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GROUNDWATER CONDITIONS IN THE MANGROVE SWAMPS OF THE WESTERN NIGER DELTA: CASE STUDY OF THE UGHOTON AREA, DELTA STATE, NIGERIA

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Groundwater conditions in the mangrove swamps of the western Niger Delta are described for the first time from the Ughoton area. The interconnected streams and creeks subdivide the 'swamps' into quasi-rectangular blocks that feature a slightly more elevated central area that slopes towards the demarcating creeks and streams. Vertical electrical soundings obtained with the Schlumberger configuration indicate the presence of four geo-electric layers with resistivity values of 31-2600, 31-2418, 323-1824 and 321-1626 ohm-m, respectively. A layered, more than 50 m thick aquifer of thin silty clay, fine-medium grained underlain by a thicker coarse sand is interpreted. The elevation of the water table above sea level is obtained from more than fourteen dug well measurements and water table contours indicate that flow is from a groundwater mound that occurs in the central area of the Ughoton 'block' westwards and north westwards towards the river. The preponderance of major ions in the wet season obtained from fourteen dug well water samples are in the order Na>Ca>Mg>K, and Cl>HCO3>SO4 for the cations and anions respectively. Chloride in ground water is low at a mean of 25.4 mg/l and 35 mg/l for the Ughoton River. The occurrence of fresh, low chloride ground water means that the brackish water conditions that support the mangroves that are confined to the river bank are maintained by tide related sea water that is propagated up river from the estuaries at high tide, as well as by slow drainage of bank storage. Mean lead level in ground water is .019 mg/l and cadmium is at 0.02 mg/l. Thus while lead is already at the threshold of the WHO and Nigerian Drinking Water Standards, cadmium level is at least one order of magnitude higher than these standards. Lead, cadmium and chromium occur at 0.05 mg/l, 0.5 mg/l and 0.06 mg/l respectively in surface water. These elevated levels in the river may be related to oil field activities to the west and south of the area.

INTRODUCTION

Ughoton and Omadino (Latitude 5^0 36N, 5^0 38N and Longitude 5^0 38E, 5^0 44E) Figure 1 and Figure 2, are two small rural communities in Delta State, Nigeria that occupy the south and north bank respectively of the Ughoton Creek, one of the numerous interconnected and meandering creeks that occur in the physiographic landform classified as the Mangrove Swamps in the Geological Map of Nigeria (GSN, 1964), Figure 3. The area is located approximately twenty kilometers north west of the city of Warri the hub of the oil and gas industry in the western Niger Delta. The Mangrove Swamps stretch from around Degema, east of the River Niger to the Benin River and are separated from the Atlantic Ocean by the beaches and barrier Islands. In Delta State, they occur as a wedge shaped physiographic region that is bound in the south by the Ramos River and in the North by the Benin River, Figure 3.

Communities in the Mangrove Swamps generally lack infrastructural facilities including water supplies for domestic use. The major reason for this, among several other endemic public policy and institutional failures, is the difficulty of access to the interior of the Mangrove Swamps. This lack of access has also made it difficult to conduct even the most routine ground water studies due to associated prohibitive costs, thus the universal assumption that shallow groundwater in the area must be brackish because of the presence of mangroves and the supposed brackish nature of creeks and streams has persisted. Indeed, the problem of access is further compounded by the absolute lack of appropriately contoured topographic maps of the western delta in spite of Abam's (1999, Figure 1) suggestion to the contrary. As a result, while the wetlands to the east of the River Niger have received some attention in terms of ground water research (Amajor 1991; Etu- Efeotor and Akpokodje 1990; Etu- Efeotor and Odigi 1983) the Mangrove Swamps of the western Niger Delta have received limited mention and only in regional discussions of the entire delta (NDES 1995;

