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# Effect of Lateral Velocity Distribution on Turbidity in River Ose, Ondo State, Nigeria

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## *Abstract*
This work investigated the relationship between lateral velocity distribution and turbidity across Ose River in Ondo State, Nigeria. Data were collected at coordinates 7º 18' 35.5" N and 5º 39' 52.5" E for two-year period. The relationship between lateral velocity distribution and turbidity values obtained were plotted. The trends showed that as velocity increases across the channel width, turbidity decreases. This could be responsible for the clearer water at the mid-section compared to those obtained near the banks which is attributed to concentration of suspended solids dispersed toward the bank/edge of the river by velocity across the channel. The clear seasonal pattern of velocities increasing laterally across the channel width with corresponding decrease in turbidity is seen across all sampling data, suggesting this is a true representation of variability in the river.

**Keywords:** Lateral Velocity Distribution, Sediment, Turbidity, River Ose.

## *Introduction*
Flow velocities affect the flow turbulence forces which in turn influence transport of suspended sediment particles (Hekal, 2003). If the current velocities increase, the number of particles in suspension increases. This big number reduces the water transparency and increase its turbidity.

In his research work Jastram (2007) observed that hydrological conditions influence sediment physical properties with results indicating that suspended solids tend to disperse with increasing stage flow.

The relationships between lateral velocity distribution and turbidity values across a channel may provide a fundamental insight into the variability in the river. These relationships give an understanding into the combined effects of sources, footpaths, biogeo-chemical cycles and watershed factors such as lithology, type of soil, climatic conditions and sediment concentrations (Inamdar et al., 2006; Fellman et al., 2009).

Suspended solids are a significant contributor to river turbidity and probable pollutants. Several studies have shown that turbidity and microorganisms such as faecal coliforms are closely related (Hamilton et al, 1998; Huey and Meyer, 2010; Maillard and Pinheiro Santos, 2008; Astron et al., 2007). (Nestor et al. 2001).

Most of the time the velocity increased with the rainfall. The velocity is always changing, from minute to minute. The precipitation and surface run-off have the biggest influence on the velocity of our rivers. Precipitation causes rivers so rise. How much a river rises is highly dependent on the size of the drainage basin. Bigger rivers have a bigger drainage basin compared to smaller rivers. Large rivers rise and fall slower since the cross-sectional area is much bigger than in small rivers, which means there needs to be much more water to see a change.

The objective of this paper is to look into the dispersion effect (if any) of lateral velocity distribution across a channel (River Ose) in relation to turbidity.

## MATERIALS AND METHODS

### Description of Study Area

River Ose is a steram (class H-Hydrographic) in Nigeria, located at an elevation of 136meters above sea level. The study portion of the river is located along the Owo-Oba Akoko expressway in Ondo State. The area lies within the coordinates 7º 18’ 35.5” N and 5º 39’ 52.5” E.

River Ose flows from Egbe-Ekiti in Ekiti State and runs through Owo and Akoko in Ondo State to Edo State. (see figure 1). This river is a seasonal river with long wet and dry seasons. The wet season lasts from April to October, when 80 percent of the annual rainfall falls, with the heaviest rains falling in June and September. The annual rainfall totals 1,830 millimetres. The average temperature ranges from 24 degrees Celsius in August to 29 degrees Celsius in February. The relative humidity is high, ranging

between 80% and 100%. (Ondo State Government, 2010). It comprises of a rainforest vegetation close to mangrove belts with significant species like Avecinia Africana, Rhizophora, RAcemosa, NypaFruitcius (palm) and a tropical rainforest environment that is determined by temperature and precipitation. Environmental factors include fishing, agriculture, hunting, and forestry by inhabitants around the river. Apart from being a source for fishing and farming activities, River Ose is an important river to Owo and its environs as it is the source of raw water supply to headworks that supply water to them.

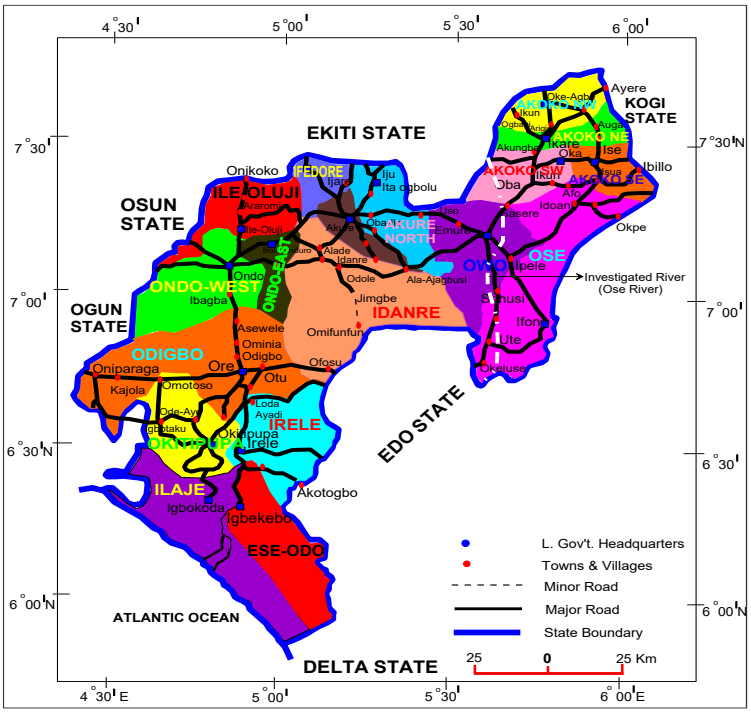



**Figure 1. Map of Ondo State Indicating the Investigating River Ose (Ondo State Government, 2019)**

## DATA/SAMPLE COLLECTION

Data and samples were collected from River Ose (figure 2) over a period of two years spanning through two seasons i.e., dry and wet seasons. Discharge (Q) was obtained by calculating the integral of the river velocity (v) over the cross-section area of the flow (A), where (v) was measured perpendicular to the cross-section.

