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Research Paper

Geotechnical Assessment of Soils within Orlu and Environs, South-eastern Nigeria

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ABSTRACT: *Geotechnical parameter assessment of soil formations within Orlu and environs, South-eastern Nigeria was carried out to assess its contributions to the gully formation within the area. The soil around gully erosion sites were investigated by collecting eight (8) unweathered soil samples from each of the designated location and these samples were then analysed. California Bearing Ratio (CBR), Soil Consistency (Moist and Dry Consistency, Wet Consistency), Atterberg Limits (Liquid Limits, Plasticity Limits, Shrinkage Limits and Plasticity Index) were carried out on the selected soil samples. The soils are generally not uniform, though similarities exist between some. The liquid limit ranges from 22.80% to 35.00% and has a mean of 28.46%. The Plastic Limit ranges from 13.70% to 25.00% and has a mean of 19.36%. The Plasticity Index ranges from 6.00% to 12.40% and has a mean of 9.10%. The Maximum Dry Density (MDD) ranges from 1.90% to 1.99% and has a mean of 1.93%. The Optimum Moisture Content (OMC) ranges from 8.80% to 12.50% and has a mean of 10.70%. These laboratory analyses indicate that the soil in the study area are majorly loose sand and contain little amount of clay which serves as a binding material. The lithology of the area has sandstone as its dominant component with very little binding material. This is one of the major reasons for the high rate of the gullies in the area. The maximum dry density values are generally low which indicates that the soils are unconsolidated and friable. Enlightenment and awareness of erosion control should include land use habits of the people in their agricultural practices and care of vegetation. Concrete terracing, and tree planting within gully affected areas is recommended to reduce the impact or the force of rain-flow. This will reduce to the barest minimum the widening of gullies. Holistic rehabilitation development programs of monitoring the earth surface to reclaim devastated land as well as to ensure a safe environment should be encouraged.*
KEYWORDS: *Atterberg Limits, Gully erosion, Plasticity Index, Orlu, Unweathered soil samples*

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I. INTRODUCTION

Soil is a very important earth natural resource as it sustains both plants and animals for their growth and development since it shelters most valuable earth resources. Threats to the soil for example, erosion, adjudged as one of the most fatal hazards to the environment, poses danger to both human and animal life. It constitutes a clear form of soil degradation and destruction. Erosion occurs where surface water runoff has high velocity as a result of topography and also influenced by soil formations of the area. This water flow erodes the channels through which it flows, making it wider and deeper.

According to United Nation's (UN) convention to combat land degradation (CCD), soil erosion automatically results in the reduction or loss of biological and economic productivity of terrestrial ecosystem, including soil nutrients, vegetation, other biota and the ecological processes that operates therein. By the year 2020, soil erosion may pose a serious threat to food production and rural development as well as urban livelihoods, particularly in poor and densely populated areas of the developing world [4]. The challenge erosion poses on structures and natural resources is of great concern to the environmental and engineering geologists.

In particular, Orlu and environs in Imo State, Nigeria have witnessed a great decrease in land for agricultural and other purposes as a result of erosion. The residents of these erosion prone vicinities are forced to learn how to cope with the problem since the rate at which erosion occur is higher than the rate at which solutions are proffered. The following factors - land slope, amount of space, percentage of water that infiltrates the ground, the amount available as run-off and geotechnical properties of the soil in the environment, have contributed immensely to this erosion menace.

1.1 Geological Setting

The study area is found within the Benin Formation, Ogwashi-Asaba Formation of the Niger Delta Basin and Ameki Formation of the Anambra Basin as shown in Figure 1 below.

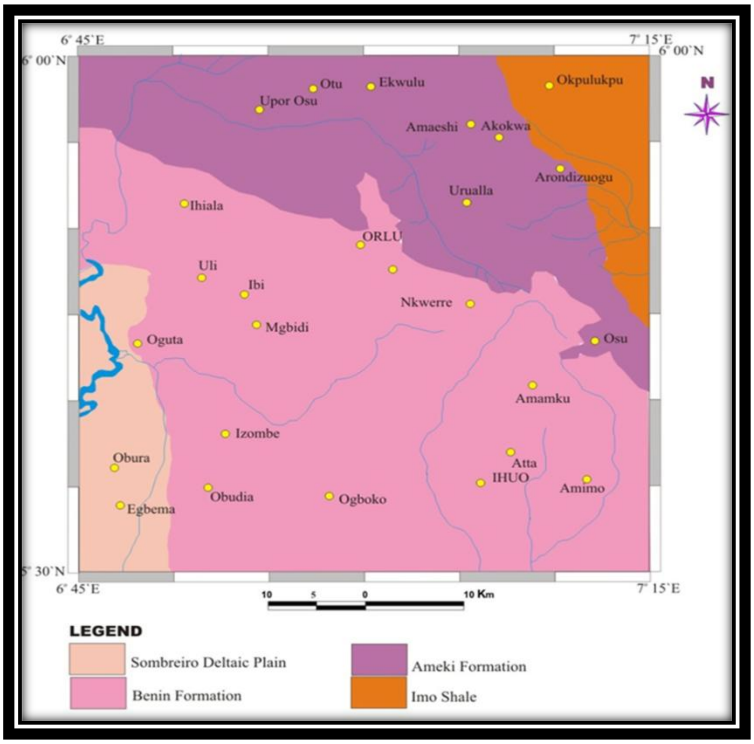

Fig. 1: Geology map of Orlu and environs

They are characterized by coastal plain sand (Miocene to Recent) with stratigraphic succession as shown in Table 1 below [6], [5] and [2].

Table 1: Stratigraphic Succession within the study area

Age	Formation	Lithology
Miocene – Recent	Benin	Medium to coarse grained, poorly consolidated with clay lenses and stringers
Oligocene – Miocene	Ogwashi-Asaba	Unconsolidated sand with lignite seams at various layers.
Eocene	Ameki	Grey clayey sandstone and sandy clay stone

II. MATERIAL AND METHODS

Geotechnical measurement of insitu soil materials were carried out to ascertain their engineering properties. Eight unweathered (fresh) soil samples were collected at designated locations within the sites. The natural moisture content of the samples collected from the field was determined in the laboratory within a period of 24 hours after collection. This was followed by air drying of the samples by spreading them out on trays in a fairly warm room for four days. Large soil particles (clods) in the samples were broken with a wooden mallet. Care was taken not to crush the individual particles. The entire laboratory tests were carried out in accordance with standard procedures, such as those recommended by the American Society for Test and Material (ASTM) or British Standard B.S. 1377 (BSI, 1975) for all the soil samples collected using well calibrated apparatus/equipment. The investigations of soil in the laboratory and the values required for calculation have led to the development of special equipment and procedure. The tests conducted on the eight different soil samples include: Atterberg limits: P-Index (Plasticity Index), L-Limit (Liquid Limit), Particle size Analysis (Hydrometer test), Moisture content, and California Bearing Ratio (CBR). The particle size distribution curve is used for classification of soil, determining the coefficient of permeability and provides an index to the shear strength.

Soil moisture content shows the change or variation in the soil characteristics; compaction is done to improve the engineering properties of soil; it generally increases the shear strength of the soil, and hence the stability and bearing capacity. It is also useful in reducing the compressibility and permeability of the soil. The Atterberg limits show the consistency of the soil, i.e. the degree of cohesion between particles of the soil at given moisture content. CBR is primarily intended for, but not limited to evaluating the strength of cohesive materials having maximum particle size less than 19mm [1]. It helps to obtain the strength of the sub grade soil.

III. RESULTS

The results from geotechnical analysis carried out within Orlu and environs are as shown below. Note the following: OMC = Optimum Moisture Content, MDD = Maximum Dry Density, LL = Liquid Limit, PL = Plasticity Limit, PI = Plasticity Index.

3.1 Grain Size Distribution of Afor-Ukwu Gully 1

Table 2: Sample statistics table for Afor-Ukwu gully Sample 1

SAMPLE STATISTICS

SAMPLE IDENTITY: **Afor-Ukwu Gully Sample 1** ANALYST & DATE: , 21/7/2014

SAMPLE TYPE: Polymodal, Moderately Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Sorted Medium Sand

	μm	ϕ
MODE 1:	462.5	1.117
MODE 2:	327.5	1.616
MODE 3:	231.0	2.119
D_{10}:	166.8	0.607
MEDIAN or D_{50}:	340.4	1.555
D_{90}:	656.5	2.584
(D_{90} / D_{10}):	3.936	4.256
$(D_{90} - D_{10})$:	489.7	1.977
(D_{75} / D_{25}):	2.057	1.993
$(D_{75} - D_{25})$:	248.5	1.040

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.0%	COARSE SAND:	18.9%
SAND:	100.0%	MEDIUM SAND:	47.7%
MUD:	0.0%	FINE SAND:	26.2%
		V FINE SAND:	6.1%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	1.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN($\bar{x}$):	388.8	337.2	1.568	358.6	1.479	Medium Sand
SORTING (s):	198.3	1.748	0.805	1.777	0.830	Moderately Sorted
SKEWNESS (Sk):	1.181	-0.664	0.664	-0.085	0.085	Symmetrical
KURTOSIS (K):	6.321	3.499	3.499	1.173	1.173	Leptokurtic

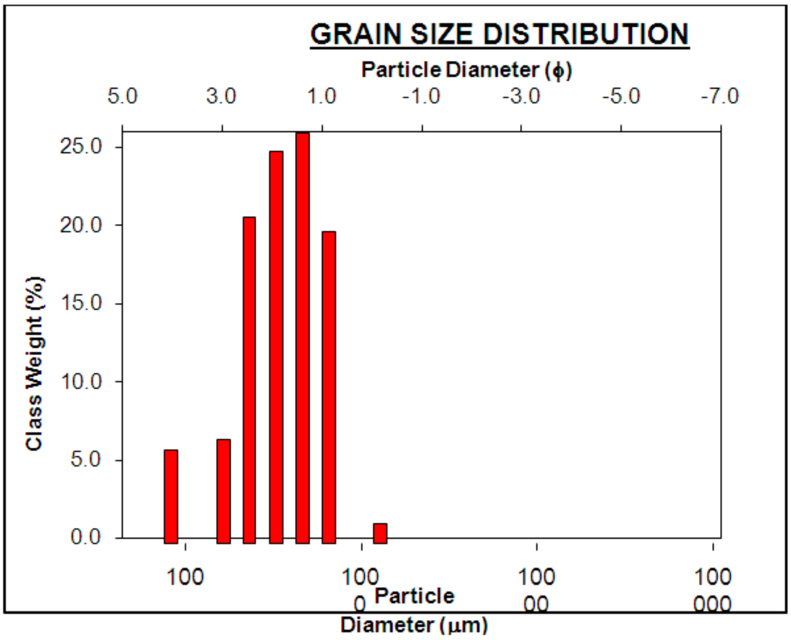

Fig. 2: Grain Size class of weight distribution chart for Afor-Ukwu gully sample 1.

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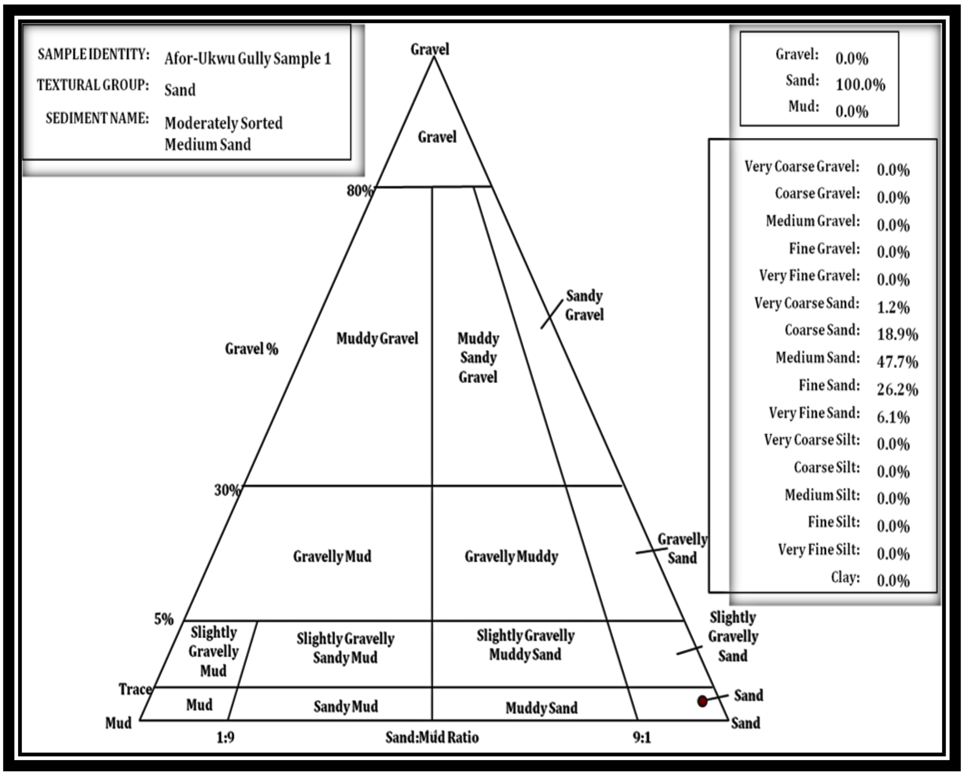

