# Determination of Ground Water Flow Direction in Ndokwa Land Area of Delta State Nigeria, using Combined Drilled Hole and Global Positioning System.

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## ABSTRACT

The Global Positioning System (GPS) was used to measure the longitudes, latitudes, and elevations above mean sea level at 36 locations evenly spread within Ndokwa Land. The water elevation contour map of Ndokwa Land revealed that the groundwater flow direction is toward the south and southwestern part of the region.

Based on the flow pattern of the aquifer system in Ndokwa Land, dumpsites should be sited in the south and southwestern parts of the area and not in the north, west, and eastern regions in order to minimize groundwater contamination.

The research not only paved the way for a clear picture of the flow system in Ndokwa Land and created awareness on the possible areas dumpsites could be sited in order to minimize groundwater contamination but also recommended that boreholes for potable water supply should be sited in the north, west, and eastern regions and not within the south and southwestern parts of Ndokwa Land.

(Keywords: Ndokwa Land, groundwater, flow direction, elevation, water table, global position system, GPS, dumpsite location)

## INTRODUCTION

Water is of fundamental importance to plants and animals, particularly humans. It is therefore very vital in maintaining life processes and growth (Ogbe, 2003). Potable (drinking) water is not commonly found and its provision limits the establishment and maintenance of villages and towns to places where a reliable potable water supply exists (Shankar, 1994 and Huisman, 1966).

Most local groundwater supplies in Ndokwa Land comes from an unconfined aquifer made up of loose soil materials such as sands, gravels, and floodplain deposits left by stream and rivers (Oseji et al. 2005; Oseji et al. 2006; and Okolie et al. 2005).

The speed of groundwater movement is measured in feet per year; this is why pollutants that enter groundwater require many years before it purifies itself or is carried to a monitored well. The size of the spaces in the soil or rock and how well the spaces are connected determine the speed at which groundwater flows.

The depth to the water table can be determined by digging a hole progressively deeper into the ground. The depth at which groundwater begins to seep into the hole indicates that the surrounding material is saturated with water and this marks the height of the local water table where there is no surface water (Buddemeier and Schloss, 2000).

The water table varies in depth according to local topography and prevailing climate. The depth is generally established by a long term balance between recharge and seasonal climatic fluctuations. The water table is not flat as its name implies. It is the top of the water surface in the saturated part of an aquifer. It has peaks and valleys that echo the shape of the land above it. The water table may be only a foot below the ground surface or it may be hundreds of feet down. It may also be deep or shallow and may rise or fall depending on many factors. Heavy rains or melting snow pack may cause the water table to rise, or an extended period of dry weather may cause the water table to fall.

Groundwater usually flows toward, and eventually drains into, stream, rivers, lakes, creeks, and boreholes. The flow of groundwater in aquifer does not always mirror the flow of water on the surface. It is therefore necessary to know the direction of groundwater flow since the awareness helps us to map out the land area that recharges the public water supply, wells, streams, rivers, lakes, or creeks and thereby supports steps to ensure that land use activities in the recharge area will not pose a threat to the quality of the groundwater. With this information, one could also predict how contaminants move through the local groundwater system, since contaminants generally move in the direction of groundwater flow.

Furthermore, it is also important to know if the groundwater system is a recharge or discharge system (gaining type or a losing type). The quality of water is affected by the quality of groundwater entering the system of water supply in the borehole. This is so because the water tables elevation is approximately the same as the gaining borehole surface elevation; both elevations may be used to construct water table maps (contour) and to predict groundwater flow direction.

The losing system is one that loses water to the adjacent aquifer. This is because the water table has dropped below the depth of the borehole. If the water supplied from the aquifer is minimal, the borehole may dry up and this could lead to a dry well.

Groundwater flow is very slow compared to surface water movement. A rough average number often used for natural flow in the high plain aquifer is a foot per day. This is thousands of times slower than river flow (typically measured in feet per second) (Buddemeier and Schloss, 2000) and means that a 'parcel' of groundwater may take over a decade to move a mile or about a century to cross a township. Groundwater, like surface water, flows 'downhill' in the direction determined by the slope of the water table. Groundwater flow is therefore, from high hydraulic head [high water level] to low hydraulic head [low water level].

