Journal of Geoscience and Environment Protection, 2017, 5, 31-42
http://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Application of Flood Routing Model for Flood Mitigation in Orashi River, South-East Nigeria

Darlington Ogbonna, Boniface Chidi Okoro, Joachim Chinonyerem Osuagwu

Department of Civil Engineering, Federal University of Technology, Owerri, Nigeria
Email: engrjcosuagwu@yahoo.com

How to cite this paper: Ogbonna, D., Okoro, B.C. and Osuagwu, J.C. (2017) Application of Flood Routing Model for Flood Mitigation in Orashi River, South-East Nigeria. *Journal of Geoscience and Environment Protection*, **5**, 31-42.
https://doi.org/10.4236/gep.2017.53003

Received: September 26, 2016
Accepted: February 12, 2017
Published: February 15, 2017

Copyright © 2017 by authors and Scientific Research Publishing Inc.
This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/
Open Access

Abstract

The study focused on the application of Flood Routing Models for Flood Mitigation in Orashi River, South-East Nigeria. Flood data were collected for the study area and subjected to statistical analysis. Three flood Routingmodels were comparatively applied including Muskingum model, Level Pool model and Modified Pul's model. Assumed routing period of 2.3 hours which helped to check excessive flood at the downstream section of the river was used. Also a dimensionless weighting factor of 0.15 was also adopted. Muskingum model and Level Pool model which represent linear relationship between measured outflow and predicted outflow for specified inflow and time change of one hour gave high and positive values of coefficients of correlations of 0.9769 and 0.9732 respectively. The Modified Pul's model which also represents a linear relationship between measured outflow and predicted outflow for specified inflow and a time change for one hour showed the highest coefficient of correlation of 0.9984 and lowest standard error of 0.1749. Though, flood models of the Muskingum method and Level Pool method exhibited good correlation, their prediction differed significantly with the corresponding models of original data sets because of high standard error and thus not adequate for field application in similar rivers. A design application was carried out using the Modified Pul's model. The values obtained for routed storage capacity was 348 m^3 while the designed capacity was 354 m^3. It is recommended that dredging of the river is carried out to achieve the designed capacity. This would eliminate the risk of flooding. The results of the study will serve useful purposes in predicting flood events and design of flood control works in similar basins.

Keywords

Flood Routing, Hydrologic Model, Parameter Estimation, Flood Mitigation, Channel Routing, Orashi River, Channel Design

1. Introduction

When it rains or snows, some of the water generated is retained by the soil depending on the degree of dryness of the soil, some are absorbed by vegetation, some evaporate and the remainder, which reaches stream channels, is called runoff. Flood is an unusual accumulation of water above the ground, which is caused by high tides, heavy rainfall or rapid runoff from paved surfaces [1]. Floods occur when soil and vegetation cannot absorb all the water; water then runs off the land in quantities that cannot be carried in stream channels or retained in natural ponds and constructed reservoirs. About 30 percent of all precipitation is runoff, and this amount may be increased by melting snow masses. Periodic floods occur naturally on many rivers, forming an area known as the flood plain. These river floods often result from heavy rain, sometimes combined with melting snow, which causes the rivers to overflow their banks; a flood that rises and falls rapidly with little or no advance warning is called a flash flood. Flash floods usually results from intense rainfall over a relatively small area. Coastal areas are occasionally flooded by unusually high tides induced by severe winds over ocean surfaces.

