FLO()D MAPPING AND RISK IDENTIFICATION OF KABUL RIVER BASIN

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FINAL APPROVAL

It is certificate that we have read the thesis submitted by Ms. Rafia Iftikhar and it is our judgment that this project is of sufficient standard to warrant its acceptance by the International Islamic University, Islamabad for the M.S Degree in Environmental Sciences

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Dedicated to

My Respectable

Parents

& Brothers

DECLARATION

I hereby declare that the work present in the following thesis is my own effort, except where otherwise acknowledged and that the thesis is my own composition. No part of the thesis has been previously presented for any other degree.

Date: 04 /11/2016

Rafia Iftikhar

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Acknowledgment

All praise to ALAH most beneficial most merciful

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Abstract

Pakistan is flood prone country facing very destructive floods during last few years. This research present the precipitation runoff, flood mapping of destructive flood of 2010 in Kabul River Basin. Two models i.e. HEC-HMS (Hydrological Model) and HEC-RAS (Hydraulic Model) is used in ArcGIS. Hydrological model is widely used to formulate the precipitation runoff. In current study Hydrological modelling is used to simulate the precipitation runoff and for flood inundation mapping of Kabul river basin hydraulic modelling is used. The Kabul River basin has a catchment area of 92,605 square kilometers. Kabul River is the tributary river of Indus River System. 80% arear of Kabul River Basin is in Afghanistan while only 20% is in Pakistan. Hydrological modelling use the rainfall data collected from gauges located at Nowshehra installed by Pakistan Meteorological Department (PMD) for runoff. Heavy rainfall occurred during the last week of July 2010. Therefore rainfall data of the disastrous event was simulated and the result of simulation the peak discharge at outlet is 9213 CFS with 50 % model accuracy due to lack of Afghanistan climatic data. HEC-RAS was used for the mapping. This modelling enable the two and three dimensional flood mapping and analysis in the GIS.

The whole results of both modelling is supportive in the mitigation of future devastating flood and overwhelmed its influence on population and landscape. Through the assistance of hydrological modelling outcome, the simulated runoff values can be used for flood control and flood mutilation assessment studies. This study will be helpful for creating awareness among local authorities for avoiding and prolonging the adverse effects of flood on local population.

Key words:

Kabul River Basin, Flood event 2010, HEC-HMS, Precipitation runoff and Flood mapping

LIST OF FIGURES

LIST OF ABBREVIATION

GIS	Geographic Information System
KPK	Khyber Pakhtun Khawa
RRI	Rainfall Runoff Inundation model
WMO	World Meteorological Organization
IFAS	Integrated flood analysis system
SRTM	Shuttle Radar Topographic Mission
HMS	Hydrological Modeling System
PMD	Pakistan Meteorological Department
DEM	Digital Elevation Model
IPCC	Intergovernmental Panel on Climate Change
NARC	National Agricultural Research Centre

LIST OF SYMBOLS

cfs	cubic feet/sec
In	Inches
Sq.km	square kilometer

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Introduction & Review of Literature

Flood is the rising of water and its overflowing onto normally dry land. Flood is natural and persistent phenomenon in areas below the sea level, it consider as beneficial for soil fertility but also precarious as it threatening the human life, and country's economy. The rise in temperature is the cause of climate change, inconstant rainfall and life threatening weather events occur are also cause due to climate change. Floods are one of the most overwhelming natural hazard worldwide. Natural singularities including floods which can't be stopped; though a number of human actions subsidize to a rise in the probability and adverse influences of flooding (European Parliament Council, 2007). Floods possibly caused by repeated heavy rainfall, infrequent unembellished storms or by some other reasons. A complete security from flood hazard is difficult. Floods can be somewhat avoided but its hazards can never be ruled out. Pakistan has different type of land and changing climate. Climate of Pakistan is commonly hot and dry but shows substantial noticeable distinctions in pervious few years.

Alike further SAARC associate state, Pakistan also has extended past of floods. The country has tackled 19 main floods that cause of loss of 10,668 valuable human lives, accumulative flood of above 594,700 sq km area with 166,075 villages affected and total cumulative losses to the tune of about US $ 30 billion during previous 60 years (Flood risk Management in South Asia, 2012). A UN scientific body of the IPCC in 2007 statement established, "it is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent." IPCC also notifies; "the floods of the kind that hit Pakistan in 2010 may become more frequent and more intense in the future in the same region and other parts of the world". Pakistan has best irrigation system in the world depend on the rivers i.e. River Jhelum, River Chenab, River Sutlej and Kabul, upper and lower part of the Indus river and these rivers are consider as the main source of flood in country. Rivers are the foremost source of fresh water. In current scenario river systems have been greatly obstructed by human intrusions along with climate change.

According to the specialists from WMO, the climate change was obvious indication and main subsidizing aspect in "unprecedented sequence of extreme weather in Pakistan" during months of July and August 2010. Due to such conditions disastrous floods increased in recent years. One of the main sources of fresh water is rivers and has played a main part in the improvement of individual development. The Indus River is the biggest rivers in the world in relation of its length (3,180 km), drainage area (960,000 km^2), and normal yearly release (7,610 m^3/s). From the entire drainage area, about 506,753 km^2 area deceits in the semiarid section of Pakistan and the other deceits in foothills and mountains (Hovius 1998; Khan *et al.* 2009).Pakistan tackled many floods in history but 2010 flood was the disastrous one. It was the disastrous flood in Indus River, which affected the millions of people in Pakistan. Many districts and different urban areas located along the riverside or nearby to rivers are always on a great danger of diverse type of flood like riverine and flash flood. Effects of some floods are native that effect only native community but some floods are disastrous effecting the whole nation. Though extreme rainfall from months of July and September 2010 has been considered as the foremost contributor to this tragedy and human being interference in the river system form this disaster a catastrophe. In Pakistan mostly floods are occurred due to unexpected early monsoon rainfall and abnormal release of water from India.

Flood of 2010 was the historically disastrous causing millions of people affected. Due to heavy rainfall during 27 July 2010 to 30 July 2010 most part of the country was severely affected. Tributaries Kabul and Swat faced record floods in extreme of 400,000 cfs crossing earlier historic recorded flows of 1929 (250,000 cusecs) that caused backlog of Charsada, Nowshehra and adjoining areas (Hashmi *et al.*, 2012). It has been projected that the flood 2010 was a 600 years unusual incident (IPD, 2011). This tragic monsoon floods drowned an area as huge as the size of England (AFP, 2010). Flood risk mapping is a significant component design for suitable land use in inundated areas. It generates easily read, quickly available tables and maps which eases the recognition of risky areas and rank their mitigation belongings (Bapalu and Sinha, 2005).

Since 2010 to onward Pakistan is repeatedly facing terrible floods mainly the 2010 flood was utmost devastative (since the creation of Pakistan in 1947) in nature and cost enormous sum of property, farming crops and a huge number of social lives. The flood of 2010 was not comparable and unexpected in the acknowledged history of the Indus river system and the flood heights were far in excess of the documented historic floods (Haq and Zaidi, 2011).

Pakistan is very susceptible to natural catastrophe like earthquakes, landslide, floods, drought, and cyclones. Flood are the natural disasters, destroying the human settlement, crops, landscape and change the ecology of the pathways. The areas where frequent floods occur may not be worth living for human beings because their livelihood is always at stake. Floods bring lot of fertile silt to add fertility to the agricultural soil but at the sometime cause erosion of fertile soils as well as.

The main question was to convert this challenge to opportunity so that the benefits take over the losses through vulnerability mapping of the area. During the 27 July to 4 August 2010 record breaking rainfall in different areas of KPK.

Present study was conducted on Kabul river basin for flood mapping and risk assessment for 2010 flood. The main purpose of study was to calculate the precipitation runoff, prepare inundation flood map and recommend the mitigation measure. To assess the flood risk, calculate the precipitation runoff of Kabul River basin through hydrological and mapping by hydraulic modelling. Present study was concentrated on the flood mapping, precipitation runoff and identification of flood risk area of the Kabul river basin, so that the vulnerable population may not suffer from recurring losses of lives and livelihood. The hydrological model HEC-HMS was used for precipitation runoff and hydraulic model HEC RAS for flood mapping.

The Kabul River basin has an area of 92,605 square kilometers that holds the water body. Kabul is the branch of Indus River System. Kabul River is one of the tributaries of Indus River. The Kabul River invents from Afghanistan. It reaches in Pakistan through northwestern areas and connects to the Indus River nearby the city of Attock and lastly links the Arabian Sea, Karachi. Indus River has many tributaries including Swat and Konar Rivers which are important tributaries. The barrages on the Kabul river basin are consider as the main source of irrigation system of Pakistan. Already study has been done on Kabul River basin but using different methodology with different model i.e. Integrated Flood Analysis System (IFAS) and 2D Rainfall runoff Inundation model (RRI). IFAS was used for flood forecasting of Kabul River basin. This system with adjusted limitations was used to simulate rainfall–runoff. RRI model is basically a mathematical model explaining the rainfall-runoff relation of rainfall catchment area.

Floods are of different types like flash flooding, increase level of ground water and damage or opening of canals, dams and reservoir cause flooding. Different hydrological and hydraulic techniques are used for the risk assessment of different types of water flood. In present study Hydrological modelling system (HEC-HMS) is used for flood risk assessment. The hydrological model HEC-HMS (Hydrologic Engineering Center, Hydrologic Modeling System), practiced in combination with the Geospatial Hydrologic Modeling Extension, HEC-GeoHMS, is not a site-specific hydrologic model. The HMS is planned to simulate the precipitation-runoff processes of drainage basins. This modelling system is applicable in geographic areas for resolving the extensive kind of problems including slight or natural urban and watershed runoff and flood hydrology. Although HEC-RAS model is used for the hydraulic models of water flow via rivers or channels.

1.2 Literature Review:

Pakistan is well-known for its summer inundations, but the 2010 flood is considered to be the era's most horrible. It has broken all the previous histories in terms of discharge, harms and amount of rainfall occurred. Due to wide belief on remnant based fuel particularly by developing nations, greenhouse gases are being gathered in atmosphere. There is a chronicled rise of around 55 ppm of CO_2 concentrate in atmosphere which initiated 1.5^0C temperature rise in Pakistan and neighboring regions. Effects of global heating are exponentially hostile; it basically gives rise to happenings of abnormal climatic events such as famines, floods, wild fires, glaciers melting etc. Floods are one of the most devastating meteorological hazards. Many countries around the globe face this turmoil mainly due to excessive rainfall in the catchments of any particular river (Garg, 2002).

As determined in post flood study by Pakistan Meteorological Department, current floods in Pakistan are consequence of global warming. Flood is normal events which happen all over the world. According to Keller,1985 maximum river inundating is a function of the entire quantity and distribution of rainfall and the frequency at which it penetrates the soil or rock and the landscape, nevertheless some of flood consequences from quick melting of ice and snow in the spring and on rare occasion from failure of a dam. Global Warming is evolving as a main initiative of catastrophes, with repeated and penetrating floods and storms, increasing dislocation as an enormously probable consequence.

The world weather crisis that is causing floods in Pakistan, rock fall in China and wildfires in Russia is indication that global warming forecasts are truthful. According to climate change professionals, all these tragedies occurred approximately instantaneously is the outcome of a worldwide climate pattern; however all were reported as a distinct happening and interpreted as though there was no connection. According to the professionals from World Climate Research Programme and the World meteorological Organization (WMO), the climate change is a foremost contributing aspect in this "unprecedented sequence of extreme weather in Pakistan" in couple of months July and August 2010. In Pakistan the flood of 2010 is mainly caused by unparalleled rainfalls throughout the monsoon period. The main reason of floods in Pakistan is heavy intense rainfall in the river catchments, which occasionally increased by snowmelt flows, usually consequences into floods in rivers in the monsoon spell.

As in the reports of the International Federation of Red Cross and Red Crescent during the previous ten years from 1993 to 2002 floods have exaggerated an average 140 million people each year (IFRC, 2003). According to Flood Annual Report 2010 and 2012, mostly, floods are caused by the intense concentrated rainfall throughout the torrential rain period, which are occasionally increased by melting of snow and flows in rivers. Sometime harsh floods are also caused because of torrential rain streams originating in the Bay of Bengal and subsequent depressions which frequently result in heavy inundation in the Himalayan foothills, which is sometime enlarged by the weather systems from the Arabian Sea (Seasonal Low) and from the Mediterranean Sea (Westerly Wave) cause damaging flood moreover or in the entire central rivers of Indus systems.

Pakistan having peculiar location over the globe receives rainfall in winter as well as in monsoon. Pakistan, also, has been facing catastrophic floods in the past such as during the years 1958, 1974, 1988, 1992 etc., all of them occurred during the summer monsoon. The Asian monsoon has two components; the South and East Asian monsoon in which the South Asian downpour is the main source of precipitation over Pakistan. Sometimes, it yields very heavy rainfall in the area when cold air advection aloft takes place due to westerly waves during summer (Rasul *et al.*, 2005). The regularity of manifestation of heavy rainfall events is higher in the northern half of Pakistan (Chaudhary, 1991) while it sharply decreases towards the southern half of the country (Rasul *et al.*, 2005).