## STUDY AREA – NDOKWA LAND

Ndokwa Land consists of three Local Government Areas: (Ndokwa West, Ndokwa East, and Ukwuani). It is in the Southeastern region of Delta State situated in the South southern part of Nigeria and lies between latitudes $5^0$ $48^1$ N and $5^0$ $60^1$ N and longitudes $6^0$ $08^1$ E and $6^0$ $32^1$ E. It has common boundaries in the North with Ika South and Aniocha South Local Government Areas. Isoko South and Isoko North bound it in the south while it also has a common boundary with Ughelli North and Ethiope East Local Government Areas and Edo State as well as River Niger in the west and east, respectively. The important rivers in the region are Niger, Ethiope, Adofi, and Umu while the Ase creek is the major creek. The base map of Ndokwa Land showing GPS, drilled hole and hand-dug well locations are shown in Figure 1.

## FIELD PROCEDURES

Three major stages of field procedures were used in this research; six holes evenly distributed and spaced 7.5 km apart were drilled within Ndokwa Land. The depth at which water begins to seep into the hole indicates that the surrounding material is saturated with water and this mark the depth to water level in the well.

With the aid of a meter rule and tape, the depths to the water levels in the hand-dug wells within Ndokwa land were measured and recorded. (Figures 2 and 3, respectively).

The Global Positioning System (GPS) of type 310 was used to measure the longitude, latitude, and the surface elevations with respect to the mean sea level at points within Ndokwa Land. The mean sea level is the lowest surface within the earth. All elevations are taken with respect to the mean sea level.

The surface elevations at different points vary due to topographic variations, the true water levels were obtained by subtracting the measured depths to the water level in the hand-dug wells from the surface elevation to get uniform water level otherwise known as the elevation of the water level (Buddemeier and Schloss 2000) and hence reduce topographic variations

This uniform water level coincides with the static water level in the case of an unconfined aquifer while it is the piezometric surface if the aquifer is confined (Buddermeier and Schloss, 2000).

Let $D_{wl}$ = the depth from the surface of the earth to the water level in the hand-dug wells (Direct Bore-hole logging)

$E$ = the surface elevation with respect to the mean sea level

$S_{wl}$ = the true or uniform water level otherwise known as the static water level in the case of an unconfined aquifer.

$$S_{wl} = E - D_{wl}$$

The values of the static water levels were contoured on the map of Ndokwa land. These lines represent the water table contours. According to Buddermeier and Schloss (2000), groundwater flows from the highest values of contour lines to the lowest values in a direction perpendicular to the contour lines.