$$Q = \int v\delta A$$

Where, Q is the discharge in $m^3/s$; V is the velocity I m/s and A is the cross-section area in $m^2$. The velocity V was measured in discrete interval along the river cross-section using Vale Port BFM001 open channel flow meter. In order to determine the flow, the channel width was divided into 5 equal sections of 6m X 6m grid, while the 2 edges of the river are 2m from the bank. Thus, measurements and data were collected

at seven points moving from the Left River Bank (LRB) to the Right River Bank (RRB) (figure 2). In-situ turbidity was monitored across the river channel moving from LRB to RRB using a high precision Turbid Meter TDS 5031 ESODO to provide direct measurement in unit of NTU (Nephelometric unit, 0-10,000). Turbidities were measured at mid-point of each section as adopted in the measurement grid at a particular time interval tested to match the resolution of the turbid meter.

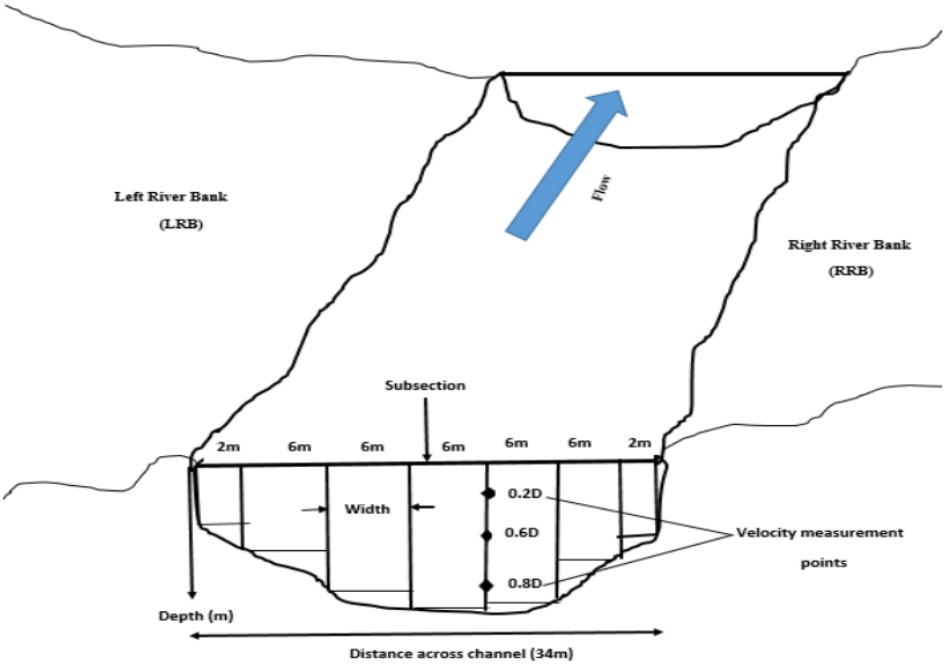



**Figure 2. Measurement Grid**




**Figure 3. River Ose (Google Map, 2018)**

## RESULTS AND DISUSSION

Table 1-12 below show the summary of result obtained from the study conducted from April 2017 to December 2018 which spanned two seasons (wet and dry). For each month, the lateral velocity distribution was plotted from the LRB of the channel towards the RRB. The middle section (mean value) was adopted to represent the whole section in order to have a reasonable plot, resulting in twelve plots. The relationship between lateral velocity distribution and turbidity values obtained during the study period are plotted as shown in Figures 4 – 15.

**Table 1. Data and Sample results for the month of April 2017 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.26 | 0.26 | 0.6 | 2.0 | 2.0 | 0.52 | 46 |
| 2 | 0.33 | 0.3 | 0.24 | 1.3 | 6.0 | 7.8 | 2.34 | 40 |
| 3 | 0.44 | 0.39 | 0.30 | 1.3 | 6.0 | 7.8 | 3.04 | 16 |
| 4 | 0.65 | 0.51 | 0.40 | 1.4 | 6.0 | 8.4 | 4.28 | 16 |
| 5 | 0.81 | 0.62 | 0.55 | 1.4 | 6.0 | 8.4 | 5.21 | 18 |
| 6 | 0.41 | 0.35 | 0.22 | 1.2 | 6.0 | 7.2 | 2.52 | 43 |
| 7 | | 0.28 | 0.28 | 0.7 | 2.0 | 1.4 | 0.39 | 46 |
| | | | | | Total | | 18.30 | |

