CHARACTERISATION OF SOIL PHYSICAL PROPERTIES FOR POND DESIGN FOR AQUACULTURE AMONG RICE FARMERS AT KWABRE DISTRICT

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DECLARATION

I hereby declare that this submission is my own work towards the MSc. and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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ABSTRACT

Agriculture, the backbone of the Ghanaian economy employs around 51% of Ghana's work force. Currently most younger farmers are quitting and moving to urban centres for other forms of employments because they claim it is not lucrative.

There are various ways of minimising this drift and one of them is by developing alternative livelihood for small-scale farmers so that the full potential of the land and the farming skills of the farmers will be achieved. This study concentrates on the way of developing aquaculture through the initial soil study so as to develop alternative livelihood in fish production in earthen ponds.

The study area of this project was a valley bottom site at Adawonmase in the Kwabre District of the Ashanti Region in Ghana.

Farmers grow rice at the start of the rainy season (April/May) and harvest within three to four months (August/September). After harvesting the rice, they do not do any meaningful agriculture since by then the rains have stopped.

In a bid to develop an alternative livelihood for the farmers, an initial reconnaissance study was undertaken to interact with the farmers.

The farmers showed keen interest after a series of interviews on possible alternative livelihood to rice farming that they can practice in the off season. They expressesd interest in practising off-season aquaculture as a better alternative to farming in their locality.

In a bid to shape up this development of an alternative livelihood in fish farming, a lot of soil data was collected from two different sites (flood plain and upslope part of the valley bottom) and tested at the soils laboratory for their various soil physical properties so as to know the soils' water holding capacities which will aid in modelling a pond type for construction in the future.

Finally, after numerous soil analyses, an embankment pond, was proposed to be constructed on the upslope part of the valley bottom. This is because of the compactive nature of the clayey soils there and how easy and inexpensive it was construct these types of ponds.

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Again I would like to express gratitude to the rice farmers at Adanwonmase in the Kwabre District of the Ashanti Region of Ghana for expressing interest in the project and giving me all the necessary information for the locality I needed.

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Thank you and may God bless you all.

CHAPTER 1

INTRODUCTION

1.1 General Introduction

Agriculture, which is still a labour-intensive sector, remains the backbone of the Ghanaian economy, employing around 51% of the work force. However, its labour intensiveness is seen to be one of its major drawbacks. Ghana is still perceived to be overly dependent on the small-scale farmer, whose productivity in terms of land area put under cultivation, is low. This is largely due to the overdependence on rainfed agriculture for crop production, inadequate capital base for farm development and low levels of technological availability and know-how of the local small scale farmer. A major way of still keeping this workforce economically empowered is to develop alternative sustainable agricultural systems for their sustenance. Development of alternative livelihoods has become a popular policy to uplift the socioeconomic status of small-scale farmers and to reduce pressure on over-exploited farmlands (Crawford *et al*, 1999).

1.2 Agricultural Sustainability

Sustainable agriculture uses locally available renewable resources, appropriate and affordable technologies and minimises the use of external and purchased inputs, thereby increasing local independence and self-sufficiency and ensuring a source of stable income for peasants, families and small farmers and rural communities. This allows more people to stay on the land, strengthen rural communities and integrate humans with their environment (Gupta *et al*, 1996).

1.3 Ways of Alternative/Sustainable Farming

There are several examples of inculcating different methods of farming into the regular conventional farming practiced by small-scale farmers to always keep them in business. Three of such ways are:

- Farmers can extensively rear livestock in their tree crop plantation for their own consumption and make sales of the surplus to supplement their incomes
- According to Crawford *et al* (1999), seaweed farming has been incorporated into many community-based coastal resources management projects and fisheries management initiatives in China, Japan, Korea and other Asian countries as an alternative livelihood option for their fishermen. This is typically based on several assumptions. First, it is often assumed that small-scale fishermen are poor and that this is related in many cases to the overexploited nature of the resource. Secondly, it is also assumed that fishers are willing to give up fishing in favour of more lucrative economic opportunities, such as seaweed farming. Lastly, it is assumed that as fishers take up alternative livelihoods such as seaweed farming, this will reduce pressure on the fisheries. This is an excellent example of a project logic framework whereby certain inputs (e.g. promotion of seaweed farming) will lead to specific outputs (e.g. improved socioeconomic status of fishers, reduced fishing pressure and improved resource status)
- In China, fish is raised in rice fields in the southeast and southwest mountainous areas where there are few bodies of water for growing fish and fishing regions and towns are far away. Rice–fish culture is a traditional and popular way for the people to grow their own supply of fresh fish in the mountainous areas of

Qingtian and Yongjia in Zhejiang Province. Rice–fish farming is an effective way to make full use of rice field resources and to cultivate freshwater fish. It offers remarkable advantages: it does not require the use of other land and water bodies; it has a short cycle, requires small capitalisation, gives fast results and benefits, is easy to manage and uses simple technology. It also fully uses the productive potential of water in the rice fields. In agriculture, ecological and multiple uses of land should not be overlooked. Rice–fish cultivation can improve the ecological environment of the field, whilst providing economic benefits. It makes good use of water resources in the rice field, decreases competitors in the waters, makes reasonable use of fertiliser and sunlight, and improves the fertility and permeability of soil (Defu *et al*, 2006).

1.4 Study Area

For the purposes of this project, the inland valley plain at Adanwomase in the Kwabre District in the Ashanti Region of Ghana was used. Inland valleys correspond to the upstream parts of river systems and these lowlands have an important potential for the intensification and diversification of agricultural production and are a privileged environment for biodiversity conservation. This is due primarily to their specific characteristics: a zone of high water concentration, relatively fertile soils, and lower risk for ecological degradation.

Despite this potential, the use of inland valleys is currently still limited, both in time (limited use in dry season) and in space (numerous valley bottoms are not exploited yet).

This under-exploitation of inland valleys is due to various constraints such as land tenure problems, difficulty in developing and working the land, health risks and so on.

1.5 Background

A section of farmers who work on about 40.5 ha of farmland at the eastern part of Kwabre District, which borders Ejisu-Juaben District for some time now grow mainly rice in the farming season. This is primarily due to the valley nature of the topography that creates flood plains and hence the swampy nature of the land that allows for the type of rice produced called the "*valley bottom*" rice. Another important feature in the area is the perennial Oda River, which is very much at its peak during the rainy season, which the farmers can use for the irrigation of their farms. Water from the river is never utilised at all for any form of farming.

The farmers normally plant just at the start of the rainy season (April/May) and harvest within three to four months (August/September). After harvesting the rice, they do not do any meaningful agriculture since by then the rains are gone and they do not have the technology of using water from the river as a source of irrigation water aside the fact that it is also expensive to have an irrigation project so as to grow rice all year round. Production of rice has not been very economical to them, yet they practice due to the fact that it is their only source of livelihood.

Another alternative is to channel some water from the river to ponds for use in off-season aquaculture and vegetable production.

This research was carried out because farmer groups in the locality showed interest in an alternative livelihood such as fish farming after the production period of their rice for sale. The idea is to develop an alternative livelihood for such farmers in the community and Ghana as a whole to farm all year round so as to supplement their income, provide a relatively cheaper source of protein and keep themselves in business till the next planting season.

1.6 Statement of Need

Agricultural production in Ghana has generally not kept pace with global developments. Reasons for these include, slow adoption rate of improved technologies, continuous use of traditional implements not suited to large scale production, advanced age of subsistence farmers, coupled with the youth migrating to the cities, lack of credit facilities, inadequate infrastructure development, marketing and inappropriate policy measures. In addition to most of the agricultural problems faced in Ghana, most farmers depend on rain-fed agriculture but since rainfall is seasonal, farmers are redundant throughout most part of the season. One of the ways of minimising this redundancy and other militating issues is by developing alternative livelihood for these farmers.

The concentration of this dissertation is on valley bottom rice farmers. This category of farmers have their complexity due to the very wet nature of their land, with heavy rainfall, high water table and flood water which is not easily controlled contributing to the difficulty of rice growth coupled with intensive weed and pest control. In spite of this, valley bottom rice farmers have the potential of fully utilising their wet lands during the off-seasons so as to utilise the full stretch of the year.

One of such simple ways is to practice an off-season aquaculture production. To set up an aquaculture system in any area including the valley bottoms require some study into the nature of the soil types, hence the need for the site characterisation of the soil physical properties for its suitability for fish farming. Site explorations enable the soils engineer to provide answers to the main problems of:

- Seepage and
- Pond slope stability.

It also helps to furnish information to the designer of the structures about the foundation conditions.

This project sought to study the site characteristics of soil physical properties for aquaculture implementation among rice farmers in the Kwabre District and until proper study and documentation of the countries flood plain areas are kept, developments like aquaculture will be laborious and time consuming to undertake.

1.7 Aim and Objectives

The main aim of the project was to develop an alternative livelihood source for a group of rice farmers in the Kwabre District and the specific objectives were to:

- Assess technological and training needs of the farmers,
- Determine site conditions for farm pond design and construction and
- Propose a design of fish pond for implementation.

CHAPTER 2

LITERATURE REVIEW

2.1 Brief History of Rice Fish Culture

According to De la Cruz *et al* (1992), cultivating rice and fish together has been a 2,000-year-old tradition in some parts of Southeastern Asia. However, this beneficial cultivation system was gradually abandoned due to population pressures, decreasing stocks of wild fish and the "Green Revolution" which emphasised high-input monoculture using high-yield rice varieties, pesticides, and herbicides (which are toxic to fish). During the 1980s and early 1990s, rice-fish culture as managed cultivation systems experienced a revival, as concerns over the widespread use of pesticides emerged. In several Southeast Asian countries, rice fields as natural fisheries are more important than as places where cultured fish are raised. Native fish species are favoured over species that are generally cultured like the common carp, Nile tilapia and silver barb.

According to studies by Gupta, *et al,* (1996), rice fish culture can actually increase rice yields (up to 10% in some cases) whilst providing farmers with an important source of protein and extra income. Implementation is relatively inexpensive and low-risk. It was conclusively shown that integration of aquaculture with agriculture can increase rice yields, besides being a viable, low-cost, low-risk, sustainable economic activity, with multiple benefits:

- Production of diversified products, rice and fish from the same land area
- Increased incomes and nutrition to farm households
- Reduced labour costs in rice cultivation
- Lesser use of pesticides and spread of risks due to diversity of produce.

Thus integration is economically and ecologically beneficial and is a way for securing food for small farmers. In spite of the small size of fish at harvest due to the short rearing period, farmers were continuing integrated farming indicating it sustainability.

2.2 Experiments in Rice Field Fish Culture in Ghana

Various experiments in the past conducted by Ghana Fisheries Department in the 1960's, showed that combining rice and fish has been in existence in Ghana for a long time now. These experiments were started in 1960 in two ponds (A and B) each of about 0.1 ha (¼ acre) in size in the Turi-Kalsari experimental fish farm at Lawra in the Upper West Region of Ghana. Pond B was the experimental pond and pond A the control. Experimental pond B was first fertilised with about 4.5 kg of superphosphate before sowing with swamp rice. After the rice had germinated, the pond was flooded with water and then stocked with 820 Tilapia fingerlings on 13 June 1960. Species used were *T. nilotica, T. zillii and T. galilaea* (all less than 8 cm long). The same number and size of fingerlings were stocked in control pond A which was flooded with water only and no fertilisers used. The numbers and sizes of fish harvested are shown in Table 2.1.

Table 2. 1: Fish production in experimental ponds in Ghana

Year	1960		1961	
Pond	Rice pond (B)(fertilized)	Control (A)	Rice pond (B)(unfertilized)	Control (A)
No. of fish stocked	820	820	710	710
No. of fish harvested	21,000	12,200	1,997	1,008
Size distribution of fish harvested				
< 10 cm	4,000	3,900	209	308
10 – 14 cm	15,000	8,000	100	200
15 – 20 cm	2,000	100	1,688	500

This experiment was repeated in 1961. But this time no fertilizer was used in the rice pond. At the beginning of the rains in May the ponds were filled with water after pond B had been sown with rice. Both were stocked with 710 Tilapia fingerlings (all less than 8 cm long). Again the species used were *T. nilotica*, *T. zillii and T. galilaea.*

Results obtained from the experiments were very encouraging and rice farmers who had their fields flooded during the rains were often advised to stock their fields with Tilapia fingerlings. This idea, however, did not become popular because the farmers had some difficulties. Most of them had their farms very far away from the Turi-Kalsari fish farm, or far away from any other fish pond where they could obtain fingerlings. Transportation facilities were not easily available to them and the idea could not get good publicity.

2.3 Benefits in Using Farm Ponds

Numerous benefits realisable by farmers include:

1. An increase in income from the production of both rice and fish
2. A reliable source of protein for farmers and their families, countering the decrease in available wild fish in many countries
3. Water reservoir for supplementary irrigation
4. Pond for fish rearing
5. Wastewater from pond for vegetable production hence reduction in using fertilisers

2.4 Types of Rice–Fish Culture

There are three ways to combine rice and fish:

- **Rice and fish together**: Planting rice whilst raising fish is the main method used. The method makes full use of time, space, energy, and resources of the rice field and provides economic benefits. Its shortcoming is the rather high requirement for labour and management.
- **Rice and fish in rotation**: Planting rice and raising fish are carried on alternately; therefore, the contradictions between growing rice and raising fish are avoided. After the rice is harvested, fish are raised in deepwater fields, which can improve fish yields. The disadvantages are that the growing period for the fish is shortened, and that the mutually beneficial and efficient relationship of rice–fish culture is lost. In regions with two rice harvests, the rotation of rice and fish will reduce rice yields.
- **Special ponds creation**: Special but simple ponds are created at identified suitable location of the rice field for fish rearing. This system is suitable for small-scale rice farms where the rice bunds have not been developed. Water from the ponds can be channelled onto rice fields appropriately for irrigation.

2.5 Pond Types

The two major types of ponds are:

- An embankment pond and
- An excavated pond

An **embankment pond** is made by building an embankment or dam across a stream or watercourse where the stream valley is depressed enough to permit storing 1.52m depth or more of water. The land slope may range from gentle to steep.

An **excavated pond** is made by digging a pit or dugout in a nearly level area. Because the water capacity is obtained almost entirely by digging, excavated ponds are used where only a small supply of water is needed. Some ponds are built in gently to moderately sloping areas and the capacity is obtained both by excavating and by building a dam. The criteria and recommendations are for dams that are less than 10.7m high and located where failure of the structure will not result in loss of life; in damage to homes, commercial or industrial buildings, main highways, or railroads; or in interrupted use of public utilities.

2.6 Design Criteria

Ponds are essential components of most fish and aquaculture farms. Lowlands or valleys are usually selected as sites for these ponds and this is often the decisive consideration in selecting the site for the entire project. The ponds are normally shallow, and are surrounded or impounded in the majority of cases by low earth dykes or dams.

The ponds are usually filled and drained through open canals and other methods, such as filling through a pipeline, being exceptional (Váradi, 2006).

2.6.1 Water Source

An adequate water source is needed to maintain water levels. A supply is available from four types of sources.

a. Overland drainage

Surface runoff from precipitation or a flowing spring travelling overland as sheet flow or concentrated in a drainage way, can be collected in a pond basin. Ponds with this type of water source are located on or below sloping lands. Annual precipitation rates and drainage area characteristics determine the adequacy of the water supply for each potential pond site.

b. Groundwater

In areas where groundwater is near the surface, excavating into and below it will create a pond. Groundwater fed ponds are generally located in flat low lying areas and do not require a surrounding embankment.

c. Flowing waters by in-stream impoundment

Constructing a water impounding structure or dam across a water course will capture water and create a water body. Careful consideration should be undertaken before pursuing a pond of this nature. Environmental concerns such as blockage of fish passage or warming of down stream waters can cause adverse impacts. Also, sediment from upstream areas will become trapped behind the structure requiring periodic removal to prevent loss of water depth in the pond basin.

d. Flowing waters through diversion

A water source can be provided by diverting a portion of a stream's flow to an impoundment area or excavated basin. The diversion may use a weir or similar structure to direct water through a pipe or ditch to the pond site.

