



Expanding Hydro-Geotechnical Considerations in Eia Studies: A Case Study of Ogorode – Sapele, Delta State, Nigeria

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ABSTRACT: Hydro-geotechnical mapping of the study area, which lies within the Sombreiro – Warri deltaic plain in the Niger Delta area, comprised the drilling of representative boreholes as monitoring wells. Three (3) boreholes were sunk in the area with soil and water samples collected for laboratory analyses according to Department of Petroleum Resources (DPR) and international standards. The physical properties of the soils were determined and used as indices of their infiltration capacity and classification. Water quality analysis was for physicochemical and microbiological parameters. Boreholes logged to the maximum – drilled depth of 10m, revealed fine – grained, high plasticity clay and medium to coarse –grained sands with fines of silt and clay overlying the aquifer. Static water levels were in the range of 1.2 to 2.0m below ground elevation. The aquifer was determined to be confined in one area but was mostly semi – confined (leaky) and this condition may permit gradual infiltration of pollutants into the upper aquifer. Environmental hazards that may occur in the area may include sheet erosion and flooding. It is recommended that the provision of dedicated flow lines will ensure a flood free environment. @ JASEM

This study is meant to provide guidance of geological / hydro-geotechnical information which are required for effective Environmental Impact Assessment studies. Environmental Impact Assessment (EIA) is widely used in Nigeria to ensure that the effects of projects on the environment, natural resources and on the community as a whole are properly evaluated and mitigated where necessary.

The uncertainties associated with soil and water quality degradation caused by pollution, growing flood and erosion risks as a consequence of man made interventions in catchments, and possible hydrological impacts of climatic change, will require improved hydro-geotechnical data collection and analysis in order to determine the local groundwater flow direction, and how the pollutants reaching the ground water will migrate along these flow paths (Guidicini, et al, 1979; Rodriguez, 2006; Hasfurther & Turner, 2008). Several environmental problems are expected to occur if no secure and environmental friendly measures associated with development are carried out, as this can prevent severe contamination in soil and groundwater (Bruno, 2007; Barends & Hagenaar, 2008; Depountis et al, 2009).

In this study, the physical properties of the soil samples were examined to obtain parameters used as indices of the infiltration capacity of the soils at the study area. Water level monitoring and baseline water quality data were also examined.

To meet the challenges, the geo-environmental monitoring plan as revealed by this study will help in

flood and sheet erosion monitoring in the area, as well as determine whether or not groundwater contaminants introduced into the soil will reach the aquifer or not.

The aim of this paper, therefore, is to present an integrated study on the hydro-geotechnical aspects, for better understanding of their importance in EIA studies.

GEOLOGY OF THE STUDY AREA

The study area, Sapele in Delta State Nigeria is located in the Niger Delta region of Nigeria. The present-day Niger Delta was formed during the Tertiary period as a result of the interplay between subsidence and deposition arising from a succession of transgressions and regressions of the three main Tertiary subsurface lithostratigraphic units of Akata, Agbada and Benin Formations (Short and Stauble, 1967), with an overall approximate thickness of over 5,000m of sediment body. Table 1 shows the geologic units of the Niger Delta.

The study area lies within the Quaternary Sombreiro – Warri deltaic plain with prominent seasonal freshwater swamps, which overlie the Benin Formation. Its geomorphologic setting is flat to sub-horizontal and slopes gently seawards. It comprises variable deltaic sediments of moderate to highly plastic clays that usually occur in the back swamps linking river channels, to sands and cohesive silty and clayey soils that are partly permeable.