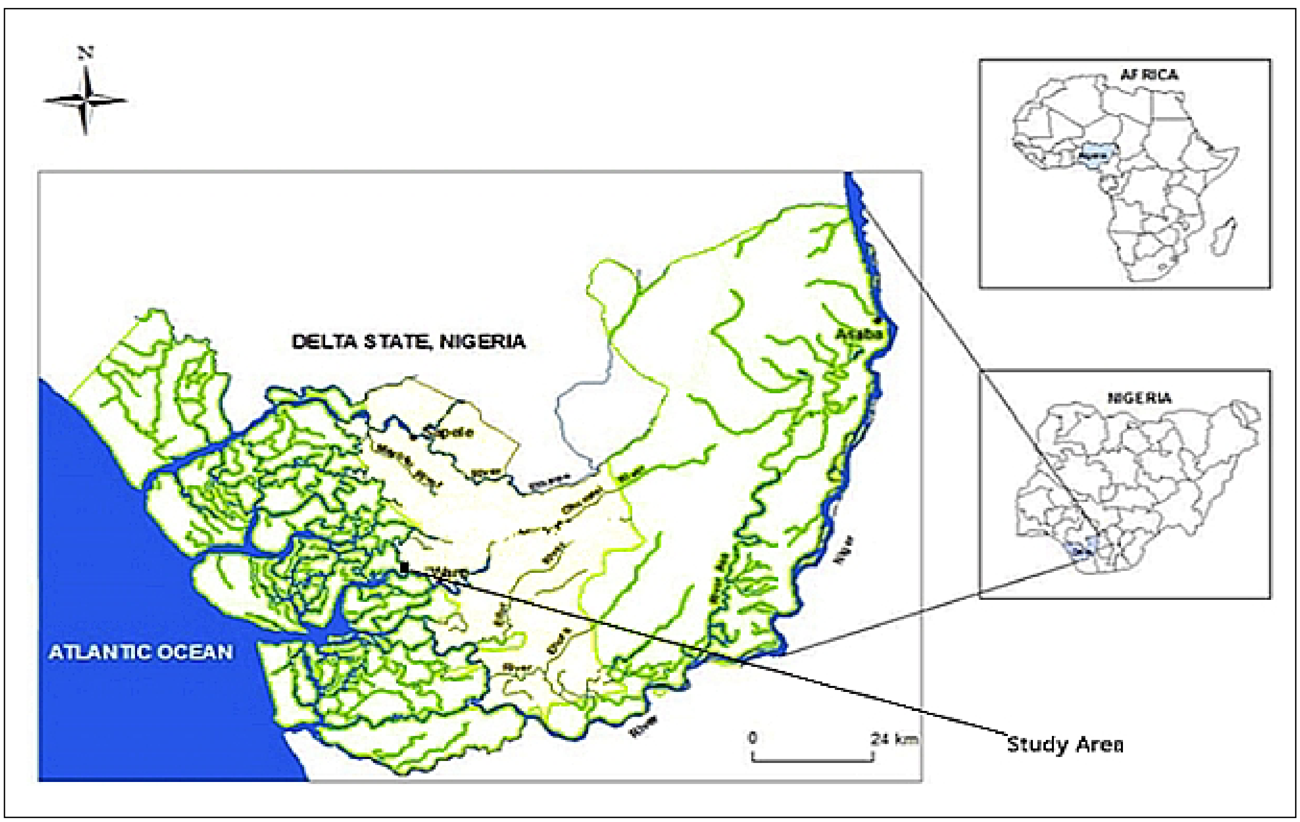

Figure 1. Location map of study area in Delta State, Nigeria.

NDDC, 2005; Abam 1999, 2001). Localized and project site specific environmental impact assessment studies for oil field developments at Saghara and Jones Creek (SPDC 1998, 2004) and at Tuomo (NAOC, 2005) have also provided some insight into ground water quality. For example the baseline assessments show that shallow groundwater in the Tuomo Well Field southwest of Omadino is fresh (NAOC, 2005) while at the Saghara Oil Field situated on the north and south bank of the Escravos River estuary and west of the study area, shallow groundwater is definitely saline (chloride ion at 1,737 - 20,990 mg/l), and decreases rapidly in salinity eastwards with distance from the coastline (SPDC, 1998).

The completion of the bridge over the Ughoton Creek at Ughoton in 2005 has opened up the Omadino area that had hitherto been inaccessible except by river craft, thus the primary objective of this study is to formally define and describe the groundwater conditions at the Ughoton – Omadino area as this would provide an insight into the general conditions that might exist in the western Mangrove Swamps and serve as a basis for further water resources studies.

PHYSIOGRAPHY AND DRAINAGE

The Mangrove Swamps are low lying, generally at less than about 5 m above sea level, drained and crisscrossed by tidal creeks that divide the swamps into somewhat quasi-rectangular blocks. Within each block, elevation increases gradually away from the demarcating creeks towards the 'centre' of the block; the land in this central area is drier and supports vegetation that is different from the mangroves that line creek banks. The Ughoton area as can be seen from Figure 2 is one such blocks, albeit surrounded on only three sides by creeks.

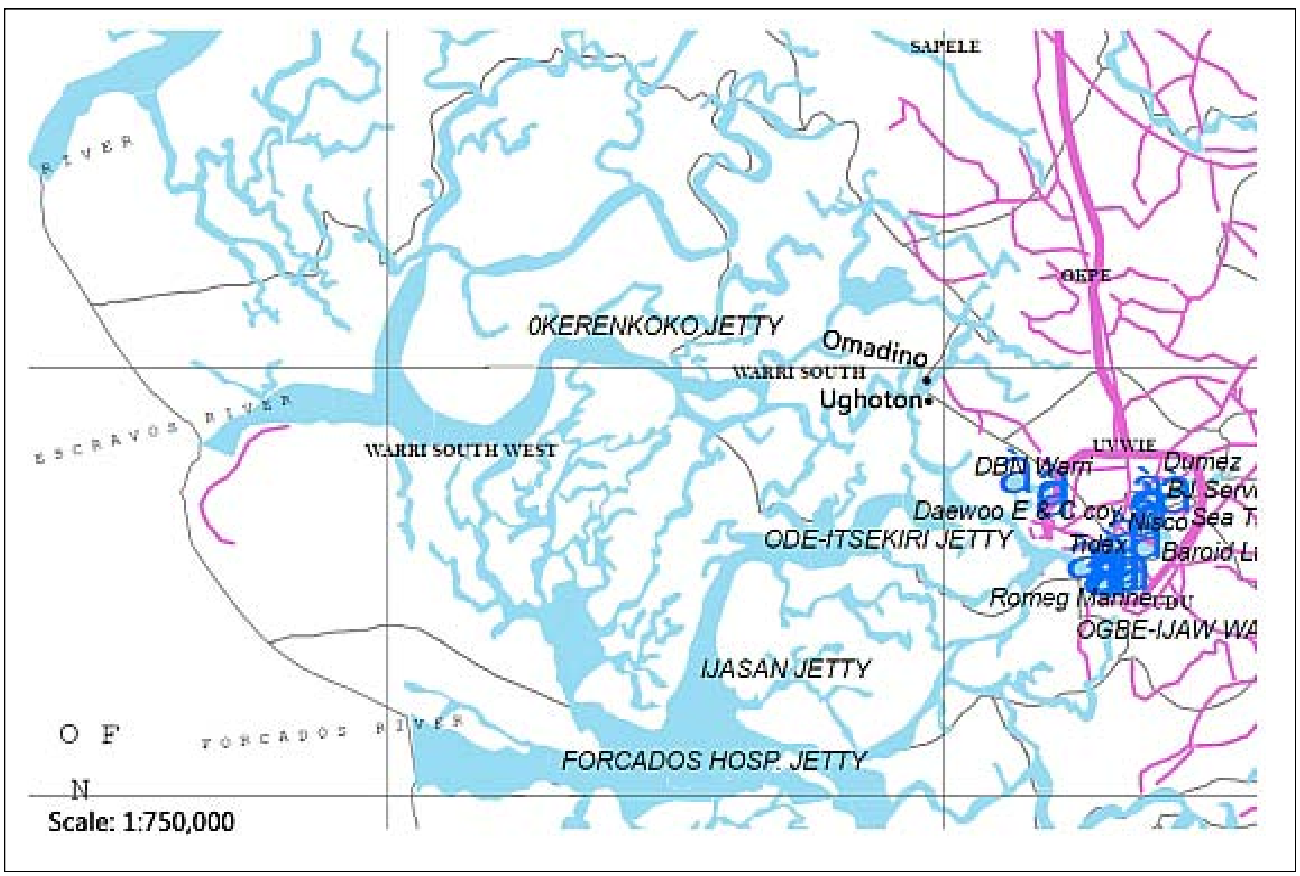

Figure 2. Drainage distribution in the mangrove swamps in the vicinity of Ughoton-Omadino.(After Delta State Economic Atlas, 2011)

Climatic conditions in the area typically tropical rain forest. Rainfall is high at an annual 30 -year average of about 3000 mm (NIMA, 2003). There is a wet and dry season: the dry season occurs between the months of November and March, while the wet season is from April to October.

