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Effect of flood analysis on the foundation investigation using integrated approach

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Summary

The effect of flood analysis on the foundation investigation of the proposed Gas-Fired Power Plant in Badagry, Lagos, Nigeria was carried out using geophysical, geotechnical and geographical information system (GIS) methods. The subsurface information was obtained by using two electrode arrays for the resistivity data acquisition. Geotechnical data were obtained through two boreholes via percursion drilling within the study area. The integration of geophysical and geotechnical data reveals that the subsoil materials comprises fibrous peat, organic silty clay, clayey sand, sandy clay and sand. The analysis of the subsoil conditions via geotechnical data shows the feasibility of foundation around 25 m via piling while the safe grade elevation has been worked out to be 6.672 m for 100yrs return period via GIS approach. Thus, in order to avoid adverse effect of flood on the proposed structure, the safe grade elevation value has to be added to the foundation floor.

Introduction

The growing population in Lagos State, Nigeria is on a geometrical rise because it is considered as the economic beehive of the country. This rising population has overstressed the infrastructural facilities which have led to the mass movement of people from the cities to the suburb arising from its development via the provision of infrastructure. The initiative has led to the proposed Gas-Fired Power Plant in Badagry Lagos in order to cope with demand of the people and business environment. The proposed site is a flood plain. More than thirty-five years, the flood's magnitude and frequency are tremendously accelerated particularly triggered by human actions; for example land clearing for urbanisation or farming activities,building of structure such as freeways, roads, and bridges which repeatedly alters the flood behaviour (Rabie et al., 2007;Toriman et al., 2009).

The impacts of floods on any society are primarily dependent on the management of flood reduction. Mitigation is a series of activities and measures that are put in place before the occurrence of any natural hazard event in order to reduce or eliminate the impacts of such hazards on the society and the environment at large (Adiat et al., 2012). The identification of the vulnerable or risk zones will assist in the effective implementation of the other aspects of the preparedness phase which includes early warning, alert system and awareness raising campaign and flood response by emergency and disaster relief (Chapman and Canaan, 2001)

Many studies have been conducted on floor susceptibility mapping using remote sensing data and GIS tools (Adiat et al., 2012). The integration of GIS and 2D imaging was used to investigate the effects of subsurface condition on flood occurrence in Kedah State, Peninsula Malaysia (Adiat et al., 2012).The application of geophysical and geotechnical methods becomes necessary as they are capable of imaging the subsurface targets or providing additional information useful for generating geological models and understanding the engineering properties of the soil in order to ensure stability of structures (Rucker et al ., 2011).

In this study, the geophysical, geotechnical and GIS data were integrated to assess the effect of flood analysis on the foundation investigation.

