Journal of Civil, Construction and Environmental Engineering
2017; 2(2): 59-65
http://www.sciencepublishinggroup.com/j/jccee
doi: 10.11648/j.jccee.20170202.13

Electrical Resistivity and River Flow Velocity Studies of Ebonyi River Bridge Sites at Onicha-Oshiri and Idembia Areas, Southeastern Nigeria

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To cite this article:
Ibeneme Sabinus Ikechukwu, Ibe Kalu Kalu, Eluwa Ndidiamaka Nchedo, Chinyem Felix Iwebunor, Nwankwo Stephen, Bulus Joseph Azi, Echendu Obi Kingsley. Electrical Resistivity and River Flow Velocity Studies of Ebonyi River Bridge Sites at Onicha-Oshiri and Idembia Areas, Southeastern Nigeria. *Journal of Civil, Construction and Environmental Engineering.* Vol. 2, No. 2, 2017, pp. 59-65.
doi: 10.11648/j.jccee.20170202.13

Received: March 4, 2017; **Accepted**: March 16, 2017; **Published**: March 30, 2017

Abstract: Pre-design Geoelectrical and River Velocity studies have been carried out at two bridge locations: Ebonyi River at Onicha-Oshiri road and Ebonyi River at Idembia Ezza. The objectives of the studies are to determine the geoelectrical parameters with respect to structure and rock type at these locations in combination with geology and carry out the analysis of the river velocity at various points. Four Vertical Electrical Sounding (VES) stations and six Velocity profiles were established (two VES stations and three velocity profiles per bridge site). Three geoelectric layers were proposed for Onicha-Oshiri and four to five geoelectric layers for Idembia. These layers comprise of the Top soil with resistivity range of 290-950Ωm, Silty lateritic soil with resistivity range of 140-181Ωm, Hard lateritic soil with resistivity range of 724-860Ωm, Silty sand with resistivity range of 163-494Ωm and Mudstone with resistivity range of 52-100Ωm. Results of Onicha-Oshiri lot show that the velocity values range from $1.28ms^{-1}$ to $1.95ms^{-1}$. Along profile D, velocity values rise from point 1 to point 3. Along the present bridge profile, the values are nearly the same for points 1 and 2 and rise to $1.37ms^{-1}$ at point 3. However along profile F, the velocity value is higher at point 2 (middle of the river). At Idembia site velocity values range from $0.634m\ s^{-1}$ to $0.99m\ s^{-1}$. Apart from profile B where the value is highest at point 3 (edge of the river) values at profiles A and C have higher amounts at the edges and lower amounts at the central portion indicating increased scouring at the edges. The river at Onicha-Oshiri site has higher velocity possibly on the account of this site being at the youthful stage of the river. At Onicha end, the top lateritic matter is interbedded with fresh blue shale which may be offensive to any structure. This must be taken care of during construction by aiming at the hard sandstone below.

Keywords: Asu-River, Electrical Resistivity, Idembia, Oshiri, Schlumberger, Velocity

1. Introduction

Rivers are, in first approximation, nearly one-dimensional flows driven by gravity down a slope and resisted by friction [1]. Rivers are not straight; their current is twisting (meandering) [2]. The velocity of a river is the speed with which water runs along the rivers full length. The velocity normally changes along the way and is determined by several factors including the shape of the river channel, the volume of water and the amount of friction created by the plants, bed and rocks. Flow velocity in rivers has a major impact on the residence time of water and thus on high and low water as well as on water quality [3]. It is often assumed that the flow velocity of a river increases logarithmically with the distance from the bed [4]. Because river slope generally decreases in a downstream direction, it is generally supposed that velocity of flow also decreases downstream. Near the streambed, shear in the vertical profile of velocity (rate of decrease of velocity with depth) tends to decrease downstream [5]. [6] have utilized simple approaches like constant river flow velocity and opined that if a single or a limited number of catchments are modeled, complex flow velocity equations can be parameterized with observed catchment-specific values. [7] used an electromagnetic current meter to measure flow in a fast-flowing, bedrock-controlled river in Ontario, and a number of researchers have made flow measurements in mountain streams and rivers (e.g. [1], [8], [9], [10]).