GEOLOGY

The aerial distribution of geological formations in the Niger Delta region is shown in Figure 3. The basin fill of the Niger Delta Basin has been described by Short and Stauble (1967), Murat (1970), among others and consists of three formations, namely, from the oldest to the youngest, the Akata Formation, Agbada Formation both of Eocene to Recent and the Miocene to Recent Benin Formation. The Benin Formation underlies much of the Niger Delta basin. However, south of Asaba through Abraka and Sapele to the coast, it is masked by the younger Holocene deposits of the Sombreiro-Warri Deltaic Plain merges with the Mangrove Swamp and Freshwater Swamp wetlands to the west and south west.

The Freshwater Swamps are typically filled by a succession of thinly bedded silts and clays that are interbedded with sands (Allen, 1965; Amajor 1991, Akpoborie, 2011). A lithologic log of a recently drilled borehole at Ughoton, Figure 4, shows a succession of thin, fine-coarse sand and thin silty clay that is similar to the Freshwater Swamp deposits. The nomenclature of the physiographic regions of the delta, namely, the Sombreiro-Deltaic Plain, the Freshwater Swamps and the Mangrove Swamps retained in Figure 3 is a carryover from the 1964 edition of the Geological Map of Nigeria (GSN, 1964) wherein no formal geological names are assigned to the deposits. In discussing the Niger Delta however, there has been a tendency to erroneously refer to the deposits they contain as geological "formations" (NDDC, 2004).

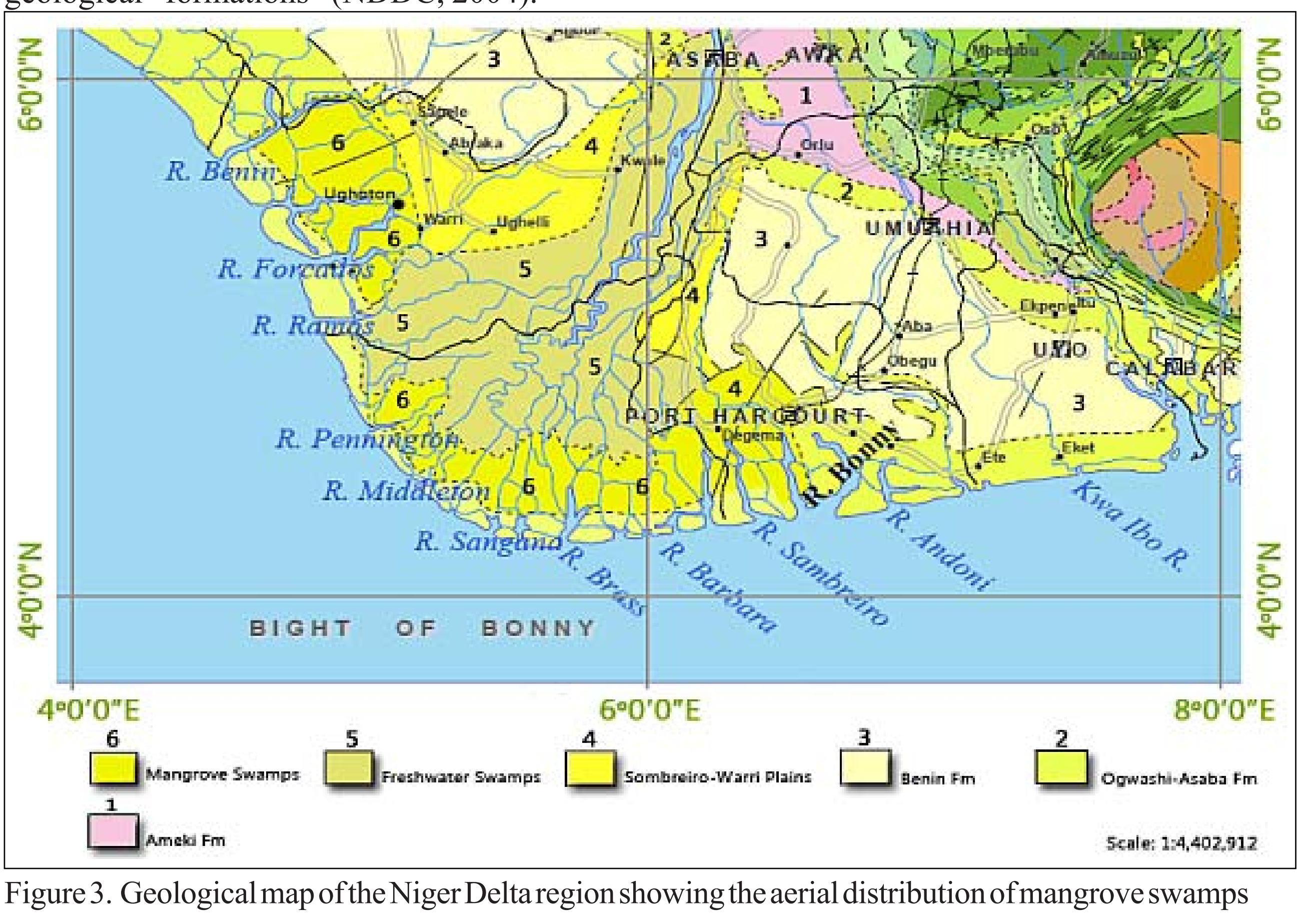

Figure 3. Geological map of the Niger Delta region showing the aerial distribution of mangrove swamps and the Benin Formation (Adapted from NGSA, 2004).

