AN INVESTIGATION INTO THE CAUSES OF WATERLOGGING AT ZAURO POLDER PILOT PROJECT SCHEME, BIRNIN KEBBI.

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CERTIFICATION

This is to certify that, this project on an investigation into the causes of waterlogging at Zauro Polder Pilot Project Scheme Birnin Kebbi was carried out in partial fulfillment for the award of Post graduate diploma (PGD) in Agricultural Engineering and has been read and approved by: -

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ABSTRACT

It was imperative to investigate the cause of waterlogging at Zauro Polder Project Pilot Scheme when the situation kept deteriorating. It was realized that presently less than eighty percent of the arable land in the scheme is in cultivable condition. In order to find out these causes, a reconnaissance survey was carried out, observations made from this survey coupled with close study of the soil map and level of grid points on the scheme showed that waterlogging might be due to either one or more of the following factors: - Lack of surface outflow, lack of effective drainage, excessive inflow of water, sub-soil flows and lack adequate percolation. To improve the conditions in the pilot scheme, a proper leveling of the site should be carried out so that free surface outflow can be achieved, the drains and the canals should be regraded so that smooth inflow and outflow can be obtained and there should be adequate monitoring of the lateral canals in order to forestall illegal activities of the farmers.

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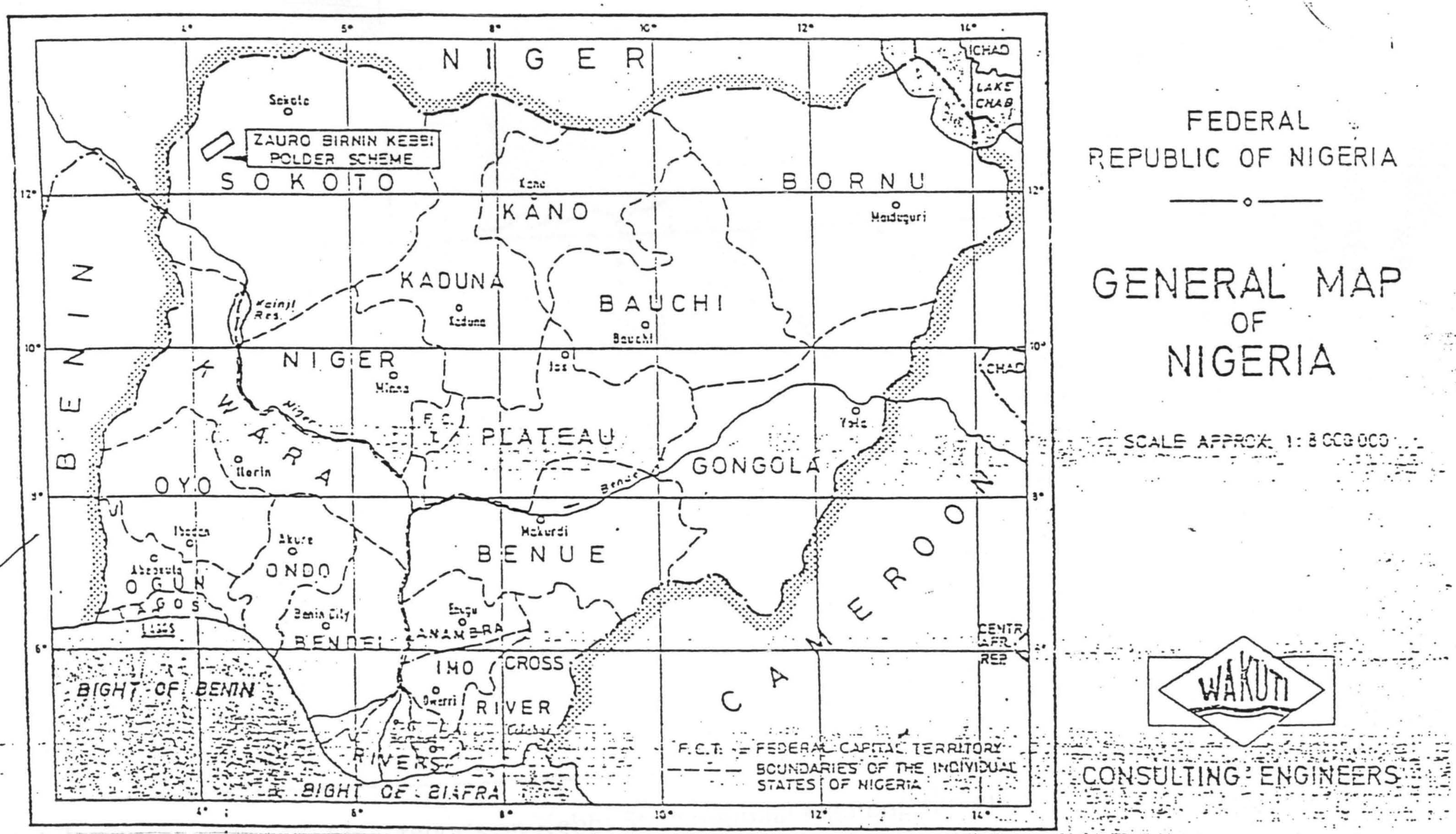


Fig 1.0 General map of Nigeria showing project town { Source: 5)

CHAPTER ONE

GENERAL INTRODUCTION

Water is very important and is indispensable natural resource in every day-to-day activity. Water is life, it marks the beginning of life, and it is the medium of life as there is no plant or animal that can survive for a long period without using or depending on water in one way or the other, directly or indirectly.

Water must be readily available in the form that it can be utilized by man, animal or plant's body without necessarily causing any harm.

For some years, in the history of irrigation development in Nigeria, the River Basin Development has remained neglected.

Irrigation can be defined as artificial application of water to the soil for the benefit of crops planted. Irrigation has been practiced for several years but it has been improved upon with time and has increased in practice with a view to achieve one or more of the following: -

- To supply moisture essentially for plant growth.
- To provide crop insurance against short duration draught.
- To leach or dilute undesirable salt in the soils.
- To control the environment of growing plants by preventing frost action.

For the purpose of this project, my main concern is the Sokoto Rima River where the irrigation project, Zauro Polder Project Pilot Scheme (Z.P.P) Birnin Kebbi is situated.

The Zauro Polder Project was designed to irrigate over 11000 hectares, which is being managed by 7790 farmers, Wakuti (1980). The scheme was designed for the Sokoto Rima River Basin Development Authority (S.R.R.B.D.A) to be used as a model for the farmers or irrigation water management. The scheme is 100 hectares and it is sited on the northern part of Birnin Kebbi along the southern bank of Sokoto Rima valley.

The pilot scheme is equipped with a 2.65 km flood protection dyke, 3.5 metres high, a temporary pumping station with a standby generator, a main canal which is connected to a compensation reservoir, four lateral canals and a collector drain. Those infrastructures are expected to enhance water distribution and management in order to effectively operate the surface irrigation basically practiced in the scheme.

The main problems encountered in the scheme is that of waterlogging and waterlogging is a phenomenon which is associated with the rise in the ground water table especially when the rise is beyond what is considered as the critical limit. This could turn land into unproductive area due to salinity and alkalinity. Since the inception of the scheme in 1982 the conditions have kept deteriorating.

It was imperative to investigate the cause of waterlogging at the Zauro Polder Project as the situation kept deteriorating. Presently less than eighty percent of the arable land in the scheme is cultivatable. (Isrealsen, 1979)

1.2 DESCRIPTION OF PROJECT SITE

1.2.1 LOCATION

The scheme is within the Birnin – Kebbi local government area. It is overlooked by Birnin – Kebbi town (2 km away) that is 120 km South – West of Sokoto town, overlooks it. The Rima River flows along one side of the project.

The project area lies North – East of Birnin – Kebbi at 4°10' East to 4°31' East and 12°29' North to 14°42' North at the southern bank of the river.

1.2.2 TOPOGRPHY

Generally, Birnin Kebbi is not mountainous. The topography of the land surface is characterized by two distinct features namely, the Fadama lowland of the River Rima system stretching westwards from Argungu and the rather flat – elevated upland and an extension of the Sokoto plains.

1.3 CLIMATE

1.3.1 TEMPERATURE

The harmattan being the coldest period of the year, the day minimum temperature may fall down to 16 °c (60 ° F). The hottest month of the year is April whereby the maximum temperature may rise as high as 46.7 °c (105 ° F) and the average monthly maximum temperature of 34.27 ° c and the average monthly maximum temperature of 19.01 ° c have been recorded. (Wakuti, 1980).

1.3.2 RAINFALL

Most of the precipitation is concentrated within the wet season period, which is between the months of May and October. Due to the fact that the rainfall data of the project area were not available at the time of this project operation, thus the present year rainfall data cannot be presented.

