# Satellite enhanced snowmelt flood and drought predictions of Kabul river basin with surface and ground water modelling

**Annual Report submitted by**
**Prof. Dr. Muhammad Abid**
**PI - Pakistan**

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## Team Members

A detailed report is submitted by PI-Pakistan through the joint work from Pakistan Researchers team as follows;

1. Ms Rabbia Murtaza
2. Mr. Alamgeer Hussain
3. Mr. Maqbool Ahmad
4. Mr. Muhammad Zahir
5. Dr. Toqeer Ahmed
6. Dr. Shahina Tariq
7. Mr. Mohsin Shabbir

## Project Subgroups and Researchers Involved from Pakistan Side

Following sub-groups are formed to achieve objectives of the project during meeting in Almaty in May 2017. Researchers mentioned against each subgroup are involved under guidance of Dr. Muhammad Abid for working actively from Pakistan side.

1. Web Geoportal, Remote Sensing (RS) and Geographical Information Systems (GIS) (Ms Rabbia Murtaza)
2. Snow Glacier (Mr. Maqbool Ahmad)
3. Hydro Meteorological Modelling (Mr. Alamgeer Hussain)
4. Hydrological Modelling (Ms Rabbia Murtaza)
5. Hydraulic Modelling (Mr. Alamgeer Hussain)
6. Underground Water Modelling (Mr. Muhammad Zahir)
7. Integrated Water Modelling
8. Data Collection and Coordination with different departments (Dr. Muhammad Abid)

In future more potential researchers will be involved related to the activities of project.

**Most details of Events and News are available on https://www.ckrb.org/events**

## Publications

1. Prospects of floating photovoltaic technology and its implementation in Central and South Asian Countries**;** Cited as; Abid, M., Abid, Z., Sagin, J., Murtaza, R., Sarbassov, D., & Shabbir, M. (2018). Prospects of floating photovoltaic technology and its implementation in Central and South Asian Countries. *International Journal of Environmental Science and Technology*, 1-8.
2. Ahmed, M., Tariq, S., Sagin, J., 2018, Climate Change Adaptation and Assessment with Remote Sensing and GIS Technologies for the Chitral-Kabul Trans-Boundary Basins, Vietnam National University Press, 6 edition, pages 13-22, March, 2018,

https://riseandfallmekong.com/wp-content/uploads/2018/03/inovative_water_solution_VACI2018.pdf

3. Zaineb Abid, Muhammad Abid, Qudsia Zafar, Shahbaz Mahmood. Detrimental Effects of Climate Change on Women. Earth Systems and Environment. 1-15;10.1007/s41748-018-0069. http://link.springer.com/article/10.1007/s41748-018-0063-9
4. Sagin Jay, Muhammad Abid, Alamgeer Hussain. Flood Hydraulic Modeling of Chitral River using HEC-RAS and GIS

**International Journal Papers Submitted (Contributors are mentioned)**

1. **Regional cooperation in climate change adaptation by the efficient use of water and energy resources through CASA-1000 project**

   Georgiv Petrova, Khakim Akhmedova, Khasan Karimov, Muhammad Abid, Jay Sagin, Jamal Abdul Naser Shokory, Mohammad Najaf Ibrahim

   Submitted to IWA; Water Policy

2. Water quality of Kabul River and its impacts on health, agriculture, aquatic life with Relation to Climate Change

   Toqeer Ahmed, Muhammad Abid, Muhammad Zahir, Rabbia Murtaza, Jay Sagin, Maqbool Ahmad

   Submitted to; Journal of Water by MDPI

3. **Environmental Change Detection Using Spatial Techniques: A Case Study of Lower Chitral Kabul River Basin, Pakistan**

   Maqbool Ahmad, Shahina Tariq, Muhammad Abid, Jay Sagin, Muhammad Zahir, Aatif Zeeshan

   Submitted to IWA; Water Supply

4. **Water Harvesting techniques to alleviate Climate Change Effects in Afghanistan**

   Jamal Abdul Naser Shokory, Muhammad Abid, Jay Sagin, Jun-ichiro Giorgos Tsutsumi, Tooryalay Ayoubi, Ezatullah Rabanizada

   Submitted to: Journal of Climate and Development by Taylor and Francis (online)

