HYDROMETEOROLOGICAL FACTORS OF GULLY EROSION ALONG ENUGU - ONITSHA EXPRESS CORRIDOR

BY

ANYAJI, FELICIAL NNEAMAKA
M.TECH/SSSE/91/92/032

A RESEARCH PROJECT SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTERS OF TECHNOLOGY DEGREE IN GEOGRAPHY AND METEOROLOGY, SCHOOL OF SCIENCE AND SCIENCE EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY, P. M. B. 65, MINNA - NIGER STATE.

DECEMBER, 1993.

APPROVAL PAGE

This Project Report Written by:

ANYAJI, FELICIA NNEAMAKA (MISS)

Under the Supervision of Professor D. O. Adefolalu,
Dean, Post Graduate School, Federal University
of Technology, P. M. B. 65, Minna - Niger State
is hereby Approved

....

Professor A. A. Oladimeji
Dean, School of Science and Science Education
Federal University of Technology, Minna.

Dr. G. N. Nsofor
Head of Geography Dept.

Professor D. O Adefolalu
Dean. Post-Graduate School
(Project supervisor)

------------------------------ 18/11/93
Professor E. E. Balogun
Obafemi Awolowo University,
Ile-Ife (External Examiner)

Anyaji, Felicial Nneamaka
Department of Geography
Federal University of Tech.,
Minna - Niger State.

DEDICATION

To God Almighty for saving my Brother's life and Professor A. C. Aghaji (UNTH, ENUGU) whom HE used.

<u>TABLE OF CONTENT</u>

ACKNOWLEDGEMENT

My unalloyed gratitude goes to my research supervisor Professor D. O. Adefolalu, Dean of Post Graduate School, F. U. T. Minna, He is responsible for the intellectual backing of this work and without whos positive criticisms, corrections and guidance, the whole exercise could not have been successful. His private and official advice are of immense importance.

I am greatly indebted to Professor E. C. Adibe (Dean faculty of Environmental Sciences, Enugu State University of Technology), he supervised my undergraduate research work. He encouraged me to to pursue my Masters degree immediately. I would have wasted this opportunity. I will never forget his advice and guidance.

My thanks goes to Dr. G. N. Nsofor my head of department. He contributed in no small measure in making the research a reality. I equally acknowledge the criticisms of my colleagues - Mallam Usman, M.T. and Abubakar, A. S. which have helped to balance the project. My thanks also goes to Professor B. C. E. Egboka and Dr. P. I. Orajaka both of Nnamdi Azikiwe University, Awka campus. I will not fail to mention Mr. James and Mr. Irabor both of meteorological Institute Oshodi, Lagos for their guidance during my data collection; Mr. Ogbonna of material laboratory (F.M.W.H.T) Enugu, who analysed my soil samples; Mr. J. O. Omotayo for tracing my map works and Mallam Zubairu A. Mohammed for typing my research work both are in Geography department of FUT. Minna.

I owe my greatest regards to the members of my family, My father Mr. Uzor Anyaji, whose sweet memory had kept me in check. My mother Mrs. Eunice Anyaji, whom I am very proud of. My brothers Adulphus A. Anyaji, Ernest A. Anyaji, Benneth Anyaji and my sister Mrs. Monic Onwuegbu, who with love, gives their strong moral and financial support in my academic pursuit.

I appreciate the contributions of various Authors whose work I have used in writing my project.

May God bless you all ...... Amen.

Anyaji, Felicia Nneamaka (Miss).

A B S T R A C T

Gullying processes of some selected sites in Enugu-Onitsha express corridor were studied. The factors that generate gully erosion a• selected points were highlighted and their general characteristics were discussed based on the intensity of gullying in the corridor, two types of gully development were identified, that is the young and intermediate states. Consequently, the gullies were classified into three categories namely; baselevel, scarp, and incidential gullies in accordance with their mode of initiation, present material and processes within them.

It was observed that gullies concentrates on the sandstone areas of the geologic formations along the corridor. From the discussion, it was observed that rainfall intensity, geomorphic pattern and geologic setting, groundwater condition and the surface vegetal cover are factors that influence gully erosion.

Finally, the contribution of these factors in predicting gully erosion in the selected sites and some implication for checking soil erosion in the study area were highlighted.

P R E F A C E

This project presents the report of the research carried out on "Hydrometeorological consequences of gully erosion", a case study of Enugu-Onitsha Expressway.

The structure of the project is fairly simple. There are five chapters altogether. Chapter one deals with the introductory aspect of the project. This includes the background of the project, the objective, justification of the study, literature review and its summary and theoretical frame-work.

Chapter two explores the environmental setting of the study area, which is the climate, vegetation, soil, geology, geomorphology of the study area.

Chapter three shows the representation of the field observations, and the laboratory work. The analysis was done under these headings, gullying intensity along the expressway, physiographic analysis, result of the laboratory work, patterns of gullying, rate of functioning and rainfall intensity its return period.

Chapter four shows the statistical analysis and computation of rainfall intensity and return period; the result of frequency curves; bar graph of the particule size analysis; volume of soil lost and landuse system.

Chapter five embodies the conclusion, control measure in the study area and recommendation for further studies.

LIST OF FIGURES

Figures | Page

LIST OF TABLES

LIST OF PLATES

CHAPTER ONE

1:0 INTRODUCTORY ANALYSIS

1:1 BACKGROUND OF THE STUDY

Erosion may simply be described as a process of continuous or intermittent removal of soil including plants' nutrient from the land surface and its deposition in another location. There are various causative agents of soil erosion such as water, wind, but above all, man is the most important agent of soil erosion, Sagua (et al 1986). In general, soil erosion is a natural phenomenon and a response to environmental forces which lead to displacement of the soil to varying degrees. Normal erosion occurs with wind action but this is suitahle and slow, such that the displaced soil can be replaced by normal process. Sheet-wash erosion is more persistent and covers an extensive area of the country. In some other cases, erosion can be accelerated when the rate of displacement and removeal of the soil from land surface far exceeds its replacement by pedological processes.

All over the world, it is now being recognised that about 2.5% of soil, when land is used carelessly, can be swept away in a very short time. Yet it has taken from 100 to 300 years to form. It has been estimated with available measurement that at least 3 billion tonnes of soil are wasted out of the field and pasture of the nation every year, (Schwarb et al 1981).

In Nigeria, soil erosion has reached endemic proportions. Both old and fresh gullies are seen on farmlands, roadsides, urban centres and river banks. Gullies adorn much of the landscape especially in the eastern part of the country - Anambra, Enugu, Imo, Akwa Ibom, Rivers, Cross River and former Bendel state.

In former Anambra state, which is easily the worst affected state, canyons created by erosion have become a common feature of the state's than double the 276 identified in Imo and 200 in Akwa Ibom states. In former Anambra state, estimated damage between 1985 and 1990 was ₦6 billion, with 160 deaths. In 1988 alone, Rivers state recorded ₦106 million losses and 11 deaths when 183 villages were flooded. According to Newswatch of 26th August, 1991 former Anambra state requires ₦50 billion ($5 billion), Bendel state 14 billion, former Imo state 1.03 billion, Cross River state ₦16 billion and Akwa Ibom state ₦555 million for the capital Uyo and environs, for erositon control.

Only recently however, the presidency released ₦512 million for coastal erosion control works in seven state. In Rivers state alone, more than ₦100 million had been spend by the Federal authority by December 1990 to combat coastal erosion there. In 1989, ₦369.9 million was disbursed for control works in 12 states. But state officials see it as a mere drop of water in the ocean.

The military Administration of former Anambra state had set up an interministerial committee in 1984 to study the problems imposed on the state by soil erosion. The result of this committee revealed that Anambra state was being seriously devastated by soil erosion of all types. In February, 1986, the University of Nigeria, Nsukka held an international workshop on soil erosion, land clearing and soil testing and presented a communique to the Military Governor of Anambra state, Group Captain Emeka Omeruah. He responded by setting up a Task Force on soil erosion control. The disaster caused by soil erosion, especially gully erosion in the state is of such a magnitude that every good citizen of Anambra state should join in the fight against soil erosion menace. A better tomorrow awaits the citizens of Anambra and Enugu states, if the battle against soil erosion is won now, (Task force on soil erosion control in Anambra state, 1986).

1:2 STATEMENT OF RESEARCH PROBLEMS:

The environmental hazard of gully erosion in former Anambra state has attracted the attention of many researchers and governmental organizations, to the extent that in 1986, Anambra state set up a task force on soil erosion control. The task force started their work by enumerating the number of gully erosion sites in the state and came up with seven hundred (700) locations. The Agulu-Nanka area of Anambra state, has become notorious throughout the country because of this environmental hazard.

The regretable aspect of this erosion hazard is its effect on the newly constructed Enugu-Onitsha expressway. Before the construction of the road, there was no kind of soil erosion much less of gullying in this part of the states. But since the road came into being erosion problems have set in giving rise to land degradation. The cost of construction of the road is highly prohibitive and since the construction, the capital imput has not been adequately utilized, rather more capital is being allocated for resurfacing and maintance of degraded part of the road. There has been an increase in the gully sites and slope failure along this road. The Task force on soil erosion has identified twelve gully sites on this road. Irrespective of huge construction cost, parts of this road have undergone reconstruction because of this problem. Evidence of this has been seen in the number of diversion signals along the expressway. The diversion signals are either due to new gully sites or reconstruction of the erosion-damaged part of the exptessway. This gives rise to the use of one road lane by vehicles travelling in opposite directions. It should be borne in mind that the volume of vehicular traffic on this expressway is very high. Therefore a number of accidents have been recorded as a result of these sudden diversions along the expressway.

The focus of this research therefore is to evaluate the hydrome-

1:3 OBJECTIVE OF THE STUDY:

The specific objectives of this research are:

(1) to assess recent intensity of destruction caused by gullying;

(2) to identify the hydrometeorological factors responsible for gully erosion on the expressway; and

(3) to recommend ways of preventing this gully erosion.

1:4 SCOPE OF THE STUDY

The research was concentrated on the gully sites along the expressway and its sides. But will not consider those gullies that are inside the towns and local government areas through which the road traverses. The reason being that a lot of research works have been done, comprising these towns and local government areas, (Ofomata, 1964-1965, 1978, 1981 a,b,c and 85 a,b). These literature will be seen in the literature review. It will also concentrated only on gully erosion aspect of erosional processes.

The research will crate some awareness or some necessary precautionary measures which should be taken to prevent this gullying.

1:5 JUSTIFICATION FOR THE STUDY

Ecological problems are among the most threatening natural disasters on the earth today. The recent United Nations summit on environment in Rio De Janeiro Brazil was specifically convened to draw attention on a global scale to the immediate and long term dangers consequent upon deterioration of our environment. Ecological problems featured prominently in the dicussion to highlight the reality of this issue.

Here in Nigeria, ecological problems in general and gully erosion in particular have recently assumed a most worrisome dimention. Hardly does a day pass without either the print or electronic media carrying a news item or two about fresh occurrence in parts of the country of when it is not flood disaster in Lagos or River states, it will be gully erosion disaster in Anambra, if it is not a section of a community being caught off from the rest as a result of washing away of a bridge, it will be washing away of roads, houses, vegetables, animal farms and very often accompanied by collosal loss of life.

It therefore becomes pertinent to take a close look at this issue in form of a thesis that will not only examine the genesis of the problem but define the scope, forecast the future trends, consequences and proper scientific solutions. This is what this study modestly seeks to achieve.

1:6 LITERATURE REVIEW

In the environmental sciences dealing with problems of gully erosion like Geography, geology, soil science, civil engineering etc, it has been noticed that attention has been towards the causes and effects of gully erosion on the physical environment especially soil resources.

In Nigeria incidence of soil erosion and guly has been of much concern to every good citizen of Nigeria. However, Ofomata, (1987) on soil erosion in Nigeria: the view of a geomorphologist, argued that the phenomenon of soil erosion is a system made up of complex interacting components. Any changes in any one of its components will affect the other components of the soil erosion system and thereby affecting the entire system itself.

Sada and Omuta, (1977) in their study of soil erosion and environmental problems in Auchi area discovered that the problems are man-made, because they are the results of a thoughtless and careless disturbance of the ecological balance of the area, and lack of planning of human habitations and their associated activities.

Similarly, Jeje, (1982) on soil erosion and changes in physio-chemical properties of soil in Ejiba area of Kwara state, revealed that the very low nutrient status of the eroded soils and their hydraulic characteristics especially the poor moisture retention capacity of the surface horizons are responsible for the poor yield associated with soil experiencing accelerated sheet erosion. Ologe, (1988) studied the characteristics, processes and extent of soil erosion in the savanna region of Nigeria. In this study, he found out that gully erosion is widespread in the Nigerian savanna and appears to have been triggered off by incision of the main rivers, an event which must have taken place several hundred years ago.

However, in the case of Eastern Nigeria, of which the study area is an integral part, a greater proportion of geomorphological researches which now pose a very serious threat to the effective use and conservation of land resources. The Udi forest reserve in Enugu state was created in (1922), followed by an Anti-Erosion Plantation also in Udi, in (1928), Syke, 1940. These measures are directed towards combating the degradational effects of soil erosion. In 1938, there was a general review of soil erosion states in Nigeria by Sir Dulley Stamp. This was followed by Groove, (1951) Floyd, (1965) and Ofomata, (1964, 1965, 1966, 1967, 1973, 1978, 1980, 1981, 1982, 1984, 1985 a and b).

Ofomata, (1973) studied the nature or characteristics, causes and some possible control measures in some places like Owerri, and Onitsha province, Enugu, Uzoitem village. Ofomata (1965), Ogbukagu, (1976); Igbozurike, (1977); Niger-Techno limited (1978) have also studied the Agulu-Nanka gully erosion in the region of Anambra state. All these settled on the physical and anthropogenic processes of the area in different perspectives and processes.

Therefore in considering the inumerable havoc done to our land infact retards the growth of human and cultural civilization e.g roads, building, dams and sometimes entire villages are seriously affected.

Faber and Imeson, (1983) undertook a research work on gully hydrology and its related soil properties and they found out that runoff in the gullies are generated at the gully heads and soil slump, land-slides, rock fall have resulted from this. They concluded that gullies in eastern Nigeria are resultant effect of steep slopes, high rainfall intensities, low soil water storage capacities and reduced infiltration rates due to crusting induced by raindrop imputs.

Ofomata (1988) in his studies on the characteristics of soil erosion in the forest zone of south eastern Nigeria concluded that running water is the main agent of erosion in this area, and depends on the manner in which runoff is organised. Gully erosion occurs where runoff is concentrated along defininte channels. Infact, all kinds of soil erosion in this area, depend on the manner in which runoff is organised. Gully erosion occurs where runoff is concentrated along definite channels. Infact, all kinds of soil erosion manifest themselves in alarming rates and give rise to all kinds of gullies. The reasons are: the total annual rainfall is high, characterised by high intensity and soils (surface material) are highly erodible.

Kalu and Goodwill, (1987) on climatic impact on soil erosion revealed that geomorphic processes on the surface of the earth respond actively to climatic variation trends. And most important impact is to cause a difference in the soil moisture content and coherence of the soil strata. Clay soil regime responds to this type of climatic variability. First rains, or "red rains" in Nigeria at the onset of the rainy season have an increase P.H value and thus mildly acidic. And this plays an important part in chemical weathering.

Babalola (1987) who studied the effect of soil properties on infilteration and runoff in Eastern Nigeria, revealed that sheet wash is an effective erosion process on sandy soils, whereas on coherent soils there is resistance to splash and sheet erosion. Rills and gullies are usually the main processes of an accelarated erosion, because of increase in hydraulic gradient induced by increase in slope gradient, and high rainfall intensity because surface is exceeded and incision takes place at the point of low.

Jungerius (1963) who worked on the soils of eastern Nigeria includes a description of the physical conditions of the region. He examined the problem of the soil which is subdivided into five categories according to their morphology and the degree of evolution of their profile. Each category is then subdivided into several units according to the characteristics of the substratum and soil colour.

Lal (1976) worked on kaolinitic (fine white clay) in western Nigerian and observed that top soil removal resulted in increased gravel and decreased silt and clay contents of the surface layer of the exposed subsiols. In southern Nigeria, Obi and Asiegbu (1980), indicated that a high dominance of the sand fraction is much evidence in top layer of all the eroded soil studied. Lal (1981) in his study, also reported a decreased moisture retention capacity and increase infilteration rate following several years of erosion. The reduced saturated hydraulic conductivities according to Mbagwu et al (Ibid) were due to structure degradation as reflected in increased bulk densities and reduced macro and total porosities of exposed soils of eroded zone of southern Nigeria.

These works of Lal, (1976, 1981); Obi et al, (1980); Mbagwu, (1986) focus toward the physical properties of eroded soil. And it also exposed some of the havoc done to our natural soil by erosion

Ofomata (1964) on soil erosion in Enugu Region of Nigeria Geographical picture of the phenomenon in all its aspects, with some examples in the Enugu region). In the geological and hydrological sections of the report, the causes and consequences of soil erosion are adequately commented upon. From the social and agricultural point of view, the author describes sheet erosion as a very dangerous phenomenon for the living populations while gully erosion, even though it causes a very real loss of land seems to limit itself to reasonably small areas. In (1965), Ofomata studied also the factor of soil erosion in Enugu and he commented that the most important human factors is cutting of natural vegetation exposing the soil to erosion. And also in the road construction and various other excavation works. And also the continuous encroachment on market-places at Enugu. Ofomata listed climate as the prime physical factor of erosion. The Enugu area is a transition belt between humit coastal regions and interior dry climatic areas. The rainfall is important above all for their nature and intensity, the rainfall is usually heavy and lasts for short duration which causes severe erosion. Where soil lacking vegetation cannot control the impact of rain water. The author attributed the erosion in Enugu to comparatively steep slope, generally over 5° and some parts up to 25°.

In the bid to put the processes of erosion under control, effective measures have been suggested. Groove (1951), advocated for the increase in the degree of vegetative cover through afforestation. Ofomata, (1985) and Floyd, (1965) suggested the change of farming methods through education of farming near gullies. And Igbozurike, (1977) suggested a four pronged approach for a permanent solution of the problem, namely: Enclosure zonation, resettlement, structural alternation and community surveillance.

... et al (1951) succinctly state that the four fundamental to prevent water from concentrating and moving down a slope in a narrow path; to impede the falls and soil creep in the gullies affect the smooth flow of runoff. Runoff in the final analysis according to Hard (1970) are products of precipitation, and any relationships existing according to Andrews (1962) is largely independent of the size and topography of the catchment area and of their geology and structure of the soils.

SUMMARY OF THE LITERATURE REVIEW:

The foregoing literatures have revealed all aspects of soil erosion in different parts of Nigeria and the various part of eastern Nigeria where the study area formed an integral part. The topics of different scholars have been reviewed, bringing out their various findings in their various findings in their areas of research.

However, despite the studies alone in these areas, non has been done along the Enugu-Onitsha expressway. It should be borne in mind that this expressway is of crucial importance because it serves as a quick and connecting link between Enugu and Onitsha, the two great cities of Anambra and Enugu States. The volume of traffic flow in this expressway is very high, since it is also an interstate expressway. Considering the financial aspect of the road construction and maintenance which is also very high, the road is very important as ther e is life in Anambra and Enugu states in particular and Nigeria at large.

Therefore, this research wil l help to fill the gap that has been created in this area of study.

1:7 DATA COLLECTION AND METHODOLOGY

The topographical, political and vegetational maps of the study area wqs collected from the Enugu State Ministry of works, lands, transport and survey, Enugu. The maps was used as a base maps from which the background information was obtained, and also compilation of the study area map. This has been also used to extract some information about the physiographic and landuse pattern of the sites which was not possible to obtain practically from the field.

Infact, data collection for this research was based on primary and secondary data. The primary data or field work for the research paper includes:

(i) The measurement of the morphormetric characteristics of the gullies - depth, length, width and the number of gullies in each site, the slope and its orientation was measured using linean tape and ranging poles. After which the density of the gullies was calculated using the formula:

$$\frac{A}{X1} \text{ ------------------ } (1)$$

where A = in (Km^2), $X1$ = mean length (m).

The variahce (r^2) of the length, width and depth was calculated.

(ii) The volume of soil lost was calculated from the formula: Vol = (L x W x D) ---------------------- (2)

where vol = Volume in (M^3), $X1$ = mean length (m),

D = mean depth in (m) and W = mean width in (m).

(iii) Soil samples was collected randomly from different gully sites along the expressway and was tested in the material laboratory of the Ministry of Works and transport, Enugu. The samples were tested for particule size, the liquid limit and plastic limit. Plasticity index was calculated using the formula: IL = Pl = plastic limit.

(iv) The physiographic and landuse pattern of these area was identified

(a) total stream length in (km);

(b) Basin area in (Km^2);

(c) Forest cover in percentages;

(d) Forest cleared and built up area in percentage;

(e) Mean elevation in (M);

(f) Mean channel slope (Mcs)

(g) Drainage density.

The mean channel slope was obtain by:

(i) defining the drainage basin

(ii) finding 10% of the distance and its elevation;

(iii) finding 85% of its elevation and distance;

(iv) subtracting the value of elevation at 10% from that of 85%.

(v) Finally dividing the value by the whole distance of the drainage basin marked.

Using planimeter, the value of basin area total stream length was obtained. To calculate drainage density, the total length of stream in each catchment was divided by the catchment area in (sqkm).

Thus the drainage density expresses the closeness or spacing of the stream channels.

The formular is $Dd = \frac{lu}{Au}$ ---------------4

where Dd = drainage density, Lu = sum of all the stream length and Au = area of the Basin.

The secondary data for the research includes:

(i) Rainfall, temperature and relatives humidity. The data was collected from Ministry of Agriculture, Agrometeorological section at Market Garden, Enugu from (1984-1992) as was available. The data was collected from three stations along the road, namely Enugu, Onitsha, at two extremes of the study area and Nkwelle in the middle.

