APPRAISAL OF SEDIMENT YIELD AND DEPOSITION IN SMALL EARTH DAMS: A CASE STUDY OF BOSSO DAM MINNA, NIGER STATE.

BY

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CERTIFICATION

This project entitled "Appraisal of Sediment Yield and Deposition in Small Earth Dams: A Case Study of Bosso Dam, Minna, Niger State" by Attah, Ileh Benjamin, meets the regulations governing the award of Degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

I dedicate this work to God Almighty and in memory of my late father Mr. A.J Attah who slept in the lord shortly before the completion of my degree programme. Daddy I must say this to you " A handsome man could be an accident of nature but a man of integrity is a product of choice" thank you for not just building for me an inheritance but leaving in me an eternal legacy. And also to the management of Niger State Water Board.

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ABSTRACT

Sediments are the most pervasive form of Agricultural pollution. It is the highest in terms of volume when deposited in water bodies. Survey data for the watershed were used in the hydrologic design and developed models as well as rectangular wedge systems placed across the main channels were used to estimate the accumulated reservoir sedimentation. Various soil tests were conducted to determine the Engineering properties of the soil as well as their stress history. The soil is poorly graded as the coefficients of uniformity and that of curvature for the two samples analysed are respectively 5.10 and 0.58 for sample 1, 4.8 and 0.57 for sample 2. A BEME (Bills of Engineering Measurement and Evaluation) was prepared for the recommended method of desilting the dam as over $48m^3$ of the Reservoir capacity was lost to accelerated sedimentation during Rainy season with $2.52m^3$ of runoff as the runoff rate contributing to the sedimentation. This led to the conclusion that $2880m^3$ of the capacity was lost in 60 years of the dam's existence to sedimentation and thereafter recommendations were made on appropriate maintenance practices.

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CHAPTER ONE

1 INTRODUCTION

1.1 Background of the Study

The development of water resources is a key factor in the development of nearly all industrial and domestic activities. Hydraulic structures were put in place by relevant authorities to meet these needs.

Dams which are artificial structures together with its appurtenant works constructed in or across a waterway for the purpose of impounding or diverting water. Wisconsin Department of Natural Resources (2008).They can be either rigid or non rigid types. Earth dams are examples of the rigid types which are constructed of some type of earth material or soil, Modi (2006).

These structures are however prone to various associated problems when very strict regulations are not put in place to ensure their safety. Consequently the actual purpose of their construction may not be achieved as they may become polluted and unsafe or unfit for human consumption.

Sediment is the most pervasive form of agricultural pollution. It is the largest pollution on terms of volume when deposited in water bodies. Annual sediment yield and runoff are closely related. Factors as soil, geology, topography, e.t.c influence sediment yield much more as drainage area. Lal (1999), Gippi and Pretty (1999) and Isikwue (2001) reported that transport to a surface water body from a non point sources is characterized by the response of the drainage area to defined rainfall events.

The activities of man (herdsmen and their cattle, dumping of refuse/debris into the reservoir) lead to high siltation deposits in the dam. High erosion rate occurs due to the fact that the dam was located in low laying area hence eroded soil easily wash and move into the reservoir.

Water from dams can be applied in Agriculture for irrigation purposes and for various processing activities. The ability to control water flows make dams important for controlling flooding and maintaining navigable water ways by small boats in the area of fishing. Settlers around lakes build ıumerous small scale dams to help the farming activities bloom.

n recent years, about eighty percent of the west (developed countries) yearly supply of water has gone nto irrigation. Water diverted for use in homes, businesses and industry accounts for most of the emaining twenty percent (20%) of the supply. Modern dams are also used to generate hydro-electricity, ıydraulic mining (use of large quantity of pulverized water to hose down hillsides containing valuable ninerals).Kereselidze *et al* (1991).It can also be used as guard against floods by capturing flood waters nd releasing them after heavy storm and high waters have passed.

ilt: is the moving sand, soil or mud that is carried in water and then settles at bend in a river, an ntrance or port e.t.c. It can also be referred to as the minute level of sand particles conveyed by water nd settles at bends.

ediments: sediments are dead particles of animals, organic or inorganic matter that flows into an area ıd settles. Here particles flow from higher elevation towards lower elevation and settles.

sing dams, water can be diverted or stored for latter use, consequently dams fall into two basic types; e. diversion dams and storage dams. Diversion dams are small barriers placed across rivers and creeks. ıey allow water to be diverted out of stream beds and transported through canals. Diversion dams can so significantly affect local patters of water use but they do not store significant quantity of water and us are dependent on natural river flow. Kereselidze *et al* (1991).

In contrast, storage dams store water from streams, floods, rainfall for use later in the year. Normally storage dams store water in the reservoir on a long time basis allowing it to be released gradually over a period of months or even years.

By combining systems of diversions of storage dams, there is increase in all year round availability of water and thereby expands use of these scarce natural resources. Dams help provide water for irrigation and mining for municipal use and for generating hydroelectric power.

However, small earth dams are constructed across stream, lakes to create artificial lake or reservoir ehind themselves. The purpose which these reservoirs are meant to serve may be either for flood ontrol or conservation purposes. Conservation may either be for irrigation or livestock water supply. ienerally these dams have different sizes but typical small earth dams have the following dimensions; ength-60m, depth-3m, and width 5-10m.

he process of siltation in reservoirs in most part of the world obeys the same laws namely: the process minishes with time as the volume of the reservoir diminishes. In a number of cases, mounting servoir loose the greater part of their storage volume after several years of service. The causes of tation are the abundant sediment load of mounting rivers, falls, landslides, reservoir band reworking oduct, Kreselidze *et al* (1991).

! Statement of the problem

draulic structures are put in place to meet the demands for water supply for human consumption. wever certain problems or reasons are attributed to their failures to meet with the purpose of their nstruction. Bosso community is currently experiencing erratic water supply even though a structure s put in place to meet these needs .This inadequacy of supply necessitated this project which tends to lress or contribute to the eradication of these problems.

1.3 Objectives of the Study

1. To determine the quantity of sediments generated and deposited in the reservoir during the rainy season.

2. To determine the runoff rate of the catchment that is contributing to the sedimentation.

1.4 Justification of the Study

The outcome of this project will enable us to know the amount of sediments deposited in Bosso dam during the rainy season as a result of runoff. This will give an idea of the quantity of sediments deposited over the years to aid in the process of desilting the dam. This work will make it easy for recommendations to be made by the relevant authorities to the state government on the suitable method for desilting of Bosso dam.

1.5 Scope of the Study

This work only accounts for sedimentation as a result of annual rainfall over the years and does not account for sedimentation due to wind erosion within the catchment area. It also suggests a method of desilting and gives appropriate recommendations.

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Reservoir Sedimentation

The sediment is produced in the catchment of the river by erosion. Rivers carry a large amount of sediment load along with water. These sediments are deposited in the river in the upstream of the dam because of reduction of velocity. Sedimentation reduces the available capacity of the reservoir. With continuous sedimentation, the useful life of the reservoir goes on decreasing, Arora (1996).

The average annual sediment produced from a catchment is dependent upon many factors as climate, soil type, land use, topography and presence of reservoirs. Analysis of these factors is limited by inadequacy of data.

2.2 Types of Sediment Load

Sediment load in a river can be divided into two types:

1. Suspended load
2. Bed load

1. Suspended Load: This is that part of sediment load which is held in suspension against gravity by the vertical component of eddies of the turbulent flow. It usually consists of fine material dispatch throughout the river cross section.

2. Bed load: This is that part of the sediment load which remains in contact with the head when moving with water. It consists of relatively coarse material, Arora (1996).