Although these deposits are thought to be recent expressions of the Benin Formation, and are merely the upper and shallow horizons of the Formation they possess distinct hydraulic and other engineering characteristics (Abam, 2007) that distinguish them from the Benin Formation outcrop proper. These characteristics are important for water supply as well as other engineering construction purposes.

METHODOLOGY

In order to understand further the nature of occurrence and distribution of the deposits in the Mangrove Swamps in the area, 10 vertical electrical soundings were undertaken with the ABEM SAS 1000 Terrameter using the Schlumberger configuration in which two outer current electrodes and two inner electrodes were arranged along a line symmetrically about their middle point. The current separation AB for this study was varied from 2 m to a maximum of 300 m is usually five or more times the potential electrode separation MN (Deppermann, 1954). In the Schlumberger configuration apparent resistivity is approximated by the following relationship (Keller and Frischknecht, 1979):

$$\rho_a = \pi R\left[\frac{a^2}{b} - \frac{b}{4}\right] \tag{1}$$

where a = half current electrode separation

b = potential electrode separation

R = measured ground resistance in ohm (Ω)

The data obtained were plotted on a log-log graph paper of apparent resistivity against half current electrode separation. A typical field curve for the area, VES 6 is shown in Figure 4. The electrode spacing at which inflection occurs on the graph provides an idea of the depth to the interface. A useful approximation is that the depth of investigation is equal to two thirds (2/3) of the maximum electrode separation (Vingoe, 1972).

The field curves were interpreted by partial curve matching using master curves and the corresponding auxiliary point charts (Orellana and Mooney, 1966). The layer resistivity and thickness values obtained from the partial curve matching were then subjected to an inversion using the winResist software (Vander Velpen, 2004) which reduced the interpretation error to acceptable levels (Barker, 1989).

With respect to the quality of water, 20 dug wells were selected for ground water sampling and depth to water level measurements. Samples were collected from all selected dug wells and screened for the major anions and cations as well as selected heavy metals. Replicate water samples were collected from the dug wells into sterilized polyethylene bottles. The set of samples designated for heavy metal analysis were immediately stabilized with acid. Electrical conductivity and Total Dissolved Solids were measured in situ using the HACH Conductivity/TDS meter. The pH was determined by means of a Schott Gerate model pH meter. Nitrate was determined with the HACH Spectrophotometer using the cadmium reduction method, while the sulphate content of all the samples was determined by the turbidimetric method. Major cations and anions Na^+, K^+, Ca^{2+}, Mg^{2+}, HCO_3^-, CO_3^-, Cl^-, NO_3^- and metals Pb^{2+}, Cd^{2+}, Cr^{2+} and Cu^{2+} were determined in the laboratory with the appropriate titrimetric, flame photometric and atomic absorption spectrometric methods (APHA,

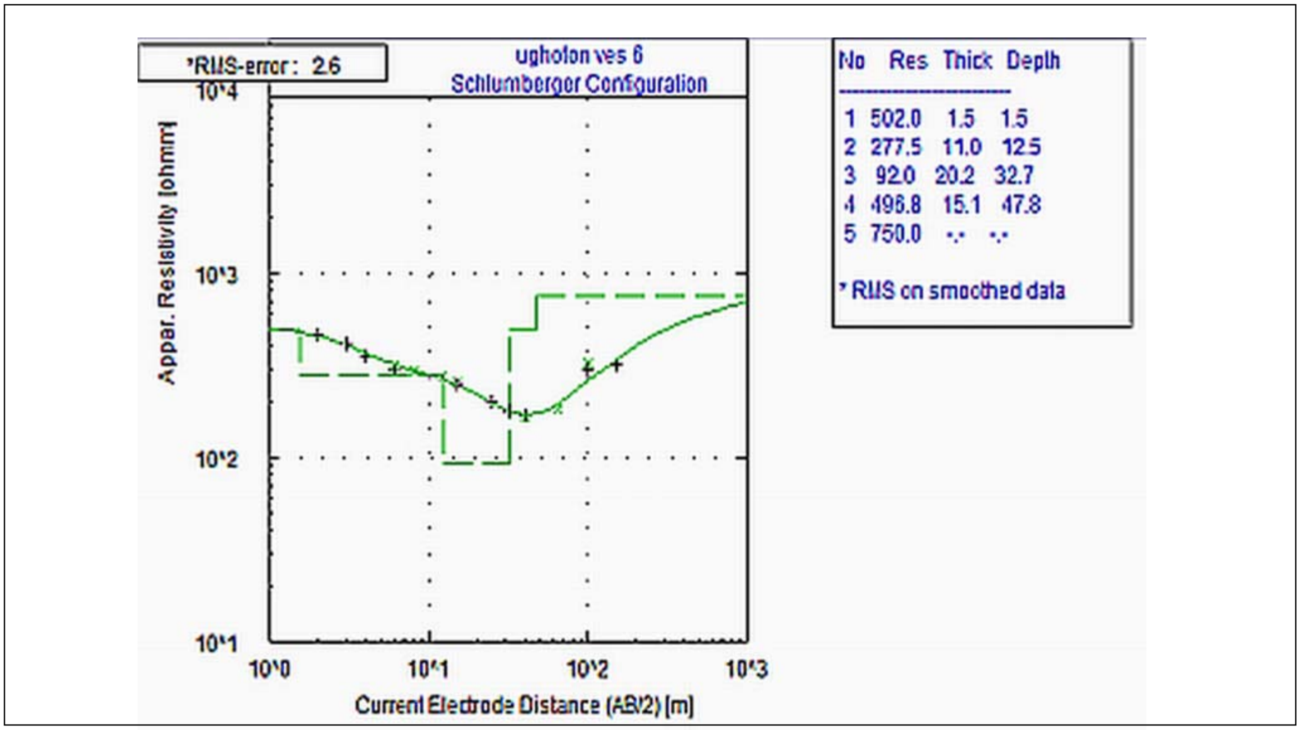

Figure 4. VES 6 curve from Ughoton.

1992).

