EVALUATION OF KPAKUNGU GULLY EROSION IN BOSSO LOCAL GOVERNMENT AREA OF NIGER STATE AND DESIGN OF A FLOOD CONTROL STRUCTURE

BY

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MATRIC. NO. 2005/23546EA

BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

NOVEMBER, 2008

DECLARATION

I hereby declare that this project is entirely a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

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CERTIFICATON

This project entitled **"Evaluation of Kpakungu Gully Erosion in Bosso Local Government Area of Niger State and Design of a Flood Control Structure"** by JOHN ADEBAYO OLADIPO meets the regulations governing the award of the degree of Bachelor of Engineering (B.Eng) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific and engineering knowledge and literary presentation.

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DEDICATION

This project is dedicated to the people affected by the evil hand of gully erosion and flood in all ecological zones of my dearest country (Nigeria), and to the people of the other parts of the globe facing a similar environmental problem.

ACKNOWLEDGEMENTS

Foremost, my sincere and greatest gratitude goes to the Almighty God, the source of all knowledge, who has provided me with all the needed wherewithals of knowledge, understanding, wisdom, guidance and good health to function throughout the duration of this course of study.

My deepest thanks particularly go to my vey able project supervisor in the person of Mr. Adebayo Segun for his enormous and unquantifiable support, contribution and word of encouragement from time to time. I sincerely appreciate his efforts in terms of tireless guidance, useful and meaningful supervisory role and suggestions at the various stages of the project.

I also acknowledge with thanks the contribution of my Head of Department, Engr. Dr. (Mrs) Z.D. Osunde for her encouragement throughout the time of the study.

My rich appreciation equally goes to my level adviser, and co-supervisor, Mr. P.A. Adeoye for his contribution and word of encouragement at the various stages of the project and for the pain he has taken to go through the thesis and make useful corrections where necessary. And also to all other distinguished technical staff and lecturers in the Agricultural and Bioresuources Engineering Department for their contributions. I am particularly grateful to them in the aspect of encouragement and knowledge imparted to me.

My thanks also go to Mrs. Naomi A. Ndakotsu of Upper Niger River Basin Development Authority, Minna for her financial assistance during the course of the study, and to Mr. K.K. Gold for his encouragement and material support.

Finally, my appreciation goes to my very amiable wife, Mrs. Felicia Moyosore Oladipo and my dearest children, Michael Ayokunle, Joseph Olusegun (a.k.a.Jolojolo), and their coming most juniors for their inspiration, love, spiritual, moral and financial support, and for their marvelous understanding when the terrain of home front was rough.

Thanks and God bless you all (Amen).

ABSTRACT

This study presents the Evaluation of Gully Erosion at Kpakungu in Bosso Local Government Area of Niger State and Design of a flood control structure. The catchment characteristics of the gully were studied and analyzed and annual rainfall records of Minna and its environs covering 1987 – 2007 period were collected and analysed for rainfall intensity. The physical properties of the soil samples of the area were also determined. The catchment area of the gully was found to have an average length of 1280m and an average width of 20m. The length of the gully was measured to be 730m and its average width and slope were found to be 10m and 2%. The soil samples from the upper, middle and lower slope areas of the gully were found to have their coefficients of uniformity (Cu) between 8 and 12 which show that they are within the range of well-graded particles while the coefficients of curvature (Cc), indication of densely packing, of the six soil samples collected at different points and soil layers in the field were between 0.3 and 2, implying loosely packed soils and high vulnerability to erosion. The infiltration rate of the soil ranged between moderate (3.0cm/hr) and moderately rapid (10.0cm/hr). A concrete channel structure was designed to control the gully and flood. The design channel has a flow depth of 1.2m (including 20% freeboard) and width of 0.8m. The designed channel, if constructed, will solve the problem of gully erosion, damage to lives and properties and seasonal flooding of affected part of Kpakungu area.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to Study

Soil erosion and flood are a serious environmental problem all over the world, and Nigeria is not an exemption. This is owing to the fact that most human activities such as farming, construction, mining, excavation, drilling, *et cetera* are land and environmental based and have direct influence on the land and consequently on the environment. Michael and Ojha (2003) have maintained that one of the major reasons for low productivity in Agriculture today is the progressive deterioration of soil by erosion.

In its simplest definition, soil erosion is the detachment and transportation of soil materials from one place to another through the action of wind, water in motion or by the beating action of the raindrops. Soil erosion and flood are inter-related as runoff provides the erosive force with which the soil particle is detached, moved and deposited from one point to another.

Aina *et al* (1977) have reported that soil erosion is a serious problem in most of the agro-ecological regions of Nigeria. It is obvious that due to the numerous human activities on land, the surface of land is made to change and this could have a serious impact on the soil resources. Soil erosion is a complex interaction process of many factors, but the most basic are the edaphic (soils) and rainfall factors.

Wischmeier and Smith (1978) refer to soil factor as soil erodibility and which is the susceptibility of the soil to erosion, and it is described as a function of infiltration, crusting susceptibility, and detachability and transportability. The rainfall factor is referred to as erosivity and this is ability of the rain to cause erosion.

There are few causes of erosion; these are, rainfall, wind and human activities such as over- grazing, deforestation, bush- burning, felling of trees for fuel (domestic uses) and lumbering, indiscriminate tillage practices leading to detachment of soil particles and consequently aggravating soil erosion and environmental degradation. The consequences of soil erosion are barren soil surface which could no longer support the growing of crops, poor infiltration capacity and flooding. Babalola (1988) and Lal (1990) have reported that infiltration rate is not limiting when water is available at the surface of the soil but it determines the amount of runoff which would form over the soil surface, and hence the hazard of erosion during rainstorms.

According to the current national policy on soil erosion and flood control, soil erosion involves a general removal of the soil by the action of wind and water. This has, however, been accelerated by certain human activities such as agriculture, construction, deforestation, bush-burning, excavation, *et cetera.*

In the past, the problems of soil erosion in Nigeria were peculiar to certain Nigerian Ecological zones, but today, the problems have been spatially distributed across the various ecological areas of the country. For instance, Ofomata (1988) has reported that in South-eastern Nigeria, soil erosion is one of the most striking features on the landscape. This implies that features of soil erosion especially gully development are now a common landmark in all nooks and crannies of the country.

From the above analysis, different agents cause erosion but man largely aggravates it. For instance, the increased population pressure on land in area where land is limited in supply has resulted in a rapid expansion of cropping into marginal areas, and an intensification of agricultural activity on highly erodible soils resulting in an accelerated erosion (Jeje, 1988).In addition to this, soil erosion is one of the most physical and socio-economic problems affecting our development in this part of the globe, and something urgent needs to be done to address the problem.

Besides the fact that erosion constitutes a menace to the environment and it destroys public infrastructures such as buildings, roads, water supply pipelines, communication lines, power supply lines, *et cetera*, it also creates a major problem on agriculture by destroying the soil structures and soil fertility and crops, and thereby undermining the campaign on mass food production by government.

The reasons highlighted above are some of the reasons why the study of Kpakungu gully erosion and flood control is being undertaken at this present time to proffer an engineering solution to the problem posed by the gully erosion to lives and property and future development of the area.

1.1.1 Aims and Objectives of Study

The aims and objectives of conducting this study are as follows:

1. To study and ascertain the causes of gully erosion and flooding in Kpakungu area of Minna.
2. To investigate the properties of soil in the study area.

3. To design a flood control structure as a way of finding engineering solution to ameliorate the problem of gully erosion and flood facing the area.
4. To safe lives and property of the people living around the study area.
5. To make technical recommendations to the appropriate authorities based on the findings of the study and engineering design of control measure , so that the problem could be solved at once before it becomes a disaster
6. To contribute to knowledge on how environmental problem of this nature could be solved using engineering approach and solution.

1.2 Problem Statement

Inspite of the fact that soil erosion is an age old problem in Nigeria, it is presently taking a new dimension because of its impact on man as well as on the environment and its consequences which inherently cause alarming feelings of concern, considering the fact that many productive farmlands have been turned into unproductive lands due to indiscriminate human activities as well as unchecked animal grazing. This has led to barrenness of most arable lands and degradation of most urban areas and consequently urban erosion and flooding.

The magnitude of the problem of gully erosion in Kpakungu area of Minna has left untold hardship on people and threats to many residential buildings, roads, culverts and public facilities. In other words, the study area is characterized by a lot of environmental problems as a result of seasonal flooding and gully erosion causing environmental hazards, land degradation and damage to lives and property of which if the problem is not addressed on time, there is tendency that the area may face a serious catastrophe (great disaster) in the nearest future.

1.3 Justification

Since it has been identified that soil erosion and flood are not a friend of man, it become s clearly important that soil erosion and urban flooding problem is a worthwhile study that must be conducted to serve as a solution to any environmental problem of this magnitude. According to Jimoh (1999) most areas identified as flood affected areas needing drainage channels in most parts of urban areas of Niger State only 13% of them have drains with adequate sections and 75% of the drains have silted up with refuse. Jimoh (1999) in his paper on *"Causes of Urban Flooding in Niger State:" A case study of Bida and Minna Towns* further concludes in part that a post - disaster management approach will only provide succour to the affected community, but will not stop the occurrence of flooding. He therefore suggested that pre-disaster management steps should be taken to avoid urban flooding and erosion.

The findings stated above have clearly shown that there is the need to provide drainage channels with adequate hydraulic sections to prevent or mitigate possible future occurrence of flood and erosion in all affected areas of the state, of which Kpakungu community is one. In line with this, there is therefore the need to conduct study on gully erosion and flood problem presently facing the area, and when this is done the environment of Kpakungu area would be better protected.

1.4. Scope of Study

The study is intended to solve an environmental problem, and as such, its scope will cover the engineering survey of the gully erosion site, the collection of necessary and relevant data on hydrology (climate) of the area, the soil investigation to determine the particle-size distribution of the soils of the erosion site and their vulnerability to erosion, the extent of damage that gully erosion and flood have done to the property and public infrastructures in the area; and the engineering design of flood control channel to serve as ameliorating measures to the menace of gully erosion and flood ravaging the area.

1.5 Significance of Study

The study of soil erosion and flood control has much to do with the environment. Incidentally, most human activities are environmental based. It has been generally realized that to ensure a sustainable agricultural production in Nigeria while maintaining the environment there is the need to safeguard against the menace of erosion and flood on the farms in terms of provision of drainage facilities to control surface runoff.

Similarly, the problem of erosion and urban flooding is another peculiar problem requiring the study of this nature so as to proffer a suitable engineering solution. Obaja (2004) has stated that we need not to wait for soil erosion and flood to cause their havoc before appropriate steps are taken to solve the environmental problem. In other words, pre-disaster approach of solving the environmental problem is better than post-disaster approach (Jimoh, 1999).

Moreso, since prevention is always better than cure, it suggests that conducting this study now is a worthwhile effort to solve the problem of gully erosion and flooding in Kpakungu community area of Minna, the state capital. It is hoped that the study apart from providing solution to the problem, will also help to protect lives and property of the people in the study area. This will ensure a stable and safe environment devoid of degradation and worthy of living.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Erosion and Flood Disaster

One of the major environmental problems in the world today is erosion. Nigeria too is affected by this problem since erosion has become a global issue. Gully erosion is the more advanced form of rill erosion because of its remarkable effects on the landscape. Rills develop easily in areas of soft bedrocks and often rapidly grow into enormous gullies. Areas of spectacular gully erosion in Nigeria are Anambra, Abia, Akwa-Ibom, Cross-River, Imo, Plateau, Bauchi, Gombe,and Sokoto states (Obaja,2004)

Gully erosion is particularly severe in Abia, Imo, Anambra, Enugu, Ondo, Edo, Delta, Ebonyi, Kogi, Adamawa, Jigawa states, and some parts of the Federal Capital Territory (FCT). Anambra and Enugu states alone have over 50 active gully sites, with some extending over 500 metres long, 30 metres wide and 20 metres deep. Coastal and marine erosion occur particularly in the coastal areas of Ogun Lagos, Ondo, Delta, Rivers, Bayelsa, Akwa-Ibom and Cross- River states.

The most significant case of coastal erosion is the overflow of the Bar- Beach of the Atlantic Ocean now a regular feature since 1990, threatening the prime property areas of the Ahmadu Bello way and Victoria Island in Lagos. Runoff and erosion have adverse effects on the environment because rapid generation of runoff causes flash floods while erosion of lands leads to pollution and environmental degradation.

2.1.1 Types of Flooding in Nigeria

Flooding occurs throughout Nigeria in three main forms, namely:

(i) Coastal flooding

(ii) River flooding, and

(iii) Urban flooding

Coastal flooding occurs in the low- lying belt of mangrove and fresh water swamps along the coast. River flooding occurs in the flood plains of the larger river while sudden, short -lived flash floods are associated with rivers in the inland areas where sudden heavy rains can change into destructive torrential rainfall within a short period. Urban flooding, on the other hand, occurs in towns or cities located on flat or low-lying terrain especially where little or no provision has been made for surface drainage, or where existing drainage channels have been blocked with municipal waste, refuse and eroded soil sediments (Aneke, 1985).Extensive urban flooding is a common phenomenon in every rainy season in places like Ilorin, Lagos,Aba, Warri, Benin, Ibadan, Maiduguri, Gombe and even Minna in Niger state.

2.1.2 Causes of Flooding

A flood is the result of runoff from rainfall in quantities far in excess of what can be confined in channels of stream or rivers. Wilson (1978) has stated that when the rain is particularly intense or prolonged, or both, the surplus runoff becomes large and the stream and river channels cannot accept all the water suddenly arriving, then they become filled and overflow and in so doing they do great harm to the activities of man. He went further to state that man can do little to prevent major floods but he may be able to minimize the associated damages to properties, crops, lands, and loss of lives. From this analysis, it may be said that flood is a natural phenomenon and man cannot prevent it but he can only provide safety measures to protect his life and property in his environment when flood strikes.

It has also been reported that most major cites and towns in Nigeria are poorly drained and where drainage channels are provided they are inadequate and they get often blocked through human activities such as dumping of refuse (Jimoh, 1999). Therefore, flooding problem is caused by a number of factors among which are excess precipitation (rainfall), dam breaks (dam failures), blockages of river course either by natural cause or through human activities, lack or inadequate provision of drainage structures, and indiscriminate removal of natural vegetative cover.

2.1.3 Effects of Flooding

According to Wilson (1978), the most serious effect of flooding may be the washing away of the fertile top soil in which crops are grown, and of which there is already a scarcity on the earth. In urban areas there is great damage to property, pollution of water supplies, danger to life and often total disruption of communications. In agrarian societies, floods are feared like pestilence because they may destroy crops, cattle and habitations, and bring famine in their wake.

Nigeria has witnessed a lot of erosion and flood problems. For instance, in 1980, the city of Ibadan in Oyo State was flooded by the Ogunpa River causing instantaneous loss of lives and properties worth millions of naira. A similar occurrence was experienced at Ndoni in Edo State in 1988 where flood destroyed lives and properties of people. In like manner, in 1994 the Northern part of the country was hard hit by flood and throughout the length and breadth of the country, the story about flood was the same for that year (Upper Niger Basin News, 1995).

Virtually, every part of Nigeria is vulnerable to disasters either natural or man-made. In every raining season, wind gusts arising from tropical storms claim lives and property worth millions of naira across the country. Flash floods from torrential rains wash away thousands of hectares of farmland. Dam breaks or bursts are common following such floods. In August 1988, for instance, about 150 people died, 18,000 houses were destroyed and 14,000 hectares of farm-lands were swept away when the Bagauda dam collapsed following a flash flood (Halilu, 2000).

Other effects of urban flooding are water pollution and disruption of socio-economic services. The pollution of major water reservoirs could be as a result of siltation and sedimentation. Flooding can also cause health hazards resulting from water borne diseases (William, 1991).

2.2 Gully Erosion

Gully erosion has been described as a form of soil erosion that produces channels larger than rills. Michael and Ojha (2003) have defined gully erosion as the removal of soil by excessive concentration of running water, resulting in the formation of channels ranging in size from 0.3m to 10m or more. Any concentration of surface runoff is a potential source of gullying.

These channels carry water during and immediately after rains, and, as distinguished from rills (runnels), gullies cannot be obliterated (smoothened off) by tillage operation. The amount of sediment from gully erosion is usually less than from upland areas, but the nuisance from having the fields divided by large gullies has been the greater problem. In tropical areas, gully growth following deforestation and cultivation has led to severe problems from soil loss, and damage to buildings, roads, and airports (Aneke, 1985).

The rate of gully erosion depends largely on the runoff-producing characteristics of the watershed; the drainage area; soil characteristics; the alignment; size, and shape of the gully; and the slope in the channel (Bradford *et al,* 1973). A gully develops by processes that may take place either simultaneously or during different periods of the growth. These processes include:

(i) Waterfall erosion or head-cutting at the gully head.

(ii) Erosion caused by water flowing through the gully or by raindrop splash on exposed gully sides.

(iii) Alternate contraction and expansion of the exposed soil banks, and

(iv) Slides or mass movement of soil into the gully.

Evaluation and prediction of gully development are difficult because the factors are not well defined and field records of gully are inadequate, and in most cases not available, especially in Nigeria (Aneke, 1985). From aerial photographs and field topographic surveys, Schwab *et al* (1992) reported that Beer and Johnson (1963) developed a prediction equation for the deep loess region in Western Iowa in the USA based on watershed runoff characteristics and soil properties. In a similar research finding, Bradford *et al* (1973) reported that gully formation depends on soil strength, infiltration rate of the soil, and depth of water table.

In many cases, an impeding layer results in saturated soil conditions at the floor of the gully. The saturated soils tend to be weak, leading to undercutting and side sloughing. Runoff from subsequent storms would then remove loose soil from gully floor. Generally, gully erosion is advanced stage of rill erosion as rill erosion is advanced stage of sheet and inter-rill erosion.

2.2.1 Classification of Gully Erosion Channels

Gullies are classified according to the size, depth and area of watershed or catchment area as tabulated below.

Table 2.1 Classification of gully erosion channels

Relative Size	Gully Depth (m)	Watershed/ Drainage Area (Ha)
Small gully	< 1	≤2
Medium gully	1- 5	2-20
Large gully	> 5	> 20

Source: Schwab, *et al* (1992). Soil and Water Conservation Engineering

Gullies may also be classified as V-shaped or U-shaped depending on the shape of their cross-sections and the soil parent materials. V-shaped gullies are common on soils with soft or weak parent materials such as sedimentary formations while U-shaped gullies are common on soils with relatively erosion resistant hard and stable parent materials such as basement rocks (Michael and Ojha, 2003).

2.2.2 Causes of Gully Erosion

Gullies are caused by runoff water cutting, or collecting in, surface depressions and flowing at a velocity sufficient to detach and carry away soil particles. The power to erode the soil increases as the stream increases in size, velocity, and duration. If the depression or drainage way is not protected from erosion a gully will form and be enlarged by each flow through it.

Many large gullies have formed because simple steps are not taken to stop them in the beginning (USDA-SCS 1984).

In most urban towns, gully erosion is caused by improper landuse resulting from human activities such as excavation of land for local building materials (mud-block making) and a host of other environmental abuses.

2.3 Runoff

Runoff is that portion of the precipitation that makes its way towards stream channels, lakes, or oceans as surface or subsurface flow. The term runoff usually refers to surface flow, and it is synonymous to flood as flood is a product of runoff (Schwab *et al.* , 1992). To design the channels and structures to handle natural surface flows, we are concerned with peak rates of runoff, with runoff volumes, and with temporal distribution of runoff rates and volumes.

2.4 Mechanism of Surface Runoff

For runoff to occur, precipitation must satisfy the demands of evaporation, interception, infiltration, surface storage, surface detention and channel detention. Runoff will only occur when the rate of precipitation exceeds the rate at which water may infiltrate into the soil.

The factors affecting runoff at a place may be divided into those factors associated with the precipitation and those associated with the watershed. These are: rainfall, watershed, topography, geology and soil.

2.4.1 Rainfall

Rainfall duration, intensity, and areal distribution influence the rate and volume of runoff. Total runoff for a storm is clearly related to the duration for a given intensity. Infiltration will decrease with time in the initial stages of a rainfall. For instance, a storm of short duration may produce no runoff, whereas a storm of the same intensity but of long duration may result in runoff. According to Miller (1994) in Fig. 2.1, rainfall intensity, therefore, influences both the rate and the volume of runoff as well as duration and flood return period.

2.4.2 Watershed

The watershed factors affecting runoff are size, shape, orientation, topography, soil, vegetation and surface culture. Schwab *et al* (1992) reported that both runoff volumes and rates increase as watershed size increases; however, both rate and volume per unit of watershed area decrease as the runoff area increases. Watershed size may be used to determine the season at which high runoff is expected to occur.

2.4.3 Topography of Watershed

Topographic features, such as slope of up-land areas, the degree of development and gradients of channels, and the extent and number of depressed areas affect rates and volumes of runoff. Watershed, having extensive flat areas or depressed areas without surface outlets have lower runoff than areas with steep and well-defined drainage patterns. It has been found that slope characteristics can have effect on the surface runoff especially in the urban areas where the environment has been mismanaged.

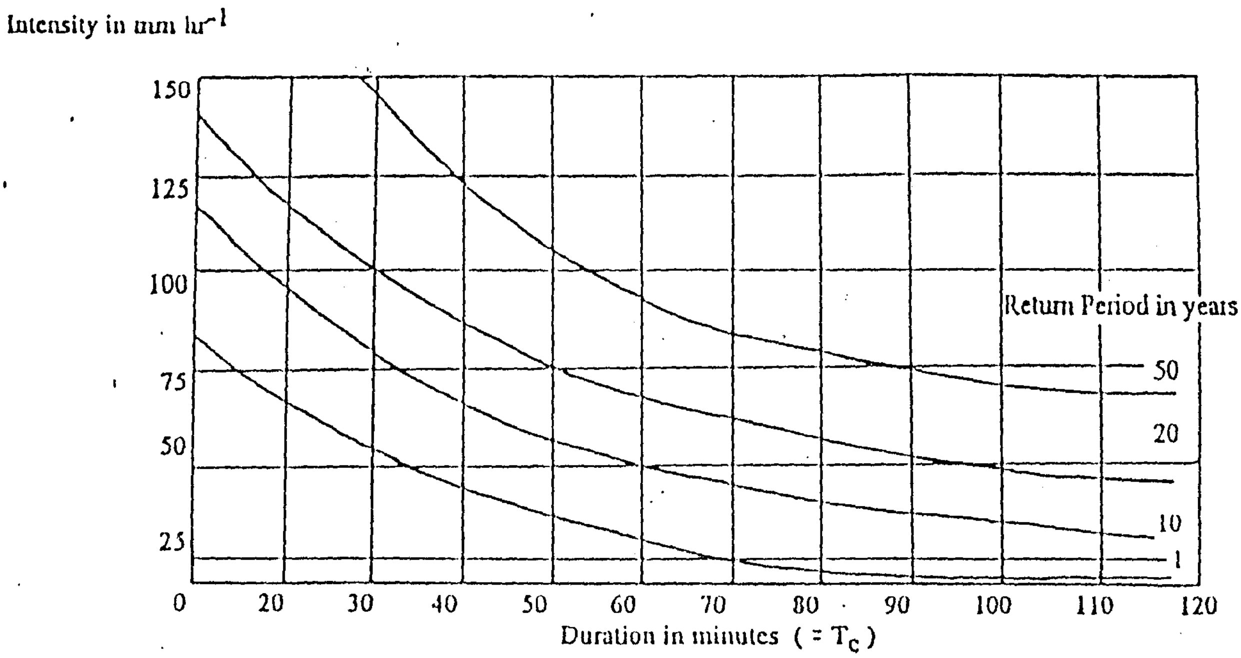


Figure 2.1 - Graphs of Return Period, Intensity and Duration (which $=T_c$)

Example return periods used widely for different structures are: Field structures, 5-10 years; Gully control and Small farm dams, 20 years; Large farm dams, 50 years.

