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Grain Size Distribution and Sedimentological Characterization of Clough Creek, Bayelsa State, Nigeria.

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Abstract
This study examines the grain size distribution and sediment properties of sediments collected from Bayelsa State's Clough Creek in Nigeria's lower Niger Delta.Sediment cores were taken using a percussion drilling rig at intervals of 0.75 meters from 0 to 30 meters. Dry sieve methods was used in accordance with ASTM D422 guidelines, and only samples with a sizable sand content were chosen for grain size examination. A total of 12 sand-rich samples were analyzed from BH1 (4.5m, 12m, 21m), BH2 (4.5m, 12m), BH3 (12m, 21, 24 m), and BH4 (4.5m, 12m, 21m, 24m).The findings indicate that the sediments are primarily very coarse to coarse sand, with mean grain sizes ranging from 0.13 to 0.50 φ. This suggests that the sediments were deposited in moderate to high-energy settings, such as active tidal channels.The sediments were classified as very well sorted to well sorted based on the sorting values (σi), which varied from 0.14 to 0.38 φ. This suggests that the sediment supply and transport energy were consistent over the majority of the sampling depths. Most samples were fine-skewed, with skewness values (Sk) ranging from -0.12 to +0.67, indicating a minor dominance of finer particles and a decrease in flow energy, a coarse-skewed (–0.12) was noticed on a sample from BH4 (4.5 m) which probably indicates a high-energy entry point or closeness to a more erosive zone. Broad grain size distributions and varied depositional energy conditions, characteristic of tidally influenced settings, were indicated by the typically low kurtosis (Kg) values, which ranged from 0.00 to 0.20, placing them in the platykurtic to highly platykurtic categories. Grain size metrics vary both vertically and laterally between boreholes, indicating the interaction of tidal, fluvial, and estuarine processes that shaped Clough Creek's sedimentary structure. The investigation comes to the conclusion that the creek's sediments were deposited in an active and dynamic environment, with texture and grain size distribution being influenced by localized variations in flow regimes. These results provide important information about the movements of sediment in Niger Delta creek systems and set a baseline particle size profile for Clough Creek.

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I. Introduction

Grain size analysis is a fundamental tool in sedimentary research (Nnurum et al., 2025), giving vital details regarding the energy conditions of the sedimentary environment and the physical properties of the sediments.The quantitative evaluation of the ratios of different grain sizes, from clay to gravel, aids in the identification of depositional environments, hydrodynamic regimes, and sediment transport processes. In a design, the gradation of the in situ or on-site soil often controls the design and ground water drainage of the site (Nnurum et al, 2021;Nnurum et al., 2025).Grain size analysis enables researchers to evaluate the origin, distribution, and behaviour of sediments in a range of natural systems using metrics such as mean grain size, sorting, skewness, and kurtosis (Folk & Ward, 1957;Nnurum et al., 2025; Evwienure et al., 2025). Grain size analysis is a crucial technique for comprehending the dynamics of deltaic and tidal sedimentation in the Niger Delta, where intricate networks of rivers, creeks, and estuaries dominate the landscape. The distribution and texture of sediment are impacted by the varying energy conditions brought about by seasonal flooding, fluvial discharge, and tidal intake in these ecosystems. In this regard, Clough Creek in Bayelsa State is an example of a typical deltaic creek system whose sediment composition has not been thoroughly studied.Previous research in comparable Bayelsa environments, including studies on the Odi River by Akpofure and Eteh (2023) and Epie Creek by Seiyaboh et al. (2016), has demonstrated how grain size data can support environmental assessment, identify transitions between high- and low-energy zones, and reveal trends in sediment deposition. This study focuses on conducting a detailed grain size analysis of sediments collected from borehole samples at Clough

Creek.The result will help us better understand the dynamics and distribution patterns of sediment in deltaic creek systems by providing information on how the texture of the sediment changes over space and with depth in Clough Creek.

