APPROVED FINAL YEAR PROJECT PROPOSAL

By

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FREQUENCY ANALYSIS OF MAXIMUM DAILY RAINFALL FOR SELECTED TOWNS IN NORTH-CENTRAL NIGERIA

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1.0 INTRODUCTION

Frequency Analysis is a statistical method of prediction. It consists of studying past events and process characteristics to define the probabilities of future occurrences. This prediction is based on fitting the act of probability to the empirical frequencies of past observation. Maximum rainfall predictions are often used to estimate peak flood discharges into drainage channels and on watersheds. In the design of hydraulic structures, an initial step is to determine the peak discharge which a particular culvert, channel, dam spillway, or bridge opening must safely allow.

The need for accurate rainfall predictions is readily apparent when considering the many benefits such information would provide for river control, reservoir operations, forestry interests, flashflood monitoring, etc. The accuracy of estimated flood peaks depends on the accuracy of extreme rainfall values being determined for any given geographical location with a specified frequency of occurrence or return period.

Frequency analysis of rain helps to predict the characteristics in terms of quantities, return period, and response time of the watershed. The analysis is used to quantify the extent of flooding and to take decisions necessary for storm-water drainage (size of storm network, discharge time) to mitigate the impact of these events generally on the urban map.

Rainfall frequency analysis are used as references for design, regulatory and hydrologic applications. The periodic updating of these studies are essential when additional data and new technology become available (MacVicar, 1981;Pathak, 2001). Subsequently this study will attempt to undertake rainfall frequency analysis of two states capital in north-central Nigeria.

2.0 AIM AND OBJECTIVES

This project aims at providing empirical model for forecasting maximum rainfall in Ilorin and Lokoja towns. The objective is to achieve this empirical prediction model through statistical analysis of existing rainfall data which would constitute a predictive input for engineering designs for such as flood control and its related hydraulic structures.

3.0 SCOPE AND LIMITATION OF STUDY

This study will only cover the towns of Lokoja in Kogi state and Ilorin in Kwara State. Both towns are in the north-central Nigeria and are the state capitals. Analysis will be carried out to establish the Intesity-Duration-Frequecy (IDF) relationship for the two towns.

4.0 LITERATURE REVIEW

Time series of daily rainfall records are often required as input for water resources projects. The availability of such records is often constrained by economic, technical and personnel factors. As an alternative, Haan et al., (1976) developed a first-order Markov chain rainfall model and also used probability matrices to simulate rainfall which was applied on seven rainfall stations. The simulated rainfall was compared with actual rainfall. The results of the comparisons indicated the model to be generating annual rainfall forecast.

Stern, 1980a; Stern, 1980b and Jackson, 1981 reported that Markov chain models of various orders are adequate for describing the occurrence of daily rainfall in Nigeria. Jimoh and Webster (1996) however, showed that the order 1 Markov model is sufficient for representing the occurrence of daily rainfall in the country as whole but not representing regional cases. This observation was based upon the ability of the model to reproduce the characteristics of the observed series, rather than formalized statistical tests. However, a comparison of the Gumbel, Log-Pearson III and Log-Gumbel for analysis of rainfall-duration-Frequency reveals that Gumbel is more reliable and easy to work with for regional analysis (Kerr et al., 1970).

Kerr et al., (1970) carried out analysis using the three aforementioned distribution methods and observed that when the largest values from the annual series are more than 40 percent greater than the next largest value in the series, the log-Gumbel curve may fit the data best, but the extrapolation curve may become so concave upward that it loses all significance. The log-Pearson III curve also becomes highly concave upward. The Gumbel line,in trying to fit all the points, does not fit any very well, but does give the most believable extrapolation.

Regional rainfall analysis research results by Oyebande (1982) in deriving intensity-duration-frequency (IDF) relationships have been found useful and they are in line with the objective of this study. In most cases, the choice between the Gumbel and log-Pearson III is very difficult and in many of these cases there is little difference between the two distributions (Kerr et al., 1970).The log-Pearson III distribution requires log-transformed data and a third statistical moment and has not proved to be as easy a tool to work with as the Gumbel distribution which plots as a straight line on extreme value paper. Therefore, the Gumbel distribution is the choice distribution to use in approximating the distribution of maximum rainfall in this study.