In Nigeria alone, it is estimated that approximately 12% of the land area is within the 100-year flood plain [2]. However, the percentage of urban and rural areas within the flood plain is much higher (about 20%). The total property value within the flood plain already exceeds hundreds of millions of Naira and is growing at a rate of about 5% per annum. Flood disasters have increased tremendously everywhere in Nigeria in recent times, resulting to loss of lives and properties, rendering, thousands homeless, and disruption of economic activities. Without flood control and adequate drainage structures, the extent of destruction and damage would increase at an even faster pace. There were over 200 floods affecting over 180 million people, 8,000 deaths and over £40 billion in damages in 2007 [3]. It is in fact the most common of all environmental hazards and it regularly claims over 20,000 lives per year and affects around 75 million people worldwide [4]. The result or implication of human development is the evolution of serious environmental problems such as flooding, deforestation, erosion, etc. These environmental problems have prevailed more in the developed and developing nations of the world and urban centers in general. Flooding particularly has caused a lot of the world. Floods cause about one third of all damages from natural disaster [5]. Flood is a body of water which rises to overflow land, which is normally submergered [6]. They are environmental hazards that occur regularly every year in different parts of the country especially during the rainy season. Flood water overflow expanse of land, submerging the land. Flood occurrence is usually due to the increase inthe volume of water within the water body such as rivers and lakes. This causes water to exceed the drainage channel capacity and overflow its bounds. Flooding occurs also when excess runoff is created owing to the inability of thesoil to infiltrate water or when the soil has reached its field capacity or saturation. The result is excess runoff which submerges the landscape. This form of flooding is particularly the case in most urban centers of the world and Nigeria in particular, where urbanization has disturbed or altered the natural process of infiltration.

The main purpose of the study was to apply flood routing models for flood mitigation in South-East Nigeria, also to compare the different methods of unsteady flow modelling using Regression approach. The study was conducted in the Orashi river watershed covering 10,000 km^2 and lying between latitudes 4˚15' and 7˚00'N and longitudes 5˚50' and 9˚00'. Natural stream flood routing was performed using different methods for solving the unsteady flow equations in order to compute stages and discharges of wave propagation. The river reach is approximately 8 km long. The channel bed is lined with mostly gravel and large boulders. The Orashi River flows past the Oguta Lake in its southwestern portion. It picks up volume and speed with the extra flow from Njaba River via Oguta Lake before flowing parallel to the River Niger.

Flood Routing impacts the magnitude of the peak discharge, the time of the peak discharge, depth and extent of flooding and environmental factors such as stream bank erosion, flood plain scour, sediment transport and deposition [7]. It is a technique of determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one or more upstream sections. The hydrologic analysis of problems such as flood forecasting, flood protection, reservoir design and spillway design invariably include flood routing. In flood studies and design, the Engineer requires estimates of both the stage and discharge along a water course resulting from passage of a flood wave. The technique of flood routing is used for this purpose [8]. The hydrograph of a flood entering a Reservoir will change in shape as it emerges out of the reservoir, because certain volumes of its water is stored in the reservoir temporarily and is let off as the flood subsides. The base of the hydrograph therefore gets broadened, its peak gets reduced, and, of course, the time of peak is delayed. The extent by which the inflow hydrograph gets modified due to the reservoir storage can be computed by a process known as flood routing [9]. Hydrograph represents how a catchment responds to rainfall [10].

2. Methodology

The data for this research were collected from National Emergency Management Agency (NEMA), FCT Abuja.

Three flood routing models were comparatively applied including Muskingum model, Level Pool model and Modified Pul's model.

2.1. Muskingum Method

The graphical procedure consists of generating graphs of $[XI + (1 - X)O]$ vs. S for different values of x, arbitrarily selected such that $0 < X < 0.5$. The optimal value of x is selected as that which produces the narrowest and straightest loop graph of $\left[XI+(1-X)O\right]$ vs. S. The available data for a series of flood events are in flow, outflow and a time increment t for every one hour (3600 s) in the calculation. The first stage of the solution was to find the average inflow and outflow, starting from the second time step. Then to find the change in the reach storage (S) which is the difference between the average inflow and outflow multiplied by the time increment t. Secondly, the cumulative volume of reach storage (S_{i+1}), where (i ranges from one to n) can be found by adding the storage at a previous time step (S_i) to the change in storage of the next time step (S_{i+1}).

Thirdly, a value of x is chosen from 0.1 to 1.0 and the storage (S) is plotted against the weighted flux $\left[XI+(1-X)O\right]$. An Excel spread sheet was used to implement the numerical procedure.

2.2. Level Pool Method

This method involved the use of Storage-Indication to route the inflow hydrograph computed for Orashi River. Storage is nonlinear function of Q.

2.3. Modified Pul's Method

Hydrographs of $\frac{2S}{\Delta t}+O$ against outflow and a hydrograph of inflow against time were developed. The solution to the Modified Pul's method was accomplished by developing a graph (or table) of [$2S/\Delta t+O$] vs. O. In order to do this, a stage-discharge-storage relationship was derived.

