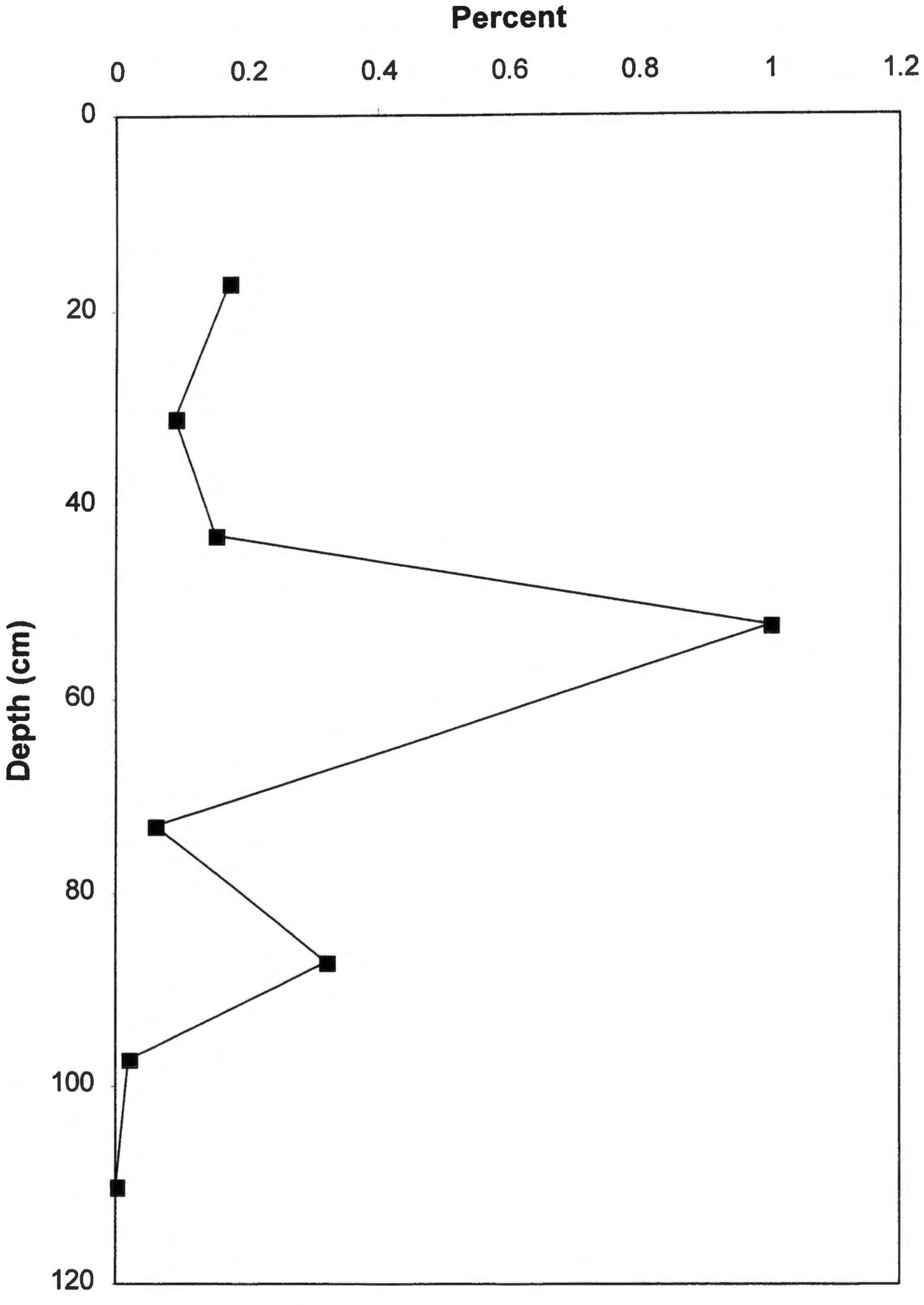

Figure 50. Organic carbon distribution for Non-Hydric Soil Profile #16.

the gleyed layers (Table 43). Calcium carbonate equivalent (CCE) was higher in the gleyed layers compared to the surface horizon in which it was the lowest (0%) (Table 43). This corresponded to the lowest pH value, which was extremely acidic at 2.8. As stated above, the low pH values in the surface horizon and in Cg3 can be attributed to pyrite oxidation which produces extremely acidic conditions. pH values increased from 2.8 in the surface horizon to 6.1 in C2, and fluctuated with depth throughout the soil profile. pH values did not necessarily correspond to CCE values in this profile, except for C1 in which the pH was low and CCE was also low. In addition, according to Table 42, no reaction to 10% HCl in C1 indicated that free carbonates were not present. Unlike the other soil profiles, reaction to 10% HCl was not consistent throughout the soil profile and fluctuated within each horizon (Table 42).

Because the surface pH was so low in this profile, sulfur fractionation, a part of acid-base accounting was performed to fractionate different parts of total sulfur. Sulfur fractionation is important because it is used to determine and measure the potential acidity. In addition, neutralization potential (CCE in units of tons of $CaCO_3$/1000 tons of material), a part of base accounting, is used in conjunction with sulfur fractionation to determine the total acid producing potential, if any (Sobek, et al., 1978). Sulfur was fractionated into sulfates and sulfides (HCl extractable), pyritic sulfur (HNO_3 extractable), and organic sulfur (Non-extractable) (Table 46). Most of the sulfur generated was in the form of organic sulfur. Pyritic sulfur consisted of a very small percentage of the total sulfur. Therefore, most of the pyrite had already been oxidized, yet organic sulfur percentages were still extremely high.

The particle size control section had the highest percentage of sand as fine sand making it sandy (Fig. 51). Mineralogy class was mixed. This soil was an Entisol. This soil had aquic conditions, such as permanent saturation with water and a reduced matrix in all horizons below 44 cm. In addition, between 40 and 50 cm below the soil surface, this soil had aquic conditions and enough ferrous iron to give a positive reaction to alpha, alpha-dipyridyl and put it in the aquent suborder. This site was classified as a sandy, mixed, mesic Typic Endoaquent.

Non-Hydric Soil Profile #20

Non-hydric soil profile #20 was located at N 35° 02'56.3" and W 84°21'02.2" east on the mine tailings pond on a floodplain position at an elevation of 566.9 m above mean sea level. The slope was at 1%. This site did not have any hydrophytic vegetation present. There were pine trees and lespedeza surrounding the site. There was not any surface water visible. Soil samples were collected and morphology was described to a depth of 100 cm. The parent material was alluvium.

In this profile, evidence of gleying began at 26 cm (Fig. 52). This profile was not hydric because gleying did not begin until 26 cm. Gleyed horizon colors (moist) ranged from 10GY 2.5/1, to10Y 4/1, and 10YR 5/1 (Table 47). Redoximorphic features such as iron concentrations and iron depletions were present in the horizons above the gleyed layers. The surface horizon and gleyed layers had no reaction to alpha, alpha-dipyridyl indicating that ferrous iron was either very low or removed (Table 48). In addition, there was a red layer approximately 1 cm thick between Cg3 and Cg4 which also had a very

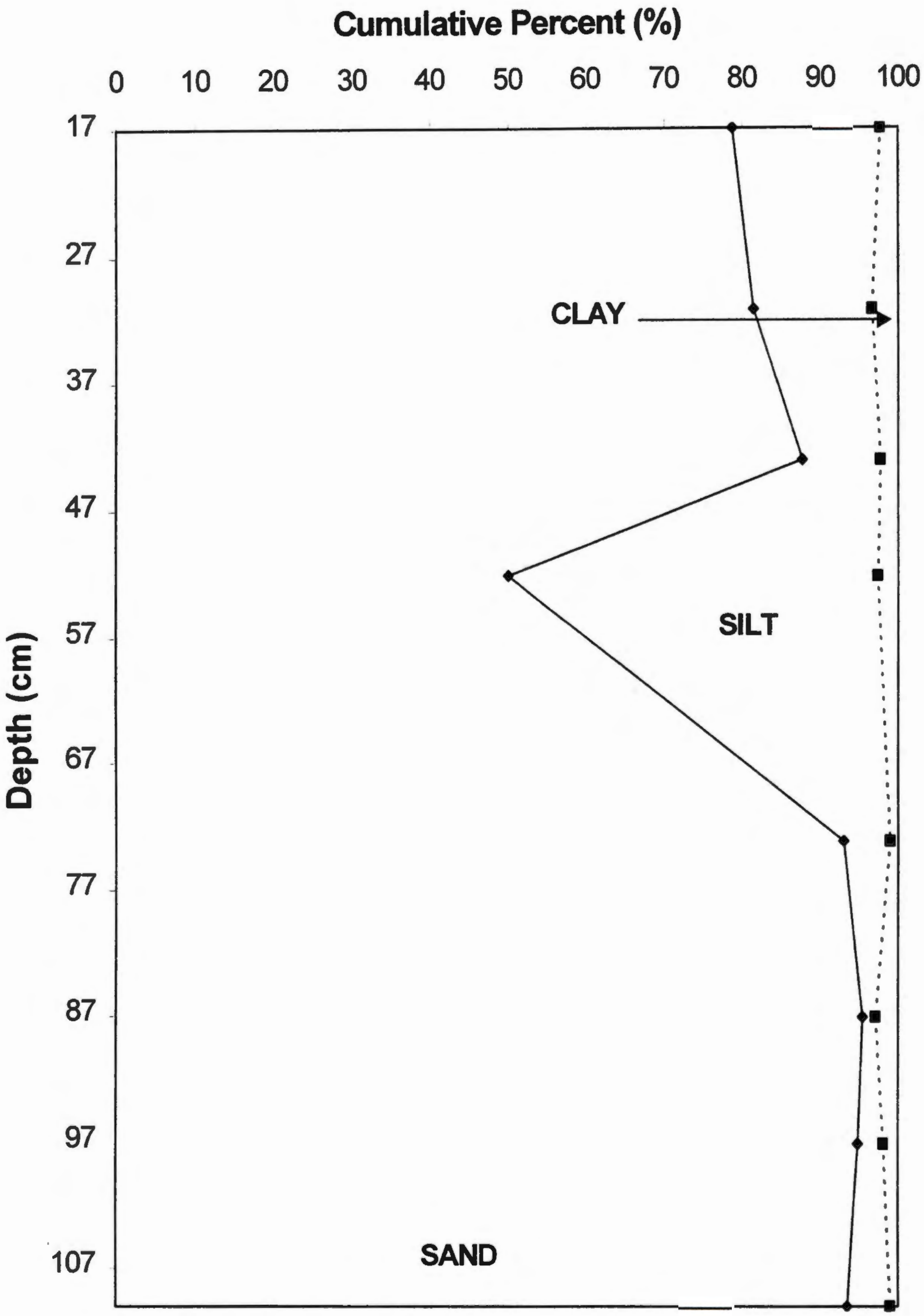

Figure 51. Particle size plot for Non-Hydric Soil Profile #16.

Figure 52. Non-Hydric Soil Profile #20.

Table 47. Morphology of Non-Hydric Soil Profile #20.*

Horizon	Lower Depth (cm)	Color Moist	Color Dry	Texture	Structure	Boundary Distinctness	Consistence Moist	Reaction 10% HCl	Redoximorphic Features
C1	13	10YR 5/6	10YR 5/8	fSL	sls sg	clear	loose	None	Fe Concentrations & Fe Depletions
C2	17	10YR 4/4	10YR 5/6	fSL	sls sg	clear	loose	None	Fe Concentrations & Fe Depletions
C3A	25	10GY 2.5/1	5GY 3/1	SiL	sls sg	abrupt	loose	None	Fe Concentrations & Fe Depletions
C3B	25	10YR 4/4	10YR 5/6	LfS	sls sg	abrupt	loose	None	Fe Concentrations & Fe Depletions
Cg1	32	10GY 2.5/1	10Y 4/1	SiL	sls sg	clear	loose	None	Gleyed Matrix
Cg2	48	10Y 4/1	10Y 5/1	LvfS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg3	79	10GY 2.5/1	10Y 5/1	Si	sls sg	clear	loose	Very Strong	Gleyed Matrix
red layer	80	7.5YR 4/4	10YR 6/3	SiL	sls sg	clear	loose	None	
Cg4	89	10YR 5/1	10Y 5/1	LvfS	sls sg	clear	loose	Very Strong	Gleyed Matrix
Cg5	100+	10GY 2.5/1	10Y 5/1	Si	sls sg	-	loose	Very Strong	Gleyed Matrix

*Abbreviations for morphology designations are given in Appendix A.

Table 48. Calcium carbonate equivalent, pH, citrate dithionite iron, hydroxylamine HCl-manganese, KCl extractable aluminum and acidity, cation exchange capacity (pH=7), sodium acetate extractable bases, percent base saturation, and reaction to alpha, alpha dipyridyl, for Non-Hydric Soil Profile #20.

Horizon	Lower Depth (cm)	$CaCO_3$ Equivalent (%)	pH (1:1 H_2O)	Free Iron (%)	Mn g kg^{-1}	Total Acidity cmol+ kg^{-1}	KCl/Al^{3+} cmol+ kg^{-1}	H^+ cmol+ kg^{-1}
C1	13	0	2.4	3.16	0.1007	8.85	4.28	4.57
C2	17	0	2.7	2.96	0.0154	2.82	0.76	2.06
C3A	25	0	3.7	5.56	0.0294	51.26	10.50	40.76
C3B	25	0	3.7	0.16	0.1012	24.11	14.24	9.87
Cg1	32	13.16	5.6	5.57	0.8232	1.00	0	1.00
Cg2	48	16.56	7.0	2.60	1.1198	0.05	0	0.05
Cg3	79	15.15	6.6	7.65	1.0304	0.05	0	0.05
red layer	80	2.86	6.9	2.40	0.2415	0.05	0	0.05
Cg4	89	13.95	6.4	1.17	0.8298	0.03	0	0.03
Cg5	100+	12.70	6.2	8.61	0.8558	0.11	0	0.11

Horizon	Lower Depth (cm)	CEC cmol+ kg^{-1}	Ca^{2+} cmol+ kg^{-1}	Mg^{2+} cmol+ kg^{-1}	Bases K^+ cmol+ kg^{-1}	Na^+ cmol+ kg^{-1}	Base Saturation (%)	alpha,alpha dipyridyl
C1	13	6.41	94.33	2.70	0.02	1.71	>100	Negative
C2	17	7.82	63.19	0.99	0.04	3.20	>100	Positive
C3A	25	6.81	107.83	2.00	0.05	1.40	>100	Positive
C3B	25	2.76	100.20	1.09	0.07	1.47	>100	Positive
Cg1	32	1.73	93.15	3.17	0.10	1.19	>100	Negative
Cg2	48	2.68	96.39	4.27	0.14	1.23	>100	Negative
Cg3	79	2.32	96.49	4.65	0.21	1.07	>100	Negative
red layer	80	7.43	38.72	3.87	0.59	0.14	>100	Positive
Cg4	89	1.34	27.01	1.20	0.06	0.15	>100	Negative
Cg5	100+	3.41	67.76	6.26	0.30	0.94	>100	Negative

strong reaction (deep red color) to alpha, alpha-dipyridyl. This red layer was most likely a deposition from the mining process and part of the stratification which is common in Entisols. C2, C3A, and C3B had positive reactions to alpha, alpha-dipyridyl indicating there was enough ferrous iron in the sample to react with the dye. The soil drainage class was somewhat poorly drained. Depth to the water table was not reached within 100 cm.

Textures ranged from fine sandy loams to silt loams, loamy fine sands, silts, and loamy very fine sands (Table 47). Total sand percentages ranged from 8.53% in Cg3 to 81.34% in Cg4. Total silt percentages increased in this soil profile. Silt percentages ranged from 15.82% in Cg4 to 85.79% in Cg3 (Table 49). Both fine sand percentages and very fine sand percentages made up the majority of the distribution of sand size fractions (Table 50). Total clay percentages were highest in this profile compared to any of the other profiles and increased in two horizons (C3A-12.02% and the red layer-24.41%). Total clay percentages ranged from 2.83% in Cg4 to 24.41% in the red layer (Table 49).