Human intrusions by the creation of banks, barrages, dams, land clearance, and land use modification etc. have also bothered the river system in relations of residue load and their run-off, leading to more rigorous floods (Ali and De Boer 2007; Walling, 2008; Sinha, 2009). In circumstances of enormously severe disasters like the Pakistan flood, numerous towns and villages become inaccessible due to the distraction of both transportation and the communication network (Relief International, 2010). Pakistan has agonized an overwhelming flood catastrophe in 2010. Largescale riverine and flash floods in the Kabul River basin (92,605 km^2), caused harsh destruction with more than 1100 fatalities (Takahiro Sayama *et al.*, 2012).

Inundation can cause destruction to the inhabitants unswervingly and incidentally for example in terms of unswerving influence it can cause mutilation to land, farming, infrastructure, deaths and grievances and in relation of incidentally impact it bothers the agriculture production, water networks and water endured infections (WHO, 2011).

According to Pakistan's National Disaster Management Authority, one-fifth of the whole area of Pakistan was underwater at the high water streak (Sayah and Desta, 2010), disturbing 84 out of 121 districts (UN-OCHA, 2010). Decline in glacier mass will result in increased river discharge and increased danger of flood events (Aizen et al., 1997; Kundzewicz et al., 2007).

Snowline has been fluctuating promptly uphill affecting the biodiversity to drift and precipitation in the form of rainfall instead of snowfall. Such up-rise of thermal system has started melting the low altitude glaciers at a more rapidly rate. As a consequence the development of new glacial lakes and enlargement of present lakes to the threat of outburst flood has amplified (M. Afzaal *et al*, 2009). In the Northern part of the country heavy rainfall rise water level in rivers and periodic nullahs instigating heavy flood in River Indus. Far ahead through the input of River Swat and Kabul to Indus directed to extraordinary flood in zones of Punjab province i.e. Jinnah Barrage to Taunsa Barrage Range (Annual Flood Report, 2010).

Inundations because of floods have the prospective to cause mortalities, movement of people, and destruction to the environment and therefore rigorously conciliate economic growth. Overflowing accounts for 40% of entirely natural vulnerabilities worldwide and partial of all the deceases caused by natural calamities (Ohl and Tapsell, 2000; Jonkman and Vrijling, 2008). One of the foremost requirements of flood disaster management is the real-time checking of maximum flood magnitude for taking up instant response, short- and long-term reclamation, and future mitigation actions (Wang 2004). The outpost remote sensing data, owing their synoptic observation and repetitively combined with the initiation of GIS techniques, have verified to be enormously operative in flood inundation mapping and monitoring on actual- period basis (Kumar Gaurav *et al.*, 2011).

Hydrological modeling is a normally used instrument to guesstimate the basin's hydrological response in arrears to rainfall. It permits to calculate the hydrologic response to several watershed management applies and to have an improved understanding of the effects of these practices (Kadam, 2011). It is obvious from the wide-ranging review of the literature that the studies on comparative assessment of watershed models for hydrologic simulations are very much limited in emerging countries (Kumar and Bhattacharya, 2011; Putty and Prasad, 2000). The model was found precise in spatially and temporally forecasting watershed response in incident based and incessant simulation as well as simulating numerous circumstances in flood forecasting and forewarnings (Kishor Chaudhry, *et al.*, 2014).

Numerous studies have been led using the HEC-HMS model in different areas under different soil and climatic conditions. Chu and Stenman (2009) used HEC-HMS model for both event and continuous hydrological modeling in Monalack watershed in west Michigan. HEC-HMS model has been similarly used to simulate rainfall-runoff process with geo-informatics and atmospheric models for flood forecasting and early forewarnings in different regions of the world (Abed et al., 2005; Anderson et al., 2002; Hu et al., 2006; Yusop et al., 2007; Yener et al., 2012; Ali et al., 2011;).

Hydraulic model, HEC-RAS is planned to perform one-dimensional hydraulic calculations for a full system of natural and built networks (Brunner, G. W. 2006). An HEC-RAS model can be used for both steady and unsteady flow, and sub and supercritical flow systems (Goodell, C.; Warren, C).

Materials & Methods

The purpose of present study is to make the inundation map of Kabul river basin and identify the vulnerable areas and recommend the mitigation measures. The large area of Kabul river basin is present in Afghanistan (approx. 80%) and 20% in Pakistan. Information used in the study is collected from the gauges that are installed by PMD and WAPDA. SRTM DEM of Kabul river basin is shown in fig 2.1.

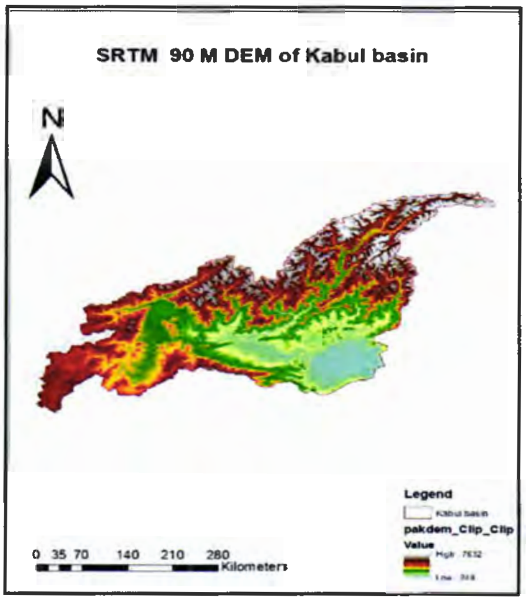


Fig 2.1 Kabul River Basin

2.1 Data Collection:

For this study software ARCGIS and two models have been used. Hydraulic model was used for the flood inundation and Hydrological Model was used for the precipitation runoff of the study area, Kabul river basin. Topographic data i.e. Shuttle radar topographic model (SRTM) digital elevation model (DEM) for the HEC geoRAS and HEC HMS was downloaded from the U.S Geological Survey (USGS) website. Rainfall data that is collected from the gauges located at Nowshehra and daily temperature of selected areas during the last week of July 2010 to 04 August 2010 was collected from Pakistan Meteorological Department (PMD) which was the input for both hydrological and hydraulic models. Land cover and land use data was collected from the National Agriculture Research Council (NARC) that was the basic input in hydraulic model.

2.2 Methodology:

Methodology is divided into three stages, preparation stage in which DEM was generated and create Triangulated Irregular Network (TIN). Next stage is execution stage in which models were processed and last stage was the verification of the results of both models. Methodology flow chart was given below.

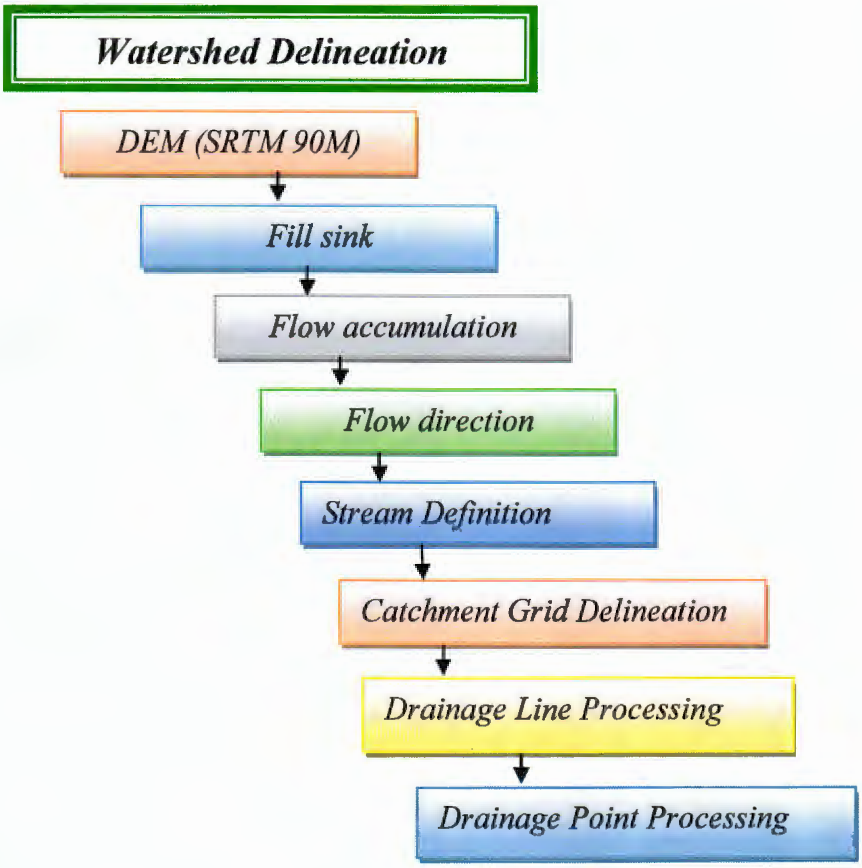


Fig 2.2 Flowchart of methodology

In ArcGIS there is extension of Arc Hydro tool by which water delineation was done. First level of watershed delineation was fill sink. Sinks or peaks are frequently mistakes due to the resolution of the statistics or turning of elevations to the close numeral value. Sinks should be filled to confirm appropriate delineation of basins and streams. If the sinks are not filled, a resulting drainage network may be irregular. Next stage was flow accumulation and flow direction. Stream definition, catchment grid delineation, drainage line processing and drainage point processing were the next steps following flow direction and accumulation.

Arc Hydro Tool:

In order to run the model, first the arc hydro tool is used. Arc Hydro operates in the ARCGIS environment. Arc hydro tools are grouped in different categories with different function. Terrain preprocessing is one of the tool that is used for the fill sink, flow accumulation, flow direction, stream definition and segmentation, catchment grid delineation, catchment polygon processing, adjoint catchment processing, drainage point processing (Shown in fig 2.3)

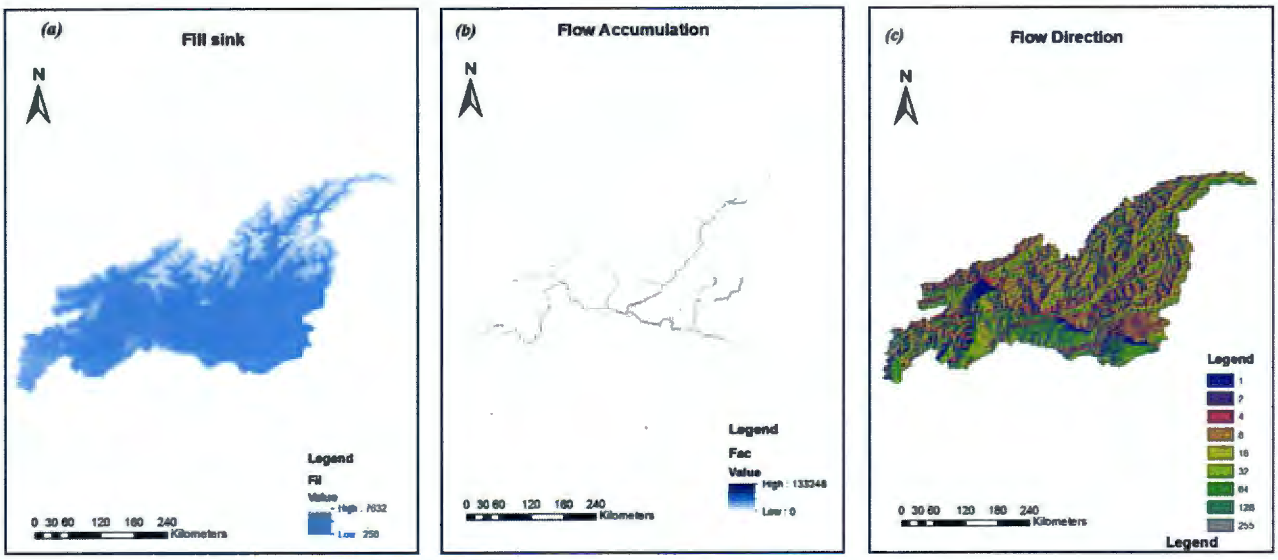


Fig 2.3: (a) Fill sink (b) Flow Accumulation (c) Flow Direction

The Fill Sinks function transforms the elevation value to eradicate these problems. If the fill sink is not done, a resultant drainage network may be discontinuous and error may occur in the result. The output of flow accumulation indicate the amount of rain that flow over each cell and supposing that all rain become the runoff and there was no capture or intrusion, evaporation or loss to groundwater and the flow direction tool has the capability to determine the direction of the flow from each of the raster cell.