Source: Miller (1994): Handbook for Agrohydrology
Natural Res. Inst., UK.

2.4.4 Geology, Soil materials and Vegetation

The geologic or soil materials determine to a large degree the infiltration rate, and thus affect runoff. On the other hand, vegetation and practices incident to agriculture and forestry also influence infiltration. Vegetation retards overland flow and increases surface detention to reduce peak rates of runoff. Structures such as dams, levees, bridges, and culverts all influence runoff rates.

2.5 Design runoff rates

The capacity to be provided in a structure that must carry runoff may be termed the design runoff rate. Structures and channels are planned to carry runoff that occurs within a specified return period. Vegetated controls and temporary structures are usually designed for a runoff that may be expected to occur once in 10 years; expensive permanent structures will be designed for runoffs expected only once in 50 or 100 years (Schwab *et al.*, 1992).

Selection of the design return period, also called recurrence interval, depends on the economic balance between the cost of periodic repairs or replacement of the facility to reduce the frequency of repairs or replacement. For instance, the downstream damage potentially resulting from failure of the structure may dictate the choice of the design frequency.

2.6. Methods of Predicting Peak rates of runoff

To design soil erosion and flood control structures with their capacity to meet the needs of their respective conditions, it is necessary to estimate peak rates of runoff. There are a number of methods for calculating the maximum rate of runoff from a given area, most of which are applicable to specific localities and conditions peculiar to such localities.

2.6.1 Rational Method of Predicting runoff rates

The rational method of predicting a design peak runoff rate is expressed by the equation

$$Q = 0.0028CIA \qquad (2.1)$$

where Q = the design peak runoff rate in m^3/s

C = the runoff coefficient

I = rainfall intensity in mm/hr for the design return period and for a duration equal to the "time of concentration "of the watershed

A = the watershed area in Ha or Km^2

(Highway Design Manual, 1976)

Rational method is commonly used in predicting peak rate of runoff of small watersheds (Michael and Ojha, 2003).

2.6.2 Modified Rational Method of Predicting runoff rates

The modified rational method is a modified form of the original rational method which takes into account storage in drains and canals (channels). The modified rational method formula is expressed as:

$$Q = C.Cs.I.A \qquad (2.2)$$

where Q = the peak discharge of return period in m^3/s

C = runoff coefficient

Cs = storage coefficient

I = the average rainfall intensity for a duration (Tc) and a return period (T) in mm/hr

A = catchment area in sq Km

(Highway Design Manual, 1976)

2.6.3 Time of Concentration (Tc)

The time of concentration of a watershed or drainage area, otherwise known as duration time, is the time required for water to flow from the most remote point of the catchment area to the outlet (or the point of investigation) once the soil has become saturated and minor depressions filled. It is the time required for the entire drainage area to contribute to the flow.

It is assumed that when the duration of a storm equals the time of concentration, all parts of the watershed are contributing simultaneously to the discharge at the outlet. One of the most widely accepted methods of computing the time of concentration developed by Kirpich (1940) and adopted by Miller (1994) and Michael and Ojha (2003) is given in the equation below:

$$Tc = 0.0195L^{0.77} S^{-0.385} \qquad (2.3)$$

where Tc = time of concentration in minutes

L = maximum length of flow in metre

S = watershed gradient in m/m or the difference in elevation between the outlet and the most remote point divided by the length, L

Time of concentration (Tc) comprises of two components:

(i) the overland flow (To), and

(ii) the time of flow in the drainage system to the point being investigated (Td)

Therefore, Tc = To + Td.. (2.4)

The overland flow component (To) is affected by factors such as distance, nature of the terrain and the nature of the ground (soil).

Time of concentration (Tc) can also be calculated using another formula similar to equation (2.3), developed by the Federal Highway (1976) expressed as:

$$Tc = 0.0197L^{0.77} S^{-0.385} \quad (2.5)$$

where Tc = time of concentration or duration time in minutes

L = maximum length of gully in meters

S = watershed slope in percentage

2.7 Design Criteria for Drainage System

Open channels are the most convenient system of storm water drainage for a town in Nigeria. They are less expensive to construct and easier to maintain than close conduits (pipes), covered channels or sewers. Flow computation to determine the required sizes for the channels can be made using any one of the following methods (Highway Design Manual, 1976).

1. Darcy -Weisbach equation method
2. Talbot formula method

3. Chezy formula method

4. Manning's formula method

All the above methods are variations of the basic volume rate of flow equation stated below:

$$Q = A.V. \qquad \text{...(2.6)}$$

where Q = discharge capacity of the channel in m^3/s

A = cross –sectional area of the channel in m^2

V = velocity of flow in m/s

It is in relating the velocity of flow to other factors such as depth of channels, slope of channel, shape of channel *et cetera* that the above methods vary.

2.7.1 Darcy –Weisbach Method

Darcy- Weisbach equation states that:

$$V = \sqrt{8g\, R.S\, x\, \frac{1}{f}} \qquad \text{...(2.7)}$$

Therefore ,

$$Q = A\sqrt{8g\, R.S\, x\, \frac{1}{f}} \qquad \text{...(2.8)}$$

where Q = discharge capacity of the channel in m^3/s

A = area of channel in m^2

g = gravitational acceleration in m/s^2

R = hydraulic radius of channel (m)

S = slope of channel in m/m

f = resistance coefficient

2.7.2 Talbot Method

This is only an approximate approach where accuracy is not required, and a quick result is desired. It relates the area of the channel section to the catchment area of the runoff flow. The equation is stated below:

$$a = C\,(A^3)^{1/4} \quad \text{...(2.9)}$$

where a = cross-sectional area of channel in ft^2

C = Talbot's coefficient which has been tabulated for different slopes, terrain, land , etc.

A = catchment area in acres

2.7.3 Chezy Method

Chezy's formula for designing open channel hydraulic structure is given as:

$$Q = AC\,(RS)^{1/2} \quad \text{...(2.10)}$$

where Q = discharge capacity of the channel in m^3/s

A = cross-sectional area of channel in m^2

C = roughness coefficient (chezy constant)

R = hydraulic radius or hydraulic mean depth in metre

S = slope of channel in m/m

Therefore,

$$V = C\sqrt{RS} \quad \text{...(2.11)}$$

where V= velocity of flow in the channel in m/s

2.7.4 Manning's Method

The Manning's open channel hydraulic formula is expressed as:

$$Q = A.\ \frac{R^{2/3}S^{1/2}}{n} \quad \text{...(2.12)}$$

where Q = flow rate of channel in m^3/s

A = cross-sectional area of channel in m^2

R = hydraulic radius in metre

S = slope of channel in m/m

n = Manning's coefficient of roughness

The Manning's formula does not assume a uniform flow such that the slope of the water in the channel is not equal to the slope of the bottom of the channel as in Chezy's formula. The major advantage of this method is that it can be used outside the range of normal size channels as it takes into consideration relative roughness and turbulence of flow.

2.7.5 **Hydraulic Radius**

The parameter called the hydraulic radius, R, is defined as the ratio of the cross-sectional area of the channel to the wetted perimeter of the channel, that is,

R = A/P ....(2.13)

where R = hydraulic radius in metre

A = area of the flow section in m^2

P = wetted perimeter of the section in metre

2.7.6 **Coefficient of Flow**

The coefficient of flow can be derived from various formulae such as the Manning's formula and the White-Coolebrook's formula. Both formulae give almost identical values and both take into account the roughness of the channel lining. The lining to be adopted in this study in unfinished concrete lining using timber as formwork. The two formulae are stated as follows:

Manning's formula: **$C = R^{1/6}/n$** ....(2.14)

White –Coolebrook's formula: **C = 10log12/k** ....(2.15)

where C = coefficient of flow (as used in Chezy's formula)

n and k =the respective roughness coefficients for the channel lining

The values of Manning's 'n' and White -Coolebrook's 'k' are given in Tables 2.2 and 2.3 respectively.

Table 2.2 Manning's 'n' values

Type of open channel	'n'
Metal:	
Smooth steel surface	0.012
Corrugated steel surface	0.025
Non-metal:	
Trowel finished concrete	0.013
Float finished concrete	0.015
Unfinished concrete	0.017
Irregular excavated rock	0.027
Good excavated rock	0.020
Glazed brick	0.013
Brick in cement mortar	0.015
Cemented rubble	0.025
Dry rubble	0.032
Smooth Asphalt	0.013
Rough Asphalt	0.013
Straight and uniform clean earth drain	0.018
Straight weathered uniform earth drain	0.022
Straight uniform gravel drain	0.025
Straight uniform earth drain with grass	0.027
Windy, sluggish earth drain with no vegetation	0.025
Windy, sluggish earth drain with dense weeds or aquatic plants in deep channel	0.035
Windy, sluggish earth drain, stony bottom and weedy blanks	0.035
Windy, sluggish earth drain with cobble and clean s ides	0.040

Source: Highway Design Manual (1976), Michael and Ojha (2003)

Table 2.3 White –Coolebrook's 'k' values

Material of channel	Values of 'k'
Stone blocks	0.350
Stone bricks	0.100
Broken stone	0.048
Gravel	0.020
Bad brick work	0.008
Natural stone pitching	0.003
Good brick work	0.001
Old concrete	0.015
Unfinished concrete	0.004
Finished concrete	0.001
Very smooth concrete	0.0003
Centrifugal concrete	0.00007

Source: Highway Design Manual (1976), Michael and Ojha (2003)

Table 2.4 Runoff factors for hydraulic design

Land-use/ Topography	Flat	Rolling 2-10 %	Hilly over 10%	Land –use + Code
Sub-urban normal residential area	0.45	0.50	0.55	SRA/NRA
Dense residential area	0.50	0.65	0.70	DRA
Side slopes Earth area	0.60	0.60	0.60	SSEA
Side slope, turf area	0.30	0.30	0.30	SSTA
Cultivated land clay and loam	0.50	0.45	0.60	CCA/CLA
Unimproved areas	0.10	0.20	0.30	UA
Cultivated land, sand and gravel	0.25	0.30	0.35	CSA/CGA

Source : Federal Highway Design Manual (1976)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of Study Area

The study was conducted at Kpakungu area of Minna in Bosso Local Government Council of Niger State. Kpakungu community is located at Kilometre 1 along Minna - Bida road in the Southern axis of the state capital. The study area lies between Latitude 9^0 30^1 N and Longitude 6^0 28^1 E of the equator. It has a population of about 50,000 people. Major occupation of the inhabitants of the area is farming. There are also civil servants, petty traders, artisans and school children in large numbers. The community covers an area of about 1sq kilometre in size (Fig. 3.1).

3.2 Physical Environment of Study Area

The physical environmental factors in the study area considered important for this study are climate, geology, topography, soil, vegetation and drainage.

3.2.1 Climate

The study area (Kpakungu) falls within the tropical climate characterized by high temperatures and rainfall. The temperatures range between 20°C (minimum temperature) and 38°C (maximum temperature) throughout the year. The climate of the study area depends largely on the climatic data of Minna, obtained from the Nigerian Metrological Agency (NIMET) office at Minna Airport. The average annual rainfall of Minna and its environs is 1214.8mm (Alabi and Ibiyemi, 2000 - Long term average).

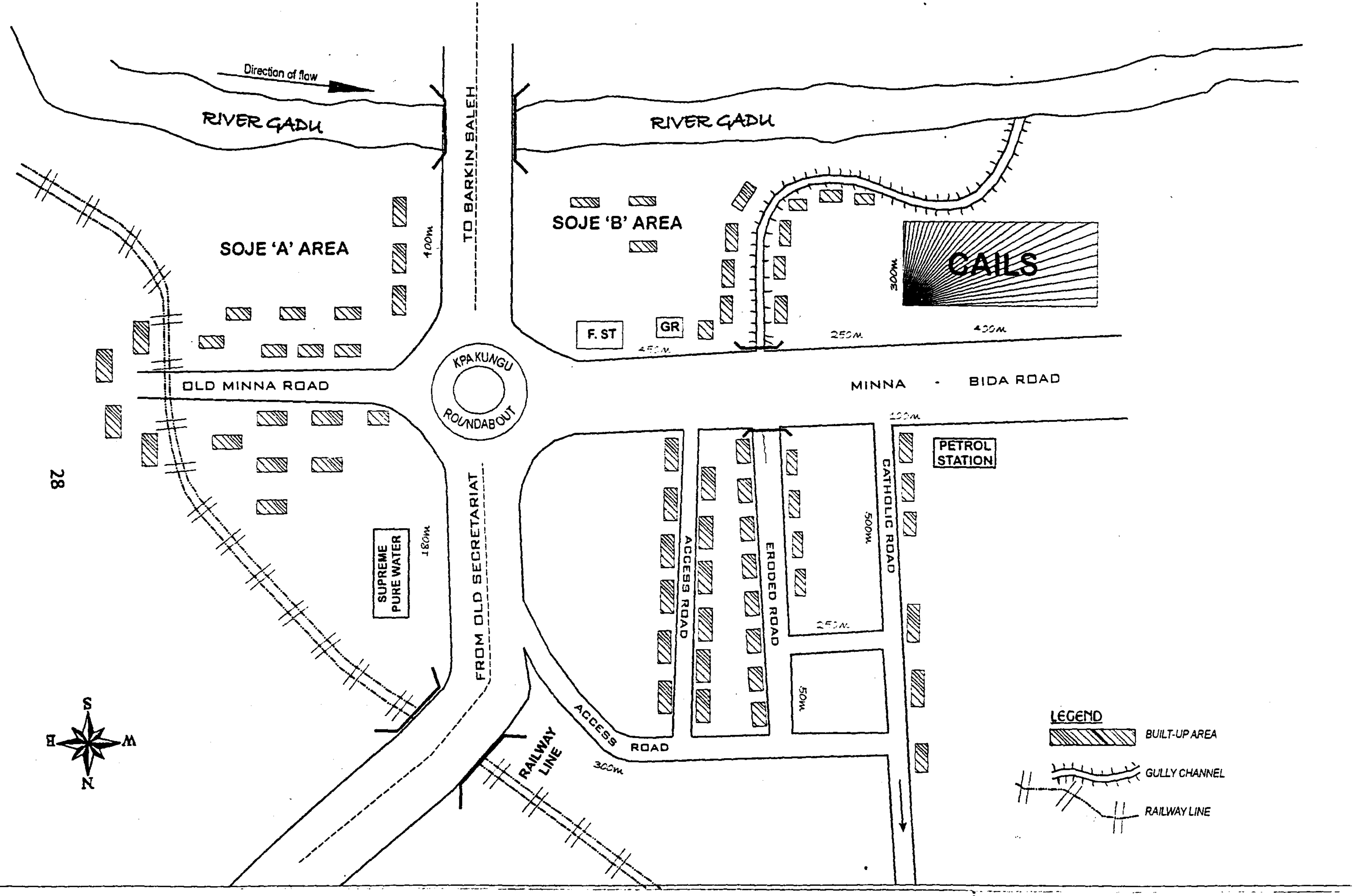


Fig. 3.1 Location Map of Study Area

3.2.2 Geology

The geology of the study area is undifferentiated basement complex rocks. The formations are basically made up of granites, schists, micas, gneisses, quartzites and intercalations of ironstones (laterites). These geological materials were found dominating the parent materials of soils in the gully site (FDALR, 1990).

3.2.3 Topography

The topography of a place is the degree of lowness (flatness) or steepness. The general landform of the study area is of rolling topography permitting the flow of surface runoff from the water divide upslope to the lower slope towards River Gadu located in the Eastern axis of the area. The slope ranged from 2-3% (1:50,000 scale Topographic Map of Minna S. W.).

3.2.4 Soil

The soils of Kpakungu and its environs where the gully erosion site was located have been described as *Alfisols* derived from basement complex rocks (Odofin, 2005). They are brown to red sandy or clayey soils with gravely sandy clay and loamy sand surface and subsurface materials. They are ferruginous tropical soil materials. They are formed from gneisses, saprolites, schists and magmatites and underlain by iron pan at varying depths, hence their susceptibility to erosion. They are relatively light to medium soil materials.

3.2.5 Vegetation

The study area falls within the Southern Guinea Savanna vegetation zone of Nigeria. That is, the area lies within the middle-belt agro-ecological zone of the country. The study area being a residential area undergoing rapid development almost on daily basis, has lost 90% of its natural vegetation to construction activities permitting excessive flow of runoff without interception by natural vegetation. The absence of natural vegetation cover has given rise to the formation of erosion channels (gullies) ravaging the area.

3.2.6 **Drainage**

The drainage of any area of land is a function of topography. The drainage of the study area follows the trend of slope of the area. The upper and middle parts of the gully site are well-drained having a perfect internal drainage while the lower slope area is poorly drained and it is situated on the flood plain (*fadama*).

River Gadu located in the South-Eastern part below collects the runoff discharge from the gully channel. The variation in drainage characteristics and soil moisture regimes coupled with non-existence of drainage facilities to control the flood has been identified as one of the factors responsible for the seasonal flooding of the area particularly in the peak of rainy season.

3.3 **Materials**

The following materials were used in carrying out the study of the gully erosion site.

Surveying Instruments:

- Level (Automatic level)
- 50m- measuring (linear) steel tape
- Wooden pegs
- Arrow pins
- Survey book
- Prismatic compass

- Theodolite
- Ranging rods
- Leveling staff
- Tripod stand and plum-bob

Soil Testing Equipment:

- Double-ring infiltrometers
- Proctor soil penetrometer
- Soil core-ring samplers
- Atterberg limits instrument
- Geological hammer
- Set of soil sieves
- Drying ovens
- Digger, cutlass, hand-trowel, shovel, mallet, hand tape, soil samples bags
- Soil colour charts
- Top loading weighing balances.

3.4 Method of Data Collection

- Topographical map of Minna (*Cadastral map*) covering Kpakungu area was obtained from Niger State Ministry of Land and Survey.
- Highway Design Manual from Federal Ministry of Works and Housing (presently Federal Ministry of Transportation).

- Annual rainfall data (20 years average), mean monthly temperature and relative humidity for Minna and environs collected from Nigerian Meteorological Agency (NIMET) of Minna Airport covering 1987-2007.
- Runoff coefficient for urban area from the Federal Ministry of Works and Housing.
- Spots photography of gully site.

3.5 Site Survey

The entire terrain was surveyed and studied, the possible solution to check the gully erosion impact on the environment, topography, slope, soil type and design of engineering works and techniques for preventive measure to control the problem was analyzed (Plates 3.1 -3.3).

The survey carried out on the site included cross-section and longitudinal section of the gully channel to provide the required existing ground information for the hydraulic design of control structure.

3.6 Soil Investigation

The soil of the study area was investigated to determine its engineering properties which were considered relevant to the study.

The soil infiltration rate and load bearing capacity tests were carried out directly on the field (i.e. in-situ) at chainages CH 0 +20, CH 0 + 490 and CH 0 + 640. Six representative soil samples from three test pits (profile pits) were also collected from these locations for further analysis in the laboratory. The depth of profile pits ranged from 1.2m to 1.9m. The various soil tests were conducted in accordance with code of practice CP 2001-site investigation. The following soil physical parameters were determined:

- Sieve Analysis for particle-size distribution
- Atterberg Limits tests (Liquid limit, Plastic limit, plasticity index and Linear shrinkage)
- Soil Infiltration rate test
- Soil bulk density, particle density and porosity
- Soil unit weight
- Soil load bearing capacity (soil resistance test)
- Soil angle of repose

3.6.1 Methods of Soil Analysis

The engineering (physical) soil parameters mentioned above were analyzed using the following procedures:

- Sieve analysis was done with a set of sieves of varying diameter sizes (apertures), and from the grain size tests, the classification of the soil was determined.
- Atterberg Limit test was conducted using the Atterberg Limit test instrument (Casagrande instrument) and from the tests the consistency and classification of the soil samples were also determined. Soil classification was done in accordance with Unified Soil Classification System for engineering purposes.
- Soil infiltration rate test was done in-situ with a double-ring infiltrometer.
- Soil bulk density was determined by core- ring method in which the soil samples collected were oven-dried thermogravimetrically for 24 hours at a constant temperature of 105°C.
- Soil particle density (specific gravity) was determined by *pycnometer* method of particle density test.

Plate 3.1: Marking out a chainage point along the gully

Plate 3.2: Setting up the level for field observation

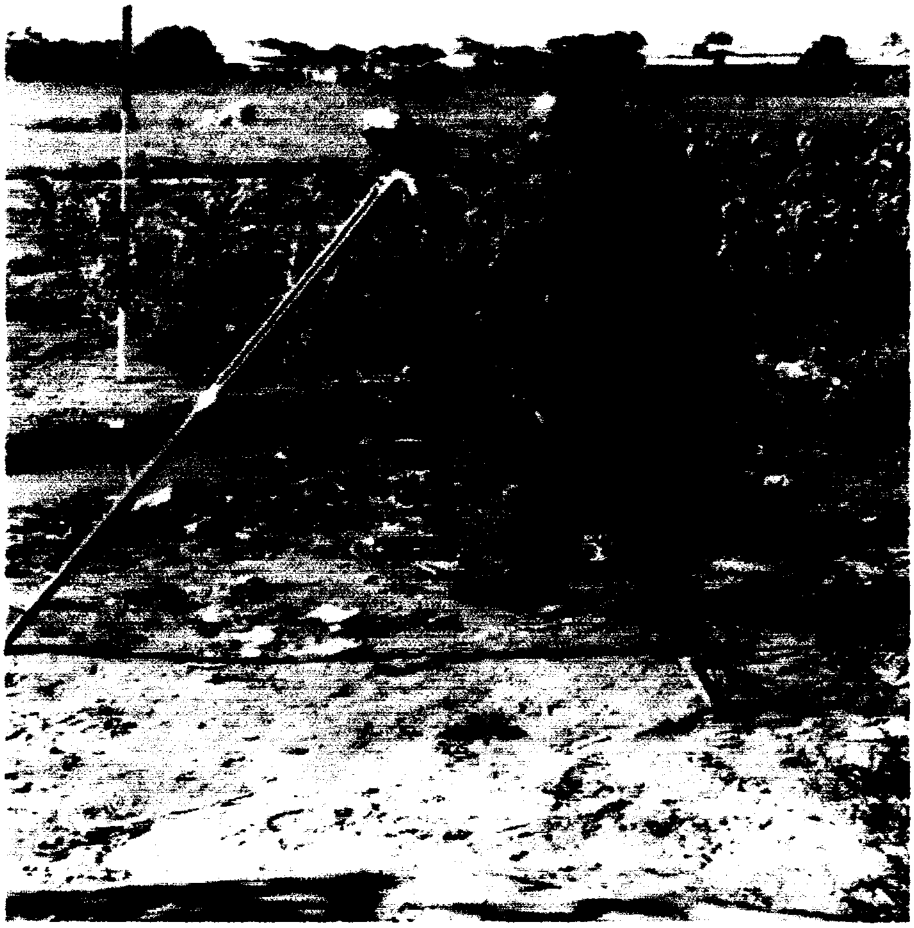


Plate 3.3: Taking an instrument reading in the field

- Soil porosity was determined from the data of bulk density and particle density to ascertain the distribution of voids in the soil.
- The soil unit weight was determined from the data of bulk density and particle density.
- Soil load bearing capacity (soil resistance) was determined in-situ using a manually operated proctor penetrometer (Plates 3.4 - 3.5) in accordance with British Standard.
- The angle of repose of soil sample was determined with the angle of repose apparatus designed for engineering materials in the laboratory. Angle of repose is a measure of soil angle of internal friction.