Like profiles #5, #7, and #8, there was a hard restrictive layer somewhat resembling an iron pan directly above the gleyed layers. Like profile #16, easily reducible (hydroxylamine) manganese concentrations fluctuated throughout the soil profile and did not reflect any pattern. However, manganese concentrations were lower in the horizons preceding the gleyed layers and higher in the gleyed layers indicating that anaerobic microorganisms were actively reducing Mn^{4+} to a more usable form (Table 48). The highest easily reducible manganese concentration was in Cg2. The highest total manganese concentration was in Cg1. Both hydroxylamine manganese and total

Table 49. Particle Size Distribution of Non-Hydric Soil Profile #20.

Horizon	Lower Depth (cm)	Total Sand %	Total Silt %	Total Clay %
C1	13	73.48	21.58	4.94
C2	17	57.46	32.90	9.65
C3A	25	31.03	56.95	12.02
C3B	25	76.89	19.51	3.59
Cg1	32	33.98	62.18	3.83
Cg2	48	76.46	19.29	4.25
Cg3	79	8.53	85.79	5.69
red layer	80	11.56	64.03	24.41
Cg4	89	81.34	15.82	2.83
Cg5	100+	10.92	80.39	8.69

Table 50. Distribution of Sand and Silt Particle Size Fractions for Non-Hydric Soil Profile #20.

Horizon	Lower Depth (cm)			SAND			SILT	SILT
		VCOS %	COS %	MS %	FS %	VFS %	COSi %	F Si %
C1	13	2.18	8.20	11.00	39.54	11.62	5.22	16.36
C2	17	2.10	10.80	7.23	27.68	8.39	19.01	13.88
C3A	25	9.90	7.59	2.31	4.84	5.50	9.89	47.06
C3B	25	4.86	19.75	4.75	24.19	23.03	13.13	6.38
Cg1	32	0.58	1.45	0.58	4.45	23.24	29.42	32.76
Cg2	48	0	0.40	0.60	17.08	55.51	16.55	2.74
Cg3	79	0	0.29	0.29	0.59	5.49	17.76	68.03
red layer	80	0	0.60	0.60	3.42	5.23	3.46	60.56
Cg4	89	0.30	1.30	1.50	36.09	40.87	11.00	4.82
Cg5	100+	0.20	1.21	0.51	1.72	5.86	12.37	68.02

manganese concentrations did not follow the same pattern (Fig. 53). It was likely that manganese concentrations never decreased substantially in the gleyed layers because the water table was so deep and probably did not fluctuate as often to leach manganese from the profile.

Free iron percent also fluctuated throughout the soil profile. The highest free iron percent was in the Cg3 horizon (7.65%) and Cg5 horizon (8.61%) (Table 48). These high percentages did not correspond to the cation exchange capacities which were actually lower in these horizons. The substantial increase in total iron in C1, C2, C3, Cg1, Cg3, and Cg5 could be attributed to the high Fe^{3+} concentrations. These horizons also have high total sulfur percentages (Table 51). Fe^{3+}, total sulfur, and sulfuric acid are products of pyrite oxidation. In addition, very acidic pH values corresponded to these values, especially in the C horizons (Table 48). Free iron and total iron curves followed similar patterns throughout the gleyed layers (Fig. 54). Fine sand decreased substantially in C3A, Cg1, Cg3, the red layer, and Cg5. This corresponded to a decrease in total sand percent and an increase in total silt and total clay percentages (Table 49). The decrease in fine sand corresponded to a higher free iron oxide concentration in all horizons (Fig. 54).

Cation exchange capacity (CEC) was higher in the horizons preceding the gleyed layers and also in the red layer. This profile also had the highest CEC's compared to the other profiles. This can be attributed to the higher total clay percentages (Table 49). CEC ranged from 6.41 cmol+ kg^{-1} in C1 to 7.82 cmol+ kg^{-1} in C2, and 7.43 cmol+ kg^{-1} in the red layer (Table 48). Like profile #16, the highest organic carbon content was in Cg1 (1.09%). Organic carbon percentages were 0% or negligible in horizons above the gleyed

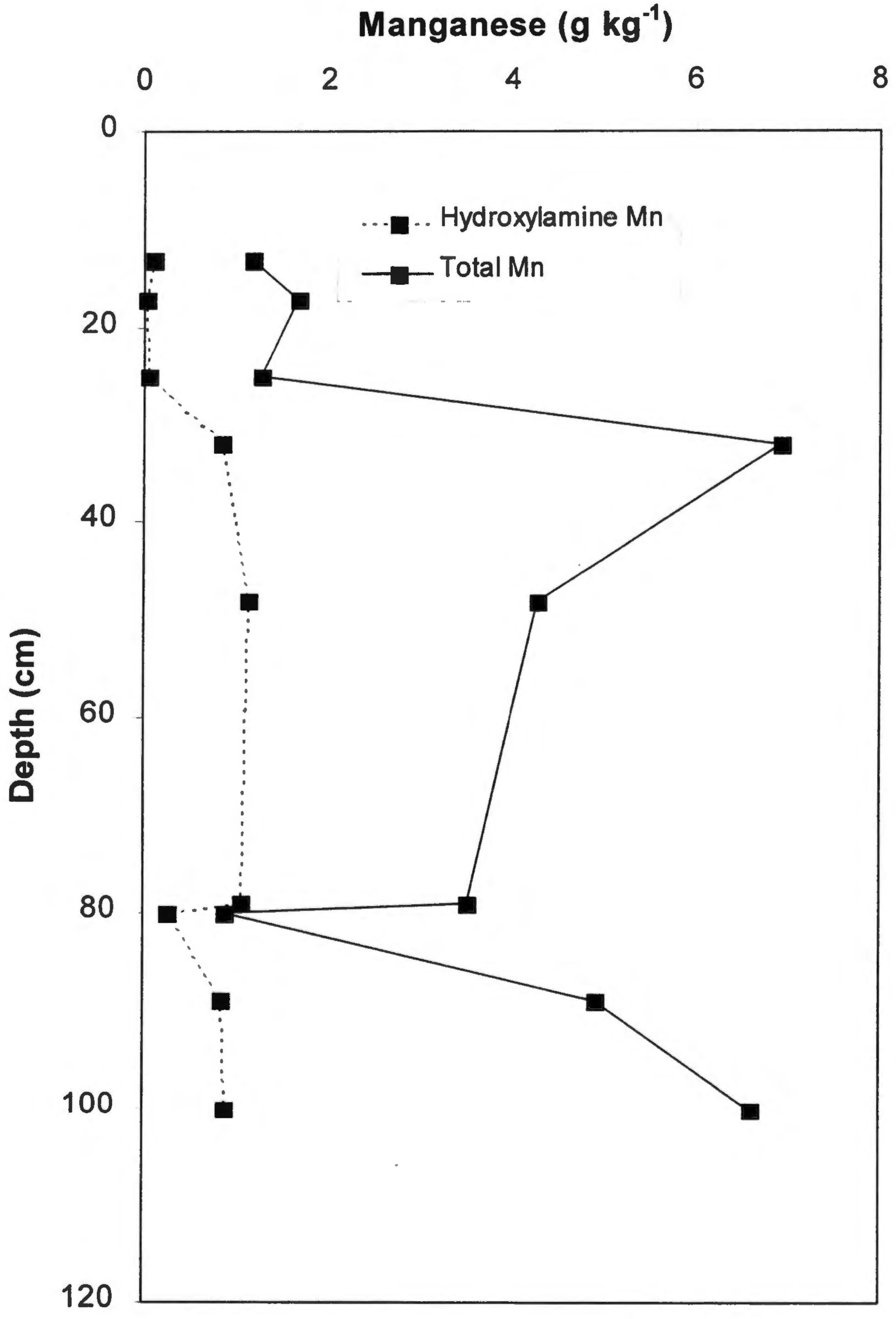

Figure 53. Total manganese and HCL-hydroxylamine manganese for Non-Hydric Soil Profile #20.

Table 51. Total carbon, nitrogen, sulfur, organic carbon, HCl extractable sulfur, HNO_3 extractable sulfur, and non-extractable sulfur percent for Non-Hydric Soil Profile #20.

Horizon	Lower Depth (cm)	Total Carbon (%)	Total Nitrogen (%)	Total Sulfur (%)	Organic Carbon (%)	HCl Extractable Sulfur (%)	HNO_3 Extractable Sulfur (%)	Non-extractable Sulfur (%)
C1	13	0.18	0.07	3.08	0	2.14	0	0.94
C2	17	0.19	0.06	3.39	0	2.29	0	1.10
C3A	25	0.16	0.05	9.35	0.05	0.32	1.48	7.55
C3B	25	0.13	0.05	2.47	0	1.68	0.24	0.55
Cg1	32	1.35	0.05	4.69	1.09	0.70	0	3.99
Cg2	48	1.70	0.05	1.63	0.13	0.32	0	1.31
Cg3	79	1.43	0.04	6.73	1	0	1.10	5.63
red layer	80	0.58	0.06	0.88	0.32	0.17	0.06	0.64
Cg4	89	1.48	0.04	1.06	0.02	0.10	0	0.96
Cg5	100+	1.07	0.04	5.43	1.00	0	0.31	5.12

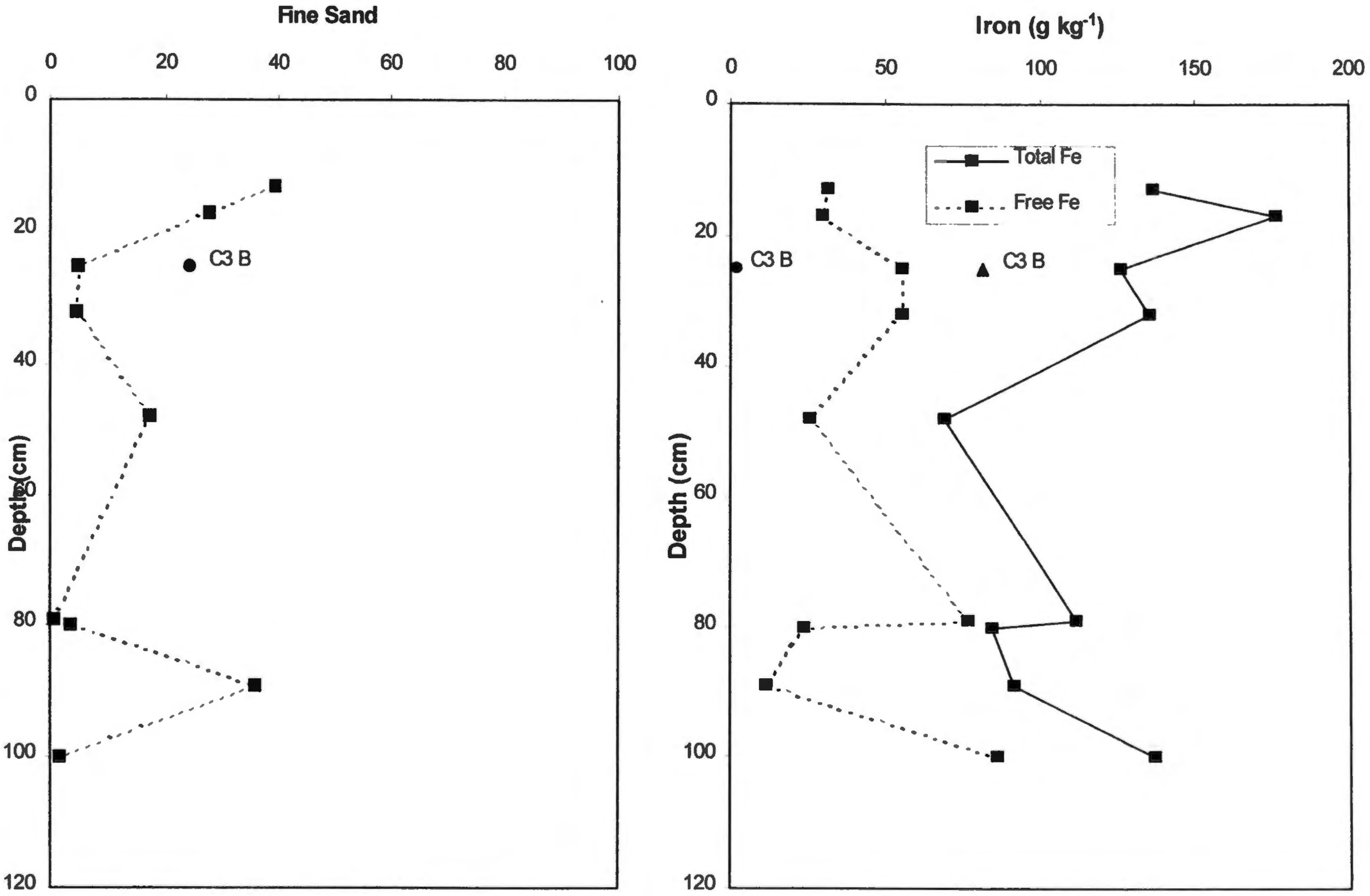

Figure 54. Fine sand, total iron, and free iron for Non-Hydric Soil Profile #20.

layers. Organic carbon percentages fluctuated throughout the gleyed layers (Fig. 55). Horizons with fine textures of silts and silt loams had higher organic carbon percentages.

As in the other profiles, high base saturation (>100%) was observed in all horizons (Table 48). This can be attributed to the high calcium concentrations in each horizon. Unlike the other profiles, calcium concentrations fluctuated in the gleyed layers and those horizons preceding the gleyed layers. The highest calcium concentrations were recorded in the C3 horizon (Table 48). Calcium carbonate equivalent (CCE) was higher in the gleyed layers compared to the horizons preceding the gleyed layers (Table 48). These corresponded to the lowest pH values, which were also extremely acidic and ranged rom 2.4 in C1 to 3.7 in C3A and C3B (Table 48). As stated above, low pH values can be attributed to pyrite oxidation which produces extremely acidic conditions. Because of the low pH values in this profile, sulfur fractionation was also performed, as in profile #16, to measure sulfates, pyritic sulfur, and organic sulfur (Table 51). Again, most of the total sulfur can be attributed to organic sulfur. pH values increased in the gleyed layers and ranged from 5.6 in Cg1 to 7.0 in Cg2. According to Table 47, no reaction to 10% HCl was noted in all horizons above the gleyed layers indicating that free carbonates were not present. There was also no reaction to10% HCl in Cg1 and the red layer while all other horizons reacted very strongly to10% HCl (Table 47).