Depth to water level in each of the dug wells were measured with an electronic water level indicator in two days on October 29-30, 2009 in the wet season. An Ertec model GPS instrument was used to determine wellhead coordinates. Because existing topographic maps of the entire area are devoid of contours, averaged elevation readings from three GPS instruments at each site were used with the sparsely distributed benchmarks established for oil exploration activities to approximate the elevation of each well location. Surfer 8 (Golden Software Inc., 2002) was employed in generating the water table map.

RESULTS AND DISCUSSION

Resistivity Survey

The interpreted sounding curves from the locations at Ughoton revealed four (4) geoelectric layers, Figure 5. The geoelectric layers include the following: topsoil, clay/silty sand and sand. The first layer has resistivity values ranging from 32.1-2600.1 ohm-m while its thickness ranges from 1-1.5 m. This represents the topsoil of the area. The second layer has resistivity values ranging from 31.2-2418.2 ohm-m and thickness of 3.8-13.1 m. The deduced lithologies include clay, silty clay, silty sand and sand. The third layer comprising of sand with resistivity values ranging from 323.1-1824.1 ohm-m and a thickness of 8.5-42.9 m correspond to a potential aquifer. The depth to the aquifer varies from 4.4 m (VES 7) to 32.7 m (VES 6). The fourth layer consists of sand with resistivity values ranging from 321.0-1626.0 ohm-m except at VES 4 where a clay overburden with resistivity value of 93 ohm-m was intercepted. The exact thickness of this layer could not be determined as the electrode current terminated within this layer.

The result of this investigation showed that the aquiferous in the study area is encountered at an average depth of 9.1 m and having an average thickness of 22.87 m. The results of the geophysical study are in agreement with the lithology described from a borehole recently drilled at Ughoton whose lithology is included in Figure 4 for comparison.

Groundwater Conditions

Depth to water level measurements and calculated heads are presented in Table 1 which represent wet season conditions. It is expected that water levels would drop significantly in the dry season as has been reported for the Okurekpo and Ndokwa areas by Akpoborie et al. (2000) and Akpoborie (2011).

Unconfined conditions are prevalent in the area because the results of the resistivity studies indicate that existing silty clay layers are thin as well as discontinuous. Furthermore, the oral evidence is that during manual construction of dug wells, the excavated material is mostly sandy and the wells are bottomed in the first layer of clay when and if such a layer is encountered during the dug well construction operation. The dug wells are usually no deeper than about 7-10 m. That is to say, the water table aquifer consists of sandy layers. Hydraulic conductivity of similar sandy layers in the Warri area are reported to range between 2.8 x 10^{-4} and 3.5 x 10^{-4} m/sec. (Akpoborie et al, 2000).

The data shown in Table 1 were used in sketching the groundwater contours using Surfer 8 (Golden Software, Inc., 2002), Figure 6. The contours indicate that a mound occurs in the elevated central portion of the semi- rectangular block that is demarcated by creeks and the Ughoton River. The water table gradient indicates that groundwater flow direction in the upper part of the Mangrove

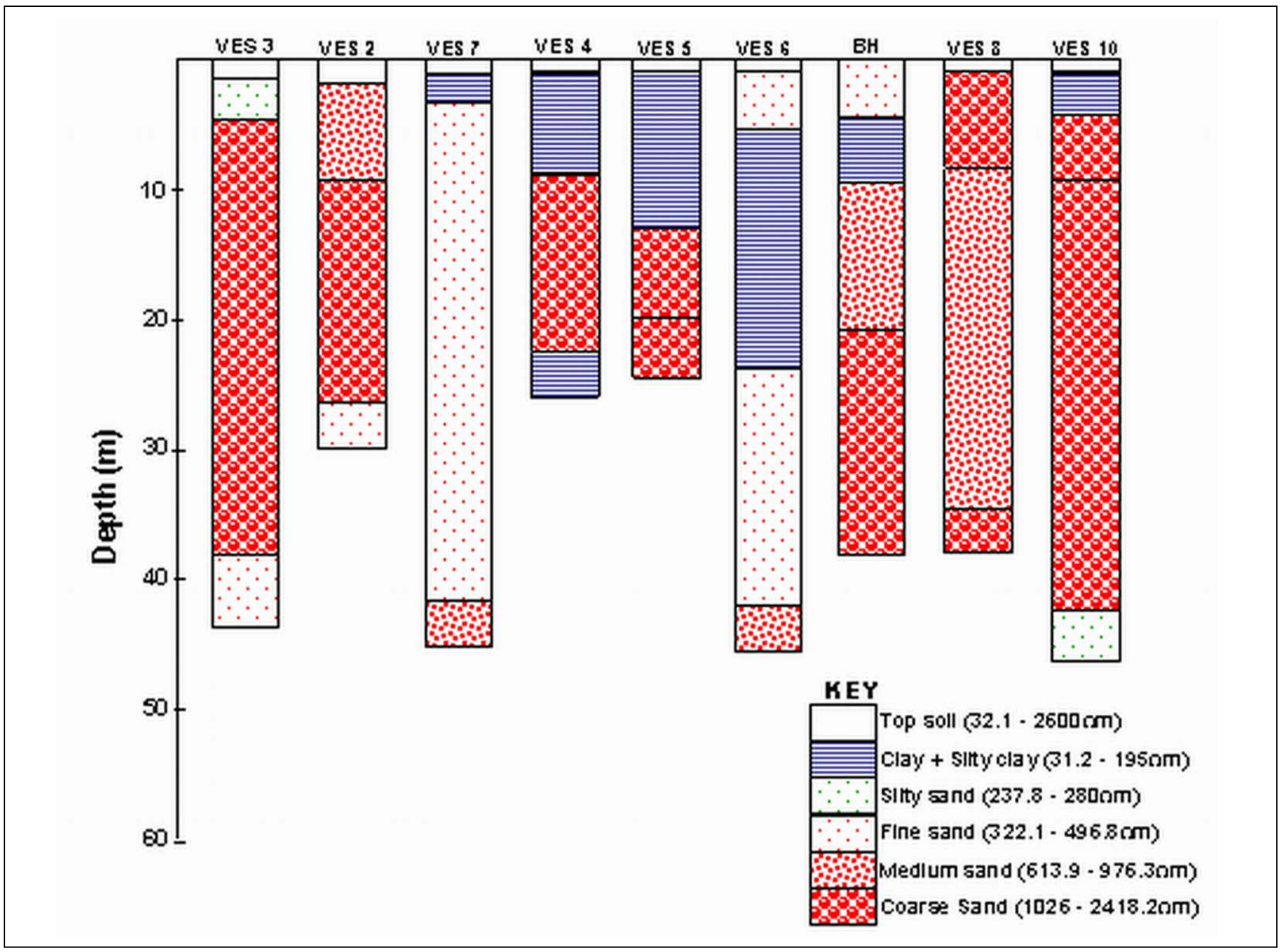

Figure 5. Geoelectric sections from selected VES locations at Ughoton and lithology of borehole (BH). VES locations are shown in Figure 6.