**NOTE: D is the depth of the river at each section.**

**Table 2. Data and Sample results for the month of May 2017 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.35 | | 0.8 | 2.0 | 1.6 | 0.88 | 46 |
| 2 | 0.71 | 0.52 | 0.33 | 1.1 | 6.0 | 6.6 | 3.43 | 45 |
| 3 | 0.80 | 0.75 | 0.60 | 1.3 | 6.0 | 7.8 | 5.85 | 30 |
| 4 | 1.0 | 0.80 | 0.65 | 1.3 | 6.0 | 7.8 | 6.24 | 20 |
| 5 | 0.9 | 0.60 | 0.75 | 1.4 | 6.0 | 8.4 | 5.04 | 25 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **6** | 0.8 | 0.59 | 0.55 | 1.2 | 6.0 | 7.2 | 4.25 | 40 |
| **7** | | 0.57 | | 0.7 | 2.0 | 1.4 | 0.80 | 48 |
| | | | | | **Total** | | 26.49 | |

**NOTE: D is the depth of the river at each section.**

**Table 3. Data and Sample results for the month of June 2017 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| **1** | | 0.55 | | 0.8 | 2.0 | 1.6 | 0.88 | 50 |
| **2** | 0.70 | 0.44 | 0.39 | 1.2 | 6.0 | 7.2 | 3.17 | 40 |
| **3** | 1.1 | 0.8 | 0.77 | 1.4 | 6.0 | 8.4 | 6.72 | 20 |
| **4** | 1.43 | 1.0 | 0.92 | 1.5 | 6.0 | 9.0 | 9.0 | 20 |
| **5** | 1.20 | 0.8 | 0.6 | 1.3 | 6.0 | 7.8 | 6.24 | 40 |
| **6** | 1.0 | 0.66 | 0.42 | 1.2 | 6.0 | 7.2 | 4.75 | 50 |
| **7** | | 0.57 | | 0.7 | 2.0 | 1.4 | 0.80 | 60 |
| | | | | | **Total** | | 31.56 | |

**NOTE: D is the depth of the river at each section.**

**Table 4. Data and Sample results for the month of October 2017 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| **1** | | 0.44 | | 0.8 | 2.0 | 1.6 | 0.70 | 13 |
| **2** | 0.69 | 0.53 | 0.41 | 1.0 | 6.0 | 6.0 | 3.18 | 12 |
| **3** | 0.66 | 0.55 | 0.41 | 1.0 | 6.0 | 6.0 | 3.3 | 10 |
| **4** | 0.89 | 0.75 | 0.65 | 1.2 | 6.0 | 7.2 | 5.4 | 10 |
| **5** | 0.93 | 0.77 | 0.55 | 1.3 | 6.0 | 7.8 | 6.01 | 12 |
| **6** | 0.72 | 0.56 | 0.44 | 0.9 | 6.0 | 5.4 | 3.02 | 14 |
| **7** | | 0.45 | | 0.7 | 2.0 | 1.4 | 0.63 | 14 |
| | | | | | **Total** | | 22.24 | |

**NOTE: D is the depth of the river at each section.**

**Table 5. Data and Sample results for the month of November 2017 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.45 | | 0.6 | 2.0 | 1.2 | 0.54 | 12 |
| 2 | 0.63 | 0.44 | 0.32 | 0.95 | 6.0 | 5.7 | 2.51 | 12 |
| 3 | 0.6 | 0.5 | 0.2 | 1.20 | 6.0 | 7.2 | 3.6 | 8 |
| 4 | 0.86 | 0.63 | 0.54 | 1.10 | 6.0 | 6.6 | 4.16 | 8 |
| 5 | 0.69 | 0.52 | 0.33 | 1.10 | 6.0 | 6.6 | 3.43 | 8 |
| 6 | 0.6 | 0.41 | 0.30 | 0.82 | 6.0 | 4.92 | 2.02 | 12 |
| 7 | | 0.28 | | 0.45 | 2.0 | 0.9 | 0.25 | 14 |
| | | | | | Total | | 16.51 | |

**NOTE: D is the depth of the river at each section.**

**Table 6. Data and Sample results for the month of December 2017 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.29 | | 0.45 | 2.0 | 0.9 | 0.26 | 12 |
| 2 | 0.63 | 0.41 | 0.25 | 0.72 | 6.0 | 4.32 | 1.77 | 12 |
| 3 | 0.81 | 0.51 | 0.34 | 0.77 | 6.0 | 4.62 | 2.36 | 8 |
| 4 | 0.88 | 0.60 | 0.41 | 0.80 | 6.0 | 4.80 | 2.88 | 8 |
| 5 | 0.86 | 0.65 | 0.40 | 0.80 | 6.0 | 4.80 | 3.12 | 8 |
| 6 | 0.75 | 0.58 | 0.39 | 0.69 | 6.0 | 4.14 | 2.40 | 12 |
| 7 | | 0.31 | | 0.40 | 2.0 | 0.8 | 0.25 | 14 |
| | | | | | Total | | 13.04 | |

**NOTE: D is the depth of the river at each section.**

**Table 7. Data and Sample results for the month of April 2018 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.36 | | 0.5 | 2.0 | 1.6 | 0.36 | 20 |
| 2 | 0.39 | 0.35 | 0.25 | 0.7 | 6.0 | 4.20 | 1.47 | 18 |
| 3 | 0.38 | 0.35 | 0.25 | 0.7 | 6.0 | 4.20 | 1.47 | 15 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **4** | 0.45 | 0.39 | 0.30 | 0.81 | 6.0 | 4.86 | 1,89 | 15 |
| **5** | 0.40 | 0.31 | 0.28 | 0.75 | 6.0 | 4.50 | 1.39 | 15 |
| **6** | 0.40 | 0.30 | 0.25 | 0.70 | 6.0 | 4.20 | 1.26 | 18 |
| **7** | | 0.32 | | 0.4 | 2.0 | 0.80 | 0.26 | 20 |
| | | | | | | **Total** | 8.1 | |