The objectives of the studies are to determine the geophysical parameters with respect to structure and rock type at these locations in combination with geology and carry out the analysis of the river velocity at various points at the period of study assuming the highest values for effective erosion takes place between July and November when the river is full. Furthermore the velocity of the river is a function of eroding power hence foundation effects. The engineers need this information for working a standard design for these areas.

2. Location and Accessibility

While the Idembia site is accessible through Afikpo and Onueke, the Onicha-Oshiri lot is not only accessible through these routes but also through an old road from Idembia (Figure 1).

As the Idembia Bridge site is at latitude 6°6.40’N and on longitude 7°57.0’E, the Onicha-Oshiri site is located on latitude 6°8.9’N and longitude 7°57.4’E. Heights above sea level for Idembia range from 23.8m to 30.8m and from 33.2m to 42.7m for the Onicha-Oshiri site. From these, the Onicha-Oshiri site is at the youthful stage. It is narrow in width and higher in altitude than the Idembia site.

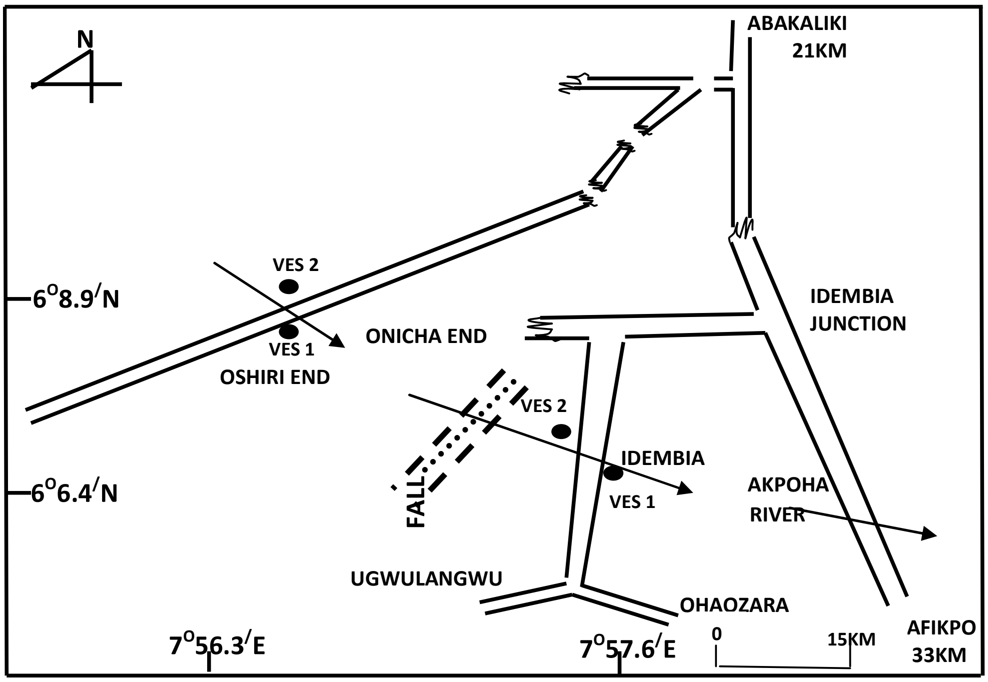

Figure 1. Location map of the study area (Onicha-Oshiri and Idembia bridge sites).

3. Geological Setting

Both Idembia and Onicha-Oshiri sites are underlain by the Albian Asu-River Formation. The area has sandstone (Onicha-Oshiri area) as rock units, being outcrops observed on the surface. In fact at Idembia, a water fall across one sandstone unit crosses the river (Figure 1) NW at 250m from the bridge point. At Onicha end of the bridge, the hard sandstone is seen at the southeast end of the river. Most valley areas are underlain by shale while higher areas are either underlain by sandstones, faults or quartzite dikes. The general dip direction is NW at amounts of 25°-35° and striking NE-SW. Thus the river flows up dip. Siltstones and mudstones are typical of Asu-River Formation in eastern Nigeria sedimentary formations.