2.6.2 Drainage Area

Drainage area is a measure of the amount of land surface contributing water by runoff to a pond site and is presented in square kilometres or hectares. Runoff volumes are determined by precipitation, soil type, vegetative cover and topography. For ponds relying on surface runoff the drainage area must provide an adequate supply of water to maintain pond water levels. Too large a drainage area should be avoided as excess runoff during storms can damage embankments and spillways or result in pond washout.

2.6.3 Soil Requirements

Ponds fed by surface runoff must have impermeable soils beneath the pond basin to prevent excess downward seepage, otherwise the pond will not maintain water. Soils containing sufficient percentages of silt or clay content are best suited to pond establishment. The excavating of test pits at the proposed pond site allows for an evaluation of soil type and suitability. If suitable soils are not available on site, appropriate soils or soil amending products may be obtained from off site.

Required Soils for Ponds:

Such soils by nature should:

- Hold water
- Have stable side slopes and dams
- Have properties sufficient to form embankment
- Hold the pipes: soils with relatively high contents of silts and/or very fine sands tend to flow when saturated with water, which results in mass washing either at the surface or in tunnels through the embankments
- Have less organic matter because soils with high organic matter do not compact well, thus create unstable embankment. Excess grass, leaves, stumps should be kept out of the embankment
- Not have soil materials which do not compact to maximum dry density because this will not form a stable and usable embankment. Compaction is necessary, to reduce the permeability of the embankment and prevent settling problems following construction.

If the land was used for crops, test the soil for accumulated pesticide residues. Avoid areas with acidic soils. Areas with high groundwater also cause problems. It is difficult, or impossible, to build ponds if in such areas a pond is built, it cannot be completely drained and dried, basic steps which are necessary for efficient management. The land should be flat and slope gently away from the source of water or reservoir. An area for the accumulation of surplus water should be available below the pond. An 'open' site is advantageous because it allows wind to aerate water in the pond (Rowland and Bryant, 1995).

2.7 Pond Design Options

Materials and structural choices vary depending on needs and site conditions. Good pond design and construction are key to efficient functioning of the farm and the costs of construction and management. A well-designed and properly constructed operation also makes controlling potential and environmental impacts easier. The basic options are the extensive and intensive systems (FAO, 1983).

Table 2. 2: Characteristics of Extensive and Intensive Systems

SYSTEMS	MAKE	CHARACTERISTICS
Extensive	Earthen pond	Built to farm fish, specific and shape; water level and water quality monitored and maintained; some supplementary feeding; predator control.
Intensive	Tanks, raceways, troughs, cages, small earthen ponds	Complete feeding. Generally, prepared feeds; highly managed ponds with regular water exchange/management

Table 2. 3: Advantages/Disadvantages of Extensive and Intensive Systems

System	Advantages	Disadvantages
Extensive	Requires less water, hence lower pumping costs	Large area of land required
	Fewer disease problems	Monitoring of disease organisms more difficult
	Fewer water quality problems	Control of disease, water quality and weed and algae growth may be difficult and costly
	Lower feed costs	Less control over size of fish. Harvesting is a major operation
Intensive	Less land required	Requires abundant water and subsequent pumping cost
	Monitoring and control of disease is relatively easy	More disease problems
	Monitoring size and culling easy, harvesting easy; may be partial or selective	Closer monitoring of water quality required High feed costs

In extensive aquaculture systems, fish are stocked at relatively low densities in earthen ponds. Feeding is based partly or completely on the natural food in the ponds. Extensive cultures need only enough water to fill and maintain the water level in ponds.

In intensive aquaculture, fish are stocked at high densities in troughs, raceways, tanks, cages or small ponds. Their growth is based mainly on artificial feed (normally specially formulated diets in pellet form). As the level of intensity increases (that is, as stocking density increases) the level of management and technological input also increases for successful culture.

2.7.1 Site Selection

- Sites should be selected for fish farms only where water of the required volume and quality is available at the times needed for operating the farm
- Preference should be given to sites where a gravity water supply to the farm is possible
- The quality of the water available must be such that the desired fish can be raised, e.g. fresh, brackish or salt water
- Gravity drainage of the ponds should be possible
- The soil in the area selected should, if possible, be impervious
- For low construction costs, plain areas with slope less than one percent should be selected and
- In the proximity of inhabited areas, consideration of the necessity of guarding against poachers should be kept in mind.

2.7.2 Shape

Ponds should be square or rectangular to make the most efficient use of available land. It is more economical to construct square ponds; however, rectangular ponds are easier to manage.

Rectangular ponds are the most common pond shape because this maximises the benefits of water exchange in a semi-intensive culture pond since water enters on one side and drains from the other.

Circular ponds have very good water circulation characteristics, but poorly utilise available space. Although use of a square pond would minimize erosion, these are rarely used except in intensive culture systems because they have circulation problems reducing the benefits of water exchange (FAO, 1983).

2.7.3 Supply and Drainage

The pond should have a separate inlet and outlet. Both should be screened; the inlet to prevent the entry of trash fish and other undesirable aquatic fauna, and the outlet to prevent the loss of stocked fish. The diameter of supply and drainage, if pipes are used, should be at least 15 cm. Lay all pipes underground and do not plant trees close to drainage or supply lines.

Construct ponds so that it can be drained completely and rapidly. This will enable the removal of all fish during harvesting and facilitate efficient management, particularly when water quality and disease problems occur. Complete drainage can be achieved by a raceway or well in the deeper section of the pond. The bottom of the pond should be level and slope gradually towards this area.

The outlet structure should enable the adjustment of water level and also allow for the overflow of excess water. It is important that water can be drained from the bottom as well as the surface, so that the 'dead' water (low or deficient in oxygen) can be removed.

Pond should have a deep (at least 2 metres) and a shallow (1-metre) section; however, the preferred depth varies with the species and the locality. A deep section has the following advantages:

- the deeper water is a buffer against extreme temperatures
- facilitates harvesting
- increases production (at least up to depths of about 3 metres)
- reduces evaporation during warm climates
- reduces or eliminates the growth of macrophytes

Banks are constructed wide enough to ensure strength, stability and vehicular access. The latter is extremely important and enables efficient management of ponds. Banks are built with slopes of about 3: 1 (Figure 2.1). Line the banks with topsoil and plant with grasses to ensure stability and prevent erosion. Use animals to eliminate or reduce the need to mow pond banks. Cattle should not be used as they erode the banks and may enter the water and increase turbidity and nutrients to undesirable levels: sheep or goats are a better alternative.

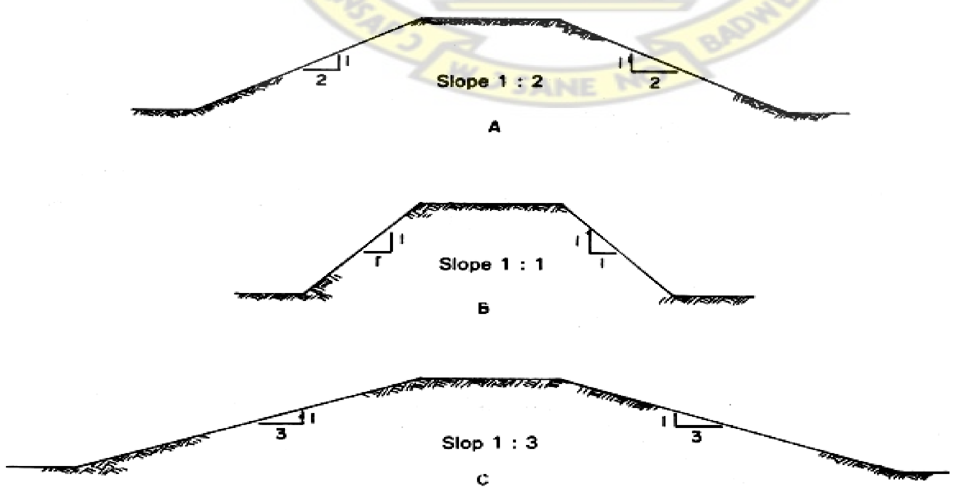

Figure 2. 1 Typical design of dyke (FAO, 1983)

There is a large variation in the size of earthen ponds used in aquaculture throughout the world and authorities disagree on the optimum size of ponds. Ponds used in the channel catfish industry in the United States of America vary from < 0.4 hectares to 40 hectares; ponds in Israel are generally no larger than 10 hectares. Ponds range from 0.1 to 1.0 hectare in the silver perch industry.

A number of factors will determine the preferred size of ponds on each farm: the function (that is, broodfish, larval rearing, grow-out) fish species to be farmed, techniques and stocking densities, cost of land, topography, capital and equipment available for construction and the planned production capacity. Large ponds have a lower cost of construction per unit area than small ponds. However, there are a number of disadvantages in using large ponds:

- difficult to monitor and control disease outbreaks
- difficult to manage water quality problems
- difficult to control algae blooms
- costly to control disease outbreaks and algae blooms, as the entire pond must be treated
- erosion of banks
- difficult to sample or catch fish
- slow to drain, leading to stress, deterioration of water quality and possibly predation by birds during and after harvest, there is a large quantity of product to handle and market.

Construct ponds no larger than about 2 ha to enable the efficient management necessary under intensive conditions, Boyd (1999).

2.8 Design Considerations

Some important pond design considerations are:

2.8.1 Pond Size, Depth and Configuration

Determining adequate pond surface area and depth are often a function of volumes of water necessary to meet usage needs. Pond depth may also be predicated on recreational uses such as swimming, fish rearing, or wetland creation. According to Boyd (1999), the configuration or shape of the pond is often a matter of aesthetic consideration.

An irregular shoreline that blends in with the surrounding terrain is generally most pleasing to the eye. Physical conditions may also dictate pond dimensions, such as depth of impermeable soils or slope of lands adjoining the pond site. Site conditions that result in back flooding of neighbouring properties must be avoided. Wind directions and velocities should be considered since it has three major effects on water in culture ponds:

- It circulates the water, thus mixing the layers of differing density which tend to form in ponds (stratification);
- It tends to lower the water temperature by increasing evaporative cooling; and
- It generates waves in a pond which can cause erosion of pond banks.

The potential of the waves to cause damage is proportional to the velocity of the wind and the distance of the fetch (Fetch = the distance that wind travels across a pond).

The larger the pond, the higher the probability of damage from erosion. Prevailing wind direction and velocity exhibit a distinct, seasonal variation. As a general rule of thumb, wind will blow from the direction of a major body of water (ocean, bay, etc.). The length or longer axis of the rectangular ponds should be orientated perpendicular to the wind (Figure 2.2). Thus, the strongest and most persistent winds will blow across the shortest axis (width) rather than down the longest axis (length) of the ponds. This will minimise the wave generation and the resulting erosion.

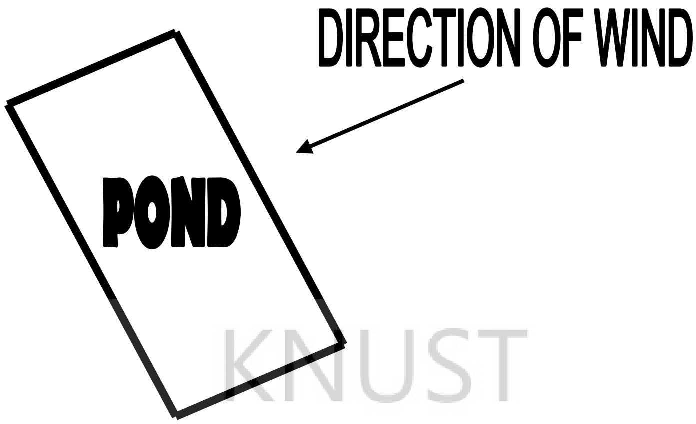

Figure 2. 2 Pond orientation (longer axis should be perpendicular to the prevailing wind)

2.8.2 Spillway Capacity

The spillway, such as a vegetated earthen channel around the dam, provides an outlet for excess water. It is critical that the spillway be sized to pass flood waters and be stabilised to prevent erosion or washout of the structure.

2.8.3 Dykes

Dykes do not only serve as boundaries to indicate pond size and shape but also function to hold water within the pond as well as protecting other farm facilities from flood. Dyking materials must preferably be tested for load bearing capabilities and compactibility. In some cases where the quality of the soil is inferior for dyking, other materials, viz: concrete or clay must be used as core materials to be placed at the pond bottom. Design and construction of embankment must be based on sound engineering principles and economic feasibility. Top of the dyke is usually made wide enough to facilitate truck movement. Where possible, dykes are shared between ponds to reduce earth movement costs. A typical design of perimeter dykes facing the sea or a river is shown in Figure 2.3.

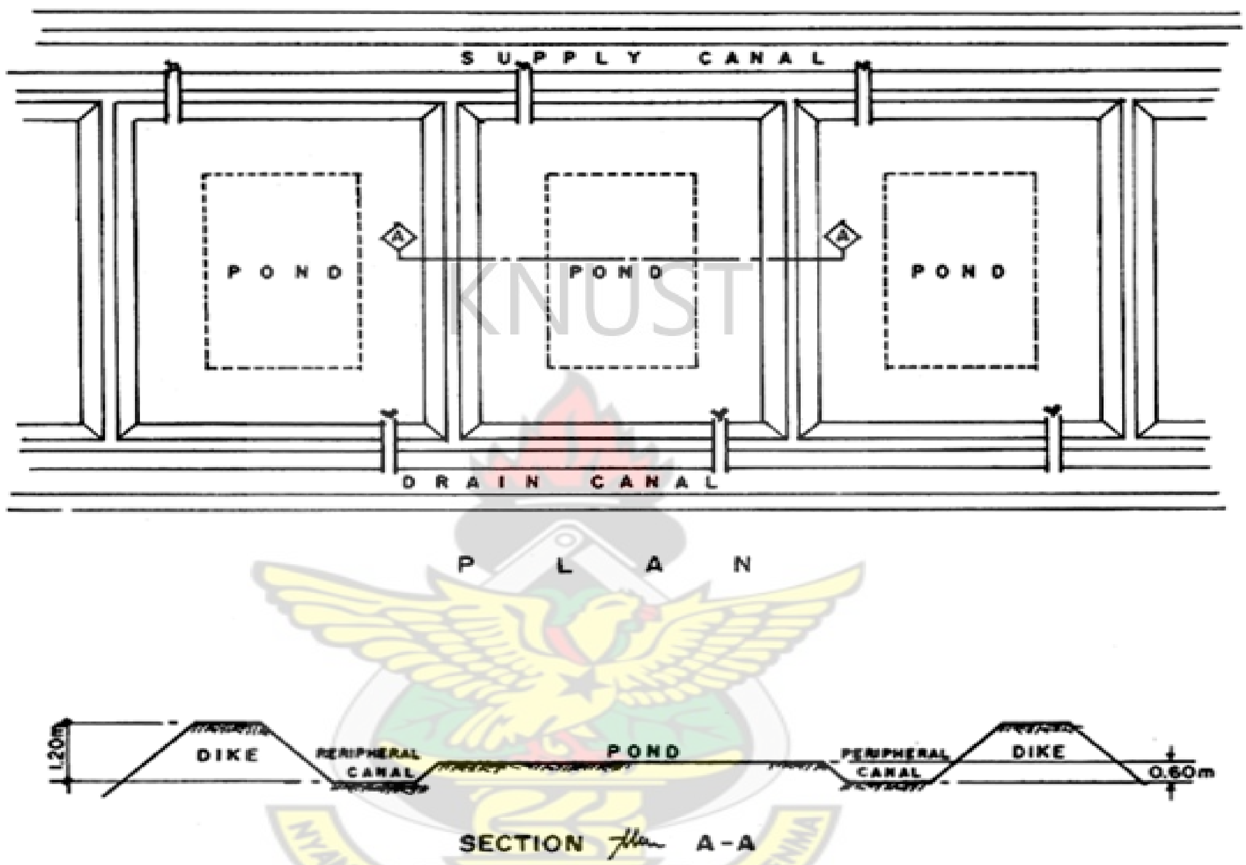

Figure 2. 3 Layout of earthen pond with peripheral canal (FAO, 1983)

2.8.4 Structural Integrity

Foundation preparation, construction specifications and spillway design, are the most important components of a pond created by an impounding structure. These factors determine the structural strength, water retaining capability and safe function of the structure.

