TREND OF PERCHED WATER TABLE FLUCTUATION IN THE INLAND VALLEY OF GUIDAN KWANO NIGER STATE, NIGERIA

BY

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DEDICATION

This work is specially dedicated to Almighty God and my lovely parents, Hadiza Amma and Zahadi Hassan.

CERTIFICATION

This is to certify that Zahadi Hassan Ali carries out this project work under the supervision of Engr. (Dr.) N.A. Egharevba of Agricultural Engineering Department

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AKNOLEDGEMEN T

My sincere gratitude goes to Almighty ALLAH, the most Excellent and most merciful for preserving and sustaining my life till now and for preserving me grace, privilege, guidance and protection through out the duration for my studies.

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ABSTRACT

An investigation on the trend of perched water table fluctuation was carried out in the inland valley of Gidan Kwano Niger State Nigeria. An integral portion of 12,330 m^2 of the field across the valley was considered within which three piezometers were installed and the water table was measured each week. The measured values were plotted to observe the water table trend. From this investigation a peak value of 45.33 cm depth and a low value of 128 cm were found. These values could be used to determine the type of crops that can fit the site, the amount of water to be drained if necessary. In addition, comparison was made between the water table depth for year 2001 and 2002, which gives almost the same trend.

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CHAPTER ONE

INTRODUCTION

Water as a carrier of large amount of nutrients is required in a large measure for the successful growth of crops. To increase productivity the study of possible relationship between surface and ground water becomes increasingly important since the distribution of water within the soil profile and the proportion that remains in the root zone for the plant to utilize appears to be a more crucial limitation than the total rainfall.

In such an environment an understanding of the water uses is particularly important for rotational management strategies are to be formulated, to monitor and more efficient use of the limited seasonal rainfall.

Immediately below the surface, the soil pores contain both water and air in varying amounts. After a rain, infiltrated water may move downward through this zone of aeration or vadose zone. Some water is dispersed through the soil and held by capillary forces in the small pores or by molecular attraction around the soil particles. Water, in this upper layer of the zone of aeration is known as soil moisture. If the retention capacity of the soil in the zone of aeration is satisfied, water moves downward into region where the pores of the soil or rock are completely filled with water. The water in this zone of saturation is called the ground water.

The boundary between the vadose zone and the zone of saturation in termed the water table. Its location is determinate by the elevation to which water rises in unpumped wells just penetrating the top of the zone of the saturation.

To be effective without seriously restricting growth, water should be near both below the depth from which the major portion of the plant needs are extracted. If ground water is too near the surface, the land ability to economically produce most crops becomes almost nil. The optimum depth of water table is that depth which gives the maximum economic return. Preferred drainage practices could allow water at a depth, which will supply water by sub-irrigation for crops but not so shallow that root aeration becomes a problem (Benz et al, 1985).

It should be noted that the optimum water table varies from crops to crops. Its location is found by sinking borehole into the ground water body. Water from the surrounding soil will flow into the hole and fill it into the water table level. The records of this water table level fluctuations or piezometric heads are used to analyze the ground water occurrence, storage, movement, recharge and discharge as well as the direction of flow.

Man's activities, moving vehicles, time lag features and some natural phenomenon affect the water table fluctuation such factors as well as hydrographs, water table profile and contours are used for water table fluctuation analysis.

1.1 JUSTIFICATION

1. Possible relationship between surface water and ground water.
2. To advise on irrigation periods and frequency, from seasonal flux of water table.
3. To advise farmers on the amount of water to be drained from the estimation of the next water requirement.
4. To investigate the availability and rate of contribution of ground water to the net water requirement of field crops during growth stage, maturity and pre-harvest.
5. To advise farmers on the best possible irrigation system layout.

1.2 OBJECTIVES

1. To identify pattern of fluctuation in inland valley of Gidan Kwano (F.U.T permanent site).

2. To identify period of recharge and discharge.

3. To identify direction of ground water flow.

CHAPTER TWO

LITERATURE REVIEW

2.1 GEOLOGICAL FORMATION

The geology of Niger state is divided into two district geological zones, the basement complex and Nupe sandstone (Max lock group Nigeria ltd1980). Final report on Niger state regional planning. The dividing line runs approximately straight line to n-w se. Orientation from just south of kontagora to just Northern of Lapai (see appendix). The other significant, but much smaller, zone is the area of river alluvium which is mainly found along the lower reaches of the kaduna and gbaco rivers as they flow over the Nupe sandstones zone along the rivers Niger as it runs alongside the state southern boundary. Each geological formation exhibits different topographical, hydrological and soil features which are highly influential in determining existing settlement distribution.

a. The basement complex zone

The greater part of the area underline by the basement is composed of banded gneisses and migmatrites. The meta-sediments comprise schist phillytes, quartzite and marbles. The metamorphosed representatives of ancient sediment, such as clays, sandstones and limestones respectively. The terrain of the basement complex varies from small areas of plain through large areas of undulating land scope to severally scraped slopes and rock out crops. The basement mandate crop of the form. However, crops like cowpea, Soya-beans and pigeon pea are planted to replenish the soil, complex terrain exhibit a fairly dense pattern of rivers. However, they are of only marginal value in that the majorities are seasonal and some very short lived. Indeed only those with a very large catchments area are perennial. The Suleja, Paico, Minna, Kuta, Kagara, Pandagariand Rijan area are conspicuous examples of these features [Max lock group Nigeria ltd,1980]

b. The Nupe Sandstone

The Nupe sandstone consist of weakly cemented fine to coarse-grained clays, siltstones and sandstones with locally inter bedded thin beds of carbonaceous shale. Lenses of conglomerate and pebbly sandstone also occur particularly near the contact with the underlying basement rocks.

Generally the terrain of Nupe is much more hospitable than the basement complex. Topography, therefore presents few constraints. The agricultural potential of the land is higher than that of the land is classified. The rivers network in the Nupe sandstone zone is closely related to the permeability of the geological formation, which varies from high in the north western cross to low in the Kutigi-Bida-Agaie areas. The more permeable, the less rivers it can carry rivers are less common on the Nupe sandstone zone than in the basement complex but are usually perennial for most of their course river density however varies enormously from almost non in Auna and western Mashegu district to a density equivalent to that of the basement complex in Gbako and western Agaie LGA (Max Lock group Ltd Nigeria Ltd, 1980)

2.2 HYDROLOGICAL CYCLE

All streams flow into the sea, yet the sea is not full though the streams are still flowing (Ecclesiastics 1:7). The explanation of this enigma is so well known today even to the school child that we often forget that the role play by evaporation and transpiration is far from obvious and it was not fully understood until modern times. The origin ad