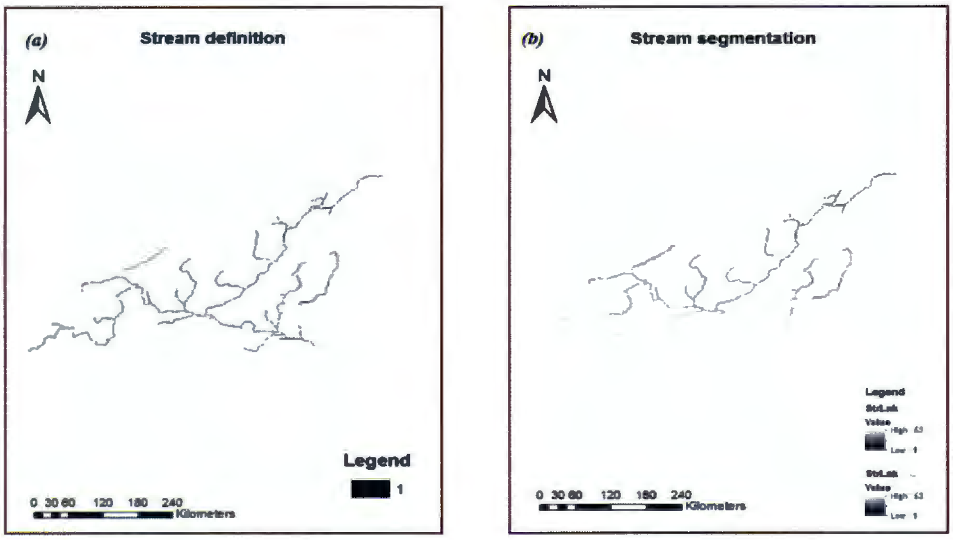


Fig 2.4: (a) Stream definition (b) Stream segmentation

Stream segmentation (Shown in fig 2.4) makes a grid of stream segments that have a distinctive identification. Either a segment may be a head segment, or it may be distinct as a segment between two segment junctions. All the cells in a certain segment have the same grid code that is particular to that segment.

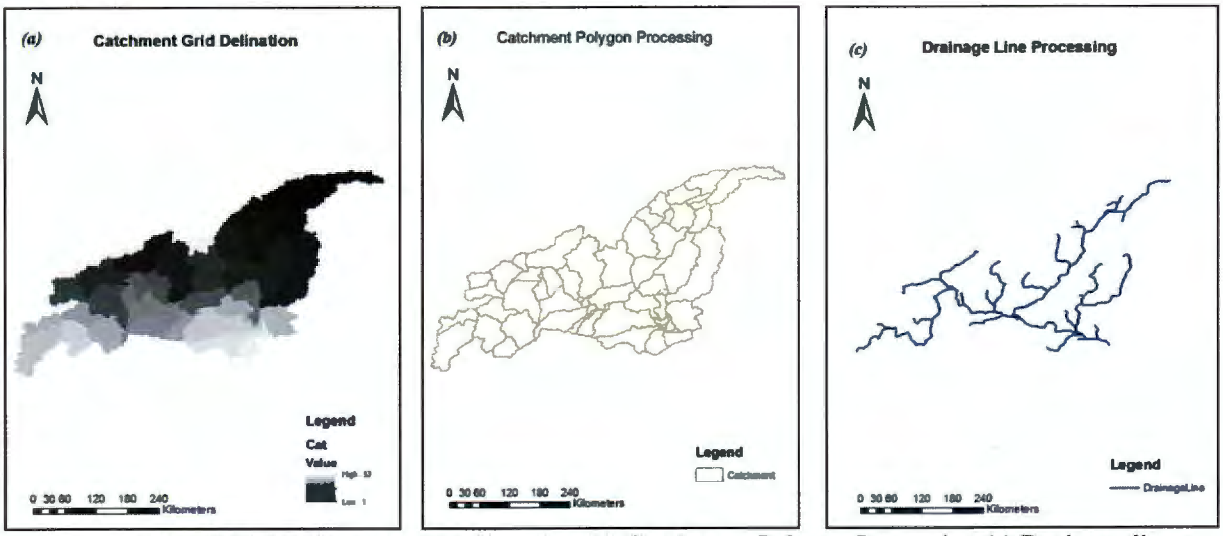


Fig 2.5 (a) Catchment grid delineation (b) Catchment Polygon Processing (c) Drainage line Processing

The catchment grid delineation form a network in which each had a value or specific grid code to indicate to which catchment belongs (fig 2.5 (a). The three purposes catchment polygon processing, drainage line (fig 2.5b & c) and drainage point processing (fig 2.5) the raster data converted into vector data. Completion of catchment processing assigned the unique HydroID to each catchment with its length and area attribute within Arc Hydro.

2.3 Hydrological Modeling (HEC GeoHMS):

HEC HMS software has been downloaded from the US website (www.hec.usace). Hydrological modeling is the part of the methodology. SRTM DEM and satellite images were used in HEC GeoHMS which is the extension in ArcGIS. This extension of ArcGIS creates the HMS model and export to the hydrological model (HEC-HMS). Meteorological rainfall data, daily temperature, air pressure, wind speed and humidity of the selected subbaisns during the last week of July 2010 to 04 August 2010 and hydrological data are used as input of model to get the runoff of Kabul River Basin.

In the present study Hydrological modeling system (HEC-HMS) is used for the precipitation runoff of Kabul river basin. Before starting modeling first step was terrain processing. Terrain data was used as the input .Terrain processing involves using the DEM to generate a stream network and catchments.

Hydrological Modelling System (HEC-HMS):

In HEC-HMS there is a basin model that arranged for each subbasin in study area and used two hydrologic features i.e. subbasin and junction. Subbasin elements handle the intrusion loss and base flow calculations, and precipitation runoff conversion process. Junction element grips the perceived flow information and is mostly used for the assessment of the observed flow hydrographs with the simulated flow hydrographs.

Another HEC-HMS element that is major component is Meteorologic model which is liable for the classification of the meteorologic boundary circumstances for the subbasin. It includes precipitation, evapotranspiration means that include in the simulations.

Flow Chart of methodology used for hydrological modelling (HEC-HMS) is given below:

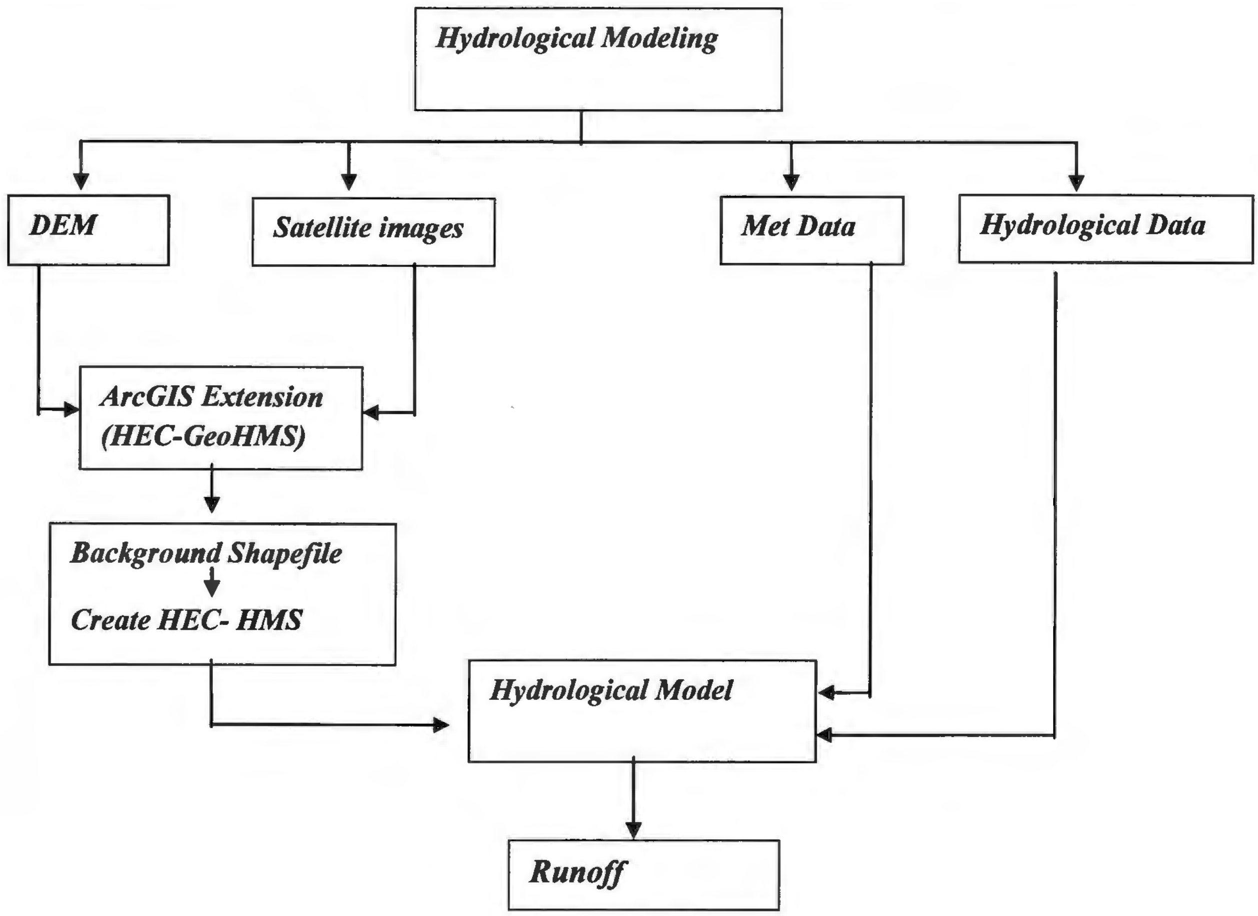


Fig 2.5 Flow chart for Hydrological Modeling

2.4 Hydraulic Modeling (HEC GeoRAS):

The HEC RAS software is also download from US website (www.hec.usace). In hydraulic modeling first we created triangulated irregular network (TIN). In ArcGIS there is extension RAS geometry for the HEC GeoRAS. Phases of RAS geometry include RAS layer (shown in fig 2.6). Key purpose of HEC RAS is giving hydrologic data and allocating boundary condition and initial condition. After calculating inundation area the data was imported to the ArcGIS and get final inundation map of study area.

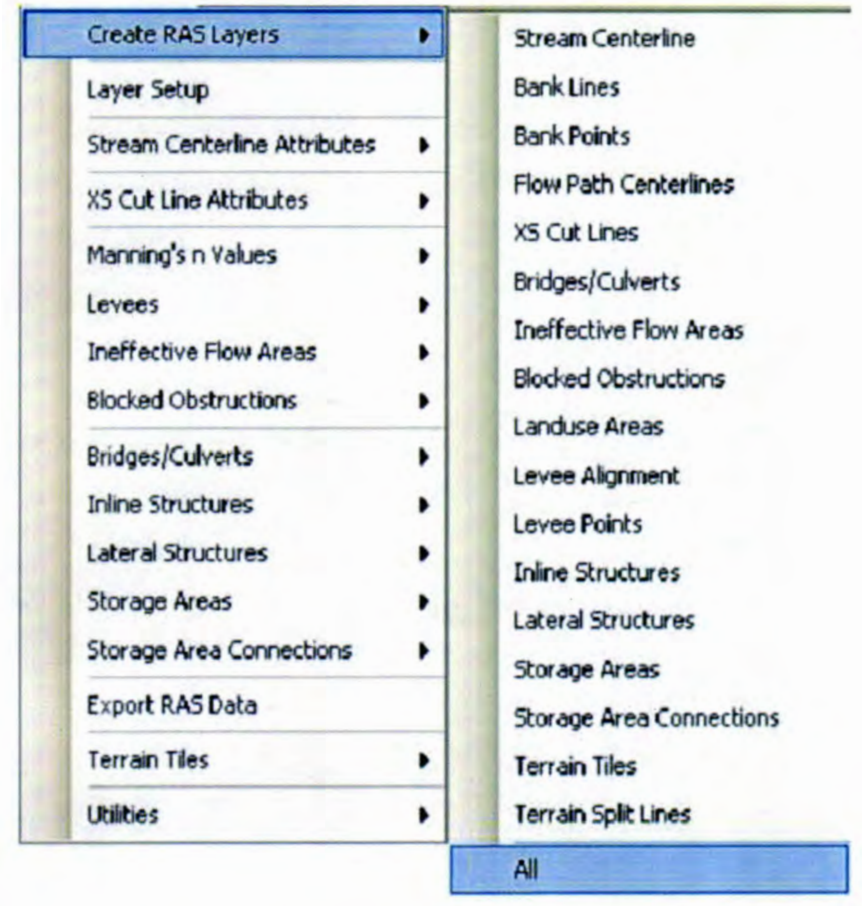


Fig 2.6 List of RAS Layer

In HEC-GeoRAS spatial analyst and 3D analyst extensions in the ArcGIS is used. It is particularly used to process the geospatial data and it is used to create the HEC-RAS import file. This import file comprises of attribute data from digital elevation model (DEM).The geometric data developed in HEC-GeoRAS including stream centerline, reaches (tributaries), cross sectional cutline, downstream reach lengths, main channel, right over bank, left over bank and then export to the HEC-RAS.

