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# Investigation of the Correlation of Turbulent Waves from Engine Boats Movement and Shoreline Erosion

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## ABSTRACT

*This paper investigated the Correlation of Turbulent Waves from Engine Boats Movement and Shoreline Erosion. Site and laboratory experimentations were used to obtain values of turbulence level and shoreline erosion rate which were used in the computation of their correlation in order to acquire the level of their correspondence with each other. It was found that turbulence and erosion correlates positively and that the effects of turbulence waves generated from boats actions affected the rate of shoreline erosion negatively in both site and laboratory experimentations.*

***Keywords:*** *Turbulent Waves, Shoreline Erosion Rate, Engine Boat Classification, Soil Type Test*

**1. Introduction**

Formation of Turbulent Waves by Boats: When speed of flowing water exceeds the terminal velocity, the flow pattern becomes extremely irregular and complex. This irregular or chaotic flow is called turbulence. These irregularities are caused by variations in the density of the water and this follows a curling or changing paths called eddies or whirlpool patterns. Generally, in fluid flow, flow of liquids moving in a straight line (about Reynolds number of 100) is referred as a Laminar flow. Liquid flow in a non – laminar flow is referred as a turbulent flow (flow with Reynolds number above 104). From the diagram below, apart from medium sized fishes, the micro invertebrates and small fishes cannot withstand the force exerted in the turbulent environment due to the chaotic nature. These flows categorized using Reynolds number and their shapes can be seen below;
In terms of erosion, they posse higher treat to banks of river, ocean and other flowing water bodies than the normal erosive force from the water current. While a boat generates the force which propels it forward, air bubbles are release into the water and a path is left behind the boat on the surface of the water. This path left is known as wake which possesses a turbulent flow naturally. Thus, kinetic energy is introduced into the water capable of causing erosion.
Example of wave impact on shoreline erosion is the case of wave generated from boat passage causing the waves to strike on the shoreline at the river bank. This is presented below;

Figure 1: Turbulent wave striking on an eroding shoreline

Implications of Wave Impact on Shoreline: Wave impact generated from boats action could facilitate other aquatic conditions which may go beyond the normal physical processes. Examples include; washing out of the coastal vegetation, loss of submerged vegetation, loss of fish and other aquatic habitat, decreased photosynthesis, disruption of fish and other aquatic life, etc. The shoreline is one of the rapidly changing coastal landforms; Therefore, accurate detection and frequent monitoring of shorelines are very essential to understand the coastal processes and dynamics of various coastal features (Prasad and Kumar, 2014).

**Engine Boat Classification:** Engine boat classification is divided into boat type classification and boat size classification.
Engine boat classification using boat engine types are divided into; (i) outboard engine boat have boat engine mounted outside the boat, usually behind the boat (to play role of boat powering & steering). (ii) inboard engine boat has automotive engines mostly four strokes attached inside the boat to power the drive shaft connected to a propeller otherwise blade (it does not play two roles of powering and steering because it has the rudder behind the propeller which controls the steering wheel). (iii) the stern drive engine boat has engine type with both features of the outboard and inboard (it has a drive unit used to steer the boat like outboard engine type and it uses four stroke automotive engine mounted inside the boat hull like inboard engine type).

Outboard engine boat

Inboard engine boat

Figure 2: Outboard and inboard engine boat types

Engine boat classification using boat size classification is done using boat length which is obtained by measuring along the centre line from the outside bow (boat front) to the outside stern (boat back). Four classes of recreational boats determined by length (classifications as applicably used by the US coast guard federal regulatory) are; (i) class a: less than 16 ft. (ii) Class 1: boats measuring more than 16 ft but less than 26ft, (iii) class 2: boats measuring more than 26 ft but less than 40ft, and (iv) class 3: boats measuring more than 40 ft but less than 65ft.