There are models now developed to describe and predict soil erosion and sediment yield. These have taken unit account erosion processes on a micro scale Mutchler *et al* (1987), soil loss from sloping plot, Rudra *et al* (1985), soil detachment and transport fields, Kinsel (1980), fluvial transport (Alonso *et al*; 1981; Gilley et al; 1985, Julian and Simons, 1985), erosion and sediment yield from watershed areas, Young *et al*, (1987).

Surface sealing generally reduces infiltration and increases runoff. Its effect on sediment delivery is more complicated because on one hand, the raindrop detachment is decreased due to an increase in surface strength but on the other hand an increased runoff increases shallow flow detachment and transport, (Shainberg and Levi, 1995).

Independent studies in southern Nigeria (Lal, 1976 and Maduike *et al* 1990) aimed at establishing rainfall erosivity of the indices applicable to specific location of the region were carried out. Lal (1976) suggested the product of rainfall amount and the maximum7.5 minute intensity (AI_M) as the best way to estimate soil loss in Ibadan. Maduike *et al* (1990) recommended the rainfall amount (A), the rainfall kinetic energy (E_K), the product of kinetic energy and rainfall amount (E_KA) and the product of kinetic energy and the maximum 7.5- minute intensity ($E_K I_M$) in that order for Owerri location.

Gerlach (1976) developed a method for measuring sediment loss and runoff, using a simple metal gutters 0.5m long and a breath 0.1m closed at the sides fitted with a movable lid. An outlet pipe runs from the gutter base to a collecting bottle. In a typical layout, two or three gutters are placed close together side by side across the slope and the groups of the gutters are installed at different slope length with arranged en encleon in place to ensure a clear run to each gutter from the crest of the slope, (Gerlach, 1976, Morgan 1977).

These mixture of water and sediment are collected in each bottle and then subjected to sedimentation, thereafter a known volume is oven dried a weighed.

The relationship between the amount of soil in suspension and the difference in weight between a given volume of water and equal volume of suspension in which the amount of soil in suspension is calculated from

$$P=100S(x-y)/x(S-1) \quad \textbf{(2.1)}$$

Where P=percent of soil in suspension

S= specific gravity of the soil and x and y are weights of equal volume of suspension and water respectively at the same temperature , provided the specific gravity of soil in the various suspension are relatively constant, Mulean and Turner (1980).

2.3 **Runoff**

Runoff according to Modi (2006) is that part of precipitation as well as any other flow contribution which is transmitted through natural surface channel or streams or rivers.

In general sense, runoff includes:

i. Surface Runoff or Overland flow received in the stream immediately after a heavy rain

ii. Interflow which is a portion of soil moisture that flows laterally through the upper soil layers and joins the streams before joining the ground water.

iii. Delayed runoff of ground water flow that enters the stream after passing through deeper portion of the head.

iv. Other delayed runoff that have been temporarily detained as snow cover or stored in natural lakes and swamp. Thus runoff is the total quantity of water received by a stream from each drainage basin or catchment area. The runoff is generally classified as direct runoff and base flow (base runoff)

The direct runoff comprises the over land flow and the interflow which are usually grouped together while ground water flow that enters the stream is termed the base flow (or base runoff).The runoff is generally considered in terms of the total flow carried by a stream during a month, season or year accordingly. It is termed as monthly, seasonal or annual runoff. It is expressed in cubic metres or hecter-metres of water carried by a stream in certain duration.

2.4 Factors Affecting Runoff

The runoff from a catchment area or a drainage basin of a natural stream depends on

1. Characteristics of precipitation: the pertinent characteristics of precipitation which may affect runoff are the type of precipitation (such as rain or snow), its intensity, areal extent and direction of storm movement.

2. Characteristics of drainage basin: the runoff is considerably affected by the characteristics of drainage basin such as size, shape, surface, orientation, altitude, topography and geology of the drainage basin.

3. Meteorological characteristics; runoff is significantly affected by meteorological characteristics such as temperature, humidity, wind velocity, pressure variation e.t.c.

4. Storage characteristics: A storage characteristic affects runoff. If the drainage basin has a large number of natural depression, pools, lakes e.t.c and a number of artificial reservoirs or tanks which will store a part of the precipitation, then the runoff at the outflow point of the basin will be reduced, hence the drainage basin will have large capacity, Modi (2006).

2.5 Soil Erosion

Erosion is the most important agricultural problem in the world. It is the primary source of sediments that pollute streams and fills reservoirs. Some estimate in the 1970's shows about 4 billion metric tons per hectare annually in the United States which represents about a 30 percent of that of the 1930's even though government subsidies in educational programmes, Glenn *et al* (1992).

Since the early 1970's greater emphasis has been given to erosion as a contributor to non-point pollution. Non point refers to erosion from the land surface rather than from channels and gullies. Eroded soil can carry nutrients to waterways and contribution to entrophication of lakes and streams. Absorbed particles are also carried with eroded sediments adversely affecting surface water quality, Glenn *et al* (1992).

The two major types of erosion are geological erosion and erosion from human or animal activities. The geological erosion includes soil eroding process that maintains the soil in favorable balance suitable for growth of most plants. Human or animal induced erosion includes a breakdown of soil aggregates and accelerated removal of organic and mineral particles resulting from tillage and removal of natural vegetation, Glenn *et al* (1992).

Geological erosion contributes to the formation of soils and their distribution on the earth surface. This long time eroding process caused most of our present topographic features such as steams, channels, and valleys.

Water erosion is the detachment and transport of soil from the land by water, including runoff from melted snow and ice. A water erosion type includes interill (raindrop and sheet), rill, gully and steam _ channel erosion. Water erosion is accelerated by farming, forestry and construction activities, Delmer *et al* (1992).

2.6 Factors Affecting Erosion by Water

The major variables affecting soil erosion are climate, soil, vegetation and topography. Of these, vegetation and to some extent soil and topography may be controlled. The climatic factors are uncontrollable.

2.6.1 Climatic

Climatic factors affecting erosion are precipitation, temperature, wind, humidity and solar radiation. Temperature and wind are most evident through their effect on evaporation and transpiration. However, wind also changes rainfall velocities and impact angle. Humidity and solar radiation are indirectly involved in that they are associated with temperature and rate of soil water depletion, Delmer *et al* (1992).

2.6.2 Soil

physical properties of soil affect the infiltration capacity and the extent to which particles can be detached and transported. The corresponding soil characteristics that describe the ease with which soil particles may be eroded are soil detachability and transportability.

Generally soil detachability increases with soil particles size or aggregates while transportability increase with decrease in particles size. e.g clay particle is more difficult to detach than sand but clay is more easily transported. Soil properties like texture, structure, organic matter, water content, clay mineralogy, density or compactness as well as chemical or biological characteristics of the soil influences erosion, Glenn *et al* (1992).

2.6.3 Vegetation:

The major effect of vegetation in reducing erosion includes

1. Interception of rainfall by absorbing the energy of the raindrop and thus reducing surface sealing and runoff.
2. Retardation of erosion by decreased surface velocity
3. Physical restraint of soil movement
4. Improvement of aggradations and porosity of the soil by roots and plant residue

2.6.4 Topography

Topographic features that influence erosion are degree of slope, shape and length of slope, size and shape of watershed. On steep slopes runoff water is more erosive and can transport detached sediments down slope. On longer slopes, an increased accumulation of overland flow tends to increase rill erosion. Concave slopes, with lower slope at the foot of the hill are less erosive than convex slopes.

2.7 Erosion by Water

Raindrop erosion is soil detachment and transport resulting from the impact of water drops directly on soil particles or on thin water surfaces. However, raindrop impact on shallow stream may not splash but does not increase turbulence, providing greater sediment carrying capacity, Glenn *et al* (1992).

Tremendous quantities of soil are splashed into the air, most particles more than once. The amount of soil splashed into the air is indicated by the splash losses from small elevated pans was found to be fifty(50) to ninety(90) times greater than the runoff losses. On bare soil it is estimated that as much as 200mg/ha is splashed into the air by heavy rains. The relationship among erosion, rainfall momentum, and energy is determined by raindrop mass, size distribution, shape, velocity and direction. Glenn *et al* (1992).