3. Results and Discussions

The inflow and outflow hydrographs of the river reach are tabulated in Table 1. The Attenuation which is the reduction in the peak discharge as it moves downstream could be observed from the Table resulting in a broader flat hydrograph. The value of relative percentage attenuation computed using Equation (1) was 7.09%.

$$\%\ \text{Relative attenuation}=\left[\frac{Q_{P1}-Q_{P2}}{Q_{P1}}\right]\times 1001 \quad (1)$$

where Q_{P1} and Q_{P2} are peakinflow and outflows (m^3/s) respectively.

Using the collected data, the mean storage of the river was determined through application of mass balance equation.

3.1. Results of the Basic Muskingum Method Application

The data in Table 1 was used to obtain the Muskingum routing parameters k and x for this river reach. The initial storage in the system was 715,000 m^3. By applying the storage calculation on a number of flood events storage loops were developed.

X value was taken as 0.15 since the graph of $X = 0.15$ gave a straight line (see Figure 1). Based on the value of X the Muskingum constant K which indicate the routing period was then computed from the slope of the graph; k = slope of graph = 8205 sec; which was taken as 2.3 hours approximately. This indicated the released period that would allow for effective storage andprevent excessive flood at the downstream section of the river.

Table 1. Cumulative mean storage at $X = 0.15$.

Storage	Inflow (m^3/s)	Outflow (m^3/s)	$Ix + (1 - x)O$ for $x = 0.15$
715000	93	85	86.2
812200	137	91	97.9
1064200	208	114	128.1
1523200	320	159	183.15
2189200	442	233	264.35
2965000	546	324	357.3
3742600	630	420	451.5
4424800	678	509	534.35
4932400	691	578	594.95
5229400	675	623	630.8
5308600	634	642	640.8
5179000	571	635	625.4
4837000	477	603	584.1
4329400	390	546	522.6
3778600	329	479	456.5
3209800	247	413	388.1
2628400	184	341	317.45
2093800	134	274	253
1649200	108	215	198.95
1312600	90	170	158

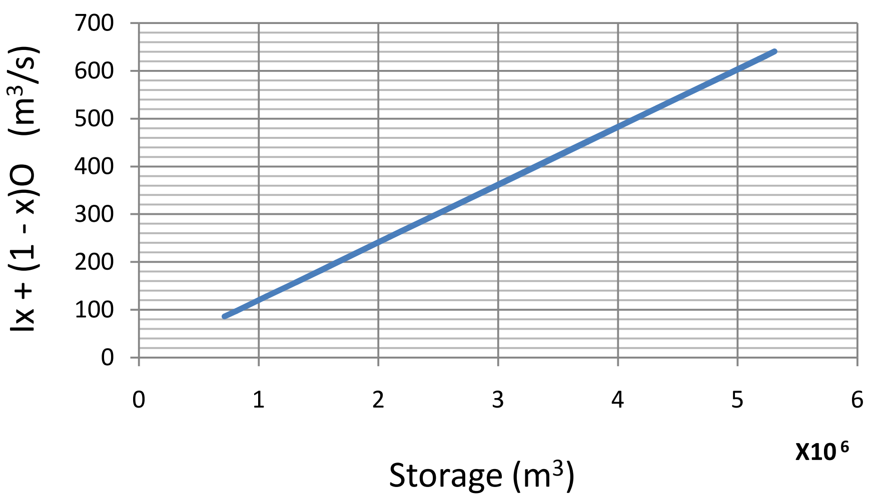

Figure 1. Plot of Weighted flux $[xI + (1 - x)O]$ against Storage.

3.2. Determination of Outflow Values of Orashi River Using the Muskingum Routing Equation

The Muskingum routing procedure was used to route the hydrograph in Table 1.

Since $\Delta t = 1$ hr, as suggested by the inflow data. However, check that with the selected Δt, parameter values meet restrictions: $X < 0.5\ \Delta t/k < 1 - X$.

For this case: $0.15 < (0.5)\ (3600)/8205 < 1 - 0.15$. Thus, OK. Proceed with routing, by obtaining C_1, C_2, and C_3 using Equations (7) - (9) respectively.