Fig. 3: Pyramidal chart of Afor-Ukwu Gully sample 1 grain size distribution

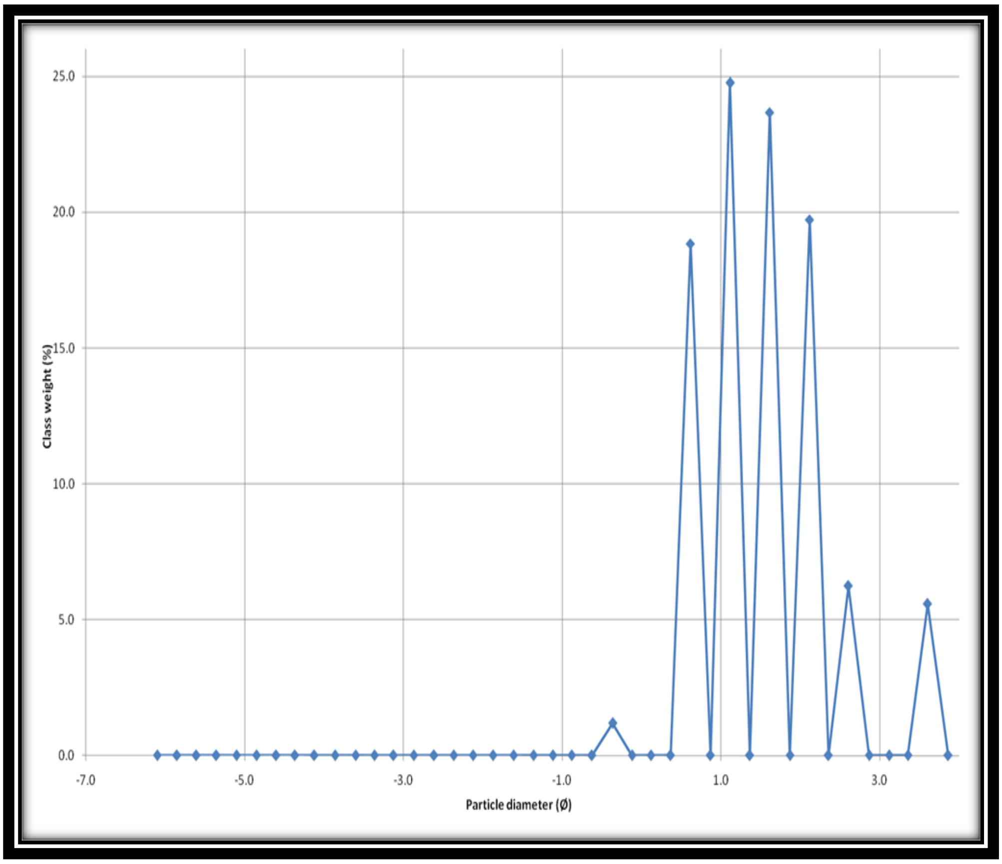

Fig. 4: Afor-Ukwu Gully Sample 1 grain size class of weight graph in phi

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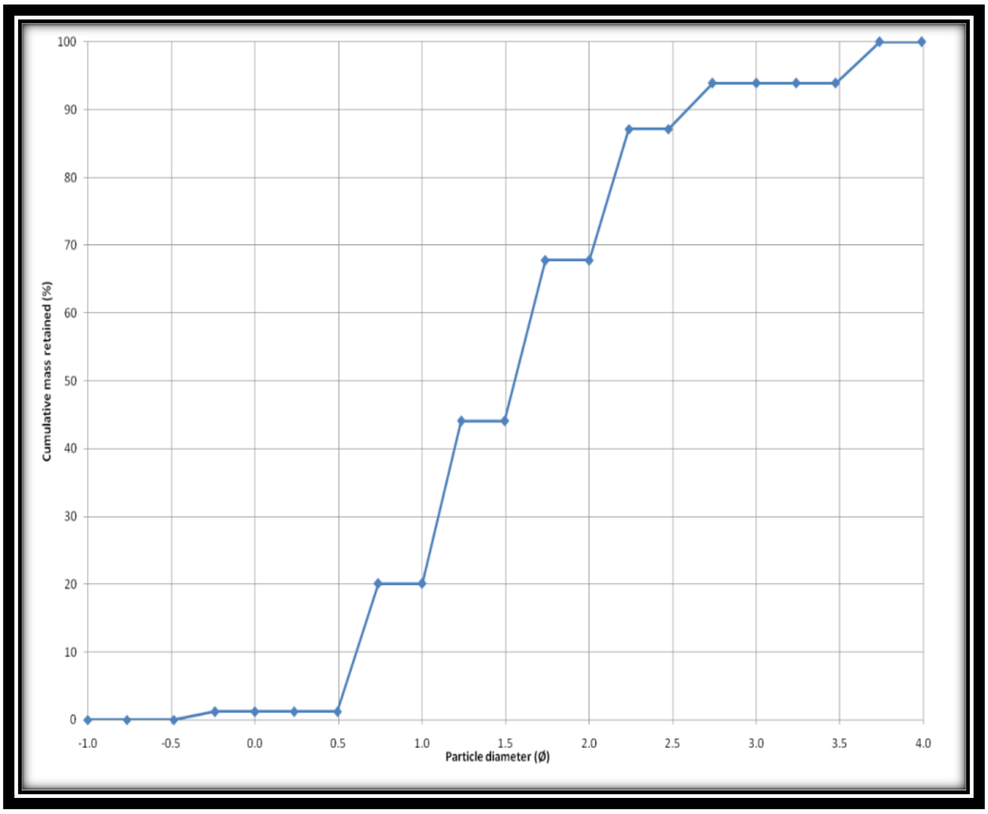

Fig. 5: Afor-Ukwu Gully Sample 1 Grain Size Cumulative Mass Retained graph in phi

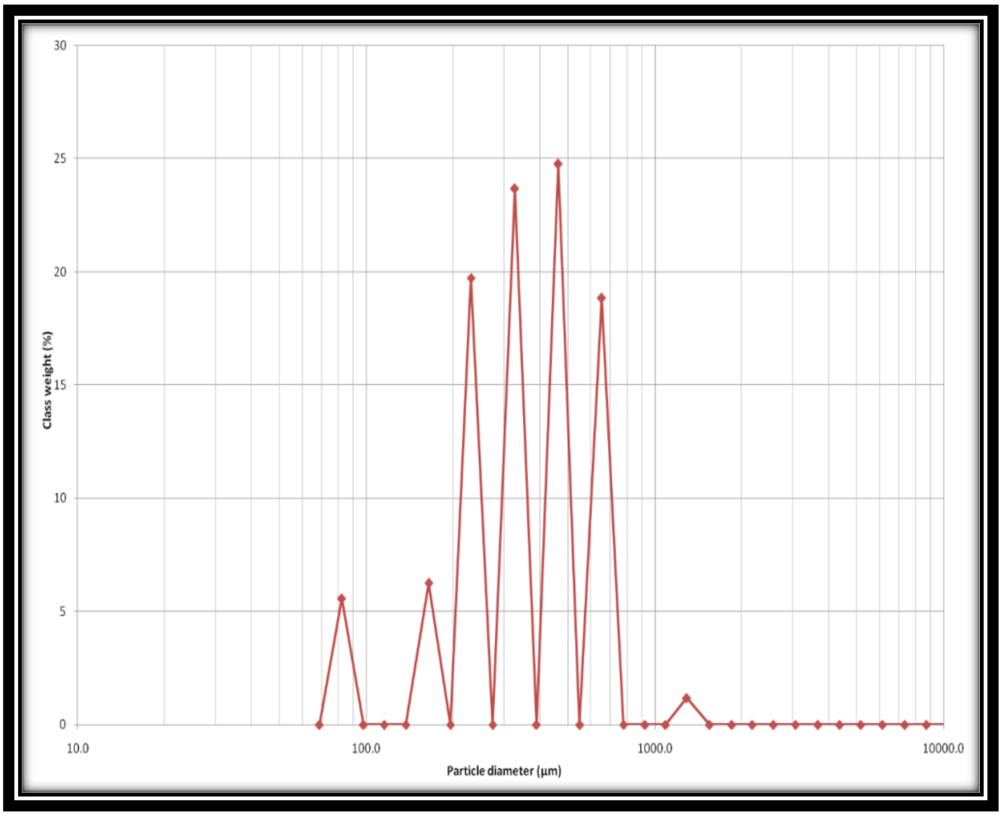

Fig. 6: Afor-Ukwu Gully Sample 1 class of weight graph in microns

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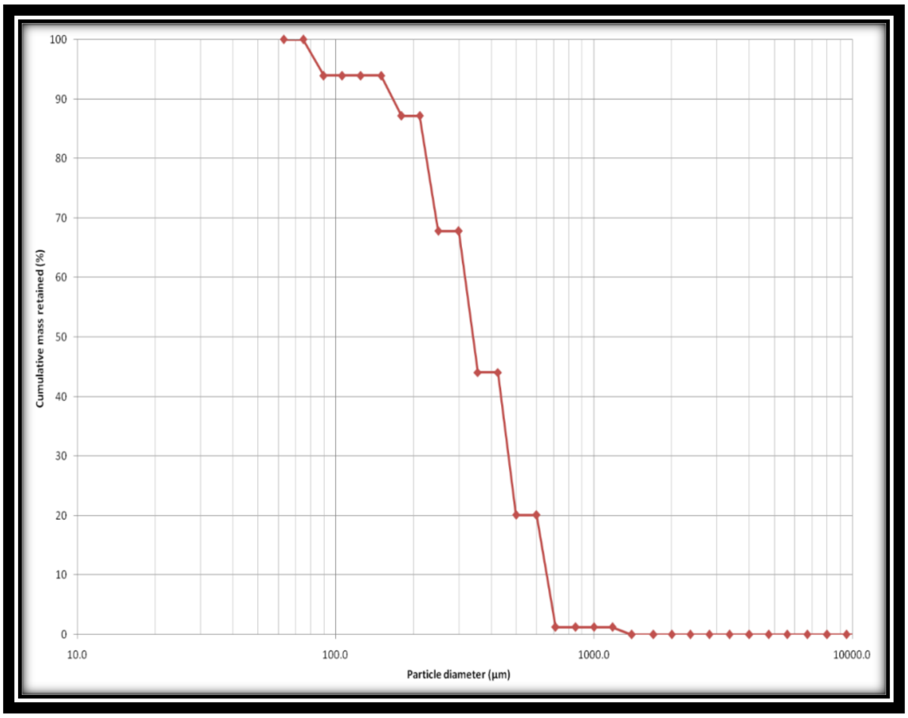

Fig. 7: Afor-Ukwu Gully Sample 1 cumulative mass retained graph **in microns**

The analysis of sample 1 collected at Afor-Ukwu gully shows that gavel and mud are 0% present while sand is 100%.It further revealed that the soil type within the area is polymodal, moderately sorted, symmetrical and also leptokurtic. This makes the area less compacted and easily eroded in the presence of running water.

3.2 Grain Size Distribution of Afor-Ukwu Gully 2

From the analysis of sample 2 collected at Afor-Ukwu gully, it shows a similar result to that of sample 1, which is predominantly 100% sand grains, while mud (clay-size particles) and gravel are absent (0%). These sand particles were found to be polymodal, moderately sorted, very fine skewed and leptokurtic. This implies they are prone to erosion in the presence of agents of erosion as no binding material was found present.
This analysis is shown in Table 3 below.

Table 3: Sample statistics table for Afor-Ukwu gully Sample 2

SAMPLE STATISTICS

SAMPLE IDENTITY: **Afor-Ukwu Gully Sample 2** ANALYST & DATE: , 21/7/2014
SAMPLE TYPE: Polymodal, Moderately Sorted TEXTURAL GROUP: Sand
SEDIMENT NAME: Moderately Sorted Medium Sand

	µm	ϕ
MODE 1:	462.5	1.117
MODE 2:	327.5	1.616
MODE 3:	231.0	2.119
D_{10}:	174.3	0.592
MEDIAN or D_{50}:	429.2	1.220
D_{90}:	663.6	2.521
(D_{90} / D_{10}):	3.808	4.261
$(D_{90} - D_{10})$:	489.4	1.929
(D_{75} / D_{25}):	1.976	1.958
$(D_{75} - D_{25})$:	242.6	0.983

GRAIN SIZE DISTRIBUTION

GRAVEL:	0.0%	COARSE SAND:	19.5%
SAND:	100.0%	MEDIUM SAND:	52.8%
MUD:	0.0%	FINE SAND:	20.0%
		V FINE SAND:	5.6%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	2.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic µm	Geometric µm	Logarithmic ϕ	Geometric µm	Logarithmic ϕ	Description
MEAN($\bar{x}$):	416.6	362.2	1.465	393.0	1.347	Medium Sand
SORTING (s):	211.8	1.744	0.802	1.769	0.823	Moderately Sorted
SKEWNESS (Sk):	1.392	-0.783	0.783	-0.396	0.396	Very Fine Skewed
KURTOSIS (K):	7.191	3.963	3.963	1.240	1.240	Leptokurtic

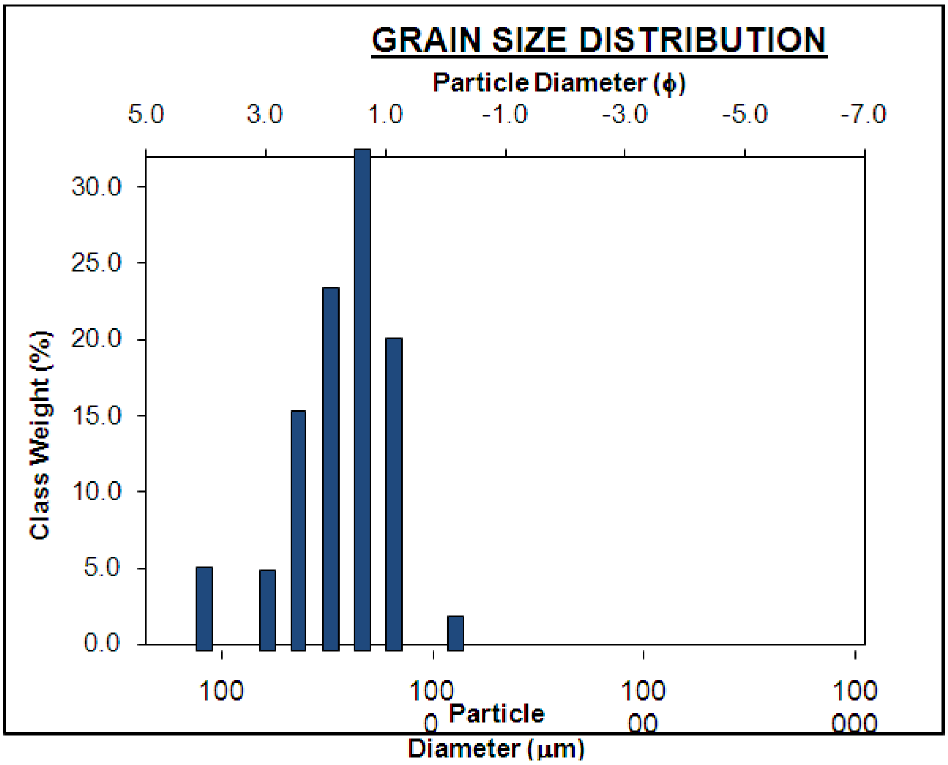

Fig. 8: Grain Size class of weight distribution chart for Afor-Ukwu gully sample 2.