The particle size control section had in the fraction less than 75 mm in diameter, less than 15% fine sand or coarser particles and less than 18% clay making it coarse-silty (Fig. 56). Mineralogy class was mixed. The CEC/clay ratio in the control section (25-100 cm) was active (0.46). This soil was in the non-acid reaction class because in the

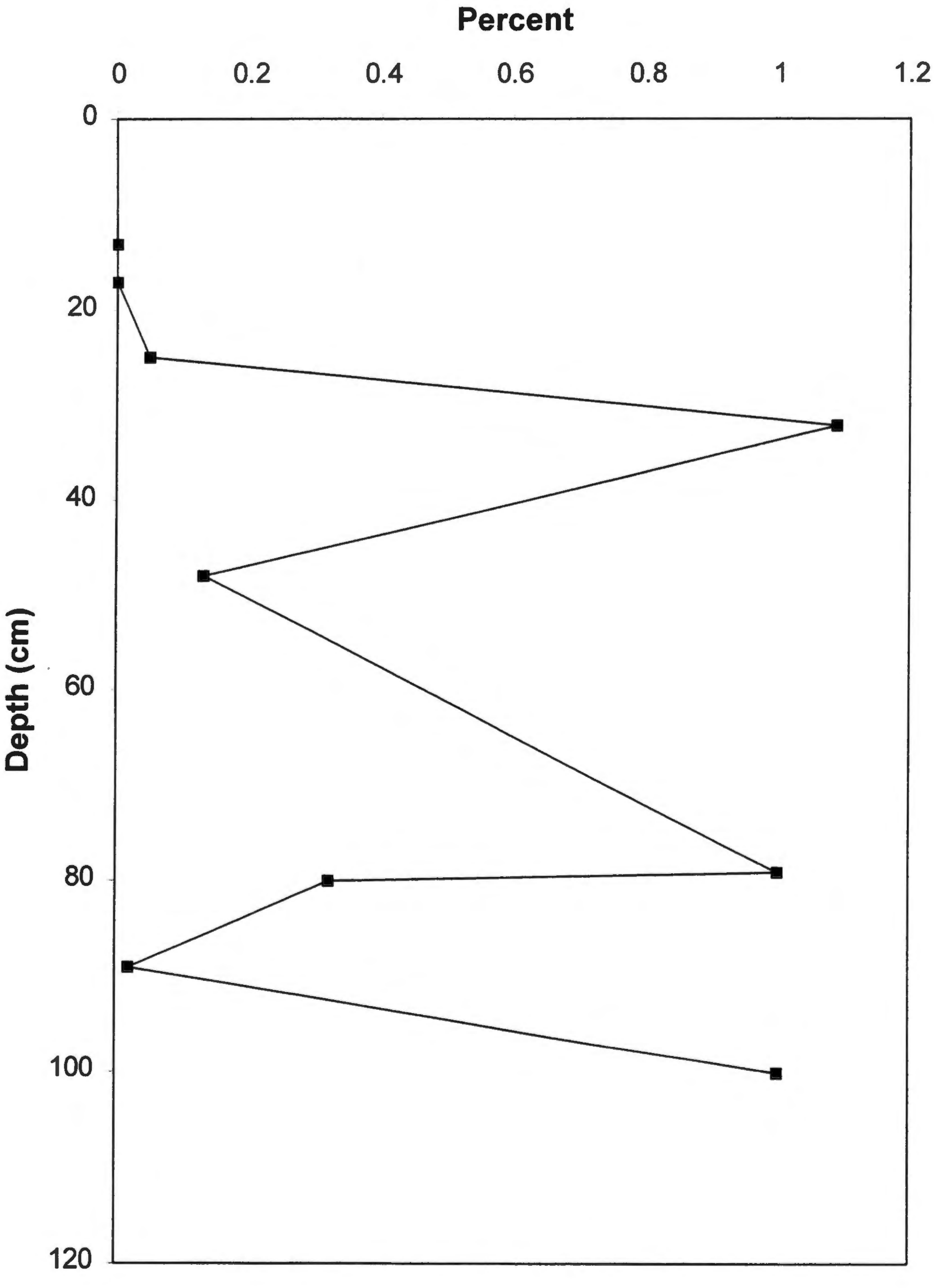

Figure 55. Organic carbon distribution for Non-Hydric Soil Profile #20.

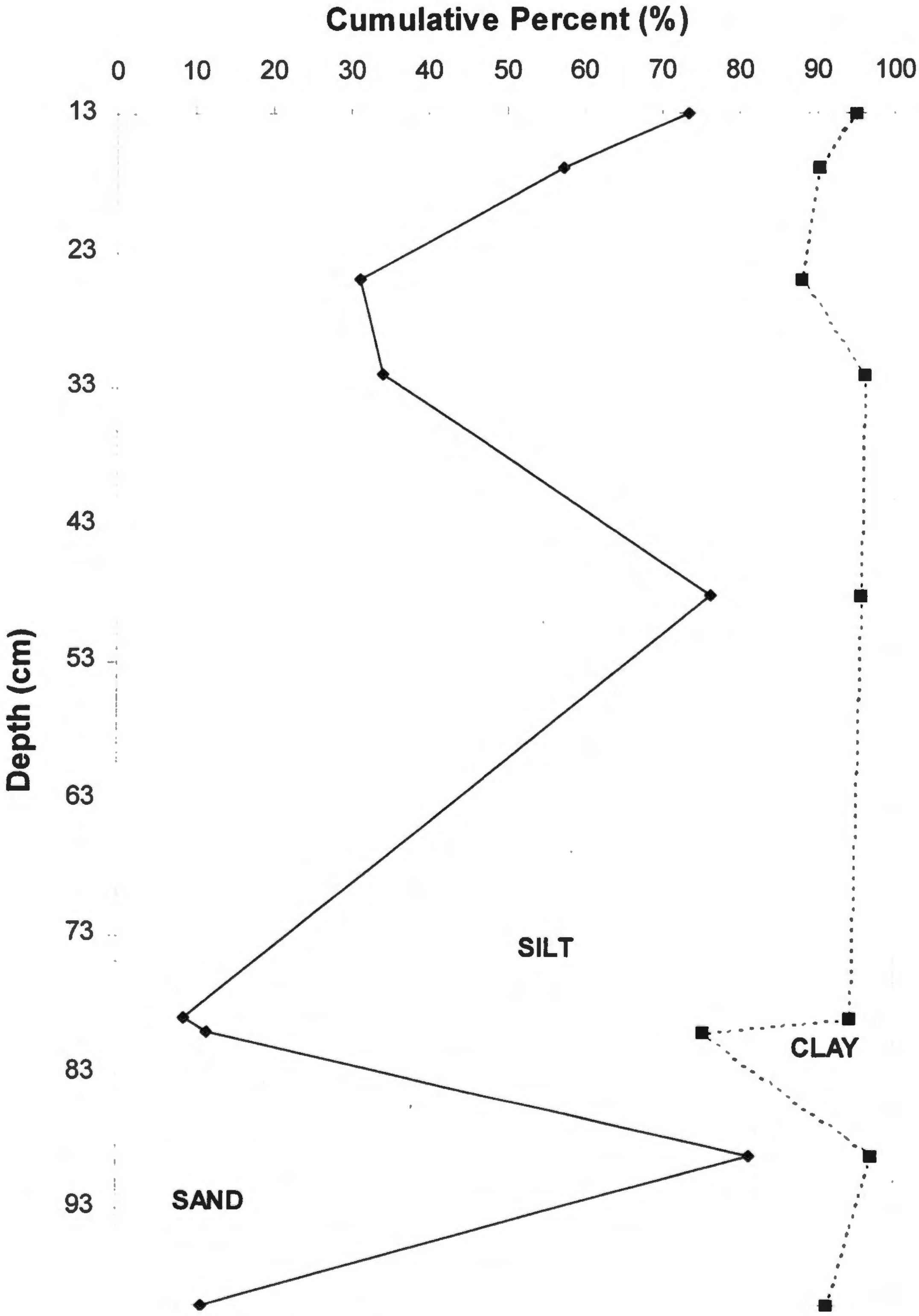

Figure 56. Particle size plot for Non-Hydric Soil Profile #20.

control section, had a pH of 5.0 or more in some or all of the layers. This soil was an Entisol. This soil had a reduced matrix in all horizons below 26 cm from the soil surface. Within 40-50 cm, a moist value of 4 and chroma of 1 was recorded which put it in the aquent suborder. This site was classified as a coarse-silty, mixed, active, non-acid, mesic Typic Epiaquent. Epiaquent was used because the soil had unsaturated layers within 200 cm of the soil surface. Cg1, Cg3, and Cg5 were very saturated layers because of the higher water holding capacities and silt textures while Cg2, Cg4, and the red layer, were dry layers with lower water holding capacities. Water was impeded because of the finer textures in Cg1, Cg3, and Cg5.

CONCLUSIONS

1. All hydric soil profiles were identified as hydric because within 25 cm below the soil surface at least 50% of the soil matrix was gleyed or had a chroma ≤2.
2. Textures ranged from fine sands to silts. Sands, loamy sands, and sandy loams were found in profiles #5, #6, #7, #8, and #16. Profiles #12, #13, #14, #15, and #20 consisted of some finer textures of silts and silt loams. Coarser grained textures were found in profiles located closer to the outlet where the tailings were released. Finer textures increased in some horizons in those profiles located farther east from the outlet where the tailings where released.
3. Total clay percentages were low in all profiles indicating little pedogenic development. Stratification was also evident in all horizons making the morphology a series of C horizons and classified in the Entisol soil order.

4. In all soil profiles, except for #20, the cation exchange capacity was low because of the sandy textures. The cation exchange capacity was highest in the surface horizon except for those horizons which had an increase in clay percentage.
5. Manganese and iron concentrations changed and corresponded to the depth to the water table. Manganese concentrations were higher in the gleyed layers in those profiles with deep water tables. In addition, they were lower in the gleyed layers in those profiles with shallower water tables. Iron concentrations were lower in the gleyed layers for those profiles with shallower water tables. Iron concentrations increased in horizons preceding the gleyed layers. For those profiles with deeper water tables, there were usually higher iron concentrations in the gleyed layers until the water table was reached and lower iron concentrations in horizons preceding the gleyed layers. In some profiles, an increase in iron concentrations in the gleyed layers also was attributed to pyrite oxidation.
6. In all hydric soil profiles except for #14 and #15, alpha, alpha-dipyridyl tests for ferrous iron were positive in horizons above gleyed layers indicating that ferrous iron was abundant and negative in gleyed layers indicating that it was low or removed. Tests varied in two of the non-hydric soil profiles (#16 and #20).
7. All profiles had high base saturations (>100%) due to the high calcium concentrations which were a result of high amounts of calcium carbonate used during the mining process.
8. Calcium concentrations were highest in horizons preceding the gleyed layers and decreased in the gleyed layers indicating that calcium was mobile and moved with

the fluctuating water table.

9. Horizons with a very strong reaction to 10% hydrochloric acid (fizz test) indicated that free carbonates were abundant. This corresponded to high calcium carbonate equivalent in those horizons.

10. pH values ranged from 6 to 7 in and corresponded to a higher calcium carbonate equivalent. pH values decreased to extremely acidic values in some of the surface horizons, especially profiles #16 and #20. The low pH values corresponded to a lower calcium carbonate equivalent and none to slight reactions to 10% hydrochloric acid. The lower pH values also corresponded to a higher total sulfur percent and higher ferric iron (Fe^{3+}) concentrations. These products, along with sulfuric acid, are products of pyrite oxidation.

11. All profiles had an irregular distribution of organic carbon. Some profiles had an increase in organic carbon percent in horizons above the gleyed layers while other profiles had higher organic carbon percentages in the gleyed layers. An increase in organic carbon percent corresponded to an increase in finer textures and an increase in water holding capacity and nutrient capacity in those horizons. Organic carbon percent was less than 5% and was not particularly high in any of the surface horizons.

12. Soil chemical, physical, and morphological characterization were successful in classifying the soils to the family level using *Keys to Soil Taxonomy*.

13. • Soil profiles #5, #6, and #7 were classified as mixed, mesic Typic Psammaquents.

- Soil profiles #8 and #16 were classified as sandy, mixed, mesic Typic Endoaquents.
- Soil profile #12 was classified as a coarse-loamy, mixed, semiactive, calcareous mesic Typic Endoaquent.
- Soil profiles #13 and #14 were classified as coarse-silty, mixed, subactive, calcareous, mesic Typic Endoaquents.
- Soil profile #15 was classified as a coarse-silty, mixed, superactive, calcareous, mesic Typic Endoaquent.
- Soil profile #20 was classified as a coarse-silty, mixed, active, non-acid, mesic Typic Epiaquent.

CHAPTER 3

WETLANDS AND SIGNIFICANCE OF HYDROLOGY, HYDROPHYTIC VEGETATION, AND HYDRIC SOIL FORMATION

INTRODUCTION

Wetland formation depends on three major factors. These are hydrology (water in the area), hydrophytic vegetation (water loving plants), and the development of hydric soils (waterlogged soils in absence of free oxygen). At least one parameter from each criteria must be present in order to positively identify a wetland (Wetland Training Institute, Inc.; 1995).

Recently, wetlands have become an increasingly hot topic especially delineating areas as wetlands, wetland trading and drainage, and controversies over wetland laws which are constantly being changed. Unfortunately, there are problems with identifying and delineating wetlands. Nevertheless, identifying and delineating wetlands are very important, especially as rural land is converted to urban land.

The objective of this chapter is to delineate the hydric soil fringe around anthropogenic wetlands on the mine tailings pond.

LITERATURE REVIEW

Wetlands

Wetlands can be defined as "those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions, (Federal Register, 1982; EPA, Federal Register, 1980; Wetland Training Institute, Inc., 1995), (Fig. 57). According to the *Field Indicators of Hydric Soils in The United States* (USDA, NRCS, 1998), soil saturation implies that the pores are completely filled with water.

Wetlands are transitional zones from land to water. Because they act as transitional zones, they provide a unique and irreplaceable natural habitat critical for the survival of aquatic species, birds, and migratory waterfowl including many endangered species (Council for Agricultural Science and Technology, 1994).

Types of Wetlands

Wetlands form depending on the type of landform they are located on, hydrology, and type of hydrophytic vegetation they support. Erosion and sedimentation are critical factors in wetland formation. As sedimentation and erosion increase and basins or depressions are filled, the potential for wetland formation decreases. Land use, size of an area, slope gradient, soil chemistry, and vegetation are all factors related to filling (Mausbach and Richardson, 1994). Table 52 lists different types of wetlands commonly found in Tennessee.

Hydrology becomes important when determining the type of wetland. Lack of water flow is characteristic of a closed drainage system such as a depression or basin, or where water flow exceeds the capacity of a system to remove water. In closed drainage systems, organic matter can accumulate and water can stagnate. These closed drainage systems are where wetlands are most likely to form. On the other hand, open drainage

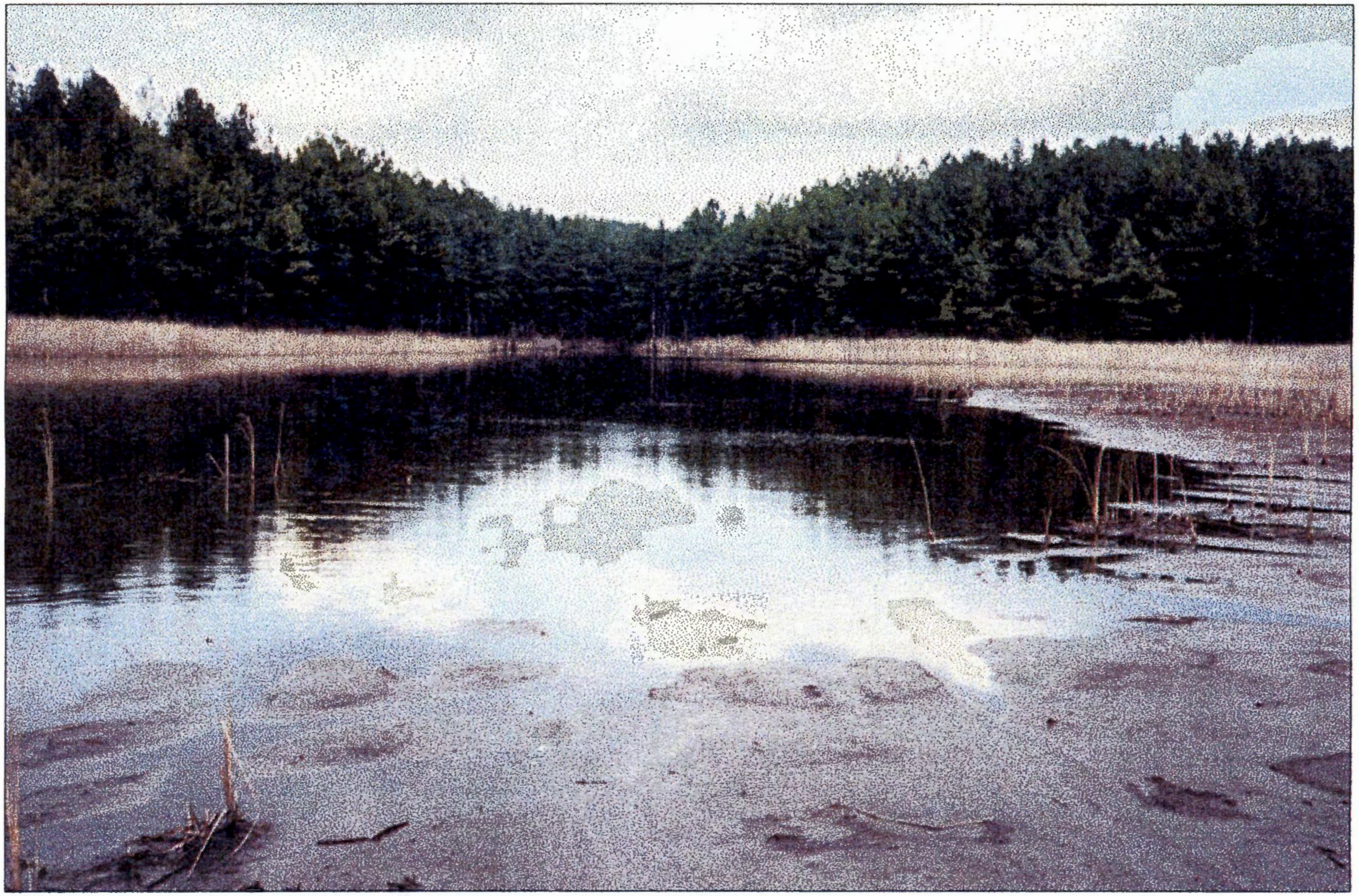

Figure 57. Wetland on mine tailings pond in Polk County, Tennessee.

