

Appendix 2: Soil hydraulic properties of the Mfabeni peatland

**Research Title:**  
**The soil hydraulic properties of the peatlands in Mfabeni wetland**

**By: Esley Karupa (20052357)**



**University of Zululand**

**November 2008**

**Supervisor:**  
**Prof B Kelbe**

*Honours Thesis.*

**A wetland hydrology research programme in partnership with the Water  
Research Commission – Project 1857**



**Water Research Commission**

**DRAFT**

## 1 CHAPTER 1

### 2 1.1 INTRODUCTION

Peat and peat land are defined interchangeable where former is an unconsolidated soil material consisting largely of decomposing, or only slightly decomposed, organic matter accumulated under conditions of excessive moisture (Brady and Weil, 1984). Strahler and Strahler (1992) defined peat as partially decomposed, compacted accumulation of plant remains forming in a saturated environment that may be either a fresh water bog or a salt water marsh. But Grundling et al (1998), defined peat as brownish black organic soil that is formed when decaying organic matter accumulates in moist, anaerobic and low energy wetland condition. Peat is composed of humified organic matter, which, as a biofuel, has characteristics that lie between wood and lignite (Grundling *et al*, 1998). If dried, peat is a combustible material, which may be used for fuel and which can ignite spontaneously (Grundling *et al*, 1998). While peat is always associated with wetlands, it is noted by Grundling (1998) that not all wetlands have peat. In terms of composition and characterization, peat soils contain more than 50% organic matter (Brady and Weil, 1998).

Previous research by the Council for Geoscience (1994) showed that peatland occurs in areas where the rainfall exceeds 600 mm/year (Grundling *et al*, 1998).

Peats form an active part of wetlands which influence their hydraulic nature and are important source of fresh water, fodder and biomass fuel (Grundling *et al*, 1998). Peat however, cannot only be used in horticulture as a growing medium for flowers, vegetables and mushroom cultivation but also represents a sustainable source of potable water (Grundling *et al*, 1998).

The peat soil has different hydraulic properties and the most notable ones are their porosity, hydraulic conductivity, specific yield, yield retention capacity and bulk density (Ward and Robinson, 2000).

The volume percentage of the total soil bulk not occupied by soil particles is known as porosity and is expressed as:  $\alpha = V_i / V$

where,  $V_i$  is the volume of the interstices within a soil sample, and  $V$  is the total volume of the rock sample. These spaces are also known as voids, pores or pore-spaces (Ward and Robinson, 2000). They serve as space for water storage and water conduits.

Hydraulic conductivity in the Darcy equation refers to the characteristics of both the porous medium (grain size and porosity) and the fluid (Ward and Robinson, 2000). With water as a fluid, hydraulic conductivity has high values for coarse sand and gravels and lower values for compact clays and consolidated rocks (Shaw, 1994). Hydraulic conductivity of a soil depends on a variety of factors and the most important ones are the porosity, particle size and distribution, shape of particles, arrangement of particles. In unconsolidated materials, the hydraulic conductivity varies in terms of particle size; clay mineral having a low hydraulic conductivity, and sand and gravel having high hydraulic conductivity (Todd and Mays, 2005).

The specific yield of a soil is the ratio of the volume of water that, after saturation can freely drain from a saturated soil under the influence of gravity (Ward and Robinson, 2000). It can also be defined as the volume of water released by dewatering from storage per unit surface area of the aquifer per unit decrease in water table level. The values of specific yield range from 0.01 to 0.30 and relate solely to the porosity (Shaw, 1994). The specific yield of soil or rock can be expressed as:  $S_y = W_y / V$

where,  $W_y$  is the volume of the drained water and  $V$  is the total volume of the soil (sample or formation).

The remaining volume of water, which is retained by surface tension forces as films around the individual grains and in capillary openings, is referred to as yield retention capacity (specific retention) (Ward et al, 2000). In other words, after the volume of water has been drained by gravity, a particular volume of water will be held within soil against the force of gravity. This can be expressed as:  $S_R = W_R / V$

where,  $W_R$  is the volume occupied by the retained water, and  $V$  is the total volume of the rock (sample and formation).

The bulk density of soil is the mass of drying soil per unit of bulk volume, including space. The bulk volume is determined before drying to constant weight. It is determined by the volume of pore space and solid soil. Therefore, soils with a high proportion of pore space to solids have lower bulk densities than those that are more compact with less pore space. Fine textured surface soils such as silt loams, clays, and clay loams have lower bulk densities than sandy soils.

Solid particles of the fine textured soils tend to be organized in porous grains or granules, especially if adequate organic matter is present. This condition assures high total pore space and a low bulk density (Brady and Weil, 1998).

3

#### 4 1.2 PROBLEM STATEMENT

The eastern shores host a variety of wetlands which might be hydrologically linked. They also play an uncertain role in the hydrological function of the area. Currently the hydraulic properties (e.g. hydraulic conductivity, specific yield, porosity, field retention capacity and bulk density) of different soils and wetlands at Mfabeni are not well known, and this makes it difficult to

determine movement of water into the ground. Different soil layer also differs in their composition and features due to biological reactions which occur in top soil.

#### 5 1.3 AIM

The main aim is to establish soil water characteristics of peat soil in the Mfabeni swamp

#### 6 1.4 OBJECTIVE (S):

1. Establish and map the location of peatland (peat soil) of the Mfabeni swamp
2. Collect and document the soil samples at different depth and position around the swamp
3. Identify the important indicators of peat soil characteristics (whether peat, sand or clay) and measure these indicators
4. Analyze the measurements (data) in the laboratory
5. Write a report that contain map (spatial map), model and statistical properties (characteristics) of overall samples

#### 7 1.5 CONCLUSION

Peatland covers a small part of South Africa's surface. The Mfabeni peatland is part of the low-lying wetlands of the eastern Shores ecosystem in Greater St. Lucia Park. It is mainly a groundwater fed. It has a subtropical climate and sixty percent of mean annual precipitation falls in summer (Grundling, 1998).

## 8 CHAPTER 2

### 9 STUDY AREA

The study area is the Mfabeni swamp which is situated on the Maputaland coastal plain in northern KwaZulu-Natal (Figure 1). Mfabeni is situated west of the prominent vegetated coastal dune. It stretches north-south for 12 km from Lake Bangazi South near Cape Vidal to Catalina Bay (Grandling, 1998).

Most of the extensive wetlands and best developed peat deposits are found in Maputaland (Grandling, 1998). More than 70% of Maputaland peatlands are located in proclaimed conservation areas and most peatlands outside and even some inside conservation areas are utilized by local inhabitants as a water, horticultural and biomass resource (Grandling, 1998).

Wetlands containing peat have formed within valleys of palaeo-dune landscape and are the result of a very shallow water table. Peatlands and enclosing wetlands are groundwater fed. Perched aquifers within the sand dunes are a prominent source of water for wetlands (Grandling, 1998). The peat deposits of KwaZulu-Natal North and South Coast and greater Mozambique Coastal Plain are controlled by high rainfall (+800 mm per annum), and low energy conditions (Grandling, 1998.)