(ii) The rainfall intensity and the return period for these areas was determined from the daily authographic records of Enugu and Onitsha stations. That of Enugu is between (1956 - 1987),while that of Onitsha is between (1971-1988) giving the totals of 31 and 18 years respectively. The data was collected from climat section of Meteorological Institute Oshodi, Lagos. The rainfall intensity was calculated using the formula (mm/hr) ---------------------(5).

The partial duration return period of each intense rainfall was determined using the formular:

$$Tr = \frac{N + 1}{M} \quad \text{------------------(6)}$$

where m is the order of ranking, N is the number of water years for each duration. The value so obtained was plotted on extreme probability paper and the return period of 1, 2, 3, 5, 10, 15, and 25 of intensity versus return period was extracted. The intensity that was extracted were then plotted against duration as a function of return period on log-log paper.

Finally the bar-graph for 1, 2 and 3 years return period of the two stations was plotted to determine the variations between the two stations. The bar-graph of some variable were also drawn to know the once that has a high effect on each gully site and the reasons.

1:8 THEORETICAL FRAMEWORK

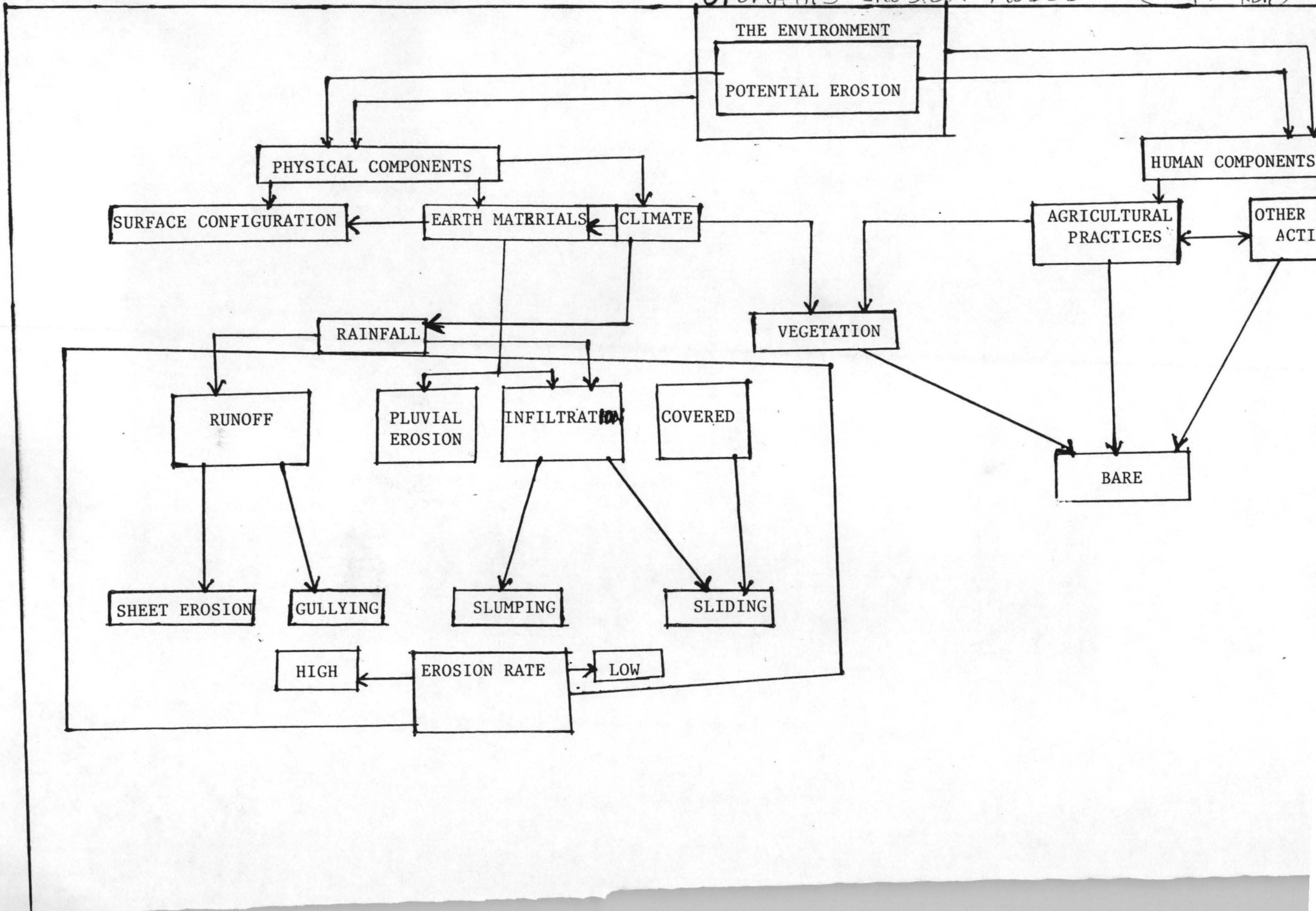
The theoretical framework of this research is based on the soil Erosion model by Ofomata, (1987). A model as defined by Lee, (1973) is an obstracfion from reality which is used to gain conceptual clarity to reduce the world to a level we can understand and specify. The basic assumption of this Model is that each factors of erosion is capable of being considered on its own as well as in conjuction with other factors. The various relationships between the factors of soil erosion and the phenomenon of erosion are given in fig. 1:8:1, as for the humid topics is emphasized by the fact that rainfall is the principal element of climate considered.

The model is self-explanatory. Briefly, potential erosion of the environment has both physical and human components. Each component is itself made up of a number of constituent factors which interact in different way and at varying degrees to produce different types and rates of erosion from one part to the other of the humid topics. Rainfall is a major factor in the observed relationships. Direct relationships are shown by solid lines while indirect connections are shown by pecked lines. The erosion rates box represents only an attempt at a general indication of what is expected from certain soil erosion components.

Of various factors of soil erosion recognised, only population density, surface configuration (relief), rainfall, vegetation and surface materials have been isolated as critical to the development of the soil erosion phenomenon and used as the parameters for formulating the model.

In my study area, population is not important so there is no data on it. But on the other hand this was represented by the magnitude of antropogenic forces expressed in terms of percentage of cultivated and forested areas, (fig. 1:8:1).

OFOMATA'S EROSION MODEL (FIG. 1.8.1)



CHAPTER TWO

2:0 ENVIRONMENTAL INFORMATION OF THE STUDY AREA

2:1 LOCATION OF STUDY AREA

The study area is Enugu - Onitsha expressway. The expressway covers about one hundred and eight kilometers (108 km) in length. This is the major link road connecting Enugu and Anambra States. The study is on gully erosion along the road and the road sides.

The Enugu-Onitsha expressway lies approximately between latitude 6° 06'N and 6° 30'N and longitude 6° 40'E and 7° 30'E. The study area is clearly represented in the fig. (2:1:1) below. This area lies within an elevation of 100m and 1,500m above mean sea level at its high and lowland areas respectively. The highland araa with elevation of 1,500m is around Enugu while the lowland with elevation of 100m is around Onitsha.

2:2 CLIMATE:

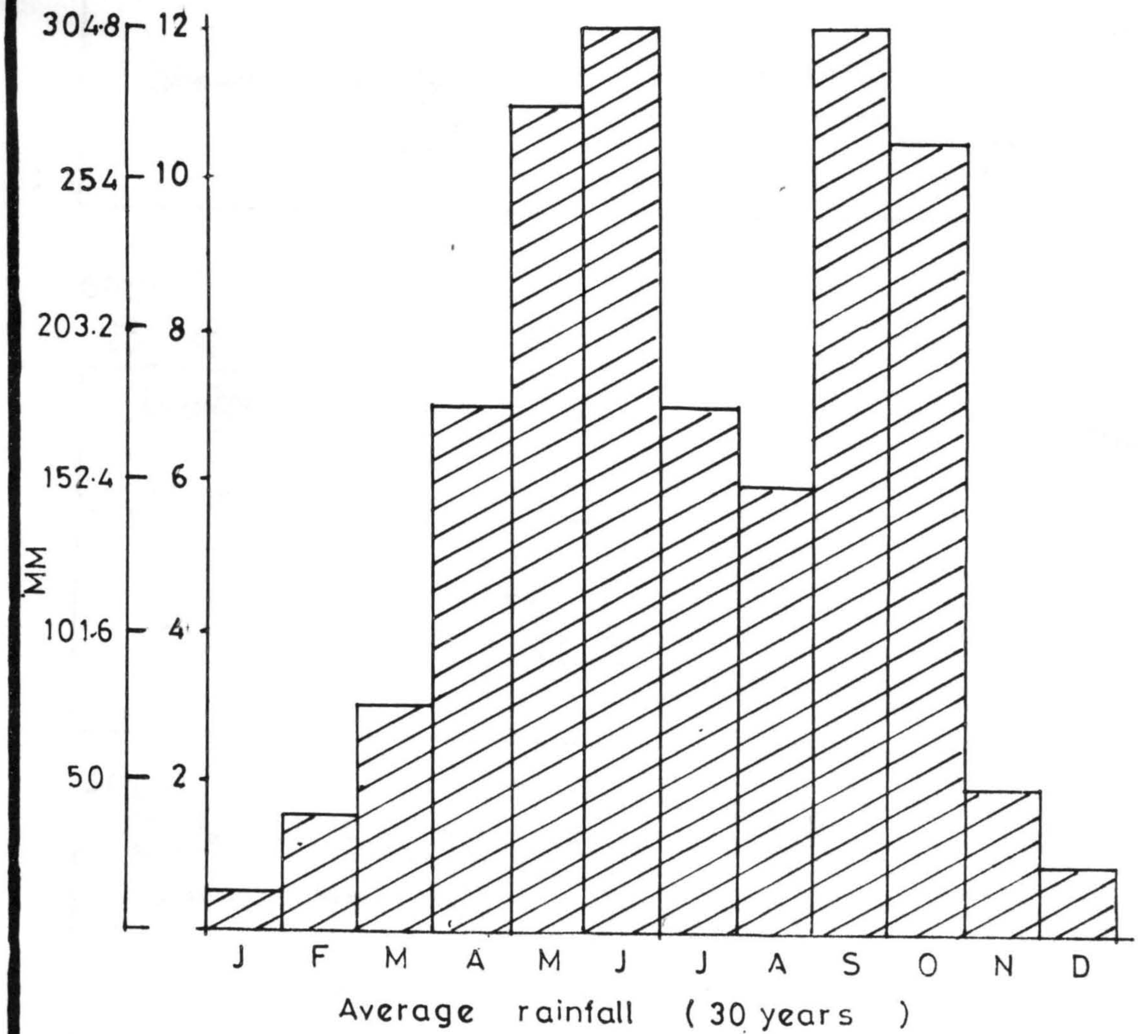
The project area has a typical tropical climate, which is marked by two prominent seasons. The wet and dry climate, refered to as "NW" under the KOPPEN - GEIGER system of climate classification. The area lies within the zone B of the homogeneous ecological and rainfall regions of Nigeria, according to Kalu and Godwill (1988).

> "Zone B extends from the coastal magines inland to about 9°N and covers the rainforest areas of Nigeria. Its rainfall parttern is definitely bimodal, with an annual maximum in most parts in June and a secondary maximum in September as in Zone A. In most places in this zone, the characteristic mid-

"August break", is observed especially in the central and western areas of Nigeria. The effect decreases both eastwards and northwards due to the decreasing influence of the lowlevel anticyclonic ridge emanating from the nearer presence of the south hemispheric subtropical anticyclone over the Atlantic".

The climate of this area is influenced by two major contrasting air masses which are, tropical continental (cT) and tropical maritime (mT). The tropical maritime originates from the southern hemispheric subtropical anticyclone over the south atlantic. This air mass influences the rainy season of this area. And its influence starts from late March to October. This airmass is moisture-laden and thus "rain bearing wind". It should be noted that the gross features of rainfall pattern in Nigeria, as in other parts of West Africa, are usually considered in association with the inter-tropical Discontinuity (ITD), (Hamitton and Archbold 1945; Adejokun, 1965). Thus an inherent association of the daily rainfall patterns with the space and time variations of the ITD, (Ilesami, 1979). Therefore, the areas with the highest rainfall are in south-western Nigeria where the rain-bearing south-westerlies accompanying the (mT) air strike the coast more or less at a right angle, (Ojo, 1977). The study which is in south-eastern NIgeria shows some micro-variation in rainfall as a result of coastal and influence of River Niger in Onitsha. The Nkwelle station which represents Onitsha area has a mean annual rainfall total of one thousand eight hundred and twenty five millimeters (1825mm) and monthly maximum of three hundred and ten millimeters (310mm). Enugu, which is at the other extreme has annual rainfall total of one thousand two hundred and forty seven (1247mm) and monthly maximum

FIG. 2.2.1(A) DISTRIBUTION OF RAINFALL FOR ENUGU AREA



of these two extreme stations has an annual rainfall of one thousand three hundred and twenty five (325mm) and monthly maximum of two hundred and four (204mm). These values were calculated from the 10 years rainfall records of these areas.

The tropical airmass which originates from the subtropical high pressure belt of sahara influences the dry season of the area. This is dry wind and dust laden. It takes position from November to early March. It is characterised by dry Harmattan wind blowing from the northeast to this area. During the Hammattan both visibility, temperature and relative humidity are generally low.

Throughout the year, the temperature of the area is high ranging from the mean of 32°C in dry season to 27°C in wet season. But due to some local influence the temperature of the study area varies. At Enugu the annual maximum is 36°C while the annual manimum is 24°C. Onitsha has an annual maximum of 33°C with the minimum of 22°C. And Awka 34°C and 22°C for maximum and minimum temperature respectively.

The relative humidity also varies. At Enugu the annual maximum relative humidity in the rainy season is 82 per cent with the minimum of 53 per cent in the dry season. Onitsha has an annual maximum of about 93 per cent in rainy season with 74 per cent maximum in the dry season. Awka has an annual maximum of 87 per cent and minimum of 74 percent in the wet and dry season respectively. These figures were also calculated from 10 years record of temperature, relative humidity and rainfall of these stations collected from market Garden Enugu.

2:3 VEGETATION:

The vegetation of Enugu-Onitsha Expressway was typical rainfores, but due to intense landuse system which has degraded the forest to derived savanna. Remnants and patches of high rainforest can be seen

stream sides as "galary forest". For instance.

sides of Mamu, Ekulu river and Ever-valley. Also as some areas especially from Nkwo to some parts of Oji-River, tall trees are seen dried but still standing. This is evidence of changing forest.

However, the detailed existing vegetation of the selected gully sites as was observed in the field and read in the vegetation and landuse map with scale of 1:250,000 can be summerised as follows:

Awkuzu:- Farmland and immature forest with derived savanna.

Ifite-Awka: Farmland and immature forest.

Awka:- This is also under farmland and consist of derived savanna. Crops found here are bannana, Grasses are antropogen spp. Digitaria spp, the shrubs are Afromosia Caxiflora, combritum.

Nsude/Idor-Puve and Ugwuoba:- Wooded shrubs, oil palm and farmland, immature forest and patches of woodland.

2:4 SOIL:

The soil of the qully affect area in the study area consist of mainly reddish earth of about 9-10m in depth. This belongs to the great soil Groups of latosols according to the classification of the United States Department of Agriculture, (1938). However, Barbour, Oguntoyinbo et al (1972) classified the soil of the study area as belonging to ferrallitic soil because of the presence of iron-oxide from which the soil derived its colour. The soil of the area is highly weathered, leached and contained comparatively smaller amount of humus which could have helped to bind the soil particules together. Some parts consist of clay which is rather prone to soil creep and landslide.

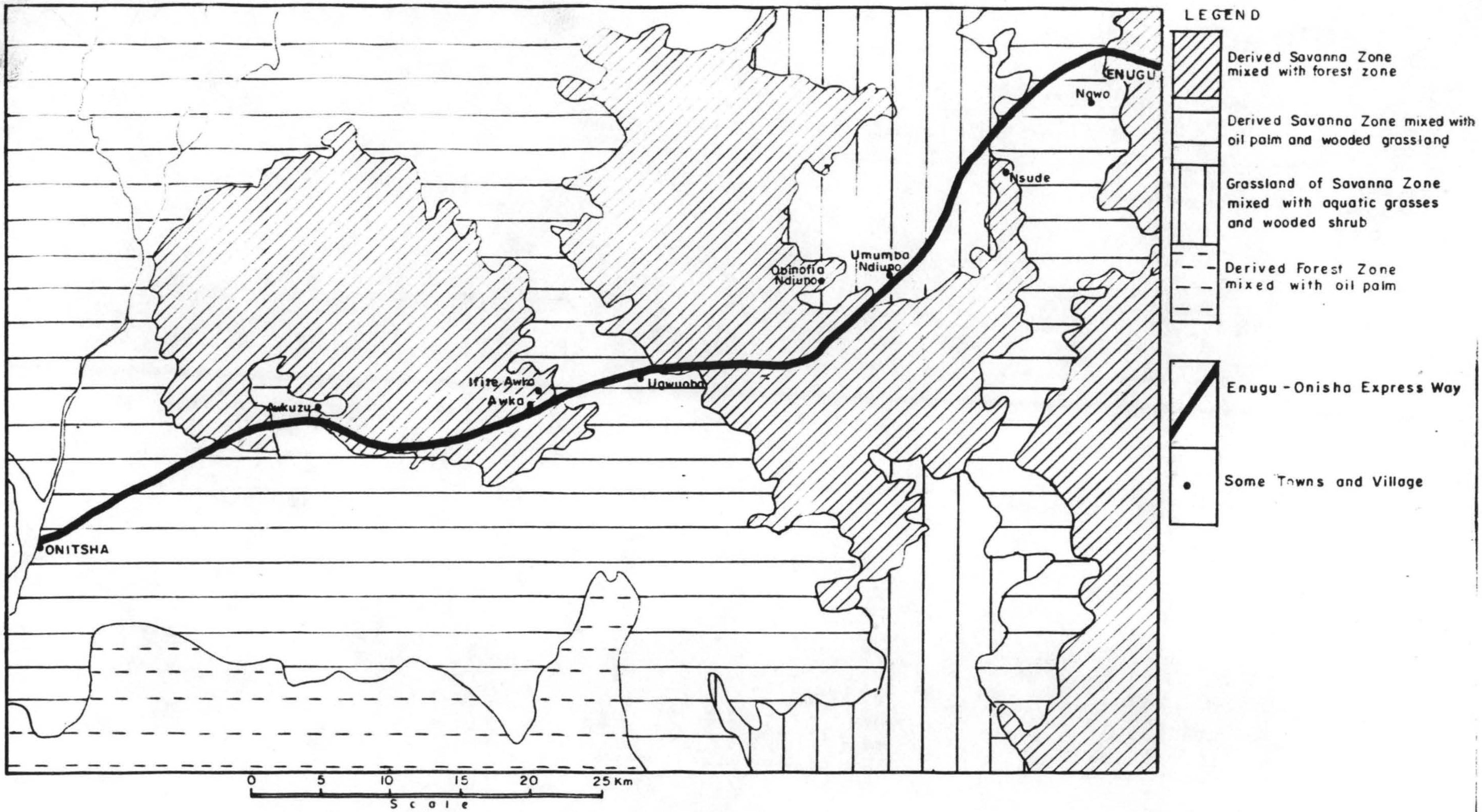


Fig. 2.3.1 : VEGETATION MAP OF ENUGU - ONITSHA EXPRESS WAY

2:5 GEOMOPHOLOGY:

The Enugu-Onitsha expressway of Anambra and Enugu states exhibits a bad-land type of topography which is characterised by a dissected scarp slope with adjacent low land, and valleys. The scarp slope is part of a regional system of escapement stretching from Awka to Orlu in Imo state (the Awka/Orlu upland). Still in this area we have the Udi sandstone plateau which terminates in gigentic east-facing scarp, and passes westwards to the Imo River clay valley, which is part of the Niger syncline covered with sands and clay. Over the whole region the elevation ranges between 120-150 meters in the valleys to over 240 meters on the plateaux - through highlands of 300 meters are exceeded in places on the plateaux. The scarp edge of the enscap-ment in most places consist of steep and vertical walls of depressional complex structures. The scarp exhibits two generations of ravine type, tending generally north or south with the revines cut exclusively into unconsolidated materials often showing a characteristics broad, almost semi-circular valley heads. These gullies also exhibits sharp pointed peaks, steep sided walls, and jagged knife like ridges along some parts of the road.

The unconsolidated materials in which the gullies are carved; predominantly loose sediments with an overburden of red earth, and this is prone to mudflow, soil slump, soil creep as well as landOslide along the expressway.

2:6 GEOLOGY:

The main geologic units of the study area are the Manu formation (lower maestrichtian), Ajali formation (middle maestrichian), Awgu formation (companion), Amaki formation (Eocene). The distribution of this formation is seen in the geologic map provided (fig. 2:6:1). Lithologically the Enugu-Onitsha expressway consist of sand, shale, located at Enugu side of the expressway. The Imo shale at some part of Oji-River around manu river and Awka area, this is the younger type of manu shale. Therefore they are subjected to expansion and contraction during the rainy and dry seasons respectively. Sands are highly erodible especially the sandstone. The Ajali sandstone of part of Awka and Oji-River and Amaki formation are highly affected by erosion.

The manu formation consists of rapidly altering beds of sandstone, mudstones with coal seen at several horisones (Orajaka reporting Basin and Wilson 1925). He also reported that the sequence of the slope escarpment is cyclo the mix. The succession consists from bottom upwards of grey and sandy shale within bands of fine grained sandstone containing thing bends of grey shale, sandy shale and then coal.