II. Location of the Study Area

The study was carried out in Clough Creek**,** a tidal creek located in Bayelsa State, within the core of the Niger Delta region of southern Nigeria**.** The Niger delta region essentially illustrates the influence of river movements and sediment transport from several distances inland as it drives towards the oceans (Okorobia*et al.,* 2020). Clough Creek is a component of the vast and intricate system of estuary systems, wetlands, and water channels that define this deltaic environment. The area lies approximately between latitude 4°50′N to 4°52′N and longitude 5°40′E to 5°42′E as shown in fig 1, placing it within the Southern Ijaw Local Government Area (LGA)of Bayelsa State. The low-lying and riverine communities that encircle Clough Creek are particularly Azagbene, Ogbainbiri, and Ajatiton.These communities socioeconomic importance is highlighted by the creek's heavy reliance on it for domestic water usage, transportation, and fishing. The creek itself is directly influenced by both tidal actions from the AtlanticOcean and freshwater inflow from inland rivers**,** leading to mixed hydrological conditions that contribute to the dynamic sedimentation processes in the area. Due to the swampy terrain and the lack of extensive road networks, accessibility to Clough Creek is mainly by water, utilizing wooden boats and canoes. Because of its isolation, a large portion of the natural sedimentary environment has been preserved, which makes it perfect for research on sediment transport, grain size distribution, and depositional processes in deltaic environments that have not been significantly altered.

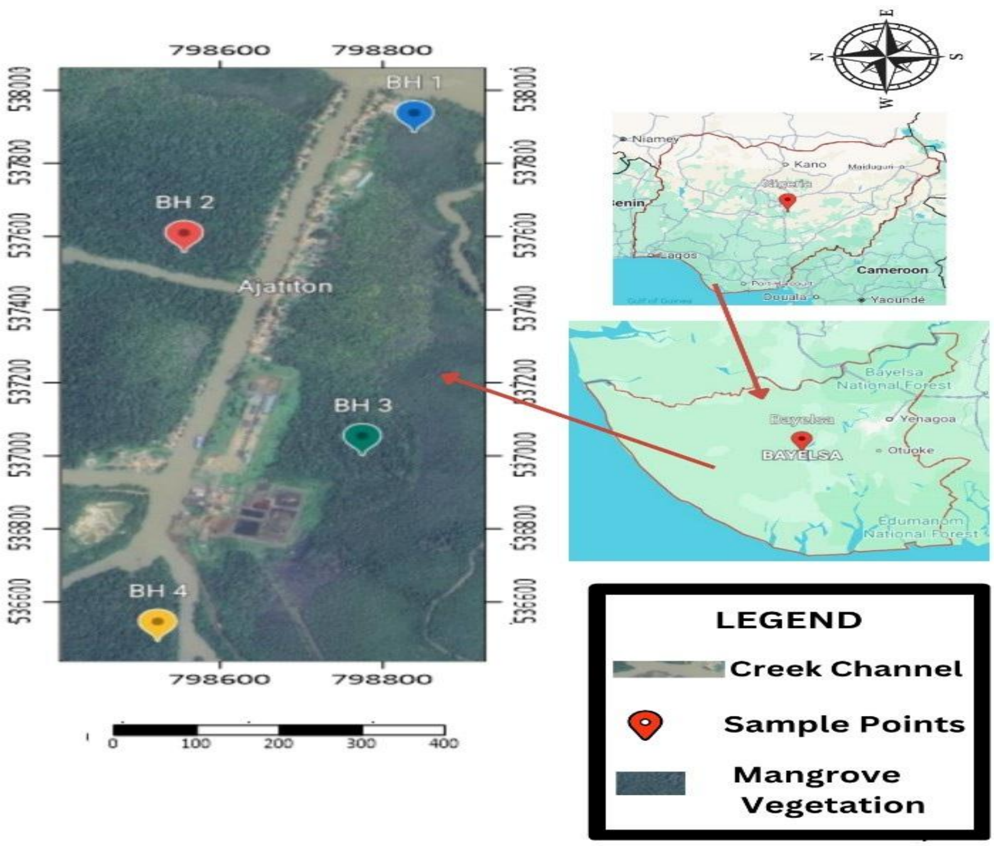

Fig 1: Map of the study area

III. Materials and Methods

3.1 Field Sampling Procedure

A percussion drilling rig was used to sample sediments for this study at Clough Creek in Bayelsa State. This technique was chosen due to the swampy topography and saturated nature of the area, making standard dry sampling impractical. Four boreholes were drilled strategically throughout the creek to record spatial heterogeneity in sediment distribution. Each borehole was drilled to a maximum depth of 30 meters and water level was encounter at about 0.2 to 0.5 meters across the borehole because of its closeness to the creek channel**,**As noted by Udoh et al. (2023), areas closer to active water bodies tend to exhibit higher and more variable subsurface moisture due to frequent saturation and shallow water tables.The samples were collected at 0.75-meter depth intervals**,** only samples with a significant amount of sand were selected for grain size analysis. The depths at which these sand-rich layers occurred were carefully recorded and labelled and the sand samples were transported to the laboratory. In the laboratory, using a mechanical sieve shaker, the samples were allowed to air dry, disaggregated, and then run through a number of standard ASTM sieves. The weight retained on each sieve was noted after sieving, and equation 1 was utilized to compute the cumulative weight % in order to create a grain size distribution curve for every sample. The sieves employed ranged in size from 4.75 mm to 0.075 mm.