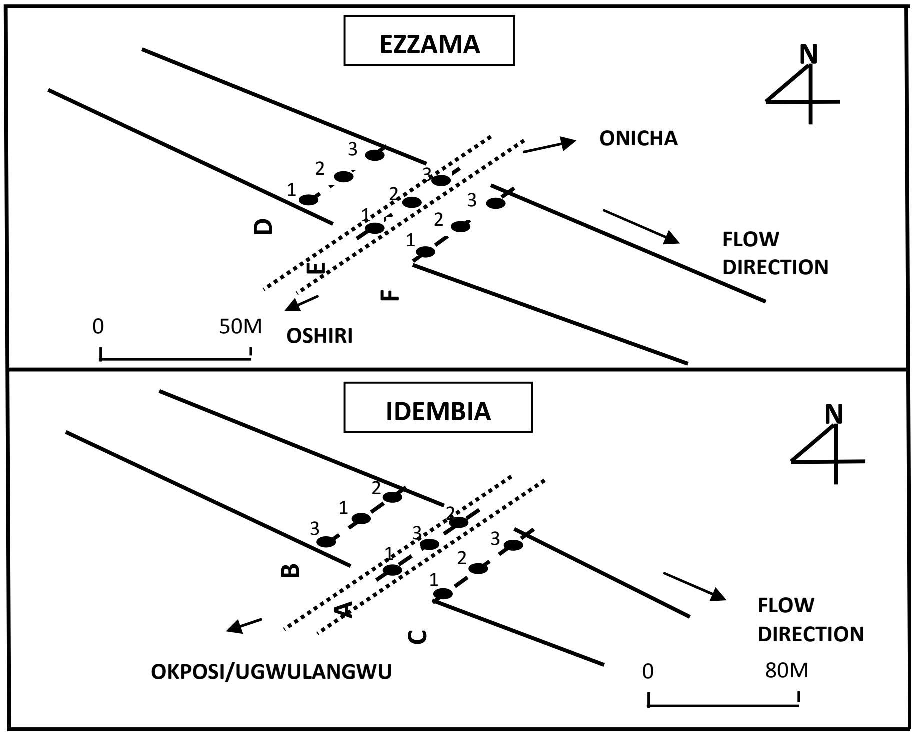

Figure 2. *Details of river velocity measurements in the study area.*

4. Methodology

4.1. Vertical Electrical Sounding (VES)

The method involved the use of the electrical sounding technique of Schlumberger where the Vertical Electrical Sounding (VES) was employed. The use of the Schlumberger technique has been variously documented ([11], [12] and [13]). AB/2 values ranged from 1.5m to 55m, ensuring up to 20m depth of investigation at the four VES locations. Four VES stations (two per bridge site) were established, using cross-sounding for the sites where the direction profiles were made mutually perpendicular per site. The ABEM Terrameter Model SAS 1000C was used and the Schlumberger configuration adopted is shown in figure 3.