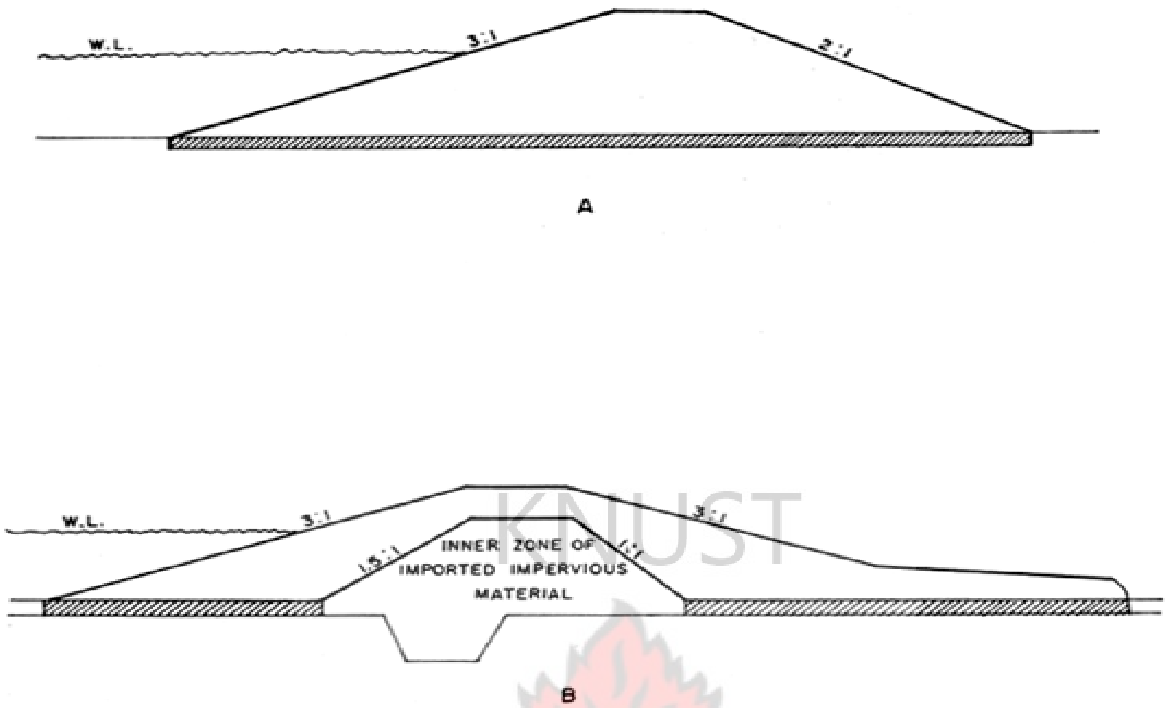

Figure 2. 4 Cross section of dyke (FAO, 1983)

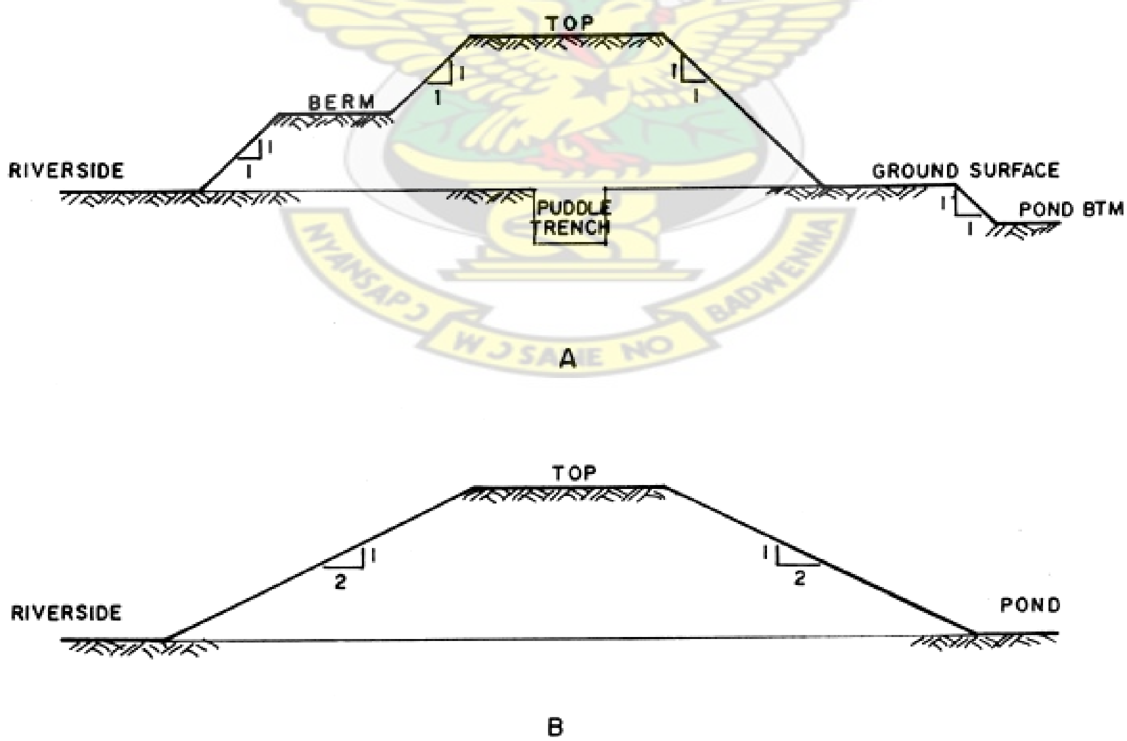

Figure 2. 5 Sample design of perimeter dyke (FAO, 1983)

2.8.5 Other Design Considerations

The steepness of pond basin side slopes affects light penetration to the pond bottom. To minimise areas supporting rooted aquatic vegetation, pond side slopes should be steep to maximise the area of deep water. On the other hand a pond with steep banks will be subject to aquatic rodent problems. Shallow tapering side slopes create broader areas for establishment of rooted aquatic vegetation. Provide a structure that allows draining of the pond or provide for a constant release of water from the pond bottom. This can be accommodated through installation of a pipe under a dam or embankment with a valve for controlling water flow. A drop inlet trickle tube can be installed to release normal overflow waters through the pipe, rather than regularly utilising an over the top of structure spillway.

Table 2. 4: Soil classification based on particle size

Soil Type	Range
Gravel	75 - 5 mm
Sand	5 - 0.07mm
Silt	0.07 - 0.002 mm
Clay	Less than 0.002 mm

2.8.6 Pesticide Use

Pesticides may be applied to ponds to control weed growth, algae blooms or to remove undesirable fish. Chemical treatment must only be performed by a registered pesticide applicator.

CHAPTER 3

MATERIALS AND METHODS

3.1 Introduction

During the study, it was realised that for development to be meaningful and sustainable, the community must first have interest in the awareness of rearing fish in ponds as an alternative livelihood to supplement their rice production. There is a village or community belief that "no one knows everything and no one is totally ignorant." People have different perceptions, based on their own experiences. Development must, therefore, be pursued by enhancing real dialogue among the farmers and also between other individuals and stakeholders. The listening-survey approach was therefore used. This method involves observing and listening to people and discovering their concerns.

Through this animation, farmers were assisted in developing a critical awareness of their conditions of life and therefore their roles and responsibilities in their own development. Because effective and active participation of the farmers are needed to achieve the objectives and overall goal of development, participatory dialogue and focus-group discussions were also used. The advantage of these approaches is that they prepare people to be involved in all phases of the planning process: problem identification, potential analysis, project selection, implementation, monitoring, and evaluation. Further information was obtained through field observation and physical inspection.

3.1 Materials

Frequent visits were made to the project site at Adawonmase in the Kwabre District of Ghana in order to execute this project successfully.

Both quantitative and qualitative methods of data collection were used. Digital cameras were used to capture on site images. A 5cm diameter and 20cm deep core sampler was used to extrude soil samples. A weighing scale was used to measure the weight of extruded soil samples. An oven was used to dry extruded soil samples at 105°C for 24 hours so that the moisture content of the soil could be calculated. A computer and associated software, (Microsoft office, excel 2003) was then used to analyse the data collected from site and the laboratory.

3.2 Methods

The research process and methods used played an important role in bringing about integrated approaches to developing an alternative livelihood for the farmers. The research methods were largely participatory, cost effective, and rapid. The data collection was designed not only to gather objective facts but also to facilitate an understanding of the processes going on behind the observed facts. This facilitated interaction with farmers and other citizens within the immediate vicinity. The process was designed to ensure maximum participation and the main steps were:

Collecting data and conducting field studies — a search to identify available data and assess its usefulness to the study preceded the field work. Published and unpublished reports, local newspapers and newsletters, and topographical maps were reviewed. These sources allowed for the development of profiles — physical geographic characteristics, socioeconomic status, and land-use patterns. Field data were collected during several visits, which used a combination of the following techniques:

- Direct observation and site visits and

- Informal discussions with farmer groups and other individuals.

Analysing, synthesising, and verifying data **—** the data collected were reviewed and analysed for information gathered at each step of the project.

3.2.1 Procedure

- **A reconnaissance study**

A reconnaissance study was conducted at the farm area. Here the farmers were grouped and verbally questioned on how they practice their rice farming and how they appreciate an alternative livelihood in fish farming practice during the off-season of their rice production. A sample of the questionnaire is in Appendix A-1.

- **Acquisition of topographical maps**

A topographical map of 1:50,000 scale of the specific location of the farm (Adanwomase) in the Kwabre District of Ashanti Region of Ghana (Figure 3.1) was acquired from the Department of Geomatic Engineering at the Kwame Nkrumah University of Science and Technology (KNUST), Kumasi. This map gives the specific location of the Oda River catchments which also indicates the elevations of the area. This helped in knowing the river course and the appropriate siting of the pond.

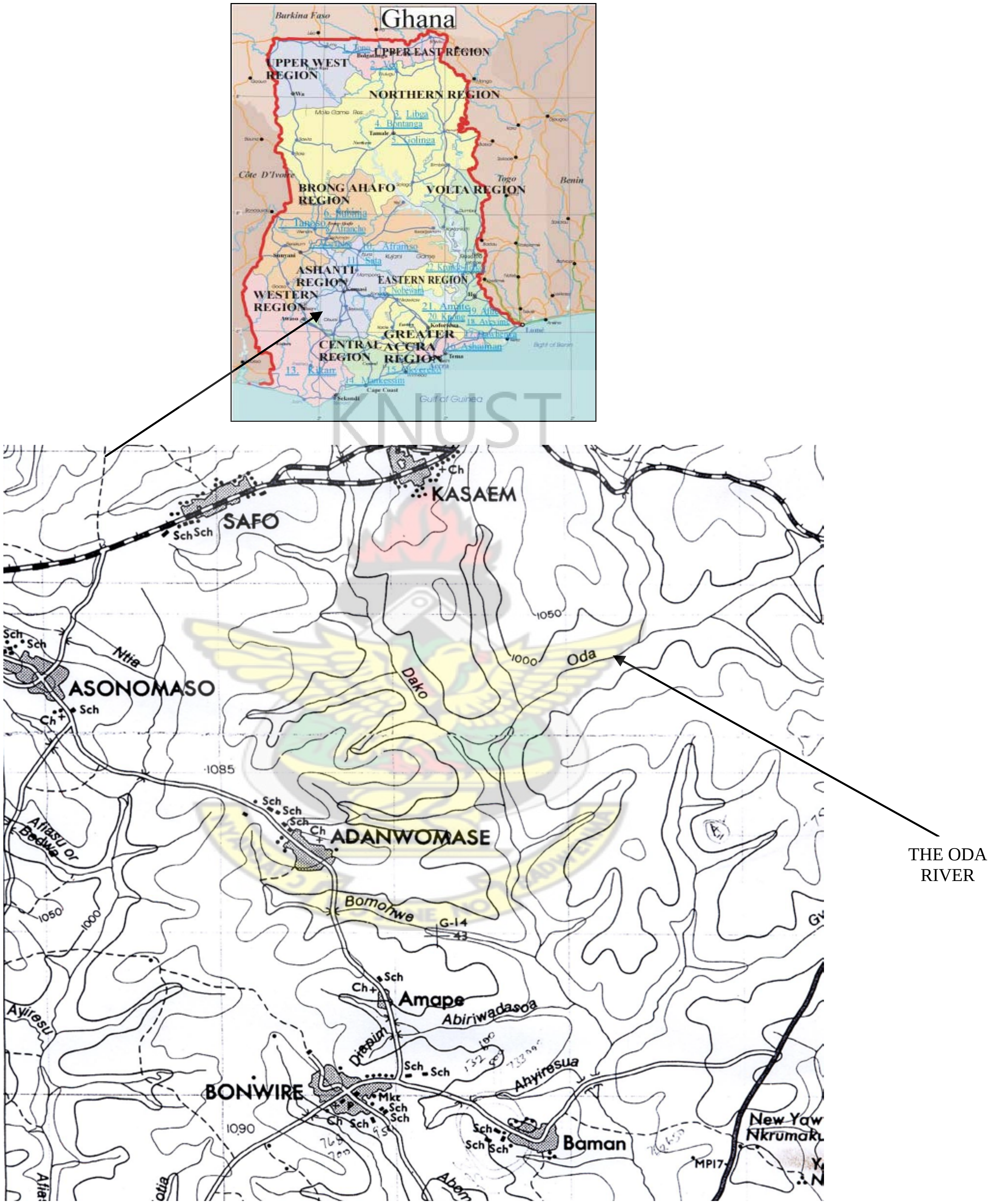

Figure 3.1 A topographical map of the River Oda catchments area of Kwabre District of the Ashanti Region of Ghana (Scale 1:50,000)

- **Pictures taken on site**

Various images were captured on site during regular visits as shown below.

Figure 3.2 A bank of River Oda

Figure 3.3 Swampy land (about 5m) from the bank

Arrow in Figure 3.2 is pointing away from the river and its bank to a swampy surrounding area of the River Oda catchments, (Figure 3.3) about 5m away from river bank which constitutes the flood plain (downslope) area.

Figure 3.4 Farmers crossing the River Oda

Figure 3.4 was taken in a period of very low rainfall but it was observed that, the Oda River was still flowing at a higher level.

3.2.2 Laboratory Testing

- **Soil sample test**

About 0.70 m by 0.55 m cross sectional area and 1m depth of soil was dug in two locations of the proposed pond area in the dry season on March 4, 2007. The first was made about 30 m from the river bank which constitutes the flood plain and about 50 kg of composite soil sample was taken to the soil laboratory at the Civil Engineering Department for laboratory testing and further analysis.

The second dugout was made about 40 m away from the first dugout. This area constituted the upslope part of the farm location. Another 50 kg of composite soil sample was collected for laboratory testing and further analysis. The laboratory tests made on the two 50 kg soils collected were:

- **Grading test:** The distribution of grain sizes is used by soil scientists to define a soil's texture. Soil texture is determined by the relative amounts of sand-, silt- and clay-sized particles. A coarse soil has a relatively large amount of sand or gravel. A soil dominated by clay-sized particles is generally described as fine. The grain-size distribution of a soil can easily be defined by laboratory tests.