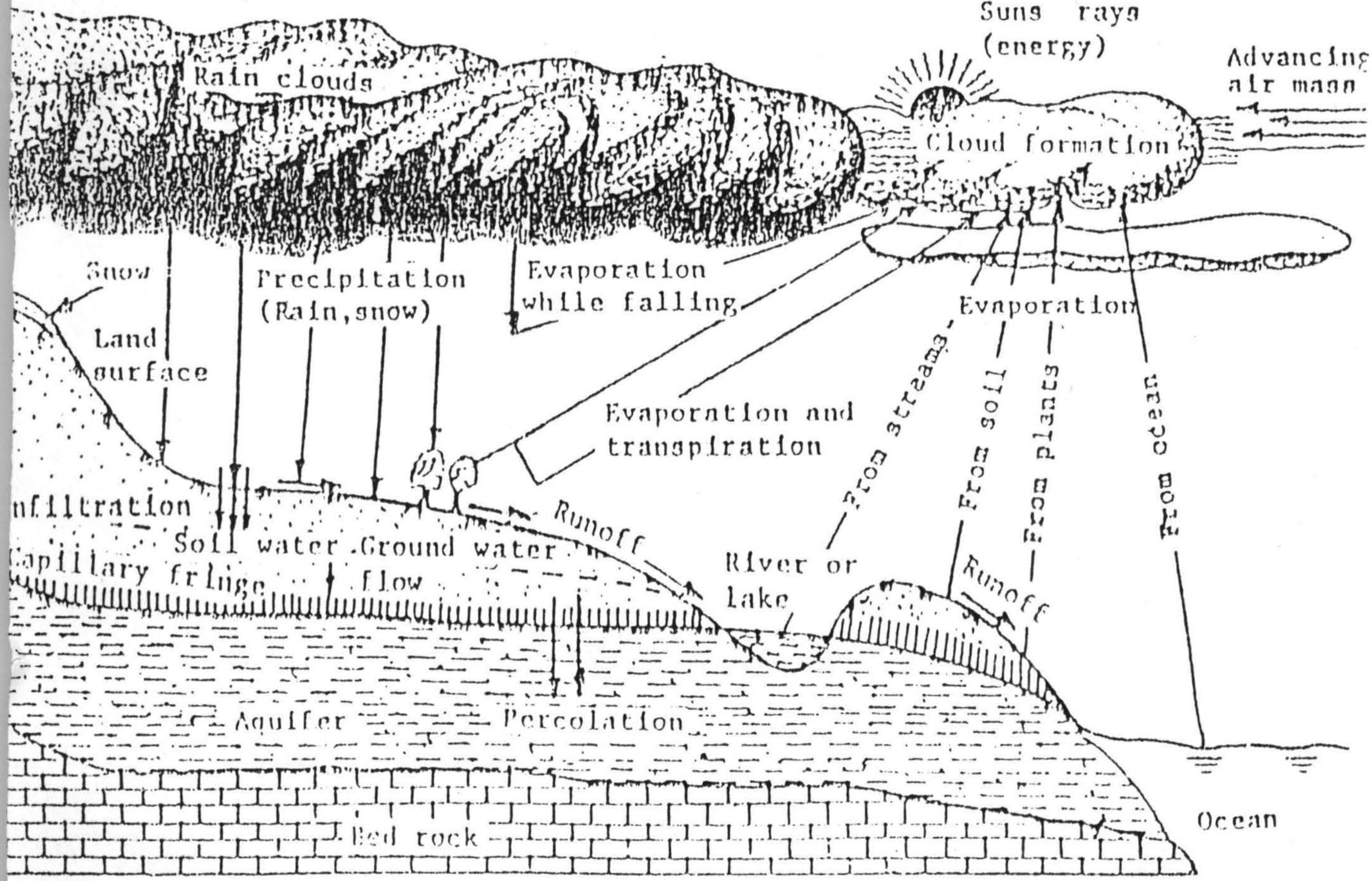


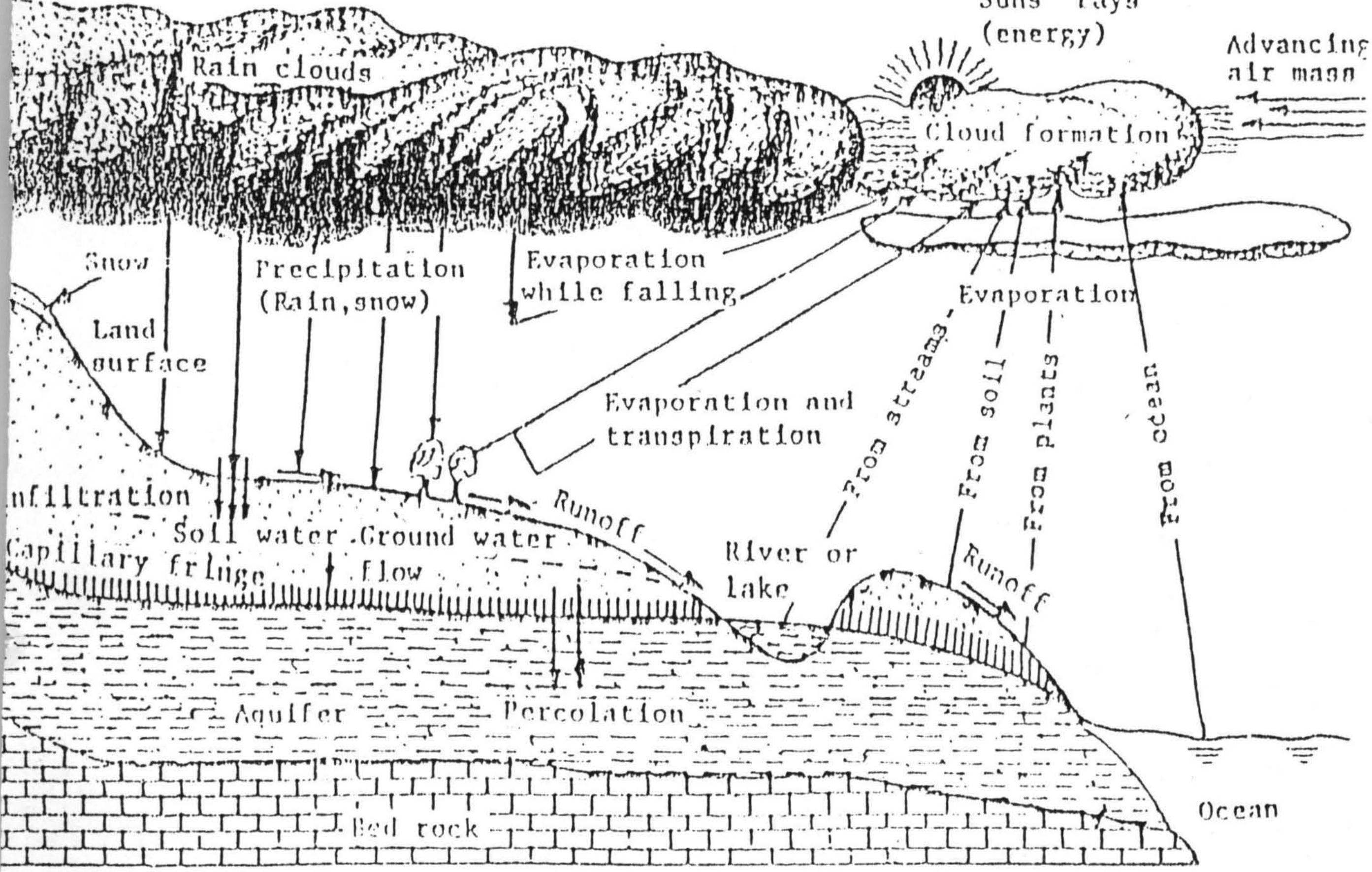
Fig 2.1: schematic diagram of hydrology cycle

2.3 PRECIPITATION

Precipitation includes all water that falls from atmosphere to the earth's surface Precipitation occurs in a variety of forms, ligerial precipitation (rain fall) and frozen precipitation (Dirisu, 1997) movement of ground water was even less obvious to the ancients. Today we can visualize the ever-changing migration of atmospheric, surface and ground water as a complex interdependent called collectively the hydrological cycle. Figure (2.1). Although the hydrologist is concerned chiefly with ground water, all aspects of the hydrological cycle must be understood at least in general way before an accurate picture of the subsurface portion of the cycle can be achieved.

The oceans are the immense reservoir from which all water returns. This statement is somewhat simplistic because not all water particles are in the process of completing the hydrological cycle at all times. They are built in loops for example when water evaporates and so on. But in it's most evaporate cycle from the ocean forms cloud, which moves inland and condense to fall to the earth as precipitation. From the earth through river and underground water runs off to the ocean. There is slow addition of water from magmatic metamorphic sources but there is also a constant subtraction of water that is incorporated in the structure of minerals within sedimentary deposits.

Geologic evidence strongly suggests that the volume of water in the oceans has remained reasonably constant during the past 500,000,000 years, so the total amount within the hydrologic cycle must have also remained nearly constant. (Stanley Davies and Roger 1966).



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2.4 HYDRAULIC CONDUCTIVITY

The hydraulic conductivity k, as applied to an aquifer, is defined as the rate of flow of water in litres per day through a horizontal cross section area of one square meter per meter at the prevailing temperature of water.

The rate of the flow of groundwater in response to a given hydraulic gradient is dependent upon the hydraulic conductivity of the aquifer (Mazumder 1983)

2.5 PERMEABILITY

Permeability is defined as the readiness with which a soil transmits fluid. Generally, water moves slowly downward through a highly dispersed soil because the swelling of dispersed clay clogs the micro pores.

Soil permeability also depends on soil texture structure and depth of water table (David, Eagle and Finney 1986).

2.6 INFILTRATION

The term infiltration refers specifically to entry of water into the soil surface. Infiltration rate has the dimensions of volume per unit of area. These units reduce to depth per unit time. Infiltration is the sole source of soil moisture to sustain the growth of vegetation and of the ground water supply of wells, springs and streams

The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile. Although such restriction often occurs at the soil surface, it may occur at some points in the lower ranges of the profile. The most important items influencing the rate of infiltration have to do with the physical characteristics of the soil and the cover on the soil surface, but such factors as soil moisture, temperature, and rainfall intensity rare also involved (Michael, 1985)

2.7 PERCOLATION

The term percolation refers to the downward movement of water through saturated or nearly saturated soil in response to the force of gravity. Percolation occurs when water is under pressure or when the tension is smaller than the atmosphere.

2.8 SEEPAGE

Seepage is the infiltration (ver4tically) downward and lateral movements of water into soil or strata from a source of supply such as a reservoir or irrigation canal. Such water may reappear at the surface as wet spot or seeps or may percolate to join the ground water or may join the subsurface flow to springs or streams. Seepage rate depends on the wetted perimeters of the reservoir or canal and the capacity of the soil to conduct water both vertically and laterally (Vaugun, 1986).

2.9 RUNOFF

Runoff is that portion of the precipitation that makes i9ts way toward stream channel, lakes, or oceans as surface or subsurface flow. The term "runoff" usually means surface flow.

Before runoff can occur, precipitation must satisfy the demands of evaporation , interception, infiltration, surface storage, surface detention and channel detention,(Orso and Glen, 1980).

2.10 SOIL-PLANT-WATER RELATIONSHIPS

Soil-plant water relationships relate to the property of soil and plant that affect the movement, retention and use of water Soil provides the room for this water to be used by plant through the roots present in the same medium. Water, as such and also are a carrier of large amount of nutrient is required in large measure for the successful growth span of a crop, it becomes essential to apply additional water to the soil for plant use in the form of irrigation. The rate of entry of water into the soil and its retention, movement and availability to plant roots are physical properties of soil in the relation to water from efficient management of irrigation agriculture. (Michael 1985)

2.11 GROUND WATER

Such surface water available for development is normally referred to as ground water. Ground water predominantly results from precipitation that has reached the zone of saturation in the earth through infiltration and percolation.

Ground water is developed for use through wells, springs and dugout ponds

In many areas where ground water is an important source of water supply, it is being withdrawn much faster than it is being replenished from infiltration and percolation of precipitation.

2.12 OCCURRENCE OF GROUND WATER

Immediately below the ground surface the soil contain both water and air .This portion is called zone of aeration and over her a saturated zone where the soil pores are filled with water under hydrostatic pressure.

After a rain infiltrated water may move downward through the zone of aeration or vadose zone. Some water dispersed through the soil and held by capillary forces in the in the smaller pores or by molecular attraction around the soil particles. Water in this upper layers of the zone of aeration known as moisture. If the retention capacity of soil in the zone of aeration is satisfied, water moves downward into regions where the pores of the soil are completely filled with the ground water will appear on the surface in a seepage zone or as a spring. it is equally possible for a ground water aquifers to become over line by impermeable material and so be under pressure such an aquifer fed from a distance ,is called a confined aquifer and surface to which the water would rise it could is called the piezometric surface. Another name, used for well drilled into such confined aquifer, its artesian wills, and the word artesian is sometimes applied also to the aquifer

2.13 WATER TABLE

The boundary between the vadose zone and the zone of saturation is termed the water table (fig2.2). Its location is determined by elevation to which water rises in unpumped wells just penetrating the top of the zone of saturation. The water table is often described as a subdued replica of the surface topography. It is commonly higher under hills than under valleys, and a contour map of the water table in area may look much like the surface topography. The water is the surface of a water body that is constantly adjusting itself towards an equilibrium condition. If there were no recharge to or out outflow from the groundwater in a basin, the water table would eventually become horizontal. Few basins have uniformed recharge conditions at the surface. Some areas receive more rain than others. Some portions of the basin have more permeable soil.

Thus, when intermittent recharge occurs, mounds and ridges form in the water table under the area of greatest recharge. Subsequent recharge creates additional mounds perhaps at other points in the basin, and the flow pattern is further changed. Super impose upon this fairly simple picture of a water table constantly adjusting toward equilibrium is rarely attained before additional disturbances occur.