Figure 3: Class A, class 1, and class 2 engine boat types

**II. MATERIALS**

**The Study Area:** The study area, otherwise the ground base upon which this research project was conducted is a major material used for this work. The study area is Asaba - Kebul - marine section of river Niger, in Asaba. The historic Niger River is a trans-African link beginning from West Africa and down into the Atlantic Ocean (Asaba Progressive Union, 2016). Asaba is located in south - west of Nigeria, in West Africa. It is the capital of Nigeria's Delta State (Nwosu, 2014). Unlike the northern part were wind erosion thrive, its major soil loss agent is water erosion. The area can be seen in the geographical map of Africa below;


Figure 4: Location of Asaba – Kebul - marine section of river Niger in map of Africa

Generally, the various materials used in this research are grouped according to the respective work used for and are presented below;

i. **Materials Used for soil test:** 18 soil samples with 4 sub - samples each (used for laboratory analysis in deciding soil type), soil auger (used for digging out soil particle from the ground), 90 plastic bags (used for arranging the 72 sub - samples into their 18 main group of samples and for carrying them to the laboratory), soil dryer (used for elimination of water content for accurate or even measurement of soil particles), weighing machine (used to obtain the required measurement of each sub - samples for even mixture needed to form the amount of each main samples for test), transparent cylindrical container (used to contain or house the samples for mixture and experimentations), water (used as an agent of separation for the soil particles), table spoon (used for taking small amount of weighed soil into the cylinder), laundry detergent (to aid well separation of the soil particles), soil textural class diagram (used for identifying soil property for classification) and work book (used to record values).

ii. **Materials Used for Obtaining Turbulence Level:** Workbook (paper sheet used for record documentation through writing with the pen), swim goggles (used for eye protection and increased vision in the water environment for water condition investigation), 5.0 MP site camera (for capturing water surface condition) and hand gloves (for hand - skin protection in the site).

iii. **Materials Used to Obtain Shoreline Erosion Rate:** Yahama engine boat (used for transportation within the aquatic parts of the site), Google GIS/ satellite (used for site mapping), 5.0 megapixels (2592 x 1944 resolution) camera (used for shoreline position imaging), workbook (used for shoreline record documentation), 7.5 x 25mm PO9A Professional Putero Power Tape (used for measuring length of shoreline change), and hand gloves (for skin protection while obtaining shoreline change measurements).

iv. **Materials Used for control laboratory experiment of wave action:** Sand and silts (used as soil particles for the design of laboratory coast), Water (used for the design of aquatic environment for experimentation), plastic container/flat tank (used to house the designed coast for experiment), mini – stir bar board (used for wave generation), lab spoon (used for scooping of soil particles for required design), workbook (used for recording values), microscope (used for intensive observation of soil).

**3. Methodology and Data Analyses**

The research design used in this study is presented in the figures below;

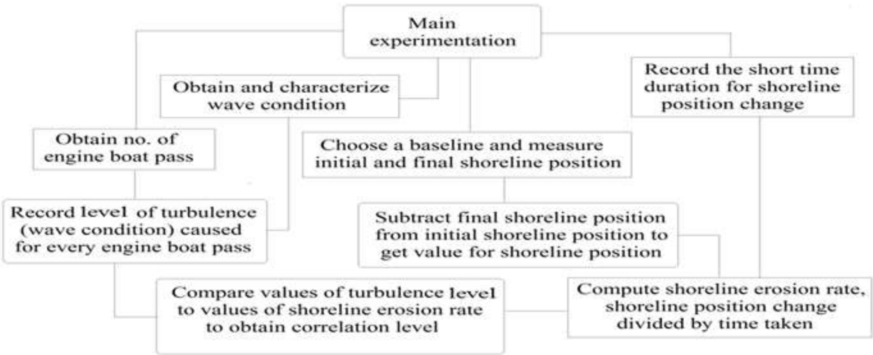


Figure 5: Experimental design for main experimentation

**Site Identification for Erosion Proneness**

Site identification as erosion prone area was carried out using visual experimental technique and the guidelines from common visual indicators for identifying erosion problems by (FAO, 2015).

**Study Area Soil Type Test:** Using the Jar Test Procedure, 36 soil materials (9 soil samples, each with 4 replicates sub – samples) dug 15cm from 9 different shoreline points within the site were taken for laboratory experimentation. 28g of each soil samples were poured into a transparent cylindrical container, filled second quarter with water and a mixture of half table spoon of laundry detergent (for separation of soil components). Each container was shaken for a minute and kept undisturbed for 5days to allow settlement of particles in layers for observatory measurement of the height of each layer for their percentage (ratio of height of each component to height of the sample in mm) computations. Using soil textural class diagram by American Gardening Resource (2019), percentage height of measured soil components was used to trace their soil type through the lines from the percentage values (presented in table below) of the diagram.