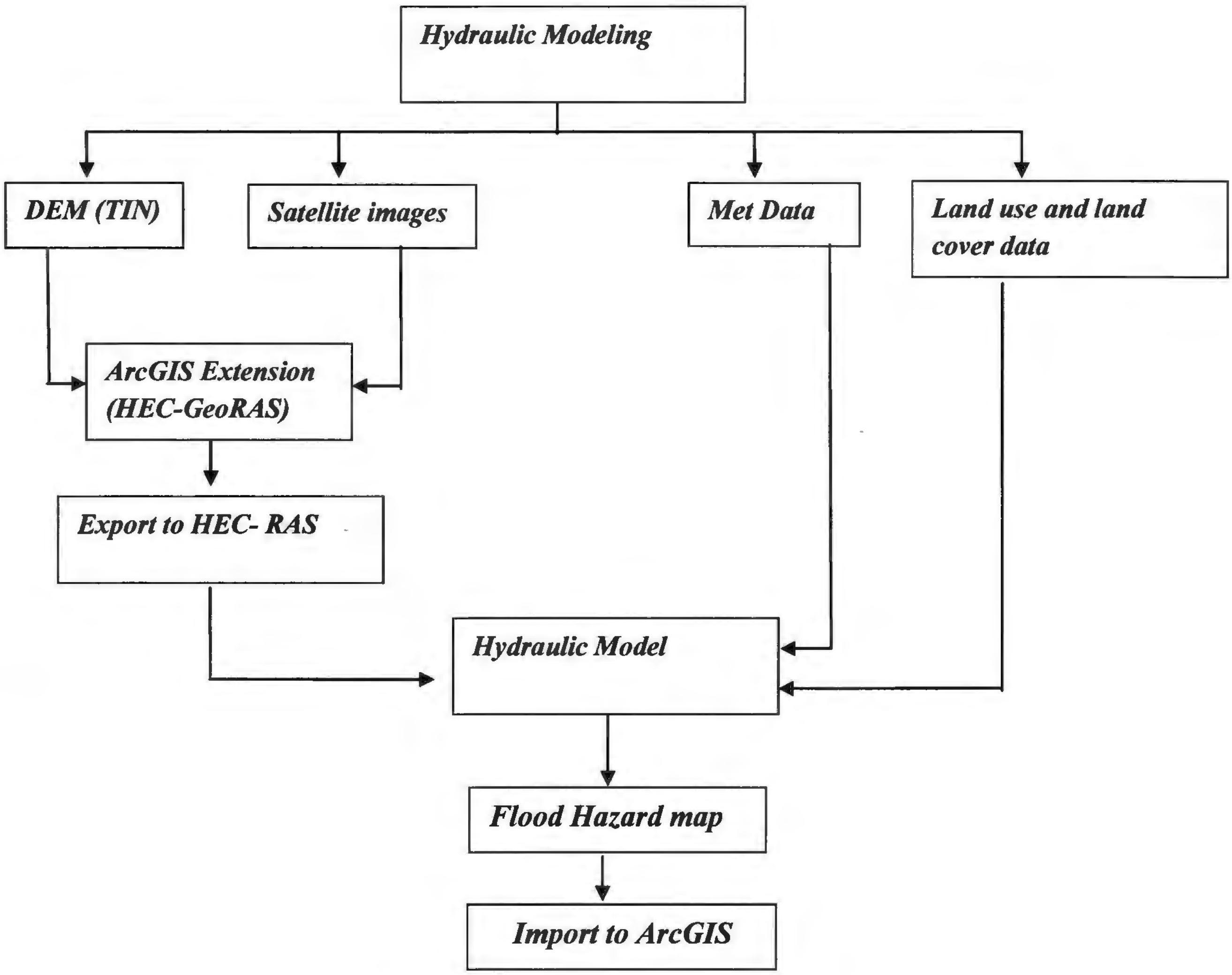


Fig 2.7 Flowchart of Hydraulic Modelling

Results & Discussion

In order to produce 3D map to run the hydrological and hydraulic model, Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (DEM) is used in the Arc GIS. The SRTM DEM has highest resolution of topographic data; its resolution is 90m which is good to view the hydrological area.

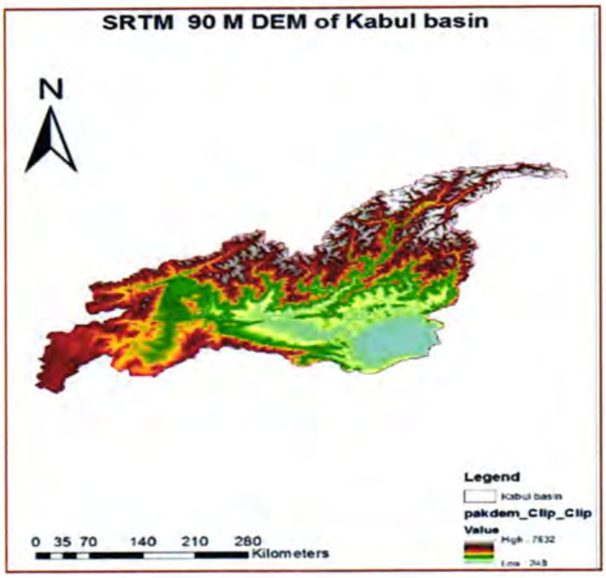


Fig 3.1: SRTM DEM of Kabul River

3.1 HEC Geo HMS (Hydrological Modeling):

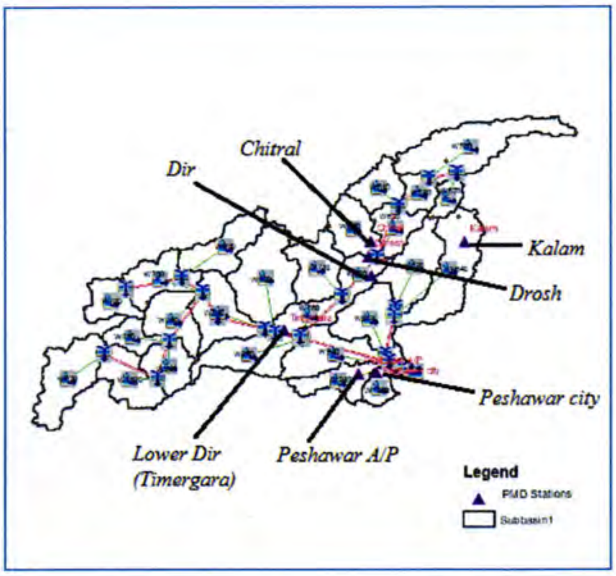


Fig 3.2: Selected subbasin of study area with PMD stations

In the present study Hydrological modeling system (HEC-HMS) has been used for the precipitation runoff of Kabul basin. As shown by the fig (Fig 3.2), there are seven subbasins i.e. Chitral, Dir, Drosh, Lower Dir (Timergara), Kalam, Peshawar city and Peshawar A/P (Airport) where PMD gauges are present and represented by purple triangle. Daily rainfall data from 20th July 2010 to 4th Aug 2010 has been gathered from these gauges.

Before starting modeling first step was terrain processing. Terrain data was used as the input .A stream network and catchment of study area was created by using the DEM in terrain processing.

3.1.1 Basin Processing:

Basin processing involved the basin and river merge. Different subbasin and rivers were merged to form subbasin. Subbasin could be merged if they are flowing together or head-to-head in downstream and upstream manner.

3.1.2 River profile:

River profile gives the information about slopes and grades breaks as shown in fig 3.3. The following river profile was created by elevation value from terrain model along the stream line.

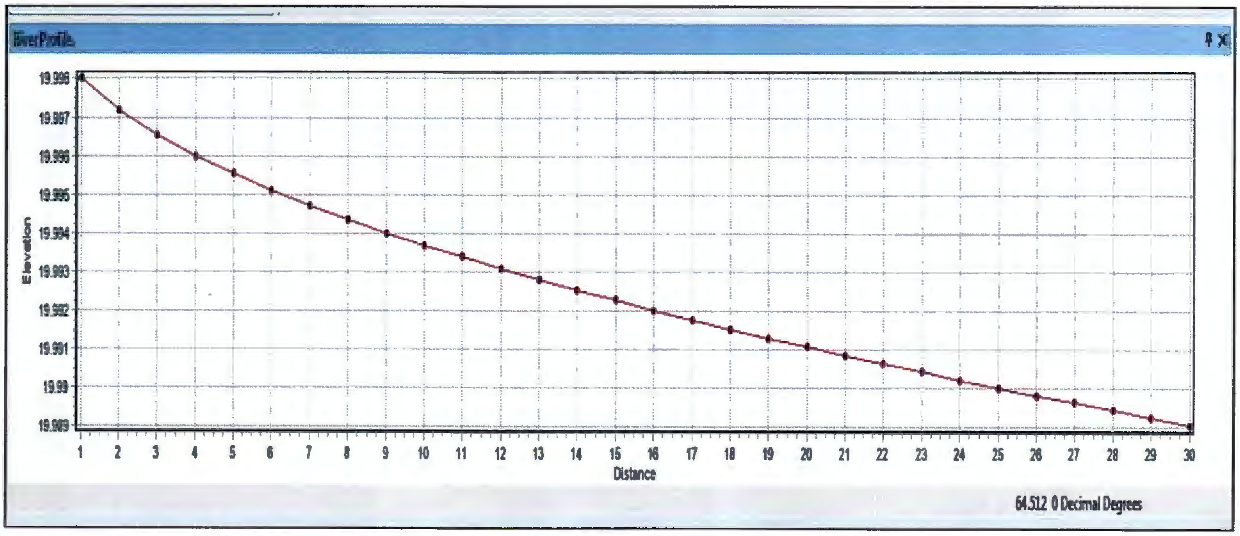


Fig 3.3: River Profile of one subbasin of study area

3.1.3 Stream and Basin Characteristics:

River length, river slope, basin length, longest flowpath, basin centroid and centroid elevation of Kabul river basin is shown in fig (Fig 3.4). River length and river slope tools are used to compute the length and slope of each river segments and stores them.

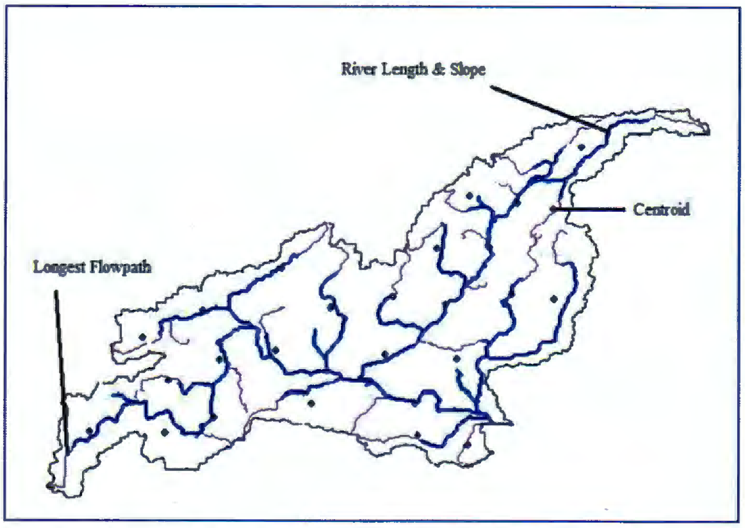


Fig3.4: Longest flow path, centroid, river length and slop of Kabul River Basin

3.1.4 Hydrological Parameters:

Hydrological parameters assessed as subbasin average and grid based value via soil and landuse database. Time of concentration and Muskingum routing parameters computed from terrain and precipitation data. Attribute table for subbasin and river layers are shown in fig 3.5 that is used in the HEC-HMS model generated by HEC-Geo HMS.