The approach by Oyebande (1982) assumes that a sample of rainfall in a region or zone is sufficiently varied to represent the population of a long period. The present knowledge of the storm characteristics in Nigeria indicates that the showers which account for most of the intense falls are highly localized and further concluded that the Gumbel EV-1 is sufficiently skewed to warrant the use of the maximum likelihood method to obtain the final estimates. Fitting of model is also of importance in the use of models where limited observed data are available for parameter identification. Fitting of the model parameters can be achieved using mathematical functions. For example, Coe and Stern (1982) and Zucchini and Adamson (1984) used Fourier functions to smooth the model parameters at some stations in Africa. Although Jimoh and Webster (1996) reported that the sequences of wet and dry days generated with the unfitted model parameters are similar to the observed sequences, the ability of these unfitted parameters to reproduce the characteristics of the historical sequence has not previously been identified. Before finally accepting the Gumbel distribution, this study will utilize similar approach by fitting the model. Its assumption of a fixed skewness coefficient will be investigated from the annual series of the stations by plotting the probability distribution line. Points falling outside of the line are deviations from the theoretical model while the points on the line comply strongly with the empirical model.

5.0 STUDY AREA

Ilorin, Kwara State

Ilorin is the capital of Kwara State in the north central region of Nigeria. It is approximately on longitude 4°35'E and latitude 8°30'N (Federal Republic of Nigeria, 2013). It has an estimated area of 50.2km^2 and a population of 847,582 by 2006 census. Ilorin has an annual rainfall range of 1000mm to 1500mm and average maximum temperatures between 30^{o}C and 35^{o}C (Kwara State Government, 2013). See figure 1 for map of Nigeria showing Ilorin, Kwara State.

The city is populated by Yoruba, Hausa, Nupe, Baruba, other Nigerians and foreign nationals.
Economy of Ilorin is progressing forward with the establishment of bank branches and improved banking services. Many small-scale enterprises are working with the banks in opening business. Ilorin has a number of manufacturing companies e.g. Global Soap & Detergents, Lubcon and Tuyi Pharmaceuticals. It is also a home to higher institutions like University of Ilorin, Kwara State University, School of Nursing, College of Education, Kwara State Polytechnic and few more others. (Kwara State Government, 2013)

Lokoja, Kogi State

Lokoja is the capital city of Kogi State in central Nigeria. Kogi state lies on latitude 7.49^{o}N and longitude 6.45^{o}E and bounded by the Niger in the north Kwara State in the west. Lokoja was the capital of the British Northern Nigeria Protectorate and remained a convenient administrative town for the British colonial government after the amalgamation of Northern and Southern Nigeria in 1914 (Kogi State Government, 2013). See figure 1 for map of Nigeria showing Lokoja, Kogi State.

Lokoja is also a Local Government Area in Kogi State. It has an area of 3180 km^2 and a population of 195,261 at the 2006 census. Lokoja has average maximum temperature between 27^{o}C and 32^{o}C. There are three main ethnic groups and languages in Kogi: Igala, Ebira, and Okun (part of Yoruba) with other minorities like Bassa, a small fraction of Nupe mainly in Lokoja, Gwari, Kakanda, Oworo people (similar to Yoruba), ogorimagongo and the Eggan community under Lokoja Local Government. It is a trade center for its agricultural region because it sits at the confluence of the Niger and Benue rivers, and is close to the new federal capital of Nigeria in Abuja. It is also home to Kogi State Polytechnic, Kogi State University and Federal College of Education in close-by towns (Kogi State Government, 2013).