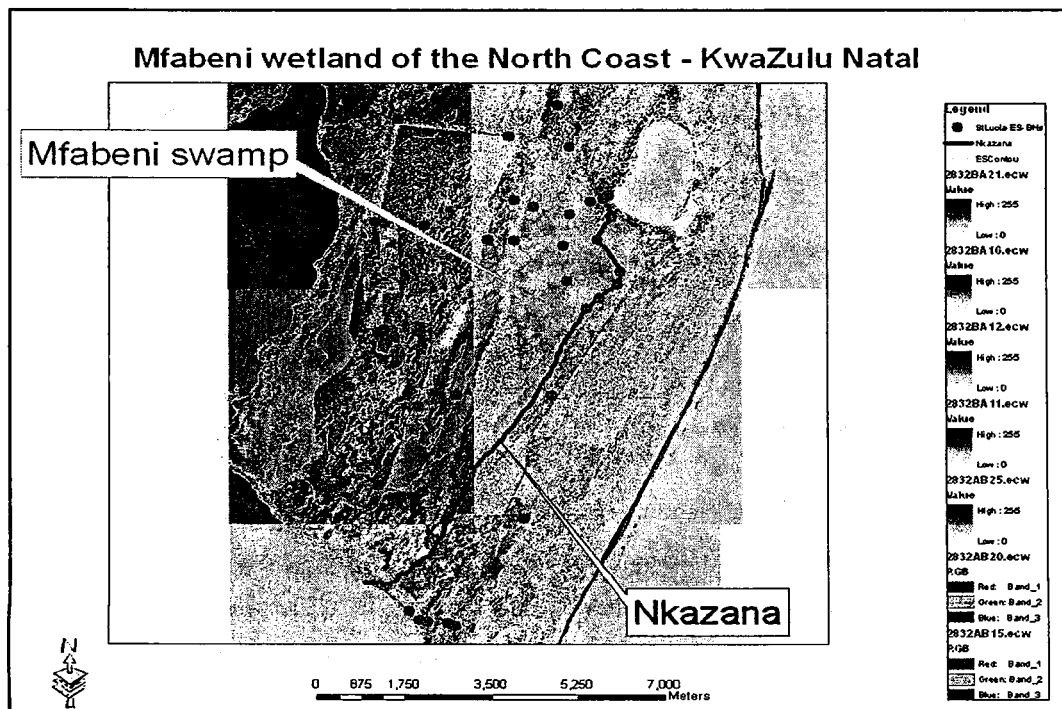


Figure 1. The map of Mfabeni wetland in the north Coast- KwaZulu Natal

## CHAPTER 3

### LITERATURE REVIEW

#### 3.1 Introduction

This chapter presents the literature review of various researches or studies that are related to the research topic. Two studies (researches) done in two different areas of the world are discussed in this chapter. The topics of previous studies that are discussed in this chapter are as follow: Soil physical properties of peat soil and Hydraulic properties of South Florida wetland peat.

#### 3.1. Soil physical characteristics of peat soils

A project to determine the soil physical characteristics of peat was done by Schwarzel, Renger, Sauerbrey, and Wessolek (2002). The aim of the study was to determine the hydraulic function (water retention and hydraulic conductivity) for different peat soils. Schwarzel *et al* (2002) used a model to predict the soil water components and CO<sub>2</sub> release for different peat soils, various climatic conditions and groundwater levels in a study area located 60 km northwest of Berlin (Germany). It is part of the Havelland basin, a fen area of 87000 hectare (Schwarzel, 2002). The peat formation in the Rhinluch was dominated by bogginess. The average thickness of the peat was 120 cm, underlying are glaciuvial sands (mostly fine sand) and limnic sediment such as detritus or calcerous mud (Schwarzel, 2002). According to Schwarzel *et al* (2002), the upper peat layers were strongly decomposed and pedolgenically altered. Earthified and strongly earthified peat soils are mostly at the surface. The deeper layers are dominated by sedge and reed peats, often showing a mixture of both. The average annual temperature is 8.1<sup>0</sup> C and the average annual precipitation is 526 mm (Schwarzel *et al*, 2002). The characteristics determined in the laboratory and the methods used are listed in Table 3.1.

Table 3.1. The laboratory methods used by Schwarzel *et al* (2002)

Characteristics	Methods
Dry Bulk Density dB (g cm <sup>-3</sup> )	Thermo-gravimetricl dessication at 105 <sup>0</sup> C (DIN 19683, 1998)
Mean Particle Density dF (g cm <sup>-3</sup> )	Helium-pyknometer (Quanta Chrome)

	(DIN 19683)
Total Pore Volume P	Mathematically out of dB and dF (DIN 19683, 1998)
Water retention curve	Up to pF 2.0 hanging water column, above pF 2.2 overpressure in a pressure pot, fourfold repetition, 100 cm <sup>3</sup> short core samples
Unsaturated hydraulic conductivity	Stationary and non-stationary according to Plaggae (1991) with threefold repetition on 10 cm high short core samplers (237 i.e 550 cm <sup>3</sup> )
Shrinkage	Measuring with a caliper rule after each pF level

### Statistical evaluation

Schwarzal *et al* (2002) summarize the distribution of the characteristics the arithmetic average to mark the central tendency and the standard deviation to mark the variation of the data were used.

### Result and discussion

#### Influence of fen formation and pedogenesis on soil physical characteristics

The groundwater regulation of fen peat soils in the northeast of Germany led to the formation of characteristics soil horizons, depending on the intensity of drainage (Schwarzal *et al*, 2002). The horizons differ mainly in the developments of soil structure and in order to standardize these developments of soil structure, Schmidt and Illner (1976) developed a classification system based on the differentiation of various soil structures for fen in East Germany.

Based on the classification system by Shmuidt and Illner (1976), Zeitz (1992) divided the fen peat soils into substrate-horizon-groups (SHG) in order to evaluate locations. Zeitz (1999) determined the soil physical parameters to assign these SHG. The mean and standard deviations of the soil physical parameters were determined for each SHG. The methods described above were used for establishing which soil physical parameters differed between the SHG.

The results obtained by Schwarzel *et al* (2002) were compared with Zeitz results to verify their own results. The former are based on a set of data consisting of more than 800 samples which were collected and analyzed from various fen regions of Northern Germany (among others from the Rhinluch) between 1975 and 1985, (Schwarzel *et al*, 2002).

It was concluded that, the predicted soil physical parameters showed good agreement with the results of Zeitz (1992). It was also proved that peat shrinks during draining cycles, especially at higher water tensions. Peat soils also showed substantially higher volumetric water content at high water tensions. Thus, deriving the pore size distribution only from water retention data leads to an underestimation of water content for high water tensions.

Results also showed the effect of hydrophobicity on soil wetting resistance of peat soils inhibits the soil water uptake by plants. As a results of the water repellency processes, the water infiltration moves faster to greater depths and groundwater level rises very quickly. In this case, a preferential transport of water and solutes to the groundwater might be possible. In contrast to the water retention, the unsaturated hydraulic conductivity functions, especially that of highly degraded peat layers, are under-presented in the modeling literature (Schwarzel *et al*, 2002).

It was recommended that, more research is needed to understand the relationship between peat soil development and unsaturated hydraulic conductivity.

### **3.2. Hydraulic properties of South Florida wetland peats**

A study by Myers (1999) examined the hydraulic properties of peat samples taken from isolated wetlands in Southern Florida.

This wetland is approximately round with diameter of about 60 m (Myers, 1999). The thickness of the peat layer ranges from about 0.3 m to 2 m (Myers, 1999).

The study had two main objectives, which were to examine the ability of peat samples to transmit water in the saturated condition, and to examine the water retention and release of unsaturated peat as the elevation of the water table beneath it changed.

Five samples were taken at two sites in South Florida from the field by digging just below the leaf layer near the edge of a forest and transported to the laboratory in 18.9 liter buckets. The sampling locations were chosen to represent a range of conditions. Two samples were collected near the edge of standing water, under the cypress canopy. One sample was collected nearer to the center of the wetland. The other two samples were collected on the western side in the area dominated by *Lachnanthes caroliniana*. The cores were obtained with a peat sampler.

#### **Grain size distribution for sand**

The grain size distribution of the sand samples was determined according to the standard method described by Das (1992) as cited by Myers (1999). Approximately 600g of sand was dried for 24 hours at 105 °C. The sand was sifted through five sieve sizes: 20, 40, 60, 140, and 200. The sieves were shaken for 15 minutes before weighing (Myers, 1999).

#### **Peat physical properties analysis**

The physical properties of fresh peat samples, including bulk density, saturated volumetric water content (effective porosity), and ash content, were measured in order to characterize the structure of the peat. From each sample location one small brass ring core was taken at the surface and the one was taken at the depth of approximately 20 cm (Myers, 1999). These cores were collected from the sides of the holes created by extraction of the undisturbed peat samples. The bulk density and saturated water content were determined by the first saturating and then drying and

weighing a known volume of the soil. The ash content was determined by igniting a known weight of oven dry soil, (Das, 1992).

The bulk density, gravimetric and volumetric water contents, and ash content were calculated as functions of the measured raw data as follows (Myers, 1999):

$$\rho_b = M_s / V_T ,$$

$$w_g = M_w / M_s = M_T - M_s / M_s ,$$

$$\theta = V_w / V_T = \rho_b W_g / \rho_w \quad \text{and}$$

$$\text{ash content} = M_{\text{ignited}} / M_s$$

where  $\rho_b$  = dry (M/L<sup>3</sup>) bulk density,

$w_g$  = gravimetric water content (fraction),

$\theta$  = volumetric water content, approximate effective porosity (fraction),

$M_s$  = mass of dry solids (M),

$V_T$  = total volume (L<sup>3</sup>),

$M_w$  = mass of water (M),

$M_T$  = total mass (M),

$V_w$  = volume of water (L<sup>3</sup>),

$\rho_w$  = density of water at given temperature (M/L<sup>3</sup>), and

$M_{\text{ignited}}$  = mass of ignited sample (M)

### Saturated hydraulic conductivity

Studies of the saturated hydraulic conductivity were performed on sand and on two-layer peat-sand systems in the two-tube peat testing apparatus. By saturating the peat layer and creating a difference in water level between the two tubes, flow was induced through the sample. A range of initial head differences was applied in order to account for possible compression effects. Higher absolute heads may compress the soft soil structure of peat, reducing pores sizes and hydraulic conductivity. The water level in each tube was recorded at, at least five different times (Myers, 1999).