However, the amount of rainfall is about 762 – 1016 mm over much of the area (Kebbi State) per annum.

1.4 VEGETATION

Birnin Kebbi is considered to have Sahel Savannah type. Therefore, the vegetation of the area is mainly of nim trees, Mango (UB), Guava e.t.c.

1.5 SIZE OF THE PROJECT AREA AND ITS STRUCTURES

This consists of main canal 545 metres long, four lateral canals of 5290 metres of length. The main canal has bed width of 0.5 metres, inside is 1:1:5 with a clear depth of 1.05 metres.

Also, there are four lateral drainage canals having a length of 4700 metres, which collect the drainage water from basins and then convey them to two secondary drainage canals having a total length of 745 metres. Water is collected in the collector reservoir. The drainage water is discharged by gravity outlet.

1.6 AIM OF ZAURO POLDER PROJECT

The aims of the project are to provide the area for all – year – round (both rainy and dry season) farming, and also to harness the potential of the Fadama area located.

1.7 LAYOUT

The 100-hectare Pilot Scheme is surrounded with a dyke. The scheme has a main canal 545 m long, conveying a discharge of 404 L/S, with four lateral take off of about 940 m, 1470 m, 1165 m and 1715 m long respectively (Fig. 3.2). The off take of the lateral canals is trough 400 mm diameter pipes, sluice valves are used to discharge water and control the discharge respectively. Water is supplied to the main canal by the temporaly pumping station through a compensation reservoir equipped with special outlet facilities.

The lateral canals are unlined and they convey water directly to the fields where the farmers with the aid of siphon applied to the basin or border.

1.8 SOIL TYPE

The soil of the area are part of the Sokoto Rima River flood plain, they are mostly clay with some sandy areas and some sandy – clay areas and they are particularly suitable for rice cultivation, through basin and border irrigation. "Wakuti (1979)" carried out detailed soil survey of about 100 ha, and revealed several patches of saline and alkaline soils, as shown in fig. 3.0. There were also salt horizons observed on deterite outcrops and rocks in the vicinity of the project area. Wakuti Consulting engineers (1980).

1.9 STATEMENT OF THE PROBLEM

The main problem in the scheme (Z.P.P) is that no efforts has been made to find out the causes of the waterlogging and hence find a lasting solution to the problem, as a result of which, the farmers are experiencing shortage of plots due to waterlogging.

1.10 AIM AND OBJECTIVE OF THE PROJECT

This project is aimed at determining the causes of waterlogging in the pilot scheme of Zauro Polder Project (Z.P.P). The results of this research will be used to provide expert advice to the authorities concerned on ways of solving this problem of waterlogging in some places and draught at certain other places in the scheme, and hence improve the productions.

1.11 LIMITATIONS OF THE PROJECT

The extent of poor outflow from the scheme may not be known due to lack of information on the relative topography of farms and the drains.

CHAPTER TWO

LITERATURE REVIEW

2.1 REASON FOR IRRIGATION

Irrigation can be defined as the artificial application of water to the soil for the benefit of the crops planted. Irrigation has been practiced for several years now, but it has been improved upon and increased in scope to achieve one or more of the following: -

- To supply moisture essential for plant growth.
- To provide crop insurance against short duration draught.
- To leach or dilute the undesirable salt in the soils.
- To control the environment of growing plants by preventing frost action. (Isrealsen, 1979)

2.2 METHOD OF IRRIGATION

Irrigation water can be applied to the crops by flooding it on the field surface, by applying it beneath the soil surface, by spraying it, under pressure by applying it in drops. Basically, the common methods of irrigation are classified as follows: -

a. Surface irrigation.
b. Sub – surface irrigation.
c. Sprinkler irrigation.
d. Drip (trickle) irrigation. (Michael, 1978).

The water supply, type of soil, the topography of the land and the crop to be irrigated determines the method appropriate for irrigation to be used. Whatever the method adopted, it is necessary to design the system for the most effective use of water by the crops.

2.2.1 SURFACE IRRIGATION METHOD

In surface irrigation, water is supplied directly to the surface from a channel located at the upper reach of the field. Water can be distributed to the crops in border strips, check basin or furrows. The two general requirements that are of prime importance are to obtain high efficiency in surface irrigation methods and to properly construct water distribution system to provide adequate control of water to the fields and proper land management to permit uniform distribution of water over the field. (Michael, 1978).

2.2.2 OPERATION OF SURFACE IRRIGATION SYSTEMS

This section describes the three basic methods of surface irrigation.

2.2.3 BORDER STRIPS

In this method, the land can be divided into a number of long parallel strips called borders, which are separated by low ridges. Each strip is irrigated independently by turning in a stream of water at the other end. The water is spread and allowed to flow down the strip in a sheet confined by the border ridges. The irrigation streams must be large enough to spread water over the entire width between the border rides without overlapping.

When the advancing water reaches either the lower end or a few metres before or after that stream is turned off. The water temporarily stored in the border moves down the stream and infiltrates, thus completing the irrigation.

2.2.4 CHECK BASIN

Check basin involves dividing the land (field) into smaller units of areas so that each has a nearly level surface. Bunds or ridges can be constructed around the areas forming basins within which the irrigation waters can be controlled. The basins are filled to the desired depth and the water is retained until it infiltrates into the soil.

The supply channel is aligned at the upper side of the area and there is usually one lateral for every two rows of check basins. Water from the laterals is turned into the beds and is turned into the beds and is cut off when sufficient water has been admitted to the basin. Water is retained in the basin until it soaks into the soil. (Michael, 1978).

2.2.5 FURROW METHOD OF IRRIGATION

In this type of irrigation, water is applied by running a small stream of water in furrows between the crop rows. The water infiltrates into the soil and spreads laterally to irrigate the areas between the furrows. The length of time for the water to flow into the furrows depends on the amount of water required to replenish the root zone and the infiltration rate of the soil and the rate of lateral spread of water in the soil.

2.3 SUB – SURFACE IRRIGATION METHOD

In sub – surface irrigation, water can be applied below the ground surface by maintaining an artificial water table at some depth depending upon the soil texture and the depth of the plant roots. The water reaches the plant roots, through capillary action.

Water can be introduced through the open ditches or underground pipelines such as tile drain or mole drains. Basically, the water application system consists of field supply, to cover the field adequately and drainage ditches for the disposal of excess water. (Michael, 1978).

2.4 SPRINKLER IRRIGATION METHOD

Basically, the method of applying water to the surface of the soil in form of a spray, somewhat as in ordinary rain, is known as sprinkling.

The spray is developed by water under pressure through small orifices or nozzles. The pressure is usually obtained by pumping. With careful selection of nozzle sizes; operating pressure and sprinkler spacing, the amount of irrigation water required to refill the crop root zones can be applied nearly uniformly at a rate to suit the infiltration rate of the soil, thereby obtaining efficient irrigation. (Michael, 1978).

2.5 DRIP (TRICKLE) IRRIGATION METHOD

This method of irrigation is one of the latest methods of irrigation which is becoming increasingly popular in areas with water scarcity and salt problems. This is a method of watering plant frequently and with a volume of water approaching a consumptive use of the plants, thereby minimising such conventional loss as deep percolation, run off and soil water evaporation. However, this method of irrigation is accomplished by using small diameter plastic lateral lines with devices called "emitters" or " dripper" at selected spaces to deliver water to the system, applying water slowly to keep the soil mixture within the desired range for plant growth. (Michael, 1978).

2.6 SURFACE IRRIGATION SYSTEMS

The surface irrigation system could be one of the following methods: -

a. Border method.

b. Basin method.

c. Furrow method.

d. Corrugation method.

e. Wild flooding method.

2.6.1 BORDER METHOD

In this type of irrigation method, a sheet of flowing water moves down the slope. This method is suited for: -

i. Where soil depth and topography permits the required land leveling at reasonable cost without reduction in soil fertility or productivity.

ii. Moderately low to moderately high infiltration.

iii. All close growing crops like wheat, folder crops and legumes, e.t.c. But it is not suitable in coarse sandy soils and for crops like rice.

iv. For large field of four (4) hecterage or more. (Isrealsen, 1979).

2.6.2 BASIN METHOD

The basin method of irrigation which make use of bunds or ridges around a nearly level surface, within which water is filled to the desired depth and retained until it infiltrates into the soil, this is suitable for: -

i. Soil having moderately slow infiltration rates, and for smooth, gentle and uniform land slopes.

ii. Both row crops and close growing crops, as long as the crop is not affected by temporary undulation or is planted in beds as that it will remain above the water level, is mostly used on grains like rice and folder crops.

iii. Very permeable soil which must be covered with water rapidly to prevent excessive deep percolation losses at the up stream end and in heavy soils where water is absorbed very slowly and is required to stand for a relative long time to ensure adequate irrigation.

iv. When leaching is required to remove salt from the soil profile. (Adeesoun, 1982).