Table 1: Soil type computation for shoreline

| **Samples** | Replicates | % clay | % Sandy | % Silt | Soil type |
|---|---|---|---|---|---|
| 1 | 4 | 28 | 71 | 1 | Sandy clay loam |
| 2 | 4 | 92 | 5 | 3 | clay |
| 3 | 4 | 53 | 47 | 0 | Sandy clay |
| 4 | 4 | 41 | 54 | 5 | Sandy clay |
| 5 | 4 | 46 | 2 | 52 | Sandy clay |
| 6 | 4 | 54 | 46 | 0 | Sandy clay |
| 7 | 4 | 38 | 62 | 0 | Sandy clay |
| 8 | 4 | 47 | 51 | 2 | Sandy clay |
| 9 | 4 | 51 | 48 | 1 | Sandy clay |
| Av. | | | | | Sandy clay |

**Obtaining Turbulence Level**

Turbulence level was obtained from observed wave condition using wave characterization technique by Tomkins et al. (2014).

Where;

Turbulence level values are: 0 (very low, VL) for Ripples of 0 > 25% disturbance, 1 (Low, L) for Small waves of 25 > 50% disturbance, 2 (High, H) for Medium waves of 50 > 75% disturbance, 3 (Very high, VH) for Large waves of 75 > 100% disturbance. The obtained averaged values from appendices 1.1.1 to 1.2.4 are presented below;

Table 2: Monthly boating data for 2016 and 2017

| Month | 2016 | | 2017 | |
|---|---|---|---|---|
| | Total number of Engine boats passed | Average Turbulence Level | Total number of Engine boats passed | Average Turbulence Level |
| Jan | 336 | 2 | 249 | 2 |
| Feb | 303 | 2 | 251 | 2 |
| March | 297 | 3 | 275 | 2 |
| April | 365 | 2 | 315 | 2 |
| May | 350 | 2 | 256 | 2 |
| June | 296 | 2 | 313 | 3 |
| July | 397 | 3 | 343 | 3 |
| Aug | 386 | 3 | 290 | 3 |
| Sept | 304 | 3 | 292 | 3 |
| Oct. | 327 | 2 | 304 | 2 |
| Nov | 193 | 1 | 296 | 1 |
| Dec | 222 | 1 | 335 | 1 |
| **AV.** | **314.7** | **2** | **293.25** | **2** |

**Obtaining Shoreline Erosion Rate**

Shoreline erosion rate was computed on the bases of obtaining the shoreline variation per time. The rate of erosion could be defined as the distance (or depth) eroded over the time (Etuonovbe, 2006). This was used to back up the shoreline erosion rate formulas given by Cox et al., (1994) as below;

$$\text{Short term erosion rate} = \frac{x}{t} = \frac{\textit{Shoreline position change in short time period}}{\textit{Short time period}} \quad \text{.......... (Eq. 1)}$$

The shoreline position change was obtained by choosing a baseline (20m on shore) on the coast from where shoreline positions (initial and final positions) were measured from for necessary computations. These computations are tabulated below;