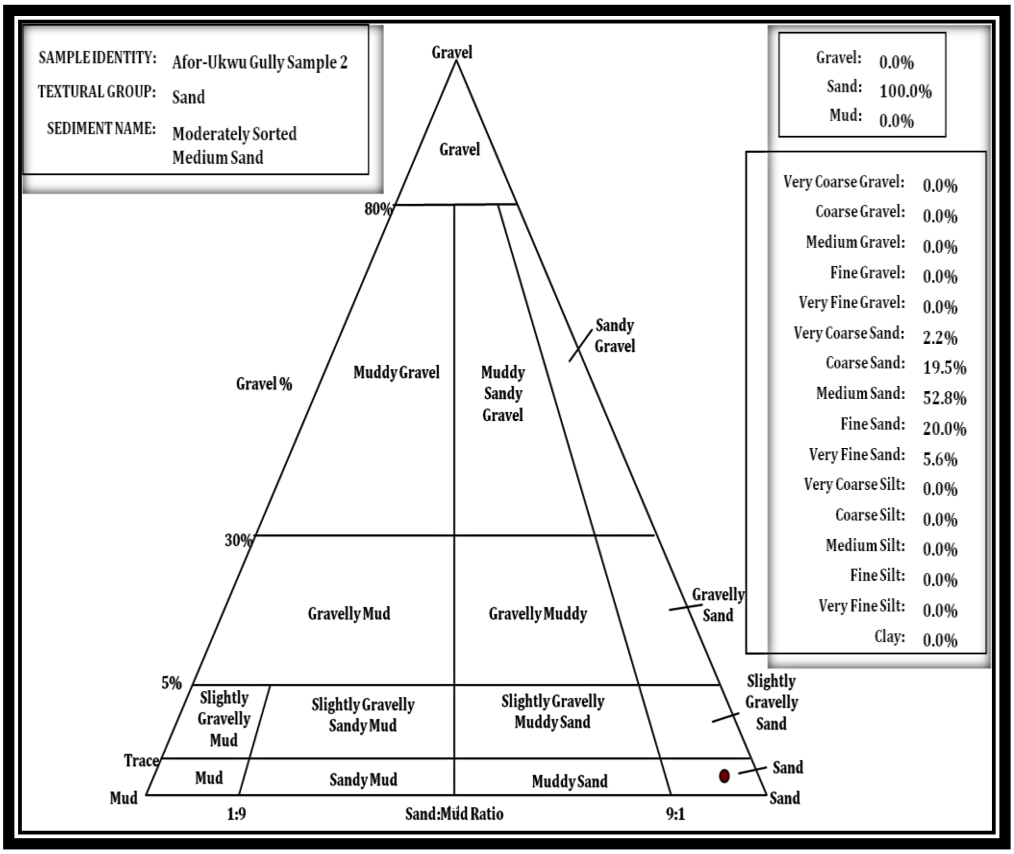

Fig. 9: Pyramidal chart of Afor-Ukwu Gully sample 2 grain size distribution

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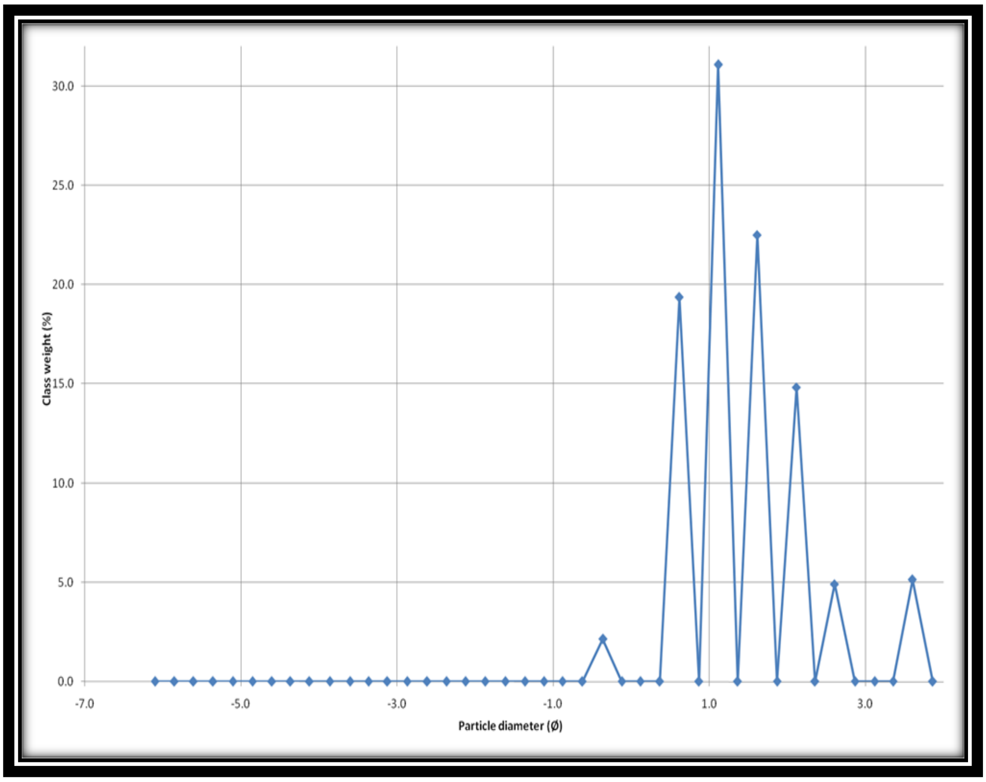

Fig. 10: Afor-Ukwu Gully Sample 2 Grain Distribution class of weight graph in phi

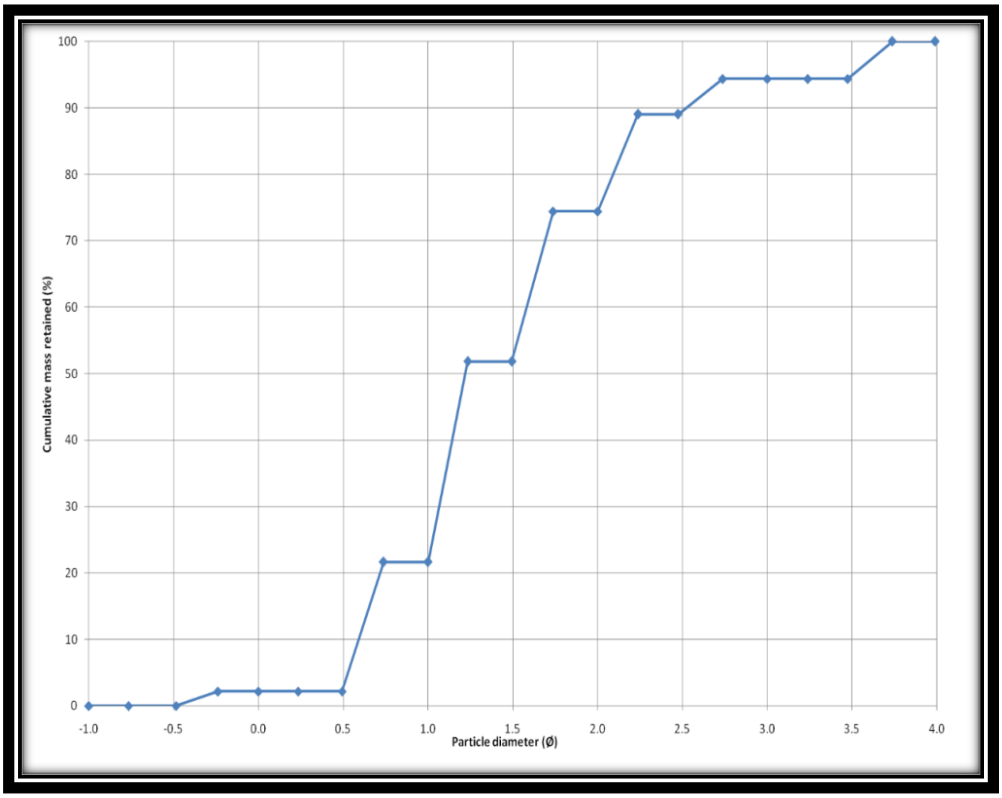

Fig. 11: Afor-Ukwu Gully Sample 2 Grain Size Cumulative Mass Retained graph in phi

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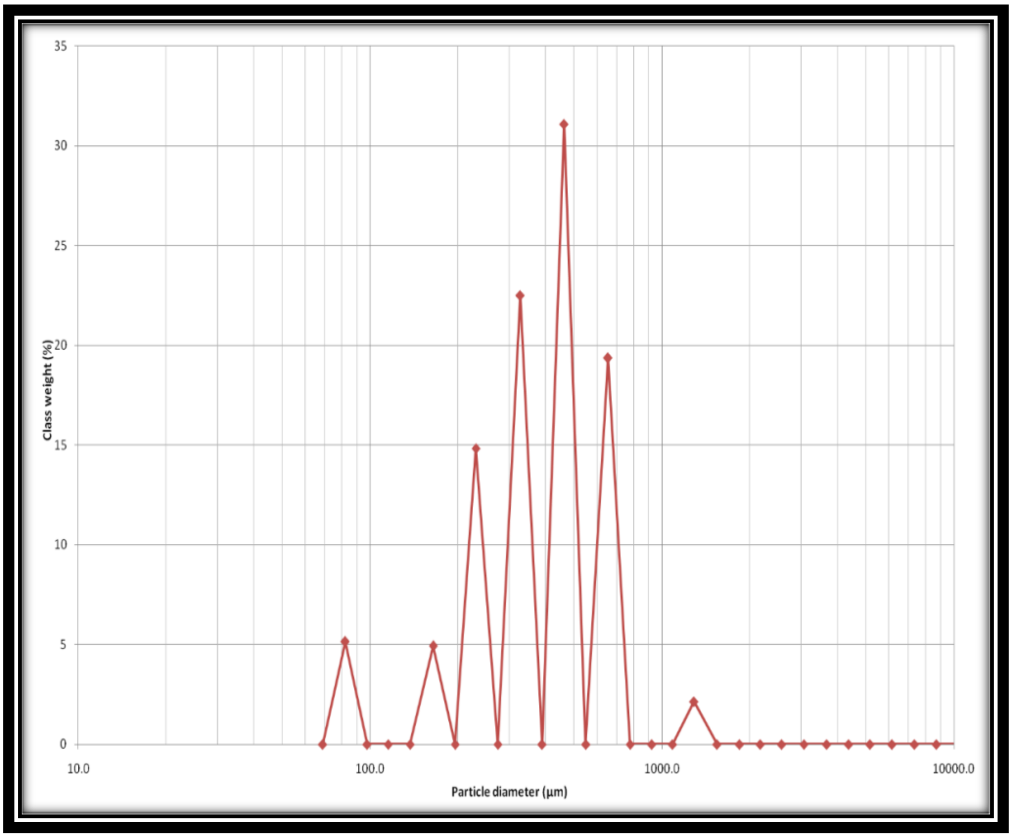

Fig. 12: Afor-Ukwu Gully Sample 2 class of weight graph in microns

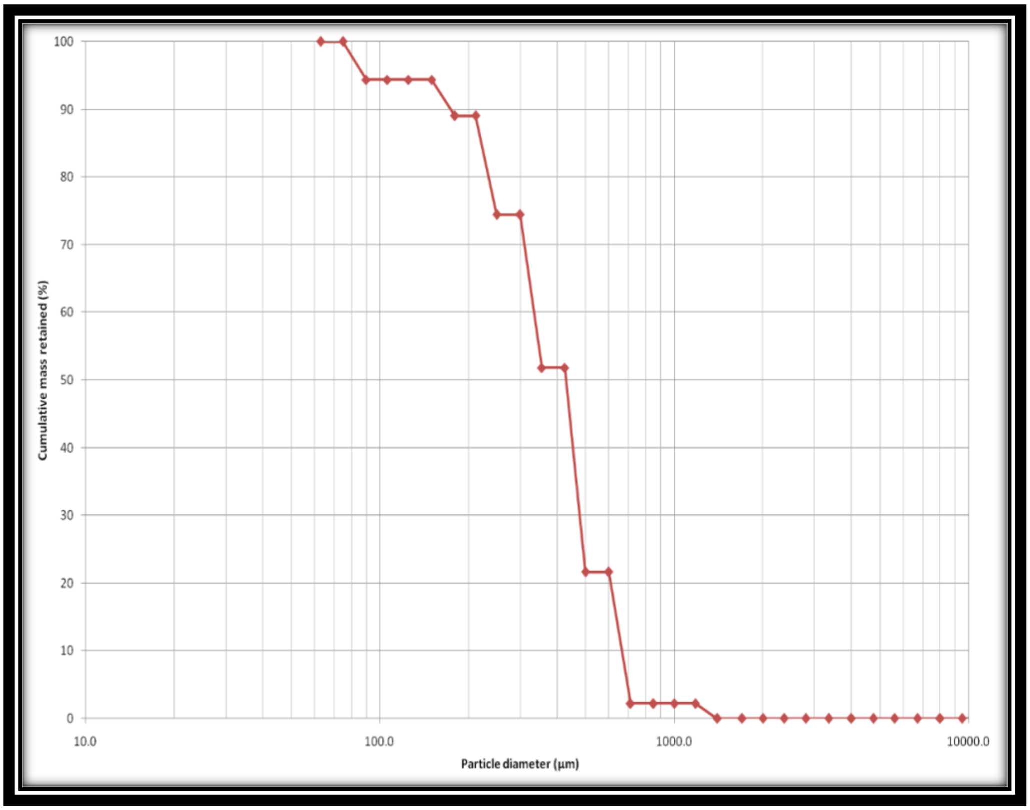

Fig. 13: Afor-Ukwu Gully Sample 1 cumulative mass retained graph in microns

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3.3 Grain Size Distribution of Ihioma Gully Head

Table 4: Sample statistics table for Ihioma Gully Head

SAMPLE STATISTICS

SAMPLE IDENTITY: **Gully Head Ihioma Orlu** ANALYST & DATE: , 21/7/2014

SAMPLE TYPE: Trimodal, Moderately Well Sorted TEXTURAL GROUP: Sand

SEDIMENT NAME: Moderately Well Sorted Medium Sand

	µm	ϕ
MODE 1:	462.5	1.117
MODE 2:	327.5	1.616
MODE 3:	655.0	0.616
D_{10}:	179.3	0.671
MEDIAN or D_{50}:	441.9	1.178
D_{90}:	628.1	2.480
(D_{90} / D_{10}):	3.503	3.695
$(D_{90} - D_{10})$:	448.8	1.809
(D_{75} / D_{25}):	1.500	1.554
$(D_{75} - D_{25})$:	160.3	0.585