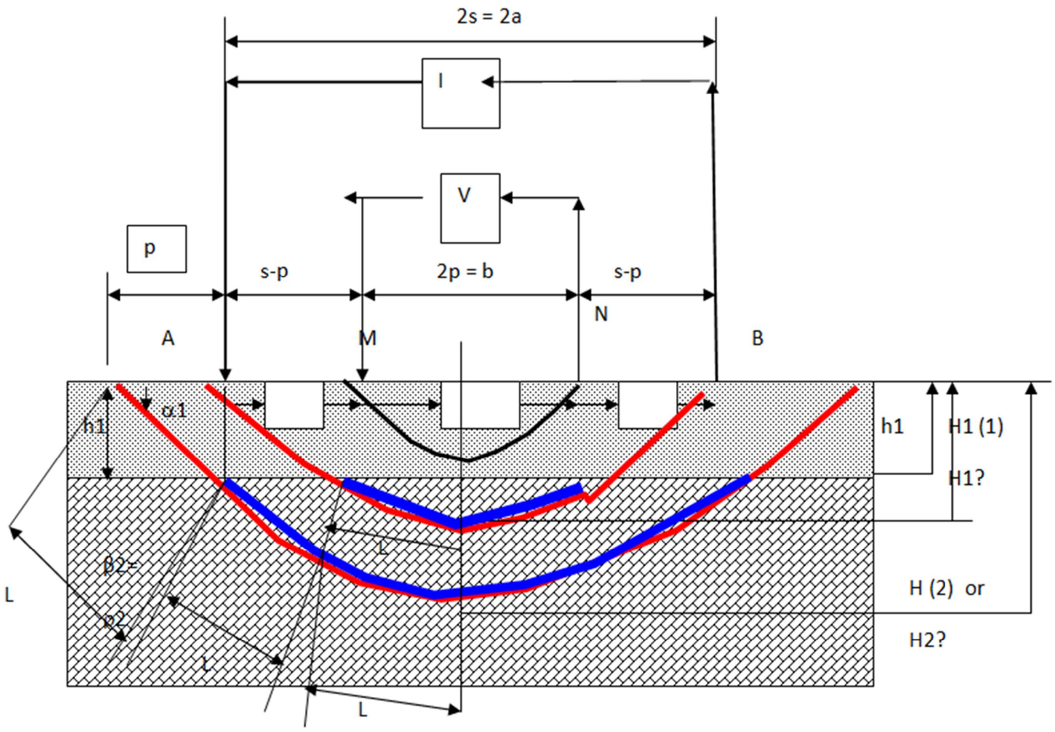

Figure 3. *Schlumberger configuration used for the survey (source: ScienceDomain International).*

Field readings in Ohms were reduced to apparent resistivity values through the Schlumberger equation:

$$\beta = l_a = \pi\left[\frac{a^2}{b} - \frac{b}{4}\right] \bullet R \qquad (1)$$

where

β = apparent resistivity in Ohm-m

a = AB/2, the Half Current Electrode Separation in meters

b = Potential electrode separation in meters

R = Instrument reading in Ohms

A Plot of β values against AB/2 (a) values on log-log graph yields the field curves from which the models shown in Figures 4 and 5 were generated.

4.2. Floating Method for the River Flow Velocity

The river flow velocity can be measured using very simple equipment. A watch capable of timing in seconds, something to float on the water and a tape measure are all that is required to find the velocity of the water surface. If one wishes to find the velocity of the water below the surface, a velocity meter of some kind will also be required. This method usually enhances velocity values, making them higher than normal. Weighted particle method gives lower velocities. Strengths proposed for stagnant water site are usually lower than those for vibrant streams. Lighter weights give high V-values and subsequently high design strengths [5]. Measurements were made along three NE-SW profiles per site, each profile having three measurement points (Figure 2). This enabled nine (9) points for velocity per bridge site. The known distance was made out and the floating material dropped and timed with digital Samuel clock with 0.01 seconds accuracy. Tables 1 and 2 show the results of the measurements. Plots of the data on the arithmetic graph are shown in Figure 6.

5. Interpretation

5.1. Vertical Electrical Sounding (VES)

Preliminary data from the field were fed into the Zohdy software to get real resistivities and depths to geoelectric horizons. Curve shapes and not necessarily the apparent resistivity (ℓa) are often considered in VES interpretation. This is sequel to the fact that apparent resistivity (ℓa) values may change due to the wetness of the over-burden as during rainy periods but the depths to geoelectric layers remain the same unless sudden structural changes occur [11]. Thus curve shape was used to propose models for the four VES data set generated by the sub-surface effects. On the basis of curve shapes preliminary input data were used to propose approximately four (4) to five (5) geoelectric layers for Idembia and three (3) geoelectric layers for Onicha – Oshiri. On the basis of the models, the following results were obtained.

5.1.1. Idembia Site (VES 1 and 2)

LAYER 1

This is made up of top agricultural soil with a thickness of 1.3m and 290 Ohm-m resistivity at the SW end while with 1.4m thickness, the value of resistivity goes to 590 Ohm-m at VES 2 location (NS end).