2.6.3 FURROW METHOD

In furrow method of irrigation, row crops with furrows developed between the crop rows during the planting and cultivation process and upon which the water is supplied to, is suitable for: -

i. Deep, moderately permeable soil with uniform relatively flat slopes (30%) to reduce erosion.

ii. Crops cultivated in rows such as maize, sugarcane, potatoes, vegetable e.t.c. And crops that cannot tolerate standing in water.

iii. Any size of field or plot. (Israelsen, 1979).

2.6.4 WILD FLOODING

The wild flooding or uncontrolled flooding method of irrigation is the method in which the water is applied from field ditches without any levels to guide or restrict it's movement, and is suitable for: -

i. Where irrigation water is abundant and inexpensive.

ii. Lands that have such irregular surface where the other methods are impracticable.

iii. Close growing crops, particularly where slopes are steep. (Israelsen, 1979).

2.7 FACTORS MILITATING AGAINST PROPER IRRIGATION OPERATION

The factors that hinder the proper operations of surface irrigation system are: -

i. Natural factors.

ii. Artificial factors. (Michael, 1978).

2.7.1 NATURAL FACTORS

The natural factors that hinder operations of surface irrigation include: -

i. Poor natural drainage.

ii. Rainfall.

iii. Flood. (Michael, 1978).

2.7.2 POOR NATURAL DRAINAGE

The poor natural drainage of the sub – soil under unfavorable geology, is like the existence of hard pans or rocks stratification of the sub - soil strata and their characteristics have great influence on waterlogging. (Michael, 1978).

2.7.3 RAINFALL

Rainfall can be one of the major contributions to the ground water storage. Excessive rainfall will create waterlogging temporarily and if there is no proper drainage facilities, it may lead to continued waterlogging. (Murty, 1985).

2.7.4 FLOOD

The continuous submergence of land due to floods encourages growth of marshy grass weeds, which obstructs natural's surface drainage, the depression with poor drainage continued to hold water. (Murty, 1985).

2.7.5 ARTIFICIAL (MAN – MADE) CAUSES

This includes: -

2.7.6 BAD METHOD OF CULTIVATION

This includes failure to smoothen the field after tillage and inadequate disposal of the soil banks. (Adesoun, 1982).

2.7.7 BAD METHOD OF IRRIGATION

This can be due to high intensity of irrigation irrespective of the soil and the sub – soil conditions, wrong and defective method of irrigation, and non-maintenance of natural drainage.

Blocking up of natural drainage, hydraulic flow from saturated areas at high elevation and heavy seepage losses from tributaries. (Adeseun, 1982).

2.8 DRAINAGE IN IRRIGATION SCHEME

Usually, in flat areas, the main problem is the removal of stagnant water in shallow topographic depressions, while in sloppy areas; it is the removal of excess water without causing erosion.

The practice of surface drainage may be defined as the diversion of excess water over the ground surface and topsoil to an open drainage system with an adequate outlet.

Depth and spacing of drains depend on the soil's permeability, the rate of supply of drainage water and the degree of protection required are measured by minimum acceptable rate of rainfall after a sudden inflow. Drain's depth is limited by cost drainage machine capacity and the hydraulic of the disposal system. (Isrealson, 1950).

2.8.1 TYPES OF SURFACE DRAINAGE

There are essentially five types of surface drainage system. These are: -

a. Bedding system.

b. Interception system.

c. Random ditch system.

d. Parallel or diversion system.

e. Field ditch system.

The use of these systems depends on some factors: -

i. Soil types.

ii. Topography.

iii. Types of crops.

iv. Farmer's preference.

2.8.2 BEDDING SYSTEM

This consists of a collection of furrows spaced apart by means of shallow ditches called dead furrows. The dead furrows must have a continuous grade without any obstruction that might interfere with the flow of water. The furrows drain to the collection ditches, which in turn drain to an outlet channel.

2.8.3 PARALLEL OR DIVERSION DITCH SYSTEM

On flat, poorly drained soils that have numerous shallow depression, the parallel ditches system is suitable. In general, the parallel ditches is slopped and smoothened to eliminate any minor depression or obstruction to the over – land flow of water.

2.8.4 FIELD DITCH SYSTEM

Land water is removed from the soil by a system of irregular spaced ditches. (Israelson, 1950).

2.9 WATERLOGGING IN IRRIGATION SCHEME

Waterlogging is a phenomenon, which is associated with the rise in the ground – water table especially when the rise is beyond what is considered the critical limit of 1.5 m to 2.0 m below the ground surface. This could also turn land into unproductive due to salinity and alkalinity.

This restricts the proper operation of surface irrigation system, because, where there is slopping land devoid of vegetation, water flows so quickly that it has no time to sink into the soil. On the other hand, on flat plains where there is bad drainage, irrigation may eventually raise the water table so that land becomes waterlogged. (Murty, 1985).

2.9.1 MODE OF OCCURANCE OF WATERLOGGING IN IRRIGATION SCHEME

Waterlogged soil means a soil saturated with water in the root zone. "Also a soil is said to be waterlogged when the ground water table gets connected to soil water in the crop root zone and remains like this for the remaining period in a year." (Dahigaonkar, 1985).

It may be temporary, seasonal or permanent. Soil having permanent ground water near the surface is considered to be waterlogged. Waterlogging may or may not be associated with salinity. Waterlogging may also occur as a form of standing water in the farm, which does not lower with time. (Murty, 1985).

2.9.2 CAUSES OF WATERLOGGING IN IRRIGATION SCHEME

Usually, in irrigation region, small-waterlogged areas are caused by surface or underground water flowing to them from higher irrigated lands, or from canals, ponds or reservoirs.

However, the basic causes of waterlogging in irrigation scheme are as follows: -

i. General rise in the water table.

ii. Excess inflow of water into farmland or basins. (Murty, 1985).

A. GENERAL RISE IN WATER TABLE

This usually takes place when the inflow exceeds the outflow, the surface ground water table rises, and hence the storage is positive. And when the outflow exceeds the inflow, surface ground water falls. This also implies that storage is negative. (Murty, 1985).

The following factors are responsible for excessive inflow of water into an irrigation scheme.

i. <u>Infiltration from excessive rainfall: -</u> This is especially true on a flat land having excessive rainfall and poor outflow or poor surface drainage. → Drainage required.

ii. <u>Induced seepage: -</u> This could be from reservoirs, rivers and unlined canals in irrigation scheme into the ground water.

iii. <u>Flooding of land: -</u> Spillage from river overflowing their banks. →Drainage from excess flood during overflow period.

iv. <u>Over irrigation: -</u> Deep percolation losses due to uncontrolled irrigation water to agric lands by flooding and other unspecific techniques.

v. <u>Sub – soil flow: -</u> Flow of underground water from high lands to low lands. All these lead to waterlogging of basins.

vi. Bad tilling, creating obstruction to the flow in the farm by way of depressions, ponds, e.t.c.

vii. Improper land grading. (Murty, 1985).

<u>The following factors are responsible for poor out flow of irrigation scheme.</u>

i. <u>Inadequate surface drainage</u>: - sediment easily silts up natural surface drainage and wash loose, wheat and other vegetative growth also reduce such drainage.

ii. Natural and artificial obstruction to subsoil and surface outlet.

iii. The presence of impervious layers in the subsoil lead to poor outflow and consequently rise in water table, hence waterlogging.

Artificial obstruction such as human activity e.g. foundations of high rise buildings and water tight dams are also responsible for subsoil natural flow.

iv. Poor topography: - Usually flat areas with low-lying depressions, inadequate land slope and impervious strata give rise to poor outflow and waterlogging. (Isrealsen, 1979).

2.9.3 EFFECTS OF WATERLOGGING IN IRRIGATION SCHEME

i. Waterlogging prevents oxygen from reaching plan's root, which then suffocate them, hence reduction in crop yield because of the stoppage of air circulation.

ii. Waterlogging in soils does not encourage crops to develop deep roots, so that during draught they are unable to tap from the deeper moist soil.

iii. Waterlogging also has effects on flat plains, where there is bad drainage, irrigation may eventually raise the water table.

iv. Salt efflorescence, because the water flowing upwards, bring dissolved salts in the root zone, where the salt concentration increases and causes either loss of fertility or total damage to soil.

v. Growth of aquatic weeds increases, causing more tilling expenses.

vi. Causes unhealthy, marshy atmosphere with high humidity in the weather, thus causing skin irritation and mosquito breeding, leading to malaria.

vii. Difficulty in planning and other tilling practice. (Dahigaonkar, 1985)

2.9.4 PREVENTIVE MEASURES

There are certain precautions to be taken to avoid occurrence of waterlogging, called preventive measures. These are:

i. Proper investigation of the substructure of the irrigable soil.

ii. Lining of the canals.

iii. Proper field management by giving suitable grades and leveling of lands, removal of weeds, e.t.c.

iv. Volumetric assessment of the water charges so that farmers use only necessary quantity of water for irrigation. (Dahigaonkar, 1985).

