Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 6, Issue 12, December -2019

RUNOFF MODELLING USING HEC HMS FOR RURAL WATERSHED

Salah Ud Din1, Noor Muhammad Khan2, Muhammad Israr3, Hazrat Nabi4, Mansoorullah Khan5

[1,2,3] *Department of Civil Engineering,University of Engineering and Technology, Peshawar.*
[4,5]*Department of Agricultural Engineering, University of Engineering and Technology, Peshawar.*

ABSTRACT
Due to climate change it is very essential to do hydrological modelling. Reliable models are essential for planning, developmental works, prediction and safety of the population. Hydrological models are used to determine catchment discharge/flow through an efficient way. HEC-HM (Hydrological engineering centre Hydrological modelling system) is one of hydrological modelling tool developed by United States army corps of engineer (USACE) for event as well as for continuous simulations. Models, especially continuous simulations are useful for future predictions of stream flow due to land-use changes or extreme events phenomenon. In this study continuous hydrologic modellingwas carried out using HEC HMS modelling tool.

Deficit and Constant Loss methods with Clark transform methods were selected. The calibrated model (period 1986-1988) was validated with data set of the period of 2009-2013. Study concluded that the model recommended and can be used for stated River as decision support tool in the design and operation.

KEYWORDS: *HEC HMS, Model, Catchment, Flow, Rainfall, Temperature, Buner*

I. INTRODUCTION

Among the various natural resources, water is a key component for agricultural production and power generation. The net productivity of crops and generation of power depends on the proper utilization and management of this resource. To meet the urbanization and industrialization demands, water is becoming a limited resource for agricultural production as well as for power generation almost everywhere across the world. Land-use planning, land management practices and Urbanization have adversely effect on surface runoff quantities for power generation and agricultural production as well as ground water recharge. To overcome the related problems of water, extensive attention should be given to this key component of nature. Precise estimation and quantification of river or channel flow produces from the respective catchments are essential for hydraulic design of infrastructure in any developmental interventions. The design of any hydraulic structure requires sufficient knowledge of hydrological phenomenon like variation in runoff with change in climatic, geographic or physical factors. It would be ideal to estimate the stream flows with respect to time of occurrence and extent during the construction period as well as economic life of the project. If data and information is available at the project planning design and operation stages, then an optimized output may be planned and designed accordingly.

The river or channel flow characteristics that influence hydrological system and its modelling are include the variation of flows in daily as well as longer time basis, temporal variability of flows and its spatial changeability trend, seasonal distribution and characteristics of high and low flows. The flow measured at gauging station is the surface outflow of the basin/watershed. The flow record depends on the topography, geology, climate which gives temporal and spatial distribution of the runoff.There are various methods for estimation of runoff from catchments among them one is hydrological modelling.With limited data, the estimation of runoff and prediction of the processes of runoff generation and transmission to the outlet is much serious problem in developing countries. There is need of simulation and predictions models for each part of the country.

Numerous researchers have used various methods to simulate and predict the Flow from the watersheds.[1] discussed a holistic use of HEC HMS. They check the applicability of the model for future flood prediction in basins. Two catchments were selected, 16 flood events in the seven years period were used for one catchment and 15 flood events were used for the second catchment. Initial and constant infiltration, SCS unit hydrograph, Muskingum routing model and exponential recession model for base flow and were used. Model was calibrated and verified using Nash Sutcliffe Efficiency tool for evaluation of calibration. It was concluded that, a good relation between observed and simulated flow were developed. It was proved that the complexity of the model structure does not determine its suitability and efficiency. Though the structure of HEC HMS is simple, it is a powerful tool event and continuous simulations.Other several hydrologic models have been developed for rainfall runoff modelling and flood forecasting [2], [3], [4], [5], [6],[7].

In Short, it is clear from the extensive review of the literature that the research on available flow models are scarce in much part of the country. No such study has been done on simulation of rainfall-flow process using any watershed software including HEC HMS model in District Buner. The aim of this study was to simulate the rainfall-runoff for long term using HEC HMS hydrological model in study catchment. The study will be useful in infrastructure development projects in the basin as well as in other basins having same characteristics.

@IJAERD-2019, All rights Reserved

II. MATERIAL AND METHODS

A. STUDY AREA

In this study hydrological modelling of Brandu river has been carried out. An important river that flow through district Buner.Location map is given inFigure 1.Most of the people of the project area depend on agricultural [8]. Catchment area isabout 598 Sq.km. coordinates of gauging stations and data availability isgiven in Table 1.