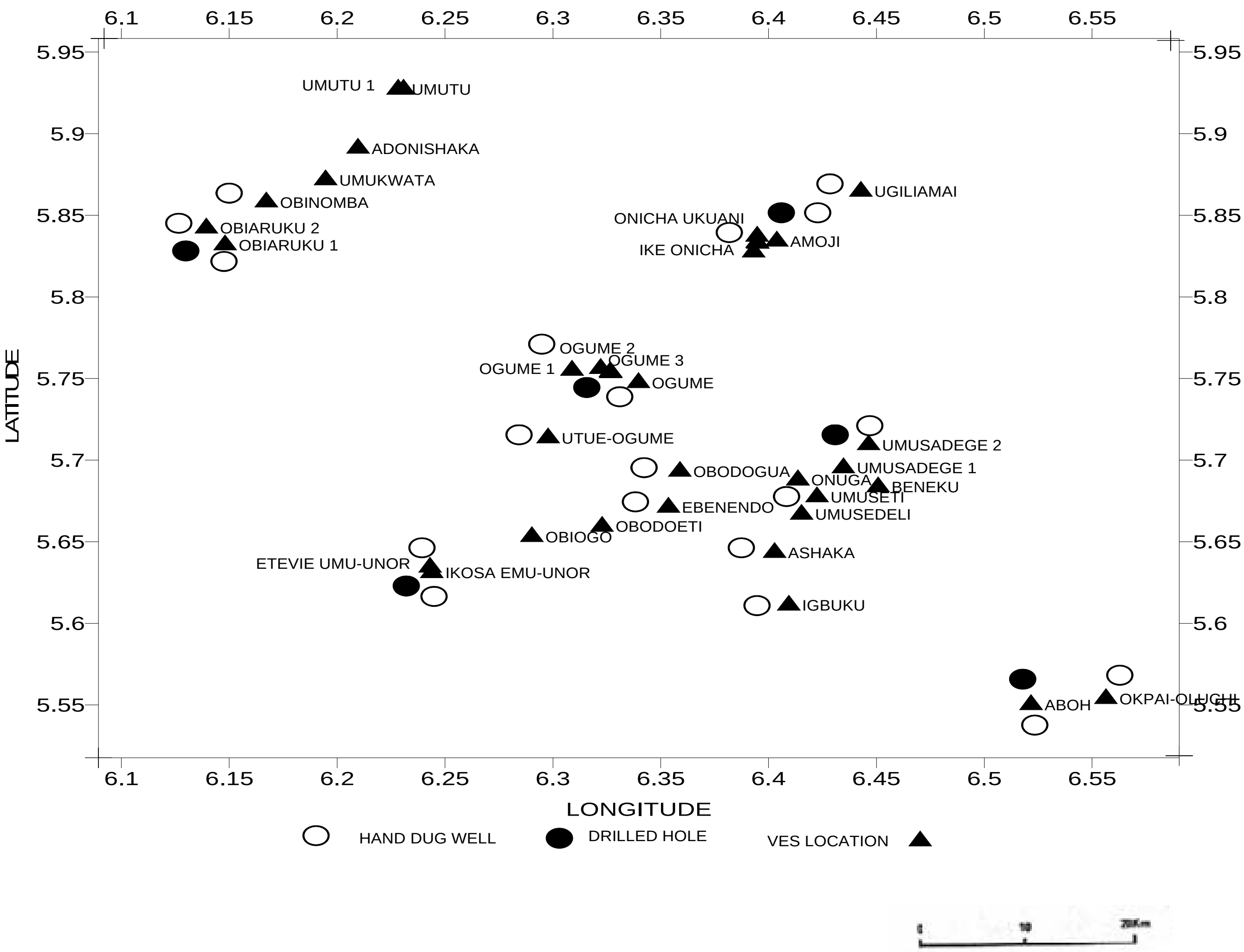


**Figure 1:** Base Map of Ndokwa Land Showing GPS, Drilled Holes, and Hand-Dug Well Locations.

## GROUNDWATER CONTOUR MAP OF NDOKWA LAND

The values of the static water levels shown in Tables 1 and 2, respectively, were contoured on the map of Ndokwa Land by joining equal values of elevation water levels and making sure that none of the lines overlapped or cut across each other.

This was improved upon by using computer Surfer 8 computer package to the elevation map of the water level in the study area (Figure 2).

The contour map of Ndokwa Land using colors to represent the elevation of water is shown in Figure 3, while the wire frame of Ndokwa Land in three dimensions is also shown in Figure 4.