  The finer soil material will pass through all the sieves. This material is then gathered and allowed to settle in a column of water, where the amount of silt and clay-size materials is determined. Further information about soil testing can be seen in the American Society of Testing and Materials standard D (ASTM D), 422, (1999).

- **Permeability test:** Permeability is defined as the readiness with which soil transmits water under standard field conditions. It depends primarily on the size and shape of the soil grains, the porosity of the soil, the shape and arrangement of the pores, and the degree of saturation.

- **Soil consistency (Atterberg limit test):** soil consistency describes how a soil behaves in contact with water. It states whether the soil is hard, friable, firm, plastic or liquid when it comes in contact with water. Atterberg Limits Test is used to measure soil consistency. Most soils with clay have plastic limits between the friable and sticky or liquid zones. Sand has not got any plastic limit because sand particles are inert and have no links with water. Same goes for silt. For a soil with up to 10 % clay content, clay dominance of soil behaviour and plasticity begins to set in, (Appendix C-1).
- **Compaction test:** Soil compaction is defined as the volume change produced by momentary load application caused by rolling, tamping or vibration. It involves the expulsion of air without significant change in the amount of water in the soil mass. One of the ways to determine compaction of a soil is in terms of dry density, and with this, it is necessary to find the bulk density and moisture content and this is usually done using the Standard Proctor Test (Appendix C-1).

  Soil compaction is desirable in most engineering situations and through it certain advantages in engineering works are achieved. Some of these advantages are:

- Reduction of detrimental settlement of soil
- Soil strength increases and improvements of slope stability
- Reduced soil permeability to water and airflow

- **Triaxial test:** The triaxial compression test is used to measure the shear strength of a soil under controlled drainage conditions. (Appendix C-1).
- **Particle size distribution:** Particle size analysis is the standard laboratory procedure for the determination of the particle size distribution of a soil.

  Principle

  Soil consists of an assembly of ultimate soil particles (discrete particles) of various shapes and sizes. The object of a particle size analysis is to group these particles into separate ranges of sizes and so determine the relative proportion by weight of each size range. The method employs sieving and sedimentation of a soil/water/dispersant suspension to separate the particles. The sedimentation technique is based on an application of Stokes' law to a soil/water suspension and periodic measurement of the density of the suspension.

- **Soil sample tests**

A core soil sampler of 5 cm cross sectional diameter that can extrude 20 cm depth of soil was used to take soil samples, (Fig 3.5-3.8) on proposed sites both at the flood plain area and the upslope area. In five successive extrusions of 20 cm deep into the soil from the surface, a depth of 100 cm of soil was also collected on both sites and each 20 cm extruded sample weighed instantly with a scale to note its mass in the fresh state. Each weighed sample was then dried in an oven at 105 °C for 24 hours. Each dried sample was then weighed again and the new mass recorded. After, several calculations were made to note the mass of moisture evaporated from the soil samples, the dry bulk density of the soils, the soil wetness and the porosity of the soil.

Figure 3.5 A core sampler in use

Figure 3.6 Sampler driven deep into the earth

Figure 3.7 Sampler being downloaded of extruded soil

Figure 3.8 Downloaded sample

CHAPTER 4

RESULTS AND DICUSSION

4.1 Introduction

Farmers were grouped and were made to indulge in participatory discussions about how they practiced their rice farming and how they will appreciate off-season fish farming. Table 4.1 is a descriptive summary of answers and views ascertained.

Table 4. 1: A summary of information gathered from farmers

Personal details of farmers	
Number of farmers interviewed	13 farmers – all male (they farm as a group)
Average age of farmers	30 years
Level of education	Majority of the farmers interviewed were primary school drop-outs
Origin of farmers	Settler farmers from Northern Ghana origin
Experience of farmers	Very skilled in rice production because of their experience in vast rice fields in Northern Ghana since childhood.
Farm operations	
Type of farming	Farmers employ manual farming methods. Occasional use of weedicides
Nature of farm land	Farm lands are fairly flat and swampy from observation and have not been designed (there are no bunds in place) prior to planting
Planting times	Rice is planted in February to await the first of two rainfalls in the Ashanti Region
Harvesting times	Rice is harvested about five months later (June/July), processed and sold for income Farmers claim to normally break-even after rice sales (no amounts specified) and will appreciate an alternative farm production for additional income
Priorities and importance	
Agreed alternative livelihood	Aquaculture (fish farming)
Utilisation of the Oda River	Zero to minimal usage of the river for agricultural purposes
Experience in aquaculture	Farmers have observed pond fishing in the Northern Region of Ghana due to numerous dam projects but have minimally been engaged in its practice

4.2 Soil Physical Properties on Proposed Site

Site explorations enable the soils engineer to provide answers to the main problems of seepage and pond slope stability and to furnish information to the designer of the structures about the foundation conditions. For the purposes of this project, two sites were selected and dugouts (0.70 m by 0.55 m cross sectional area and 1m depth) made on them to analyse soil physical properties. One at the flood plain (downslope) about 30 m away from the river bank and the other at the upslope about 40 m away from the first site. This was to ensure that an optimum site was proposed based on optimal soil properties on site for fish pond construction and sustainability as discussed on pages 37 to 39.

4.2.1 Dugouts Made

The first dugout made in the flat plain (about 1m deep) after a day had some water, depth of about 20cm collected in it even though it had not rained on site but the second dugout made on the upslope part had no water collected inside.

An explanation for this is that, the water table in the first dugout might be high to contribute to filling the pond even in the dry season, whilst the upslope dugout was dry based on the assumption that the water table is low.

Under normal circumstances, various soil samples that made up the 1m profile, were supposed to be collected and tested in the laboratory. On the proposed pond site chosen for this project, the two dugouts made had only the same clayey looking soil profile. Hence laboratory work needed to be conducted on the various samples.

According to Hora *et al* (1962) it was asserted that seepage losses are liable to occur mainly by underseepage and infiltration from the ponds, but when embankments are built normally of cohesive soils, placed and compacted carefully so that they will be practically watertight, these losses are prevented. Soils found near the Oda River in the Adanwonmase town were by observation, clayey, which is normally cohesive and hence good for a well compacted earth design works.

Table 4. 2: Soil bulk density at different depths on the down slope and upslope site

Bulk Density (ρd) g/cm³		
Depth (cm)	**Downslope**	**Upslope**
0-20	1.682	1.551
20-40	1.672	1.685
40-60	1.657	1.573
60-80	2.083	1.584
80-100	1.923	1.611
Average (ρd)	**1.803**	**1.601**

The higher the bulk density of a soil the better compacted the soil structure is and this minimises water seepage (Appendix B 1). Soils extruded from 20cm downwards to 100cm depths with a core sampler were analysed and the dry bulk density (ρ_d), wetness (Pm), and porosity (P) were determined (Appendix D 1). The average dry bulk density for the flood plain site from Table 4.2 was found to be 1.803 g/cm^3 which is higher than that of the upslope site 1.601 g/cm^3 selected. This result makes the flood plain site soils a very good choice to be proposed for pond construction. However, the upslope site is rather proposed. This is because upon careful physical site observations, when the two sites were excavated, the first dugout made in the down slope (about 100 cm deep) after a day had some water of about 20 cm collected in it as shown in Figure 4.1 even though it had not rained on site but the second dugout made on the upslope part had no water collected (Figure 4.2).

Figure 4.1 Dugout at the flood plain (downslope)

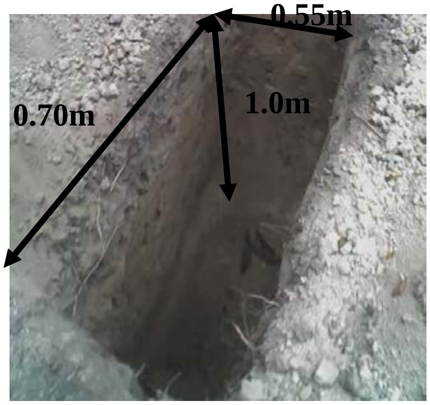

Figure 4.2 Dugout at the upslope

This amount of groundwater can potentially contribute to the designed water needed to operate a simple pond to be constructed. However, a lot of data will be needed to know the exact ground water generation that will contribute to the pond water requirements. In order to avoid a tedious data collection process and further calculation but to select an appropriate site for a simple pond design, and also have adequate supply of water from the river, the upslope site was proposed for fish pond dugouts.

A compaction test was also carried out in the Geotechnical Laboratory of the Civil Engineering Department at Kwame Nkrumah University of Science and Technology, Kumasi in June 2007 to ascertain the compactiveness of the soil. Appendix D-1 gives the full details of the compaction result.

Table 4. 3: Compaction test results – downslope and upslope soils

	DOWNSLOPE		UPSLOPE	
	Average Water content (%)	**Density (Kg/m^3)**	**Average Water content (%)**	**Density(Kg/m^3)**
1.	0.56	1.832	0.45	1.807
2.	5.34	1.869	3.17	1.873
3.	7.79	2.013	6.39	2.044
4.	10.58	1.952	9.96	1.981
5.	-	-	12.55	1.867

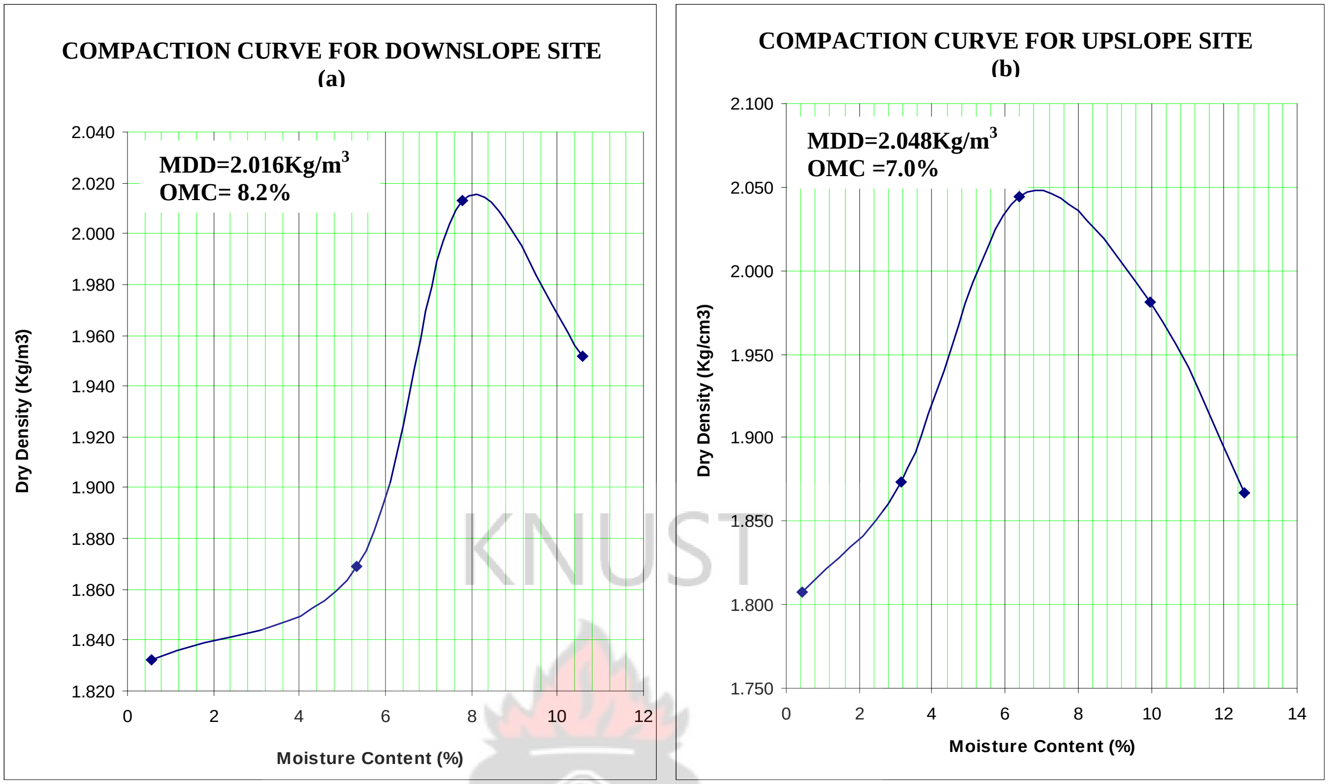

Figure 4. 3: Compaction curve for downslope and upslope soil samples

Compaction basically is increasing the bulk density by driving out air from the soil. The amount of compaction is quantified in terms of the density (dry unit weight) of the soil. Soils which are well compacted can hold water with minimum seepage. At the downslope site (from Figure 4.3) soils can be compacted to a dry bulk density of 2.016 Kg/m^3 at an optimum moisture content (OMC) of 8.2% which is relatively lower than the dry density as compared to that of the upslope values of 7.0% OMC and 2.048 Kg/m^3 dry bulk density. This gave a clear indication that the upslope soils were relatively more compact for pond development than the downslope soils.

Embankment Formation – The fill material to form the embankment has to be compacted at the OMC of 7% at the upslope part of the site. The procedure is to obtain the *in-situ* moisture content. Before construction, the moisture content is checked with the

OMC. If the moisture content is above the OMC, the soil is dried appropriately to OMC. On the other hand, water is added to bring the soil to the right OMC when water content is less and after, the compaction process done.

Case A: when the natural (*in-situ*) moisture content is below OMC.

Take for example, one kg of wet soil, at a natural water content of X%. The soil is to be mixed with water to achieve a water content Y% at OMC. The amount of water that needs to be added per kg of soil is calculated as follows:

Let the mass of dry soil be A kg.

Natural moisture content = (Mass of wet soil – Mass of dry soil) / Mass of dry soil

$$= (1-A) / A$$

For example: $0.03 = [(1 / A) - 1]$

$$(1-A) = 0.03A$$

$$0.03A + A = 1$$

$$A = 1 / 1.03$$

$$A = 0.971 \text{ Kg}$$

Hence total mass of dry soil per kg, A, at X% is 0.971 Kg.

At Y% (OMC) = 7% at upslope conditions

Gravimetric moisture content % = Mass of Dry Soil / Mass of Water

Mass of Water = Mass of Dry Soil / Gravimetric moisture content %

$$= A / Y\%$$

At X% (Natural water content)

Mass of water = A / X%

Amount of water to add = (A / Y %) – (A / X %)

Hence the amount of water to be added per kg will be [A ((1 / Y) - (1 / X))] to be able to compact the soil at OMC.

Volume of water per kg of soil = (Density of water) **x** (Mass of water per kg of soil).

Case B: when the natural (*in-situ*) moisture content is above OMC.

On the other hand, if soil needs to be dried to bring it to the right moisture content before compaction, the amount of moisture to be lost will be:

At natural moisture content Z%,

The mass of water, M_w at Z% = Mass of Dry soil **/** %Moisture content

At OMC (Y %), M_w at OMC = Mass of Dry soil **/** %Moisture content at OMC

Amount of water to be lost by evaporation = M_w at Z% – M_w at OMC

Table 4.4: Particle size distribution

Sample Identification	Percentage Sand %	Percentage Silt %	Percentage Clay %
Upslope	85.2	9.2	5.6
Downslope	89.2	5.2	5.6

After soils have been analysed to know its permeability to water, the other was to determine the particle size distribution i.e. proportions of coarse (sand and gravel) and fine materials (silts and clays) in the soil. This is very important because this helps the pond designer to know the right sealing method (i.e. a method of preventing water infiltration into the pond soil) to make ponds impervious. Where clay particles have been found to be less than 10 %, clayey soils may be dug from elsewhere to improve the soil quality of the pond location.

Clark, *et al* (1988), indicated that, if the soil material at the site is well graded from small gravel or coarse sand to fine sand, silt and clay, a pond could be made relatively impervious by compaction alone.