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.0%	COARSE SAND:	12.7%
SAND:	100.0%	MEDIUM SAND:	70.3%
MUD:	0.0%	FINE SAND:	9.8%
		V FINE SAND:	6.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	0.8%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic µm	Geometric µm	Logarithmic ϕ	Geometric µm	Logarithmic ϕ	Description
MEAN($\bar{x}$):	413.6	371.2	1.430	378.8	1.401	Medium Sand
SORTING (s):	165.9	1.671	0.741	1.622	0.698	Moderately Well Sorted
SKEWNESS (*Sk*):	0.796	-1.521	1.521	-0.630	0.630	Very Fine Skewed
KURTOSIS (*K*):	7.927	5.551	5.551	2.072	2.072	Very Leptokurtic

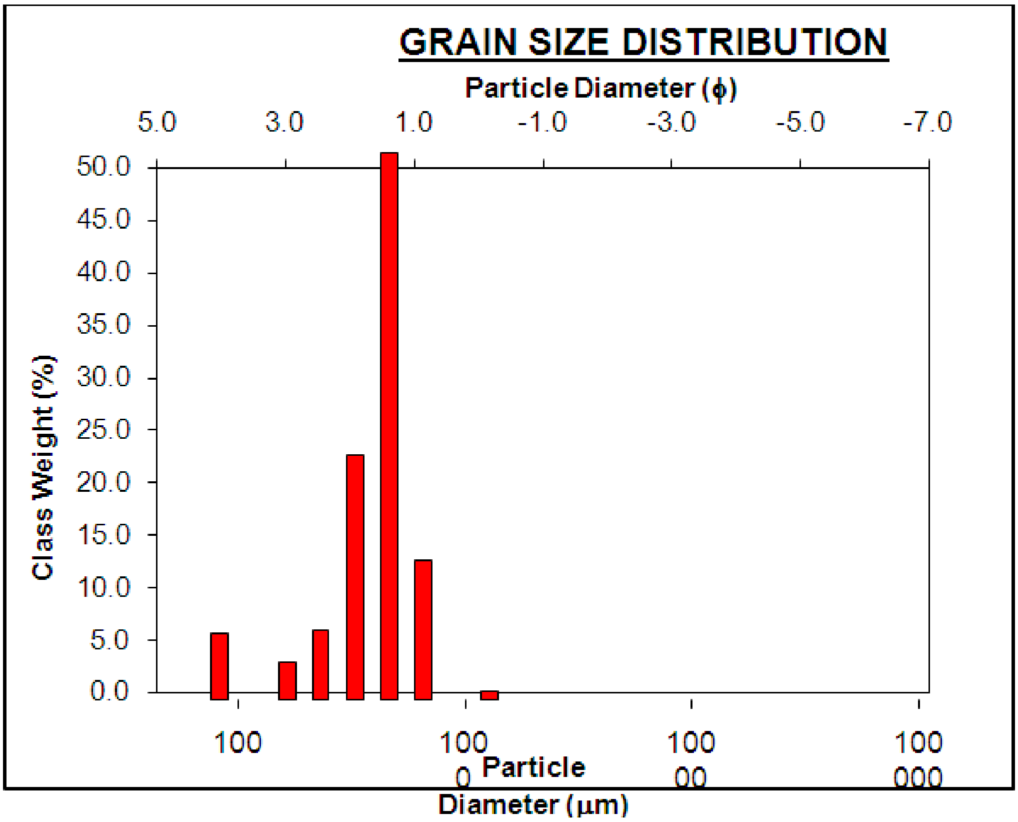

Fig. 14: Grain Size class of weight distribution chart for Ihioma Gully Head.

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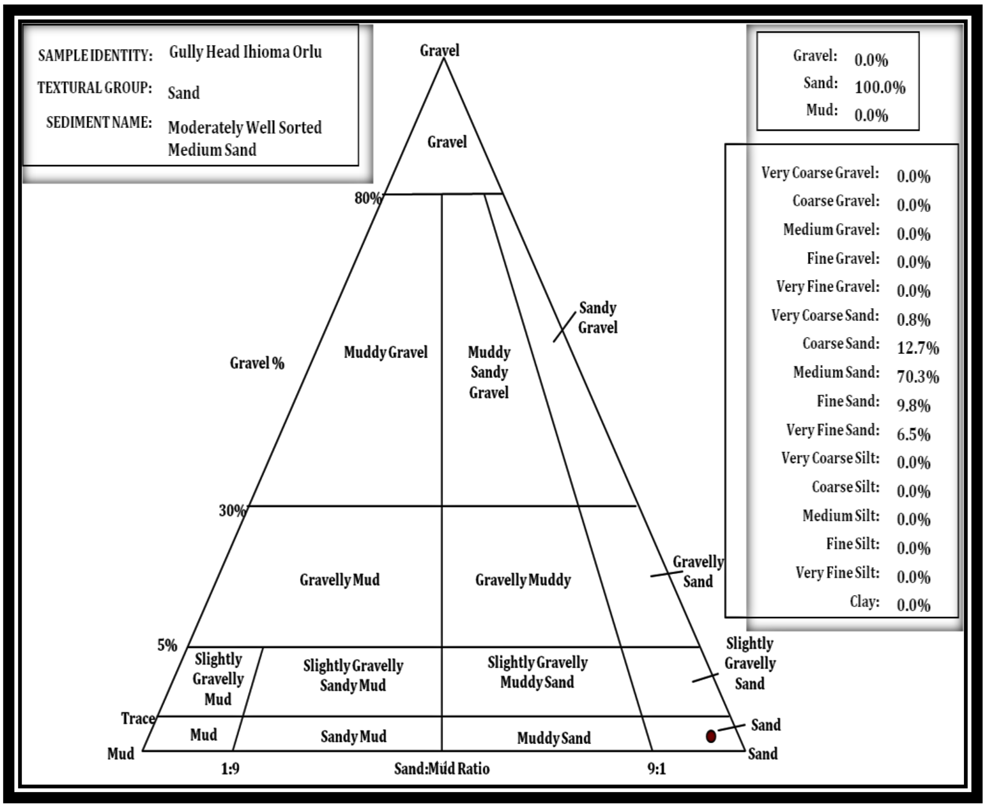