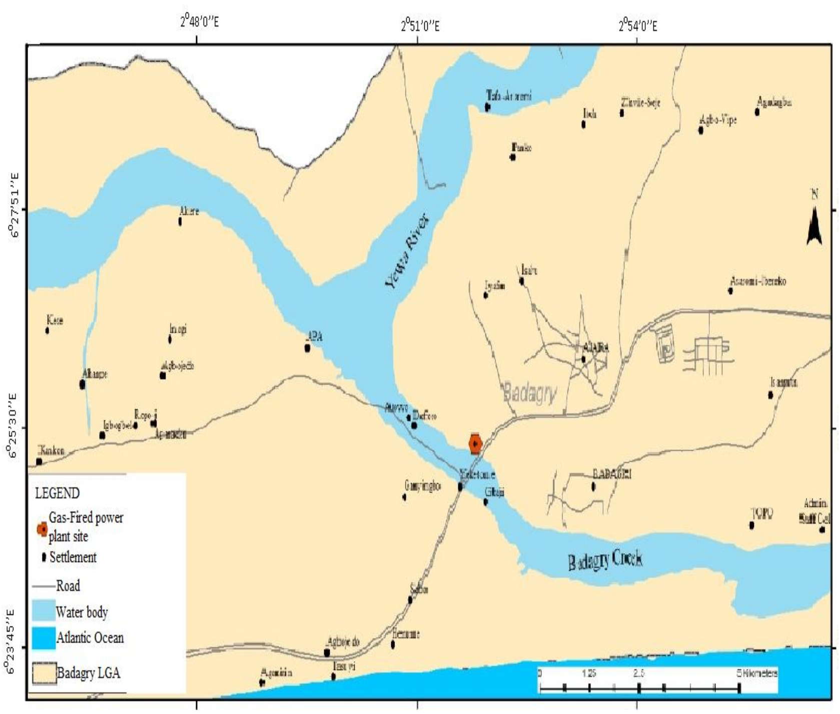

Figure 1. Map of the study area

Site Description & Geology

The site of the proposed project is located near Iyafin village within Badagry town, Badagry local government area of Lagos State. Geographically, it lies approximately within latitudes $6^{0}22'$ N and $6^{0}36'$ N and longitudes 2^{0} 50' E and 2^{0} 54' E. The land area of the proposed project site is about 4.093 Ha (40,930 m^2). It is proximate to the Badagry Creek (Figure1). The proposed project site is located entirely within the floodplain of the Badagry creek. The creek is influenced by tides and floods from the Lagos Lagoon and Cotonou harbour through Lake Nokue and Lake Porto-Novo (Anyanwu and Ezenwa, 1988).The general geology of Lagos and its environs can be described as an integral part of Dahomey basin, which is the eastern part of sedimentary basin that extends from Volta Delta in Ghana to Okitipupa ridge in Nigeria (Jones and Hockey, 1965; Whiteman, 1982). The area investigated is situated in the southern part of Dahomey basin and consist of stratified series of sedimentary sequence made up of silt clay, peat and sand.

Methods

In geophysical survey, twenty (20) Vertical Electrical Sounding (VES) via schlumberger array and three (3) 2D resistivity data using Wenner configuration distributed along three traverses (T1-T3) were acquired by resistivity meter called PASI. The electrode spread (AB) for schlumberger area varied from 2 m to 320 m while the total spread of the 2D array configuration varied from 0 to a maximum of 200 m with the electrode spacing between 10 m and 60 m. The geotechnical data comprised drilling two, shell and Auger boreholes to 30.00 m depth.

Table 1. Data set used

s/n	Data	Data Scale & Resolution	Data Extracted	Data Source
1	Badagry Creek Gauge Height Data (1980-2012)	Point-based	Annual average water level	Ogun Osun River Basin Development Authority (OORBDA)
2	Topographic maps of Badagry Sheet 278A NE 1, 2	1:25,000; graticle interval (7' 30"N by 7' 30"E)	Spot heights and contour	Federal Surveys Department. Data acquired in 1982
3	Shuttle Radar Topographic Mission	30 metre	Digital Elevation Model (DEM)	USGS via EarthExplorer portal. Data acquired in 2014

Boring was executed using a shell and Auger cable percussion boring technique by means of a pilcon wayfarer Rig equipped with the in-situ standard penetration tests (SPT) accessories. During boring, samples were recovered at regular intervals of 0.75m while standard penetration tests (SPT) were carried out at 1.5m intervals in cohesionless strata. The dataset used for determining the safe grade elevation are shown in Table 1. Design flood estimation was based on both probabilistic approach on L-moments methods using rainfall frequency analysis (Gumbel EV-1 distribution) and deterministic approach using unit hydrograph method that incorporated tidal effect and long term ocean surges. The maximum flood level above mean sea level (Safe Grade Elevation) was determined for the various flooding conditions for 2yrs, 5yrs, 25yrs, 50yr, 100yrs and 200yrs return periods. However, the severe flooding condition of 100-year flood with additional freeboard of 1.0 m was considered for this study. Analysis of inundation area for the 100- year return period was conducted using Digital Elevation Model (DEM) derived from USGS via EarthExplorer portal in a GIS environment.

Results & Discussion

Samples of the results of the 2-D inverse resistivity models, geoelectric section and borehole log obtained for the study area are presented in figure 2 (A-C) respectively. The resistivity profile show relevant changes in the vertical direction as well as lateral changes typically occurring along the survey lines. On the pseudo-section, arrows were used to indicate the position of the two VES and a borehole with a view to constraining the 2D inverse resistivity model. The range of resistivity values of 2D structure vary from a low value of 0.45 Ohm-m to a high close to 87 Ohm-m. The low resistivity values are indicative of conductive subsurface soil materials which are representative of peat, organic silty clay, clayey sand, silty sand, and sand. The integrated approach shows that subsoil materials are highly saturated and affirms the susceptibility of the study area to flood. The borehole log reveals the feasibility of the foundation via piling at about 25m.

The statistical distribution of the area and proportional analysis of the spatial extent of inundated and non flooded area within the basin for seven return periods (Table 2) shows flood elevation is not uniform within the study area for flood elevation which depends on surface topography and storm intensities. Hence, a single maximum flood elevation level might not be anticipated in the entire proposed project area. The computed flood frequency elevation by considering the 100-year flood elevation gave 5.672 m. This reveals the maximum flood level during the simulation and computation of the flood level extremes. This was adopted as the maximum expected flood level around within the study area. This now led to the generation of the 2D flood inundation map for modeled return period of 100yrs which reflects areas liable to flood and the non-flooded area as shown in figure 3. Considering this level as base flood elevation or flood submersion line and adopting freeboard of 1.0 m, the safe grade elevation was calculated as 6.672 m.. Furthermore, the maximum flood level is not uniform within the study area, therefore a land development plan may be considered in which the topography of the site is retained while the land is filled to maximum flood level + freeboard. With this elevation (6.672 m), the dimensions of the study area will be at safe grade for developmental purposes.