#### **The results of samples collected**

Grain size distribution of sand sample was well sorted with most grains having diameters between 0.1 and 0.3 mm (Myers, 1999). The saturated hydraulic conductivity of sand, determined by a least- squares fit of the mathematical model ranged from 5.04 to 5.28 m/day (Myers, 1999).

Observation of peat core collected showed that the upper 5-10 cm of each core contains nearly pure peat with only a slight degree of decomposition (Myers, 1999). Below 10 cm the organic material was well decomposed and unidentifiable (Myers, 1999).

Myers (1999) showed that the bulk density increases with depth, porosity decreases with depth, and ash content increases with depth.

The hydraulic conductivity for forest samples had values ranging from  $5.4 \times 10^{-6}$  cm/s to  $5.8 \times 10^{-5}$  cm/s and for SV5 samples had values ranging from  $4.6 \times 10^{-5}$  cm/s to  $2.4 \times 10^{-4}$  cm/s (Myers, 1999).

## **CHAPTER 4**

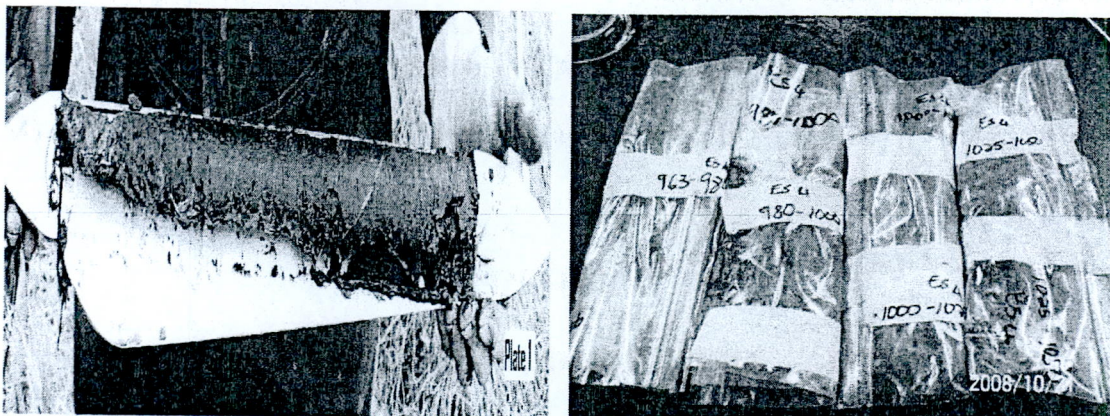
### **METHODOLOGY (PROCEDURES)**

## 4.1 Introduction

This chapter explains how the soil samples were collected in the field and it also explains in detail the laboratory work done. The laboratory work consists of three sections which are: the drying and burning of the soil sample; the determination of hydraulic conductivity, specific yield and specific retention, and porosity; and the determination water (moisture) content and grain size analysis (separation of fine sand from silt particles).

### 9.1 4.2 Collection of soil samples

Samples of soil were cored by means of a hand auger (plate 4.1). This instrument allowed the collection of undisturbed sample to be taken from the specified intervals from the top to the bottom of peat beds. The sample hole was approximately 10 x10 cm in extent and 2 to 12 meter deep. Six samples were augured in the peatland and two at adjacent sites (all at existing water level monitoring sites). All samples were logged in the field for soil type, color, express fluid, fiber content and Von Post Humification scale (H scale), and the sample were labeled appropriately (plate 4.2). The samples collected were taken to the laboratory for further analysis. The position (X, Y and Z) and attribute of each sample site were recorded using GPS (Geographical Positioning System) (Table 4.1) and were captured in ArcGIS.



*Plate 4.1. Photograph of a peat auger used to collect samples and Plate 4.2. Photograph showing how the samples were labeled*

*Table 4.1. The table showing the position (X, Y and Z) of eight sample sites*

Sample site (Reg. No.)	Location (°)		Elevation (m)
	South	East	
UW1E1	28 9 16.7	32 31 46.1	8.37
MPS1W	28 9 15.4	32 31 43.7	6.54
MPS1OC	28 9 13.9	32 31 40.9	7.09
MPS5	28 9 6.8	32 31 35.9	6.81
MPS4	28 10 23.5	32 30 44.2	7.21
UW1W	28 9 33.13	32 30 8.0	12.71
WSF1ES7	28 08 39.3	32 30 28.01	9.5
MSP3	28 8 17.65	32 31 55.00	6.16

### 4.3 Laboratory work

The samples were then taken to the laboratory and were analyzed for:

1. Hydraulic conductivity
2. Bulk density
3. Grain size distribution
4. Organic content
5. Porosity
6. Specific yield
7. Yield retention capacity
8. Moisture content (water content)

#### 4.3.1 Methods of drying and burning of the soil samples

First the ring and the tray were weighed and then each sample was placed in the ring. The ring and tray with soil sample (wet sample) inside it were weighed again, and then placed in the

drying Oven at 100 °C to dry for 8-10 hours. The reason for drying the soil was to remove water in soil sample so that the weight of dry soil will be determined. The dried soil sample was allowed to cool in the desiccators (with silica gel in it) for 20 to 30 minutes then weighed again to determine the initial moisture content.

The furnace was switched on to a constant heat of 400 °C and the dried soil samples were incinerated for 8-10 hours. The reason for these was to burn all the organic matter in the soil so that the soil organic content can be determined. The sample were removed and allowed to cool for 20 to 30 minutes and then weighed again. All this was recorded (Table 4.2).

*Table 4.2. The weight of soil before and after dried, and of soil after incinerated*

Sample site (Reg. No.)	Sample depth (cm)	Weight of the Ring & Tray: S1 (g)	Weight of Ring & Tray and Wet soil: S2 (g)	Weight of the Ring & Tray and Dry soil: S3 (g)	Weight of the soil after incinerated (g)
<b>UW1E1</b>	<b>0-10</b>	<b>32.78</b>	<b>70.4</b>	<b>68.71</b>	<b>67.64</b>
	10-40	34.61	77.73	76.2	74.89
	40-80	34.28	82.45	80.2	79.85
	80-120	33.71	79.12	76.77	76.33
	120-160	33.34	83.84	79.21	78.87
	160-180	34.05	100.09	88.52	88.21
	180-200	32.35	97.17	86.15	85.87
	200-240	33.43	100.58	88.53	88.32
	240-280	33.98	104.16	90.96	90.77
	280-310	34.75	109.55	95.56	95.35
	310-340	35.04	109.46	96.39	96.16
<b>MPS1W</b>	<b>0-15</b>	<b>32.51</b>	<b>64.47</b>	<b>35.8</b>	<b>33.02</b>
	15-40	34.11	76.81	43.15	38.84
	40-70	33.48	82.75	57.7	53.35
	70-90	34.2	97.73	82.72	79.7
<b>MPS1OC</b>	<b>0-15</b>	<b>34.35</b>	<b>92.71</b>	<b>80.05</b>	<b>78.38</b>
	15-50	33.32	93.12	80.48	79.14
	50-90	33.59	100.7	88.49	87.77
	90-120	39.38	114.06	98.8	98.37
	120-180	33.89	104.52	91.15	90.79
<b>MPS5</b>	<b>0-40</b>	<b>32.77</b>	<b>69.77</b>	<b>36.56</b>	<b>33.2</b>
	40-60	33.7	73.18	37.01	33.83
	60-100	33.96	71.47	40.95	34.52
	100-140	33.43	65.76	39.13	33.75
	140-185	34.6	74.88	44.72	35.43
	185-210	34.74	74.74	41.81	36.81
	210-260	33.34	68.18	39.46	34.29
	260-300	34.04	68.96	40.15	35.23
	300-330	32.35	68.02	38.99	34.43