**Conference papers and posters presented (Contributors are mentioned)**

1. **Water quality assessment of Kabul river with emphasis on catchment area in Pakistan** in 7th International Conference on Environmentally Sustainable Development; August 26-28, 2017, COMSATS University Abbottabad, Pakistan. Presented By Mr. Muhammad Zahir,
2. **Relationship of Women and Climate Change for Sustainable Development** in International Science Policy Conference on Climate Change (SP3C), 18-20 Dec 2017, Islamabad, Pakistan. Poster presented by Ms Zaineb Abid, Department of Environmental Sciences, QAU, Islamabad Pakistan.
3. **Hydro Meteorological Hazard Mapping and Modeling of Chitral-Kabul River Basin's** in 6th Vietnam International Water Week (*VACI2018*) on 4-8 March, 2018 in Hanoi, Vietnam.

**International Visits and Meetings**

1. 4th CAWA Summer School was attended on "Methods and Tools for the assessment and monitoring of Central Asian Water and Land Resources" from 5-18 June 2017 in Almaty, Kazakhstan. Dr. Abid and a team of 8 researchers participated.

2. Dr. Muhammad Abid attended "The Indus Basin: New Knowledge Frontiers for Development and Resilience" during 3-6 July 2017 in Columbo, Srilanka
3. Dr. Muhammad Abid attended "ISTC SAC Central Asian Water Forum" on 2-3 Nov, 2017 in Almaty Kazakhstan
4. Dr. Toqeer Ahmed attended workshop on "Water resource management and sustainable development strategies in arid regions" from 17-30 Sep 2017 in China
5. Dr Toqeer, Mr. Muhammad Zahir and Mr. Maqbool Ahmed attended a workshop In NUST in August 2017.

**Work in Progress**

1. Hydrological modeling **(Ms. Rabbia Murtaza)**
2. Hydro metrological modelling **(Mr. Alamgeer Hussain)**
3. Underground water modelling **(Mr. Muhammad Zahir)**
4. Women and Water related to CKBR **(Ms. Zained Abid)**
5. Snow melt run-off (SRM) model, and satellite image analyses **(Mr. Maqbool Ahmad, Dr Shahina Tariq)**
6. Data mining and Supervision **(Dr. Muhammad Abid)**

**Progress Meetings by Dr Abid with Team Members**

Regular meeting to discuss and monitor research progress with different team members

**Webpage Updates**

Webpage is up to date from Pakistan side based on activities performed. Thanks to Ms Rabbia for good work.

***Reports will be updated on website; but draft papers submitted cannot be done till they are published but must be counted as work progress and can be uploaded after accent of all.***

**Acknowledgements**

To all team members from Pakistan, Afghanistan and Kazakhstan

## Reports by all team members are shared in the following sections

## Mr. Maqbool Ahmad

**Meteorology Department, COMSATS UNIVERSITY Islamabad**


***Chitral watershed*** is selected. This is situated in North West part of Pakistan having watershed area of about 11,400 $km^2$ (Fig.1). The River Chitral is fed by the melts of snow and glaciers. It has a characteristic of flowing steadily over the whole year with runoffs enhancing in monsoons. Chitral watershed is highly elevated area and the average elevation is 3921 m a.s.l. (meter above sea level). Remote sensing (RS) and Geographic Information System (GIS) are used. HEC-HMS model will be used for snow melt run-off (SRM) model, and satellite image analyses.

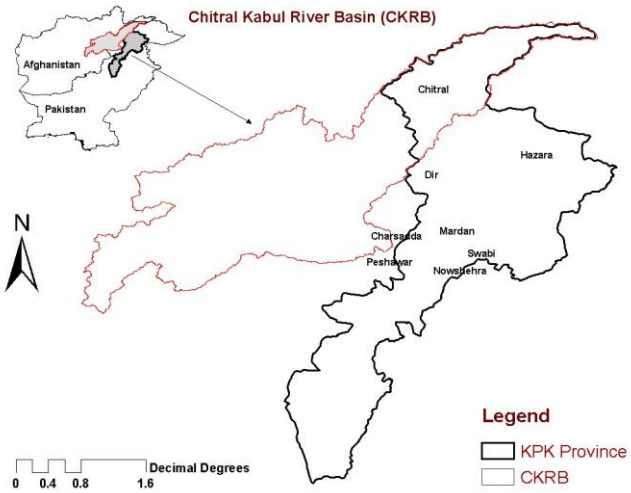



**Figure 1**: Study Area (CKRB with respect to Pakistan and Afghanistan)

**Objectives**

This study aims to exemplify the importance of land-cover change detection by RS image analysis in providing relevant information.