The Ajali sandstone overlies the manu formation and attains an average thickness of 150m, Orajaka (1985). It is essentially a friable coarse-grained white sandstone. Lithologically, boreholes on the Udi plateau show that the formation consists of fine coarse grained sandstone. Clay and coal units occur towards the bottom of the boreholes, indicating that the transition zone between the Ajali sandstone sequence is covered by a mantle of red earth.

The Imo shale lies below the Ajali sandstone. And it is the younger form of manu formation.

This is a clay-shale interbedded with sand bodies at different horizones, siltstone, calcareous mudstone, grey to dark.

The Awgu lies below the Imo shale from Enugu to Onitsha. This is a fine to medium grained sandstone, massive pebble and locally cross-bedded mirox siltstone and carbonaceous shale.

The Amaki formation lies within Awkuzu-Onitsha area. And within Awka and Awkuzu lies Nanka sandstone. These are loose and friable, fine to medium coarse grains. They are Porous and permeable with cariegated colour. These are highly affected by erosion and gullies in particular.

- Table 2:6:1: Geological age and lithostratigraphic sequence in Anambra/Enugu State.

Geologic Age in Million years	Lithologic sequence
Moicene (26)	Benin formation lignite series
Paleocene (65)	Imo shale formation (Ebenebe sandstone)
Campanian	Enugu shales formation Awgu shales formation (Awgu sandstone)

Source: Ofoegbu C. O. (1985).

2:7 HYDROLOGY

The aspect of hydrology of the study area that is going to be considered are the rainfall amount, intensity and drainage characteristics.

One of the most important characteristics of rainfall in this area is its intensity, usually expressed in millimetres per hour. Very intense storms are not necessarily more frequent in this area of its high total annual rainfall. Therefore, the frequency of occurrence of high storms including the rate and depth of rainfall are important for soil and water conservation structures. In general, storms of high intensity last for fairly short periods and covers small area. Storms covering large area are seldomly of low intensity, but may the gullies still retain the top soils of red clay sand. The rate of gully development is slow at this level.

In the intermediate stage, the gullies have cut through the clayey soil into the subsoil of loose cohesionless sands and silts with intercolations of claystone, mudstone and shale. At this stage the gullies have a dish appearance showing the widening of V-shape of youthful stage. The rate of downcutting and sidewall processes become rapid.

The parent material, the relative position of the water table and rainfall intensity greatly influenced the advancement of gullies of the intermediate stage. Where the water table is far below gully floor, even during the rainy season, active down cutting continues concurrently even as the gully floor approaches the local baselevel in the area. The gullies tend to develop several prongs due to differential weathering in response to the general slopes of the ground surface and the runoff directions. With time these gullies coalescence, leaving isolated knife edge sand within the gulllies, (Plate 1 and 3).

Gradually the red earth capping these sand are removed by the effects of faulting or fracturing and gravity slides on soil. The exposed loose cohesionless sands are then quickly removed to the gully floor level by splash erosion. In localities where the water table is close to, or rise above the gully floor during periods of gully precipitation, downcutting becomes negligible and sidewall processes and headward gullying become rapid. Where the gullies have truncated the water table e.g Plate 4 and 5, there is vertical slopes and terrance development.

The combination of relatively high intensity and long duration storms occurs infrequently, but when it does occur a large amount of rainfall results. These infrequent storms cause much of our erosion damages and may result in devastating floods.

These groundwater efluents or discharge in this area gives rise to spring and streams that drain the area in small volumes constituting headwaters of Awka and Awkuzu gully sites, which are perennial streams.

CHAPTER THREE

3:0 OBSERVATIONS

3:1 GULLYING INTENSITY ALONG THE EXPRESSWAY:

Okagbue and Ezechi (1988), have identified three types of gully development in the south eastern Nigeria: the youthful, intermediate and old stages.

In the gully morphology of the Enugu-Onitsha Expressway both the youthfull and intermediate stages were identified. Gullies in this expressway have not reached the old stage, because the road was constructed about 13 years ago, and also the frequent interference by the Federal Ministry of Works has not allowed the gully to stabilize or become dormant. Both the youthful and intermediate stages are associated with active down-cutting and lateral expasion of the gullies.

The gully intensity depends on the local parent materials (geology); the rate of functioning (to be disoussed) depends on the operating factors, the depth and the stages of development. This can be seen in the geology map provided in (fig. 2:6:1) that the sites are concentrated in the Ajali and Nanka sandstone with one in Imo shale, two in Ebenebe sandstone, Their intensities can be seen in the (Table 3:1:1) below. In the youthful stage, the gullies are actively down-cutting and have V-shaped valleys with high slope angles. In the study areas, where recent slides or slumps have occured the angle ranges from 15° to 20°. Vertical slopes are common. Generally, in the youthful stage

3:2 RESULT OF THE LABORATORY ANALYSIS:

The soil sample were collected by the walls of each gully sites in each location. Laboratory of the geological survey under the Ministry of works, Housing and Transport, Enugu state.

The results were plotted into graphs, that is percentage passing against size of soil particules in millimetres, (see appendex II). Then, the gramilometric parameters were obtained from the particule size curve. The percentage clay and silt materials lies between 0.0001 millimetres to 0.6mm; fine sands, 0.6 millimetres to 0.2 millimetres; medium sands, 0.2 millimetres to 0.2 millimetres medium samds, 0.2 millimetres to 0.6mm; coarse sand, 0.6 to 2mm, and gravel 2mm to 10mm.

Plates 4 & 5

Therefore, to get the actual value for each particule size in the sample, the percentage of each material point was taken. In each material, the lower percentage is subtracted from the higher material point of each gravel size. And this provides the nature of particule size distribution in each location, see the table below:

Table 3:2:1 - Gramilometric Analysis of soil texture in percentage:

Location	A	B	C	D	E	F	G	H	I	J
Clay and silt	17	19	38	28	34	16	10	30	25	21
Fine sand	14	5	13	14	22	12	12	26	29	20
Medium sand	40	36	37	38	33	43	51	28	27	40
Coarse sand	20	39	10	13	8	19	27	12	19	12
Gravel	9	1	2	1	3	10	1	4	4	7

A	=	Onyeama MIN	(8km)
B	=	Uwani	(11km)
C	=	Nsude	(14km)
D	=	Umumba Ndiuno	(20km)
E	=	Obinofia Mdiuno	(30km)
F	=	Ugwuoba	(63km)
G	=	Awka	(69km)

From the overall result, it is noticed that in all the gully affected areas sampled, the percentage of sand is the greatest and ranges from 70 percent, the percertage of medium sand dorminates and ranges from 33 percent to 51 percent. Fine sand and coarse sand ranges from 5 percent to 26 percent and 8 to 39 percent respectively. The presence of clay/silt and gravels is insignificant. Clay and silt ranges from 10 to 30 percent and gravel from 1 to 9 percent.

Table 3:1:2 The limites of moisture Retention in percentage:

Location	Liquid limit(LL)	Plastic limit(Pl)	Plasticity Index
A	28	20	8
B	30	15	15
C	30	12	13
D	38	23	15
E	37	21.4	6.6
F	29	24	5
G	30	24	6
H	36	20.5	5.5
I	35	22	12
J	35	20	7

Source: Lab. work.

The plastic, liquid limit and plasticity index, indicate the moisture range through which the soil materials have the properties of plastic material. That is when it can flow as liquid and when it can be rolled into thread. it also shows the degree of cohesiveness of the soil. The plasticity index declines with increase in sandiness and increases with increase in clay content.

The range of liquid limit as seen in the result of laboratory work is 28 to 38 percent with a mean of 32.3. The moderates indicates that the soil material are capable of storing reasonable amount of water, which is considered to be detrimental to slope stability. The variation of liquid limit with depth is not considered to be detrimental to slope stability. The variation of liquid limit with depth is not

The plastic limit ranges from 12 to 24 per cent and tends to be higher with increase in clay content of each sample. The range of plasticity index is 5 to 16.6 percent, showing that the soil materials are of low or non-plasticity according to Jumikis, 1962.

3:3 Physiographic and landuse characteristic of the Gully site Basins.

The local control suggested by the seasonal allocation of runoff are indicative of the importance of basin physiography and landuse. The physiographic parameters determined are basin areas of the selected gully sites, main channel slope, drainage density, forested and farmed areas, total stream length and mean elevation. These were abstracted from vegetation and topographical map of 1:50,000. The drainage channels not shown by the blue lines on the maps were identified by a method suggested by Ebisemiju (1976). The mean channel slope was obtained by:

(i) defining the drainage basin,

(ii) finding 10% of the distance and its elecation

(iii) finding the 85% of its elevation and distance

(iv) subtracting the value of elevation at 10% from that of 85%.

(v) finally dividing the value by the whole distance of the drainage basin marked.

Using planimetre, the value for basin area and total length of streams were obtained. To calculate the drainage density, the total lenght of stream in the catchment is divided by catchment area in square kilometres. Thus the drainage density expresses the closeness or spacing of the stream channels.

The formula is:

$$D = \frac{lu}{Au} \quad \text{----------} \ (4);$$

where D = drainage density; Lu = sum of the length of all streams;

PHYSIOGRAPHY OF THE GULLIES IN THE EXPRESSWAY

		Volume of SOIL LOST	LENGHT (M)	VARIA-NCE (R^2)	WIDTH (M)	VARI-ANCE (r^2)	DEPTH (M)	VARIA-NCE (r^2)	DRAINAGE EENSITY (DD)	BUILD-UP FOREST CLEARED (%)	SLOPE 0°	Area (Km^2)	NO. of Gullies per location	DDensity of Gullied (M/Km^2)	GULLY STAGES
1.	ONYEAMA MIN (A)	55513.25	403	98	14.5	6.4	9.5	5.03	0.151	30	34°	3.5	5	245.2	IN
2.	UWANI (B)	11625.12	243	30	9.2	1.21	5.2	1.01	0.135	30	25°	2.4	12	101.5	YO
3.	NSUDE (C)	1398.6	90	15	7.4	1.02	2.1	0.04	0.11	30	18°	1.2	5	75	IN
4.	UMUMBA-NDIENO (D)	24817.8	311	87	10.5	4.0	7.6	3.2	0.75	25	24°	1.8	8	172,7	YO
5.	OBINOFIA-NDIUNO (E)	3336.6	134	46	8.3	2.5	3.0	1.48	0.06	70	20°	1.5	6	89.3	IN
6,	UGWUOBA (F)	1004.91	57	29	4.1	0.7	4.3	.57	1.8	60	23°	0.21	4	271.4	IN
7.	AWKA (C)	1305.72	78	34	5.4	0.01	3.1	0.62	0.1	45	15°	1.15	5	67.8	Y
8.	IFITE-AWKA (H)	7938	150	18	9.8	2.84	5.4	1.4	1.5	65	21°	1.04	7	144.2	I
9.	AMAWBIA (I)	21598.1	184	98	11.7	4.5	6.5	3.7	0.65	52	28	3.2	8	194	I
10.	AWKUZU (J)	38336.22	387	90	12.7	5.1	7.8	4.05	0.03	50	48	4.1	15	94.3	[illegible]

determines the total rain water that can be transmitted as runoff. Since clay content influences soil infilteration rate. Therefore percentage of clay content was got from the soil analysis. Mean elevation is the lowest point in the basin and are subtracted from the highest.

Then the land use parameters which are the percentage of basin area covered by forest together with tree crops and farmlands including plantations. This was estimated f.om the drainage are used from the vegetation map.

Table 3:3:1.

3:4 Annual Rainfall and Runoff:

It was not possible to take "on the spot" runoff and rainfall in this gully sites due to lack of instruments and a very short time duration. However, runoff was calculated from the runoff eoefficient derived from the annual rainfall and runoff of the drainage basin which was given by Anyajidike and Phil-Exe, (1989) in their study of runoff respond to drainage basin in south eastern Nigeria.

They came up with runoff coefficient (RC) of some basins in the south-eastern Nigeria. This parameter was used because the study area Enugu-Onitsha expressway falls within these basins.

The annual rainfall data of Enugu, **Awka and Nkweke** were collected from market Garden Enugu (1984-1989). And this expressway was constructed about (13 years) ago. Therefore the data covered half of the roads life. Since gullying is a continuous process, out-of the ten locations in the stud· area, three falls within the Nyaba drainage basin and Enugu rainfall station; six fall within the Ajali drainage basin and Awka rainfall station. and one in Anambra basin and Nkwelle station.

The annual runoff was computed by multiplying the runoff coefficient of each drainage basin by the total annual rainfall for each station

ANNUAL RAINFALL AND RUN OFF

TABLE : 3:4:1

LOCATIONS	NAME OF BASINS	RAINFALL DATA IN EACH STATION		1984	1985	1986	1987	1988	1989	1990	1991	1992
IDOW-RIVER UWANI NSUDE	NYABA	ENUGU	ANNUAL RAINFALL	1586.6	989	787	1078.6	1073.2	1189.3	1097.3	1156.4	1176.2
			RUNOFF COEFFICIENT (RC)	0.260								
			ANNUAL RUNOFF	4±1.26	257.4	199.4	280.4	2080	309.2	290.4	300.2	207.4
AWKA UGWUOBA OBINOFIA UMUMBA-NDIANO IFITE-UKPO AMAWBIA	AJALI	AWKA	ANNUAL RAINFALL	1980	1705.2	1007.6	1603.2	1685.5	1656.8	1716.2	1645.3	1831.4
			RUNOFF COEFFICIENT (RC)	0.127								
			ANNUAL RUNOFF	251.4	216.5	127.9	203.6	214.0	210.3	212.4	201.3	257.1
AWKUZU	ANAMBRA	NKWELLE	ANNUAL RAINFALL	1799	1905.8	1628.2	1517.4	2155.5	1943.0	1827.2	1767.1	1952.2
			RUNOFF COEFFICIENT (RC)	0.064								
			ANNUAL RUNOFF	115.2	121.9	104.2	97.1	137.9	124.3	118.9	108.1	127.3

3:5 Patterns of Gullying

The patterns of gullying depends on the nature of flow surface, nature of the soil and the underground water. For instance loose, friable, fine and unconsolidated sands are easily eroded, while coarse and consolidated shales are poorly eroded. Permeable, saturated and cohesionless sand are easily pried out and carried away by running water (Egboka and Orajaka 1986). The gradient of the ground surface is a determining factor for velocity of running water. Then the lithologic and sedimentological properties of grain size, degree of concentration also affects the rate of gullying. Based on the best favoured factors, gullying can be initiated from slope failure in the following processes through flowage, sliding or slumping.

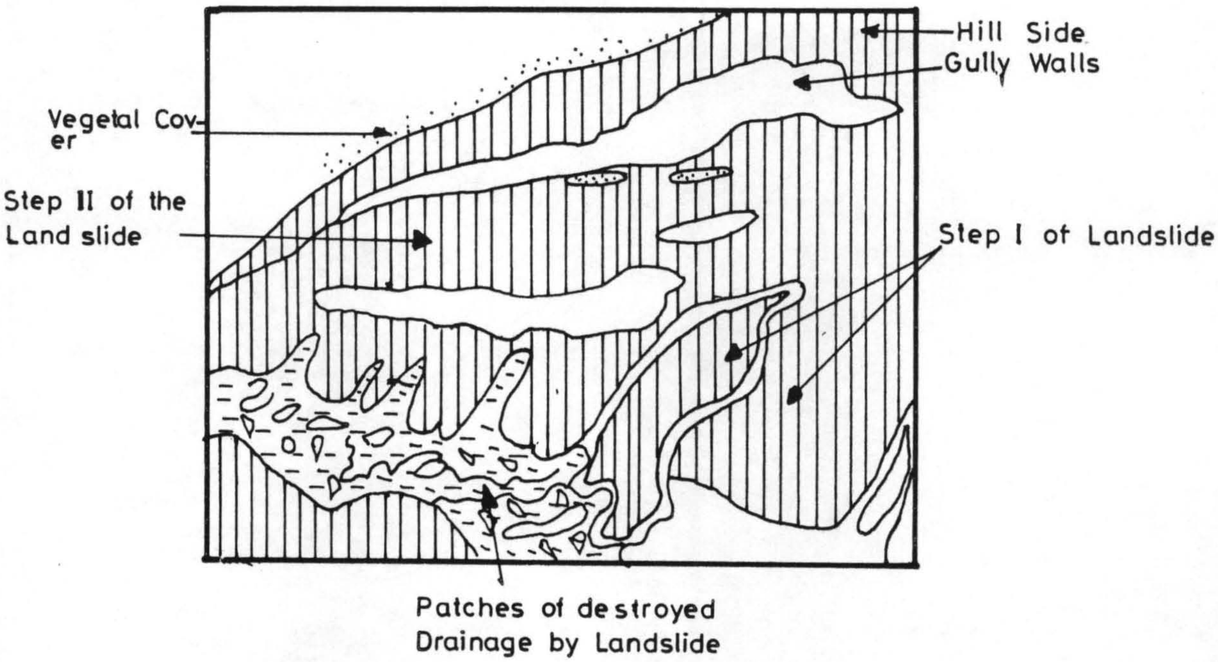
FLOWAGE:

This is as a result of slope failure which is often initiated by tension fracturing or cracking caused by slope undermining. The undermining involves the soaking and subterranean erosion of the loose sands at the lower levels of the loose sands at the lower levels of the gullies. Gullying initiated by flowage was observed to cover at:

(a) locations where the gullies have exposed the cohesionless sands and silts, plates 3 and 4;

(b) locations where construction was truncated the water table and slope toes are constantly in contact with equitard, fig. 3:5:1. Flowage does not occur in gullies still located within the clayey sands, hence condition (a) above is controlling factor for occurrence of slope failure by flowage. The combination effect of pore water and seepage pressure coupled with the slaking action of the water cause the strained sands at the slope too to loose their strength and become soaked into liquid. The liquid sands

Awkuzu (79Km) from Enugu



movement of unfiltering rain water within the exposed loose sands tends to subterean erosion as sin in the fig. 3:5:1. The topstratum eventually falls into the bottom. This process repeats itself, and the gully if not protected advances through the prough the progressive soaking to liquid, flowage, cracking or fracturing and sliding.

SLIDING:

The field observation shows that sliding takes place after the slope toes has been undermined and topstratum has lost its foundation. The stresses in the topstratum are shown by the cracking and fracturing behind the crest of the slope. Therefore, the earth mass begins the downslope movement. The shape of the failure surfaces depends on the size of the moving earth mass. The moving mass may reach the guly bottom undisturbed but in most instances the materials disintegrate before reaching the slope toe as screes.

TOPPLING:

This is a form of slope failure. This was observe in some locations at Awka and Ugwuoba areas. This process is controlled by the parent material surfaces. Toppling failure occur at gully locations where the parent material section is made up of discontinuous sandstone beds or lateritized shale beds mixed with clay material, underlain by the cohesionless white sands. The process is initiated by the undermining by overland flow, infilterating rainwater and sliding of earth material continuously until the layer of sandstone or lateritized shaly beds is left projecting into the gully (fig. 3:5:2). This projecting rock layer is acted upon and weakened by alternate wetting and drying until finally a fracture or crack develops on its upper surface. The rock body then bends into the gully depth and later falls or tumbles to the gully floor. This process is termed toppling.

The materials are broken into rubbles. These rubbles are carried away by flood in the intermediate stage of gully development. But at the youthful stage the rubbles remain at the slope toe and contribute to stability of the slope.

BLOCK FAILURE:

This occurs at locations where parallel tension fractures or cracks run ahead with advancement of the gully fronts (fig. 3:5:3). This is common where gully is rapid that at active gullies like my study area, especially where the clayey sand topstraum is thin with very thin vegetation or bare surfaces. When this fracturing develops in the gully front, large bodies or earth materials are often affected and slide down into gully. This is observed at Awka and Idow Rivers (Plates 3 and 4).

RILLYING TO GULLYING:

This is the process of gullying which was formally described in (fig. 3:5:4). This process occurs especially in a bare soil or scanty vegetation which is also slopy. It is initiated by overland flow which develops into concentrated runoff. This concentrated runoff working on the bare and slopy lands cut into channel or rill erosion. If this is not protected the concentrated runoff using its tools (debris) eats into the sides of the channel which will later develop into gully erosion. This process of gully is seen in umumba Ndiuno site Plate 1.

3:6 Rate of Functioning:

It is understood from the field studies that the gullies can be classified into three genetic types, namely Basal level, scarp gullies and incidental gullies.