LAYER 2

This layer has a base at 1.6m in VES 1 and 3m at VES 2. Resistivity is 140-181 Ohm-m and is modeled as silty lateritic matter.

LAYER 3

This layer, with resistivity range of 161-494 Ohm-m is sandy with silt fractions. The base at VES 1 is 2.6m while at VES 2 the same base goes down to 6.4m.

LAYER 4

This layer is modeled as mudstone with 52-100 Ohm-m resistivity with bases at 17.8m at VES 1 and extending to below 20m in VES 2.

LAYER 5

This layer, which is modeled as being shaley, was only encountered at VES 1 point (SW end) dipping geoelectrically to the NE. (Figure 5).

5.1.2. Onicha-Oshiri Site (VES 1 and 2)

Three geoelectric layers have been modeled in the Onicha-Oshiri site as follows:

LAYER 1

This is made up of hard lateritic matter often mixed fissile shale. Resistivity ranges from 724 to 860 Ohm-m. The thickness ranges from 1.8 in Oshiri end to 3.6m in Onicha end.

LAYER II

This layer is made up of hard sandstone with the base at 13.0m at Oshiri end and 6.6m at Onicha end. Resistivity values range from 218 to 771 Ohm-m.

LAYER III

This layer is modeled as the sub-stratum in the site, made up of mudstone of resistivity of 72.5 to 88 Ohm-m and extending to over 20m in both ends. The geoelectric dip conforms to that of Idembia for the first layer but there is a reversal from the second layer at Oshiri end.

In all, the geoelectric model tends to confirm the surface geology as observed in the two locations. Though geological mapping was not carried out, the vicinity of the bridge site at both locations were mapped and rock units identified.

The geoelectric sections for the VES results are shown in Figures 4 and 5.