Table 3: 2016 Shoreline Erosion Rate computation

| Month | Initial shoreline position (in m) | Final shoreline position (in m) | Shoreline change | | Short time duration, t (No. of days x 24hrs) in hr | | Shoreline erosion rate | | Level of Shoreline erosion rate |
|---|---|---|---|---|---|---|---|---|---|
| | | | (in m) | Cm | | | (m/hr) | Cm/hr | |
| Jan. | 20.00 | 33.71 | -13.71 | -1371 | 31 x 24 | 744 | - 0.0184 | -1.8427 | 3 |
| Feb. | 33.71 | 53.67 | -19.96 | -1996 | 29 x 24 | 696 | -0.0287 | -2.8678 | 3 |
| March | 53.67 | 60.69 | -7.02 | -702 | 31 x 24 | 744 | -0.0094 | -0.9435 | 2 |
| April | 60.69 | 62.68 | -1.99 | -199 | 30 x 24 | 720 | -0.0028 | -0.2764 | 1 |
| May | 62.68 | 62.22 | 0.46 | 46 | 31 x 24 | 744 | 0.0006 | 0.0618 | 1 |
| June | 62.22 | 55.98 | 6.24 | 624 | 30 x 24 | 720 | 0.0087 | 0.8667 | 2 |
| July | 55.98 | 38.84 | 17.14 | 1714 | 31 x 24 | 744 | 0.0230 | 2.3038 | 3 |
| Aug, | 38.84 | 27.45 | 11.39 | 1139 | 31 x 24 | 744 | 0.0153 | 1.5309 | 3 |
| Sept. | 27.45 | 23.32 | 4.13 | 413 | 30 x 24 | 720 | 0.0057 | 0.5736 | 2 |
| Oct. | 23.32 | 21.48 | 1.84 | 184 | 31 x 24 | 744 | 0.0025 | 0.2473 | 1 |
| Nov. | 21.48 | 22.27 | -0.79 | -79 | 30 x 24 | 720 | -0.0011 | -0.1097 | 1 |
| Dec. | 22.27 | 22.59 | -0.32 | -32 | 31 x 24 | 744 | -0.004 | -0.0430 | 1 |
| Av. | 40.19 | 40.41 | -0.22 | -21.5833 | 732 | | 0.0007 | -0.0416 | |

Table 4: 2017 Shoreline Erosion Rate

| Month | Initial shoreline position (in m) | Final shoreline position (in m) | Shoreline position change | | Short time duration, t (No. of days x 24hrs) in hr | | Shoreline erosion rate | | Level of shoreline Erosion rate |
|---|---|---|---|---|---|---|---|---|---|
| | | | (in m) | Cm | | | (m/hr) | Cm/hr | |
| Jan. | 22.59 | 38.90 | -16.31 | -1631 | 31 x 24 | 744 | -0.0219 | -2.1922 | 3 |
| Feb. | 38.90 | 44.84 | -11.86 | -1186 | 28 x 24 | 672 | -0.0176 | -1.7649 | 3 |
| March | 44.84 | 50.78 | -5.94 | -594 | 31 x 24 | 744 | -0.0080 | -0.7984 | 2 |
| April | 50.78 | 50.12 | 0.66 | 66 | 30 x 24 | 720 | 0.0009 | 0.0917 | 1 |
| May | 50.12 | 49.81 | 0.31 | 31 | 31 x 24 | 744 | 0.0004 | 0.0417 | 1 |
| June | 49.81 | 46.02 | 3.79 | 379 | 30 x 24 | 720 | 0.0053 | 0.5264 | 2 |
| July | 46.02 | 36.40 | 9.62 | 962 | 31 x 24 | 744 | 0.0129 | 1.2930 | 3 |
| Aug, | 36.40 | 12.66 | 23.74 | 2374 | 31 x 24 | 744 | 0.0319 | 3.1909 | 3 |
| Sept. | 12.66 | 9.34 | 3.32 | 332 | 30 x 24 | 720 | 0.0046 | 0.4611 | 1 |
| Oct. | 9.34 | 7.21 | 2.13 | 213 | 31 x 24 | 744 | 0.0029 | 0.2863 | 1 |
| Nov. | 7.21 | 11.22 | -4.01 | -401 | 30 x 24 | 720 | -0.0056 | -0.5569 | 2 |
| Dec. | 11.22 | 11.71 | -0.49 | -49 | 31 x 24 | 744 | -0.0007 | -0.0659 | 1 |
| **Av.** | **31.66** | **30.75** | **0.41** | **41.3333** | **730** | | **0.0004** | **0.0427** | |

Note: Shoreline Erosion rating (1 = less than 0.0050, 2 = 0.0050 to 0.0099, 3 = 0.0100 and above).

**Obtaining Correlation**

BYJUS, 2020 presented the Pearson correlation coefficient (r) formula below;

$$r = \frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{[n(\sum x^2-(\sum x)^2][n(\sum y^2-(\sum y)^2]}} \quad \text{....... (Eq. 2)}$$

Where:

r = Pearson correlation coefficient

x = Values in the first set of data

y = Values in the second set of data

n = Total number of values.