Table 1: Geologic Units of the Niger Delta (Short and Stauble, 1967)

Geologic Unit	Lithology	Age
Alluvium (General)	Gravel, sand, clay, silt	
Freshwater Backswamp and meander belt	Sand, clay, some silt and gravel	Quaternary
Mangrove and salt water / backswamps	Medium – fine sand, clay and some silt	
Sombreiro – warri deltaic plain	Sand, clay and some silt	
Benin Formation (coastal plain sand)	Coarse to medium sand with subordinate silt and clay lenses	Miocene
Agbada Formation	Mixture of sand, clay and silt	Eocene
Akata Formation	Clay	Paleocene

BASELINE DATA ACQUISITION

Monitoring Wells, Soil Stratigraphy and Index Properties

Three (3) water wells were drilled at the study area to obtain baseline water quality data, water level monitoring and sub – soil analysis for infiltration characteristics. The boreholes were drilled with the use of a light cable percussion rig to a depth of 10m in each borehole. This drill type permits more accurate determination of groundwater levels and sampling of ground water for quality analysis. The wells were logged on site with soil samples recovered at intervals where distinct changes in soil type occur, for laboratory analysis. Water samples were also collected into appropriately labeled containers for physico – chemical and microbiological analyses. The static water levels recorded in the boreholes were 2.0m, 1.5m and 1.2m for boreholes 1, 2 and 3 respectively. The water level in the boreholes is

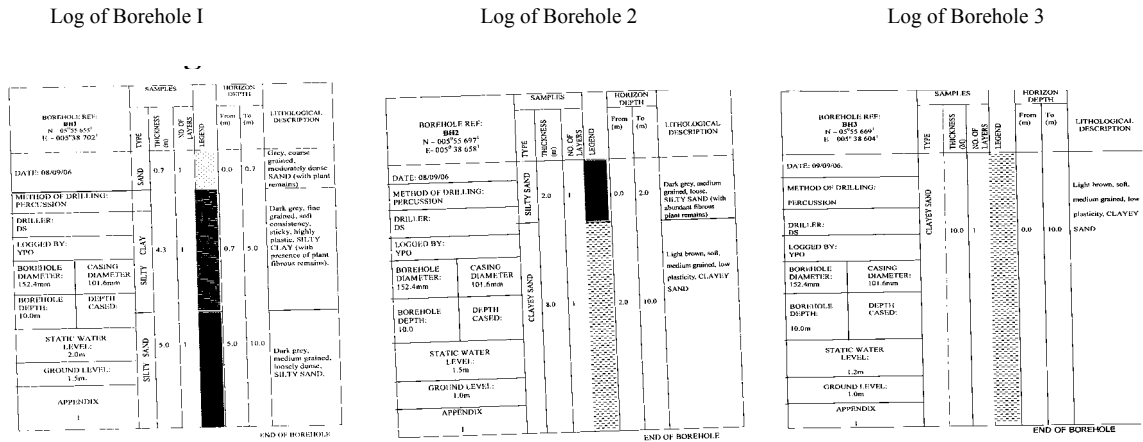
subject to seasonal fluctuations. These values were observed during the rainy season (September). The physical properties of the soil samples recovered from the boreholes were examined to obtain parameters used as indices of the infiltration capacity of the soils in the study area.

Laboratory tests were carried out on representative soil samples in accordance with British Standards (B.S). 1377, which are equivalent to the ASTM Standards. The tests were grain size distribution analysis, permeability (using the constant and falling head permeameters) and Atterberg (consistency) limits. These tests were conducted to enable the evaluation of the gradation, hydraulic conductivity (coefficient of permeability) and consistency (water absorbing and adsorbing ability) properties of the soil samples, as well as their classification. The summary of the results is shown in Table 2, while the details are presented in the borehole logs.