Figure 1: Location Map of Buner

Table 1.
Coordinated of gauging stations

Sr. No	Station	Longitude	Latitude	Parameter	Period
1	Daggar	34°29'	72°39'	Daily rainfall and Flow	1986-2013
2	Saidu Sharif	34°44'	72°02'	Daily rainfall	

The catchment areais analyzed for altitude variations through Arc-GIS. Altitude wise thecatchment is divided into five (05) numbers of bands of various elevations. Highest and lowestelevations are 2872m (A.M.S.L) and 687m (A.M.S.L), respectively. Catchment area map along with altitude wise variation isshown in Figure 2.Catchment was also divided in five sub basins. Sub basin 1(S.B1), Sub basin 2(S.B2), Sub basin 3(S.B3), Sub basin 4(S.B4), Sub basin 5(S.B5).

There are six (06) streams originates from springs at high altitudes of the catchment. These streams change its name with change of locality and ultimately adopted name Brandu near Dagger village. All names are taken from GT Sheet map of Pakistan. Among six streams, five stream flows from north towards south and one from south towards north. At gauge point the flow direction is almost from West towards East.

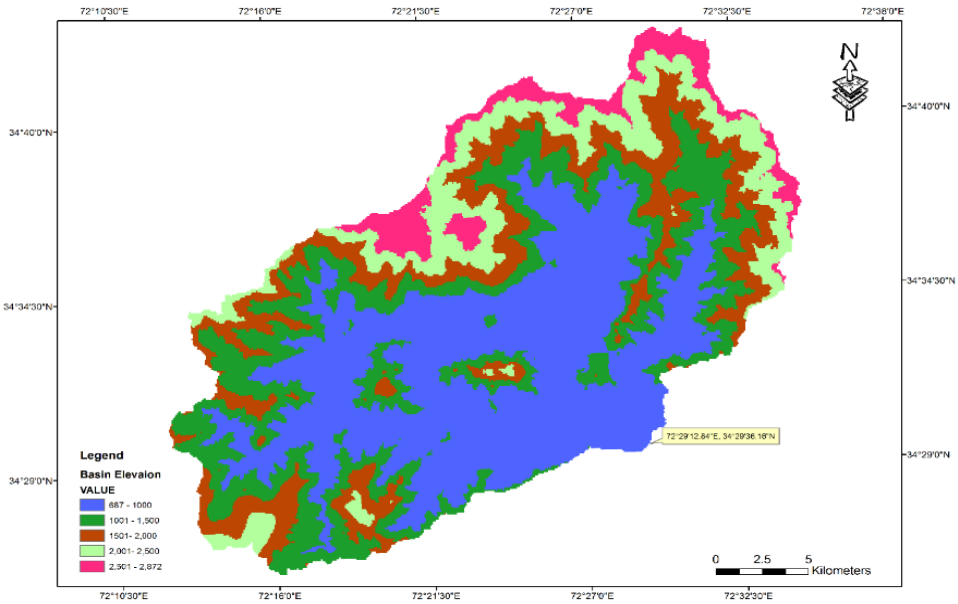

Figure 2: Catchment/ Altitude wise variation in Catchment

@IJAERD-2019, All rights Reserved

All these streams at the origination point arenamed as 1). KotKhwar 2). Malang Khwar 3). BurjokanraiKhwar 4). SabagaKhwar 5). ChuranoKhwar and 6).CharaiKhwar. While going into detail:

1. KotKhwar ultimately named as SundusKhwar near gauge location.Ja Khwar, KadatakKhwar, ToghnanKhwar, JabaKhwar, BaridreKhwar and HissarKhwar joinSunduskhwar at various locations during its course of flow. Catchment of these Khwars are named as S.B1.
2. Malang Khwar join by SiparaiKhwar, Koga khwar, Tanta Khwar, GogaiKhwar, LoeKhwar andGogaKhwar during its course of flow.
3. Burjokanraikhwar join by GogaiKhwar and KajazangKhwar during its course of flow. Malang and Burjokanraikhwar joins each other near Towda china and then join Brandu River at downstream location. Catchment of these streams is named as S.B2.
4. ChuranoKhwaron the extreme north side stream in the catchment (this Khwar also has a tributary name asgiraraikhwar) combine with Pao Khwar during it course of flow. This stream adopted the nameof wuchkhwarnear NikanaiGhar. Catchment is named as S.B3.
5. SabagaKhwar join by KuhafKhwar which adopt the named of Pao Khwar at downstream side. Catchment is termed as S.B4.
6. CharaiKhwarJoins WuchKhwarnear Tor Warsak. Before joining BranduKhwar this Khwar adopt the name of sangria Khwar. Catchment is named as Sub Catchment.River/khwar along with name of its tributaries are shown in Figure 3.