Table 52. Types of Wetlands in Tennessee (Revised from Talley, 1994)

Wetland Type	Description
Deep floodplain basins	Meander scars, oxbows, deep sloughs, or small lakes in floodplains.
Floodplain depressions	Shallow oxbows or sloughs of floodplains.
Back Swamps	Concave positions on floodplains that are frequently flooded or poorly drained.
Overflow flats	Broad slightly sloped flats between back swamps and uplands or river levees.
Floodplain ridges	Highest elevation within floodplains; still subject to inundation.
Low fringes	Occur in natural lakes, reservoirs, or ponds. Long inundation duration.
Elevated fringes	Saturation exists for most of the year from the adjacent water body.
Flow-through depressions	Meandering drainageways in low gradient upland landscapes.
Closed depressions	Depressions in upland or terrace positions. No outlets are present.
Slope seeps	Located on terrace or upland slopes or footslopes. No flooding or ponding.
Terrace flats/upland flats	Temporary flooding or ponding after rainfall.

systems can be found on the hillslopes, head slopes, side slopes, and nose slopes. Here, water flows freely in and out of the system. Wetlands and hydric soils are less seldom found in open drainage systems because of the constant movement of water. The water table may also be too deep to meet the hydric soil criteria (Mausbach and Richardson, 1994).

Importance Wetlands Play in Trace and Toxic Metal Retention and Release

Wetlands act as a source, sink, or transformer for nutrients and pollutants. Specifically, wetlands can release metals to the surface from sediment, uptake metals from plants, accumulate metals from benthic and wetland animals, and accumulate pollutants from runoff and leaching losses (Gambrell, 1994). Natural and constructed wetlands have been used to effectively treat wastewater because of their ability to assimilate nutrients (Reddy and Gale, 1994).

Soils contain different amounts of metals. The type of metal present, metal concentration, chemical forms, and processes affecting transformation and mobility affect the metal content in the soil. Metals which are water-soluble are the most mobile. Exchangeable metals, which are weakly bound to soil surfaces, are also mobile. Metals precipitated by inorganic compounds and those complexed with organics can be mobile and available to plants if certain conditions persist. If the oxidation status of the soil is constantly changing, metal transformation between chemical forms affects the mobility and the availability of metals to plants. As reduced soils become oxidized and the soil pH becomes more acid, metals may be released and become more mobile. Other metals, such as those bound within clays, are usually immobile because they are so tightly bound within the crystalline lattice structure of the clays (Gambrell, 1994).

Hydric soils act as sinks and filters for metals and pollutants such as NO_3^- (Richardson, 1989; McKee and McKelvin, 1993). These soils are capable of removing pollutants and metals washed down from upland soils (Sistani et al., 1995). Metals are retained more efficiently in hydric soils as compared to upland soils (Gambrell, 1994) because of high organic matter content. Organic matter complexes and adsorbs metals (Kentula, et al., 1992; Sistani et al., 1995).

Physical properties such as soil texture and clay type are important aspects to consider in metal retention. Coarse-textured soils such as sand, have a low tolerance for retention of trace and toxic metals, therefore, contamination problems are low. Finer textured soils, such as those higher in clay, tend to accumulate toxic metals and contaminants (Gambrell, 1994).

The value of wetlands has increased, especially with increased awareness of the benefits that wetlands provide, including wildlife and fish habitat, water quality improvement, flood storage, shoreline stabilization, nutrient retention and removal, groundwater recharge and discharge, and recreation. Today, efforts to preserve, restore, enhance, and even create wetlands are increasing every day (Marburger, 1992).

Hydrophytic Vegetation

Hydrophytic vegetation is "the sum total of macrophytic plant life that occurs in areas where the frequency and duration of inundation or soil saturation produce permanently or periodically saturated soils of sufficient duration to exert a controlling influence on the plant species present" (Wetland Training Institute, Inc., 1995). These hydrophytic species have specific adaptations such as tolerance for anoxic conditions that allow them to grow in oxygen deficient soil conditions (Wetland Training Institute, Inc., 1995). Some examples of hydrophytic vegetation include cattails (*Typha latifolia L.*), rushes (*Juncus L.*), reeds (*Phragmites Adans.*), cypress (*Taxodium sp.*), and sedges (*Carex L.*).

Hydrophytic vegetation includes dominant species of plants, such as obligate wetland plants (plants that almost always (99%) occur in wetlands), facultative wetland plants (plants that usually (67-99%) occur in wetlands), and facultative plants (plants with a similar likelihood of occurring in either wetlands or nonwetlands). If more than 50% of the above plant types occur around a wetland, there is hydrophytic vegetation present (Wetland Training Institute, Inc., 1995).

There are four types of dominant aquatic plants found in the water of wetlands. These include emergent, floating leaved, submerged, and free-floating. Plant development depends on water depth, temperature differences, amount of oxygen, solubility of ions, and sediment characteristics (Marburger, 1992).

Vegetation can be the most visual criteria of the three to determine if there is a wetland present, but caution must be used. Hydrophytic plants can grow in either wetlands or non-wetlands, therefore hydric soils and hydrology must also be present to have a wetland. In addition, the presence of a single hydrophytic plant does not necessarily mean that hydrophytic vegetation is present (Wetland Training Institute, Inc., 1995).

Hydrology

The second criteria critical for wetland determination is hydrology. The landscape is "inundated either permanently or periodically at mean water depths ≤ 6.6 ft, or the soil is saturated to the surface at some time during the growing season of the prevalent vegetation" (Wetland Training Institute, Inc., 1995). Hydrology is the least exact of all three criteria because it is sometimes difficult to locate water in the field (Wetland Training Institute, Inc., 1995).

Natural wetlands store excess runoff water and control flooding from storms. In doing so, wetlands slow runoff to streams and recharge groundwater to underground aquifers. They filter excess pesticides, nutrients such as nitrogen, phosphorus, and potassium, heavy metals, and toxic chemicals. As wetlands filter excess nutrients, water quality is enhanced. Wetlands hold and help settle sediment which in turn helps the clarity of nearby streams and rivers. They act as buffers by controlling and reducing erosion especially during heavy periods of rain (Talley, 1994).

Attention to changes of landscape over short distances becomes critical when dealing with the hydrology of a potential wetland. Landscape position and direction of water flow are important. Soils become wet because of their position in landscapes (Mausbach and Richardson, 1994). Landscape positions range from summit or upland, which is the highest landscape position, shoulder, backslope, footslope, toeslope, floodplain, or stream terrace, which are the lowest landscape positions. Hillslopes with a concave position accumulate water. Convex hillslopes have a maximum runoff of water. If the landscape is flat, water accumulates in depressions. Landscape position, water movement, a restricting layer where water perches, and recharge/discharge contribute to soil wetness (Mausbach and Richardson, 1994).

Hydric Soils

The third criteria critical for wetland determination is the presence of hydric soils. Hydric soils are defined as "soils that form under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part" (Federal Register, July 13, 1994; USDA, NRCS, 1998). According to the *Field Indicators of Hydric Soils in the United States* (USDA, NRCS, 1998), anaerobic conditions indicate conditions in which molecular oxygen is virtually absent from the soil. Ponding indicates standing water in a closed depression for less than 7 days (USDA, NRCS, 1998). Hydric soils occur in the lowest and wettest part of a landform, including floodplains along rivers, depressions, and potholes. However, hydric soils can also be found on uplands and hillslopes (Mausbach and Richardson, 1994).

Hydric soils are commonly identified by the presence of one or more characteristics, including a gleyed, gray, or low chroma layer (50% with chroma ≤2), redoximorphic features such as iron or manganese concentrations and/or iron depletions, and/or a surface horizon high in organic matter (Megonigal, et al., 1993). The presence of hydrogen sulfide gas, which gives off a distinct sulfur odor, is an indicator of a hydric soil, but this only occurs in the wettest sites that are rich in sulfur (USDA, NRCS, 1998).

Boundaries marked by hydric soils estimate wetland acreage. Hydric soil identification becomes important in land management issues such as construction, future land development, habitat management, and agriculture. The fluctuating water table and flooding potential common where hydric soils are located could be problematic to builders, farmers, and engineers.

Redoximorphic Features

The most important characteristic critical in hydric soil identification is the presence of redoximorphic features. "These features are associated with wetness which results from periods of reduction or oxidation of iron and/or manganese" (Soil Survey Staff, 1998). Redoximorphic features are used to designate well drained from poorly drained soils. Water drives the development of redoximorphic features by assisting in additions, removals, transfers, and transformations of substances in the soil (Mausbach and Richardson, 1994). Whether ions are oxidized or reduced gives the soil its characteristic color. As soil saturation increases and soil drainage decreases, the soil color becomes lighter or chroma becomes lower (Soil Survey Staff, 1998).

Reduction

Reduction occurs during periods of saturation with water (Soil Survey Staff, 1998). When oxygen becomes limited, microorganisms turn to other forms of energy. This process of anaerobic respiration is referred to as oxidation-reduction where an electron is transferred from a donor to an acceptor. Under aerobic conditions, organisms respire by passing electrons to oxygen. In the absence of oxygen, or in anaerobic conditions, organisms carry on respiration by passing electrons to alternate electron acceptors. As the oxygen is depleted, other oxidants are used in order of their ease of reduction. The order is as follows: NO_3^-, Mn^{4+}, Fe^{3+}, SO_4^{2-}, and reducible C, which forms methane (CH_4). Both manganese and iron are the oxidants of interest in hydric soils (McKee and McKelvin, 1993).

Manganese is reduced from Mn^{4+} to a more usable form (Mn^{2+}. As manganese is reduced, the solubility of the metal increases. Reduction of iron occurs when ferric iron (Fe^{3+}) is reduced to ferrous iron (Fe^{2+}). Ferrous iron and reduced manganese are very mobile and move through the profile with water. Reduction of iron coincides with a change in soil pH (McKee and McKelvin, 1993). The pH of the soil is very important when determining any reduction or oxidation processes that may or may not take place (Soil Survey Staff, 1998). As oxygen becomes depleted and anaerobic conditions develop, iron is reduced, and a gray, blue, or green soil color forms indicating the absence of free iron oxides (Stucki et al., 1988). This is termed gleying (Wetland Training Institute, Inc., 1995). According to van Breemen (1987), important criteria for reduction of iron include: the presence of organic matter (as a food source for microorganisms), soil saturation so oxygen is depleted by microorganisms, and organisms that have the ability to reduce iron to the ferrous form (Stucki et al., 1988). Following iron reduction, microorganisms reduce $SO^2{}_4^-$ to S^{2-}. Hydrogen sulfide (H_2S) forms which can be toxic to plants, but at the same time can react readily with other toxic heavy metals and remove them from the soil (Connell, 1966; McKee and McKelvin, 1993). Once hydrogen sulfide forms, carbon is reduced to methane (CH_4) by the slow decomposition of the organic matter. Another term for this methane gas is swamp gas or "marsh gas" (Mausbach and Richardson, 1994). In order for methane formation to occur, organic matter must be present and other compounds must be reduced (McKee and McKelvin, 1993).

Because wetlands are waterlogged and stagnant, low oxygen conditions develop and persist. Not only do anaerobic conditions develop because of low oxygen conditions, but fermentation also begins. When oxygen levels decrease, anaerobic decomposition of organic matter occurs (McKee and McKelvin, 1993). This results in the production of organic acids such as fulvic and humic acids (Mausbach and Richardson, 1994). As organic matter content increases, peat formation increases, and methane production by anaerobic microorganisms increases (McKee and McKelvin, 1993).

Two types of redoximorphic features associated with reduction are redox depletions and a reduced matrix. According to the *Field Indicators of Hydric Soils in the United States* (USDA, NRCS, 1998), "redox depletions are bodies of low chroma (2 or less) with a value of 4 or more where iron/manganese oxides and clay have been stripped. They contrast distinctly with the matrix." Redox depletions come in two forms; as iron depletions or clay depletions. "Iron depletions have low amounts of iron and manganese oxides, but have clay content similar to the adjacent matrix" (Soil Survey Staff, 1998). Clay depletions are low in iron, manganese, and clay. "A reduced matrix occurs when the soil matrix has a low chroma (less than or equal to 2), in situ, but undergoes a change in hue or chroma after exposure to air after 30 minutes" (Soil Survey Staff, 1998). The time it takes for a reduced matrix to develop can be anywhere from decades to thousands of years, but can also be as little as days beginning with the formation of ferrous iron redoximorphic features (Stucki et al., 1988).

Oxidation

Oxidation occurs when the soil is in an unsaturated state (Soil Survey Staff, 1998). Oxidation results in the formation of redox concentrations. According to the *Field Indicators of Hydric Soils in the United States* (USDA, NRCS, 1998), "redox concentrations are bodies of accumulations of iron (transformation of Fe $^{2+}$ to Fe $^{3+}$) or manganese oxides. Redox concentrations include soft masses, pore linings, nodules, and concentrations" (Soil Survey Staff, 1998), which are often evident around root zones where oxygen accumulates. According to the *1998 Keys to Soil Taxonomy*, both nodules and concretions can be removed from the soil. Nodules do not have an internal structure, but concretions do. Masses are noncemented concentrations of iron or manganese. Accumulation of iron or manganese also occurs along pore linings as coatings (Soil Survey Staff, 1998).

Identifying Hydric Soils

Terms used to identify and describe hydric soils include: 1) Hydric soil definition, 2) Hydric soil criteria, 3) Hydric soil lists, 4) Hydric soil field indicators, and 5) Hydric soils. All hydric soils must meet the requirements of the hydric soil definition. Hydric soil criteria are used to generate hydric soil lists (Table 53). Lists are created by comparing soil properties in each of the hydric soil criteria. Soil properties are found in published soil surveys. Caution must be used because a soil can appear on the hydric soil list and may or may not be hydric. Hydric soil indicators are used in the field to identify hydric soils. At least one hydric soil indicator is needed to meet the hydric soil definition (Hurt and Carlisle, 1997).