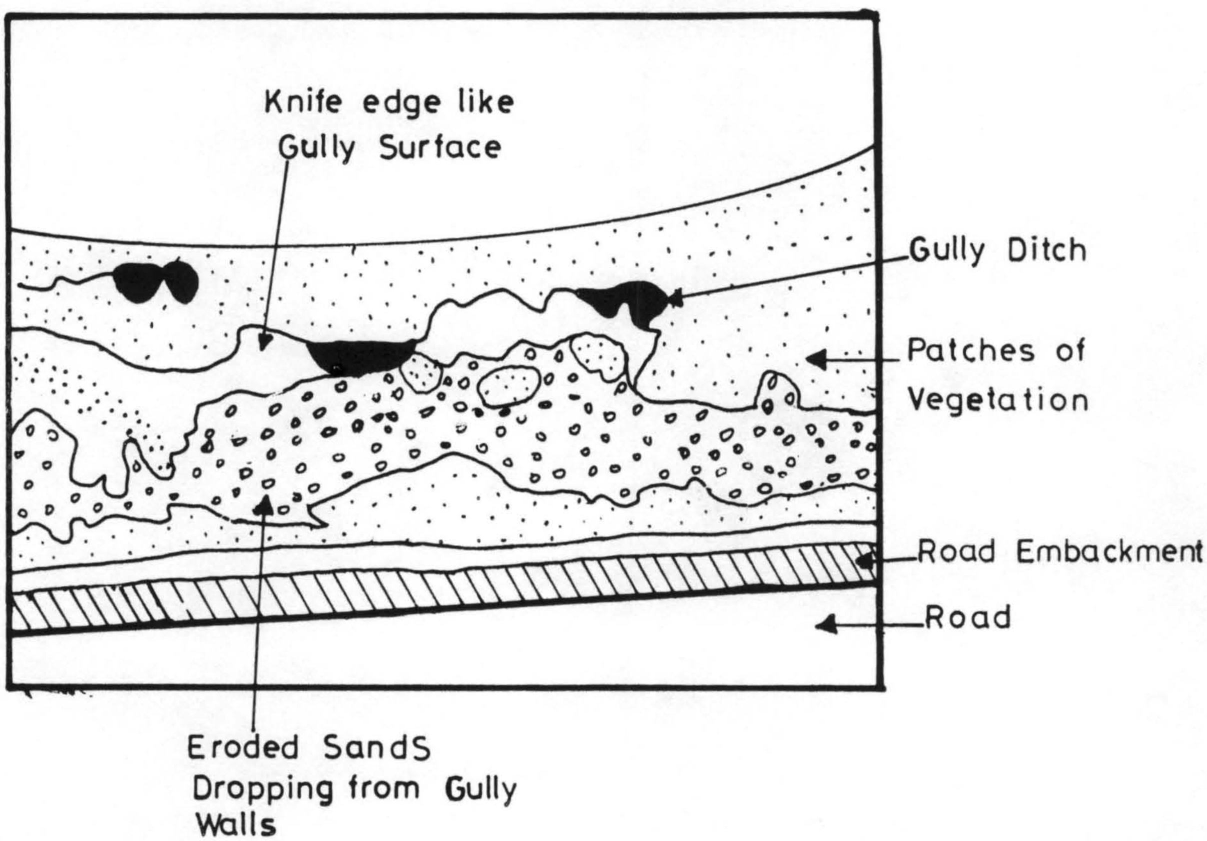
Base level gullies originate at the local base level streams ... groundwater recharge along their flow channels. This gully flow path is directed upwards and seepage forces lead to the formation condition termed (Boiling ground) on the stream bed. Gradually the quick condition leads to soil flowage and retreating of the stream banks as the loosened soil materials are removed by the flowing stream. Slope failure by sliding and slumping flow by dispersal of slide material by the stream banks which are thus over strained. This overstraining leads to increase in pressure which causes faulting, cracking and factiring of subterranean surfaces. The gully site near the fly over of Ekulu River opposite the filling station at Eva-valley is a good example of this feature. This has nearly cut the express into two, but for the timely intervention of the Ministry of Works (Plate 6). There is also a lot of accidents here because of gully retreat coupled with the sharp bend in this area. If this type of gully is not quickly protected it continues until the whole hill is reduced to the level of the stream.

SCARP GULLIES

This type of gully originates at levels where changes in elevation are due to variations in lithology and soil properties such as permeability and cohesion. The outcroping of cohesionless sands on a valley slope provides favourable environment for the initiation of this type of gullies by flood. As runoff flow from the more resistant topstream, it floods the underlying loose sands, robbing them of their apparent cohesion and transporting them downslope, plate 1 and 3. This creates scarp which is soaked with further flooding by water and leads to soil creap or flow down the slope.

Scarp gullies were also seen in localities where the landscape is a little slopy, rill erosion will develope. During rainstorms concentrated runoffs deep cuts into the lower surface. When the upper resistant soil cannot support itself again it developes cracks on

The contact of Ajali Sandstone and Mamu Shale at Uwani in Ngwo (11Km from Enugu).



Incidental Gullies

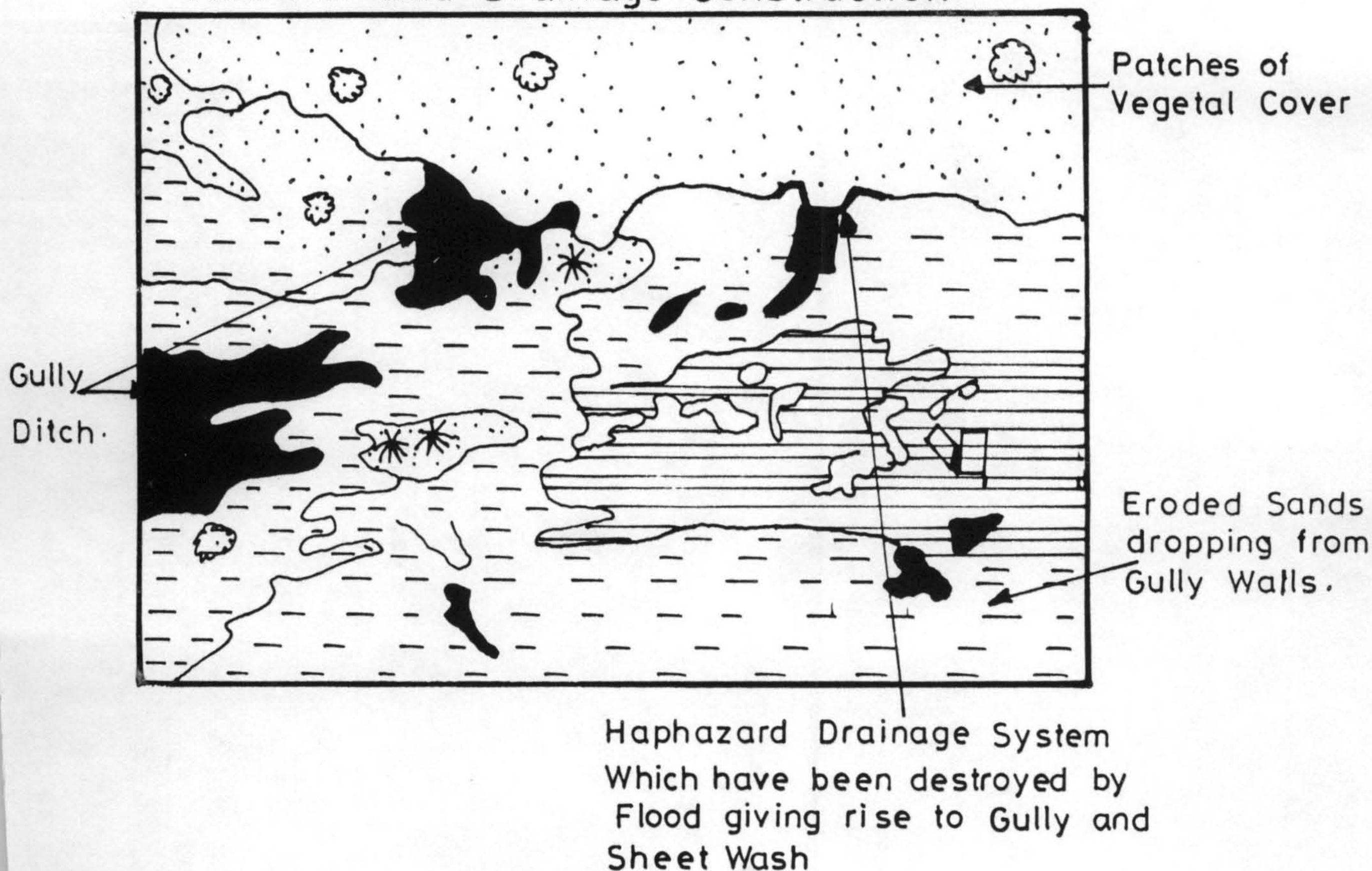
Incidental gully result from the direct human interference with the environment. Civil Engineering works, particularly road construction (which is the background of this project) contributes immensely to the development of incidntal gullies. Road cutting which expose the cohesionless sands ultimately lead to gully erosion. The seasonal scarping of local roads remove the cohesive topstratum and most often give rise to roadside gullies which is covered in almost all the attached plates. The haphazard construction of culverts and drainage channels results in the development of runoff which, with adequate slopes, acquires enough momentum which is used by the flood to work on the unprotected weak sands. This leads to falling of concrete livnning and extensive gullying, plate 7.

3:7 RAINFALL INTENSITY AND RETURN PERIOD

Precipitation is the most important component of the hydrologic cycle and has a dominating influence on several hydrologic phenomena occuring as a result of complex interactions. It is the primary source of water for infilteration, percolation in to the soil, runoff, floods and it is the basic cause of erosion.

Therefore, rainfall intensity frequency data are required for design of engineering structures, and the analysis of erosion and flood problems. It is essential that collected rainfall data should be analysed using hydrologic techniques so that they can be converted into usable forms. Rainstorms, whose intensities are analysed are mostly of relatively short periods of uninterrupted rainfall. It has been noted in chapter (2:7) that combination of relatively high intensity and long duration occurs infrequently, but when it does occur, a large total amount of rainfall results. Generally the rains

Obinagu Ndiuno Showing Gullying as a result of bad Drainage Construction



come in form of intensive violet showers of short duration especially at the beginnings and ends of the rainy season. While rain may fall continuously for two or more hours it is noticed that most of it falls during the first minutes of the period of the storm. In former Anambra state, most rains are supplied by convectional storms which have initial peak of high intensity and then tails off into a drizzle which may last for several hours. This is seen in the computation that intensities are always high at 0.2 mins, and deminishes from there to 6 hrs and so on. Appendix ( ).

CHAPTER FOUR

4:0 ANALYSIS

4:1 Computational Method of Rainfall Intensity and Return Period:

Intense falls from threshold values of 12:7mm, 15.2mm, 20.3mm, 25.4mm, 25.4mm, 25.4mm, 30.4mm, 38.1mm and 38.1mm were recorded for durations; 0.2mins, 0.4mins, 0.7mins, 1hr., 2.0hrs, 3.0hr, 6.0hrs, 12hrs. and 24hrs respectively. These were extracted from Met 141 and converted to the corresponding average intensities using the formula (mm/hr). For example, an intense fall of 12.7mm of a duration of 0.2hr has an average intensity of 63.5mm/hr. These average intensities were then ranked in descending order of magnitude, where the highest was accorded the value of order M = I, the second highest of the order M = 2, and so on.

To obtain the partial duration data set, all peak intensities above the given threshold for each duration were used, assuming that each peak value is independent of the proceding one. The number of values used for each duration may be greater or equal to the number of water years N on the record.

The return period of each of the ranked intensity was computed using the expression

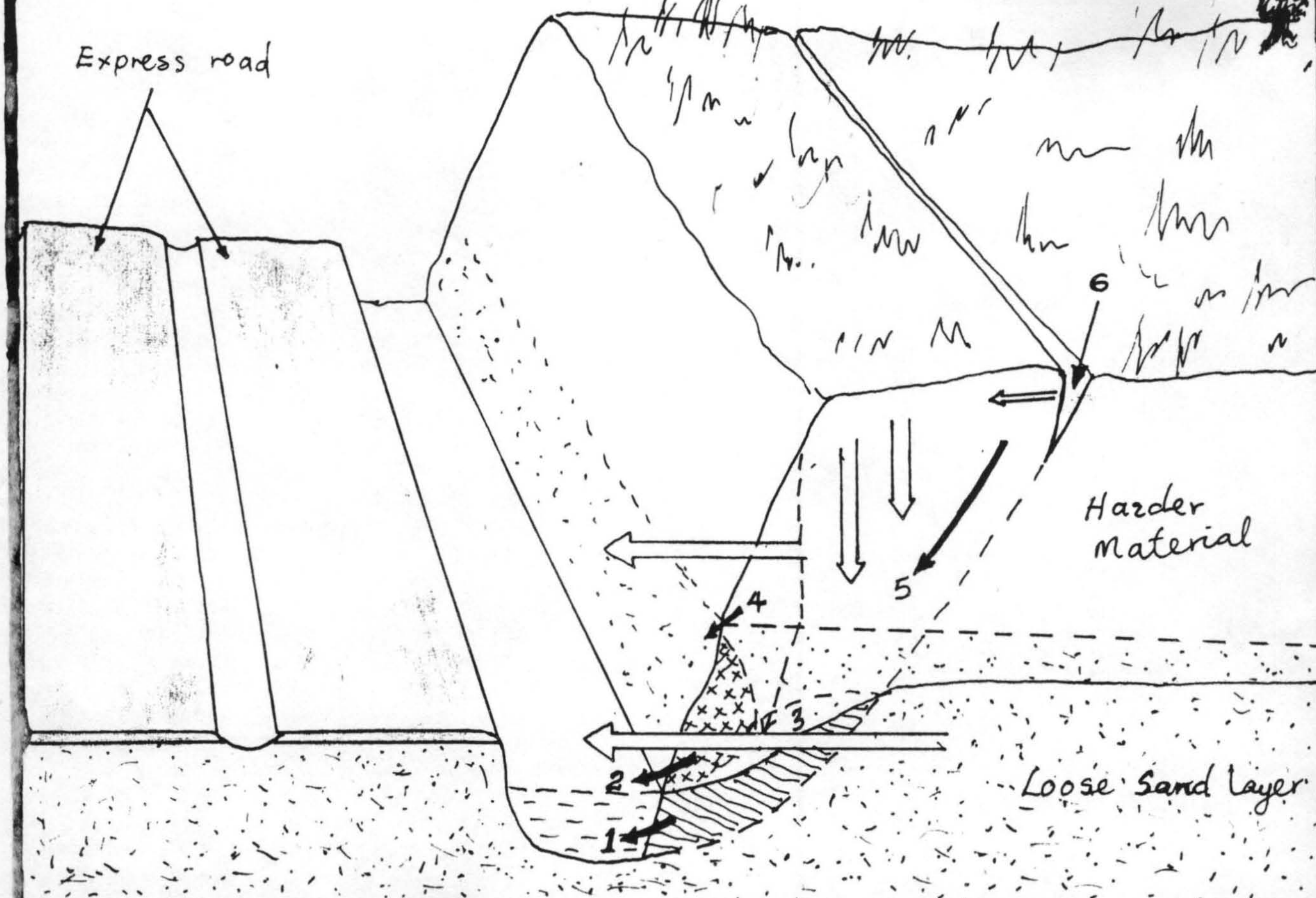
$$Tr = \frac{N + 1}{m} \qquad \text{---------- (6)}$$

where M is the order of ranking, N is the number of water years for each duration in the partial duration series (Table 3:7:1).

These values were then plotted on extreme probability paper and the desired values of intensity/return period extracted. The desired return periods for these study were 1,2,3,5,10,15 and 25 years.

The intensity so extracted were then plotted against duration as a function of return period on Log-log paper.

FIG. 3.5.1 FLOWAGE INITIATING GULLY SIDE WALL PROCESSES WHERE THE WATER TABLE HAS BEEN TRUNCATED



1 = soaked and undermining by flowage

2 = slumping of saturated loose sands

3 = undermining by subterranean erosion

4 = sliding failure

5 = Larger landslide resulting from extensive undermining by progresive soaking to liquid.

⟹ Forces and weight of material

6 = Tension fracture / crack.

FIG. 3.5.4: MODE OF BLOCK FAILURE

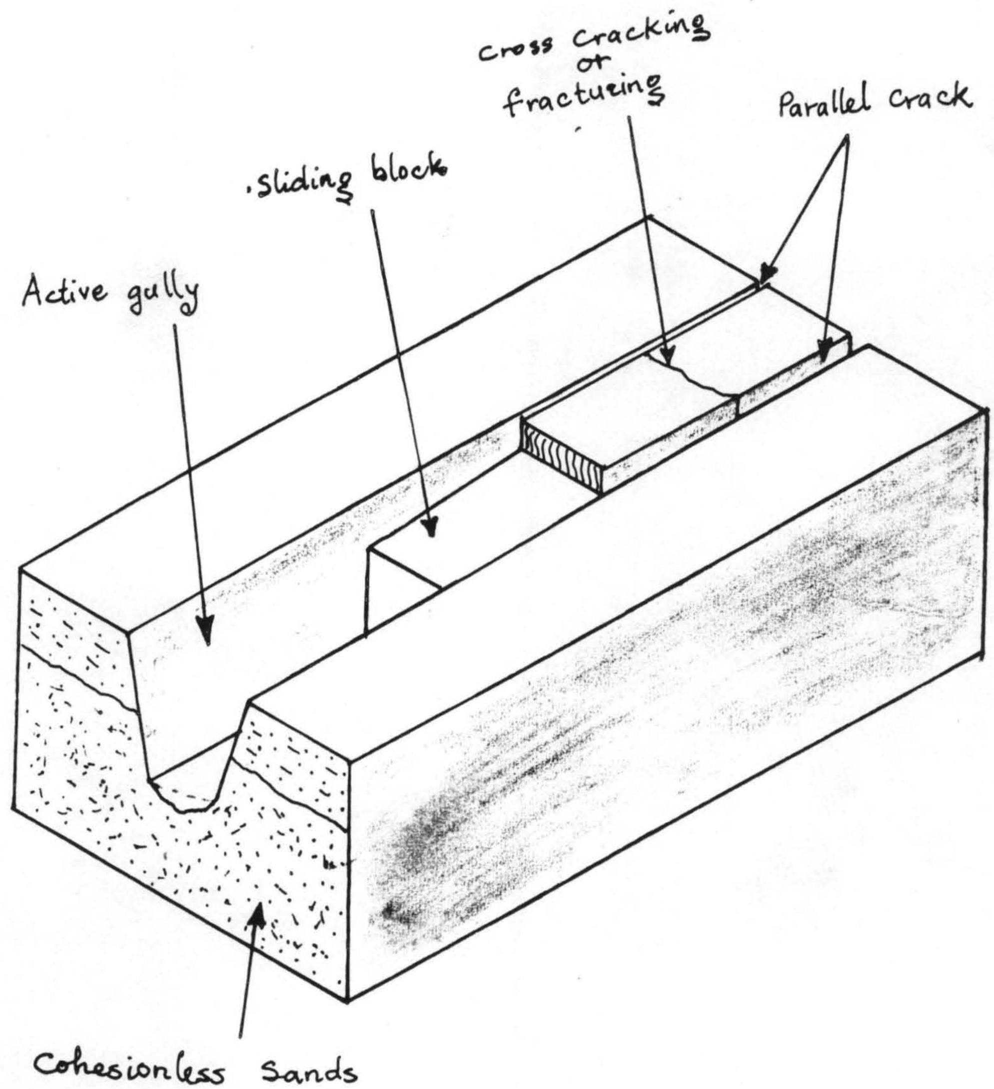
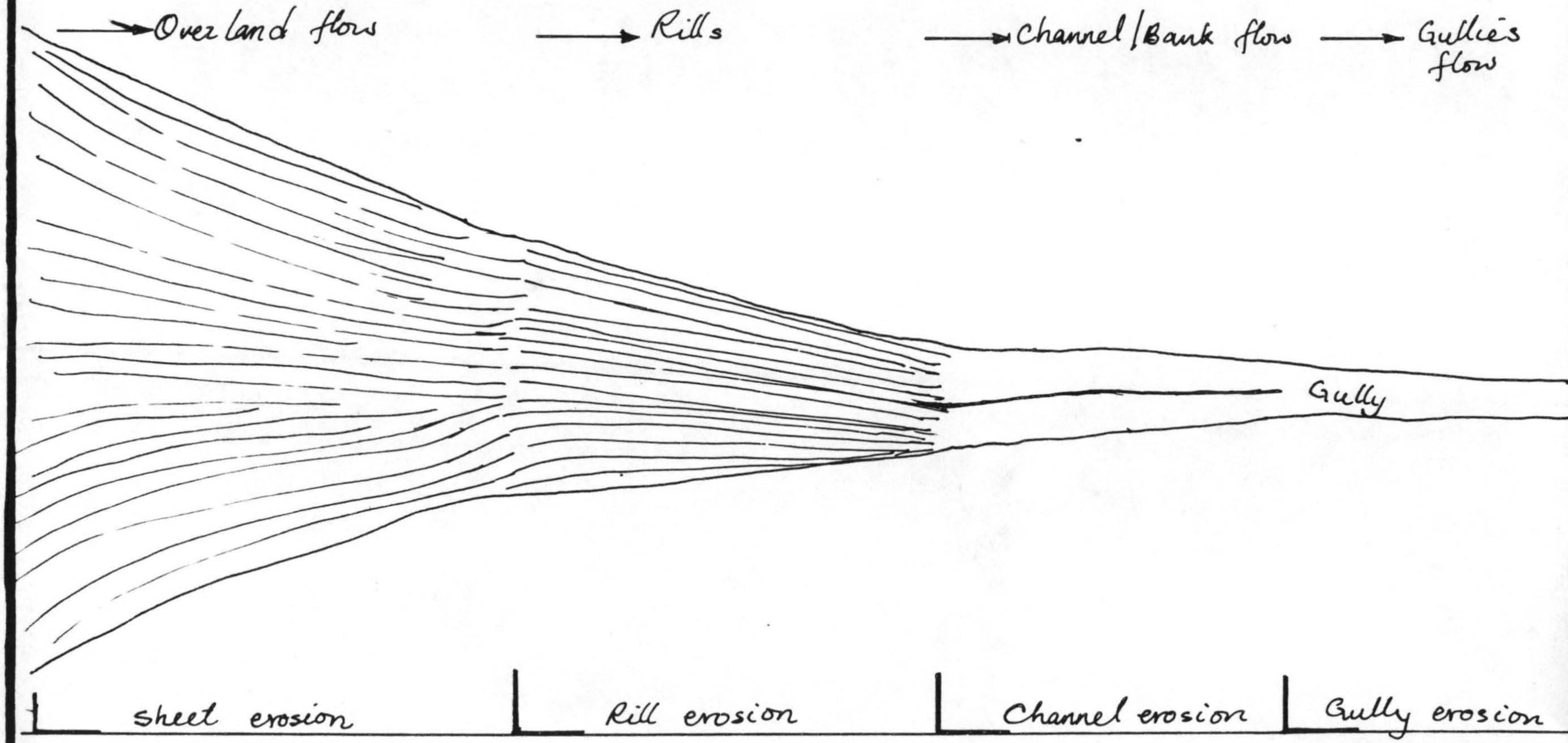


FIG3.5.2: TYPES OF SOIL EROSION



Sourse Egboka & Orajiaka, 1985.