**NOTE: D is the depth of the river at each section.**

**Table 8. Data and Sample results for the month of May 2018 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| **1** | | 0.48 | | 0.7 | 2.0 | 1.4 | 0.67 | 66 |
| **2** | 0.68 | 0.52 | 0.35 | 0.9 | 6.0 | 5.4 | 2.81 | 60 |
| **3** | 0.71 | 0.58 | 0.38 | 1.3 | 6.0 | 7.8 | 4.52 | 40 |
| **4** | 0.71 | 0.58 | 0.38 | 1.3 | 6.0 | 7.8 | 4.52 | 40 |
| **5** | 0.9 | 0.62 | 0.44 | 1.4 | 6.0 | 8.4 | 5.21 | 55 |
| **6** | 0.69 | 0.55 | 0.38 | 1.0 | 6.0 | 6.0 | 3.3 | 66 |
| **7** | | 0.44 | | 0.7 | 2.0 | 1.4 | 0.62 | 75 |
| | | | | | | **Total** | 21.65 | |

**NOTE: D is the depth of the river at each section.**

**Table 9. Data and Sample results for the month of June 2018 (wet season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6DxArea | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| **1** | | 0.65 | | 0.9 | 2.0 | 1.8 | 1.17 | 85 |
| **2** | 0.62 | 0.45 | 0.35 | 1.0 | 6.0 | 6.0 | 2.7 | 85 |
| **3** | 1.20 | 0.8 | 0.6 | 1.3 | 6.0 | 7.8 | 6.24 | 35 |
| **4** | 1.43 | 1.10 | 0.85 | 1.5 | 6.0 | 9.0 | 9.9 | 30 |
| **5** | 1.25 | 0.79 | 0.6 | 1.3 | 6.0 | 7.8 | 6.16 | 35 |
| **6** | 0.68 | 0.42 | 0.33 | 1.0 | 6.0 | 6.0 | 2.52 | 70 |
| **7** | | 0.52 | | 0.7 | 2.0 | 1.4 | 0.73 | 75 |
| | | | | | | **Total** | 29.42 | |

**NOTE: D is the depth of the river at each section.**

**Table 10. Data and Sample results for the month of October 2018 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6Dx Area | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.32 | | 0.45 | 2.0 | 0.9 | 0.28 | 16 |
| 2 | 0.61 | 0.43 | 0.32 | 0.92 | 6.0 | 5.52 | 2.37 | 14 |
| 3 | 0.68 | 0.55 | 0.37 | 1.25 | 6.0 | 7.5 | 4.13 | 11 |
| 4 | 0.90 | 0.73 | 0.64 | 1.38 | 6.0 | 8.28 | 6.04 | 11 |
| 5 | 0.80 | 0.69 | 0.55 | 1.30 | 6.0 | 7.8 | 5.38 | 10 |
| 6 | 0.71 | 0.55 | 0.38 | 1.0 | 6.0 | 6.0 | 3.3 | 12 |
| 7 | | 0.28 | | 0.4 | 2.0 | 0.8 | 0.22 | 14 |
| | | | | | | Total | 21.72 | |

**NOTE: D is the depth of the river at each section.**

**Table 11. Data and Sample results for the month of November 2018 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6Dx Area | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.29 | | 0.4 | 2.0 | 0.8 | 0.23 | 14 |
| 2 | 0.60 | 0.41 | 0.30 | 0.83 | 6.0 | 4.98 | 2.04 | 13 |
| 3 | 0.58 | 0.38 | 0.22 | 1.0 | 6.0 | 6.0 | 2.28 | 12 |
| 4 | 0.56 | 0.38 | 0.23 | 1.0 | 6.0 | 6.0 | 2.28 | 12 |
| 5 | 0.7 | 0.35 | 0.38 | 0.9 | 6.0 | 5.4 | 2.97 | 11 |
| 6 | 0.7 | 0.52 | 0.36 | 0.9 | 6.0 | 5.4 | 2.81 | 14 |
| 7 | | 0.21 | | 0.4 | 2.0 | 0.8 | 6.17 | 14 |
| | | | | | | Total | 12.78 | |

**NOTE: D is the depth of the river at each section**.

**Table 12. Data and Sample results for the month of December 2018 (dry season)**

| Section | Flow Velocity (m/s) | | | Depth (m) | Width (m) | Area ($m^2$) D x W | Discharge ($m^3/s$) 0.6Dx Area | Turbidity (NTU) |
|---|---|---|---|---|---|---|---|---|
| | 0.2D | 0.6D (Mean) | 0.8D | | | | | |
| 1 | | 0.22 | | 0.33 | 2.0 | 0.66 | 0.15 | 9 |
| 2 | 0.56 | 0.32 | 0.22 | 0.50 | 6.0 | 3.0 | 0.96 | 9 |
| 3 | 0.6 | 0.41 | 0.23 | 0.70 | 6.0 | 4.2 | 1.72 | 8 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **4** | 0.81 | 0.53 | 0.32 | 0.81 | 6.0 | 4.86 | 2.58 | 7 |
| **5** | 0.75 | 0.56 | 0.40 | 0.65 | 6.0 | 3.90 | 2.18 | 7 |
| **6** | 0.7 | 0.55 | 0.41 | 0.65 | 6.0 | 3.90 | 2.15 | 12 |
| **7** | | 0.25 | | 0.38 | 2.0 | 0.76 | 0.19 | 12 |
| | | | | | | **Total** | 9.93 | |