Hydric soils are classified as either mineral or organic. Organic soils (Histosols), as in criterion I, are all hydric except for Folists. Folists are not hydric because they are

Table 53. Hydric Soil Criteria (Soil Survey Staff, 1998).

I. All Histosols except Folists, or

II. Soils in Aquic suborders, great groups, or subgroups, Albolls suborder, Aquisalids, Pachic subgroups, or Cumulic subgroups that are:

  a) Somewhat poorly drained with a water table equal to 0.0 foot (ft.) from the surface during the growing season, or
  b) Poorly drained or very poorly drained and have either:

    i) Water table equal to 0.0 feet during the growing season if textures are coarse sand, sand, or fine sand in all layers within 20 inches, or for other soils,
    ii) Water table at less than or equal to 0.5 feet from the surface during the growing season if permeability is equal to or greater than 6.0 inches/hour in all layers within 20 inches, or
    iii) Water table less than or equal to 1.0 feet from the surface during the growing season, if permeability is less than 6.0 inches/hour in any layer within 20 inches, or

III. Soils that are frequently ponded for long or very long duration during the growing season, or

IV. Soils that are frequently flooded for long or very long duration during the growing season

* Criteria I, III, and IV are hydric with or without an indicator. Criteria II must have an indicator present.

freely drained soils which are not saturated. Other hydric soils that are not organic fall in the mineral category (Wetland Training Institute, Inc., 1995).

Soil moisture regime plays a very important role in classifying hydric soils "The soil moisture regime is identified by the level of ground water in terms of seasonal presence or absence of water held at a tension of less than 1500 kPa in the moisture control section" (Soil Survey Staff, 1998). Water held at 1500 kPa or more is not available to keep most mesophytic plants alive (Soil Survey Staff, 1998). The aquic moisture regime is the most common moisture regimes found in hydric soils. It is "a reducing regime in a soil that is virtually free of dissolved oxygen because it is saturated with water" (Soil Survey Staff, 1998). The amount of time a soil must be saturated is a few days. Microorganisms, roots, and soil fauna are needed to remove dissolved oxygen so soil temperature must be above biologic zero for some time while the soil is saturated; this is 5 °C in Soil Taxonomy (Soil Survey Staff, 1998).

"Soils with aquic conditions undergo continuous or periodic saturation and reduction" (Soil Survey Staff, 1998). Aquic conditions have three criteria which are: saturation, amount of reduction, and the presence of redoximorphic features (except in Histosols or Histels). "Saturation is characterized by zero or positive pressure in the soil water and can generally be determined by observing free water in an unlined auger hole" (Soil Survey Staff, 1998). There are three types of saturation: endosaturation, episaturation, and anthric saturation. According to the *1998 Keys to Soil Taxonomy*, endosaturation indicates soil saturation in all layers from the upper boundary of saturation to a depth of 200 cm or more from the mineral soil surface. Episaturation is soil saturation with water in one or more layers within 200 cm of the mineral soil surface and also has one or more unsaturated layers with an upper boundary above a depth of 200 cm, below the saturated layer. Anthric saturation applies to flood irrigation or cultivated areas.

In criterion IIa (Table 53), somewhat poorly drained indicates that "soil is wet at a shallow depth for significant periods of time during the growing season"(Soil Survey Staff, 1993). Redoximorphic features must be present within a depth of 50 cm. In criterion IIb (Table 53), poorly drained indicates that "water is removed so slowly that the soil is wet at shallow depths periodically during the growing season or remains wet for long periods" (Soil Survey Staff, 1993). This is due to a high water table or slowly permeable layer within the soil profile. These soils have a dark thin surface and a gray matrix below the surface horizon. Also in criterion IIb, very poorly drained soils have "water that is removed from the soil so slowly that free water remains at or very near the ground surface during much of the growing season" (Soil Survey Staff, 1993). These soils have a thick dark surface and a strong gray matrix below the surface horizon (Soil Survey Staff, 1993).

Field Indicators of Hydric Soils in the United States

The current field guide used to confirm the presence or absence of hydric soils is the *Field Indicators of Hydric Soils in the United States: A Guide for Identifying and Delineating Hydric Soils, Version 4.0 (March, 1998),* (USDA, NRCS, 1998). Indicators are only used with hydric soils. They are used as an on-site method of assessment to help determine if a wetland exists (USDA, NRCS, 1998).

Field indicators are described by, 1) Alpha-numeric listing (All soils, sandy soils, or loamy and clayey soils), 2) Short name, 3) Land Resource Region (LRR) used, 4) Description of indicator, and 5) User notes to aid in identification. A section for test indicators of hydric soils is also present. These are testing series that could be added. Supporting data with descriptive morphologies are proposed with the test indicators (USDA, NRCS, 1998).

To identify hydric soils, the correct procedure is to first remove loose organic matter to expose the surface, dig a hole, describe the profile to a depth of 50 cm, and determine if there are any hydric soil indicators that match the soil description. If none of the indicators match, dig the hole greater than 50 cm up to 1 meter +. Measure the depth of the hole from muck or mineral surface (USDA, NRCS, 1998).

Field indicators are constantly changing and new criteria are sometimes added. These indicators are not meant to replace the hydric soil definition and are landform specific (USDA, NRCS, 1998). Each indicator is used in a specific LRR. LRR's are assigned a letter of the alphabet. The letters relate to the climate, geology, hydrology, and land use of a specific region. To properly use the indicators, a basic knowledge of soils, soil landscape relationships, and soil survey procedures are necessary (USDA, NRCS, 1998).

Problems with Delineation

Hydric soil delineation and wetland determination are both important issues, especially with the increase in population and with farmland conversion to other uses. Yet, with hydric soil criteria and indicators constantly changing, and new wetland laws being passed or changed, it is hard to define a hydric soil. There is no universal hydric soil delineation protocol.

Problems with identifying hydric soils occur because some areas are only saturated for short periods of time, but a hydric soil could be present. Hydric/non-hydric sequences may also be present which may make the identification of a hydric soil difficult (USDA, NRCS, 1998). Therefore, the soil morphology of the profile becomes important. It is also important to understand, that although hydric soils are characteristic of being found in low-lying landscapes, they may also occur on uplands or hillslopes. To add to the confusion, some soils could be non-hydric in there native condition but would be hydric if the native plants were removed because the water table would no longer be severely depressed by the plants (Mausbach and Richardson, 1994). Other hydric soils difficult to interpret are those soils that form in red or gray parent materials, soils with high pH, or low organic matter, Mollisols or Vertisols, relict redox features (do not represent recent conditions of saturation and anaerobiosis and have abrupt or changes from one color to another) (USDA, NRCS, 1998), or disturbed soils.

MATERIALS AND METHODS

Field Methods- Mapping and Delineating Hydric Soils

An initial site investigation of the wetlands surrounding the mine tailings pond was performed using a USGS topographic map (Isabella Quadrangle; USGS, 1978) to identify contour lines and slope and drainage patterns, and aerial photographs to identify the hydric soil fringe.

Once the location on the aerial map was identified (scale 1:1800), an on-site physical investigation of the mine tailings pond was completed by identifying dominant species and density of plants (especially hydrophytic) and surface hydrology (including drainage patterns and potential wet areas on the tailings pond). Hydric soil physical, chemical, and morphological characterization was performed on selected soil profiles, as described in Chapter 2. Soil profile positions were recorded using a Trimble Geoexplorer™ GPS unit and marked on the aerial photographs. A map of the hydric soil fringe around the wetlands was completed for future land use planning using ArcView 3.2™.

Selected points were sampled with an auger to determine how far the hydric soil fringe extended from the wetlands and to determine the point where the wetland boundaries were located. Depth to the gleyed layer, color, depth to the water table, changes in topography, and any other distinguishable characteristics were recorded at each sampling point.

RESULTS AND DISCUSSION

Seven soil profiles were designated as hydric because at least 50% of the matrix had a chroma ≤2 or were gleyed within a depth of 25 cm (10 in). Three soil profiles were non-hydric including site #6 which was located on a hydric/non-hydric fringe. Redoximorphic features were evident in all soil profiles and sampling points, especially in the horizons above the gleyed layers. These characteristic features of hydric soils indicated anoxic conditions, a fluctuating water table, and repeated soil saturation were apparent.

Using ArcView™, it was determined that hydric soils comprise approximately 15.4 ha (38 ac) of the total 86-ha (212-ac) mine tailings pond (Fig. 58). Wetlands on the mine tailings pond meet the three criteria critical for wetland identification. In addition to having hydric soils, they have the ability to support hydrophytic vegetation including cattails, rushes, and sedges. These wetlands also have the hydrology necessary to provide a unique natural habitat for migratory waterfowl, aquatic species, and other wildlife.

Hydric soils which are anthropogenic in origin are unique because they have formed naturally on man-made materials, yet they exhibit the same physical processes inherent to the development of natural hydric soils. These oxidation-reduction processes are essential in the development of the chemical and physical characteristics of hydric soils. The development of colors which form as a result of oxidation-reduction processes plays an important part in hydric soil identification and delineation. The formation of redoximorphic features, how certain elements such as iron and manganese are oxidized or reduced, anaerobic conditions, and water table fluctuations are all important in the development and the identification of hydric soils. Using the hydric soil delineation map, hydrology, and hydrophytic vegetation, these areas could be delineated as wetlands for future land use management.

CONCLUSIONS

1. Using soil chemical, physical, and morphological characterization, aerial photographs, and ArcView™, it was possible to delineate the hydric soil fringe

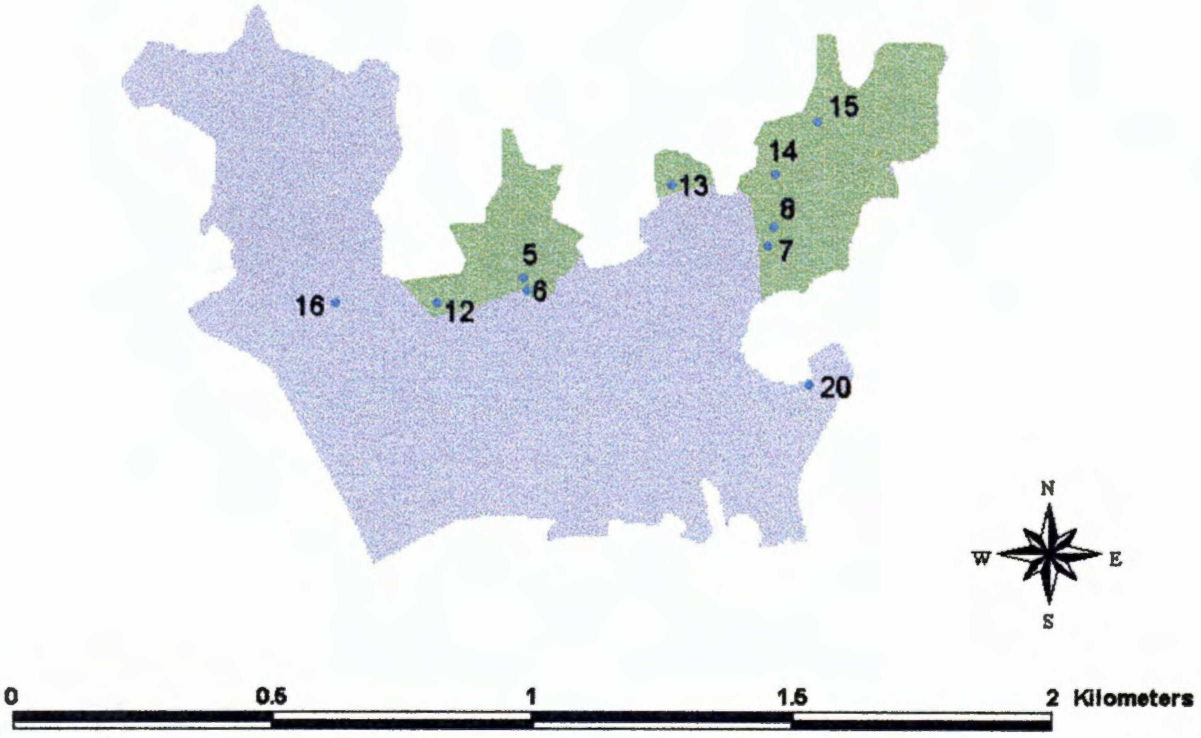

Figure 58. Map of mine tailings pond showing profiles and hydric soil fringe (in green).

around anthropogenic wetlands for future land use management.

2. Using ArcView™, it was determined that hydric soils comprise approximately 15.4 ha (38 ac) of the total 86-ha (212-ac) mine tailings pond.
3. Together using the hydric soil delineation map, hydrology, and hydrophytic vegetation, it will be possible to designate and delineate areas on the mine tailings pond as wetlands.

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Appendices

Appendix A
Definitions of Abbreviations used in Soil Morphology

Appendix A: Definition of Abbreviations used in Soil Morphology

I. Soil Texture

A. Textural class

fS = fine sand
LfS = loamy fine sand
S = sand
VfSL = very fine sandy loam
LvfS = loamy very fine sand
SiL = silt loam
L = loam
Si = silt
fSL = fine sandy loam

II. Soil Structure

sls = structureless
sg = single grain

Appendix B. Soil Profile Descriptions and Laboratory Data for Site #5.

Soil Profile Description for Hydric Soil Profile #5.

Pedon- Hydric Soil Profile #5
Area- West on mine tailings pond
Taxonomy class- mixed, mesic Typic Psammaquent
Dominant Site Vegetation- Scarce brown sedges, some cattails
Roots- Medium roots up to 16 cm
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude- N 35°02'59.4" W 84°21'25.6"
Elevation- 577.9 m
Aspect- North
Infiltration Rate- Rapid
Available Water- Very low (< 7.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Very poorly drained
Depth to Water Table- 42 cm
Slope- 1%
Erosion- None
Surface Runoff- Ponded

Morphology-

C 0-8cm; (10YR 4/6) dark yellowish brown; (10YR 4/4) dark yellowish brown-dry; (5G 4/1) dark greenish gray; (5YR 5/8) yellowish red; (5GY 5/1) greenish gray-moist; fine sand; structureless single grain; abrupt boundary; loose consistence; stratification; iron and manganese concentrations; few medium roots; pH = 6.60.

Cg1 8-20cm; (10YR 4/4) dark yellowish brown; (2.5Y 4/4) olive brown; (5GY 4/1) dark greenish gray; (N4) dark gray-dry; (5Y 4/2) olive gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron depletions; few medium and fine roots; pH=6.20.

Cg2 20-27cm; (5Y 4/3) olive; (2.5Y 4/4) olive brown-dry; (5GY 4/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; no roots present; pH=6.30.

Cg3 27-42cm; (2.5Y 4/4) olive brown; (5Y 4/3) olive-dry; (5GY 4/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron depletions; no roots present; pH=6.00.

Cg4 42-50cm; (N4) dark gray-dry; (N3) very dark gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; no roots present;

pH=6.80.

Cg5 50-55+cm; (N4) dark gray-dry; fine sand; structureless single grain; loose consistence; stratification; no roots present; pH=6.90.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #5.

		--------------------mg kg^{-1}--------------------							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	8	8.64	8.43	329.70	390.50	284.02	15352.00	185.46	11.20
Cg1	20	0.86	6.23	539.28	482.79	346.39	17190.20	135.96	10.27
Cg2	27	0.16	8.17	432.18	503.25	324.06	17341.70	129.50	9.17
Cg3	42	3.25	8.18	648.44	319.13	275.22	8835.99	99.90	7.14
Cg4	50	8.11	18.94	576.77	374.76	328.48	11090.00	316.17	17.25
Cg5	55+	2.97	13.48	433.86	514.69	312.07	16644.80	109.80	9.19

Total Elemental Analysis for Hydric Soil Profile #5.

