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- Stochastic Finite Element
- Analysis for Transport Phenomena
- Housing Acceptability Factor
- Hydrological Modeling with HEC

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By Er. Narayan Prasad Gautam

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HYDROLOGICALMODELINGWITHHEC-HMSINDIFFERENTCHANNELSECTIONSINCASEOFGANDAKIRIVERBASIN

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Er. Narayan Prasad Gautam

Abstract- The conceptual and physically based models can be categorized as lumped, semi-distributed and distributed. Lumped model treats the catchment area as one or more homogeneous land segments where the inputs are averaged. Distributed model explicitly represents the spatial variability by dividing the catchment into grids and modeling each grid cell individually. Semi distributed model is a conceptual model that bridge the gap between lumped and distributed models. It utilizes conceptual relationships for hydrological processes that are applied to several relatively homogeneous sub-areas of the catchment area. The main objective of this research paper is to assess the effect of channel geometry of basin at the outlet of basin in semi-distributed rainfall-runoff modeling and to determine performance of the different channel sections that will produce the best results for that basin. From study on the Gandaki river basin, the efficient section for routing depends upon the purposes of the simulating rainfall runoff process. Trapezoidal section is more efficient than other sections for determination of flood forecasting and both trapezoidal and triangular section is efficient for simulating to determine the total annual runoff volume.

Keywords: semi-distributed, geometry, modeling, simulation, Gandaki basin, trapezoidal section, routing.

I. Introduction

Hydrologic models have been developed to simulate the large river basin water supply, flood hydrograph and small urban or natural watershed runoff. The success of development projects (bridge, culverts and sewers) depends on the availability of accurate information describing the volume of runoff that a particular watershed will generate in response to a certain depth of precipitation falling on the basin. The aim of any watershed rainfall-runoff model is to provide a hydrograph showing the variation of volume flow rate of direct runoff over time at a particular point of interest, usually taken as the watershed outlet. Hydrographs produced by models are used directly or in conjunction with other software for the study of water availability, urban drainage, flood forecasting, future urban impact, flood damage reduction, floodplain regulation and systems operation[8] and the performance of hydrographs obtained in different channel section.

The conceptual and physically based models can be categorized as lumped, semi-distributed and distributed. Semi distributed models is a conceptual model that bridge the gap between lumped and distributed models. They utilize conceptual relationships for hydrological processes that are applied to several relatively homogeneous sub-areas of the catchment area[4]. Hydrological simulation could be performed using lumped to physically distributed hydrological models. Since lumped model has no physical meanings and distributed model is difficult and quite sophisticated as it requires large number of parameters, semi-distributed model with lesser set of available data is commonly used as it requires less number of parameters. Semi-distributed hydrological models generally have advantage of short calculation time, comparative low calibration needs and high model efficiency.

Spatial discretization either in terms of grid cell size or number of sub divisions of watersheds in hydrological modeling is an essential issue. The optimal spatial scale can be adapted to the modeling objectives for determination of the dominant hydrological processes (Dehotin and Brand, 2008). It has been observed that the sub basin scale have various effects on runoff simulation such as peak time, total runoff, temporal distribution of discharge, flow components and response processes [1]. Therefore, stabilized number of sub basin should be identified for the efficient simulation of hydrological behaviors of catchment using hydrological models. It is more cumbersome job to simulate the river basin considering the different geometries of channel section and various numbers of subdivisions of basin simultaneously and analyzing by semi distributed hydrological model. Definitely it increases the input data preparation effort and the subsequent computational evaluation[6]. The effect of watershed subdivision (or discretization) on the prediction accuracy of hydrological models on 12 watersheds was evaluated by Hromadka et al. (1988). They used a simple model based on the unit hydrograph method. Since most of rainfall runoff models achieve their greatest accuracy for smaller to medium sized watershed. It is beneficial to divide the main watershed into sub-watershed to increase the accuracy of model results.

Furthermore, stream flow may be significantly affected by the difference in soil, vegetation, land use or

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topography of the watershed and geometry of channel. The flow of water through soil and stream channels of watershed is a distributed process because the flow rate, velocity and depth vary in space throughout the watershed. Estimate of the flow rate or water level at important location in the channel system can be obtained using a distributed flow routing model. This type of model is based on partial differential equations (the Saint Venant equations for one dimensional flow) that allow the flow rate and water level to be computed as functional space and time.

Depending upon the drainage pattern, geometry of the channel and existence of dams, reservoirs, bridge etc. within the basin is to be routed during its journey to the watershed outlet to compute out flow hydrograph on the outlet reach. Stream flow may be significantly affected by the geometry of the channel of the stream. In this paper, Channel flow is simulated using a channel geometry relationship reflective of the natural channel shape. Alternative channels (Trapezoidal, rectangular and triangular) will be used to determine the output hydrograph of the given watershed at the end (outlet) of the basin. The simulated hydrographs will be compared with the observed hydrograph of the given basin at the outlet at different channel geometries (Rectangular, Trapezoidal and Triangular) on the routing process also finding the channel cross section of the stream give the best results.

II. Scope of the Study

The scope of this research paper, as per the objectives, contains application of the semi-distributed model to simulate the channel geometries on watershed. The study deals with pre processing and spatial analysis of the Digital elevation model (DEM) for the automated delineation of sub basins and river. GIS extension tools will be used for the extraction of physical characteristics of sub basin and rivers.

Required other model parameters such as daily precipitation, evapotranspiration are collected from department of hydrology and metrology of Nepal and analyze by thiessen polygon method. Hydraulic conductivity, suction head, initial moisture deficit and roughness coefficient are extracted on the basis of soil and land use map of the study area and these models parameters are used in HEC-HMS model simulation.

Hydraulic parameters are routed by using kinematic wave method for overland and Muskigum cunge method for channel routing. Simulated flow is compared with the observed flow at the outlet of the basin and analyzes the performance of the result to achieve the objective of the study[14].

III. Principle and Tools

a) *Infiltration process*

Infiltration is the vertical entry of the water into the soil surface and its subsequent vertical motion through the soil profile. It is the most important loss process. The major factors that influence the infiltration rates are soil texture, vegetation cover, the soil surface condition, land use, soil porosity, soil hydraulic conductivity and soil moisture content. Some of the popular infiltration models are the model developed by Green and Ampt (1911), Horton (1933, 1939), and Philip (1957).

Green and Ampt (1911) developed an infiltration loss model based on the physical theory in which the wetting front moves vertically downward. The wetting front is a sharp boundary dividing the soil with saturated moisture content from the underlying soil with lesser moisture content. The water moves vertically downwards from saturated soil to unsaturated soil. Horton (1933, 1939) developed an empirical equation for infiltration capacity based on the infiltration rate[15] begins at some rate fo and then decreases exponentially until it reaches a constant saturated infiltration rate fc Philip (1957) solved Richard's equation and proposed an equation to estimate the infiltration capacity.

b) *Parameters for the Green & Ampt equation*

Required parameters for the Green and Ampt model to estimate the excess runoff are the hydraulic conductivity of the soil at saturation, volumetric moisture deficit at the beginning of rainfall, and wetting front capillary action.

Table 3.1 : Green-Ampt infiltration parameter for various soil classes

Soil class	Porosity (η)	Effective porosity θ(c)	Wetting front soil suction head Ψ(cm)	Hydraulic conductivity K(cm/h)
Sand	0.437 (0.374-0.5)	0.417 (0.345-0.480)	4.95 (0.97-25.36)	11.78
Loamy sand	0.437 (0.363-0.506)	0.401 (0.329-0.473)	6.13 (1.35-27.94)	2.99
Sandy loam	0.453 (0.351-0.555)	0.412 (0.283-0.541)	11.01 (2.67-45.47)	1.09
Loam	0.463 (0.375-0.551)	0.434 (0.334-0.534)	8.89 (1.33-59.38)	0.34
Silt loam	0.501 (0.42-0.582)	0.486 (0.394-0.578)	16.68 (2.92-95.39)	0.65

Sandy clay loam	0.398 (0.332-0.464)	0.33 (0.235-0.425)	21.85 (4.42-108.0)	0.15
Clay loam	0.464 (0.409-0.519)	0.309 (0.279-0.501)	20.88 (4.79-91.10)	0.10
Silty clay loam	0.471 (0.418-0.524)	0.432 (0.347-0.517)	27.3 (5.67-131.5)	0.10
Sandy clay	0.43 (0.37-0.49)	0.321 (0.207-0.435)	23.9 (4.08-140.2)	0.06
Silty clay	0.479 (0.425-0.533)	0.423 (0.334-0.512)	29.22 (6.13-139.4)	0.05
Clay	0.475 (0.427-0.523)	0.385 (0.269-0.501)	31.63 (6.39-156.5)	0.03

Source: [1]

c) Routing

Routing is simply a method of translating the hydrograph in time and accounting for the hydrographs change in shape as it moves through the stream system. Hydrologic routing accounts for changes in the time distribution of volume and employs a relatively straightforward computation procedure. There are many methods available within the semi-distributed mode (HEC-HMS) as Clark unit hydrograph, Kinematic wave, Mod Clark, SCS unit hydrograph, Snyder hydrograph and User specified unit hydrograph. Among them kinematic Wave method is selected for both overland flow model and stream channel routing to accomplish the objectives of study.

For hydrograph routing, Kinematic Wave method is selected. Channel properties are extracted with the help of Geographical Information System (GIS) tool with the extension HEC Geo-RAS. Manning's roughness coefficient (n) is taken from the soil map.

d) Tools for model

i. *Arc view GIS*

GIS is a powerful tool for simulation and modeling of water resources engineering. Arc view GIS developed by ESRI that is equipped with excellent graphical user interface that enables visualization, exploring and the analysis of spatial data[2]. it has capable of displaying, viewing, editing vector dataset also the facility to display tables, charts, layouts associated with the shape files. The processing, modeling, visualization and interpretation of grid based raster data can be performed using the spatial analyst extension[2].

ii. *HEC-GeoHMS*

HEC-GeoHMS uses DEMs to determine watershed boundaries and flow path by analyzing the direction of steepest descent at each gird cell also watersheds are automatically defined by HEC-GEOHMS based on the user defined threshold for water shed size and at stream confluences. The user can manually add a watershed by defining an outlet on the stream network[3], and user can merge connected watershed. It creates the basic input for the HEC-HMS.

iii. *HEC-GEORAS*

For implementing the kinematic model in HECHMS the description of channel shape (triangular, rectangular or trapezoidal), principle dimension of channel cross section and channel side slope. HEC-GeoRAS is an ArcView GIS extension specifically designed to process geospatial data for use with the Hydrologic Engineering Center's River Analysis System (HEC-RAS). To create the import file, an existing Digital Terrain Model (DTM) of the river system in the TIN (Triangulated Irregular Network) format is required.

IV. Study Area

a) Description of Study Area

Gandaki river basin called also Narayani river basin of Nepal is situated in the Western and Central development Region between latitudes 27.63 N to 29.87N and 82.83 E to 86.79 E. It has the elevation from 73 m to about 7163 m which extends from the Himalayan range to the Nepal to India border.

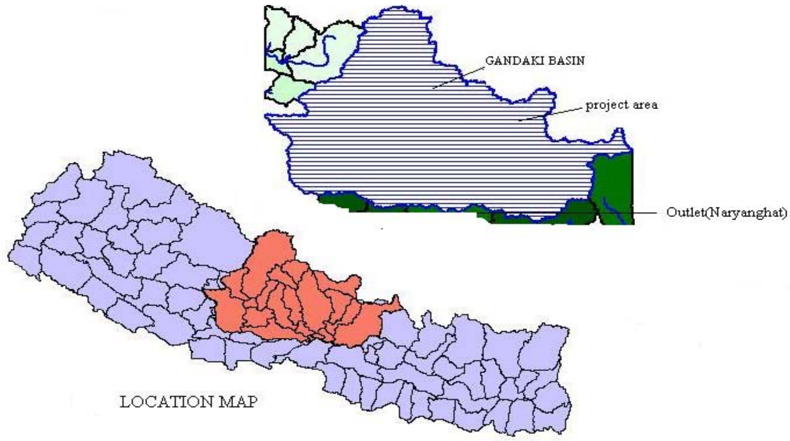

Fig. 4.1 : Location Map of the study

It covers 19 districts of Nepal and some area of China also. The catchments area of the basin is 30162 sq Km in Nepal and 10590 sq. Km in China. The Major river in this basin are Kali Gandaki river originated from Mustang district. The major tributaries forming the Sapta Gandaki in Gandaki river basin are Kaligandaki, Seti river, Modi river, Madi river, Budhi Gandaki, Marshyandi and Trisuli. Among them, three main confluences of the Trisuli, Seti and Kaligandaki are the narayani in east of the region, Downstream of the confluence, the river is named as narayani whereas in the upstream it is named after the name of three major tributaries namely Trisuli, Marsyandi and Seti. The location map of the studied basin is shown in fig: 4.1.

V. Methodology

The objective of the study is to assess the effect of channel geometries in semi-distributed rainfall-runoff modeling with the help of input data including precipitation, discharge, DEM (digital elevation model), soil, land use and metrological data. Kinematic wave method is used both catchment and channel routing. To fulfill this objective, the HEC-HMS Model is used. Finally, the output is compared with the observed discharge at selected gauging of the basin. The conceptual frame work for overall methodology is followed by GIS based processing and Rainfall runoff modeling.

a) *GIS Based Processing*

Topographical data, soil data and meteorological data are common inputs for GIS based processing. The type of data used in this study and their sources are shown in table 5.1.

Table 5.1 : Data used in the study

Data Type	Resolution	Source
DEM	100m Horizontal, 1m Vertical	STRM, U.S.A.
Soil and Landuse	250 m	DoS, Nepal
Rainfall-runoff	Average daily	DHM, Nepal
Temperature and Humidity	Average daily	DHM, Nepal

b) *Topographical Data (DEM) and its processing*

Before performing any spatial analysis of a river basin we should first prepare a three dimensional replica of the catchment. Digital elevation model (DEM) is one of such 3D model, which is prepared by generating a surface passing through the nodes of a triangular irregular network (TIN). DEM is a sampled array of elevations for a number of ground positions at regularly spaced intervals. DEM describes the elevation of any point in the study area in digital format and contains the information on drainage, crest and breaks of slopes. DEM is the primary spatial data source based on which GEOHMS extract catchments boundary, topographic variables such as basin geometry, stream networks, slope, aspect, flow direction, etc. The work was made simpler by the availability of 100m resolutions DEM of whole Nepal in free downloadable web site. The DEM for Gandaki basin was clipped out. Stream and watershed delineation has been conducted using HEC-GeoHMS Extension. This extension uses 8-Direction pour point Model to determine flow path.

c) *Hydro-Meteorological Data*

Hydro-Meteorological, vegetation and soil data of Gandaki watershed was collected from Department of Hydrology and Meteorology. Meteorological data used in this study includes precipitation, maximum and minimum temperature, maximum and minimum relative humidity data of daily duration.

VI. Model Execution

a) Digital Elevation Model (DEM)

The DEM is the important input to describe the topography of the watershed on the based of semi distributed model. The DEM used in this study is of 100 meters resolution i.e. 100*100 m grid size. Stream map and stream network are also derived by imposing digitized stream network on the DEM.

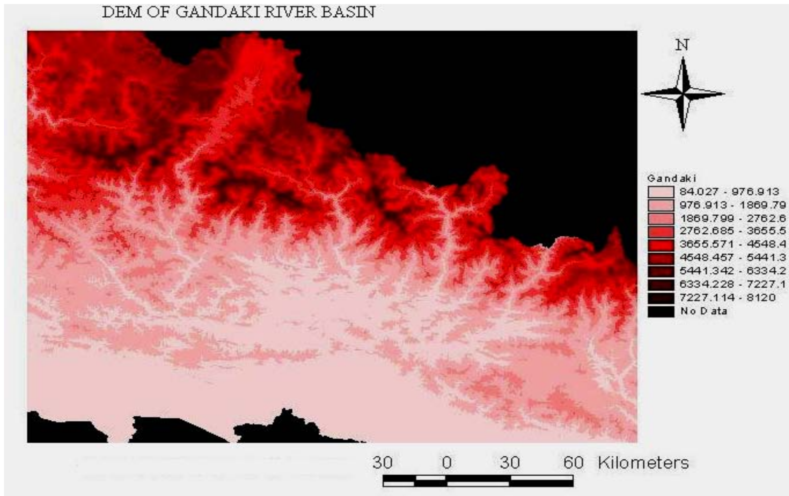

Fig. 6.1 : DEM of Gandaki Basin

b) Spatial Analysis (terrain processing)

Terrain processing is used to generate hydrologic parameters from a digital elevation model. Hydrologic derivatives include fill sink, flow direction, flow accumulation, watershed sub delineation and stream segmentation[9].

Flow accumulation: Drainage area to a given cell can be computed by multiplying the number of contributing upstream grid cells and cell size in the flow accumulation process.

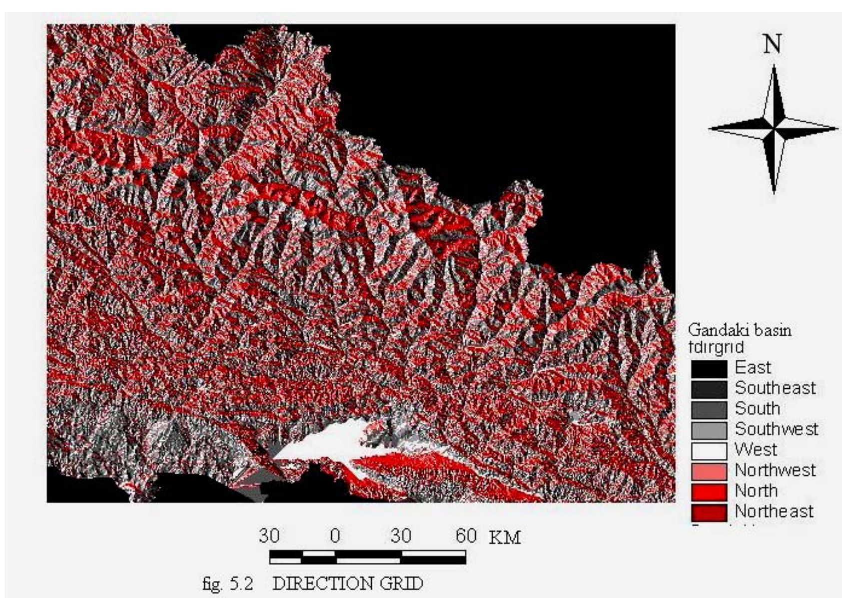

Fig. 6.2 : Direction Grid of Gandaki basin

c) Research input parameters

i. *Topographical (Spatial) data*

Digital elevation model (DEM) is required to describe the topography of the basin. DEM describes the elevation of any point in the study area in digital format and contains the information on drainage, crest and breaks of the slopes [7]. DEM is a primary spatial data source based on which Geo HMS extract the catchment boundary, stream networks files indicating stream properties are generated from the DEM using GIS.

ii. *Reach parameters extracted from HEC-GeoRAS*

Besides the movement of excess precipitation over the land surface, flow within a river channel and flood banks are required to predict the rate at which water will flow through a given point in the stream in the hydrologic stream routing. While there are many methods of predicting stream routing in HEC-HMS, the model in this study is the kinematic wave method.

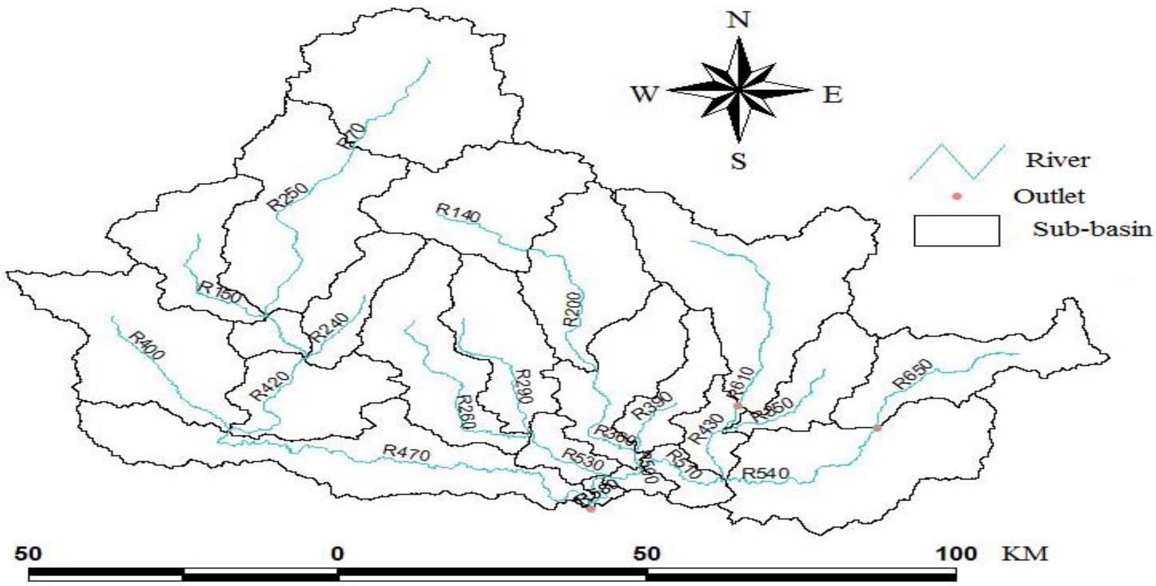

Fig. 6.5 : Delineation of river

The physical characteristics of watershed and river includes the sub basin area, river length, river slope, stream invert profile, sub basin centroid location, elevation, longest flow path for each sub basin and length along the stream path from the centroid to the sub basin outlet. In order to access such physical characteristics of the natural channel, the extension of Arc View GIS developed by USACE HEC-GEORAS can be used.

Table 6.3 : Stream reach parameters extracted from GeoHMS

S.No	Reach Name	Reach Length (M)	Energy Slope (m/m)	Cross section shape			
				Trapezoidal		Rectangular	Triangular
				Bottom width (M)	Slope(H:V)	Botom width (M)	Slope(H:V)
1	R70	45102	0.0128	40	37.5	71.667	65.33
2	R140	32586	0.0285	90.000	48.333	140.000	100.000
3	R250	77369	0.0262	61.667	43.333	85	71.667
4	R150	49206	0.0261	11.250	8.578	27.500	10.969
5	R270	23204	0.0055	20.000	18.540	43.750	26.250
6	R240	32251.9	0.0255	15.000	36.019	62.500	35.324
7	R200	64020	0.0316	56.667	143.333	170.000	186.667
8	R220	11691	0.0053	12.500	8.333	21.667	19.000
9	R350	43863.2	0.0182	24.000	28.000	45.000	65.567
10	R290	58737.8	0.0138	32.500	17.500	47.500	40.000
11	R400	61316.6	0.0102	20.000	27.833	41.667	45.833
12	R420	27829.1	0.0065	16.750	7.375	34.500	14.917
13	R260	78026.7	0.0104	31.250	59.375	100.000	87.500
14	R360	7718.4	0.0031	66.667	94.333	105.000	121.110

15	R390	25902.8	0.0089	36.250	29.167	80.000	46.667
16	R500	7718	0.0031	66.667	94.333	105.000	121.110
17	R530	29980.6	0.0028	32.500	12.500	42.500	30.000
18	R560	13301.2	0.0025	24.167	14.500	44.167	28.000
19	R430	22938	0.004	25.000	30.000	43.667	48.333
20	R540	60598.5	0.0042	18.333	20.333	32.500	30.833
21	R510	33843.4	0.0018	22.500	20.000	35.000	30.000
22	R470	150230.3	0.0021	40.000	32.667	80.667	53.833
23	R580	18458	0.0023	100.000	10.000	130.000	35.000
24	R600	2036	0	100	10	130	35
25	R610	81099	0.0316	12.500	8.333	21.667	19.000
26	R630	1631.4	0.0219	18.333	20.333	32.500	30.833
27	R650	74889.4	0.044	16.667	12.833	32.500	23.833

iii. *Overland flow parameter*

Watershed represents the two plane surfaces over which water runs until it reaches the channel. The water then flows down the channel to the outlet. The physical parameters used in this model are length, slope and area of each sub basin.