**NOTE: D is the depth of the river at each section.**

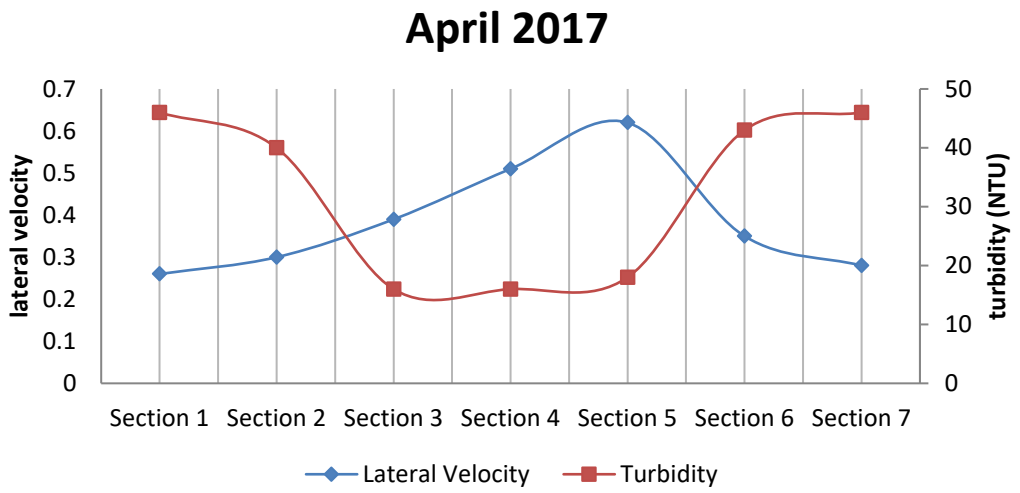



**Figure 4. Lateral Velocity-Turbidity Relationship (April, 2017)**

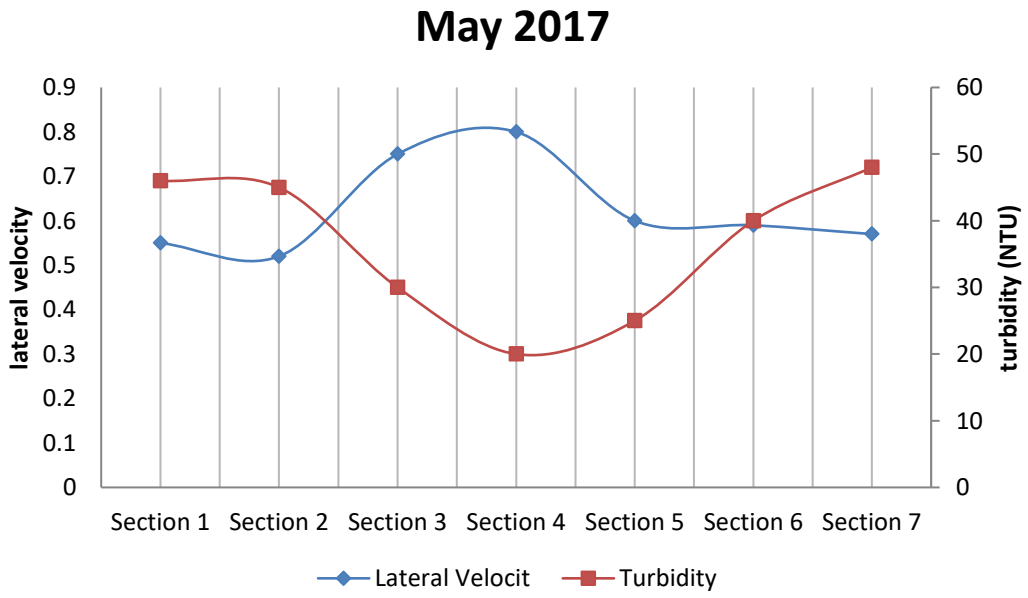



**Figure 5. Lateral Velocity-Turbidity Relationship (May, 2017)**

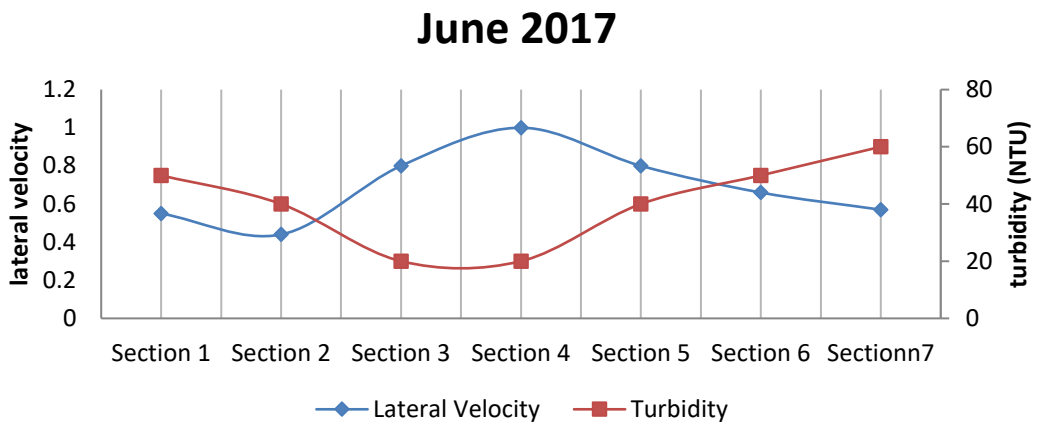



**Figure 6. Lateral Velocity-Turbidity Relationship (June, 2017)**

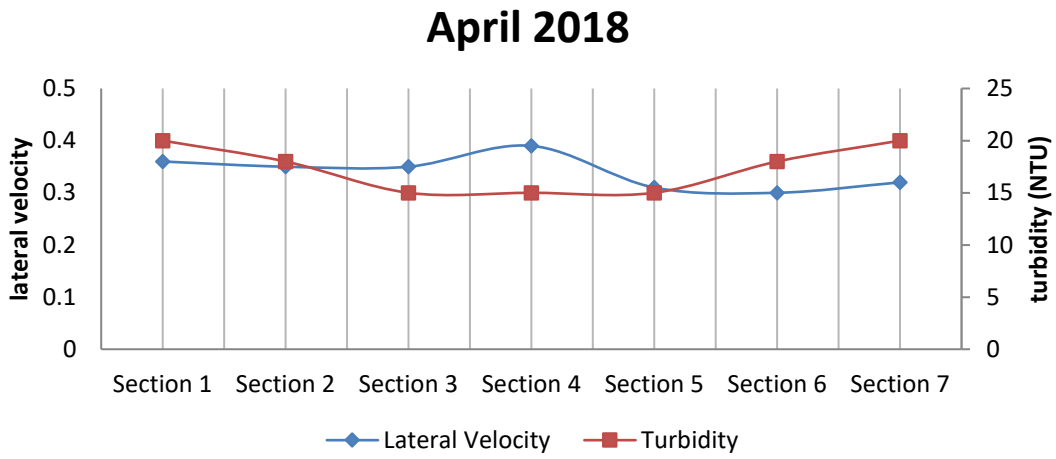



**Figure 7. Lateral Velocity-Turbidity Relationship (April, 2018)**

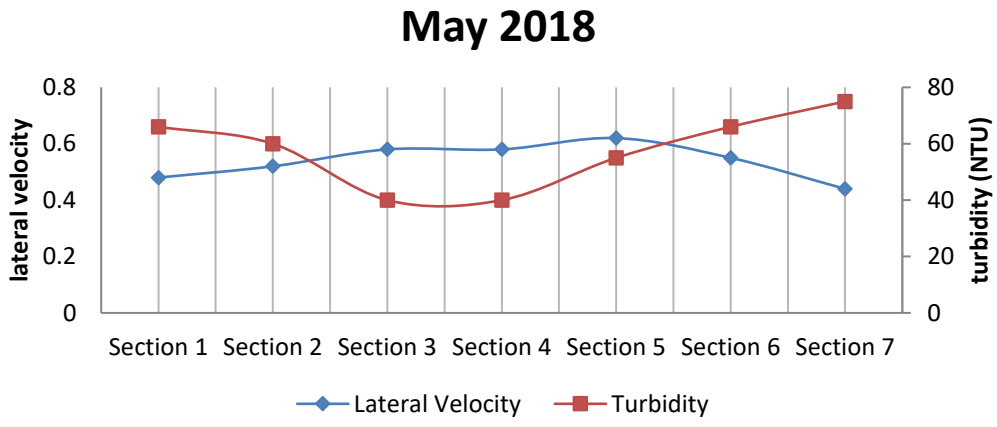



**Figure 8. Lateral Velocity-Turbidity Relationship (May, 2018)**

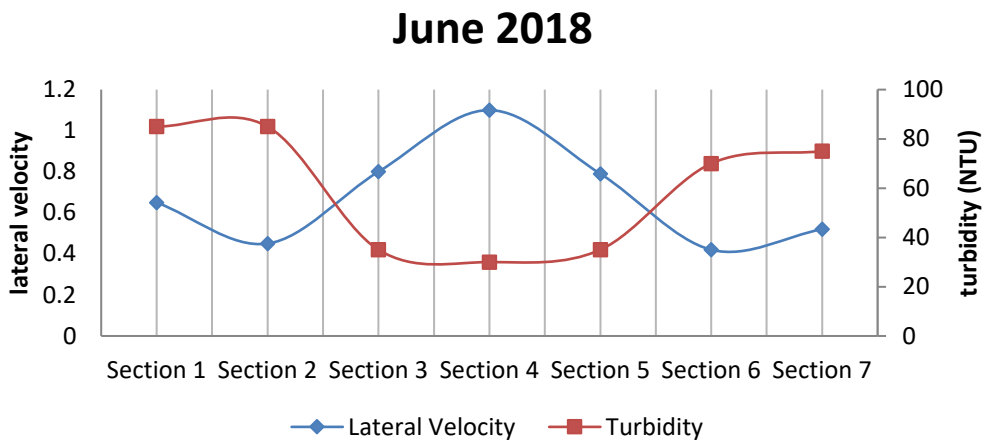



**Figure 9. Lateral Velocity-Turbidity Relationship (June, 2018)**

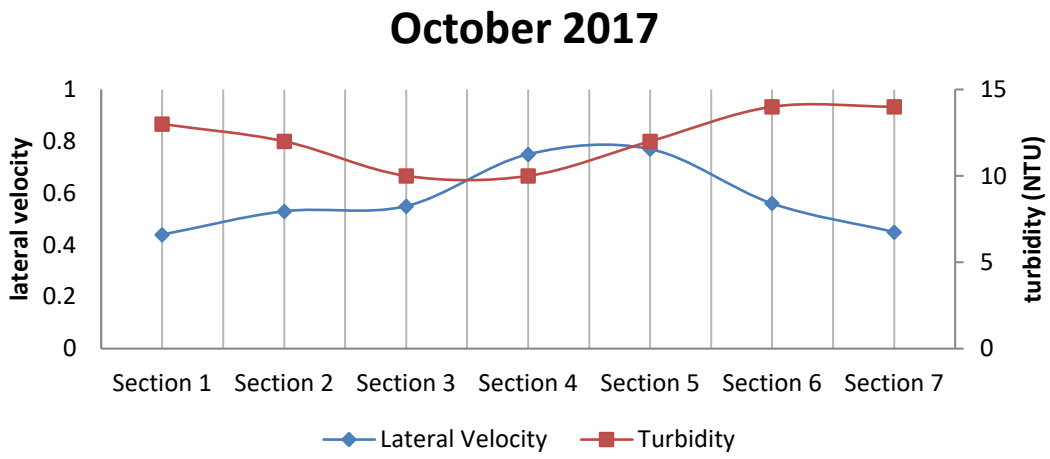



**Figure 10. Lateral Velocity-Turbidity Relationship (October, 2017)**

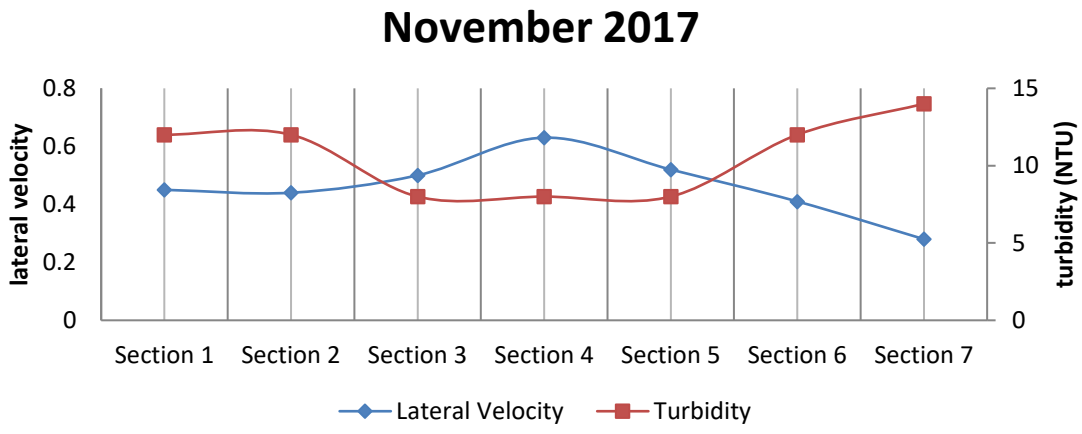