2.9.5 SOLUTION OF MENACE OF WATERLOGGING (CURATIVE MEASURES)

All waterlogged lands weather or not impregnated with alkali, are improved for ordinary crops by lowering the water table. This means a permanent lowering under the farmer's control so that the rise of water above the given elevation in the soil for any length of time may be wholly prevented. The first step in lowering the water table is to learn the source of water that caused it to rise. In isolated cases, on small tracks, it is sometimes possible for one farmer alone, or a small group of farmers to find the source and cut it off by construction of one or more of intercepting ditches or drains. (Isrealsen, 1979).

The following steps may be taken to remove the waterlogging conditions from an affected area.

i. Lift irrigation by wells and tube wells effectively lowers the ground water table.

ii. Intercepting drains on one or both sides of unlined canals restrain spread of seepage.

iii. Lining of the existing unlined canals.

iv. Designing canals with lower depth to reduce seepage.

v. Constructions of drainage systems of open drains or perforated pipes laid below the ground level. This is very costly.

vi. Improvement to the natural drainage. (Dahigaonkar, 1985).

2.10 SEEPAGE

Water that flows through the pores (interstices, voids and spaces) of the soil is called seepage. Seepage can take place when the pores are fully saturated. The effects of seepage are: -

i. Loss of water.

ii. Upward pressure called pore pressure that causes reduction in strength, and

iii. Failure if in excess gradient.

When the seepage water is coming out of the dam's face at a greater velocity than the velocity sufficient to dislodge and transport a soil particle (this being called as critical velocity for that soil and size of that particle), is called the excess gradient. Seepage is less through the soils, which are properly consolidated, and through clayee soils.

However, as the seepage cannot be prevented totally, an effort is made to :

i. Reduce it to minimum, and

ii. Remove the seepage water effectively, quickly and without allowing soil particles to flow with it.

Seepage takes place through the body of the dam and through its foundations. If more seepage takes place through the body of the dam, it is called horizontal piping and if through the foundation, it is called vertical piping. (Dahigaonkar, 1985).

2.10.1 SEEPAGE CONTROL

Seepage occurs through earth embankment. The seepage has to be controlled to ensure the safety of the embankment as well as to minimize the losses of water. When water is standing against earth embankment a seepage line or saturation line is established which is line below where there are positive hydrostatic pressures. On the line itself the pressure is atmospheric which is zero. Above the seepage line in the capillary fringe the pressure is negative.

In a given embankment section it is necessary to predict the position of the seepage line in order to: -

i. Ensure that the seepage line does not cut the down stream face of the dam and cause softening of the toe.

ii. To obtain the dividing line between the wet and dry soil for the purpose of stability computations.

iii. To obtain the top boundary line for drawing the flow net for seepage computations. (Murty, 1985).

Seepage losses in open channel can be controlled by compaction and lining of the canals with use of masonry concrete, metal sheet, e.t.c. Many materials are employed in channel lining, these include the following: -

i. Concrete (insitu or precast).

ii. Brick or burnt clay tiles lining.

iii. Stone masonry.

Asphaltic concrete lining (buried type membrane lining)

i. Spray in place asphaltic membrane lining.

ii. Prefabricated asphaltic membrane lining.

iii. Synthetic rubber and plastic film membrane.

iv. Bentonite and clay membrane. (Wilson, 1974).

Losses of water by seepage depend on the permeability of the soil strata through, which the water penetrates both in the canals and at the field especially when using basin or border method of irrigation. Seepage is through the periphery of the channel's sections.

The condition of the channels affects seepage loss through a canal silted up with fine silt is less than the loss in a newly constructed canal. The steam flow velocity also affects seepage loss in canals. The more the velocity the less will be the percentage loss. Losses are more in channels which intermittently, in comparison to those who run continuously. At the field of irrigation, seepage depends upon the capacity of the soil to conduct water vertically and laterally.

The most common method employed in determining water seepage losses is: -

i. Seepage meter method.

ii. Inflow – outflow method.

iii. Ponding method.

Among these methods, the ponding method is used in carrying out this research.

2.10.2 PONDING METHOD

This method involves construction of dykes in the channel filling the intervening sections with water and drop in water level is measured per unit time. Ponding method could be successful and accurate if leaks through the dykes are prevented.

During the test, unforeseen circumstances like rainfall and evaporation allowance should be made at both ends of the channel to eliminate the effect of land on water level. Seepage is computed for different depth of water.

Condition as area $A = h(b + wh)$ … where h = height of water lost, b = width of channel and w = slope of canal.

This method allows for determining of small losses and could be used as a standard for comparison to other methods of seepage measurements. The small dimension helps for convenience and accuracy in carrying out the work successfully.

2.10.3 DESIGN OF CHANNEL AND SLOPE

A trapezoidal channel with speculations as follows: -

i.	Length of the channel	= 100 cm.
ii.	Depth of the channel	= 30 cm.
iii.	Bed width of the channel	= 30 cm.
iv.	Slope of the channel	= 2:1

The design slope is: -

Sandy soft clay	3:1.
Sandy clay, silt loam, sandy loam is	2:1.
Fine clay, clay loam is	1:5:1.
Heavy clay is	1:1.
Line canal is	1:5:1.

2.11 INFILTRATION

The rate at which water can enter soil when not limited by the rate of supply is measured in the field where water either ponded on the surface or falling on it as artificial or natural rain at a rate sufficient to cause run off. It is expressed in (m/s) or some convenient multiple of these units and is called infiltration capacity (Horton, 1940) or infiltrability (Hillel, 1971). It is potential rate that is characteristic of the soil under specified conditions. In particular, it varies with time during a test and with initial water content. Three methods of estimating infiltration characteristics of soils include: -

i. Water entry rate into soil are measure in the field "intake rate".
ii. Measurement of subsidence of free water in a large basin, and
iii. Estimation of accumulated infiltration from the water front advance data.

Among these methods, the use of cylinder infiltrometer is most popular and adopted in this study. See section (3.10.2).

2.11.1 FACTORS AFFECTING INFILTRATION RATE

The movement of water into the soil by infiltration may be limited by any restriction to the flow of water through the soil profile. The major factors affecting the infiltration of water into the soil are; the initial moisture content, condition of the soil surface, hydraulic conductivity of the soil profile, texture porosity, degree of swelling of soil colloids and organic matter, vegetation cover, duration of ponding water, irrigation or rainfall and viscosity of the water.

Infiltration rates are generally lower in soils of heavy texture than on soils of light texture. Many workers investigated the influence of water depth over soil on infiltration rate. It has been established by Horton (1940) and Green and Ampt (1911) that surface irrigation depth increases initial infiltration slightly but the head has negligible effect after prolonged irrigation.

The high rate of infiltration in the tropics under otherwise comparable soil conditions are due to low viscosity of warm water.

CHAPTER THREE

METHODOLOGY

3.1 METHOD OF DATA COLLECTION

3.1.1 RECONNAISSENCE SURVEY

At the date of the visit, some of the farmers were harvesting and some were threshing the rice they have harvested. Most portions of the basins were still covered with water.