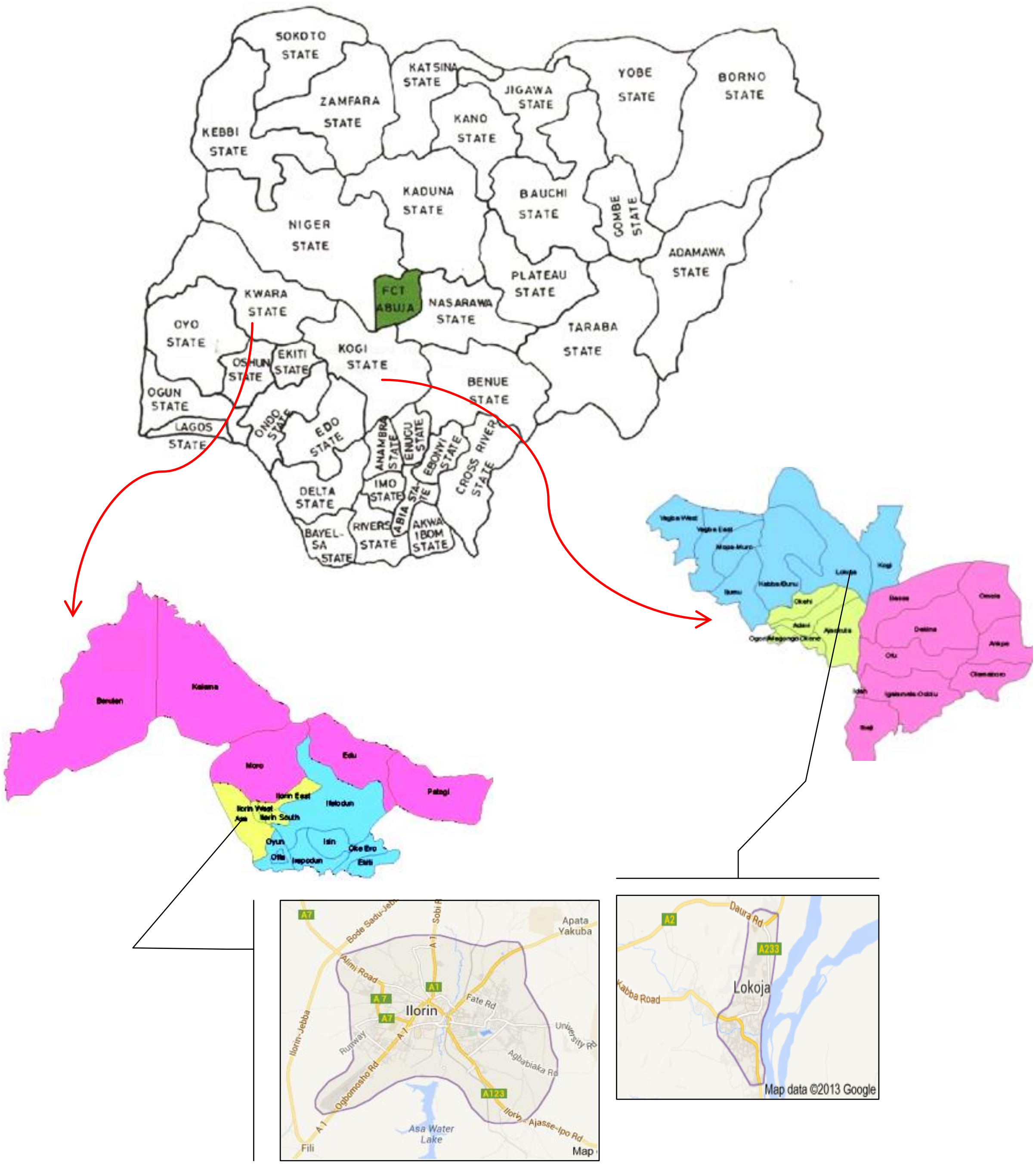


Figure 1: Study Areas; Ilorin and Lokoja

6.0 METHODOLOGY

The procedural approach that will be used to execute this study is as outlined in Figure 2