4:2 The result of intensity duration curves and Bar Graph

4:2:1 Fig. (4:2:1) showing the relationship between the intensity and return period. There are 9 lines of best-fit, each representing the probability of the reoccurrence interval (return period) of various intensities of a given duration. It can be seen that the recurrence interval varies directly with rainfall intensity over a given duration. The variation tends to be higher for short durations than the longer ones.

4:2:2 The log-log plots (fig. 4:2:2) of intensity/duration curves shows an inverse variations. Therefore, the greater the intensity, generally, the shorter the length of time it continues. Care has been taken to plot the curves approximately as a straight and parallel lines in other to remove the non linearity for duration ($t < 1.0h$). The curves become closer with increasing return period. This is because the number of event involved in the subsequent return period is high compared with the latter. And with the nature of calibrations in the log-log paper which has been done to come closer to accommodate this increasing return periods.

4:2:3 In the fig. (4:2:3) the bar graph of the return period of 1:2 and 3 years. It has been observed from the two stations that intensity decreases with time. And has confirmed the above statement that "the higher the intensity the shorter the length of time it continues and vise versa".

The contractors of the Enugu-Onitsha expressway did not take the critical intensities and their return periods into consideration, before the construction. And this has resulted to the flooding and destruction of some culverts along this road. For instance in Obinofia Ndiuno junction and Awkuzu area of this road, flood has destroyed [illegible]ior part of the culvert which has agravated the damage of gully

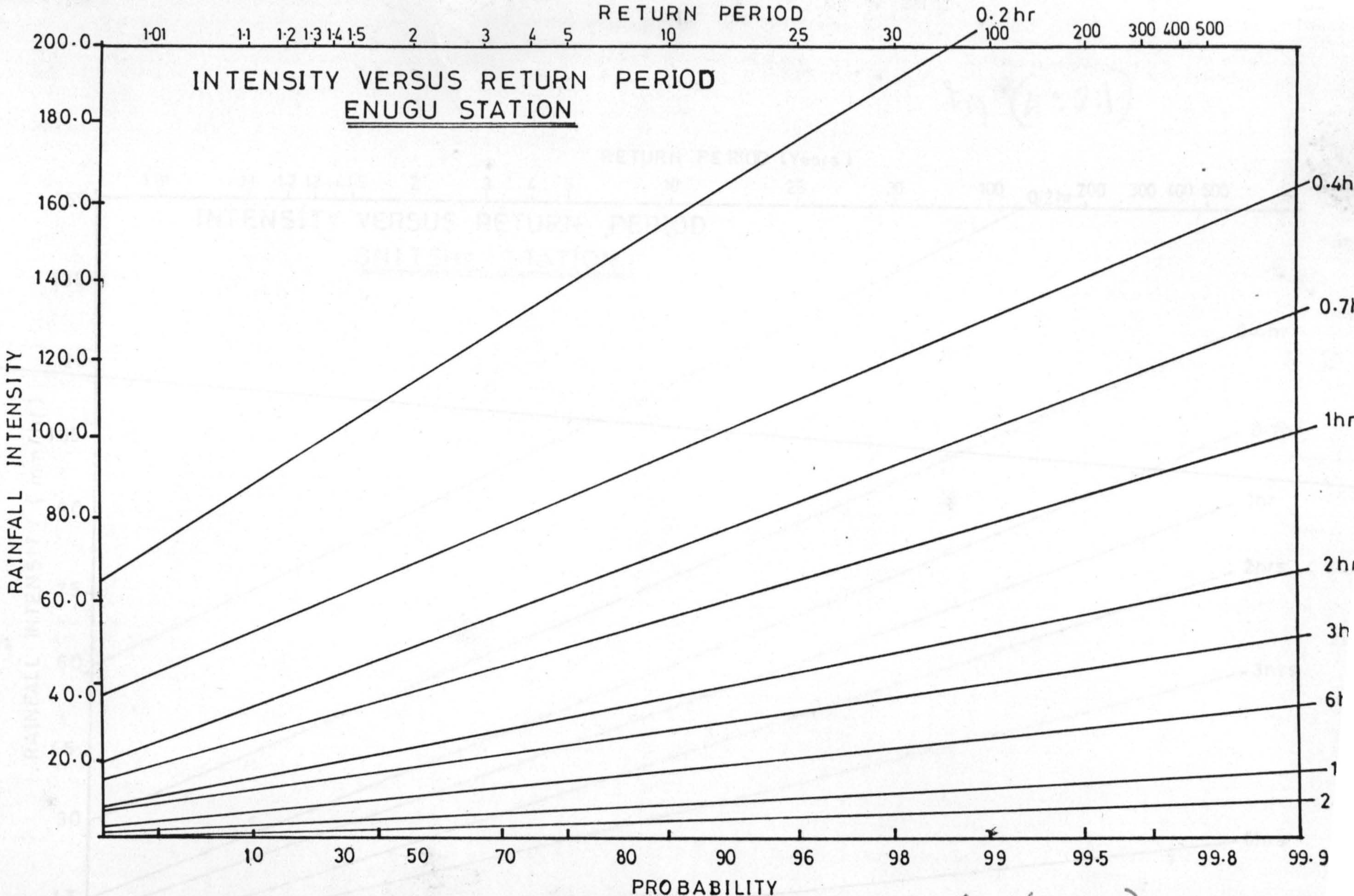

RETURN PERIOD
1·01
1·1
1·2
1·3
1·4
1·5
2
3
4
5
10
25
30
100
200
300
400
500
INTENSITY VERSUS RETURN PERIOD
ENUGU STATION
RAINFALL INTENSITY
200·0
180·0
160·0
140·0
120·0
100·0
80·0
60·0
40·0
20·0
0·2hr
0·4h
0·7h
1hr
2hr
3h
6h
1
2
10
30
50
70
80
90
96
98
99
99·5
99·8
99·9
PROBABILITY

Fig. (H: 2·1)

Fig. (4:2:2)

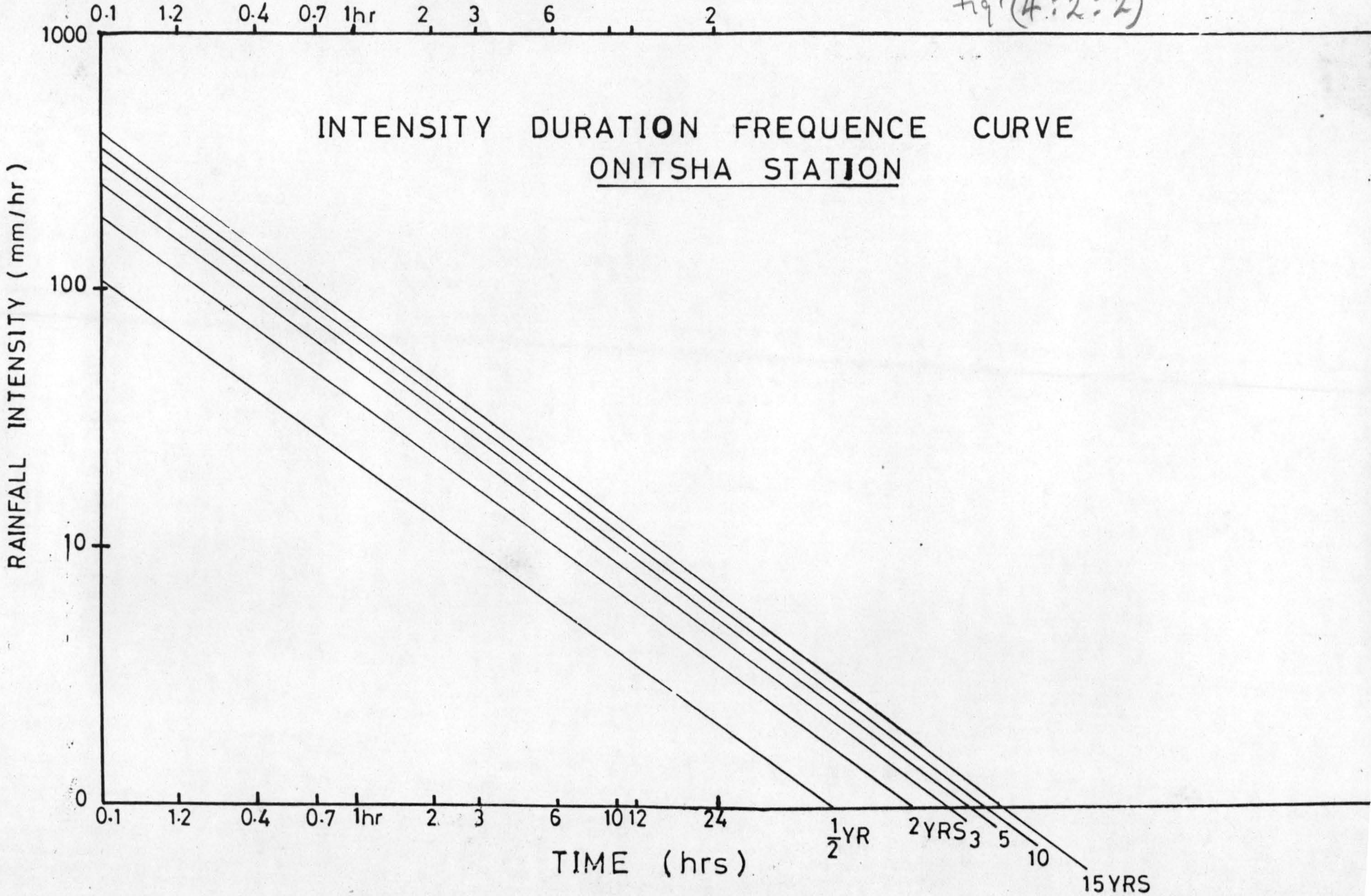
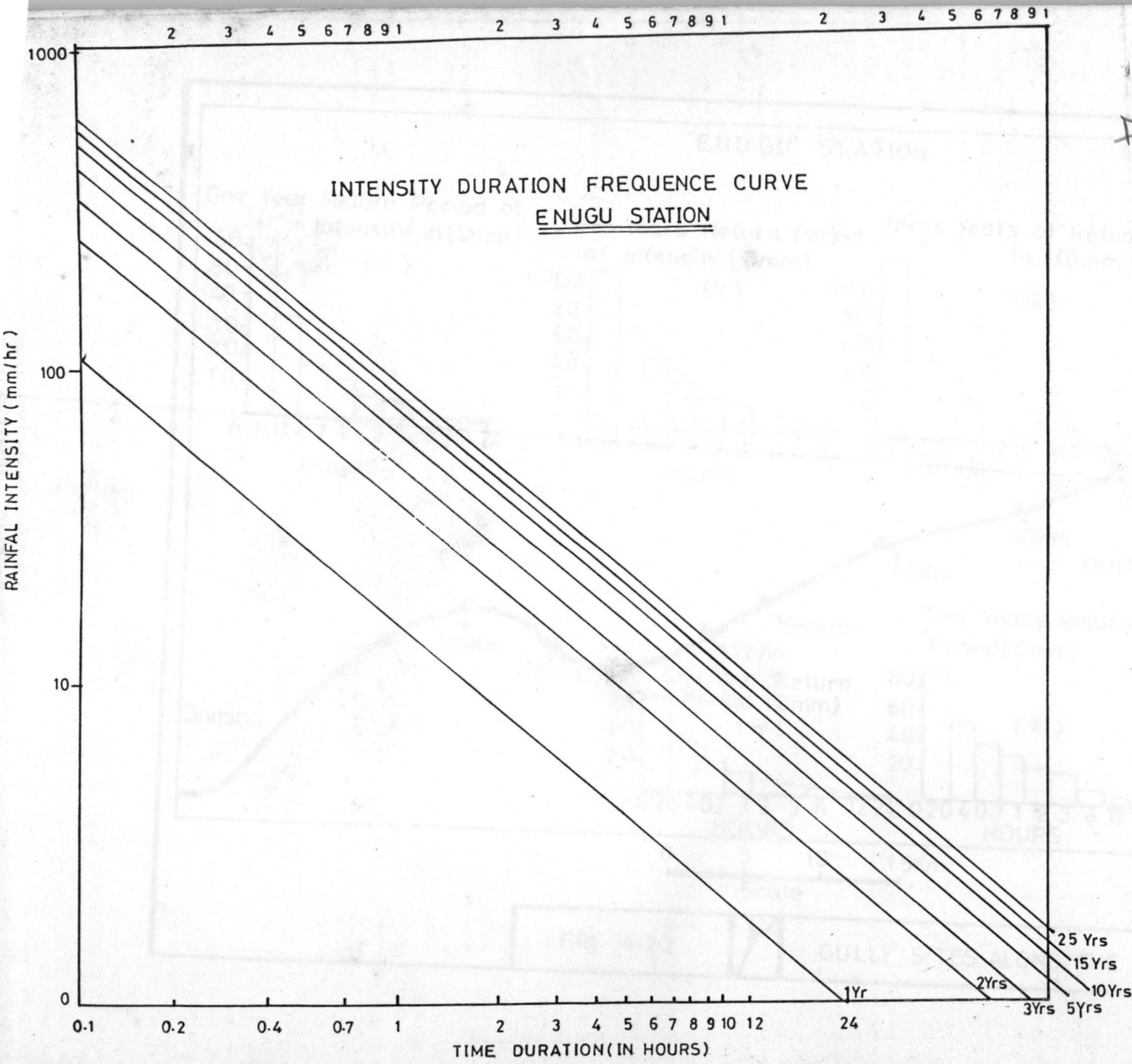

INTENSITY DURATION FREQUENCE CURVE
ONITSHA STATION
RAINFALL INTENSITY (mm/hr)
1000
100
10
0
0.1
1.2
0.4
0.7
1hr
2
3
6
10
12
24
TIME (hrs)
1/2 YR
2 YRS
3
5
10
15 YRS

Fig. (4:2:2)


INTENSITY DURATION FREQUENCE CURVE
ENUGU STATION
RAINFAL INTENSITY (mm/hr)
1000
100
10
0
0·1
0·2
0·4
0·7
1
2
3
4
5
6
7
8
9
10
12
24
TIME DURATION (IN HOURS)
1Yr
2Yrs
3Yrs
5Yrs
10Yrs
15Yrs
25 Yrs

4:3 BAR GRAPHS OF PARTICULE SIZE SOIL ANALYSIS

4:3:1 From the bar-graph drown, it has been observed that in the number (i) which is the percentage of clay and silt, the highest peak is observed in c and d which is the false bedded sandstone of Ajali formation. The high clay and silt content is explained by the presence of Imo shale which has been bedded by the Ajali sandstone. The type of gully that is observed here are highly landslide and slope failure. The peaks that are following them are that of E, H, and I. E which is in the Imo shale while H and I are in Nanka sandstone. This means that the capping of the sandstone by the clay of Imo shale coupled with the slope of the land joins hand to intensify the gullies of these areas through down-cutting.

The percentage of fine sand shown in (ii) means that I has the highest content of fine sand followed by H and E which are in Nanka and upper coal measure. The type of gullies that take place here are rillying to gully. The fine sand are being washed away by the runoff, thereby using some particule as tool to scrub its part-way and as such increases the sides of the gully wall, see fig. ( ). The gullies found here are still in its youthfull stage and does not has much sign of future development to intermediate stage because of the even nature of the parent material.

Medium sand shows its peaks in G,A,F and J which are in the false bedded Ajali and Nanka sandstone. The percentage of gravel in J,F and A are also high from the graph. In the geologic formation, this explains why there is always sudden landslide in these are because of native down-cutting.

The percentage of coarse sand in B and G which has a high peak are beirg helped by the shallow nature of the water table along these are left alone the coarse sand would not lead to much gully development but this water is perenial along hhese area help to increase the sideward cutting of the sites. There is high effect of this especially in

... the gully development is more rapid.

4:4 BAR GRAPH OF THE VOLUME of soil lost and landuse system

In fig. (4:4:1) the volume of soil lost is very high. It is not because the percentage of forest cleared and built up area is high. The number of gullies is not also high. But the moderate slope in this area coupled with the bedding of sandstone. The slope here naturally is high because of the valley along the Idow-river. But on the process of road construction the slope have been reduced to moderate as a result of the cut and feel which was down here.

Therefore, the high volume of soil lost here can also be explained to be the result of human interference. For instance the cut and feel which was down here lies very close or side by side with the Idow river, and the side facing the river is not well protected. Hence when the pressure from the vehicular traffic along the road is too high, this result to landslide and slope failure which is constant along this particular road lane.

In "E" which follows the highest volume A directly, this is cleared and high built up area. The imparcial landuse system has exposed the delicate fine and medium sand of this area, and the hungry runoff resulted from high intense rainfall has been feed to their satisfaction.

Volume of soil lost in J is explained by the peak slope of the site and moderately landuse system shown in the percentage of soil lost and built-up area of the site. The slope here is being helped by the nature of the parent material soil, which is in Nanka sandstone leads to landslide and slope failure. In "F" which has the smallest soil lost though the landuse and the slope is moderate, the number of gullies is also the smallest. It is interesting to know that the parent material here is Imo shale intercullated by the Ebenebe sandstone. The Ebenebe sandstone is not easily affected by erosion; Ofoeglu, (1985). Therefore the characteristic feature of

CHAPTER FIVE

5:1 Summary of the major findings:

Presently in Enugu and Anambra states, the distructive effects of gullying and slope failures originated by the hydrometeorologic events, have rendered many people homeless and caused loss of lifes, properties and agricultural lands. Desperate and confused control programmes by individuals, groups and governments in the affected areas are in vogue. Some of these erosion and gully control and anthropogenic activities like road construction tend to exacerbate the problems. The causative effects are not yet fully understood and appreciated by environmental planners and managers. The effects of the environmental characteristics and anthropogenic effects in soil gully erosion generation and growth have been outlined. However, the present study is the first attempt to explain the effects and implication of hydrometeorology in gully formation. Numerous anthropogenic factors (Urbanization, agriculture, road construction, mining, etc) have tempered with the stabilized natural system which is accustomed to the hydrometeorological characteristics of this area and resulted in gully erosion and landslide.

The hydrometeorological investigations of the Enugu-Onitsha expressway corridor of former Anambra state, Nigeria have contributed to the delineation of different hydrogeological and geomorphic units corresponding to sand and rocks different characteristics and composition due to the climate of this area. The result shows that hydrometeorological factors in conjuction with geomorphic and geological factors contribute immensily to the intense gully erosion in this area.

Generally, the area is made-up of loose and incohessive sandstones. The area revealed high intensive landuse from the bar-graph shown in (fig. 4:4:1). Additionally, the construction of the reoad which left some of these incohessive sandstone practically bay also join lead to aggravate the problem of gully erosion. The construction uncontrolable sideward incision caused by the springs in some site like the Ifite-Awka and Awkuzu, kilometer 75 and 79 respectively. In Onyeama min, where the presence of Idew river has iniciated the base level stream or rivers by combined effects of bank erosion, seepage forces and soaking to liquid at higher elevation by runoff which exploits tensions and fractures to make the initial incisions into the sub-surface. The high rainfall intensity which is obtain in this area should also borne in mind, as it is revealed by the volume of individual intensity (fig. 3:7:1). This means that both the surface water with its high runoff and underground water contribute in not small measure to gully intensity of this area.

However, gully erosion generation and growth underlies their implications in the management of natural and man-made hazards as presently occuring in the study area. Some massive failure of some control programmes on erosion has been traced to nonconsideration of hydrometeorological, geomorphic and geological history in the design and construction processes. Major human activities in this area has set off flooding, landslide and gullies. Thus control and monitoring programmes must consider the implications of hydrometeorological, geomorphic and geological events for such programmes to succeed and endure. This will drastically reduce the continued economic waste (human and financial losses) that now occurs in affected area.

5:2 Implication for checking gully soil erosion in the study area

The implication for checking erosion in these area are obvious from the study. Since the gully erosion here seems to have grown due to the road constructions, the return period of critical intensities should be used to construct culverts and drainages along this road. It is also observed that the vegetal cover has been reduced from the bar-graph of cleared forest and built up areas. Maintanance of soil vegetal cover and planting some grasses like vetiver. Some development one of its worst enemies erosion of valuable cropland topsoil, (Thursday, July 1, 1993 Daily Sketch). When planted in rows, vetiver forms a thick hedge which slows down rainfall intensedrop and its runoff and eliminate the volume of soil lost through sedimentation from flowing through. This can be used in areas of steep slopes like Onyeama Min, Awkuzu and Obinofia-Ndiuno areas, A. J and E respectively from the bar-graph (fig. 4:4:1). Efforts should also be made to minimize the collection of runoff from a wide area by creating diversions at intervals. This means in effect shortening the stream length so as to diminish drainage density.

5:3 RECOMMENDATIONS*

Gully erosion studies are multidisciplinary in nature and for the combined efforts of hydrometeorologist, geomorphologists, geologist engineers etc. Intensive research work on the three main soil degradation (splash, sheet and gully erosions) should be pursued all over the country so that their influences on our various environments might be understood. The various factors and processes involved in gully erosion study in eastern Nigeria and other parts of the country should be completely identified. This calls for further work in line with the present study. Improvement in the sampling technique, the use of computer for computation of multiple regression in other to forecast the future trend of gully erosion. Federal and state government as well as interested private organizations should be involved in the funding of these research.