**Table 1:** Field Data Acquired for the Static Water Levels and Elevations within the Study Area (Ndokwa Land).

| G. P. S LOCATIONS | | LATITUDE | LONGITUDE | ELEVATION "E" "m" | DEPTH TO WATER LEVEL IN THE HAND-DUG WELL $D_{HDW}$ "m" | STATIC WATER LEVEL $S_{WL} = E - D_{HDW}$ "m" |
|---|---|---|---|---|---|---|
| 1 | MAJOR ROAD IN ABOH | $5^{0}$ $33^{1}$ $07^{11}$N | $6^{0}$ $31^{1}$ $18^{11}$E | 12.80 | 3.66 | 9.14 |
| 2 | MAJOR ROAD IN OKPAI-OLUCHI | $5^{0}$ $41^{1}$ $14^{11}$N | $6^{0}$ $33^{1}$ $23^{11}$E | 17.09 | 1.56 | 15.53 |
| 3 | IGBUKU | $5^{0}$ $36^{1}$ $40^{11}$N | $6^{0}$ $24^{1}$ $34^{11}$E | 20.73 | 9.14 | 11.59 |
| 4 | ASHAKA | $5^{0}$ $38^{1}$ $37^{11}$N | $6^{0}$ $24^{1}$ $10^{11}$E | 10.67 | 8.23 | 2.44 |
| 5 | BENEKU | $5^{0}$ $41^{1}$ $01^{11}$N | $6^{0}$ $27^{1}$ $03^{11}$E | 10.57 | 7.62 | 2.95 |
| 6 | UMUSEDELI | $5^{0}$ $40^{1}$ $05^{11}$N | $6^{0}$ $24^{1}$ $55^{11}$E | 12.09 | 3.20 | 8.89 |
| 7 | UMUSETI | $5^{0}$ $40^{1}$ $39^{11}$N | $6^{0}$ $25^{1}$ $21^{11}$E | 5.19 | 3.66 | 1.53 |
| 8 | OBIOGWA UMUSAM | $5^{0}$ $41^{1}$ $16^{11}$N | $6^{0}$ $24^{1}$ $49^{11}$E | 18.59 | 4.57 | 14.02 |
| 9 | 2ND OWESSEI ST.UMUSADEGE | $5^{0}$ $41^{1}$ $43^{11}$N | $6^{0}$ $26^{1}$ $05^{11}$E | 6.32 | 3.66 | 3.66 |
| 10 | OSEJI ESTATE UMUSADEGE | $5^{0}$ $42^{1}$ $34^{11}$N | $6^{0}$ $26^{1}$ $47^{11}$E | 7.62 | 3.66 | 3.96 |
| 11 | UGILIAMAI | $5^{0}$ $51^{1}$ $53^{11}$N | $6^{0}$ $26^{1}$ $34^{11}$E | 14.33 | 5.49 | 8.84 |
| 12 | ONUGA | $5^{0}$ $41^{1}$ $16^{11}$N | $6^{0}$ $24^{1}$ $49^{11}$E | 11.28 | 5.49 | 5.79 |
| 13 | AMOJI | $5^{0}$ $50^{1}$ $03^{11}$N | $6^{0}$ $24^{1}$ $14^{11}$E | 29.88 | 4.57 | 25.31 |
| 14 | ADOH PRI. SCH. EWESHI/IKE-ONICHA | $5^{0}$ $50^{1}$ $14^{11}$N | $6^{0}$ $23^{1}$ $41^{11}$E | 17.37 | 3.66 | 13.71 |
| 15 | OKPALA-UKU ONICHA-UKWUANI | $5^{0}$ $50^{1}$ $00^{11}$N | $6^{0}$ $23^{1}$ $41^{11}$E | 16.46 | 3.66 | 12.80 |