Table 6.4 : Plane overflow parameters extracted from GeoHMS

S.N	Reach Name	Basin Area (Sq km)	Plane1 (Right plane)				Plane2 (Left plane)			
			Length (Km)	Slope	Area (Sq km)	% Area	Length (Km)	Slope	Area (Sq km)	% Area
1	R140W120	1,620.23	8.88	0.21	1,242	77	29.52	0.09	377.66	23
2	R150W150	1,095.41	7.03	0.39	336.90	31	16.64	0.14	758.51	69
3	R200W170	1,406.8	15.51	0.29	712.96	51	11.93	0.26	693.88	49
4	R240W240	674.79	5.51	0.37	315.54	47	11.90	0.19	359.25	53
5	R250W90	2,204.18	16.71	0.18	1,256.7	57	17.70	5.27	947.46	43
6	R260W260	1,470.94	11.94	0.04	615.10	42	10.85	0.06	855.84	58
7	R270W270	258.17	6.53	0.25	94.98	37	12.94	0.12	163.19	63
8	R290W290	1,122.47	11.28	0.14	694.02	62	9.54	0.11	428.45	38
9	R350W350	748.26	9.78	0.22	418.95	56	7.61	0.21	329.31	44
10	R500W330	1,146.93	10.61	0.15	481.43	42	11.21	0.08	665.50	58
11	R430W220	379.15	4.96	0.11	114.20	30	7.89	0.11	264.95	70
12	R470W440	2,240.17	12.40	0.11	1,170.5	52	12.83	0.12	1,069.9	48
13	R400W310	1,994.20	14.86	0.11	758.61	38	18.75	0.10	1,235.6	62
14	R420W300	1,060.42	30.92	0.03	775.78	73	8.39	0.23	284.64	27
15	R530W530	353.27	6.69	0.10	226.06	64	7.33	0.11	127.21	36
16	R650W630	1,278.41	8.97	0.33	675.06	53	12.56	0.34	603.35	47
17	R540W280	2,129.80	11.58	0.12	558.99	26	5.90	0.21	1,570.8	74
18	R610W180	2,487.68	21.91	0.21	1,513.4	61	15.86	0.26	974.21	39
19	R510W510	286.36	5.09	0.20	114.20	40	6.87	0.08	172.16	60
20	R560W560	122.65	7.81	0.13	23.15	19	3.06	0.26	99.50	81
21	R600W580	66.72	2.05	0.09	41.26	62	1.88	0.12	25.46	38
22	R70W20	2,329.30	27.95	0.09	932.41	40	24.90	12.0	1,396.9	60
23	R390W390	611.25	5.86	0.24	342.36	56	5.57	0.16	268.89	44

VII. Result and Recommendation

The main objective of this paper was to find out the channel section of the study area which gives the best result. To achieve the main objective, the temporal variation of the flow by using different channel sections was analyzed and examined the result of different channel geometries at the outlet of the watershed at Narayanghat by considering the model's response of three-year separate precipitation.

a) Model calibration

The model is calibrated using 2004 and 2005 daily rainfall runoff data. Manual and automatic calibration techniques are applied to estimate values of parameters.

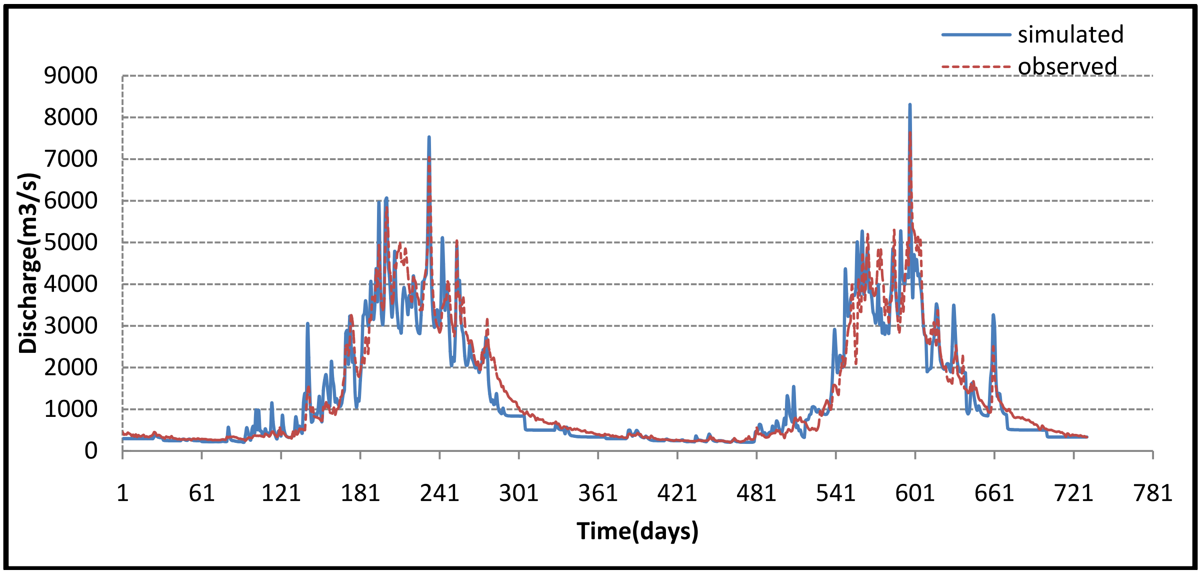

Fig. 7.1 : Simulated with observed hydrograph using trapezoidal channel section for calibration

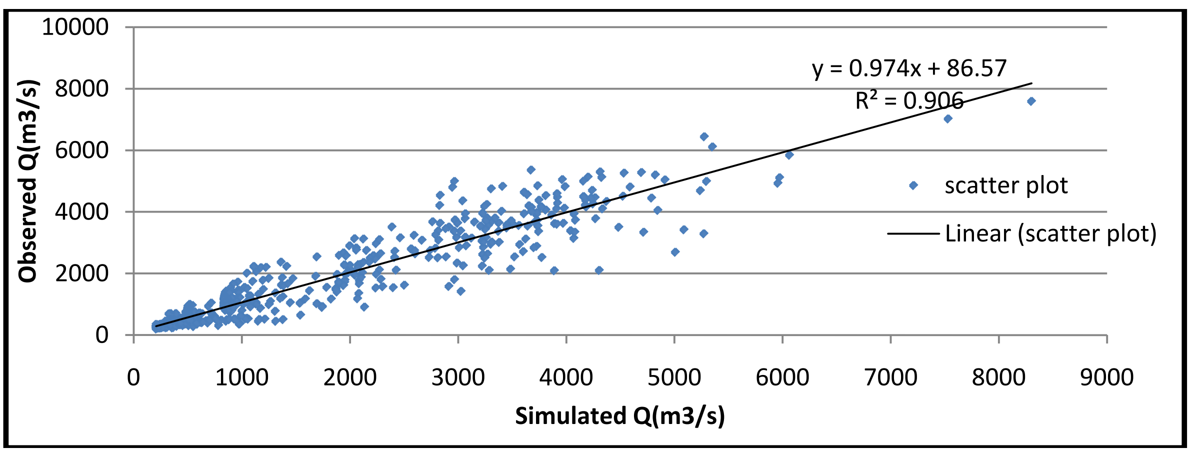

Fig. 7.2 : Scatter plot using Trapezoidal section for calibration period 2004 and 2005

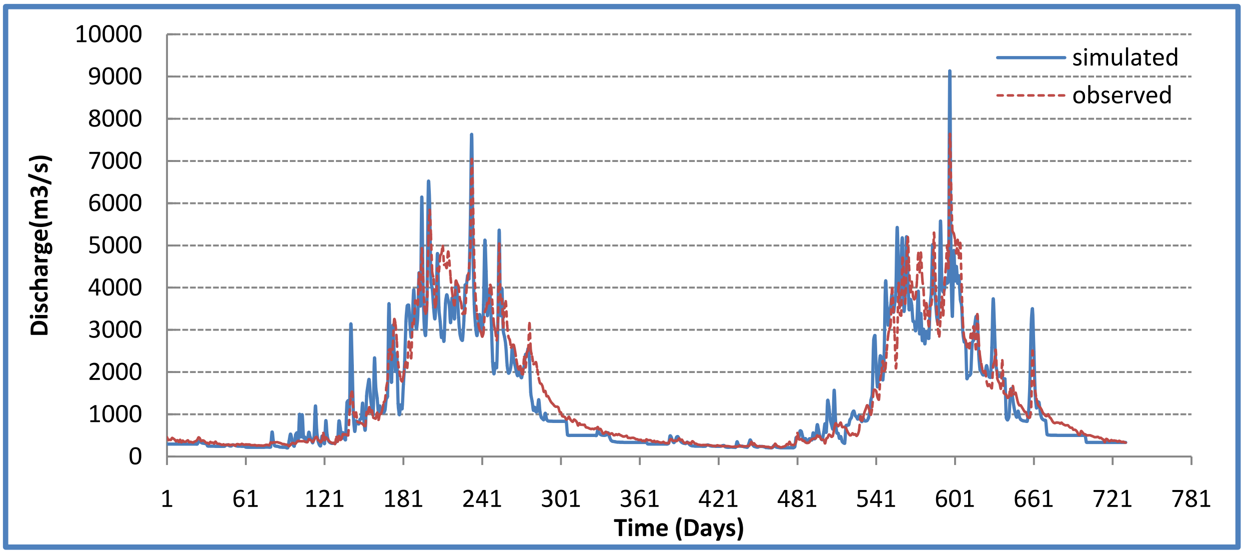

Fig. 7.3 : simulated and observed flow using triangular section

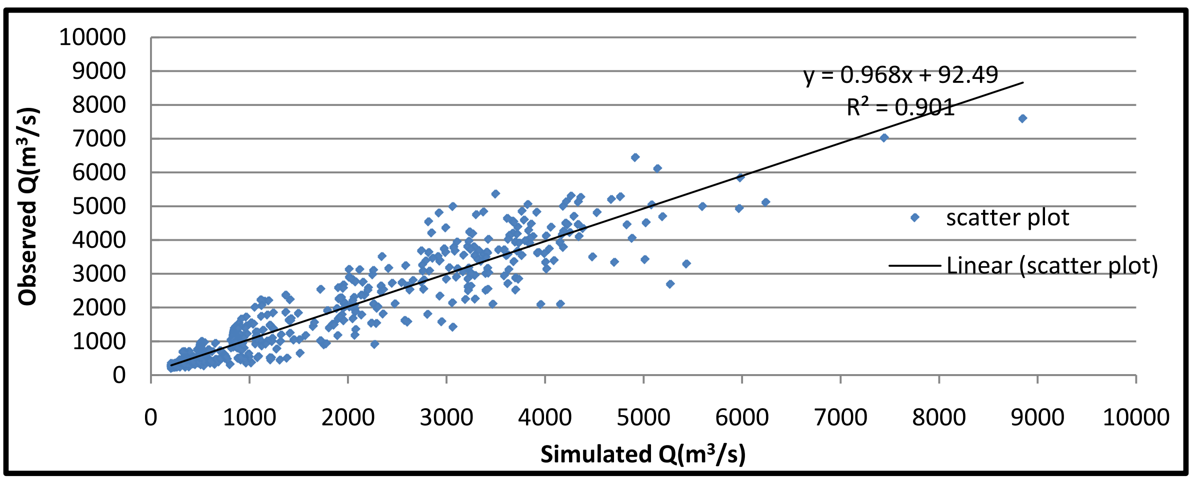

Fig. 7.4 : Scatter plot using triangular section for calibration

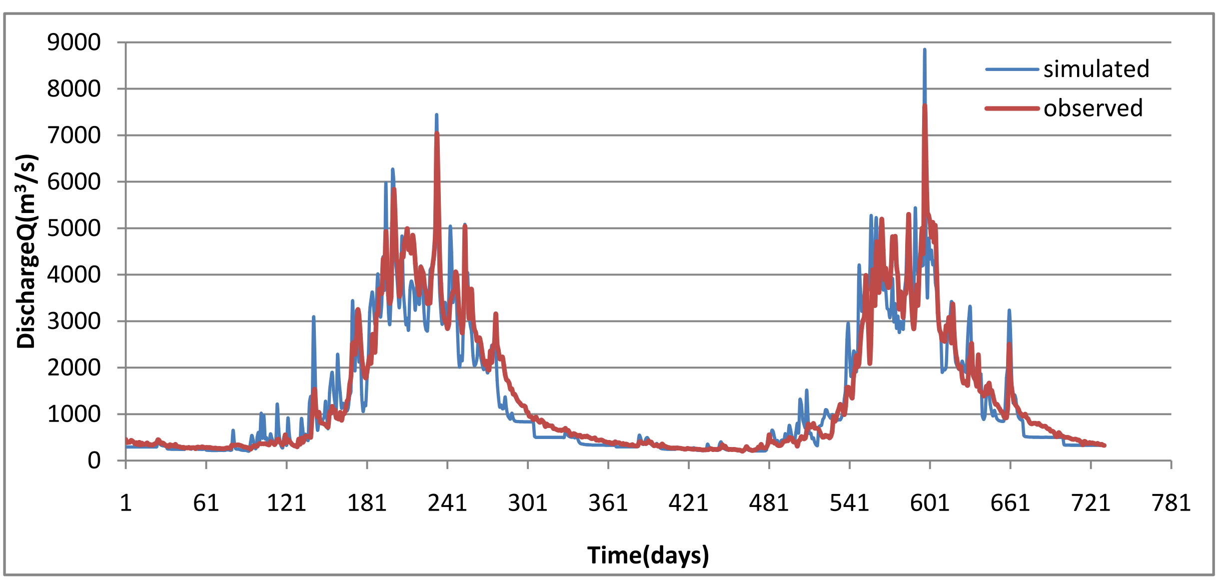

Fig. 7.5 : Simulated and observed hydrograph for rectangular section

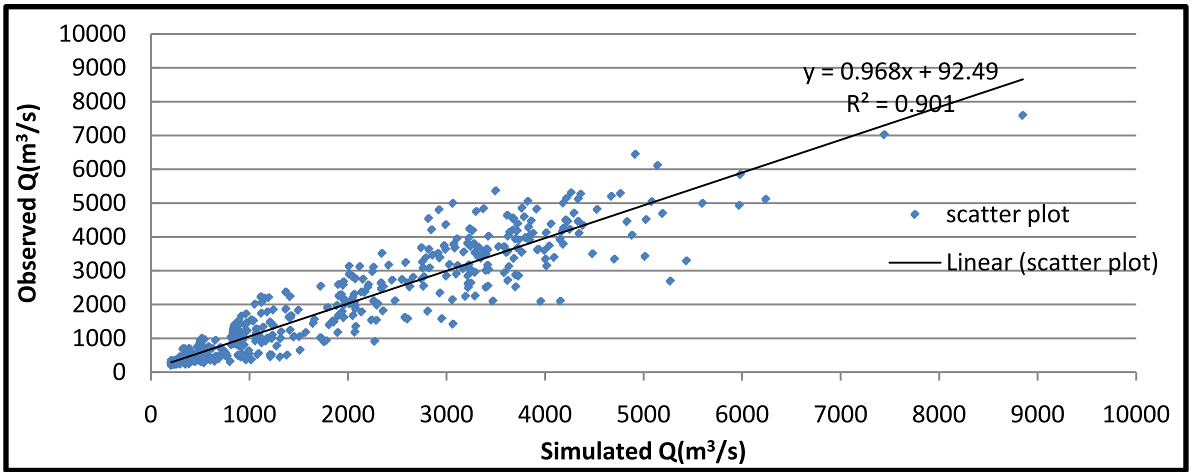

Fig. 7.6 : Scater plotter for rectangular section

b) Model validation

The model is run for one year's daily rainfall runoff data. The runoff is simulated using 2006 daily rainfall-runoff data in model validation. The calibrated model parameters are applied in model validation.

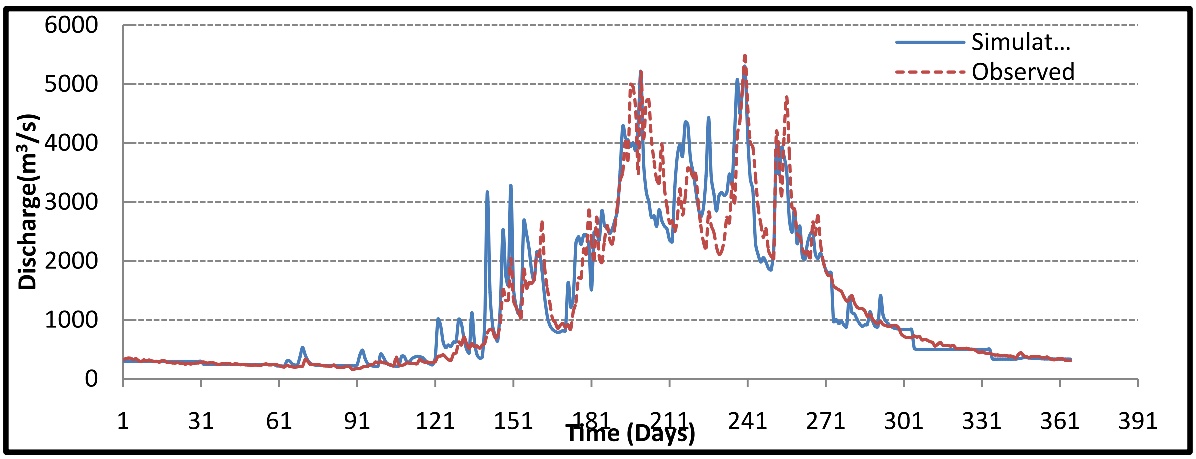

Fig. 7.7 : simulated and observed hydrograph for trapezoidal channel for validation period 2006

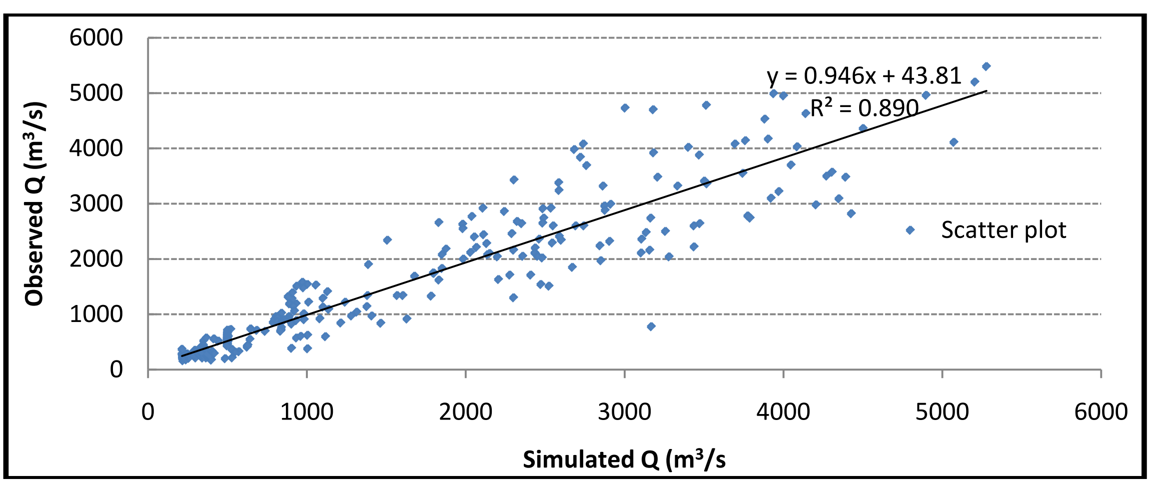

Fig. 7.8 : Scatter plot for validation period 2006 for trapezoidal section

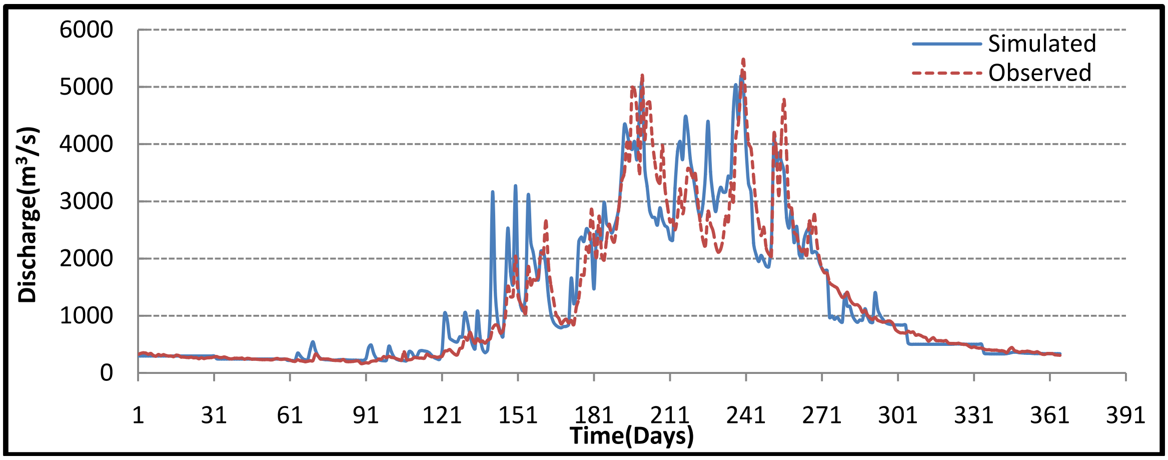

Fig. 7.9 : Simulated and observed hydrograph using Triangular channel for validation period 2006

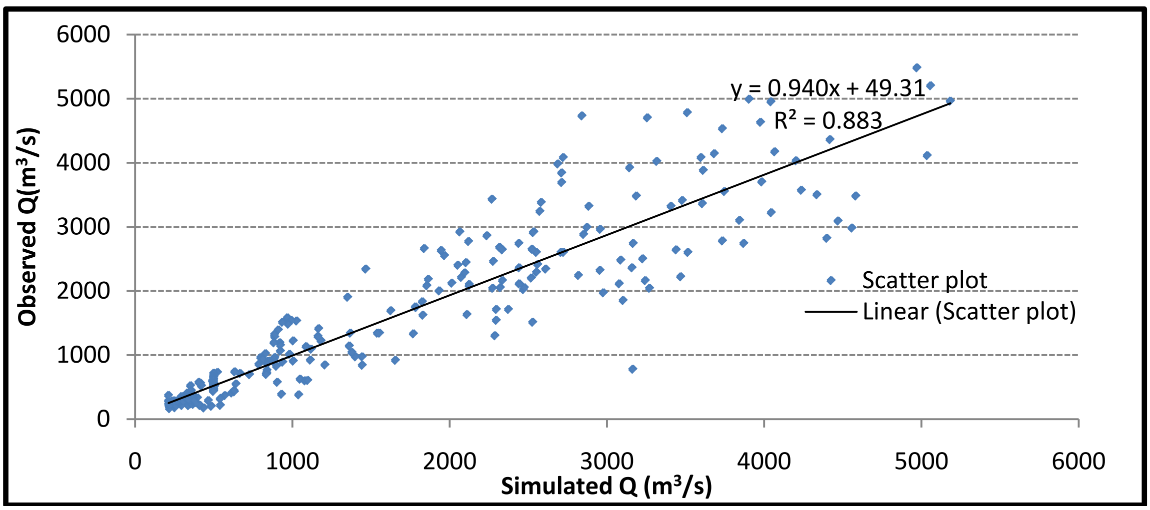

Fig. 7.10 : Scatter plot using triangular channel for validation period 2006

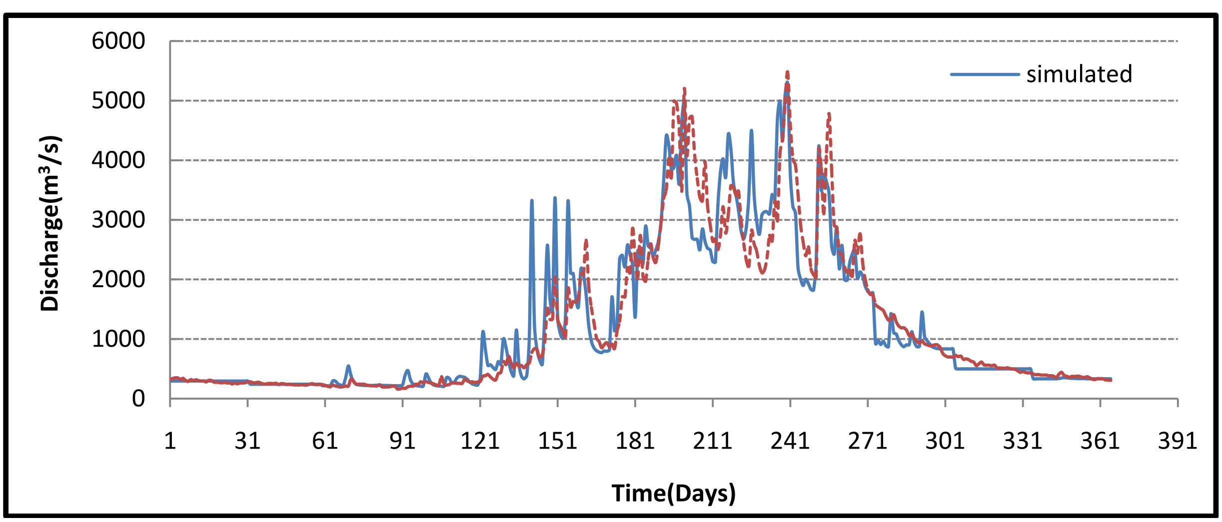

Fig. 7.11 : Simulated and observed hydrograph using Rectangular channel for validation period 2006