Table (a)

Subbasin1

OBJECTID *	Shape *	grid_code	Shape_Length	Shape_Area	HydroID	DrainID	Description	PrecipGage	LossMet	TransMet	BaseMet	Name	TotStormP	BasinSlope
5	Polygon	5	7.0334	0.713528	56	56	<Null>	Precip Gage 1	SCS	SCS	None	W560	<Null>	3978041.5
6	Polygon	6	2.217	0.124588	57	57	<Null>	Precip Gage 2	SCS	SCS	None	W570	<Null>	3362192.5
7	Polygon	7	2.4334	0.165971	58	58	<Null>	Precip Gage 3	SCS	SCS	None	W580	<Null>	3494338
10	Polygon	10	3.0834	0.247498	61	61	<Null>	Precip Gage 4	SCS	SCS	None	W610	<Null>	3241717.25
11	Polygon	11	3.2996	0.241111	62	62	<Null>	Precip Gage 5	SCS	SCS	None	W620	<Null>	3299269.5
12	Polygon	12	4.5002	0.369862	63	63	<Null>	Precip Gage 6	SCS	SCS	None	W630	<Null>	2592609.25
13	Polygon	13	6.233	0.608053	64	64	<Null>	Precip Gage 7	SCS	SCS	None	W640	<Null>	2459398.5
14	Polygon	14	3.25	0.310903	65	65	<Null>	Precip Gage 8	SCS	SCS	None	W650	<Null>	3192110
16	Polygon	16	4.4998	0.439366	67	67	<Null>	Precip Gage 9	SCS	SCS	None	W670	<Null>	2448574.75
17	Polygon	17	2.7666	0.200909	68	68	<Null>	Precip Gage 10	SCS	SCS	None	W680	<Null>	2603889.75
19	Polygon	19	4.0334	0.331449	70	70	<Null>	Precip Gage 11	SCS	SCS	None	W700	<Null>	1790095.875
20	Polygon	20	4.1172	0.380895	71	71	<Null>	Precip Gage 12	SCS	SCS	None	W710	<Null>	2823957
21	Polygon	21	2.9508	0.222575	72	72	<Null>	Precip Gage 13	SCS	SCS	None	W720	<Null>	1995197.5
23	Polygon	23	3.8004	0.328494	74	74	<Null>	Precip Gage 14	SCS	SCS	None	W740	<Null>	947452.375
25	Polygon	25	3.1166	0.218802	76	76	<Null>	Precip Gage 15	SCS	SCS	None	W760	<Null>	1807046.375
31	Polygon	31	5.3842	0.637508	82	82	<Null>	Precip Gage 16	SCS	SCS	None	W820	<Null>	2371512
32	Polygon	32	4.3994	0.413243	83	83	<Null>	Precip Gage 17	SCS	SCS	None	W830	<Null>	1484431
37	Polygon	37	2.7338	0.168943	88	88	<Null>	Precip Gage 18	SCS	SCS	None	W880	<Null>	1654905.75
38	Polygon	38	5.2326	0.420492	89	89	<Null>	Precip Gage 19	SCS	SCS	None	W890	<Null>	1269435.25
39	Polygon	39	2.967	0.264646	90	90	<Null>	Precip Gage 20	SCS	SCS	None	W900	<Null>	805623.125
40	Polygon	40	3.8336	0.393615	91	91	<Null>	Precip Gage 21	SCS	SCS	None	W910	<Null>	1341148.75
42	Polygon	42	5.0668	0.496404	93	93	<Null>	Precip Gage 22	SCS	SCS	None	W930	<Null>	839013.75
43	Polygon	43	6.5504	0.486511	94	94	<Null>	Precip Gage 23	SCS	SCS	None	W940	<Null>	820219.3125
47	Polygon	47	4.3334	0.247665	98	98	<Null>	Precip Gage 24	SCS	SCS	None	W980	<Null>	1200999
49	Polygon	49	2.2328	0.124577	100	100	<Null>	Precip Gage 25	SCS	SCS	None	W1000	<Null>	426934.5625
51	Polygon	51	3.7332	0.350695	102	102	<Null>	Precip Gage 26	SCS	SCS	None	W1020	<Null>	1006581.4375

Table (b)

River1

OBJECTID *	Shape *	arcid	grid_code	from_node	to_node	Shape_Length	HydroID	NextDownID	DrainID	Slp	ElevUP	ElevDS	RivLen
1	Polyline	1	2	1	2	0.185582	1	4	56	1039.973457	2440	2247	0.185582
2	Polyline	2	3	3	2	0.215128	2	4	56	1891.893714	2654	2247	0.215128
3	Polyline	3	1	4	5	1.172503	3	5	56	962.897034	3397	2268	1.172503
4	Polyline	4	4	2	6	0.351635	4	10	56	1097.728334	2247	1861	0.351635
5	Polyline	5	5	5	6	0.359433	5	10	56	1132.337442	2268	1861	0.359433
6	Polyline	6	6	7	5	0.220236	6	5	57	2156.776685	2743	2268	0.220236
7	Polyline	7	8	8	9	0.146904	7	9	61	4928.378296	2525	1801	0.146904
8	Polyline	8	9	10	9	0.169418	8	9	61	1953.749985	2132	1801	0.169418
9	Polyline	9	10	9	11	0.169541	9	12	61	1574.838096	1801	1534	0.169541
10	Polyline	10	7	6	11	0.529979	10	12	58	617.005885	1861	1534	0.529979
11	Polyline	11	14	12	13	0.834566	11	18	65	2368.895558	3033	1056	0.834566
12	Polyline	12	11	11	13	0.81717	12	18	62	584.945778	1534	1056	0.81717
13	Polyline	13	12	14	15	0.966004	13	16	63	1545.542422	3000	1507	0.966004
14	Polyline	14	21	16	17	0.0125	14	15	72	-1520.000091	2044	2063	0.0125
15	Polyline	15	18	17	15	0.741274	15	16	70	750.060339	2063	1507	0.741274
16	Polyline	16	19	15	18	0.310708	16	24	70	-254.257987	1507	1586	0.310708
17	Polyline	17	20	19	20	0.812127	17	32	71	1870.396356	2341	822	0.812127
18	Polyline	18	17	13	20	0.711216	18	32	68	329.013984	1056	822	0.711216
19	Polyline	19	22	21	17	0.128033	19	15	72	1015.363139	2193	2063	0.128033
20	Polyline	20	27	22	23	0.094447	20	22	91	-1058.797555	708	808	0.094447
21	Polyline	21	16	24	23	0.981779	21	22	67	911.610865	1703	808	0.981779
22	Polyline	22	28	23	25	0.122206	22	40	91	1718.416214	808	598	0.122206
23	Polyline	23	26	26	27	0.233556	23	29	83	1348.714593	1323	1008	0.233556
24	Polyline	24	30	18	27	0.485868	24	29	83	1190.113315	1586	1008	0.485868
25	Polyline	25	13	28	25	1.701312	25	40	64	963.961749	2238	598	1.701312
26	Polyline	26	24	29	30	0.348179	26	28	82	1760.590003	1297	684	0.348179
27	Polyline	27	15	31	30	1.125738	27	28	82	1558.977617	2439	684	1.125738
28	Polyline	28	31	30	32	0.125561	28	30	82	645.106407	684	603	0.125561
29	Polyline	29	32	27	32	0.686256	29	30	83	607.874491	1008	603	0.686256
30	Polyline	30	33	32	33	0.142302	30	31	82	182.709747	603	577	0.142302
31	Polyline	31	35	33	34	0.308973	31	33	89	168.299425	577	525	0.308973

Table (c)

HMSLink999

Shape *	OID *	Shape_Length	HydroID	LinkType	CanvasX	CanvasY	FromCanvasX	FromCanvasY	FeatureID	DownElemID
Polyline	49	0.950653	136	1	72.0125	34.0333	71.0803	34.2197	94	134
Polyline	50	0.500312	139	1	68.3833	34.2333	67.9668	33.9561	93	138
Polyline	51	0.443823	142	1	71.6583	34.225	71.4761	34.6297	91	141
Polyline	52	0.275329	145	1	69.1417	34.375	69.1457	34.0997	90	144
Polyline	53	0.634608	148	1	70.6917	34.4	70.0811	34.2271	89	147
Polyline	54	0.428145	150	1	69.1417	34.375	68.7163	34.4234	88	144
Polyline	55	0.5477	153	1	70.2583	34.5167	69.7404	34.6949	83	152
Polyline	56	0.631314	156	1	70.375	34.4667	70.2687	35.089	82	155
Polyline	57	0.275275	159	1	70.6667	34.425	70.7872	34.6725	76	158
Polyline	58	0.454426	162	1	69.5333	34.925	69.2001	34.616	74	161
Polyline	59	0.221457	165	1	68.6417	34.9667	68.4681	34.8292	72	164
Polyline	60	0.428945	168	1	71.1583	34.8833	70.865	35.1963	71	167
Polyline	61	0.512756	170	1	69.5333	34.925	69.0427	35.0741	70	161
Polyline	62	0.325258	172	1	71.1583	34.8833	71.3736	35.1271	68	167
Polyline	63	0.512861	175	1	71.7833	34.7583	72.0068	35.2199	67	174
Polyline	64	0.412963	178	1	71.5583	35.325	71.2922	35.6408	65	177
Polyline	65	0.832081	181	1	71.7583	34.6583	72.4066	35.1799	64	180
Polyline	66	0.617595	184	1	69.2917	35.0917	69.7958	35.4485	63	183
Polyline	67	0.39648	186	1	71.5583	35.325	71.7803	35.6535	62	177
Polyline	68	0.308805	189	1	71.8167	35.9083	71.5902	36.1182	61	188
Polyline	69	0.27754	191	1	71.8167	35.9083	72.0554	36.0499	58	188
Polyline	70	0.294614	194	1	72.4917	36.275	72.3956	35.9965	57	193
Polyline	71	0.605715	197	1	72.1667	36.225	72.6612	36.5748	56	196
Polyline	72	0.319616	200	1	69.0083	33.95	68.6667	33.9468	102	199
Polyline	73	0.322557	203	1	71.8417	34.0417	71.5866	33.8443	100	202
Polyline	74	0.694467	206	1	71.7833	34.1	71.1119	33.9225	98	205
Polyline	75	0.328824	207	2	72.1667	36.225	72.4917	36.275	5	196
Polyline	76	0.472016	208	2	71.8167	35.9083	72.1667	36.225	10	188
Polyline	77	0.637973	209	2	71.5583	35.325	71.8167	35.9083	12	177
Polyline	78	0.66191	210	2	69.2917	35.0917	68.6417	34.9667	15	183
Polyline	79	0.293529	211	2	69.5333	34.925	69.2917	35.0917	16	161

1 (0 out of 48 Selected)

HMSLink999

Fig 3.5: Attribute Table for (a) Subbasin, (b) Flowpath Parameter, (c) TR55 Flowpath segmentation

3.1.5 Export TR55 Data

TR55 flow path segment is used to define different flow regimes along the longest flow path. This tool places two points along the longest flow path for each subbasin. The obtained data of TR55 flow segments has been shown in MS excel spreadsheet. This function was operated on a selected data of subbasin of study area i.e. Kalam, Chitral, Drosh, Dir Lower Dir, Peshawar A/P and Peshawar city from subbasin layer and these selected areas of Kabul river basin has assigned a specific subbasin name as W640, W620, W650, W680, W670, W980 and W1000 respectively. In the Excel spreadsheet, the blue area shows the data that is taken from HEC-Geo HMS and it is GIS defined data. This data is editable but changes cannot be transferred back to HEC Geo HMS. Green areas shown in the fig comprised of verified data that is specified while white and yellow area comprised of calculated computational values. The worksheet for computation of time of travel according to TR55 methodology is shown in fig 3.6.

1	**Worksheet for computation of time of travel according to TR-55 methodology**							
2	Blue - GIS defined, Green - user specified, White and yellow - calculated, Red - final result							
3	**Watershed Name**	**W620**	**W640**	**W650**	**W670**	**W680**	**W980**	**W1000**
4	**Watershed ID**	**62**	**64**	**65**	**67**	**68**	**98**	**100**
5	Sheet Flow Characteristics							
6	Manning's Roughness Coefficient	0.25	0.25	0.25	0.25	0.25	0.25	0.25
7	Flow Length (ft)	3.0913	7.1851	4.4491	5.1861	3.1761		
8	Two-Year 24-hour Rainfall (in)							
9	Land Slope (ft/ft)	0	0	-2.2123	-7.5914	-8.2638		
10	Sheet Flow Tt (hr)	#DIV/0!	#DIV/0!	#NUM!	#NUM!	#NUM!	#DIV/0!	#DIV/0!
11	Shallow Concentrated Flow Characteristics							
12	Surface Description (1 - unpaved 2 - paved)	1	1	1	1	1	1	1
13	Flow Length (ft)	-3.0913	-7.1851	-4.4491	-5.1861	-3.1761		
14	Watercourse Slope (ft/ft)	0	0	-2.2123	-7.5914	-8.2638		
15	Average Velocity - computed (ft/s)	0.00	0.00	#NUM!	#NUM!	#NUM!	0.00	0.00
16	Shallow Concentrated Flow Tt (hr)	#DIV/0!	#DIV/0!	#NUM!	#NUM!	#NUM!	#DIV/0!	#DIV/0!
17	Channel Flow Characterisitics							
18	Cross-sectional Flow Area (ft2)	20	20	20	20	20	20	20
19	Wetted Perimeter (ft)	20	20	20	20	20	20	20
20	Hydraulic Radius - computed (ft)	1.00	1.00	1.00	1.00	1.00	1.00	1.00
21	Channel Slope (ft/ft)	0	0	-2.2123	-7.5914	-8.2638		
22	Manning's Roughness Coefficient	0.03	0.03	0.03	0.03	0.03	0.03	0.03
23	Average Velocity - computed (ft/s)	0.00	0.00	#NUM!	#NUM!	#NUM!	0.00	0.00
24	Flow Length (ft)	3.0913	7.1851	4.4491	5.1861	3.1761		

Fig 3.6: Worksheet of TR55 Flowpath Segment

3.2 HMS (Hydrological Model System):

In HMS tool prepared dataset is import to the HEC-HMS model. Background shape of rivers and subbasin of study area was created along with added Met data (meteorological data).Finally create the HEC-HMS project and imported to the HEC-HMS model.