	330-350	35.03	80.17	54.44	50.19
	350-365	34.26	91.87	78.97	78.09
	365-400	39.38	75.65	50.43	45.49
	400-430	33.3	65.97	40.43	36.31
	430-460	34.2	70.7	41.55	36.07
	460-500	32.51	63.44	37.85	33.37
	500-525	34.11	68.61	39.6	34.73
	525-555	33.47	66.02	39.33	35.21
	555-575	36.37	72.79	42.81	38.39
	575-595	33.58	70.42	41.19	37.03
	595-615	33.81	81.54	64.05	61.7
	615-650	34.31	74.79	50.64	46.67
	650-690	32.78	67.61	41.64	37.28
	690-720	33.7	70.57	41.49	36.15
	720-750	33.97	71.44	44.72	39.02
	750-780	33.42	71.7	45.08	38.06
	780-810	34.6	75.79	51.61	46.43
	810-850	34.74	70.42	41.76	36.39
	850-880	33.34	65.51	40.2	35.28
	880-920	34.04	67.48	40.4	35.73
	920-963	32.35	64.66	40.66	33.87
	963-1000	35.03	79.68	54.29	52.89
	1000-1050	34.31	84.65	56.06	54.56
<b>MPS4</b>	<b>0-40</b>	<b>32.37</b>	<b>67.06</b>	<b>35.75</b>	<b>32.96</b>
	40-80	33.53	69.46	38.72	33.85
	80-115	34.2	69.61	38.59	34.49
	115-150	33.47	68.82	39.11	33.66
	150-180	33.63	66.58	38.24	34.38
	180-210	33.03	74.01	50.04	45.62
	210-240	34.58	85.72	62.57	57.05
	240-265	33.92	93.13	81.42	79.67
<b>UW1E1S6</b>	<b>0-10</b>	<b>36.37</b>	<b>75.82</b>	<b>63.79</b>	<b>60.65</b>
	010-30	34.26	79.03	72.31	70.91
	30-50	34.75	81.28	77	76.42
	50-70	35.13	89.18	83.05	82.78
	70-90	33.8	91.22	81.73	81.52
	90-125	33.72	95.41	85.04	84.8
	125-170	32.37	85.28	75.63	75.57
	170-180	34.28	93.4	83.48	83.4
	180-210	33.08	86.24	77.41	77.33
	210-230	34.79	94.19	83.7	83.68
	230-250	34.33	101.69	89.38	88.99
<b>MSP1ES7</b>	<b>0-25</b>	<b>33.62</b>	<b>68.4</b>	<b>42.09</b>	<b>35.32</b>
	25-65	32.79	66.27	39.92	33.78
	65-100	34.2	68.66	39.54	35.14
	100-135	32.37	65.93	36.95	33.06
	135-170	35.83	76.88	42.87	37.14
	170-200	33.59	67.79	40.83	36.49
	200-250	33.38	83.47	59.07	53.7
	250-275	34.41	78.74	52.2	47.88
	275-310	33.58	96.75	79.57	78.25

MPS3	0-65	34.65	77.47	39.62	35.15
	65-110	33.09	70.03	39.79	33.81
	110-150	34.25	70.5	41.02	35.33
	150-235	32.57	68.73	39.17	34.77
	235-270	34.34	94.66	79.75	78.6
	270-290	34.73	90.86	74.27	71.03
	290-310	33.81	88.92	74.36	72.44
	310-335	33.6	83.29	70.34	68.78

#### 4.3.2 Methods for the determination of soil moisture content, bulk density and porosity

The bulk density, gravimetric and volumetric water content were calculated and determined using the following methods (Rowell, 1994):

Gravimetric water content in percentage (%) was determined by using the following equation:

$$\Theta_m = 100 (m_t - m_s) / m_s$$

where,  $\Theta_m$  is gravimetric water content,  $m_t$  is the weight of wet soil sample, and  $m_s$  is the weight of dry soil sample.

The weight of dry soil sample ( $m_t$ ) in grams, was determined (calculated) by deducting  $S_1$  from  $S_2$ , thus:  $m_t = S_2 - S_1$

where,  $S_1$  was the weight of the ring and the tray and  $S_2$  was the weight of the ring, tray and wet soil sample.

The weight of dry soil sample ( $m_s$ ) in grams, was determined (calculated) by subtracting  $S_1$  from  $S_3$ , thus:  $m_s = S_3 - S_1$

where,  $S_3$  was the weight of the ring, tray and dry soil sample. Gravimetric water content is expressed in percentage.

Bulk density which is expressed in  $\text{g/cm}^3$ , was determined using the following equation:

$$\rho_t = m_s / V_t$$

Where,  $\rho_t$  is the bulk density and  $V_t$  is the volume of wet soil sample.  $V_t$  was calculated by determining the area of the ring and then multiply with the length of the ring. Area is  $\pi r^2$  and the length was measured.

Volumetric water content in percentage (%) was determined using the following equation:

$$\Theta = \Theta_m (\rho_b/\rho_t)$$

where,  $\Theta$  is the volumetric water content and  $\rho_t$  is particles density which is assumed to be 2.73 g/cm<sup>3</sup> (standard value for sand particles) and 1.4 g/cm<sup>3</sup> (for dried peat).

Porosity expressed in percentage (%) was determined or calculated using the following equation:

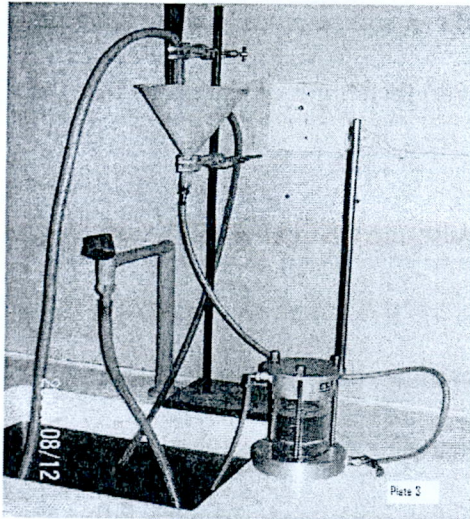
$$\alpha = 100 - [100(\rho_b/\rho_t)]$$

#### **4.3.3 Methods for the determination of hydraulic conductivity, specific yield and specific retention**

First, the weights of some apparatus used in this step were recorded. The apparatus used are as follows: the permeameter tube, glass dish, bronze ring, filter paper, two base plates (with holes), hard wire rod with the diameter of 2mm, and a ruler.

The raw soil sample was packed into the permeameter tube on the base plate and gently packed with the wire rod to close big air gaps (empty spaces) in the permeameter tube so that water cannot move between the permeameter glass and soil but through the soil. The filter paper was placed below and on top of the soil (between the base plates and soil) to allow only water to pass through it. A bronze metal weight of a constant (known weight) was then dropped three times from a height of 1cm onto the soil, to create a uniform compaction of the disturbed sample.

The permeameter glass tube with soil inside it was then weight and the height of the soil column (in cm) was measured. A constant water head was established using a funnel with overflow set (see plate 4.3). The total head of water above the sample outlet and the water level of the outflow point) was also measured (plate 4.3).



*Plate 4.3. Photograph showing permeameter set*

The device was set up and run until the permeameter was full and water was flowing out of the discharge pipe. The constant head permeameter maintains a constant head at both the inflow and outflow end of the device. The time and volume of water flowing out of the device was taken and the flow rate was recorded.

To estimate the yield, the excess water in the permeameter glass above and below the soil sample was removed and permeameter tube and saturated sample was placed on a glass weighed again. The water in the soil was then allowed to drain under gravitational force in the dish glass for 20 to 30 minutes or until the water was not dripping anymore. The reason for allowing water to drip was to determine the specific yield and specific retention. Retained soil sample and water loss were weight separately for analysis.

The hydraulic conductivity (in cm/s) was calculated by using Applying Darcy's equation to a constant head permeameter the following equation (Todd, 2005 and Schwartz *et al*, 2003):

$$K = LQ/H\pi R^2$$

Where K is the hydraulic conductivity (cm/s)

- H is the total head loss across the sample (measured as a vertical distance between constant water level above the sample and the water level of the outflow point (cm)
- L is the height (length) of the soil sample (cm)
- Q is the volume rate of flow (cm<sup>3</sup>/s)
- R is the radius of the soil sample in the permeameter

The radius of the soil sample in the permeameter was determined by measuring the diameter of the inner part of the permeameter.

#### **4.3.4 Separation of sand and silt soil**

Three labotec test sieve with aperture opening of 75 µm and a diameter of 190 cm were used to separate the sand from silt in the soil sample. All the soil particles with less than 75 µm passes through the sieve leaving those that are more than 75 µm on the sieve. Soil samples used in the step had no organic matter (the organic matter was burned with the furnace).