Laerd, 2018 presented a proposed interpretation of ‘r’ values: Positive = + 0.1 to + 0.3 (Small), + 0.3 to + 0.5 (Medium), + 0.5 to + 1.0 (Large) and, Negative = - 0.1 to - 0.3 (Small), - 0.3 to - 0.5 (Medium), - 0.5 to - 1.0 (Large).

Table 5: 2016 Correlation Computation table for Turbulence level (T) and erosion level (E)

| Month | 2016 | | | | |
|---|---|---|---|---|---|
| | T | E | $T^2$ | $E^2$ | T. E |
| Jan. | 2 | 3 | 4 | 9 | 6 |
| Feb. | 2 | 3 | 4 | 9 | 6 |
| March | 3 | 2 | 9 | 4 | 6 |
| April | 2 | 1 | 4 | 1 | 2 |
| May | 2 | 1 | 4 | 1 | 2 |
| June | 2 | 2 | 4 | 4 | 4 |
| July | 3 | 3 | 9 | 9 | 9 |
| Aug, | 3 | 3 | 9 | 9 | 9 |
| Sept. | 3 | 2 | 9 | 4 | 6 |
| Oct. | 2 | 1 | 4 | 1 | 2 |
| Nov. | 1 | 1 | 1 | 1 | 1 |
| Dec. | 1 | 1 | 1 | 1 | 1 |
| $\sum$ | $\sum T$ =26 | $\sum E$ =23 | $\sum T^2$ =62 | $\sum E^2$ =53 | $\sum T.E$ =54 |

$$r = \frac{n(\sum T.E) - (\sum T)(\sum E)}{\sqrt{[n(\sum T^2 - (\sum T)^2][n(\sum E^2 - (\sum E)^2]}}$$ ....... (Eq. 3)

$$r = \frac{12x54 - 26x23}{\sqrt{[12x62 - (26)^2][12x53 - (23)^2]}}$$

$$r = \frac{648 - 598}{\sqrt{[744 - 676][636 - 529]}}$$

$$= \frac{50}{\sqrt{[68][107]}}$$

$$= \frac{50}{85.2995}$$

$\text{Thus, } r = +0.6$ (correlation is large)

Table 6: 2016 Correlation Computation table for Turbulence level (T) and erosion rate (E)

| Month | 2016 | | | | |
|---|---|---|---|---|---|
| | T | E | $T^2$ | $E^2$ | T.E |
| Jan. | 2 | -1.8427 | 4 | 3.3955 | -3.6854 |
| Feb. | 2 | -2.8678 | 4 | 8.2243 | -5.7356 |
| March | 3 | -0.9435 | 9 | 0.8902 | -2.8305 |
| April | 2 | -0.2764 | 4 | 0.0764 | -0.5528 |
| May | 2 | 0.0618 | 4 | 0.0038 | 0.1236 |
| June | 2 | 0.8667 | 4 | 0.7512 | 1.7334 |
| July | 3 | 2.3038 | 9 | 5.3075 | 6.9114 |
| Aug, | 3 | 1.5309 | 9 | 2.3437 | 4.5927 |
| Sept. | 3 | 0.5736 | 9 | 0.3290 | 1.7208 |
| Oct. | 2 | 0.2473 | 4 | 0.0612 | 0.4946 |
| Nov. | 1 | -0.1097 | 1 | 0.0120 | -0.1097 |
| Dec. | 1 | -0.0430 | 1 | 0.0018 | -0.0430 |
| $\sum$ | $\sum_{=26} T$ | $\sum_{=-0.499} E$ | $\sum_{=62} T^2$ | $\sum_{=21.3966} E^2$ | $\sum_{=2.6195} T.E$ |

Using equation 3 above, correlation was thus computed below;

$$r = \frac{12x2.6195 - 26x - 0.499}{\sqrt{[12x62 - (26)^2][12x21.3966 - (-0.499)^2]}}$$

$$r = \frac{31.434 - (-12.974)}{\sqrt{[744 - 676][256.7592 - 0.249001]}}$$

$$r = \frac{44.408}{\sqrt{[68][256.5102]}}$$

$$r = \frac{44.408}{\sqrt{17{,}442.6936}}$$

$$r = \frac{44.408}{132.0708}$$

$\text{Thus}, r = +\,0.3$ (correlation is medium)

Following same procedure, correlation were computed for; 2017 turbulence level and erosion level, and 2017 turbulence level and erosion rate.