3.2 Grain Size Statistical Parameters

The Folk and Ward (1957) approach was used to compute the following grain size statistical parameters in order to have a better understanding of the textural characteristics of the sand samples:

$$\%\text{ Cumulative Retained} = \Sigma(\%\text{ Retained on each sieve}) \quad (1)$$

$$\text{Mean Grain Size } (Mz) = \frac{\phi16+\phi50+\phi84}{3} \quad (2)$$

$$\text{Sorting } (\sigma i) = \frac{\phi84-\phi16}{4} + \frac{\phi95-\phi5}{6.6} \quad (3)$$

$$\text{Skewness (SK)} = \frac{(\phi16+\phi84-2\phi50)}{(\phi84-\phi16)} + \frac{(\phi5+\phi95-2\phi50)}{2(\phi95-\phi5)} \quad (4)$$

$$\text{Kurtosis (Kg)} = \frac{\phi95-\phi5}{2.44(\phi75-\phi25)} \quad (5)$$

IV. Results and Discussion

4.1 Soil Description:

According to the physical description, the soil of Clough Creek is primarily overlain with silt clay or organic rich, as is usual in low-energy tidal/mangrove creek habitats, and is underlain by a sand layer at a higher depth, most likely representing buried high-energy deposits.This is clearly show in the lithology as described in Fig. 2

