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# Soil Gradation Distribution across Port Harcourt, South-eastern Nigeria.

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***ABSTRACT***
*Soil Investigation reports, were used to prepare maps of Soil Grading of Port Harcourt on a scale of 1:5000 meters at depths of 3-10m, 11-15m and 16-20m. Data from 73 Soil reports were processed, interpreted and used to produce soil Gradation maps with the help of different professional computer software. The aim was to prepare these maps as a quick guide to design and construction of civil engineering structures. The average values of coefficient of uniformity (Cu) at depths 3 to10 m, 11 to 15 m and 16 to 20 m are 3.68, 2.83 and 3.56 respectively. According to Unified Soil Classification System (USCS), the soils are mostly classified as poorly Graded Sands (SP) with Cu < 6. Some locations like Rumueme have well graded soils with Cu greater than or equal to 6. The Poorly graded soils in the Study Area will more susceptible to soil liquefaction than well graded soils. Also, Poorly Graded sands mostly lead to high immediate settlement due to increased pore spaces. In this case an appropriate type of foundation should be considered to suit the soil type. The well graded soils will be good for construction because it can be easily compacted into a dense mass with minimum voids. These engineering geological maps were produced to guide decision makers and planners in the land use allocation of the areas for sustainability.*

***Keywords**: Coefficient of Uniformity, Immediate Settlement, Distribution, Soil Grading, Sustainability*

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## I. INTRODUCTION

Most recent definitions of engineering geology take into cognizance the perspective of social responsibility and environmental protection.[1] Consequently, engineering geology is now elaborately defined as the application of all branches of the geosciences, especially hydrogeology, geomechanics, and engineering geophysics, to ensure the safety, efficiency, and economy of engineering and environmental projects. From the various definitions of engineering geology, we can see that the primary purpose of engineering geology is to make available basic information for planning of land use, which covers the planning, design, construction, and maintenance of civil engineering works. There are key factors that create the engineering geological conditions of an individual site or area. These include rocks and soil water, geomorphological conditions, and geodynamic processes.

The character and variety of engineering geological conditions, their components, and their relationships with each other can be represented on a map as maps give the best impression of any geological environment. Engineering geological maps should be based on geological, hydrogeological, and geomorphological maps. At the same time, it must present and evaluate the basic facts provided by these maps in engineering geological terms. [2] An engineering geological map is a type of geological map that makes available a generalized representation of all those components of a geological environment of significance in land use planning and design, construction, and maintenance as applied to civil and mining engineering.

[1] The engineering geological map delineates the broad pattern of the geological materials and includes comments on their general engineering characteristics.

To accomplish a proper evaluation of engineering geological conditions of an area, a complex engineering geological survey is recommended. [7] This includes the collection of all archival data (borehole and auger holes) of the area, their analysis, and a thorough study of the works describing the area of interest. [3] In comprehensive maps of engineering geological conditions, the principal components of the engineering geological environment are depicted. Engineering geological mapping is essential as a means of gathering and presenting useful information on the physical aspects of the environment. [5] An engineering geological map can reflect not only the history of engineering geological conditions but also the dynamic appearing and expansion of these conditions by showing distribution and the local relationships of these essential elements of engineering geological conditions.

An engineering geological assessment also interprets the geology of the area. [8] It presents geological data relevant to the geotechnical engineer or planner in a spatial form accompanied by quantitative data on soil and bedrock types. [11] Engineering Geological maps are essential tools for preserving information on terrains and are also necessary documents where spatial distribution and mechanical properties are presented.

Soil gradation which has to do with the uniformity of soil particles is an important aspect of soil mechanics and geotechnical engineering because it is an indicator of other engineering properties such as compressibility, shear strength, and hydraulic conductivity. In a design, the gradation of the in situ or on-site soil often controls the design and ground water drainage of the site. A poorly graded soil will have better drainage than a well graded soil, if it is not high in clay quality.

When a fill material is being selected for a project such as a highway embankment or earthen dam, the soil gradation is considered. A well graded soil is able to be compacted more than a poorly graded soil. These types of projects may also have gradation requirements that must be met before the soil to be used is accepted. Also Poorly graded soils are more susceptible to soil liquefaction than well graded soils. When options for ground remediation techniques are being selected, the soil gradation is a controlling factor.