From Table 4.4, the upslope soil is a typical example of a well-graded soil. This has a well-graded particle size distribution of 85.20% of coarser sandy materials through to the very fine 5.60% clayey particles unlike the downslope soil particles. This method of sealing is the least expensive amongst different methods, but its use is limited to well-graded soils as described above.

4.3 Grading Curve

Figures 4.4 and 4.5 represent a cumulative grain-size curve, where each size fraction is expressed as a percentage. This curve is cumulative, so the amounts of all size fractions add up to 100%. The graph is expressed on a log scale. It has demarcations in both sieve size and in millimetres (x axes). It also expresses the percent of soil material that either passes through each sieve size or is retained on a sieve (y axes). Reading this graph, one may tell whether the soil being tested is relatively uniform in size or is well graded (i.e. displays a range of sizes) in particle size. This can be observed because soils predominantly composed of one particle size will have very steep or vertical slopes in a cumulative grain-size curve while well graded soils will have shallow slopes. Judging from the graph, one may observe in Figure 4.4, the downslope soils showing sharper curves as compared to the upslope soils shown in Figure 4.5. Hence the upslope soils are well graded and recommended in pond dyke construction. Dykes need to be fairly stable to avoid sloughing.

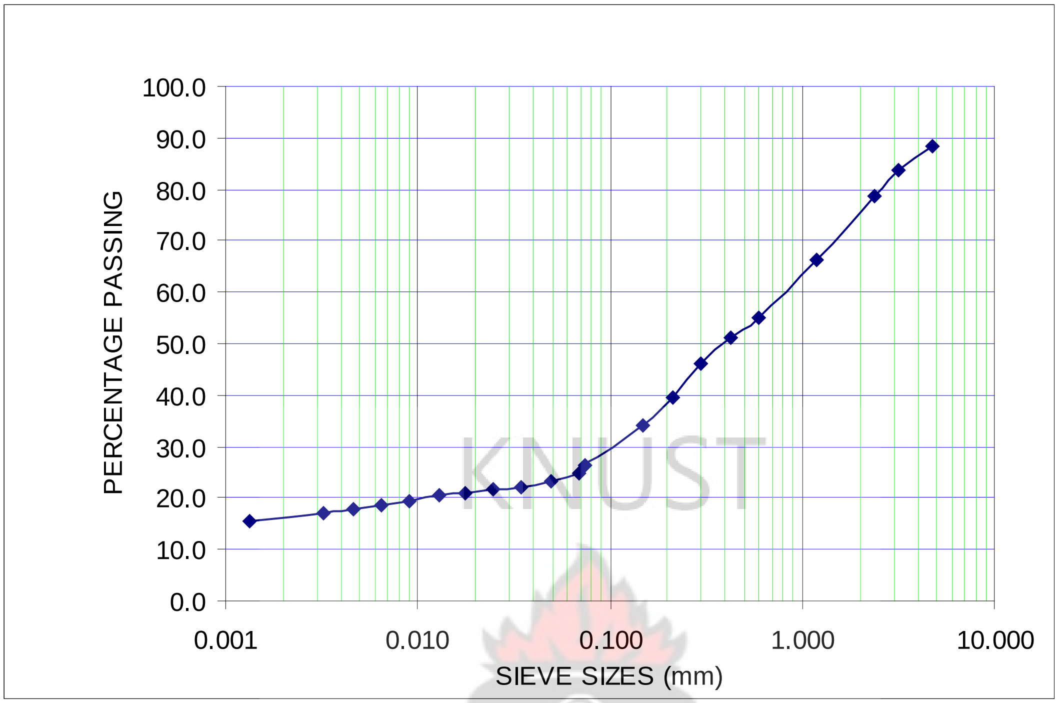

Figure 4. 4: Grading curve for downslope soil sample

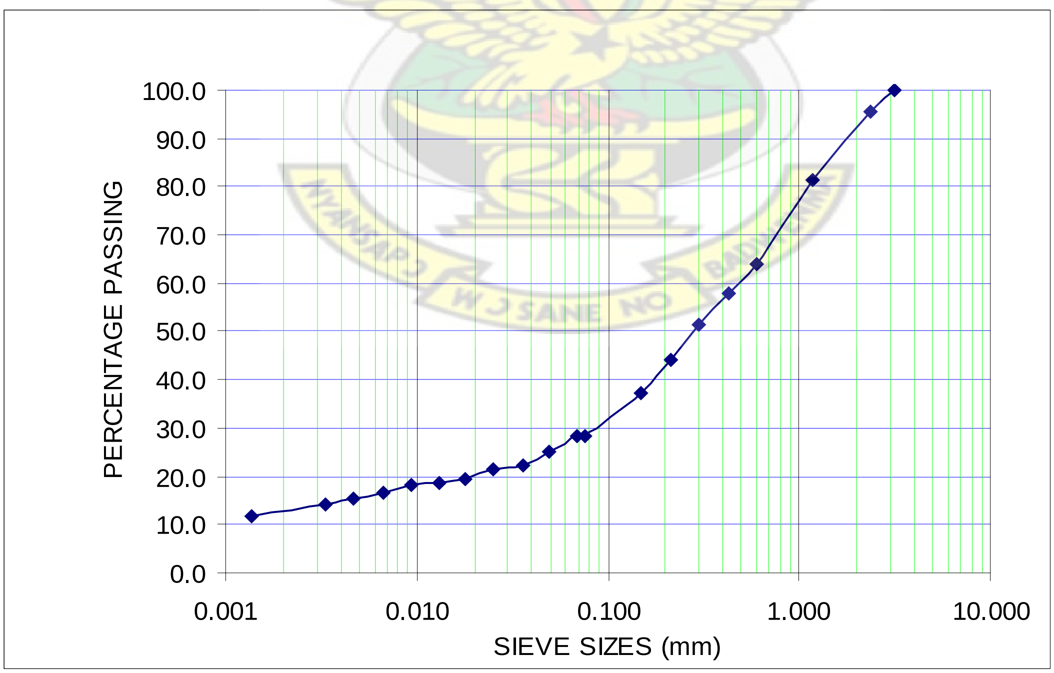

Figure 4. 5: Grading curve for the upslope soil sample

4.4 Soil Consistency

Good soils for pond construction are the ones with enough clay in them to minimize crumbling. In Table 4.5, soils collected exhibited different plasticity index as determined using the Atterberg limits test.

Table 4. 1: Atterberg limit result

	Downslope soils	Upslope soils
	% water content	
Liquid limit (LL)	22.90	22.90
Plastic limit (PL)	12.40	11.80
Plasticity index (PI)	**10.50**	**11.10**

The larger the plasticity index, the smaller the apparent friable zone that may lead to soil crumbling, (Appendix C-1, Table AD-4 and AD-5). From test results, soils upslope exhibits a larger PI, hence the smaller its apparent friable zone as compared to the downslope soils.

4.5 Shear Strength

Soil cohesion (C), is the natural ability of soil particles to bond to each other under no confining stress. This may be caused by cementation of the soils hence, minimizing the soils void ratio. The lower the soils shear strength, the higher its susceptibility to fail under pressure. This important factor guides in choosing a suitable location for pond construction. Table 4.6, indicates the soils strength parameters at both locations and this results give effective strength parameters which is very useful for pond side slope construction.

Table 4. 2: Shear strength parameters of soils

	Downslope	Upslope
Angle of soil to soil (internal soil) friction (Ø)	24.98°	27.40°
Soil cohesion (C)	56.43 KPa	103.29 KPa

Internal soil friction (**Ø**) is the effective angle of shearing resistance. This is the angle the dry soil will form a pile but not steeper. This important factor helps the pond designer to know the angles of the pond slope that will be stable when above soils are used.

4.6 Proposed Design of Pond

It must be emphasised that, actual pond construction was not made during this project but designing with safety, efficiency and minimum cost as ultimate criteria, the area at the upslope part with the steepest slope is chosen with an embankment pond construction in mind.

An embankment pond is relatively easier to construct as compared to an excavated pond because appropriate data gathered help to form a simple dyke against a natural slope.

In the starting data, a process of successive approximation is done, which includes:

- Expected income levels of the farmers and the type of fish to be cultured
- Deciding on height of the structure (depth of water plus the safety free board)
- The foundation conditions (compactible, well graded soils are readily available)
- An occasional minimum crest width enough to accommodate the movement of equipment on the crest is required and
- Pond inlet and outlet designs.

Expected income levels

Farmers expressed interest in tilapia fish rearing. This was a very laudable idea because tilapia is a delicacy with many advantages as seen in Table 4.7

Table 4. 3: Fish spicies selected for proposed pond

Fish Spicies Selected	Reasons For Selection
Tilapia (*Oreochromis niloticus, Sarotherodon galilaeus, Tilapia zilli*)	It is culturally acceptable They grow fast They are known to be disease resistant They are known to survive in unfavourable conditions
Cat fish (*Clarias gariepinis, Heterobranchus, Chrysichthys*)	Tilapia reproduce at a high rate and Cat fish feed on tilapia to keep their population controlled.
Catfish should be stocked at 10% the number of Tilapia	This prevents stunted growth because there is minimal competition for food.

An approximate length and breadth of 5.18m and 4.88m respectively whilst maintaining a constant depth of 2m will yield a surface area of 25.28m^2 as seen in Figure 4.6.

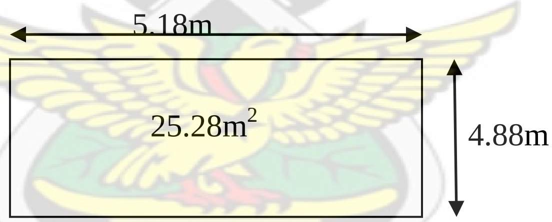

Figure 4. 6: Cross sectional area of proposed pond

$$\mathbf{25.28m^2 \approx 0.00003Km^2 \approx 0.0750Acre \approx 0.0303Ha}$$

From local market survey:

A grow-out pond surface area of 0.0303Ha asserted by Clifton *et al* (1990) can yield approximately 11kg per annum of tilapia fish at harvest. Eleven kg per annum of tilapia fish cost approximately GH¢ 50.00 ($ 52.00), local market survey, 2007, and if farmers desire to achieve sales of about GH¢ 600.00, then, approximately thirteen (13) of such ponds will yield a total surface area of 0.4 Hectare (1 Acre).

Hence, 1 Acre of total area of pond will yield:

13 ponds x GH¢ 50.00 per annum = GH¢ 650.00 per annum

A good fish pond can also provide recreation and can be an added source of income should one wish to open it to people in the community for a fee. Ponds that have a surface area of 0.1 hectare to several hectares can be managed for good fish production. Ponds of less than 0.81 hectares are popular because they are less difficult to manage than larger ones, (Clifton *et al*, 1990).

Tilapias are usually stocked at low rates to reduce competition for food and promote rapid growth. One month-old, l-gramme fry are stocked at 2,000 to 6,000 per 0.4 Ha into grow out ponds for a 4- to 5-month culture period.

Calculating the wave height

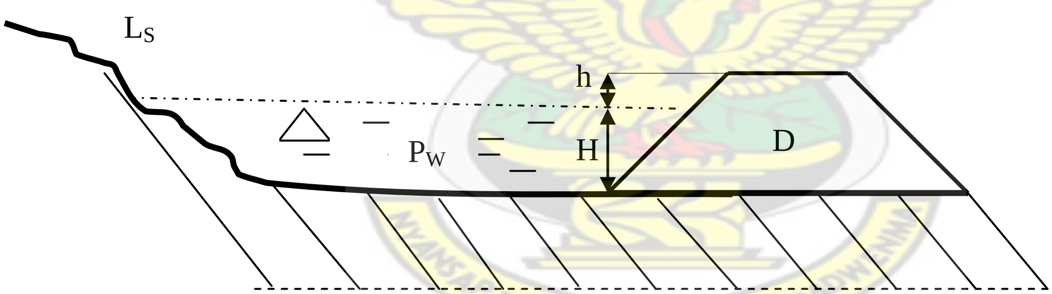

Figure 4. 7: A schematic design of pond with a dyke

D – Dyke
H – Water depth
h – Free board height
P_W – Pond water
Ls – Land slope

Free board (h) is governed by the wave action to which the dyke is exposed. The wave height is found by taking the direction and force of the prevailing wind, the fetch length and the depth of water into consideration. Below is an equation useful for calculating the wave height (U.S. Department of the Interior, Bureau of Reclamation, 2007).

$$\mathbf{h_w = 0.00186W^{0.17}B^{0.24}H^{0.54}} \textbf{ and}$$

$$\mathbf{h_w = 1/3 \sqrt{B}}$$

Where:
hw is the wave height in m
W is the wind speed in m/s
B is the pond width in the wind direction (fetch length) in km
H is the water depth in m

Calculating the pond foundation conditions

Even though actual pond construction was not made during this project, the seepage through the dykes can be estimated if the following factors are known: the coefficient of permeability of the dyke; the effective level of water in the pond; the width of the dyke; the nature of the soil on which the dyke is built (permeable soil or impermeable). When the soil used for the construction of the dyke is of homogenous material, the percentage of seepage will be calculated with Casagrande's formula:

A. When the dyke is on permeable foundation, seepage is the sum of seepage through the dyke and through the foundation beneath the dyke.

$$\mathbf{q = K\,[\{\sqrt{(h^2 + w^2)}\} - w] + K_1\,(h/w)\,(H)}$$

Where: q = Percentage seepage flow per cm length of dyke (cm^3/h)
K = permeability of coefficient of the dyke (cm/h)
K_1 = permeability coefficient of the permeable foundation (cm/h)
h = height of water level, cm
w = effective width of dyke, cm
H= Depth of impermeable soil layer below the dyke, cm

When calculated from the level of water in the pond:

$w = L – 0.7c$

Where L = width of the dyke at the bottom

$c = h \times a$.

h = height of water in the pond.

a = slope of the dyke, e.g. 1:a, where a, is the second number and a = 2.

For the dyke to be constructed at the upslope section of the site, from appendix D-1, Table A D-3,

K = 0.0000128 cm/h

K_1 = 0.0000128 cm/h upon the assumption that the soil is homogenous.

h = 2 m

$c = 2 \times 2$

$= 4$ m

For a 5 m width of the dyke at the bottom, and a depth of 1.5 m depth of impermeable soil layer below the dyke, the effective width of dyke, w, then becomes:

$= 5 – 0.7 \times 4$

$= 2.8$ m

$q = 0.0000128 [\{\sqrt{(2^2 + 2.8^2)}\} – 2.8] + 0.0000128 (2/2.8) (2)$

$q = 0.0000128 \times (3.44-2.8) + 0.000018269$

$q = 0.0000082 + 0.000018269$

$q = 0.0000265$ cm^3/h (per cm length of the dyke)

Hence, the rate of seepage at the upslope side is 0.0000265 cm^3/h (per cm length of the dyke)

B. When dyke is on impermeable foundation, the equation becomes:

$$\mathbf{q = K [\{\sqrt{(h^2 + w^2)}\} – w]}$$

When H approaches zero, the pond foundation is said to be impermeable, hence

$K_1 (h/w) (H) \approx 0$

The effective width of dyke can be calculated by referring to the above equations. In the same manner, a quantity of water is lost through the supply in earthen channels of the farm. A percentage of seepage of 1 to 2 cm/day is acceptable. If it exceeds this rate some measures to stop the excessive seepage should be taken. The losses through evaporation depend on the climate of the region and in particular of the temperature, sunlight, humidity of the wind and of the area of water exposed. The determination of the losses by evaporation can be estimated by the percentage of evaporation recorded in any meteorological station with the help of the class A Pan- or with the Penman method. As the evaporation in a small tank (evaporation tank) is higher than the evaporation in nature, the percentages in the pan are too high and have to be reduced by a corrective factor.