**Data Collection**

- MODIS Satellite Snow data procurement (2001-2015).
- DEM (high resolution) data collection. (www.opentopography.org)
- Daily discharge data is collected from the Chitral gauging for the period of 2000-2012. Climatological data such as temperature, and precipitation is collected from PMD.
- Chital shape file extraction/generation/collection. (This step has been accomplished)

**Data Analysis**

- ***Snow cover mapping (2001-2015):*** HEC-HMS and SRM model are being in process to learn and apply in Chitral Kabul River Basin (CKRB) in Pakistan.
- ***Trend assessment and analysis of snow cover over upper Chitral River sub Basin: S***now data from MODIS is downloaded for 2005-2015.

**Trainings on Project relevant activates**

- Attended 4th CAWA Summer School on "Methods and Tools for the assessment and monitoring of Central Asian Water and Land Resources", 5-18 June 2017, Almaty, Kazakhstan.
- Training on HEC-RAS and HEC-HMS at NUST and NARC, Islamabad.

**Contribution in Papers/Conferences:** 2 Journal papers are submitted, Very good performance


## MS. Rabbia Murtaza,

**Centre for Climate Research and Development (CCRD), COMSATS UNIVERSITY, Islamabad, Pakistan**


Tasks involved as team member

- Web-portal ***(Regularly updated as per activities)*** and Hydrological modelling using HEC-HMS
- Hydrological Modelling of Upper Chitral basin, Pakistan using HEC-HMS Model

**Hydrological Modelling of Upper Chitral basin, Pakistan using HEC-HMS Model**

**a) Characteristics of study area**

The Chitral watershed is situated in North West part of Pakistan having watershed area of about 11,400 km$^2$ (Fig. 1). The River Chitral is fed by the melts of snows and glaciers. It has a characteristic of flowing steadily over the whole year with runoffs enhancing in monsoons. Chitral watershed is highly elevated area and the average elevation is 3921 m a.s.l. (meter above sea level). A very interesting feature of the watershed is that most of the area stay covered with snow and glaciers in winter. For this study, the applications of GIS were used. A number of LandSat images were obtained by the help of which the area elevation bands were established for the watershed. This is shown in Fig.1. The rest of analysis will be performed by HEC-HMS. RS and GIS technology has enhanced capabilities and increased confidence in the accuracy of modeled watershed conditions, improved the efficiency of the modelling process and increased the estimation capability of hydrologic models.