Civil engineering work should be carried out in recognision with the hydrometeorological, geomorphic nature and geologic setting. Socio-Psychological aspect of the control programme must include public involvement and enlightenment activities whereby the inhabitants of the affected areas are properly educated on the dangers of erosion

R E F E R E N C E S

1. Adejokun, J. A. (1965) 'The three dimentional structure of the intertropical discontinuity over Nigeria', Nigerian Met. Service, Tech. Note, No. 39, 7 pp.

2. Andrews, F.M. (1962) "Some aspect of hydrology of fluid basin", Proc. Inst. Civil Engr. Vol. 21 PP 55-90.

3. Babalola, O. (1988) Soil properties affecting infiltration, runoff and Erodibility. Published by the Federal Ministry of Science and Technology, Lagos Nigeria.

4. Egboka, B.C.E and Orajaka, I.P (1987), soil and gully erosion models for effective control programmes, Geoforum J. 18,² 333-341.

5. Faber, T. H. & Imeson, A.C (1982), "Gully hydrology and related soil properties in Lesotho" In walling P.E (ed). Recent development in the explanation and prediction of Erosion and sediment yield". <u>Proc. Exeter symposium</u> IAHS Published Vol. 134 pp 135-144.

6 Floyd, B. (1965): Soil erosion and deterioration in eastern Nigeria. Nig. Geographical Jour. Vol. 8 No 1 pp. 33-43.

7. Fubara, M.J. (1988). The menance of soil erosion: An Environmental Disaster, combat plan; Published by Federal Ministry of science and Technology, Lagos, Nigeria.

8. Grove A.T. (1957) Landuse and soil conservation in parts of Onitsha and Owerri provinces. Geological survey of Nigeria Bulletin No. 21 pp. 25-58.

9. Igbozurike, U. M. (1977). Erosion in the Agulu-Nanka Region of Nigeria. A suggestion of control measures: Paper presented at the conference of the soil sciance society by Nigeria, University of Nigeria Nsukka 29 Aug. to 2nd Sept.

10. Jeje C. K. (1982) Soil erosion and changes in some physiological properties of the soils in Ejiba area, Kwara state. <u>Silver Jubilee Conference</u> of the Nigeria Geographical Association, University of Ibadan.

11. Kalu, A. E and Godwill, A.O (1987). "Climatic impact of soil erosion in Nigeria", Ecological Disaster in Nigeria. <u>Soil erosion Proc.</u> Published by Federal Ministry of Science and Tech., Lagos Nig. pp. 103-123.

12 Lal, R. (1976). Soil erosion on alfilsols in Western Nigeria. IV nutrient element losses in runoff and eroded sediments. Geoderma 16. pp. 403-147.

13. Lal, R. (1981) Soil and water conservation and management in humid and sub-humid tropics <u>Monograph series No. 2 International Institute of Tropical Agriculture,</u> Ibadan Nigeria.

14. Newswatch, (August 26, 1991) "The Ravages of Erosion", by Utiba Ukim, Chris Uroh and Abdulrazaq Magaji.

15. Ofomata G.E.K (1965) "Factors of soil erosion in the Enugu areas of Nigeria". Nigerian Geogr. Journ. 8 No. 1, pp. 45-59.

16 Ofomata, G.E.K (1964). Soil erosion in Enugu Region of Nigeria. African Soils Vol. 9 No. 2 pp. 26-32

17 Ofomata G.E.K (1973) Village erosion characteristic in the forest zone of south eastern Nigeria, Ecological Disaster in Nigeria: Soil erosion. by Federal Ministry of Science and Tech. Lagos, Nigeria.

18. Ofomata G.E.K. (1973) b Village erosion in Uzoitem, East Central state of Nigeria. Ikenga II, No. 1.

19. Ofomata G.E.K (1978) Man as a factor of soil erosion in South eastern Nigeria. Geog. Eco. Trop. Vol.1 pp. 143-154

20. Ofomata G.E.K (1987) soil erosion characteristic in the forest zone of Southeastern Nigeria, Ecological Disaster in Nigeria Soil erosion. by Fed. Min. of Science and Tech.

21. Okulaja, F.O. (1963); On Rainfall intensity, climate, vegetation and weather zones. Tech. Note No. 40, Department of Meteorological service, Lagos, Nigeria.

22. Orajaka, P.I (1979). Economic geology of Nigeria coal,Unpublished company report, NAPCO Inc. Tulsa Okahoma.

23. Pitty, A.F (1977) Introduction to geomophology Meteum and Co. London.

24. Raymond N.C. et al (1989), Runoff response to Bain parameters in southeastern Nigeria Geogr. Ann. 71A (1-2); 75-84.

25. Ripper, J.E.V (1962). Man's physical World Mcgraw H. New York.

26. Sada, P. O. and Omuta G.E.D (1979) Auchi Urban Area: A preliminary Report on erosion and environmental problems and planning 22nd annual conference Nig. Geogr. Association.

27 Sampson, A. (1954) The Nigerian coal field; The geology of parts of Onitsha, Owerri and Benin Pronvinces; Bull Geological survey Nigeria, No. 4.

28. Sykes, R. A. (1940) A history of anti-erosion work at Udi farm and forest Vol. 1 pp. 36.

Taylor, D.W (1937) "stability of earth slope" Journ. of Boston Soc. Civil Engr. Vol. 24. pp. 197-246.

(Thursday, Oct. 10, 1991) Securing succour for

APPENDIX (1) Rainfall intensity and selected return periods. (ONITS

Tim(t)	0.2mins	0.4mins	0.7mins	1hr	2hrs	3hrs	6hrs	12hrs	24hrs
	67	38	23	18	12	10	5	3	2
	92	59	42	36	27	23	11	7	3
	99	64	48	41	33	26	12	8	4
	107	71	54	47	39	30	15	9	5
	117	78	63	55	45	35	17	10	6
	123	85	67	60	49	38	18	11	7
	129	90	73	63	54	41	20	12	8
	138	99	81	70	60	45	23	13	9

APPENDIX (|) Rainfall Intensity and Selected Return Period

0.2mins	0.4mins	0.7mins	1hrs	2hrs	3hrs	6hrs	12hrs	24hrs	Years
63	36	18	14	8	7	3	2	1	1 YEAR
114	69	49	37	23	18	11	5	2	2 Years
126	77	55	42	27	21	12	6	3	3
139	85	63	48	29	24	14	7	4	5
146	95	72	56	36	27	17	8	5	10
165	102	78	60	38	30	18	9	6	15
175	110	84	65	42	32	20	10	7	25
190	120	93	72	48	36	23	11	8	50

APPENDIX 2

GOVERNMENT OF ANAMBRA STATE OF NIGERIA **MW (AN) 175**

MATERIALS LABORATORY — MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

PROJECT :			
SAMPLE No. :	Awka		
LABORATORY No. :	TAKEN BY :		
	TESTED BY : Ogbonna J.	DATE :	
		DATE : 20/6/92	

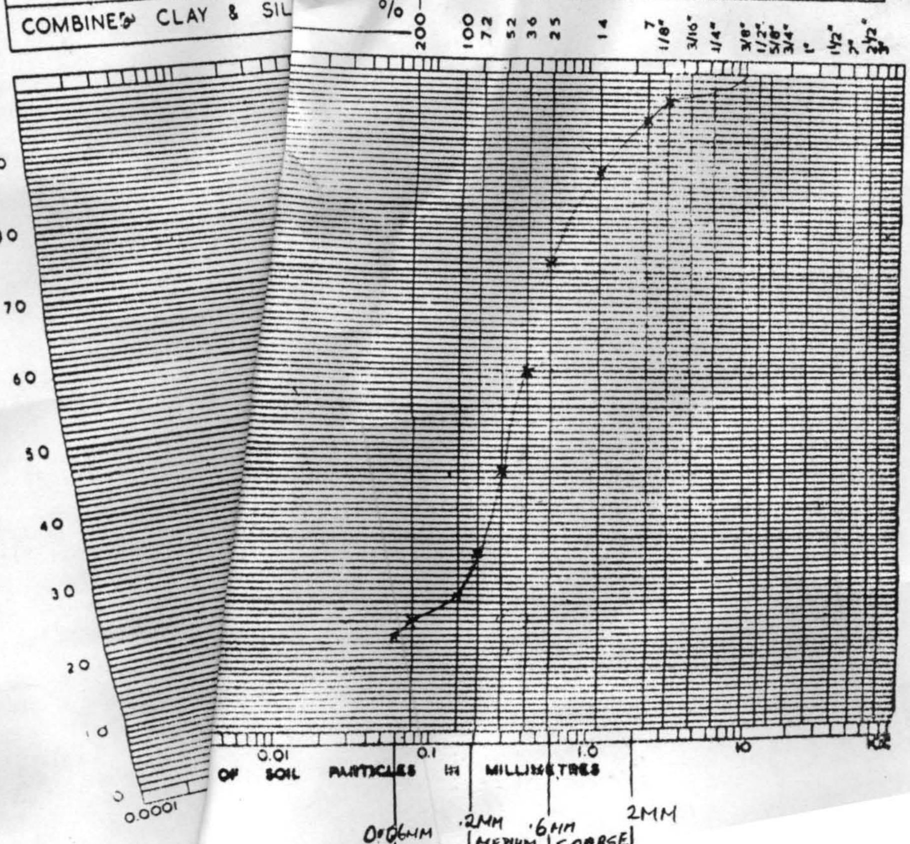
GPE 633/1278/10,000

TOTAL SAMPLE WEIGHT, DRY		
WEIGHT OF +3/16" FRACTION	GM.	FACTOR = TOTAL DRY WEIGHT PASSING 3/16" SIEVE / DRY WEIGHT OF -3/16" SOIL USED = ——— =
WEIGHT OF -3/16" FRACTION	GM.	WEIGHT OF DRY SOIL PASSING 3/16" USED 198 GM.
	GM.	WEIGHT OF DRY SOIL +200 SIEVE 163 GM.
		WEIGHT OF DRY SOIL -200 SIEVE 35 GM.

SIEVE SIZE	WEIGHT RETAINED GM.		PASSING WEIGHT GM.	PASSING PERCENT %
3"				
2½"				
2"				
1½"				
1"				
3/4"				
1/2"				100
3/8"	5	2	2	98
1/4"	3	1	3	97
3/16"	2	1	4	96
TOTALS				

SIEVE No.	WEIGHT RETAINED GM	WEIGHT PASSING ACTUAL GM.	WEIGHT PASSING X FACTOR GM.	PERCENT OF WHOLE SOIL PASSING %
7	6	3	7	96
14	16	8	15	93
25	28	14	29	85
36	31	16	45	71
52	29	15	60	55
72	23	12	72	40
100	13	7	79	28
200	7	3	82	21
200	35	18	100	18 /

CLAY %	SILT %	SAND %	GRAVEL %
COMBINED CLAY & SILT %			



GOVERNMENT OF ANAMBRA STATE OF NIGERIA **MW (AN) 175**

MATERIALS LABORATORY — MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

GPE 633/1278/10,000

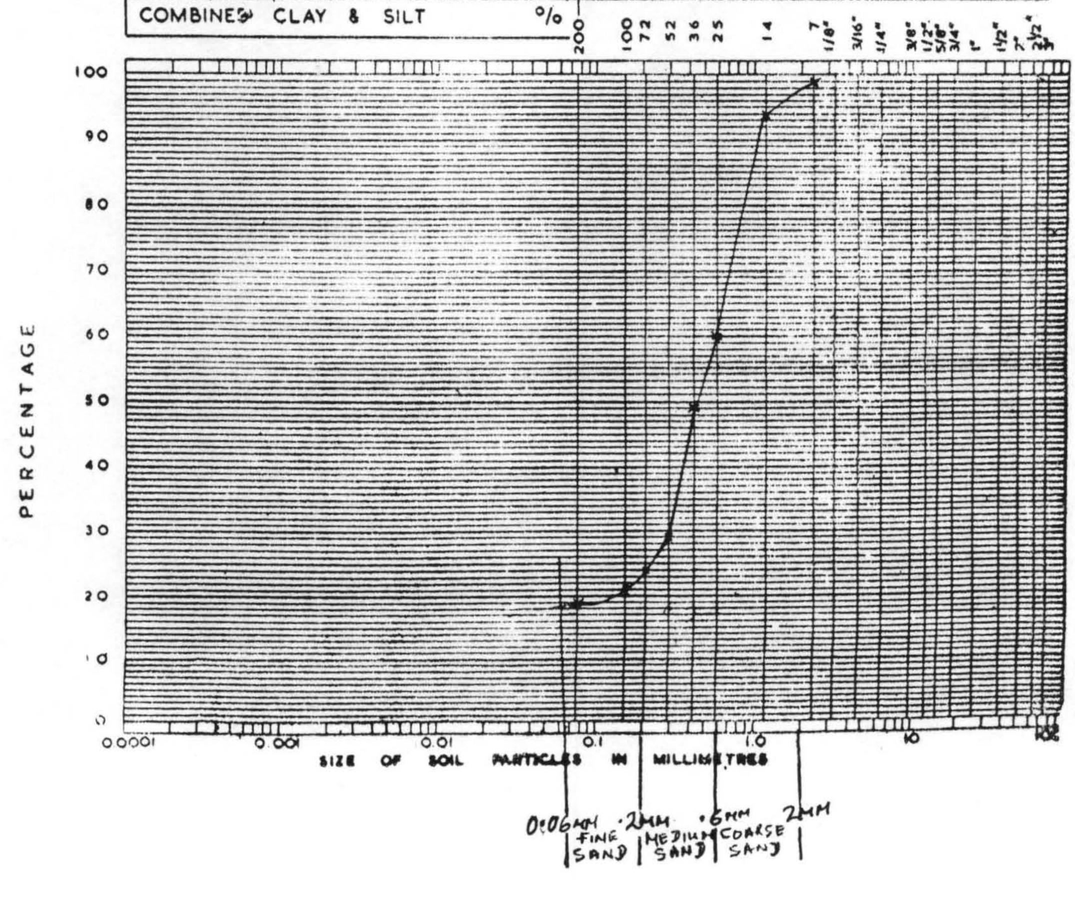
PROJECT :		
SAMPLE No. :	TAKEN BY :	DATE :
LABORATORY No. :	TESTED BY :	DATE : 20/6/92

LOCATION 2

TOTAL SAMPLE WEIGHT, DRY	GM.	FACTOR = TOTAL DRY WEIGHT PASSING 3/16" SIEVE / DRY WEIGHT OF -3/16" SOIL USED = ______ :	
WEIGHT OF +3/16" FRACTION	GM.	WEIGHT OF DRY SOIL PASSING 3/16" USED	200 GM.
WEIGHT OF -3/16" FRACTION	GM.	WEIGHT OF DRY SOIL +200 SIEVE	162 GM.
		WEIGHT OF DRY SOIL -200 SIEVE	38 GM.

SIEVE SIZE	WEIGHT RETAINED GM.	PASSING WEIGHT GM.	PASSING PERCENT %	SIEVE No.	WEIGHT RETAINED GM	WEIGHT PASSING ACTUAL GM.	WEIGHT PASSING X FACTOR GM.	PERCENT OF WHOLE SOIL PASSING %
3"								
2½"								100
2"				7	2	1	1	99
1½"				14	10	5	6	94
1"				25	67	34	40	60
3/4"				36	43	21	61	39
1/2"				52	20	10	71	29
3/8"				72	10	5	76	24
1/4"				100	6	3	77	21
3/16"				200	4	2	81	19
TOTALS					38	~~19~~	~~100~~	/

CLAY %	SILT %	SAND 80 %	GRAVEL 22 %
COMBINED CLAY & SILT %			



GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MATERIALS LABORATORY — MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

GPE 633/1278/10,000

PROJECT: EZEAGU 20KM FROM ENUGU

SAMPLE No.:

LABORATORY No.:

TAKEN BY:

TESTED BY: OGBORINA S.

DATE:

DATE: 20/6/72

TOTAL SAMPLE WEIGHT, DRY

WEIGHT OF +3/16" FRACTION — GM

WEIGHT OF −3/16" FRACTION — GM

FACTOR = TOTAL DRY WEIGHT PASSING 3/16" SIEVE / DRY WEIGHT OF −3/16" SOIL USED = ——

WEIGHT OF DRY SOIL PASSING 3/16" USED — 278 GM.

WEIGHT OF DRY SOIL +200 SIEVE — 247 GM.

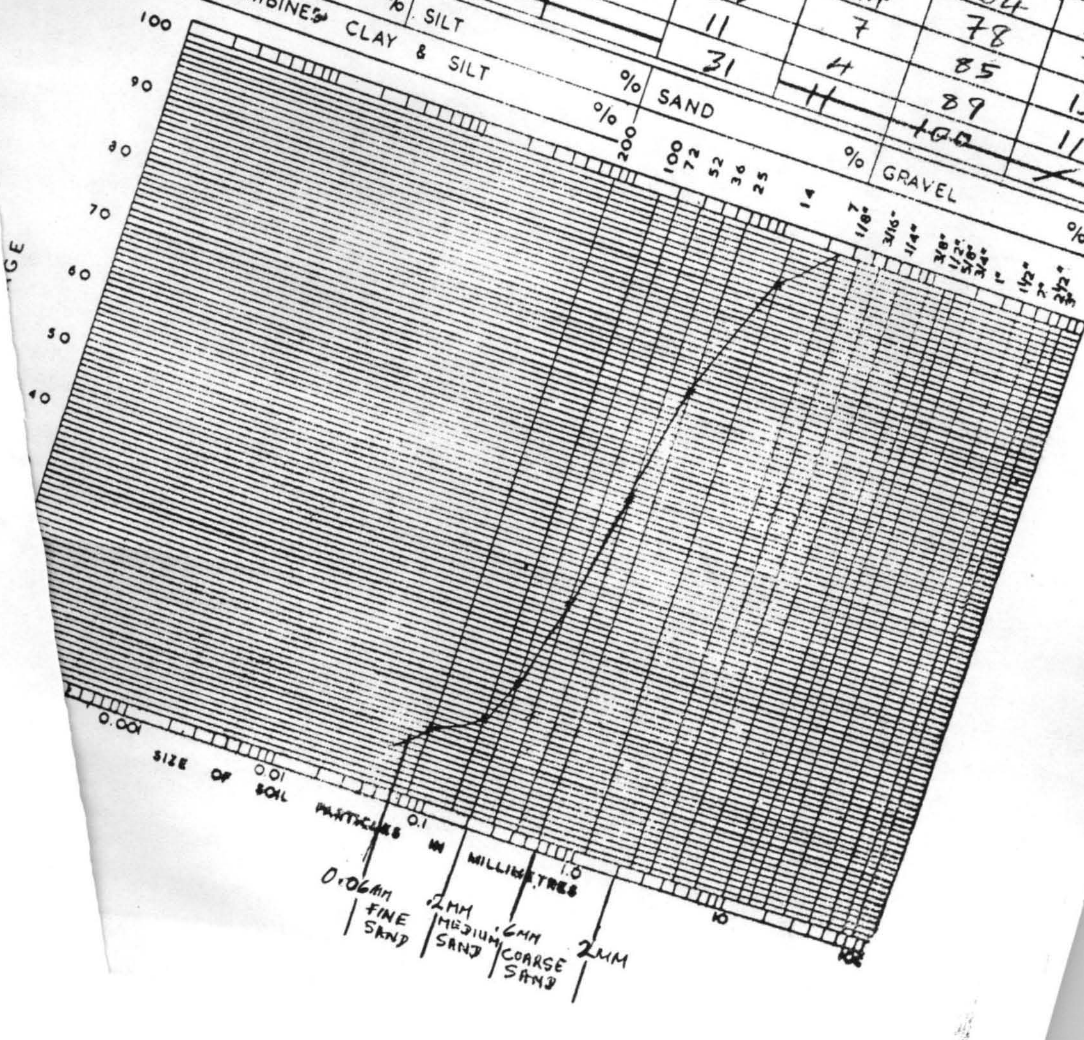
WEIGHT OF DRY SOIL −200 SIEVE — 31 GM.