Since K = 2.3 hours, time interval = 1 hours, and $X = 0.15$

Values of K, t, and X into the Equations (7) - (9)

Applying Muskingum routing Equation:

$$O_{i+1} = C_1 I_i + C_2 I_{i+1} + C_3 O_i \tag{2}$$

$$S = K\left(\frac{I}{2} + \frac{O}{2}\right) \tag{3}$$

But we also have

$$\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2} = \frac{S_2 - S_1}{\Delta t} \tag{4}$$

Note: Δt = 1 hour = 3600 sec.

$$S = K\left[XI + (1?\ X)O\right] \tag{5}$$

where S is storage (m^3), K is the travel time in seconds between the two channel sections, O (m^3/s) is the outflow (m^3/s), I is the inflow (m^3/s), and x is a dimension less factor between 0.0 and 0.5 that weights the influence of the inflow and outflow hydrograph to thestorage within the reach.

$$O_{i+1} = C_1 I_i + C_2 I_{i+1} + C_3 O_i \tag{6}$$

where:

$$C_1 = \frac{\Delta t - 2KX}{2K(1 - X) + \Delta t} \tag{7}$$

$$C_2 = \frac{\Delta t + 2KX}{2K(1 - X) + \Delta t} \tag{8}$$

$$C_3 = \frac{2K(1 - X) - \Delta t}{2K(1 - X) + \Delta t} \tag{9}$$

C_1, C_2, and C_3 are also known as Courant factors.

The results using Muskingnum method to determine the outflow data are presented in Table 2.

3.3. Level Pool Routing Method

This hydrograph flows into a reservoir whose storage and discharge characteristics are as presented in Table 3. The initial storage in the system is 0 m^3 and the initial outflow is 85 m^3/s.

For a given set of conditions, the outflow is unique, independent of how that stage is achieved. The peak outflow occurs when the outflow hydrograph intersects the inflow hydrograph.

Hydrographs of $\frac{2S}{\Delta t} + O$ against outflow and inflow against time were prepared. The concept involved development of the function

$$\frac{2S}{\Delta t} + O = f(O)$$

And solving sequentially for every time step.

The following data were relevant in preparing the Table;

- Elevation vs. Storage

- Elevation vs. Outflow discharge and hence storage vs. outflow discharge.
- Inflow hydrograph
- Initial values of inflow, outflow O, and storage S at time $t = 0$.

3.4. Modified Pul's Method

The results using Pul's method to determine the outflow data for the River are presented in Table 4.

Again, the general continuity equation was adopted. However, in this case, a finite difference form of the continuity equation was used. A graph of $[2S/\Delta t + O]$ vs. O was derived. In order to do this, a stage-discharge-storage relationship was developed and plotted as a curve. The basic assumption is that a unique and single-valued stage-storage-outflow relationship exists for each reach.

A Summary of measured inflows/outflows and predicted outflows from the three models are presented in Table 5.

The results indicate that Level pool method gave highest value of predicted peak outflow (657 m^3/s) while the modified Pul's method gave the least value (629 m^3/s). The derived Regression models are presented in Table 6.

The weighing factor, X value was taken as 0.15.

Based on the value of X, the storage constant K which indicate the routing period was then computed from the slope of the graph; k = slope of graph = 8205 sec; which was taken as 2.3 hours approximately.

Table 2. Prediction of outflow data of Orashi using Muskingum method.

Time (hr)	Inflow (m^3/s)	C_1I_i	C_2I_{i+1}	C_3O_i	Outflow (m^3/s)
1	93				85.000
2	137	5.859	47.128	55.149	103.392
3	208	8.631	71.552	64.12465	141.494
4	320	13.104	110.08	85.57444	207.090
5	442	20.16	152.048	123.7938	295.012
6	546	27.846	187.824	175.529	390.612
7	630	34.398	216.72	231.981	482.751
8	678	39.69	233.232	286.4777	559.193
9	691	42.714	237.704	331.724	612.020
10	675	43.533	232.2	363.0002	638.661
11	634	42.525	218.096	378.7688	639.347
12	571	39.942	196.424	379.1582	615.499
13	477	35.973	164.088	365.0058	565.052
14	390	30.051	134.16	335.0846	499.287
15	329	24.57	113.176	296.0823	433.823
16	247	20.727	84.968	257.2602	362.952
17	184	15.561	63.296	215.2324	294.088
18	134	11.592	46.096	174.395	232.082
19	108	8.442	37.152	137.6252	183.219
20	90	6.804	30.96	108.649	146.413

Table 3. Orashi River results of outflows for various inflows using Level Pool method.