Table 1. Dug well, sample locations and associated calculated total head above m.s.l.

Loc.	Lat. (N)	Long. (E)	Calculated Head
River	5^0 37.302	5^0 37.127	
1	5^0 37.310	5^0 39.185	7.6
2	5^0 36.870	5^0 39.64	6.43
3	5^0 36.830	5^0 39.68	9.28
4	5^0 36.670	5^0 39.68	4.2
5	5^0 36.530	5^0 39.71	1.14
6	5^0 36.590	5^0 39.57	7.15
7	5^O 37.660	$5^0$39.001	6.17
8	5^O 37.698	$5^0$39.612	4.98
9	5^O 36.672	$5^0$39.768	-1.15
10	$5^0$36.669	$5^0$39.782	3.35
11	$5^0$36.658	$5^0$39.730	2.24
12	$5^0$37.308	$5^0$39.184	5.1
13	$5^0$36.588	$5^0$39.758	3.55
14	$5^0$36.584	$5^0$39.789	3.59

Swamps is north-northeast towards the dominant and perennial Ughoton River as well as westwards from the ground water mound. The effect of ground water extraction is evident at central Ughoton as well as at Omadino where the combined cone of influence of sustained groundwater extraction from the dug wells exerts distortions on the local gradient. Fresh groundwater recharges the Ughoton River and tide related brackish water that supports the mangroves is provided from the slow drainage of bank storage from the silty banks. The dark grey silt on which the mangroves thrive is deposited by silt laden tides that regularly inundate the banks and which could explain the restriction of mangroves to the banks.

The confinement of mangroves to the stream banks is thus a result of the daily influx of brackish water from the tidal regime and which brackish water is prevented from recharging groundwater because of the prevailing differential in water table head and stream water level.

The cone of depression resulting from ground water extraction at the Omadino community that is much smaller than Ughoton but is located directly on the bank of the River has already spread into the stream channel resulting in direct connection of ground water with the stream.

Furthermore, because the Ughoton River is connected to the numerous distributaries and creeks of the dominant Escravos River to the west as well to the Forcados River also to the west and south, Figure 2, and indeed all of the distributaries of the delta (Abam, 1999) it receives recharge from all these combined sources, such that it is up to 150 m wide in the vicinity of Ughoton–Omadino that is less than 5 km from it source.

An insight into the quantum of groundwater recharge is provided by Akpoborie (2011) who has shown that groundwater contributes up to 85 % to the total flow of the Adofi River that like the Ughoton flow on the Quaternary deposits in the western Niger Delta physiographic terrain. It is also conceivable that some of the groundwater recharge would be from intermediate or regional groundwater flow systems that occur deeper in the underlying Benin Formation (Tooth, 1967). This is consistent with the general ground water recharge model for rivers and lakes explained by Winter