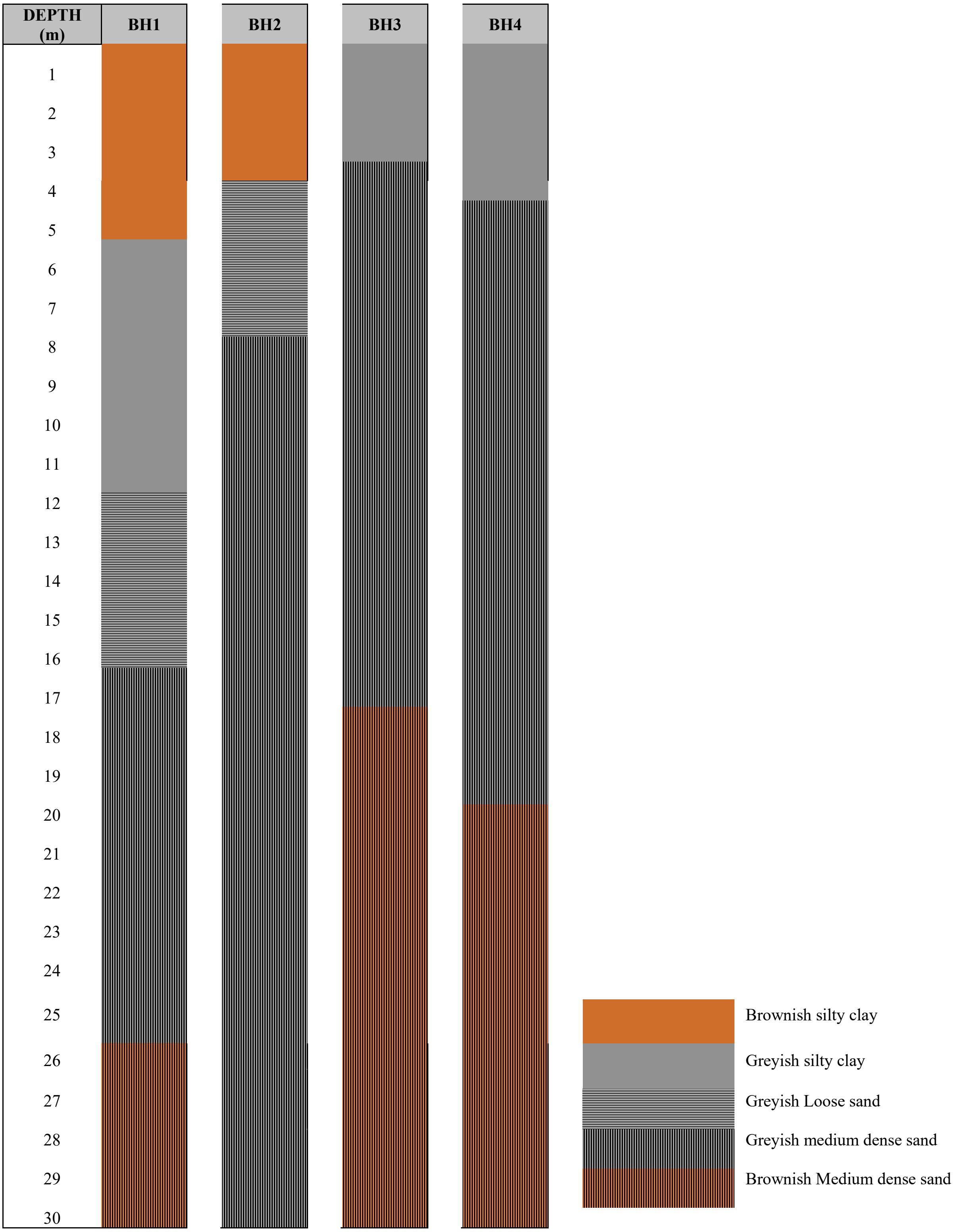

Fig. 2: Lithology Description of the Four Boreholes

4.2 Grain Size Analysis:

The Statistical parameters obtained from grain size analysis were used to plot the cumulative frequency curve as shown in Fig 3 to 6. From the graphical plotting, statistical size frequency parameters such as graphic mean, sorting, skewness and kurtosis were calculated using equation 2, 3, 4, and 5. And the statistical parameters are shown in Table 1.