Plate 3.4: Soil load bearing capacity (soil resistance) determination with proctor soil penetrometer

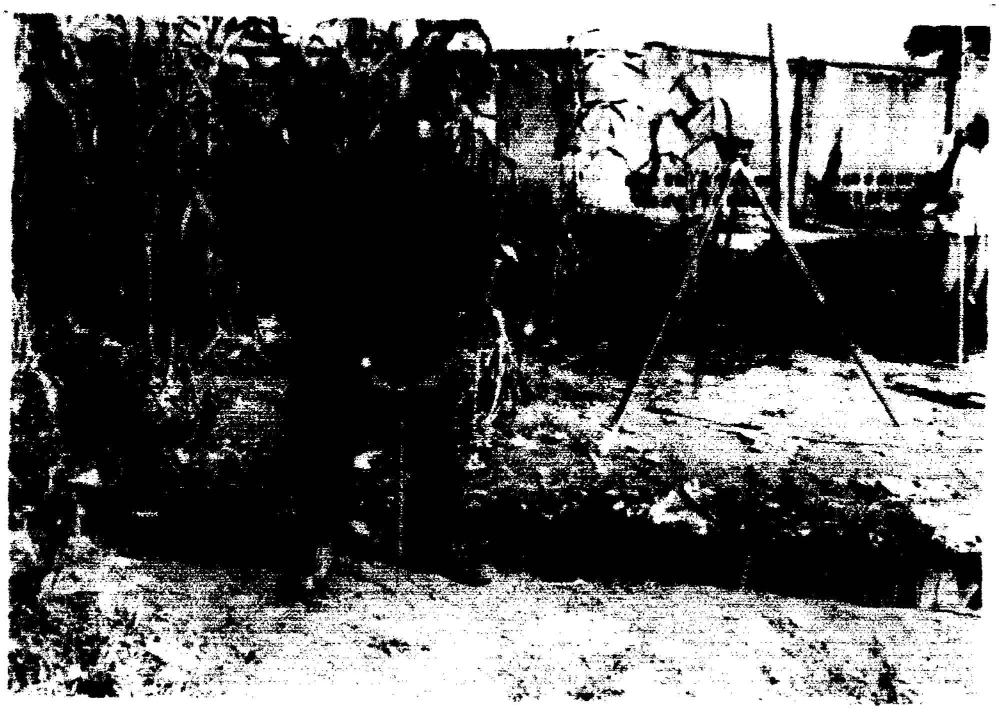


Plate 3.5: Determination of soil vertical loading capacity (soil resistance)

3.7 Rainfall Data

Mean monthly rainfall for Minna and its environs covering a period of 20 years (1987 – 2007) were obtained alongside with temperature and relative humidity data and five years moving average over this period was used. The detail of rainfall data and other climatic data collected for the purpose of this study is in Appendix I.

3.8 Rainfall intensity Data Analysis

The rainfall amount data were collected for each of the years considered and the maximum recorded amount of rainfall was extracted for each year. The corresponding duration of the recorded highest quantity of rainfall was also collected from the rainfall data record. Then the intensity of rainfall for each year was calculated by dividing the maximum rainfall amount recorded by the corresponding recorded duration. The rainfall intensity for Minna and its environs were computed as follows:

Table 3.1 Computation of Rainfall Intensity for Minna and its environs (1987 – 2007)

Year	Maximum Rainfall Amount (mm)	Duration (hrs)	Intensity	=	Rainfall Amount / Duration (mm hr^{-1})
1987	77.3	2.56	77.3/2.56	=	30.2
1988	92.3	5.02	92.3/5.02	=	18.4
1989	78.4	3.50	78.4/3.50	=	22.4
1990	49.0	3.17	49.0/3.17	=	15.5
1991	68.6	2.50	68.6/2.50	=	27.4
1992	54.4	2.14	54.4/2.14	=	25.4
1993	69.3	2.18	69.3/2.18	=	31.8
1994	86.7	2.14	86.7/2.14	=	40.5
1995	64.2	2.50	64.2/2.50	=	25.7
1996	62.9	3.50	62.9/3.50	=	18.0
1997	68.1	5.20	68.1/5.20	=	13.1
1998	94.6	5.80	94.6/5.80	=	16.3
1999	88.6	4.80	88.6/4.80	=	18.5
2000	48.5	3.05	48.5/3.05	=	15.9
2001	67.7	6.07	67.7/6.07	=	11.2
2002	95.6	5.34	95.6/5.34	=	17.9
2003	53.5	4.31	53.5/4.31	=	12.4
2004	107.0	6.12	107.0/6.12	=	17.5
2005	73.9	4.75	73.9/4.75	=	15.6
2006	77.8	3.50	77.8/3.50	=	22.2
2007	94.5	1.17	94.5/1.17	=	80.8

Source: Nigerian Meteorological Agency (NIMET),Minna Airport, Minna

3.9 Runoff Coefficient

Runoff coefficient (C) is a measure of the proportion of rain which becomes runoff. The constant is dependent upon such factors as rainfall intensity, duration, topography, and nature of soil and land use. The area under study is a residential urban area with moderately steep slope.

Table 3.2 Values of runoff coefficient for urban area

ITEM	DESCRIPTION OF TOPOGRAPHY AND LAND USE	C-VALUE
1	Flat, residential area with 30% of area impervious	0.40
2	Moderately steep, residential area with about 50% of area impervious	0.65
3	Moderately steep, built-up with about 70% of area impervious	0.80

Source: Highway Design Manual-FMW&H (1976), Schwab *et al* (1992)

The description of the gully erosion site goes with item (2), and hence the runoff coefficient for the site is 0.65.

3.10 Design of Drainage Channel

The Highway design manual of the Federal Ministry of Works and Housing of the Federal Republic of Nigeria was used for all design analysis and calculations. Considering the longitudinal profile of the gully channel obtained from the engineering survey of the gully site at Kpakungu (Appendices III & IV), the gully has a length of 730m and a slope of 2%.

3.11 Calculation of Time of Concentration

Time of concentration of the watershed (Tc) was calculated using the following equation:

$$Tc = \frac{0.0197L^{0.77}}{S^{0.385}} \quad \text{.......(3.1)}$$

where Tc = time of concentration or duration time (min.)

L = maximum length of gully (m)

S = watershed gradient (m/m)

Applying the equation (3.1) above,

L =730m , S =2% = 2/100 = 0.02

$$Tc = \frac{0.0197 \ X \ (730)^{0.77}}{(0.02)^{0.385}}$$

Tc = 14.2 min.

3.12 Runoff Design Equation

The hydrological design of the drainage system is normally based on the rational formula recommended in the Highway design manual. The rational formula is particularly suitable for small catchment areas (Michael and Ojha, 2003). It is expressed as:

Q = 0.028 CIA ....(3.2)

where Q = catchment area runoff rate (m^3 /s)

C = runoff coefficient (dimensionless)

I = rainfall intensity (mm/hr)

A = catchment area (Hectares)

Using Fig. 2.1, the 1-hour intensity of 80.8mm/hr to 14.2 minutes intensity at 20-year return period (T) recommended for gully erosion control and small earth dam structure, gives 62.5 mm/hr.

C = 0.65 (runoff coefficient for urban residential area with 2-10% slope)

I = 62.5mm/hr

A = 1280m x 20m =25600m^2 = 2.56 ha

(represents catchment area of the gully as obtained from survey data of the gully site)

Q = 0.028 x C x İ x A

= 0.028 x 0.65 x 62.5 x 2.56

= **2.91m^3/s**

3.13 **Rectangular Channel Hydraulic Capacity Design**

For this study, calculation of capacity design of the rectangular open channel was based on the Manning's open channel hydraulic equation expressed as:

$$Q^* = A.V = A \frac{(R^{\frac{2}{3}} . S^{\frac{1}{2}})}{n} \quad \text{.......... (3.3)}$$

where Q* = design channel discharge (m^3/s)

A = cross-sectional area of the channel (m^2)

V = velocity of flow (m/s)

R = channel hydraulic radius (m)

S = slope of channel (dimensionless)

n = Manning's coefficient of roughness

(depending on the material)

3.13.1 **Design Calculation**

Final discharge rate of the channel was calculated after trial test of channel variables; width and depth (b, d) to obtain an acceptable and adequate hydraulic capacity that can safely handle the runoff (Clarkson and Hicks, 1982).

The drainage channel to be lined with unfinished reinforced concrete and using wooden formwork. Manning's roughness coefficient 'n' = 0.017 (from Table 2.2).

Cross-sectional area, $A = bd$

Width of channel, $b = 0.8m$

Depth of channel, $d = 1.0m$

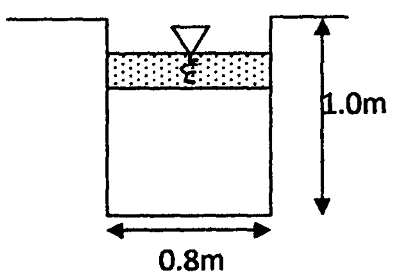


Fig. 3.2: Designed drainage channel

Area of cross-section, A =0.8m x 1.0m

$= 0.8m^2$

Wetted perimeter, P = b +2d

= 0.8m + 2(1.0m)

= 0.8 +2.0

= 2.8m

Hydraulic radius , $R = \frac{A}{p} = \frac{bd}{b+2(d)}$

$= \frac{0.8 X 1.0}{0.8 + 2(1.0)}$

$= \frac{0.8}{2.8}$

= 0.29m

Velocity of flow, $V = \frac{(R^{\frac{2}{3}} . S^{\frac{1}{2}})}{n}$ ....(3.4)

$$V = \frac{(0.29)^{\frac{2}{3}} . (0.02^{\frac{1}{2}})}{0.017}$$

$$V = \frac{(0.29)^{0.666} X (0.02)^{0.5}}{0.017}$$

V = 3.65 m/s

Discharge, $Q^* = A \times V$

$= 0.8 \times 3.65$

$= \mathbf{2.92\ m^3/s}$

This design capacity of the channel is sufficient to safely dispose of the runoff in the study area. That is, since $Q^* = 2.92 m^3/s$ is greater than $Q = 2.91\ m^3/s$, the required section designed is adequate.

3.13.2 **Freeboard**

A Freeboard of 200mm (0.2m) is provided to prevent overtopping of channel structures that may be caused by wave action of water or the development of unforeseen conditions. Freeboard is the vertical distance between the highest water level anticipated in the design and the top of the retaining walls.

In engineering design of flood control structures, it is normally advisable to take into design consideration the excess runoff water which may likely overtop the drainage channel during heavy storm, at least once in every 20 years. In this case, the channel is further provided with a freeboard of 0.2m to accommodate the anticipated excess runoff.

Design depth of the rectangular channel =1.0m.

Therefore, the overall depth of the channel = 1.0m+0.2m (freeboard, 20%)

= 1.2m

The overall discharge of the channel was calculated as follows:

Width of the channel, b = 0.8m

Overall depth of the channel, d = 1.2m (including 20% freeboard)

Area of the channel, A = bd

= 0.8m x 1.2m

= $0.96m^2$

Wetted perimeter of the channel, P = b +2(d)

= 0.8m +2 (1.2m)

= 0.8m +2.4m

= 3.2m

Hydraulic radius , R $= \frac{A}{p} = \frac{bd}{b+2(d)}$

$= \frac{0.8 \, X \, 1.2}{0.8 + 2(1.2)}$

$= \frac{0.96}{3.2}$

= 0.3m

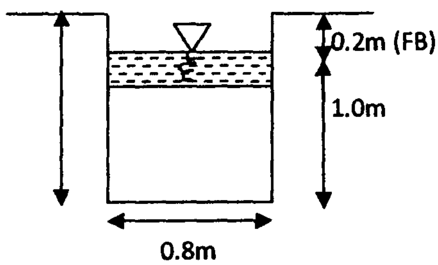


Fig. 3.3: Designed drain with freeboard

NB: FB =Freeboard

Slope of the channel = 0.02 (from survey data)

Manning's roughness coefficient = 0.017 (from Table 2.2)

Therefore, discharge of the channel, Q** = A x V

$$= A.\frac{(R^{\frac{2}{3}}.\ S^{\frac{1}{2}})}{n}$$

$$= \frac{0.96\ x(0.3)^{\frac{2}{3}}.\ (0.02)^{\frac{1}{2}}}{0.017}$$

$$= \frac{(0.3)^{0.666}\ x\ \ (0.02)^{0.5}}{0.017}$$

$$= \mathbf{3.58m^3/s}$$

This discharge rate of the channel, Q** = 3.58 m^3/s is also considered adequate to handle any excess of runoff in the area.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Results of Site Survey

The results of site survey of the gully are presented in Appendices III and IV. The results showed an elevation difference of -15.132m between chainage 0 + 0.00 and chainage 0+730 indicating that the gully erosion has caused a serious depression and land degradation of which there would be need for cutting and filling with stable borrow materials, if the land is to be reclaimed back to its original natural state.

4.2 Rainfall and Rainfall Intensity Analysis Results of Minna and environs

The results of rainfall and rainfall intensity analysis for the study area are shown in Tables 4.1- 4.4. These could also be found in Figures 4.1- 4.4. The results of the analysis showed that the mean annual rainfall of Minna over a long period of 20 years was 1220.8mm while the maximum rainfall intensity within the same period was 80.8mmhr^{-1}.

These values showed that the study area falls within the zone of high intensity of rainfall characterized by middle-belt agro-ecological zone of the country. In other words, the area is liable to heavy rainfall between the months of June and September every year. This amount of rainfall was observed to be high enough to cause erosion especially where vegetation has been severely destroyed through the activities of people. High intensity of rainfall occurring occasionally in the study area has no doubt contributed to the severity of gully erosion. The erosive force of rain on the soil surface can cause soil detachability and eventual formation of erosion channels.

4.3 Engineering Soil Test results

4.3.1 Soil Classification Tests

Soil classification tests comprised the particle-size distribution by sieve analysis and the Atterberg limits tests. The classification was done in accordance with the Unified Soil Classification System (USCS). The results of sieve analysis and Atterberg limits tests on test pits samples collected from the gully area are shown in Tables 4.5 and 4.6. The loggings of the test pits based on the laboratory tests are also presented in Fig. 4.5. The soils of the test pits locations are sand, silty sand, clayey sand, gravely clay, clay, clayey loam and sandy loam.

The results also showed that the soil materials are within the range of well-graded as revealed by coefficient of uniformity (Cu), but poorly packed as determined by coefficient of curvature (Cc) indicating that the soils are loosely packed. This inconsistency in particles distribution can aggravate soil erosion especially in loosely packed soil on sloping ground.

4.3.2 Soil resistance, Unit weight, Specific gravity and Porosity Tests

The results of the tests conducted on soil resistance, unit weight, specific gravity and porosity are shown in Table 4.7 and Fig. 4.12.The results indicated that the soil of the gully area have the required strength to carry the weight (load) of the drainage structure if it is to be constructed. For example, the unit weights of concrete and reinforced concrete range from $22kN/m^3$ to $24kN/m^3$ (Ojha and Michael, 2005; Mijinyawa, 2004), the units weights of the soils of the study area are within this neighbourhood in values.

The load bearing capacity of the soil is a function of soil bulk density. As soil bulk density increases, bearing capacity of the soil increases. It is also an established fact that the soil resistance increases (when subjected to vertical loading) as soil moisture content decreases due to increasing cohesion between soil particles and aggregates.

The soils also have a satisfactory distribution of voids which could permit a free interval drainage thereby reducing lateral pore pressure behind the retaining walls of the channel which is common in most shearing soils such as heavy clay.

4.3.3 Soil Infiltration rate Test

Soil infiltration rate tests were conducted to determine the rate of entry of water into and through the soil strata, and its impact on soil erodibility. The results of infiltration rate test are shown in Tables 4.8-4.10 and in Figures 4.13-4.15. The infiltration rates of the soil in the gully site are between the range of moderate (3.0cm/hr) and moderately rapid (10.0cm/hr).

4.4 Physical Analysis of the present state of Gully site

The result of physical analysis of the gully site indicated that the site has been badly affected by the gully erosion. Most residential buildings and public utilities like water supply lines have suffered a serious threat of damage and destruction. More importantly, the lands along the gully channel have been destroyed causing a lot of havoc to the people in the neighbourhood and also to their properties. Plates 4.1- 4.6 represent the present state of the gully erosion in the study area.

Plate 4.1: Gully gradually digging the culvert base and public utilities at CH 0 + 00 – CH 0 +10

Plate 4.2: Gully threatening residential buildings at CH 0 + 10 – CH 0 + 50

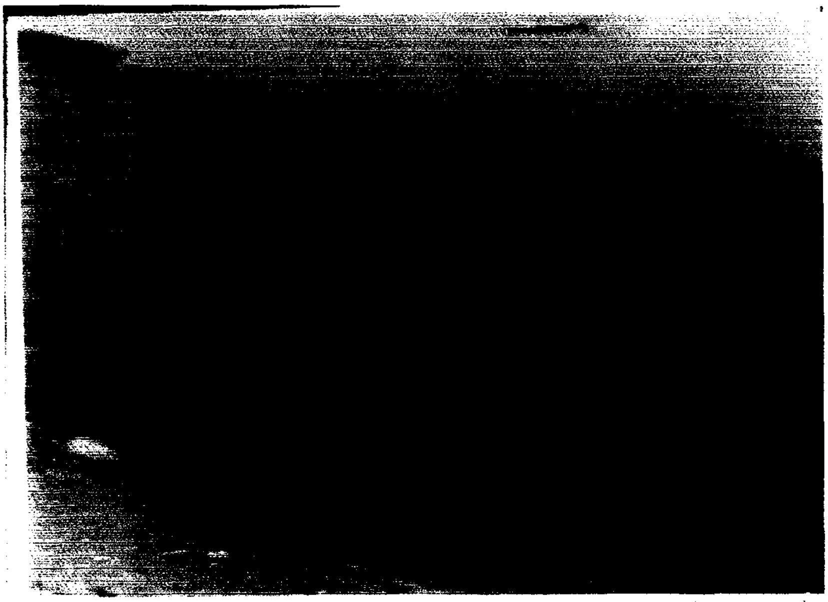


Plate 4.3: Gully erosion and flood endangering some residential buildings coupled with environmental abuse by people at CH 0 + 50 – CH 0 + 160

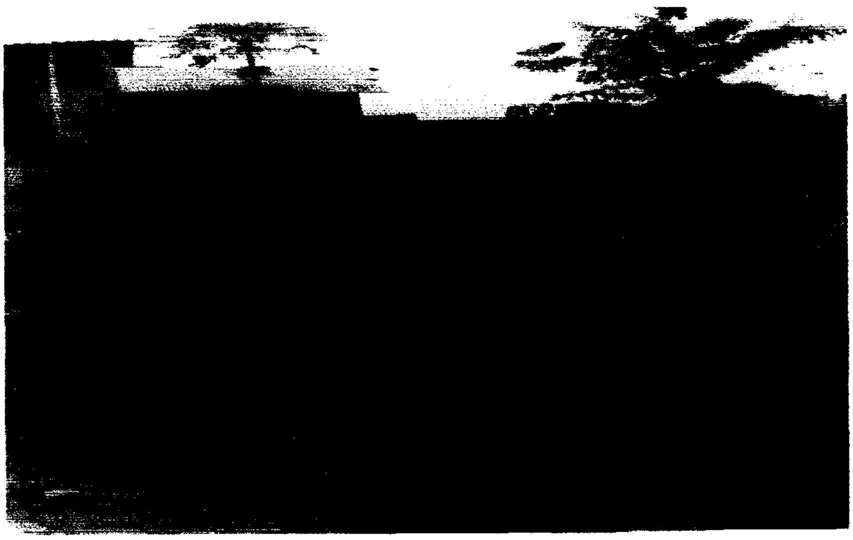


Plate 4.4: Gully expanding toward residential buildings at CH 0 + 500 – CH 0 + 610

Plate 4.5: Gully widening towards residential buildings at CH 0 + 620 – CH 0 + 720

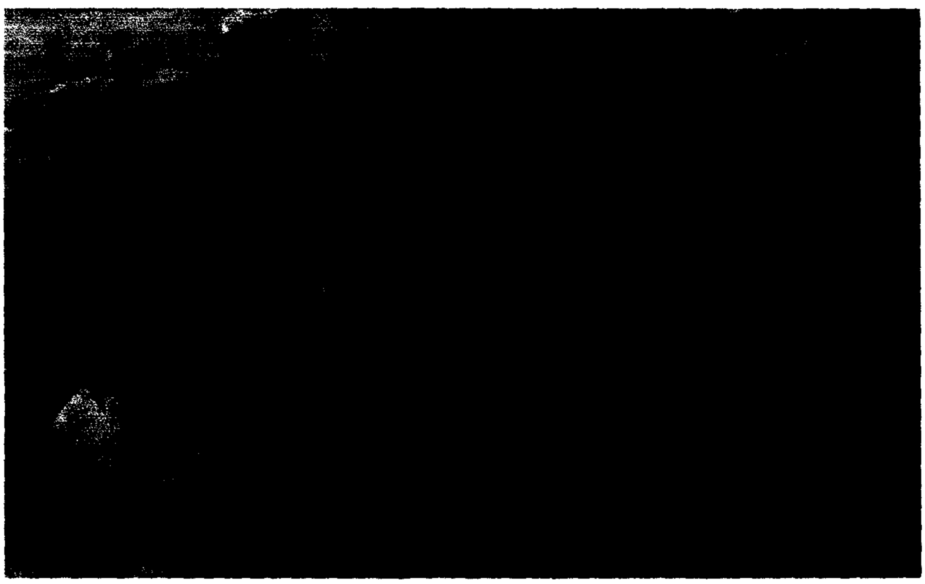


Plate 4.6: Gully discharging into River Gadu at CH 0 + 730

Table 4.1 Mean monthly rainfall of Minna and its environs from 1987 - 2007

Month	Mean rainfall (mm)
Jan	0.5
Feb	0.4
Mar	2.1
April	55.3
May	156.2
June	182.1
July	206.9
Aug	256.5
Sep	233.3
Oct	122.3
Nov	3.4
Dec	1.8
Annual Mean	**1220.8**

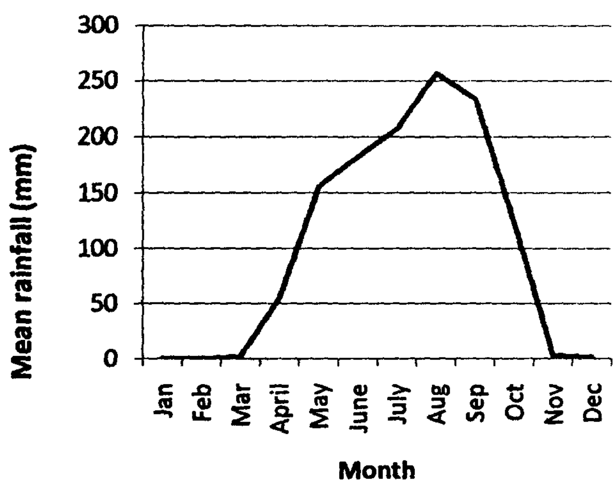


Fig. 4.1: Average monthly rainfall of Minna (1987- 2007)

Table 4.2 Result of rainfall five-year moving average

Year	Rainfall five -year moving average (mm)
1987-1991	1139.9
1991 -1995	1222.2
1995 -1999	1244.1
1999 -2003	1230.9
2003 - 2007	1256.7

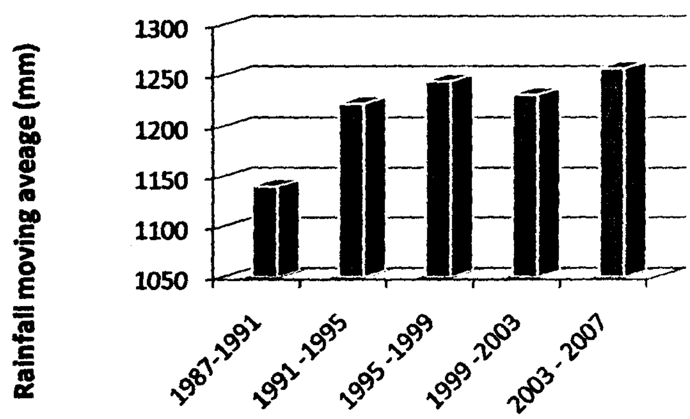


Fig. 4.2: Five - year moving average rainfall chart

Table 4.3 Rainfall Intensity for Minna and its environs from 1987 - 2007

Year	Intensity ($mmhr^{-1}$)
1987	30.2
1988	18.4
1989	22.4
1990	15.5
1991	27.4
1992	25.4
1993	31.8
1994	40.5
1995	25.7
1996	18.0
1997	13.1
1998	16.3
1999	18.5
2000	15.9
2001	11.2
2002	17.9
2003	12.4
2004	17.5
2005	15.6
2006	22.2
2007	80.8