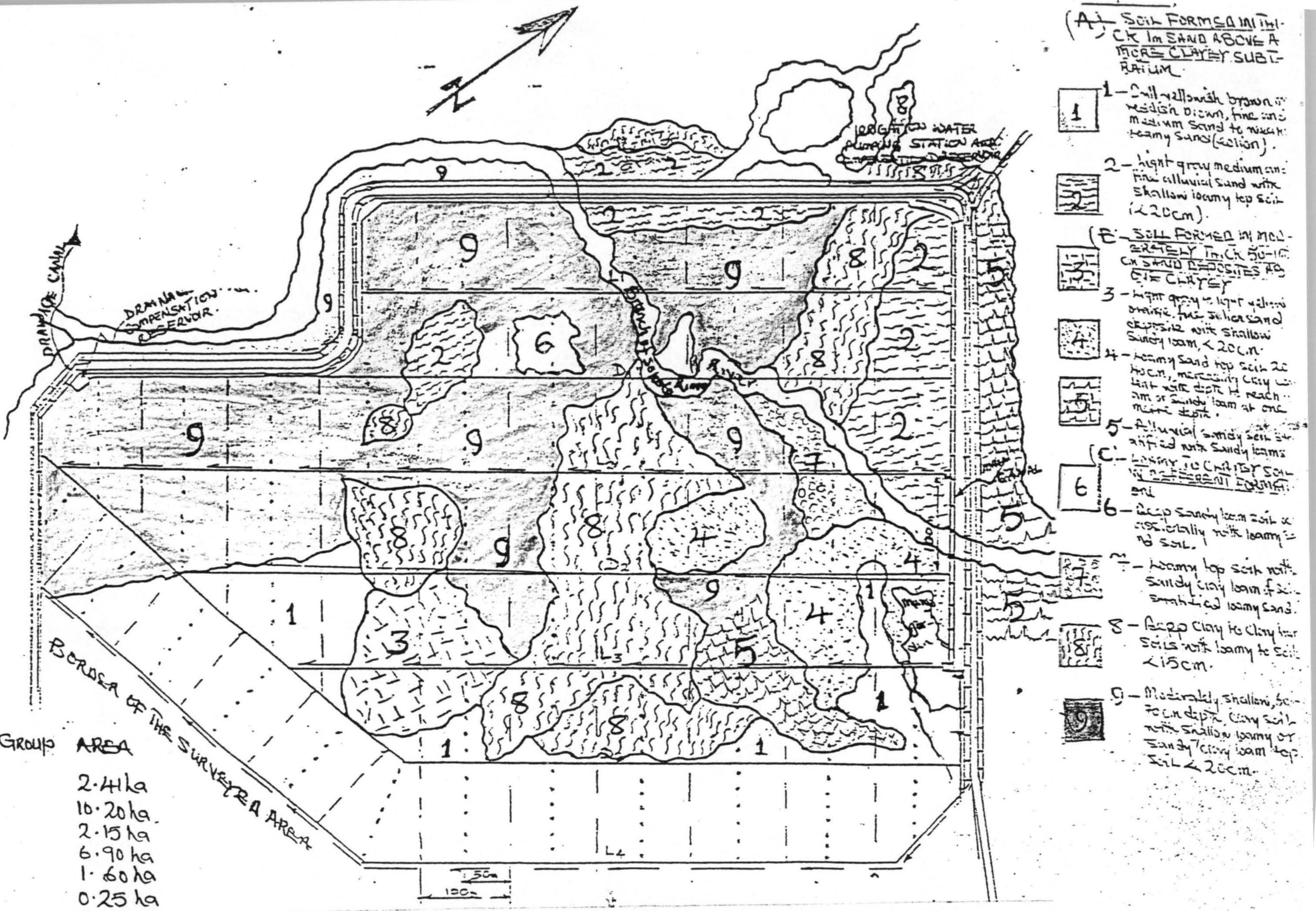
The Rima River flows along one side of the project. The source of water is man made diversion channel from the Rima River from which water is pumped into the scheme. The project area is surrounded by an earth – fill dyke that is designed to protect the farmland from flooding from the river. This is a brick – lined main canal and four lateral canals that are in trapezoidal shape and have some growing grasses inside. There is one drain at the lower end of the project that discharges water by gravity back to the river.

The Polder Project has one main pumping station located at the intake collector reservoir with three (3) intake pipes. The pump station consists of six (6) water pumps of which three (3) were functioning. There was also one electrical power generator to power the pumps.

The road leading to the down to the project was significantly eroded by run – off and there were no villages within or near the project.

3.1.2 TOPOGRPHIC DATA COLLECTION

The Zauro Polder Project Pilot Scheme is a 100 ha fairly level land, with alluvial deposit of sandy – clay loam which dominated almost all the area as it accounts for 75 % (percent) of the total soils in the area.



Soil Group	Area
1	2.41 ha
2	10.20 ha
3	2.15 ha
4	6.90 ha
5	1.60 ha
6	0.25 ha
7	3.46 ha
8	16.75 ha
9	51.31 ha

Fig 3.0 Area of soil groups enclosed by the project boundary.
{Source: Wakuti Consulting Engineers, Kaduna 1980}

The land slopes gently down the southern bank of the Rima River through which water is drained by the conversion outlet that reduced the problem of drainage in the scheme.

The area with low flood plain was grid and paged at 30 m interval as shown on the map (Fig. 1.0) of the area. The ground level was taken on the point of grid using leveling instrument. The levels were reduced with reference to benchmark very close to the area of height (265.44 m). Using those levels the contour lines were drawn at an interval of 30 m.

3.2 FIELD EXPERIMENT

3.2.1 PONDING METHOD

In carrying out this research, the channel selected is not among those used for irrigation in the scheme. This is because the shape of those old channels is altered and secondly to obtain the maximum seepage loss rate of the silt, as seepage loss value is high in a newly constructed canal than in old and silted channels. The volume required is also adopted because there is difficulty of adding too often large quantity of water into the pond especially if the channel is long.

Therefore, a trapezoidal channel was used and was constructed A&B with the following specifications.

Channel	Depth	Bed width	Length
A	30 cm	30 cm	100 cm
B	30 cm	30 cm	100 cm

The channel ends were covered with metal sheets to prevent leakage. The values were chosen in small dimensions so that the changes of water level can be manifested easily in small ditch than in a large ditch of water. The small dimension

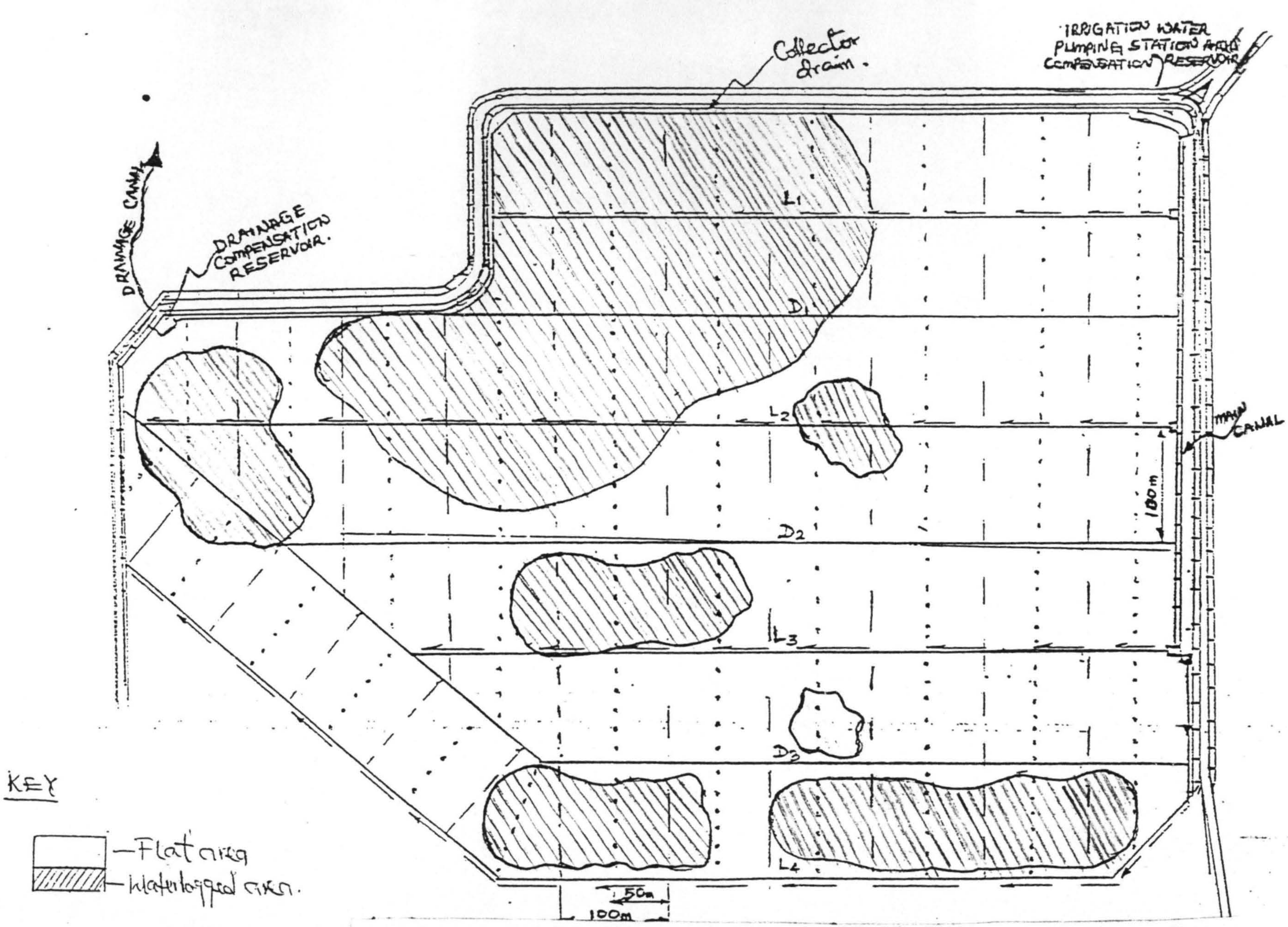


Fig 3.1-reconnaissance survey of the water logged area at the pilot scheme

helps for convenience and accuracy in carrying out these method of investigation. The slope was chosen to be 2:1 because of the soil type of the side, which is sand – clay loam, as discovered from the design of slope of a channel. (Varshney, 1979).