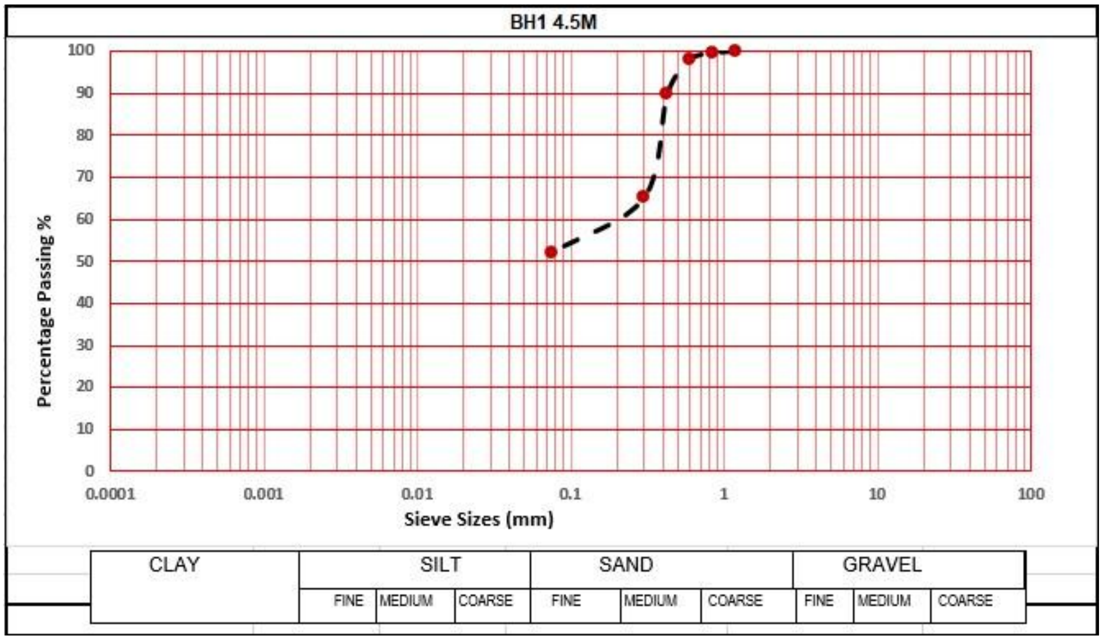

Fig. 3: Cumulative curve of BH1 4.5M

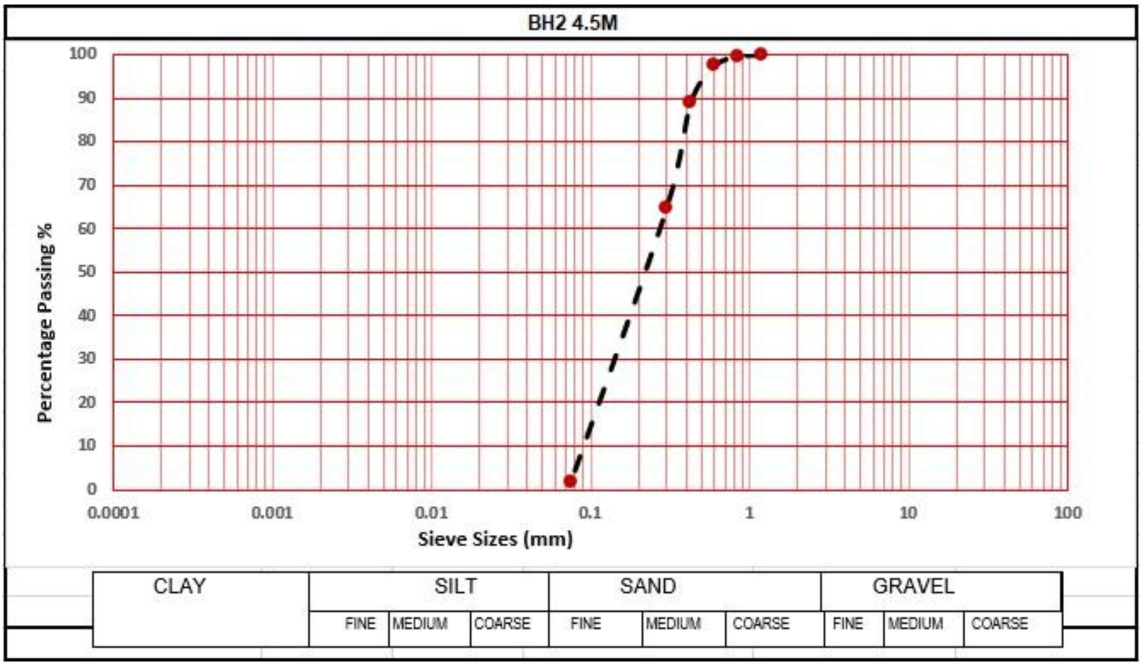

Fig. 4: Cumulative curve of BH2 4.5M

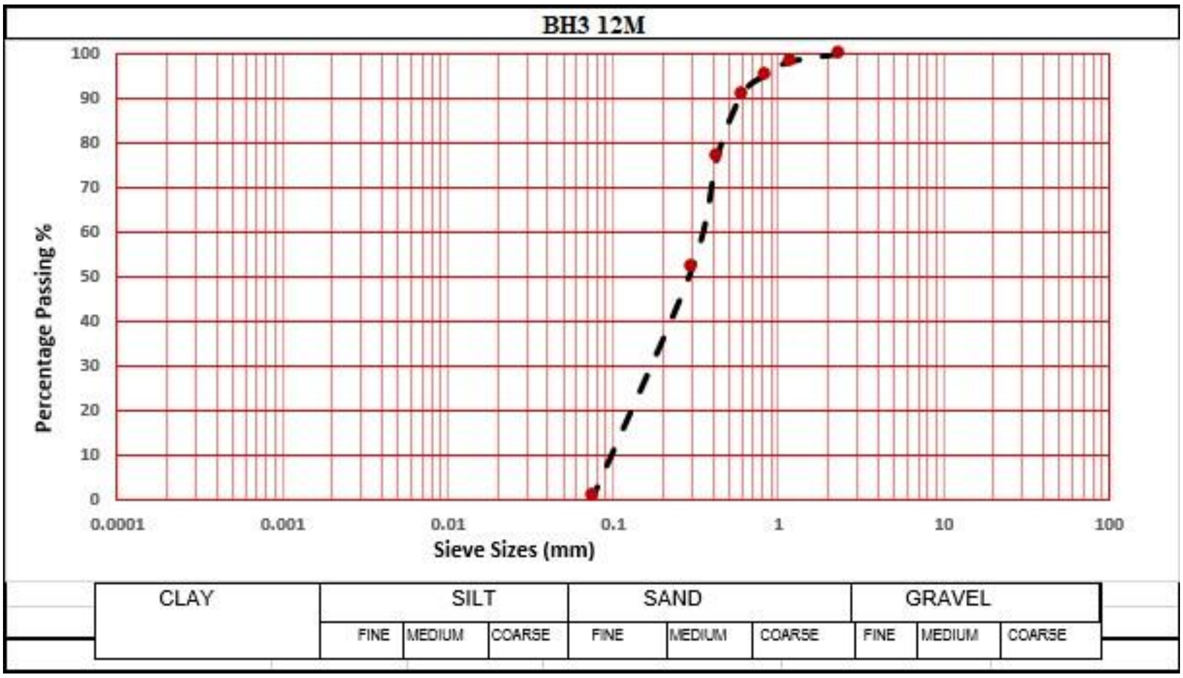

Fig. 5: Cumulative curve of BH3 12M

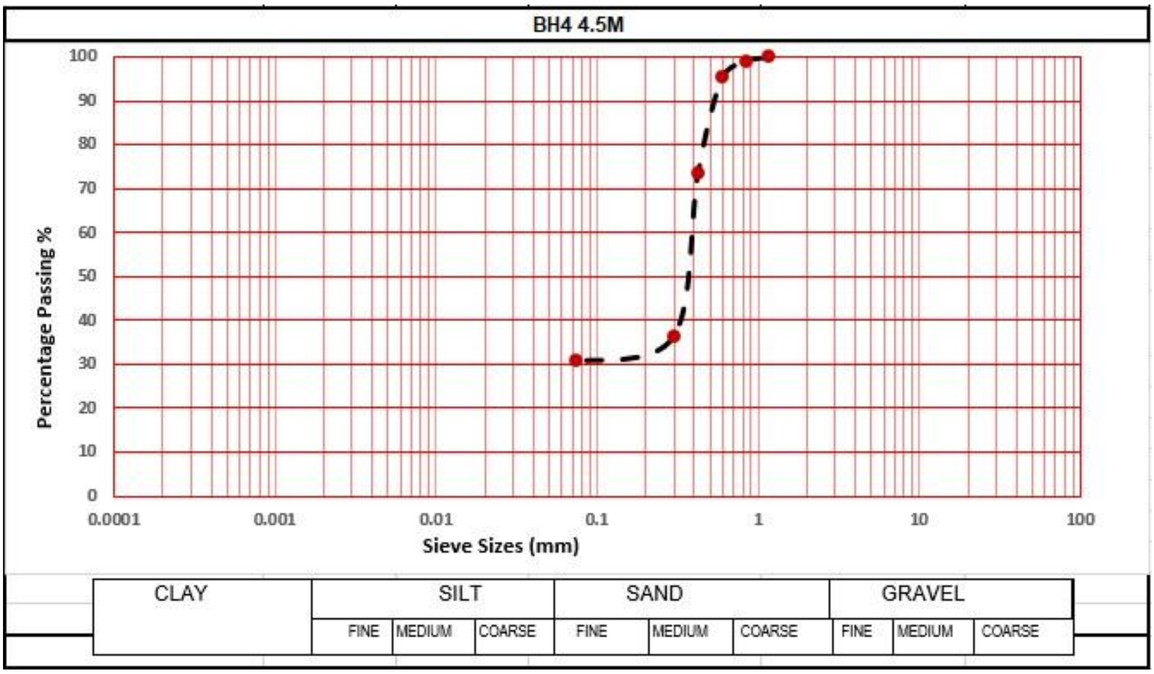

Fig. 6: Cumulative curve of BH4 4.5M

Table 1: Statistical Parameters of sediments from Clough creek

BH	Depth	Mean	Sorting	Skewness	Kurtosis	Description
BH1	4.5M	0.13	0.18	0.21	0	Very coarse sand, very well sorted, fine skewed, mesokurtic, High-energy, uniform transport
	12M	0.48	0.28	0.26	0.09	Coarse sand, very well sorted, fine skewed, Strong channel flow
	21M	0.42	0.28	0.15	0.093	Coarse sand, very well sorted , moderately fine skewed, Moderate energy, consistent transport
BH2	4.5M	0.24	0.14	0.04	0.035	Very coarse sand, very well sorted, near-symmetrical, High-energy beach-like or channel
	12M	0.36	0.19	0.01	0.058	Coarse sand, very well sorted, symmetrical, Uniform deposition, active transport

BH 3	12M	0.29	0.19	0.09	0.07	Coarse sand, very well sorted , slightly fine skewed, Moderate-high energy
	21M	0.50	0.38	0.67	0.20	Coarse sand, well sorted, strongly fine skewed, Lower energy transition