Fig. 15: Pyramidal chart of Ihioma Gully Head grain size distribution

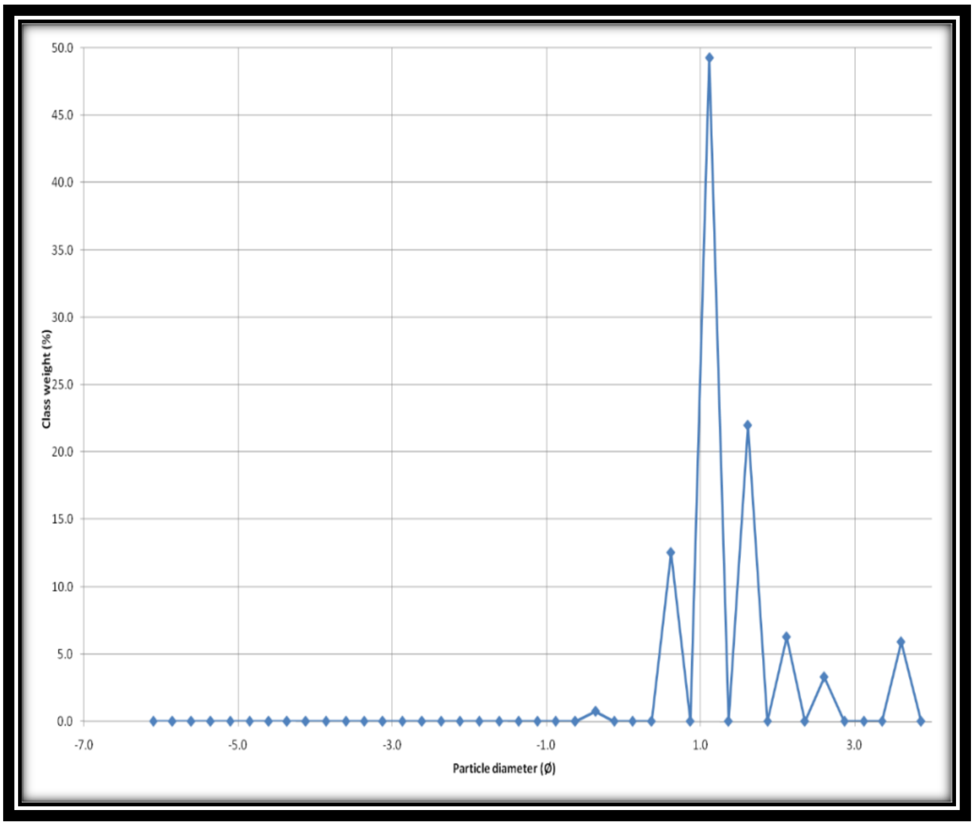

Fig. 16: Ihioma Gully Head Grain Size Distribution class of weight graph in phi

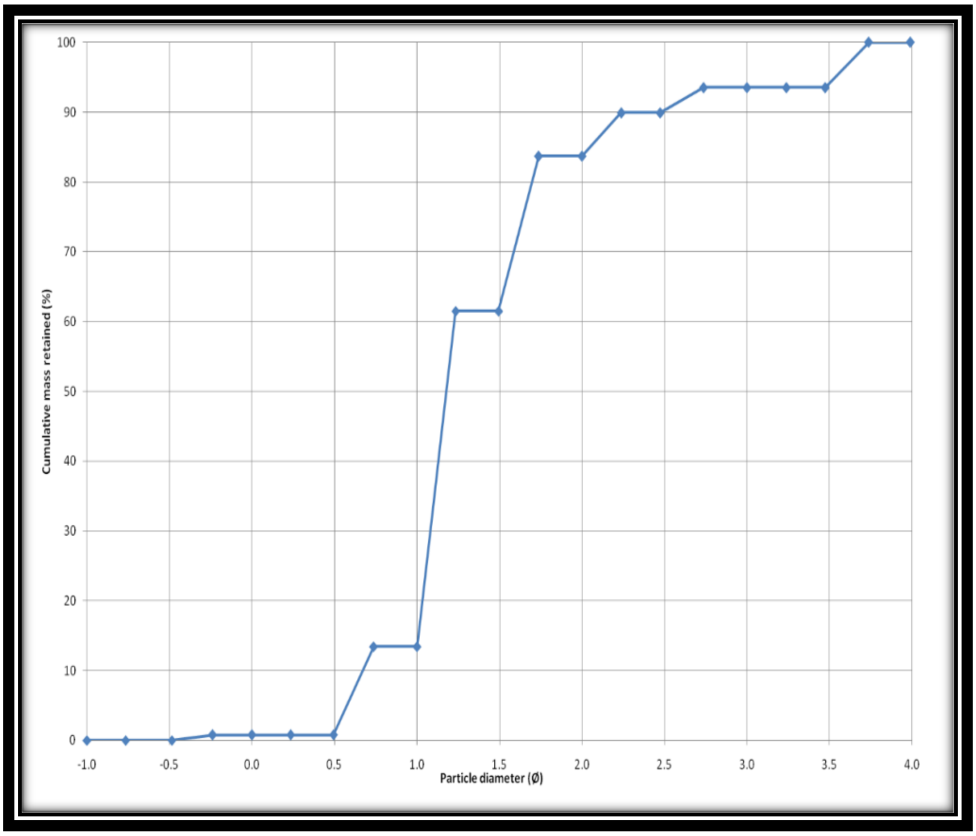

Fig. 17: Ihioma Gully Head Grain Size Cumulative Mass Retained graph in phi

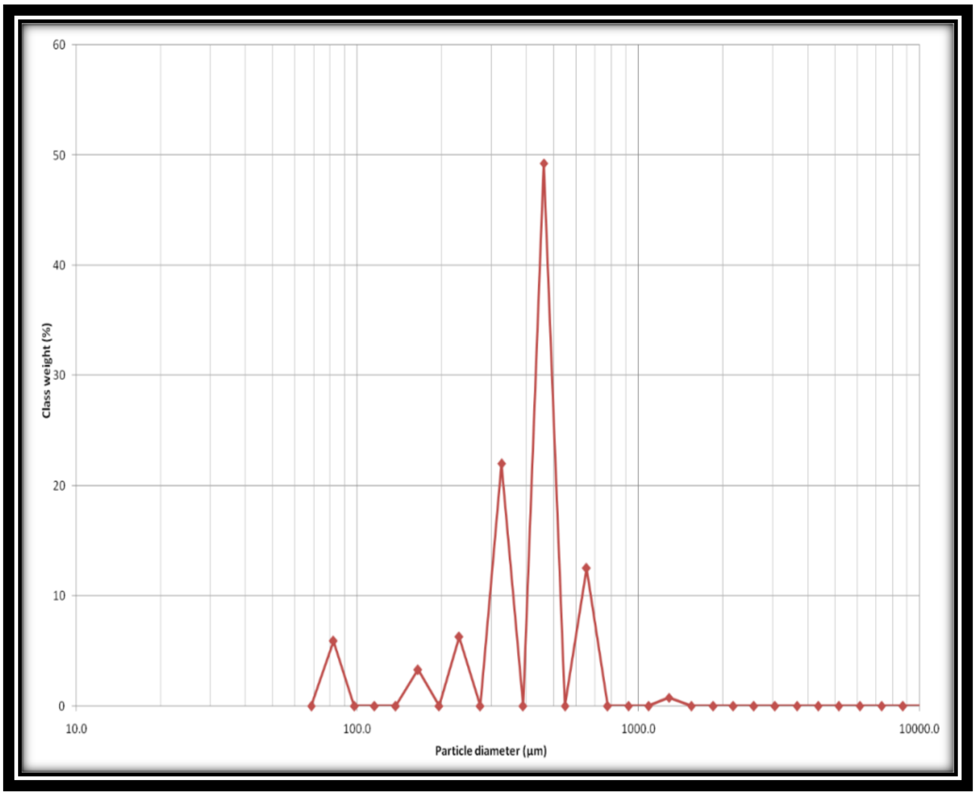

Fig. 18: Ihioma Gully Head class of weight graph in microns

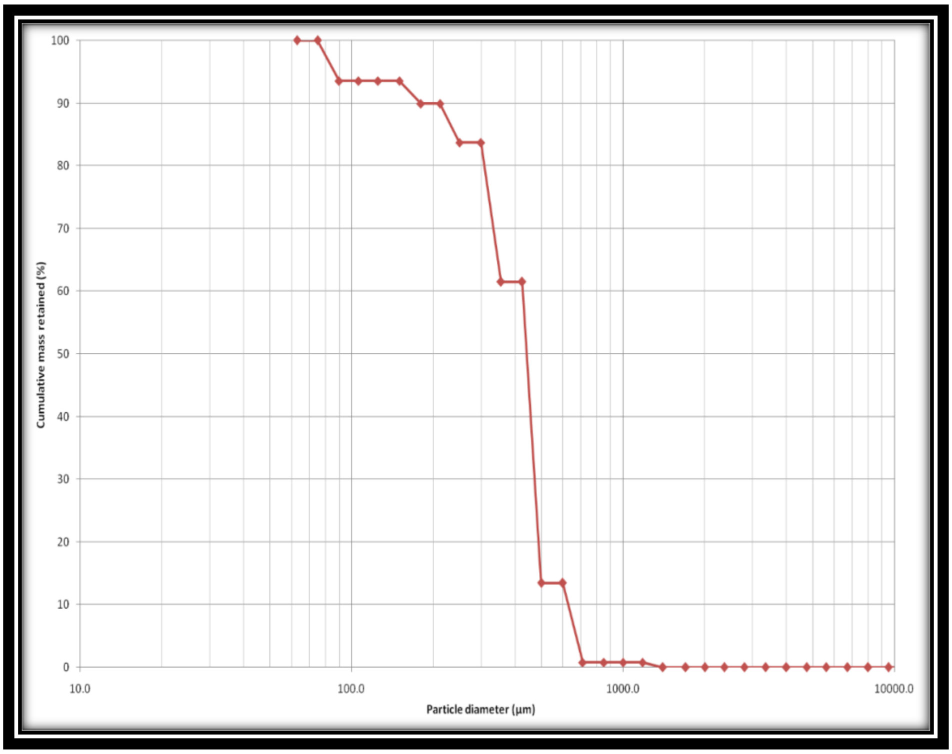

Fig. 19: Ihioma Gully Head cumulative mass retained graph in microns

In Ihioma Gully Head Sample, mud and gravel are 0% present while sand is 100% present. The sand in the area is trimodal and moderately sorted. They are very fine skewed and as well, leptokurtic. These properties as enumerated in Table 4 and Figure 15 make the area prone to erosion.

3.4 Grain Size Distribution for Middle of Ihioma Gully

Table 5: Sample statistics table for Middle of Ihioma Gully

SAMPLE STATISTICS

SAMPLE IDENTITY: **Middle Gully Ihioma Orlu** ANALYST & DATE: **, 21/7/2014**

SAMPLE TYPE: Polymodal, Moderately Sorted TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

	μm	ϕ
MODE 1:	462.5	1.117
MODE 2:	327.5	1.616
MODE 3:	231.0	2.119
D_{10}:	89.26	0.584
MEDIAN or D_{50}:	348.8	1.520
D_{90}:	667.2	3.486
(D_{90} / D_{10}):	7.474	5.970
$(D_{90} - D_{10})$:	577.9	2.902
(D_{75} / D_{25}):	2.154	2.087
$(D_{75} - D_{25})$:	264.5	1.107

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.5%	COARSE SAND:	20.7%
SAND:	99.5%	MEDIUM SAND:	44.8%
MUD:	0.0%	FINE SAND:	21.7%
		V FINE SAND:	10.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.5%	V FINE SILT:	0.0%
V COARSE SAND:	1.8%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	406.3	332.1	1.590	335.1	1.577	Medium Sand
SORTING (s):	271.6	1.940	0.956	1.923	0.943	Moderately Sorted
SKEWNESS (Sk):	3.202	-0.541	0.541	-0.223	0.223	Fine Skewed
KURTOSIS (K):	23.98	3.212	3.212	1.142	1.142	Leptokurtic

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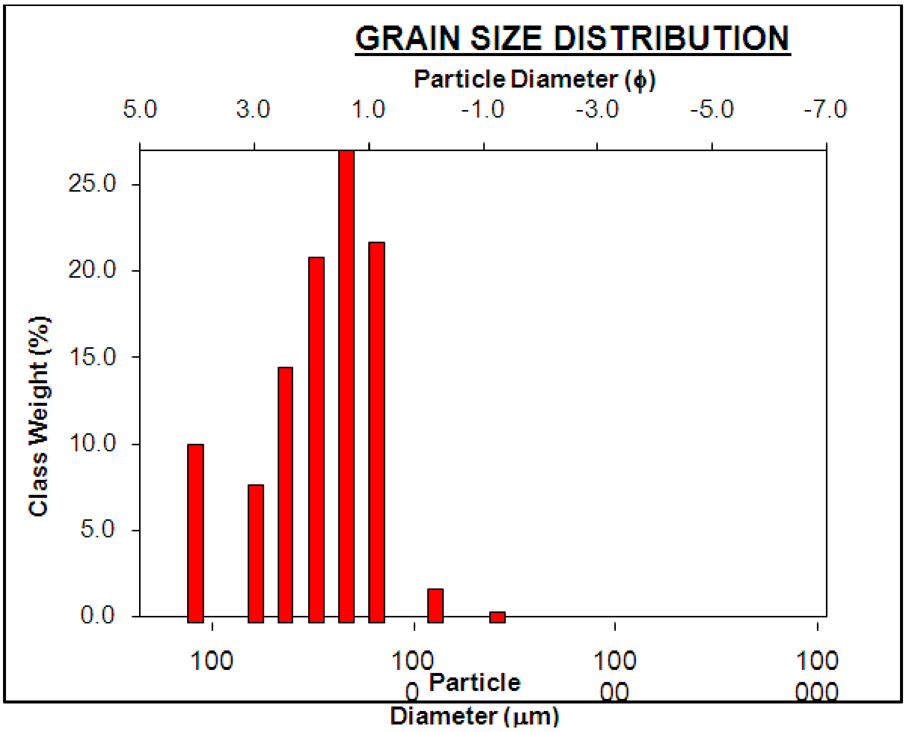

Fig. 20: Grain Size class of weight distribution chart for Middle of Ihioma Gully**.**

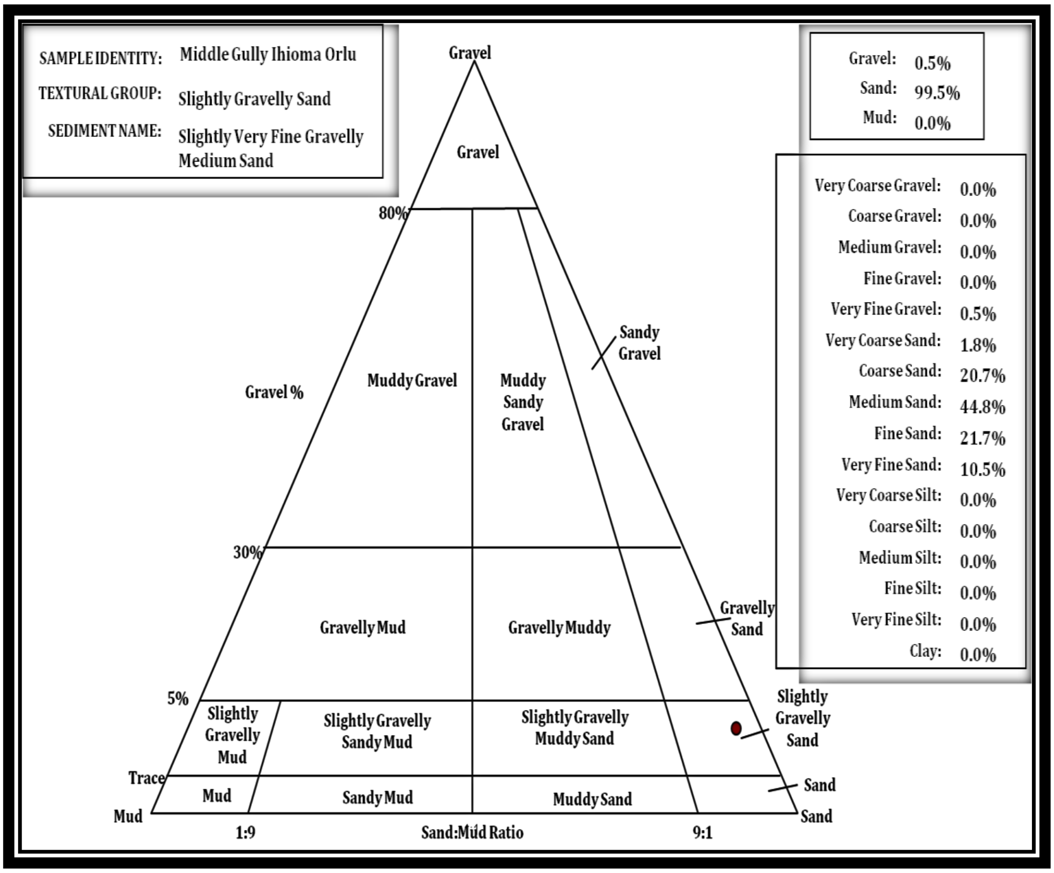

Fig. 21: Pyramidal chart of Middle of Ihioma Gully grain size distribution

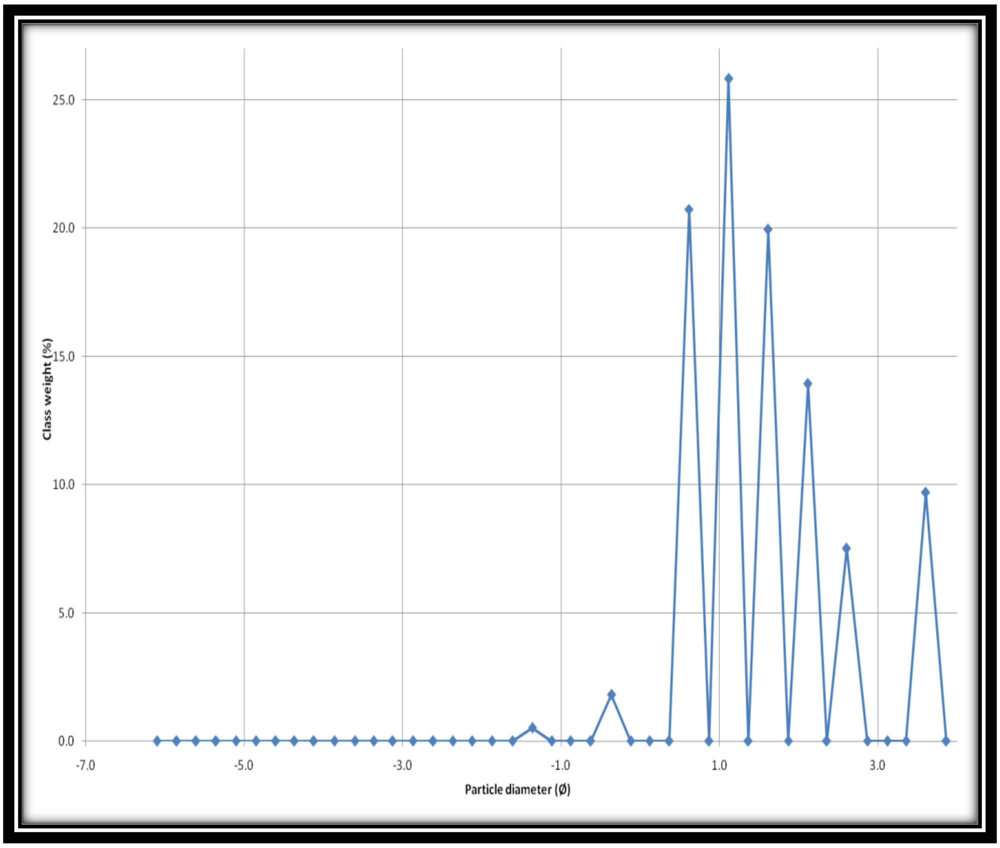

Fig. 22: Middle of Ihioma Gully Grain Size Distribution class of weight graph in phi