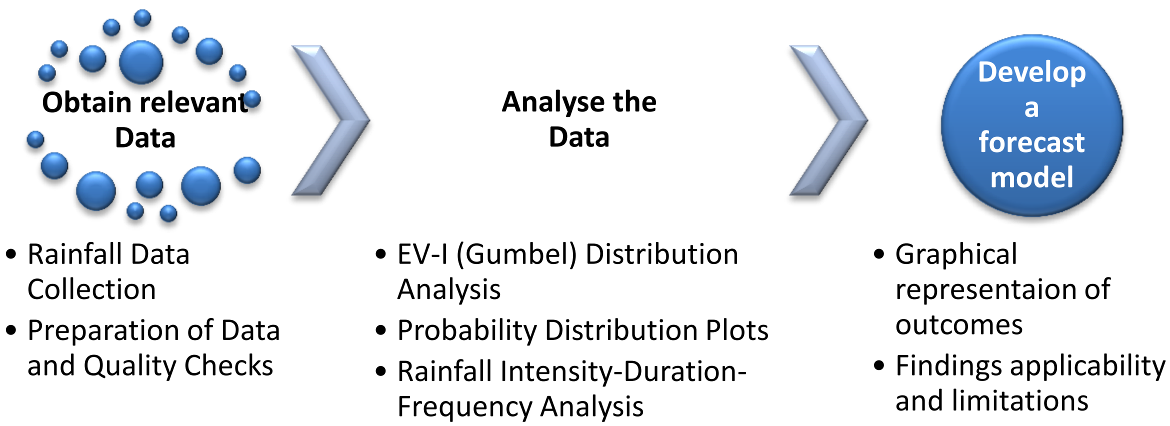


Figure 2: Summarized methodology

6.1 Rainfall Data Collection

The methods generally used for data collection and compilation of precipitation data may vary among different agencies, however, the primary types of rainfall data in the region are daily measurements and rainfall intensity (depths accumulated at various times) data.

Rainfall data will be sourced from Nigerian Meteorological Agency (NIMET) in Oshodi, Lagos. The actual method used for data collection at each station will be of interest to this study in determining the reliability and accuracy of the data.

6.2 Preparation of Data and Quality Checks

Depending on the level of information available, missing data will be checked for continuity and consistency against possible causes like;

- Damaged or faulty rain gauge during a period
- Change of gauge type
- Multiple use or change of observers
- Change of gauge location
- Remarkable change in the neighborhood of the station

For adequacy, the data will be checked to ensure the minimum number of rain gauges required to achieve a desired level of accuracy is satisfied. This will be done by coefficient of variation approach and will be discussed further if the data source is found to have enough information to do the adequacy check.

6.3 Gumbel Distribution (Extreme Value Type I)

If M_1, $M_2 \dots M_n$ be a set of daily rainfall and let x = max(M_i) be the maximum for the year. If M_i is independent and identically distributed, then for large n, x has an extreme value or Gumbel distribution represented as:

$$f(x) = \exp\left[-exp\left(-\frac{x-u}{\alpha}\right)\right]$$

$$where\ \alpha = \frac{\sqrt{6s}}{\pi}\ \ and\ u = \ \overline{x} - 0.5722\alpha$$

Define a reduced variable y such that

$$y = \frac{x-u}{\alpha}\ then\ f(x) = exp[-exp(-y)]$$

$$y = \ -\ln\big[-\ln\big(f(x)\big)\big] = \ -\ln[-\ln(1-p)]\ where\ p = Probability\ P(x \geq x_T)$$

$$hence, y_T = \ -\ln\left[-\ln\left(1 - \frac{1}{T}\right)\right]$$

$$or\ simply\ written\ as\ y_T = \ -\ln\left[\ln\left(\frac{T}{T-1}\right)\right]$$

Now for any return period T, the frequency factor y_T can be obtained; hence rainfall depth x_T can be computed from equation (Ibrahim, 2012):

$$x_T = \ u + y_T\alpha$$

$$= \ \overline{x} - 0.5772\frac{\sqrt{6}}{\pi}s + \frac{\sqrt{6}}{\pi}s\left\{-\ln\left[\ln\left(\frac{T}{T-1}\right)\right]\right\}$$

$$= \ \overline{x} - \frac{\sqrt{6}}{\pi}\left\{0.5772 + \ln\left[\ln\left(\frac{T}{T-1}\right)\right]\right\}s$$