	24M	0.40	0.24	0.14	0.07	Coarse sand, very well sorted , slightly fine skewed, Channel edge or bar top
BH4	4.5M	0.30	0.22	-0.12	0.10	Coarse sand, very well sorted, slightly coarse skewed, Transitional flow regime
	12M	0.36	0.20	0.03	0.06	Coarse sand, very well sorted, symmetrical, Likely uniform energy, steady current
	21M	0.46	0.31	0.26	0.13	Coarse sand,very well sorted, fine skewed, Low to moderate energy
	24M	0.42	0.34	0.47	0.17	Coarse sand, well sorted, strongly fine skewed. Slower water, settling fines

4.3 Mean Grain Size (Mz)

All analyzed samples fall within the coarse to very coarse sand range (mean φ values between 0.13 and 0.50).This supports deposition under moderate to high-energy conditions, which are typical of tidal channels, active stream beds, or point bars. Larger sediment particles can be transported and deposited by active settings, which is represented by coarser grains (Folk & Ward, 1957; Pettijohn, 1975).Similar discoveries were stated by Akpofure and Eteh (2023) in their study of the Odi River sediments in Bayelsa State, where coarser textures showed strong fluvial or tidal dynamics. The mean grain size was calculated using equation 2 and the contour map is clearly shown in fig 7.