The soil sample was placed in the labotec test sieve and both the soil sample and the labotec test sieve were weight. The water was then used to help separate the sand from silt. Both the labotec test sieve and soil left on the sieve were placed in the Oven for 1 to 2 hours (at 100 °C) to dry the soil (to remove water out of the soil). This was then weighed again. The weight of soil determined after been dried was subtracted from weight of soil determined before being washed.

#### **4.3.5. Particles size analysis**

##### *Sample preparation*

The 500 ml beaker was accurately weighed and approximately 25g of dried soil was placed into this weighed beaker. The soil used here was the one that had already been burned to remove the organic content. 100 ml of 20% (volume) hydrogen peroxide was added into the beaker and stirred well. This was allowed to stand overnight. The hydrogen peroxide was added on order to

attack and destroy any remaining organic content. The beaker was then placed on a hot plate at approximately 40 °C to destroy the remaining organics if there were any (Rowell, 1994).

The distilled water was added to make the volume up to approximately 150 ml and stirred well. This was allowed to stand for 8 to 10 hours, so that any remaining organic particles can float to the surface (Rowell, 1994).

Clear fluid was then poured out (removed) carefully making sure that solid matter is not disturbed. The remaining liquid was boiled to remove as much water as possible. The remainder was placed in the drying oven for 4 to 6 hours.

This was cooled in the desiccators and then weighed, subtracting the weight of the beaker to give the weight of mineral soil free of organic matter.

#### *Procedure 1*

Approximately 150 ml of distilled water and 10 ml of 5% Calgon solution were added to the peroxidised soil sample (while in the beaker). It was stirred for about 15 minutes to disperse the aggregates in the soil (Rowell, 1994).

Soil suspension was poured into measuring cylinder through 53µm sieve, to retain the liquid and fine particles beneath the sieve. This was done to separate the clay and silt from sand. To make sure that all the soil is transferred from the beaker, the jet of distilled water was used to lightly wash fine particles. This was done in such a way that no suspension is lost. Fine suspension from the sieve base was also transferred into the measuring cylinder with a jet of distilled water.

On the other hand, the sand left on the sieve was washed from the sieve into crucible and dried in the oven at 100°C for approximately 8 hours. The soil fraction was removed from the oven, placed in the desiccators to cool, and then weighed. Three sieve set of 212, 500, and 2000 µm were placed on top of each other in the ascending order on the shaker. The soil fraction was

poured on the sieve and allowed to shake for 5 minutes. The contents of each sieve was transferred to a weighed beaker and weighed. The weight of each fraction was then calculated.

*Procedure 2*

*Procedure for sedimentation*

The measuring cylinder with fine suspension was filled with distilled water to the 1000 ml mark (to the volume of 1000 ml). The stem of a 25 ml pipette was marked at exactly 9 cm from its tip. Vigorously the suspension was stirred so that the soil is evenly distributed throughout the cylinder for 30 seconds. This was stirred making sure that no air bubbles are introduced into the suspension. Immediately after stirring the temperature of the suspension was taken (recorded) and then stirred again for 30 seconds. On withdrawing of the stirrer, the stopwatch was set on (started counting). At the exact time shown below (Table 4.3) a sample from a depth of 9 cm below the surface was taken with a pipette and placed in the crucible. About 20 seconds before the time, the pipette was lowered to the required depth and a sample was taken at the exact time (Table 4.3). The pipette sample was transferred in the weighed crucible and placed in the oven for 8-10 hours and cool down in the desiccators, and then weighed (Rowell, 1994).

*Table 4.3. The temperature (<sup>0</sup>C) and particles size (mm)*

<b>Temperature <sup>0</sup>C</b>	<b>Particles&lt;0.002mm</b>	<b>Particles &lt;0.02 mm</b>	<b>Particles &lt;0.2mm</b>
20	7hrs 05mins	4mins 12secs	1min 31secs
21	6hrs 55mins	4mins 08secs	1min 28secs
22	6hrs 45mins	4mins 03secs	1min 26secs
23	6hrs 39mins	3mins 54secs	1min 24secs
24	6hrs 27mins	3mins 45secs	1min 23secs

## **CHAPTER 5**

### **RESULTS AND DISCUSSIONS**

#### **5.1 Introduction**

This chapter present in details the analysis and results determined in the laboratory. The discussion on how the results of some soil properties (the hydraulic conductivity, bulk density, moisture content, porosity, grain size analysis, organic content, specific yield, and specific retention) varies or their similarities with each other are also explained here. The interpretations of the results are discussed in this chapter.

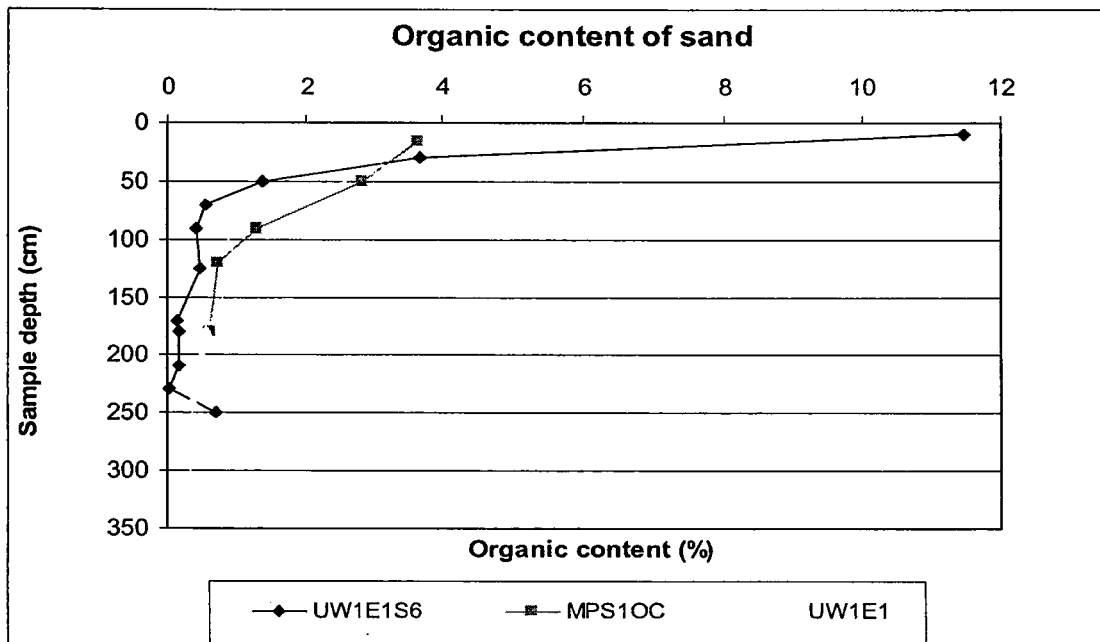
#### **5.2 Results of some soil hydraulic properties**

##### **5. 2.1. Organic content of sand and peat soil**

The organic content in all eight sites were high near the soil surface than further deep. Soil samples UW1E1 and UW1WES6 had lower organic content than the sample collected within the swamp area. The highest organic content was 96.63% at MPS4 (at 185cm deep) and the lowest organic content was 0.04% at UW1WES6 (at 230 cm deep) (figure 5.1). The organic content at