Immediately above the water table there is often a capillary fringe or tension-saturated zone. In this region the pore space is completely filled with water, but capillary and molecular forces are significant so that the pressure in the water is less than atmospheric (Linsley, 1992)

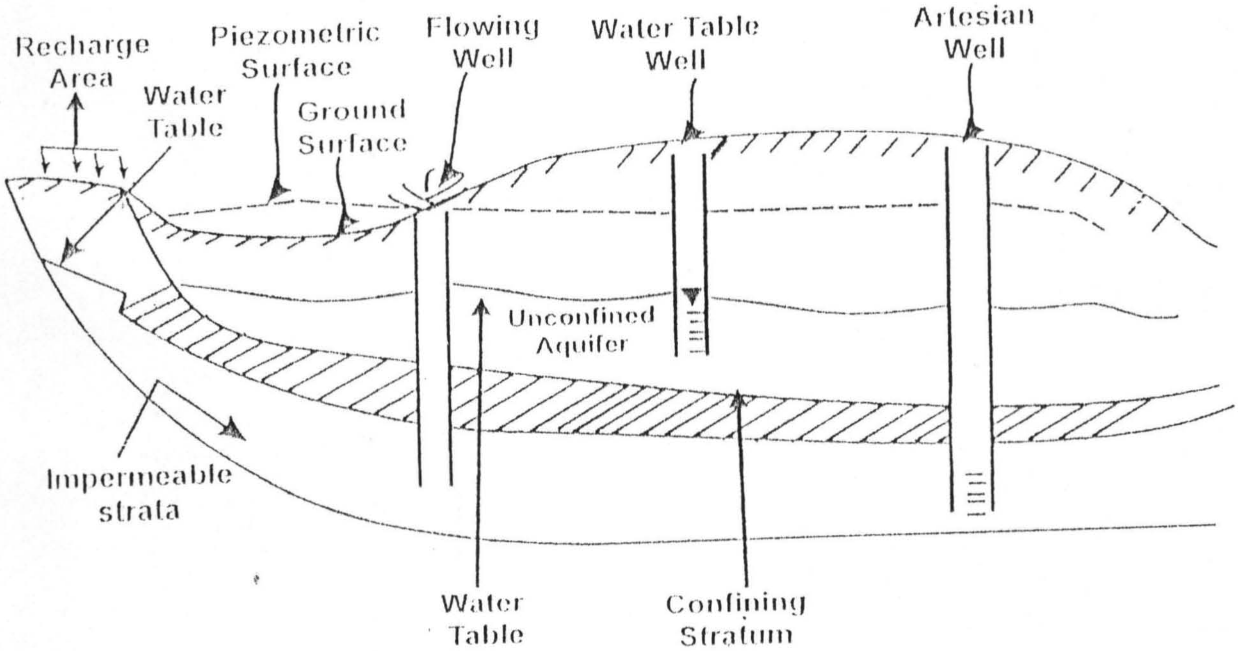


Fig 2.2: schematic diagram showing the water table

2.14 GROUND WATER LEVEL

A ground water level, whether it is the water table of an unconfined or aquifer or the piezometric surface of a confined aquifer, indicates the elevation of atmospheric pressure of the aquifer. Any phenomenon that produces a change in pressure on ground water will cause the ground water level to vary. Difference between supply and withdrawal of ground water cause levels to fluctuate. Stream flow variations are closely related to ground water levels. Other diverse influences on ground water levels include meteorological and tidal phenomena, urbanization earthquakes and external load

2.15 TIME VARIATION OF LEVELS

Secular variations: secular variations of ground water levels are those extending over periods several years or more. Alternating series of wet and dry years, in which rainfall is above and below the mean, will produce long period fluctuation of levels

Seasonal variations: many ground water levels show a seasonal pattern of fluctuation. This result from influences such as rainfall and irrigation pumping that follow well-defined seasonal cycles.

2.16 SOURCES OF GROUND WATER

The main source of ground water is precipitation, which may penetrate the soil directly to the ground water or may enter surface streams and percolate from these channels to the ground water. It should be emphasized that the ground water typically has the lowest priority on the water from precipitation. Interception, depression storage and soil moisture must be satisfied before any large amount of water can percolate to the ground water. This low priority is an important factor in limiting the rate at which groundwater may be utilized. Except where sandy soils occur, only prolonged periods of heavy precipitation can supply large quantities of water for ground water recharge. Ground water recharge is an intermittent and irregular process.

Geologic conditions determine the path by which water from precipitation reaches the zone of saturation. If the water table is near the surface their may be considerable percolation through the soil. Relatively impermeable layers above the water table may prevent such direct percolation. Stream channels that cut through permeable alluvial deposit offer a path for water to reach the ground water (figure).

Other sources of water include water from deep in the earth that is carried upward in intrusive rocs and water trapped in sedimentary rocs during their formation.

2.17 AQUIFER

Geologic formations that contain and transmit ground water are known as aquifers. Aquifers are generally classified as either confined or unconfined. A confined or artesian aquifer is bounded above and below by relative impermeable starter, so that the pressure in the aquifer may be maintained above atmospheric pressure. In contrast an unconfined (phreatic water-table) aquifer is bounded above solely by the water table and over lining vadose zone. Clearly there are various types of confining beds; the following types are well established.

Aquiclude: A saturated and relative impermeable material that does not yield appreciable quantities of water to wells, clay is an example.

Aquifuge: A saturated impermeable formation neither containing nor transmitting water, solid granite belongs to this category.

Aquitard: A saturated but poorly permeable stratum that impedes ground water movement and does not yield water freely to well, but that may transmit appreciable water to or from adjacent aquifers and, where sufficiently thick, may constitute an important ground water storage zone: sandy clay is an example.

Aquifers that are completely confined or unconfined occurred less frequently than leaky, or semi confined aquifers these are a common feature in alluvial valleys, plains or former lake basins where a permeable stratum is overlain or underlain by semi pervious aquitard or semi confined layer.

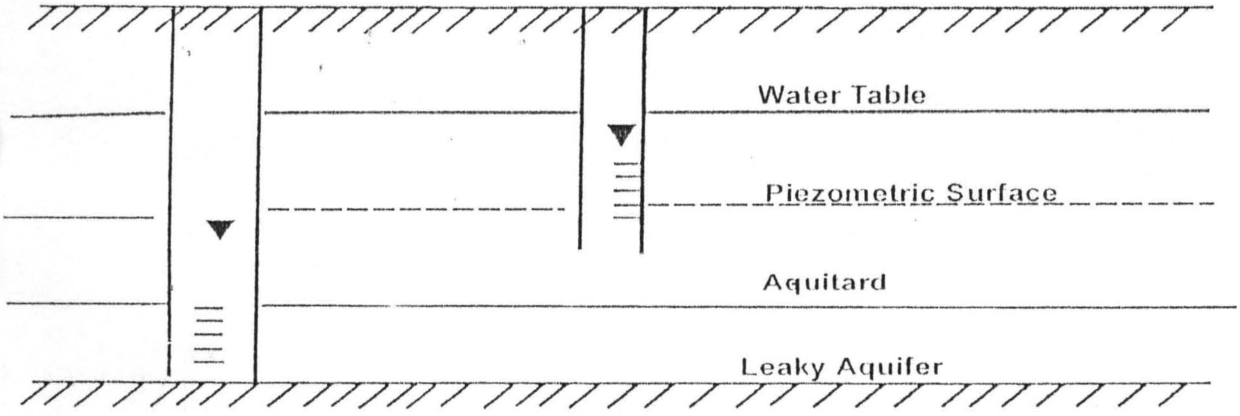


Fig 2.3: sketch of a leaky, impermeable strata or semi confined aquifer

Pumping from a well in leaky aquifer removes water into two ways; by horizontal flow within the aquifer flow and by vertical flow through the aquitard into the aquifer.

For mathematical calculations of the storage or flow of ground water, aquifers are frequently assumed to be homogenous and isotropic a homogenous aquifer possesses hydrological properties that are everywhere identical

An isotopic aquifer is one way with its properties independent of direction Such idealized aquifers do not exist; however good quantitative approximations can be obtained by these assumptions particularly where average aquifer conditions are employed on a large scale An isotropic aquifer, which possesses directional characteristic (Jacob et al 1973)

2.18 GROUND WATER BASINS

A ground water basin may be defined as a hydro geologic unit containing one large aquifer or several connected and inter-related aquifer. Such a basin may or may not coincide with physiographic unit.

The concept of water table basin becomes important because of the hydraulic conductivity that ,exist for the contain ground water resources In order to ensure contain availability of surface water, basin wide management of ground water become essential

2.19 SPRINGS

A spring is concentrated discharge of ground water appearing at the ground surface as a current of flowing water. To be distinguished from springs are seepage areas, which indicated a slower movement of ground water to the ground surface. Water in seepage area may pond and evaporates or flow depending on the magnitude of seepage, the climate and the topography

Most springs fluctuate in their rate of discharge. Fluctuations are in response to variation in rate of recharge with periods ranging to minutes to years dependent on geologic and hydrologic conditions (Fennia 1928)

2.20 IRRIGATION

Irrigation generally is defined as the application of water to soil for the purpose of supplying the moisture essential for the plant growth. However, a broader and more inclusive definition is that irrigation is the application of water to the soil for a number of the following eight purposes.

1. To add water to soil, to supply the moisture essential for plant growth
2. To provide crop insurance against short duration droughts
3. To cool the soil and atmosphere, thereby making more favourable environment for plant growth
4. To reduce the hazard of soil piping.
5. To wash out or dilute salts in the soil.
6. To reduce the hazard or frost.
7. To soften tillage pans and clogs.
8. To delay bud formation by evaporative cooling

Irrigation may be accomplished in five different ways.

1. By flooding
2. By means of furrows, large or small

3. By applying water underneath the land surface through sub irrigation thus causing the water table to rise
4. By sprinkling
5. Or trickle systems.

Water to supply moisture essential for plant group may come from five sources, none of which should be ignored when irrigation water requirements are estimated.

1. Precipitation.
2. Atmospheric other than precipitation.
3. Flood water.
4. Ground water.
5. Irrigation.

Failure to consider all five sources and the proportion of water that each supply to total plant needs may result in faulty design of an irrigation system. In some areas one of the five sources may supply the major portion of plant needs. In other areas two or more will contribute appreciable amount for plant growth. (Vaughn, Orson and Glen 1980).

2.21 DRAINAGE

Adequate drainage of crop producing Land requires a general lowering of shallow water tables. Experience has demonstrated fully the need for drainage of irrigated land. In some valleys the higher land never required drainage, but the need for drainage of the lower land is frequently a result of the irrigation of the higher land. From 20 to 30 percent of the irrigated land is arid regions need drainage to perpetuate their productivity. The reclamation of saline and alkali soils has many important phases, but adequate lowering of the water table by drainage is a first and basic necessity.

Irrigation and drainage in aerial regions are complementary particles, the necessity for drainage being increased by low efficiency in the conveyance and application of irrigation water.

Adequate drainage improves soil structure and increases and perpetuates the productivity of soils. Drainage is the first essential in reclamation of water logged saline and alkali soils.