The relationship between rainfall intensity and energy has been found to be

$$E = 0.11 + 0.0873log10^I \quad (2.2)$$

Where E= kinetic energy in mj/ha-m

I= intensity of rainfall in mm/h Foster *et al* (1981)

Below is a differential soil movement caused by raindrop splash.

2.8 Sheet Wash Erosion

This is the uniform removal of soil in thin layers from sloping land resulting from sheet or overland flow. It rarely occurs; minute rilling takes place almost simultaneously with the first detachment and movement of soil particles. The beating action of raindrop combined with surface flow causes initial microscopic rolling. Raindrops detach the soil particles and the detactched sediments can reduce the infiltration rate by sealing the soil pores. Glenn *et al* (1992)

The eroding and transporting power of sheet flow is a function of rainfall intensity, infiltration rate, and field slope for a given size, shape and density of soil particles or aggregate, Delmer *et al* (1992)

2.8.1 Interill Erosion

Splash and sheet erosion are sometimes combined and called interill erosion. Research has shown interill erosion to be a function of soil properties, rainfall intensity, and slope. The relationship among the parameters is generally expressed according to Watson and Laflien (1986) as

$$D_{i} = K_{i} I^{2} S_{f} \quad (2.3)$$

Where D_i= interill erosion rate in kg/m²-s

K_i= interill erodibility of soil in $kg - s/m^4$

I= rainfall intensity (m/s)

S_f= slope factor= $1 \cdot 05 - 0 \cdot 85e^{(-4sin\theta)}$ Liebenow *et al* (1990)

And where θ = slope in degrees

2.8.2 Rill Erosion

This is the detachment and transportation of soil by a concentrated flow. Rills are small enough to be removed by normal tillage operation. It is the predominant form of erosion under most conditions, occurs on soils with high-runoff-producing characteristics and highly erodible top soil.

Rill erosion is a function of the hydraulic sheer τ of the water flowing in the rill, and two soil properties, the rill erodibility K_r and the critical shear τ_c the shear below which soil detachment is negligible. Lane *et al*, (1987). Detachment rate D_r is the erosion rate occurring beneath the submerged area of the rill. The relationships among these variables are shown below.

$$D_r = kr(\tau - \tau_c)(1 - Qs/Tc) \qquad \textbf{(2.4)}$$

Where D_r= rill detachment rate in

K_r = rill erodibility resulting from shear in s/m

τ_c =critical shear below which no erosion occurs in pa

Qs = rate of sediment flow in the rill in kg/m-s. Lane *et al*, (1987).

Tc = sediment transport capacity of rill in kg/m-s

τ= hydraulic shear of flowing water in Pa= ρgrs where Pa= pgrs **(2.5)**

And ρ = density of water in kg/m^3

g= acceleration due to gravity in m/s^2

r= hydraulic radius of rill in m

s= hydraulic gradient of rill flow

2.8.3 Gully Erosion

Gully erosion produces channels larger than rills. These channels carry water immediately and after rains and they cannot be obliterated by tillage which distinguishes them from rill. The amount of sediments from gully is usually less than that from upland area but poses a problem of having fields divided by large gullies. In tropical areas gully growth resulting from deforestation and cultivation led to sever problem of soil loss and damage to buildings and roads, (Aneke,1985).

The rate of gully erosion depends primarily on the runoff-producing characteristics of watershed, drainage area, and slope of the channel. Gully formation is also dependent upon soil shear strength, infiltration, and depth of water table, Bradford *et al* (1973).

However, a gully develops by process that may take place either simultaneously or during different periods of growth. The processes are outlined below

a. Waterfall erosion or headcutting at the gully head

b. Erosion caused by water falling through the gully or by raindrop splash on exposed gully sides

c. Alternate freezing and thawing of the exposed soil banks.

2.8.4 Stream Channel Erosion

Stream channel erosion consists of soil removal from stream banks, or soil movement in the channel. Stream channel erosion applies to the lower end of headwater tributaries and the streams with nearly continuous flow and relatively flat gradients whereas gully erosion generally occurs in intermittent steams near the upper ends of headwater tributaries, Glenn *et al* (1992).

Stream banks erode either by runoff flowing over the side of the stream bank or by scouring or by undercutting below the water surface. Stream erosion is increased by removal of vegetation, overgrazing, tilling too near the bank or straightening of the channel. Scour erosion is influenced by velocity and direction of flow, depth and width of channel and soil gradient. Poor alignment and presence of obstruction such as sand-bars increase meandering the major cause of erosion along banks, Glenn *et al* (1992).

2.9 Sediment Transport

Sediment transport is the phenomenon involving displacement of granular material (sediments) by flowing water, the resulting direction being in the direction of the flow, Vanoni (1975). The two kinds of transport are suspended load and bedload.

The transport capacity of individual rill is given by

$$T_c = B\tau^{1.5} \qquad \textbf{(2.5)}$$

Where T_C = transport capacity per unit width in kg/m-s

B= transport coefficient based on soil and water properties.

τ = hydraulic shear of rill channel in pa

τ = hydraulic shear of rill channel in pa

2.10 Annual Soil Loss

The universal soil loss equation is a widely accepted method of estimating sediment loss despite its simplification of the many variables involved. It is useful for determining the adequacy of conservation measures in farm planning and for predicting non-point sediment losses in pollution control programs. The average annual soil loss as determined by Wiscmeier and Smith (1978) is given by

$$A = RKLSCP \quad \textbf{(2.7)}$$

Where A = Average annual soil loss in mg/ha

R = rainfall and runoff erosivity index for geographical location

K= soil erodibility factor

L= slope length factor

S= slope steepness factor

C= cover management factor

P= conservation practice factor. Wiscmeier and smith (1978)

In RUSLE, k varies to account for seasonal variation in soil erodibility. The topographic factors L and S adjusts the erosion rates on longer and/ or steeper slope when compared with a USLE standard slope of 9% and slope length of 22m.The difference are attributed to increasing rill erosion rates as more runoff accumulates with longer slopes and greater erosive forces occurring with steeper gradient; These forces are calculated thus. McCool *et al* (1989).

$$L = (l/22)^m \quad \textbf{(2.8)}$$

Where L = slope length factor

l = slope length in m

m = dimensionless exponent

The following were recommended for these conditions.

Where rill erosion and inerill were about equal on a 9%, 22-m-long slope, then m could be found by

$$m = \frac{sin\theta}{sin\theta + 0.269(sin\theta)^{0.8} + 0.05} \quad \textbf{(2.9)}$$

Where θ = field slope steepness in degree = $\tan^{-1}(s/100)$

And s= field slope in %

Also for conditions where rill erosion is greater than interill erosion (like soils with a large silt or fine sand content) m should be increased up to 75 percent , where rill is erosion is less than interill erosion (on short slopes or high clay- content soils), m should be decreased to 50 percent. McCool *et al* (1989)

Moreover McCool *et al* (1987) presented a set of S factors based on slope steepness

For slopes shorter than 4m, S= 3.0($\sin\theta$)

For slopes longer than 4m and s <9% S = 10.8 sin θ + 0.03

For slopes longer than 4m and s ≥ 9 percent, S= $16.8 sin\theta - 0.05$

Slope length is measured from the point where surface flow originates to the outlet channel where deposition begins.

Cover management factor c: includes the effect of cover, crops sequence, productivity level, length of growing season, tillage practice, residue management and expected time distribution of erosive agents, McCool *et al* (1989).

The conservation practice factor p is given as

$$P = pc \times ps \times pt \quad \textbf{(2.10)}$$

Pc= contouring factor based on slope

Ps= strip cropping factor for crop strips width (1.0 for contouring only or for alternating strips of corn and small grain, 0.75 for 4-year rotation with 2-years of row crop and 0.50 with 1-year of row crop)

Pt= terrace sedimentation factor (1.0 for no terrace, 0.2 for terraces with graded channel sod outlets and 0.1 for terraces with underground outlets).