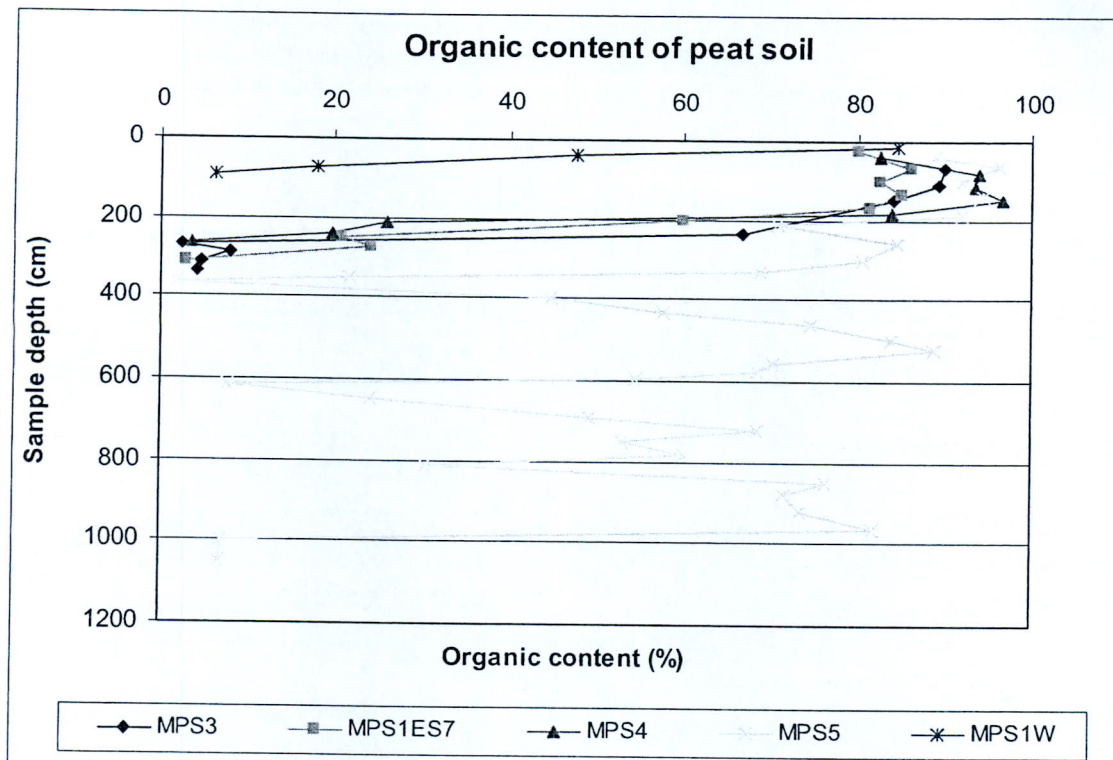
site MPS1OC was decreasing with depth. Soil samples taken near the surface had high organic content than those taken further deep. In this case the organic content is decreasing when the depth is increasing.

Peat soil shows high organic content (figure 5.2) than sand soil, even in those layers where there is sand content in swamp area had little organic matter. Clay soil at lower depth from 963 to 1050 cm (at site MPS5) had no organic content. All eight sample sites show large variations and the pattern is not uniform.



Figure

5.1. The organic content of soil samples collected at the edge of the swamp (peat) area.



Figure

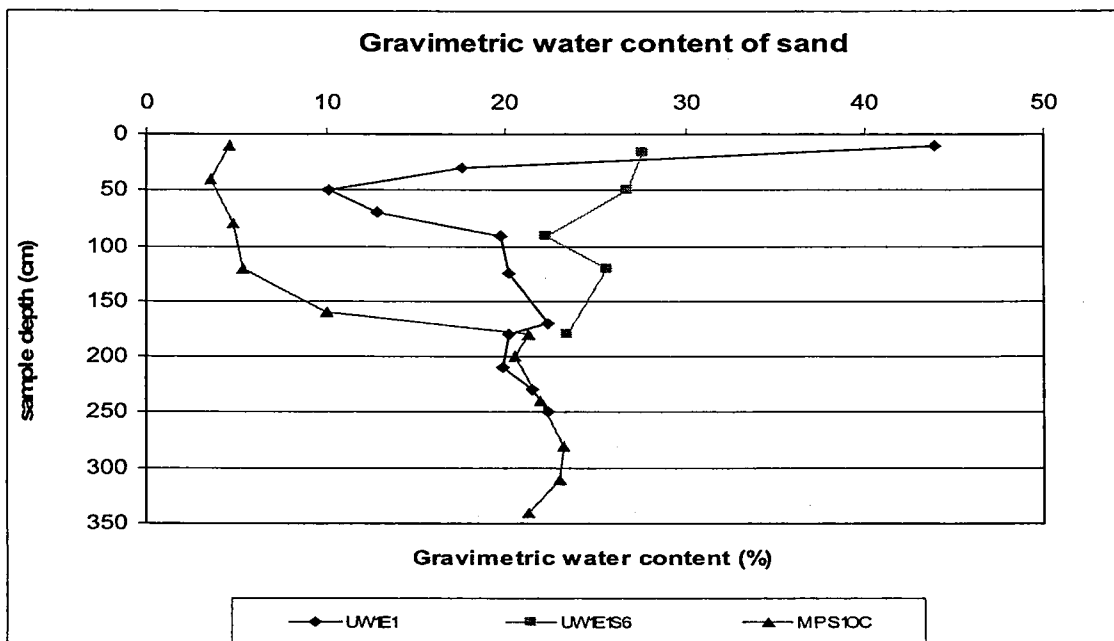
5.2. The organic content of soil samples collected in the swamp (peat) area.

### 5.2.2. Gravimetric water content and volumetric water content of sand and peat soil

The gravimetric water content (percentage) of eight sample sites varied depth at all sites. The highest gravimetric water content occurred at sample site MPS5. At three sample sites along the edge of the swamp (UW1E1, MPS1OC and UW1WES6) the gravimetric water content was significantly lower (Figure 5.3) low at almost all depth than other sample sites inside the swamp. Gravimetric water content at sample site MPS1 W (figure 5.4) was decreasing with depth, with the highest water content of 871.43 % (at 15 cm deep) and with the lowest of 30.94 % (at 90 cm deep). Sample site MPS5, MPS4, MS1ES7 and MPS3 (figure 5.4) their gravimetric water content varied at different depth. The gravimetric water content of those soil samples collected adjacent the swamp area were lower than those collected in the swamp area. This is indicating or showing that peat soil hold more water than sandy soil.

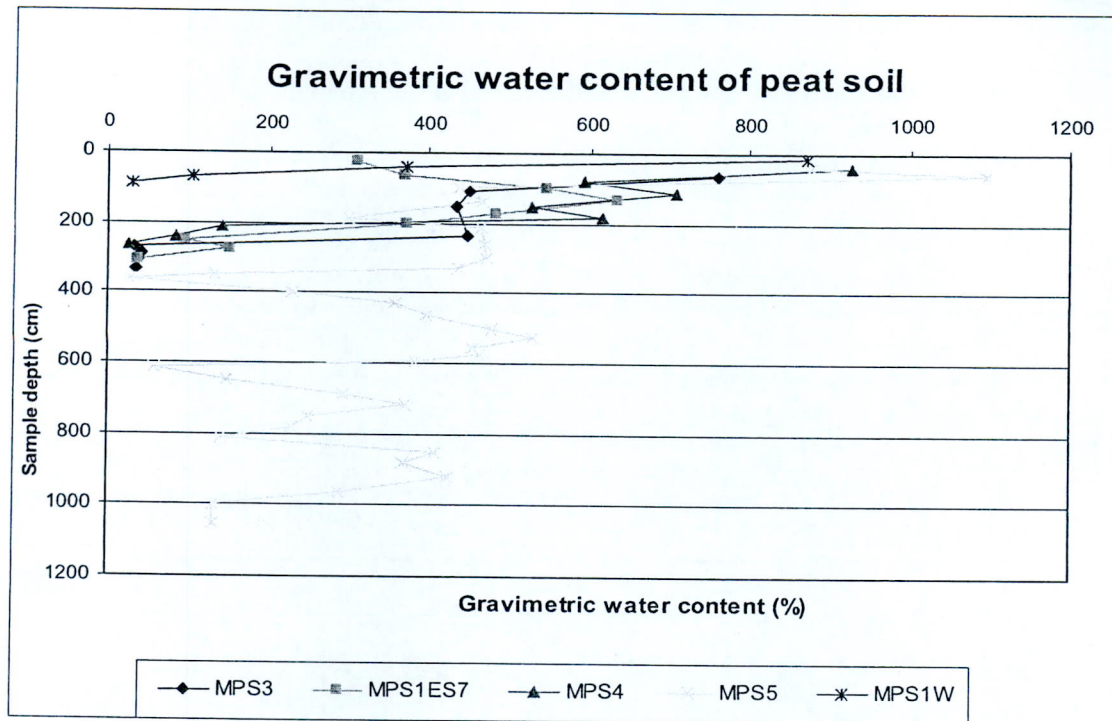
The gravimetric water content of three samples sites collected on sand shows large variations (pattern is not uniform) from the surface to the depth of 180 cm. The uniformity appears from 180 cm deep downwards for two sites (MPS10C and (UW1E1). For those samples sites collected in swamp area, there was not uniformity among the sites.

The volumetric water content shows the same pattern as the gravimetric water content. Where there is high gravimetric water content there is high volumetric water content, and vice versa.