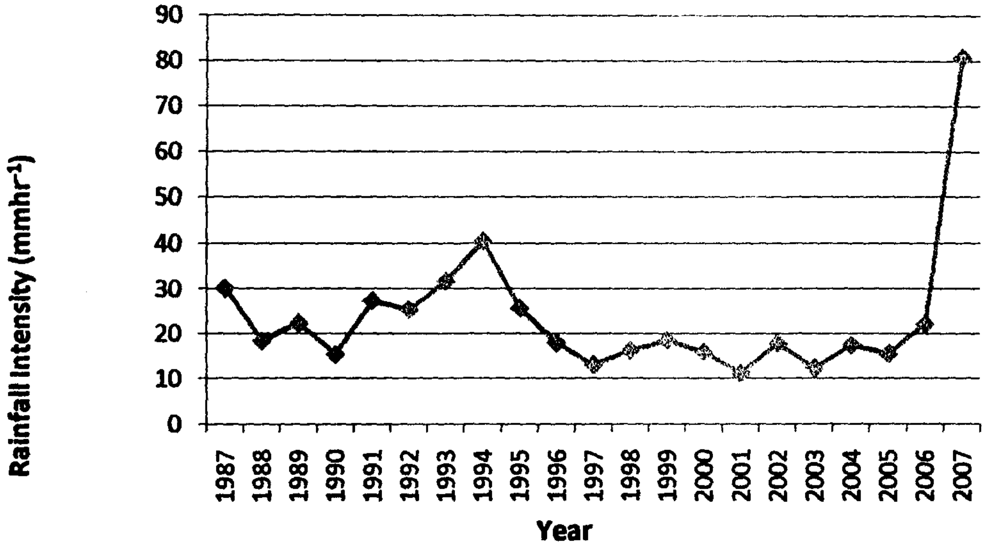


Fig. 4.3: Intensity of rainfall in Minna From 1987- 2007

Table 4.4 Rainfall Intensity and duration for Minna and its environs

Duration of rainfall (hr)	Intensity ($mmhr^{-1}$)
0.00	00.0
2.56	30.2
5.02	18.4
3.50	22.4
3.17	15.5
2.50	27.4
2.14	25.4
2.18	31.8
2.14	40.5
2.50	25.7
3.50	18.0
5.20	13.1
5.80	16.3
4.80	18.5
3.05	15.9
6.07	11.2
5.34	17.9
4.31	12.4
6.12	17.5
4.75	15.6
3.50	22.2
1.17	80.8

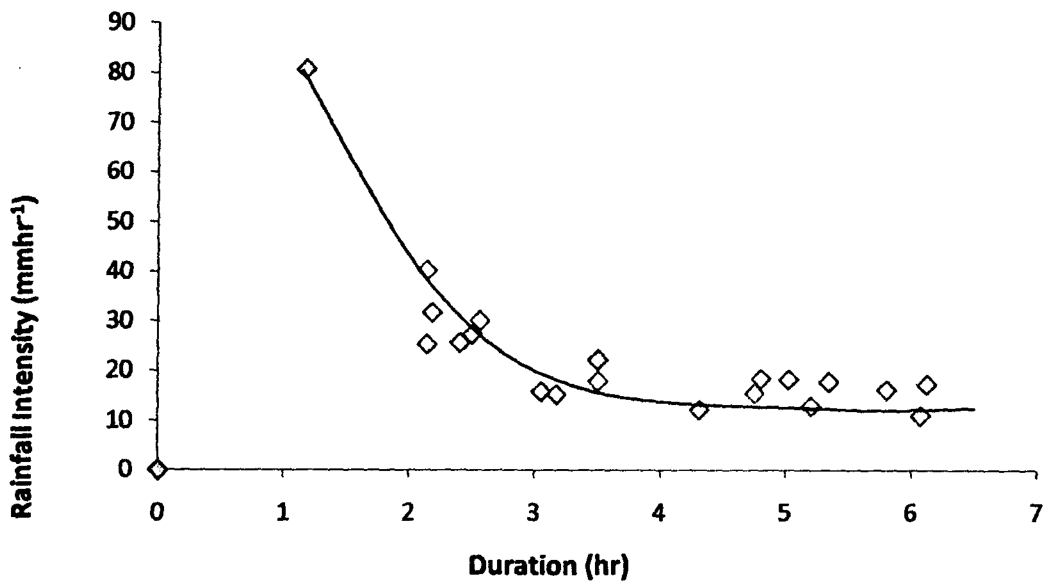


Fig.4.4 Rainfall Intensity Distribution as related to duration

4.5 Soil Test pits Logging

The soil test pit log charts are presented in the figure below. The pits logs indicate the naturally occurring layers of soil materials from the earth's surface to some meters of depth under the ground.

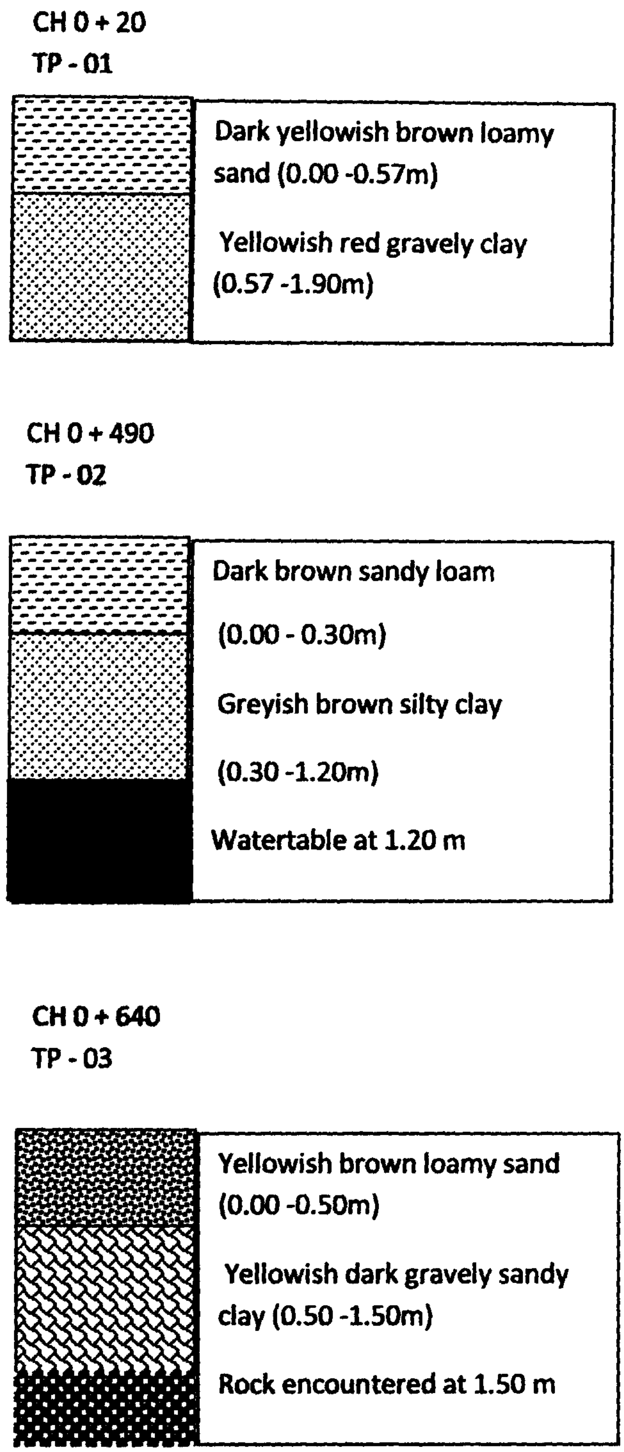


Fig 4.5: Soil profile loggings of naturally occurring soil layers in the project site

Data Sheet

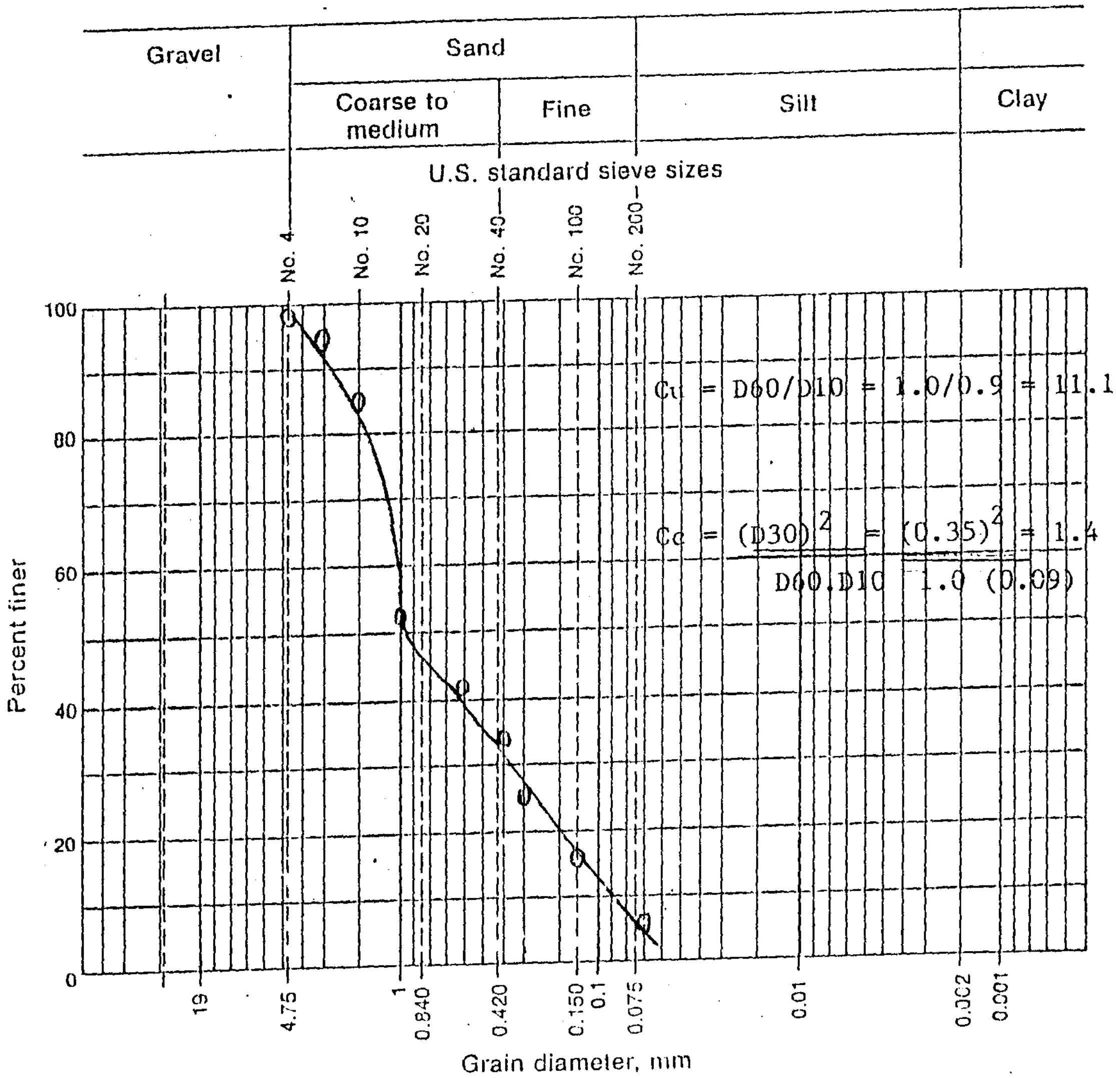
GRAIN SIZE DISTRIBUTION

Project Gully Erosion Study Job. No. -

Location of Project Kpakungu Boring No. - Sample No. TP1/1

Description of Soil Loamy Sand Depth of Sample 0.00 - 0.57m

Tested By. J.A. Oladipo Date of Testing 24-7-08



Visual soil description Well drained soil

Soil classification: SW System Unified soil classification system (USCS)

Fig. 4.6 Particle-size distribution graph of soil sample at CH 0+20

Data Sheet

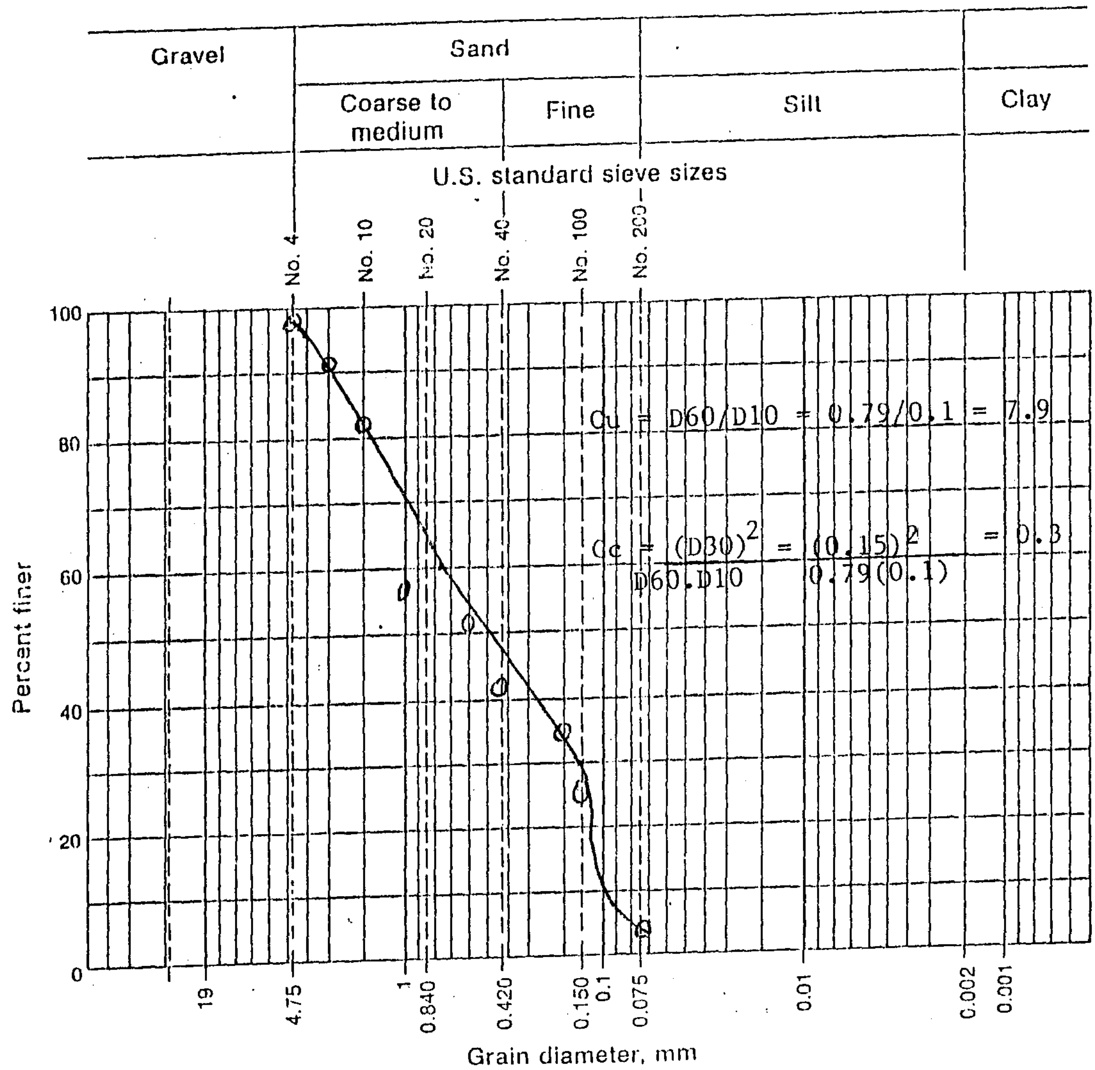
GRAIN SIZE DISTRIBUTION

Project Gully Erosion Study Job. No. -

Location of Project Kpakungu Boring No. - Sample No. TP1/2

Description of Soil Sandy clay Depth of Sample 0.57 1.90m

Tested By. J.A. Oladipo Date of Testing 24-7-08



Visual soil description Well drained soil
poorly graded sandy clay soil

Soil classification:
SC System Unified soil classification system (USCS)

Fig. 4.7 Particle- size distribution graph of soil sample CH 0+20

Data Sheet

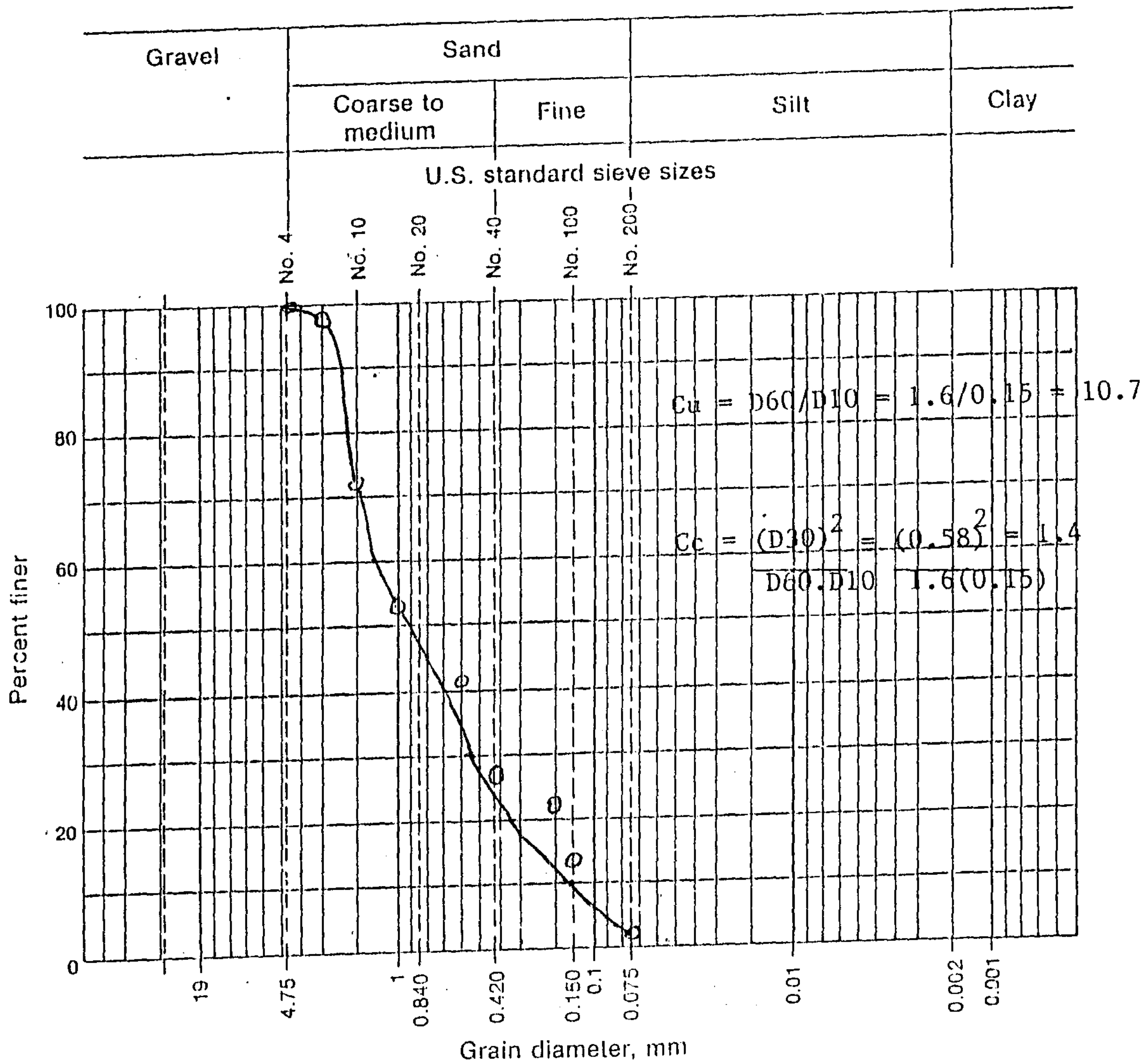
GRAIN SIZE DISTRIBUTION

Project: Gully Erosion Study — Job. No.: –

Location of Project: Kpakungu — Boring No.: – — Sample No.: TP2/1

Description of Soil: Sandy loam — Depth of Sample: 0.00 - 0.30m

Tested By: J.A. Oladipo — Date of Testing: 24-7-08



Visual soil description: Poorly drained soil

Soil classification: SW — System: Unified soil classification system (USCS)

Fig. 4.8 Particle - size distribution graph of soil sample at CH 0+490

Data Sheet

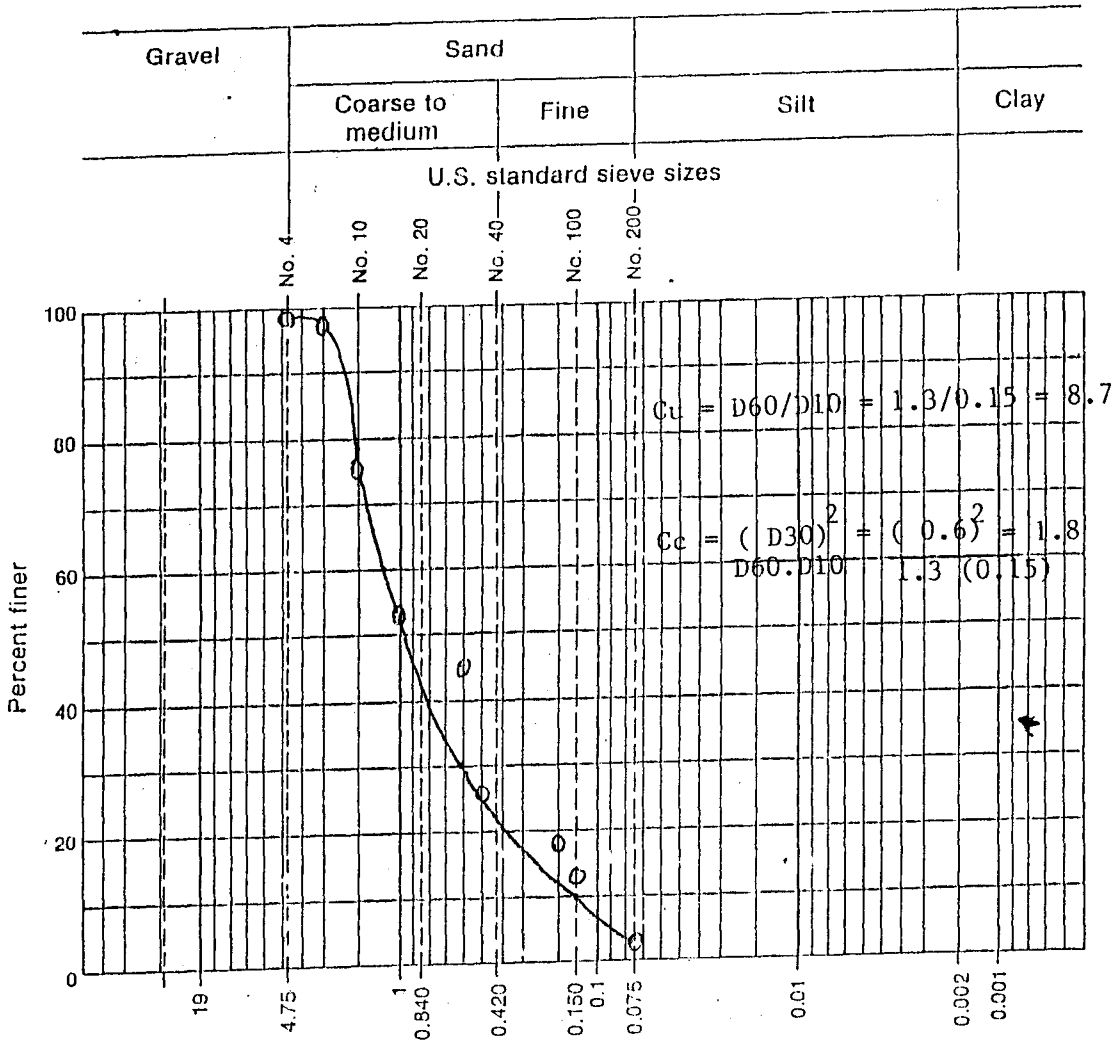
GRAIN SIZE DISTRIBUTION

Project Gully Erosion Study Job. No. -

Location of Project Kpakungu Boring No. - Sample No. TP2/2

Description of Soil Silty clay Depth of Sample 0.30 - 1.20m

Tested By. J.A. Oladipo Date of Testing 24-7-08



Visual soil description Poorly drained soil

Soil classification: ML System Unified soil classification system (USCS)