Time(hr)	Inflow (m^3/s)	Outflow (m^3/s)	$I_i + I_{(i+1)}$ (m^3/s)	$\frac{2S}{\Delta t}+O$ (m^3/s)	$\frac{2S_i}{\Delta t}+O_i$	$\frac{2S_{(i+1)}}{\Delta t}+O_{i+1}$	O (m^3/s)
1	93	85	93	482	387.6	405.2	77.3
2	137	91	230	542	501.9	617.6	101.6
3	208	114	345	705	734.7	846.9	135.3
4	320	159	528	1005	1045.4	1262.7	201.9
5	442	233	762	1449	1380.3	1807.4	295.4
6	546	324	988	1971	1706.8	2368.3	396.2
7	630	420	1176	2499	1981.3	2882.8	492.9
8	678	509	1308	2967	2173.6	3289.3	572.3
9	691	578	1369	3318	2276.1	3542.6	626.1
10	675	623	1366	3528	2276.6	3642.1	657.3
11	634	642	1309	3591	2229.2	3585.6	641.5
12	571	635	1205	3512	2042.7	3434.2	623.8
13	477	603	1048	3290	1812.3	3090.7	569.5
14	390	546	867	2951	1583.9	2679.3	497.2
15	329	479	719	2578	1333.4	2302.9	431.4
16	247	413	576	2196	1079.8	1909.4	360.7
17	184	341	431	1801	862.1	1510.8	287.5
18	134	274	318	1437	682.4	1180.1	224.4
19	108	215	242	1131	549.5	924.4	174.9
20	90	170	198	899	−282.6	747.5	141.3

Table 4. Results of the Modified Pul's method for Orashi River.

Time (h)	Inflow, I (m^3/s)	$I_n + I_{n+1}$	$2S_n/dt - O_n$	$2S_n/t + O_{n+1}$	O_{n+1}
1	93	230	59	93	17
2	137	345	183	289	53
3	208	528	331	523	96
4	320	762	545	860	157
5	442	988	829	1307	239
6	546	1176	1153	1817	332
7	630	1308	1477	2329	426
8	678	1369	1767	2785	509
9	691	1366	1989	3136	573
10	675	1309	2128	3355	613
11	634	1205	2180	3437	629
12	571	1048	2147	3385	619
13	477	867	2027	3195	584
14	390	719	1835	2894	529
15	329	576	1620	2554	467
16	247	431	1392	2196	402
17	184	318	1157	1823	333
18	134	242	935	1475	270
19	108	198	747	1177	215
20	90	90	600	945	173

Table 5. Summary of Orashi River predicted outflow by Muskingum, Level Pool Routing and Modified Pul's methods.

Time (hr)	Measured inflow (m^3/s)	Measured Outflow (m^3/s)	Predicted Outflow by Muskingum method (m^3/s)	Predicted Outflow by Level Pool routing (m^3/s)	Predicted Outflow by Modified Pul's (m^3/s)
0	0			85	0
1	93	85	85	77	17
2	137	91	103	102	53
3	208	114	141	135	96
4	320	159	207	202	157
5	442	233	295	295	239
6	546	324	391	396	332
7	630	420	483	493	426
8	678	509	560	572	509
9	691	578	612	626	573
10	675	623	639	657	613
11	634	642	639	641	629
12	571	635	615	624	619
13	477	603	565	569	584
14	390	546	499	497	529
15	329	479	434	431	467
16	247	413	363	361	402
17	184	341	294	288	333
18	134	274	232	224	270
19	108	215	183	175	215
20	90	170	146	141	173

Table 6. Summary of predicted/measured outflow models for Orashi River.