Table 2: Summary of Laboratory Soil Test Results

BOREHOLE NUMBER	CO-ORDINATE LOCATION		SAMPLE NUMBER AND DEPTH	SOIL TYPE	GRAIN SIZE DISTRIBUTION (Percent Passing Sieves)				CONSISTENCY LIMITS			PERMEABILITY (cm/sec.)	CLASSIFICATION UNIFIED SOIL CLASSIFICATION SYSTEM (U.S.C.S.)
	EASTINGS	NORTHINGS			No. 4	No. 10	No. 40	No. 200	LL (%)	PL (%)	PI (%)		
					(4.75mm)	(2.00mm)	(0.425mm)	(0.075mm)					
BH1	005°38' 702"	05°55' 655"	BH1/0m	SAND	97.7	92.24	49.81	6.51	-	-	Non Plastic	7.33 x 10 ⁻¹	SW
			BH1/0.7m	SILTY CLAY	-	-	-	-	89.2	20.0	49.2	2.17 x 10 ⁻²	CH
			BH1/10m	SILTY SAND	98.17	94.04	60.09	15.14	-	-	Non plastic	7.66 x 10 ⁻¹	SM
BH2	005°38' 650"	05°55' 677"	BH2/0m	SILTY SAND	99.47	97.35	59.89	20.84	-	-	Non Plastic	8.68 x 10 ⁻¹	SM
			BH2/10m	CLAYEY SAND	100	95.20	61.14	31.01	-	-	-	8.67 x 10 ⁻¹	SC
BH3	005°38' 614"	05°55' 669"	BH3/0m	CLAYEY SAND	100	99.6	74.50	31.47	27.6	15.9	11.7	8.00 x 10 ⁻¹	SC
			BH3/10m	CLAYEY SAND	100	96.16	64.61	31.88	-	-	-	7.75 x 10 ⁻¹	SC

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Lithologic profiles of the soils from each of the three (3) boreholes drilled are detailed in the borehole logs, while the lithostratigraphic correlation is depicted in Figure 1. In borehole 1 (BH1), a 0.7m thick deposit of grey, coarse grained, moderately dense sand overlies a silty clay layer that extends to a depth of 5m. This is the only predominantly clayey soil found at the site and it is dark grey, fine – grained and

highly plastic. Below this is a dark grey, medium grained, loosely dense, silty sand to the bored depth of 10m. Borehole 2 (BH2) shows the silty sand of 2m thickness as its overburden. Following it is a light brown, medium grained, low plasticity, clayey sand to 10m. The entire unit of borehole 3 (BH3) displays the clayey sand stratum.

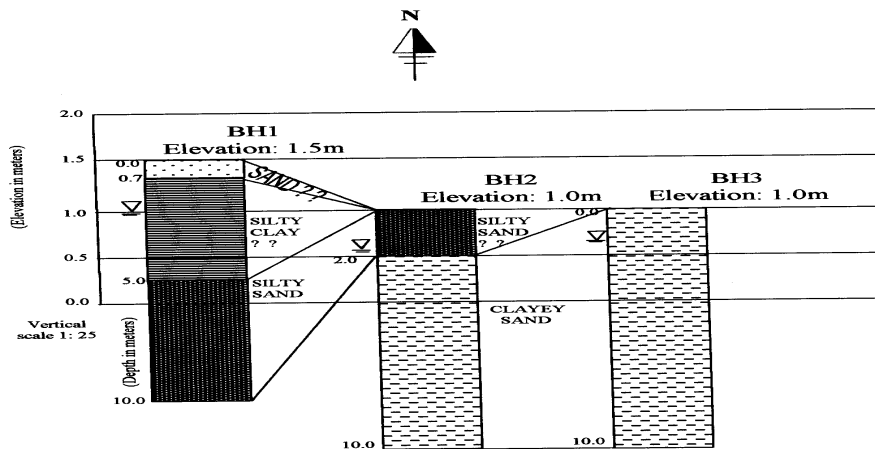


Fig. 1: Ground Elevation and Lithostratigraphic Correlation of borehole units.

Grain size analysis involved dry sieving on field obtained samples. The results show from the data and gradation curves that the sandy soils from all three (3) boreholes are well graded (poorly sorted) with fines (silt/clay fractions) ranging from 6.51% to 31.88%. The coarse grained sands possess greater infiltration capacity since the number of particles per unit area is large and void spaces are greater.

Atterberg limits (also known as consistency limits) expresses the water absorbing and adsorbing ability of fine grained, cohesive soil, with the plasticity index indicating the range of water content, through which the soil remains plastic. The results show a high plasticity value (49.2%) for the silty clay and low (11.7%) for the clayey sand, while the clean sand and silty sands are non – plastic. Atterberg limit tests are applicable only to fine grained, cohesive soils.