2.11 Mechanics of Water Erosion

2.11.1 Hydraulic action

Hydraulic action is a form of mechanical weathering caused by the force of moving water currents rushing into a crack in the rockface. The water compresses the air in the crack, pushing it right to the back. As the wave retreats, the highly pressurised air is suddenly released with explosive force, capable of chipping away the rockface over time. Thus, the crack is gradually widened so the amount of compressed air increases like a balloon, and hence the explosive force of its release increases. Thus, the problem intensifies (a 'positive feedback' system).It helps the river to get lower (rejuvination). Susan *et al*,(1992).

2.11.2 **Abrasion**

Abrasion occurs when larger rock particles roll and strike against bedrock walls, chipping and splintering particles and pieces of rock, (Strahler, 2006). As these cobbles and boulders roll across the stream bed, they continue to crush and grind the bedrock, producing an assortment of eroded rock sizes (Ritter, 2006). Again, the severity of this type of erosion is dependent upon stream velocity and stream load (i.e. the presence of larger rock particles).

2.11.3 **Suspended load**

Suspended load is comprised of fine sediment particles suspended and transported through the stream. These materials are too large to be dissolved, but too small to lie on the bed of the stream, (Mangelsdorf, 1990). Stream flow keeps these suspended materials, such as clay and silt, from settling on the stream bed. Suspended load is the result of material eroded by hydraulic action at the stream surface bordering the channel as well as erosion of the channel itself. Suspended load accounts for the largest majority of stream load, (Strahler , 2006).

2.11.4 Bed load

Bed load rolls slowly along the floor of the stream. These include the largest and heaviest materials in the stream, ranging from sand and gravel to cobbles and boulders. There are two main ways to transport bed load: traction and saltation. Traction describes the "scooting and rolling" of particles along the bed (Ritter, 2006). In stream load transport, saltation is a bounce-like movement, occurring when large particles are suspended in the stream for a short distance after which they fall to the bed, dislodging particles from the bed. The dislodged particles move downstream a short distance where they fall to the bed, again loosening bed load particles upon impact, (Ritter, 2006).

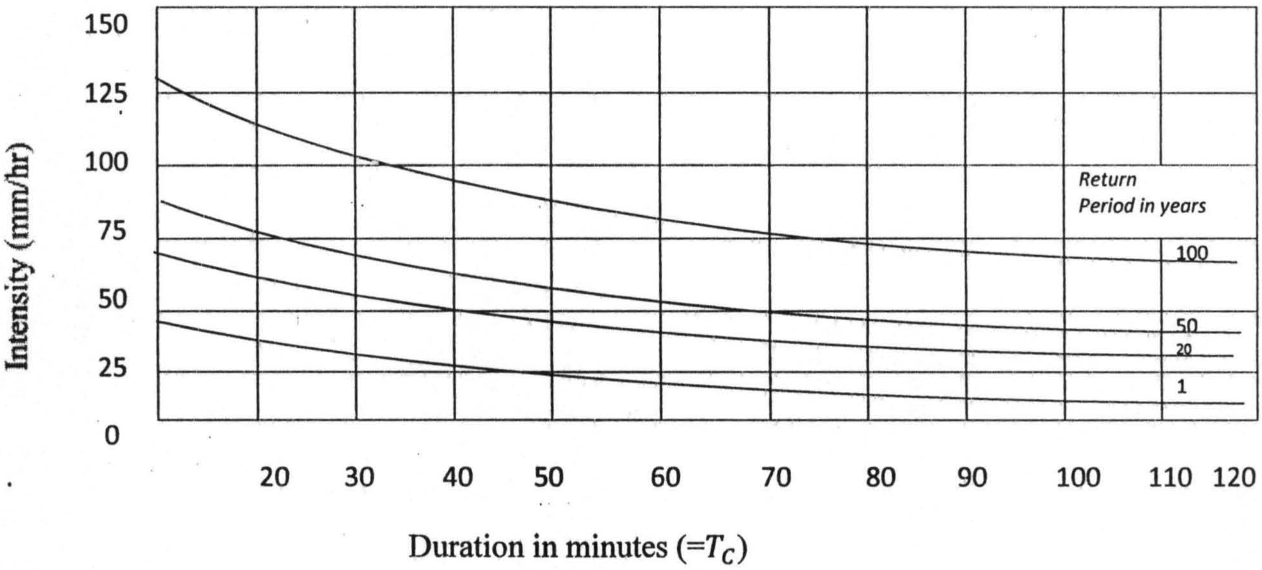

Fig 2.1 Chart for Return Period, Intensity and Duration (=T_C)

Examples of 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, Miller(1994).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Location of Study Area

Bosso Dam is located in Minna Niger State on latitude 9°39′N and longitude 6°33′E, Microsoft enchanter (2008).The area is bounded to the North by Taige village, to the south by college of Arts and Islamic studies (CAIS), to the east by Pyata village and to the west by Hills and water divide .The area has distinct seasons, wet and dry with temperature and humidity varying with the seasons. The average of mean annual rainfall for the area is1200mm, while the temperature ranges from 21°Cto 30°C

The dam was constructed in 1949 in which case it has exceeded the average useful life estimated at 50years.United States Bureau of Reclamation (1977).

3.2 Methodology

Catchment area measured from ordinance map (1969) and topographic Map for Minna. Niger State Ministry of Lands and Survey (2009) on scale 1:250000 revealed a total catchment (watershed) area of 100 hectares

Assuming a Runoff coefficient of 0.2 on the annual runoff. Ahaneku (2003)

Total annual runoff= CPA (3.1)

Where C=runoff coefficient

P= Annual precipitation for Minna

A= catchment area in hectares

Table 3.1 Computation of Rainfall Intensity for Minna and its Environs for 20years.

Year	maximum Rainfall Amount (mm)	Duration (hrs)	Intensity (i) = (Max Rainfall Amount / Duration) mm/hr
1989	78.4	3.50	22.4
1990	49.0	3.17	15.5
1991	68.6	2.50	27.4
1992	54.4	2.14	25.4
1993	69.3	2.18	31.8
1994	86.7	2.14	40.5
1995	64.2	2.50	25.7
1996	62.9	3.50	18.0
1997	68.1	5.20	13.1
1998	94.6	5.80	16.3
1999	88.6	4.80	18.5
2000	48.5	3.05	15.9
2001	67.7	6.07	11.2
2002	95.6	5.34	17.9
2003	53.5	4.31	12.4
2004	107.0	6.12	17.5
2005	73.9	4.75	15.6
2006	77.8	3.50	22.2
2007	94.5	1.17	80.8
2008	84.2	2.50	33.5
2009	109.8	3.50	31.3

Source: Nigerian Meteorological Agency (NIMET), Minna Airport, Minna (1989-2009).

3.3.1 Runoff Coefficient

Runoff coefficient(c) is a measure of rainfall proportion that becomes runoff. The constant is dependent on such factors as rainfall intensity, duration, topography, and nature of soil and land use. The area under study is a slight forest area and sandy in nature with moderately steep slope

Table 3.2 Values of Runoff Coefficients for Different Catchment Characteristics

Item	Type of catchment	runoff coefficient
1	Heavy forest	0.1-0.2
2	sandy soil	0.2-0.3
3	cultivated absorbed soil	0.3-0.4
4	cultivated or covered with vegetation	0.4-0.6
5	slightly permeable bare sand	0.6-0.8
6	rocky and impermeable areas	0.8-1.0
7	urban areas	0.3-0.5
8	commercial area, asphalt or concave pavement	0.85-0.90

Source: Irrigation Water Power and Water Resources Engineering, Arora (2006).