The rise in foundation failure and building collapse has been a cause for concern. These Problems range from collapse of high-rise buildings to differential settlement in foundations carrying various Structures which may be attributed to Soil Grading in the Study Area. This issue has led to the quest for sustainable means of proffering solution to the situation. The negative impact of foundation failure cannot be over emphasized as several lives and properties have been lost due to these sad occurrences. Civil and geotechnical engineers have a great role to play in the stability of buildings. One of the major challenges is the absence of substantial information concerning the geotechnical properties of soils for land use and planning to the Civil Engineers. This information when displayed on maps and charts gives vital information for land use and planning. Geotechnical maps of Port Harcourt will serve as a tool for curbing the failure of superstructures in Port Harcourt. One of the reasons for producing an engineering geological map of Port Harcourt is that conventional maps such as geological, geographical, agricultural maps, etc. have shortcomings and are not suitable for engineering purposes. Thus, there is need engineering geological map for the planning of engineering structures. This will enable a better quantitative evaluation of the performance of engineering structures and possible improvements. Since there is no engineering geological map of Port Harcourt, it will be meaningful to produce a Soil Grading map with a suitable scale.

Port Harcourt is located between Latitudes 4°45'N and 4°55'N, and Longitudes 6°55'E and 7°05'E in Rivers State (Figs 1).

[10] The Niger Delta which is located in the continental margin of West Africa on the Gulf of Guinea evolved as a consequence of the separation of the African plate from the South American plate in the Jurassic and in a rift like setting into a triple R junction, two of the arms developed into a collapsed continental margin while the third, a failed arm(aulacogen) formed the Benue trough. [13] This rifting was accompanied by subsidence of the African continental margin. Soon after the breakup in the Albian time, marine sedimentation commenced in the early Delta, depositing thick successions of marine and marginal marine sediments in cycles of transgressions and regressions of the sea. The stop of the Albian rift-fill phase by the compressional stress field in the Santonian marked the beginning of the rise of the true Niger Delta in tertiary times ever since the Delta has prograded towards the oceanic crust while assuming a convex shape to sea morphology.

## II. LITERATURE REVIEW

[9] created Engineering Geology Maps for Planning and Management of Natural Parks. They used geographical information systems technology by combining the cartographies for the most influential parameters on the stability of the area (lithology, hydrogeology, geomorphology, slopes, lineament/fractures, and seismicity) with geomechanical mapping generated from geotechnical parameters obtained through field and laboratory tests. The results of the work allowed them to confirm that the mapping of natural hazards from thematic maps at a scale of 1:50,000, characterized by a series of assays representative of each geotechnical area and zone, offers a useful tool for the governance of future human activity in natural parks. To characterize the area, [6] worked on Engineering Geological Mapping of in South Ethiopia by use of observations of the geology, geo-botanical condition, measuring of horizontal and vertical variation of the lithology, drilling trial test pits and trenches, as well as engineering characterization of soils in the laboratory. Based on these, different zones of engineering geological maps were produced depending on different situations. The parameters were geological structural measurements, surficial geo-dynamic activities, geotechnical characteristics of geological materials, and geo-botanical conditions. The basic scenario identified during this research is soil types and its thickness, the undulating surface of the sound rock surface, and groundwater fluctuation. Based on these results, the researchers concluded that it is better to use deep foundation or deep excavation to get sound rock with uniform bearing capacity or to replace weak geological materials by better geological materials.

[12] worked on Insights from the Engineering Geological Mapping of Four Basement Rocks Derived Soils. They carried out a reconnaissance survey, fieldwork, and generalized geological mapping of the study area. A total of twenty-five dug pits from which a total of fifty (50) soil samples comprising of twenty-five (25) disturbed, and twenty-five (25) undisturbed soil samples were collected at a depth of about 1m in each of the pits. It was deduced that drainage alone does not directly influence the settlement rates of soils, rather the interaction between the underlying geology and the drainage. This also confirm that the soils ranged from fairly competent to competent in bearing very substantial loads at shallow depth.