Drainage benefits irrigation agriculture and the public in many ways for example, adequate drainage.

1. Facilitate early ploughing and planting.
2. Lengthens the crop-growing season.
3. Provide more available soil moisture and plant food by increasing the depth of root-zone soil.
4. Helps in soil ventilation.
5. Decrease of the soil erosion and gulling, by increasing water infiltration into soils.
6. Favors the growth of soil bacteria.
7. Leaches excess salt from soil, and
8. Assures higher soil temperature.

Drainage also improves sanitary and bealth condition and rural life more attractive. (Vaughn, Orson and Glen 1980)

2.22 SOIL WATER BALANCE STUDY

Once the extent of and aquifer has been established and its boundaries identified, it should be possible to quantify the volume of water that are passing through the ground water system. The amount of recharge can be assessed using information about rainfall and evaporation. Discharge from the aquifer can be estimated from spring flow measurement, stream gauges and amount of water pumped from local well. This stage of investigation constitutes a summary of all previous work and is the point at which it becomes possible to start to answer those questions, which caused you to initiate the investigation in the first place. This may include the availability of ground water resources and the suitability of the resources abstraction, or the treat of pollution from the proposed waste disposal operations.

Ground water recharge to an aquifer cannot be measured, directly but only, inferred from other measurements. As ground water is part of the hydrological cycle, measurements of other components of the cycle can be used to estimate the value of the resources, using a technique called a water balance. In this type of calculation, it is assumed that all the water leaving an area, plus or minus any change in storage. This can be written more fully as in the equation below (Barrsington, 1993).

Inflows:

The addition: (of rainfall, recharge from surface water, sea water intrusion, inflow from other aquifers, leakage, artificial recharge) equal to (abstraction, spring flow, baser flow in rivers, discharge to sea, flows to other aquifers, evaporation plus or minus (change in aquifer storage).

Type of flow:

a. Inflows

1. Rainfall: this is the most significant recharge component and consists of that proportion of rainfall, which percolates into an aquifer. Some rainfall is lost in evapotranspiration or run-off. Estimates are based on rainfall and evapotranspiration data and the consideration of the geology and ground water levels.
2. Recharge from surface water: when stream, rivers, lakes or ponds have a permeable bottom or sides, water can percolate into an aquifer when the ground water levels are lower. This recharge is estimated using Darcy's law by considering of the geology and difference between surface and the ground water levels.
3. Sea water intrusion: when the water levels in coastal aquifers are lowered by pumping, the potential exists for sea water intrusion apply Darcy's law to calculate inflows from information on ground water levels and aquifer hydraulic conductivity.
4. Flow from the aquifers: ALL aquifers, which are adjacent to the study area, should be examined as the potential sources of recharge. Geological information, ground water levels and chemical evidence will help to decide if flow is taking place across boundaries. Estimate inflow using Darcy's law.
5. Leakage: this is an artificial type of inflow caused by leakage from water supply reservoirs, water pipes and sewers, resulting from damage or deterioration.

Leakage is estimated by measuring inflows and outflows of the water supply or sewers system.

6. Artificial recharge: In some aquifers, actual recharge is artificially supplemented by water being recharge through special lagoons or boreholes. This component of recharge can be easily quantified from direct readings. Sewage disposals may sometimes also be another source of recharge water.

b. Outflows

1. Abstraction: Use metered records whenever possible otherwise estimate from the pump capacity and hours run or from the water requirement of crop.
2. Spring flows: Ground water discharge from springs can be assessed by measuring each of separately or from stream flow measurements, which will include the flow from a number of springs.
3. Base flow: The ground water component of surface water flow can be estimated from stream flow records.
4. Discharge to the sea: Ground water may discharge directly into the sea. Sometime this forms a spring-line between high and low watermarks which may be identified from the observation, temperature or conductivity measurements. Apply Darcy's law to estimate quantities involved.
5. Flow to other aquifer: Use ground water level information and flow net analysis to estimate quantities. Discharge to other aquifers may occur along boundaries, and these should be estimated in the similar manner. Used geological information,

ground water level records and chemical information to decide if such flow can occur.

6. Evapotranspiration: in areas where the water table lies close to the ground surface, plants taking water up through their leaves may remove ground water. Generally, however, evapotranspiration removes water from the soil, thereby creating a deficit, which is made good by the following precipitation. This process reduces the quantity of rainfall for recharge. Evaporation also takes place from bare soil, with water flowing upwards under capillary forms to replace losses.

CHAPTER THREE

MATERIALS AND METHODS

3.1 LOCATION AND CLIMATE OF THE PROJECT AREA

The project site was located at the inland valley of the permanent site of Guidan kwano , Nigeria (longitude 8^0- 10^0 N, latitude 5^0 7^0 E)

The climate of Nigeria is characterized by distinct wet and dry season; the wet season starts in April and ends in October with a mean maximum rainfall record in august. A maximum me\an temperature is record in March and August respectively, and relative air humidity highest in August but least in January.

3.2 EXPERIMENT LAYOUT

The site was an area spreading across a valley formation, which is 100m in breadth and 20m widths.

Only an integral portion of the field was considered for the purpose of this work. This was due to some limitations and scope of this work.

The integral portion considered covered an area of 2000 mm^2. The area was divided into section according to the slope; the upper part and the lower part of the slope. Three points A, B and C where the wells would be drilled were located along the slope; A at the upper part, B at the interface between the two sections and C at the lower part precisely at the neck of the valley. The points were located at the distance of 30m apart at the middle of the considered area.

3.3 MATERIALS AND METHOD

The materials used are hand driven auger pvc pipes, cutlass, dumpy level pegs and staff.

3.3.1 PIEZOMETER INSTALLATION

Hand driven auger of 4.2m long and 5.5×10^{2}m screw diameter was used to drill out wells at the specified locations A, B and C to the depth of 2.73, 2.61, and 1.26m respectively. The pipes were buried with their perforated end below the ground surface. At the neck of the pipe on the ground surface the clearance, between the well and the pipe was sealed up using concrete mix to disallow the vertical flow of water into the well, by run off or precipitation fig 3.1

3.3.2 INVESTIGATION METHODS

The pipes were installed on the 6th March 2001 and the readings were taking subsequently on one-week interval by using a graduated wood. The wood was inserted in the installed pipe The reading which is determined on the wood is the height of water from the bottom of well to water table. Subtracting the reading from the given piezometer gets the level of water beneath ground surface.

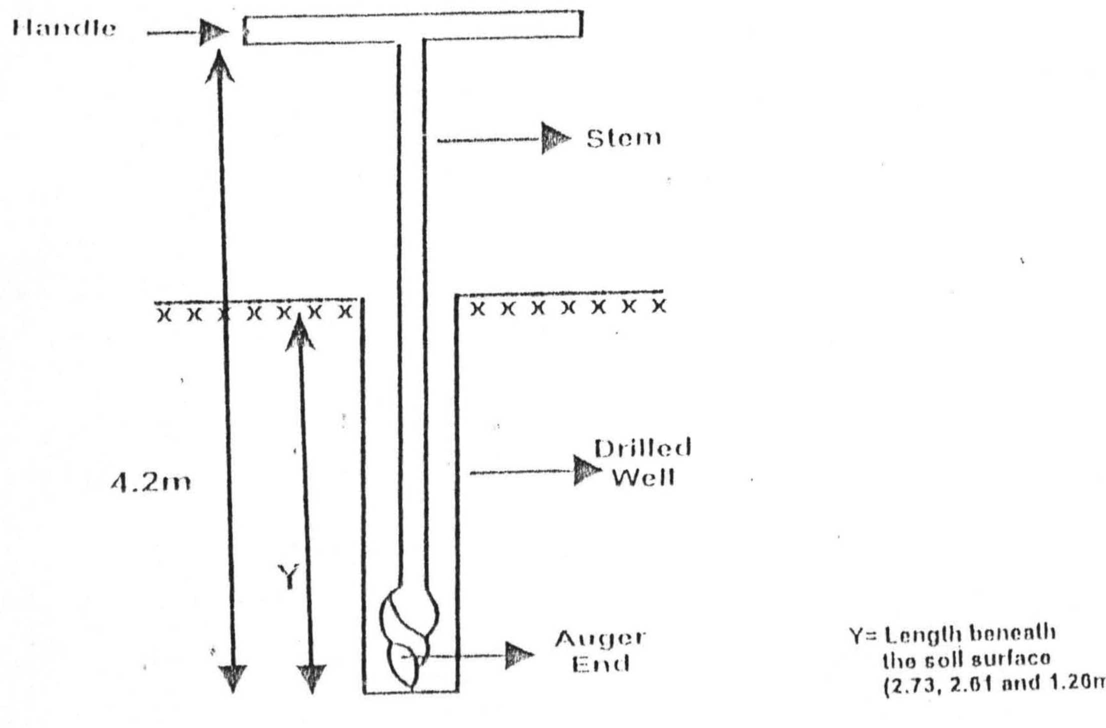


Fig 3.1: Hand drive auger used to drill out well.