SIEVE SIZE	WEIGHT RETAINED GM.	PASSING WEIGHT GM.	PASSING PERCENT %
3"			
2½"			
2"			
1½"			
1"			
3/4"			
1/2"			
3/8"			
1/4"	5 | 1		
3/16"	3 | 1	2	100
TOTALS	2 | 1	2	99
		3	98
			97

SIEVE No	WEIGHT RETAINED GM	WEIGHT PASSING ACTUAL GM.	WEIGHT PASSING X FACTOR GM.	PERCENT OF WHOLE SOIL PASSING %
7				
14	1			
25	10	—		
36	65	4	—	
52	54	23	4	100
72	49	19	27	96
100	39	18	46	73
200	19	14	64	54
	11	7	78	36
	31	4	85	22
	~~11~~		89	15
			~~100~~	11
				/

CLAY % | SILT

COMBINED CLAY & SILT % | SAND % | GRAVEL %



GOVERNMENT OF ANAMBRA STATE OF NIGERIA **MW (AN) 176**

MATERIALS LABORATORY — MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

GPE 633/1278/10,000

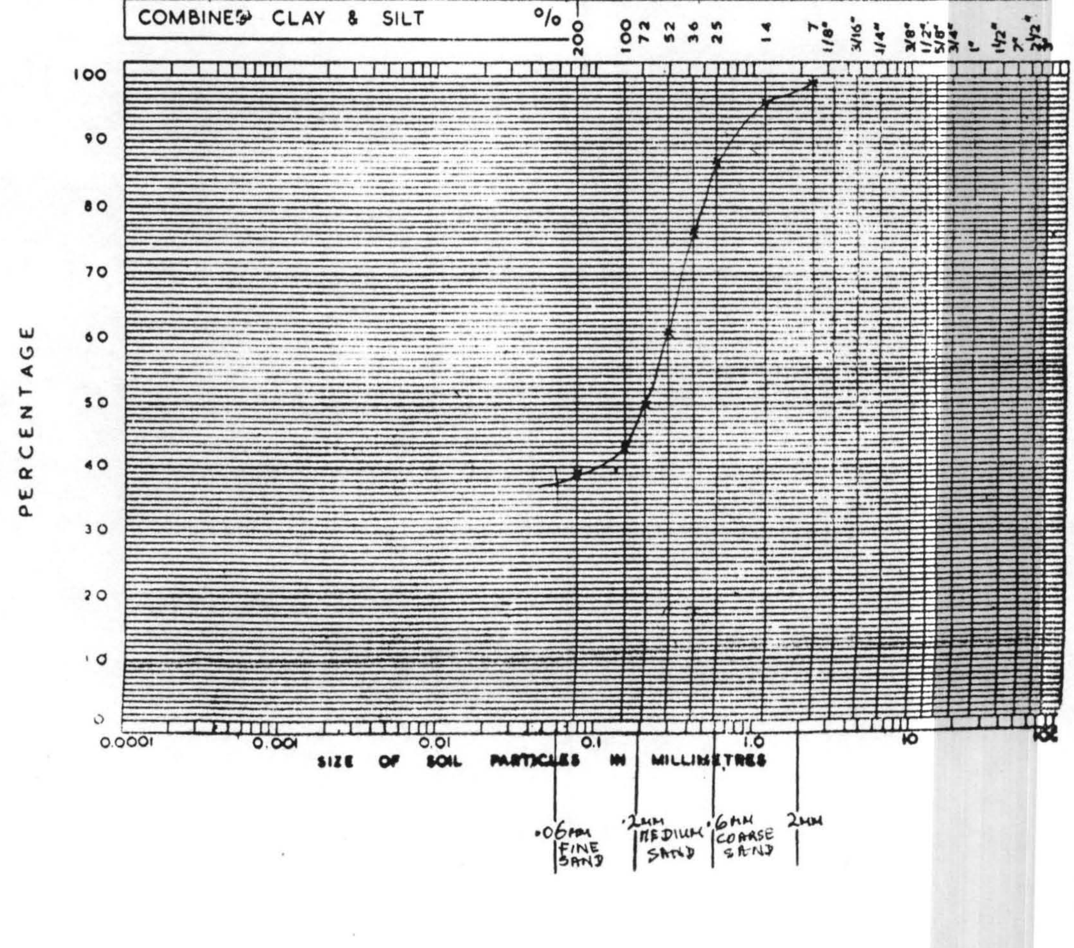
PROJECT :		
SAMPLE No. :	TAKEN BY :	DATE :
LABORATORY No. :	TESTED BY : OGBONNA J.	DATE : 20/6/92

LOCATION 3

TOTAL SAMPLE WEIGHT, DRY GM	FACTOR = TOTAL DRY WEIGHT PASSING 3/16" SIEVE / DRY WEIGHT OF -3/16" SOIL USED = ——— =	
WEIGHT OF +3/16" FRACTION GM.	WEIGHT OF DRY SOIL PASSING 3/16" USED	200 GM.
WEIGHT OF -3/16" FRACTION GM.	WEIGHT OF DRY SOIL +200 SIEVE	122 GM.
	WEIGHT OF DRY SOIL -200 SIEVE	78 GM.

SIEVE SIZE	WEIGHT RETAINED GM.	PASSING WEIGHT GM.	PASSING PERCENT %	SIEVE No.	WEIGHT RETAINED GM	WEIGHT PASSING ACTUAL GM.	WEIGHT PASSING X FACTOR GM.	PERCENT OF WHOLE SOIL PASSING %
3"								
2½"							1	100
2"				7	2	1	1	99
1½"				14	7	3	4	96
1"				25	18	9	13	87
3/4"				36	21	11	24	76
1/2"				52	30	15	39	61
3/8"				72	22	11	50	50
1/4"				100	14	7	57	43
3/16"				200	8	4	61	39
TOTALS					78	~~39~~	~~100~~	/

CLAY %	SILT %	SAND %	GRAVEL %
COMBINED CLAY & SILT %			



/

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MW (AN) 275

MATERIALS LABORATORY — MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

GPE 833/1278/10,000

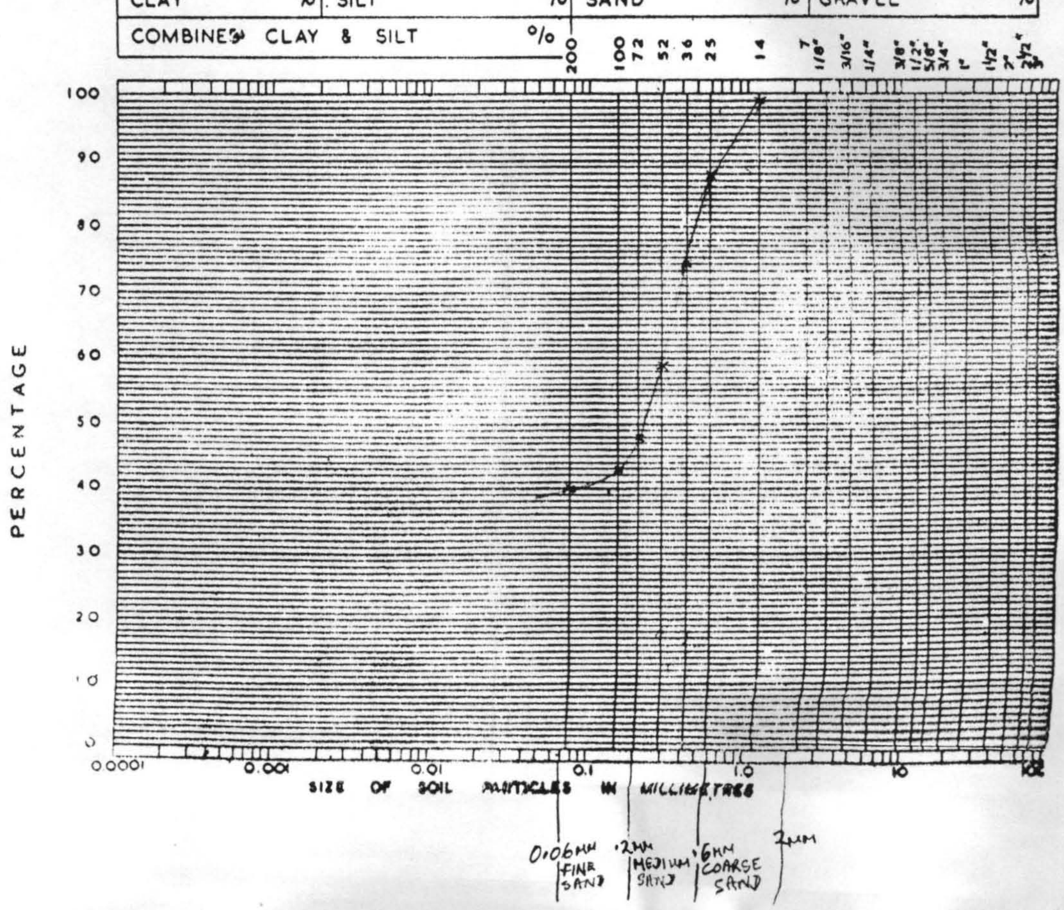
PROJECT :		
SAMPLE No. :	TAKEN BY :	DATE :
LABORATORY No. :	TESTED BY : OGBONNA J	DATE : 20/6/92

LOCATION 4

TOTAL SAMPLE WEIGHT, DRY	GM	FACTOR = TOTAL DRY WEIGHT PASSING 3/16" SIEVE / DRY WEIGHT OF -3/16" SOIL USED = ______ :	
WEIGHT OF +3/16" FRACTION	GM.	WEIGHT OF DRY SOIL PASSING 3/16" USED	200 GM.
WEIGHT OF -3/16" FRACTION	GM.	WEIGHT OF DRY SOIL +200 SIEVE	119 GM.
		WEIGHT OF DRY SOIL -200 SIEVE	81 GM.

SIEVE SIZE	WEIGHT RETAINED	PASSING		SIEVE No.	WEIGHT RETAINED	WEIGHT PASSING		PERCENT OF WHOLE SOIL PASSING
	GM.	WEIGHT GM.	PERCENT %		GM	ACTUAL GM	X FACTOR GM.	%
3"								
2½"								
2"				7				100
1½"				14	3	1	1	99
1"				25	23	12	13	87
3/4"				36	25	13	26	74
1/2"				52	30	15	41	59
3/8"				72	22	11	52	48
1/4"				100	10	5	57	43
3/16"				200	6	3	60	40
TOTALS					81	~~40~~	~~100~~	/

CLAY %	SILT %	SAND %	GRAVEL %
COMBINED CLAY & SILT %			



GOVERNMENT OF ANAMBRA STATE OF NIGERIA — MW (AN) 175

MATERIALS LABORATORY -- MINISTRY OF WORKS, HOUSING AND TRANSPORT

MECHANICAL ANALYSIS

GPE 633/1278/10,000

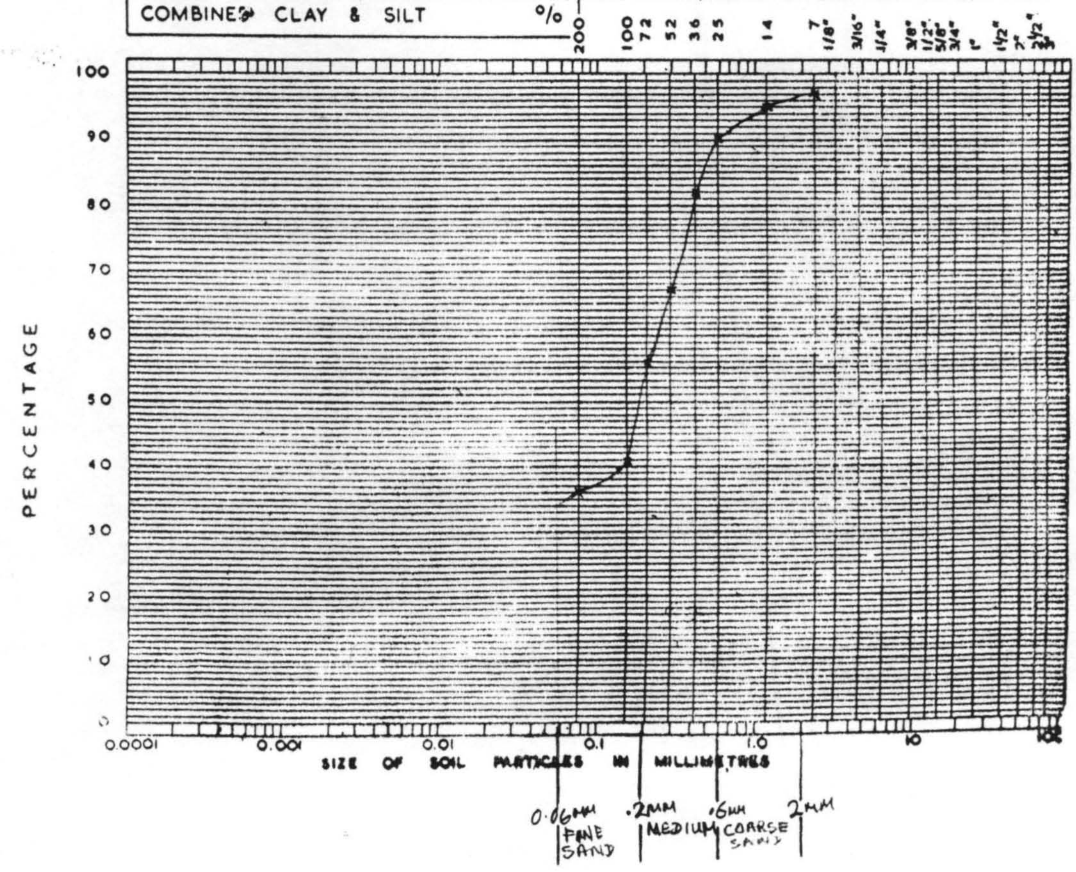
PROJECT :		
SAMPLE No. :	TAKEN BY :	DATE :
LABORATORY No. :	TESTED BY : OMBINNA J.	DATE : 20/6/92

LOCATION 5

TOTAL SAMPLE WEIGHT, DRY	GM	FACTOR $\frac{\text{TOTAL DRY WEIGHT PASSING 3/16" SIEVE}}{\text{DRY WEIGHT OF -3/16" SOIL USED}}$ = ——— =	
WEIGHT OF +3/16" FRACTION	GM.	WEIGHT OF DRY SOIL PASSING 3/16" USED	GM.
WEIGHT OF -3/16" FRACTION	GM.	WEIGHT OF DRY SOIL +200 SIEVE	GM.
		WEIGHT OF DRY SOIL -200 SIEVE	GM.

SIEVE SIZE	WEIGHT RETAINED GM.	PASSING WEIGHT GM.	PASSING PERCENT %	SIEVE No.	WEIGHT RETAINED GM	WEIGHT PASSING ACTUAL GM.	WEIGHT PASSING X FACTOR GM.	PERCENT OF WHOLE SOIL PASSING %
3"								
2½"								100
2"				7	6	3	3	97
1½"				14	4	2	5	95
1"				25	10	5	10	90
3/4"				36	16	8	18	82
1/2"				52	27	13	31	67
3/8"				72	26	13	44	56
1/4"				100	300	15	59	41
3/16"				200	10	5	64	36
TOTALS					70	36	100	

CLAY %	SILT %	SAND %	GRAVEL %
COMBINED CLAY & SILT %			



RED

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

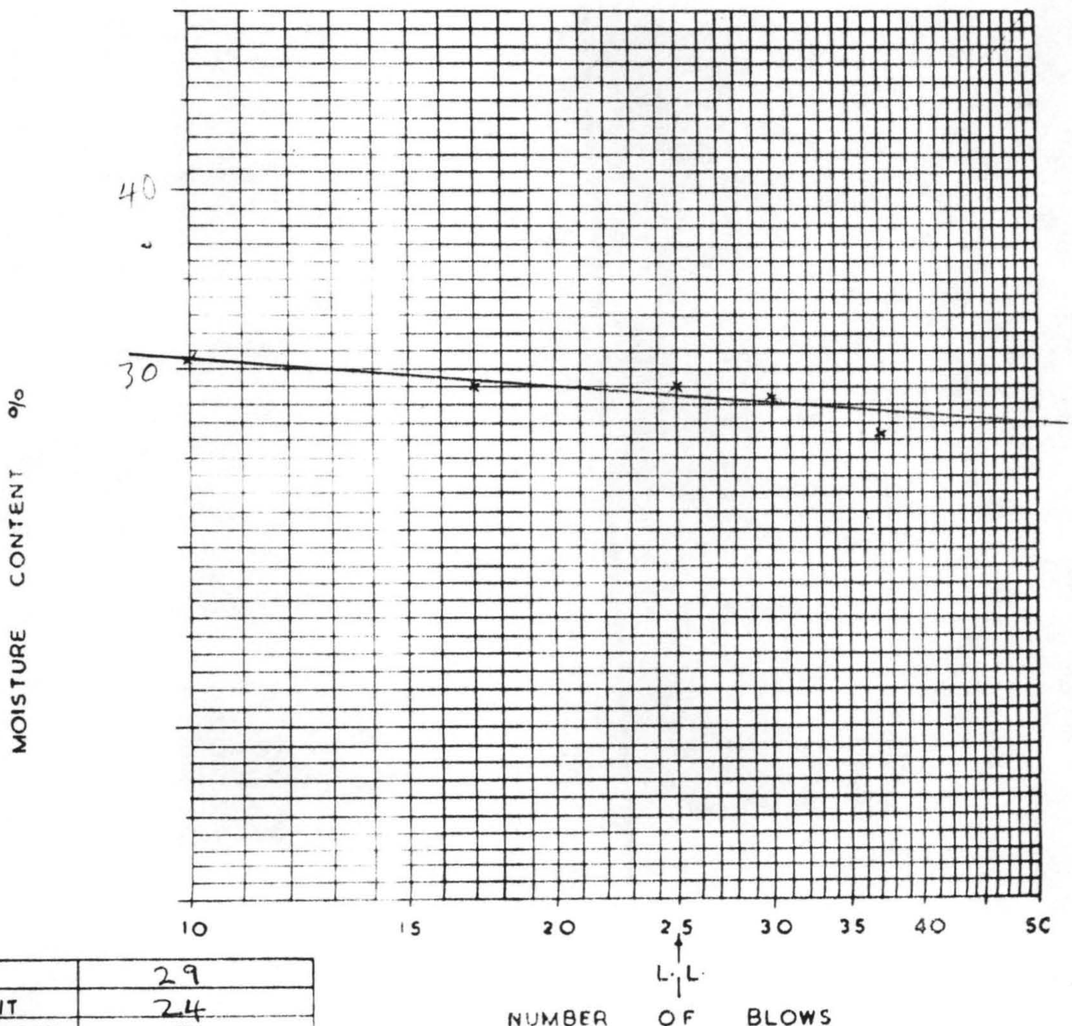
MATERIALS LABORATORY MINISTRY OF WORKS

ATTERBERG LIMITS

PROJECT :	EZEAGU 20KM from Enugu.	
SAMPLE No.:	TAKEN BY: ANYAJI F.N	DATE: 22/6/92
LABORATORY No.:	TESTED BY: UGBONNA J.	DATE: 25/6/92

									PLASTIC LIMIT		
NUMBER OF BLOWS		10	17	24	30	36					
MOISTURE CONTENT TIN No.		25	31	95	63	71			203		195
WEIGHT OF TIN PLUS WET SOIL	g	27.24	24.50	25.23	26.82	22.98			29.22		26.69
WEIGHT OF TIN PLUS DRY SOIL	g	24.62	22.52	23.16	24.46	21.56			26.95		24.59
WEIGHT OF TIN	g	16.10	15.75	16.04	16.16	16.15			17.31		15.85
WEIGHT OF WATER	g	2.62	1.98	2.07	2.36	1.42			2.27		2.10
WEIGHT OF DRY SOIL	g	8.52	6.77	7.12	8.30	5.41			9.64		8.74
MOISTURE CONTENT	%	30.52	29.3	29.1	28.5	26.4			23.6		24.1
ONE POINT METHOD FACTOR									AVERAGE P.L.		
ONE POINT METHOD LIQUID LIMIT	%								23.8		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	29
PLASTIC LIMIT	24
PLASTICITY INDEX	5

GPE 631/1278/10,000

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

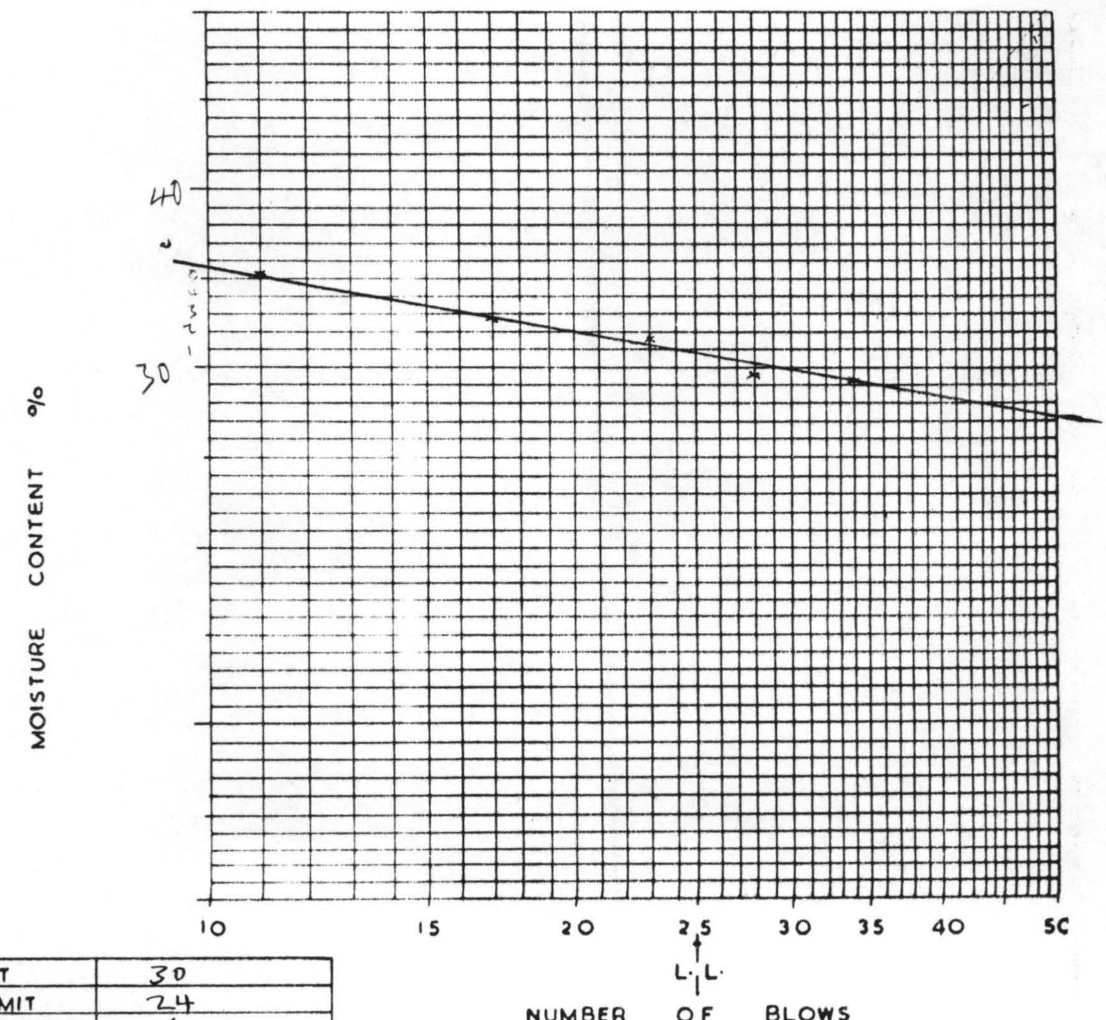
MATERIALS LABORATORY MINISTRY OF WORKS

ATTERBERG LIMITS

PROJECT :	Awka from Enugu	
SAMPLE No.:	TAKEN BY: Anyaji F. N.	DATE: 22/6/92
LABORATORY No.:	TESTED BY: Ogbonna J.	DATE: 25/6/92