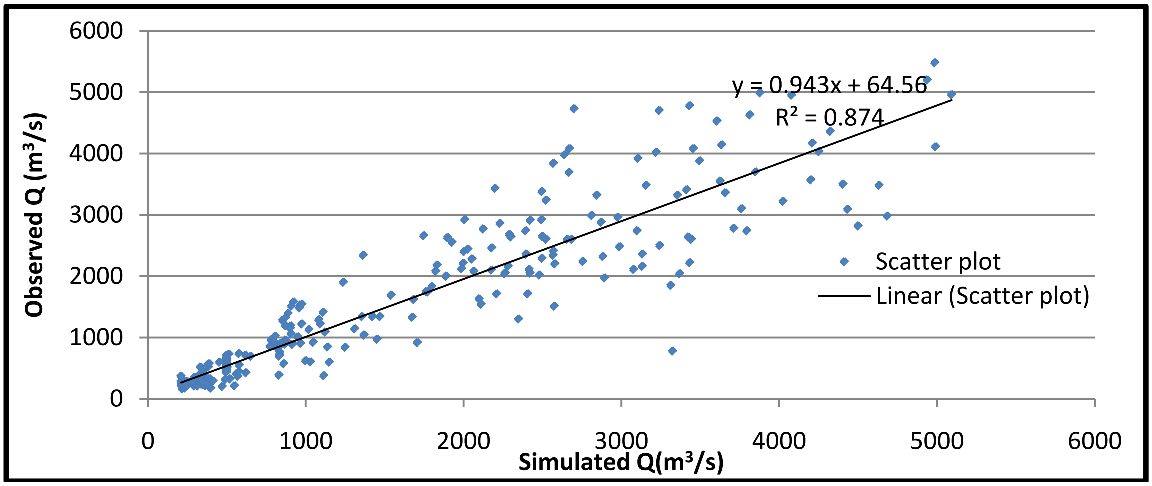

Fig. 7.12 : Scatter plot for rectangular section for validation 2006

c) *Performance analysis*

i. *Volume deviation using different channel section*

The simulated annual stream flow volume that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.1 and fig.7.13.The volume deviation using trapezoidal and triangular section obtained almost similar but in rectangular channel the volume deviation is higher than other section

Table 7.1 : Annual stream flow volume at the outlet

Channel section	2004		2005		2006	
	Observed volume (10^7m^3)	simulated volume (10^7m^3)	Observed volume (10^7m^3)	simulated volume (10^7m^3)	Observed volume (10^7m^3)	simulated volume (10^7m^3)
Trapezoidal	4591.8	4264.458	4066.3	4060.03	3840.46	3909.9
Triangular		4276.44		4063.27		3916.41
Rectangular		4191.34		3998.9		3854.42

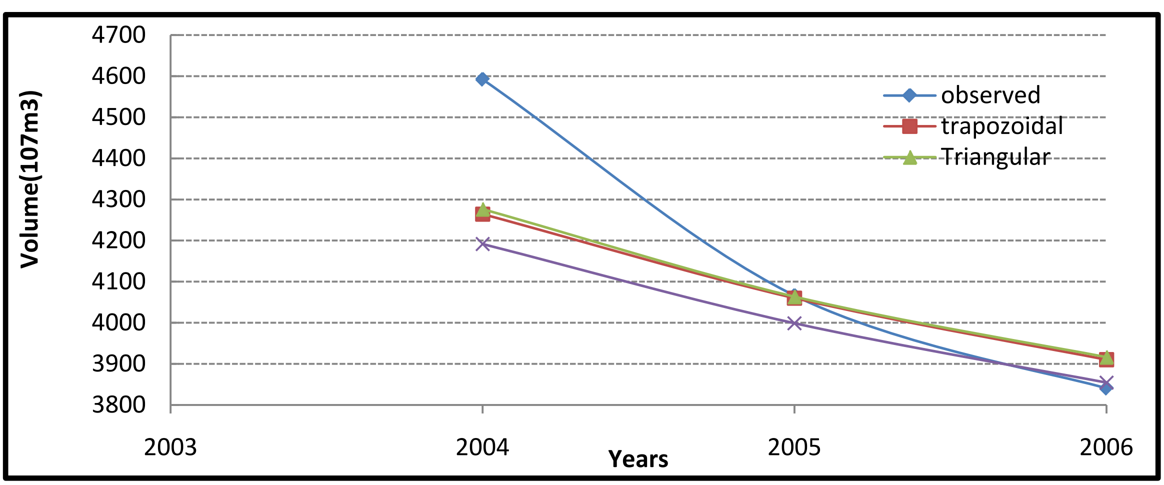

Fig. 7.13 : Annual stream flow volume using different channel section at the outlet

ii. *Annual mean flow using different channel section*

The simulated annual mean stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.2 and fig.7.14.The annual mean flow using trapezoidal and triangular section obtained almost similar but in rectangular channel the annual mean flow is higher than other section.

Table 7.2 : Annual mean flow using different channel geometry at the outlet

Channel section	2004		2005		2006	
	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)	Observed Peak flow (m^3/s)	SimulatedPeak flow (m^3/s)
Trapezoidal	7020	7531.3	7590	8302.1	5480	5277.8
Triangular		7445.1		8850.5		5184.2
Rectangular		7621.7		9131.5		5093.3

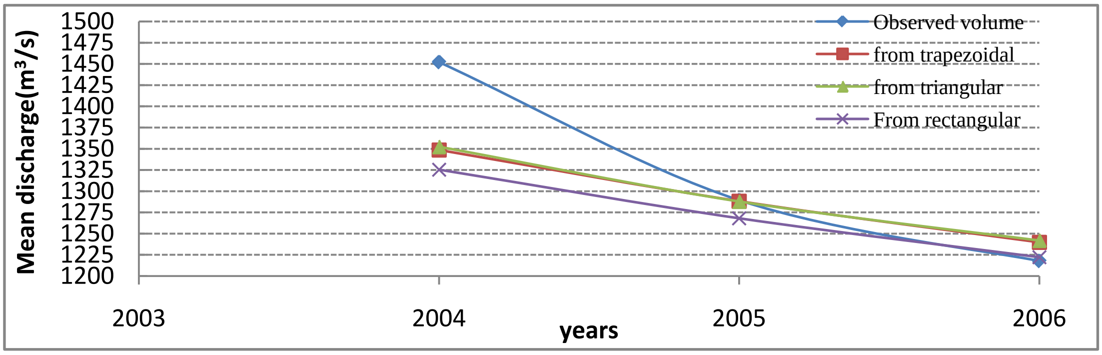

Fig. 7.14 : Annual mean stream flow using different channel section at the outlet

iii. *Peak flow using different channel section*

The simulated peak stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in table 7.3 and fig.7.15.The peak flow using trapezoidal near to the observed flow but for triangular and rectangular section, the peak flow is higher than the observed peak. The time of peak using trapezoidal channel exactly same to the observed time of peak in calibration and validation period, but time of peak using triangular and rectangular section is same in calibration period and slightly different in validation period.

Table 7.3 : Peak flow using different channel geometry at the outlet

Channel section	2004		2005		2006	
	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)	Observed Peak flow (m^3/s)	Simulated Peak flow (m^3/s)
Trapezoidal	7020	7531.3	7590	8302.1	5480	5277.8
Triangular		7445.1		8850.5		5184.2
Rectangular		7621.7		9131.5		5093.3

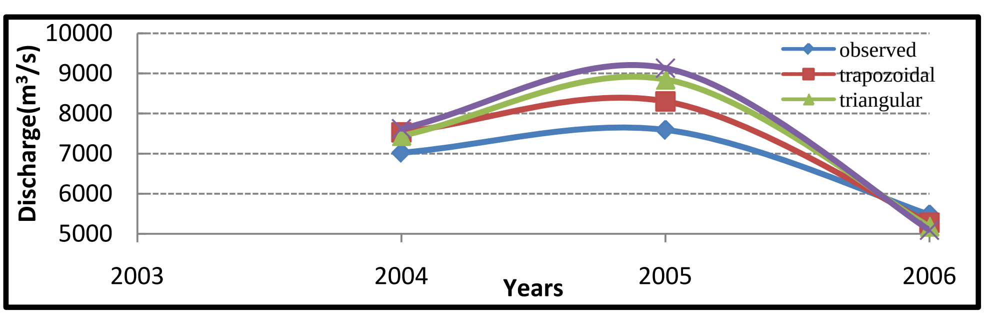

Fig. 7.15 : Peak flow volume using different channel section at the outlet

iv. *Efficiency using different channel section*

The Nash -Sutcliffe (1970), efficiency of stream flow that occurred at the outlet of the basin in response to the channel geometries during calibration and validation period are presented in fig.7.16.The efficiency of flow using trapezoidal channel is higher than the triangular rectangular section.

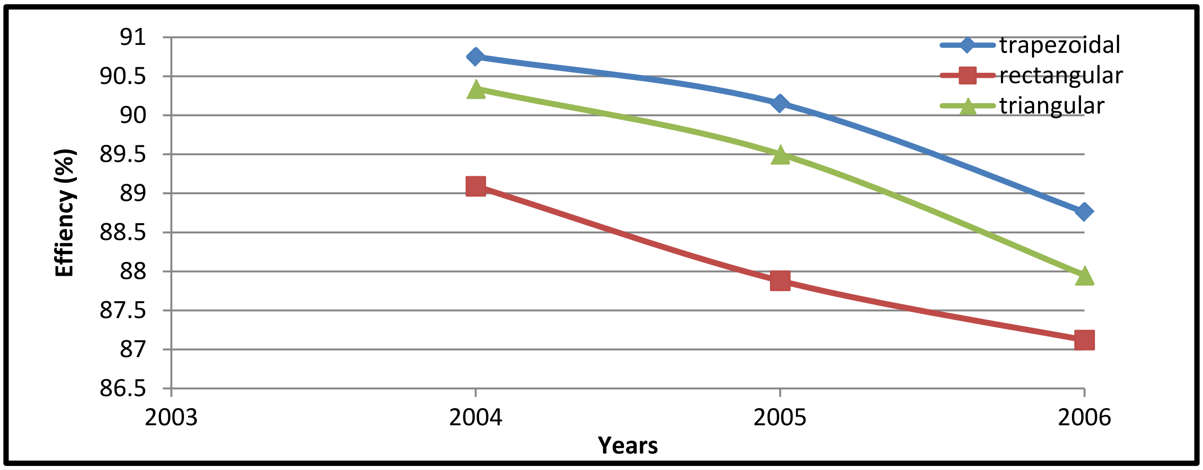

Fig. 7.16 : Efficiency using different channel section

It is clear from simulated hydrographs that different channel section show different degree of agreement between molded and observed discharge. Explanations for the results obtained can be pointed out in the following bullets.

- The precipitation, the infiltration parameters and channel routing method and parameters cause the difference in Peak flow, peak timing, and total volume, annual mean flow of observed and simulated hydrographs.
- Basins with a greater diversity of basin characteristics, including topography, soils and land use will produce poorer results than homogenous basins.
- Stream flow is affected by selection of channel geometry.
- Errors in peak flow due to inaccurate precipitation, inaccurate sub basin runoff parameters, incorrect timing of tributaries or the wrong amount of attenuation in channel routing.

VIII. Conclusion and Recommendation

The main objective of this research was to identify the efficient channel section in the computer-based rainfall runoff processes for Gandaki river basin. The GIS based semi-distributed model named HEC-HMS was used for this study. The response of channel geometry in simulating rainfall runoff was analyzed for the basin using DEM, Evapotranspiration soil type, and land use data. The GIS based extension tool HEC-GEOHMS and HEC-GEORAS were mainly used for preparation of inputs for HEC-HMS.

The model was calibrated for two years flow data and verification of the calibrated parameters for one year's flow data. For this study, especially trapezoidal, rectangular and triangular channel section were taken to account for the simulation. The result shows that using trapezoidal channel section is more efficient than triangular and rectangular section on the basis of Nash efficiency and degree of determination (R-squared value). The peak flow and time to peak at the outlet using trapezoidal channel section is nearly matched to the observed peak flow and time to peak for calibration and verification period than other sections. However the average annual flow and total annual volume at the outlet is nearly same using trapezoidal and triangular sections and slightly deviated from observed mean flow and annual volume respectively.

From the above result of this study which is the efficient section for routing that depends upon the purposes of the simulating rainfall runoff process. Trapezoidal section is more efficient than other for determination of flood forecasting and both trapezoidal or/and triangular section is efficient for simulating to determine the total annual runoff volume.

- Following are the specific conclusion from the analysis.
- The model provide the best result using trapezoidal channel section as a function of peak flow and time to peak.
- Hydrologic modal parameters can be derived from historic stream flow, precipitation and GIS database.
- The reasonable result were obtained using different channel sections for semi distributed model with efficiency ranging from 88.51% to 90.47% for calibration period and 87.12% to 88.76% for verification period respectively.

- Based on the result of this study, the trapezoidal channel section is most suitable for flood forecasting with continuous simulation.

a) Recommendations

From the study result, suitable channel section can be used for similar channel routing model. To develop capability of the model, following significant concepts are needed for further similar studies.

Digital elevation model plays vital role to enhance the capability of model. It is recommended to use high resolution digital spatial database for real replication of topography for the better performance of the model.

Channel cross sections are derived using HEC-GeoRAS extension of GIS. It should be checked by field surveys to get better result.

It is recommended to consider contribution of snow for better result.

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Component Analysis of Design and Construction as Housing Acceptability factor of Public Housing Estates in Anambra State, Nigeria

By Architect Dr. Chikadibia Michael Eni

Federal Polytechnic, Nigeria

Abstract- The thrust of this study was to evaluate the design and construction as a housing acceptability factor of nine public housing estates in Awka and five others in Onitsha towns in Anambra State using Principal Component Analysis (PCA) method. The universe of the study consisted of 2,805 housing units in Awka and Onitsha by house type and 2,955 occupants including 50 persons each from Anambra State Housing Development Corporation/Anambra Homeownership Company Limited (ASHDC/ AHOCOL), Non Estate Occupiers (NEOs) and Private Estate Developers (PEDs) involved. The sample size for the study was 899 which represented 30% of the total population which were drawn using proportionate cluster sampling technique, while 887 were complete responses. One research question and one hypothesis were formulated for the study. An 18-item structured questionnaire (QAHPH) was developed; face and content validated and reliability test was done using Cronbach Alpha Technique index value of 0.90 and pre-tested on a sample of 30 respondents/residents of another housing estate.

Keywords: housing acceptability, public housing and Principal component.

GJRE-E Classification : FOR Code: 290804

COMPONENTANALYSISOFDESIGNANDCONSTRUCTIONASHOUSINGACCEPTABILITYFACTOROFPUBLICHOUSINGESTATESINANAMBRASTATENIGERIA

Strictly as per the compliance and regulations of :

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Architect Dr. Chikadibia Michael Eni

Abstract- The thrust of this study was to evaluate the design and construction as a housing acceptability factor of nine public housing estates in Awka and five others in Onitsha towns in Anambra State using Principal Component Analysis (PCA) method. The universe of the study consisted of 2,805 housing units in Awka and Onitsha by house type and 2,955 occupants including 50 persons each from Anambra State Housing Development Corporation/Anambra Homeownership Company Limited (ASHDC/ AHOCOL), Non Estate Occupiers (NEOs) and Private Estate Developers (PEDs) involved. The sample size for the study was 899 which represented 30% of the total population which were drawn using proportionate cluster sampling technique, while 887 were complete responses. One research question and one hypothesis were formulated for the study. An 18-item structured questionnaire (QAHPH) was developed; face and content validated and reliability test was done using Cronbach Alpha Technique index value of 0.90 and pre-tested on a sample of 30 respondents/residents of another housing estate. T-test, Correlation Matrix and Principal Component analysis were used in answering research questions, while t-test were used to test hypotheses at 0. 05 level of significance. The major findings of the study was (1), there is a significant difference between the mean perception of the occupants and the staff of ASHDC/AHOCOL on the design and construction of public housing. It was concluded that (1).That the design and construction of public housing in Awka and Onitsha met the expectations and preferences of the end-users. The adoption of flexibility in design which increased densities encouraged mix uses and changed urban land use form based on different interpretations given to blueprints for developments and targeting of different income groups made for improvement of public housing estate delivery.

Key Terms: housing acceptability, public housing and Principal component.

I. Background to the Study

Housing is a major concern to governments across the world. Since man transited from primitiveness to modernity, the problem of providing adequate housing has been of critical consequence. The significance of housing in human well-being needs not be overemphasized. Housing has been universally acknowledged as the second most indispensable item in human need after food (Sultan Sidi, 2012). Housing has a profound impact on the health, welfare and productivity of individuals and human beings (Federal Republic of Nigeria 1997 and Gilbertson et al, 2008). Housing fulfils physiological needs through the provision of security to life and property and also protects individuals from adverse weather and climatic conditions. It fulfils psychological needs through the provision of a sense of personal space and privacy (Buddenhagen, 2003) and fulfils sociological needs by providing a gathering area and communal space for the family, which is the basic unit of any given society (So and Leung, 2004 and Sultan Sidi, 2012). In many societies, it also fulfils economic needs by functioning as a centre for commercial production (Kothari, 2001 and Kothari, 2009). According to Apparicio and Seguin (2006), it is of immense psychological importance, because it is part and parcel of the description of a people's quality of life and social standing.

Non-provision of adequate housing is a problem that affects different strata of the society differentially, the rich, the vulnerable poor and the middle class (Akeju, 2007 and Eni, 2014). However, millions of people never experience these positive benefits.

The best conservative United Nations estimate of 2013 is that of 2005 estimates which puts the number of homeless at 100million which translates to over 100million homeless people who are forced to live with no shelter at all and another 100million hidden homeless people bringing the conservative UN estimate of total population of homeless to 200 million and over 1 billion people worldwide who are inadequately housed (Cronley, 2010). A UN-Habitat (2009) estimate had indicated that more than one billion of the world's city residents live in low quality housing, mostly in the sprawling slums and squatter settlements in developing nations. In Lagos, many hidden homeless people live "*as homes*" under public bridges and flyovers on the high ways (Ehingbeti 2008). With a Nigerian population of over 174,507,539 persons (Nation Bureau of

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Statistics, July 2013), United Nations (2013) and Nigerian Demographic Profile (2013) studies put the overall Nigerian housing deficit at 17 million units while Nigeria National Bureau of Statistics estimates were between 12 and 14 million housing units (National Bureau of Statistics, 2013). As of 2009, there was a deficit of 16 million housing units in Nigerian urban centres (Kolawale, 2009).

The above statistics were evidence of the difficulty governments have in guaranteeing access to housing for their citizens. However, as part of government's effort to provide suitable and adequate shelter for the citizenry, she went into public housing provision initiative (Akeju, 2007 and Obeng-Odoom, 2009). Public housing is usually owned and operated by the government although some public housing projects are managed by subcontracted private agencies. Public Housing is housing financed, constructed and allocated by the state, usually for persons in low income category (Sengupta and Sharma, 2008) or Public housing is a form of housing tenure in which the property is owned by a government authority, which may be central or local. Social housing is an umbrella referring to rental housing which may be owned and managed by the state, by arm-length non-profit organizations, or by a combination of the two, usually with the aim of providing affordable housing. Social housing can also be seen as a potential remedy to housing inequality. Although the common goal of public housing is to provide affordable housing, the details, terminology, definitions of poverty and other criteria for allocation vary within different contexts (Wikipedia, the free encyclopedia).

It is indeed regrettable that in Nigeria despite the fact that the 1999 Constitution Section 16(3) (d) under "*Fundamental Objectives of State Policy*" compelled the Nigerian State "to provide suitable and adequate shelter for all citizens" (Federal Republic of Government, 1999). The attainment of such a goal is still unrealizable.

In many states of the Nigerian Federation different public housing schemes abound ranging from low-cost, middle-class and upper-class housing projects (Eni, 2014). These are meant to cushion the effect of dearth of housing (Obeng-Odoom, 2009) However, Muoghalu (1986, 1989 and Eni, 2014) stressed that government is attracted to public housing because of its visibility and the money accruing from contracts and politicians can point with pride at the highly visible, public-aided housing projects as a measure of their concern for people and their social accomplishment. Unfortunately, private investment and involvement in housing provision still dominates the effort to provide housing which is a good development. The benefits of public housing, despite efforts and activities of governments are lost to millions of Nigerians because Private Estate Developers (PEDs) or Real Estate Developers' Association of Nigeria (REDAN) appear to be dominating the so called affordable housing scene with the government efforts trailing far behind them, which ordinarily is a healthy development (Raji, 2008) nevertheless in an economy where many are exceptionally poor and earn less than $2.5 a day (Olotua, 2000a) this would be counterproductive. In the United States of America the share of total expenditure of the poorest 10% is about 1.9%, that of the richest 10% is about 33.2% whereas about 70.8% earn less than $1.00 (US dollar) a day between 1990 and 2005 (United Nations Development Programme, 2008). In Nigeria over 70% of Nigerians live on less than $2.5 a day (Olotua, 2000b).

There seem to be a severe dearth of public housing generally in Nigeria and Anambra State in particular; the available estates also suffer a number of limitations including keen competition from Private Estate Developers (PEDs) and corporate organizations. It may be recalled that some of the available estates have survived for years and have become nerve-centres of some towns and cities where they are located (Ndubeze, 2009). There is no doubt, that in the absence of these estates, the accommodation problem of the citizenry would have worsened. This situation called for appraisal of Federal and State governments' effort in providing affordable and habitable public housing with a view to identifying the perceived problems, proffering suggestions on how to overcome the problems and improving affordable adequate housing (Ademiluyi and Raji, 2008). To this end, the issue of evaluating the design and construction as a housing acceptability factor of public housing became crucial. It was the above scenario that led to the articulation of the problem of this research.

II. Identification of the Problem

Public housing delivery in Awka and Onitsha cities seemed to have a multiplicity of housing design styles and construction methods. Different interpretations were given to blueprints for development unlike the usual monolithic housing use which follows master plan zoning, where there was usually uniformity of design and construction criteria (Nuefert, 2012 and Eni, 2014). Some public housing catered exclusively for the low income group, while in some public housing estates, a variety of income groups were lumped together with varying design and construction options. This was in contrast to what obtained in most public housing estates and there was need to investigate if this flexibility in design which increased densities encouraged mix uses and changed urban land use form made for improvement of public housing estate delivery (Eni, 2014).

As the philosophical basis of this study is on equity and social justice in housing environment or built environment, this study surveyed the ratio of contributions (inputs) and rewards/benefits/ costs (output) of occupants at the various locations in Awka and Onitsha cities. It is acknowledged that there are subtle and variable major factors of public housing provisioning such as design and construction of public housing that affect an occupant's assessment and perception of their relationship with their public housing estates and their housing providers. The idea was to have the rewards (outcomes) directly related with the quality and quantity of the occupants' contributions (inputs) in the spirit of egalitarianism in the distribution of housing resources (Eni, 2014). If occupants of Awka and Onitsha public housing estates were possibly rewarded alike, it would help the occupants realize that the organizations were just, attentive, and appreciative.

This study assessed how public housing in the study area had achieved its intended goals in terms of the design and construction as a housing acceptability factor of public housing estates in Anambra State of Nigeria. The public housing estates studied were either owned by the Federal government or Anambra State governm.

In Awka Urban, these seven public housing estates were studied; Iyiagu Housing Estate, Real Housing Estate, Udoka Housing Estate, Ngozika Housing Estate, Oganiru Housing Estate Phases1&2, AHOCOL (Inner City Layout) Housing Estate, AHOCOL (Think Home) Housing Estate Phase 1 (or Ahocol 1 and AHOCOL (Think Home) Housing Estate Phase 2 (or Ahocol 3) while in Onitsha urban, these two housing estates were studied; Niger Bridge-head Housing Estate and Federal (Site and Services) Housing Estate, Trans-Nkissi (or 33), Onitsha making a total of nine housing estates in all.

III. Aim and Objective

The aim of this study was to specifically determine design and construction as housing acceptability factor of public housing estates in Anambra State. The specific objective was to:

a) determine the perception of adult occupants and the staff of ASHDC/AHOCOL on the construction and design of public housing, while the study sought answer to the following research question: What was the perception of adult Occupants and the Staff of ASHDC/AHOCOL on the design and construction of public housing as a housing satisfactoriness factor?

The null hypothesis H_o: There is no significant difference between the perception of Occupants and the staff of ASHDC/AHOCOL on the construction and design of public housing was tested.

The study looked at residence in public housing and not private housing and the occupants may have different design and construction problems quite different from what obtains in private housing. At best, it described post occupancy housing tolerability challenges in public housing estates in Anambra State than a generalized housing acceptability challenges in other genre of housing.