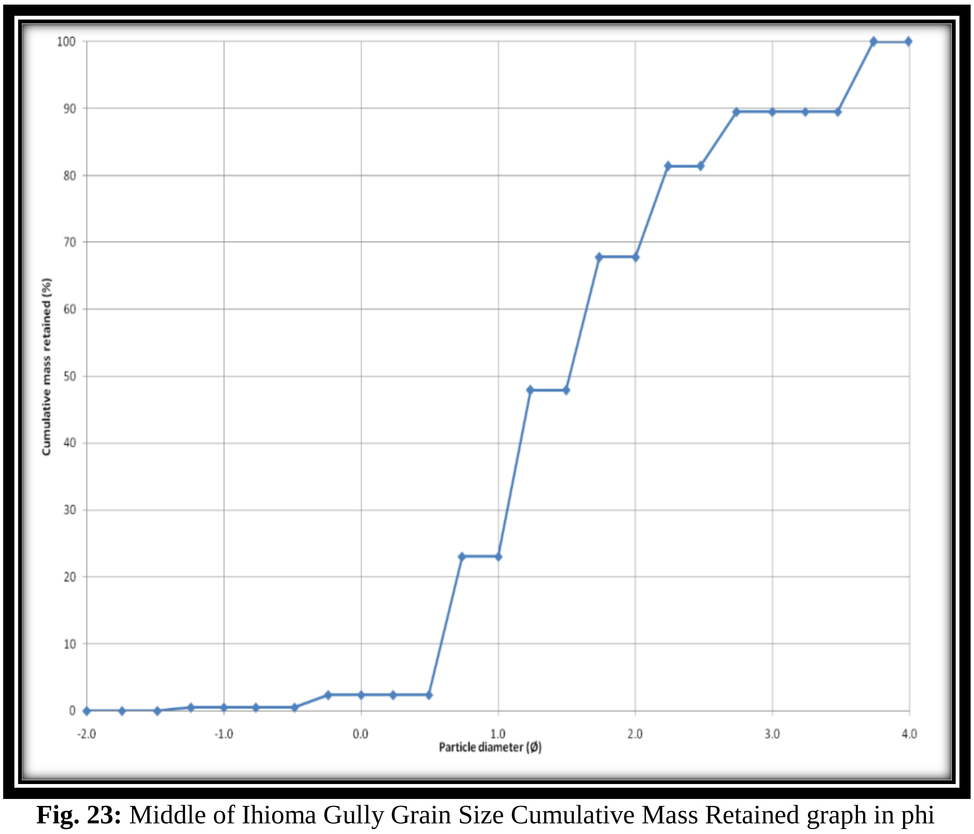

Fig. 23: Middle of Ihioma Gully Grain Size Cumulative Mass Retained graph in phi

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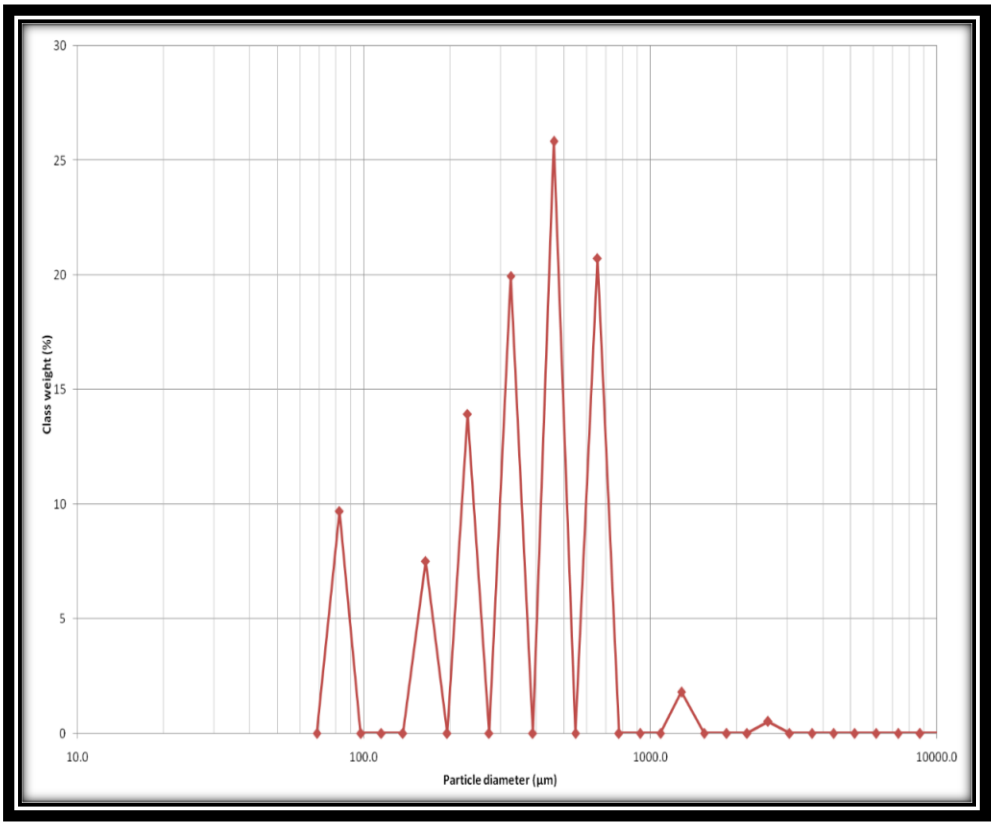

Fig. 24: Middle of Ihioma Gully class of weight graph in microns

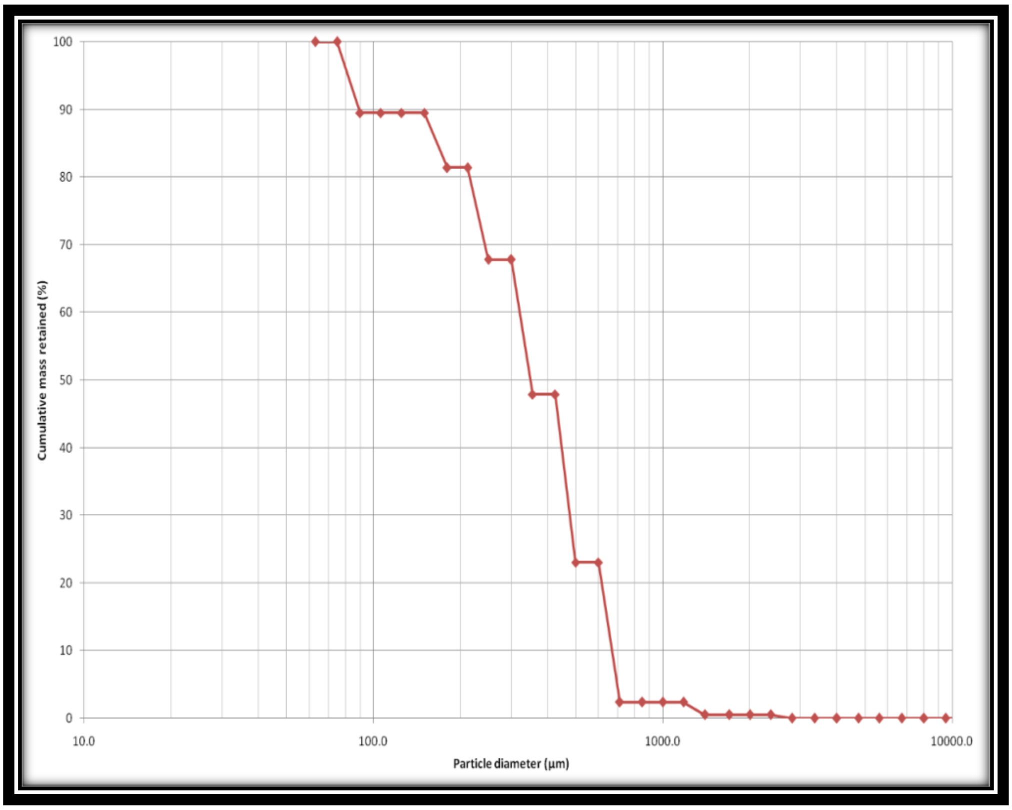

Fig. 25: Middle of Ihioma Gully cumulative mass retained graph in microns

The sample collected at middle of Ihioma Gully sample shows that gravel is 0.5%, mud 0% and sand 99.5%. It is polymodal, moderately sorted; fine skewed and leptokurtic as seen from Table 5 and Figure 21 above.

3.5 Grain Size Distribution of Njaba Gully Sample 1

Table 6: Sample statistics table for Njaba gully Sample 1

SAMPLE STATISTICS

SAMPLE IDENTITY: Njaba Gully Sample 1 — ANALYST & DATE: , 18/7/2014

SAMPLE TYPE: Polymodal, Moderately Sorted — TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

	μm	ϕ
MODE 1:	655.0	0.616
MODE 2:	462.5	1.117
MODE 3:	327.5	1.616
D_{10}:	225.4	0.502
MEDIAN or D_{50}:	473.3	1.079
D_{90}:	706.2	2.150
(D_{90} / D_{10}):	3.134	4.284
$(D_{90} - D_{10})$:	480.9	1.648
(D_{75} / D_{25}):	1.992	2.616
$(D_{75} - D_{25})$:	325.1	0.994

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.5%	COARSE SAND:	32.2%
SAND:	99.5%	MEDIUM SAND:	42.3%
MUD:	0.0%	FINE SAND:	13.2%
		V FINE SAND:	3.3%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.5%	V FINE SILT:	0.0%
V COARSE SAND:	8.5%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	538.0	457.8	1.127	431.4	1.213	Medium Sand
SORTING (s):	318.6	1.792	0.842	1.754	0.811	Moderately Sorted
SKEWNESS (*Sk*):	2.095	-0.534	0.534	-0.148	0.148	Fine Skewed
KURTOSIS (*K*):	10.94	4.219	4.219	1.210	1.210	Leptokurtic

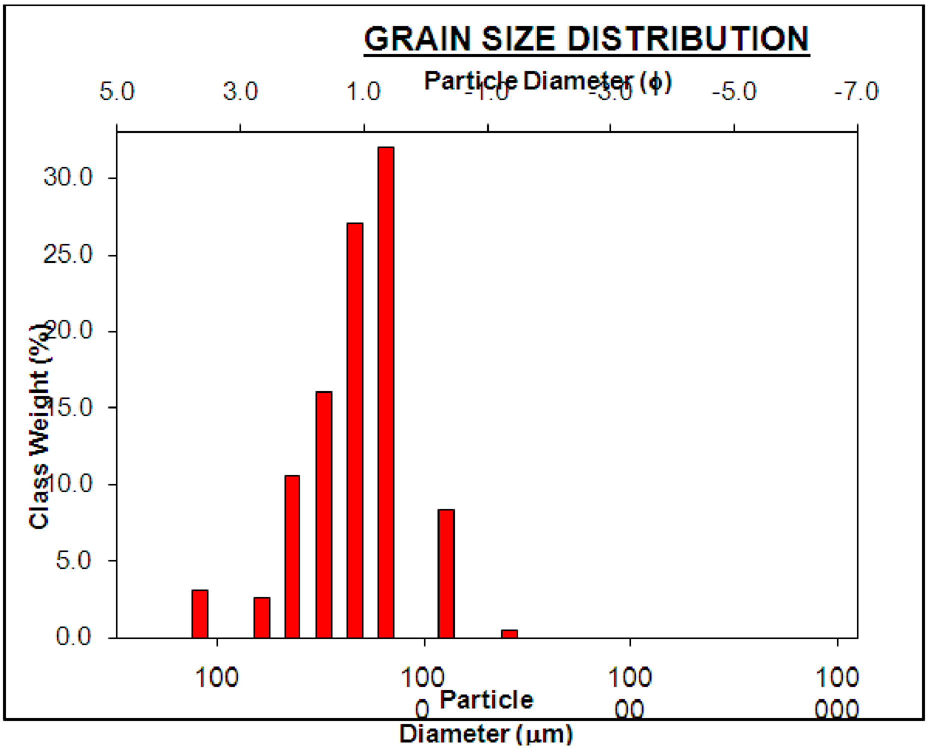

Fig. 26: Grain Size class of weight distribution chart of Njaba Gully sample 1.

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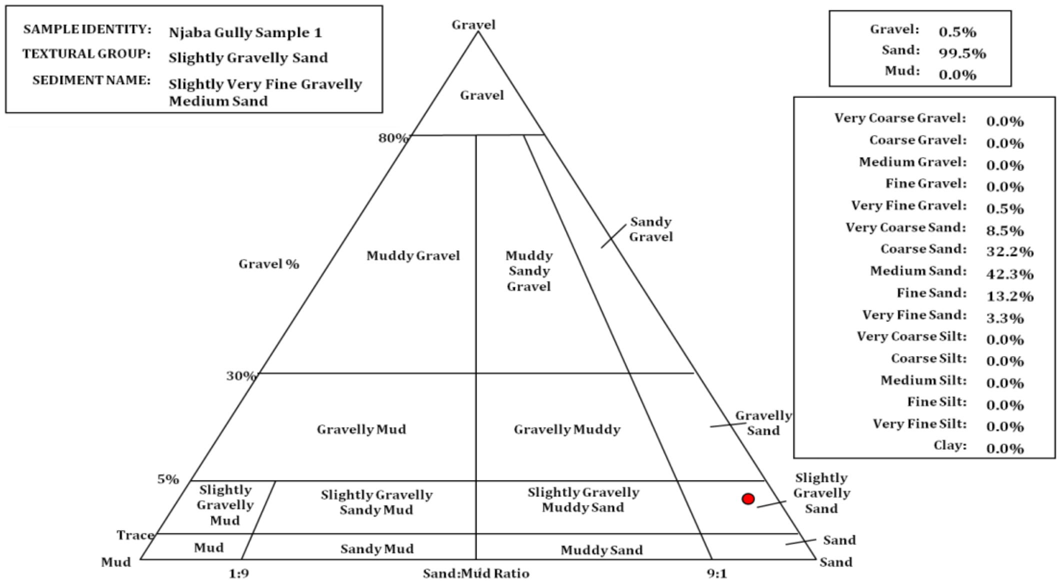

Fig. 27: Pyramidal chart of Njaba Gully sample 1 grain size distribution

Njaba gully Sample 1 analysis shows no significant change as compared to that of Middle Ihioma Gully Sample. At Njaba Gully Sample 1, gravel is 0.5%, mud 0% and sand 99.5%. The soil is polymodal and contains slightly very fine gravel, moderately sorted; fine skewed and leptokurtic as seen in Table 6 and Figure 27 above.