HEC-HMS Model:

HEC-HMS model give the precipitation runoff of Kabul river basin. Subbasin and river data was add to the model with historic event of 2010 flood in Pakistan for the period of the last week of July to August. The collected data of rainfall and precipitation from 20 July 2010 to 30 July 2010 was added to the model. There was a precipitation gauges for each subbasin. Basin model is shown in fig (Fig 3.7) with different subbasins their reach and junction. Each subbasin has specific name represented by W. most of the area of Kabul river basin is located in Afghanistan therefore only seven subbasins are included in this study that are located in Pakistan. There was gauge present at Kabul River near Nowshehra at Jehangira Bridge damaged due to heavy flood in Kabul river basin.

Fig 3.7 Kabul River Basin Model Map

3.3 Simulation Results:

Simulation result of Kabul river basin shows the drainage area, peak discharge and volume in inches for each hydrologic element i.e. subbasin (W), reach (R), junction (J) and for outlet in global summary table. For simulation 12 hourly data is added to the hydrologic element i.e. meteorologic model (include precipitation, evotranspiration). As shown fig 3.8, there is a window time series with 12 hourly data added to each precipitation gauge of study area.

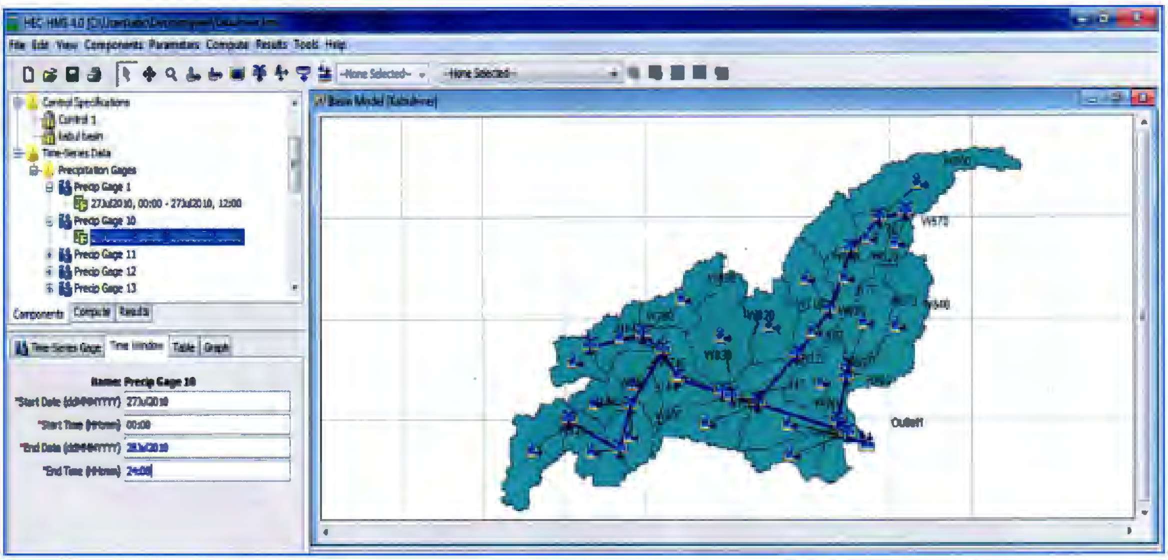
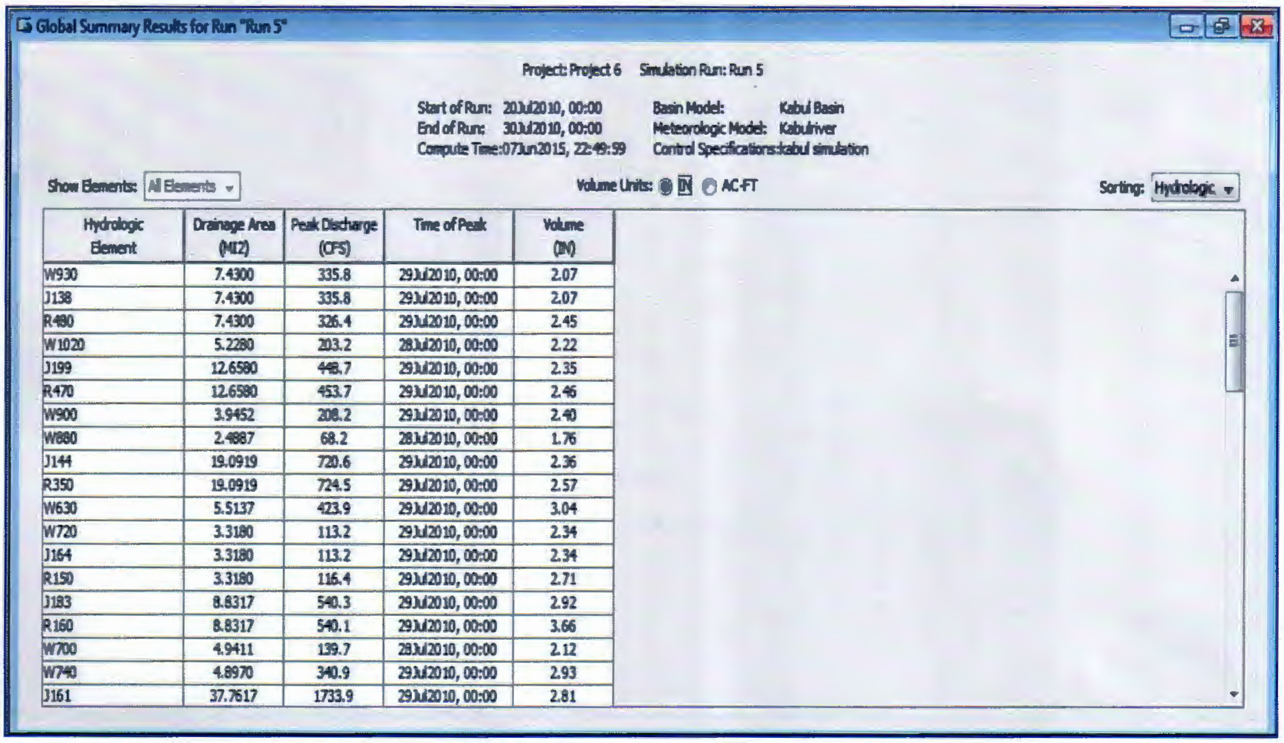


Fig 3.8: Kabul River Basin with hydrologic element and time series window

In simulation result seven subbasins (W) are of Pakistan i.e. W620 for Chitral, W640, and W650 are for Kalam and Drosh respectively. W680 and W760 are for Dir and Lower Dir (Timergara), W980 & W1000 are for Peshawar (A/P) and Peshawar city respectively.

3.3.1 Global Summary Result of 20-30 July 2010 Simulation:

The simulation run for 20-30 July 2010 showed that the heavy rainfall started during the last week of July 2010. According to the available data of daily rainfall from July – August 2010 discharge peak is 9213.0 CFS (cubic feet/sec) and volume is 4.43 inches. Global summary result for 20-30 July 2010 simulation is shown in fig 3.9.


Global Summary Results for Run "Run 5"

Project: Project 6 Simulation Run: Run 5

Start of Run: 20Jul2010, 00:00 Basin Model: Kabul Basin
End of Run: 30Jul2010, 00:00 Meteorologic Model: Kabulriver
Compute Time: 07Jun2015, 22:49:59 Control Specifications: kabul simulation

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
W930	7.4300	335.8	29Jul2010, 00:00	2.07
J138	7.4300	335.8	29Jul2010, 00:00	2.07
R480	7.4300	326.4	29Jul2010, 00:00	2.45
W1020	5.2280	203.2	28Jul2010, 00:00	2.22
J199	12.6580	448.7	29Jul2010, 00:00	2.35
R470	12.6580	453.7	29Jul2010, 00:00	2.46
W900	3.9452	208.2	29Jul2010, 00:00	2.40
W880	2.4887	68.2	28Jul2010, 00:00	1.76
J144	19.0919	720.6	29Jul2010, 00:00	2.36
R350	19.0919	724.5	29Jul2010, 00:00	2.57
W630	5.5137	423.9	29Jul2010, 00:00	3.04
W720	3.3180	113.2	29Jul2010, 00:00	2.34
J164	3.3180	113.2	29Jul2010, 00:00	2.34
R150	3.3180	116.4	29Jul2010, 00:00	2.71
J183	8.8317	540.3	29Jul2010, 00:00	2.92
R160	8.8317	540.1	29Jul2010, 00:00	3.66
W700	4.9411	139.7	28Jul2010, 00:00	2.12
W740	4.8970	340.9	29Jul2010, 00:00	2.93
J161	37.7617	1733.9	29Jul2010, 00:00	2.81

Fig 3.9: Global Summary of Simulation Run for 20-30 July 2010

As heavy rainfall started in study area on 27th July 2010, therefore individual simulation of consecutive two to three days has been prepared.

3.3.2 Simulation result of 26-28 July 2010:

The simulation result of 26-28 July 2010 show the peak discharge of 199.4 CFS at outlet with 4.50 inches volume of outflow (shown in fig 3.10). As shown in the simulation result, on 27th July 2010 high discharge peak was 207.4 CFS with 3.75 In volume at W640 (Kalam).

Global Summary Results for Run "Run 98"

Project: Project 3 Simulation Run: Run 98

Start of Run: 26Jul2010, 00:00 Basin Model: Kabulriver
End of Run: 28Jul2010, 00:00 Meteorologic Model: Kabulriver
Compute Time: 28May2015, 14:13:56 Control Specifications: Simulation

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
W640	2.3477	207.4	27Jul2010, 00:00	3.75
W670	1.6964	26.1	27Jul2010, 00:00	0.69
R220	1.6964	24.0	27Jul2010, 00:00	0.68
J174	1.6964	26.1	27Jul2010, 00:00	0.69
J180	4.0441	231.5	27Jul2010, 00:00	2.46
R400	4.0441	213.6	27Jul2010, 00:00	2.42
W910	1.5198	2.7	27Jul2010, 00:00	0.08
J141	5.5639	216.3	27Jul2010, 00:00	1.78
R420	5.5639	199.6	27Jul2010, 00:00	1.75
J223	68.2707	3486.6	28Jul2010, 00:00	2.09
R430	68.2707	3516.8	28Jul2010, 00:00	2.01
W980	9.5624	32.2	27Jul2010, 00:00	0.14
J205	77.8331	3525.9	28Jul2010, 00:00	1.78
R440	77.8331	3534.4	28Jul2010, 00:00	1.71
W940	1.8784	199.4	27Jul2010, 00:00	4.50
R460	0.0000	0.0	26Jul2010, 00:00	n/a
Outlet1	1.8784	199.4	27Jul2010, 00:00	4.50

Fig 3.10: Global Summary of Simulation Run for 26-28 July 2010

3.3.3 Simulation Result of 27-30 July 2010:

There is heavy rainfall during the 27 July -30 July 2010 therefore from simulation run of 27-30 July high discharge peak of 539.1 CFS (cubic feet/sec) at outlet with 10.49 inches volume has been obtained. As shown by fig 3.11 high peak discharge was on 29th July at W640.

Global Summary Results for Run "Run 2"

Project: Project 4 Simulation Run: Run 2

Start of Run: 27Jul2010, 00:00 Basin Model: Kabulriver
End of Run: 30Jul2010, 00:00 Meteorologic Model: Kabulriver
Compute Time: 02Jun2015, 10:12:54 Control Specifications: Simulation

Show Elements: All Elements Volume Units: IN AC-FT Sorting: Hydrologic

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
W640	2.3477	1662.6	29Jul2010, 00:00	19.26
W670	1.6964	83.6	29Jul2010, 00:00	1.77
R220	1.6964	77.9	29Jul2010, 00:00	1.95
J174	1.6964	83.6	29Jul2010, 00:00	1.77
J180	4.0441	1740.5	29Jul2010, 00:00	12.00
R400	4.0441	1640.7	29Jul2010, 00:00	18.14
W910	1.5198	622.3	29Jul2010, 00:00	10.45
J141	5.5639	2263.0	29Jul2010, 00:00	16.04
R420	5.5639	2120.2	29Jul2010, 00:00	16.53
J223	68.2707	15292.8	29Jul2010, 00:00	12.99
R430	68.2707	15153.8	29Jul2010, 00:00	12.91
W980	9.5624	3594.2	29Jul2010, 00:00	9.62
J205	77.8331	18748.0	29Jul2010, 00:00	12.51
R440	77.8331	18262.9	29Jul2010, 00:00	12.45
W940	1.8784	539.1	28Jul2010, 00:00	10.94
R460	0.0000	0.0	27Jul2010, 00:00	n/a
Outlet1	1.8784	539.1	28Jul2010, 00:00	10.94

Fig 3.11: Global Summary of Simulation Run for 27-30 July 2010

3.4 Graphs of Subbasin:

HEC-HMS simulation gives the different graphs for different subbasin according to their sink, precipitation, rainfall and runoff. Graph of rainfall, direct runoff and precipitation shows the high peak at 29th July 2010 as shown by the fig 3.12 (a) (b) and (c).