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K	Mg
C	8	20059.7	60.7	85818.6	14.4	18.07	693.1	48568.5	4145.5	35175.7
Cg1	20	19861.8	64.2	77153.8	36.4	13.21	700.3	82667.3	4230.1	33703.2
Cg2	27	18263.4	91.9	73125	26.1	14.25	851.6	55387.1	4506.1	31777.4
Cg3	42	18619.4	74.2	71025.6	15.9	12.52	661.3	52140.3	4766.0	32752.9
Cg4	50	26196.6	129.7	60712.4	16.7	19.44	770.4	53996.9	8492.2	35923.6
Cg5	55+	21391.9	130.8	72611.7	16.7	15.45	779.4	53959.0	5719.2	35187.5

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Mn	Na	Ni	P	Pb	S	Sr	Ti	Zn
C	8	3693.8	6660.2	55.5	4.995	100.0	16382.7	245.9	820.9	1202.3
Cg1	20	3359.0	5817.8	66.8	4.995	117.3	39195.5	210.2	816.8	1118.2
Cg2	27	3802.1	5991.6	58.8	4.995	125.5	18578.5	232.7	798.1	1396.2
Cg3	42	3745.4	6033.7	48.8	38.8	101.4	17372.9	221.9	798.2	1204
Cg4	50	3489.1	6543.8	51.4	53.5	109.4	15789.0	219.0	1143.3	1338.6
Cg5	55+	3959.5	6480.8	50.7	95.9	100.3	10917.5	241.5	886.1	1605.5

*Dilution factor is 500.

Appendix C. Soil Profile Descriptions and Laboratory Data for Site #6.

Appendix C: Non-Hydric Soil Profile #6.

Pedon- Non-Hydric Soil Profile #6
Area- West on mine tailings pond
Taxonomy class- mixed, mesic Typic Psammaquent
Dominant Site Vegetation- Less scarce brown sedges
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude- N 35°02'58" W 84°21'24.8"
Elevation- 577.9 m
Aspect- North
Infiltration Rate- Rapid
Available Water- Very low (< 7.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Shallow (25-50 cm)
Soil Drainage Class- Very poorly drained
Depth to Water Table- 49 cm
Slope- 1%
Erosion- None
Surface Runoff- Ponded

Morphology-

C1 0-10cm; (10YR 4/6) dark yellowish brown-dry; (10YR 4/6) dark yellowish brown; (7.5YR 4/6) strong brown-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron and manganese concentrations; no roots present; pH = 7.10.

C2 10-17cm; (10YR 4/6) dark yellowish brown; (7.5YR 4/4) brown; (10YR 4/4) dark yellowish brown-dry; (10YR 4/4) dark yellowish brown; (2.5Y 5/4) light olive brown-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron and manganese concentrations; no roots present; pH=7.10.

C3 17-28cm; (10YR 3/3) dark brown; (2.5YR 4/4) reddish brown-dry; (5YR 3/4) dark reddish brown; (7.5YR 5/6) strong brown-moist; fine sand; structureless single grain; abrupt boundary; loose consistence; manganese concentrations; no roots present; pH=6.90.

Cg1 28-43cm; (5Y 4/3) olive-dry; (2.5YR 3/2) dusky red-moist; fine sand; structureless single grain; clear boundary; loose consistence; manganese concentrations; no roots present; pH=6.50.

Cg2 43-56cm; (5Y 4/3) olive; (5Y 4/2) olive gray-dry; (5GY 4/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.40.

Cg3 56-66+cm; (5GY 5/1) greenish gray-dry; fine sand; structureless single grain; loose consistence; no roots present; pH=6.60.

Mehlich I Double-Dilute Acid Extraction for Non-Hydric Soil Profile #6.

Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
		mg kg^{-1}							
C1	10	5.10	12.15	173.05	518.18	239.68	17157.95	66.33	13.85
C2	17	1.98	4.52	164.70	533.82	254.77	11184.29	93.94	11.47
C3	28	2.22	9.01	869.38	554.47	314.39	10560.91	86.78	8.95
Cg1	43	2.42	8.45	578.34	530.83	287.05	11015.44	88.50	8.34
Cg2	56	0.20	3.63	442.46	530.40	283.93	11020.00	67.73	8.58
Cg3	66+	2.85	6.53	473.13	547.92	324.52	10844.42	92.95	9.65

Total Elemental Analysis for Non-Hydric Soil Profile #6.

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K	Mg
C1	10	16943.0	69.8	86406.7	18.4	18.4	1020.1	55470.8	4246.1	33578.9
C2	17	16653.6	54.7	89636.4	26.1	6.5	1253.9	71273.6	3639.5	36858.3
C3	28	17789.4	66.7	79801.5	32.0	9.7	817.2	83490.6	3726.2	33577.2
Cg1	43	18398.6	75.4	79401.6	18.6	8.8	670.4	59243.2	4246.1	33198.4
Cg2	56	19908.0	77.0	77267.0	13.8	10.0	600.7	52448.0	4852.7	33976.8
Cg3	66+	21165.1	96.3	75978.2	42.6	17.0	920.3	69682.7	5632.6	35448.3

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Mn	Na	Ni	P	Pb	S	Sr	Ti	Zn
C1	10	3698.7	5392.1	52.4	69.8	118.4	28638.1	225.9	820.4	1601.3
C2	17	4053.5	5421.4	46.2	227.3	133.9	33225.9	247.5	903.8	1632.7
C3	28	3354.3	5901.7	42.5	88.1	104.4	47141.6	213.9	810.1	954.6
Cg1	43	3937.8	6462.5	55.9	49.7	102.7	222098	233.7	781.3	1254.1
Cg2	56	3894.6	7077.3	54.1	4.995	113.7	14700.0	231.8	761.7	920.2
Cg3	66+	4199.1	6628.9	81.4	143.5	128.5	22699.4	259.9	1062.0	1610.9

*Dilution factor is 500.

Appendix D. Soil Profile Descriptions and Laboratory Data for Site #7.

Appendix D: Hydric Soil Profile #7.

Pedon- Hydric Soil Profile #7
Area- East on mine tailings pond in between two vegetated areas
Taxonomy class- mixed, mesic Typic Psammaquent
Dominant Site Vegetation- Sedges, rushes, and reeds
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude- N 35°02'58.6" W 84°20'42.8"
Elevation- 577.9 m
Aspect- North
Infiltration Rate- Rapid
Available Water- Very low (< 7.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Poorly drained
Depth to Water Table- 30 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C1 0-8cm; (10YR 4/6) dark yellowish brown; (7.5YR 4/4) brown-dry; (5YR 4/4) reddish brown-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron and manganese concentrations; no roots present; pH = 6.50.

C2 8-17cm; (2.5Y 5/6) light olive brown-dry; (7.5YR 4/4) brown; (10YR 4/4) dark yellowish brown-moist; fine sand; structureless single grain; abrupt boundary; loose consistence; darker stratification; hard restrictive layer; iron and manganese concentrations; iron depletions; no roots present; pH=6.80.

Cg1 17-33cm; (2.5Y 6/4) light yellowish brown-dry; (10YR 4/2) dark grayish brown; (2.5Y 4/2) dark grayish brown-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; iron concentrations; iron depletions; no roots present; pH=6.80.

Cg2 33-43+cm; (5Y 4/4) olive; (N5) gray-dry; (5GY 4/1) dark greenish gray; (N3) very dark gray-moist; sand and loamy fine sand for dark gray layer, very fine sandy loam for blue-gray layer; structureless single grain; loose consistence; iron concentrations; iron depletions; no roots present; pH=6.80.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #7.

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C1	8	86.08	184.22	248.77	658.79	231.20	9191.81	108.18	12.48
C2	17	26.21	49.84	218.82	632.83	239.91	8054.75	120.10	10.25
Cg1	33	9.46	9.14	416.87	466.68	276.09	7850.09	127.14	8.48
Cg2A	43+	1.64	4.98	444.31	594.57	346.91	10896.31	90.39	8.86
Cg2B	43+	0.08	7.86	27.66	670.65	509.91	11158.38	266.44	14.40

Total Elemental Analysis for Hydric Soil Profile #7.

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K	Mg
C1	8	22260.8	114.8	59111.0	22.8	18.4	673.6	61907.6	6152.5	28169.7
C2	17	21236.2	117.2	62581.0	27.4	14.5	608.9	61411.6	6325.8	28644.3
Cg1	33	27548.8	175.5	63842.8	17.2	27.8	413.7	51959.8	9185.4	33616.0
Cg2A	43+	20073.1	87.5	77624.2	17.4	15.2	606.2	53482.1	5632.6	36307.9
Cg2B	43+	38543.3	316.2	53648.9	20.7	56.3	409.2	58453.0	16204.5	38733.2

		mg kg^{-1}								
Horizon	Lower Depth (cm)	Mn	Na	Ni	P	Pb	S	Sr	Ti	Zn
C1	8	2768.4	6661.0	41.3	147.6	117.5	25486.6	162.2	1090.4	1401.7
C2	17	3185.2	6055.9	53.1	147.7	110.7	26177.4	181.3	1201.0	1461.7
Cg1	33	3068.7	7484.2	46.2	182.8	105.1	17847.1	196.5	1202.5	949.8
Cg2A	43+	3920.3	6401.1	42.3	211.8	89.2	17504.3	236.9	1451.3	1221.4
Cg2B	43+	3147.2	7197.1	52.9	100.2	117.4	18065.4	183.5	1549.7	1288.2

*Dilution factor is 500.

Appendix E. Soil Profile Descriptions and Laboratory Data for Site #8.

Appendix E: Hydric Soil Profile #8.

Pedon- Hydric Soil Profile #8
Area- East on mine tailings pond
Taxonomy class- sandy, mixed, mesic Typic Endoaquent
Dominant Site Vegetation- Scarce sedges and rushes
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°03'03.2" W 84°21'06.0"
Elevation- 577.9 m
Aspect- North
Infiltration Rate- Rapid
Available Water- Very low (< 7.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Poorly drained
Depth to Water Table- 28 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C	0-10cm; (5YR 3/4) dark reddish brown; (10YR 4/6) dark yellowish brown-dry; (7.5YR 4/4) brown; (5YR 3/4) dark reddish brown; -moist; loamy fine sand; structureless single grain; abrupt boundary; loose consistence; stratification; iron concentrations; iron depletions (N4) dark gray; (N7) light gray; no roots present; pH = 5.70.
Cg1	10-15cm; (2.5Y 5/4) light olive brown; (N4) dark gray-dry; (5GY 4/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; stratification; iron depletions; no roots present; pH=6.60.
Cg2	15-33+cm; (N5) gray-dry; (N3) very dark gray-moist; loamy very fine sand; structureless single grain; loose consistence; no roots present; pH=7.00.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #8.

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	10	61.49	170.42	317.71	477.87	252.74	7095.05	203.74	12.75
Cg1	15	3.26	3.52	267.41	395.28	459.45	8081.00	130.67	10.70
Cg2	33+	9.57	11.16	541.38	441.54	555.45	8458.75	209.00	12.81

Total Elemental Analysis for Hydric Soil Profile #8.

		---mg kg^{-1}---								
Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K	Mg
C	10	24161.8	160.0	54571.2	28.1	25.7	493.7	68532.6	8145.6	26201.4
Cg1	15	23729.9	127.9	67670.2	14.1	17.6	362.3	44439.7	7019.1	33295.3
Cg2	33+	25718.4	159.1	66896.3	23.3	26.4	736.8	61367.0	8925.5	35918.1

		---mg kg^{-1}---								
Horizon	Lower Depth (cm)	Mn	Na	Ni	P	Pb	S	Sr	Ti	Zn
C	10	2334.9	6402.4	50.7	46.3	117.4	33185.7	159.0	1664.7	1187.6
Cg1	15	3204.7	7536.7	48.6	114.4	91.9	15602.2	223.2	1080.2	839.7
Cg2	33+	3282.3	7066.1	35.0	338.7	111.2	22175.7	214.3	1275.4	1394.0

*Dilution factor is 500.

Appendix F. Soil Profile Descriptions and Laboratory Data for Site #12.

Appendix F: Hydric Soil Profile #12.

Pedon- Hydric Soil Profile #12
Area- West on the mine tailings pond
Taxonomy class- coarse-loamy, mixed, semiactive, calcareous, mesic Typic Endoaquent
Dominant Site Vegetation- Sedges, rushes, reeds, and cattails
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°03'00.3" W 84°21'32.1"
Elevation- 577.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Very low (< 7.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Very poorly drained
Depth to Water Table- 67 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C 0-12cm; (10YR 4/6) dark yellowish brown; (10YR 5/4) yellowish brown-dry; (10YR 3/4) dark yellowish brown-moist; fine sand; structureless single grain; abrupt boundary; loose consistence; stratification; iron concentrations (10YR 5/6) yellowish brown and (10YR 3/4) dark yellowish brown; iron depletions (5 PB 3/1) dark bluish gray; no roots present; pH = 6.6.

Cg1 12-23cm; (10Y 5/1) greenish gray-dry; (5G 2.5/1) greenish black-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.80.

Cg2 23-32cm; (10Y 5/1) greenish gray-dry; (5G 3/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; few light iron concentrations; no roots present; pH=7.05.

Cg3 32-47cm; (10Y 5/1) greenish gray-dry; (N2.5) black-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.70.

Cg4 47-60cm; (10Y 5/1) greenish gray-dry; (5GY 3/1) dark greenish gray-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.70.

Cg5 60-70+cm; (10Y 5/1) greenish gray-dry; (5BG 2.5/1) greenish black-moist; silt loam; structureless single grain; loose consistence; no roots present; pH=6.1.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #12.

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	12	15.86	28.83	325.92	561.33	429.24	11433.20	219.67	30.60
Cg1	23	7.24	16.32	400.72	379.95	277.63	7792.72	169.06	10.32
Cg2	32	3.10	8.69	351.26	487.10	350.20	10200.80	197.82	11.84
Cg3	47	4.87	26.10	382.41	551.43	540.75	10847.40	218.79	12.61
Cg4	60	2.58	23.80	379.42	656.93	582.52	10260.96	256.92	14.94
Cg5	70+	49.88	50.10	2232.30	839.85	1732.15	8885.98	604.12	17.78

Total Elemental Analysis for Hydric Soil Profile #12.

Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
		--mg kg^{-1}--							
C	12	34909.2	162.1	77655.3	18.3	15.1	727.0	73355.7	8265.3
Cg1	23	37352.2	170.5	84619.3	22.5	18.2	1131.0	76967.6	8367.3
Cg2	32	43721.8	186.4	67882.4	17.7	13.3	345.5	54453.0	9311.7
Cg3	47	61735.5	323.7	75470.4	25.1	27.1	560.7	74866.0	15081.0
Cg4	60	50760.8	263.7	57765.0	26.0	31.2	528.8	75430.8	12651.8
Cg5	70+	62420.4	432.7	44936.7	40.5	152.5	609.7	109248.2	19534.4

Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
		--mg kg^{-1}--							
C	12	3885.5	40.9	341.2	114.9	22214.6	257.5	1490.7	2093.8
Cg1	23	4295.1	42.5	449.6	143.3	23528.0	287.4	1781.2	2382.5
Cg2	32	3532.1	38.5	242.8	106.7	12982.9	250.5	1807.6	1318.1
Cg3	47	4411.5	56.9	373.0	131.0	24653.1	282.9	2330.3	2742.3
Cg4	60	3701.3	43.1	405.3	131.2	32007.9	216.7	1909.6	2998.6
Cg5	70+	3344.5	50.1	156.4	142.7	55501.2	167.5	2360.4	2387.5

*Dilution factor is 500. .

Appendix G. Soil Profile Descriptions and Laboratory Data for Site #13.

Appendix G: Hydric Soil Profile #13.