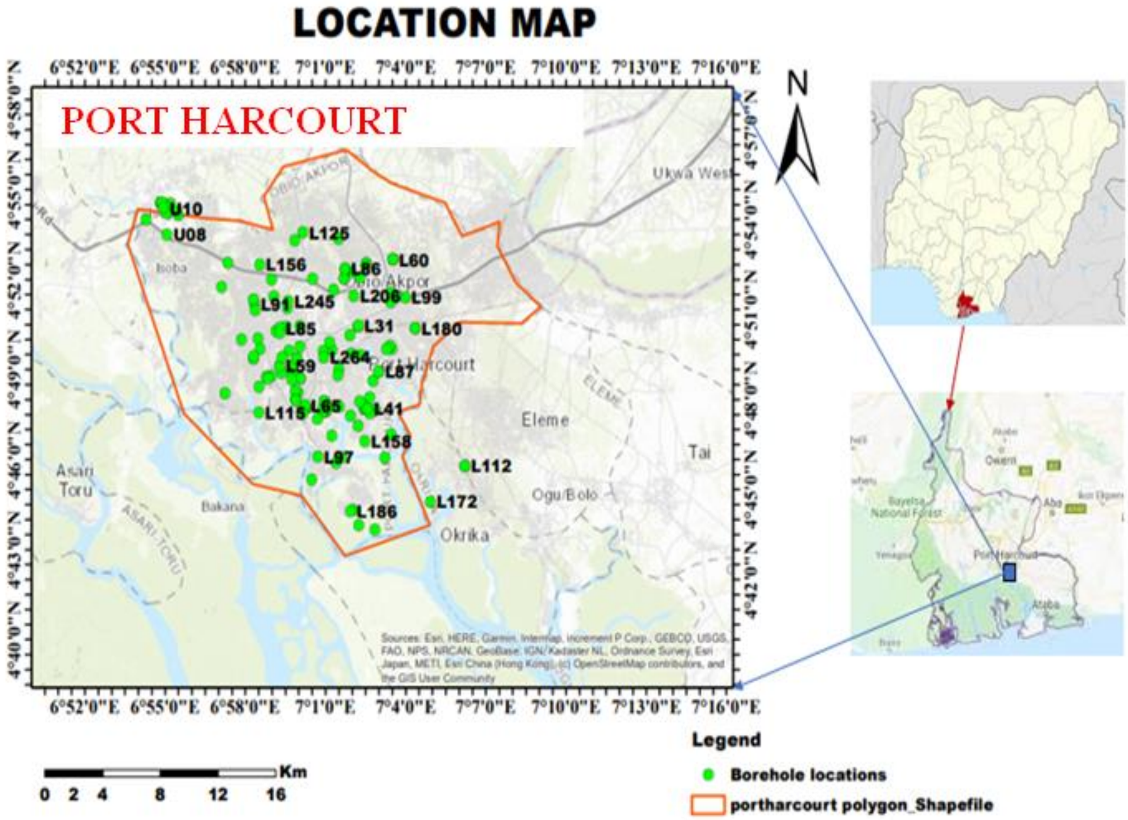


**Fig. 1:** Location Map of Study Area

## III. MATERIALS AND METHODS

Site investigation reports on the area were collated from consulting and contracting civil engineers in Port Harcourt. Soil investigation reports for one hundred and forty-seven locations were collated (from Groundscan Services Nigeria Limited and physical and Urban planning department, University of Port Harcourt) and examined for the accuracy of data. The borehole record collated was then scanned, assessed for quality. Experimental plans were prepared by a computer-aided technique to aid the production of Geotechnical maps which will show the distribution of the geotechnical properties of soils in the study area and their variations. These data were collected from various sources such as engineering geological data of the area accumulated over time, soils survey reports and maps. Review of similar studies and cases in Nigeria and different parts of the world with emphasis on previous works done in the Port Harcourt area was carried out.
The topographic map of Port Harcourt area was used and enlarged to the required scale and used as a base map. The topographic map was imported online into the Arc GIS software and used as base map.

### 3.1 Data Processing

The following approaches were used:
Data processing and interpretation were made with the help of different professional computer software. Some of the softwares were; Microsoft office tools for preparation, synthesis and analysis of data, Arc GIS 10.7, Strater 5, Google Earth Pro, surfer 16, for preparation and manipulation of different maps.

### 3.2 Computation for Coefficient of Uniformity

The Uniformity of Particle Size of the soils expressed by the uniformity coefficient was computed using the relationship

$$Cu=D60/D10 \quad (1)$$

Where, D60 = diameter at which 60% of the soil is finer and
D10 = Corresponding Value at 10% finer.

## IV. RESULTS AND DISCUSSION

The Result of Coefficient of Uniformity derived from analysis are presented in Table 1 below.