Fig. 4.9 Particle - size distribution graph of soil sample at CH 0+490

Data Sheet

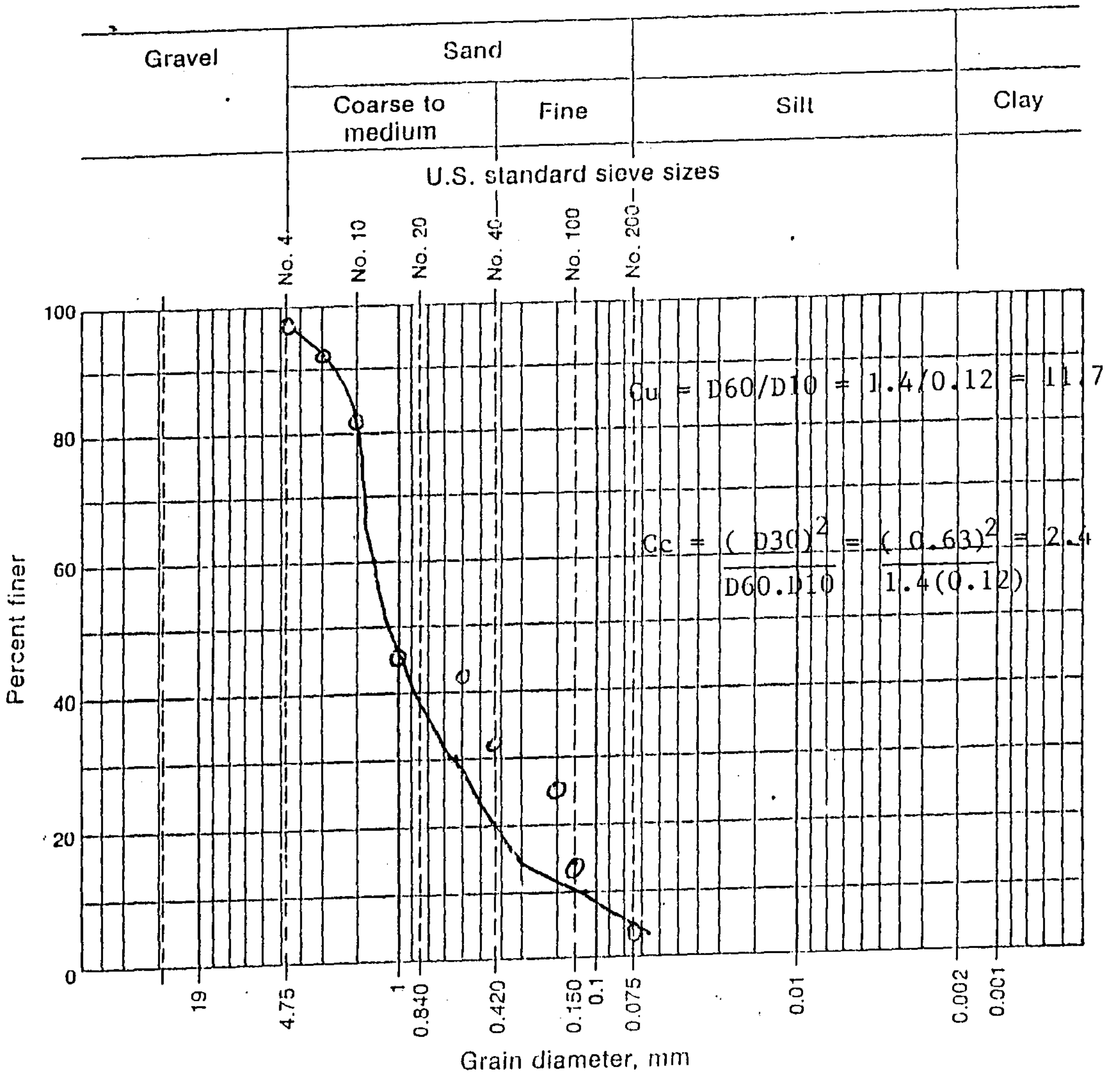
GRAIN SIZE DISTRIBUTION

Project Gully Erosion Study — Job. No. -

Location of Project Kpakungu — Boring No. - — Sample No. TP3/1

Description of Soil Loamy sand — Depth of Sample 0.00 - 0.50m

Tested By. J.A. Oladipo — Date of Testing 24-7-08



Visual soil description Well drained soil

Soil classification:

SW — System Unified soil classification system (USCS)

Fig. 4.10 Particle - size distribution graph of soil sample at CH 0+640

GRAIN SIZE DISTRIBUTION

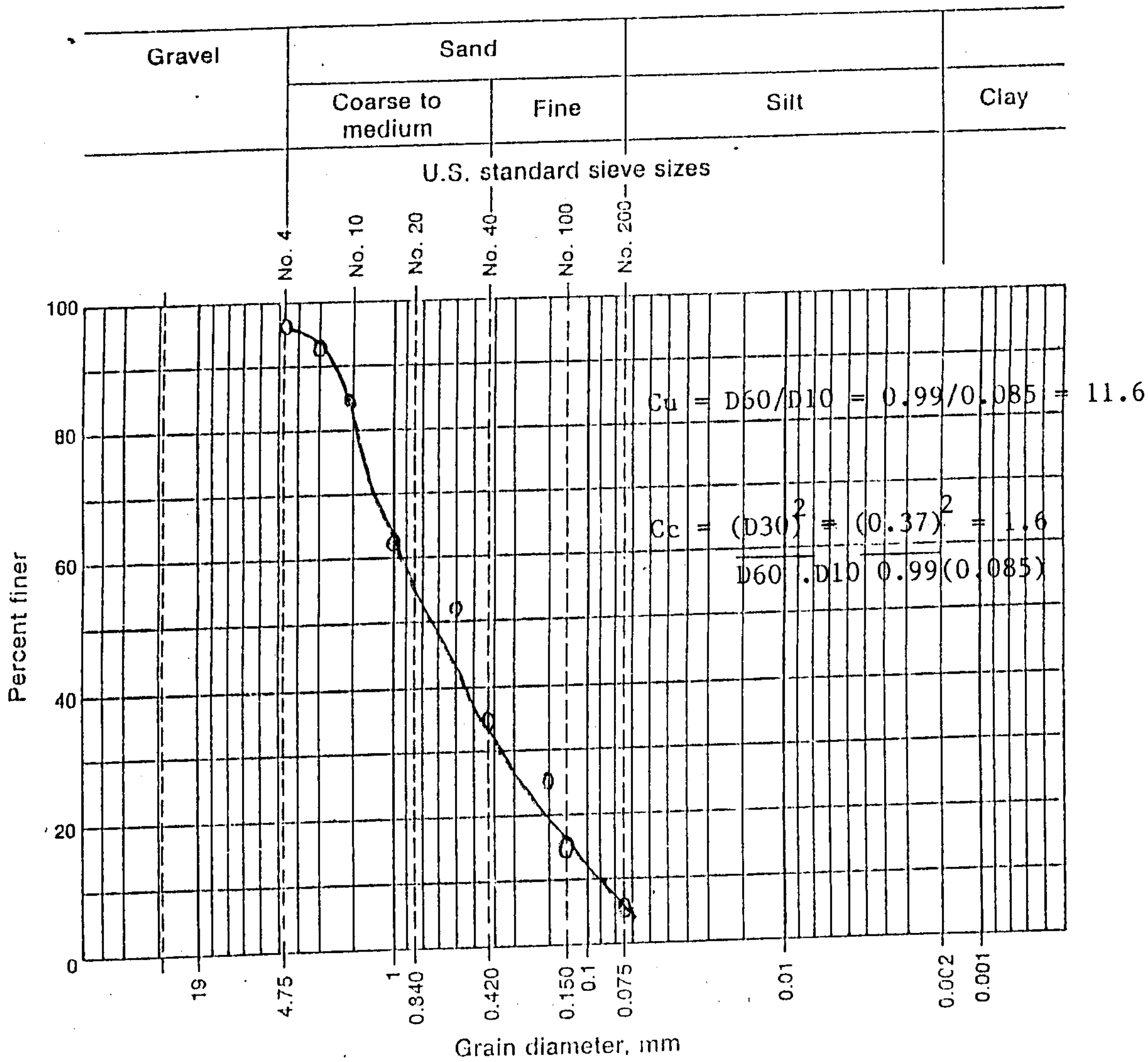
Data Sheet

Project: Gully Erosion Study — Job. No. –

Location of Project: Kpakungu — Boring No. – — Sample No. TP3/2

Description of Soil: Sandy clay — Depth of Sample: 0.50 - 1.50m

Tested By: J.A. Oladipo — Date of Testing: 24 - 7 -08



Visual soil description: Well drained soil cla

Soil classification: GC — System: Unified soil classification system (USCS)

Fig. 4.11 Particle- size distribution graph of soil sample at CH 0+640

Table 4.5 Results of Sieve Analysis of soil samples of project site

Sample No./Location	Depth of sampling (m)	Sieve Analysis (% Passing) — SIEVE SIZES (mm)											SOIL CLASSIFICATION (USCS)
		4.75	2.36	2.00	1.18	0.60	0.425	0.212	0.150	0.075	Cu	Cc	
CH O+ 20													
TP1/1	0.00-0.57	99.1	97.6	86.3	52.4	43.4	36.2	29.8	18.4	5.1	11.1	1.4	SW - SM
TP1/2	0.57-1.90	98.4	90.5	82.2	58.1	52.2	45.4	39.4	26.8	2.3	7.9	0.3	GC- SC
CH 0 + 490													
TP2/1	0.00 -0.30	100	98.1	71.8	53.1	41.8	28.9	21.4	15.2	1.5	10.7	1.4	SW -CL
TP2/2	0.30 -1.20	100	99.5	76.2	54.3	45.1	27.8	19.1	14.7	2.6	8.7	1.8	ML -CL
CH 0 + 640													
TP3/1	0.00-0.50	98.8	91.3	81.7	48.6	42.1	31.8	27.3	14.6	3.6	11.7	2.4	SW - SM
TP3/2	0.50 -1.50	97.6	95.4	85.2	63.6	50.8	34.6	24.9	16.1	4.8	11.6	1.6	GC - SC

C_U = coefficient of uniformity **USCS = UNIFIED SOIL CLASSIFICATION SYSTEM**

Cc = coefficient of curvature

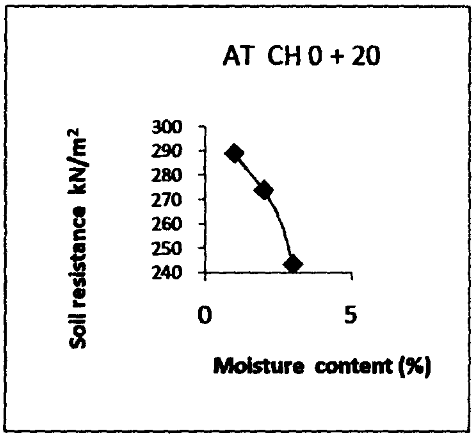
Table 4.6 Results of Atterberg Limits Test of Soil Samples of Project Site

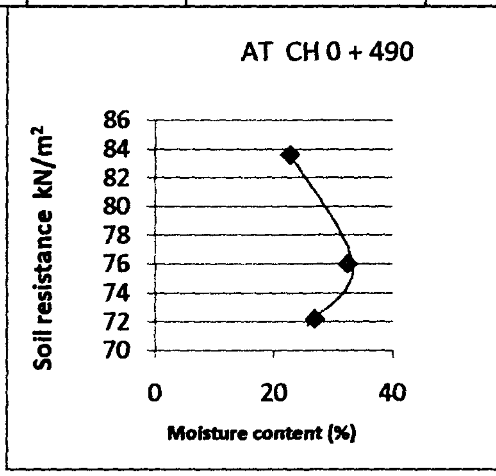
Sample No./Location	Depth of sampling (m)	ATTERBERG LIMITS				SOIL CLASSIFICATION (USCS)
		LIQUID LIMIT (LL)	PLASTIC LIMIT (PL)	PLASTICITY INDEX(PI)	LINEAR SHRINKAGE (LS)	
CH O+ 20						
TP1/1	0.00-0.57	21.8	NP	21.8	19.3	SW - SM
TP1/2	0.57-1.90	31.9	16.4	15.5	12.1	GC - SC
CH 0 + 490						
TP2/1	0.00 -0.30	44.7	19.5	25.2	14.4	SW - CL
TP2/2	0.30 -1.20	39.2	21.6	17.6	13.5	ML - CL
CH 0 + 640						
TP3/1	0.00-0.50	20.3	NP	20.3	17.9	SW - SM
TP3/2	0.50 -1.50	38.6	15.8	22.8	14.2	GC - SC

Soil classification is by unified soil classification system (USCS)

Table 4.7 Results of soil resistance (Load bearing capacity), Moisture content, unit Weight, specific gravity and porosity of project area soils test.

Sample No/ Location	Soil resistance (soil Load – bearing capacity kN/m²)	Moisture content (%)	Angle of repose(Ø)	Unit Weight (kN/m³)	Specific gravity(g/cc)	Porosity (%)
CH O+20						
P1	289.0	4.82				
P2	273.8	6.22	29^0	15.9	2.23	28.9
P3	243.4	6.77				
CH O+490						
P1	83.6	22.73				
P2	76.0	32.40	19^0	13.0	2.41	46.1
P3	72.2	26.88				
CH O+640						
P1	266.1	7.91				
P2	281.4	7.55	26^0	15.9	2.22	28.4
P3	250.9	7.31				





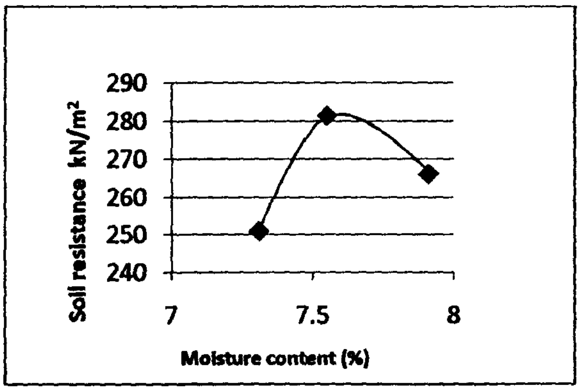


Fig. 4.12: Soil resistance characteristics charts of gully area

Result of Infiltration rate Test

Project: Kpakungu Gully Erosion Study

Test Point: CH 0 + 20

Topography /slope: Gently sloping (2% slope)

Soil Classification /description: Dark yellowish brown loamy sand top soil to yellowish red gravely sandy clay subsoil materials

Landuse: Residential

Date: 18 /7/2008

Table 4.8: Infiltration rate data in the upper slope soil

Elapsed Time(min)	Initial infiltrometer reading (cm)	Final infiltrometer reading (cm)	Water intake (cm)	Cum. water intake (cm)	Infiltration rate (cm/min)	Infiltration rate (cm/hr)
0	1.8	1.8	-	-	-	-
10	1.8	4.9	3.1	3.1	0.31	18.6
20	4.9	7.0	2.1	5.2	0.26	15.6
30	7.0	8.4	1.4	6.6	0.22	13.2
40	8.4	9.7	1.3	7.9	0.20	12.0
50	9.7	10.8	1.1	9.0	0.18	10.8
60	10.8	11.8	1.0	10.0	0.17	10.2
70	1.4	3.3	0.9	10.9	0.16	9.6
80	3.3	4.9	1.6	12.5	0.156	9.4
90	4.9	6.3	1.4	13.9	0.154	9.2
100	6.3	7.5	1.2	15.1	0.151	9.1
110	7.5	8.7	1.2	16.3	0.15	9.0*
120	8.7	9.8	1.1	17.4	0.15	9.0*

Soil infiltration rate class: Moderately rapid.

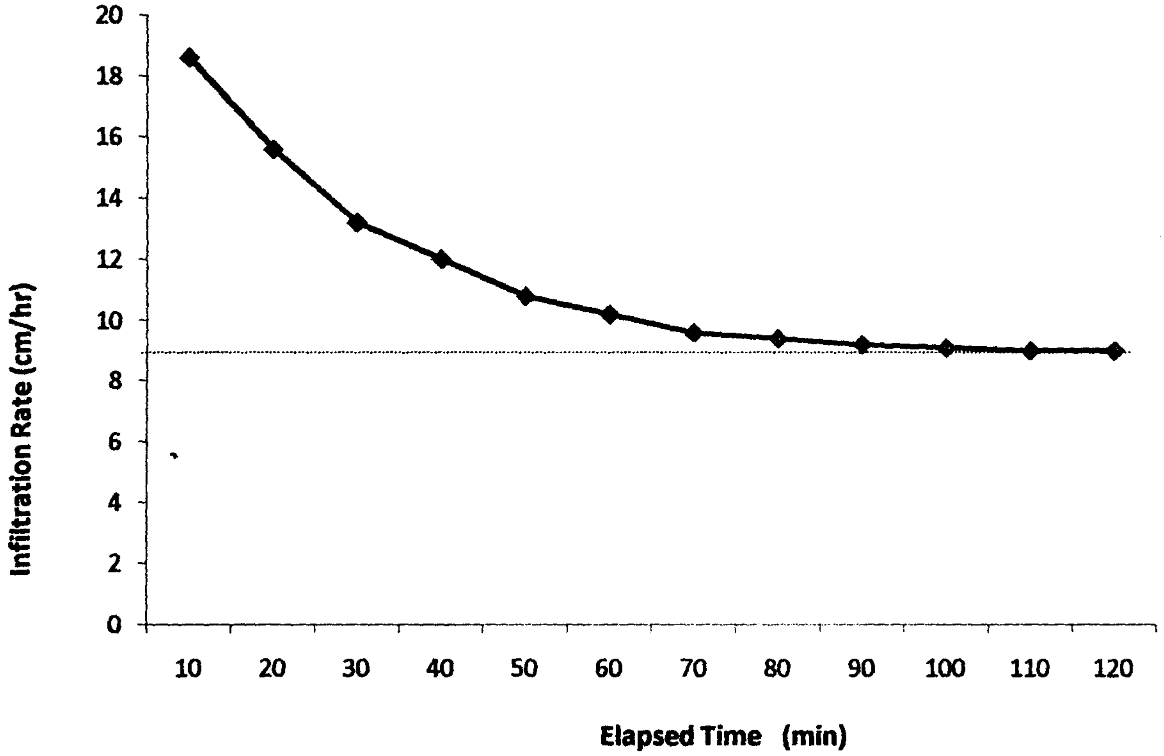


Fig. 4.13: Infiltratin rate of soil in the upper part of gully area (CH 0 + 20)

Project: Kpakungu Gully Erosion Study

Test Point: CH 0 + 490

Topography /slope: Gently sloping (1-2% slope)

Soil Classification /description: Dark brown brown sandy loam top soil to poorly drained greyish brown sandy clay subsurface soil

Landuse: Residential and maize farm (*Fadama* land)

Date: 18 /7/2008

Table 4.9: Infiltration rate data in the middle slope soil

Elapsed Time(min)	Initial infiltrometer reading (cm)	Final infiltrometer reading (cm)	Water intake (cm)	Cum. water intake (cm)	Infiltration rate (cm/min)	Infiltration rate (cm/hr)
0	1.1	1.1	-	-	-	-
10	1.1	2.1	1.0	1.0	0.1	6.0
20	2.1	2.8	0.7	1.7	0.09	5.4
30	2.8	3.4	0.6	2.3	0.08	4.8
40	3.4	4.0	0.6	2.9	0.073	4.4
50	4.0	4.6	0.6	3.5	0.07	4.2
60	4.6	5.1	0.5	4.0	0.067	4.0
70	5.1	5.5	0.4	4.4	0.063	3.8
80	5.5	5.9	0.4	4.8	0.06	3.6
90	5.9	6.3	0.4	5.2	0.058	3.5
100	6.3	6.7	0.4	5.6	0.056	3.4
110	6.7	7.1	0.4	6.0	0.055	3.3*
120	7.1	7.7	0.6	6.6	0.055	3.3*

Soil infiltration rate class: Moderate.

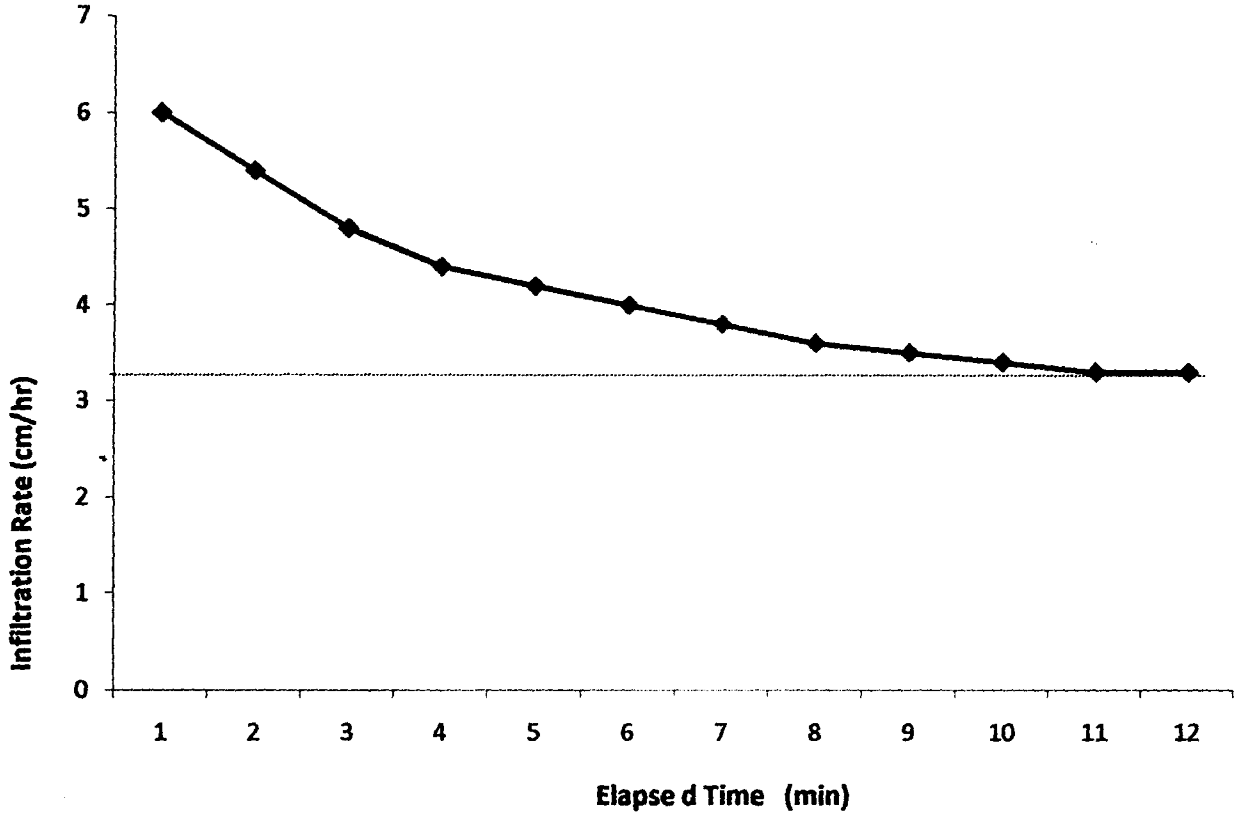


Fig. 4.14: Infiltration rate of soil in the middle part of gully area (CH 0 + 490)

Project: Kpakungu Gully Erosion Study

Test Point: CH 0 + 640

Topography /slope: Gently undulating (2% slope)

Soil Classification /description: Yellowish brown loamy sand top soil to yellowish dark gravely sandy clay subsurface soil

Landuse: Residential

Date: 18 /7/2008

Table 4.10: Infiltration rate data in the lower slope soil

Elapsed Time(min)	Initial infiltrometer reading (cm)	Final infiltrometer reading (cm)	Water intake (cm)	Cum. water intake (cm)	Infiltration rate (cm/min)	Infiltration rate (cm/hr)
0	3.2	3.2	-	-	-	-
10	3.2	6.8	3.6	3.6	0.36	21.6
20	6.8	9.1	2.3	5.9	0.295	17.7
30	9.1	11.2	2.1	8.0	0.267	16.0
40	3.7	5.5	1.8	9.8	0.245	14.7
50	5.5	7.3	1.8	11.6	0.232	13.9
60	7.3	8.8	1.5	13.1	0.218	13.1
70	8.8	10.3	1.5	14.6	0.209	12.5
80	10.3	11.5	1.2	15.8	0.198	11.9
90	3.1	4.3	1.2	17.0	0.189	11.3
100	4.3	5.9	1.6	18.6	0.186	11.2
110	5.9	7.5	1.6	20.2	0.18	10.8*
120	7.5	9.0	1.5	21.7	0.18	10.8*

Soil infiltration rate class: Moderately rapid.