IV. Literature Examination

Relevant literature related to the present study was extensively reviewed. The objective was to critically examine the existing body of knowledge on issues bordering on design and construction as a housing acceptability factor of public housing in Awka and Onitsha urban areas in order to eliminate duplication of efforts and to call attention to gaps in literature that prompted this study. According to Wikipedia, architects plan, design and review the construction of buildings and structures for the use of people. It is the professional duties of the architects to produce building design. According to Ruskin (1986) the need for housing design is to ensure not only a good production of the drawing, but also to guarantee its functional and structural integrity and provide a guide for carrying out the actual construction/development, so as to achieve optimum comfort for human habitation and functional requirements of other usages. The need and importance of housing design before eventual construction cannot be over emphasized. The truth, however, is that the design stage provides opportunity for cost reduction in housing, It is relatively cheaper to correct, redesign and change design criteria on a piece of paper than during construction. Fourteen studies relating to the design and construction of public housing were reviewed. In a heuristic study previously done by Oladapo, in 1993, Jiboye (2008) used co-relational research method and found out the need for technocrats to identify appropriate design criteria and to use them as inputs to housing design and development. He advised that the tasks confronting architects, planners, policy makers and all those concerned with providing housing, is to identify the factors which determine adequate and satisfactory housing. Similarly, Jiboye, (2010) employed a conceptual model and found the need to consider relevant factors of the environment, dwelling and management in housing design and development.

He systematically surveyed 1,232 (10%) households out of a total of 12,323 households in six randomly selected public housing states in Lagos. This followed the study by Onibokun, (1973) and Muogahlu, (1984a). Globally, some research findings and recommendations seem to support these findings. Kellekc et al (2005) found that housing design and construction were important determinants of users' satisfaction and environmental quality in Turkey in his study "Determinants of Users' Satisfaction and Environmental Quality: Sample of Istanbul Metropolis".

So and Leung (2004) found that the Chinese consider design and construction (appearance) of their housing a very important issue in housing satisfaction. They employed survey research technique in surveying the attitudes of Chinese towards buildings in three Chinese cities: Hong Kong, Shanghai and Taipei. They found that attractiveness of design contributed to housing satisfaction. In the same vein Amerigo et al (1990) established that appearance of council housing contributes towards housing satisfaction in the UK, while using survey research to assess residential satisfaction in council housing there. However Prew (1961) used historical research method and found out that the poverty of the masses and shortage of adequate technical know-how were the bane of building design/construction and recommended subsidizing the poor to own or rent adequate housing. Djebarni et al (2000) found that public housing is better assessed through users' assessments as against designers' opinions. They employed survey research technique to assess satisfaction level within neighbourhoods in low-income public housing in Yemen. Anantharajan (1983) used survey research method and found out, in a research conducted in randomly sampled public housing in Miami Florida that those end users point of view is important in the evaluation of their housing perception and recommends the evaluation of residential development through users' ratings and rankings of both design and environmental attributes and in Nigeria. Onibokun (1973) who studied Onatario, Canada used survey research method and found that a dwelling that is adequate from the physical or design point of view may not necessarily be adequate or satisfactory from the users' point of view and recommended the use of subjective criteria of resident satisfaction with public housing. Diogun (1989) studied "Housing Problems in Nigeria: Low-Income Housing survey" and found that government's direct involvement in housing development and delivery has been on the increase and advised against it and suggested that government should be seen as a regulator and setter of standards, while Muoghalu (1984) used survey research method in an empirical study of two public housing estates in Enugu. It was found that a critical mass of occupants felt dissatisfied with the design and construction of their housing units and suggested the need to combine objective criteria with subjective indicators of resident satisfaction with public housing. Oladapo (2006) employed co-relational research approach, which showed that tenants satisfaction could be measured by housing attributes such as the function and physical adequacy of the dwelling, quality and adequacy of social and community facilities, the nature and effectiveness of official policies and personnel attitudes, convenience for living, the condition and maintenance of the home environment, maintenance of the dwelling facilities, privacy, territoriality and neighbourhood security among other variables and recommended that tenants satisfaction should be measured by housing attributes such as the functional and physical adequacy of the dwelling, quality and adequacy of social and community facilities. His findings tallied with those of Muoghalu, (1984a). Technically speaking, Fletcher (1961 and Neufert, 2012) contend that architects plan, design and review the construction of buildings and structures for the use of people. A good building should satisfy the three principles of *firmitatis, utilitatis, venustatis*, which translate roughly to - Durability - it should stand up robustly and remain in good condition. Utility - it should be useful and function well for the people using it. Beauty - it should delight people and raise their spirits. Similarly, Vaughan (1967) used a case study research approach to look at the revolution in housing both in the world and in Nigeria and concluded that Nigeria has been subjected to three major influences such as, the Indigenous mud architecture, P. W.D Colonial brick block wood and pan and the Machine age.

However, the Nigerian architect has come under intense criticisms. Nigerian architects have been accused of over-designing. According to Muoghalu (1984a) what appeals to technocrats will not necessarily appeal to consumers. It is obvious that he was advocating inclusion of, and enlistment of residents' co-operation in design, as well as in environmental management. According to Michelson (1968) most people do not want what architects want. Most researchers such as Jiboye (2008 and 2010); Kellekc, et al (2005); So and Leung, (2004) and Anantharajan (1983) recommend the appraisal of residential development through users' ratings and rankings of the design and construction attributes, while Onibukun, (1973) states that though a dwelling unit may be adequate from the physical or design point of view, it may not necessarily be adequate or satisfactory from the users' point of view.

According to Wikipedia (2014), part of the architectural profession and also some non-architects feel that architecture has not been a personal philosophical or aesthetic pursuit by individuals; rather it had to consider everyday needs of people and use technology to give a liveable environment.

V. Study Area

The study area, Awka and Onitsha cities are located in Anambra State of Nigeria. Anambra State was created on 27th August, 1991. Its name is derived from 'Oma Mbala' now known as Anambra River, a tributary of the famous River Niger.

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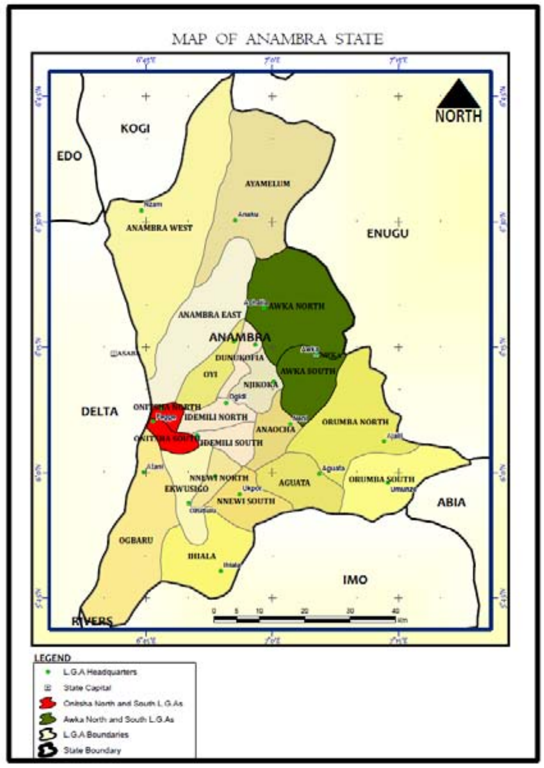
Source: Wikipedia, the Free Encyclopedia, 2014.

Fig. 1 : Relative position of Nigeria in the world map

Source: Adapted from Wikipedia, the Free Encyclopaedia, 2014.

Fig. 2 : Location of Anambra State in Nigeria

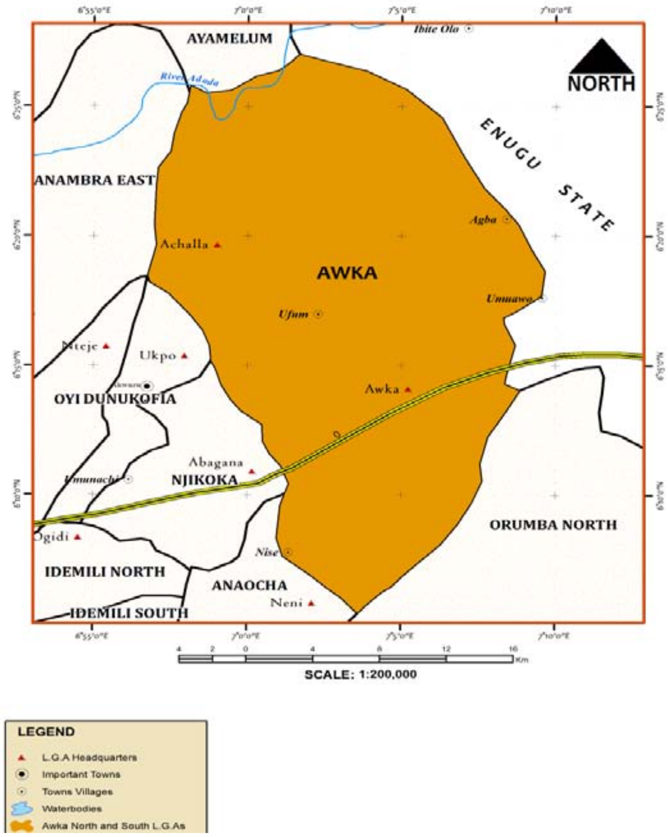


Source: Adapted from Nwabu, (2010) Google Maps.

Fig. 3 : Map of Anambra State Showing the Study Area

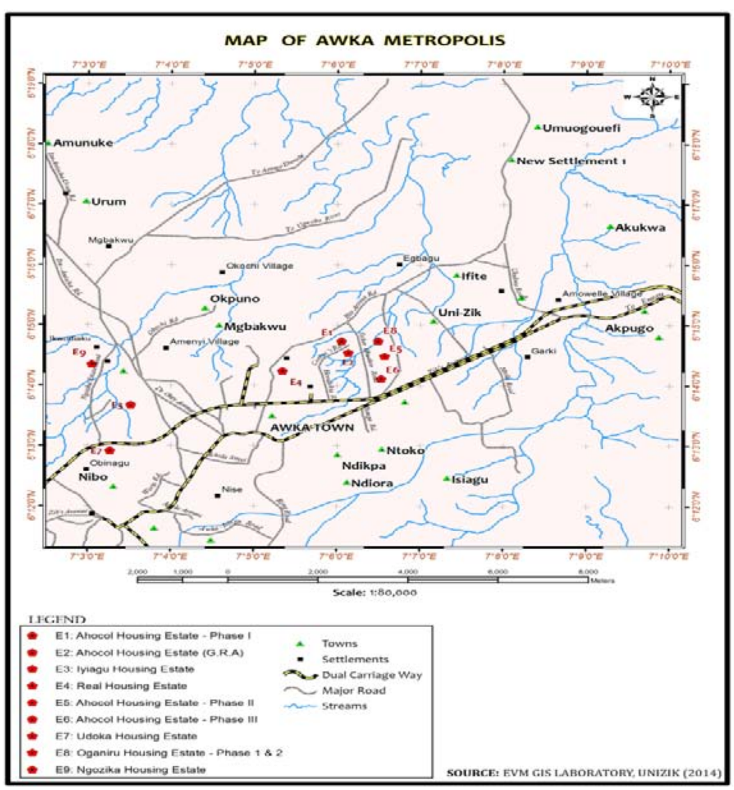
VI. Awka City

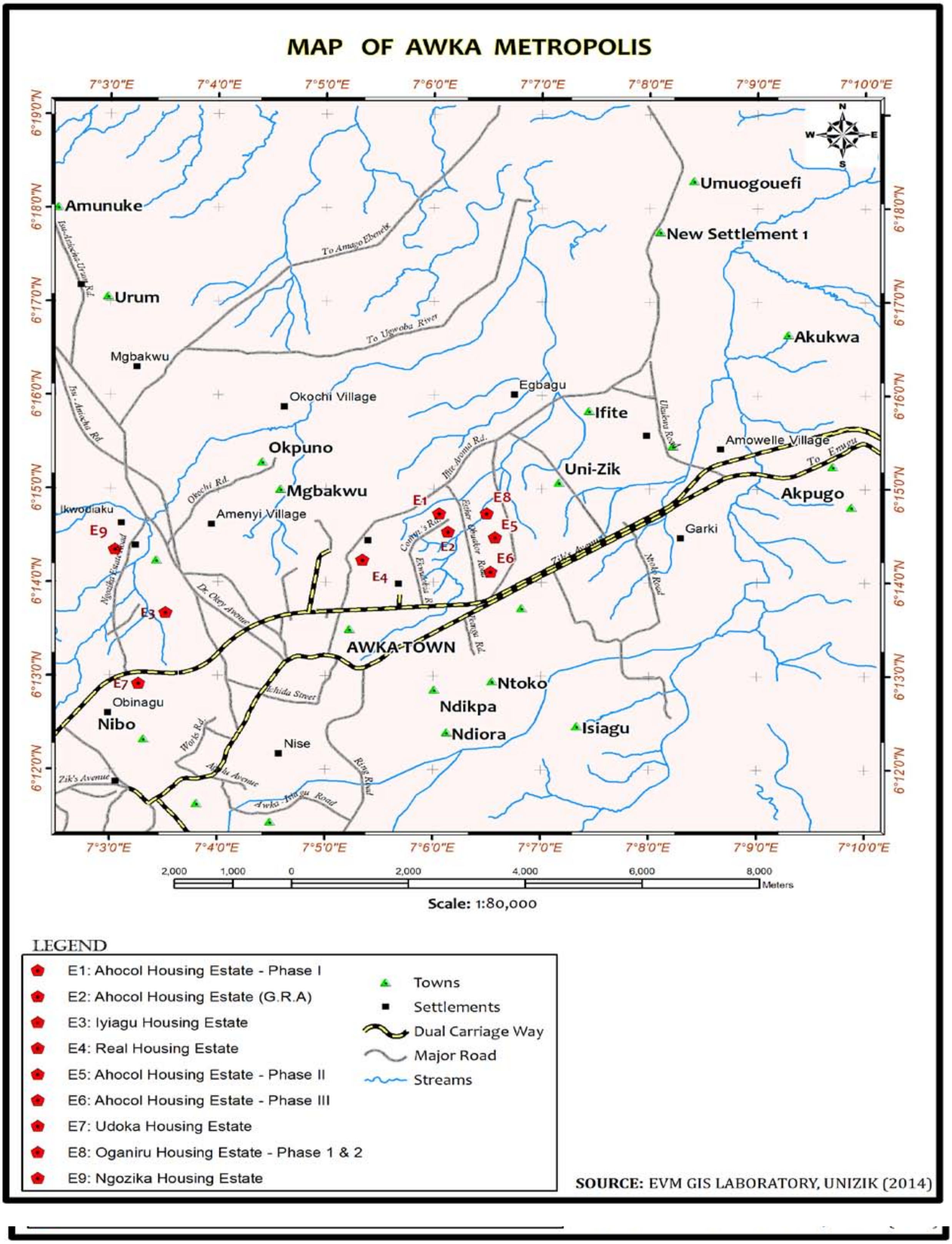
Awka became the capital of Anambra state after it was carved out of the old Anambra State in 1991. Awka South had a population of 189,045 persons and Awka North 112 had 6,080 persons (National Population Commission, 2006). This figure is considered doubtful because Awka town had grown from a population of 11,243 in 1953, 40,725 in 1963, and 70,568 in 1978 to 141,262 in 1983. The surprise is that the population of Awka town as at the National Census conducted in 1991 stood at 58, 225. This is made up of 28,335 males and 29,890 females (National Population Commission, 1991). However, the extrapolation of census figures of 1953, 1963, 1978, 1983 and 2006 put the population of Awka town at approximately 90,573 for the year ended 2007 and *375, 000* persons in 2010.



Source: EVM GIS Laboratory, NAU, 2014.

Fig. 4 : Map of Awka Metropolis showing the neighbouring towns



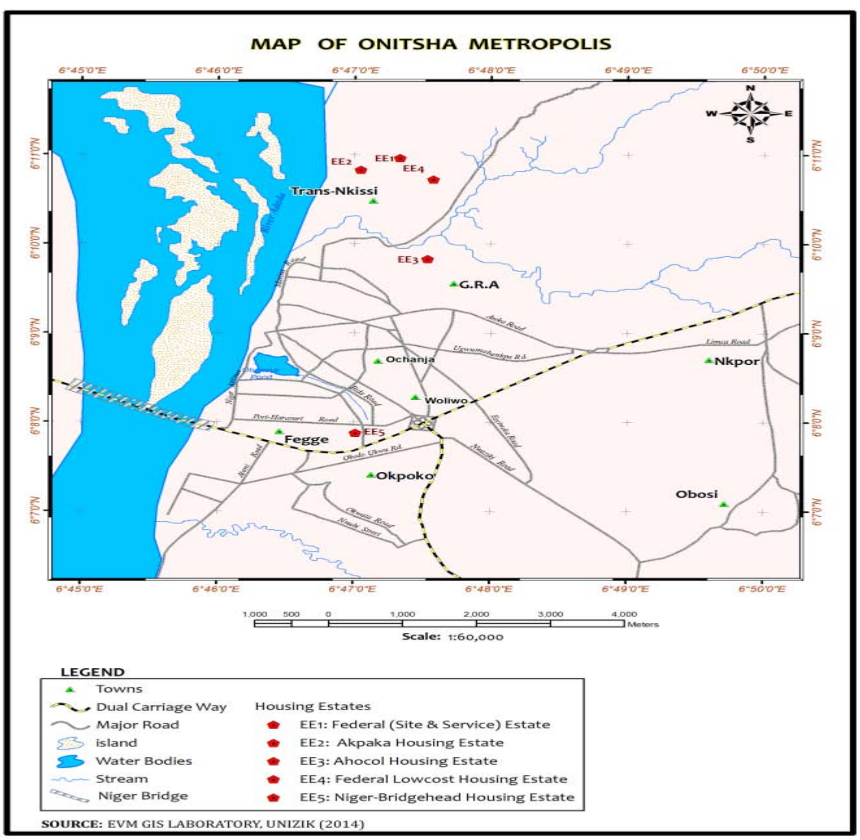


Source: Environmental Mgt GIS Lab NAU, 2014.

Fig. 5 : Street Map of Awka Metropolis viewing Public Housing Estates

VII. Onitsha City

Onitsha is located on the western part of the State and on the eastern bank of the River Niger and situated between Latitudes 6°.09' N and 7.03'N and Longitudes 6°.45' E and 6°.50'E with an estimated land area of 104sq.km (Onitsha Town Planning Authority, 1998). It has nine (9) residential wards or quarters such, Otu, Fegge, Okpoko, GRA, Woliwo, Odakpu, Awada, Inland Town, Omagba and its peri-urban communities. Onitsha had an estimated population of 511,000 with a metropolitan population of 1,003,000 (Minahan, 2002). The population of Onitsha is not well reflected in the Nigerian census figures because the traders migrated to their bases, neighbouring villages and states during census events reducing the official figures. Even the population of the town 623,274 in 2006 is contested (National Population Commission, 2006). This includes the population of the legal city of Onitsha and its peri-urban communities. However, the United Nations' Habitat has rated Onitsha among the world's fastest growing cities (*Daily Sun*, 2010, p 5). In terms of geology, relief and drainage, Onitsha lies on the Niger Anambra flood plain underlain by Nanka sands. The relief shows a general westward trend towards the River Niger; although local variations of relief exist in some parts of the town (Orajiaka, 1975 and Ofomata, 1975). According to Azikiwe, (1930), Igbos call it N'Idu Ado N'Idu. The city was founded in 1550. The indigenous people of Onitsha are primarily of Igbo ethnicity. Anioma people (an Igbo subgroup), and settlers from the Kingdom of Benin are believed to have settled in Onitsha in the 16th century, which was originally called Ado N'Idu (Azikiwe, 1930). It soon became capital of an Igbo Kingdom (Nipost Postcode Map, 2009). Eze Aroli was the first Obi of Onitsha, the monarch of the city (Azikiwe, 1930). In 1884, Onitsha became part of a British protectorate. The British colonial government and Christian missionaries penetrated most of Igboland to set up their administration, schools and churches through the river port at Onitsha.



Source: EVM GIS Laboratory, NAU, 2014.

Fig. 6 : Map of Onitsha Metropolis showing Public Housing Estates

The British colonial government and Christian missionaries penetrated most of Igboland to set up their administration, schools and churches through the river port at Onitsha. In the mid 1850s, Onitsha became an important trading port for the Royal Niger Company following the abolition of slavery and with the development of the steam engine when Europeans were able to move into the hinterland. Trade in palm kernels and palm oil which was going on along the coast of the Bight of Biafra since the 12th century was now moved upwards and other cash crops also boomed around this river port in the 1800s. Migrants from the hinterland of Igboland were drawn to the emerging town as did the British traders who settled there in Onitsha, and coordinated the palm oil and cash crops trade. In 1965, the River Niger Bridge was built across the Niger River to replace the ferry crossing. Onitsha is a commercial centre and a river port on the eastern bank of the Niger River in Anambra State, southeastern Nigeria (Muoghalu, 1983).

VIII. Method of Data Collection

An 18-item structured questionnaire on design and construction of public housing (QPH) was developed. Section A had open-ended questions or unstructured responses on demographics which elicited from respondents why they chose a particular scale, it tapped preliminary / personal information on respondents' and was analyzed using percentages such as gender, age, occupation, marital status, educational qualifications of respondents and section B which focused on design/ construction of public housing estates and had multiple-choice structured 5-point Likert Scale questions of possible responses from which respondents chose as appropriate. This represented a 5-point Likert rating scale in which respondents indicated the extent to which they considered the listed variables in the design and construction for occupants. The mid-point was 3 and this implied that any result significantly different from this mean value was assumed to be either positive or negative. The universe of study consisted of 2,805 respondents comprising mainly households, and secondly, 2,805 house units, comprising 1,032 in Awka town and 1,773 in Onitsha town. The sample size of 30% consisted of 842 housewives. Women were used as primary respondents in each household because they interact with the housing environment more than men. A stratified random sampling of these fourteen disparate public housing estates was studied. This instrument was face and content validated. Cronbach Alpha Technique index was used for reliability test which gave a value of 0.90. This technique was pre-tested on a sample of 30 respondents/residents of another housing estate. Out of a total of 842 respondents, 797 responded representing 94.7% complete responses. A stratified random sampling of these public housing estates, were studied as shown in Tables 1 and 2 below: A simple random sampling was then drawn from housing units in each stratum.

Table 1 : Distribution of Public Housing Population and Sample Size in Awka

	Name of Estate									Housing Units
Parameters	Iyiagu	Real	Udoka	Ngozika	Ahocol (GRA)	Ahocol (1)	Ahocol (2)	Ahocol (3)	Oganiru	Total
Population	94	90	500	25	8	27	34	174	80	1032
Sample size	28	27	150	8	2	8	10	52	24	310
Awka town percentage	9.03%	8.70%	48.40%	2.60%	0.65%	2.60%	3.22%	16.80%	7.75%	100%
Overall percentage	3.32%	3.20%	17.81%	0.95%	0.24%	0.95%	1.88%	6.18%	2.85%	36.82%

Table 2 : Distribution of Public Housing Population and Sample Size in Onitsha

	Name of Estate					Housing Units
Parameters	Fed. Trans Nkissi	Niger Bridge	Fed. Low Cost	Akpaka	Ahocol (GRA)	Total
Population	1177	554	15	17	10	1773
Sample size	353	166	5	5	3	532
Onitsha town percentage	66.35%	31.20%	0.94%	0.94%	0.56%	100%
Overall Percentage	41.92%	19.71%	0.60%	0.60%	0.36%	100%

IX. Evaluation of Perceptions of the Respondents on Design and Construction as a Housing Acceptability Factor of Public Housing

Research questions on mean perception of respondents of public housing estates at Awka and Onitsha, professionals from housing institutions ASDHC/AHOCOL and private estate developers and non estate occupants, on design and construction as a housing acceptability factor of public housing were answered.

a) Variables of Housing Acceptability in the Study Area

The following variables were deemed necessary in the investigation of design and construction as a housing acceptability factor;

i. *Design and Construction of Public Housing Component (DC)*

Perception on Design and Construction with Building Design (PDCBD)

Perception on Design and Construction with Nature of Materials (PDCNM)

Perception on Design and Construction with Block Work (PDCBW)

Perception on Design and Construction with Roofing Pattern (PCDCRP)

Perception on Design and Construction with Burglary Protections (PDCBP

Research Question: What is the perception of adult occupants and the Staff of ASHDC/AHOCOL on the design and construction of public housing?