**Table 1: Coefficient of Uniformity Result**

| LOCATION | LATITUDE (˚) | LONGITUDE (˚) | ELEVATION(m) | BOREHOLE | DEPTH(m) | d10(mm) | d60(mm) | cu=d60/d10 | ASTM D-2487 CLASS |
|---|---|---|---|---|---|---|---|---|---|
| L68 | 4.811706 | 7.000869 | 9 | 1 | 5.0 | 0.20 | 0.42 | 2.38 | SP |
| L164 | 4.780778 | 7.05756 | 2 | 1 | 12.0 | 0.20 | 0.70 | 3.50 | SP |
| L109 | 4.790992 | 7.032322 | 13 | 1 | 15.0 | 0.12 | 0.29 | 2.60 | SP |
| L106 | 4.738569 | 7.033714 | 14 | 1 | 3.0 | 0.24 | 0.68 | 2.80 | SP |
| L155 | 4.727692 | 7.047508 | 9 | 1 | 10.0 | 0.09 | 0.28 | 3.29 | SP |
| L167 | 4.876212 | 6.955643 | 13 | 1 | 15.5 | 0.20 | 0.36 | 1.84 | SP |
| L208 | 4.862631 | 6.951889 | 14 | 1 | 12.5 | 0.10 | 0.31 | 3.10 | SP |
| L51 | 4.840851 | 7.000584 | 13 | 1 | 8.5 | 0.25 | 0.56 | 2.24 | SP |
| L152 | 4.86675 | 6.983081 | 12 | 1 | 9.8 | 0.23 | 1.00 | 4.35 | SP |
| L157 | 4.878117 | 7.058672 | 15 | 1 | 14.5 | 0.13 | 0.32 | 2.67 | SP |
| L31 | 4.840783 | 7.037075 | 14 | 1 | 10.5 | 0.19 | 0.30 | 1.57 | SP |
| L53 | 4.8724 | 7.028964 | 16 | 1 | 4.5 | 0.05 | 0.20 | 4.44 | SP |
| L65 | 4.797069 | 7.003881 | 3 | 1 | 10.0 | 0.10 | 2.90 | 2.90 | SP |
| L136 | 4.84003 | 6.989568 | 18 | 1 | 10.5 | 0.08 | 0.28 | 3.50 | SP |
| L124 | 4.819997 | 6.996989 | 8 | 1 | 10.0 | 0.16 | | 2.60 | SP |
| L61 | 4.794778 | 7.041194 | 9 | 1 | 4.5 | 0.45 | 0.20 | 4.40 | SP |
| L122 | 4.822789 | 6.971744 | 14 | 1 | 9.5 | 0.10 | 0.30 | 3.00 | SP |
| L100 | 4.828339 | 7.057991 | 15 | 1 | 8.8 | 0.22 | 0.95 | 4.32 | SP |
| L160 | 4.794358 | 7.047508 | 9 | 1 | 12.5 | 0.11 | 0.32 | 2.91 | SP |
| L240 | 4.812692 | 6.979983 | 15 | 1 | 12.0 | 0.20 | 0.42 | 2.10 | SP |
| L210 | 4.817023 | 7.025028 | 14 | 1 | 0.3 | 0.15 | 0.50 | 3.33 | SP |
| L206 | 4.857594 | 7.034286 | 14 | 1 | 11.5 | 0.12 | 0.28 | 1.47 | SP |
| L207 | 4.763244 | 7.103739 | 14 | 1 | 12.0 | 0.10 | 0.32 | 3.20 | SP |
| L140 | 4.795528 | 7.00425 | 9 | | 3.0 | | 0.34 | | SP |
| L127 | 4.878117 | 7.058672 | 15 | 1 | 10.0 | 0.11 | 0.32 | 2.60 | SP |
| L202 | 4.815553 | 7.049844 | 1 | 1 | 15.5 | 0.15 | 0.68 | 4.53 | SP |
| L135 | 4.84985 | 6.972928 | 16 | 1 | 9.8 | 0.10 | 0.28 | 2.80 | SP |
| L125 | 4.893055 | 7.002551 | 19 | 1 | 9.5 | 0.18 | 0.40 | 2.22 | SP |
| L42 | 4.794972 | 7.041125 | 7 | 1 | 4.5 | 0.05 | 0.20 | 4.44 | SP |
| L41 | 4.792517 | 7.044475 | 5 | 1 | 10.5 | 0.20 | 0.60 | 3.00 | SP |
| LN2 | 4.793253 | 7.01493 | 5 | 1 | 6.0 | 0.24 | 0.63 | 2.63 | SP |
| L119 | 4.834058 | 6.974481 | 16 | 1 | 12.0 | 0.12 | 0.30 | 2.50 | SP |
| L112 | 4.763244 | 7.103739 | 14 | 1 | 12.0 | 0.05 | 0.27 | 3.42 | SP |
| L121 | 4.832008 | 7.019158 | 0 | 1.00 | 9.0 | 0.18 | 0.420 | 2.33 | SP |
| L93 | 4.803953 | 6.999603 | 9 | 1 | 6.5 | 0.14 | 0.32 | 2.29 | SP |