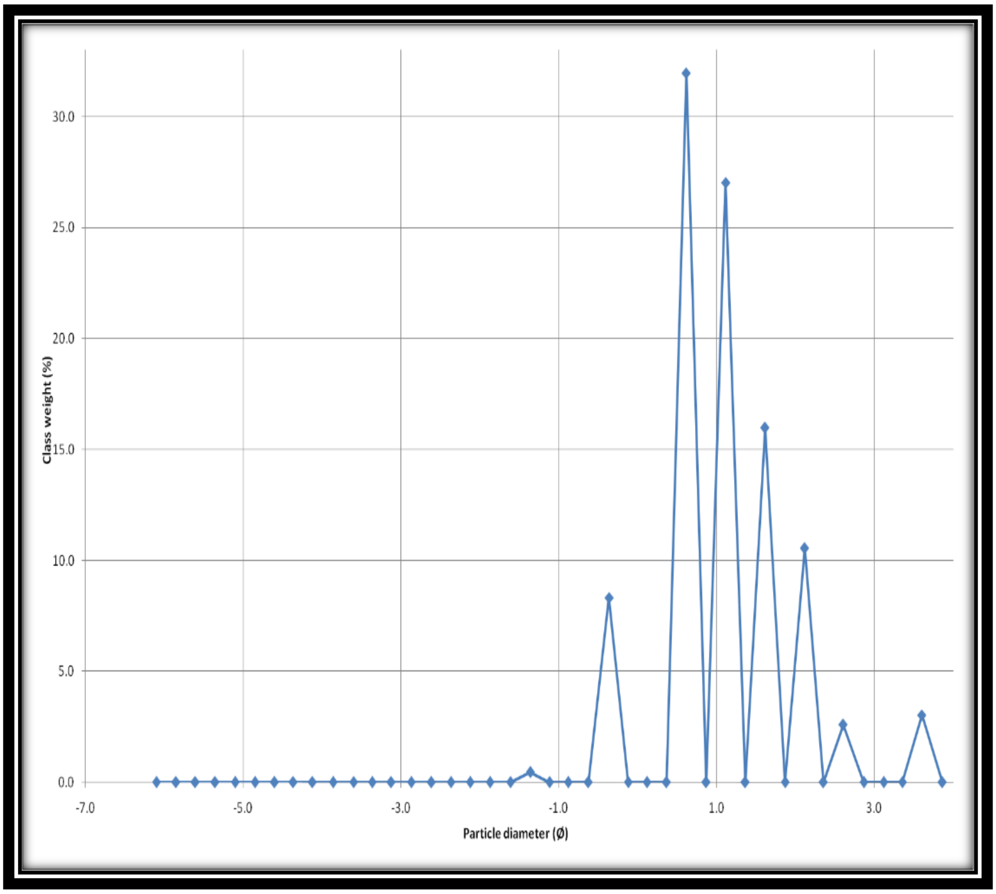

Fig. 28: Njaba Gully Sample 1 Grain Size Distribution class of weight graph in phi

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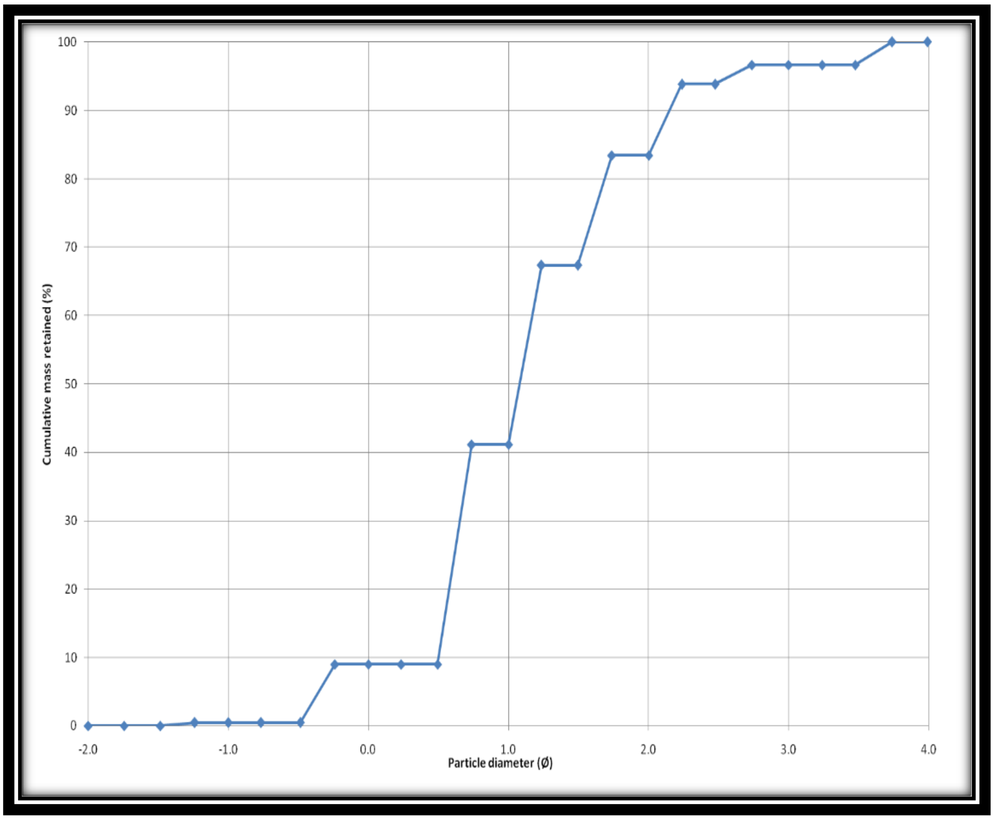

Fig. 29: Njaba Gully Sample 1 Grain Size Cumulative Mass Retained graph in phi

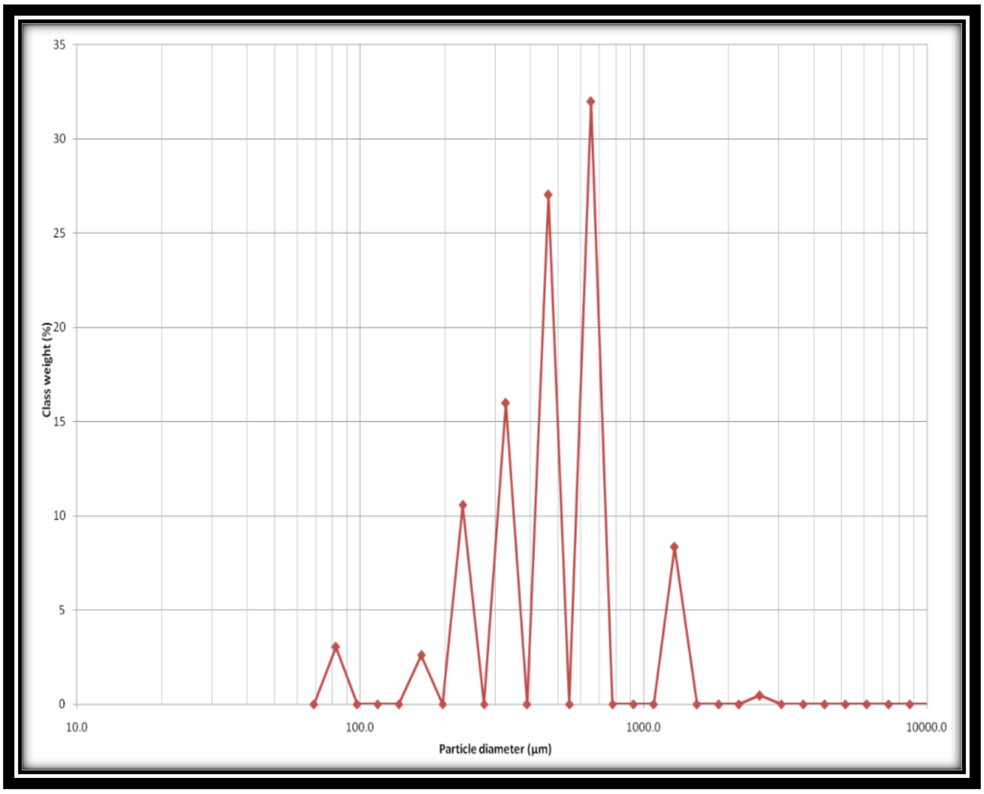

Fig. 30: Njaba Gully Sample 1 class of weight graph in microns

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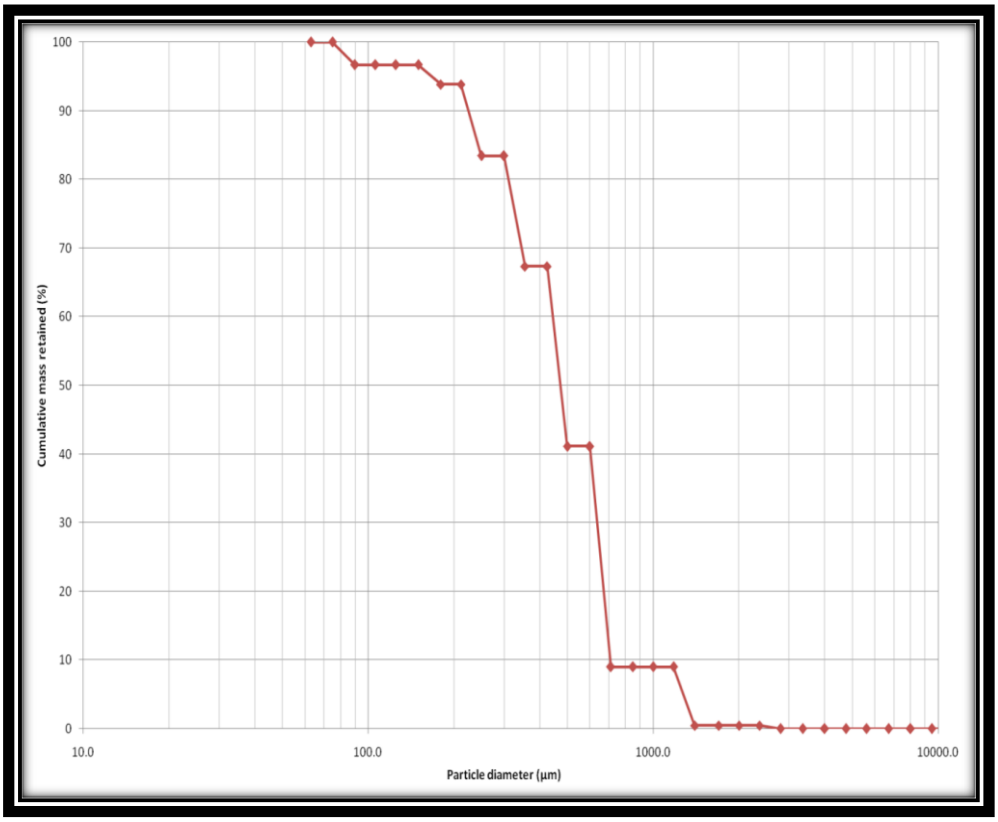

Fig. 31: Njaba Gully Sample 1 cumulative mass retained graph in microns

3.6 Grain Size Distribution of Njaba Gully Sample 2

Table 7: Sample statistics table of Njaba gully Sample 2

SAMPLE STATISTICS

SAMPLE IDENTITY: **Njaba Gully Sample 2** ANALYST & DATE: , 18/7/2014

SAMPLE TYPE: Polymodal, Moderately Sorted TEXTURAL GROUP: Slightly Gravelly Sand

SEDIMENT NAME: Slightly Very Fine Gravelly Medium Sand

	µm	ϕ
MODE 1:	655.0	0.616
MODE 2:	462.5	1.117
MODE 3:	327.5	1.616
D_{10}:	220.8	0.507
MEDIAN or D_{50}:	467.0	1.098
D_{90}:	703.6	2.179
(D_{90} / D_{10}):	3.186	4.297
(D_{90} - D_{10}):	482.8	1.672
(D_{75} / D_{25}):	2.000	2.592
(D_{75} - D_{25}):	323.5	1.000

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.2%	COARSE SAND:	30.1%
SAND:	99.8%	MEDIUM SAND:	43.8%
MUD:	0.0%	FINE SAND:	14.2%
		V FINE SAND:	3.5%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.2%	V FINE SILT:	0.0%
V COARSE SAND:	8.2%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic µm	Geometric µm	Logarithmic ϕ	Geometric µm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	522.0	444.4	1.170	426.0	1.231	Medium Sand
SORTING (s):	301.6	1.796	0.845	1.768	0.822	Moderately Sorted
SKEWNESS (Sk):	1.802	-0.567	0.567	-0.151	0.151	Fine Skewed
KURTOSIS (K):	8.851	4.051	4.051	1.220	1.220	Leptokurtic

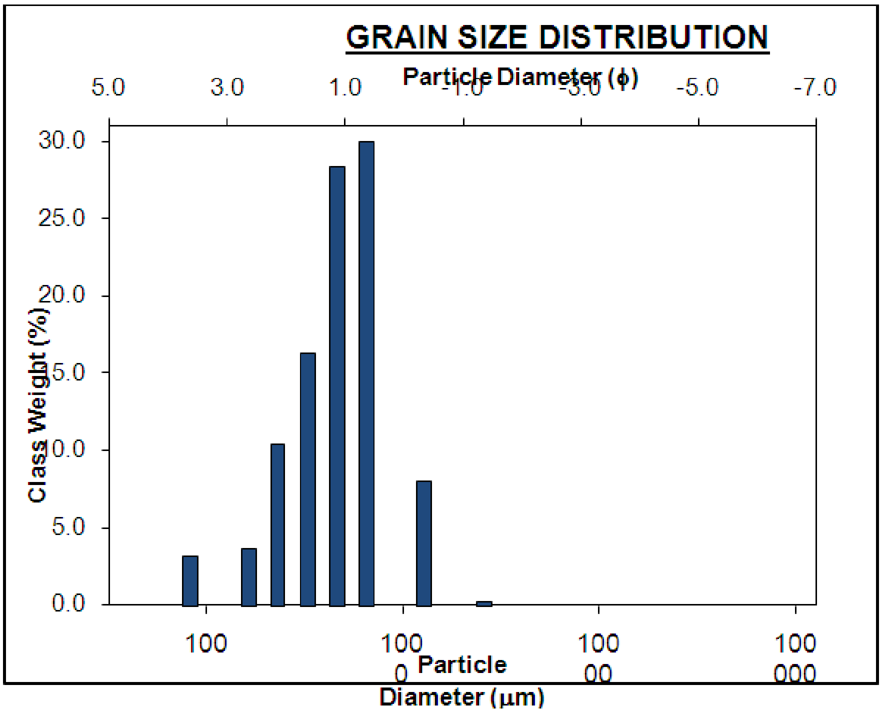

Fig. 32: Grain Size class of weight distribution chart for Njaba gully sample 2.