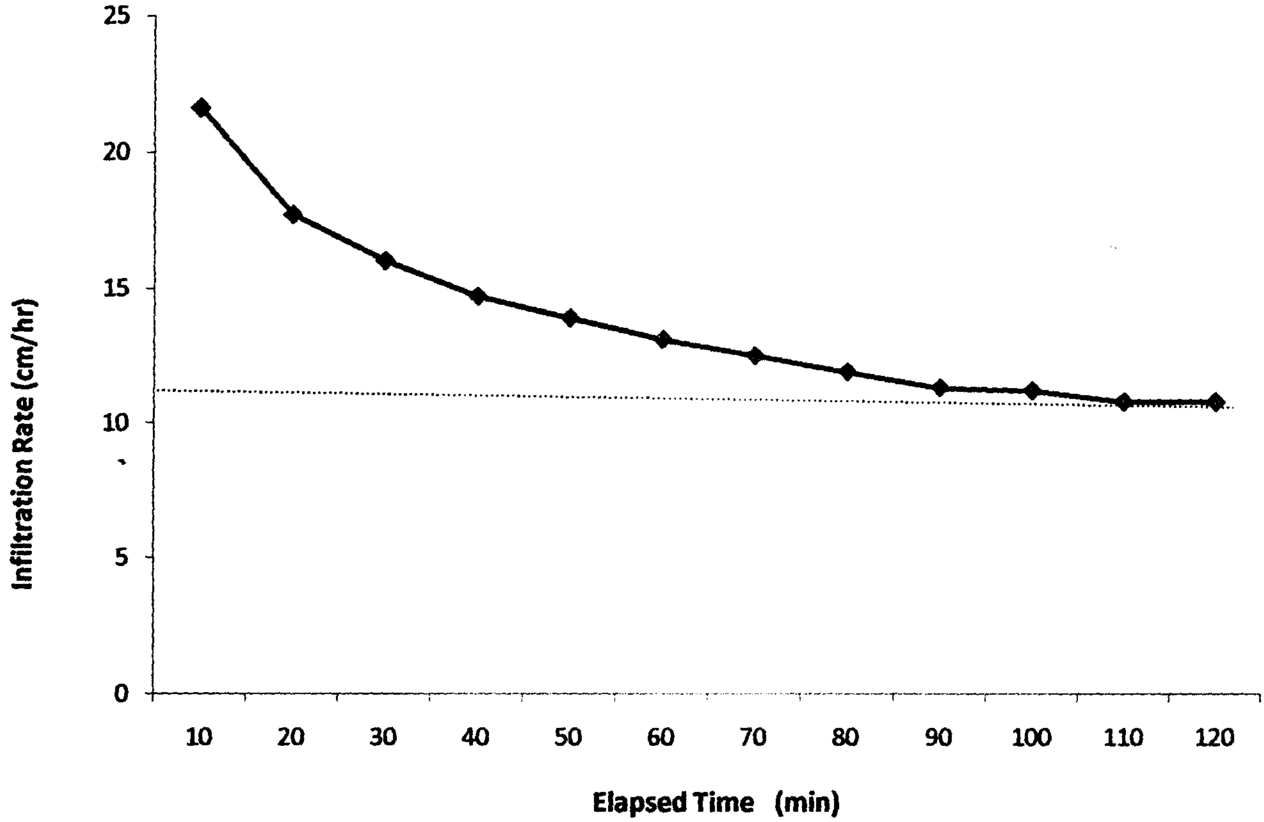


Fig. 4.15: Infiltratin rate of soil in the lower part of gully area (CH 0 + 640)

4.6 Design Drawings

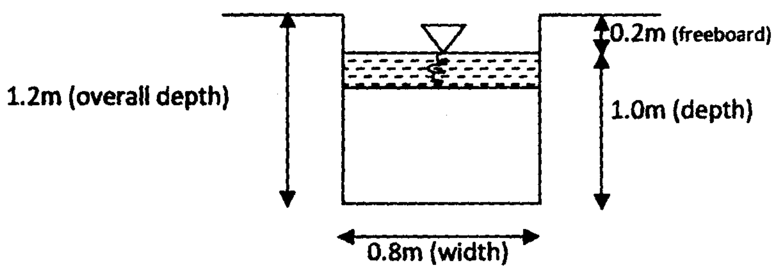


Fig. 4.16: Cross-section of designed channel

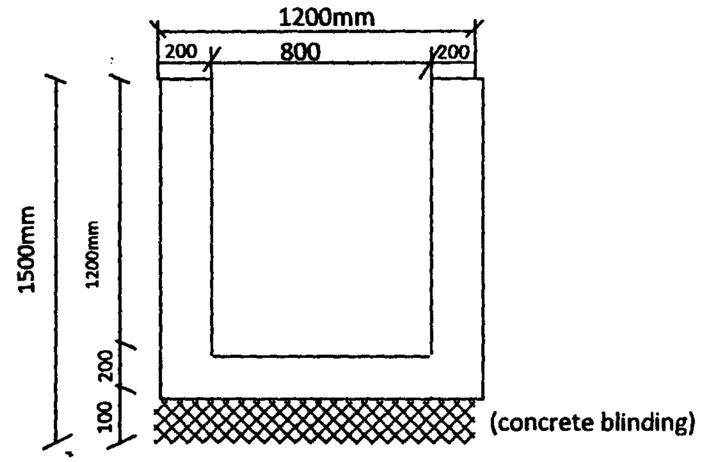


Fig. 4.17: Typical designed drain section

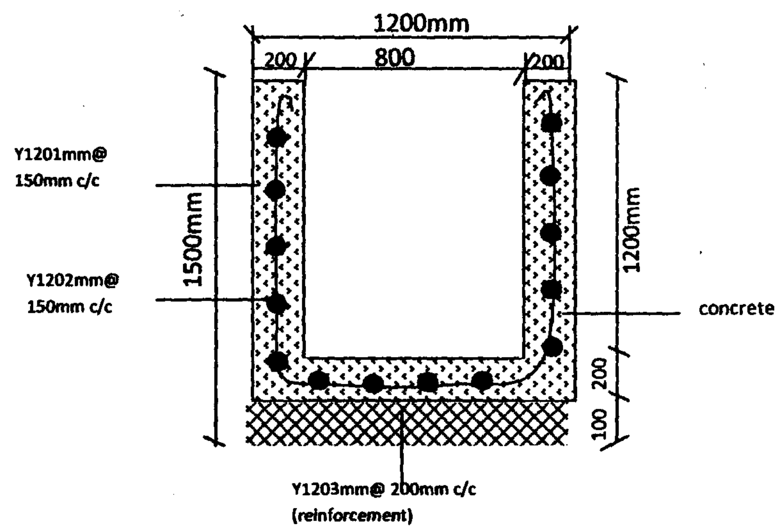


Fig.4.18: Typical designed drain section with reinforced concrete

4.7 Material Costing Analysis

1. Cost of excavation

Excavation for drainage channel foundation is required in order to get to a stable foundation material for the structure; hence this is costed as follows:

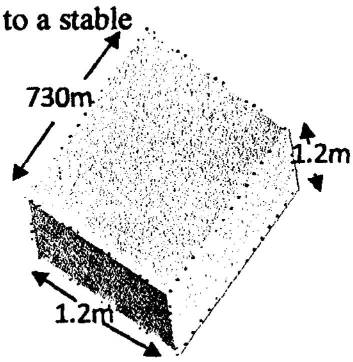


Fig. 4.19: Soil materials to be excavated or borrowed as fill material

Volume of excavation = l x w x depth

= 730m x 1.2m x 1.2m

= 1,051.2m^3

Cost of excavation per $1m^3$ = ₦450 :00

Cost of excavation of $1,051.2m^3$ = $1,051.2m^3$ x ₦ 450

= ₦ 473,040.00

NB: This also covers backfilling cost

if there is need for filling the

channel with stable soil material (laterite) in place of excavation.

2. ***Cost of wooden formwork***

The required size of wood is 1 inch x 12 inch x 12 feet

Number of wood required per 3m-length = 16

Total number of woods required per drain length = $\frac{730}{3}$ x 16

= 3,893woods

Area of 1 wood = w x l

= 0.3048m x 3m

= $0.9144m^2$

Area of 3,893 woods = 3,893 x 0.9144

= $3,560m^2$

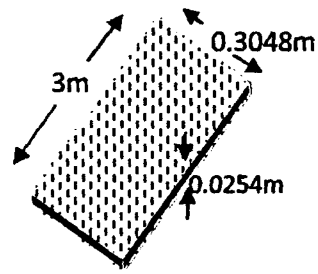


Fig 4.20: Size of wood for formwork

Cost of $1m^2$ ($1'' \times 12'' \times 12'$) wood = ₦ 985:00

Cost of $3,560m^2$ wood = 3,560 x ₦ 985:00

= ₦ 3,506,600:00

3. **Cost of concrete**

Volume of concrete blinding = l x w x thickness

= 730 m x 1.2m x 0.1m

= 87.6m^3

Cost of 1m^3 of concrete blinding = ₦ 30, 000:00

Cost of 87.6m^3 of concrete blinding = 87.6 x ₦ 30,000:00

= **₦ 2,628,000:00**

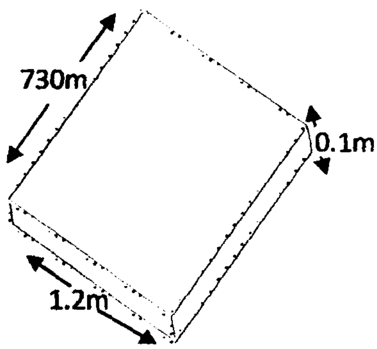


Fig 4.21: Volume of concrete required for blinding

Volume of concrete per metre length of walls = l x w x thickness x 2

= 1m x 1.2m x 0.2m x 2

= 0.48m^3

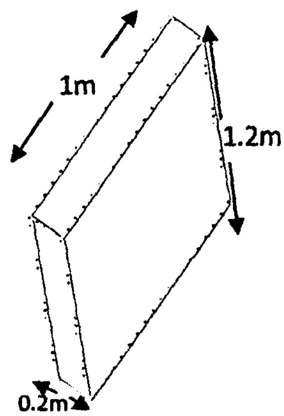


Fig 4.22: Volume of concrete required per metre length of wall

Volume of concrete per metre length of base = l x w x thickness

= 1m x 1.2m x 0.2m

= 0.24m^3

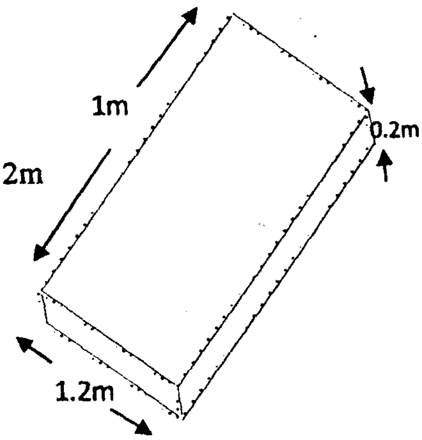


Fig 4.23: Volume of concrete required per metre length of drain base

Volume of concrete per metre length of walls and base = 0.48 + 0.24

= 0.72m^3

Total volume of concrete per 730m

length of rectangular channel = 0.72 x 730

= 525.6.m^3

Cost of 1m^3 concrete = ₦ 30,000:00

Cost of 525.6m^3 concrete = 525.6 x ₦ 30,000:00

= ₦ 15,768,000:00

Total cost of concrete = ₦ 2, 628, 000:00 + ₦ 15,768,000:00

= **₦ 18,396,000:00** (including concrete blinding)

4. Cost of Steel Bar (Reinforcement)

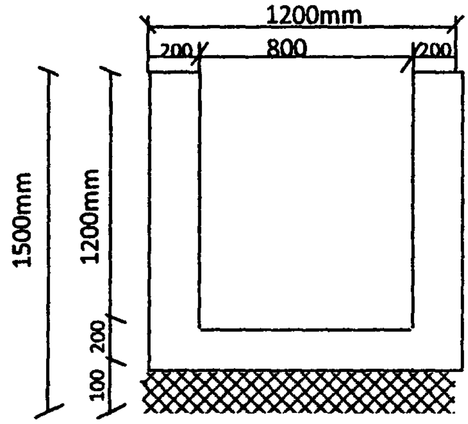


Fig. 4. 24: Typical drain section

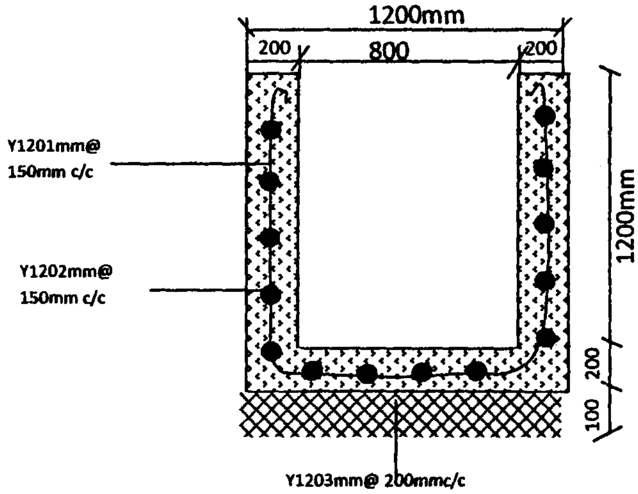


Fig. 4.25: Typical drain section with steel reinforcement and cor

Bar size = Ø 12mm

Unit weight of steel bar = 0.888 kg/m

Member: Drain (channel walls and base)

Bar mark: 01

Bar type and size: Y12

Number of member: 1

Number of bars: 4,866.67

Length of each bar: 3.20m

Total length of bar required = 4,866.67 x 3.2m

= 15,573.34m

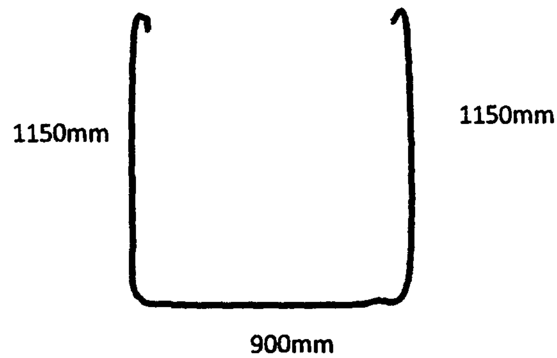


Fig. 4.26: Shape and dimension of wall and base bar

Weight of required bar = 15,573.34 x 0.888kg

=13,829.13kg

Cost per kg of Y12mm steel bar = ₦ 250:00

Cost of steel bar for drain walls and base = 13,829.13 x ₦ 250:00

= **₦ 3, 457,282:50**

Member: Drain (channel walls)

Fig. 4.27: Shape and dimension of bar for channel walls

Bark mark: 02

Bar Type and size: Y12

Number of member: 1

Number of bars: 16

Length of each bar: 730m

Total length of bar required = 16 x 730m

= 11,680m

Unit weight of bar = 0.888kg/m

Weight of required bars = 11,680 x 0.888kg

=10,371.84 kg

Cost per kg of Y12mm steel bar = ₦250:00

Cost of steel bar for drain walls = 10,371.84 x ₦ 250:00

= ₦ 2, 592,960:00

Member: Drain (channel base)

Bark mark: 03

Bar Type and size: Y12

Number of member: 1

Number of bars: 5

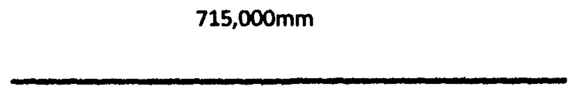


Fig. 4.28: Shape and dimension of bar for channel base

Length of each bar: 715m

Total length of bar required = 5 x 715m

=3,575m

Unit weight of Y12 bar = 0.888kg/m

Weight of required Y12 bars = 3,575 x 0.888kg

3,174.6 kg

Cost per kg of Y12 mm bar = ₦250:00

Cost of steel bar for drain base = 3,174.6 x ₦250:00

= ₦793, 650:00

Member: Drop structure

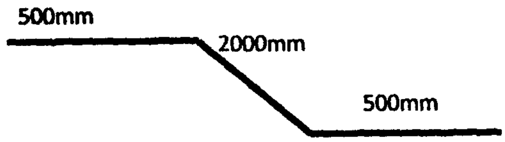


Fig. 4.29: Shape and dimension of bar for drop structure

Bar Type and size : Y12

Number of member: 5

Number of bars in each member: 5

Total number of bars required =5 x 5 =25

Length of each bar: 3.0m

Total length of bar required along the drop structures @150 mm c/c = 25 x 3.0m

= 75m

Total length of bar required across the drop structures @ 200mm c/c =20 x 0.9 x 5 = 90m

Total length of bars required for all the 5No. drop structures = 75m + 90m =165m

Unit weight of Y12 bar = 0.888kg/m

Weight of required Y12 bars = 165 x 0.888kg = 146.52kg

Cost per kg of Y12 mm steel bar = ₦250:00

Cost of steel bar for drop structures =146.52 x ₦250:00

= ₦36, 630:00

Total cost of steel reinforcement (Y12 mm bar) = ₦3,457,282:50 + ₦2,592,960:00 + ₦793, 650:00 +₦36,630:00

= ₦6,880,522:50

Total cost of material is summarized in the Table below.

Table 4.11 Cost of materials for designed gully erosion and flood control structure (drain)

Item	Material	Quantity	Unit	Rate (₦)	COST (₦)
1	Excavation of foundation	1,051.2	m^3	450.00	473,040:00
2	Wooden formwork ($1'' x 1' x 12'$) wood	3,560	m^2	985:00	3,506,600:00
3	Concrete (1:2:3) concrete grade C30 (U 3000)	613.2	m^3	30,000.00	18,396,000:00
4	Steel bar (reinforcement) Y12 (12mm diameter)	27,522.09 (27.52209)	Kg (tonne)	250.00 (250,000.00)	6,880,522:50
	Total cost				**29,256,162:50**

Total cost of materials = **₦ 29,256,162:50**

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

Kpakungu gully erosion site in Bosso Local Government Area of Niger State was surveyed and found to cover a distance of 730m (0.73kilometre) with average width of 10m. The depth of the gully varied with slope ranging from 3.8m in the upslope to 2.5m in the downslope. The depth of the gully in the middle part was between 0.5m and 1.0m. The watershed area is 2.56ha. It is therefore a medium gully. These site characteristics have revealed that the present state of the gully is a serious environmental problem if it is not addressed on time.

The physical assessment of the gully erosion site also conducted showed that apart from sloping nature of the area and fragile nature of the soil, other contributory factors were prominent. For instance, there was no provision for drainage facilities in most parts of Kpakungu area and no proper layout for residential buildings and existing roads. The absence of proper layout plan has encouraged mismanagement of limited available land as well as encouraging environmental abuse by the inhabitants of the area. There were dug out pits found all over the place where people collect their soil materials for construction purposes. These unguided human activities were also observed to have widened the gully channel continually and most residential houses built close to the gully bank are under serious threats.

The channel designed for the area, if constructed will eliminate the gully erosion and flood and their adverse effects on the environment, thereby saving lives and properties that can be lost. Although gully erosion is caused by hydraulic force of water cutting deep into the soil and by human activities, if this structure can be provided in the area it will alleviate the suffering of the people and protect the environment.

5.2 Recommendation

The need to arrest the hazard of soil erosion and adverse effects of flood has been widely recognized and various soil conservation measures must be put in place to deal with the problem. However, in order to control this menace, practical soil erosion control measures have to be used to reduce the frequency and magnitude of erosion damages. There are two (2) broad measures of control. The first one is curative measure whose side line of action depends mostly on the types of erosion involved while the second is preventive measure, which in most cases, is an attempt to prevent or avoid as much as possible erosion from reaching the area. Generally, based on our findings, the following recommendations are made.

5.2.1 Provision of Concrete Channel

The designed concrete channel for the gully erosion control is aimed at solving an environmental problem in Kpakungu area, and as such it is recommended that government should come to the aid of the community to ensure that the designed structure is provided as soon as possible before a disaster is caused.

5.2.2 Drainage Channel Maintenance

Maintenance of concrete drainage channel is of the utmost importance after it has been provided. An efficient channel capacity is brought about by periodical clearing and cleaning of channel to remove debris, snags and waste materials capable of blocking the channel. Incidentally, many Nigerians lack drainage channel maintenance culture especially in our towns and cities. In this case, the beneficiaries of the structure should be educated on how to maintain the drainage channel if eventually constructed.

5.2.3 Backfilling and Weep-holes

The designed drainage channel should be provided with suitable backfill materials to support its retaining walls (sidewalls) if constructed while the concrete walls should be provided with weep-holes at an interval of 1m on both sides for lateral flow of water into the channel. This will ensure durability of the structure.

5.2.4 Stone-pitching and Provision of Pedestrial slabs

As part of control, where found necessary, the shoulders of the concrete drain should be stone-pitched with suitable rock materials and mortar. This is necessary so as to prevent erosion occurrence from the sides. Stone-pitching proves as hard non-erodible and non-permeable surface for water. It also ensures a non-erosive flow of water from the land along the periphery of the drain, thereby preventing the soil from cracking and shearing under its own weight.

It is also recommended that pedestrial concrete slabs should be provided at strategic locations for easy crossing of the drainage channel by people. Also, blockwork side drains should be provided for all existing roads as temporary measures while awaiting the construction of designed permanent structure.

Finally, it is hoped that this study and its accompanying design will serve as basis to provide the much needed drainage facility for Kpakungu community to alleviate the suffering of the people. When this is actualized, the area will get rid of serious environmental problem endangering lives and properties of the people.