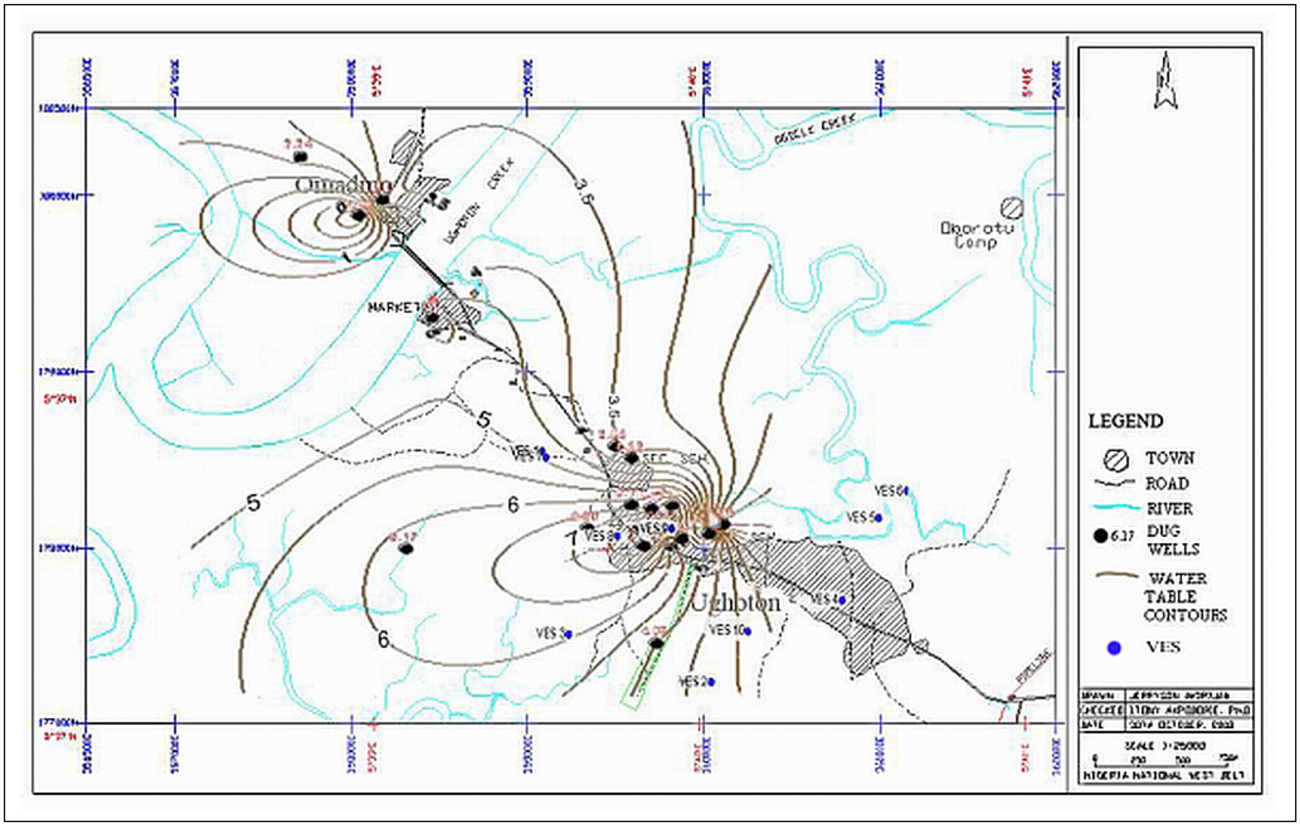

Figure 6. Elevation of water table in metres above sea level. VES locations also indicated.

(1999) and for the Niger Delta region by Ophori (2007, Fig.8, page 186) and has important implications for the entire Mangrove Swamp terrain as well as the entire Niger Delta wetland groundwater system. Thus as shown by Akpoborie (2011) for the Ndokwa wetlands and Amajor (1991) for the eastern Niger Delta, the main recharge area for the Mangrove Swamps is probably the extensive Benin Formation outcrop area to the north, Figure 3, from which mound the groundwater front moves south and southwestwards to recharge the entire Niger Delta wetlands.

Water Quality

Physical and chemical characteristics of Ughoton River water are shown in Table 2 while those of ground water in the area are provided in Table 3. Ground water is generally soft and the order of abundance of the major cations is Na>Ca>Mg>K. For anions, it is $Cl>HCO_3>SO_4$. The dominance of sodium ions is probably due to natural softening caused by the replacement of Ca^{2+} ions by the sodium ion. This is in agreement with the observation by Akpoborie (2011) that in the Benin Formation outcrop and recharge area at Ndokwa to the east where groundwater is likely more representative of pristine conditions and cation occurrence is in the order Ca>Mg>K>Na.

The chloride content of all water is low contrary to the general assumption that groundwater in the Mangrove Swamps would be brackish due to the presence of mangroves in contrast to groundwater in the Freshwater Swamps. However, Akpoborie (2011) has reported mean TDS and chloride content from the Freshwater Swamp groundwater at Ndokwa to be 109 mg/l and 21 mg/l respectively; values that compare favorably with those shown in Table 2. Furthermore, river water shows a pH of 8.7 and ground water, a range of 5.8-8.3 with a mean of 7.1 thus showing none of the acidity that is associated with gas flaring that has been reported in several studies in the region (for example, Olobaniyi and Efe, 2007; Otu- Efeotor and Ogidi, 1983).

Table 2. Water quality analytical results from Ughoton River. Units in mg/l except pH.

pH	TDS	Ca	Mg	Na	K	SO_4	HCO_3	NO_3	Cl	Cd	Cr	Pb
8.7	342	9.3	5.7	39	34	0.06	3.4	2.5	35	0.5	0.06	0.05

Table 3. Water quality from dug wells. Sample location numbers and coordinates are same as in Table 1.

Parameters	Sample Location Numbers														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Mean	Std. Dev.
pH	7.6	7.4	8.1	7.3	7.4	7.3	6.1	5.8	8.1	8.3	5.8	6.7	7.7	6.4	7.14	0.82
TDS (mg/l)	64	56	63	61	59	60	17	64	285	494	160	61.9	304	167	136.9	130.7
EC (µs/cm)	125	107	120	115	110	118	38	128	571	989	319	124.1	636	335	273.9	265.39
Ca^{++} (mg/l)	2.30	3.40	3.10	3.30	3.50	3.70	4.85	1631	12.5	22.1	1.78	0.87	17.21	12.3	7.65	6.69
Mg^{++} (mg/l)	1.90	2.60	1.70	1.60	2.10	1.80	3.31	11.51	9.39	18.9	1.03	0.76	15.65	7.8	5.71	5.74
Na^{+} (mg/l)	5.0	3.1	7.0	6.1	6.3	6.8	2.79	9.63	16.7	21.67	7.82	1.29	17.05	4.6	8.32	5.80
K^{+} (mg/l)	5.0	2.1	6.0	5.8	5.7	5.6	1.2	5.32	9.01	13.98	1.22	0.98	12	1.95	5.41	3.86
SO_4^{++}(mg/l)	0.00	0.00	0.01	0.01	0.01	0.00	1.65	2.98	2.35	4.00	2.23	1.50	2.45	1.20	1.31	1.29
$HCO_3^{=}$ (mg/l)	1.1	1.0	1.4	1.3	1.6	1.4	7.32	3.12	9.5	19.31	6.87	2.44	13.67	7.9	5.56	5.38
NO_3- (mg/l)	0.60	0.30	0.70	0.80	0.60	0.90	0.75	0.50	1.25	2.5	1	0.5	1.75	0.75	0.92	0.6
Cl^{-} (mg/l)	22.0	20.0	23.0	24.0	28.0	26.0	6.50	14.23	34.22	54.50	21.66	12.6	2.10	24.6	25.24	11.71
Fe^{+} (mg/l)	0.00	0.00	0.01	0.01	0.00	0.00	0.44	0.77	0.87	1.42	0.06	0.02	0.04	0.02	0.26	0.46
Cd^{+} (mg/l)	0.01	0.01	0.03	0.02	0.03	0.01	0.00	0.001	0.02	0.07	0.01	0.00	0.04	0.02	0.02	0.02
Cr^{++} (mg/l)	0.00	0.00	0.00	0.00	0.00	0.00	.001	.001	0.02	0.04	0.00	0.00	.03	0.02	0.008	0.013
Pb^{+} (mg/l)	0.00	0.00	0.01	0.00	0.00	0.00	.001	.001	0.04	0.09	0.02	0.01	.06	0.03	0.019	0.03

Ground water from dug wells is generally used for domestic purposes in the rural areas of the western delta without prior treatment and there are concerns about health implications (Emeshili, 2008.) The levels of occurrence in groundwater of lead, cadmium and chromium when compared with the Maximum Acceptable Limits (MAL's) set by World Health Organization (WHO, 2006) which are the same as those of the Nigerian Standards Organization (SON, 2007) indicate that there is indeed cause for concern at Ughoto –Omadino. Mean chromium ion levels at 0.02 mg/l are just below the MAL of 0.05 mg/l and the highest reported value at well location 13 is 0.04 mg/l With respect to Cadmium, the MCL is 0.003 mg/l, the mean value of occurrence is 0.02 mg/l and 78 per cent of all samples show cadmium at one order of magnitude higher than the MAL. Lead levels also exceed the MAL of 0.01 mg/l at fifty percent of all locations sampled. Lead, chromium and cadmium levers in surface water all exceed the MALs by several orders of magnitude.