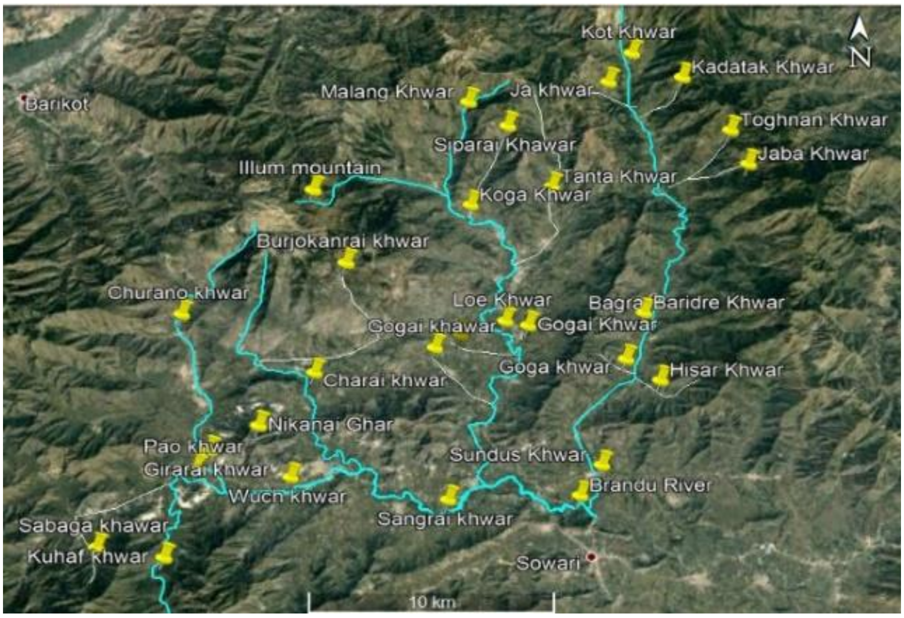

Figure 3: Catchment channel tributaries

Catchmentswere divided into five sub catchments as detailed in the aforementioned paras. In modelling, two rain gauge stations were used. i.e. Daggar and Saidu Sharif.

B. SOIL TYPE IN THE CATCHMENT

For soil type identification of the project area FAO soil data base was used. The stated soil database shows that the catchment has soil type Haplic yermosols or simply yermosols. pH values for this type of soil varies from 6.6 to 7.0. Land slopes in the upper areaswere more than lower portion of the catchments. The soil texture of the study area is loam with sand, silt and clay percentagesare70.5, 16.5 and 13 respectively. Average value of bulk density is 1.4 gm/cc. Average electrical conductivity and organic carbon are 0.1dS/m and 1.0%, respectively. The watershed comes under VI Agroclimatic Zone. The areais composed of undulating topography andsurrounded by Peak Mountains. The general drainage pattern is dendrites.Brandu River is right tributary of Indus river and join Indus river upstream of Tarbela dam.

C.LAND USE

Land use has a very elementary role in calculating Flow. Changing land use could change infiltration and percolation significantly. Anthropogenic activities have significant role in land use. Forest, grass land, wood land and imperviousness could change the runoff process.Catchment area has been divided into paved or urban area, forest and grass land. Brief description of each land use is as follow. And detail of land use is given in Table 2 and Figure 4.

C 1.PAVED LAND

Paved land included roads, houses, hospitals,Rocky Mountains, bare exposed rocks and permanent wet lands.

C 2.FOREST LAND

Forest comprises of dense and thick canopy of trees. It included ever green needle, mixed forest and woody savannas etc.

@IJAERD-2019, All rights Reserved

C 3. GRASS LAND

Grass land include closed shrub lands, open shrub lands, grass lands and crop lands. Due to sub humid region the area most part covered by this type of land cover.

Table 2

Illustrates different land uses and percentage area covered by each land use in all five sub catchments.