| L115 | 4.792989 | 6.975181 | 6 | 1 | 9.0 | 0.12 | 0.29 | 2.60 | SP |
| L91 | 4.853403 | 6.972306 | 16 | 1 | 10.5 | 0.20 | 0.61 | 3.04 | SP |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| L209 | 4.803544 | 6.953997 | 10 | 1 | 12.0 | 0.09 | 0.29 | 3.22 | SP |
| L118 | 4.785508 | 7.037106 | 8 | 1 | 10.5 | 0.23 | 0.61 | 3.05 | SP |
| L154 | 4.835981 | 7.031864 | 16 | 1 | 13.5 | 0.12 | 0.30 | 2.50 | SP |
| L166 | 4.810408 | 7.046317 | 6 | 1 | 12.5 | 0.11 | 0.32 | 2.91 | SP |
| L52 | 4.850902 | 6.992883 | 9 | 1 | 10.0 | 0.22 | 1.00 | 4.55 | SP |
| L154 | 4.780036 | 7.020692 | 0 | 1 | 1.5 | 0.19 | 0.39 | 23.00 | SW |
| L41 | 4.792517 | 7.044475 | 5 | 1 | 10.5 | 0.20 | 0.60 | 3.00 | SP |
| L161 | 4.811706 | 7.000869 | 9 | 1 | 10.5 | 0.10 | 0.30 | 3.00 | SP |
| L57 | 4.840605 | 6.992063 | 13 | 1 | 10.0 | 0.10 | 0.29 | 2.90 | SP |
| L171 | 4.85416 | 7.057255 | 20 | 1 | 9.5 | 0.07 | 0.34 | 4.12 | SP |
| LN9 | 4.909 | 6.914083 | 9 | 1 | 15.0 | 0.20 | 0.53 | 2.65 | SP |
| L168 | 4.827127 | 6.99377 | 14 | 1 | 10.5 | 0.10 | 0.30 | 3.00 | SP |
| LN11 | 4.829493 | 7.000644 | 15 | 1 | 10.0 | 0.10 | 0.29 | 2.90 | SP |
| L224 | 4.859503 | 7.057393 | 19 | 1 | 9.0 | 0.12 | 0.28 | 0.65 | SP |
| L185 | 4.867335 | 7.028321 | 18 | 1 | 0.5 | 0.20 | 0.60 | 3.00 | SP |
| L104 | 4.867105 | 7.008676 | 17 | 1 | 9.8 | 0.23 | 1.00 | 4.35 | SP |
| APA IHE | 4.799955 | 6.997851 | 11 | 1 | 10.0 | 0.12 | 0.29 | 2.60 | SP |
| L59 | 4.818764 | 6.988033 | 10 | 1 | 7.5 | | 0.16 | | SP |
| L105 | 4.824806 | 7.038727 | 11 | 1 | 6.0 | 0.26 | 1.00 | 3.85 | SP |
| L48 | 4.825645 | 7.032897 | 13 | 1 | 12.5 | 0.20 | 0.55 | 2.75 | SP |
| L225 | 4.823554 | 6.989642 | 8 | 1 | 5.0 | | 0.15 | | SP |
| L181 | 4.810978 | 6.995733 | 10 | 1 | 9.0 | 0.07 | 0.36 | 4.50 | SP |
| L177 | 4.828096 | 6.975925 | 12 | 1 | 12.0 | 0.09 | 0.29 | 3.22 | SP |
| L220 | 4.798924 | 7.037945 | 15 | 1 | 12.5 | 0.10 | 0.27 | 2.84 | SP |
| L102 | 4.874859 | 7.041779 | 23 | 1 | 10.0 | 0.12 | 0.29 | 2.60 | SP |
| L87 | 4.815554 | 7.049844 | 8 | 1 | 9.0 | 0.07 | 0.36 | 5.14 | SW |
| L186 | 4.738028 | 7.032285 | 8 | 1 | 9.5 | 0.07 | 0.32 | 4.13 | SP |
| L86 | 4.872765 | 7.028778 | 17 | 1 | 9.5 | 0.12 | 0.32 | 2.67 | SP |
| L172 | 4.743216 | 7.082116 | 8 | 1 | 10.8 | 0.20 | 0.61 | 3.05 | SP |
| L169 | 4.839769 | 7.072702 | 16 | 1 | 3.0 | | 0.28 | | SP |
| L177 | 4.828096 | 6.975925 | 12 | 1 | 10.5 | 0.22 | 0.60 | 2.72 | SP |
| L170 | 4.867335 | 7.028321 | 18 | 1 | 9.8 | 0.24 | 0.75 | 3.13 | SP |
| L83 | 4.872765 | 7.028778 | 17 | 1 | 12.5 | 0.13 | 0.32 | 2.62 | SP |
| L264 | 4.823543 | 7.015768 | 8 | 1 | 5.0 | | 0.32 | | SP |
| L260 | 4.789275 | 7.01169 | 12 | 1 | 23.5 | | 0.14 | | SP |
| L223 | 4.81475 | 6.989389 | 5 | 1 | 6.0 | 0.20 | 0.40 | 2.00 | SP |