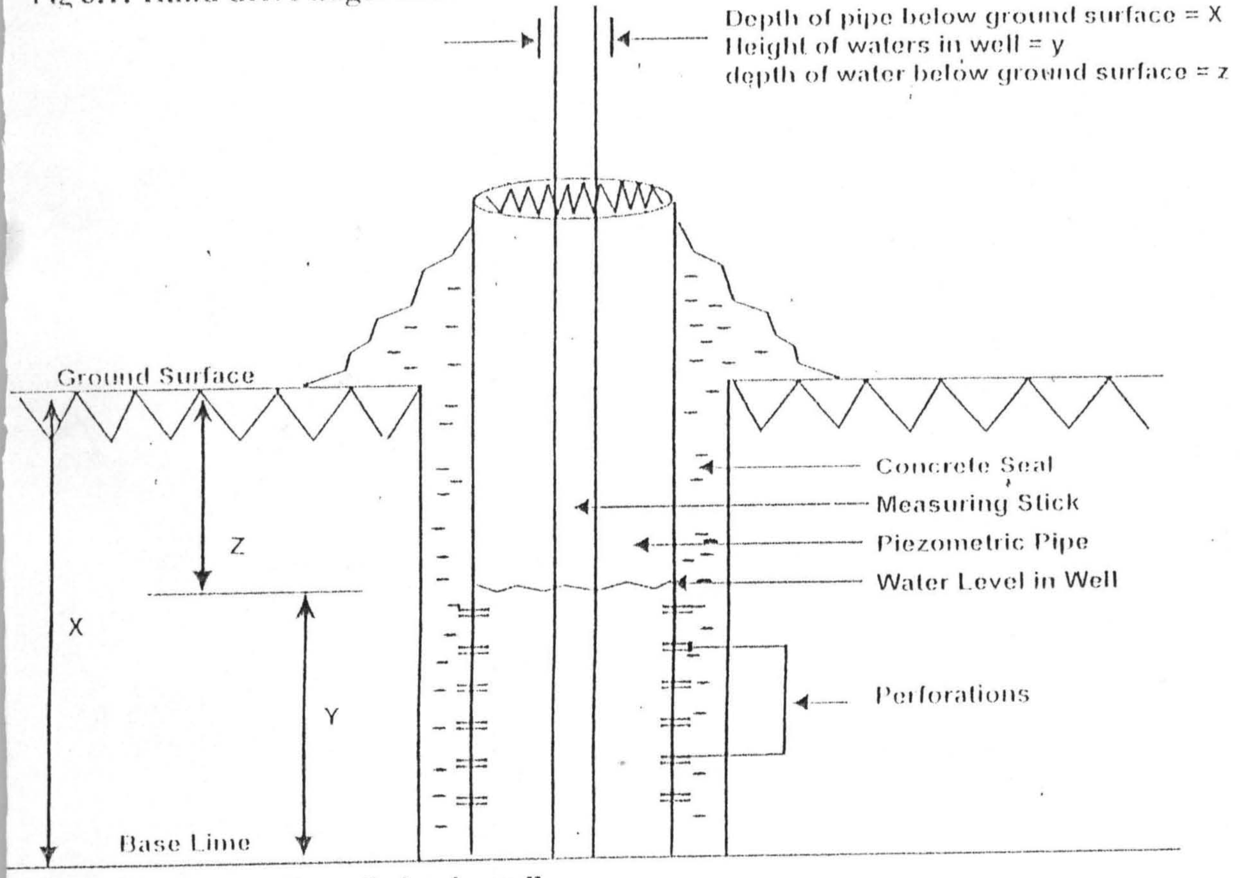


Fig 3.2: Cross section of pipe in well

3.3.3 DETERMINATION OF MOISTURE CONTENT, BULK DENSITY AND POROSITY

Core ring was used to take undisturbed soil samples. The cylinder of the core sampler, which has its cutting edge, was driven into the soil and an undisturbed soil sample was obtained within the tube. It was then removed gently by placing a cutlass under the core sampler, and then the soil was transferred into a moisture can and covered immediately so as to avoid moisture loss or gain by evaporation or condensation. The same procedure was then repeated for (20-40) cm, (40-60) cm, (60-80) cm and (80-100) cm soil depth at the upper and lower part of the slope.

The cans were clearly labeled to distinguish the sample depth and location then conveyed to the laboratory where they were weighed using an electronic weighing balance and dried in an oven at 105°C for about 24 hours until all the moisture was driven off and the sample was weighed again. The initial and final weight, the volume and weight of the can sampler were taken. The moisture content, bulk-density, and porosity were then calculated (table 4.1).

3.3.4 GRAIN SIZE GRADUATION

The soil samples were over dried and then ready for grain size analysis. The main major equipments used here are beam balance (about 0.1g sensitivity), Mechanical sieve smaller metal trays set of sieve, and brush for cleaning the sieves. The sieves were arranged in order of reducing aperture sizes. A known mass of each of the soil sample (1kgwas used throughout the project) was placed in the upper most sieves. The set of the sieve were allowed for shaking operation for five minutes for proper saving of the soil sample. After this period of time the material retained on each sieve is transferred in turn to the plan of a suitable balance onto a weighed container, any particles lodged in the soil sample retained on each sieve are recorded against the sieve aperture size. The data obtained is presented in table (4.2).

3.3.5 HYDAULIC CONDUCTIVITY

A plot of land (5x5) m^2 was marked out at the upper and lower part of the slope. Ridges were constructed around the marked plots. The plots were then saturated (flooded) with water for two days to allow the water to sink to a depth of 1m. The plot were then mulched and covered with polythene sheets to prevent evaporation.

Soil s ample were collected hourly at depths (0-20) cm, (20-40) cm and (80-100) cm for six hours on the first day and there after, daily for the next six days.

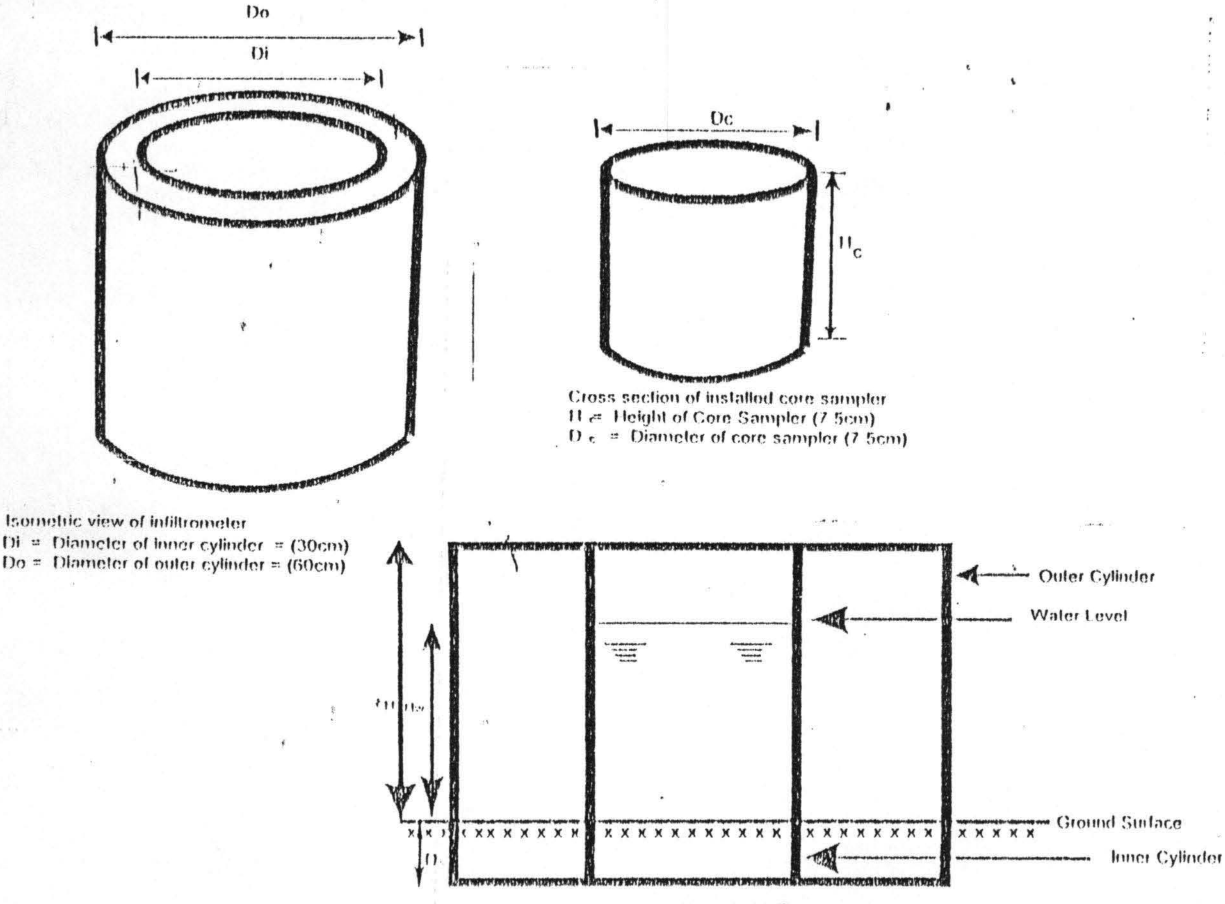
The soil samples were collected in tins a covered with polythene sheet to prevent gain or loss of moisture. The tins and their contents were conveyed to laboratory, where they were weighed and oven dried for 24 hours, after which they were reweighed. The volumetric moisture content for each dept was determined and the hydraulic conductivity was calculated as in table4.3.

3.3.6 DETERMINATION OF INFILTRATION RATE

The infiltration rate was determined by using the cylinder infiltrometer method. The cylinders were about 25cm deep and were formed of 2mm rolled steel thin enough to enter the soil with a minimum of disturbance. The inner and outer cylinders were 30 and 60cm diameter respectively. They were installed at about 10cm depth in the soil. Care should be taken to keep the installation depth. This was accomplished by marking the outside of the cylinder at the desired level and driving the cylinders up to the mark by using a falling weight type hammer striking on a wooden plank placed on the top of the cylinder. The water was poured in the inner and outer cylinder on a small grass placed to avoid pudding.

Simultaneously the stopwatch was started. An ordinary plastic ruler measures the water level in inner cylinder at an interval of 20 minutes.

After each reading the cylinders were filled back to the referential level, which is 11cm(see table 4.4)



Cross section of installed core sampler
H c = Height of Core Sampler (7.5cm)
D c = Diameter of core sampler (7.5cm)

Isometric view of infiltrometer
Di = Diameter of inner cylinder = (30cm)
Do = Diameter of outer cylinder = (60cm)

cross section of installed infiltrometer
H = Height of cylinder (25cm)
Hw= Height of water ponded (11cm)
Ds = Depth of cylinder in the soil (4cm)

Fig3.3 : Inflitrometer

CHAPTER FOUR

RESULTS AND DISCUTIONS

The focus of this chapter is on of the results of different experiment carried out ranging from field to laboratory experiment as well as the discussions of theses results and comparison of present water table data (2002) and the former one (2001)

4.1. PHYSICAL PROPERTIES OF THE SOIL

The mechanical analysis of the soil sample collected both at the upper and lower part of the slope and at different depth was tabulated in table (4.1)

From this table both the upper lower part had almost the same percentage of sand, silt and clay fraction.

While measuring on the textural triangle, it was discovered that the samples flitted into loamy class at the depth of (0 to20 cm), loamy clay at the depth (20 to 40 cm) and clay class at depth (40-100cm).

Table (4 2) contains the parameters obtained for soil moisture con tent analysis carried out on the field and in the laboratory. Moisture content was observed to be higher at the upper part of the slop. This could be as a result of ponding that usually take place in the area as a result of depression storage precipitation. The low moisture content recorded at the lower part of the slope could be as a result of the seasonal stream channel situated at the bottom of the slope which serves as a point of discharge or drainage channel for the water in the lower part of the slope. At both the upper and the lower part of the slope, the moistures content decreased with increase in depth up to 60cm. But from60cm, the moisture content started increasing up to 100cm. This could be attributed to capillary rise above water table as the water tables were at a depth of about 100cm. Porosity and available moisture holding capacity were observed to increase with increase in moisture content. On the other hand both wet bulk density and dry bulk density varies from depth to depth.