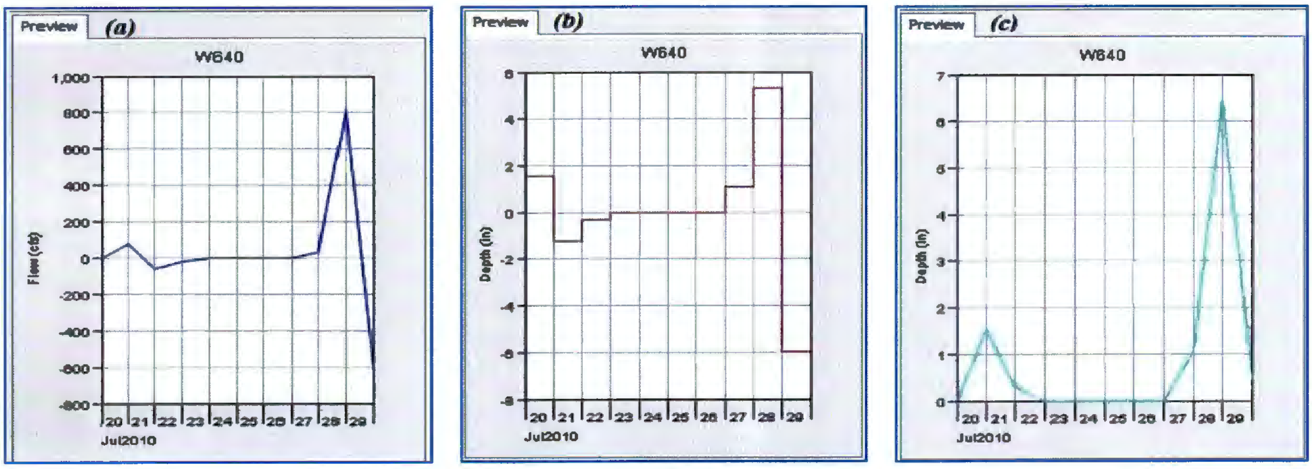


Fig 3.12: Graph of subbasin (a) Rainfall, (b) Direct Runoff and (c) Precipitation

3.4.1 Graph for Subbasin:

Simulation of study area gives the graph for subbasin showing depth and flow of the water during the selected dates of the flood event 2010 (fig 3.13). In fig precipitation loss and total precipitation of subbasins W640 (Kalam) has been shown. Each subbasin has different precipitation and precipitation loss with different peak of outflow.

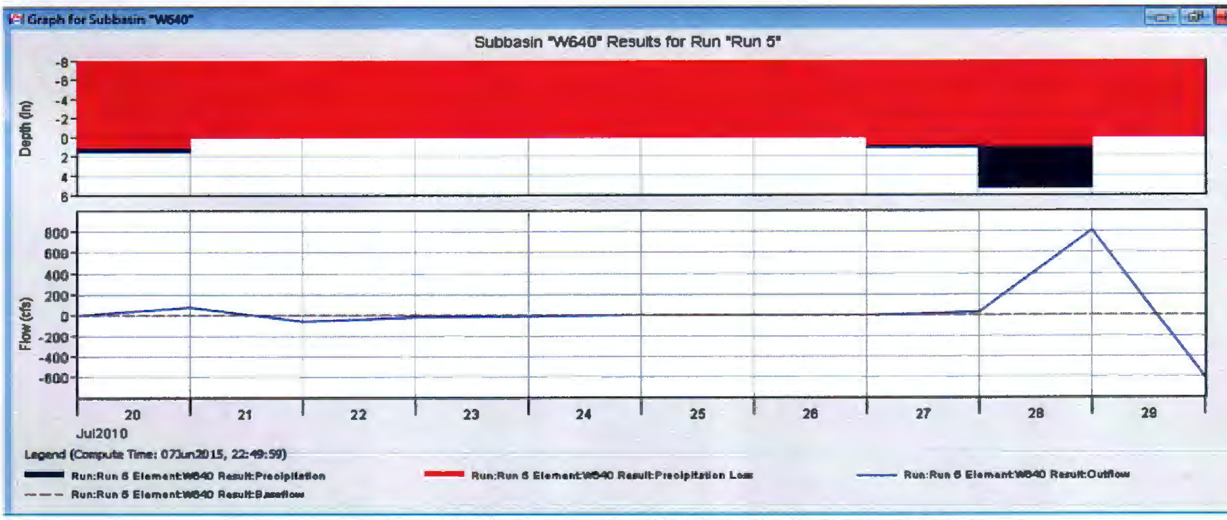


Fig 3.13: Graph of Subbasin showing the depth in inches and flow in cfs.

3.4.2 Graph for Sink at outlet:

The graph for sink showing the peak of hydrologic elements that is outlet; reach (R) and subbasin (W). Hydrologic elements showing the outflow of precipitation but at different peak. The following graph shows the difference between their outflows.

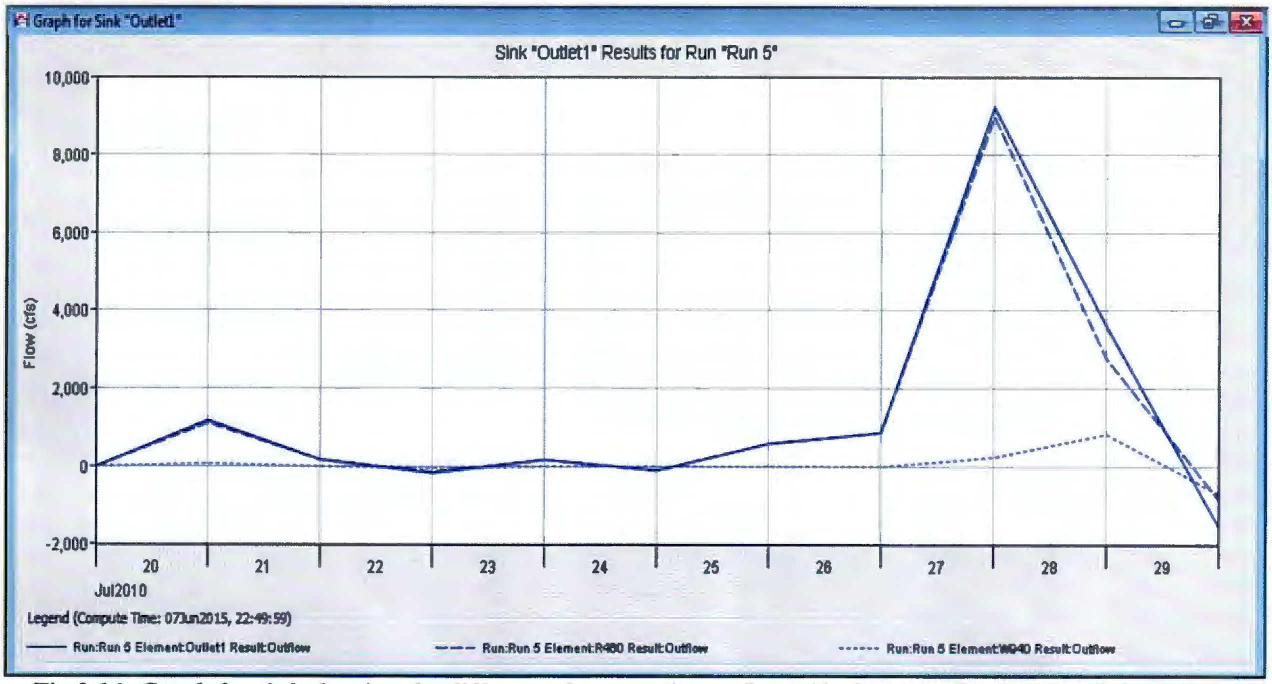


Fig 3.14: Graph for sink showing the difference between the outflow of hydrologic elements i.e. Outlet, Reach (R) and Subbasin (W).

The outflow of subbasin (W940) seems very low as compared to the outflow of out and reach. There is very little difference between the outlet and reach peak that is shown in fig 3.14 on 28 – 29 July 2010 with approx. 9,000 cfs flow.

3.4.3 Graph for daily rainfall data from 15 July to 15 August 2010:

Daily rainfall data from 15 July to 15 August 2010 of study area was collected from PMD. In the following graph selected areas for this study with PMD gauges are included. Mostly areas are located in Afghanistan only seven subbasins present in the study area with PMD and WAPDA gauges. Shown in fig 3.15.The graph shows that during 15th July to 15th Aug 2010 Dir received the highest rainfall and Chitral received less as compared to Dir.

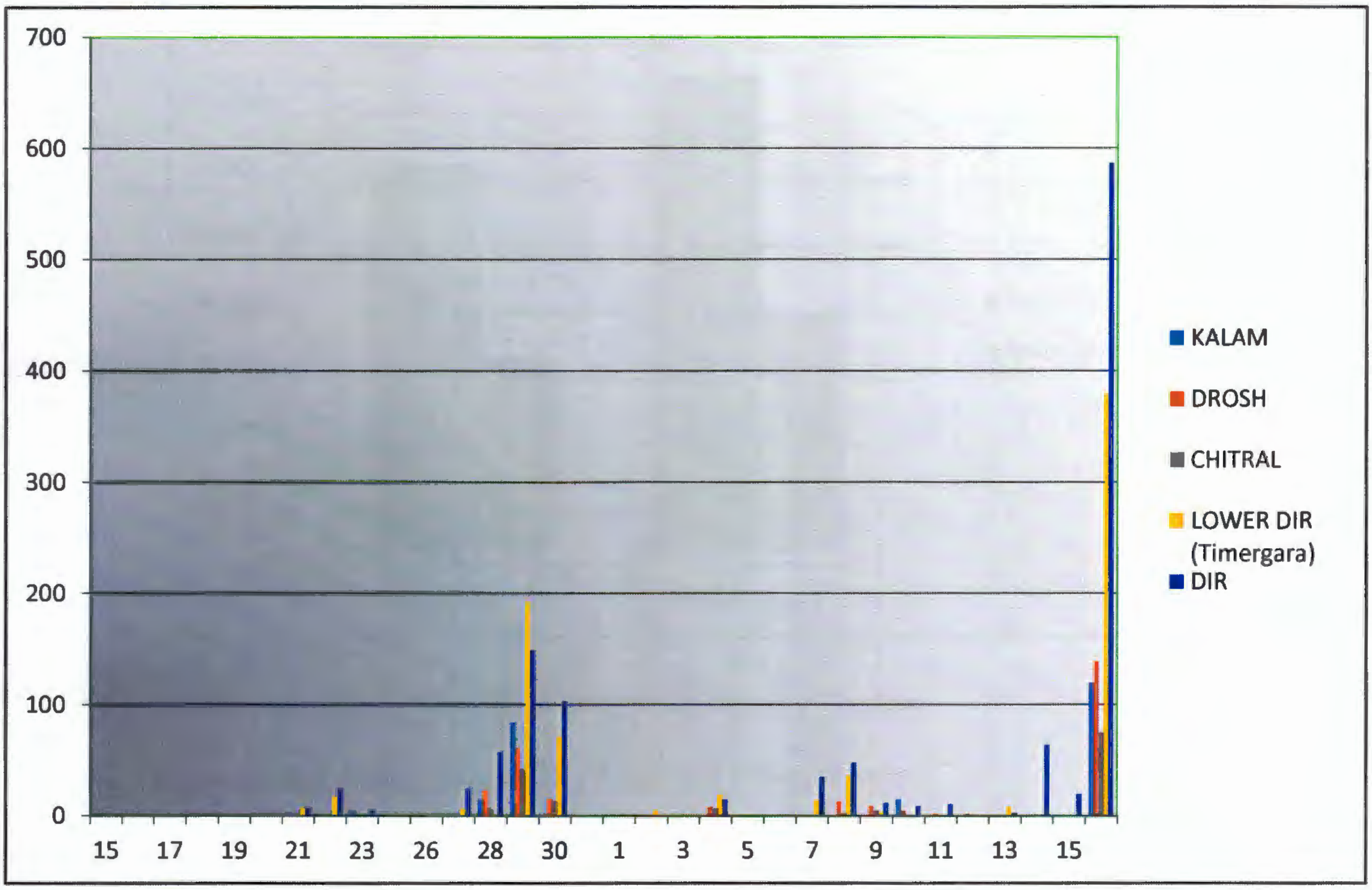


Fig3.15: Daily Rainfall Graph from 15 July – 15 August 2010

3.5 *Comparison between Observed Data and Model Data:*

Simulation result has been show in the form of graph and compared with the observed data which shows some difference in discharge peak. Observed data was the actual rainfall in the month of July and August on selected period of time and date. Some rainfall data is missing due to lack of Afghanistan climatic data and some gauges present in study area of Pakistan were damaged due to heavy flood. Therefore, there is a large difference between actual and model data.