The corrective factor to be applied under tropical conditions is 0.75, (Kovari1984). The values of evaporation obtained are then multiplied by 0.75 and by the area under water in view to get the total volume of water evaporated. Usually in the tropics, the amounts of evaporation estimated are around 2.5 cm/day. The quantity of rain water added to the ponds is calculated from the volume of rain water collected in a rain-gauge multiplied by the area of the ponds and a part of the area of the dykes (about half). But one must be careful in the calculation of the area of the dykes because they absorb also a quantity of rain water. Sometimes the rains are not falling uniformly everywhere and the quantity of rain water varies according to each spot in the farm.

According to Pillay (1979), the need in water supply for a fish farm can be approximated. This figure allows for the losses, while still keeping a reasonable margin of safety.

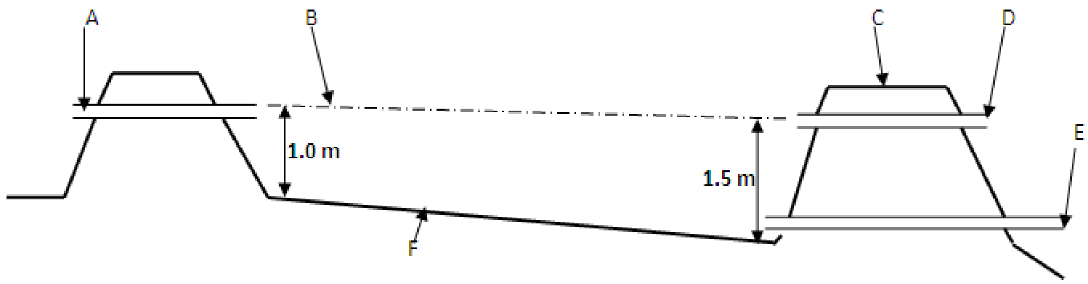

Figure 4.8: Cross section of an embankment pond

A – Water inlet pipe B – Water surface of pond

C – Embankment D – Overflow pipe

E – Water outlet pipe F – Natural sloping land

An overflow pipe (D) as shown in Figure 4.8 is fixed during pond construction to prevent seepage into the embankment. Excess water above the designed pond height is carried in this pipe; this provides precaution for the water storage structure.

4.7 Pond Construction

After selecting a suitable location for a pond based on the conditions of the soil physical characteristics discussed earlier, several activities have to be undertaken to construct it. A step-by-step procedure is discussed below:

4.7.1 Pond Excavation

It is proposed that before pond excavation takes place, the site is cleared of all bushes, tree stumps and roots. As much as possible very large trees and boulders must be avoided. Land must be surveyed to determine its contours.

➢ **Remove the Top Soil:**

Remove the top soil from the area to a depth of about 5-10cm and put aside for a later use.

➢ **Levelling:**

- Mark a straight line along the slope of the site, using siting poles
- Begin levelling from lower ground to higher ground. Use improvised T-Bone level or other levelling equipment, a graduated levelling staff of about 2.5m length and a tape measure
- Record the elevation of the points marked at about 10 metre intervals
- Use the data to determine the maximum depth of the pond and the slope of the pond bottom so that the pond can be filled and drained by gravity

Inlet pipe: The inlet pipe should be placed at a level slightly lower than the water supply canal.

Pond layout: Mark out the pond area with pegs and a rope. Mark out another area about 1 metre outside the first marked area. Mark out a third area about 2 metres outside the second area.

➢ **Digging:**

Dig soil from the inner area and deposit it between the second and third perimeter lines marked.

Deposit soil in layers of 15-25 cm and ram the deposited soils to form dykes. Slope the dykes as follow:

Inner slopes: 2:1, Outer slopes: 1.5:1

Provide a crest of a minimum width of 1-metre depending on the proposed use of the crest and the texture of the soil. Slope pond bottom by about 1.5% toward the outlet. A maximum water depth of 1.5 metres in the deepest part of the pond is recommended.

- **Pipe Installations:**

- **Outlet Pipe:**

Leave a gap in the lower dyke at the point demarcated for the outlet pipe. Make a trench wide enough to accommodate the pipe and reaching to the bottom of the pond. Lay the pipe slopping at about 1m on both sides of the dyke. Cover it with clayey soil and ram well to fill the gap. The outlet pipe may be closed by any of the following:

a) L-pipe system
b) Valve system
c) Wooden stopper/sieve or net
d) Monk

- **Inlet Pipe:**

Place an inlet pipe in the upstream dyke about 5cm above maximum water level. Let the pipe project about 1m on both sides of the dyke. The outer portion must be aligned with the water supply canal. Place stones below the inlet pipe inside the pond to break the impact of in-flowing water. Cover the pipe with clayey soil and ram well.

- **Overflow Pipe:**

A separate overflow pipe may be installed at the maximum water level in the downstream dyke if the outlet pipe is to be controlled by a valve or a stopper. However, L-pipes and monks already incorporate overflows. The overflow pipe drains excess water away. Let the pipe project about 1m on both sides of the dyke. Cover the pipe with clayey soil and ram well.

Openings:

All openings of the pipe installations should be screened with 6mm mesh non-rust material to prevent the entry of wild fish and escape of fish. PVC pipes are recommended.

Grassing Dykes: Spread the topsoil on the dykes and pond bottom and after plant grass on the top of the dykes to prevent erosion of the dykes.

Pond Preparation: Lime the bottom of the pond and inner sides of the dykes. Types of lime which can be used include limestone, quick-lime/agricultural lime and slake lime. Sprinkle lime at the rate of 1 tonne/ha or 10g per 100m. Ordinary wood ash can also be used. Manure the bottom of the pond with any or a combination of the following types of manure:

Table 4. 4: Manure types for basal dressing

Types of Manure	Rate of Basal Dressing
Poultry manure (Pure)	10 25kg/100m^2
Pig manure	30 40kg/100m^2
Cow dung	40 50kg/100m^2
Goat/Sheep manure	40 50kg/100m^2

Fill pond with water 10 days after liming to about 60cm and allow algae to develop. (Allow about 1-2 weeks) then flood to the desired depth of about one metre.

Check water quality by checking acidity (pH), and greenness. For the latter, the hand can be dipped into the water until the fingers can barely be seen. If at that depth the water is at the elbow, the greenness is enough. If it is way above the elbow, it is not green enough.

4.8 Proposed trend of farming

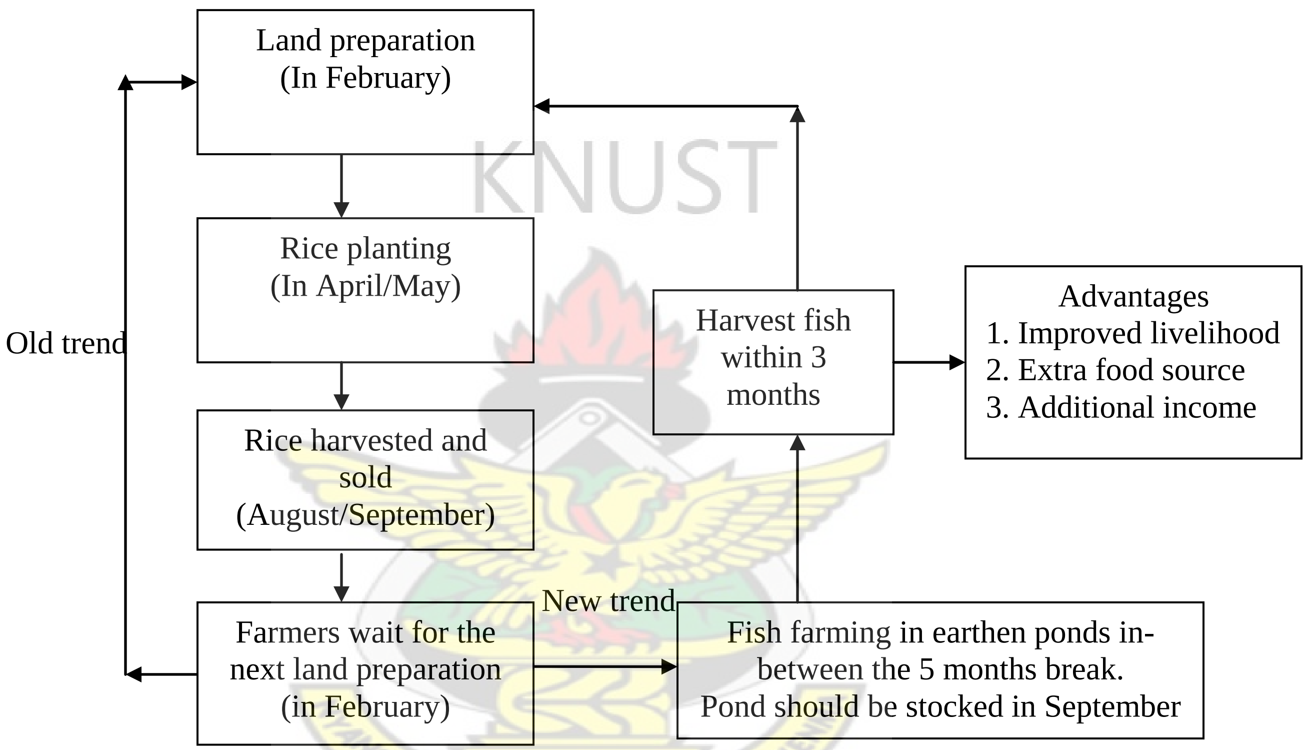

Figure 4. 9 A schematic diagram of a proposed trend of farming

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study reveals that, there is a possibility of establishing an alternative livelihood through off-season aquaculture practice for local rice farmers.

Simple embankment ponds can be constructed with little expertise and capital.

Soil test results indicate that, the upslope soil is a better option for a pond construction since they are easily compacted with good water holding capabilities. From analysis, a grow-out pond with surface area of 0.0303Ha; can yield approximately 11kg per annum of tilapia fish at harvest. Eleven kg per annum of tilapia fish cost approximately GH¢ 50.00 ($ 52.00), local market survey, 2007, and if farmers desire to achieve sales of about GH¢ 600.00, then, approximately thirteen (13) of such ponds will yield a total surface area of 0.4 Hectare (1 Acre).

For a development like this to be established, local farmers were taken into consideration through brainstorming on how best to spend their off-season times.

There is expression of immediate interest in aquaculture when opinions were sought. In one way or the other the farmers had practiced aquaculture before and adaptation will be easier as claimed by them.

During the study it was realised that, until proper documentation of the countries flood plain areas are kept, development like this will be laborious and time consuming to undertake. There are numerous benefits in doing site characterisation during this dissertation:

- This brought to bear, the feasibility of constructing a holding pond through the various soil properties studied
- soil quality impacts the design and engineering of the farm and soils analysed for both upslope and downslope gives an option for the designer
- compaction test, one of the important soil characterisation, helped to know the optimum moisture content to which actual compaction may be done to avoid seepage in final pond construction
- to know if the added cost that characterises pond lining to prevent seepage can be avoided because the nature of soils was tested for both upslope and downslope,
- finally, it is worth emphasising that data collated is important for permeability and structural stability in pond construction.

Results of soil physical properties on site are neatly tabulated at the appendix and areas with such conditions can fall on the Adanwomase flood plain results for easy comparison and analysis for future development.

5.2 Recommendations

Farm ponds have been an important economic unit in many farming programmes. Ponds are used as part of a soil and water conservation programme to practice aquaculture, water livestock, as an irrigation water source, and for fire protection and recreation. For this study to really take shape it is suggested that:

- Further studies into soil physical properties should be conducted on other flood plain areas in Ghana to establish the necessary information needed to maximise their development

- Pond structures should be developed on pilot basis using the soil physical properties studied

- After pond is constructed, finally, the local people should be educated on appropriate pond usage.

Studies of this nature needs to be documented properly and kept for future development and/or comparison with other similar areas.

If farm ponds are finally developed, one should be careful of accidental drownings. Children are the victims of the majority of farm pond drownings. Small children get too close to the water and lose their balance on the soft bank. Many wade in the cool shallow water only to fall into deep holes. Lack of close adult supervision contributes to pond drownings. It is the farm operator's responsibility to ensure that the farm pond is as safe as possible. In most cases it is recommended that all ponds be fenced and sign posted to keep out unwanted persons. Accidents can be prevented and lives saved by placing sign posts warning of specific dangers or indicating safe areas to stand.

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APPENDICES

APPENDIX A-1: Questionnaire

(i) **Personal details**

Farmers' name……………………………………………………… Age…

Sex of farmer…. □ male □ female

Level of education?

□ Primary school level □ J.S.S. level □ others specify…………………

How many years have you been farming? ……………

(ii) **Farm operations**

How do you prepare the land before planting?

□ Manual clearing of the weeds. What is the cost?………………………………..

□ Tractor operations. What is the cost? ……………………………….

What type of rice do you grow?………………………

Why that type?

□ It needs minimum attention □ it is tasty when eaten □ consumers want that variety

What is the cost of seeds used? …………………………..

When do you plant the rice?……………………. Duration of growth………………

Do you use fertiliser? □ Yes □ No

If yes, what type of fertiliser do you use? □ Organic fertiliser □ Inorganic fertiliser

What is the cost of fertilizer used for planting? ……………………………………..

How many times do you plant in a year? □ Once □ Twice □ Others, specify……….

Why?……………………………………………………………………………….

What is the major rain season pattern like? □ Falls once in a year □ Falls twice in a year

Apart from rice farming would you like other types of farming? □ Yes □ No

If "No", why?…………………………………………………………………..

If "Yes", why? ……………………………………………………………………

Who are the consumers of the rice you produce?

□ Me and other family members □ Others outside my family

How much profit do you make after harvest?………………………………………….

What type of farming do you practice?…………………………………………….

What do you do after selling the rice?………………………………………………..

(iii) **Priorities and importance**

Is the River water utilised for farming and/or other activities? □ Yes □ No

If "No", why? …………………………………………………………………………

If "Yes", what do you use the river water for?

□ Domestic activities □ Dry season farming □Livestock watering

□ Others Specify…………………………………………………………..

Do you know the River can be used as a source of water for farming all year? □ Yes □ No

Would you like to engage in an off-season farming? □ Yes □ No

If no, what is the reason?……………………………………………………….

If yes, what will you like to engage in?

□ Aquaculture (fish farming)

□ Vegetable production

□ Others Specify……………………………….

What is the reason for your answer?……………………………………………………..

What is the main source of protein in the Kwabre District?

□ Fish □ Other livestock, e.g. goat, cow… □ Bush meat □ Others, specify…………….

APPENDIX B-1: GLOSSARY OF TERMINOLOGIES

Bulk density (ρ_d): This is defined as the mass of a unit volume of dry soil. This includes both solids and pores. The values of bulk density range from 1.0 for loose open soil to 1.7 g/cm^3 for compacted soil. Values of bulk density are mainly affected by soil texture (sandy soils have more density than silty and clay soils), degree of soil aggregation and is reduced by soil organic matter content.

Porosity (P): It is defined as the proportion of the volume of soil pores (air and water) in comparison with the total volume of soil. It normally ranges from 0.2 (20%) to 0.6 (60%). One of the main reasons for measuring soil bulk density is that this value can be used to calculate soil porosity. For the same particle density, the lower the bulk density, the higher the porosity.

Sealing: According to Clark, *et al* (1988) it is a method used to reduce water seepage losses in a pond. Different methods are available and some of them are:

-Sealing by compaction

-sealing by using clay blankets

-sealing with bentonite

-sealing with flexible membranes, e.g. polyethylene and

-sealing by treatment with chemical additives.

APPENDIX C-1: LABORATORY TESTS

(1) Proctor Test

The standard proctor test is a method of finding the optimum moisture content for compaction of a soil.