The description of the catchment area of Bosso Dam corresponds with item (2) hence the runoff coefficient for the site is 0.2.

3.3.2 Topographic Conditions

The ordinance or topographic map obtained from the Niger state ministry of lands and survey was used for all design analysis and calculations. Considering the topographic parameters obtained from the engineering survey of the area, the field has a length of 1800m, and a slope of 3.3%.

3.4.1 Calculation of Time of Concentration

Time of concentration is the time taken for a given quantity of runoff to flow from the longest length of the catchment into the reservoir. It was calculated using the following equation:

$$T_{C} = \frac{0{,}0197L^{0.77}}{S^{0{,}385}} \quad (3.2)$$

Where T_C = time of concentration in min

L= length of catchment

S= slope steepness in percent

From the ordinance map, L= 1800m, S= 3.3%, = 3.3/100 = 0.33

$$T_C = \frac{0\ 0.197X1800^{0.77}}{0.033^{0.385}} = 23.58 \quad (3.3)$$

T_C= 24mins

3.4.2 Runoff Design Equation (Runoff Rate)

Hydrological design of drainage systems is normally based on the rational formula recommended by different organizations like the highway design manual of the Federal Ministry of Works and

Housing Federal Republic of Nigeria (1976) and some individuals. The rational method is particularly suitable for small catchment (watershed) area, Michael and Ojha (2003).

Larson and Reich (1973) also recommended rational method to be applied to small catchment (watershed) of less than 800ha. It is expressed as:

Q=0.0028CIA **(3.4)**

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

C= runoff coefficient (dimensionless)

I= intensity of rainfall in (mm/hr)

A= catchment area in (ha)

Using figure 2.1, the 1- hr intensity of 80.8mm/hr to 24 minutes duration at 20-year return period (T) recommended for gully erosion control and small earth dam structures gives 45mm/hr

C= 0.2 (runoff coefficient for predominant sandy soil)

I= 45mm/hr

A= 100ha

Q= 0.0028CIA

$= 0.0028 \times 0.2 \times 45 \times 100$

$= 2.52 m^3/s$

3.5 Reservoir Storage

3.5.1 Dead Storage

Dead storage is computed on the basis of sediment transportation and deposition. Sediment transportation is computed using a factor of 0.1% on the annual runoff (United States Bureau of Reclamation 1966)

3.6 Calculation of Storage Parameters

TAR= CPA **(3.5)**

Where TAR= total annual runoff in (m^3/s)

C= runoff coefficient (dimensionless)

P= annual precipitation for Minna in (mm)

TST= TAR X 0.1% **(3.6)**

Where TST= total sediment transport

TAR= total annual runoff

Assuming a bed load (BL) of 20% of TST and suspended load (SL) of 80% of TST

BL= 0.2TAR **(3.7)**

Where BL=Bed Load

TAR= total annual runoff

SL =0.8 TAR **(3.8)**

Assuming a trap efficiency of 100% for bed load (BL) and 80% for suspended load (SL) respectively, total annual sediments TS will be

TS= [BL+ (0.8SL)] **(3.9)**

Where TS = total annual sediments

BL =bed load

SL= suspended load

The total annual dead storage will therefore be

TDS= 60TS **(3.10)**

Where TDS= total annual dead storage for 60 years of the dams existence.

3.7 Field Data Collection

Rectangular wedges inclined at a relatively uniform inclination with the channel at 30° to the horizontal were used to collect sediment materials from runoff. The wedges have 0.5cm diameter hole inscribed beneath and has a sieve material attached to collect the sediments and drain off the water. The sediments collected were weighed in order to determine the weight of wet samples and thereafter dried to determine that of their corresponding dry sample.

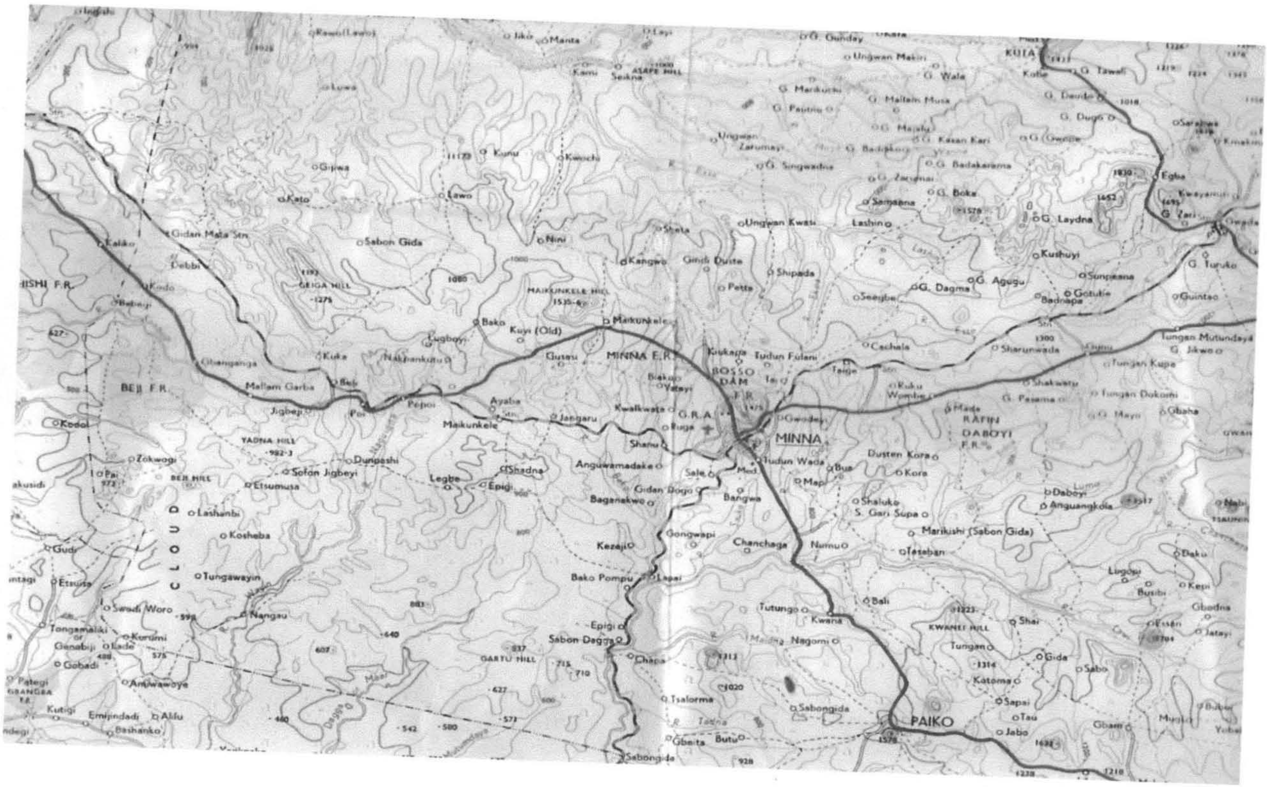

Plate 3.1 Topo sheet for Minna and its Environs.