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APPENDICES

APPENDIX I: HYDROMETEOROLOGICAL DATA

MEAN MONTHLY AND ANNUAL RAINFALL IN (mm) FOR MINNA AND ITS ENVIRONNS FROM 1987-2007

LATITUDE 09^{0}39$'$N LONGITUDE 06^{0}28$'$E

YR/MNTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL TOTAL
1987	0.0	0.0	13.5	44.6	104.5	83.0	143.7	238.5	94.6	100.1	0.0	0.0	822.5
1988	0.0	0.0	0.0	0.0	81.5	132.0	218.3	350.1	403.6	33.1	0.0	0.0	1218.6
1989	0.0	0.0	5.0	49.5	287.8	193.7	193.7	248.7	202.0	79.0	0.0	0.0	1259.4
1990	0.0	0.0	0.0	177.2	225.2	80.5	256.3	185.8	145.6	110.5	0.0	0.0	1181.1
1991	0.0	0.0	0.0	15.0	334.8	180.0	192.2	269.7	192.0	34.1	0.0	0.0	1217.8
1992	0.0	0.0	0.0	1.2	158.1	177.0	161.2	195.3	231.0	229.4	48.0	37.2	1238.4
1993	0.0	0.0	0.0	0.0	173.6	171.0	189.1	269.7	177.0	62.0	0.0	0.0	1042.4
1994	0.0	0.0	0.0	75.0	114.7	240.0	142.6	365.8	261.0	207.7	0.0	0.0	1406.8
1995	0.0	0.0	0.0	102.0	124.0	144.0	155.0	409.2	189.0	136.4	24.0	0.0	1283.6
1996	0.0	0.0	0.0	48.0	164.3	225.0	260.4	257.3	192.0	127.1	0.0	0.0	1274.1
1997	0.0	0.0	3.1	81.0	238.7	231.0	173.6	192.2	204.0	114.7	0.0	0.0	1238.3
1998	0.0	0.0	0.0	93.0	120.9	222.0	155.0	241.8	201.0	213.9	0.0	0.0	1247.6
1999	0.0	8.4	0.0	36.0	102.3	165.0	244.9	244.9	237.0	210.8	0.0	0.0	1238.3
2000	0.3	0.0	0.0	3.0	136.4	162.0	207.7	310.0	303.0	151.9	0.0	0.0	1274.0
2001	0.0	0.0	0.0	93.0	139..5	333.0	244.9	229.4	300.0	24.8	0.0	0.0	1364.6
2002	0.0	0.0	5.7	98.8	42.6	201.0	143.2	226.5	260.6	180.3	0.3	0.0	1159.0
2003	0.0	0.0	17.3	61.2	141.7	250.6	214.8	185.6	148.1	93.3	0.0	0.0	1112.6
2004	0.0	0.0	0.0	32.2	151.9	194.9	210.3	211.4	241.5	77.6	0.0	0.0	1119.8
2005	0.0	0.0	0.0	49.1	87.0	207.0	294.2	127.8	226.4	94.8	0.0	0.0	1086.3
2006	11.2	0.0	0.0	29.9	195.0	107.7	229.7	317.1	360.5	172.1	0.0	0.0	1423.2
2007	0.0	0.0	0.4	73.1	156.6	123.9	314.0	310.1	330.2	115.1	0.0	0.0	1423.4
MEAN	**0.5**	**0.4**	**2.1**	**55.3**	**156.2**	**182.1**	**206.9**	**256.5**	**233.3**	**122.3**	**3.4**	**1.8**	**1220.8**

Source: Nigerian Meteorological Agency (NIMET) ,Minna Airport, Minna.

MEAN MONTHLY TEMPERATURE OF MINNA AND ITS ENVIRONS BASED ON 20-YEARS RECORD (1987-2007)

LATITUDE $09^{0}34'$ N LONGITUDE$06^{0}28'$E

MONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL MEAN
MAX.TEMP(^{0}C)	32.1	37.5	38.5	37.5	33.9	31.i	29.7	28.3	31.0	32.1	33.3	34.0	33.2
MIN.TEMP(^{0}C)	21.0	24.3	25.9	25.6	23.7	22.8	22.0	21.8	20.8	21.4	20.2	18.5	22.3

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna

MEAN MONTHLY RELATIVE HUMIDITY OF MINNA AND ITS ENVIRONS BADED ON 20 YEARS RECORD (1987-2007)

LATITUDE $09^{0}34'$ N LONGITUDE $06^{0}28'$E

IONTH	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	ANNUAL MEAN
ELATIVE IUMIDITY %)	28.0	31.0	36.0	58.0	75.0	79.0	83.0	85.0	76.0	74.0	46.0	34.0	59.0

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna

APPENDIX II: SOILS DATA

DETERMINATION OF UNIT WEIGHT OF SOIL

Soil Sample/Location	CALCULATION
KPK1 CH 0 + 20	Diameter , d of the soil cylinder = 5cm Height, h of the soil cylinder = 5cm Volume of soil, Vs = $\pi r^2 h$ (cm^3) $= \pi(2.5)^2 \times 5$ $= 98.175\ cm^3$ Bulk density of soil, BD = mass of oven dry soil / volume of Soil $= M/_{Vs}$ $BD = \left[\frac{150.94}{98.175} + \frac{145.35}{98.175} + \frac{173.15}{98.175}\right] g/cc$ $=[1.54 + 1.48 + 1.76] g/cc$ $=[1.54 + 1.48 + 1.76]/3 g/cc$ $=1.59 g/cc$ Therefore Unit wt. of soil = 1.59g/cc Density of soil =1,590 kg /m^3 **= 15.90 kN/m^3**

KPK2 CH 0 + 490	Volume of soil, Vs = $\pi r^2 h$ (cm^3) = $\pi(2.5)^2 \times 5$ = 98.175 cm^3 Bulk density of soil, BD = <u>mass of oven dry soil</u> / volume of Soil $= M/_{Vs}$ BD = $\left[\frac{133.90}{98.175} + \frac{120.75}{98.175} + \frac{129.72}{98.175}\right] g/cc$ $=[1.36 + 1.23 + 1.32] g/cc$ $=[1.36 + 1.23 + 1.32]/3 g/cc$ $=1.30 g/cc$ Therefore Unit wt. of soil = 1.30g/cc Density of soil =1,300 kg /m^3 **= 13.00 kN/m^3**
KPK3 CH 0 + 640	Volume of soil, Vs = $\pi r^2 h$ (cm^3) = $\pi(2.5)^2 \times 5$ = 98.175 cm^3 Bulk density of soil, BD = <u>mass of oven dry soil</u> / volume of Soil $= M/_{Vs}$ BD = $\left[\frac{151.50}{98.175} + \frac{162.79}{98.175} + \frac{154.07}{98.175}\right] g/cc$ $=[1.54 + 1.66 + 1.57] g/cc$ $=[1.54 + 1.66 + 1.57]/3 g/cc$ $=1.59 g/cc$ Therefore Unit wt. of soil = 1.59g/cc Density of soil =1,590 kg /m^3 **=15.90 kN/m^3**

Calculation of Soil Specific Gravity

The specific gravity of each of the soil samples was calculated with the following formula:

$$Gs = \frac{dw(Ws-Wa)}{(Ws-Wa)-(Wsw-Ww)} \text{ -(*)}$$

where Gs = specific gravity of the soil

Dw = density of water (1g/cm^3)

Ws = weight of *pycnometer* bottle + Soil sample

Wa = Weight of *pycnometer* or density bottle

Wsw =Weight of *pycnometer* bottle + soil + water

Ww = weight of *pycnometer* bottle + water

It may be worthwhile to note that determination of soil specific gravity is a measure of soil particle density.

For CH 0 + 20 soil sample,

dw = 1, Ws =35.1, Wa = 20.4, Wsw = 80.9, Ww = 72.8

$$Gs = \frac{dw(Ws-Wa)}{(Ws-Wa)-(Wsw-Ww)}$$

$$= \frac{1(35.1-20.4)}{(35.1-20.4)-(80.9-72.8)}$$

$$= \frac{14.7}{(14.7)-80.9+72.8}$$

= 2.23

For CH 0 + 490 soil sample,

dw = 1, Ws =27.5, Wa = 18.6, Wsw = 71.8, Ww = 66.6

$$Gs = \frac{dw(Ws-Wa)}{(Ws-Wa)-(Wsw-Ww)}$$

$$= \frac{1(27.5-18.6)}{(27.5-18.6)-(71.8-66.6)}$$

$$= \frac{8.9}{(8.9)-71.8+66.6}$$

= 2.41

For CH 0 + 640 soil sample,

dw = 1, Ws =28.1, Wa = 18.1, Wsw = 74.2, Ww = 68.7

$$Gs = \frac{dw(Ws-Wa)}{(Ws-Wa)-(Wsw-Ww)}$$

$$= \frac{1(28.1-18.1)}{(28.1-18.1)-(74.2-68.7)}$$

$$= \frac{10}{(28.1-18.1)-(74.2-68.7)}$$

$$= 2.22$$

Calculation of Soil Porosity

The porosity of the soil samples collected from the field was calculated using the data of soil bulk density (soil unit weight) and particle density (specific gravity). Thus, the porosity of the soil was computed as follows:

$$P = (1 - \frac{BD}{Gs}) \times 100 \quad \text{--} \quad (**)$$

where P = porosity of the soil in percent

BD = bulk density of the soil in g/cm^3

Gs = specific gravity of the soil in g/cm^3

For CH 0+ 20 soil sample, BD = 1.59 g/cm^3, Gs = 2.23

$P = (1 - \frac{BD}{Gs}) \times 100 = (1 - \frac{1.59}{2.23}) \times 100 = 28.9\%$

For CH 0+ 490 soil sample, BD = 1.30 g/cm^3, Gs = 2.41

$P = (1 - \frac{BD}{Gs}) \times 100 = (1 - \frac{1.30}{2.41}) \times 100 = 46.1\%$

For CH 0+ 640 soil sample, BD = 1.59 g/cm^3, Gs = 2.22

$P = (1 - \frac{BD}{Gs}) \times 100 = (1 - \frac{1.59}{2.22}) \times 100 = 28.4\%$

Determination of Soil Penetration Resistance (Soil Strength)

The determination of soil penetration resistance (soil strength) was carried out in-situ on the field along the gully channel at pre-determined locations. The aim of the measurement was to determine the resistance of the soil to vertical loading (pressure), which might be generated by the hydraulic structure (concrete channel) under design consideration. The test was also to determine the workability in terms of excavation and degree of compaction of the soil in the field.

The measurement was done using a manually operated proctor penetrometer (ASMT D1558) and in accordance to British Standard (BS 1377, 1990) engineering code of practice. This engineering soil parameter also provided relevant and basic information on the bearing capacity of the soils upon which the structure would be constructed, if the need arises in the future.

Calculation of Soil Penetration Resistance (Soil Load Bearing Capacity)

Applied vertical load (force) = P (kg) (penetrometer reading)

Diameter of shank (steel needle point used, d= 12.82mm

Cross-sectional area of the steel needle point (shank) used = A

$A = \frac{\pi d^2}{4}$.

At Chainage 0+20

Test point 1: p= 3.8kg, A = 129mm^2

Penetrometer pressure $= \frac{F}{A} = \frac{3.8}{129}$ =0.02946 kg/mm^2

Soil resistance = 0.02946 x 10^6 x 9.81

=289,002.6 N/m^2

= 289.0 kN/m^2

Test point 2: P = 3.6kg, A =129 mm^2

Penetrometer pressure $= \frac{F}{A} = \frac{3.6}{129}$ =0.02791 kg/mm^2

Sol resistance = 0.02791 x 10^6 x 9.81

= 273,797.1 N/m^2

= 273.8 kN/m^2

Test point 3: P 3.2kg, A =129 mm^2

Penetrometer pressure $= \frac{F}{A} = \frac{3.2}{129}$ =0.02481 kg/mm^2

Soil resistance = 0.02481 x 10^6 x 9.81

= 243,386.1 N/m^2

= 243.4 kN/m^2

Average soil bearing capacity $= \frac{289.0 + 273.8 + 243.4}{3}$

268.7 kN/m^2

At chainage 0+490

<u>Test point 1</u>: p= 1.1kg, A = 129mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{1.1}{129}$ =0.008527 kg/mm^2

Soil resistance = 0.008527 x 10^6 x 9.81

=83,649.87 N/m^2

= 83.6 kN/m^2

<u>Test point 2</u>: P =1.0kg, A =129 mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{1.0}{129}$=0.007752 kg/mm^2

Soil resistance = 0.007752x 10^6 x 9.81

= 76,047.2 N/m^2

= 76.0 kN/m^2

<u>Test point 3</u>: P =0.95kg, A =129 mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{0.95}{129}$ =0.007364 kg/mm^2

Sol resistance = 0.007364 x 10^6 x 9.81

= 72,240.84N/m^2

= 72.2 kN/m^2

Average soil bearing capacity $= \frac{83.6 + 76.0 + 72.2}{3}$

77.3 kN/m^2

At chainage 0+640

<u>Test point 1</u>: p= 3.5kg, A = 129mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{3.5}{129}$ = 0.02713 kg/mm^2

Soil resistance = 0.02713 x 10^6 x 9.81

= 266,145.3 N/m^2

= 266.1kN/m^2

Test point 2: P = 3.7kg, A =129 mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{3.7}{129} = 0.02868 kg/mm^2$

Soil resistance = 0.02868 x 10^6 x 9.81

= 281,350.8kg N/m^2

= 281.4kN/m^2

Test point 3: P =3.3kg, A =129 mm^2

Penetrometer pressure $=\frac{F}{A} = \frac{3.3}{129} = 0.02558\ kg/mm^2$

Soil resistance = 0.02558 x 10^6 x 9.81

= 250,939.8N/m^2

= 250.9 kN/m^2

Average soil bearing capacity $= \frac{266.1 + 281.4 + 250.9}{3}$

= 266.1kN/m^2

Typical Soil Bearing Capacities

Soil type	Bearing capacity (kN/m^2)
Soft, wet, pasty or muddy soil	27-35
Alluvial soil, loam, sandy loam	80-160
Sandy clay loam, moist clay	215-270
Compact clay and almost dry	215- 270
Solid clay with very fine sand	430
Dry compact clay	320-540
Loose sand	160-270
Compact sand	215-320
Red earth	320
Compact gravel	750 -970
Rock	1700

Source: Mijinyawa, Y. (2004), Farm Structures, Aluelemhegbe publ., Ibadan, Nigeria (pp 90-100).

The load bearing capacity of soil is important because it determines the load that can be borne by the soil when constructing a structure upon the ground. Generally, however, the load bearing capacity of soil depends on the soil type and moisture content at the time of measurement.

COMPUTATION OF SOIL MOISTURE CONTENT

Let:

Wt. of can (g) = W1

Wt. of can + wet soil (g) = W2

Wt. of can + dry soil (g) =W3

Wt. of wet soil = W2 –W1= Xg

Wt. of dry soil = W3 –W1 =Yg

Wt of moisture in the soil sample = (X-Y)g

Sampling Location	Soil samples No.	1	2	3
CH 0 + 20	Wt. of can (g) = W1	26.69	27.24	25.30
	Wt. of can + wet soil (g) = W2	184.90	181.63	210.18
	Wt. of can +dry soil (g) =W3	177.63	172.59	198.45
	Wt. of wet soil = W2 –W1= Xg	158.21	154.39	184.88
	Wt. of dry soil = W3 –W1 =Yg	150.94	145.35	173.15
	Wt. of moisture in the soil sample = (X-Y)g	7.27	9.04	11.73
	Moisture content on percentage basis =Wt. of moisture in the soil / Wt. of Oven dry soil $=\left(\frac{X-Y}{Y}\right) X\ 100\%$	4.82	6.22	6.77
CH 0 + 490	Wt. of can (g) = W1	25.22	25.60	26.42
	Wt. of can + wet soil (g) = W2	189.56	185.47	191.01
	Wt. of can + dry soil (g) = W3	159.12	146.35	156.14
	Wt. of wet soil = W2 –W1= Xg	164.34	159.87	164.59
	Wt. of dry soil = W3 –W1 =Yg	133.90	120.75	129.72
	Wt. of moisture in the soil sample = (X-Y)g	30.44	39.12	34.87
	Moisture content on percentage basis	22.73	32.40	26.88

	=Wt. of moisture in the soil / Wt. of Oven dry soil $=\left(\frac{X-Y}{Y}\right) X\ 100\%$			
CH 0 + 640	Wt. of can (g) = W1	26.14	24.75	26.49
	Wt. of can + wet soil (g) = W2	189.62	199.83	191.82
	Wt. of can +dry soil (g) =W3	177.64	187.54	180.56
	Wt. of wet soil = W2 –W1= Xg	163.48	175.08	165.33
	Wt. of dry soil = W3 –W1 =Yg	151.50	162.79	154.07
	Wt. of moisture in the soil sample = (X-Y)g	11.98	12.29	11.26
	Moisture content on percentage basis =Wt. of moisture in the soil / Wt. of Oven dry soil $=\left(\frac{X-Y}{Y}\right) X\ 100\%$	7.91	7.55	7.31

Determination of Angle of repose of Soil

This soil parameter was determined using the angle of repose apparatus in the laboratory tso measure the height of cone of the soil materials and the diameter of the soil mass on the surface of the circular wooden platform. The angle of internal friction (ø) of the soil sample was then calculated using the following equation:

$$\emptyset = \tan^{-1}\left(\frac{h}{d/2}\right) \text{ --- (*)}$$

where ø =angle of repose (or angle of internal friction) in degrees)

h = height of cone of the soil in cm

d = diameter of the soil mass in cm

$d/2$= radius of the soil mass on the circular wooden platform in cm.

Accordingly, the angles of repose of the soil samples collected from the selected observation points in the field were calculated as follows:

For soil sample of Chainage 0 + 20,

$h = 5.6cm,\ d = 20.4cm$

Applying equation (*) above,

$\tan ø = \frac{h}{d/2} = \frac{5.6}{10.2} = 0.5490$

$ø = \tan^{-1}(0.5490)$

$= 29^0$

For soil sample collected at CH 0 + 490,

h = 4.1cm, d = 23.5cm

$\tan ø = \frac{h}{d/2} = \frac{4.1}{11.75} = 0.3489$

$\tan ø = 0.3489$

$Ø = \tan^{-1}(0.3489)$

$= 19^o$

For soil sample collected from CH 0 + 640,

h = 5.2cm, d = 21.8cm

$\tan ø = \frac{h}{d/2} = \frac{5.2}{10.9} = 0.4771$

$\tan ø = 0.4771$

$Ø = \tan^{-1}(0.4771)$

$= 26^o$

It may be worthwhile to note that the angle of repose (otherwise known as angle of internal friction) is the maximum slope or angle at which a soil material remains stable. When the slope exceeds the angle of repose, mass movement of soil by slippage as well as by water erosion (runoff) could occur.

APPENDIX III: SURVEY DATA

KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY

REDUCTION OF LEVELLING SURVEY DATA

STATION	CHAINAGE	BS	IS	FS	HI	ELEVATION (RL)	REMARK
BM		0.572			50.572	50.000	Benchmark reading on road shoulder
1	0+00		1.582			48.990	
2	0+10		2.831			47.741	
3			1.963			48.609	Gully left bank
4			2.035			48.537	1m
5			3.103			47.469	1m
6	0+20		3.308			47.264	Centre of gully 1m
7			2.504			48.068	1m
8			2.291			48.281	1m
9			2.000			48.572	Open field 10m
10	0+30		3.651			46.921	
11	0+40		4.446			46.126	
12	0+50	1.502		4.375	47.699	46.197	CP1
13	0+60		2.445			45.254	
14	0+70		2.745			44.954	
15	0+80		3.165			44.534	
16	0+90		2.865			44.834	
17	0+100		3.004			44.695	
18	0+110		3.774			43.925	
19	0+120		3.401			44.298	
20	0+130		3.395			44.304	
21	0+140		3.415			44.284	
22	0+150		3.699			44.000	
23	0+160		3.909			43.790	
24	0+170		4.125			43.574	
25	0+180	1.595		4.315	44.979	43.384	CP2
26	0+190		1.878			43.101	
27	0+200		1.938			43.041	
28	0+210		1.978			43.001	
29	0+220		2.091			42.888	
30	0+230		2.127			42.852	
31	0+240		2.172			42.807	
32	0+250		2.331			42.648	
33	0+260		2.489			42.490	
34	0+270	1.657		2.525	44.111	42.454	CP3
35	0+280		1.810			42.301	
36	0+290		1.650			42.461	
37			1.199			42.912	20m from right bank. Taken on untarred road at CH 0+290
38	0+300	1.412		1.635	43.888	42.476	CP4
39	0+310		1.560			42.328	

40	0+320		1.585			42.303	
41	0+330		1.603			42.285	
42	0+340		1.682			32.206	
43	0+350		1.822			42.066	
44	0+360		1.990			41.898	
45	0+370		1.845			42.043	
46	0+380		2.140			41.748	
47	0+390		2.368			41.520	
48	0+400	1.999		2.435	43.452	41.453	CP5
49	0+410		2.025			41.427	
50	0+420		1.988			41.464	
51	0+430		2.315			41.137	
52	0+440		2.208			41.244	
53	0+450		2.249			41.203	
54	0+460	1.741		2.426	42.767	41.026	CP6
55	0+470		1.745			41.022	
56	0+480		2.012			40.755	
57			3.281			39.486	Edge of right bank of R. Gadu
58			2.178			40.589	10m
59			1.085			41.682	10m
60			0.645			42.122	10m
61			0.529			42.238	10m
62			0.599			42.168	10m Open field
63			0.839			41.928	10m
64			1.017			41.750	10m
65			1.305			41.462	10m
66			1.627			41.140	10m
67			1.868			40.899	10m
68	0+490		1.981			40.786	Centre of gully channel 1m
69			1.360			41.407	10 m
70			0.980			41.787	10m Untarred road
71			0.335			42.432	10m by CAILS fence
72			0.050			42.717	10m
73	0+500		1.878			40.889	
74	0+510		1.968			40.799	
75	0+520		2.070			40.697	
76	0+530		2.322			40.445	
77	0+540		2.975			39.792	
78	0+550		3.259			39.508	
79	0+560	2.158		3.361	41.564	39.406	CP7
80			1.948			39.616	Gully left bank
81			2.327			39.237	1m
82			2.152			39.412	1m
83			1.532			40.032	1m
84			3.125			38.439	0.5m
85	0+570		3.517			38.047	Centre of gully channel 0.5m
86			1.378			40.186	0.5m
87			1.348			40.216	1m

88	0+580		3.390			38.174	
89	0+590		3.180			38.384	
90	0+600		3.331			38.233	
91	0+610		3.692			37.872	
92	0+620		3.799			37.765	
93	0+630		3.901			37.663	
94	0+640		3.965			37.599	
95	0+650	2.379		4.200	39.743	37.364	CP8
96	0+660		2.883			36.860	
97	0+670		3.681			36.062	
98	0+680		3.771			35.972	
99	0+690		3.891			35.852	
100			2.811			36.932	Gully left bank
101			3.059			36.684	1m
102			3.520			36.223	1m
103	0+700		4.336			35.407	Centre of gully channel 1m
104			3.270			36.473	1m
105			2.752			36.991	1m
106			2.550			37.193	1m
107			2.310			37.433	1m
108			2.135			37.608	1m
109			2.065			37.678	1m
110	0+710		4.532			35.211	
111	0+720		4.612			35.131	
112	0+730			4.875		34.868	End of gully (Joining R.Gadu)
		15.015		**30.147**			

REDUCTON FORMULA IS GIVEN AS:

$$\sum \textbf{Backsight} - \sum \textbf{Foresight} = \textbf{Last Elevation} - \textbf{First Elevation}$$

$$\begin{array}{lcr} 15.015 & & 34.868 \\ \underline{-30.147} & & \underline{-50.00} \\ -15.132 & & -15.132 \end{array}$$

This value shows that the gully channel requires filling at chainages 0+00 – CH0 +150 and CH 0 + 430 – CH0 +725 before the placement of concrete should be embarked upon. The slope is 2%.