Comparing this equation to the form

$$x_T = \ \overline{x} + K_T s$$

Hence,

$$K_T = -\frac{\sqrt{6}}{\pi}\left\{0.5772 + \ln\left[\ln\left(\frac{T}{T-1}\right)\right]\right\}$$

6.4 Probability Plot for Extreme Value Type I(EV-I) Rainfall Data

Probability plot is a graphical tool to assess whether or not the data fits a particular distribution. The data will be fitted against a theoretical distribution for EV-I in such a way that the points should form approximately a straight line. This way the distribution function will be linearized. The Gringorten formula will be used as it applies more accurately for EV-I distributions (Shabri, 2002).

If *n* is the total number of values to be plotted and *i* is the rank of a value in a list ordered by descending magnitude, the probability of the *ith* largest value, x_i, for large n, is shown in Table 1

Table 1: Plotting position formulas

Proponent	Formula	a	Parent Distribution
Weibull (1939)	$\frac{i}{n+1}$	0	All distributions
Beard (1943)	$\frac{i-0.3175}{n+0.365}$	0.3175	All distributions
APL	$\frac{i-0.35}{n}$	0.35	Used with Probability Weighted Moments Method (PWM)
Blom (1958)	$\frac{i-3/8}{n+1/4}$	0.375	Normal Distributions
Cunnane (1977)	$\frac{i-0.40}{n+0.2}$	0.40	GEV and PIII distributions
Gringorten (1963)	$\frac{i-0.44}{n+0.12}$	0.44	Exponential, EV1 and GEV distributions
Hazen (1914)	$\frac{i-0.5}{n}$	0.50	Extreme Value distributions
Nguyen et. al (1989)	$\frac{i-0.12}{n+0.3\gamma+0.05}$		PIII distribution

Source: Shabri, 2002

Departures from the straight line will indicate departure from the theoretical distribution
The following steps will be taken to come up with the probability plot

- Sort the data from largest to smallest
- Assign plotting position using Gringorten formula$P(X \geq x_i) = P(i) = \frac{i-0.44}{n+0.12}$
- Calculate reduced variable $y_i = -\ln[-\ln(1-P(i))]$
- Plot sorted data against y_i
- If the data falls on a straight line, the data complies with the EV-I distribution

6.5 Intensity-Duration-Frequency (IDF) Analysis

When local rainfall data are available, IDF curves can be developed using frequency analysis (Ibrahim, 2012)

Steps for IDF analysis are:

1. Select a design storm duration *D*, say *D*=24 hours.
2. Collect the annual maximum rainfall depth of the selected duration from n years of historic data.
3. Determine the probability distribution of the D-hr annual maximum rainfall. The mean and standard deviation of the D-hr annual maximum rainfall are estimated.
4. Calculate the *D*-hr*T*-yr design storm depth X_T by using the following frequency factor equation:$x_T = \overline{x} + K_T s$
   where $\overline{x}$, $s$and K_T are mean, standard deviation and frequency factor, respectively. The frequency factor K_T is distribution-specific and solved for in the Extreme Value distribution in the next section.
5. Calculate the average intensity$\bar{i}_T(D) = \frac{x_T}{D}$
   and repeat Steps 1 through 4 for various design storm durations.
6. Construct the IDF curves.