Steps involved

- A cylindrical mould $0.001m^3$ in volume is filled with a sieved soil sample in three equal layers, each layer being compacted by 25 or 27 blows in a standard hammer, weight 2.5kg dropped from a height of 300mm for each blow.
- The mould is then trimmed and weighed, to determine the bulk density of the soil.
- Moisture content of the soil is then determined to obtain the dry density.
- The test is carried out with soil at different moisture contents and a graph of dry density against moisture content is plotted.
- A heavy compaction test uses a greater compactive effort from a 4.5kg hammer dropping 450mm on to five soil layers in the mould.

Applications of the proctor test

- Proctor Compaction Soil Mechanic Test can be used to index and predict with reasonable accuracy, the compaction behaviour of agricultural soils over a wide range of soil moisture contents.
- The knowledge of the moisture content and pressure changes on dry density of a soil could be provided in order to make recommendations to the farmer or machine designer.

(2) Atterberg Limits Test

- **Lower Plastic Limit (LPL):** this is determined by adding soil moisture and at each point, rolling the soil out and remoulding up until it breaks out at 10mm length and 3mm diameter. For higher moisture content it can be longer.

- **Upper Plastic Limit (UPL):** This is also called liquid limit. This signifies the moisture content at which the water films are so thick that the film cohesion is decreased and the soil mass can flow under an applied load.

Determination of Upper Plastic Limit: Drop cone penetrometer: the soil is prepared in a core. A cone penetrometer is dropped and allowed to penetrate the soil. The UPL is the soil state or condition where the depth of penetration is 20mm measured with standard methods.

Plasticity Number or Index

It is the difference between the upper and lower plastic limits.

It gives the range of soil moisture where the soil will behave plastically

The larger the plasticity index, the smaller the apparent friable zone.

(3) Triaxial Test

Principles of the Triaxial Compression Test

The triaxial compression test is used to measure the shear strength of a soil under controlled drainage conditions. In the conventional triaxial test, a cylindrical specimen of soil encased in a rubber membrane is placed in a triaxial compression chamber, subjected to a confining fluid pressure, and then loaded axially to failure. Connections at the ends of the specimen permit controlled drainage of pore water from the specimen. The test is called "triaxial" because the three principal stresses are assumed to be known and are controlled. Prior to shear, the three principal stresses are equal to the chamber fluid pressure. During shear, the major principal stress, σ_1, is equal to the applied axial stress (P/A), plus the chamber pressure, σ_3. The applied axial stress, $\sigma_1 - \sigma_3$, is termed the "principal stress difference" or sometimes the "deviator stress".

The intermediate principal stress, σ_2 and the minor principal stress, σ_3 are identical in the test, and are equal to the confining or chamber pressure hereafter referred to as σ_3.

Procedure

Soil specimens will be loaded to failure under 3 different confining pressures (one confining pressure and thus one specimen and test per laboratory group). Failure will be defined as the peak or 3 maximum value of principal stress difference reached.

See below figures for a visual of all the equipment needed.

Figure C - 1 Equipment for the triaxial test (source: Holtz, 1981)

1. Obtain the thickness of the membrane. This thickness is best obtained by measuring the membrane doubled and then halving the measurement

2. Place a porous stone on the bottom platen.

3. Attach a rubber membrane of the proper diameter to the bottom platen with rubber "O" rings. The membrane should overlap the platen at least 1/2", see Figure C - 2

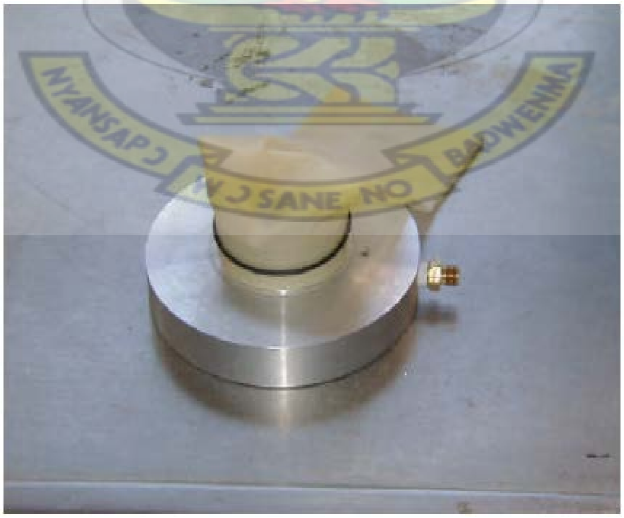


Figure C - 2 Membrane over platen with o-ring (source: Holtz, 1981)

4. Weigh to 0.1 g a dish with the dry soil which is to be tested.

5. Place a specimen mould around the rubber membrane. Fold the top portion of the membrane down over the mold, taking care that the membrane is not twisted or pinched, see Figure C - 3.

Figure C - 3 Membrane top over the mold, with sand (source: Holtz, 1981)

6. Apply a vacuum to pull the membrane against the side of the mold.

7. Place the sand in the membrane and mold by tamping each spoonful of soil, taking care not to pinch the membrane with the tamper. Scarify the top of each layer before placing the next one, to reduce stratification. The amount of tamping depends on the denseness of soil desired.

8. Again weigh the dish of soil. The difference in masses is the mass of soil used.

9. Place a porous stone and then the top platen onto the sand. Roll the membrane off the mold and onto the top platen and seal it to the platen with rubber "O-ring". Take a small level and level the top platen.

10. Release the vacuum to the mold.

11. Attach the vacuum line from the bottom platen and apply a vacuum.

12. Now remove the specimen mold and observe the membrane for holes and obvious leaks. If any are found, the sample must be rebuilt using a new membrane, see figure 4.

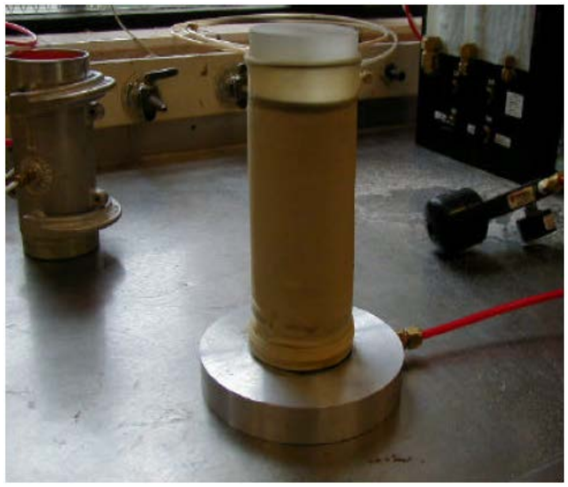


Figure C - 4 Finished sample with vacuum applied to platen (source: Holtz, 1981)

13. Obtain four height measurements approximately 90° apart and use the average value for the initial specimen height L0. Take two diameter readings 90° apart at the top, at midheight, and at the base using a pair of calipers. Take these measurements to the nearest 0.1 cm. Compute the average diameter of the specimen at each height location and then compute a final average specimen diameter as davg = (dt+ 2dm+ db)/4 where dt is the average diameter based on the two top measurements and taking into account membrane thickness, etc. Compute the corresponding value of initial sample area A0 using the average diameter just computed.

14. Turn on the loading frame and set to the desired strain rate (between 0.02 and 0.1 mm/min, as specified by the instructor), see Figure C – 5.

Figure C - 5 Sample set on loading frame (source: Holtz, 1981)

15. For the first 2% of axial strain, take a set of readings about every 0.2% of strain. For the rest of the test, take readings every 0.5% to 1% strain. Time observations need only be made every third or fourth set of regular readings. Load and deformation readings must be taken at each regular reading.

16. Continue the test until an axial strain of about 20% is reached.

Note: It is possible to run a multi-stage triaxial test (a test at more than one confining pressure). This saves time in specimen and apparatus setup, etc, and eliminates some of the variability associated with obtaining a failure envelope with three different specimens. If a multi-stage test is to be run, the steps are the same until this point. At this point, the test is carried out not until 20% strain, but until the compressive force remains constant for two readings. At this point, strain is stopped, and the cell pressure is raised to a higher level (the second desired cell pressure). The step is then repeated until; once again consecutive load readings are the same. At this point, the cell pressure is raised once again, and the specimen sheared. For the final cell pressure applied, the test should be carried out to approximately 20% strain.

17. Sketch the failed specimen. On the sketch, dimension the maximum and minimum diameters, the length of the specimen, and the angle of inclination of the failure plane, if there is one.

18. Release the vacuum and remove the specimen.

APPENDIX D-1: LABORATORY TEST RESULTS AND GRAPHS (COURTESY: CIVIL ENGINEERING DEPARTMENT, GEOTECHNICAL LABORATORY)

COMPACTION - "AASHTO" –TEST (American Association of State Highway and Transportation Officials – AASHTO)

Table A D - 1Compaction Test Results (Downslope Soil Sample)

PROJECT:

SITE :- ADANWOMASE SAMPLE No :Downslope

DESCRIPTION: Bulk Sample

mass of cylinder+wet sample(g)	6075		6197		6391		6380	
mass of cylinder	4298		4298		4298		4298	
mass of wet sample	1777		1899		2093		2082	
Bulk density	1.842		1.969		2.170		2.158	
	1		2		3		4	
container no.	E1	A27	A20	A	K4	DK	K2	E2
mass of container+wet soil(g)	85.86	87.43	62.48	60.10	60.64	62.24	78.48	92.42
mass of container+dry soil(g)	85.46	87.03	60.00	57.84	57.31	58.85	72.30	85.10
mass container	16.02	12.86	14.29	14.83	15.63	14.20	14.83	14.77
mass of wet soil(g)	69.84	74.57	48.19	45.27	45.01	48.04	63.65	77.65
mass of dry soil	69.44	74.17	45.71	43.01	41.68	44.65	57.47	70.33
mass of water	0.4	0.4	2.48	2.26	3.33	3.39	6.18	7.32
water content	0.58	0.54	5.43	5.25	7.99	7.59	10.75	10.41
average water content	**0.56**		**5.34**		**7.79**		**10.58**	
dry density	**1.832**		**1.869**		**2.013**		**1.952**	
height of mould(cm)	11.8							
diameter of mould(cm)	10.2							
volume of mould(cm³)	964.60							

380

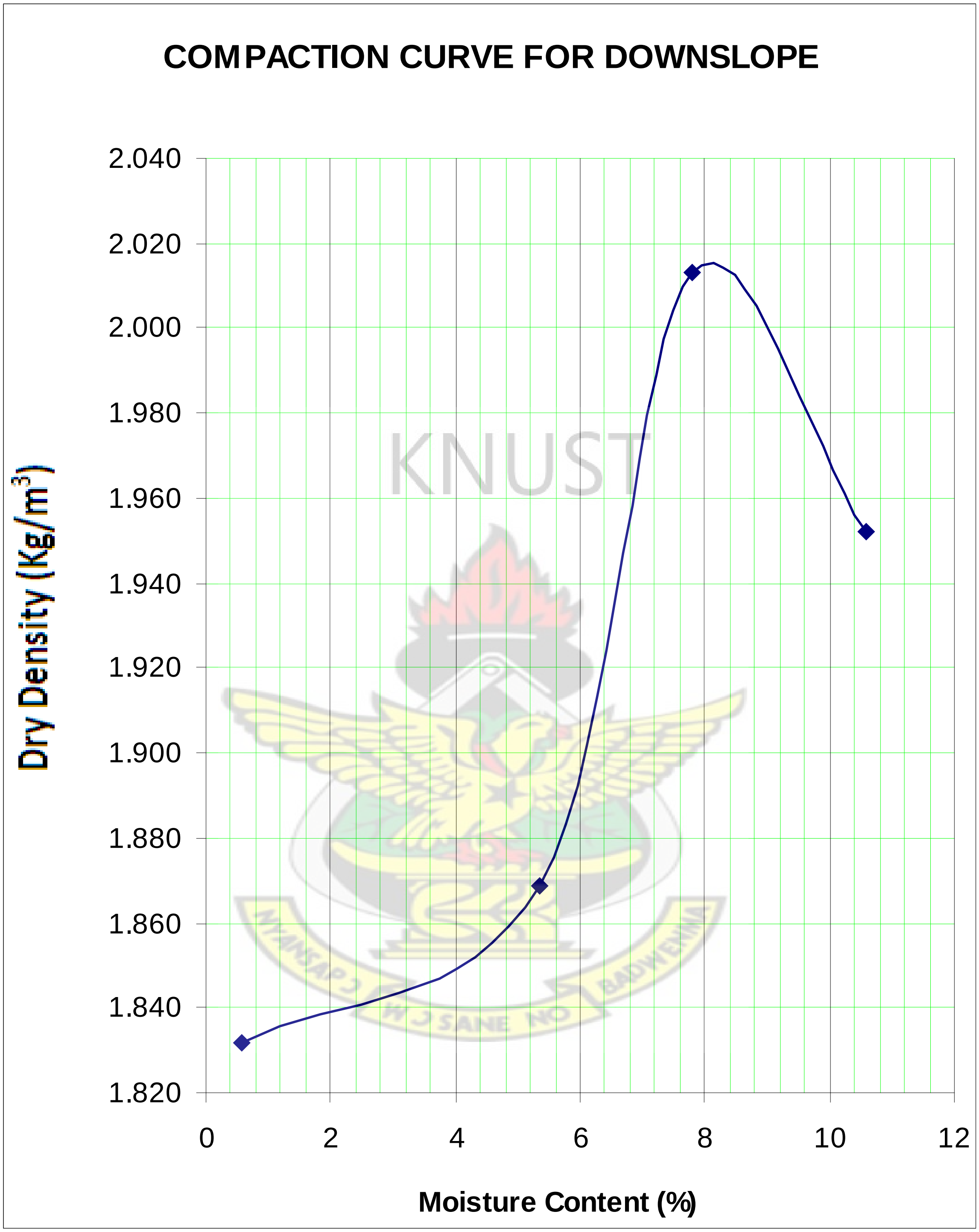


Figure D - 1 Dry density(Kg/m^3) against moisture content (%) (downslope)

Table A D - 2 Compaction Test Results (Upslope Soil Sample)

PROJECT:

SITE :- ADANWOMASE SAMPLE No :Upslope

DESCRIPTION: Bulk Sample

mass of cylinder+wet sample(g)	6049		6162		6396		6399		6325	
mass of cylinder	4298		4298		4298		4298		4298	
mass of wet sample	1751		1864		2098		2101		2027	
Bulk density	1.815		1.932		2.175		2.178		2.101	
	1		2		3		4		5	
container no.	ACM	A3	A11	A50	A21	A22	A5	B3	A31	C1
mass of container+wet soil(g)	72.17	64.29	71.17	61.52	66.00	68.51	81.94	92.74	99.24	88.69
mass of container+dry soil(g)	71.91	64.07	69.46	60.06	62.87	65.29	75.93	85.65	89.70	80.66
mass container	15.46	14.37	14.99	14.33	14.10	14.75	14.85	15.31	14.37	16.07
mass of wet soil(g)	56.71	49.92	56.18	47.19	51.9	53.76	67.09	77.43	84.87	72.62
mass of dry soil	56.45	49.7	54.47	45.73	48.77	50.54	61.08	70.34	75.33	64.59
mass of water	0.26	0.22	1.71	1.46	3.13	3.22	6.01	7.09	9.54	8.03
water content	0.46	0.44	3.14	3.19	6.42	6.37	9.84	10.08	12.66	12.43
average water content	**0.45**		**3.17**		**6.39**		**9.96**		**12.55**	
dry density	**1.807**		**1.873**		**2.044**		**1.981**		**1.867**	
height of mould(cm)	11.8									
diameter of mould(cm)	10.2						335.9			
volume of mould(cm³)	964.60									