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The low and high values of plasticity indices of the plastic soils are an indication of their fluid retaining capacities.

The soils were classified under the Unified Soil Classification Systems (USCS) as SW, SM, SC and CH, implying well – graded sands, silty sands, clayey sands and high plasticity clays.

The permeability test (constant and falling head) results reveal a low value of 2.17×10^{-3} cm/sec. for the silty clay soil, while the sandy soils display a high range of 7.33×10^{-1} to 8.67×10^{-1} cm/sec.. Infiltration capacity of soil depends on the permeability, degree of saturation, vegetation and amount and duration of rainfall (Todd, 1980).

IMPACT/IMPLICATION ASSESSMENT

The hydrology of the study area is influenced by its high precipitation rate with a mean annual rainfall of over 2,500mm, the overburden lithologic strata that over lie the aquifer, and the slightly undulating topography. Surface waters are received from non-tidal seasonal fresh water flows. Recharge of the

aquifer will be by rainwater that eventually moves through the overburden into the aquifer. Recharge depends on rainfall intensity and distribution and amount of surface run off. Groundwater occurs under confined and semi-confined conditions in the area on account of the thick clayey soil overlying the aquifer in the area of borehole 1 and bounded above by aquitards in the regions of boreholes 2 and 3. In an aquitard, the groundwater flow is assumed to be predominantly vertical (Boonstra, 1989). The existence of these overburden layers will determine whether or not groundwater contaminants introduced into the soil will reach the aquifer. Figure 2 shows the determination of groundwater flow direction as defined from the delineated groundwater contours using the Todd (1980) method. Flow lines sketched perpendicular to contours show directions of movement. The local groundwater migration in the site between boreholes 1, 2 and 3 as shown in Figure 2 is towards the southwestern direction. Pollutants reaching the groundwater will migrate along these flow paths.

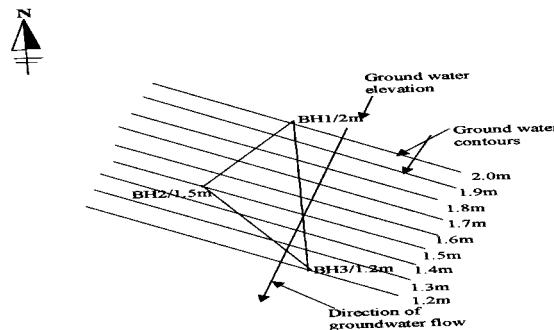


Fig. 2: Estimate of Groundwater flow Direction

ENVIRONMENTAL MONITORING PLAN (EMP)

Environmental monitoring plan in the study area may consist of:-

- (i) *Flood Monitoring*: The generally low-lying nature of the area will encourage ponding of rainwater and flooding. The provision of dedicated drainage flow lines will ensure a flood free environment.
- (ii) *Sheet erosion monitoring*:- During construction in the study area, the protective soil vegetation is removed. Concentrated surface flow of rainwater rills the soil and changes the slope value, which may eventually result in sheet/gully erosion. The essentially sandy overburden may facilitate this

environmental hazard. Caution should therefore, be exercised during the construction phase not to aggravate this phenomenon.

CONCLUSION

It has been significantly revealed from this study that the various boreholes logged to the maximum-drilled depth of 10m show fine – grained, high plasticity clay and medium to coarse-grained sands with fines of silt and clay overlying the aquifer. The static water levels were in the range of 1.2 to 2.0m below ground elevation and the local groundwater migration is towards the southwestern direction. In view of the

low lying nature of the area, ponding of rainwater and flooding is encouraged.

In order to achieve a systematic environmental monitoring without disturbing the natural hydrodynamic system of the area, the following measures are suggested:

1. The provision of dedicated drainage flow lines will ensure a flood free environment.
2. Caution should be exercised during the construction phase not to aggravate sheet erosion. This is because the protective soil vegetation may be removed and progressive and concentrated flow of rainwater is capable of changing the slope value, which may eventually result in sheet / gully erosion.

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