**Laboratory Experimentation**

A laboratory designed and built shoreline coast in a wave suitable container was used to assess the interaction between waves and shoreline (coastline) erosion in the laboratory. Sediments were placed 7cm on the container allowing the other 13cm area of the container to be filled with water. The sediments were used to build a beach angle of 59 - 70o which is a common beach angular shape for most banks in the study area. The beach design format used can be seen in figure 2.9. Two types of sediment (silts and sand) were used as Coops et al. (1996), to assess the erosive impact of waves. The water introduced in the artificial coast was stirred to generate wave movement which was used to study the wave action on the bank. An illustration of experimentation can be seen in the figure below; Where the black vessel on the water represent the boats, the air bubbles (introduced into the water using the blue round - bottom tube) to produce waves which were used to study its turbulent effect on the bank, and the microscope was used to study soil compaction structure.

Table 7: Turbulence Level and erosion Level Correlation for various slope angles

| S/N | Slope angle (in degree) | Turbulence Level | Erosion Level | $T^2$ | $E^2$ | T E |
|---|---|---|---|---|---|---|
| 1 | 58 | 3 | 3 | 9 | 9 | 9 |
| 2 | 58 | 2 | 2 | 4 | 4 | 4 |
| 3 | 58 | 1 | 1 | 1 | 1 | 1 |
| 4 | 59 | 3 | 3 | 9 | 9 | 9 |
| 5 | 59 | 2 | 2 | 4 | 4 | 4 |
| 6 | 59 | 1 | 1 | 1 | 1 | 1 |
| 7 | 60 | 3 | 3 | 9 | 9 | 9 |
| 8 | 60 | 2 | 2 | 4 | 4 | 4 |
| 9 | 60 | 1 | 2 | 1 | 4 | 2 |
| 10 | 61 | 3 | 3 | 9 | 9 | 9 |
| 11 | 61 | 2 | 2 | 4 | 4 | 4 |
| 12 | 61 | 1 | 1 | 1 | 1 | 1 |
| 13 | 62 | 3 | 3 | 9 | 9 | 9 |
| 14 | 62 | 2 | 2 | 4 | 4 | 4 |
| 15 | 62 | 1 | 1 | 1 | 1 | 1 |
| 16 | 63 | 3 | 3 | 9 | 9 | 9 |
| 17 | 63 | 2 | 2 | 4 | 4 | 4 |
| 18 | 63 | 1 | 1 | 1 | 1 | 1 |
| 19 | 64 | 3 | 3 | 9 | 9 | 9 |
| 20 | 64 | 2 | 2 | 4 | 4 | 4 |
| 21 | 64 | 1 | 1 | 1 | 1 | 1 |
| 22 | 65 | 3 | 3 | 9 | 9 | 9 |
| 23 | 65 | 2 | 3 | 4 | 9 | 6 |
| 24 | 65 | 1 | 1 | 1 | 1 | 1 |
| 25 | 66 | 3 | 3 | 9 | 9 | 9 |
| 26 | 66 | 2 | 2 | 4 | 4 | 4 |
| 27 | 66 | 1 | 1 | 1 | 1 | 1 |
| 28 | 67 | 3 | 3 | 9 | 9 | 9 |
| 29 | 67 | 2 | 2 | 4 | 4 | 4 |
| 30 | 67 | 1 | 2 | 1 | 4 | 2 |
| 31 | 68 | 3 | 3 | 9 | 9 | 9 |
| 32 | 68 | 2 | 2 | 4 | 4 | 4 |
| 33 | 68 | 1 | 1 | 1 | 1 | 1 |
| 34 | 69 | 3 | 3 | 9 | 9 | 9 |
| 35 | 69 | 2 | 2 | 4 | 4 | 4 |
| 36 | 69 | 1 | 1 | 1 | 1 | 1 |
| 37 | 70 | 3 | 3 | 9 | 9 | 9 |
| 38 | 70 | 2 | 3 | 4 | 9 | 6 |
| 39 | 70 | 1 | 1 | 1 | 1 | 1 |
| 40 | 71 | 3 | 3 | 9 | 9 | 9 |
| 41 | 71 | 2 | 2 | 4 | 4 | 4 |
| 42 | 71 | 1 | 1 | 1 | 1 | 1 |
| $\sum$ | $\sum s$ =2,709 | $\sum T$ =84 | $\sum E$ =88 | $\sum T^2$ =196 | $\sum E^2$ =212 | $\sum T.E$ =202 |