### 4.1 Coefficient of uniformity(cu)

Two distinct classes are noticeable from the spatial distribution of Cu at 3-10m **(**Fig. 2) in Port Harcourt area ,poorly graded sands (SP) where Cu is less than or equal to 6 and well graded sands (SW), where Cu is greater than or equal to 6 according to the United Soil Classification System (USCS). Areas like Rumuodara, Ikwerre Road, Rumuokorisi, Rumueme, Rumueprikom, GRA Phase II, GRA Phase III, D-line, Elekahia, Trans Amadi and Abuloma have poorly graded sands, while Eastern By-pass or Rumuomasi can be identified as having well graded sand at 3 to 10m.

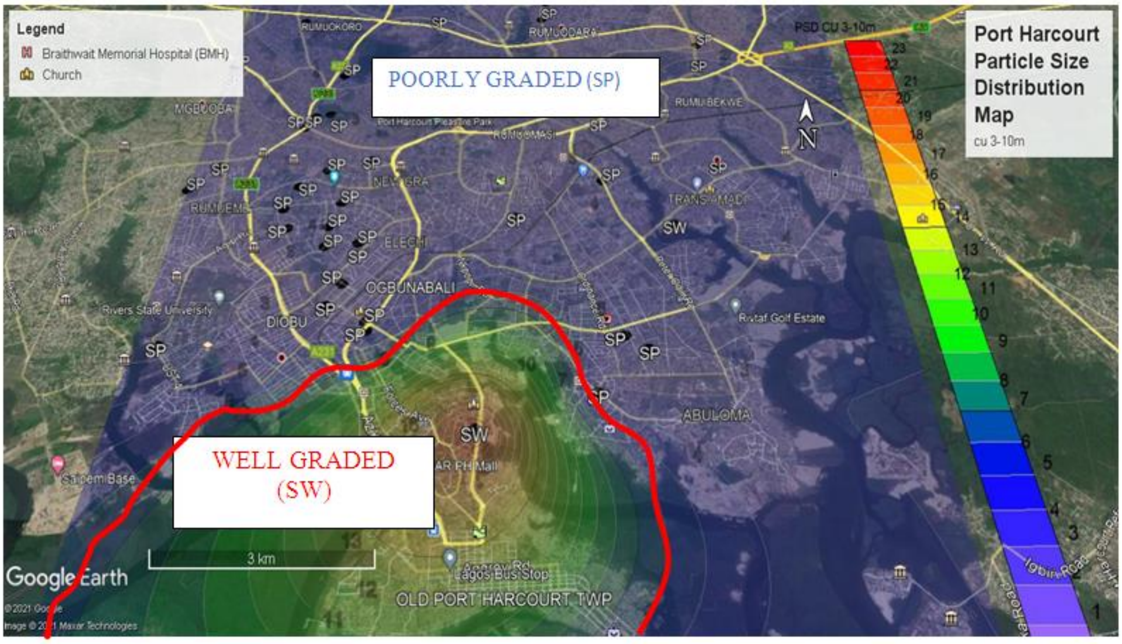


**Fig. 2:** Particle Size Distribution (cu) Map of Port Harcourt at 3-10m

At 11-15m, Cu values range between 1.47-6.32. Spatial distribution of Cu across Port Harcourt is shown in Fig. 3. Areas like Eneka, Rumuekini, Ada George, Rumuigbo, Ikwerre Road, GRA Phase I, Elimgbu, Oroigwe, Egbelu 2, Rumuogba, Monorail, Trans-Amadi, Amadi Ama and D-line show that the soils at this depth are poorly graded sands (SP) . These results agree with the work of Ezenwaka et al. (2014) in parts of Port Harcourt City. They concluded that the medium dense sand occurring at 8 – 15m has cu ranging from 2.52 – 5.2, and thus can be classified as poorly graded sand (SP). Poorly graded sands mostly lead to high immediate settlement due to increased pore spaces. In this case an appropriate type of foundation should be considered to suit the soil type.