Figure

5.3. The gravimetric water content of soil samples collected on the edge of the swamp (peat) area.



Figure

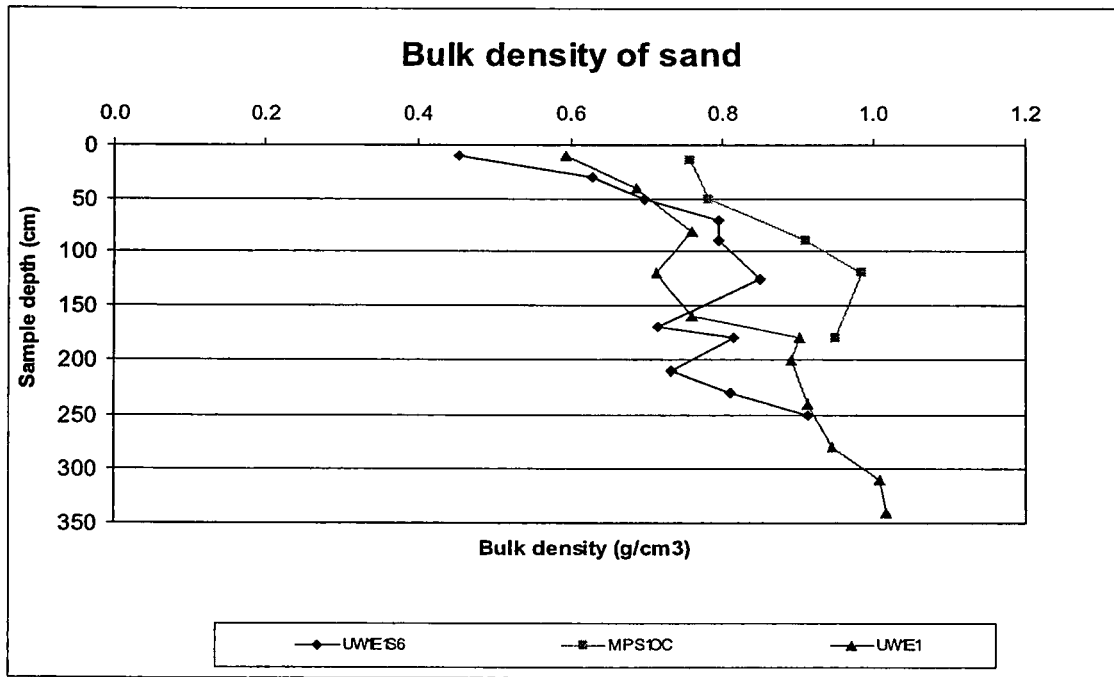
5.4. The gravimetric water content of soil samples collected in the swamp (peat) area.

### 5.2.3 Bulk density of sand and peat soil

The bulk density ( $\text{g/cm}^3$ ) of three sample sites collected on sand soil (at the edge of the swamp area) had almost the same pattern of increasing bulk density with increasing depth (figure 5.5).

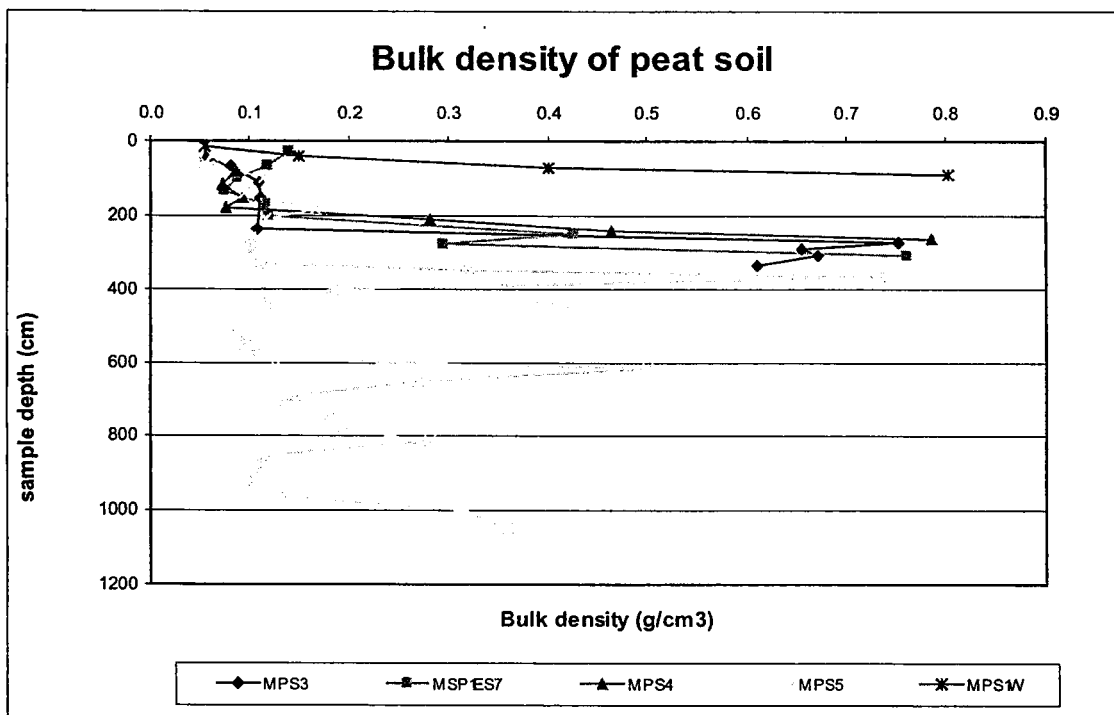
In site (UW1E1), the bulk density was increasing with depth and the highest bulk density was  $1.02 \text{ g/cm}^3$  at 310 cm deep while the lowest bulk density was  $0.6 \text{ g/cm}^3$  at 10 cm deep.

Figure 5.6 shows the bulk density ( $\text{g/cm}^3$ ) of five sample sites collected in peat soil (in the swamp area). The graph shows that the bulk density was increasing or decreasing with depth depending on the type of soil at that depth. The bulk density was not proportional to depth and the pattern varies a lot. Where there was sand within the layer the bulk density was high than where there is peat soil. The bulk densities of sample sites that have a high proportion of peat were lower than those in the sand soil.