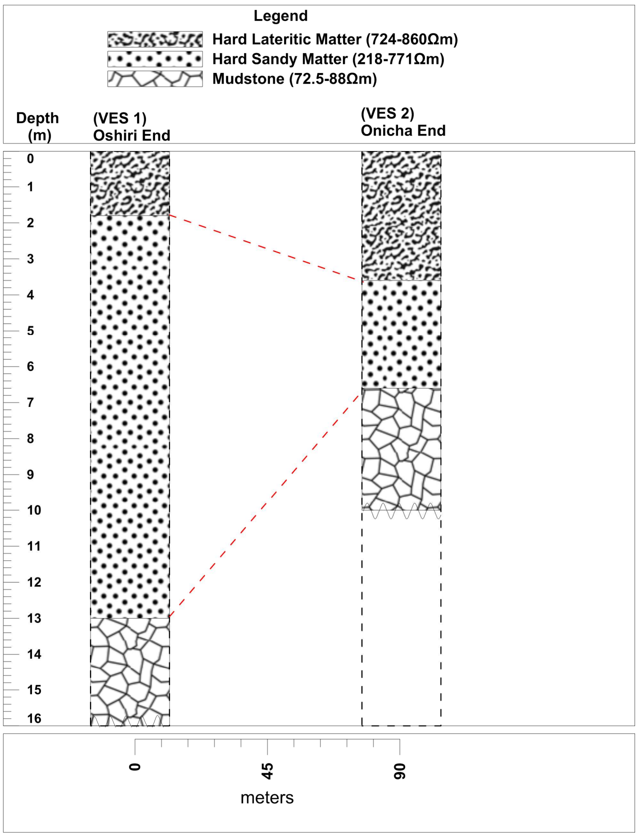

Figure 4. *Geoelectric Section across VES points at Onicha-Oshiri bridge site.*

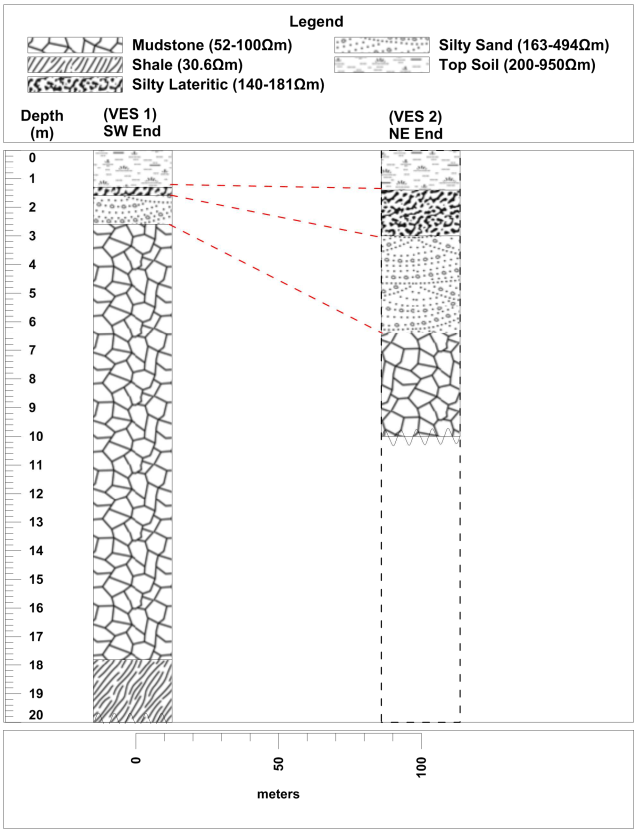

Figure 5. *Geoelectric Section across VES points at Idembia bridge site.*

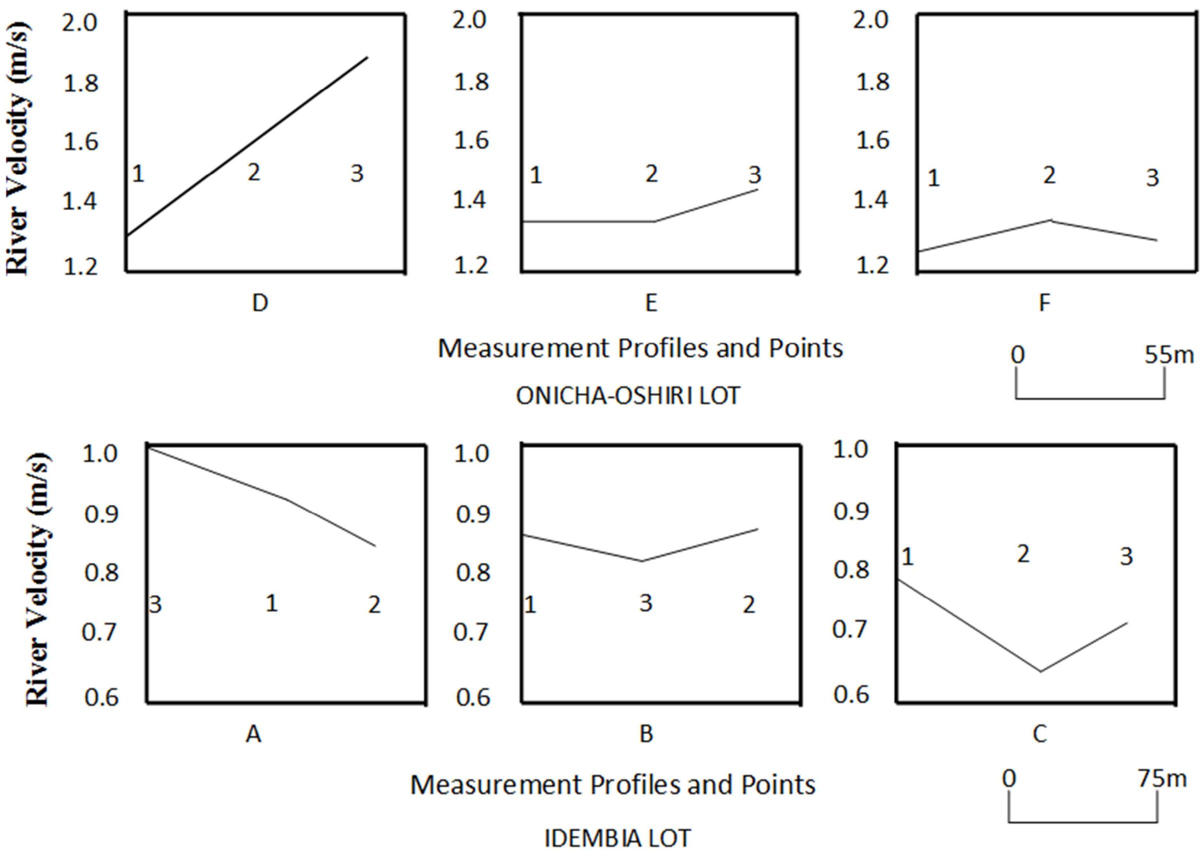

Figure 6. *Velocity plots at various measurement points along profiles across Ebonyi River at Onicha-Oshiri and Idembia lots.*

5.2. The River Flow Velocity Study

5.2.1. Onicha-Oshiri Lot

The velocity plots are shown in Figure 6 while the results are shown in Table 1. Results show that the velocity values range from 1.28ms^{-1} to 1.95ms^{-1}. Along D profile, velocity values rise from point 1 to point 3. Along the present bridge profile, the values are nearly the same for points 1 and 2 and rise to 1.37ms^{-1} at point 3. However along F profile, the velocity value is higher at point 2 (middle of the river) Figure 6.

Table 1. *Velocity Data for Ebonyi River at Onicha-Oshiri bridge.*

PROFILE	LOCATION NO	TIME (S)	DISTANCE (m)	VELOCITY 10^{-1}(ms^{-1})
	1	3.12	4.00	1.28
D	2	9.41	14.00	1.49
	3	10.31	19.09	1.85
	1	5.60	7.35	1.31
E	2	11.56	15.01	1.30
	3	14.65	20.14	1.37
	1	4.45	5.81	1.28
F	2	7.22	10.33	1.43
	3	8.38	10.00	1.31

5.2.2. Idembia Lot

The results of the velocity study for Idembia bridge site is shown in Table 2. One thing is clear: The values range from 0.6 34ms^{-1} to 0.99ms^{-1}. Apart from profile B where the value is highest at point 3 (edge of the river) values at profiles A and C have higher amounts at the edges and lower amounts at the central portion (Figure 6).

Table 2. *Velocity Data for Ebonyi River at Ikwuato–Idembia-Ezza.*

PROFILE	LOCATIONNO	TIME (S)	DISTANCE (m)	VELOCITY 10^{-1}(ms^{-1})
	1	6.84	6.0	8.77
A	2	2.51	2.0	7.97
	3	8.24	7.0	8.59