Basin			S.B1	S. B2	S.B3	S.B4	S. B5
	Area*	%	%	%	%	%	%
Paved	92.0	15.4	3.0	3.2	3.0	2.5	3.7
Forest	83.8	14.0	7.7	2.5	0.2	2.5	1.1
Grass	422.2	70.6	10.6	29.3	8.9	8.1	13.7
Total	598.0	100.0	21.3	35.0	12.1	13.1	18.5

*Area is Sq. Km

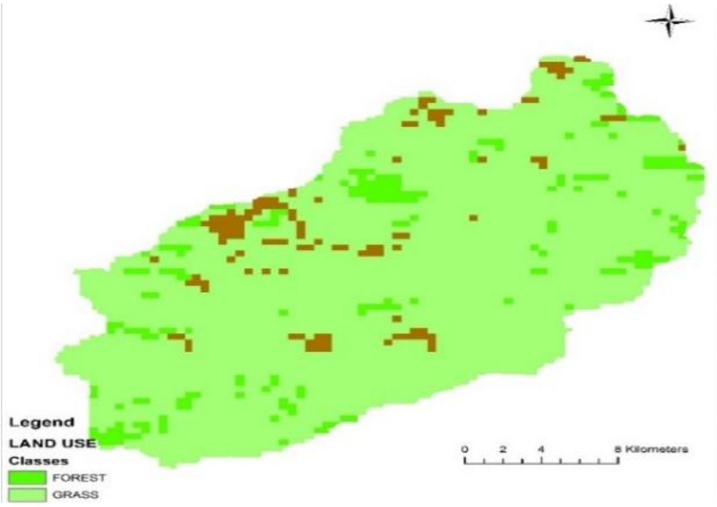

Figure 4: Land use map of the study catchment

D.SUB CATCHMENTS CLIMATOLOGY

D 1.RAINFALL

Dailyobserved flow of Brandu river at gauge near Daggarand rainfall data of Daggar and Saidusharif station has been used in this study for modelling. Before modelling data has been analysed using Mean, Maximum, Coefficient of Variation, Kurtosis and Skewness etc. Coefficient of variation is used to classify the level of variability of Flow, rainfall or any other variable under consideration. It is the ratio of standard deviation (S) to mean (X) Cv=S/X*100. Coefficient of variation is termed to be "less" when Cv<20%, "moderate" when 20%<Cv<30%, and "high" when Cv>30% [9]. Therefore, to check degree of variability, Coefficient of variation is used. Kurtosis is a measure of, whether the data are heavy tailed, or light tailed with reference to a normal distribution. Values less than 3 has been termed as low Kurtosis, Long tailed and vice versa [10]. Skewness is a measure of symmetry with respect to normal plot. Values -0.5-0, and 0-0.5 termed to be fair; -1-(-0.5), and 0.5-1 moderate and <-1,>1 show high skewness.Detail is given as follow:

D 2. RAINFALL OF DAGGAR GAUGE STATION

Annual total rainfall of Daggar gauge fluctuates 149%-72% with an annual mean of 1065.1 mm. Rainfall Kurtosis values are in the range of 2.9 to -1.1 except month of January with kurtosis value of 5.0. thus, most the data is long tail and lack of outlier. Skewness values of Daggar gauge varies 1.8 to -0.1. Rainfall of this Station is skewed to the right except the month of March which skewness is to the left. It means that, data is right tail long than left tail. Annual total rainfall is "high" coefficient of variation as it varies 118.6% to 47.1% with mean of 71.42%.

D 3.SAIDU SHARIF GAUGE STATION

Rainfall of Saidu Sharif gauge station shows that annual total rainfall varies148%-65%. While mean annual rainfall for recorded period is 1116.3 mm. Kurtosis values of annual total are 3.9 to -0.6. Most of the data is long tailed relative to normal distribution. Similarly, Skewness are varying from 1.6 to 0.6. All the rainfall data is skew to the right. Coefficient of variation values are in the range of 106.1% to 53.7% with mean of 74.41%. Hence the degree of variability of this gauge station rain termed to be "high". Monthly averages ofprecipitation of Daggar and Saidu Sharif is shown in Figure 5.

@IJAERD-2019, All rights Reserved

Figure 5: Mean monthly precipitation

D 4.TEMPERATURE

Temperature has an important role in simulatingthe rainfallrunoffin catchments. Temperature has a main function in evaporation and evapotranspiration in basins as it is strongly coupled to energy available. Mean of the Daggar temperature is same as that of Tarbela, that is why Temperature of Daggarstation is used in the model. Figure 6 show monthly average temperatures of both saidusharif and Daggar.