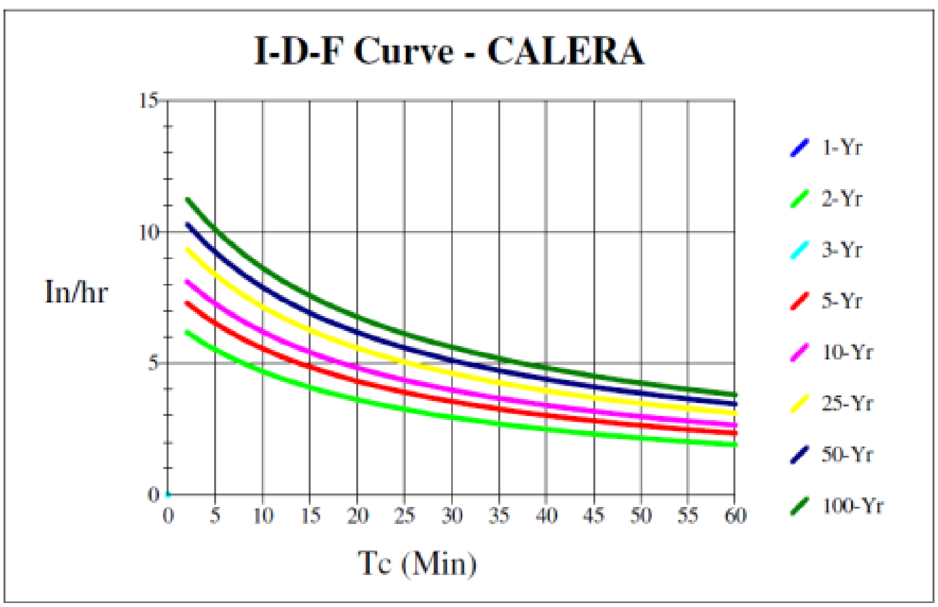


Figure 3: Sample of intensity-duration-frequency curves

7.0 EXPECTED RESULT

The target outcome of this project is to have a model that is capable of predicting maximum rainfall to expect in the future. This empirical model is expected to provide basic design input parameters for future hydraulic structures design in the case study area.

7.1 Project Deliverables

On completion of the project, the following will be submitted as project deliverables to the project supervisor/department for documentation purpose

1. Printed Project Document
2. Soft Copy of Project Document in Compact Disc

8.0 PROJECT COST

The estimated budget for the duration of the project is ₦59,500 (Fifty-nine thousand and Five Hundred Naira) and breakdown is shown in Table 2.

Table2: Project Cost Details

S/No.	Item Description	Cost (N)
1	Printing of Literature Materials	3,500.00
2	Internet Subscription (6 months)	36,000.00
3	Final Project Documentation	12,000.00
4	Logistics (Transportation/Telecommunication)	5,000.00
5	Miscellaneous Expenses	3,000.00
	Total	**59,500.00**

9.0 PROJECT TIME FRAME

9.1 Project Work Breakdown Structure

The estimated duration of this project is 6 months; 12 weeks in the Harmattan Semester and 12 weeks in the Rain Semester. In every project, early planning and proper scheduling of activities, resources and required time frame is important to the success of the project. Work Breakdown Structure (WBS) adopted in this project and activity codes are assigned to tasks as per the category and schedule they fall into.