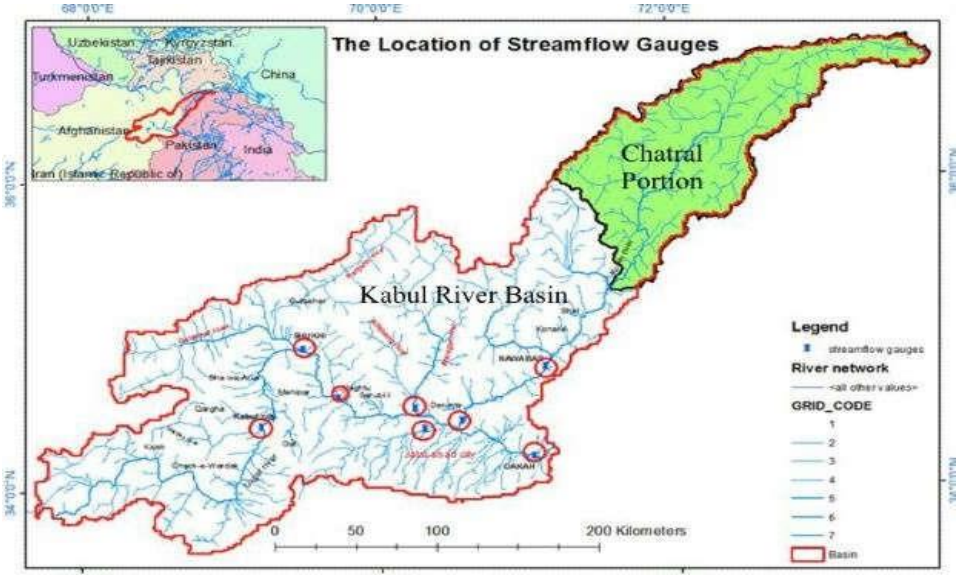



Figure 1. Study area

**b) Similar studies on Chitral River performed in Pakistan**

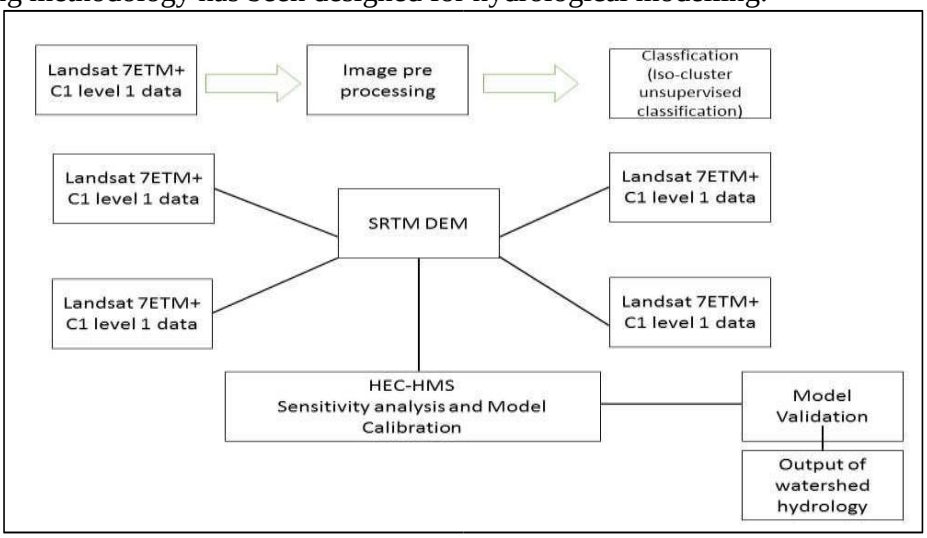
- Climate Change Impact on River Flows in Chitral Watershed by Abdul Sattar Shakir , Habibur-Rehman, Saqib Ehsan (Civil Engineering Department, University of Engineering and Technology Lahore, Pakistan)
- Hydro-meteorological characteristics of Chitral River basin at the peak of the Hindukush range by Hasina Gul
- Hydrology of Upper Indus Basin done by Daniyal and others

**c) Objectives**

This study aims to exemplify the importance of land-cover change detection by RS image analysis in providing relevant information on past and recent conditions of upper Chitral river basin. Specifically, post-classification comparison analysis of classified Landsat ETM+ images to detect land-cover change in the critical upper Chitral river basin. The changes in land-cover will be related to the responses of the watershed to rainfall events using a GIS-based hydrologic model, called HEC-HMS. The model is also used to test planned rehabilitation measures and strategies to approximate their success or failure in addressing the problems of the watershed.

**d) Methodology**

The following methodology has been designed for hydrological modelling:




**Data Collection**

The daily discharge data has been collected from the Chitral gauging during 2000-2012. Further, the climatological data such as temperature, and precipitation was collected from Pakistan Meteorological Department (PMD). SRTM 90m Digital Elevation Model (DEM) was downloaded from internet source.

**Data Analysis**

The Landsat 7ETM+ C1 level 1 data was downloaded from United States geological survey https://earthexplorer.usgs.gov/ for Chitral. It has total number of 8 bands. Landsat ETM + has nine bits, spatial resolution of 30 m. Additionally, Landsat ETM+ and OLI have a panchromatic band with a spatial resolutions of 15 m which can be used to improve the spatial resolution of other bands by using a pan-sharpening technique. However, the malfunction of the Scan Line Corrector (SLC) on the ETM+ sensor makes the application of ETM+ images limited. The digital or satellite images have picture elements also known as pixels presented at the intersection of each row and column of an

image. The higher the digital number (DN) values, the higher the radiance being presented in that pixel. While, any change in radiance values do show the change of land cover surfaces. The image is multispectral means that the same scene is recorded in multiple bands of EMR spectra.