Conclusion

The low resistivity values are indicative of conductive subsurface soil materials which are representative of peat, organic silty clay, clayey sand, silty sand, and sand. The integrated approach shows that subsoil materials are highly saturated and affirms the susceptibility of the study area to flood. The borehole log reveals the feasibility of the foundation via piling at about 25m. . In consideration of the surface slope and movement of water, with a freeboard of 1.0 m and the lowest flood elevation at par with river surface (at mean sea level), the calculated safe grade level of 6.672 m above mean sea level should be adhered to. Hence, in order to avoid adverse effect of flood on the proposed structure, the safe grade elevation value has to be added to the foundation floor.

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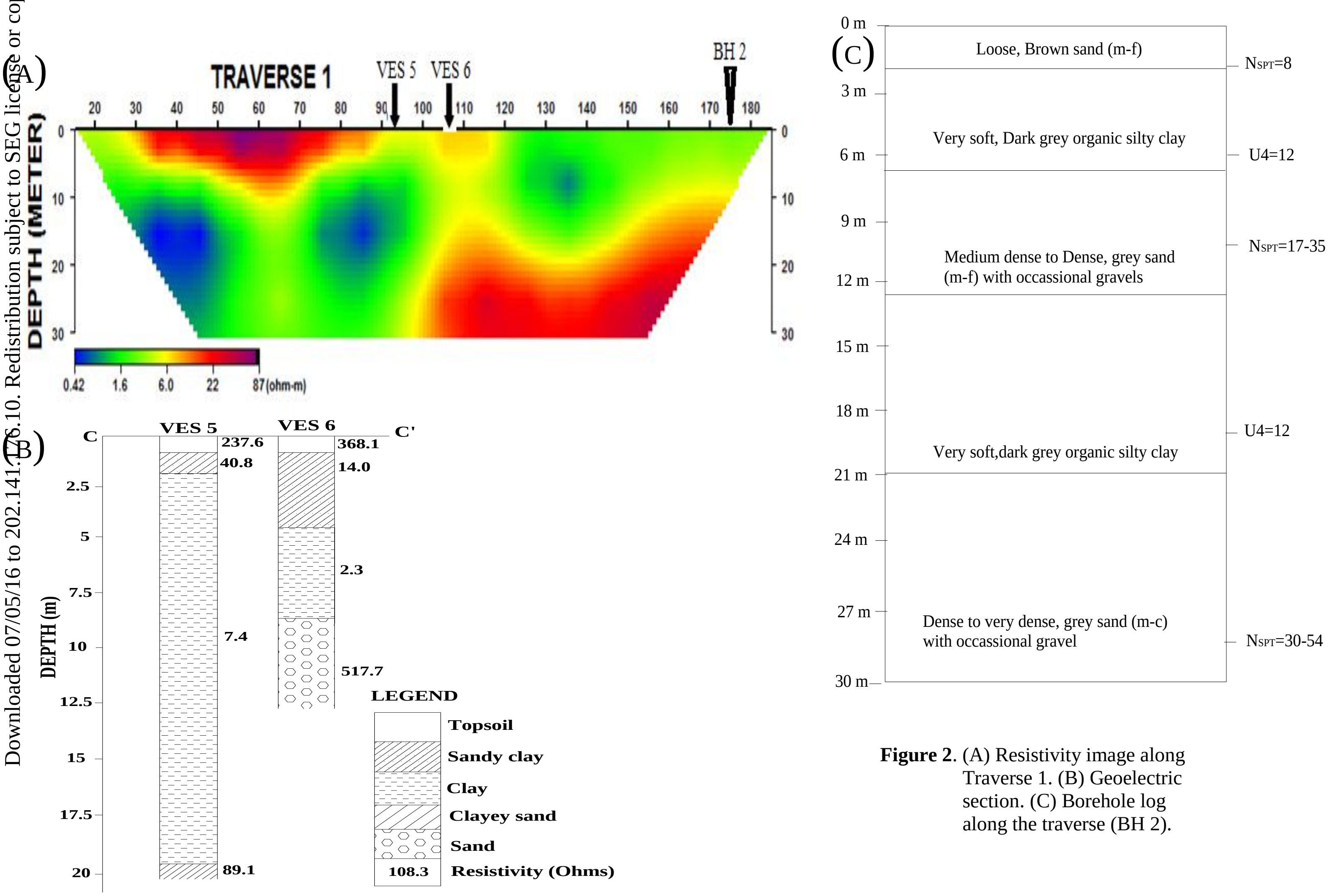

Figure 2. (A) Resistivity image along Traverse 1. (B) Geoelectric section. (C) Borehole log along the traverse (BH 2).