Elevated lead, chromium and cadmium in groundwater have been observed in the Sombreiro-Warri Deltaic Plain deposits by Akpoborie et al. (2000) and Aweto and Akpoborie (2011). Akpoborie (2011) confirms same and noted a reduction in these heavy metal levels to well below MALs in dug well water in the Fresh Water Swamps as well as below detectable limits in the Benin Formation outcrop. Similar trends of occurrence of this suite of heavy metals have been reported in shallow groundwater from the Saghara Beach area of the Forcados estuary in separate studies by the Shell Petroleum Development Company (SPDC, 1998) and the Niger Delta Development Commission (NDDC, 2005) from the Iyara area of Warri town. However, at Ogulagha on the south bank of the Forcados estuary groundwater from a 300 m deep borehole yields water that is devoid of these heavy metals (Richdrill, 2009). It thus appears that these heavy metals seem to be confined to the shallow groundwater that occurs in the Quaternary (Recent) Sombreiro –Warri Deltaic Plain deposits and Mangrove Swamps that overlie the Benin Formation in the western delta. Unfortunately, in the absence of supplies from public facilities, it is these shallow and more vulnerable aquifers that easily and cheaply exploited.

Lead in drinking water poses significant threats to human health: it damages the nervous system and which damage commonly results in behavior and learning problems (such as hyperactivity), memory and concentration problems, high blood pressure, hearing problems, headaches, slowed growth, reproductive problems in men and women, digestive problems, muscle and joint pain. Infants, children, pregnant women, and fetuses are thought to be more vulnerable to lead exposure than others because lead is more easily absorbed into the sensitive tissue of actively growing bodies (WHO, 2011; USEPA, 2011, Bellinger 2004; Canfield et al. 2003; Mendelsohn et al. 1998; Tellez-Rojo et al. 2006). Cadmium also exerts toxic effects on the kidney, the skeletal and the respiratory systems, and is classified as a human carcinogen, while chromium is also thought to be a carcinogen. The occurrence of this suite of heavy metals in dug well water which is the main domestic water supply source in the Ughoton- Omadino communities is therefore worrisome especially as they may not be removed by boiling. What is more troubling is the fact that when groundwater is exploited for public water supplies in the delta, the heavy metals are not usually included in the suite of parameters that are screened before the supply source is certified fit for distribution (Akpoborie et al, 2009). Certification is usually based on the occurrence of the major ion occurrence and nitrates on the basis of which as shown by the results in Table 2, groundwater in this area would be erroneously certified as fit for domestic usage. Water quality monitoring systems do not exist in the Niger Delta.

Furthermore, Ughoton-Omadino are both agrarian communities whose livelihoods and economy are based on the existence of the river. Farm incomes could be improved by irrigation and on the basis of the Sodium Absorption Ratio (Davis and DeWiest, 1966) of 0.784 computed from the data in Table 2, the water is good for irrigation purposes. Unfortunately, Eriyamvemu et al. (2005) have established the existence of elevated levels of lead and cadmium in vegetables grown in Niger Delta soils signifying the existence of biomagnification pathways. Fish, a major an important staple as well as economic commodity are also at risk because of the elevated levels of occurrence of the heavy metals in Ughoton River.

CONCLUSIONS

The groundwater conditions at the Ughoton- Omadino area which are a part of and may be considered representative of the Mangrove Swamps, an extensive physiographic and ecological terrain of the Niger Delta region have been described in some detail for the first time. It is shown that the swamps are demarcated into somewhat quasi-rectangular blocks by ubiquitous tidal creeks and streams. Within each block, elevation increases gradually away from the demarcating creeks towards the centre and that the land in this central area is drier and supports typical tropical forest vegetation that is different from the mangroves that line stream/ creek banks. The streams are interconnected with each other and to the major estuaries in the western delta, in this case the Escravos and the Forcados estuaries from where the tides and thus saline sea water are propagated inland. Tidal water decreases in salinity landwards and prevented from replenishing ground water, at least in the

Ughoton Omadino area, by existing groundwater gradients and any salinity is thus limited to the immediate vicinity of stream banks in the form of quickflow. The daily influx of brackish water from the tidal regime supports a fragile ecosystem that favors the development of mangroves.

Away from the banks, ground water is fresh and constantly recharged directly by rainfall as well as by local and intermediate flow systems. However, shallow groundwater which is the main source of domestic water supplies contains elevated levels of lead, chromium and cadmium that make it unsafe for domestic usage. It also appears that the presence of this suite of heavy metals may be confined to the shallow groundwater that occurs in the thin Quaternary deposits of the Mangrove Swamp terrain and the Sombreiro –Warri Deltaic Plain and are absent from the deeper Benin Formation. An important implication of this conclusion is that water supply wells should be constructed deeper into the Benin Formation in these areas and that attention be given to detailed borehole design and completion to ensure that shallow groundwater is prevented from mixing with deeper groundwater. A regime of water quality monitoring to monitor the behavior of these carcinogens is also implied. Finally, while stream water in the natural state is prevented from mixing with ground water due to existing gradients, manual groundwater withdrawals even from dug wells does have a profound effect on the existing gradient. High yield water wells when fitted with mechanized pumps could affect the gradients to the extent of reversing the gradient and causing water to be withdrawn from the stream. This will have the effect of not only increasing salinity of groundwater, the heavy metal concentrations will also be increased.

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