S/N	Method	Regression equation	Correlation coefficient (cc)	Standard error
1	Muskingum Method	Y = 0.964X + 14.67	0.9769	0.4262
2	Level Pool method	Y = 0.993X + 5.159	0.9732	0.46499
3	Modified Pul's method	Y = 1.019X − 17.83	0.9984	0.1749

This indicates the released period that will allow for effective storage and prevent excessive flood at the downstream section of the river.

The developed parameter estimation methodology was applied to determine the K, and X values for flow routing corresponding to the river inflow-outflow. The value S of K and X was used to route the flood using three different methods.

From Table 5 and Table 6, it is discovered that the Modified Pul's method gave a more accurate result of predicted outflow. Modified Pul's method should therefore be adopted as a model for flood mitigation in Orashi River.

3.5. Design Application of the Modified Pul's Model to Orashi River

The characteristics of Orashi River Channel are presented in Table 7.

$$Storage = (I - O)\Delta t$$

where I = Inflow (m^3/s), O = Outflow (m^3/s), Δt = time (s)

Inflow (I) and outflow (O) are functions of time (t), and the storage (S) is a function of the water surface elevation (H) which changes with time (t).

$$\text{Using} Y = 1.019x - 17.83 \quad [11] \quad (10)$$

where, Y = predicted outflow (m^3/s) of Orashi river, x = measured outflow (m^3/s) of Orashi river.

The values of measured outflow are shown in Table 5.

Since Inflow is greater than outflow, there will be no flood. A channel that can store 1.26×10^6 m^3 is recommended.

The river reach is approximately 8 km long and a sharp crested weir is located 3.93 km from the upstream section of the river. The channel bed is lined with mostly gravel andlarge boulders.

The Orashi River has a trapezoidal cross-section with no recent floodplain [12]. Due to the weir transition downstream the river, a cross-section which is locatedat the upstream end is only considered in modelling.

The nature of the flow in the river Orashi is non-uniform, gradually varied unsteady flow. To determine the regime of flow upstream of the channel, Equation 11wass used to calculate the Froude Number.

$$Fr = \frac{V}{\sqrt{gy_1}} \quad (11)$$

$$V = Q_0 / (b + zy_0) y_0 \quad [13] \quad (12)$$

where, V is the average velocity in (m/s) which can be defined from Equation (13), y_1 is depth of flow upstream in m and g = 9.81 m/s^2.

In channel routing where a non-uniform flow is the case, the average velocity can bedetermined using a reference discharge and the channel cross-sectional area as in Equation (12). To determine the normal depth y_0, a reference discharge is selected for a maximumflood event and can be calculated from Equation (13)

Reference discharge, Q_0:

$$Q_0 = Q_b + \left(0.5\left(Q_p - Q_b\right)\right) \quad (13)$$

where Q_b = Minimum discharge in (m^3/s), Q_p = Peak discharge in (m^3/s)

$$Q_b = 69\, m^3/s,\ Q_p = 636\, m^3/s$$

$$Q_0 = 69 + [0.5(636 - 69)] = 354\, m^3/s$$

Therefore, reference discharge is 354 m^3/s.

Table 7. Channel parameters of orashi river.

Length (L) m	Bedwidth (b) m	Sideslope (z)	Average Bed slope (S_0)
8000	22.86	1.25	0.00047

With the known values of reference discharge (Q_0), Manning roughness coefficient (n), Channel bed width and bottom slope, the value of Φ can be determined from Equation (13)

$$\varnothing = \left(Q_0 n\right) \Big/ \left(b^{\frac{8}{3}} s_0^{\frac{1}{2}}\right) \tag{14}$$

$$\varnothing = \left(354 \times 0.04\right) \Big/ \left[\left(22.86\right)^{\frac{8}{3}} \left(0.00047\right)^{0.5}\right]$$

$$\varnothing = 0.16 m^2/s$$

Upon consulting Table 7 with the above value ($\varnothing = 0.16 m^2/s$) and with z = 1.25 the value of $y_0/b \approx 0.54$, hence, y_0 = 12.34 m, where, b = 22.86 m.