The hydraulic conductivity differ from 1.25 to 0.01 cm/h at the upper part of the slope and from 1.92 to 0.01 cm /h at the lower part. The low hydraulic conductivity nature of clay soil was responsible for the low value obtained.

The rate of infiltration decreases with time and was faster at the lower part of the slope than at the upper part (see table 4.4). This could be as a result of the presence of a seasonal stream channel at the lower part of the slope, which serves as means of drainage in the area.

TABLE 42 SOME SOIL PHYSICAL PROPERTIES (MOISTURE CONTENTS, BULK DENSITY, POROSITY, AVAILABLE AT THE PROJECT SITE)

	I	II	III	IV	V	VI	VII	VIII	IX
Sections	Depth (cm)	Weight of wet soil (g)	Weight of dry soil (g)	Moisture content (%) $\frac{(II-III)}{III} \times 100$	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	Porosity (%) $1-\frac{v}{vi} \times 100$	Available moisture holding capacity (cm/m IV x V)	Available moisture holding capacity in root zone (cm/m.)
Upper part of The slope	0- 20	360.90	299.50	20.50	1.76	2.12	16.98	36.08	
	20-40	334.00	280.10	19.20	1.65	1.96	15.82	31.68	
	40 -60	351.30	295.20	19.00	1.74	2.07	15.94	33.06	
	60 – 80	352.00	288.50	22.00	1.70	2.07	17.87	37.40	
	80 -100	371.00	298.50	24.50	1.75	2.18	19.73	42.88	181.10
Lower part of the slope	0-20	365.14	307.10	18.90	1.81	2.15	15.81	34.21	
	20-40	352.66	297.60	18.50	1.75	2.08	15.87	32.38	
	40 - 60	353,13	299.01	18.10	1.76	2.08	15.39	31.86	
	60-80	345.52	285.51	21.02	1.68	2.03	17.24	35.31	
	80 - 100	367.63	297.80	23.45	1.75	2.16	18.98	41.04	174.80

N.B. VOLUME OFCORE SAMPLER = 170.00cm^3

TABLE4.3:CLINDER INFILTROMETER TEST AT F.U.T PERMANENT SITE (PROJECT SITE)

UPPER PART OF THE SLOPE

LOWER PART OF THE SLOPE

TIME (Min)	Water Level (cm)	Readings (cm)	Difference Depth (cm)	Accumulated Infiltration (cm)	Average Infiltration Rate (cm/hrs)		Readings (cm)	Difference Depth (cm)	Accumulated Infiltration (cm)	Average Infiltratio Rate (cm/hrs
0.0	11.00	11.00	-	-	-		11.00	-	-	-
10.00	11.00	9.80	1.20	1.20	7.20		9.65	1.35	1.35	8.10
20.00	11.00	9.80	1.20	2.40	7.20		9.67	1.33	2.68	7.98
40.00	11.00	10.10	0.90	3.30	2.70		9.81	1.19	3.87	3.57
60.00	11.00	10.00	1.00	4.30	3.00		9.80	1.20	5.07	3.60
80.00	11.00	10.20	0.80	5.10	2.40		9.85	1.15	6.22	3.45
100.00	11.00	10.20	0.80	5.90	2.40		9.84	1.16	7.38	3.48
120.00	11.00	10.21	0.79	6.69	2.37		9.95	1.05	8.43	3.15
140.00	11.00	10.20	0.80	7.49	2.40		9.95	1.05	9.48	3.15
160.00	11.00	10.20	0.80	8.29	2.40		9.97	1.03	10.51	3.09
180.00	11.00	10.40	0.60	8.89	1.80		9.96	1.04	11.55	3.12

TABLE 4.3:CLINDER INFILTROMETER TEST AT F.U.T PERMANENT SITE (PROJECT SITE)

UPPER PART OF THE SLOPE

LOWER PART OF THE SLOPE

TIME (Min)	Water Level (cm)	Readings (cm)	Difference Depth (cm)	Accumulated Infiltration (cm)	Average Infiltration Rate (cm/hrs)		Readings (cm)	Difference Depth (cm)	Accumulated Infiltration (cm)	Average Infiltration Rate (cm/hrs)
0.0	11.00	11.00	-	-	-		11.00	-	-	-
10.00	11.00	9.80	1.20	1.20	7.20		9.65	1.35	1.35	8.10
20.00	11.00	9.80	1.20	2.40	7.20		9.67	1.33	2.68	7.98
40.00	11.00	10.10	0.90	3.30	2.70		9.81	1.19	3.87	3.57
60.00	11.00	10.00	1.00	4.30	3.00		9.80	1.20	5.07	3.60
80.00	11.00	10.20	0.80	5.10	2.40		9.85	1.15	6.22	3.45
100.00	11.00	10.20	0.80	5.90	2.40		9.84	1.16	7.38	3.48
120.00	11.00	10.21	0.79	6.69	2.37		9.95	1.05	8.43	3.15
140.00	11.00	10.20	0.80	7.49	2.40		9.95	1.05	9.48	3.15
160.00	11.00	10.20	0.80	8.29	2.40		9.97	1.03	10.51	3.09
180.00	11.00	10.40	0.60	8.89	1.80		9.96	1.04	11.55	3.12

TABLE 4.4 HYDRUALIC CONDUCTIVITY (UNSATURATED) OF SOIL WITHIN EXPERIMENTAL PLOTS AT FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA PERMANENT SITE FARM (PROJECT SITE)

Upper Part of the slope | Lower part of the slope

$\bar{\theta}$	$L\bar{\theta}$ (cm)	t (h)	$L\Delta\bar{\theta}$ (cm)	Δt (h)	K ($\bar{\theta}$) (cm/h)		$\bar{\theta}$	$L\bar{\theta}$ (cm)	t (h)	$L\Delta\bar{\theta}$(cm)	Δt (h)	K($\bar{\theta}$) (cm/h)
0.2193	21.93	0					0.2104	21.04	0			
0.2001	20.01	1	-1.92	1	1.92		0.1979	19.79	1	-1.25	1	1.25
0.1885	18.85	4	-1.16	3	0.39		0.1870	18.70	4	-1.09	3	0.36
0.1695	16.95	18	-1.9	14	0.14		0.1690	16.90	18	-1.8	14	0.13
0.1534	15.34	42	-1.61	24	0.07		0.1532	15.32	42	-1.58	24	0.06
0.1506	15.06	66	-0.28	24	0.01		0.1505	15.05	66	-0.27	24	0.01

$\bar{\theta}$ = Average water content

L = Thickness of the profile = 100cm

t = Time (h)

K($\bar{\theta}$) = Hydraulic conductivity = $-\dfrac{L\Delta\bar{\theta}}{\Delta t}$ (cm/h)

4.2 TREND OF WATER TABLE FLUCTUATION

The water table measurement below the ground surface was shown in appendix1. It was observed that the three wells fluctuate in deferent manner. Some areas receive more recharge and discharge more than the others. It was also observed that well A was flooded from July to October with its peak being reached in July. This is due to depreciation, which usually store precipitation water (appendix 8).

Well B had the highest water table which rose from August to October with peak being reached in September. This could be as a result of its evolution compare to other wells. The rise of water table from August to October is due to the recharge water from flooded areas around A and from the seasonal stream.

But well C fluctuation depends more on the seasonal stream, which affect the well In two ways:

i. The well is discharging to the stream when its level is higher than the water level in the stream.(from march to may).

ii. The stream recharges the well during the period of August to September, because the stream was filled up that time. This explains the constant level of water through this period in the well.

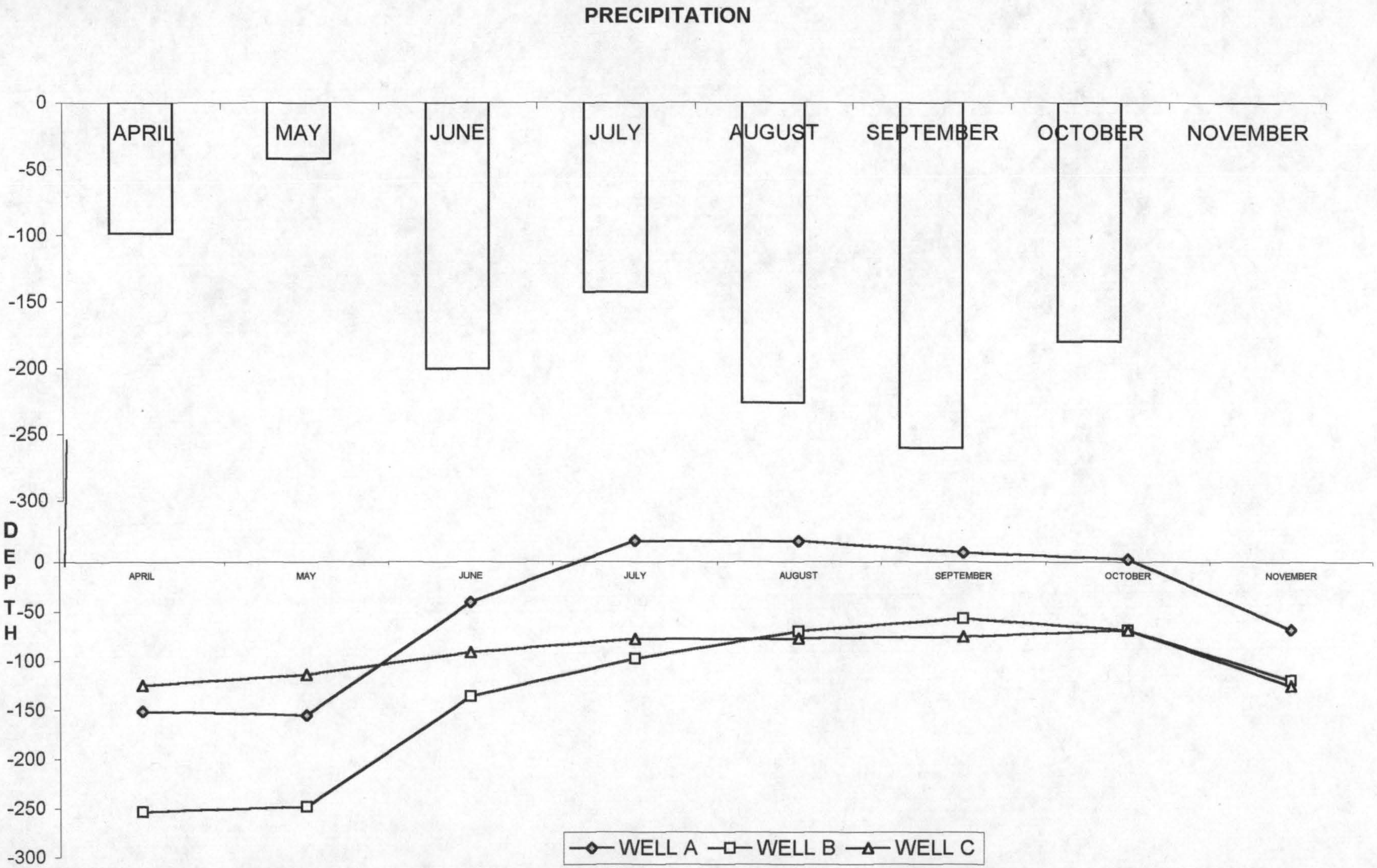


FIG 4.1 WATER LEVEL FOR WELL A, B AND C

4.3 WATER TABLE DEPTHS COMPARISION (2001&2002)

The comparison of the data of 2001 and 2002 consists of doing the difference between the two data (see appendix3).