Pedon- Hydric Soil Profile #13
Area- East on mine tailings pond. There is a small drainageway leading to the wetland
Taxonomy class- coarse-silty, mixed, subactive, calcareous, mesic Typic Endoaquent
Dominant Site Vegetation- Cattails by wetland, scarce hydrophytic vegetation, some sedges and rushes
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°03'4.8" W 84°21'13.8"
Elevation- 577.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Low (7.5 cm-15 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Very poorly drained
Depth to Water Table- 61 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C 0-10cm; (10YR 5/6) yellowish brown;(10YR 4/6) dark yellowish brown-dry; very fine sandy loam; structureless single grain; abrupt boundary; loose consistence; stratification; iron concentrations (10YR 5/8) yellowish brown; iron depletions (N6) gray; no roots present; pH = 6.70.

Cg1 10-20cm; (10Y 4/1) dark greenish gray-dry; (10Y 2.5/1) greenish black-moist; very fine sandy loam; structureless single grain; clear boundary; stratification; loose consistence; no roots present; pH=6.60.

Cg2 20-33cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; loam; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.20.

Cg3 33-51cm; (10Y 5/1) greenish gray-dry; (10Y 2.5/1) greenish black-moist; silt loam; structureless single grain; clear boundary; stratification; loose consistence; no roots present; pH=7.10.

Cg4 51-61cm; (10Y 5/1) greenish gray-dry; (N2.5) black-moist; very fine sandy loam; structureless single grain; clear boundary; loose consistence; no roots present;

pH=7.30.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #13.

		--------mg kg^{-1}--------							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	10	6.02	39.71	307.68	537.62	591.72	11276.99	250.57	13.51
Cg1	20	0.19	5.58	8.19	571.67	553.14	10423.20	182.93	9.52
Cg2	33	0.14	4.79	86.46	623.01	462.29	10641.07	133.23	16.93
Cg3	51	0.12	9.34	32.73	527.01	378.63	11089.80	240.57	9.65
Cg4	61+	0.08	221.95	12.69	565.59	474.49	11188.62	303.32	13.27

Total Elemental Analysis for Hydric Soil Profile #13.

Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
		-------------------	-------	mg kg^{-1}	-------	-------	-------	-------	-------------------
C	10	50390.3	413.8	77553.5	33.9	34.8	1172.0	91609.4	16194.3
Cg1	20	30703.6	167.4	63768.0	78.8	32.9	1551.6	162392.5	9109.3
Cg2	33	36834.5	204.0	77684.1	89.8	41.2	1721.5	193340.4	10830.0
Cg3	51	51845.5	332.0	99930.3	39.3	67.3	1174.4	115645.5	17813.8
Cg4	61+	50106.6	319.6	90392.0	36.3	61.1	667.1	106840.8	16396.8

Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
		-------------------	-------	mg kg^{-1}	-------	-------	-------	-------	-------------------
C	10	3127.8	38.2	312.8	139.5	58913.1	231.9	1661.5	2011.2
Cg1	20	3103.7	43.9	308.0	159.4	80171.9	197.2	1055.4	1978.8
Cg2	33	4320.1	62.9	337.5	202.4	94731.8	241.4	1307.3	2544.1
Cg3	51	5463.3	67.2	306.0	167.8	45438.6	308.1	1936.3	2379.6
Cg4	61+	4988.4	44.4	309.8	146.4	39793.7	289.4	3562.6	1987.3

*Dilution factor is 500.

Appendix H. Soil Profile Descriptions and Laboratory Data for Site #14.

Appendix H: Hydric Soil Profile #14.

Pedon- Hydric Soil Profile #14
Area- Left of drainageway, east on mine tailings pond
Taxonomy class- coarse-silty, mixed, subactive, calcareous, mesic Typic Endoaquent
Dominant Site Vegetation- Sedges and rushes
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°03'4.6" W 84°21'5.0"
Elevation- 577.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Low (7.5 cm-15 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Poorly drained
Depth to Water Table- 76 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C 0-10cm; (10YR 4/4) dark yellowish brown-dry; (10YR 3/6) dark yellowish brown; (10YR 4/6) dark yellowish brown-moist; very fine sandy loam; structureless single grain; abrupt boundary; loose consistence; iron concentrations (10YR 4/6) dark yellowish brown; iron depletions (N5) gray; no roots present; pH = 6.40.

Cg1 10-18cm; (10Y 5/1) greenish gray-dry; (10Y 3/1) dark greenish gray-moist; very fine sandy loam; structureless single grain; clear boundary; loose consistence; few iron concentrations; no roots present; pH=6.90.

Cg2 18-30cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; loamy very fine sand; structureless single grain; clear boundary; loose consistence; few iron concentrations and depletions; few fine roots present; pH=7.0.

Cg3 30-44cm; (10Y 2.5/1) greenish black-dry; (N2.5) black-moist; very fine sandy loam; structureless single grain; clear boundary; loose consistence; very few iron concentrations; no roots present; pH=6.70.

Cg4 44-56cm; (10Y 5/1) greenish gray-dry; (10Y 2.5/1) greenish black-moist; loam; structureless single grain; clear boundary; loose consistence; very few iron concentrations; no roots present; pH=6.80.

Cg5 56-76+cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; very fine sandy loam; structureless single grain; loose consistence; few iron depletions; no roots present; pH=6.90.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #14.

		--mg kg^{-1}--							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	10	50.37	8.41	1676.64	887.37	1564.49	8160.80	359.92	44.09
Cg1	18	0.17	9.00	3.87	681.52	781.19	10886.23	345.48	28.72
Cg2	30	0.11	9.50	18.26	525.02	402.43	11116.04	163.25	11.06
Cg3	44	0.15	7.64	2.57	661.10	588.50	11672.46	230.21	10.96
Cg4	56	0.10	12.43	5.21	605.66	552.30	11322.10	289.96	21.63
Cg5	76+	0.11	13.56	3.57	565.85	595.35	11867.00	427.64	23.06

Total Elemental Analysis for Hydric Soil Profile #14.

Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
		mg kg^{-1}							
C	10	44793.0	326.3	57890.9	70.0	85.7	1110.0	155122.1	18218.6
Cg1	18	49041.6	372.9	67773.0	48.5	87.3	1229.6	117681.5	19230.8
Cg2	30	52786.2	353.0	74827.6	53.2	36.4	1742.7	126110.2	18319.8
Cg3	44	40206.3	260.1	76574.2	73.8	73.0	1345.6	172149.7	15182.2
Cg4	56	42885.5	255.6	88835.2	45.8	65.9	937.2	129810.4	14777.3
Cg5	76+	41049.2	230.9	81628.8	37.2	58.3	1137.1	105679.2	13866.4

Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
		mg kg^{-1}							
C	10	3016.3	60.2	161.6	203.1	114696.0	173.9	1696.9	3105.7
Cg1	18	3624.0	42.0	195.3	192.2	63793.2	216.4	1858.6	2578.3
Cg2	30	3806.3	50.9	471.4	196.3	46999.6	246.7	2040.0	2259.8
Cg3	44	4234.3	53.1	263.4	207.2	97243.8	227.0	2500.4	2877.1
Cg4	56	4663.2	68.3	276.0	173.3	61167.0	261.1	1681.3	2672.4
Cg5	76+	4461.2	41.5	290.3	185.0	51611.5	246.7	2380.4	2145.9

*Dilution factor is 500.

Appendix I. Soil Profile Descriptions and Laboratory Data for Site #15.

Appendix I: Hydric Soil Profile #15.

Pedon- Hydric Soil Profile #15
Area- East on mine tailings pond
Taxonomy class- coarse-silty, mixed, superactive, calcareous, mesic Typic Endoaquent
Dominant Site Vegetation- Sedges and rushes
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°03'9.7" W 84°2'2.6"
Elevation- 577.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Low (7.5 cm- 15 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Poorly drained
Depth to Water Table- 82 cm
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C 0-8cm; (10YR 6/3) pale brown; (10YR 5/6) yellowish brown-dry; (10YR 3/4) dark yellowish brown; (10YR 5/6) yellowish brown-moist; very fine sandy loam; structureless single grain; abrupt boundary; loose consistence; iron concentrations (7.5YR 4/6) strong brown; iron depletions (N3) very dark gray; no roots present; pH = 5.80.

Cg1 8-24cm; (10Y 4/1) dark greenish gray-dry; (5GY 3/1) dark greenish gray; (5GY 2.5/1) greenish black-moist; silt loam; structureless single grain; clear boundary; loose consistence; iron concentrations (10YR 4/4) dark yellowish brown; iron depletions; no roots present; pH=6.60.

Cg2 24-41cm; (10Y 4/1) dark greenish gray-dry; (5GY 2.5/1) greenish black-moist; silt loam; structureless single grain; clear boundary; loose consistence; very few iron concentrations; no roots present; pH=6.50.

Cg3 41-57cm; (10Y 5/1) greenish gray-dry; (10GY 2.5/1) greenish black-moist; silt loam; structureless single grain; clear boundary; loose consistence; no roots present; pH=7.0.

Cg4 57-67+cm; (10Y 4/1) dark greenish gray-dry; (5PB 2.5/1) bluish black-moist; silt;

structureless single grain; loose consistence; few iron concentrations; no roots present; pH=7.0.

Mehlich I Double-Dilute Acid Extraction for Hydric Soil Profile #15.

		------------------mg kg^{-1}------------------							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C	8	167.86	780.00	1861.88	397.99	2761.47	6432.74	323.45	48.13
Cg1	24	0.49	10.82	4.03	778.58	1092.82	11372.60	265.54	17.77
Cg2	41	0.17	14.11	4.11	882.30	1168.63	10491.55	282.76	16.09
Cg3	57	0.12	17.17	2.59	572.42	526.67	11505.57	289.87	13.06
Cg4	67+	0.16	22.09	1.26	708.84	1004.95	10786.80	368.94	16.08

Total Elemental Analysis for Hydric Soil Profile #15.

-------------------------------mg kg^{-1}-------------------------------

Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
C	8	49713.9	441.8	45884.2	60.1	79.0	1224.9	123155.0	22773.3
Cg1	24	37490.3	345.0	74786.9	83.5	116.3	2942.9	193733.4	13664.0
Cg2	41	35710.4	244.5	61385.8	97.5	134.7	2552.9	218815.9	14878.5
Cg3	57	52779.0	364.9	83517.6	36.8	78.5	1032.7	109977.6	19129.6
Cg4	67+	40504.7	268.7	79223.0	61.4	131.3	1875.8	163571.3	16801.6

-------------------------------mg kg^{-1}-------------------------------

Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
C	8	2299.7	44.7	175.9	183.6	68316.2	170.8	2112.5	2412.4
Cg1	24	3859.6	56.6	360.4	314.5	146224.0	211.6	1454.3	3834.5
Cg2	41	3731.2	60.4	5.0	343.9	150413.9	173.9	4176.4	3675.2
Cg3	57	4492.4	50.1	221.3	170.7	47757.3	257.0	2653.4	2361.2
Cg4	67+	4515.4	39.0	148.1	282.6	99644.5	220.1	2997.9	4155.7

*Dilution factor is 500.

Appendix J. Soil Profile Descriptions and Laboratory Data for Site #16.

Appendix J: Non-Hydric Soil Profile #16.

Pedon- Non-Hydric Soil Profile #16
Area- West on mine tailings pond
Taxonomy class- sandy, mixed, mesic Typic Endoaquent
Dominant Site Vegetation- Scarce locust trees, no hydrophytic vegetation
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°02'59.6" W 84°21'40.6"
Elevation- 577.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Low (7.5 cm-15 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow (< 25 cm)
Soil Drainage Class- Somewhat poorly drained
Depth to Water Table- Not reached, saturated layer at Cg1, also very saturated layers at Cg4 and Cg5
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C1 0-17cm; (10YR 4/6) dark yellowish brown-dry; (7.5YR 4/6) strong brown; (7.5YR 3/4) dark brown-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; iron concentrations (5YR 4/6) yellowish red; few iron depletions (5PB 2.5/1) bluish black; few fine roots present; pH = 2.80.

C2 17-31cm; (10YR 4/6) dark yellowish brown-dry; (7.5YR 3/4) dark brown-moist; loamy fine sand; structureless single grain; clear boundary; loose consistence; stratification; few fine roots present; pH=6.10.

C3 31-43cm; (10YR 4/4) dark yellowish brown-dry; (10YR 3/4) dark yellowish brown-moist; fine sand; structureless single grain; abrupt boundary; loose consistence; no roots present; pH=6.80.

Cg1 43-52cm; (10Y 5/1) greenish gray-dry; (10Y 2.5/1)-moist; very fine sandy loam; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.50.

Cg2 52-73cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.20.

Cg3 73-87cm; (10Y 5/1) greenish gray-dry; (5GY 3/1) dark greenish gray-moist; fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=5.80.

Cg4 87-97cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.20.

Cg5 97-110+cm; (10Y 5/1) greenish gray-dry; (5GY 2.5/1) greenish black-moist; fine sand; structureless single grain; loose consistence; no roots present; pH=6.40.

Mehlich I Double-Dilute Acid Extraction for Non-Hydric Soil Profile #16.

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C1	17	65.56	18.33	391.34	16.32	66.93	5568.08	55.77	6.49
C2	31	800.26	493.63	267.13	781.83	311.03	8539.73	157.11	8.04
C3	43	61.70	183.38	275.60	746.18	412.87	8849.09	271.05	7.61
Cg1	52	27.75	55.46	1187.83	890.36	558.88	9207.39	447.38	7.67
Cg2	73	5.99	17.06	691.83	600.39	381.23	9738.13	172.25	8.23
Cg3	87	9.83	25.31	759.01	564.87	353.83	7914.34	96.77	4.05
Cg4	97	6.08	16.44	539.46	645.07	340.15	9583.91	96.61	4.20
Cg5	110+	5.70	19.38	507.88	660.33	349.86	9009.68	123.67	6.04

Total Elemental Analysis for Non-Hydric Soil Profile #16.

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
C1	17	33730.3	295.7	35754.1	36.4	16.6	1675.4	157783.9	7692.3
C2	31	39499.3	283.5	93681.3	52.7	22.8	2467.9	88162.0	9311.7
C3	43	30629.8	110.5	85465.8	39.6	15.4	999.0	103632.6	6174.1
Cg1	52	45273.5	254.2	66627.4	30.5	51.8	836.6	95071.0	15384.6
Cg2	73	37023.9	150.2	63834.7	22.3	9.1	1038.0	67440.6	8198.4
Cg3	87	15163.4	78.1	47983.3	102.7	5.0	3371.4	250000.0	3340.1
Cg4	97	30414.6	164.2	73314.3	42.7	5.0	2255.7	122638.6	7489.9
Cg5	110+	32342.7	198.0	96363.7	30.1	5.0	1598.6	91556.9	8502.0

		mg kg^{-1}							
Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
C1	17	2084.2	48.5	399.9	248.9	31027.9	123.4	2711.5	1357.1
C2	31	4824.5	54.7	203.1	155.1	66664.1	216.0	4697.5	3060.1
C3	43	4886.2	54.7	215.6	129.5	57048.6	220.8	1381.9	2443.4
Cg1	52	4640.9	56.4	272.1	167.6	49704.2	215.2	2193.5	2426.5
Cg2	73	3543.0	38.5	168.0	123.8	26838.4	222.3	1633.9	2020.0
Cg3	87	3882.2	61.5	246.7	301.4	94533.4	144.7	2232.5	9321.7
Cg4	97	5690.3	52.3	327.7	174.3	47057.6	247.5	2633.3	4546.3
Cg5	110+	7562.5	72.6	447.4	183.9	36514.7	321.4	2089.2	3553.4

*Dilution factor is 500.

Appendix K. Soil Profile Descriptions and Laboratory Data for Site #20.