	1	6.06	6.0	9.90
B	2	4.44	4.0	9.01
	3	3.21	4.0	8.15
	1	6.41	5.0	7.80
C	2	5.50	3.5	6.34
	3	6.72	5.0	7.44

6. Discussion of Results

Models for the VES data for both Onicha-Oshiri and Idembia Bridge sites indicate relatively harder rock units as the overburden or top matter, underlain by softer matter possibly shaley. Outcrops of siltstone and sandstone at both sites confirm the geophysical results. The river at Idembia site flows across one of these rock outcrops at a location 250m NW of the present boat crossing point. Resistivity values for such near surface matter range from 16.3 Ohm-m to 860 Ohm-m. A general NE geoelectric dip was not found to coincide with the geological dip in Idembia and in Onicha-Oshiri areas. While the geological dip is in NW direction, the geoelectric dip is in NE direction. However such dips are northward generally. There seems to be no consistency in velocity values at Onicha-Oshiri area while the curves show some consistency in Idembia lot. It is noted that the river is 55m wide at Oshiri end. The river gets more mature towards Idembia.

7. Conclusion

Bridge sites at Idembia and along Onicha-Oshiri road are underlain by mudstone-siltstone-sandstone sequence but further than 12m below, overriding shaley conditions are encountered. Velocity studies at these locations at 9 points per site do not show any consistency. Rather the river at Onicha-Oshiri site has higher velocity possibly on the account of this site being at the youthful stage of the river. The river flows up dip direction (SE). At Onicha end, the top lateritic matter is interbedded with fresh blue shale which may be offensive to any structures. This must be taken care of by aiming at the hard sandstone below.

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