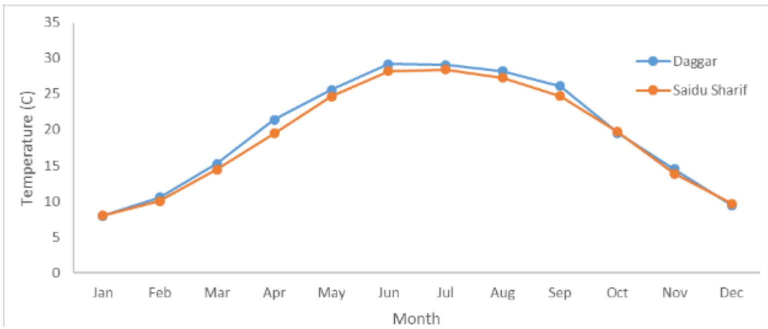

Figure 6: Mean Monthly Temperature

D 5.FLOW AT BRANDU RIVER

There is perennial flow in the Brandu river. Mean annual total flow is 2219 Cumec and varied annually from 56% to 165% of the annual mean. Kurtosis values of January, February, April, June, October and December are more than 5. Data was also checked for skewness. The recorded data shows that most of the data is skew to the right except of the month of November, which skewness is to the left. The coefficient of variations varies between 72% - 16.2%. These values indicate that the degree of variability term to be "high".Monthly mean maximum, mean, mean minimum flow shown in Figure 7.

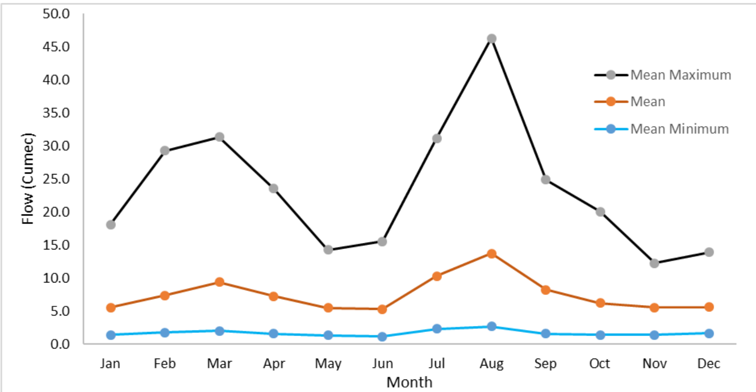

Figure 7: Mean Maximum, Mean, Mean Minimum observed Flow of Brandu river

E. PARAMETERS OF HEC HMS

E 1.BASIN MODEL

HEC HMS is hydrologic modelling software developed by the US Army Corps of Engineers-Hydrologic Engineering Centre (USACE). This modelling tool consist of Basin, Meteorological data, Time series and control specification. The loss method used in the study wasDeficit and ConstantwithClarkunit hydrograph transform method.

Basin model consist of: Sub basin, reach, junction and Outlet. While sub basin required Canopy, Surface, loss, transform and base flow input data. Canopy represent the rainfall that is captured on the leave of tress and does not reach the soil

@IJAERD-2019, All rights Reserved

surface.Surface loss represent that water which are loss due to local depression and cracks in the ground. Deficit and constant method is used as a loss method. For the transformation process Clark unit hydrograph method and Constant monthly method was used as base flow method. Mean of the Monthly minimum flows were considered as the constant monthly baseflow.Reach is used to convey flow downstream. Muskingum routing method has been used for attenuation. In this method X and K parameters are used. Theoretically, K is the parameter having unit of time, and is passing of a wave in a reach length and X parameter is constant coefficient that its value varies between 0 - 0.5. Junction and outlet element require the observed flow data. In the beginning of the simulation some initial values were fixed and then adjusted in the calibration stage.

E 2. METEOROLOGICAL MODEL

Meteorological model consists of precipitationand evapotranspiration methods. For precipitation Gage weights method is used. Thiessen Polygon method is used (Table 3) to find the contribution of Daggar rainfall and Tarbela rainfall.

Table 3
Contribution of Rainfall of each gauge station

Gauge Station	S.B 1	S. B2	S.B 3	S.B 4	S. B 5
Daggar	0.76	0.65	0.65	0.100	0.01
Saidusharif	0.24	0.35	0.35	0.0	0.99

E 3.CONTROL SPECIFICATION

Control specification isuse forfixing running period. Various period has been checked for running the model. The model was run for periods of 1986-1988 (calibration) and 2004-2006 (validation).