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA
DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING
SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY

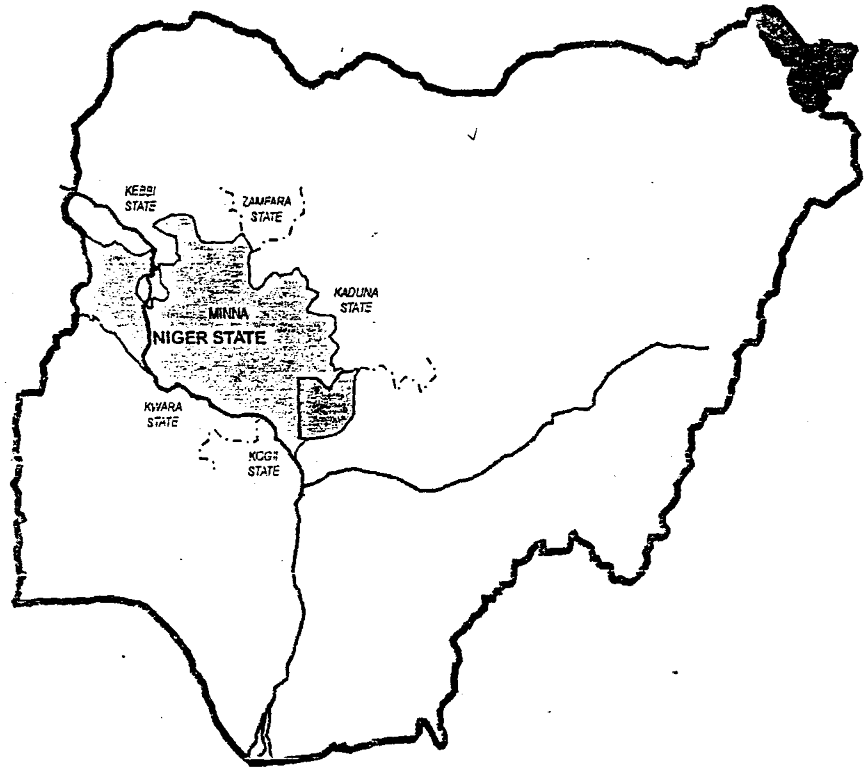
KPAKUNGU GULLY EROSION STUDY IN BOSSO LOCAL GOVERNMENT AREA OF NIGER STATE

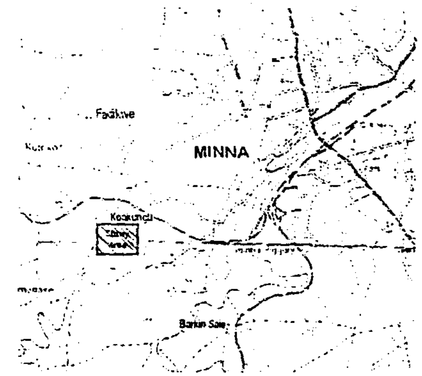
ENGINEERING DRAWINGS

APPENDIX IV

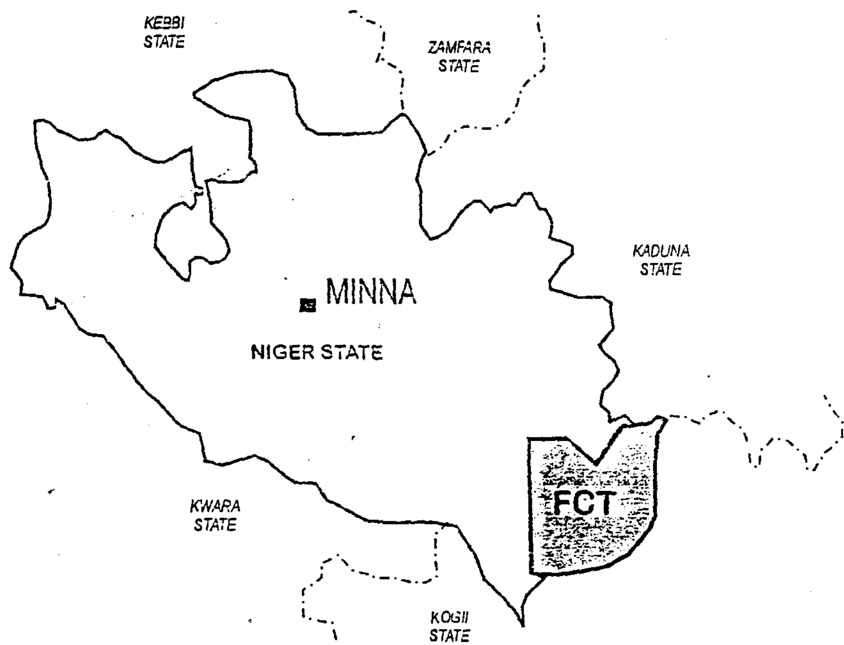
NOVEMBER, 2008

MAP OF NIGERIA SHOWING NIGER STATE



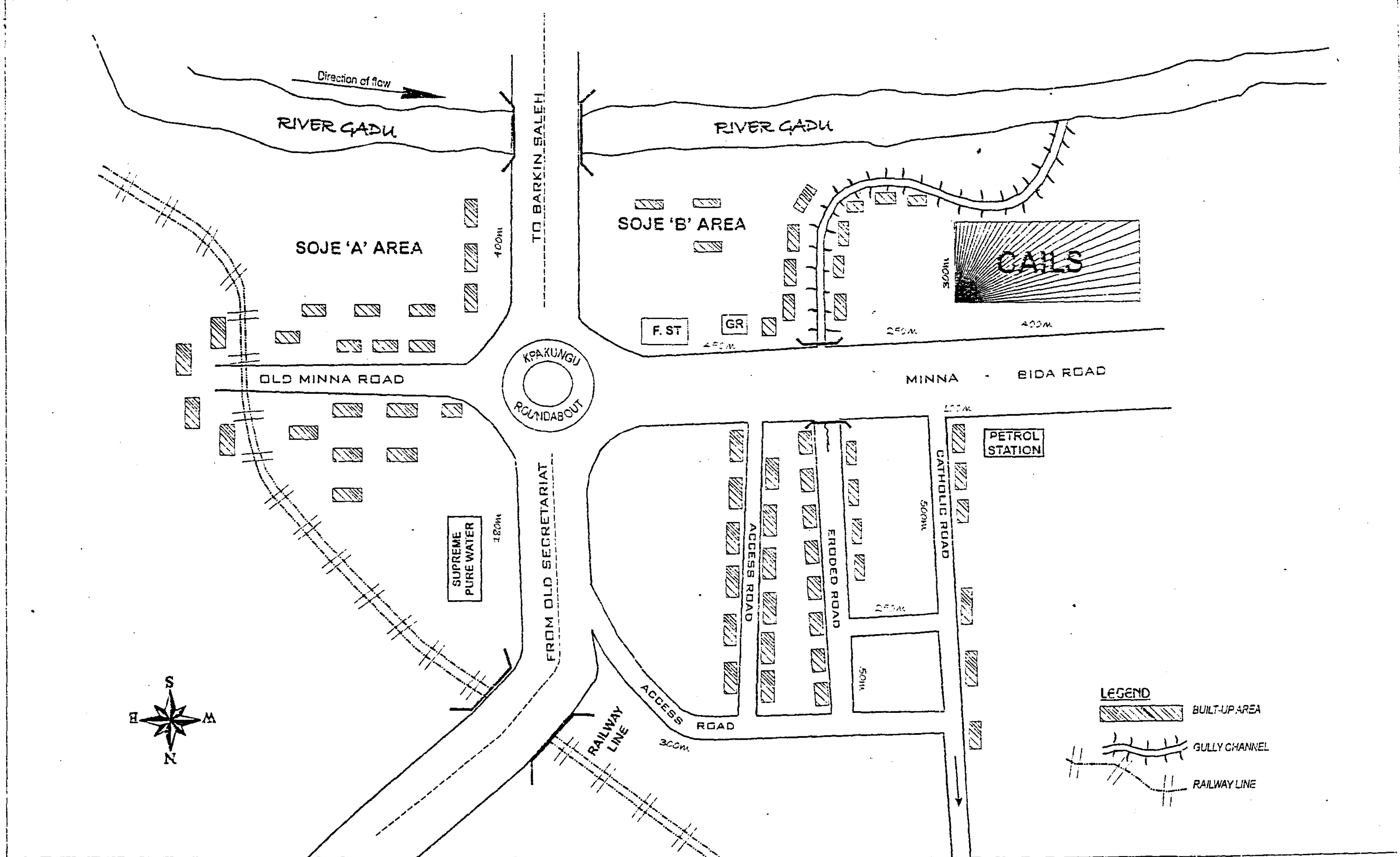


MAP OF MINNA SHOWING STUDY AREA



MAP OF NIGER STATE

PROJECT: KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY	DRAWN:	J. A. Oladipo	DRAWING TITLE: LOCATION MAP OF KPAKUNGU GULLY EROSION STUDY SITE	DRWNG NUMBER:	KPG-001
	TRACED:	J. A. Oladipo			
	CHECKED:	Engr. Adebayo Segun		DATE:	NOVEMBER,20
	APPROVED:	Engr. P. A. Adeoye	SCALE : NDS		



PROJECT:

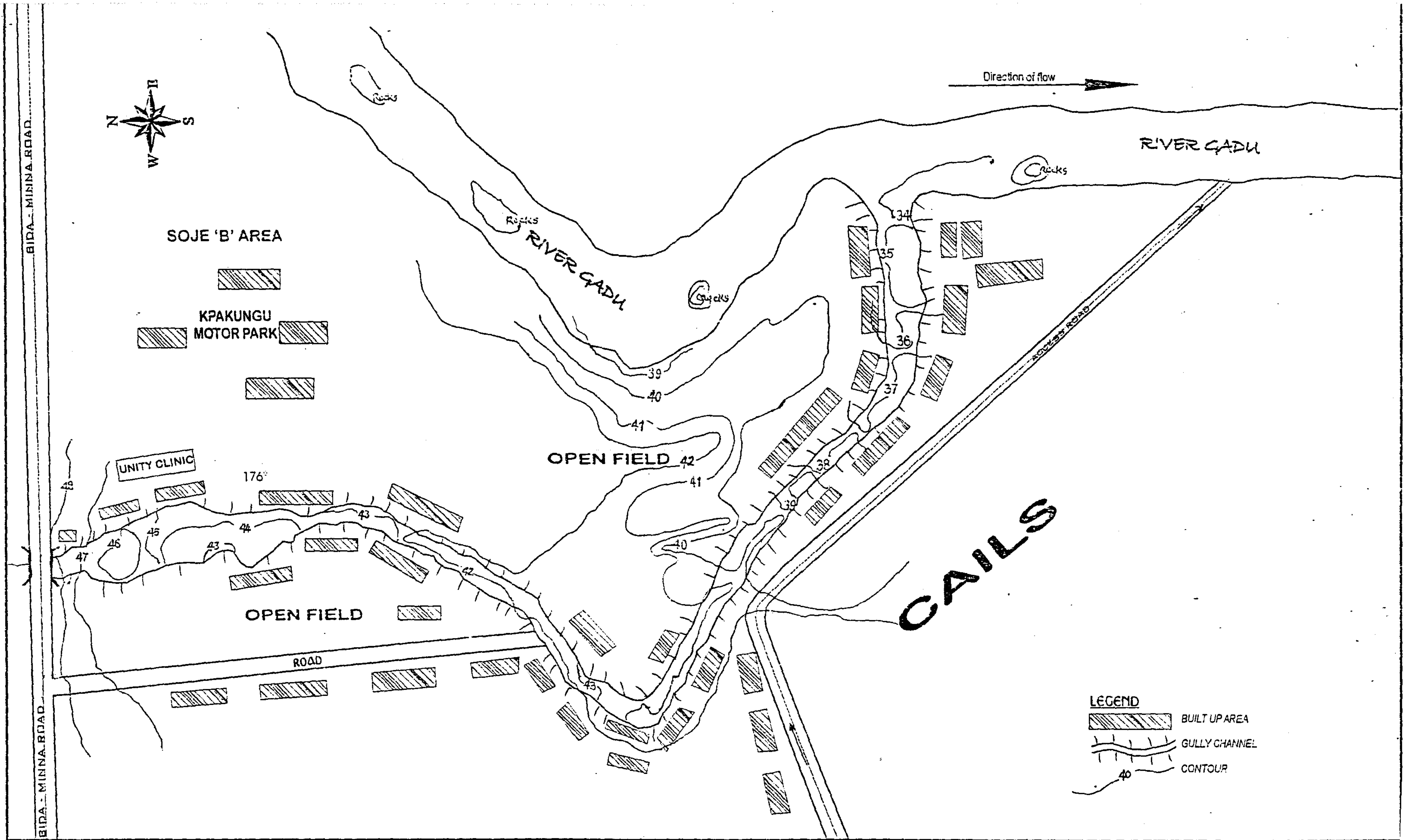
KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY

DRAWN:	J. A. Oladipo
TRACED:	J. A. Oladipo
CHECKED:	Engr. Adebayo Segun
APPROVED:	Engr. F. A. Adeoye

DRAWING TITLE: **LAYOUT MAP OF STUDY AREA**

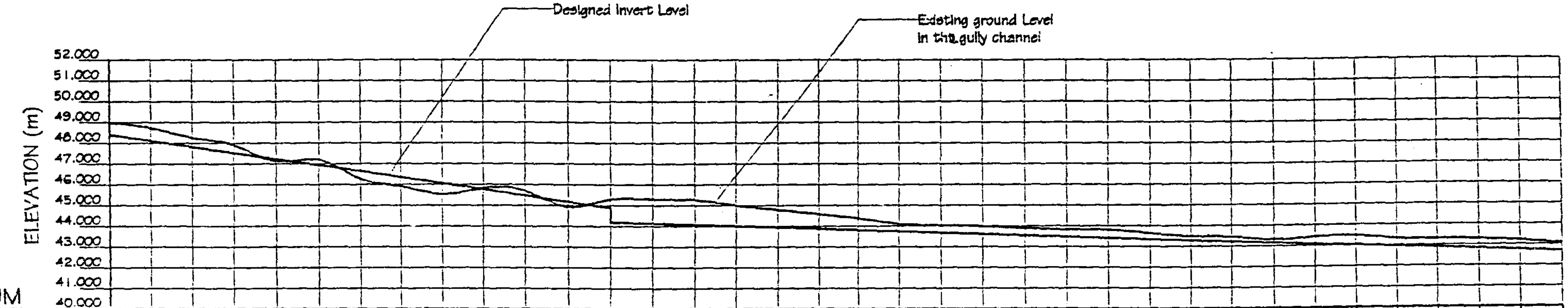
DRWNG NUMBER: KPG-002

DATE: NOVEMBER, 200



PROJECT:			DRAWING TITLE:	DRWNG NUMBER:	KPG-003
KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY	SURVEYED:	J. A. Oladipo	TOPOGRAPHICAL MAP OF KPAKUNGU GULLY EROSION SITE		
	DRAWN:	J. A. Oladipo			
	TRACED:	J. A. Oladipo			
	CHECKED:	Engr. Adebayo Segun		DATE:	NOVEMBER.2008
	APPROVED:	Engr. P. A. Adeoye	SCALE 1 : 2000		

LONGITUDINAL PROFILE ALONG CENTRE-LINE OF GULLY
(CH. 0+000 - 0+350)



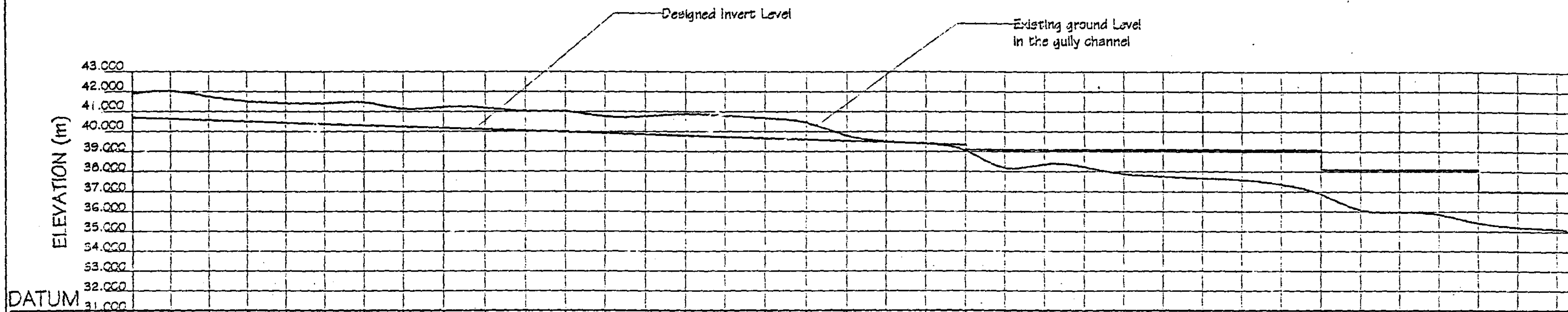
CHAINAGE (m)	0+000	0+010	0+020	0+030	0+040	0+050	0+060	0+070	0+080	0+090	0+100	0+110
ELEVATION (m)	48.990	47.741	47.264	46.921	46.126	46.197	45.254	44.924	44.534	44.834	44.695	43.925
FORMATION LEVEL (m)	48.400	47.900										

CHAINAGE (m)	0+120	0+130	0+140	0+150	0+160	0+170	0+180	0+190	0+200	0+210	0+220	0+230
ELEVATION (m)	44.298	44.304	44.284	44.000	43.790	43.574	43.384	43.101	43.041	43.001	42.888	42.852
FORMATION LEVEL (m)	43.890	43.200										

CHAINAGE (m)	0+240	0+250	0+260	0+270	0+280	0+290	0+300	0+310	0+320	0+330	0+340	0+350
ELEVATION (m)	42.807	42.648	42.490	42.454	42.301	42.461	42.476	42.328	42.303	42.285	42.206	42.066
FORMATION LEVEL (m)												41.700

PROJECT: KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY	SURVEYED: J. A. Oladejo	DRAWING TITLE: LONGITUDINAL PROFILE ALONG CENTRE-LINE OF GULLY	DRWG NUMBER: KPG-004
	DESIGNED: J. A. Oladejo	SCALE: H - 1:1000, V:1:100	DATE: NOVEMBER, 20
	DRAWN: J. A. Oladejo		
	CHECKED: Engr. Adeboye Segun		
	APPROVED: Engr. F. A. Adedoye		

LONGITUDINAL PROFILE ALONG CENTRE-LINE OF GULLY
(CH. 0+350 - 0+730)



CHAINAGE (m)	FORMATION LEVEL (m)	ELEVATION (m)
0+360	41.700	41.898
0+370		42.043
0+380		41.748
0+390		41.520
0+400		41.453
0+410		41.427
0+420		41.464
0+430		41.137
0+440		41.244
0+450		41.203
0+460		41.026
0+470		41.022
0+480		40.755
0+490		40.786
0+500		40.889
0+510		40.799
0+520		40.697
0+530		40.445
0+540		39.792
0+550		39.508
0+560		39.406
0+570	39.350 39.300	38.047
0+580		38.174
0+590		38.384
0+600		38.233
0+610		37.872
0+620		37.765
0+630		37.663
0+640		37.599
0+650		37.364
0+660	38.400 37.500	36.860
0+670		36.062
0+680		35.972
0+690		35.852
0+700	37.400 36.200	35.407
0+710		35.211
0+720		35.131

PROJECT: KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDIES

SURVEYED	J. A. Oladipo
DESIGNED	J. A. Oladipo
DRAWN	J. A. Oladipo
CHECKED	Engr. Adebayo Bagun
APPROVED	Engr. F. A. Adeoye

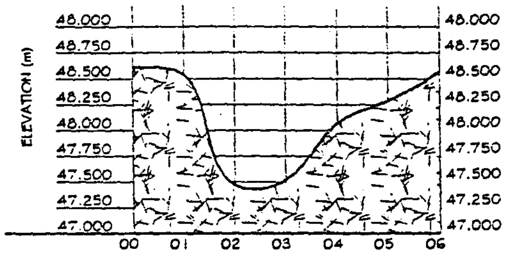
DRAWING TITLE: LONGITUDINAL PROFILE ALONG CENTRE-LINE OF GULLY

SCALE: H - 1:1000, V - 1:100

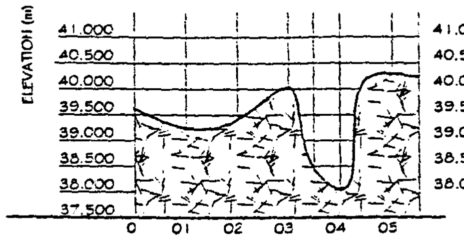
DRWG NUMBER: KPG

DATE: NOVEMB

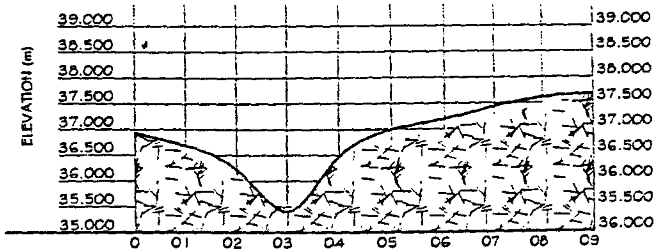
SECTIONS ACROSS THE GULLY AT SELECTED CHAINAGES



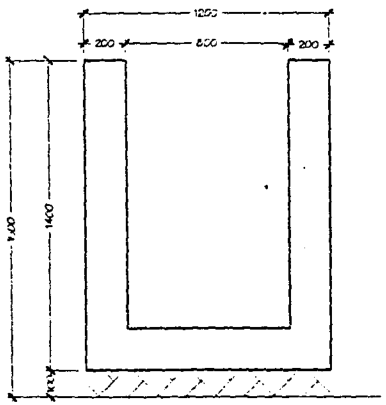
GULLY CROSS-SECTION AT CHAINAGE 0+020
SCALE - V-1:50
H - 1:100



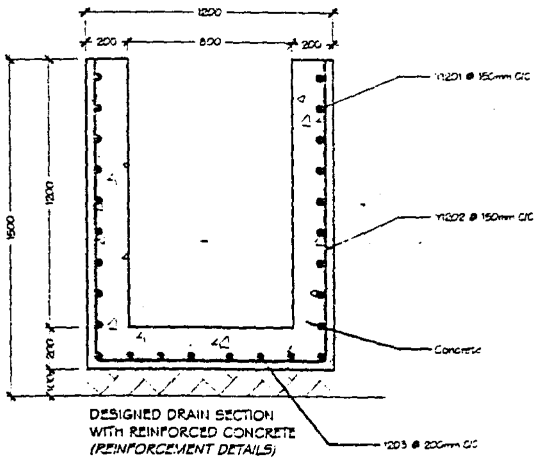
GULLY CROSS-SECTION AT CHAINAGE 0+570
SCALE - V-1:50
H - 1:100



GULLY CROSS-SECTION AT CHAINAGE 0+700
SCALE - V-1:50
H - 1:100



DESIGNED DRAIN SECTION
SCALE - 1:20



DESIGNED DRAIN SECTION
WITH REINFORCED CONCRETE
(REINFORCEMENT DETAILS)
SCALE - 1:20

REINFORCEMENT SCHEDULE

MEMBER	BAR MARK	TYPE & SIZE	NUMBER OF MEMBERS	NUMBER IN EACH	TOTAL NUMBER	LENGTH OF EACH BAR (m)	TOTAL LENGTH REQUIRED (m)	UNIT WEIGHT (kg/m)	WEIGHT IN (kg)	SHAPE & DIMENSIONS
Drain (Wall & Base)	01	Y12	1	4,867	4,867	3.20	15,573.34	0.880	13,829.13	1150 / 900 / 1150
Drain (Wall & Base)	02	Y12	1	16	16	730.00	11,880	0.880	10,371.84	[illegible]
Drain (Wall & Base)	03	Y20	1	5	5	715.00	3,575	0.880	3,174.60	[illegible]
Drop Structure	04	Y16	10	5.5	55	3.00	165	0.880	146.50	500 / 7000 / 500

PROJECT: KPAKUNGU GULLY EROSION AND FLOOD CONTROL STUDY	DESIGNED: J. A. Oladeo	DRAWING TITLE: DRAINAGE SECTION AND REINFORCEMENT BENDING SCHEDULE		SHEET NUMBER	KPG-006
	DRAWN: J. A. Oladeo				
	CHECKED: Engr. Adeyemo Segun			DWG NUMBER	NOVEMBER, 2006
	APPROVED: Engr. F. A. Adeoye	SCALE - 1:20			