The map shows that Rumueme has soils that are well graded. They are preferred for construction because it can be easily compacted into dense mass with minimum voids.

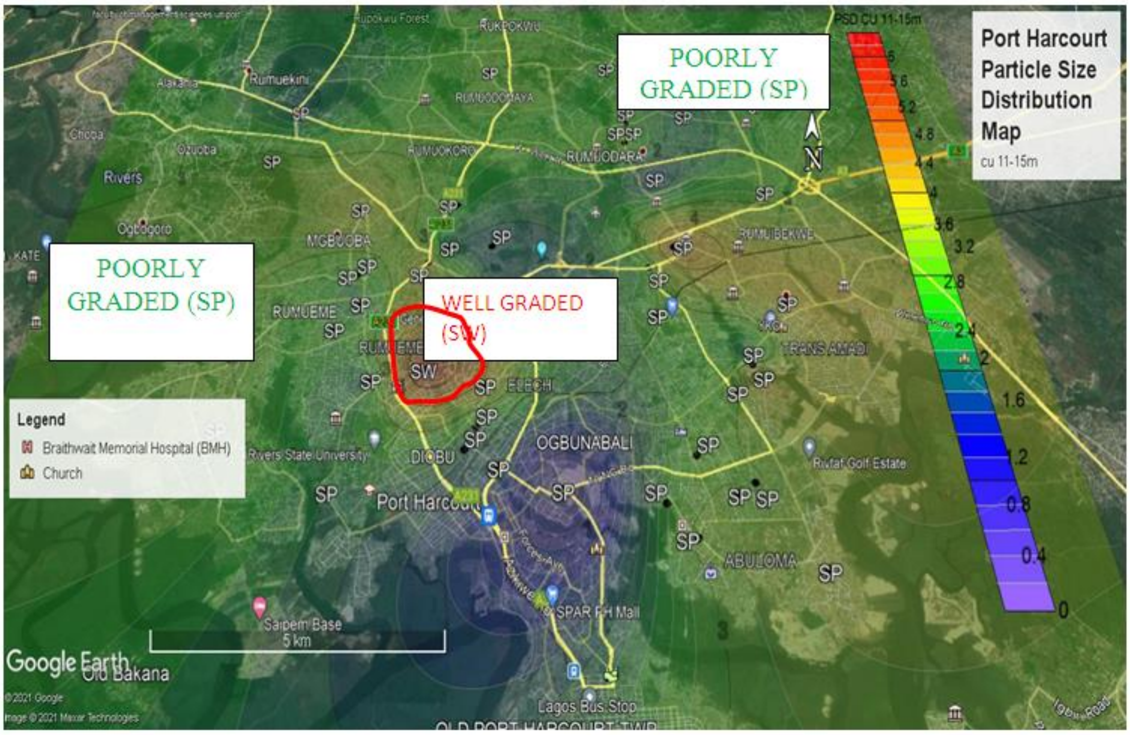


**Fig. 3:** Particle Size Distribution (cu) Map of Port Harcourt at 11m-15m

At 16 to 20m (Fig. 4), soils from areas like Mbuogba, Rumigbo, Ikwerre Road, GRA Phase I, GRA, D-line, Oroigwe, Rumuogba, Trans-Amadi, Abuloma, Amadi Ama and Nkpogu-Ogbunabali are poorly graded (SP), while soils from Eagle Island are well graded. The Poorly graded soils will be more susceptible to soil liquefaction than well graded soils.