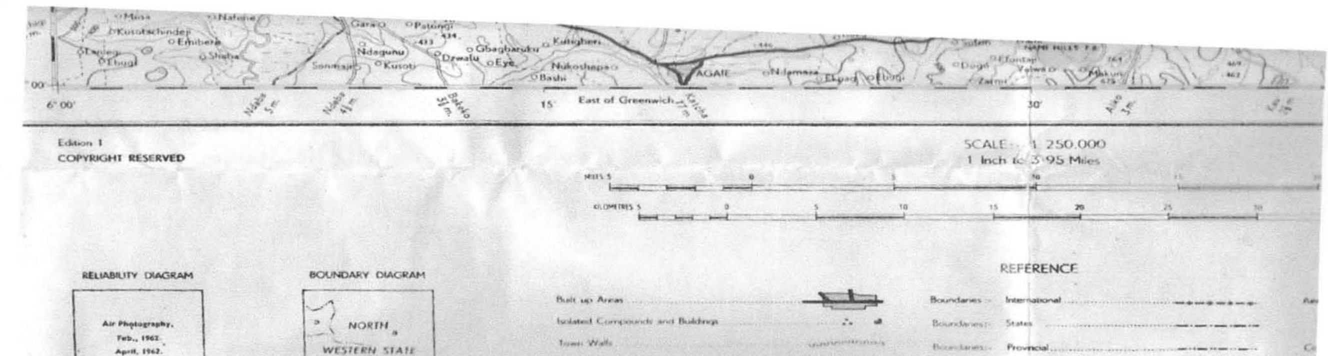

Plate 3.2 Topo sheet for minna showing scale 1: 250000

CHAPTER FOUR

4 RESULT AND DISCUSSION

4.1 RESULTS

The result obtained from the reservoir storage calculations from the sediment estimation model are displayed below showing the proportion or quantity of both suspended load and bed load of the reservoir.

From the table above the sediment parameters were calculated using simple equations from the sediment estimation model.

From equation 3.5 and item1 of Table 4.1

1. TAR= CPA

$= 0.2 \times 1.2 \times 1000000$

$= 240000\ m^3$

2. TST: The total sediment transport is taken as 0.1% of the total annual runoff.

From equation 3.6 and item 2 of Table 4.1

$$TST = \frac{0.1}{100} \times 240000$$

$$= 240m^3$$

3. B. L: The bed load is assumed to be 20% of the TST

From equation 3.7 and item 3 of Table 4.1

B.L= 0.2×240

$= 48m^3$

4. S.L = it is taken as 80% of TST

From equation 3.8 and item 4 of Table 4.1

S.L $= 0.8 \times 240$

$= 192m^3$

From equation 3.9 and item 5 of Table 4.1

5 TS= $[BL + (0.8SL)]$

$= [48 + (0.8\,X192)]$

$= 201.6m^3$

From equation 3.10 and item 6 of Table 4.1

6 TADS: Total annual dead storage is the annual storage multiply by 60 years of the dam's existence.

TADS= 60×201.6

$= 12096m^3$

4.1.2 Estimation of Accumulated Reservoir Sediment

Sediments that have accumulated in the reservoir of a small earth dam over a period of time can be estimated using the following cumulative sediment equation developed by Oladipo (2009). The equation is given as

$$TS_{n=x(N)^y} \quad 4.1$$

Where TS_n = total sediments in the reservoir of the dam in n- years (m^3)

x = total annual sediment (m^3)

N= number of years in which the reservoir of the dam has been in use

y = an exponent whose assumed value is 1

Thus from the Table 4.1 above, x = 201.6

N= 60 years

y = 1

From equation 4.1 above $TS_{n=x(N)^y}$

$= 201.6(60)^1$

$= 12096m^3$

Table 4.1 Computation of Sediment Transport and Deposition Parameters

Item	Sediment Property (m^3)	Formula		Volume Deposited (m^3)
1	Total annual runoff (TAR)	CIA	=	240000
2	Total sediment transport (TST)	0.1TAR	=	240
3	Bed Load (B.L)	0.2TST	=	48
4	Suspended Load (S.L)	0.8TST	=	192
5	Total Annual Sediment (TS)	B.L+0.8S.L	=	201.6
6	Total annual Dead Storage (TADS)	60T.S	=	12096

4.1.3 Channel Sediment Deposition Result

The results displayed below in tables 4.2-4.4, shows the variation in monthly sediment transport with rainfall amounts at the three channels; a main channel and two minor channels. The cumulative values indicate that high runoff amount is associated with high rainfall amount and a corresponding sediment transport. The sum of the monthly sediment generation and deposition for points A,B, and C in kg/m which gives total sediments and when multiplied by wedge factor of 2.0 are 40706kg/m,19938kg/m,17156kg/m respectively giving a total of 77800kg/m as the annual sediments during Rainy season.

Table 4.2 Variation of Monthly Sediment Transported along Point A (main channel)

Month	cumulative weight of monthly Wet sediment (kg/m)	cumulative weight of monthly dry sample (kg/m)	Rainfall Amount (mm)
April	660	654	89.9
May	1300	1292	101.4
June	1920	1915	108.9
July	5180	5176	246.8
August	5620	5614	497.6
September	4760	4750	273.5
October	960	952	85.2

Table 4.3 Variation of Monthly Sediment Transported along Point B (minor channel)

Month	cumulative weight of monthly Wet sediment (kg/m)	cumulative weight of monthly dry sample (kg/m)	Rainfall Amount (mm)
April	420	415	89.9
May	800	790	101.4
June	1200	1195	108.9
July	1320	1312	246.8
August	3360	3352	497.6
September	2520	2515	273.5
October	400	390	85.2

Table 4.4 Variation of Monthly Sediment Transported along Point C (minor channel)

Month	average weight of monthly Wet sediment (kg/m)	average weight of monthly dry sample (kg/m)	Rainfall Amount (mm)
April	390	382	89.9
May	710	609	101.4
June	1032	1025	108.9
July	1080	1070	246.8
August	2800	2790	497.6
September	2240	2233	273.5
October	480	469	85.2

4.2 Particle Size Tests

4.2.1 Analysis of Particle Size Distribution

Particle size test was carried out with results shown below. From the result, the percentage passing decreases with sieve size (diameter) .These samples are poorly graded for both coefficients of uniformity and that of curvature (they are below the ranges for well graded). This shows that the soil is easily erodible by water. For a wel! graded soil, the erodibility is less since the particles of the soil are close and are less porous by the flowing water. This was determined from the graph of percentage passing against sieve size (mm).

Table 4.5 Data of Particle Size Tests Analysis for Sample 1

Weight of Sieve (kg)	Diameter (mm/μm)	weight Retained (kg)	percent Retained (%)	Percent Passing (%)
0.48	5.00	0.025	1.250	81.00
0.49	3.35	0.040	2.000	79.00
0.48	2.00	0.675	33.75	45.25
0.38	1.18	0.015	0.750	44.50
0.39	850μm	0.010	0.500	44.00
0.35	600μm	0.620	31.00	13.00
0.34	300μm	0.120	6.000	7.00
0.31	212μm	0.020	1.000	6.00
0.35	180μm	0.050	2.500	3.50
0.30	150μm	0.070	3.500	0.00

Table 4.6 Data of Particle Size Tests Analysis for Sample 2

Weight of Sieve (kg)	Diameter (mm)	weight Retained (kg)	percent Retained (%)	Percent Passing (%)
0.48	5.00	0.020	1.200	79.00
0.49	3.35	0.030	0.150	67.00
0.48	2.00	0.660	33.00	43.25
0.38	1.18	0.001	0.600	41.50
0.39	850μm	0.610	0.61	39.10
0.35	600μm	0.12	31.00	12.00
0.34	300μm	0.100	6.200	6.00
0.31	212μm	0.001	5.200	5.10
0.35	180μm	0.040	2.800	2.80
0.30	150μm	0.060	2.500	0.00

Below are the graphs of particle size distribution showing the grade distribution for the two samples analysed. The C_u and C_c are coefficients of uniformity and curvature respectively. The C_u is gotten by dividing the sieve size corresponding to 60% passing by that of 10%, while the C_c is obtained by dividing the square of the sieve size corresponding to 30% passing by the product of that of 10 and 60 respectively.