Appendix K: Non-Hydric Soil Profile #20.

Pedon- Non-Hydric Soil Profile #20
Area- East on mine tailings pond, no wetlands around
Taxonomy class- coarse-silty, mixed, active, non-acid, mesic Typic Epiaquent
Dominant Site Vegetation- Pine trees and lespedeza, no hydrophytic vegetation
Roots- None
Physiography- Floodplain
Parent Material- Alluvium
Latitude/Longitude-N 35°02'56.3" W 84°21'02.2"
Elevation- 566.9 m
Aspect- South
Infiltration Rate- Rapid
Available Water- Moderate (15 cm-22.5 cm)
Hydraulic Conductivity- Slow
Soil Wetness Class- Very shallow
Soil Drainage Class- Somewhat poorly drained
Depth to Water Table- Not reached
Slope- 1%
Erosion- None
Surface Runoff- Very slow

Morphology-

C1 0-13cm; (10YR 5/8) yellowish brown; (10BG 8/1) light greenish gray layer-dry; (10YR 5/6) yellowish brown;(10YR 6/1) gray layer-moist; fine sandy loam; structureless single grain; clear boundary; loose consistence; iron concentrations; iron depletions; no roots present; pH = 2.40.

C2 13-17cm; (10YR 5/6) yellowish brown; (10B 8/1) light bluish gray bands-dry; (10YR 4/4) dark yellowish brown; (10YR 7/1) light gray bands-moist; fine sandy loam; structureless single grain; clear boundary; loose consistence; iron concentrations; iron depletions; no roots present; pH=2.70.

C3A 17-25cm; (5GY 3/1) dark greenish gray-dry; (10GY 2.5/1) greenish black-moist; silt loam; structureless single grain; abrupt boundary; loose consistence; iron concentrations; iron depletions; no roots present; pH=3.70.

C3B 17-25cm; (10YR 5/6) yellowish brown-dry; (10YR 4/4) dark yellowish brown-moist; loamy fine sand; structureless single grain; abrupt boundary; loose consistence; iron concentrations; iron depletions; no roots present; pH=3.70.

Cg1 25-32cm; (10Y 4/1) dark greenish gray-dry; (10GY 2.5/1) greenish black-moist; silt loam; structureless single grain; clear boundary; loose consistence; no roots present; pH=5.60.

Cg2 32-48cm; (10Y 5/1) greenish gray-dry; (10Y 4/1) dark greenish gray-moist; loamy very fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=7.00.

Cg3 48-79cm; (10Y 5/1) greenish gray-dry; (10GY 2.5/1) greenish black-moist; silt; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.60.

Red layer 79-80cm; (10YR 6/3) pale brown-dry; (7.5YR 4/4) brown-moist; silt loam; pH=6.90.

Cg4 80-89cm; (10Y 5/1) greenish gray-dry; (10YR 5/1) gray-moist; loamy very fine sand; structureless single grain; clear boundary; loose consistence; no roots present; pH=6.40.

Cg5 89-100+cm; (10Y 5/1) greenish gray-dry; (10GY 2.5/1) greenish black-moist; silt; structureless single grain; loose consistence; no roots present; pH=6.20.

Mehlich I Double-Dilute Acid Extraction for Non-Hydric Soil Profile #20.

		----------mg kg^{-1}----------							
Horizon	Lower Depth (cm)	Cu	Zn	Fe	Mn	Mg	Ca	K	Na
C1	13	68.15	74.13	984.48	46.96	316.47	6448.85	5.95	4.51
C2	17	20.88	29.11	363.72	14.88	163.35	4374.31	14.92	7.39
C3A	25	1424.94	5613.46	5363.17	36.37	210.45	3974.48	100.50	9.75
C3B	25	1198.00	459.24	3676.04	102.68	157.46	2972.77	92.75	6.69
Cg1	32	50.65	1623.62	2310.42	949.66	855.16	9447.24	318.32	11.13
Cg2	48	0.31	32.90	189.59	546.14	382.55	11213.23	128.86	5.62
Cg3	79	0.23	21.70	8.99	758.06	957.69	10995.32	316.74	10.70
red layer	80	54.91	129.63	1383.16	267.35	777.08	6664.39	276.31	12.07
Cg4	89	3.14	32.89	329.64	556.79	435.59	10884.66	151.09	8.89
Cg5	100+	68.27	165.60	1103.66	750.71	1417.85	9629.41	622.97	15.83

Total Elemental Analysis for Non-Hydric Soil Profile #20.

Horizon	Lower Depth (cm)	Al	Ba	Ca	Co	Cr	Cu	Fe	K
		mg kg^{-1}							
C1	13	39214.1	331.7	50288.6	26.3	40.0	385.4	137074.4	17004.1
C2	17	43039.4	353.3	60314.8	30.1	48.4	403.1	176148.2	15988.4
C3A	25	64429.3	386.3	48735.5	219.2	170.4	10559.4	126266.6	17441.9
C3B	25	87392.7	640.0	28833.4	37.7	44.0	3537.3	81504.3	23643.4
Cg1	32	58421.4	482.5	72263.6	47.3	117.0	842.9	135772.0	22189.9
Cg2	48	54535.0	381.9	77139.3	22.9	35.8	386.7	69248.3	18217.1
Cg3	79	37640.8	293.8	54070.9	31.5	136.3	690.0	111645.2	13856.6
red layer	80	128682.2	334.9	11364.0	33.3	47.2	341.7	84280.8	11240.3
Cg4	89	57577.6	223.8	85621.8	26.9	30.3	633.7	91193.9	12328.8
Cg5	100+	65408.0	353.8	90221.0	41.1	86.0	1160.7	137687.3	19406.4

Horizon	Lower Depth (cm)	Mn	Ni	P	Pb	S	Sr	Ti	Zn
		mg kg^{-1}							
C1	13	1154.7	52.8	129.8	214.3	71228.7	149.6	1909.3	1039.0
C2	17	1653.5	51.2	233.3	223.8	61700.0	175.1	3520.3	1254.5
C3A	25	1245.3	82.2	976.2	2188.0	123654.9	123.9	1883.2	12839.8
C3B	25	1586.8	49.6	340.5	321.1	38810.9	126.6	3245.2	1492.7
Cg1	32	6926.1	76.5	5.0	186.4	7166.3	212.1	2439.0	6855.2
Cg2	48	4261.7	46.3	84.1	120.5	17336.5	261.4	2359.1	1285.0
Cg3	79	3493.1	46.6	124.8	150.7	72884.8	149.5	1808.2	2453.8
red layer	80	856.2	65.8	307.1	155.6	13097.3	72.8	7224.6	654.6
Cg4	89	4905.7	107.1	861.6	202.2	19506.7	288.4	3126.8	1796.4
Cg5	100+	6601.3	113.4	361.7	243.2	52675.0	294.2	2921.2	3385.8

*Dilution factor is 500.

Appendix L. GPR and EM-31 data for selected points.

Depth to gleyed layer and color for each site on Transect A.

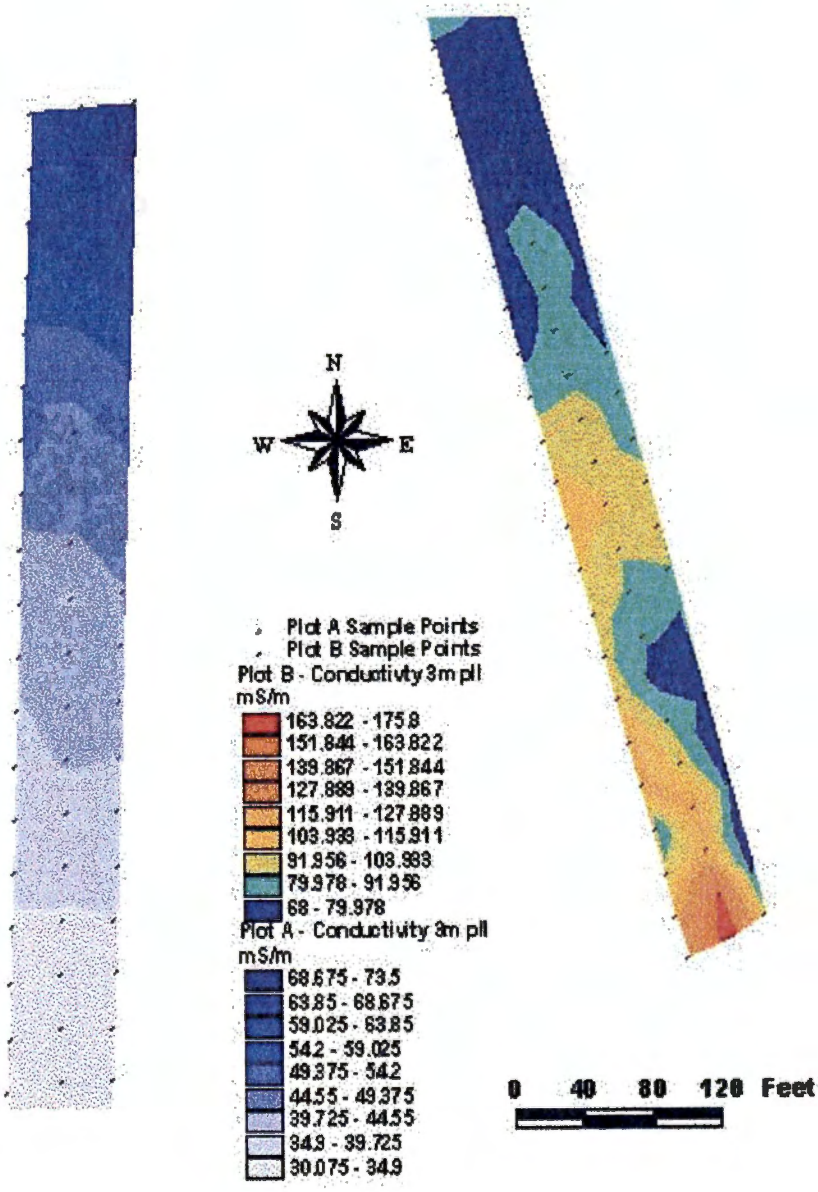
Site Number	Depth to gleyed layer (cm)	Color
1	8	10Y 3/1
2	19	10YR 3/2
3	29	10YR 3/2
4	55	10B 2.5/1
5	65	5G 2.5/1
6	71	5GY 2.5/1
7	88	10GY 2.5/1
8	84	10G 3/1
9	84	5BG 2.5/1
10	115	10YR 4/2
11	142	10B 3/1

*600 foot (182.4 m) transect. Cores taken at 60 feet (18.24 m) apart.

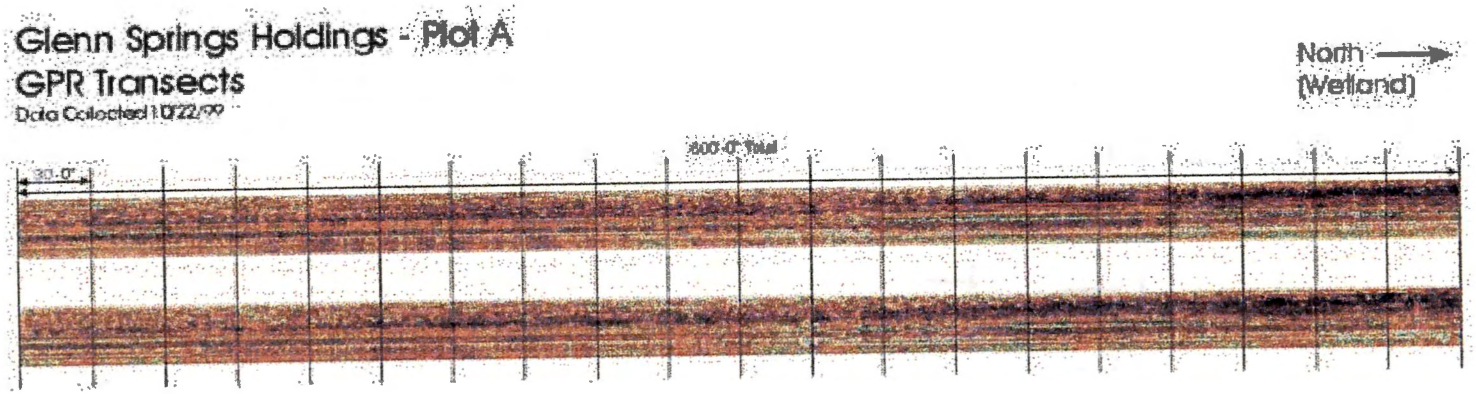
Depth to gleyed layer and color for each site on Transect B.

Site Number	Depth to gleyed layer (cm)	Color
1	33	10Y 2.5/1
2	14	2.5Y 3/2
3	40	5PB 2.5/1
4	53	5PB 4/1
5	52	5PB 4/1
6	78	5PB 2.5/1
7	84	5GY 3/1
8	82	5PB 4/1
9	95	5PB 4/1
10	102	N 2.5
11	110	5PB 2.5/1
12	105	5PB 4/1

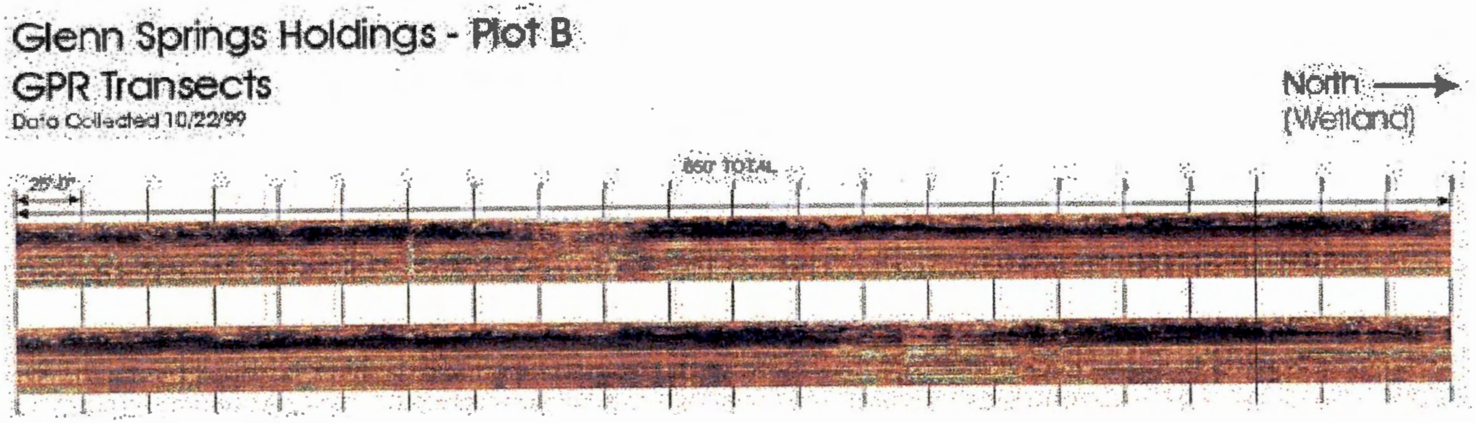
*550 foot (167.2 m) transect. Cores taken at 50 feet (15.2 m) apart.



EM-31 data for transects A and B.



GPR scan of transect A.



GPR scan of transect B.

VITA

Vanessa Catherine Stevens was born in Long Island, New York on February 13, 1974. In 1987, she moved to Camden, Tennessee where she finished high school. In 1992, she attended the University of Tennessee at Martin for two years. After two years, she transferred to the University of Tennessee at Knoxville and graduated with Cum Laude honors with a Bachelor of Science degree in Agriculture in 1997. In May 1998, she began her Master of Science degree in Plant and Soil Sciences, which was awarded to her in August 2000.

Upon completion of her M.S. degree in August, she will be continuing her education at the University of Maryland to pursue her Ph.D. degree in Pedology specifically studying hydric soils.