**Table 2:** Field Data Acquired for the Static Water Levels and Elevations within the Study Area (Ndokwa land).

| S/N | G.P.S LOCATIONS | LATITUDE | LONGITUDE | ELEVATION "E" "m" | DEPTH TO WATER LEVEL IN THE HAND-DUG WELL $D_{HDW}$ "m" | STATIC WATER LEVEL $S_{WL} = E - D_{HDW}$ "m" |
|---|---|---|---|---|---|---|
| 16 | OSEJI COMPD, IKE-ONICHA | $5^0$ $49^1$ $58^{11}$N | $6^0$ $23^1$ $42^{11}$E | 10.36 | 3.66 | 6.70 |
| 17 | OGUME ROAD IKE-ONICHA | $5^0$ $49^1$ $39^{11}$N | $6^0$ $23^1$ $35^{11}$E | 15.55 | 3.66 | 11.89 |
| 18 | OBIOGWA OGBE-OGUME | $5^0$ $45^1$ $13^{11}$N | $6^0$ $19^1$ $37^{11}$E | 13.23 | 6.10 | 7.13 |
| 19 | UTUE-OGUME | $5^0$ $42^1$ $49^{11}$N | $6^0$ $17^1$ $52^{11}$E | 13.11 | 6.10 | 7.01 |
| 20 | OBODOUGWA OGUME | $5^0$ $41^1$ $35^{11}$N | $6^0$ $21^1$ $32^{11}$E | 14.63 | 5.49 | 9.14 |
| 21 | EBENDO | $5^0$ $40^1$ $16^{11}$N | $6^0$ $21^1$ $13^{11}$E | 12.50 | 5.79 | 6.71 |
| 22 | OBODOETI | $5^0$ $39^1$ $34^{11}$N | $6^0$ $19^1$ $22^{11}$E | 7.62 | 4.58 | 3.04 |
| 23 | OBIOGO | $5^0$ $39^1$ $11^{11}$N | $6^0$ $17^1$ $25^{11}$E | 13.41 | 5.49 | 7.92 |
| 24 | ETEVIE, EMU-UNO | $5^0$ $38^1$ $04^{11}$N | $6^0$ $14^1$ $35^{11}$E | 18.90 | 4.58 | 14.32 |
| 25 | IKOSA, EMU-UNO | $5^0$ $37^1$ $52^{11}$N | $6^0$ $14^1$ $38^{11}$E | 5.48 | 3.05 | 2.43 |
| 26 | WIRE ROAD OBIARUKU | $5^0$ $49^1$ $55^{11}$N | $6^0$ $08^1$ $53^{11}$E | 17.61 | 5.20 | 12.41 |
| 27 | GHANA QUARTERS, | $5^0$ $50^1$ $32^{11}$N | $6^0$ $08^1$ $22^{11}$E | 16.87 | 4.25 | 12.62 |
| 28 | OBINOMBA | $5^0$ $51^1$ $29^{11}$N | $6^0$ $10^1$ $02^{11}$E | 24.72 | 12.36 | 12.36 |
| 29 | UMUKWATA | $5^0$ $52^1$ $18^{11}$N | $6^0$ $11^1$ $41^{11}$E | 14.33 | 5.49 | 8.84 |
| 30 | ADONISHAKA, EBEDEI | $5^0$ $53^1$ $28^{11}$N | $6^0$ $12^1$ $35^{11}$E | 21.62 | 9.00 | 12.62 |
| 31 | UMUTU MIXED SEC. SCHOOL | $5^0$ $55^1$ $44^{11}$N | $6^0$ $13^1$ $42^{11}$E | 21.82 | 9.00 | 12.82 |
| 32 | MICHELIN ROAD UMUTU | $5^0$ $55^1$ $38^{11}$N | $6^0$ $13^1$ $51^{11}$E | 19.98 | 7.62 | 12.36 |
| 33 | OGBEOLE OGUME | $5^0$ $44^1$ $51^{11}$ N | $6^0$ $20^1$ $23^{11}$E | 10.06 | 3.66 | 6.40 |
| 34 | AMAI/OGUME ROAD, OGUME | $5^0$ $45^1$ $18^{11}$ N | $6^0$ $18^1$ $32^{11}$E | 12.74 | 5.49 | 7.25 |
| 35 | OGBE-ODOLU, OGBE OGUME | $5^0$ $45^1$ $15^{11}$N | $6^0$ $19^1$ $36^{11}$E | 14.94 | 4.58 | 10.36 |
| 36 | OGUME GRAM. SCHOOL | $5^0$ $45^1$ $22^{11}$N | $6^0$ $19^1$ $20^{11}$E | 12.94 | 3.49 | 9.45 |