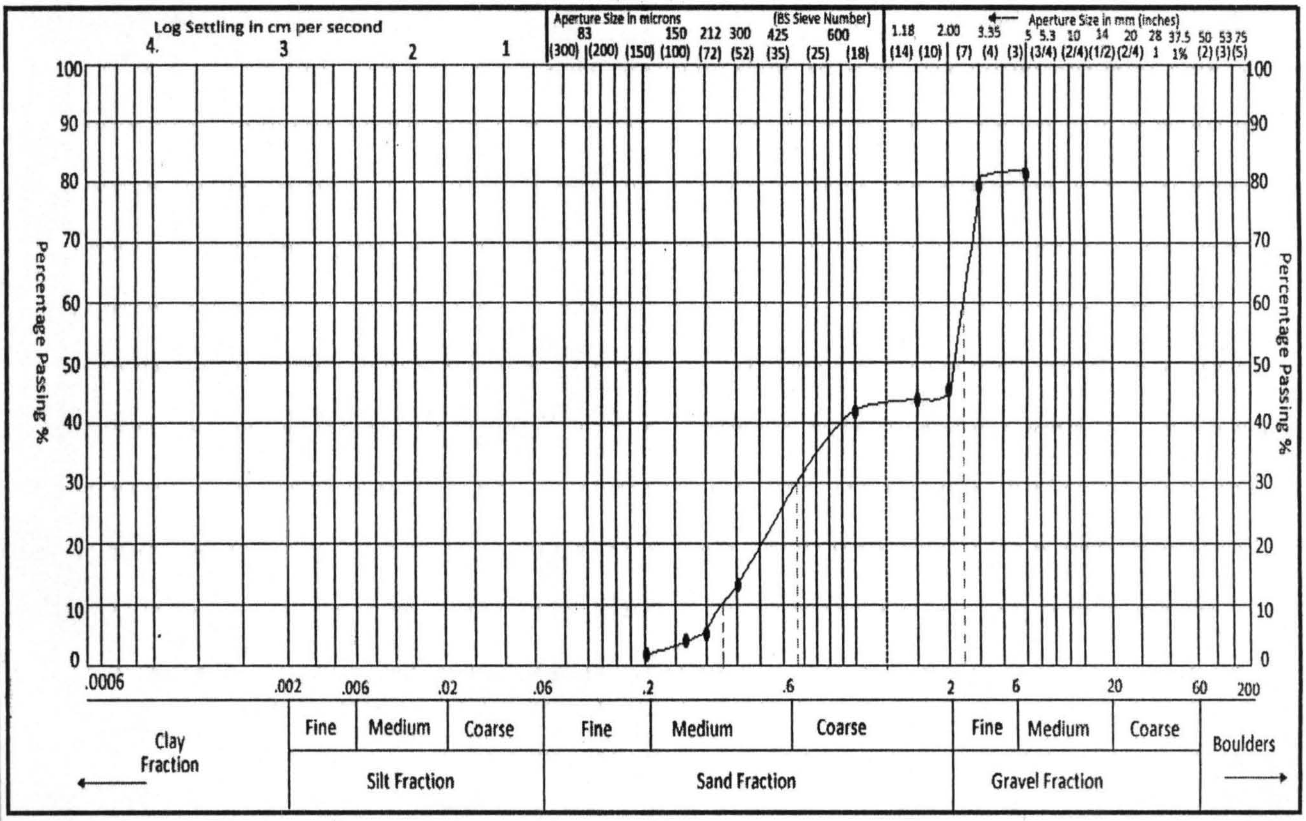

Fig 4.5 particle Size Distribution Graph for Sample 1

The coefficients of uniformity and curvature were deduced from the graph as shown below

D10= 0.47

D30= 0.81

D60= 2.4

$$C_u = \frac{D60}{D10} = \frac{2.40}{0.47} = 5.10$$

$$C_c = \frac{D30^2}{D10D60} = \frac{0.81^2}{0.47 \times 2.4} = 0.58$$

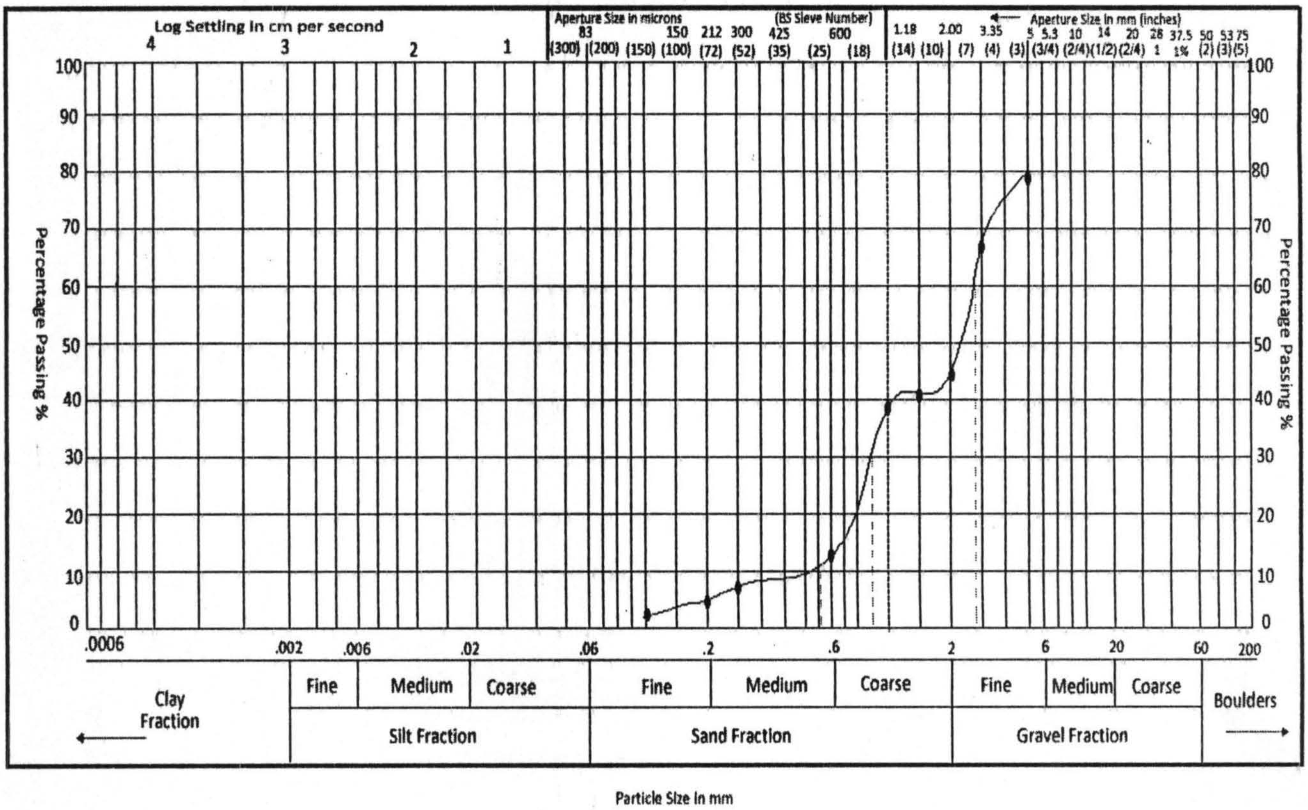

Fig 4.6 Particle Size Distribution Graph for Sample 2

D10= 0.51

D30= 0.85

D60= 2.45

$$C_u = \frac{D60}{D10} = \frac{2.45}{0.51} = 4.8$$

$$C_c = \frac{D30^2}{D10D60} = \frac{0.85^2}{0.51 \times 2.45} = 0.57$$

4.3 Atterberg Limit Test Results

The Atterberg limit correlates with the Engineering properties of soil because both Atterberg limit and Engineering properties are influenced by same factors such as clay minerals, ions in pore water and stress history of soil deposits. From the result it can be shown that the soil has a low plasticity index which is an indication that it is has high silt/sand content thereby requiring high number of penetrations before the soil can be formed.