The design slope value was chosen to ensure stability of the channel and for the safety of the channel.

The channel size and shape was excavated, the depth and width was extended to 32 cm to accommodate the metal sheets at the ends of the channel. This was preceded by making the side of the channel at an inside slope to 2:1.

3.3 DETERMINATION OF INFILTRATION RATE.

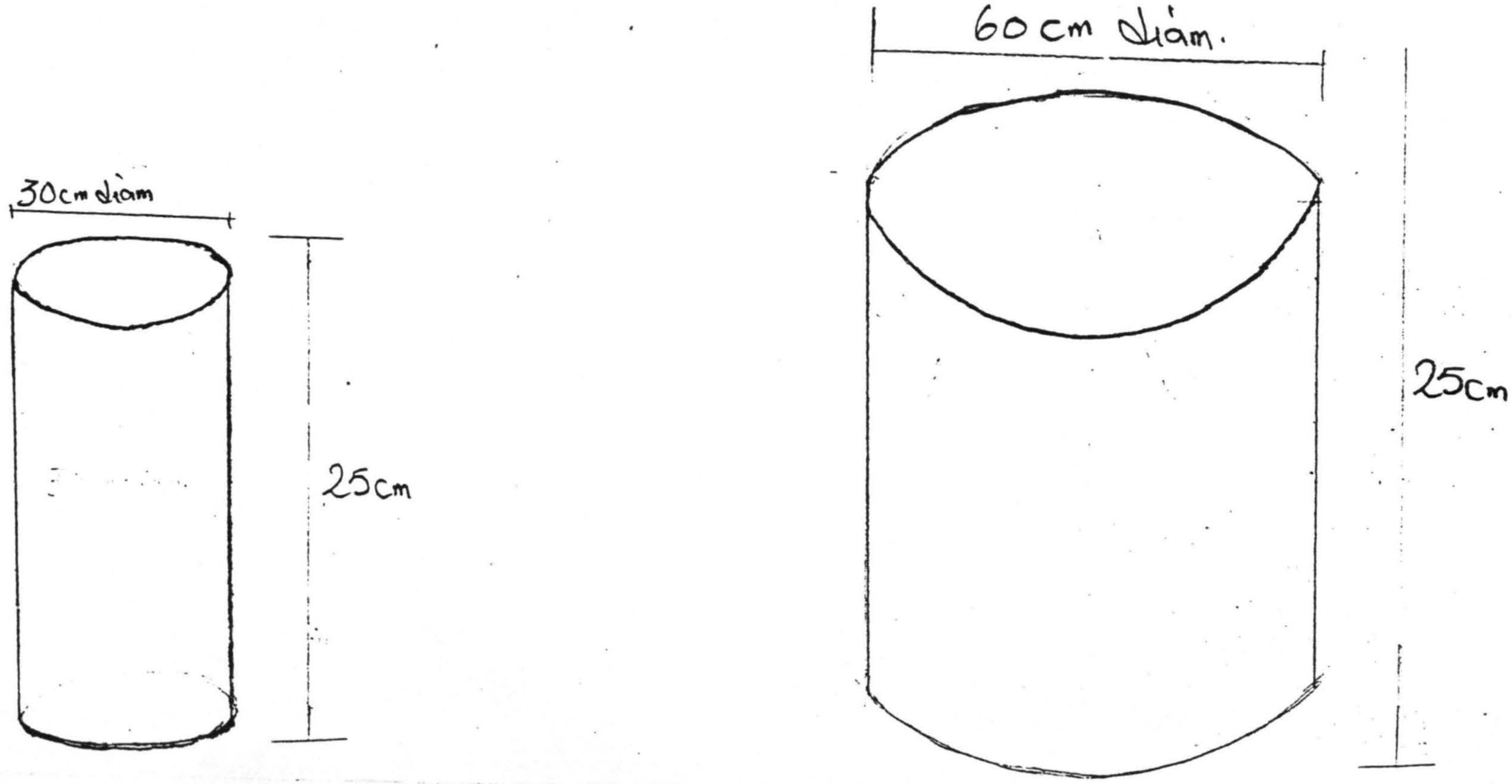
3.3.1 FIELD EXPERIMENT.

Infiltrometer of inner cylider (30 cm) diameter and outer cylinder (60 cm) ring height 25 cm to pond water on the ground surface were used to measure infiltration rate, see fig. (3.2). A stopwatch was used to observe the timing of infiltration, and a measuring jug was used to measure the quantity of water, while a ruler was attached to measure the water intake.

3.3.2 PROCEDURE.

The infiltration experiment was carried out at three (3) different locations in the scheme. The first was in channel No.1, 2, and 3 to the subsequent experiment carried out. The channel No 1 and 2 soil type, was observed to be clay with some sandy loam areas while channel No 3 was sandy clay loam.

Using the double cylinder (metal) infiltrometer, first the inner cylinder, which is of height 25cm and diameter 30cm, was placed on the soil. The ring was then inserted into soil by placing a bracing plank across the ring and tapping gently until the ring has gone into the soil to depth of 11cm. The inner ring has a ruler attached to



3.2 Cylinder infiltrometer { Source: DAHIGAONKAR J.G, the inner side or calibrated, which allows for the reading of the water level as infiltration progresses.

After the installation of the inner ring the outer ring which is also 25cm high and 60cm in diameter was also installed in the same manner to a depth of 4cm too. During the installation of the outer ring, care was taken to centralize the radial distance between the two rings (concentric) by monitoring it after each tap. The depth was checked again with ruler to ensure a perfect level before commencing the experiment.

Water was made available by using three buckets to fetch water at the bottom of the valley. A small quantity of grass was placed in the inner and outer ring of the infiltrometer to avoid puddling when pouring water in the cylinder. Water was measured with four capacity can and the watch was set at zero reading. After the infiltrometer was put in place, water was poured into the inner ring and simultaneously the watch was started.

The inner ring was ponded up a level of 17cm(or 11cm) reading on the ruler. This implies that 17cm on ruler is the reference point which is approximately the average depth to the water level expected in the border or basin irrigation. (Iwata. S, 1980). When the inner ring has been filled up to the reference point, the outer ring was also filled immediately to the same reference point to maintain a constant average infiltration rate head. The water level in the inner ring was monitored as in the outer ring. Reading was taking every 1,2,3,4,or 5 minutes (see section 4, the table of reading) as the water is lowered in the cylinder because of infiltration rate of the soil. Water percolation was very high at the initial point of the experiment.

After every reference time expires a reading is taken and then rings are filled back to the reference water level taking into cognisance the inner ring. See table 4.4.

CHAPTER FOUR

RESULTS AND ANALYSIS OF RESULTS

4.1 RESULTS

The Zauro Polder Project (Z.P.P) is such an area which is a fairly flat land surface made up of sandy – clay loam soil with alluvial deposit which dominate almost all the areas as it accounts for 75 % (fig. 3.0) out of the total soil in the area. The soil being clay – loam soil has a low tendency for permeability in percolation and hence waterlogged. Also the construction of the scheme was carried out through direct labor, which resulted in an uneven leveling of the scheme, hence the problem of waterlogging.

The contour map of the area of the scheme was obtained from the spot leveling which is presented in fig. 4.1. The contour values were obtained by using 100 cm as the benchmark. The shaded areas show all the areas of the scheme that has elevations lower than the benchmark as shown in fig. 4.1.

The results of seepage loss experiments are presented on table 4.2 to 4.5 while table 4.2 show results of transmission loss in equal and unequal time interval at channel No. 1.