Table 2. Statistical Analysis of the Return Periods based Inundation Scenarios.

Return Period	Modelled Water elevations (metres)
2	2.020
5	2.935
10	3.568
25	4.393
50	5.026
100	5.672
200	6.336

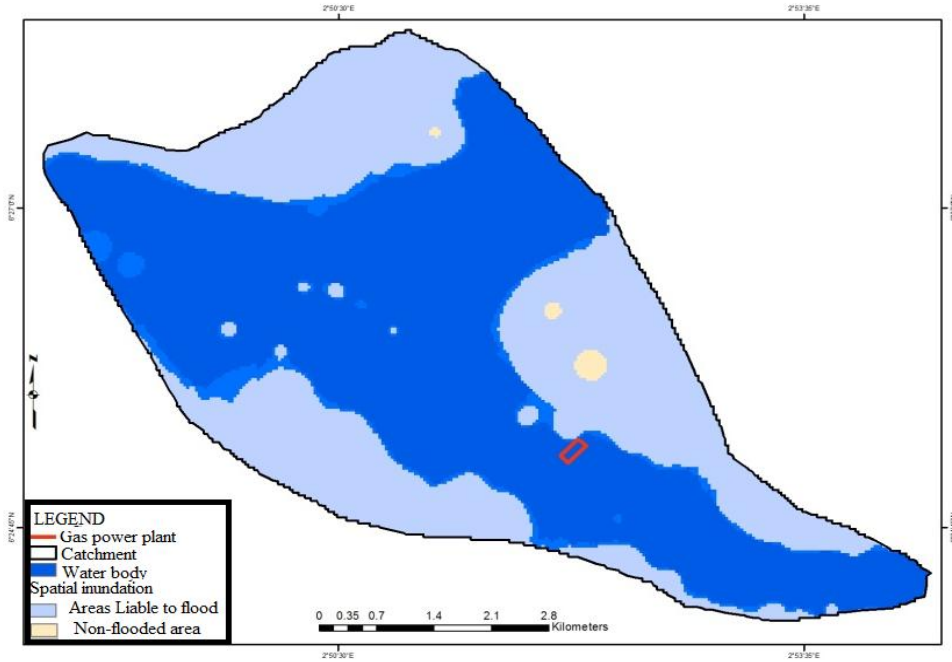

Figure 3.2D flood inundation map for modeled return period of 100yrs

References

Adiat, K.A.N., M.N.M. Nawawi, K. Abdullah, 2012, Integration of geographic system and 2D imaging to investigate the effects of subsurface conditions on flood occurrence. Modern Applied Science, 6, no.3,11-21.

Anyanwu, A. J. And B.I.O. Ezenwa, 1988, Incidence of parasitic infection of pond raised Tilapia spp. and some cultivable fish species from three ecological areas of Lagos state. Nigeria Institute of Oceanography and Marine Research, Technical ` Paper No. 32.

Chapman, J.B. and W.D. Cannan, 2001, Flood maps are key to better flood damage control. CE News, 58-60.

Jones, H.A., and R.D. Hockey, 1965, Geology of Parts of Southwestern Nigeria :Ibadan University Press.

Rabie, A.H., A.G. Aminuddin, Z. Nor Azizi, S.A. Mohd Sanusi and A.H. Zorkeflee, 2007, Modeling floodplain inundation by integrating hydrogeological with hydraulic model. Case study: Muda River, Kedah.: 2nd International Conference on Managing Rivers in the 21st century: Towards PWTC sustainable River Basins, Kuching.

Rucker, D.F., J. B.Fink and M. H. Loke, 2011, Environmental monitoring of leaks using time lapsed long electrode electrical resistivity: Journal of Applied Geophysics, **74**, 242- 254

Toriman, M.E., A.J. Hassan, M.B. Gazim, M. Mokhtar, S.A. Sharifah, O. Jaafar, O. Karim and N.A. Abdul Aziz, 2009, Integration of 1-d Hydrodynamic Model and GIS Approach in floodplain Management Study in Malaysia. Research Journal of Earth Sciences, 1,22-27.

Whiteman, A.J. 1982, Its Petroleum Geology Resources and Potential, Nigeria: Graham and Trotman.