Table 3 : t-Test for Perception of Adult Occupants and the Staff of ASHDC/AHOCOL on the Design and Construction of Public Housing

Group		N	Mean	Std. Deviation	Std. Error Mean
Perception on Design and Construction	Occupants Staff of ASHDC/AHOCOL	839 15	3.3714 3.9500	1.26407 0.66118	.01702 .10509

Significant at 0.05 level of confidence

Table 3 shows that the mean ratings of the occupants on design and construction of public housing were all greater than the cut-off point of 3.00. However, the occupants complained about lack of functional community facilities like electricity and water supply. These have environmental implication as the respondents in their free comments decried the excessive use of private generating sets that spew pollutants in to the atmosphere with the concomitant respiratory tract diseases. They also complained about the very high intensity of noise generated by this generating sets and suggested the engagement of Independent Power Providers (IPP) as is the practice in some other states especially Lagos State. The lack of portable water supply is worrisome because of the importance of water in personal hygiene, respondents' health and environmental sanitation. In the respondents' free comments, they wanted the reactivation of the water works instead of the rampant resort to use of water vendors, tanker service, hand dug wells and bore holes. There is no doubt that the extensive use of bore holes is environmentally defective because of the possibility of contaminating the aquifer. Although, there may be provisions for these facilities in the estates, but their functionality is in doubt. On the other hand, there were some disparities in the mean responses of the staff of ASHDC/AHOCOL when viewed against those of the occupants. The mean ratings of the staff were greater than the cut-off point (3.00). They were of the view that PDCNM-the building materials used in the estates were of superior quality, and also that PDCRP-the roofing patterns/materials can withstand the taste of time. The standard deviation for the respondents ranged from 0.35 to 1.44, giving the extent of spread about the mean value as 1.09 deviation units. From the cluster mean perception of the occupants (3.37) and that of the staff of ASHDC/AHOCOL (3.95), it could be concluded that the respondents perceived the design and construction of public housing in the area of study as acceptable, since these values are all greater than the cut-off point (3.00). *The result indicated no variability (significant difference) in the perception of respondents on design and construction of public housing.*

The relationship between the perception of respondents on design and construction factors associated with public housing was further established using Pearson's Product Correlation technique and 2-tailed test and the result is presented on table 4.

The result reveals serial autocorrelation as factors showed strong and significant positive correlation with each other. For example PDCRP (.094) is very highly correlated with PDCBP (.094), while PDCBW and P DCBD (.018) were lowly correlated (Turner, 1971:100). With these serious auto correlations that characterized the data, the next option is to subject the result to Principal Component Analysis (PCA) in order to transform them into defined orthogonal components. PCA was invented in 1901 by Karl Pearson (Pearson 1901). Now it is mostly used as a tool in exploratory data analysis for making predictive models. PCA can be done by eigenvalue decomposition of a data covariance or correlation matrix or singular value decomposition of a data matrix usually after mean centering (and normalizing or using Z-scores) the data matrix for each attribute (Abdi and Williams, 2010). *Principal component analysis (PCA)* is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called *principal components* (Jolliffe, 2002). The number of principal components is less than or equal to the number of original variables. This transformation is defined in such a way that the first principal component has the largest possible variance (that is, accounts for as much of the variability in the data as possible), and each succeeding component in turn has the highest variance possible under the constraint that it be orthogonal to (i.e., uncorrelated with) the preceding components. Principal components are guaranteed to be independent only if the data set is jointly normally distributed. PCA is sensitive to the relative scaling of the original variables (Miranda et al June, 2008). Depending on the field of application, it is also named the discrete *Karhunen–Loève transform (KLT), the Hotelling transform or proper orthogonal decomposition (POD).*

The results of a PCA are usually discussed in terms of component scores, sometimes called factor scores (the transformed variable values corresponding to a particular data point), and loadings (the weight by which each standardized original variable should be multiplied to get the component score)(Shaw 2003).

Table 4 : Correlation Matrix on Variables of Respondents on DC as a housing acceptability factor of Public Housing

Variables	PCDBD	PCDNM	PCDBW	PCDRP	PCDBP
PCDBD Pearson correlation	1	-019	-018	-486**	-464**
Sig. (2-tallied)		-889	890	-000	.000
N	59	59	59	59	59
PCDNM Pearson Correlation	-019	1	-468**	-304*	356**
Sig-(2-tailed)	.889		.000	.019	.006
N	59	59	59	59	59
PCDBW Pearson Correlation	.018	-468**	1	-056	-261*
Sig-(2-tailed)	.890	.000		.674	.046
N	59	59	59	59	59
PCDRP Pearson Correlation	-486**	-304*	-056	1	.094
Sig-(2-tailed)	.000	.019	.674		.481
N	59	59	59	59	59
PCDBP Pearson Correlation	-464**	-356**	-261*	.094	1
Sig-(2-tailed)	.000	.006	.046	.481	
N	59	59	59	59	59

**Correlation is significant at the 0.05 level (2-taliled).*

The result of the principal component analysis is presented on Table 5. Two principal components were extracted and explained 85.62 % of the respondents' perception on design and construction of public housing.

Component I has very high loading on "roofing patterns" (PDCRP) (0.912), high loading on "burglary protection" (PDCBP) (0.6374) and moderate positive loading on "quality of block work" (PDCBW) (0.5288), and but low negative loading on the "nature of materials" (PDCNM) (-0.9201) in the construction and building design. It has Eigen value of 3.041 and explained 60.83% of respondents' perception in the data set. This component reflected on the quality of construction, building materials and block work as perceived by respondents. Respondents argue that construction of public housing was shoddy in that quack contractors and amateurs were employed in their construction that used substandard building materials to build. They also asserted that that compliance monitoring supervisors were either negligent or casual in the supervision of such projects.

Table 5 : Variables on Design and Construction of Public Housing

	Components	
Variables	I	II
Building Design(PDCBD)	-0.8229	0.07279
Nature of Materials(PDCNM)	-0.9201	0.1093
Block Work (PDCBW)	0.5288	0.7932
Roofing Pattern (PDCRP)	0.912	0.2299
Burglary Protections (PDCBP)	0.6374	-0.7351
Eigen Value	3.04138	1.23963
% Variance	60.83	24.79
Cum. %	60.83	85.62

Significant loadings are underlined

Component II had high positive loading on block work (PDCBW) (0.7932) and low negative loading on burglary protection (PDCBP) (-0.7351). It has an Eigen value of 1.23963 and explained additional 24.79% of respondents' perception on design and construction of public housing. Component I and II explained 85.62% of the responses. They are reflective of the respondents' perception on the aesthetic appeal of both the design and construction of public housing. They were of the view that the building materials used in the estates were of superior quality, and also that the roofing patterns/materials can withstand the taste of time. This result is in conformity with the f-test result in above. The initial units of public housing estates were built by contractors, who maximized profit by cutting corners and by the using inferior materials. This problem was later solved by use of site and services, which allowed the homeowner to build according to his taste and regulated standard

b) Discussion pertaining to research question

The result tallied with Abloh (1980), who noted that housing acceptability should take into account, type of construction, materials used, and amount of space, services and facilities, condition of facilities within and outside dwelling, function and aesthetics among many others and Ebong (1983), who identified aesthetics, ornamentation, sanitation, drainage, age of building, access to basic housing facilities, burglary, spatial adequacy, noise level within neighbourhood, sewage and waste disposal, air pollution and ease of movement among others, as relevant quality determinants in housing.

This perception of the occupants (consumers) of public housing can only be a reaction that they do not want what the Staff of ASHDC/AHOCOL want or is providing for them. It was Davidoff, (1965) and Webber (1969), who argued that after technical (objective) indicators have been met, the residual and often decisive evidence is formed by the preferences, values and needs of the consumers. The officials charged with the responsibility of public housing planning, designing, constructing and administration need this kind of information system which monitors the community as a dynamic system which sustains improvement.

Hypothesis: There is no significant difference between the perception of the occupants and the staff of ASHDC/AHOCOL on the design and construction of public housing was tested.

Items 13 to 18 in the research instrument QAHPH bordering on perception of respondents on the design and construction of public housing, were statistically transformed into the following variables; DPHPW, DPHFR, DPHFH, DPHGL and DPHEC and the result is show on table 5.

Table 6 : t-Test Analysis of the Perception of the Respondents on the Design and Construction of Public Housing

Variables	Groups	N	Mean	SD	d.f	t-cal	t-crit	P- value	Decision
Perception of Design/Construction	Occupants	839	2.98	1.39	852	7.604	1.64	<0.05	Significant, Reject
	Staff of ASHDC/AHOCOL	15	3.95	1.15					

From Table 6, the calculated value of t is 7.604. The critical value of t at 0.05 level of significance and 852 degree of freedom is 1.64. Since the t-cal (7.604) is greater than the t-critical (1.64), we reject the null hypothesis and accept the alternative. Therefore, there is a significant difference between the perception of occupants and the staff of ASHDC/AHOCOL on the construction and design of public housing. From respondents' free comments the occupants complained about lack of functional community facilities like electricity and water supply. This result supports the findings in research question that there is variability (significant difference) in the perception of respondents on design and construction of public housing

From the research findings of this study, in relation to research question one on design and construction of public housing, it could be concluded that the respondents perceived the design and construction of public housing in the area of study as acceptable. Therefore also based on the findings of the study, the following conclusion was made: The design and construction of the public housing met the housing needs of the respondents; therefore the problem of public housing in Anambra State is not from design and construction viewpoint.

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Stochastic Finite Element Analysis for Transport Phenomena in Geomechanics using Polynomial Chaos

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Abstract- Transport Phenomena in Geomechanics occur under uncertain conditions and their parameters dominated by spatial randomness. The prediction of the progress of these phenomena is a stochastic problem rather than a deterministic. To solve the problem a procedure of conducting Stochastic Finite Element Analysis using Polynomial Chaos is presented. It eliminates the need for a large number of Monte Carlo simulations thus reducing computational time and making stochastic analysis of practical problems feasible. This is achieved by polynomial chaos expansion of the concentration. An example of a pollution development in a soil is presented and the results are compared to those obtained from Random Finite Element Analysis. A close matching of the two is observed.

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Stochastic Finite Element Analysis for Transport Phenomena in Geomechanics using Polynomial Chaos

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Abstract- Transport Phenomena in Geomechanics occur under uncertain conditions and their parameters dominated by spatial randomness. The prediction of the progress of these phenomena is a stochastic problem rather than a deterministic. To solve the problem a procedure of conducting Stochastic Finite Element Analysis using Polynomial Chaos is presented. It eliminates the need for a large number of Monte Carlo simulations thus reducing computational time and making stochastic analysis of practical problems feasible. This is achieved by polynomial chaos expansion of the concentration. An example of a pollution development in a soil is presented and the results are compared to those obtained from Random Finite Element Analysis. A close matching of the two is observed.

I. Introduction

The Tranposrt phenomena in geomechanics is a complex problem and cover a wide range of application. Problem as the contamination of land in many countries or recovery of oil in reservoir e.t.c, are dominated from the uncertainty and spatial variability of the properties of soil materials. Various forms of uncertainties arise which depend on the nature of geological formation, the extent of site investigation, the type and the accuracy of design calculations etc. In recent years there has been considerable interest amongst engineers and researchers in the issues related to quantification of uncertainty as it affects safety, design as well as the cost of projects.

Zhang, P. and Hu, L. (2014) presented in their study, a generalized model of preferential flow paths based on a dual-domain model which reflects contaminant transport and the dynamic transfer between two domains, and quantitatively analyzes the difference between advection-dispersion model (ADM) and dual-domain mass transfer model (DDM) in pore scale. Basic idea of this paper was the complexity of contaminant transport through highly heterogeneous soil on predicting pollution of the soil and groundwater system. Mousavi et all (2013) presented the development and the application of a numerical model for simulation of advective and diffusive-dispersive contaminant transport using a stochastic finite-element approach. Employing the stochastic finite-element method proposed in this study, the response variability was reproduced with a high accuracy. Johnson et all (2010) introduced an approach which has been incorporated into a spreadsheet model which uses a one-dimensional solution to the advection dispersion equation, which readily lends itself to Monte Carlo applications. The scope of this work was the definition of contaminant source release of contaminant mass transport simulation in the saturated zone as many sites the release history is unknown. Nadim et all (2004) proposed a three-dimensional stochastic model for the generation and transport of LFG in order to quantify the uncertainties. Using Monte Carlo simulations, multiple realizations of key input parameters was generated. For each realization, LFG transport was simulated and then used to evaluate probabilistically the rates and efficiency of energy recovery. Wörman, A. and Xu, S. (2001) developed a new modeling framework for internal erosion in heterogeneous stratified soils by combining existing methods used to study sediment transport in canals, filtration phenomena, and stochastic processes. The framework was used to study the erosion process in sediments caused by a flow of water through a covering filter layer that deviates from geometrical filter rules. By the use of spectral analysis and Laplace transforms, mean value solutions to the transport rate and the variance about the mean was derived for a transport constraint at the upstream boundary and a constant initial transport.

In this paper we present a general SFEM for transport phenomena in geomechanics using the method of Generalized Polynomial Chaos (GPC). In the first part of the paper a new algorithm based on RFEM using the Circulant Embedding method (Lord et all 2014) is presented in order to generate the random fields. In the second part, development of SFEM based on the Karhunen-Loeve Expansion for stochastic process discretisation and GPC is described. Finally in the last part of the paper, the problem of contamination of soil due to a surface source is solved by the two methods and the results are compared.

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a) Problem description and Model formulation

Let us consider a general spatial domain $D \subseteq R^3$ bounded by the surface S. Based on the conservative laws, in the domain, the transport mechanisms, such as convection (also called advection), diffusion can be described by the following equation:

$$\frac{\partial u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial t} - D_{if}(\boldsymbol{x},\boldsymbol{\omega})\Delta u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) + c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) = f(\boldsymbol{x},\boldsymbol{\omega}) \; in \; (0,T] \times D \times \Omega$$
$$u(\boldsymbol{0},\boldsymbol{x}) = \mathrm{u}_0 \; in \; B_D \tag{1}$$

In order to model the problem assuming the sample space $(\boldsymbol{\Omega}, \boldsymbol{\mathcal{F}}, \mathbb{P})$ where $\mathcal{F}$ the σ- algebra is and is considered to contain all the information that is available, $\mathbb{P}$ is the probability measure. The diffusion and convection coefficient $\{D_{if}(\boldsymbol{x},\boldsymbol{\omega}): \in D \times \Omega\}$ and the source or sink $\{f(\boldsymbol{x},\boldsymbol{\omega}): \in D \times \Omega\}$ considered as second order random fields and their functions are determined $D_{if}, c, f: D \times \Omega \rightarrow \mathbb{R} \in V = L^2(\Omega, L^2(D))$ and characterized by specific distribution. The Gaussian distribution is the default distribution in most application of probabilistic engineering mechanics. In our case the Gaussian distribution is inappropriate because of coefficients' nature. None of them cannot take negative value. Thus in order to cover all the values of them greater than zero a long normal distribution is adopted.

The expected value of a quantity of the problem is given by the following norm:

$$\|\cdot\|_{L^2(\Omega,L^2(D))} = \int_\Omega \int_D |\cdot|^2(x,\omega)dxd\mathbb{P} = \mathbb{E}\left(\|\cdot\|_{L^2(\mathrm{D})}\right) \tag{2}$$

In essence the solution of the problem is a function of the form $u_t \in \Omega \times D \rightarrow \mathbb{R}$ for every fixed t, i.e. a random field and is not a deterministic function.

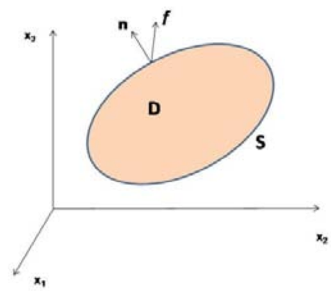

Figure 1 : Spatial Domain D bounded by the surface S

b) Variational Formulation

Using a test function$v \in V_0^h \;\; \in V = L^2(\Omega, L^2(D))$ and integrating by parts over the spatial domain $D \subseteq R^3$.

$$\int_D \frac{\partial u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial t} \cdot v(\boldsymbol{x})dx - \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\Delta u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx +$$
$$+\int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx = \int_D f(\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx \tag{3}$$

Considering the boundary condition

$$\int_D \frac{\partial u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial t} \cdot v(\boldsymbol{x})dx = \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla v(\boldsymbol{x})dx -$$
$$-\int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx - \int_D f(\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx \tag{4}$$

II. Random Finite Element

The most common way to solve this problem is to create a random field of the soil properties which is mapped to a grid of finite element and then for different every time realization of the fields $\{D_{if}(\boldsymbol{x},\boldsymbol{\omega}): \in D\times\Omega\}$ $\{c(\boldsymbol{x},\boldsymbol{\omega}): \in D\times\Omega\}$ and the source or sink $\{f(\boldsymbol{x},\boldsymbol{\omega}): \in D\times\Omega\}$ to solve an ordinary boundary value problem using the Monte Carlo method. Assuming the same randomness for all leads to computational efficiency and is not far from the reality.

In the current work the random field is generated by the Circulant Embedding method (Lord et all 2014) using the Fast Fourier Algorithm resulting, as will be shown in the following sections, an exact simulation of stochastic processes.

Following the random field generation the displacement field $u_k(\boldsymbol{x})$ for each realization is taken place. At the end of all running the statistical moment based on the Monte Carlo method is calculated. The problem for each realization of $\{D_{if}(\boldsymbol{x},\boldsymbol{\omega}): \in D\times\Omega\}$ and the source or sink $\{f(\boldsymbol{x},\boldsymbol{\omega}): \in D\times\Omega\}$ is:

$$\int_D \frac{\partial u_k(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial t}\cdot v(\boldsymbol{x})dx = \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla u_k(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla v(\boldsymbol{x})dx - -\int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u_k(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot v(\boldsymbol{x})dx - \int_D f(\boldsymbol{x},\boldsymbol{\omega})\cdot v(\boldsymbol{x})dx \qquad (5)$$

And the expected values at the end:

$$\mathbb{E}(u(\boldsymbol{x})) = \frac{1}{K}\sum_{k=1}^{K} u_k(\boldsymbol{x}) \qquad (6)$$

And the variance

$$Var(u(\boldsymbol{x})) = \frac{1}{K-1}\sum_{k=1}^{K}(u_k(\boldsymbol{x}) - \mathbb{E}(u(\boldsymbol{x}))^2 \qquad (7)$$

III. Random Field Generation

The Circulant Embedding method (Lord et all 2014) is a technique used for the generation of realizations of Gaussian stochastic processes. This technique has two main advantages among others. The first is that the statistical properties of the generated process are exactly the same process that we aim. The second advantage arises from the Fast Fourier Transform Algorithm which significantly reduces the computational cost. This method seems to have initially been studied in problems of one dimension by Davies & Harte (1987) and more systematically by Dembo et al. (1989), Dietrich & Newsam (1993, 1997), Gneiting (2000), Stein (2001), Craigmile (2003), and Percival (2006). Extension of the method to a multi-parameter problems studied by Wood (1999), Helgasonetal (2011) whereas in random fields by Dietrich & Newsam (1993), Wood & Chan (1994, 1997), Stein (2002, 2012), Gneiting et al. (2006). Considerable work was recently featured by Lord et all (2014) whose principles are followed in this work. According to the method, in the case where the samples are uniformly distributed in space in a two-dimensional problem, then the covariance matrix C is Toeplitz (Appendix A) and has as elements Toeplitz blocks (block Toeplitz with Toeplitz blocks (BTTB)). The covariance matrix can be described by the Fast Fourier Algorithm:

$$C = FDF^H \qquad (8)$$

Where:

$$F_{N=n_1n_2\times n_1n_2} = F_1 \otimes F_2 \qquad (9)$$

The $\mathrm{F}_1, \mathrm{F}_2$ are the Fourier matrices with dimension of $\mathrm{n}_1\times\mathrm{n}_1$ and $\mathrm{n}_1\times\mathrm{n}_2$ respectively and the diagonal matrix D includes the eigenvalues of the covariance matrix. For the application of the method the covariance matrix has to be circulant and for that reason using the BTTB matrix invokes a new circulant ((Appendix A)) matrix is created with n_2 blocks of circulant matrices $n_1\times n_1$ which is represented uniquely by the reduced matrix $\boldsymbol{C_{red}} = [\mathbf{c}_0,\dots,\mathbf{c}_{\mathrm{n}_2-1}]$. The latter can be replaced uniquely by the vector $\boldsymbol{c_{red}} \in \mathbb{R}^{\mathrm{n}_1\mathrm{n}_2}$.

Following the process described and provided that the covariance matrix has non-negative and real eigenvalues we get:

$$Z = D^{1/2}\xi \;\mu\varepsilon\; \xi\sim N(0,2I_N) \qquad (10)$$

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And finally

$$Z = X + iY \tag{11}$$

Where:

$$X \sim N(0, C)$$
$$Y \sim N(0, C)$$

Considering the covariance matrix:

$$C(x, y) = \sigma^2 \exp\left(-\frac{|x_j - x_i|}{\lambda_x} - \frac{|y_j - y_i|}{\lambda_y}\right) \tag{12}$$

In Figures 3 to 6, examples of random fields realization for different correlation lengths of covariance above matrix are presented.

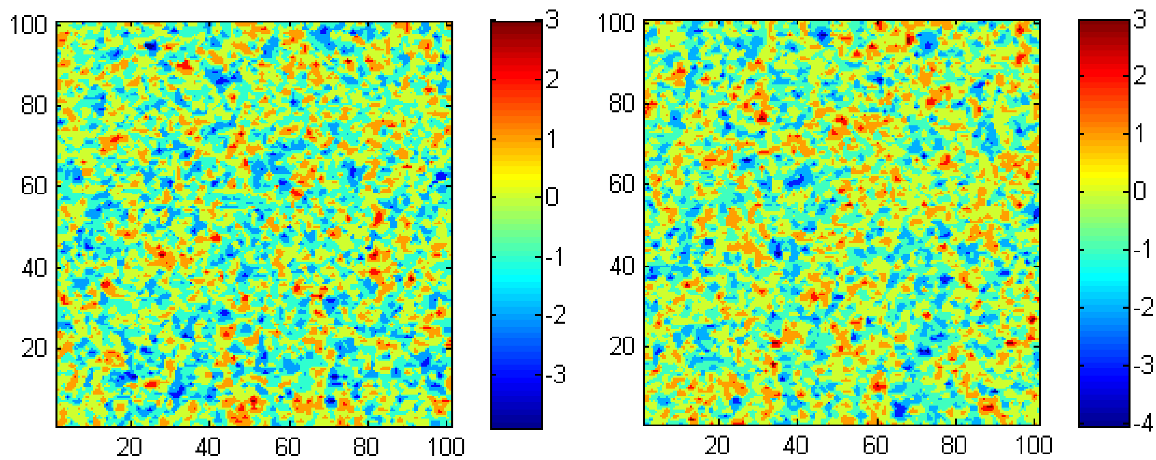

Figure 2 : Random field with dimension $D = [0,100] \times [0,100]$ and correlation length $\lambda_x = \lambda_y = \frac{1}{10}$

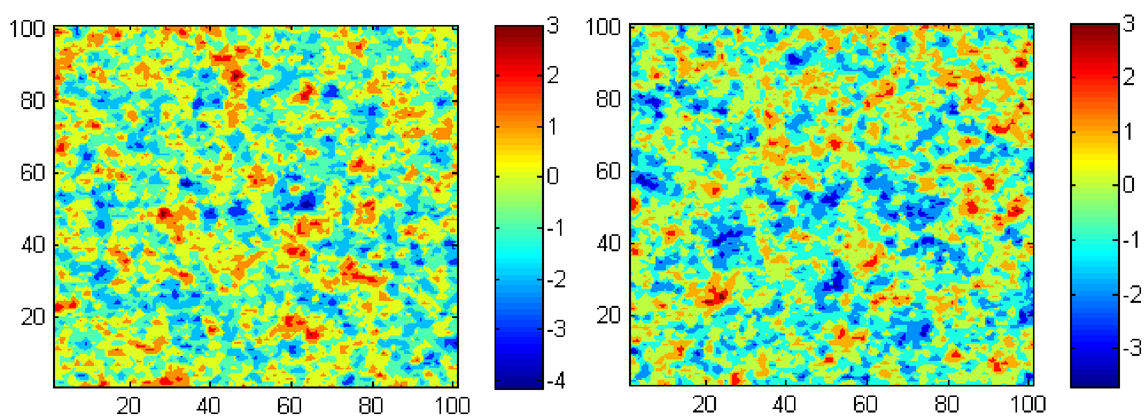

Figure 3 : Random field with dimension $D = [0,100] \times [0,100]$ and correlation length $\lambda_x = \lambda_y = \frac{2}{10}$