It was observed that when pouring water into the channel, there was a rapid fall of the water head due to rapid infiltration rate of the soil initially. This was because the existing soil voids have not been filled up with water. However, the falls become gradual after some time. Water seeps into the soil due to stress of water movement vertically and laterally at the channel sides and bed respectively. The higher the water levels the more the stress. There was a reduction in seepage when there was a fall in water level. The effect of variation in water level in the channel is illustrated in table 1. It was observed that the higher the water head the more seepage

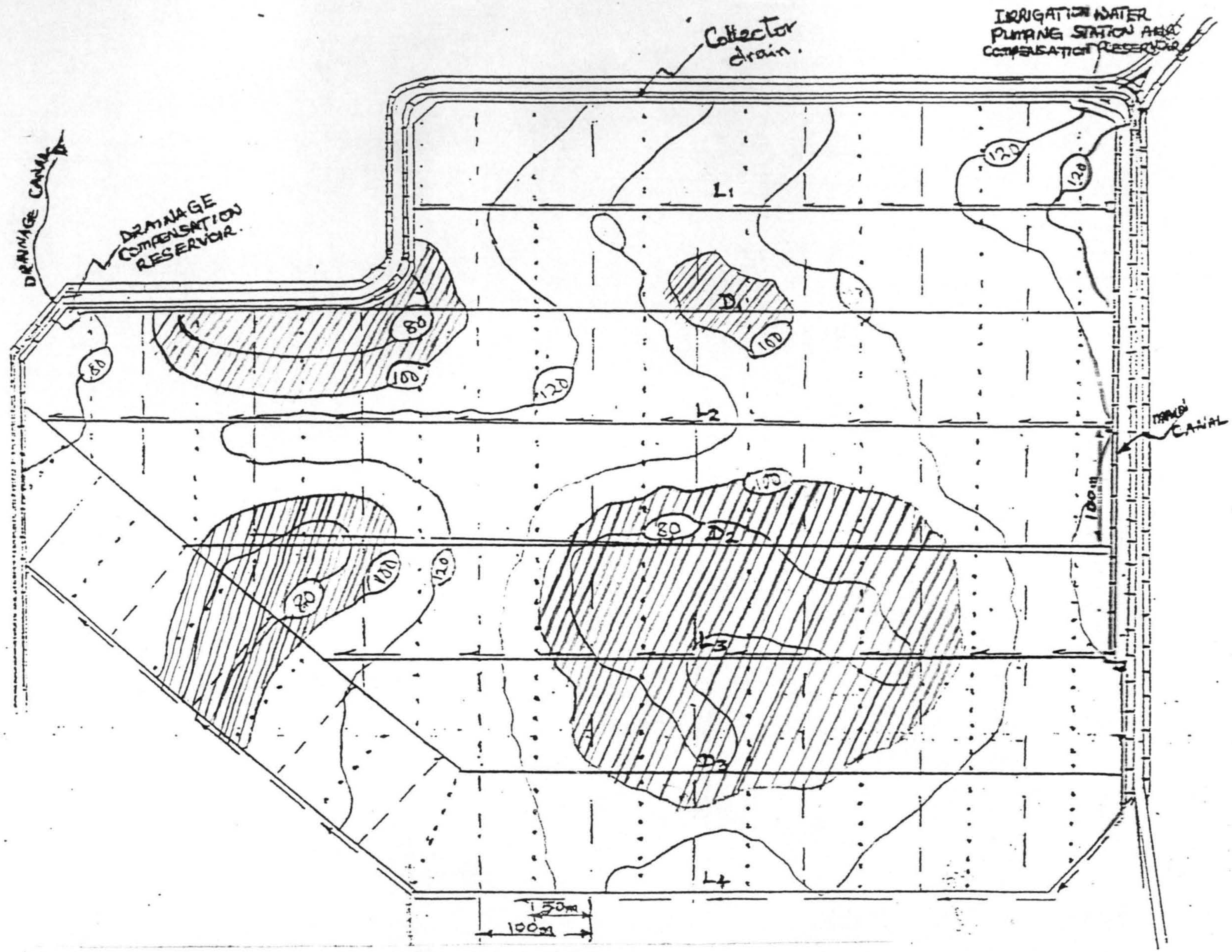


Fig 4.1 Contour map of the pilot scheme {source: `Wakuti Consulting engineers, Kaduna 1980}

loss and there was no uniformity in the losses. The effect of variable head of seepage is an important factor in determining water losses in channel.

Table 4.2 shows the rate of seepage loss at its parameters in which the highest transmission loss value is 15.72 mm / min was observed, in the second reading after the first reading of transmission loss value of 15.61 mm /min. the transmission loss continues decreasing gradually to the least value of 0.54 mm / min after 3.15 hours. The average value of 3.9 mm / min was calculated from this channel.

In table 4.3, the first transmission loss value of 14.94 mm / min was obtained and it gradually decreased to 2.93 after 4.6 hours and the mean transmission loss value was calculated.

In the infiltrometer experiment, there was no standard infiltrometer equipment; hence the calibration, which was improvised, may not be accurate enough.

Also, the time for refilling the inner and outer cylinders after every reading varies within about two seconds.

The condition of the soil varies due to historical and cultural practices on the soil.

The general observation from the table is that the highest transmission rate of 15 mm/min was observed under the head of 9 cm for the test Number 1 and the lowest of 0.54 mm/min was also observed under the head of 5 cm height for the test Number 28.

TABLE 4.1

DETERMINATION OF SEEPAGE RATE AT Z.P.P

No. Of Reading	Water Height in Channel (cm)	Time Interval (minutes)	Transmission losses mm / min
1	9	5	15.61
2	9	3	15.72
3	8.5	4	5.58
4	12	10	6.62
5	12	8	6.58
6	10.8	11	4.74
7	10.2	13	5.76
8	5	4	2.34
9	10.2	5	8.7
10	10.5	7	6.58
11	6.5	5	3.66
12	7.5	10	3.24
13	10	11	2.88
14	12	19	2.05
15	7.4	10	2.90
16	7.6	10	2.80
17	7.8	9	2.80
18	7.4	9	2.30
19	8.2	11	2.94
20	7.6	18	2.64
21	7.7	5	2.7
22	7.1	5	1.25
23	6.4	5	1.98
24	8.5	5	2.64
25	7	5	0.71
26	6.6	5	1.26
27	5.9	5	0.54
28	9.2	5	2.11
29	8	5	0.71
30	7.6	5	1.25
31	6.9	5	1.15
32	6.2	5	0.91
		242	123.65

Mean transmission value = 123.45 ÷ 32 = 3.864 mm /min

TABLE 4.2

RESULT OF TRANSMISSION LOSS WITH EQUAL TIME INTERVAL OF 5 MINUTES AT CHANNAL No. 1

No. Of Reading	Water height in channel (cm)	Time Interval (Minutes)	Transmission Loss mm / min
1	9	5	15.61
4	8.5	5	5.7
10	10.2	5	8.7
12	6.5	5	3.66
22	7.7	5	2.70
23	7.1	5	1.25
24	6.4	5	1.98
25	8.5	5	2.64
26	7	5	0.71
27	6.6	5	1.26
28	5.9	5	0.64
29	9.2	5	2.11
30	8	5	0.71
31	7.6	5	1.25
32	6.9	5	1.25
32	6.2	5	0.61
		80÷60	51.08

= 1.33 hrs

Mean transmission loss with constant time interval = 51.08 ÷ 16

= 3.195 mm /mi

TABLE 4.3

RESULTS OF TRANSMISSION LOSS IN CHANNEL No. II

No. Of Reading	Water Height In Channel (cm)	Time Interval, T in (minutes)	Transmission Loss mm / min
1	9	4	14.94
2	10.5	5	9.78
3	7.5	5	7.44
4	8.9	6	8.39
5	8.6	7	8.34
6	8.2	6	7.44
7	8	6	7.10
8	9.2	6	6.59
9	9	10	7.02
10	11.2	8	5.98
11	6.8	6	5.74
12	6.5	6	6.83
13	7.5	10	5.69
14	6.5	10	4.72
15	7.2	9	4.94
16	7.0	10	4.01
17	5.2	11	4.64
18	7.5	18	3.75
19	7.0	5	6.81
20	14.0	5	5.59
21	11.5	5	4.41
22	9.5	5	3.92
23	7.7	5	3.44
24	6.1	5	2.91
25	4.7	5	2.93
26	18.2	5	6.40
27	15.4	5	4.96
28	13.2	5	4.68
29	11.1	5	3.48
30	9.5	5	3.24
31	8.0	5	3.24
32	6.5	5	3.18
		228÷60	185.46÷32 = 5.796

= 3.8

Mean seepage loss value for the general readings of channel II results

= 5.8 mm / min

The tests on channel II show high transmission losses initially as observed in test channel No. 1 with similar reasons after that, there was a gradual drop in loss rate. The tests were conducted within 3 days.

TABLE 4.4

TRANSMISSION LOSS UNDER DIFFERENT WATER HEIGHT WITH CONSTANT TIME (5 MINUTES) INTERVAL AT CHANNEL II

No. Of Reading	Water Height In Channel II (cm)	Time Interval In Minutes	Transmission Loss mm / min
2	10.5	5	9.78
3	7.5	5	7.44
19	17.0	5	6.81
20	14.0	5	5.59
21	11.5	5	4.41
22	9.5	5	3.92
23	7.7	5	3.44
24	6.1	5	2.91
25	4.7	5	2.93
26	18.2	5	6.84
27	15.4	5	4.96
28	13.2	5	4.68
29	11.1	5	3.48
30	9.5	5	3.24
31	8.0	5	3.24
32	6.5	5	3.18
33	5.0	5	2.63

79.78

Mean seepage loss value for a constant time interval for the channel II results

$= 79.78 \div 17 = 4.69$ mm / min.