4.4 Sorting (σi)

The analyzed sediments showed a sorting range of 0.14 to 0.34 which is ≤0.35 showing very well sorted sand, and BH3 at 21m showed 0.38 which is ≤0.5 indicating well sorted sand. The samples exhibits a well to very well sorting indicating a consistent distribution of grain sizes and a comparatively steady regime of depositional energy. Environments like beaches or tidal creeks that have constant flow direction and velocity are frequently associated with well-sorted sands (Nichols, 2009). The values for the sorting was calculated using equation 3 and the contour map is clearly shown infig 8.

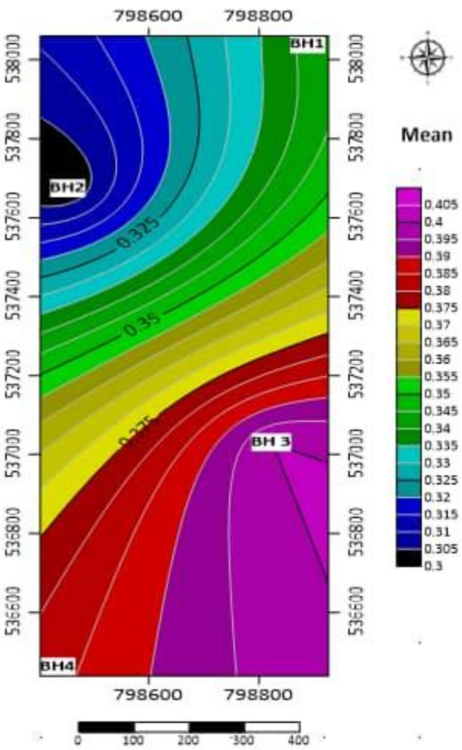

Figure 7: Contour map for mean grain size

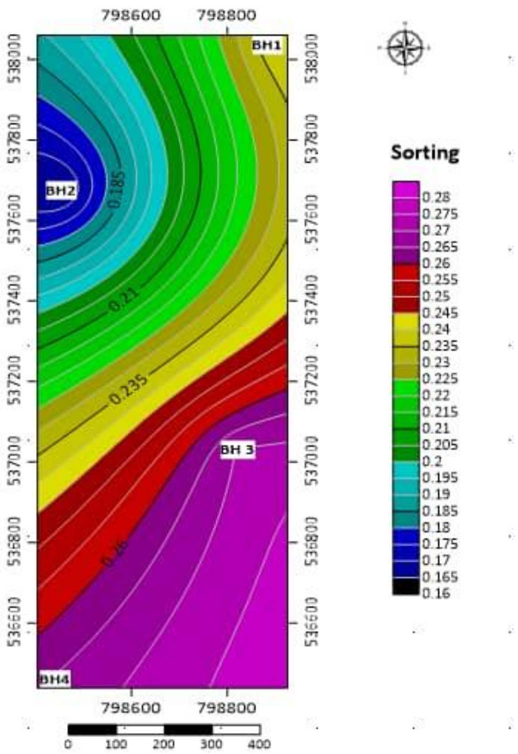

Figure 8: Contour map for Sorting

4.5 Skewness (Sk)

Most samples had a primarily fine to very fine skewed distribution (+0.1 to +0.6) as calculated using equation 4, which suggests that there are finer particles in the sand class. This could be because of a gradual settling of fine material during periods of slack water or a decrease in flow energy (Blott & Pye, 2001). Conversely, the coarse skewness (-0.12) found at BH4 (4.5 m) points to a zone of coarser input, which might be close to an erosional feature or sediment entry point. The existence of both skewness types across boreholes indicates lateral variation in current intensity and sediment delivery, as is common in tidally impacted creeks. The contour map is clearly shown in fig 9.