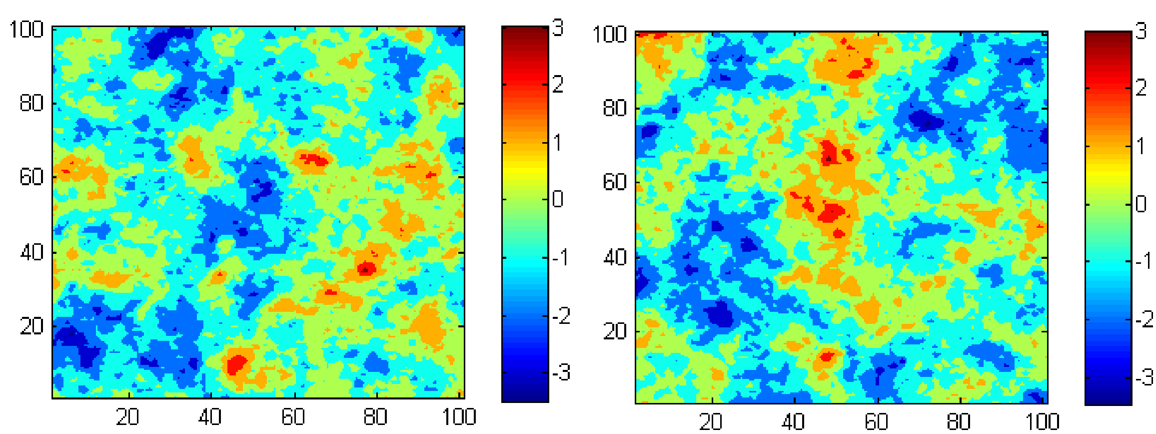

Figure 4 : Random field with dimension $D = [0,100] \times [0,100]$ and correlation length $\lambda_x = \lambda_y = 1$

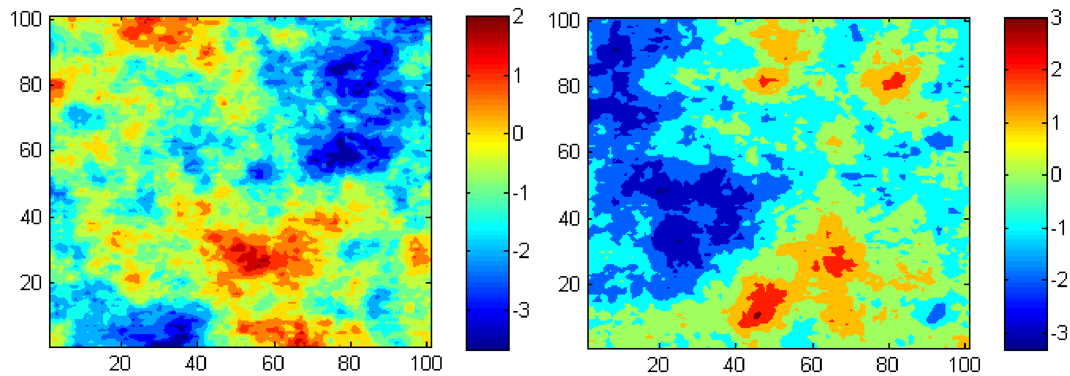

Figure 5 : Random field with dimension $D = [0,100] \times [0,100]$ and correlation length $\lambda_x = \lambda_y = 2$

IV. The Stochastic Finite Element Method (SFEM)

The SFEM based on Polynomial Chaos introduced analiatacaly by Ghanem & Spanos (1991) and have a wide range of applications and are used to solve problems in various branches of science. In the following paragraphs we introduce the procedure to solve the problems in Geomechanics using the Stochastic Finite Element Method for transport phenomena based on Generalized Polynomial Chaos (Xiu & Karniadakis 2003).

a) *Karhunen-Loeve Expansion*

One of the major points of the SFEM is the separation of deterministic part from the stochastic part of the formulation. Thus the method has two types of discretization, the ordinary FEM discretization of geometry and the stochastic discretization of random fields. In the current paper in order to reach in these results the Karhunen-Loeve expansion has been used which is the most efficient method for the discretization of a random field, requiring the smallest number of random variables to represent the field within a given level of accuracy. Based on that the stochastic process of the Diffusion and convection coefficients over the spatial domain with the known mean values $\widetilde{D}_{if}$ and $\tilde{c}(\mathrm{x})$ and covariance matrix $Cov(\mathrm{x}_1, \mathrm{x}_2)$ is given by:

$$D_{if}\big(\boldsymbol{x}, \xi(\omega)\big) = \exp\big(\widetilde{D_{if}}(\boldsymbol{x}) + \sum_{\kappa=1}^{\infty} \sqrt{\lambda_\kappa}\varphi_\kappa \xi_\kappa(\omega)\big)$$

$$c\big(\boldsymbol{x}, \xi(\omega)\big) = \exp\big(\tilde{c}(\boldsymbol{x}) + \sum_{\kappa=1}^{\infty} \sqrt{\lambda_\kappa}\varphi_\kappa \xi_\kappa(\omega)\big) \qquad (13)$$

In practice, calculations were carried out over a finite number of summations (for example 1-5) and the approximate stochastic representation is given by the trancuated part of expansion. The number of truncated is coming from the Karhunen-Loeve property where the eigenvalues λ_k decay as the k increase:

$$D_{if}\big(\boldsymbol{x}, \xi(\omega)\big) = \exp\big(\widetilde{D_{if}}(\boldsymbol{x}) + \sum_{\kappa=1}^{K} \sqrt{\lambda_\kappa}\varphi_\kappa \xi_\kappa(\omega)\big)$$

$$c\big(\boldsymbol{x}, \xi(\omega)\big) = \exp\big(\tilde{c}(\boldsymbol{x}) + \sum_{\kappa=1}^{k} \sqrt{\lambda_\kappa}\varphi_\kappa \xi_\kappa(\omega)\big) \qquad (14)$$

Where:

λ_κ : are the eigenvalues of the covariance function

$\varphi_\kappa(\boldsymbol{x})$: are the eigenfunctions of the covariance function $Cov(\mathbf{x_1}, \mathbf{x_2})$

$x \in$ D and $\boldsymbol{\omega} \in \Omega$

$\xi = [\xi_1, \xi_1, \ldots, \xi_M]: \Omega \rightarrow \Gamma \subset \mathbb{R}^M$ and

$\Gamma = \Gamma_1 \times \Gamma_1 \times \ldots \times \Gamma_M$

The pairs of eigenvalues and eigenfunctions arised by the Mercer's theorem:

$$\int_D C(x_1, x_2)\varphi(x_2) = \lambda\varphi(x_1) \qquad (15)$$

For two dimensional Domain $D = [-a_1, a_1] \times [-a_2, a_2]$ the eigenvalues are $\lambda_m = \lambda_1\lambda_2$ and eigenfunctions are equal to $\varphi_m(x) = \varphi_1(x_1)\varphi_2(x_2)$ where the values $\{\lambda_1, \lambda_2\}$ and $\{\varphi_1, \varphi_2\}$ calculated by the following equation:

$$\int_D C(x_1, x_2)\varphi_m(x_2) = \lambda_m\varphi_m(x_1), \quad m = 1,2 \qquad (16)$$

The rate of eigenvalue decay is inversely proportional to the correlation length. Thus for high correlation length (strong correlation) there is fast decay of the eigenvalues. For small correlation length (weak correlation) we have low decay. For zero correlation length there is not correlation and there is not decay of the eigenvalues. As the correlation length increases the decay rate increasing. If the correlation length is very small i.e correlation length =0.01 then the decay rate is not noticeable.

Implemented the Mercem theorem the first four eigenfunction are presented in figure 6 where in figures 7 and 8 the comparison of initial correlation matrix and the calculated based on the Mercer theorem is shown for different values of variation of diffusion coeficient. In figures 9, 10 The decay of eigenvalues in descending order are presented.

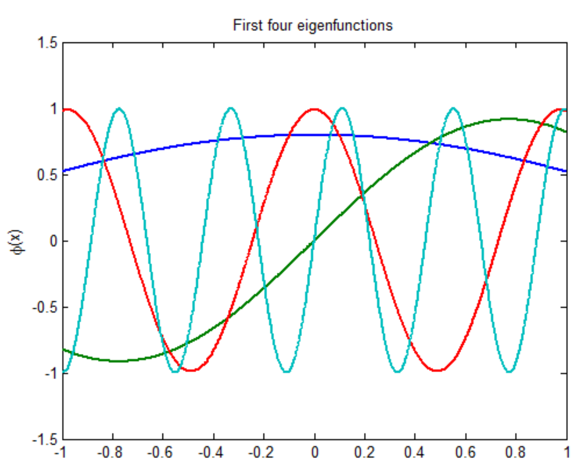

Figure 6 : First four eigenfunctions in the domain D=[-1,1]

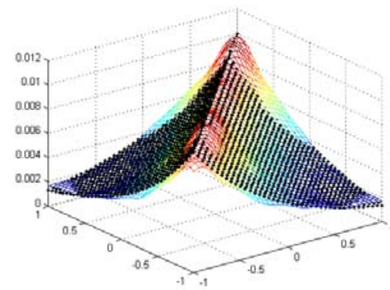

Figure 7 : Comparison of initial covariance matrix and its numerical approach with correlation length=1 and sigma=0.1

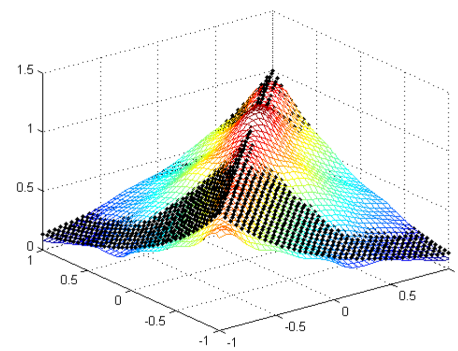

Figure 8 : Comparison of initial covariance matrix and its numerical approach with correlation length=1 and sigma=1

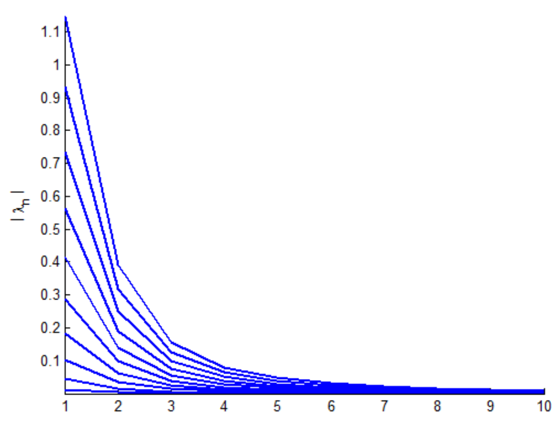

Figure 9 : Eingenvalues decay graph for different variation of diffusion coefficient

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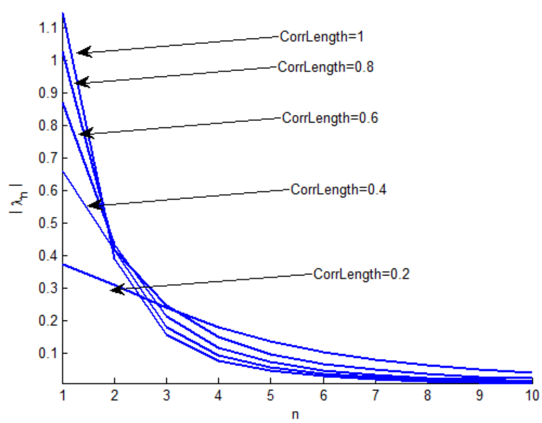

Figure 10 : Eingenvalues decay graph for different values of correlation length

b) Galerkin approximation

The Karhunen-Loeve expansion method enables to replace the calculating procedure for the expected value using instead of the abstract space Ω of random fields ξ their figures and finally to solve a deterministic problem in space $D \times \Gamma \subset \mathbb{R}^M$ instead of space $D \times \Omega$. By performing such replacements in fact a deterministic problem is solved, in contrast to the case of Monte Carlo where a large number of problems carried out. According that the test function of the weak form determined by $v \in L_p^2(\Gamma, H_0^1(D))$ while the solution of the problems in the general form of the boundaries conditions is a function $\tilde{u} \in W = L_p^2(\Gamma, H_g^1(D))$ which is satisfied the equation:

$$\int_D \frac{\partial \tilde{u}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial t} \cdot v(\boldsymbol{x})dx = \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla\tilde{u}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla v(\boldsymbol{x})dx - \\ - \int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla\tilde{u}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx - \int_D f(\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx \quad (17)$$

$\forall\, v \in L_p^2(\Gamma, H_0^1(D))$

The expected value of each side assuming that the behavior of source or sink is deterministic and constant:

$$< RHS >= \int_\Gamma \rho(\boldsymbol{y}) \int_0^H \frac{\partial \tilde{\boldsymbol{u}}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})}{\partial \boldsymbol{t}} \cdot v(x)\, dxdy \\ < LHS >= \int_\Gamma \rho(\boldsymbol{y}) [\int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla\tilde{u}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla v(\boldsymbol{x})dx - \int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla\tilde{u}(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx]dy \quad (18)$$

Where:

$\rho : \Gamma \to \mathbb{R}$ is the η joint density of independent random variables **ξ**

In order to solve the problem according to the finite element method in the current paper we consider a triangle K with nodes $N_i(x^{(i)}, y^{(i)}), i = 1,2,3$. To each node $\mathrm{N_i}$ there is a hat function φ_i associated, which takes the value 1 at node N_i and 0 at the other two nodes. Each hat function is a linear function on K so it has the form:

$$\varphi_\mathrm{i} = a_i + b_i x + c_i y \quad (19)$$

The test v function belongs to the space:

$$\mathrm{V^h} = span\{\varphi_1, \varphi_2, \dots, \varphi_N\} \subset \mathrm{H}_0^1(\mathrm{D}) \quad (20)$$

Any type of higher order shape functions can be used although it will increase the computational cost.

In order to solve the problem of equation 1 we have to create the new space $\mathrm{L_p^2}(\Gamma, \mathrm{H_0^1}(\mathrm{D}))$. For that reason the subspace $\mathrm{S^k} \subset \mathrm{L_p^2}(\Gamma)$ is considered as (Lord et all 2014).

$$S^k = span\{\psi_1, \psi_2, \dots, \psi_\mathrm{K}\} \quad (21)$$

Using the dyadic product of the space $\mathrm{V^h}$, S^k the space $\mathrm{L_p^2}(\Gamma, \mathrm{H_0^1}(\mathrm{D}))$ created. Thus

$$V^{hk} = V^h \otimes V^k = span\{\varphi_i \psi_j, \mathrm{i} = 1 \dots N, \mathrm{j} = 1, \dots Q\} \quad (22)$$

The space V^{hk} has dimension *QN* and regards the test function *v*. In the case where exists N_B finite element supported by boundaries condition then the subspace of solution belongs is:

$$\mathrm{W^{hk}} = \mathrm{V^{hk}} \oplus span\{\varphi_{N+1}, \varphi_{N+2}, \dots, \varphi_{N+NB}\} \quad (23)$$

c) Generalized Polynomial of chaos and stochastic Galerkin solution

Assuming that the S_i^k represents a space of univariate orthonormal polynomial of variable $y_i \subset \Gamma_i \subset \mathbb{R}$ with order k or lower and:

$$S_i^k = \{P_{a_i}^i(y_i), a_i = 1,2,\dots k\}, i = 1,\dots M \qquad (24)$$

The tensor product of the M S_i^k subspace results the space of the Generalized Polynomial Chaos:

$$S^k = S_1 \otimes S_2 \dots \otimes S_M \qquad (25)$$

Xiu & Karniadakis (2003) show the application of the method for different kind of orthonormal polynomials and in the current paper the Hermite polynomial was used with the following characteristics:

$$P_0 = 1, < P_i >= 0, i > 0 \qquad (26)$$

Where:

$\gamma_n =< P_n^2 >$: are the normalization factors.

δ_{mn} is the Kronecker delta

$\rho(\boldsymbol{y}) = \frac{1}{\sqrt{2\pi}} e^{-\frac{x}{2}}$ is the density function (27)

And:

$$P_n = (-1)^n e^{\frac{x}{2}} \frac{d^n}{dx^n} e^{-\frac{x}{2}} \qquad (28)$$

The function $u_t \in W^{hk}$ can be written as the summation of S^k polynomials base as

$$u_t(\boldsymbol{x},\boldsymbol{y}) = \sum_{k=1}^{P} u_k(\boldsymbol{x})\psi_\kappa(\boldsymbol{y}) \qquad (29)$$

According that and using the inner product of the weak form equation on each polynomial of the S^k base and get:

$$< LHS, \psi_p >=< \int_D \frac{\partial \sum \tilde{u}_i \varphi_i}{\partial t} \cdot \varphi_j(\boldsymbol{x}) dx, \psi_p >=$$

$$< \sum_{i=1}^{nnode} \frac{d\tilde{u}_i}{dt} \int_D \varphi_i(\boldsymbol{x}) \cdot \varphi_j(\boldsymbol{x}) dx, \psi_p >=$$

$$< \sum_{i=1}^{nnode} \frac{d}{dt} (\sum_{k=1}^{P} u_{ik}(\boldsymbol{t},\boldsymbol{x}) \psi_\kappa(\boldsymbol{y})) \int_D \varphi_i(\boldsymbol{x}) \cdot \varphi_j(\boldsymbol{x}) dx, \psi_p >=$$

$$\sum_{i=1}^{nnode} \sum_{k=1}^{P} \frac{du_{ik}(\boldsymbol{t},\boldsymbol{x})}{dt}_k \psi_\kappa(\boldsymbol{y}) \int_D \varphi_i(\boldsymbol{x}) \cdot \varphi_j(\boldsymbol{x}) dx, \psi_p >=$$

$$\sum_{i=1}^{nnode} \sum_{k=1}^{P} \frac{du_{ik}(\boldsymbol{t},\boldsymbol{x})}{dt}_k \int_\Gamma \rho(\boldsymbol{y}) \psi_\kappa(\boldsymbol{y}) \psi_p(\boldsymbol{y}) \int_D \varphi_i(\boldsymbol{x}) \cdot \varphi_j(\boldsymbol{x}) dx dy =$$

$$\frac{du(\boldsymbol{t},\boldsymbol{x})}{dt} \cdot M \otimes < \psi_\kappa \psi_p > \qquad (30)$$

Where:

$$M = \int_D \varphi_i(x) \cdot \varphi_j(x)\, dx \qquad (31)$$

$$< \psi_\kappa \psi_p >= \int_\Gamma \rho(y)\, \psi_\kappa(y) \psi_p(y) dy \qquad (32)$$

And the RHS of the weak form:

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$$RHS >=< \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla v(\boldsymbol{x})dx,\psi_p > -$$

$$-< \int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot v(\boldsymbol{x})dx,\psi_p > - \int_D f(\boldsymbol{x},\boldsymbol{\omega})\cdot v(\boldsymbol{x})dx \qquad (33)$$

Set

$$I_1 =< \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla v(\boldsymbol{x})dx,\psi_p > \qquad (34)$$

$$I_2 < \int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot v(\boldsymbol{x})dx,\psi_p > \qquad (35)$$

And let calculate these two integrals:

$$I_1 =< \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla v(\boldsymbol{x})dx,\psi_p > =$$

$$< \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega}) \sum_{\mathrm{i}}^{\mathrm{nnode}} u_i(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx,\psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} u_i(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx,\psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_i(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y}) \int_D D_{if}(\boldsymbol{x},\boldsymbol{\omega})\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx,\psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_i(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y}) \int_D e^{\widetilde{D_{if}}(x)+\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)}\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx,\psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_{ik}(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y})\, e^{\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)} \int_D e^{\widetilde{D_{if}}(x)}\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx,\psi_p > =$$

$$\sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_{ik}(\boldsymbol{t},\boldsymbol{x}) \int_{\boldsymbol{\Gamma}} \rho(y)e^{\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) \int_D e^{\widetilde{D_{if}}(x)}\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dxdy =$$

$$K \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}(t,x) \qquad (36)$$

Where

$$K = \int_D e^{\widetilde{D_{if}}(\boldsymbol{x})}\cdot\nabla\varphi_i(x)\nabla\varphi_j(\boldsymbol{x})dx \qquad (37)$$

$$< e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > = \int_{\boldsymbol{\Gamma}} \rho(\boldsymbol{y})e^{\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y})\, d\boldsymbol{y} \qquad (38)$$

Thus

$$I_1 = K \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}(t,x) \tag{39}$$

And

$$I_2 =< \int_D c(\boldsymbol{x},\boldsymbol{\omega})\nabla u(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot v(\boldsymbol{x})dx, \psi_p >$$

$$< \int_D c(\boldsymbol{x},\boldsymbol{\omega}) \sum_{\mathrm{i}}^{\mathrm{nnode}} u_i(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx, \psi_p, \psi_p >$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} u_i(\boldsymbol{t},\boldsymbol{x},\boldsymbol{\omega}) \int_D c(\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx, \psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_i(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y}) \int_D c(\boldsymbol{x},\boldsymbol{\omega}) \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx, \psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_i(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y}) \int_D e^{\tilde{c}(\boldsymbol{x})+\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)} \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx, \psi_p > =$$

$$< \sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_{ik}(\boldsymbol{t},\boldsymbol{x})\boldsymbol{\psi_k}(\boldsymbol{y})\, e^{\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)} \int_D e^{\tilde{c}(\boldsymbol{x})} \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx, \psi_p > =$$

$$\sum_{\mathrm{i}}^{\mathrm{nnode}} \sum_{\mathrm{k}}^{\mathrm{P}} u_{ik}(\boldsymbol{t},\boldsymbol{x}) \int_{\boldsymbol{\Gamma}} \rho(y)e^{\sum_{\kappa=1}^{K}\sqrt{\lambda_\kappa}\varphi_\kappa\xi_\kappa(y)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) \int_D e^{\tilde{c}(\boldsymbol{x})} \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dxdy =$$

$$C \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}(t,x) \tag{40}$$

Where

$$C = \int_D e^{\tilde{c}(\boldsymbol{x})} \cdot \nabla\varphi_i(x)\varphi_j(\boldsymbol{x})dx \tag{41}$$

Based on the above the initial equation of the transport phenomena under random behavior is equal to

$$\begin{aligned} \frac{du(\boldsymbol{t},\boldsymbol{x})}{dt} \cdot M \otimes < \psi_\kappa\psi_p > &= K \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}(t,x) \\ &- C \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}(t,x) - f(t,x) \end{aligned} \tag{42}$$

To solve this system there are various schemes to use and in the current paper the backward Euler method was applied:

$$\begin{aligned} \frac{d\tilde{u}}{dt} \cdot M \otimes < \psi_\kappa\psi_p > &= K \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}_{t_{n+1}} \\ &- C \otimes < e^{G(\xi)}\psi_k(\boldsymbol{y})\psi_p(\boldsymbol{y}) > \tilde{u}_{t_{n+1}} - f \end{aligned} \tag{43}$$

Set

$$MP = M \otimes < \psi_\kappa \psi_p > \quad (44)$$

$$KP = K \otimes < e^{G(\xi)} \psi_k(\boldsymbol{y}) \psi_p(\boldsymbol{y}) > \quad (45)$$

$$CP = C \otimes < e^{G(\xi)} \psi_k(\boldsymbol{y}) \psi_p(\boldsymbol{y}) > \quad (46)$$

$$\frac{d\tilde{u}}{dt} \cdot MP = KP\tilde{u}_{t_{n+1}} - CP\tilde{u}_{t_{n+1}} - f \quad (47)$$

After some algebra:

$$\tilde{u}_{t_{n+1}} = \frac{MP\tilde{u}_{t_n} - \Delta t \cdot f}{MP - \Delta t(KP - CP)} \quad (48)$$

The statistical moments of the displacement field arise by the properties of the Polynomial of Chaos expansion:

The expected value

$$\underbrace{u_0(\boldsymbol{x})\mathbb{E}[\psi_0(\boldsymbol{y})]}_{1} + \underbrace{\sum_{k=1}^{P} u_k(\boldsymbol{x})\mathbb{E}[\psi_\kappa(\boldsymbol{y})]}_{0} = u_0(\boldsymbol{x}) \quad (49)$$

And the variance

$$\sigma^2 = \mathbb{E}(u(\boldsymbol{x},\boldsymbol{y}) - \mathbb{E}[u(\boldsymbol{x},\boldsymbol{y})])^2 =$$

$$\mathbb{E}(\sum_{k=0}^{P} u_k(\boldsymbol{x})\mathbb{E}[\psi_\kappa(\boldsymbol{y})] - u_0(\boldsymbol{x})) \Rightarrow$$

$$\sigma^2 = \sum_{k=0}^{P} u_k^2(\boldsymbol{x})\mathbb{E}[\psi_\kappa^2 \ ] \quad (50)$$

V. Numerical Example

Considering a point source of pollution and the need to estimate its progress due to diffusion and advection phenomena. The problem and the geometry of the finite elements used presented in figure 10. The advection coefficient for simplicity is assumed to be deterministic and constant where the diffusion coefficient present spatial randomness and it is simulated as a random field (figure 11).

To solve the problem the application of the numerical algorithms described in the previous paragraphs is presented and results are compared to those obtained from RFEM using Monte Carlo simulations. The dimensionless input data of the problem is the random field diffusion coefficient with a constant average value equal to 0.1 and a fixed advection coefficient equal to 0.1. An initial source of point pollution equal to 2 is applied as described in figure 10.