Using equation 3 above, correlation was thus computed below;

$$r = \frac{42x202 - 84x88}{\sqrt{[42x196 - (84)^2][42x212 - (88)^2]}}$$

$$r = \frac{8,484 - 7,392}{\sqrt{[8,232 - 7,056][8,904 - 7,744]}}$$

$$r = \frac{1,092}{\sqrt{[1,176][1,160]}}$$

$$r = \frac{1,092}{\sqrt{1,364,160}}$$

$$r = \frac{1,092}{1,167.9726}$$

Thus, $r = +\ 0.9$ (correlation is large)

**IV. RESULTS**

The results are presented below;

**Results Turbulence Level:** The results of the 7295 number of boats observed are presented in tables below;

Table 8: Results of Turbulence Level and shoreline erosion Level

| Month | 2016 | | 2017 | |
|---|---|---|---|---|
| | Turbulence Level | Erosion Level | Turbulence Level | Erosion Level |
| Jan. | 2 | 3 | 2 | 3 |
| Feb. | 2 | 3 | 2 | 3 |
| March | 3 | 2 | 2 | 2 |
| April | 2 | 1 | 2 | 1 |
| May | 2 | 1 | 2 | 1 |
| June | 2 | 2 | 3 | 2 |
| July | 3 | 3 | 3 | 3 |
| Aug, | 3 | 3 | 3 | 3 |
| Sept. | 3 | 2 | 3 | 1 |
| Oct. | 2 | 1 | 2 | 1 |
| Nov. | 1 | 1 | 1 | 2 |
| Dec. | 1 | 1 | 1 | 1 |
| **Mode** | 2 | 2 | 2 | 2 |

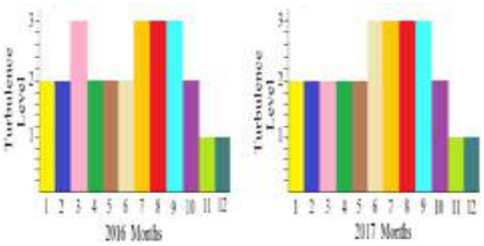


Figure 6: Results of Turbulence Level for 2016 and 2017

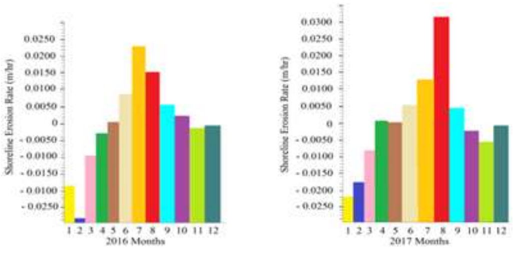

Figure 7: Results of Shoreline Erosion Rate for 2016 and 2017

**Result of laboratory experimentation:** In laboratory experimentation of wave effect on shoreline erosion, shoreline erodes faster when turbulent wave forms were introduced.

**Correlation Results:** The correlation of turbulence level and erosion level were positively large with r = + 0.6 in both 2016 and 2017. Correlation of turbulence level and erosion rate were positively medium with r = + 0.3 in 2016 and r = + 0.4 in 2017. In laboratory experimentation, correlation of turbulence level and erosion level was positively large with r = + 0.9.

**V. DISCUSSION**

**Results of Turbulence Effect from Boats Action**: From the result of 3776 total number of boats observed from January to December (2016), and 3519 boats observed from January to December (2017), the average turbulence rate (High) produced the same average erosion rate (High). This is also in accord with the results obtained from the laboratory experimentation.