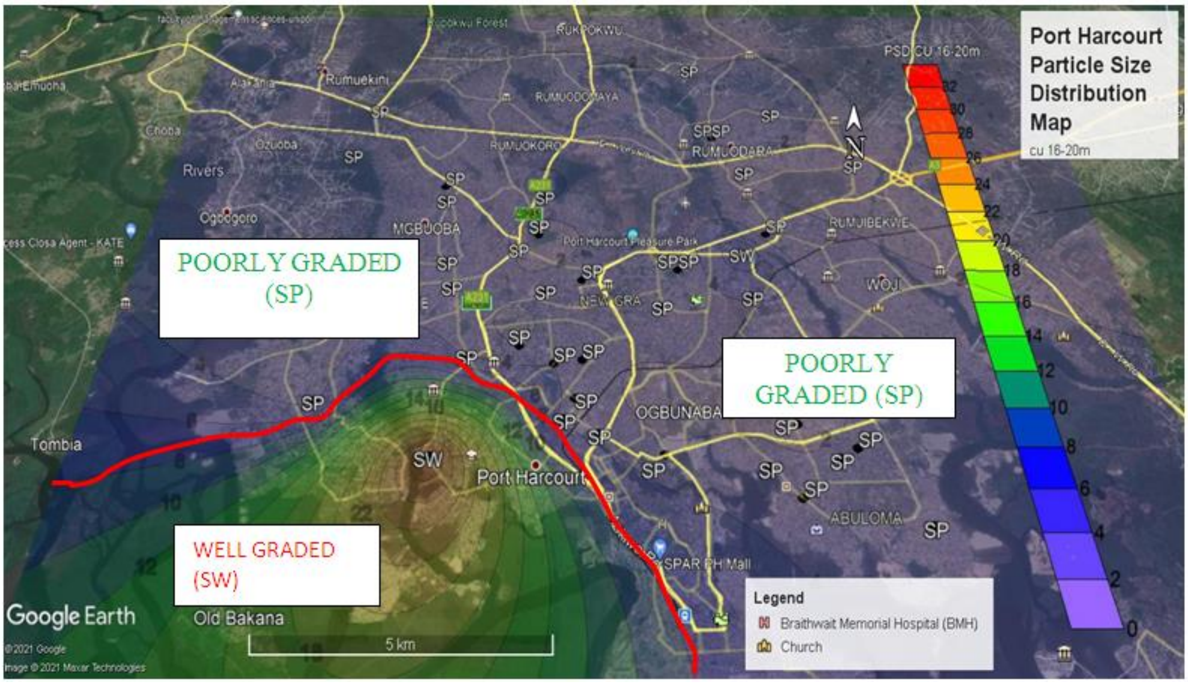


**Fig. 4:** Particle Size Distribution (cu) Map of Port Harcourt at 16m-20m

The stack diagrams (Fig.5) of the soil grading shows that the soils in Port Harcourt area are mostly poorly graded. From the stack, well graded soils can be seen at increased depth of 16 to 20m. Some soils at 3 to 10m are also well graded.

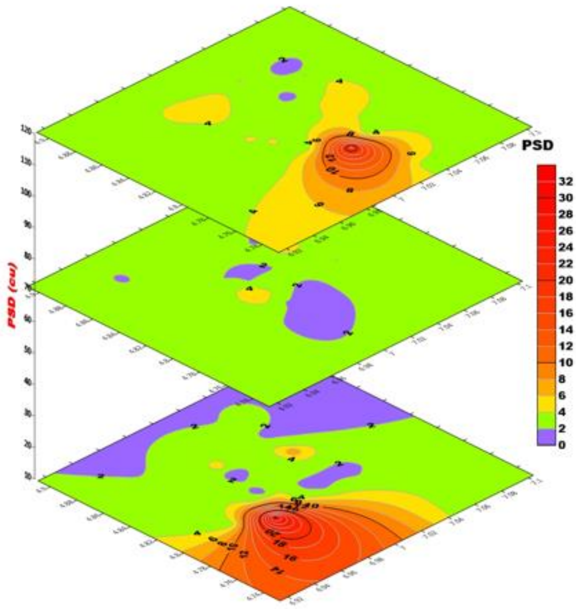


Fig. 5: Stack maps of Coefficient of Uniformity at 3-10m, 11-15m, and 16-20m

## V. CONCLUSION

i. The average values of Cu at depths 3 to 10 m, 11 to 15 m and 16 to 20 m are 3.68, 2.83 and 3.56 respectively.

ii. According to Unified Soil Classification System (USCS), the soils are mostly classified as poorly Graded Sands (SP) with Cu < 6.

iii. Some locations like Rumueme have well graded soils with Cu greater than or equal to 6.

iv. The Poorly graded soils in the Study Area will be more susceptible to soil liquefaction than well graded soils.

v. Also, Poorly Graded sands mostly lead to high immediate settlement due to increased pore spaces. In this case an appropriate type of foundation should be considered to suit the soil type.

vi. The well graded soils will be good for construction because it can be easily compacted into dense mass with minimum voids.

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