In the figures 12-14 the two methods results of the expected values and standard deviation of concentration are shown for variation coefficient $v_e = 0.4$ and number of Monte Carle samples for the RFEM equal to 1000.

The problem then was solved for three different number of Monte Carle samples for the RFEM and 5, 50, 500 simulations are executed creating 10,100, and 1000 realisation while for SFEM were used one dimensional Hermite GPC with order 3 (Xiu & Karniadakis 2003). Calculations have been made for twelve different coefficients $v_e = \frac{\sigma_E}{\mu_E}$ of the diffusion coefficient with a minimum value of 0.1 and then with step 0.1 to a maximum value equal to 1.2.

In figures 14, 15 the results for the various calculation are presented. It is observed that as the number of sample increase the results of the Monte Carlo convergence to GPC method and for number of samples equal to 1000 a great accuracy is presented. In figures 17 and 18 this reduction is shown for a variation coefficient $v_e = 0.5$.

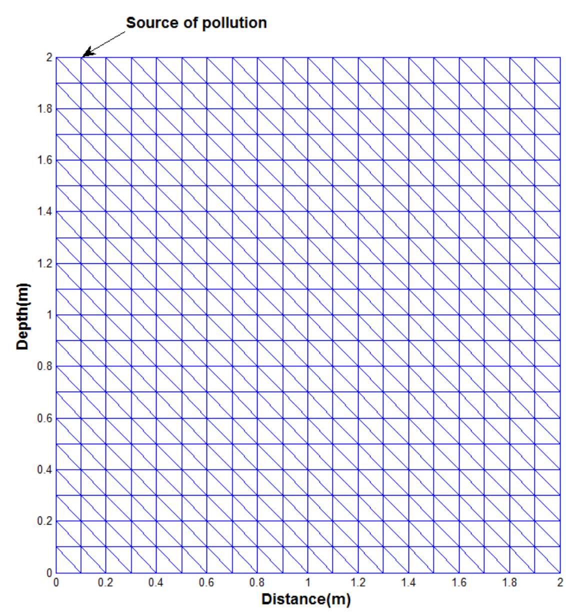

Figure 10 : Finite element mesh

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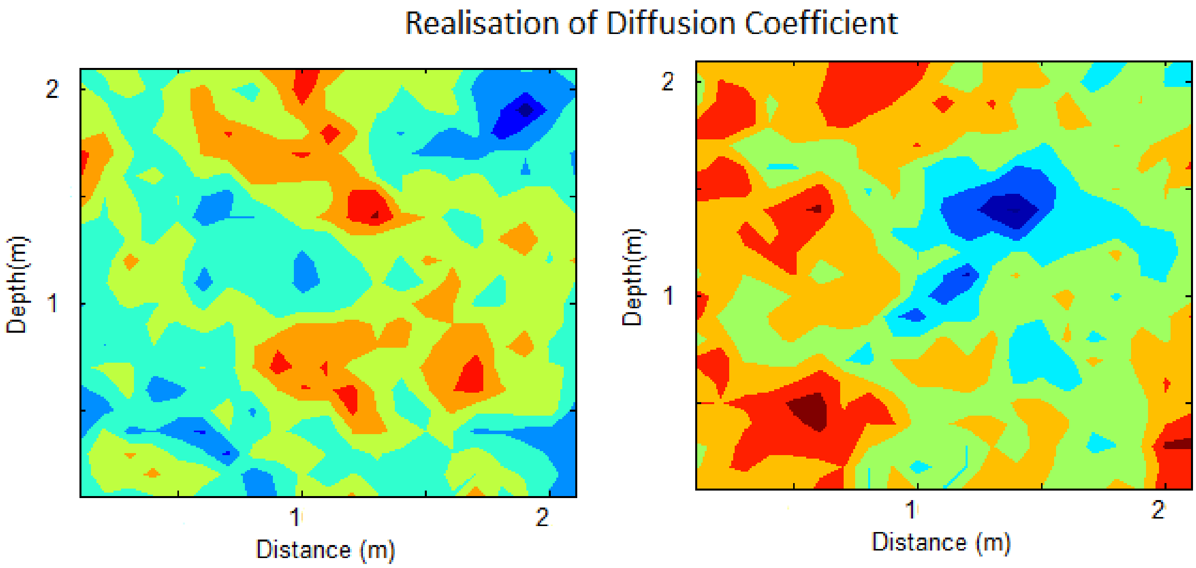

Figure 11 : Realisation of Diffusion Coefficient

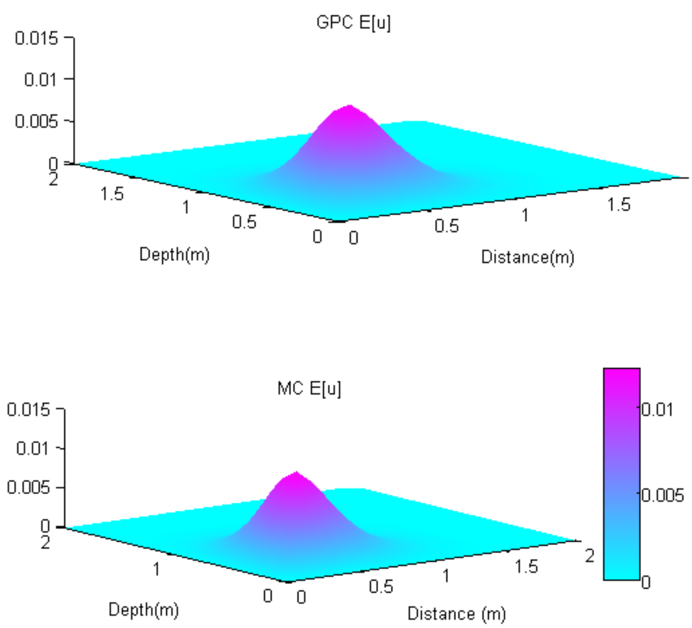

Figure 12 : Expected value of concentration at time 3dt

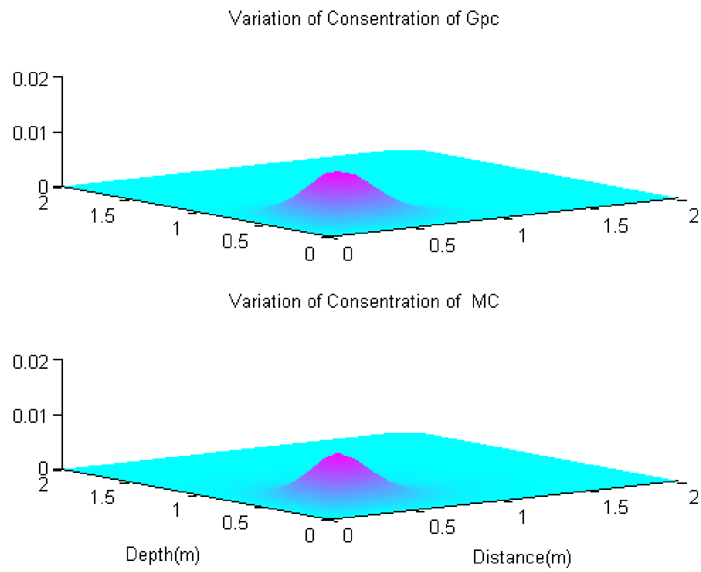

Figure 13 : Standard deviation of concentration at time 3dt

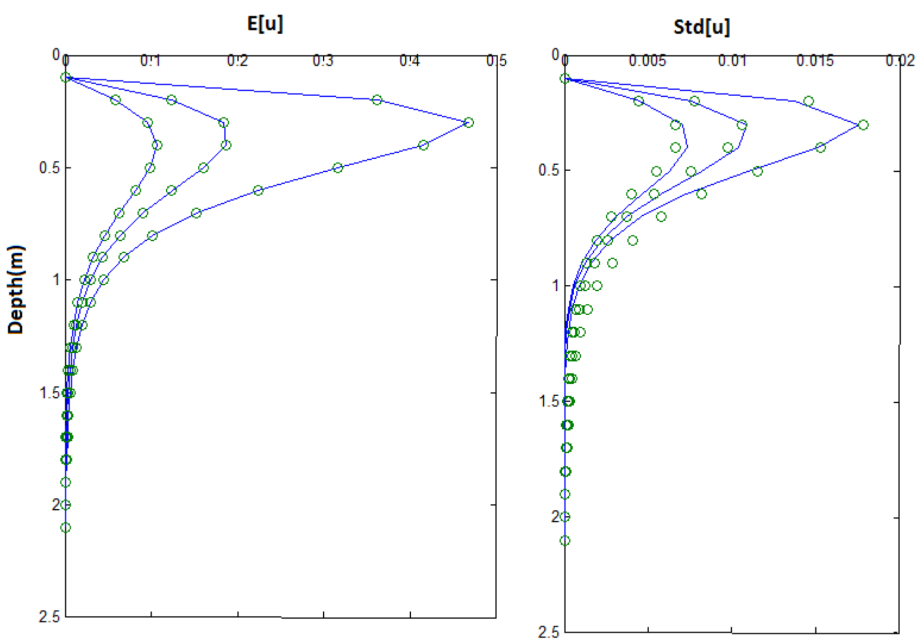

Figure 14 : Expected value and Standard deviation of concentration for tree different times (Standard deviation of diffusion coefficient σ=0.4)

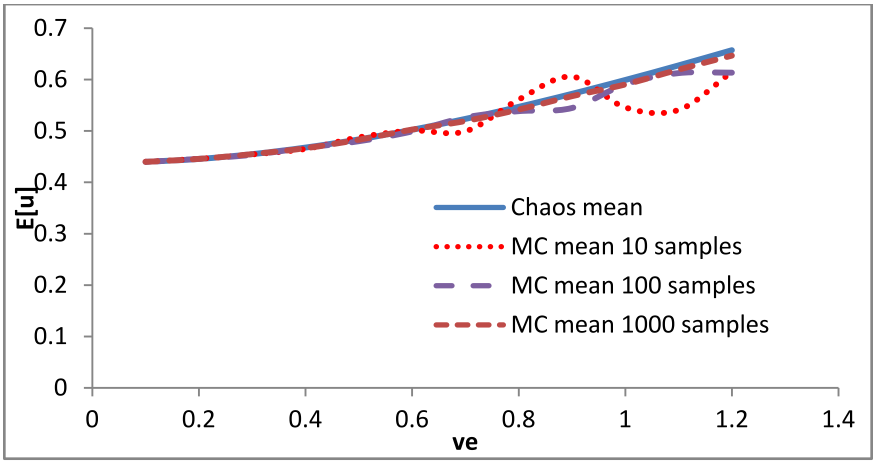

Figure 15 : Results of the expected value for twelve different values of variation coefficient and for tree different sample's number of Monte Carle method

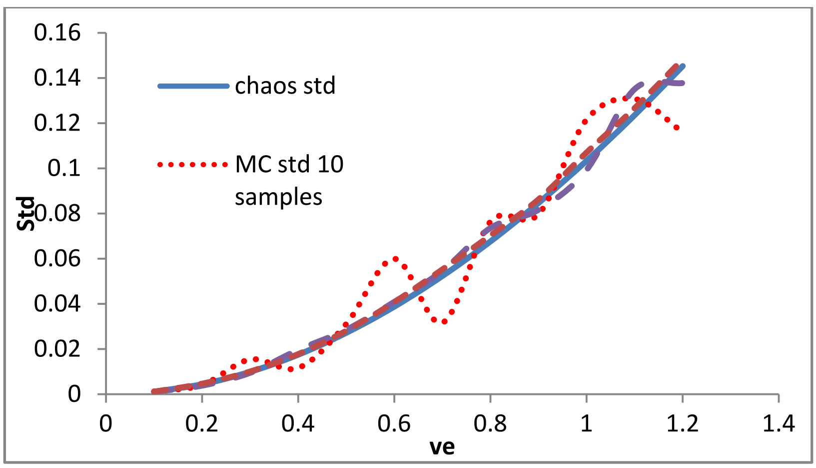

Figure 16 : Results of standard deviation of concentration for twelve different values of variation coefficient and for tree different sample's number of Monte Carle method

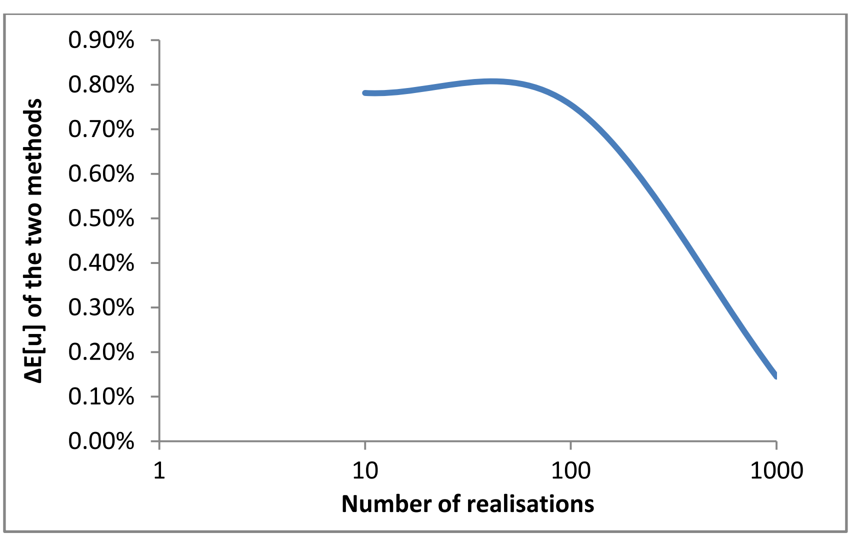

Figure 17 : Expected value different of the two methods for various numbers of realizations and for variation coefficient equal to 0.5

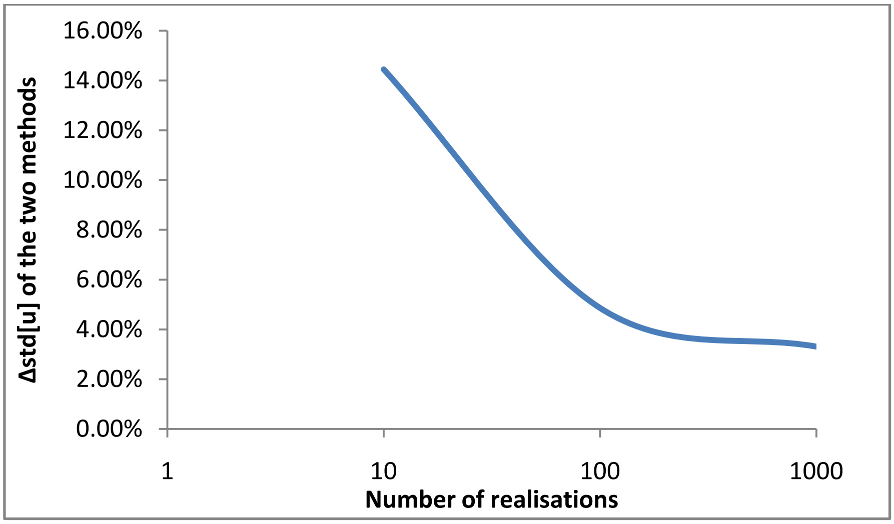

Figure 18 : Standard deviation different of the two methods for various numbers of realizations and for variation coefficient equal to 0.5

VI. Conclusions

A procedure of conducting a Stochastic Finite Element Analysis of Transport phenomena in Geomechanics where uncertainty arises due to spatial variability of mechanical parameters of soil/rock has been presented. Two different approaches in order to quantifying uncertainty are discussed. The first approach involves generating a random field based on Circulant embedding method and the second Stochastic Finite Element using Polynomial Chaos. A problem of a point source of pollution its progress due to diffusion and advection phenomena used to show the application of the methods.

It is shown that the results of SFEM using polynomial chaos compare well with those obtained from Random Finite Element Method. The main advantage in using the proposed methodology is that a large number of realisations which have to be made for RFEM are avoided, thus making the procedure viable for realistic practical problems.

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Appendix A

Definition 1. A Toeplitz matrix is an n × n matrix $T_n = [t_{k,j} : k, j = 0, 1 \dots, n-1]$ where $t_{k,j} = t_{k-j}$, i.e., a matrix of the form:

$$T_n = \begin{bmatrix} t_0 & t_{-1} & t_{-1} & \dots & t_{-(n-1)} \\ t_1 & t_0 & t_{-1} & & \vdots \\ t_2 & t_1 & t_0 & & \\ \vdots & & & \ddots & \\ t_{n-1} & & & \dots & t_0 \end{bmatrix}$$

Definition 2. When every row of the matrix is a right cyclic shift of the row above it so that $t_k = t_{-(n-k)}$ for $k = 1,2 \dots, n-1$. In this case the matrix is called Circulant and is equal to:

$$C_n = \begin{bmatrix} t_0 & t_{-1} & t_{-2} & \dots & t_{-(n-1)} \\ t_{-(n-1)} & t_0 & t_{-1} & & \\ t_{-(n-2)} & t_{-(n-1)} & t_0 & & \vdots \\ & & & \ddots & \\ t_{-1} & t_{-2} & & \dots & t_0 \end{bmatrix}$$

Definition 3. If C_k is $n_1 \times n_1$ Toeplitz matrix then the $N \times N$ matrix with $N = n_1 n_2$ and the form:

$$C = \begin{bmatrix} C_0 & C_{-1} & \dots & C_{2-n_2} & C_{1-n_2} \\ C_1 & C_0 & C_{-1} & \ddots & C_{2-n_2} \\ \vdots & \ddots & \ddots & & \vdots \\ C_{n_2-2} & \ddots & C_1 & C_0 & C_{-1} \\ C_{n_2-1} & C_{n_2-2} & \dots & C_1 & C_0 \end{bmatrix}$$

is called Block Toeplitz matrix with Toeplitz Blocks (BTTB).

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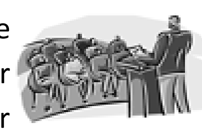
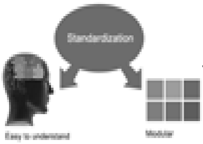


You may join as member of the Editorial Board of Global Journals Incorporation (USA) after successful completion of three years as Fellow and as Peer Reviewer. In addition, it is also desirable that you should organize seminar/symposium/conference at least once.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The FARSE can go through standards of OARS. You can also play vital role if you have any suggestions so that proper amendment can take place to improve the same for the benefit of entire research community.

As FARSE, you will be given a renowned, secure and free professional email address with 100 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.



The FARSE will be eligible for a free application of standardization of their researches. Standardization of research will be subject to acceptability within stipulated norms as the next step after publishing in a journal. We shall depute a team of specialized research professionals who will render their services for elevating your researches to next higher level, which is worldwide open standardization.

The FARSE member can apply for grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A. Once you are designated as FARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria. After certification of all your credentials by OARS, they will be published on your Fellow Profile link on website https://associationofresearch.org which will be helpful to upgrade the dignity.

The FARSE members can avail the benefits of free research podcasting in Global Research Radio with their research documents. After publishing the work, (including published elsewhere worldwide with proper authorization) you can upload your research paper with your recorded voice or you can utilize chargeable services of our professional RJs to record your paper in their voice on request.

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The FARSE is eligible to earn from sales proceeds of his/her researches/reference/review Books or literature, while publishing with Global Journals. The FARSE can decide whether he/she would like to publish his/her research in a closed manner. In this case, whenever readers purchase that individual research paper for reading, maximum 60% of its profit earned as royalty by Global Journals, will be credited to his/her bank account. The entire entitled amount will be credited to his/her bank account exceeding limit of minimum fixed balance. There is no minimum time limit for collection. The FARSE member can decide its price and we can help in making the right decision.

The FARSE member is eligible to join as a paid peer reviewer at Global Journals Incorporation (USA) and can get remuneration of 15% of author fees, taken from the author of a respective paper. After reviewing 5 or more papers you can request to transfer the amount to your bank account.

MEMBER OF ASSOCIATION OF RESEARCH SOCIETY IN ENGINEERING (MARSE)

The ' MARSE ' title is accorded to a selected professional after the approval of the Editor-in-Chief / Editorial Board Members/Dean.

The “MARSE” is a dignified ornament which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., MARSE or William Walldroff, M.S., MARSE.

MARSE accrediting is an honor. It authenticates your research activities. After becoming MARSE, you can add 'MARSE' title with your name as you use this recognition as additional suffix to your status. This will definitely enhance and add more value and repute to your name. You may use it on your professional Counseling Materials such as CV, Resume, Visiting Card and Name Plate etc.

The following benefitscan be availed by you only for next three years from the date of certification.

MARSE designated members are entitled to avail a 25% discount while publishing their research papers (of a single author) in Global Journals Inc., if the same is accepted by our Editorial Board and Peer Reviewers. If you are a main author or co-author of a group of authors, you will get discount of 10%.

As MARSE, you will be given a renowned, secure and free professional email address with 30 GB of space e.g. johnhall@globaljournals.org. This will include Webmail, Spam Assassin, Email Forwarders,Auto-Responders, Email Delivery Route tracing, etc.

We shall provide you intimation regarding launching of e-version of journal of your stream time to time.This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.

The MARSE member can apply for approval, grading and certification of standards of their educational and Institutional Degrees to Open Association of Research, Society U.S.A.

Once you are designated as MARSE, you may send us a scanned copy of all of your credentials. OARS will verify, grade and certify them. This will be based on your academic records, quality of research papers published by you, and some more criteria.

It is mandatory to read all terms and conditions carefully.

Institutional Fellow of Open Association of Research Society (USA)-OARS (USA)

Global Journals Incorporation (USA) is accredited by Open Association of Research Society, U.S.A (OARS) and in turn, affiliates research institutions as “Institutional Fellow of Open Association of Research Society” (IFOARS).

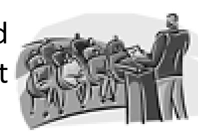
The “FARSC” is a dignified title which is accorded to a person’s name viz. Dr. John E. Hall, Ph.D., FARSC or William Walldroff, M.S., FARSC.

The IFOARS institution is entitled to form a Board comprised of one Chairperson and three to five board members preferably from different streams. The Board will be recognized as “Institutional Board of Open Association of Research Society”-(IBOARS).

The Institute will be entitled to following benefits:

The IBOARS can initially review research papers of their institute and recommend them to publish with respective journal of Global Journals. It can also review the papers of other institutions after obtaining our consent. The second review will be done by peer reviewer of Global Journals Incorporation (USA) The Board is at liberty to appoint a peer reviewer with the approval of chairperson after consulting us.

The author fees of such paper may be waived off up to 40%.



The Global Journals Incorporation (USA) at its discretion can also refer double blind peer reviewed paper at their end to the board for the verification and to get recommendation for final stage of acceptance of publication.

The IBOARS can organize symposium/seminar/conference in their country on behalf of Global Journals Incorporation (USA)-OARS (USA). The terms and conditions can be discussed separately.

The Board can also play vital role by exploring and giving valuable suggestions regarding the Standards of “Open Association of Research Society, U.S.A (OARS)” so that proper amendment can take place for the benefit of entire research community. We shall provide details of particular standard only on receipt of request from the Board.

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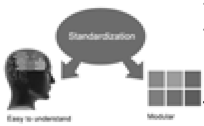
We shall provide you intimation regarding launching of e-version of journal of your stream time to time. This may be utilized in your library for the enrichment of knowledge of your students as well as it can also be helpful for the concerned faculty members.



After nomination of your institution as "Institutional Fellow" and constantly functioning successfully for one year, we can consider giving recognition to your institute to function as Regional/Zonal office on our behalf.
The board can also take up the additional allied activities for betterment after our consultation.

The following entitlements are applicable to individual Fellows:

Open Association of Research Society, U.S.A (OARS) By-laws states that an individual Fellow may use the designations as applicable, or the corresponding initials. The Credentials of individual Fellow and Associate designations signify that the individual has gained knowledge of the fundamental concepts. One is magnanimous and proficient in an expertise course covering the professional code of conduct, and follows recognized standards of practice.

Global RESEARCH RADIO

Open Association of Research Society (US)/ Global Journals Incorporation (USA), as described in Corporate Statements, are educational, research publishing and professional membership organizations. Achieving our individual Fellow or Associate status is based mainly on meeting stated educational research requirements.

Disbursement of 40% Royalty earned through Global Journals : Researcher = 50%, Peer Reviewer = 37.50%, Institution = 12.50% E.g. Out of 40%, the 20% benefit should be passed on to researcher, 15 % benefit towards remuneration should be given to a reviewer and remaining 5% is to be retained by the institution.

We shall provide print version of 12 issues of any three journals [as per your requirement] out of our 38 journals worth $ 2376 USD.

Other:

The individual Fellow and Associate designations accredited by Open Association of Research Society (US) credentials signify guarantees following achievements:

- The professional accredited with Fellow honor, is entitled to various benefits viz. name, fame, honor, regular flow of income, secured bright future, social status etc.