The area of flow A, can then be obtained from Equation (14)

$A = [b + (zy_0)]y_0 \times 15$

$A = [22.86 + 1.25(12.34)] \times 12.34$

$A = 472.44\ m^2$

Hence, Velocity, $V = (Referencedischarge)/Area$

$$V = 354/472.44$$

$$V = 0.749 m/s$$

Therefore,

$$Fr = 0.14 < 1$$

This indicates that the channel has a mild slope and the flow is characterised as gradually varied subcritical flow. The wave celerity (c) can be obtained from the relationship

$$c = \beta V 16$$

where β is assumed to be 0.5 and velocity, V = 0.749

$$C = 0.5 \times 0.749 = 0.375 m/s$$

Therefore, storage = area × velocity × time = 1272700.8 m^3.

4. Conclusions

Based on the result obtained from the Orashi flood routing studies, the following conclusions can be made.

- Three sets of mathematical modeling of Orashi river flood routing based on regression-correlation approach were analyzed namely:
  1) Muskingum routing model
  2) Level Pool routing model
  3) Modified Pul's model
- In the Modified Pul's model, very high and positive values of coefficient of correlation of 0.9984, as well as a standard error of 0.1749 was obtained. This model provided the best-fit curve for the field data.
- Plots of Modified Pul's model are in conformity with the field data. They equally agree with literature as follows:

1) During the flood routing, the rate of outflow from the reservoir did not exceed the maximum projected rate of inflow, to the extent possible, which will prevent flooding impacts downstream of the reservoir from being more severe.

2) During the determination of routing parameter, the courant factor did not exceed one, using Modified method.

Since Modified Pul's method gave the most accurate result of predicted outflow, the method should be adopted as a model for flood mitigation in Orashi River. The design capacity based on this model is 354 m^3 which is higher than the routed storage capacity of 348 m^3. To guarantee a check against flooding, it is recommended that dredging is carried out to achieve the designed capacity.

References

[1] Kulandaiswamy, V.C. (2006) A Note on Muskingum Method of Flood Routing. *Journal of Hydrology*, **4**, 273-276. https://doi.org/10.1016/0022-1694(66)90085-0

[2] NEST (1991) Flood Hazard Assessment, Management and Mitigation Measures. Nigerian Environmental Study/Action Team NEST Publication, Ibadan, 67-70.

[3] Pitt, P.H. (2007) Lessons from 2007 Floods. Pitt Review Report, Lancaster.

[4] Smith, K. (2006) Environmental Hazards. Routledge, London, 301-314.

[5] Akin, T. (2009) Strategies for Combating Urban Flooding in a Developing Nation: A Case Study from Ondo, Nigeria. *Environmentalist*, **14**, 57-62.

[6] NEST (1991) National Environmental Survey/Action Flood Report.

[7] King, L. (2014) Flood Routing. National Engineering Handbook. US Department of Agriculture. Part 630 chap 17.

[8] Chadwick, A. and Morfeit, J. (1993) Hydraulics in Civil and Environmental Engineering. E & F N Spon, London, p. 317.

[9] Garg, S.K. (2008) Irrigation Engineering and Hydraulic Structures. Khanna Publishers, Delhi, p. 937.

[10] Han, D. (2010) Concise Hydrology. Bookboon.com Ltd., London, 119-124.

[11] Ogbonna, O. (2015) Application of Flood Routing Model for Flood Mitigation in Orashi River, South-East Nigeria. PhD Thesis, Federal University of Technology, Owerri. (Unpublished)

[12] NEMA (2012) Evaluation of Flood Hazards. Prepared by EnvironmentalImpact Assessment Department, 13-16.

[13] Subramanya, K. (2009) Flow In Open Channels. 3rd Edition, Tata Mc Grow-Hill, New Delhi, 344-351.

Scientific Research Publishing

Submit or recommend next manuscript to SCIRP and we will provide best service for you:

Accepting pre-submission inquiries through Email, Facebook, LinkedIn, Twitter, etc.
A wide selection of journals (inclusive of 9 subjects, more than 200 journals)
Providing 24-hour high-quality service
User-friendly online submission system
Fair and swift peer-review system
Efficient typesetting and proofreading procedure
Display of the result of downloads and visits, as well as the number of cited articles
Maximum dissemination of your research work

Submit your manuscript at: http://papersubmission.scirp.org/
Or contact gep@scirp.org