Table 4.7 Data of Atterberg Limit Test Analysis Using cone Penetrometer Method

Can Label	No of Trails	penetration (mm)	Weight of can (g)	Weight of can + wet soil (g)	Weight of can + dry soil (g)	Water Content (%)	Indices
6b	1	3.00	24.8	30.2	29.3	20.0	
M14	2	6.20	23.2	30.3	28.8	57.6	
M34	3	16.5	24.6	37.3	34.1	33.6	
SE	4	25.0	24.8	34.6	32.2	32.4	L.L
SA	5	28.5	24.5	39.3	35.1	39.6	L.L
9D	6	PL	24.8	25.9	25.5	57.1	
C6	7	PL	23.1	24.5	23.9	75.0	

The graph of the Atterberg limit test which is used for determination of indices as plasticity index, liquid limit and plastic index is shown in fig 4.6 below. The plastic limit (P.L) is obtained from the average of the water contents before the sample begins to form; the liquid limit (L.L) is the water content at the 25th penetration. While the plasticity index (I_P) is the difference between the liquid limit and plastic limit.

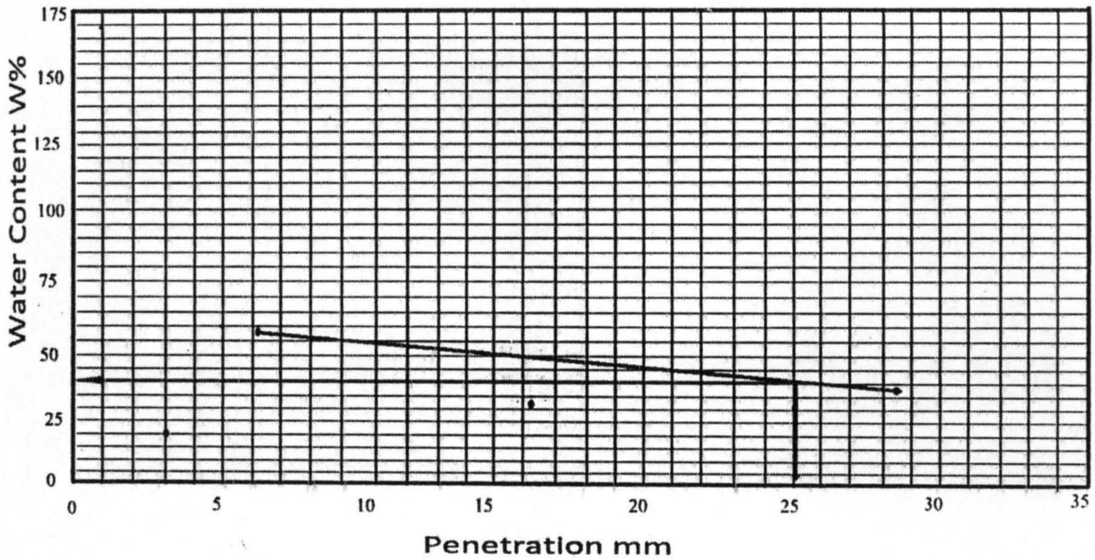

Fig 4.7 Liquid Limit Chart

From the graph above the liquid limit = 39

4.3.1 Calculations from Atterberg Limit Test Indices

Water content (W%) = $\frac{W2-W3}{W3-W1} \times 100$

Where W1 = mass of can (g)

W2 = mass of can + moist soil (g)

W3 = mass of can + dry soil (g)

Plastic limit (P.L) = $\frac{20+57.6+33.6+32.4+39.6}{5}$ = 36.64

Liquid limit (L.L) = 39

Plasticity index (P.I) = L.L- P.L = 39- 36.64= 2.36

4.4 Bills of Engineering Measurement and Evaluation (BEME)

4.4.1 Cost Analysis

1. Excavation site to receive the sediment materials

2. Hauling to spoil should be done at least 1 km downstream

Excavating $3000m^3$ site to receive $2880m^3$ of sediments from the reservoir. To achieve this, the following dimensions should be taken into consideration.

A total of 50m$\times$ $20m \times 3m$ excavated site will give a $3000m^3$ sediment reception site.

Excavation per m^3 of soil= ₦3000

Excavation of $3000m^3$= 3000×3000= ₦9000,000

Excavation and hauling to spoil

Cost of hauling of 1 m^3 of sediments = ₦2500

Cost of hauling of $2880m^3$= $2880m^3$ × ₦ 2500

= ₦7,200,000

Sub-total = ₦16,200,000

Allowing for 10% contingencies= 10% of 16,200,000 = ₦1,620,000

Total cost= 16,200,000+1,620,000 =₦17,820,000.

However these excavated sediments can serve as sharp sand for building purposes hence can be sold to tipper drivers thereby generating income for the relevant authority.

Plate 4.1 Picture of the Embankment after the Rainy Season.

Plate 4.2 Picture of the Embankment at Rainy Season.

Plate 4.3 Rectangular Wedge System Arrangement for point A

Plate 4.4 Rectangular Wedge Arrangement for point B

Plate 4.5 Rectanguler wedge Arrangement for Point C

Plate 4.6 Sediment Collected After Rainfall

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The rational method was used to estimate the runoff rate for the watershed and also for sediment transport analysis, from the results obtained from this work it was concluded that $2880m^3$ of the dam was silted in 60 years of the dams existence to bed load at the rate of $48m^3$ per annum which equals 76800kg, an amount close to that of the field data which is 77800kg/m .However, considering the dam characteristics which is a small earth dam, this amount is high and therefore conclude that sedimentation rate of the dam is high and should be desilted.

5.2 Recommendations

1 Bosso dam needs to be desilted by scooping and not dredging for cost reason.

2 The dam should be lined with lining materials such as marbles.

3 Check dams should be constructed to reduce sedimentation rate.

4 The embankment should be free from growth of small shrubs and grasses to minimize seepage losses.

5 There should be a stricter regulations on the activities of the herdsmen who uses their cattle for grazing thereafter make them drink from the reservoir and in the process looses the soil thereby making it easier for erosion to occur and other forms of activities by man.

6 The conducive environment at the downstream can be used as recreational center thereby generating revenue for the government.

For further research the sediment transport and deposition rate as a result of wind erosion and other sources should be looked into. Also, the causes of odour of the water sample should be verified.

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APPENDIX A

Table A Table for Bosso Dam parameters

PROJECT DATA FOR BOSSO DAM (1948)	
1 Designed by	R.N Exe
2 Approved by	H.E walker July 1945
3 Construction started	October 1947
4 Construction completed	November 1949
5 Time of completion	2 years
6 Deepest level of core trench	299.2m
7 maximum dept of core trench	6.1m
8 maximum original ground level	304.49m
9 Crest elevation of dam	324.0m
10 maximum height of dam	19.51m
11 maximum conservation level	321.56
12 maximum width of base	88.7m
13 width at crest elevation	4.27m
14 maximum depth of water	17.06m
15 maximum storage capacity	1.81 million ltrs(4000000gallons)
16 Active capacity	0.681×10^6m
17 purpose	Water supply

Source: Niger State Water Board (Gidan Ruwa) Minna (2009).

APPENDIX B

Table B Soil Classification Related To Plasticity Index

Item No.	Plasticity index (Ip)	Soil description
1	0	Non- plastic
2	< 7	Low plastic
3	7- 17	Medium plastic
4	> 17	highly plastic

Source: Basic and Applied Soil Mechanics Gopal Ranjan, A.S.R Rao (2005).

From the result obtained in 4.3.1(page 40) , the plasticity index is 2.36 which falls within the range of item 2. Hence the sample is of low plastic in nature.

APPRAISAL OF SEDIMENT YIELD AND DEPOSITION IN SMALL EARTH DAMS: A CASE SYUDY OF BOSSO DAM MINNA, NIGER STATE.

BY

ATTAH, ILEH BENJAMIN

MATRIC NO. 2004/18358EA

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FEBRUARY, 2010.