From fig 4.2 it can be easily observed that the water table for 2002 is higher than the water table of 2001. The statistical test shows the significant difference between the two data. This was due to the high rainfall recorded in 2001 (1363.2) compare to 2002 (1152.8). This proof that well A depends directly on the rainfall since it is located in water logged area.

For well B and c, the water table depends mostly to the recharge from the stream channel and the upstream areas. This explains the crossing of the curves at different points (see fig4.3 & 4.4).

At times 2001 data are higher than 2002 data at times lower. This proofs that the water table in these areas depends indirectly to the rainfall.

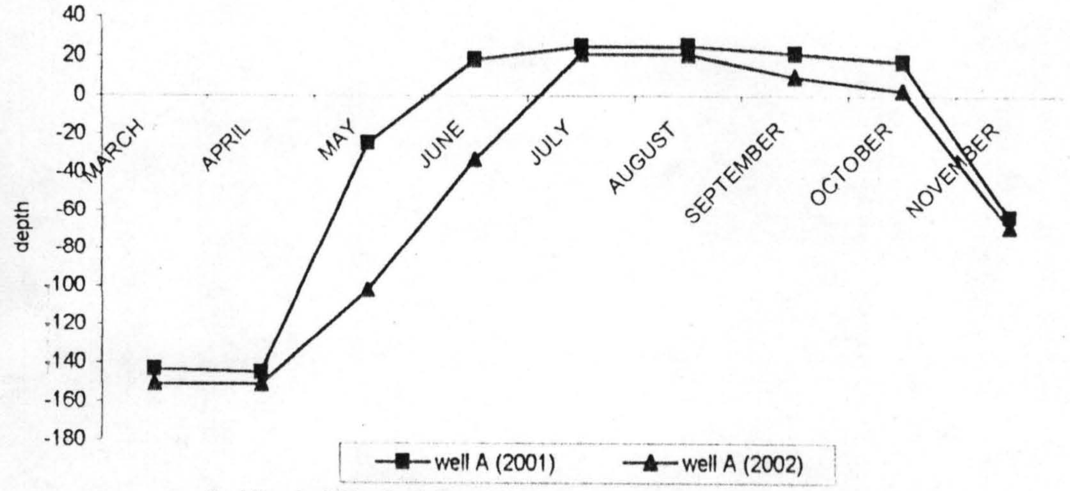


fig 4.2 water table depth in well A (2001 & 2002)

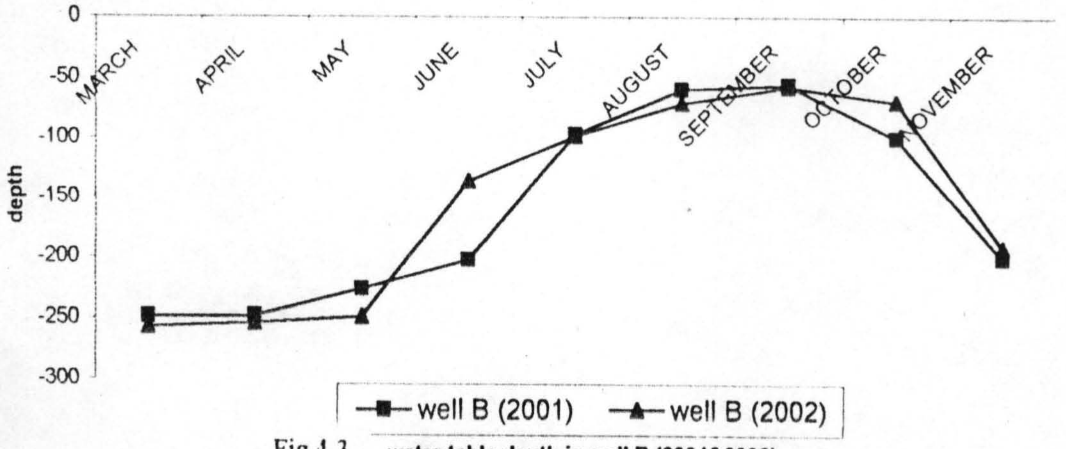


Fig 4.3 water table depth in well B (2001&2002)

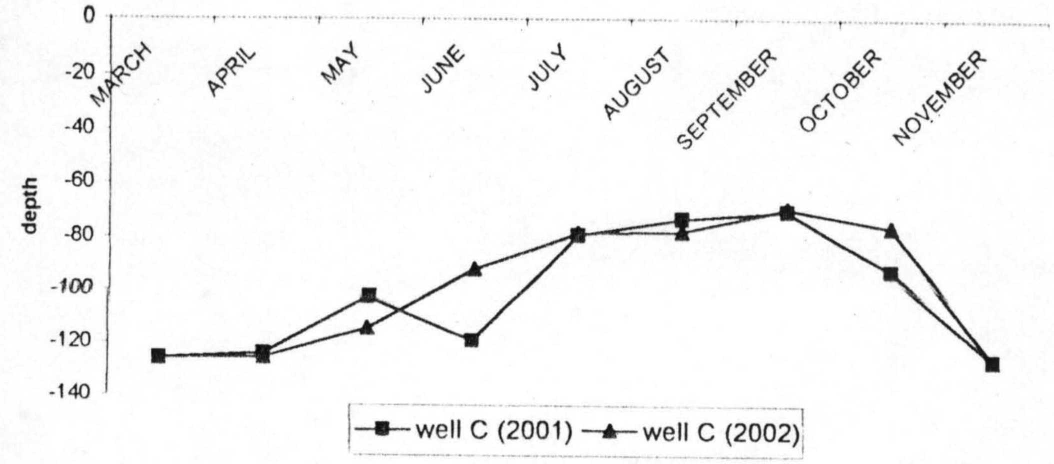


Fig 4.4 water table depth in well C (2001&2002)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

All the field and laboratory experiment carried out, it was discovered that the ject side had a loamy soil and clayey sub soil with low hydraulic conductivity and high isture content at the upper part of the slope, which decreased at the lower part.

The investigation on water table fluctuation on the project side, showed that und water flow from the upper part of the slope to the lower part. And the maximum harge stated from July to October with a water table above the depth of 100 cm while e discharge stated in October.

The analysis of 2001 and 2002 data showed that the water table had almost the me trend of fluctuation with a few difference due seasonal stream influence and the ount and distribution of rainfall.

Different crops can be planted on the pr0ject side according to their effective oting depths.

5.2 RECOMMENDATIONS

- The monitoring of the water table depth should continue for better understanding of the trend of perched water table movement
- It is recommended that crops such as maize, soybean, sugar beet, rice should be planted at the project side
- Furthermore effective monitoring of soil related properties as well as factors that cause water table fluctuation would generate more accurate data.

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APPENDIX 1 : WEEKLY WATER TABLE MEASUREMENT AT THE PROJECT SITE

MONTHS	MARCH				APRIL				MAY				JUNE				JULY			
DATES WELLS	10th	17th	24th	31th	8th	16th	24th	30th	7th	14th	21th	28th	5th	11th	18th	25th	2sd	10th	18th	27th
A				151	150	148	150	157	103	100	103	106	103	80	-10	-10	-20	-18	-25	-21
B				249	251	252	255	257	252	254	248	241	180	140	123	103	100	101	98	96
C				126	126	126	126	124	123	109	105	120	109	101	82	76	80	75	78	80

AUG				SEPT				OCT				NOV			
1st	9th	16th	25th	1st	8th	16th	24th	2nd	10th	18th	27th	4th	11th	18th	25th
-19	-21	-22	-21	-25	-3	-7	-2	-6	0	-4	0	20	34	48	173
92	59	70	63	50	57	59	63	49	53	71	104	117	124	260	261
76	74	80	81	79	82	74	69	60	71	74	72	126	126	126	126

APPENDIX 2 : MEAN MONTHLY WATER TABLE AT THE PROJECT SITE.

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBRE	OCTOBER	NOVEMBER
A	151.0	151.25	102	40.75	-21	-20.75	-9.25	-2.50	68.75
B	249	253.75	248.75	136.50	98.75	71	57.25	69.25	190.75
C	126	125.50	114.25	92	78.25	77.75	76	69.25	126

APPENDIX 3 : COMPARISION OF WATER DEPTH DURING 2001-2002 FOR : WELL A, WELL B, WELL C

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV
A_1	143.3	145	24.8	-18	-24.5	-25	-21.2	-17	63
A_2	151	151.25	102	40.75	-21	-20.75	-9.25	-2.5	68.75
A_1- A_2	-8	-6.25	-77.20	-58.75	-3.40	-4.25	-11.95	-14.50	-5.75

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV
B_1	257	248.05	226.03	202	96.08	59.03	55.04	99.08	200
B_2	249	253.75	248.75	136.05	98.75	71	57.27	69.25	190.75
B_1- B_2	8	-5.25	-22.45	65.50	-1.95	-11.70	-1.85	30.55	9.25

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV
C_1	126.00	124	102.50	119.00	79.00	73.00	70.20	92.50	126.00
C_2	126	125.50	114.25	92	78.25	77.75	76	69.25	126.00
C_1- C_2	0	-1.50	-11.75	27	0.75	-4.75	-5.80	22.95	0.00

APPENDIX 4: STATISTICAL TEST FOR THE SIGNIFICANCE OF THE DIFFERENCE IN THE DATA OF 2001 AND 2002

This test assumes that 2001data are the expected frequencies, while the 2002 data are the observed frequencies.