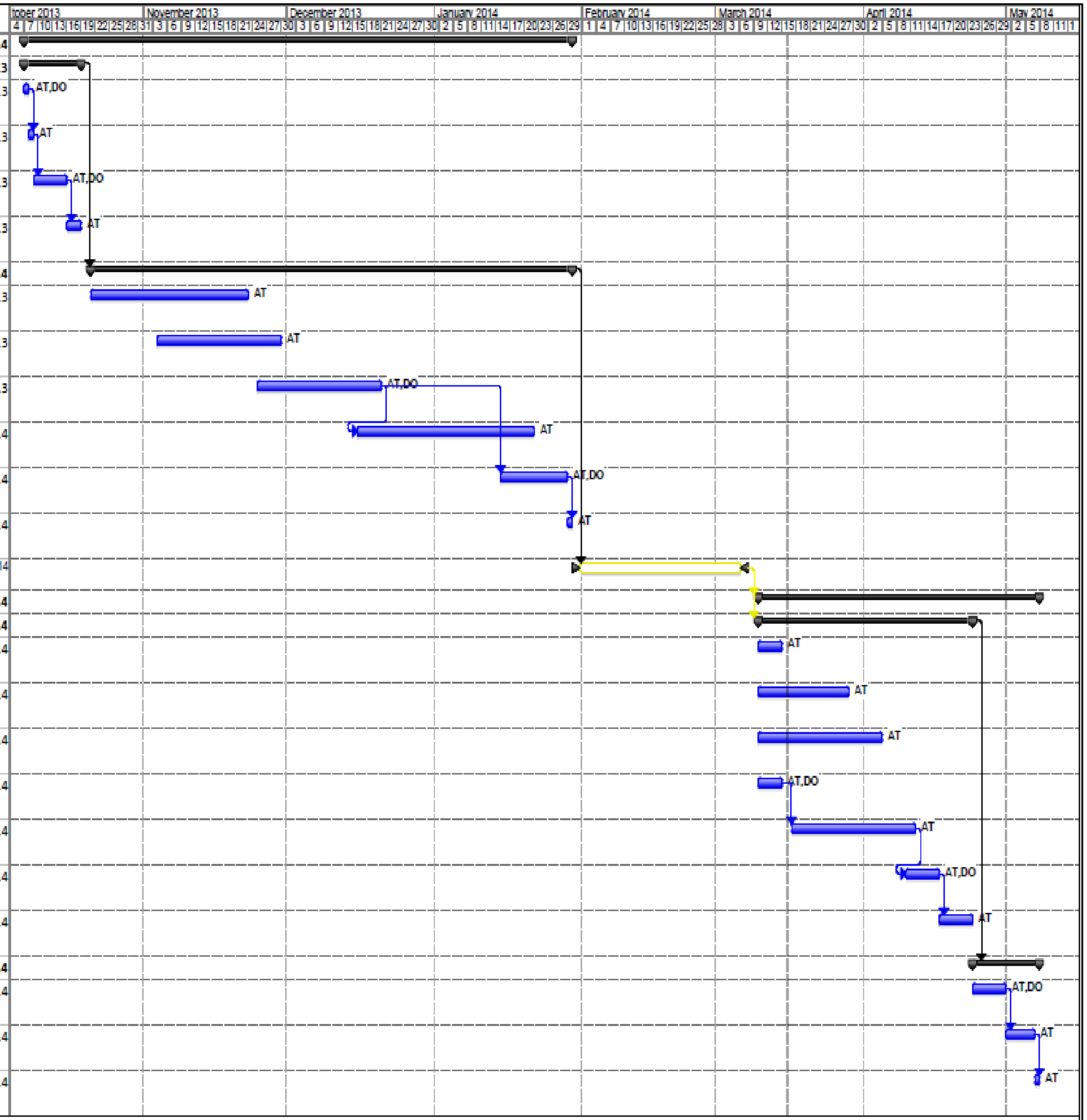
Table 3 shows the WBS which includes milestones attached to significant stages. This is developed for effective management of progress and tracking performance. It will also help in monitoring compliance to the proposed project methodology.

Table3: Project Work Breakdown Structure

Activity Code	Activity Description	Resources	Duration in weeks	Milestones
H	**Harmattan Semester**		**12 weeks**	
H1	**Project Initiation**		**2 weeks**	
H1.1	Project Topic Selection	AT, DO	1 Day	
H1.2	Refinement of Project Topic with Supervisor	AT	1 Days	
H1.3	Refinement of Project Scope of Work with Supervisor	AT, DO	5 Days	
H1.4	Identify Specific Project Needs	AT	3 Days	
H2	**Project Planning**		**10 weeks**	
H2.1	Identify and Study Existing Literature References	AT	5 weeks	
H2.2	Develop Project proposal	AT	4 weeks	Milestone 1
H2.3	Review first draft of Project Proposal with Supervisor	AT, DO	2 weeks	
H2.4	Source for & Obtain hydrological data	AT	3 weeks	Milestone 2
H2.5	Review second draft of Project Proposal with Supervisor	AT, DO	2 weeks	
H2.6	Issue Final Version of Project Proposal	AT	1 Day	Milestone 3
R	**Rain Semester**		**12 weeks**	
R1	**Project Execution**		**10 weeks**	
R1.1	Collation of hydrological (rainfall) data	AT	1 week	
R1.2	Further (detailed) literature Review	AT	3 weeks	
R1.3	Calculations and Empirical forecast model development	AT	6 weeks	Milestone 4
R1.4	Review of empirical model with Supervisor	AT, DO	1 week	
R1.5	Analysis/Interpretation of Results	AT	2 weeks	Milestone 5
R1.6	Review of Results with Supervisor	AT, DO	1 week	
R1.7	Incorporation of comments from review exercise	AT	1 week	
R2	**Project Close-Out**		**2 weeks**	
R2.1	Review Final Draft of Report with Supervisor	AT, DO	1 week	
R2.2	Print and Document Final Report	AT	4 Days	
R2.3	Issue Final Project Report	AT	1 Day	Milestone 6