TABLE 4.5

CYLIDER INFILTROMETER TEST AT Z.P.P (PROJECT SITE)

FIRST FRINGE:

A Elapsed Time (cm)	B Final Level (cm)	C Initial Level (cm)	D Water Intake B – C (cm)	E Cumulative Infiltration ΣD (cm)	F Infiltration Rate cm/min E/T	G Infiltration Rate cm / hr (Fx60)
1	3.8	3.5	0.3	0.3	0.3	18.0
2	4.0	3.8	0.2	0.5	0.25	15.0
3	4.4	4.0	0.4	0.9	0.3	18.0
4	5.1	4.4	0.7	1.6	0.4	24.0
5	5.8	5.1	0.7	2.6	0.46	27.6
10	6.8	5.8	1.0	3.4	0.34	20.4
21	8.8	6.8	2.0	5.4	0.26	15.4
30	12.1	8.8	3.3	8.6	0.29	17.2
40	16.2	12.1	4.1	12.7	0.32	19.1
50	8.1	3.5	4.6	17.3	0.35	20.8
60	12.2	8.1	4.1	21.4	0.35	21.4
120	11.7	12.2	-0.5	20.9	0.20	10.5
180	17.0	11.7	5.3	34.9	0.20	11.6
240	11.7	3.5	8.2	43.1	0.20	10.8

TABLE 4.6

CYLINDER INFILTROMETER TEST AT Z.P.P (PROJECT SITE)

SECOND FRINGE:

A Elapsed Time (cm)	B Final Level (cm)	C Initial Level (cm)	D Water Intake B – C (cm)	E Cumulative Infiltration ΣD (cm)	F Infiltration Rate cm/min E/T	G Infiltration Rate cm / hr (Fx60)
5	3.8	3.5	0.3	0.3	0.06	3.6
10	4.3	3.8	0.5	0.8	0.08	4.8
15	4.5	4.3	0.2	1.0	0.07	4.0
20	5.1	4.5	0.6	1.6	0.08	4.8
25	5.4	5.1	0.3	1.9	0.08	4.6
30	5.7	5.4	0.3	2.2	0.07	4.4
35	6.0	5.7	0.3	2.5	0.07	4.3
40	6.3	6.0	0.3	2.8	0.07	4.2
50	6.6	6.3	0.3	3.3	0.07	4.0
60	7.0	6.6	0.4	3.7	0.06	3.7
120	7.7	7.0	0.7	4.4	0.04	2.2
180	8.5	7.7	0.8	5.2	0.03	1.7
240	9.3	8.5	0.8	6.0	0.03	1.5

TABLE 4.7

CYLINDER INFILTROMETER TEST AT Z.P.P (PROJECT SITE)

3RD FRINGE:

A Elapsed Time (cm)	B Final Level (cm)	C Initial Level (cm)	D Water Intake B – C (cm)	E Cumulative Infiltration ΣD (cm)	F Infiltration Rate cm/min E/T	G Infiltration Rate cm / hr (Fx60)
5	5.6	3.5	2.1	2.1	0.42	25.2
10	8.1	5.6	2.5	4.6	0.46	27.6
20	11.5	8.1	3.4	8.0	0.40	24.0
30	14.0	11.5	2.5	10.5	0.35	21.0
40	8.4	3.5	4.9	15.4	0.39	23.1
50	12.0	8.4	3.6	19.0	0.38	22.8
60	15.1	12.0	3.1	22.1	0.37	22.1
120	12.1	3.5	8.6	30.7	0.26	15.4
180	18.2	12.1	6.1	36.8	0.20	12.3
240	7.6	3.5	4.1	40.9	0.20	10.2

4.2 ANALYSIS OF THE RESULT

From the present topography of the pilot scheme (Z.P.P), it is clear that some areas of the scheme are waterlogged, while some areas are prone to draught. All those areas having elevations less than 100 cm are waterlogged, as there is no possibility of surface outflow.

The second reason why waterlogging occur in these areas is lack of effective drainage system – the shape, slope and the depth of the drain which are in very bad state. Also, the inability of the management to disilt and reconstruct the drains as well as the secondary canals contribute to this problem, because the excess water from the main canal, as well as its tributaries do not have access to the outlet which brings about a standstill of water on the land thereby causing waterlogging. Also, over – irrigation by farmers, under the wrong impression that more water will fetch more crop yield brings about waterlogging in the scheme.

However, bad tilling, creating obstruction to the flow in the farm by way of depressions, ponds, and improper land grading, seepage through a vast network of unlined canals, contributes to waterlogging in the scheme. Irrigation of unsuitable soils, that is soil with more depth of highly clayee soil brings about waterlogging.

Sub soil flow was another reason for the waterlogging in the pilot scheme.

Erosion is also a problem that contributes to the waterlogging in the scheme because the water that has been collected through drains from the town is emptied into the irrigation area. The water, which is accompanied with silt usually, erodes and deposit materials into the scheme, which also causes waterlogging.

The project area is located at the fadama area, which is at a lower elevation than the eastern boundary of Birnin Kebbi town. However, there is a tendency for ground flow of water from the farm and consequent accumulation of water at points of lowest elevation.

As it can be clearly seen that fig. 3.1 and fig. 4.1, that shows waterlogged areas occur in clay and loamy soil formations. These soils are known for their impermeability and must have contributed immensely to poor outflow and consequent rise in the water table, hence waterlogging.

Also, the highest seepage transmission loss value of 15.72 mm /min (table 4.1) was observed in the second reading after the first reading of transmission value of 15.61 mm / min. this was because during the first reading there were some bubbles in the water which shows the presence of air in the soil. The second reading was taken after the bubbles disappeared. This implies that the volume of air was removed from the soil in contact with water and then the air voids were replaced by water. This is why the transmission loss is higher than the initial reading of 15.61 mm / min. after these two high values, the transmission loss continue decreasing gradually to the least value of 0.54mm / min after 5.15 hrs. As the depth of water was increased, the transmission loss also increased to 2.11mm / min. this also shows that transmission loss decreases when the seepage was deep. The average value of 3.9-mm/ min was calculated from this channel.

In table 4.3, the first value of 14.94 mm / min is higher than the rest values and they continue decreasing gradually to 2.93 after 4.6 hours. As in the first channel, as the volume of water increased, transmission loss increases, also the mean transmission loss value of 5.8 mm / min was calculated.

Tables 4.2 and 4.4 are the tables of constant time of the both two channels. These tables were sorted out to compare the transmission loss with time to judge whether the increase or decease of transmission loss values varies, this may be due to soil characteristics, and strata configuration. The average mean values of transmission loss of the channels were calculated and chosen as the rate of seepage loss in the scheme.

It was also observed that the infiltration increased with time until it got to its peak and remained constant afterwards. The infiltration rate at the second fringe was slightly faster than the first fringe. However, it was much more slower at the bottom since after the first one hour there was no infiltration. This is the result of the contribution from run off and the clay characteristic of the soil.

4.3 CONCLUSIONS AND RECOMMENDATIONS

4.3.1 CONCLUSIONS

The following conclusions can be drawn from this study.

a. Four places are waterlogged and can be located on the pilot scheme as shown in fig.4.1 that constitutes about thirty percent of the land.

b. Waterlogging has been caused by the followings:

   i. Lack of surface outflow.

   ii. Lack of effective drainage.

   iii. Lack of adequate percolation.

   iv. Excessive inflow of water and

   v. Sub – soil flow.

4.3.2 RECOMMENDATIONS

To improve the conditions in the pilot scheme the following recommendations should be adopted.

a. A proper leveling of the site should be carried out so that free surface outflow can be achieved.

b. The drains and the canals should be regraded so that smooth inflow and outflow can be obtained.

c. There should be adequate monitoring of the lateral canals in order to forestall illegal activities of the farmers.

d. A further study should be carried out to determine the relative elevations of the farm and the drains in order to ascertain the adequacy of outflow.

It is also important in any irrigation project especially Zauro Polder Project, that water losses both at conveyance systems and distribution over the field should be minimized. The management of irrigation water should wisely be used without incurring unnecessary wastage. The basic aims are:-

i. To deliver and apply adequate amounts of water to the field.

ii. To deliver and apply the water at the time it is needed by the crops.

iii. Convey, deliver and apply with minimum wastage, employing all measures of minimizing losses in channels and at the field help to be taken into consideration.

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