**Figure 11. Lateral Velocity-Turbidity Relationship (November, 2017)**

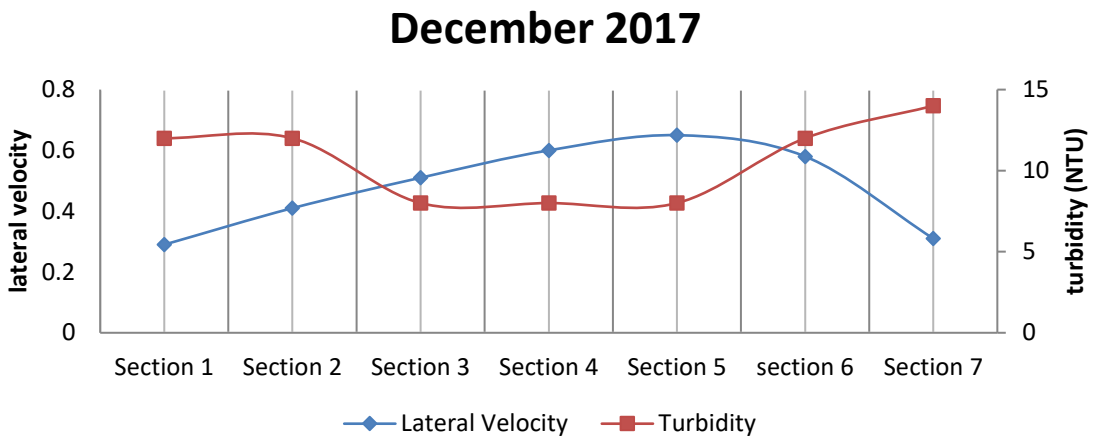



**Figure 12. Lateral Velocity-Turbidity Relationship (December, 2017)**

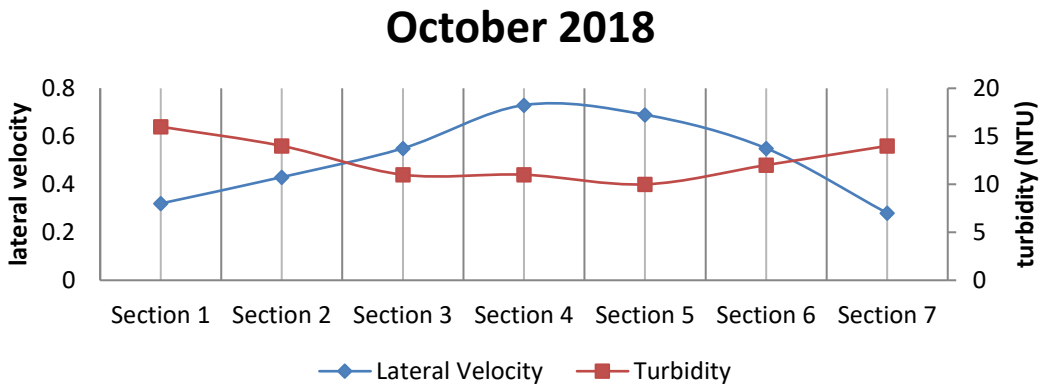



**Figure 13. Lateral Velocity-Turbidity Relationship (October, 2018).**

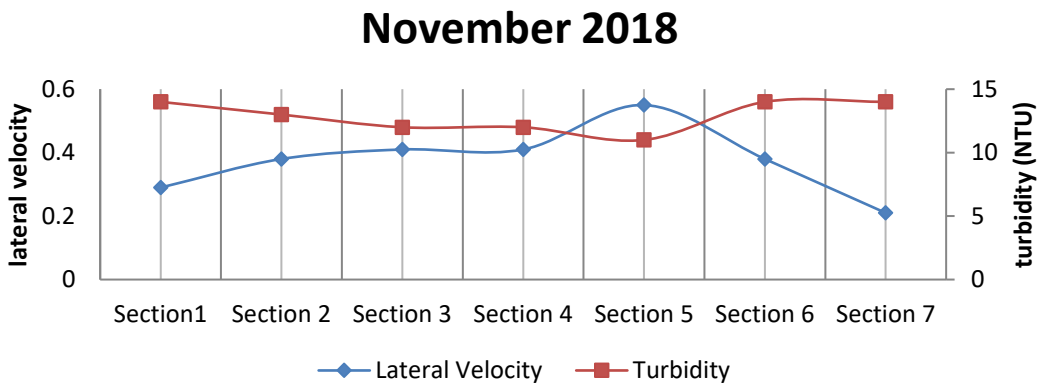



**Figure 14. Lateral Velocity-Turbidity Relationship (November, 2018)**

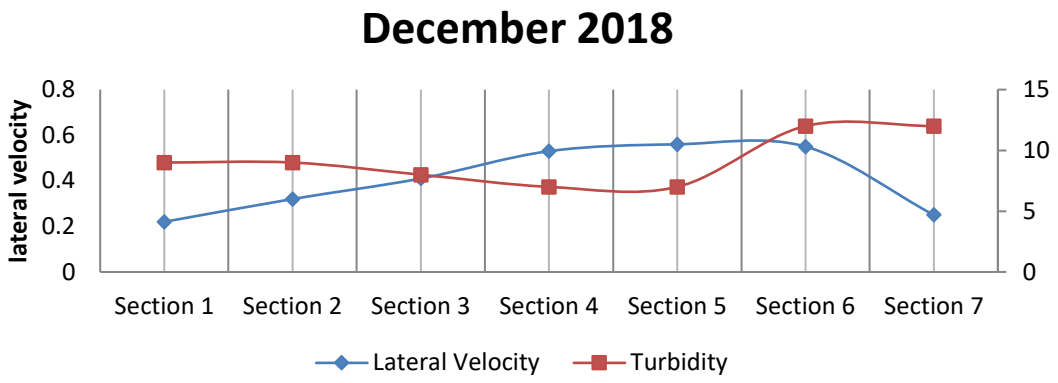



**Figure 15. Lateral Velocity-Turbidity Relationship (December, 2018)**

## DISCUSSION

The relationship between lateral velocity distribution and turbidity values obtained during the study period are plotted as shown in Figures 4 – 15. The plot generally shows that as velocity increases across the channel width, turbidity decreases. This aligns with Hudso (2003). Also in his research work Jastram (2007) observed that hydrological