- In addition to above, if one is single author, then entitled to 40% discount on publishing research paper and can get 10%discount if one is co-author or main author among group of authors.
- The Fellow can organize symposium/seminar/conference on behalf of Global Journals Incorporation (USA) and he/she can also attend the same organized by other institutes on behalf of Global Journals.
- The Fellow can become member of Editorial Board Member after completing 3yrs.
- The Fellow can earn 60% of sales proceeds from the sale of reference/review books/literature/publishing of research paper.
- Fellow can also join as paid peer reviewer and earn 15% remuneration of author charges and can also get an opportunity to join as member of the Editorial Board of Global Journals Incorporation (USA)
- • This individual has learned the basic methods of applying those concepts and techniques to common challenging situations. This individual has further demonstrated an in–depth understanding of the application of suitable techniques to a particular area of research practice.

Note :

"

- In future, if the board feels the necessity to change any board member, the same can be done with the consent of the chairperson along with anyone board member without our approval.
- In case, the chairperson needs to be replaced then consent of 2/3rd board members are required and they are also required to jointly pass the resolution copy of which should be sent to us. In such case, it will be compulsory to obtain our approval before replacement.
- In case of "Difference of Opinion [if any]" among the Board members, our decision will be final and binding to everyone.

"

Process of submission of Research Paper

The Area or field of specialization may or may not be of any category as mentioned in 'Scope of Journal' menu of the GlobalJournals.org website. There are 37 Research Journal categorized with Six parental Journals GJCST, GJMR, GJRE, GJMBR, GJSFR, GJHSS. For Authors should prefer the mentioned categories. There are three widely used systems UDC, DDC and LCC. The details are available as 'Knowledge Abstract' at Home page. The major advantage of this coding is that, the research work will be exposed to and shared with all over the world as we are being abstracted and indexed worldwide.

The paper should be in proper format. The format can be downloaded from first page of 'Author Guideline' Menu. The Author is expected to follow the general rules as mentioned in this menu. The paper should be written in MS-Word Format (*.DOC,*.DOCX).

The Author can submit the paper either online or offline. The authors should prefer online submission.Online Submission: There are three ways to submit your paper:

(A) (I) First, register yourself using top right corner of Home page then Login. If you are already registered, then login using your username and password.

(II) Choose corresponding Journal.

(III) Click 'Submit Manuscript'. Fill required information and Upload the paper.

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(C) If these two are not conveninet , and then email the paper directly to dean@globaljournals.org.

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Page Size: 8.27" X 11'"

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- Font type of all text should be Swis 721 Lt BT.
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- Main Text: Font size 10 with justified two columns section
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- Line Spacing of 1 pt
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- Numbering of First Main Headings (Heading 1) must be in Roman Letters, Capital Letter, and Font Size of 10.
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You can use your own standard format also.
Author Guidelines:

1. General,

2. Ethical Guidelines,

3. Submission of Manuscripts,

4. Manuscript's Category,

5. Structure and Format of Manuscript,

6. After Acceptance.

1. GENERAL

Before submitting your research paper, one is advised to go through the details as mentioned in following heads. It will be beneficial, while peer reviewer justify your paper for publication.

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The Global Journals Inc. (US) welcome the submission of original paper, review paper, survey article relevant to the all the streams of Philosophy and knowledge. The Global Journals Inc. (US) is parental platform for Global Journal of Computer Science and Technology, Researches in Engineering, Medical Research, Science Frontier Research, Human Social Science, Management, and Business organization. The choice of specific field can be done otherwise as following in Abstracting and Indexing Page on this Website. As the all Global

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All authors should have been credited according to their appropriate contribution in research activity and preparing paper. Contributors who do not match the criteria as authors may be mentioned under Acknowledgement.

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Appeal of Decision: The Editorial Board's decision on publication of the paper is final and cannot be appealed elsewhere.

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Manuscript submission is a systematic procedure and little preparation is required beyond having all parts of your manuscript in a given format and a computer with an Internet connection and a Web browser. Full help and instructions are provided on-screen. As an author, you will be prompted for login and manuscript details as Field of Paper and then to upload your manuscript file(s) according to the instructions.

To avoid postal delays, all transaction is preferred by e-mail. A finished manuscript submission is confirmed by e-mail immediately and your paper enters the editorial process with no postal delays. When a conclusion is made about the publication of your paper by our Editorial Board, revisions can be submitted online with the same procedure, with an occasion to view and respond to all comments.

Complete support for both authors and co-author is provided.

4. MANUSCRIPT'S CATEGORY

Based on potential and nature, the manuscript can be categorized under the following heads:

Original research paper: Such papers are reports of high-level significant original research work.

Review papers: These are concise, significant but helpful and decisive topics for young researchers.

Research articles: These are handled with small investigation and applications

Research letters: The letters are small and concise comments on previously published matters.

5.STRUCTURE AND FORMAT OF MANUSCRIPT

The recommended size of original research paper is less than seven thousand words, review papers fewer than seven thousands words also.Preparation of research paper or how to write research paper, are major hurdle, while writing manuscript. The research articles and research letters should be fewer than three thousand words, the structure original research paper; sometime review paper should be as follows:

Papers: These are reports of significant research (typically less than 7000 words equivalent, including tables, figures, references), and comprise:

(a)Title should be relevant and commensurate with the theme of the paper.

(b) A brief Summary, "Abstract" (less than 150 words) containing the major results and conclusions.

(c) Up to ten keywords, that precisely identifies the paper's subject, purpose, and focus.

(d) An Introduction, giving necessary background excluding subheadings; objectives must be clearly declared.

(e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition; sources of information must be given and numerical methods must be specified by reference, unless non-standard.

(f) Results should be presented concisely, by well-designed tables and/or figures; the same data may not be used in both; suitable statistical data should be given. All data must be obtained with attention to numerical detail in the planning stage. As reproduced design has been recognized to be important to experiments for a considerable time, the Editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned un-refereed;

(g) Discussion should cover the implications and consequences, not just recapitulating the results; conclusions should be summarizing.

(h) Brief Acknowledgements.

(i) References in the proper form.

Authors should very cautiously consider the preparation of papers to ensure that they communicate efficiently. Papers are much more likely to be accepted, if they are cautiously designed and laid out, contain few or no errors, are summarizing, and be conventional to the approach and instructions. They will in addition, be published with much less delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and to make suggestions to improve briefness.

It is vital, that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

Format

Language: The language of publication is UK English. Authors, for whom English is a second language, must have their manuscript efficiently edited by an English-speaking person before submission to make sure that, the English is of high excellence. It is preferable, that manuscripts should be professionally edited.

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Abbreviations supposed to be used carefully. The abbreviated name or expression is supposed to be cited in full at first usage, followed by the conventional abbreviation in parentheses.

Metric SI units are supposed to generally be used excluding where they conflict with current practice or are confusing. For illustration, 1.4 l rather than 1.4 × 10-3 m3, or 4 mm somewhat than 4 × 10-3 m. Chemical formula and solutions must identify the form used, e.g. anhydrous or hydrated, and the concentration must be in clearly defined units. Common species names should be followed by underlines at the first mention. For following use the generic name should be constricted to a single letter, if it is clear.

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All manuscripts submitted to Global Journals Inc. (US), ought to include:

Title: The title page must carry an instructive title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) wherever the work was carried out. The full postal address in addition with the e-mail address of related author must be given. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining and indexing.

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Many researchers searching for information online will use search engines such as Google, Yahoo or similar. By optimizing your paper for search engines, you will amplify the chance of someone finding it. This in turn will make it more likely to be viewed and/or cited in a further work. Global Journals Inc. (US) have compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Key Words

A major linchpin in research work for the writing research paper is the keyword search, which one will employ to find both library and Internet resources.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy and planning a list of possible keywords and phrases to try.

Search engines for most searches, use Boolean searching, which is somewhat different from Internet searches. The Boolean search uses "operators," words (and, or, not, and near) that enable you to expand or narrow your affords. Tips for research paper while preparing research paper are very helpful guideline of research paper.

Choice of key words is first tool of tips to write research paper. Research paper writing is an art.A few tips for deciding as strategically as possible about keyword search:

- One should start brainstorming lists of possible keywords before even begin searching. Think about the most important concepts related to research work. Ask, "What words would a source have to include to be truly valuable in research paper?" Then consider synonyms for the important words.
- It may take the discovery of only one relevant paper to let steer in the right keyword direction because in most databases, the keywords under which a research paper is abstracted are listed with the paper.
- One should avoid outdated words.

Keywords are the key that opens a door to research work sources. Keyword searching is an art in which researcher's skills are bound to improve with experience and time.

Numerical Methods: Numerical methods used should be clear and, where appropriate, supported by references.

Acknowledgements: Please make these as concise as possible.

References

References follow the Harvard scheme of referencing. References in the text should cite the authors' names followed by the time of their publication, unless there are three or more authors when simply the first author's name is quoted followed by et al. unpublished work has to only be cited where necessary, and only in the text. Copies of references in press in other journals have to be supplied with submitted typescripts. It is necessary that all citations and references be carefully checked before submission, as mistakes or omissions will cause delays.

References to information on the World Wide Web can be given, but only if the information is available without charge to readers on an official site. Wikipedia and Similar websites are not allowed where anyone can change the information. Authors will be asked to make available electronic copies of the cited information for inclusion on the Global Journals Inc. (US) homepage at the judgment of the Editorial Board.

The Editorial Board and Global Journals Inc. (US) recommend that, citation of online-published papers and other material should be done via a DOI (digital object identifier). If an author cites anything, which does not have a DOI, they run the risk of the cited material not being noticeable.

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Tables: Tables should be few in number, cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g. Table 4, a self-explanatory caption and be on a separate sheet. Vertical lines should not be used.

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For scanned images, the scanning resolution (at final image size) ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs) : >350 dpi; figures containing both halftone and line images: >650 dpi.

Figure Legends: Self-explanatory legends of all figures should be incorporated separately under the heading 'Legends to Figures'. In the full-text online edition of the journal, figure legends may possibly be truncated in abbreviated links to the full screen version. Therefore, the first 100 characters of any legend should notify the reader, about the key aspects of the figure.

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Upon approval of a paper for publication, the manuscript will be forwarded to the dean, who is responsible for the publication of the Global Journals Inc. (US).

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Before start writing a good quality Computer Science Research Paper, let us first understand what is Computer Science Research Paper? So, Computer Science Research Paper is the paper which is written by professionals or scientists who are associated to Computer Science and Information Technology, or doing research study in these areas. If you are novel to this field then you can consult about this field from your supervisor or guide.

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1. Choosing the topic: In most cases, the topic is searched by the interest of author but it can be also suggested by the guides. You can have several topics and then you can judge that in which topic or subject you are finding yourself most comfortable. This can be done by asking several questions to yourself, like Will I be able to carry our search in this area? Will I find all necessary recourses to accomplish the search? Will I be able to find all information in this field area? If the answer of these types of questions will be "Yes" then you can choose that topic. In most of the cases, you may have to conduct the surveys and have to visit several places because this field is related to Computer Science and Information Technology. Also, you may have to do a lot of work to find all rise and falls regarding the various data of that subject. Sometimes, detailed information plays a vital role, instead of short information.

2. Evaluators are human: First thing to remember that evaluators are also human being. They are not only meant for rejecting a paper. They are here to evaluate your paper. So, present your Best.

3. Think Like Evaluators: If you are in a confusion or getting demotivated that your paper will be accepted by evaluators or not, then think and try to evaluate your paper like an Evaluator. Try to understand that what an evaluator wants in your research paper and automatically you will have your answer.

4. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

5. Ask your Guides: If you are having any difficulty in your research, then do not hesitate to share your difficulty to your guide (if you have any). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work then ask the supervisor to help you with the alternative. He might also provide you the list of essential readings.

6. Use of computer is recommended: As you are doing research in the field of Computer Science, then this point is quite obvious.

7. Use right software: Always use good quality software packages. If you are not capable to judge good software then you can lose quality of your paper unknowingly. There are various software programs available to help you, which you can get through Internet.

8. Use the Internet for help: An excellent start for your paper can be by using the Google. It is an excellent search engine, where you can have your doubts resolved. You may also read some answers for the frequent question how to write my research paper or find model research paper. From the internet library you can download books. If you have all required books make important reading selecting and analyzing the specified information. Then put together research paper sketch out.

9. Use and get big pictures: Always use encyclopedias, Wikipedia to get pictures so that you can go into the depth.

10. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right! It is a good habit, which helps to not to lose your continuity. You should always use bookmarks while searching on Internet also, which will make your search easier.

11. Revise what you wrote: When you write anything, always read it, summarize it and then finalize it.

12. Make all efforts: Make all efforts to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in introduction, that what is the need of a particular research paper. Polish your work by good skill of writing and always give an evaluator, what he wants.

13. Have backups: When you are going to do any important thing like making research paper, you should always have backup copies of it either in your computer or in paper. This will help you to not to lose any of your important.

14. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several and unnecessary diagrams will degrade the quality of your paper by creating "hotchpotch." So always, try to make and include those diagrams, which are made by your own to improve readability and understandability of your paper.

15. Use of direct quotes: When you do research relevant to literature, history or current affairs then use of quotes become essential but if study is relevant to science then use of quotes is not preferable.

16. Use proper verb tense: Use proper verb tenses in your paper. Use past tense, to present those events that happened. Use present tense to indicate events that are going on. Use future tense to indicate future happening events. Use of improper and wrong tenses will confuse the evaluator. Avoid the sentences that are incomplete.

17. Never use online paper: If you are getting any paper on Internet, then never use it as your research paper because it might be possible that evaluator has already seen it or maybe it is outdated version.

18. Pick a good study spot: To do your research studies always try to pick a spot, which is quiet. Every spot is not for studies. Spot that suits you choose it and proceed further.

19. Know what you know: Always try to know, what you know by making objectives. Else, you will be confused and cannot achieve your target.

20. Use good quality grammar: Always use a good quality grammar and use words that will throw positive impact on evaluator. Use of good quality grammar does not mean to use tough words, that for each word the evaluator has to go through dictionary. Do not start sentence with a conjunction. Do not fragment sentences. Eliminate one-word sentences. Ignore passive voice. Do not ever use a big word when a diminutive one would suffice. Verbs have to be in agreement with their subjects. Prepositions are not expressions to finish sentences with. It is incorrect to ever divide an infinitive. Avoid clichés like the disease. Also, always shun irritating alliteration. Use language that is simple and straight forward. put together a neat summary.

21. Arrangement of information: Each section of the main body should start with an opening sentence and there should be a changeover at the end of the section. Give only valid and powerful arguments to your topic. You may also maintain your arguments with records.

22. Never start in last minute: Always start at right time and give enough time to research work. Leaving everything to the last minute will degrade your paper and spoil your work.

23. Multitasking in research is not good: Doing several things at the same time proves bad habit in case of research activity. Research is an area, where everything has a particular time slot. Divide your research work in parts and do particular part in particular time slot.

24. Never copy others' work: Never copy others' work and give it your name because if evaluator has seen it anywhere you will be in trouble.

25. Take proper rest and food: No matter how many hours you spend for your research activity, if you are not taking care of your health then all your efforts will be in vain. For a quality research, study is must, and this can be done by taking proper rest and food.

26. Go for seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

27. Refresh your mind after intervals: Try to give rest to your mind by listening to soft music or by sleeping in intervals. This will also improve your memory.

28. Make colleagues: Always try to make colleagues. No matter how sharper or intelligent you are, if you make colleagues you can have several ideas, which will be helpful for your research.

29. Think technically: Always think technically. If anything happens, then search its reasons, its benefits, and demerits.

30. Think and then print: When you will go to print your paper, notice that tables are not be split, headings are not detached from their descriptions, and page sequence is maintained.

31. Adding unnecessary information: Do not add unnecessary information, like, I have used MS Excel to draw graph. Do not add irrelevant and inappropriate material. These all will create superfluous. Foreign terminology and phrases are not apropos. One should NEVER take a broad view. Analogy in script is like feathers on a snake. Not at all use a large word when a very small one would be sufficient. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Amplification is a billion times of inferior quality than sarcasm.

32. Never oversimplify everything: To add material in your research paper, never go for oversimplification. This will definitely irritate the evaluator. Be more or less specific. Also too, by no means, ever use rhythmic redundancies. Contractions aren't essential and shouldn't be there used. Comparisons are as terrible as clichés. Give up ampersands and abbreviations, and so on. Remove commas, that are, not necessary. Parenthetical words however should be together with this in commas. Understatement is all the time the complete best way to put onward earth-shaking thoughts. Give a detailed literary review.

33. Report concluded results: Use concluded results. From raw data, filter the results and then conclude your studies based on measurements and observations taken. Significant figures and appropriate number of decimal places should be used. Parenthetical remarks are prohibitive. Proofread carefully at final stage. In the end give outline to your arguments. Spot out perspectives of further study of this subject. Justify your conclusion by at the bottom of them with sufficient justifications and examples.

34. After conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print to the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects in your research.

Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form, which is presented in the guidelines using the template.
- Please note the criterion for grading the final paper by peer-reviewers.

Final Points:

A purpose of organizing a research paper is to let people to interpret your effort selectively. The journal requires the following sections, submitted in the order listed, each section to start on a new page.

The introduction will be compiled from reference matter and will reflect the design processes or outline of basis that direct you to make study. As you will carry out the process of study, the method and process section will be constructed as like that. The result segment will show related statistics in nearly sequential order and will direct the reviewers next to the similar intellectual paths throughout the data that you took to carry out your study. The discussion section will provide understanding of the data and projections as to the implication of the results. The use of good quality references all through the paper will give the effort trustworthiness by representing an alertness of prior workings.

Writing a research paper is not an easy job no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record keeping are the only means to make straightforward the progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear

· Adhere to recommended page limits

Mistakes to evade

- Insertion a title at the foot of a page with the subsequent text on the next page
- Separating a table/chart or figure - impound each figure/table to a single page
- Submitting a manuscript with pages out of sequence

In every sections of your document

· Use standard writing style including articles ("a", "the," etc.)

· Keep on paying attention on the research topic of the paper

· Use paragraphs to split each significant point (excluding for the abstract)

· Align the primary line of each section

· Present your points in sound order

· Use present tense to report well accepted

· Use past tense to describe specific results

· Shun familiar wording, don't address the reviewer directly, and don't use slang, slang language, or superlatives

· Shun use of extra pictures - include only those figures essential to presenting results

Title Page:

Choose a revealing title. It should be short. It should not have non-standard acronyms or abbreviations. It should not exceed two printed lines. It should include the name(s) and address (es) of all authors.

Abstract:

The summary should be two hundred words or less. It should briefly and clearly explain the key findings reported in the manuscript--must have precise statistics. It should not have abnormal acronyms or abbreviations. It should be logical in itself. Shun citing references at this point.

An abstract is a brief distinct paragraph summary of finished work or work in development. In a minute or less a reviewer can be taught the foundation behind the study, common approach to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Yet, use comprehensive sentences and do not let go readability for briefness. You can maintain it succinct by phrasing sentences so that they provide more than lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study, with the subsequent elements in any summary. Try to maintain the initial two items to no more than one ruling each.

- Reason of the study - theory, overall issue, purpose
- Fundamental goal
- To the point depiction of the research
- Consequences, including definite statistics - if the consequences are quantitative in nature, account quantitative data; results of any numerical analysis should be reported
- Significant conclusions or questions that track from the research(es)

Approach:

- Single section, and succinct
- As a outline of job done, it is always written in past tense
- A conceptual should situate on its own, and not submit to any other part of the paper such as a form or table
- Center on shortening results - bound background information to a verdict or two, if completely necessary
- What you account in an conceptual must be regular with what you reported in the manuscript
- Exact spelling, clearness of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else

Introduction:

The **Introduction** should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable to comprehend and calculate the purpose of your study without having to submit to other works. The basis for the study should be offered. Give most important references but shun difficult to make a comprehensive appraisal of the topic. In the introduction, describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will have no attention in your result. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here. Following approach can create a valuable beginning:

- Explain the value (significance) of the study
- Shield the model - why did you employ this particular system or method? What is its compensation? You strength remark on its appropriateness from a abstract point of vision as well as point out sensible reasons for using it.
- Present a justification. Status your particular theory (es) or aim(s), and describe the logic that led you to choose them.
- Very for a short time explain the tentative propose and how it skilled the declared objectives.

Approach:

- Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done.
- Sort out your thoughts; manufacture one key point with every section. If you make the four points listed above, you will need a least of four paragraphs.

- Present surroundings information only as desirable in order hold up a situation. The reviewer does not desire to read the whole thing you know about a topic.
- Shape the theory/purpose specifically - do not take a broad view.
- As always, give awareness to spelling, simplicity and correctness of sentences and phrases.

Procedures (Methods and Materials):

This part is supposed to be the easiest to carve if you have good skills. A sound written Procedures segment allows a capable scientist to replacement your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt for the least amount of information that would permit another capable scientist to spare your outcome but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section. When a technique is used that has been well described in another object, mention the specific item describing a way but draw the basic principle while stating the situation. The purpose is to text all particular resources and broad procedures, so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step by step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

- Explain materials individually only if the study is so complex that it saves liberty this way.
- Embrace particular materials, and any tools or provisions that are not frequently found in laboratories.
- Do not take in frequently found.
- If use of a definite type of tools.
- Materials may be reported in a part section or else they may be recognized along with your measures.

Methods:

- Report the method (not particulars of each process that engaged the same methodology)
- Describe the method entirely
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures
- Simplify - details how procedures were completed not how they were exclusively performed on a particular day.
- If well known procedures were used, account the procedure by name, possibly with reference, and that's all.

Approach:

- It is embarrassed or not possible to use vigorous voice when documenting methods with no using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result when script up the methods most authors use third person passive voice.
- Use standard style in this and in every other part of the paper - avoid familiar lists, and use full sentences.

What to keep away from

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings - save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part a entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Carry on to be to the point, by means of statistics and tables, if suitable, to present consequences most efficiently.You must obviously differentiate material that would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matter should not be submitted at all except requested by the instructor.

Content

- Sum up your conclusion in text and demonstrate them, if suitable, with figures and tables.
- In manuscript, explain each of your consequences, point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation an exacting study.
- Explain results of control experiments and comprise remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or in manuscript form.

What to stay away from

- Do not discuss or infer your outcome, report surroundings information, or try to explain anything.
- Not at all, take in raw data or intermediate calculations in a research manuscript.
- Do not present the similar data more than once.
- Manuscript should complement any figures or tables, not duplicate the identical information.
- Never confuse figures with tables - there is a difference.

Approach

- As forever, use past tense when you submit to your results, and put the whole thing in a reasonable order.
- Put figures and tables, appropriately numbered, in order at the end of the report
- If you desire, you may place your figures and tables properly within the text of your results part.

Figures and tables

- If you put figures and tables at the end of the details, make certain that they are visibly distinguished from any attach appendix materials, such as raw facts
- Despite of position, each figure must be numbered one after the other and complete with subtitle
- In spite of position, each table must be titled, numbered one after the other and complete with heading
- All figure and table must be adequately complete that it could situate on its own, divide from text

Discussion:

The Discussion is expected the trickiest segment to write and describe. A lot of papers submitted for journal are discarded based on problems with the Discussion. There is no head of state for how long a argument should be. Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implication of the study. The purpose here is to offer an understanding of your results and hold up for all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of result should be visibly described. Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved with prospect, and let it drop at that.

- Make a decision if each premise is supported, discarded, or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."
- Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work
- You may propose future guidelines, such as how the experiment might be personalized to accomplish a new idea.
- Give details all of your remarks as much as possible, focus on mechanisms.
- Make a decision if the tentative design sufficiently addressed the theory, and whether or not it was correctly restricted.
- Try to present substitute explanations if sensible alternatives be present.
- One research will not counter an overall question, so maintain the large picture in mind, where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

- When you refer to information, differentiate data generated by your own studies from available information
- Submit to work done by specific persons (including you) in past tense.
- Submit to generally acknowledged facts and main beliefs in present tense.

Please carefully note down following rules and regulation before submitting your Research Paper to Global Journals Inc. (US):

Segment Draft and Final Research Paper: You have to strictly follow the template of research paper. If it is not done your paper may get rejected.

- The **major constraint** is that you must independently make all content, tables, graphs, and facts that are offered in the paper. You must write each part of the paper wholly on your own. The Peer-reviewers need to identify your own perceptive of the concepts in your own terms. NEVER extract straight from any foundation, and never rephrase someone else's analysis.
- Do not give permission to anyone else to "PROOFREAD" your manuscript.
- Methods to avoid Plagiarism is applied by us on every paper, if found guilty, you will be blacklisted by all of our collaborated research groups, your institution will be informed for this and strict legal actions will be taken immediately.)
- To guard yourself and others from possible illegal use please do not permit anyone right to use to your paper and files.

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Topics	Grades		
	A-B	**C-D**	**E-F**
Abstract	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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