									PLASTIC LIMIT		
NUMBER OF BLOWS		11	17	23	28	34					
MOISTURE CONTENT TIN No.		67	35	5	96	81			118		154
WEIGHT OF TIN PLUS WET SOIL	g	25.66	24.51	26.98	22.41	25.18			28.52		27.52
WEIGHT OF TIN PLUS DRY SOIL	g	23.11	22.42	24.37	2089	23.12			26.24		25.25
WEIGHT OF TIN	g	15.89	16.02	16.16	15.75	16.05			16.16		16.10
WEIGHT OF WATER	g	2.55	2.09	2.61	1.52	2.06			2.28		2.27
WEIGHT OF DRY SOIL	g	7.22	6.40	8.21	5.14	7.07			10.08		9.15
MOISTURE CONTENT	%	35.4	32.7	31.8	2.97	29.2			22.7		24.9
ONE POINT METHOD FACTOR									AVERAGE P.L.		
ONE POINT METHOD LIQUID LIMIT	%								23.8		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	30
PLASTIC LIMIT	24
PLASTICITY INDEX	6

GPE 631/1378/10.000

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MATERIALS LABORATORY MINISTRY OF WORKS

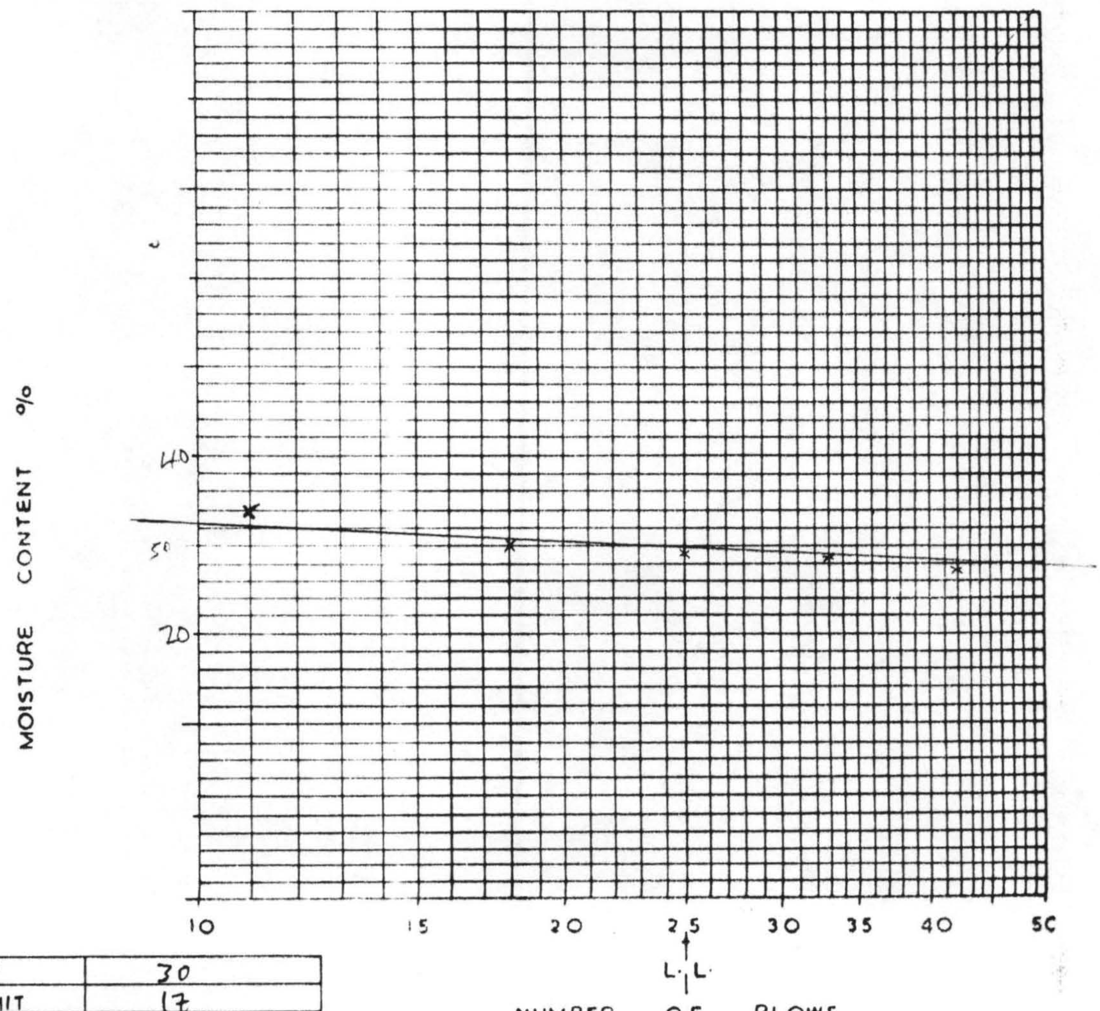
ATTERBERG LIMITS

LOCATION 3

PROJECT :			
SAMPLE No.:	TAKEN BY:	DATE:	
LABORATORY No.:	TESTED BY:	DATE:	

									PLASTIC LIMIT		
NUMBER OF BLOWS		11	18	25	33	42					
MOISTURE CONTENT TIN No.		218	13	19	81	135			4	7	
WEIGHT OF TIN PLUS WET SOIL	g	21.30	22.05	22.25	21.95	23.43			19.84	20.40	
WEIGHT OF TIN PLUS DRY SOIL	g	20.05	20.61	20.32	20.63	21.96			19.32	19.74	
WEIGHT OF TIN	g	16.40	15.90	15.85	16.16	16.41			15.90	16.04	
WEIGHT OF WATER	g	1.25	1.44	1.93	1.32	1.47			0.52	0.66	
WEIGHT OF DRY SOIL	g	3.65	4.71	6.47	4.47	5.55			3.42	3.70	
MOISTURE CONTENT	%	34.2	30.6	29.8	29.5	26.5			15.2	17.8	
ONE POINT METHOD	FACTOR								AVERAGE P.L.		
	LIQUID LIMIT %								16.5		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	30
PLASTIC LIMIT	17
PLASTICITY INDEX	13

GPE 631/1278/10.000

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MATERIALS LABORATORY MINISTRY OF WORKS

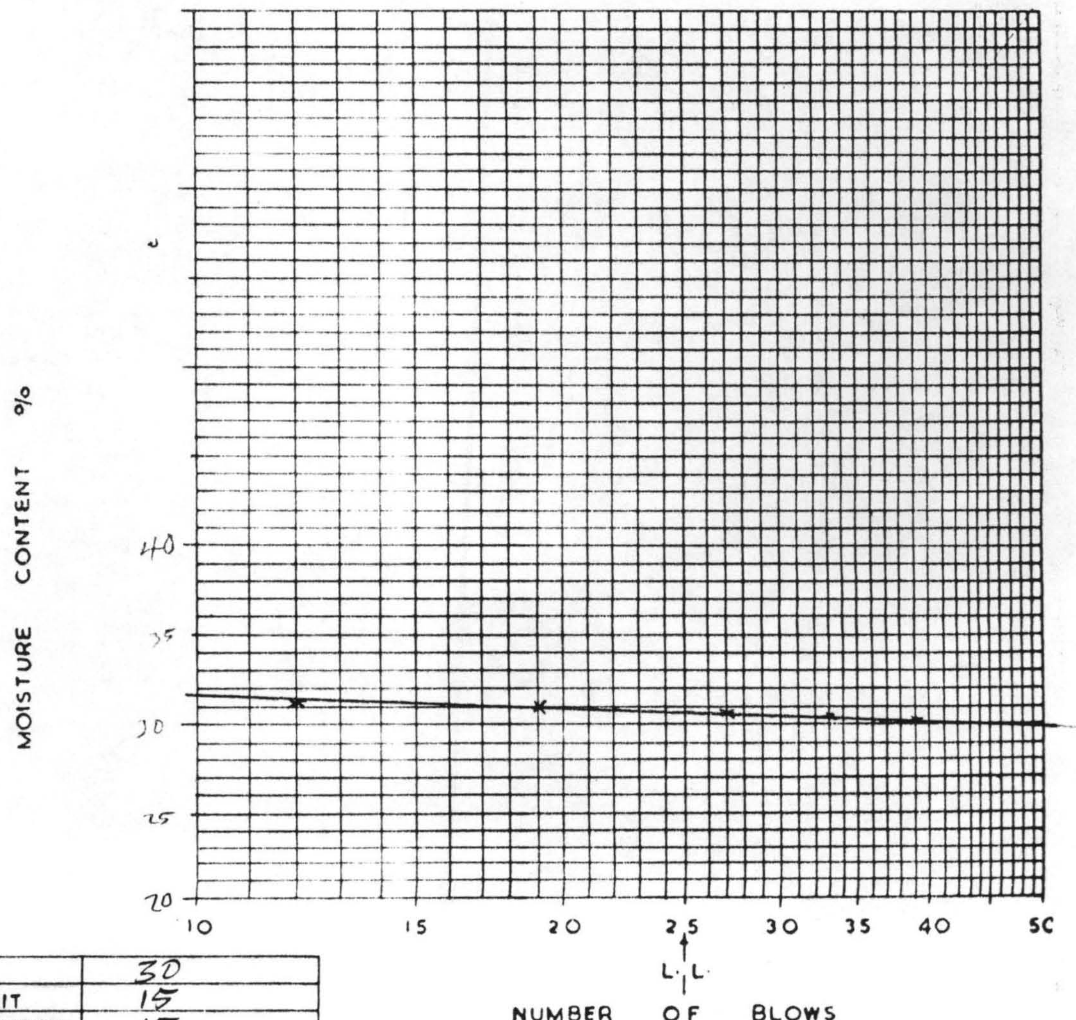
ATTERBERG LIMITS

LOCATION 2

PROJECT :			
SAMPLE No.:	TAKEN BY:	DATE:	
LABORATORY No.:	TESTED BY:	DATE:	

									PLASTIC LIMIT		
NUMBER OF BLOWS		12	19	37	33	40					
MOISTURE CONTENT TIN No.		14	86	139	158	147			160	184	
WEIGHT OF TIN PLUS WET SOIL	g	28.32	28.47	26.86	30.36	28.12			26.06	24.16	
WEIGHT OF TIN PLUS DRY SOIL	g	25.43	25.66	24.86	27.05	25.41			24.73	23.02	
WEIGHT OF TIN	g	16.28	16.56	16.13	16.25	16.50			16.10	15.44	
WEIGHT OF WATER	g	2.87	2.83	2.53	3.31	2.71			1.33	1.14	
WEIGHT OF DRY SOIL	g	9.15	9.10	8.20	10.80	8.91			8.63	7.58	
MOISTURE CONTENT	%	31.6	31.2	30.8	30.6	30.4			15.4	15.0	
ONE POINT METHOD	FACTOR								AVERAGE P.L.		
	LIQUID LIMIT %								15.2		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	30
PLASTIC LIMIT	15
PLASTICITY INDEX	15

GPE 631/1278/10,000

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MATERIALS LABORATORY MINISTRY OF WORKS

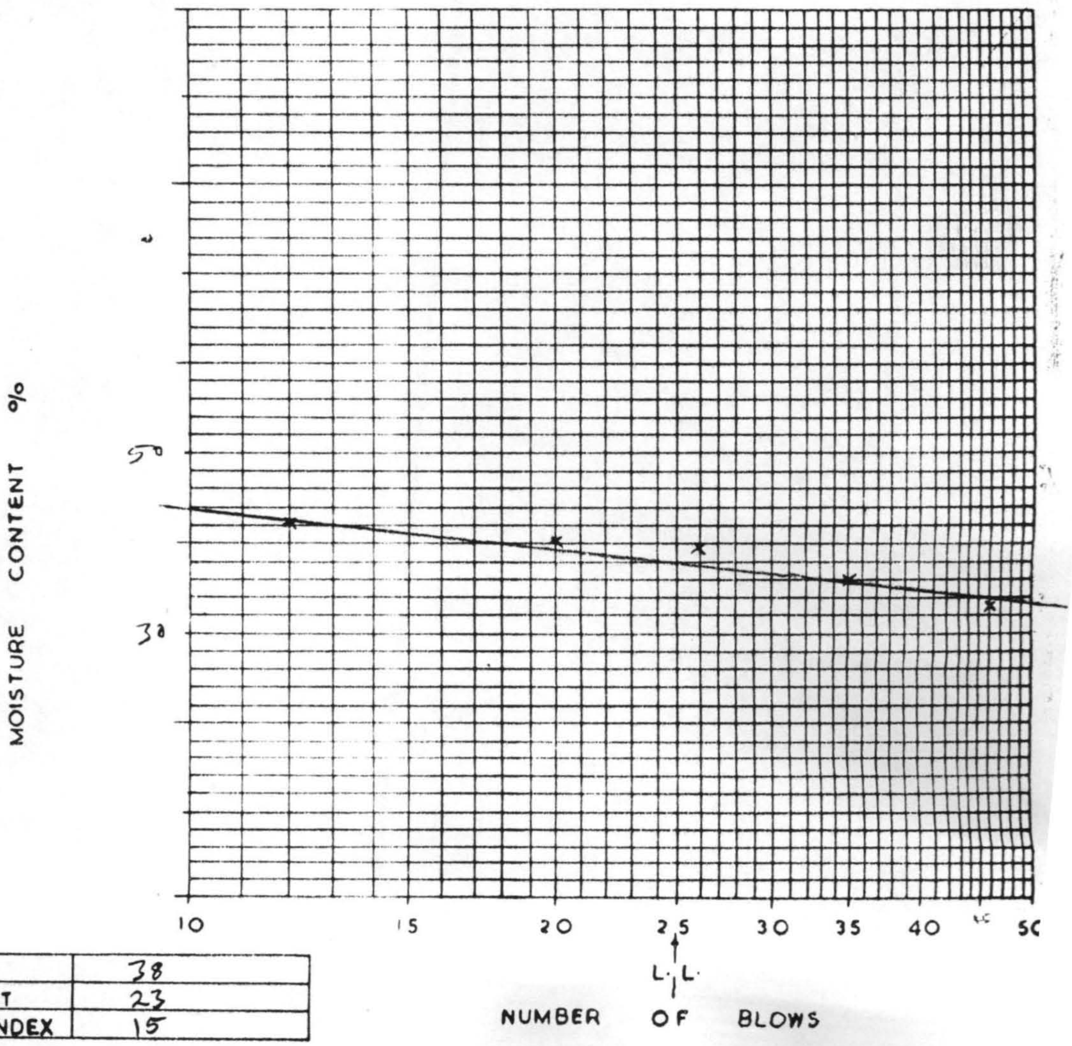
ATTERBERG LIMITS

LOCATION 4

PROJECT :		
SAMPLE No.:	TAKEN BY: Anyaji F. N.	DATE:
LABORATORY No.:	TESTED BY: OGBONNA J.	DATE: 2

NUMBER OF BLOWS		12	20	28	36	46			PLASTIC LIMIT		
MOISTURE CONTENT TIN No.		24	129	14	196	56			148	107	
WEIGHT OF TIN PLUS WET SOIL	g	27.81	30.75	30.84	27.34	33.79			33.87	33.61	
WEIGHT OF TIN PLUS DRY SOIL	g	24.42	26.60	26.60	24.00	29.24			30.43	30.33	
WEIGHT OF TIN	g	16.35	16.16	15.90	15.52	16.16			15.64	16.13	
WEIGHT OF WATER	g	3.39	4.15	4.20	3.34	4.55			3.44	3.38	
WEIGHT OF DRY SOIL	g	8.07	10.34	10.74	9.48	13.08			14.79	14.20	
MOISTURE CONTENT	%	42.0	39.4	39.1	35.2	34.8			23.3	23.1	
ONE POINT METHOD	FACTOR								AVERAGE P.L.		
	LIQUID LIMIT %								23.2		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	38
PLASTIC LIMIT	23
PLASTICITY INDEX	15

GPE 631/1275/10,000

MW (AN) 164

GOVERNMENT OF ANAMBRA STATE OF NIGERIA

MATERIALS LABORATORY MINISTRY OF WORKS

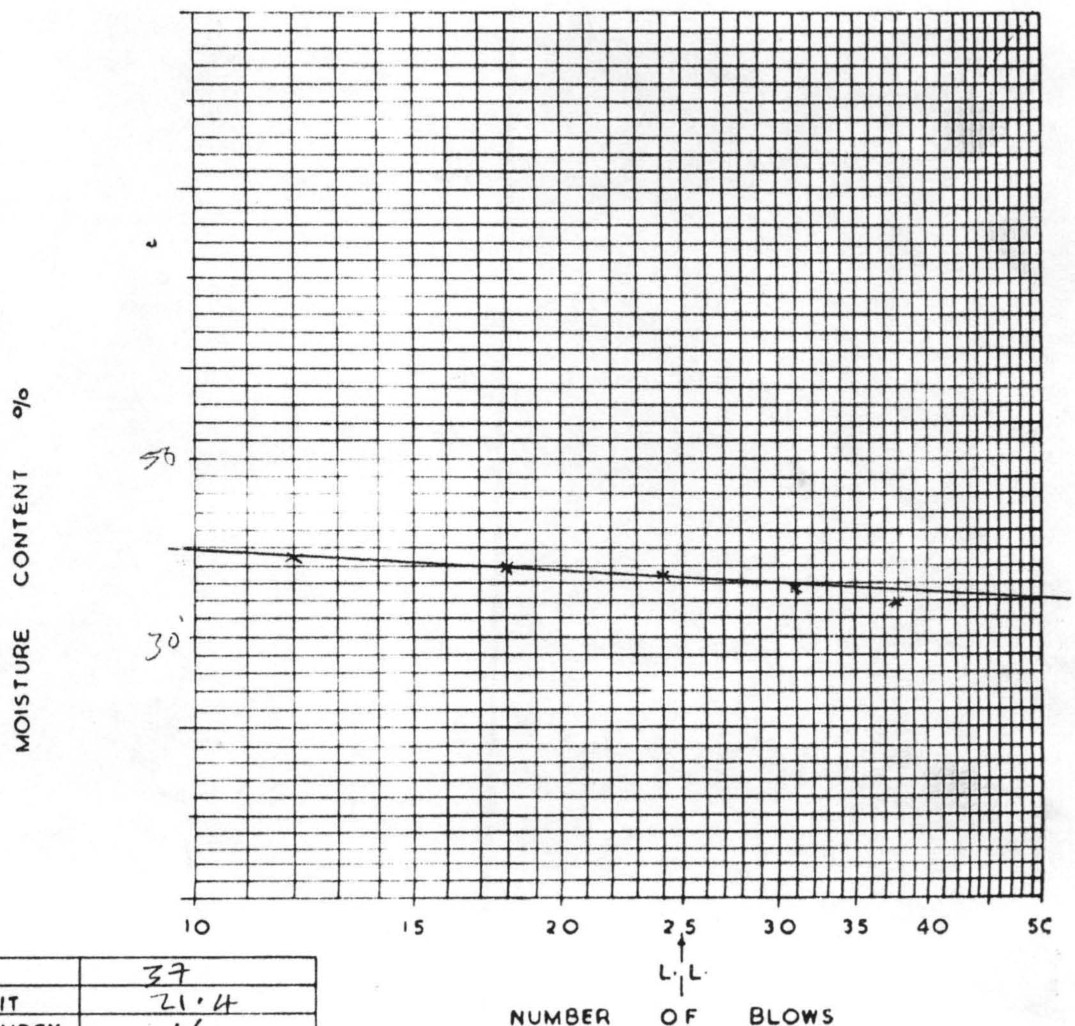
ATTERBERG LIMITS

LOCATION 5

PROJECT:		
SAMPLE No.:	TAKEN BY:	DATE:
LABORATORY No.:	TESTED BY:	DATE:

NUMBER OF BLOWS		12	18	24	31	38			PLASTIC LIMIT		
MOISTURE CONTENT TIN No.		134	40	218	135	75			81	19	
WEIGHT OF TIN PLUS WET SOIL	g	27.82	29.86	28.86	27.08	28.19			29.44	29.16	
WEIGHT OF TIN PLUS DRY SOIL	g	24.49	25.91	25.44	24.22	25.04			27.07	26.86	
WEIGHT OF TIN	g	15.90	15.90	16.41	16.41	16.04			16.16	15.85	
WEIGHT OF WATER	g	3.34	3.82	2.86	2.86	3.15			23.7	2.30	
WEIGHT OF DRY SOIL	g	8.59	10.09	7.81	7.81	9.00			10.91	10.01	
MOISTURE CONTENT	%	38.9	38.4	36.7	36.7	35.1			21.8	20.9	
ONE POINT METHOD — FACTOR									AVERAGE P.L.		
ONE POINT METHOD — LIQUID LIMIT	%								21.4		

NUMBER OF BLOWS	FACTOR
15	0.95
16	0.96
17	0.96
18	0.97
19	0.97
20	0.98
21	0.98
22	0.99
23	0.99
24	0.99
25	1.00
26	1.00
27	1.01
28	1.01
29	1.01
30	1.02
31	1.02
32	1.02
33	1.02
34	1.03
35	1.03



LIQUID LIMIT	37
PLASTIC LIMIT	21.4
PLASTICITY INDEX	16

GPE 631/1278/10,000