Processes of Shoreline Erosion as a Result of Wave Impact: The sequential processes of shoreline erosion as a result of wave impact observed from both field and laboratory experimentation can be summarized into five (5) stages.

i. In the first stage, Wave forces flowing towards the coast, strikes the shoreline. This develops concave cracks on the shoreline cliff.

ii. In the second stage, wave forces wash away the concave cracked soil from the shoreline. This is made possible through to and fro movements within the off – shore environment.

iii. In the third stage, wave forces strike on the developed concave part of the shore. This leads to further cracks (vertically) for necessary sliding of the soil above the concave part.

iv. In the fourth stage, wave forces wash away the slide soil from the shoreline. This reshapes the shoreline geographical structure as well increase off – shore dimension.

v. In the fifth stage, water body advancing forward with the wave forces striking the new shaped shoreline. This creates room for another concave crack development on the new shoreline cliff.

These stages are presented in the figure below showing processes of wave impact on shoreline erosion;

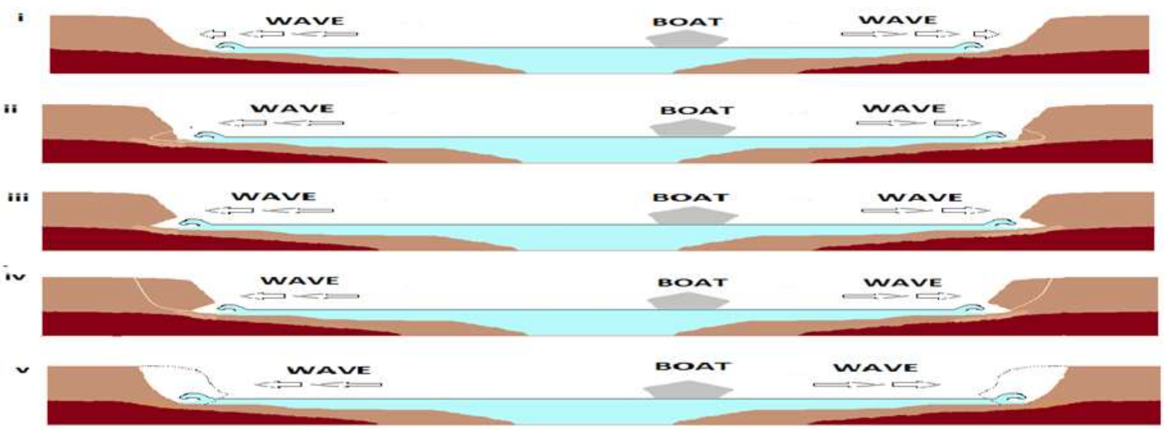


Figure 8: Sequential Processes of Wave impact on shoreline erosion on Cliffs or toe

A typical example is presented in the figure below;

Figure 9: Two erosion processes occurring at the bank of the shoreline.

From figure 9 above, it can be seen that, at the left-hand corner, the shoreline bank is experiencing an erosion process of stage III, tagged with a concave eroding bottom bank waiting for sliding of the soil within the upper part (above water reach) of the concave bank. While at the right-hand corner, the shoreline bank is experiencing stage IV, tagged with a bank with a fallen down soil sediment (from the initially concave eroding bottom bank) undergoing a wash away process of the slide soil particles. The shapes of the two erosion processes can be seen in the figure above and upon the removal of the slide soil, will be followed by the next erosion process/stage.

**CONCLUSIONS**

Turbulence and erosion correlates positively.

Effects of turbulence waves generated from boats actions affected the rate of shoreline erosion negatively in both site and laboratory experimentations.

Haven undergone these research processes, it can be said that the study objectives were achieved as well as the research questions were ushered relevant answers.

**CONTRIBUTIONS TO KNOWLEDGE**

1. This work adds to the existing knowledge by providing researched information with regards to how boats action in the waterways affects shoreline erosion. This study on how waves from actions of boats affect shoreline erosion depicts that man's action in the waterways contributes to its environment.

2. This study provides coastal information that will be of great importance to; future coastal managements and engineering design, future calibration and verification of numerical model, e.t.c. This is because engineers, scientists, researchers and coastal managers can make use of information inclined within this study to enhance their works.

**RECOMMENDATIONS**

1. Advance study on movement of wave and their interactions maybe carried out.

2. Open water regulation on usage of boat in water ways should be enforce in appropriate transport routes to reduce erosion as well as protect aquatic lives and environment.

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