E 4.TIME SERIES DATA

Daily rainfall and daily Floware put in time data series.

F.MODEL EVALUATION

The hydro-meteorological data wasgroupedin parts for running the model, simulations has been run. known parameters were put in the model and the unknown has been taken on trial basis. Various trials have been made until satisfactory results obtained. Statistical indicators such as: Root mean square errorP BIAS and Nash Sutcliff efficiency has been used in this study.

G. DEFICIT AND CONSTANT LOSS METHOD

The infiltration calculations in HEC HMS are performed by a loss method available within the sub basin. Deficit and Constant loss method, which was used for continuous simulation and to handle the percolation loss in all sub basins has four parameters which include; initial Deficit, Maximum storage, constant rate, and percent impervious area in the catchment.

H. CLARK UNIT HYDROGRAPH TRANSFORM METHOD

The computation of the surface runoff is performed by a transform method. various transformmethods are provided by the model. The loss method was performed with Clark Unit hydrograph transform method.This is a synthetic unithydrograph method and was originally developed to compute the peakrunoffdue tounit precipitation. Also, empirical methods used to calculatethe width at 50% of the peak flow and the time base of the hydrograph.

III. RESULTS AND DISCUSSION

I. RUNOFF BY DEFICIT AND CONSTANT LOSS METHOD

Deficit and Constant model were applied for the study catchment. In this method, model basins have four parameters namely: Initial Deficit, Maximum deficit, Constant rate, and percent Impervious in the basin. The Initial parameters for loss method were used in the HEC HMS model on trial basis to calibrate the model. Statistical indicator fordifferent CN numbers are given in Table 4.

Table 4
Statistical indicators

Statistical Indicator	1986-1988 (Calibration)	2004-2006 (Validation)
RMSE(Cumec)	6.35	5.13
NSE (%)	0.54	0.66
P BIAS (%)	3.31	13.71

IV. CONCLUSIONS

HEC HMS model was used for simulation for Brandu river catchment in district Buner. It is concluded that Deficit and constant loss method with Clark Transformation method has statistical indicators which are in the acceptable range.So as a loss method, Deficit and Constant method with Clark transformation and constant monthly base flow methoddoes perform well. And hence this can be used as a decision support tool in the design and operation.

Reference

[1]. Oleyiblo, J. O., & Li, Z. J. (2010). Application of HEC-HMS for flood forecasting in Misai and Wan'an catchments in China. Water Science and Engineering, 3(1), 14-22.

[2]. Yusop, Z. and Chan, C. H. A. (2007). Katimon, runoff characteristics and application of HEC-HMS for modelling stormflow hydrograph in an oil palm catchment. Water Sci. & Technol. 56: 41-48.

[3]. Yener, M. K. and Orman, A. Ü. (2008). Modelling studies with HEC-HMS and runoff scenarios in Yuvacik Basin, Turkiye. Department of Civil Engineering, Middle East Technical University, 06531 Ankara/Türkiye.

[4]. Li, S. Y., Qi, R. Z. and Jia, W. W. (2008). Calibration of the conceptual rainfall-runoff model's parameters. Proc. 16th IAHR-APD Congress and 3rd Symposium of IAHR-ISHS. Tsinghua University Press, Beijing. pp. 55-59.

[5]. Khakbaz, B. etal.(2009). From lumped to distributed via semi-distributed: Calibration strategies for semi-distributed hydrologic models. J. Hydrol. doi: 10.1016.

[6]. Amir, A. and Emad, H. (2010). Application of a conceptual hydrologic model in teaching hydrologic processes. Int. J. Engng. 26: 1-11.

[7]. James, O. and Zhi, J. L. (2010). Application of HEC-HMS for flood forecasting in Misai and Wan'an catchments in China.Water Sci. and Engg. 3: 14-22.

[8]. Pakistan Bureau of Statistics, (2010). Report on Agricultural census in Pakistan by Agricultural statistics directorate in PBS, under federal government of Pakistan.

[9]. Hare, W. (2003). Assessment of knowledge on impacts of climate change-contribution to the specification of art. 2 of the UNFCCC: Impacts on ecosystems, food production, water and socio-economic systems.

[10].Afzaal, M., Haroon, M. A., & Zaman, Q. (2009). Interdecadal oscillations and the warming trend in the area-weighted annual mean temperature of Pakistan. Pakistan Journal of Meteorology, 6(11), 13-19.

@IJAERD-2019, All rights Reserved