AT = Atoyebi T. R.
DO = Dr. O.G. Okeola

ID	WBS	Task Name	Duration	Start	Finish
1	H	Harmattan Semester	76 days	Mon 10/7/13	Wed 1/29/14
2	H1	Project Initiation	10 days	Mon 10/7/13	Fri 10/18/13
3	H1.1	Project Topic Selection	1 day	Mon 10/7/13	Mon 10/7/13
4	H1.2	Alignment of Project Topic with Supervisor	1 day	Tue 10/8/13	Tue 10/8/13
5	H1.3	Alignment of Project Scope of Work with Supervisor	5 days	Wed 10/9/13	Tue 10/15/13
6	H1.4	Identify Specific Project Needs	3 days	Wed 10/16/13	Fri 10/18/13
7	H2	Project Planning	66 days	Mon 10/21/13	Wed 1/29/14
8	H2.1	Identify and Study Existing Literature References	5 wks	Mon 10/21/13	Fri 11/22/13
9	H2.2	Develop Project proposal	4 wks	Mon 11/4/13	Fri 11/29/13
10	H2.3	Review first draft of Project Proposal with Supervisor	4 wks	Mon 11/25/13	Fri 12/20/13
11	H2.4	Source for & Obtain hydrological data	4 wks	Mon 12/16/13	Tue 1/21/14
12	H2.5	Review second draft of Project Proposal with Supervisor	2 wks	Wed 1/15/14	Tue 1/28/14
13	H2.6	Issue Final Version of Project Proposal	1 day	Wed 1/29/14	Wed 1/29/14
14	2	END OF SEMESTER EXAMS PREPARATION, EXAMINATION AND BREAK	27 days?	Thu 1/30/14	Fri 3/7/14
15	R	Rain Semester	43 days	Mon 3/10/14	Wed 5/7/14
16	R1	Project Execution	33 days	Mon 3/10/14	Wed 4/23/14
17	R1.1	Collation of hydrological (rainfall) data	1 wk	Mon 3/10/14	Fri 3/14/14
18	R1.2	Further (detailed) literature Review	3 wks	Mon 3/10/14	Fri 3/28/14
19	R1.3	Calculations and Empirical forecast model development	4 wks	Mon 3/10/14	Fri 4/4/14
20	R1.4	Review of empirical model with Supervisor	1 wk	Mon 3/10/14	Fri 3/14/14
21	R1.5	Analysis/Interpretation of Results	4 wks	Mon 3/17/14	Fri 4/11/14
22	R1.6	Review of Results with Supervisor	1 wk	Thu 4/10/14	Wed 4/16/14
23	R1.7	Incorporation of comments from review exercise	1 wk	Thu 4/17/14	Wed 4/23/14
24	R2	Project Close-Out	10 days	Thu 4/24/14	Wed 5/7/14
25	R2.1	Review Final Draft of Report with Supervisor	1 wk	Thu 4/24/14	Wed 4/30/14
26	R2.2	Print and Document Final Report	4 days	Thu 5/1/14	Tue 5/6/14
27	R2.3	Issue Final Project Report	1 day	Wed 5/7/14	Wed 5/7/14



Project: Analysis of Maximum Rainfall
Date: Sun 3/16/14

Task · Split · Progress · Milestone · Summary · Project Summary · External Tasks · External Milestone · Deadline

Figure 4: Project Gantt Chart

10.0 REFERENCES

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