3.5.1 Observed and Model data of 27-28 July 2010 Simulation:

The simulation of 27 -28 July created the following graph showing that the observed data has high discharge peak as compared to the model data. According to available rainfall data the actual (observed) rainfall on 27-28 July was 54,775 and 68,300 while simulation result of both days are 25520.2 and 32902.2 respectively.

3.5.3 Model Data of 01 Aug- 04 Aug 2010:

There was no rainfall data for 31 July to 04 Aug 2010 because of the heavy flood wave that damage the gauges at the study area. Therefore, only model data was simulated and there is no comparison between model and observed data. Model data is shown in the following graph with highest peak of 40817.5 cfs on 02nd Aug and lowest 64.9 cfs on 04th Aug 2010.

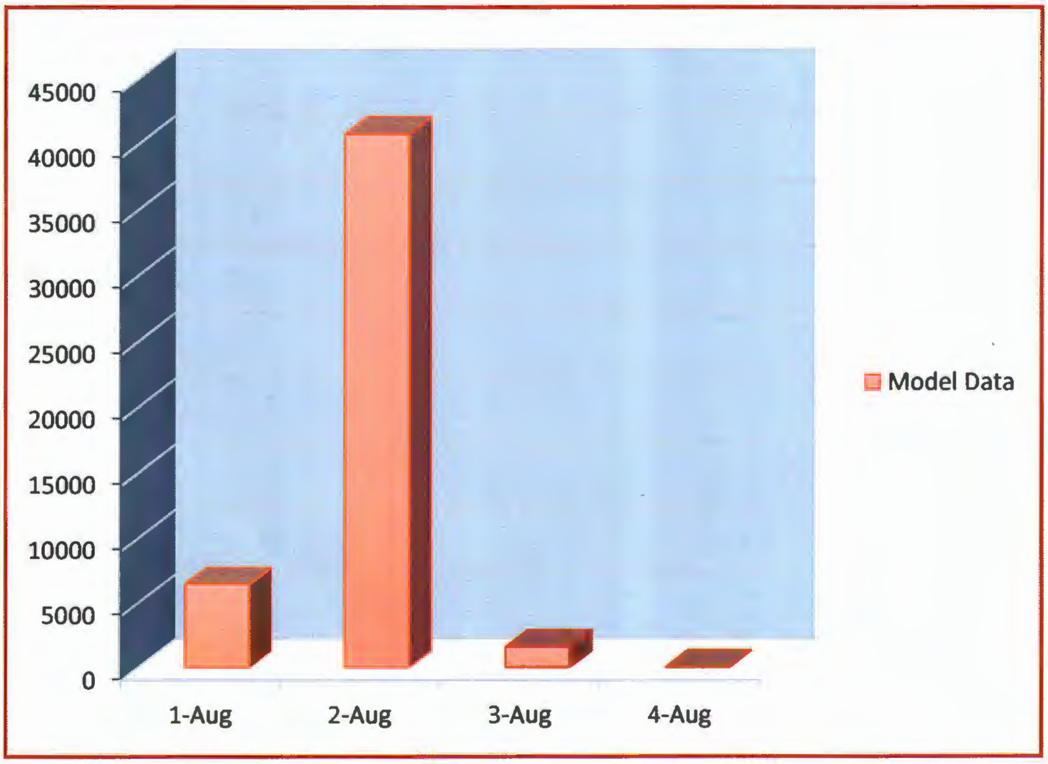


Fig 3.18: Graph of 01 Aug – 04 Aug 2010

These all graphs show the difference between observed data and the model data .Model data was obtained from HEC-HMS model. Due to the missing of Afghanistan daily rainfall data, model and computational specifications there are some difference between the model and actual rainfall data. During the 30th July 2010 to 4th Aug 2010 some gauges present at the study area were smashed due to heavy flood wave therefore rainfall data of one week was also missing.

3.6 Hydraulic Modeling:

Floods cause harsh conditions when they happen. The advanced.GIS.technology is used in the hydraulic modeling to analysis the efficiency of flood mitigation measures to overcome or compensate the flood problems in study area. Hydraulic modeling was used for the flood mapping. The important dataset for hydrological modeling is terrain data i.e. TIN (As shown in fig 3.19). As shown in the fig (Fig 3.19 b) for flood inundation main tributaries of Kabul river basin has been selected i.e. Swat river, Chitral river, Alingar and Panjshir river. Swat and Chitral are in Pakistan while Alingar and Panjshir are in Afghanistan.

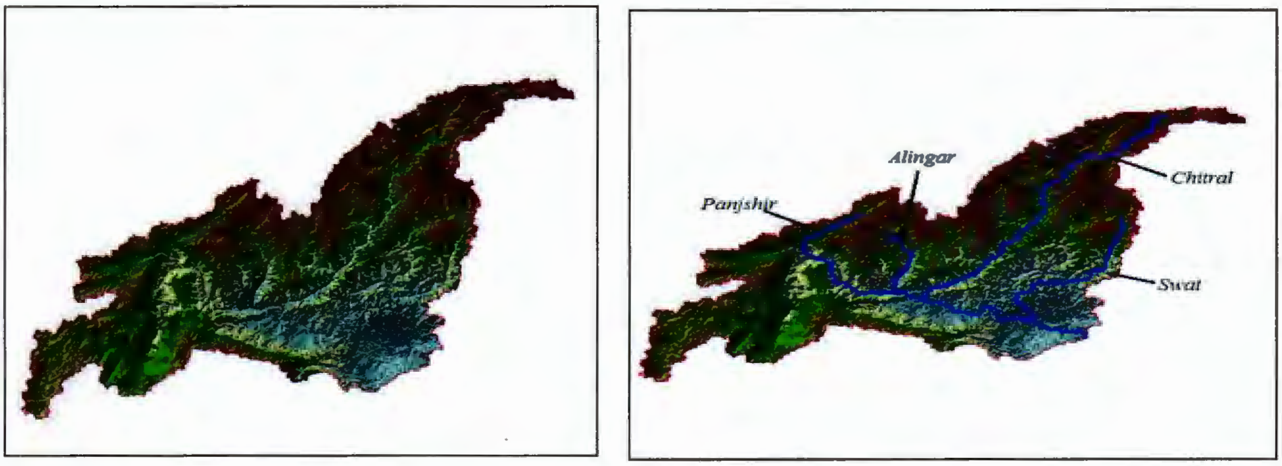


Fig 3.19: (a) Kabul River Basin (TIN), (b) Main Tributaries of Kabul River basin

3.7.1 HEC Geo RAS:

HEC Geo RAS (Hydraulic model) has been used for mapping. RAS is the river analysis system. For flood mapping SRTM DEM was first converted into TIN. Firstly main tributaries of Kabul river basin is selected for the digitizing. Selected river tributaries were Swat River, Chitral, Panjshir and Alingar. Alingar and Panjshir rivers are in Afghanistan while others are in Pakistan. HEC Geo RAS tools are applied to the TIN to create data i.e. import to the HEC RAS for mapping. As shown in fig 3.2.

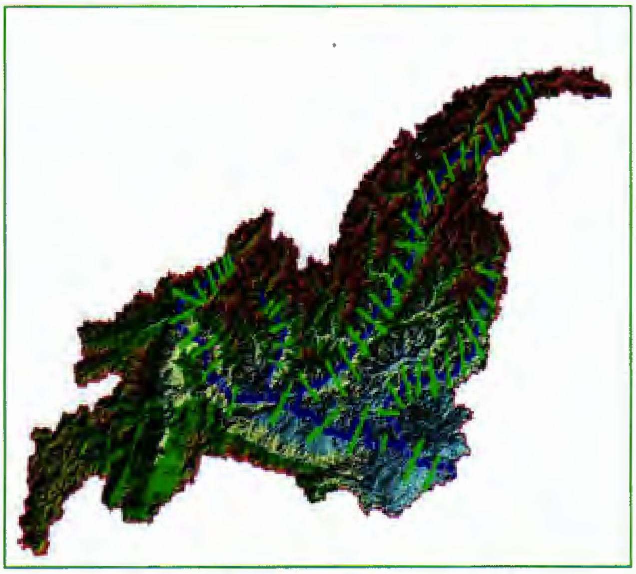


Fig 3.20: Tributary Rivers of Kabul River Basin with complete application of HEC GeoRAS tools

Kabul river basin TIN has reach (each reach has unique name), bank station, flowpath, XS cutlines and bridges. In Kabul river basin Warsak dam is located with storage capacity of

76,492,000 m^3. For inundation complete TIN with applied RAS tools are imported to the HEC RAS for further processing.

Table 3.1: Daily Rainfall data from 20th July 2010 to 5th Aug 2010

Stations	Dtaes														
	20	21	22	23	24	26	27	28	29	30	31	1	2	3	4	Total
Lower Dir	0	7	17	0	0	0	6	0	192	71	0	0	5	0	19	317
Kalam	0	2	0	4	0	0	0	1	84	*	0	0	0	0	0	104
Drosh	0	TR	TR	0	0	0	0	23	61	15	0	0	0	0	8	107
Chitral	0	0	0	0	0	0	0	6	41	13	0	0	0	0	7	67
Dir	0	7	24	5	0	0	25	57	149	103	0	0	0	0	15	385
Peshawar	0	47	20	0	0	0	TR	TR	274	59	0	0	0	0	29	429

***** TR: Trace Rainfall less than 1mm (millimeter)   Red colored data show the highest rainfall during 28 July to 30 July 2010***

Rainfall data from 20th July- 5th Aug has been added. The daily rainfall data collected from PMD is shown in following table.

3.7.2: HEC RAS:

For inundation Kabul river basin with complete dataset is imported to the HEC RAS. Imported river basin with river and reach name, bridges are shown in fig 3.20.

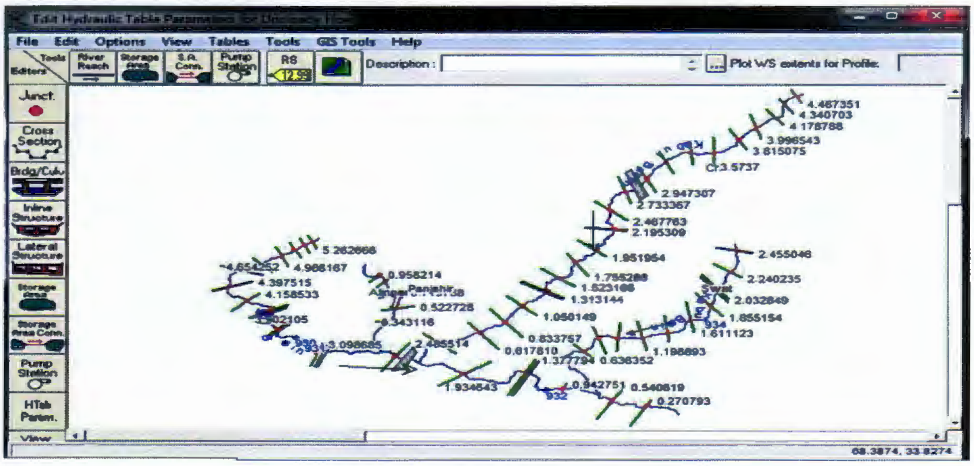


Fig 3.21: Map of Kabul River Basin in HEC RAS

The result from the HEC RAS modeling show that Nowshera and Charsada are complete inundated while Peshawar faced less flood as compared to Nowshera and Charsada. Swat and Kalam are the districts that are completely inundated areas.

3.6 Limitations:

HEC-HMS was used for the precipitation runoff of Kabul river basin. Because of limitations of the observed rainfall & temperature data there is some difference occurred due to missing of climatic data of Afghanistan. Heavy rainfall in the study area causes disastrous flooding due to which gauges present at the study area was totally damaged and therefore there is no record of the rainfall data during 31 July to 04 August 2010. So the available data is used for precipitation runoff and simulation graphs are prepared.

Conclusion

HEC-HMS is a newly developed hydrological model available in April 2006 by US Army Corps of Engineers. Heavy rainfall occurred during the last week of July 2010 in Pakistan. HEC-HMS model is used for the simulation of runoff hydrograph of Kabul river basin for 2010 flood. The simulation graph are compared with the observed data collected from PMD. This shows that the average high discharge peak of 40105.4 CFS on 28 July 2010 while observed highest discharge peak is 68,300 CFS. Similarly on 29 July 2010 highest discharge peak is 213290.5 CFS and observed discharged peak is 189,718 CFS. Due to some specifications of model and scarcity of the rainfall data of Afghanistan is missing. There are differences in the simulated and observed peak flows at Nowshehra flow gauge. Regardless of difficulties, limitations and uncertainties related to the collecting data and measured parameters, this research study ended up with 50% accuracy for the precipitation runoff process. This study can be compassionate in saving time and raise the awareness in the population living nearby and in flood susceptible areas. The result will be helpful in the further flood assessment studies and to control and reduction in flood damages.

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