Apply the x^2 (chi squared) test

i.e. $x^2 = \Sigma[(0-E)^2/E]$

0 = observe value

E = expected value

Level of significance: $\alpha = 0.05$ or 5%

Degree of freedom = (r-1) (c-1)

Where r stands for rows and c for columns.

Df = (2-1) (9 -1) = 1*8 = 8

From the x^2 table at α = 5%and Df = 9 a critical value of 15.51 is obtained (see appendix)

so $x^2 = 15.51$

For well A

Hypothesis:

H_0: there is no statically significant indifference between 2001 and 2002 data of well A

H_1: there is statically significant difference between 2001 data and 2002 data of well A.

Decision

$X^2_A = \Sigma[(0-E)^2/E] = 30.46$ (see table 4.10)

30.46 > 15.51; H_0 is rejected.

Interpretation

There is a significant difference between the data.

So H_1 is accepted.

For Well B

Hypothesis:

H_0: there is no statistically significant difference between the 2001 and 2002 data of well B

H_1: there is statistically significant difference between 2001 and 2002 data of well B

Decision:

$X^2_B = \Sigma[(0-E)^2/E] = 35.97$ (see table 4.11)

$35.97 > 15.51$, H_0 is rejected.

Interpretation

There is significant difference between the data. So the H_1 is accepted.

FOR WELL C

Hypothesis

H_0: There is a no statistical significant difference between 2001 data and 2002 data of well c.

H_1: There is statistical significant difference between 2001data and 2003 data of well c.

Decision

$X^2_C = \Sigma[(0-E)^2/E] = 14.104$ (see table 4.12)

$14.104 < 15.51$, H_o is accepted

Interpretation

There is no significant difference between the data so H_1 is rejected

APPENDIX5 :CHI SQUARED TEST TABLES FOR : WELL A, WELL B, WELL C

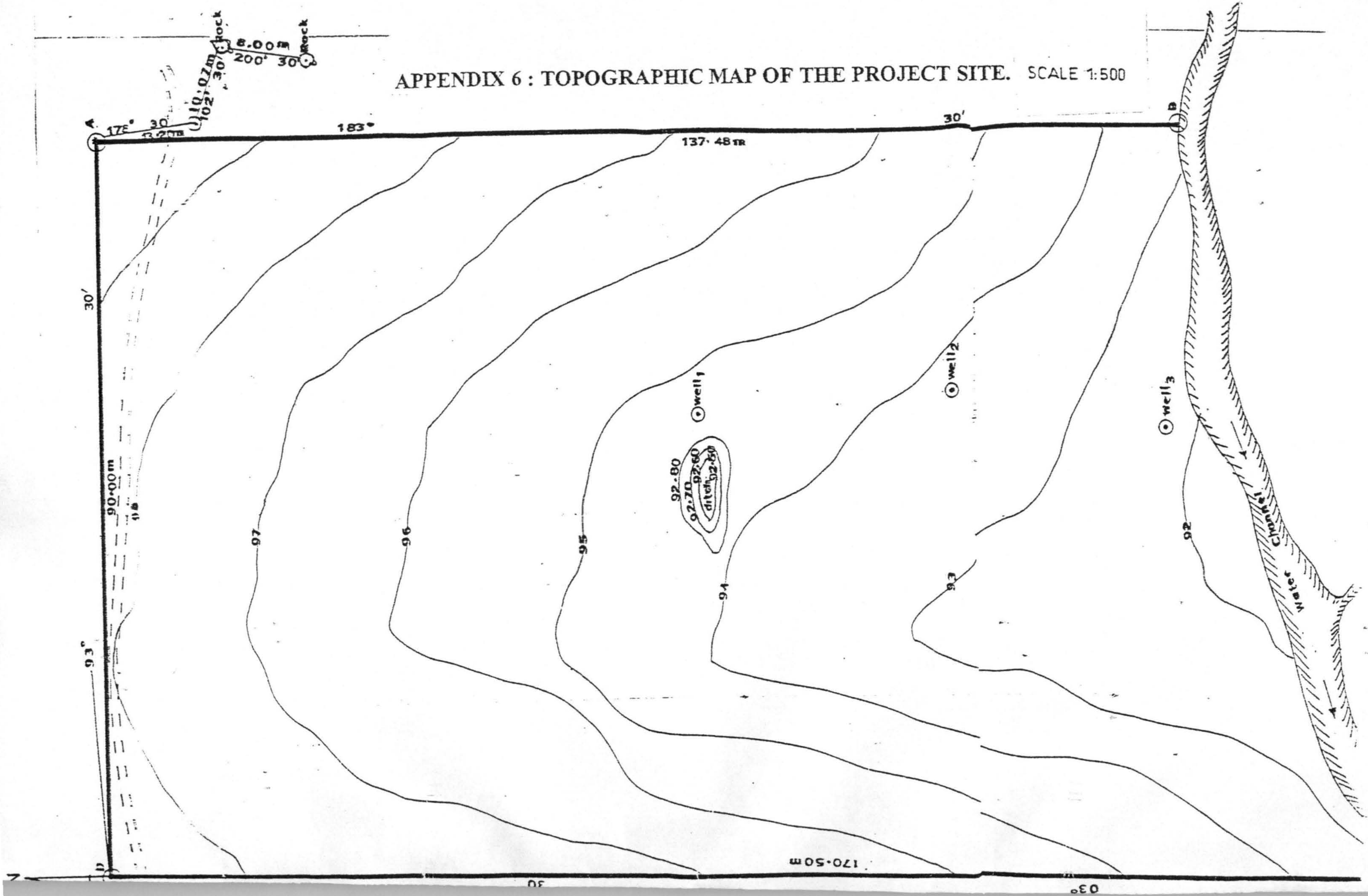
	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	TOTAL
O (A_2)	151	151.25	102	40.75	-21	-20.75	-9.25	-2.5	68.75	460.25
E (A_1)	143.3	145	24.8	-18	-24.5	-25	-21.2	-17	63	270.4
$\frac{(O-E)^2}{E}$	0.41	0.26	240.31	-191.75	-0.5	-0.722	-6.73	-12.36	0.52	30.46

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	TOTAL
O (B_2)	249	253.75	248.75	136.05	98.75	71	57.27	69.25	190.75	1375
E (B_1)	257	248.05	226.03	202	96.08	59.03	55.04	99.08	200	1445.01
$\frac{(O-E)^2}{E}$	0.24	0.11	2.22	21.23	0.039	2.30	0.061	9.35	0.42	35.95

	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	TOTAL
O (C_2)	126	125.50	114.25	92	78.25	77.75	76	69.25	126	885
E (C_1)	126.00	124	102.50	119.00	79.00	73.00	70.20	92.50	126.00	912.20
$\frac{(O-E)^2}{E}$	0.00	0.018	1.34	6.12	0.007	0.30	0.47	5.84	0.00	14.104

APPENDIX 6 : TOPOGRAPHIC MAP OF THE PROJECT SITE.

SCALE 1:500



APPENDIX7 : TOTAL MONTHLY RAIN FALL (mm) (1992-2002)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1992	0.00	TR	TR	1.30	158.20	176.80	162.90	196.40	231.50	230.30	0.00	379.50
1993	0.00	0.00	0.00	0.00	174.40	170.50	189.70	271.10	178.30	63.30	46.60	0.00
1994	0.00	0.00	7.30	72.50	114.40	239.00	142.50	367.20	261.30	208.10	0.00	0.00
1995	0.00	0.00	0.00	100.50	123.20	144.50	153.70	409.00	189.10	135.70	0.00	0.00
1996	0.00	0.00	0.00	48.60	164.70	225.00	259.70	257.00	191.10	127.90	236.00	0.00
1997	0.00	0.00	3.60	80.60	238.40	233.00	172.40	192.90	273.30	115.0	0.00	0.00
1998	0.00	TR	TR	92.20	221.20	221.00	155.50	243.00	261.90	212.60	6.10	0.00
1999	0.00	7.90	0.00	35.70	102.80	164.20	243.90	254.70	237.10	212.20	0.00	0.00
2000	0.00	0.00	0.00	3.60	135.90	161.00	208.80	308.50	303.00	153.40	0.00	0.00
2001	0.00	0.00	0.00	93.90	139.00	331.70	244.60	230.20	298.80	25.70	0.00	0.00
2002	0.00	0.00	0.00	98.80	42.60	201.00	143.00	226.50	260.60	180.30	0.25	0.00
TOTAL	0.00	7.90	10.89	408.70	1515	2268.20	2076.40	2947.20	2685.60	1664.40	288.45	379.50
MEAN	0.00	0.72	0.99	37.15	137.72	206.20	188.76	267.92	244.14	151.30	26.22	34.50

SOURCE : DEPT OF METEOROLOGICAL SERVICES
MINNA AIRPORT, NIGER STATE

APPENDIX 8: TOTAL MONTHLY TEMPERATURE (°C) (1992-2002)

YEAR	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEP	OCT	NOV	DEC
1992	26.50	29.35	31.15	29.55	28.25	26.30	25.65	25.30	25.55	27.15	27.30	27.40
1993	26.65	27.60	30.40	31.50	29.40	26.85	25.70	25.55	25.50	27.25	xxx	27.65
1994	27.25	29.90	32.20	30.50	28.45	26.65	26.05	25.25	25.80	26.20	26.70	26.45
1995	26.75	29.40	31.95	31.30	28.40	27.10	26.10	25.40	26.10	26.75	27.15	26.75
1996	27.75	30.25	31.60	31.30	20.05	26.00	25.25	24.70	25.45	25.95	26.25	26.70
1997	28.20	28.35	30.85	29.80	27.50	26.60	25.85	26.30	26.20	26.85	27.20	26.90
1998	27.30	31.15	32.25	32.35	28.95	27.10	26.10	25.35	25.95	26.95	27.80	27.65
1999	28.05	29.90	32.05	31.65	28.95	27.05	25.70	25.35	25.70	26.95	27.65	27.25
2000	28.70	28.60	31.70	31.75	30.50	26.25	25.60	25.20	25.95	26.95	27.10	26.65
2001	27.65	29.95	31.55	30.35	28.95	26.40	25.55	25.00	25.20	27.05	26.55	27.50
2002	26.80	29.62	32.24	30.85	30.30	27.00	26.23	25.858	25.85	26.55	27.35	27.20
TOTAL	301.68	324.11	347.97	340.75	317.77	293.27	284.13	279.21	283.21	293.60	271.05	298.12
MEAN	27.42	29.46	31.63	39.97	28.88	26.66	25.83	25.38	25.74	26.79	24.64	27.10

SOURCE : DEPT OF METEOROLOGICAL SERVICES
MINNA AIRPORT, NIGER STATE