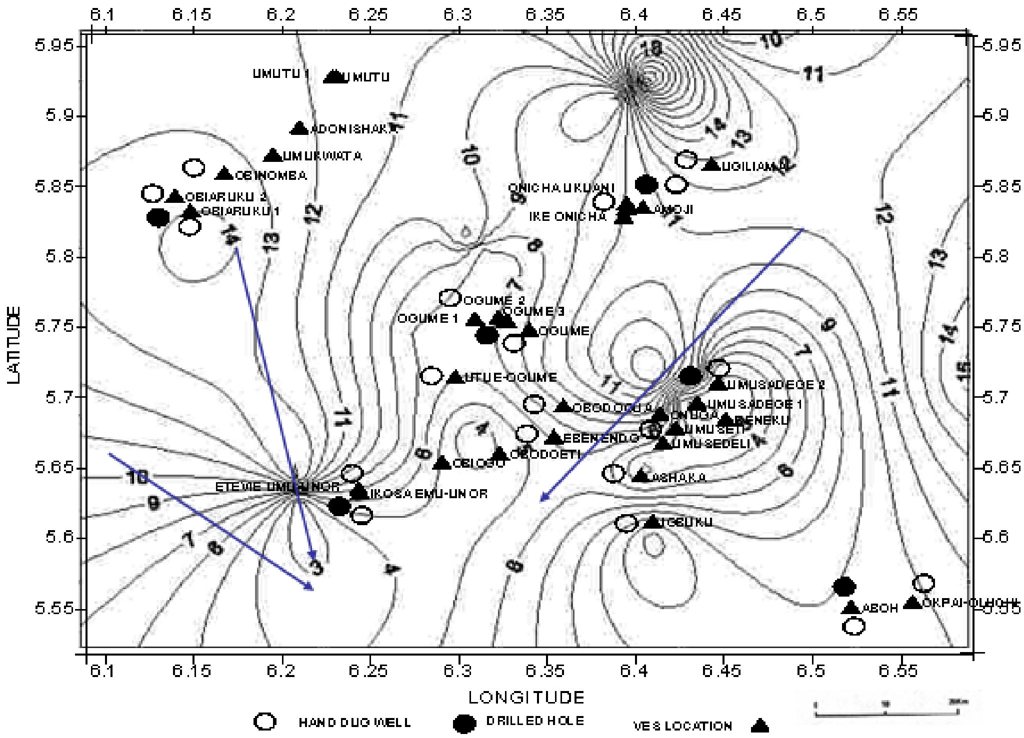


**Figure 2:** Contour Map of Ndokwa Land Showing Groundwater Flow Direction in Two Dimensions using Suffer 8 Program.

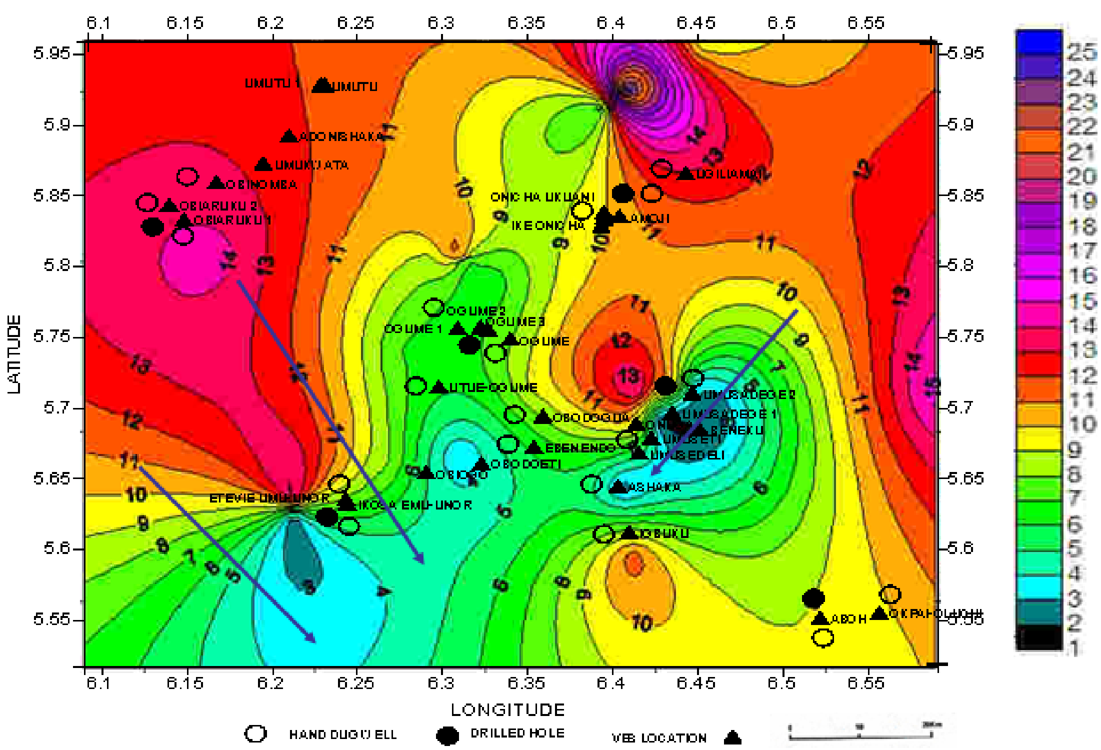


**Figure 4:** Contour Color of Ndokwa Land Showing Groundwater Flow Direction in Two Dimensions using Suffer 8 Program.

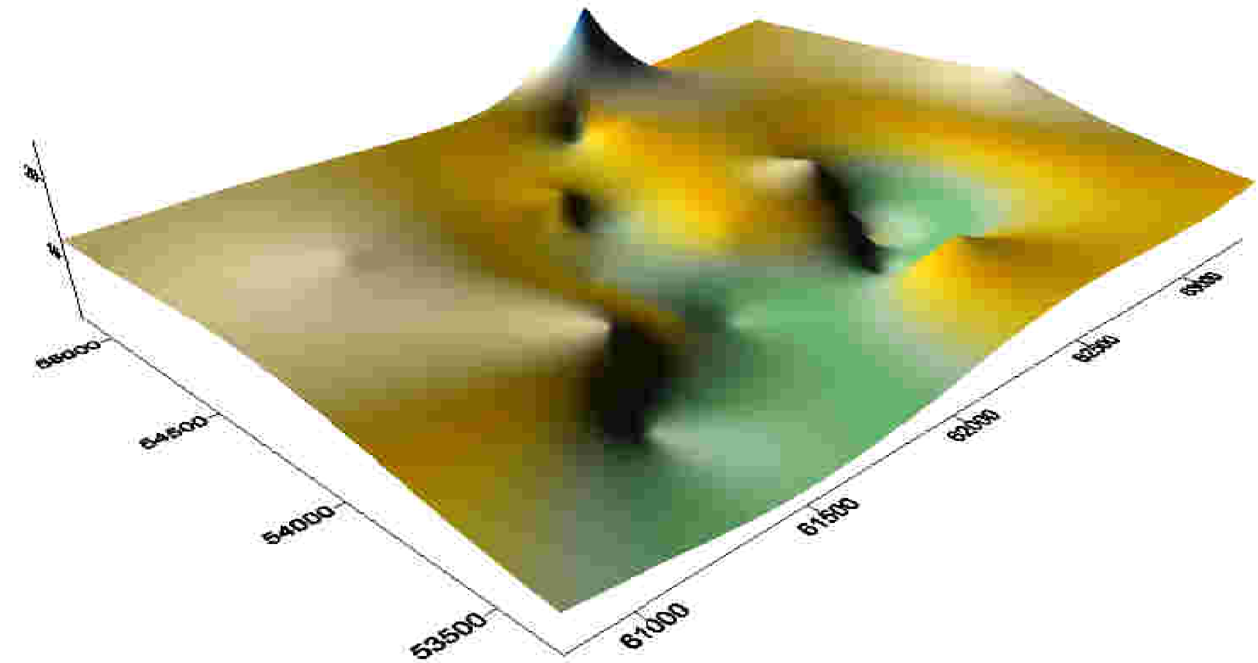


**Figure 5:** Wire Frame of Ndokwa Land Showing Groundwater Flow Direction in Three Dimensions using Suffer 8 Computer Program.

## CONCLUSIONS

The water elevation contour map of Ndokwa Land revealed that groundwater flow direction is toward the south and southwestern part of the region. Among the sources of groundwater pollution are leachates from dumpsites and the health of the inhabitants' stands at risk if leachates are allowed to interact with groundwater.

Based on the flow pattern of the aquifer system in Ndokwa Land, dumpsites should be sited in the south and southwestern parts of the area and not in the north, west, and eastern regions in order to minimize groundwater contamination.

## RECOMMENDATIONS

Based on the flow pattern of the aquifer system in Ndokwa Land, it is therefore recommended that dumpsites should be sited within the south and southwestern parts of the area and not in the north, west, and eastern regions, in order to minimize groundwater contamination by dumpsites.

This research has not only paved the way for a clear picture of the flow system in Ndokwa Land in order to create awareness on the possible areas dumpsites could be sited in order to minimize groundwater contamination, but it also recommends that boreholes for potable water supply should be sited in the north, west, and eastern regions and not within the south and southwestern parts of Ndokwa land.

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