conditions influence sediment physical properties with results indicating that suspended solids tend to disperse with increasing stage flow. Figures 4 - 15 also demonstrate that as the velocity get to maximum at the mid-section of the river, we also get the minimum values for turbidity at the mid-section. This may lead to clearer water at the middle section than that obtained in the vicinity of banks which is attributed to a larger suspended solid concentration dispersed toward the bank/edge of the river by velocity across the channel (Ongley, 1996; Williams, 1989 in Moiliere et al., 2004).

The clear seasonal pattern of velocities increasing laterally across the channel width with corresponding decrease in turbidity is seen across all sampling data, suggesting this is a true representation of variability in the river.

## CONCLUSION

The trends of lateral velocity distributions with turbidity in this research generally showed an increase in velocity across the channel leads to decrease in turbidity. This is attributed to more concentration of suspended solids dispersed toward the bank of the river by velocity distributed across the channel. Suspended solids tends to disperse with increasing stage flow which means this is in conformity with hysteresis values as

discussed by Daramola (2023) in his research work. The maximum velocity at the mid-section of the river records the minimum value of turbidity, this is responsible for clearer water at the mid-section compared to the banks. The clear seasonal patterns of velocities increasing laterally across the channel with corresponding decreases in turbidity is seen across all sampling data, suggesting this is a true representation of variability in the river.

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