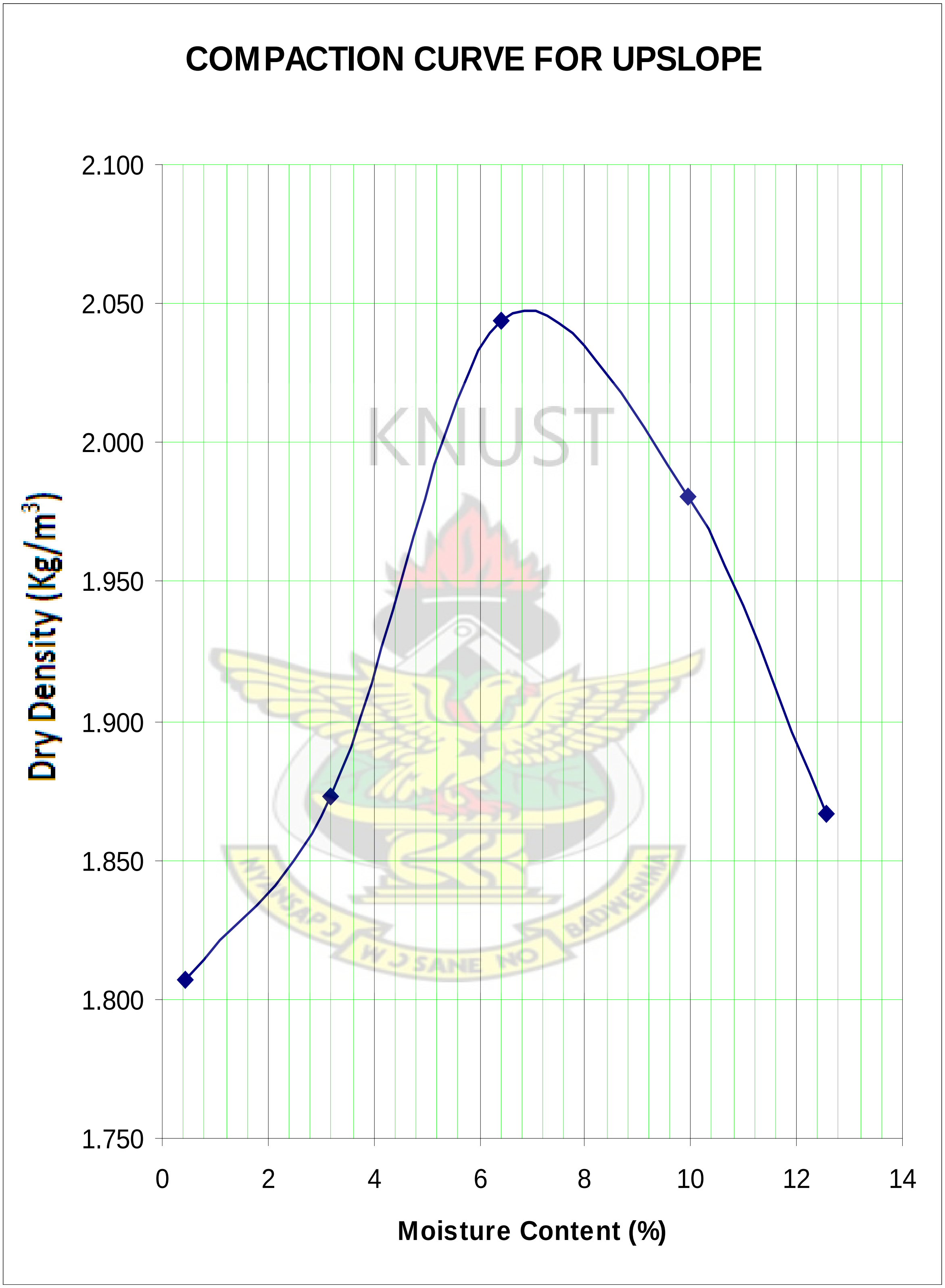


Figure D - 2 Dry density (Kg/m^3) against moisture content (%) (upslope)

Table A D - 3 Permeability Test Results

Diameter of Sample	cm	10.5			
Area of sample	cm^2	86.63			
Area of standpipe	cm^2	0.79			
Length of soil	cm	11.6			
Adjustment height	cm	95.6			
Sample No		UPSLOPE		DOWNSLOPE	
Test		1	2	1	2
Initial Water Level in the pipe	cm	97.6	97.1	97.7	99.5
Final Water Level in the pipe	cm	95.5	93.7	96.9	98.7
Time Elasped (t)	s	5400	8760	7020	6960
Intial head of water in the pipe	h_o	193.2	192.7	193.3	195.1
Final head of water in the pipe	h_1	191.1	189.3	192.5	194.3
ho/h1		1.0110	1.0180	1.0042	1.0041
2.3 Log(ho/h1)		0.0109	0.0178	0.0041	0.0041
Permeability (K)	cm/s	0.000000213	0.000000214	0.000000062	0.000000062
Average Permeability (K)	**cm/s**	**0.00000021314**		**0.00000006207**	
Average Permeability (K)	**cm/s**	**2.1314×10^{7}**		**6.207×10^{8}**	

Table A D - 4 Atterberg Limit –Test Results (Downslope)

PROJECT:

SITE :- ADANWOMASE

DESCRIPTION: BULK SAMPLE

SAMPLE NO:- DOWNSLOPE

Liquid limit

Container No	G	B1	C24	A15	A27	C3
Mass of Container	g	3.76	3.69	3.72	3.72	3.68
Penetration	mm	12.8	15.6	19.6	21.9	27
Mass of Container &Wet Sample	g	14.22	15	17.29	16.93	20.99
Mass of Container & Dry Sample	g	12.51	13.05	14.77	14.37	17.45
Mass of Water	g	1.71	1.95	2.52	2.56	3.54
Mass of Dry Sample	g	8.75	9.36	11.05	10.65	13.77
Water content	%	19.54	20.83	22.81	24.04	25.71

plastic limit

		1	2			
Container No	G	B8	X21			
Mass of Container	g	3.79	3.64			
Mass of Container &Wet Sample	g	16.78	16.57			
Mass of Container & Dry Sample	g	15.35	15.14			
Mass of Water	g	1.43	1.43			
Mass of Dry Sample	g	11.56	11.5			
Water content	%	12.37	12.43	LL	PL	PI
Average Water content	%	12.4		22.9	12.4	10

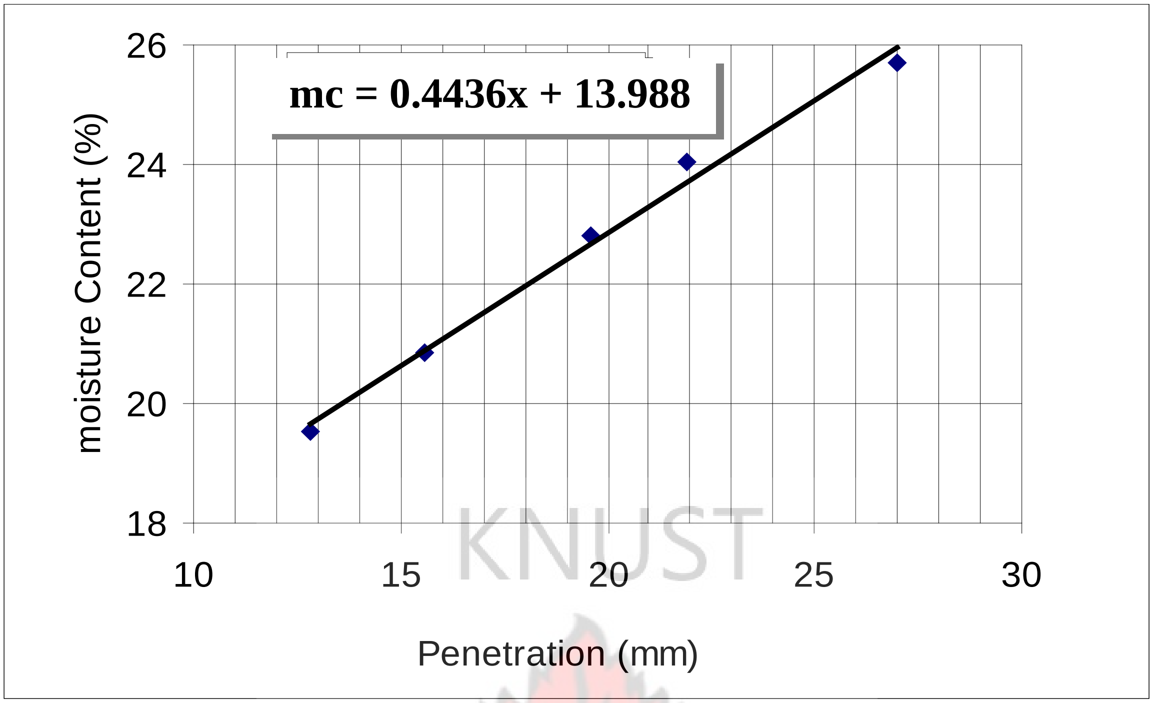


Figure D - 3 Moisture content (mc) against penetration (x) (downslope)

Table A D - 5 Atterberg Limit –Test Results (Upslope)

PROJECT:
SITE :- ADANWOMASE
DESCRIPTION: BULK SAMPLE

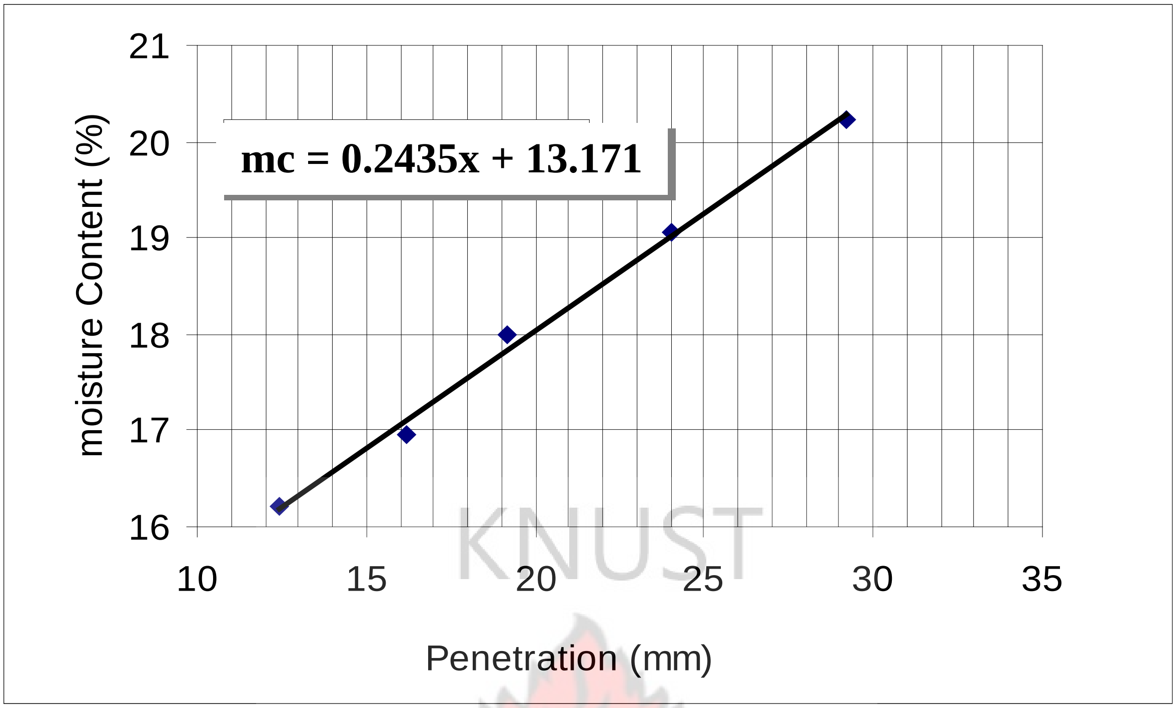
SAMPLE NO:- UPSLOPE

Liquid limit

Container No	G	B24	A9	X10	B7	C4
Mass of Container	g	3.7	3.48	3.7	3.56	3.59
Penetration	mm	12.4	16.2	19.2	24	29.2
Mass of Container &Wet Sample	g	14.24	17.2	16.49	16.24	18.51
Mass of Container & Dry Sample	g	12.77	15.21	14.54	14.21	16
Mass of Water	g	1.47	1.99	1.95	2.03	2.51
Mass of Dry Sample	g	9.07	11.73	10.84	10.65	12.41
Water content	%	16.21	16.97	17.99	19.06	20.23

plastic limit

		1	2			
Container No	G	C1	A20			
Mass of Container	g	3.68	3.6			
Mass of Container &Wet Sample	g	14.71	13.13			
Mass of Container & Dry Sample	g	13.54	12.13			
Mass of Water	g	1.17	1			
Mass of Dry Sample	g	9.86	8.53			
Water content	%	11.87	11.72	LL	PL	PI
Average Water content	%	11.8		22.9	11.8	11



mc = 0.2435x + 13.171
moisture Content (%)
Penetration (mm)
21
20
19
18
17
16
10
15
20
25
30
35

Figure D - 4 Moisture content (mc) against penetration (x) (upslope)

Table A D - 6: Soil bulk density, soil wetness and porosity at different depth on the flood plain (down slope) site

Soil collected at core sampler depth of	Mass of freshly sampled soil (g)	Mass of empty drying container (g)	Mass of container + freshly sampled soil (g)	Mass of container + dried sample soil (g)	Md (g)	Mm (g)	Pm = (Mm/Md)×100	$\rho_d = M_d/V_a$ g/cm^3	P= 1-(ρ_d/ρ_p)
soil surface - 20cm	711.25	520.48	1231.73	1181.09	660.61	50.64	7.6656	1.682	0.388280
20cm - 40cm	681.33	438.09	1119.42	1094.78	656.69	24.64	3.7522	1.672	0.391910
40cm - 60cm	674.74	465.07	1139.81	1115.72	650.65	24.09	3.7025	1.657	0.397503
60cm - 80cm	905.42	159.05	1064.47	977.02	817.97	87.45	10.691	2.083	0.242566
80cm - 100cm	832.41	403.39	1235.8	1158.53	755.14	77.27	10.233	1.923	0.300746
AVERAGE = ∑(Pm, ρ_d and P) / 5							7.2088	1.803	0.344201

Table A D - 7: Soil bulk density, soil wetness and porosity at different depth on the upslope site

Soil collected at core sampler depth of	Mass of freshly sampled soil (g)	Mass of empty drying container (g)	Mass of container + freshly sampled soil (g)	Mass of container + dried sample soil (g)	Md (g)	Mm (g)	Pm = (Mm/Md)×100	$\rho_d = M_d/V_a$ g/cm^3	P= 1-(ρ_d/ρ_p)
soil surface - 20cm	643.5	520.48	1163.98	1129.37	608.89	34.61	5.6841	1.551	0.436172
20cm - 40cm	700.42	438.09	1138.51	1099.98	661.89	38.53	5.8212	1.685	0.387095
40cm - 60cm	662.5	465.07	1127.57	1082.76	617.69	44.81	7.2544	1.573	0.428024
60cm - 80cm	666.14	159.05	825.19	781.18	622.13	44.01	7.0741	1.584	0.423912
80cm - 100cm	671.91	403.39	1075.3	1035.9	632.51	39.4	6.2292	1.611	0.414301
AVERAGE = ∑(Pm, ρ_d and P) / 5							6.4126	1.601	0.417901

P_m = soil wetness
M_m = mass of moisture lost after drying
M_d = mass of dried soil
ρ_d = dry bulk density
V_a = total volume of core sampler
V_a = cross sectional area of core sampler (cm^2) × height of core sampler, h (cm)

$$V_a \equiv \pi (d^2/4) \times h \;\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

d_d = cross sectional diameter of the core sampler = 5cm
h = height of the core sampler = 20cm
Substituting d and h in equation 1, V_a = 392.699081698724cm^3
ρ_p = particle density (for clay soils) ≈ 2.75g/cm^3
P = porosity = 1-(ρ_d/ρ_p)

Table A D - 8 Triaxial Test Results (Downslope)

Table A D - 9 Triaxial Test Results (Upslope)