4.6 Kurtosis (Kg)

The majority of the computed kurtosis (Kk) values in this study lie within the range of 0.00 to 0.20, wh ich falls into the Folk and Ward (1957) classification's highly platykurtic to platykurtic categories.In contrast to a sharp concentration, this suggests that the grain size distributions are broad and flat, with a large variation of particle sizes around the mean.In places like Clough Creek that are impacted by tides, such flat curves usually indicate inconsistent depositional energy or heterogeneous sediment populations.These environments frequently encounter fluctuations in suspended loads, backwater effects, and fluctuating current velocities.Ogamba et al. (2017) found similar results in their research of Kolo Creek, where they attributed platykurtic patterns to long-term reworking under moderate flow conditions and sediment input from several sources. The kurtosis was calculated using equation 5 and the contour map is clearly shown in fig 10.

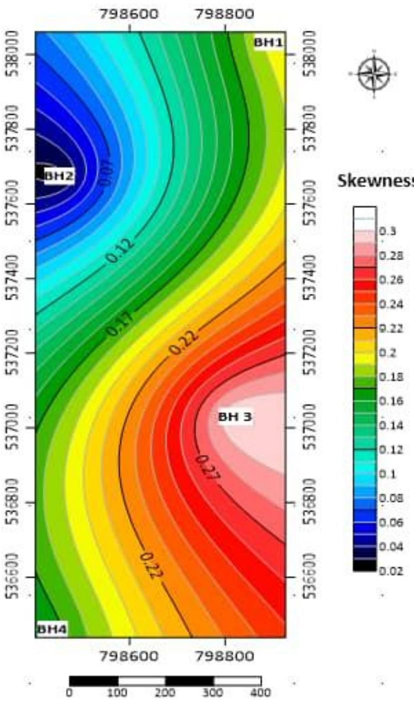

Figure 9: Contour map for Skewness

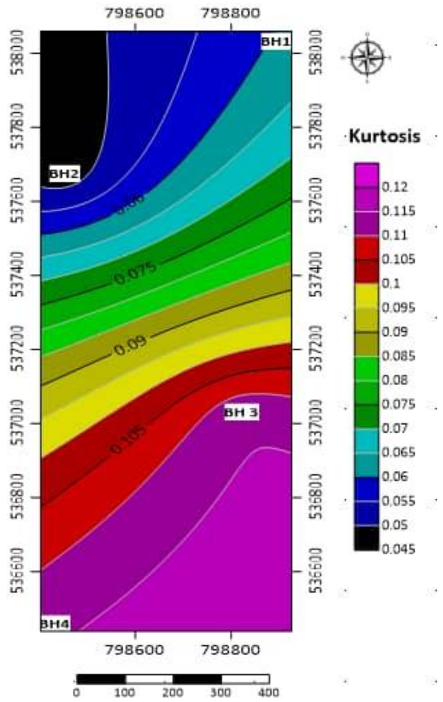

Figure 10: Contour map for Kurtosis

V. Conclusion

This study has successfully examined the grain size distribution and sediment characteristics of selected sand samples from Clough Creek in Bayelsa State, using statistical parameters derived from sieve analysis. Samples taken at various depths from four carefully chosen borehole locations across the stream system were the main focus of the analysis.The findings show that the sediments are primarily made up of coarse to very coarse sand, and mean grain size (Mz) values show that the sediments were deposited under moderate to high energy conditions, which are typical of creek thalwegs or active tidal channels. The majority of samples had sorting (σi) values that lie between well and very well sorted, indicating a consistent and rather steady sediment transport mechanism that is probably influenced by river inflow and tidal currents. Typically, skewness (Sk) values are fine-skewed, indicating that finer sand particles predominate in the distribution. This could be because of selective settling or a slow decline in energy during slack-water periods.Kurtosis (Kg) values, on the other hand, are mostly platykurtic to very platykurtic, showing broad, flat grain size curves with a variety of particle sizes. This is a common indicator of habitats that are impacted by many sediment sources and varied depositional energy.The study's overall findings demonstrate that Clough Creek is a fairly active sedimentary environment, with intricate interactions between tidal, fluvial, and estuarine processes reflected in the grain size distributions.The sediment characteristics' lateral and vertical fluctuations reveal information about the creek's current and historical depositional dynamics. These results support a more comprehensive knowledge of sedimentation processes in tidal stream systems and are consistent with comparable research carried out in other Niger Delta regions.

VI. Recommendations

Based on the findings of this study on the grain size distribution and sediment characteristics of Clough Creek,Future research should include more sampling sites and finer depth intervals, including surface sediment and silt/clay fractions, in order to provide a more comprehensive understanding of the vertical and lateral sedimentary variation within the Creek.In addition to sieve analysis, the use of X-ray diffraction (XRD), hydrometer analysis (for smaller particles), or mineralogical research would enhance sediment characterization and offer information into sediment provenance and transport pathways.

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