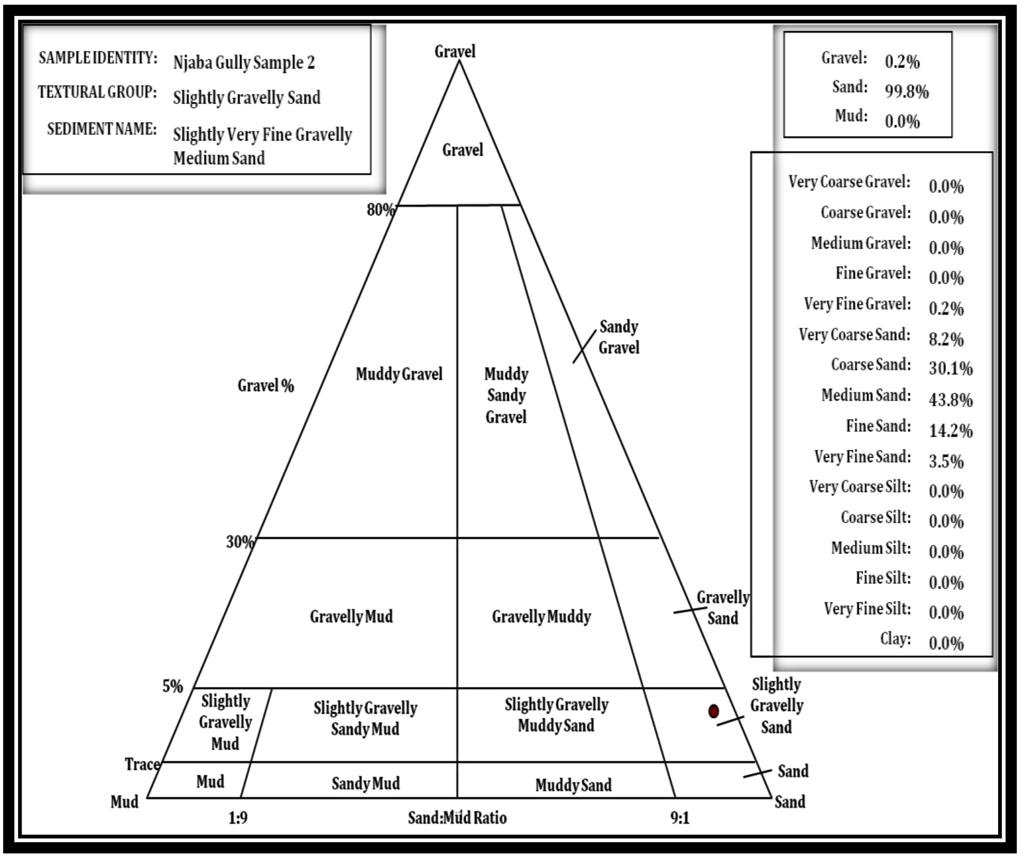

Fig. 33: Pyramidal chart of Njaba Gully sample 2 grain size distribution

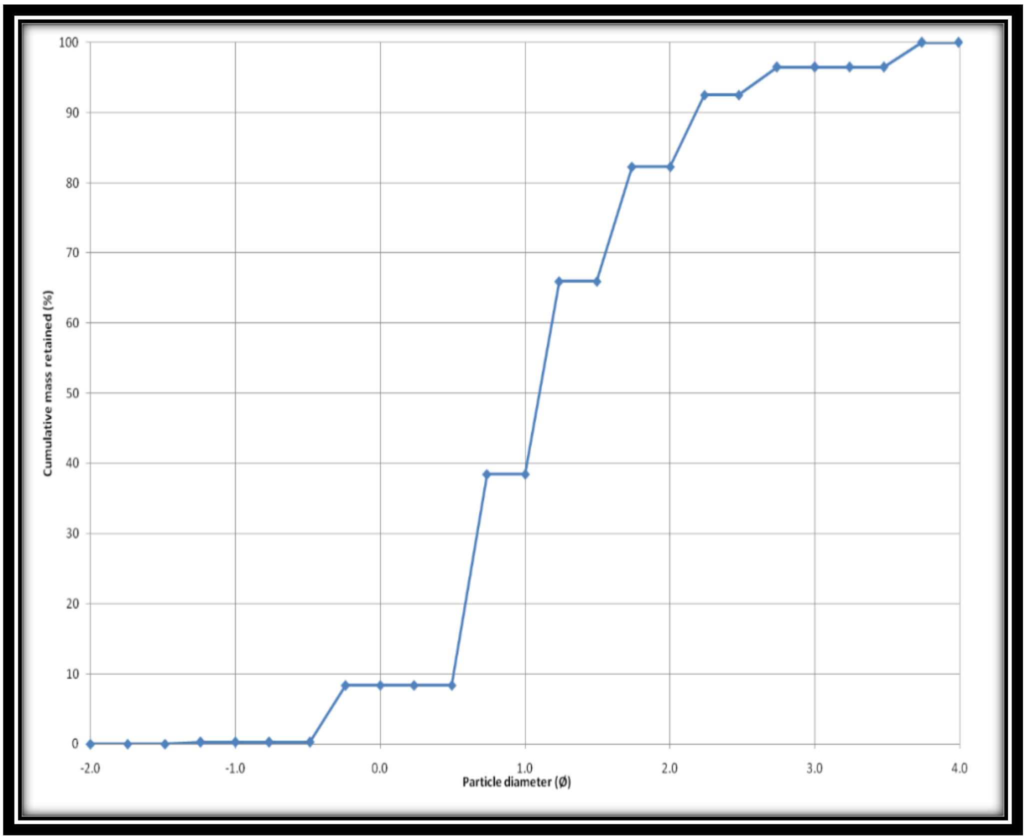

Fig. 34: Njaba Gully Sample 2 Grain Size Cumulative Mass Retained graph in phi

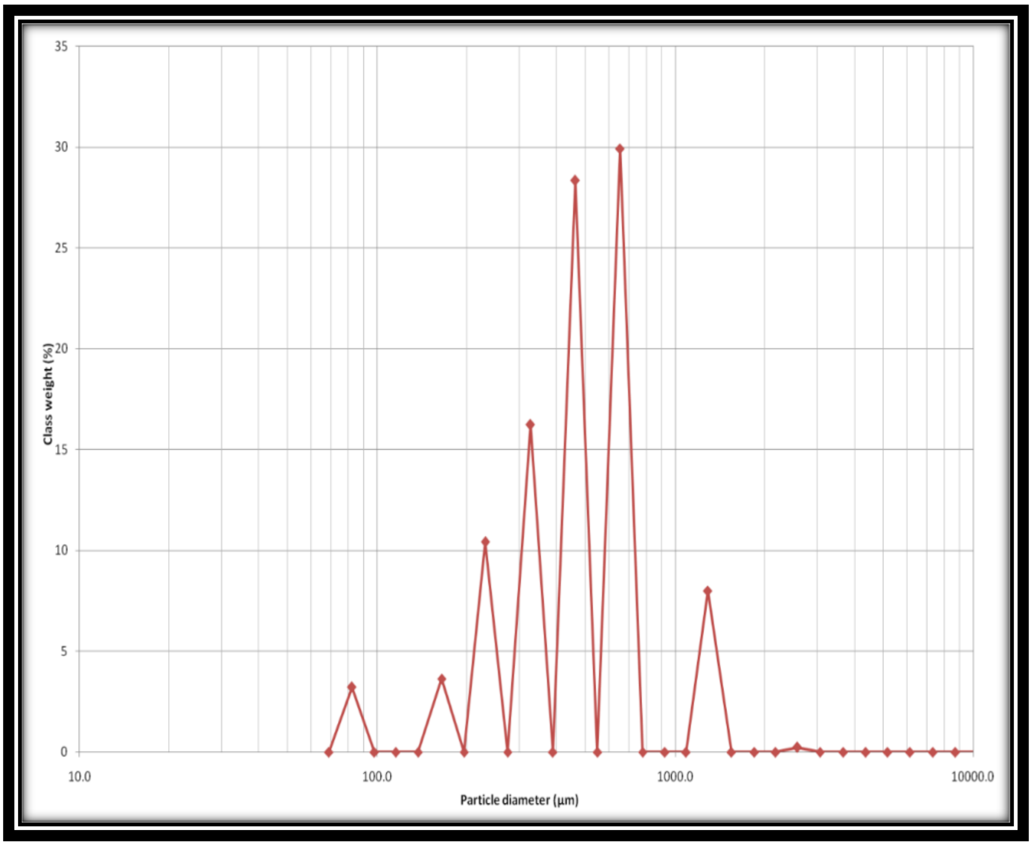

Fig. 35: Njaba Gully Sample 2 class of weight graph in microns

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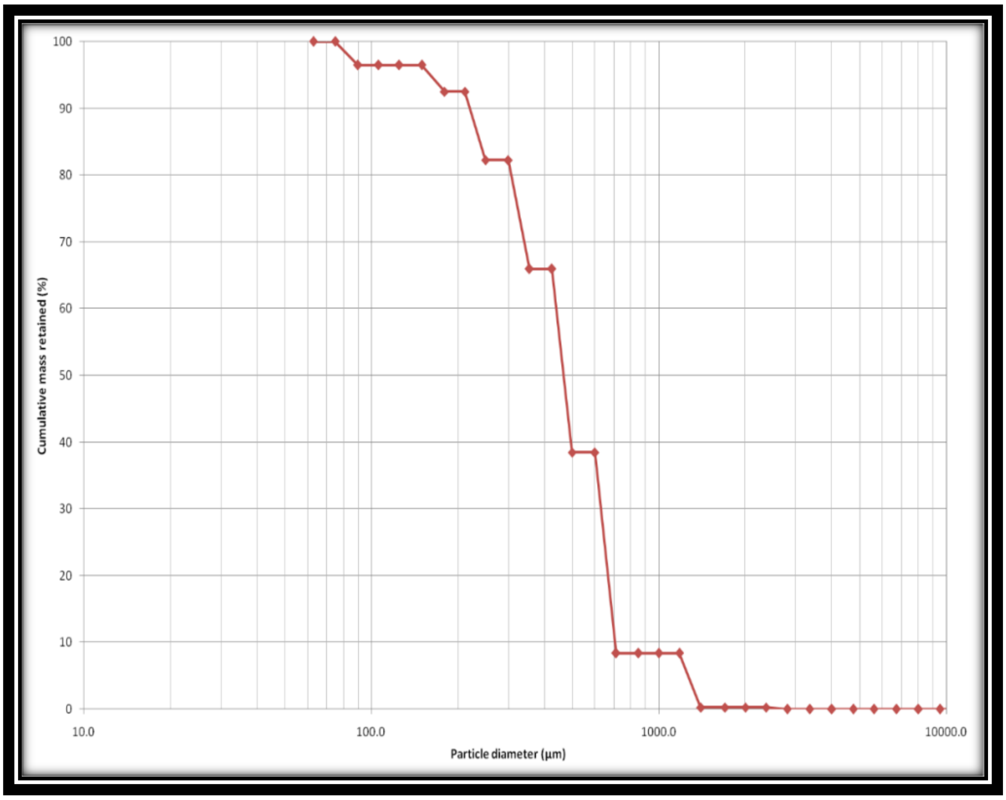

Fig. 36: Njaba Gully Sample 2 cumulative mass retained graph in microns

Njaba Gully Sample 2 and Sample 1 have almost similar results but just very slight difference in the gravel and sand contents. Sample 1 has gravel content of 0.5% and sand content of 99.5%, while sample 2 has 0.2% gravel and 99.8% sand. Just as seen in sample 1, sample 2 has 0% mud. The soil is polymodal and contains slightly very fine gravel, moderately sorted; fine skewed and leptokurtic as seen in the analysis presented in Table 7 and Figure 33.

IV. DISCUSSION

The table below summarizes the result of the geotechnical analysis carried out on the eight soil samples collected from the study area.

Table 8: Table of Grain Size Distribution, OMC, MDD, CBR, LL, PL and PI

Locations		Grain Size Distribution					OMC	MDD	CBR		LL	PL	PI
	V.Fine Sand	V.Coarse Sand	Coarse Sand	Medium Sand	Fine Sand	V.Fine Sand			Soaked	Unsoaked			
Afor Ukwu Gully Sample 1		1.20%	18.90%	47.70%	26.20%	6.10%	11.00%	1.91%		75.00%	28.50%	20.00%	8.50%
Afor Ukwu Gully Sample 2		2.20%	19.50%	52.80%	20.00%	5.60%	11.40%	1.92%		74.00%	22.80%	13.70%	9.10%
Ihioma Gully (Head)		0.80%	12.70%	70.30%	9.80%	6.50%	10.30%	1.91%		50.70%	29.10%	18.50%	10.60%
Ihioma Gully (Middle)	0.50%	1.80%	20.70%	44.80%	21.70%	10.50%	12.50%	1.90%		51.00%	31.70%	19.30%	12.40%
Njaba Gully(Okwudor Sec)	0.50%	8.50%	32.20%	42.30%	13.20%	3.30%	10.60%	1.91%		79.00%	27.80%	20.30%	7.50%

1													
Njaba Gully(Okwudor Sec) 2	0.20%	8.20%	30.10%	43.80%	14.20%	3.50%	10.30%	1.93%		87.00%	26.80%	20.8%	6.00%
Ogberuru Orlu Gully							10.70%	1.98%	35.00%	51.00%	35.00%	25.00%	10.00%
Umueshi Gully							8.80%	1.99%	39.00%	53.00%	26.00%	17.30%	8.70%

From the samples collected, it was observed that moderately sorted sand of different categories, (medium sand being the most dominant and very fine sand the least) dominated the samples, with very negligible percentage of fine gravel. No atom of silt, clay or mud was observed, thereby reducing the bonding matrix between the soil particles. This makes it easy for running water to carry away top and loose soil particles depending on the topography of the area. Optimum moisture content determination for the eight samples as shown above reveals that the moisture content of earth materials from the erosion sites ranges from 8.8% to 12.5%, with an average of 10.70%. This low natural moisture content implies that the soil loses moisture easily in its natural state. It also implies that at about 10.70% optimum moisture content within the study areas soil is compacted to its greatest density; thereby achieving its maximum dry density (the maximum dry density of the samples is approximately equal as they range between 1.90% and 1.99%). The Liquid Limits of the eight samples collected range from 22.80% to 35%, with an average of 28.46%. Due to the low value of Liquid Limits within the area, the soil easily gets saturated and thereby behaves like fluid and is transported out of their original positions.

The Plasticity Limits of the eight samples ranges between low values of 13.7% and 25%, with an average of 19.36%. Under this condition, the soil requires little or no much fluid to lose its cohesiveness or bonding. This makes the soil to be easily eroded. As Plasticity Limit and Liquid Limit are inseparable as both are directly proportional to each other, the Plasticity Index of the samples ranges from 6% to 12.40% with an average of 9.1% (Plasticity Index is the difference between the two). With this very low index, it implies that the samples are above 90% sand dominated and will not swell or shrink because of increment or reduction in water content of the soil. This property makes the soil within the area very suitable for both road and building constructions as there will not be any form of cracking or deformity on the structures due to expansion and contraction of soil. The CBR values for soaked and unsoaked samples were also determined and shown in the above table. The CBR values are low ranging from 37% to 39% for the soaked and 50.7% to 85% for the unsoaked; hence can withstand some appreciable weight or loading.

V. CONCLUSION

Even though there is a dominance of sand and sandy materials within the study area, the geotechnical analyses have shown that there are little clayey materials to act as binding materials. The absence of this clayey matrix makes the loose sand and other unconsolidated formations in the area susceptible to the influence of exogenic processes that lead to erosion and gully formation.

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