Figure

5.5. The bulk density of soil samples collected on the edge of the swamp (peat) area.

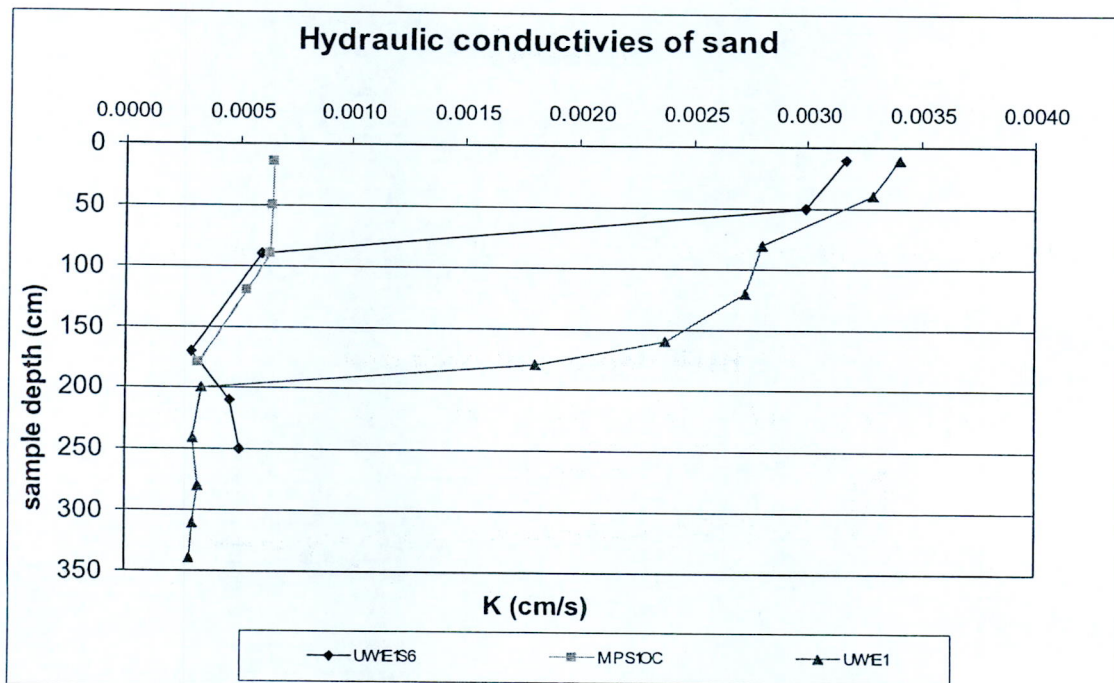


Figure

5.6. The bulk density of soil samples collected in the swamp (peat) area.

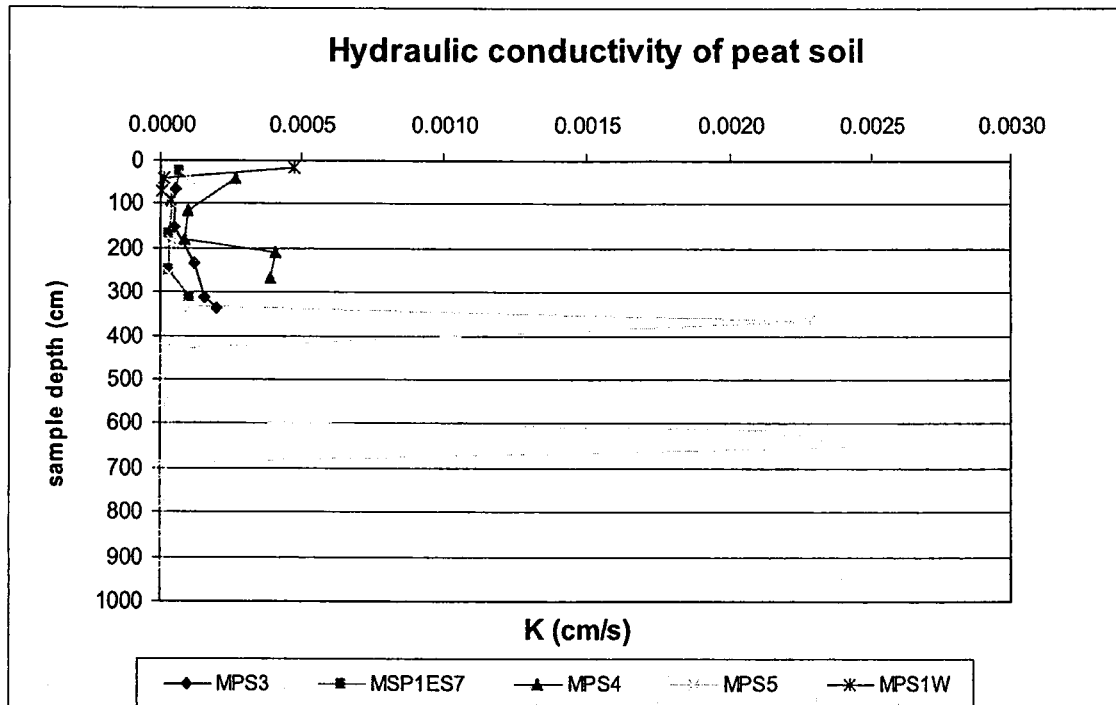
#### 5.2.4 Hydraulic conductivity of sand and peat soil

The hydraulic conductivity of peat soil was below 0.0005 cm/s (with the majority being below 0.0001 cm/s) apart from in those layers that contain large proportion sand soil. The hydraulic conductivity of sand was decreasing with depth. The soil sample (MPS10C) taken on sand soil (the outcrop) within the swamp area the conductivity was low compare to samples taken outside the swamp area, with the highest hydraulic conductivity of 0.0007 cm/s at 15 cm deep (figure 5.7).



Figure

5.7. The hydraulic conductivity of soil samples collected on the edge of the swamp (peat) area.



Figure

5.8. The hydraulic conductivity of soil samples collected in the swamp (peat) area.

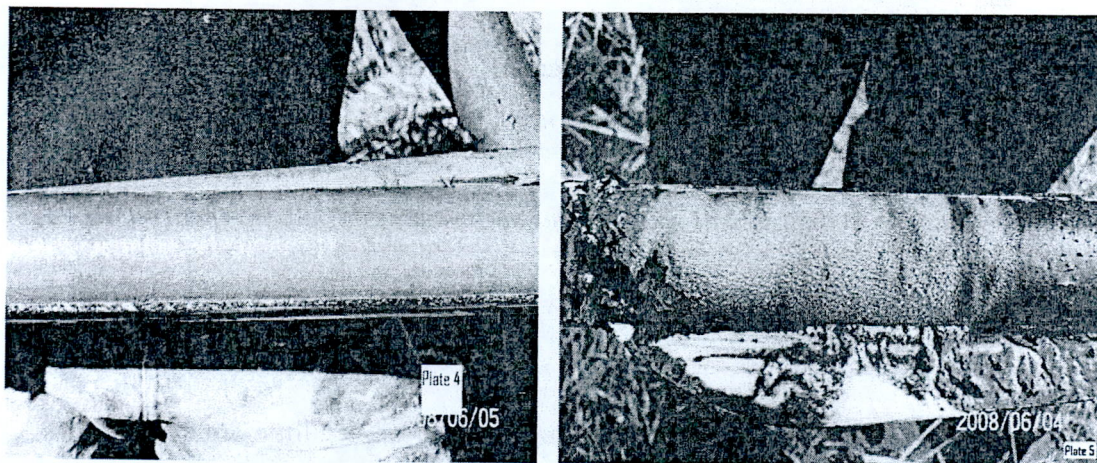
### 5.3 Discussion

The soil samples taken at the edge of the swamp area contained little organic content, gravimetric water content and volumetric water content than those collected in the swamp area. Again they had high bulk density and hydraulic conductivity than those collected in the swamp area.

Soil samples collected almost in the centre of swamp area at 963 to 1050 cm deep was just clay soil (with no peat soil in it) (plate 5.1) and their hydraulic conductivity was not determined because the permeameter was unable to control the clay.

At some depth within the peat (swamp area) there was high proportion of sand or silt particles, which makes the bulk density and hydraulic conductivity to be higher than peat free of sand and silt. At the same layers mentioned above, the organic content, gravimetric water content and volumetric water content were low.

In soil samples which were collected towards the edge of the swamp area, at the lower depth of the hole there were sand particles (layer). The upper part of samples collected at site MPS5 was mainly peat and at the depth of 350-365 and 575-615 cm a mixture of sand and peat or sand layer was observed (plate 5.1). The same was observed at site MPS3, below 235 cm deep the sample was mainly sand. That is why at the depth (the lower depth) of those soil samples (which contain sand) the bulk density is high.



*Plate 5.1. Photograph (a) clay sample at site MPS5 (at 10 meter deep) and photograph (b) sand layer in the swamp area (site MPS5) at 575 meter deep*

The field observation of soil samples collected almost in the center of the swamp (peat) area shows that the upper 0-40 cm deep of each core are poorly decomposed and from 40cm deep downwards are somewhat decomposed and muddy, well decomposed and very muddy or almost completely decomposed, provided that there are no high proportion of sand in that layer. The fibre content varied depending on the depth and type of soil available on that layer. High fibre content was mainly observed near the surface in swamp (peat) area and low at or near the surface in the swamp forest.

## CHAPTER 7

### REFERENCES

1. Ward R C and Robinson. 2005. Principles of Hydrology. Forth edition. McGraw-Hill Publishing Company, London.
2. Grundling P L, Mazus H and Baardman L. 1998. Peat resources in Northern KwaZulu-Natal wetlands. Department of Environmental Affairs and Tourism, Pretoria.
3. Grundling P, Baartman, L, Mazus H and Blackmore A. 1998. Peat resources of KwaZulu-Natal wetlands: Southern Maputaland and the North and South Coast. Department of Environmental Affairs and Tourism.
4. Todd DK and Mays LW. 2005. Groundwater Hydrology. Third edition. Jones Wiley & Sons.
5. Brady NC and Weil RR. 1998. The nature and properties of soils. Thirteen editions. Prentice Hall
6. Shaw E M. 1994. Hydrology in practice. Third edition. Chapman & Hall, London.
7. Strahler A H and Strahler A N. 1992. Modern Physical Geography. Fourth edition. Jones Wiley & Sons.
8. Schwartz F W and Zhang H. 2002. Fundamentals of groundwater. Jones Wiley & Sons.

9. Schwarzel K, Renger M, Sauerbrey R, and Wessolek G. 2002. Soil physical characteristics of peat soils. Institute of Ecology, Department of Soil Sciences and Soil Protection, Technical University of Berlin, Salzufer 12, D-10587 Berlin, Germany. And Institute of Crop Sciences, Department of Ecology and Use of Resources, Humboldt University of Berlin, Invalidenstr. 14, D- 10115 Berlin, Germany. [http://boku.forst.tu-dresden.de/Boden/pdf/01\\_Schwaerzel.pdf](http://boku.forst.tu-dresden.de/Boden/pdf/01_Schwaerzel.pdf)
10. Myers R D. 1999. Hydraulic properties of South Florida wetland peats. University of Florida. <http://etd.fcla.edu/UF/amp7399/rdmyers.pdf>
11. Rowell D L. 1994. Soil science: Methods and Applications. Addison Wesley Longman Limited, England.