**Digital Image Processing**

Digital image processing involves the mathematical transformation of digital values to form useful information relating to land cover types. Image processing generally involves three major stages: (1) pre-processing, (2) image enhancement, and (3) classification. Under pre-processing, the DN values are calibrated to rectify distortion and remove noise by conducting atmospheric and topographic correction.. The DN values are processed into radiance values which correspond to top of atmosphere reflectance and ground reflectance through different methods as explained in Song, Woodcock, Seto, Lenney and Macomber. After pre-processing, image enhancement is done to improve the quality and visual appearance of the image; however, this step is not so important and can be omitted. Classification involves mathematical grouping of pixel values (pre-processed DN) into themes which correspond to particular land cover types on the Earth's surface.

**Landsat image pre-processing**

In this study, the unsupervised classification was applied in which a class is assigned to each cluster of pixels. Under unsupervised classification, clustering algorithms are used to define and group pixels of similar classes based on spectral values. Unsupervised classification was developed first through different clustering methods such as K-means and Interactive Self-Organization Data analysis (ISODATA).

**Image Classification and land cover change detection**

Landsat 7ETM+ C1 level 1 data was downloaded from United States geological survey https://earthexplorer.usgs.gov/ for Chitral for the month of July 2010 and July 2017 to make a comparison between flood and non-flood years. Year 2010 is considered to be the super flood. Fifteen land cover classes were identified in landsat imagery through visual analysis with support of other supporting datasets such as google earth imagery, and geological map of KPK (acquired by geological survey of Pakistan). The major land cover classes that were included in analysis were water and vegetation as these two classes considered to be best landsat band combinations when it comes to hydrological modelling. Furthermore, these two classes are picked up as the starting point. For more detailed predictions and evaluations, multiple analysis will be made on Chitral river basin. Other classes will include barren areas, built-up areas, forest, grassland. Part of the river basin with exposed soil and some amount of vegetation is known as the barren land. Human settlements or built up areas are defined as those places where infrastructure has been developed on large scale. The forest cover is a land comprised of tree crown density of 10% and closely packed with trees that produce wood and timber. Grasslands are the areas where vegetation is grown as grasses. Because of high spatial resolution of landsat ETM + images, the built up areas are easily identified.

**SRTM DEM**

SRTM 90m DEM has been downloaded from http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp. The ArcHydro model was developed to assist the hydrologic modelling, but in order to obtain the catchment delineation and the stream network, one needs to go through a considerable number of steps such as filling the artifact sinks from DEM creation, computing the flow direction, the flow accumulation and so on. Thus, the process of drainage lines, points, catchments and adjoint catchments identification was automatically implemented in Model Builder. The main goal is to convert the output from ArcHydro model to an HEC-HMS project through HecGeoHMS tools (by creating a new project). However, before taking this step, the catchment will be delineated by using

the function of batch watershed delineation (after the batch point at the location of our interest is created). Then, the hydraulic length will be computed through the function of longest flow path for catchments and the slope grid by using Terrain preprocessing-Slope (percent rise). The average slope value for each sub-basin will be calculated through Zonal Statistics as Table. The next step will be to create the curve number (CN grid), in order to extract the CN for the watershed and the subwatersheds. This parameter is based on the catchment's soil and land use characteristics, being used for the computation of runoff or infiltration from rainfall excess in the HEC-HMS modeling system.

**Description of Hydrologic Model**

HEC-HMS is a physically based, semi-distributed hydrologic model developed by the US Army Corps of Engineers to simulate the hydrologic response of a watershed subject to a given hydro meteorological input. The model uses underlying DEM information to partition the basin into sub-watersheds. The size of the sub-watershed is determined a priori by the modeller, and few or no guidelines are available for sub-watershed selection. In most cases, the balance between the resolution of the distributed information and the computation time required for simulation is the main factor considered for this selection. The model can simulate individual storm events as well as continuous precipitation input at minute, hourly, or daily time steps.

## Results

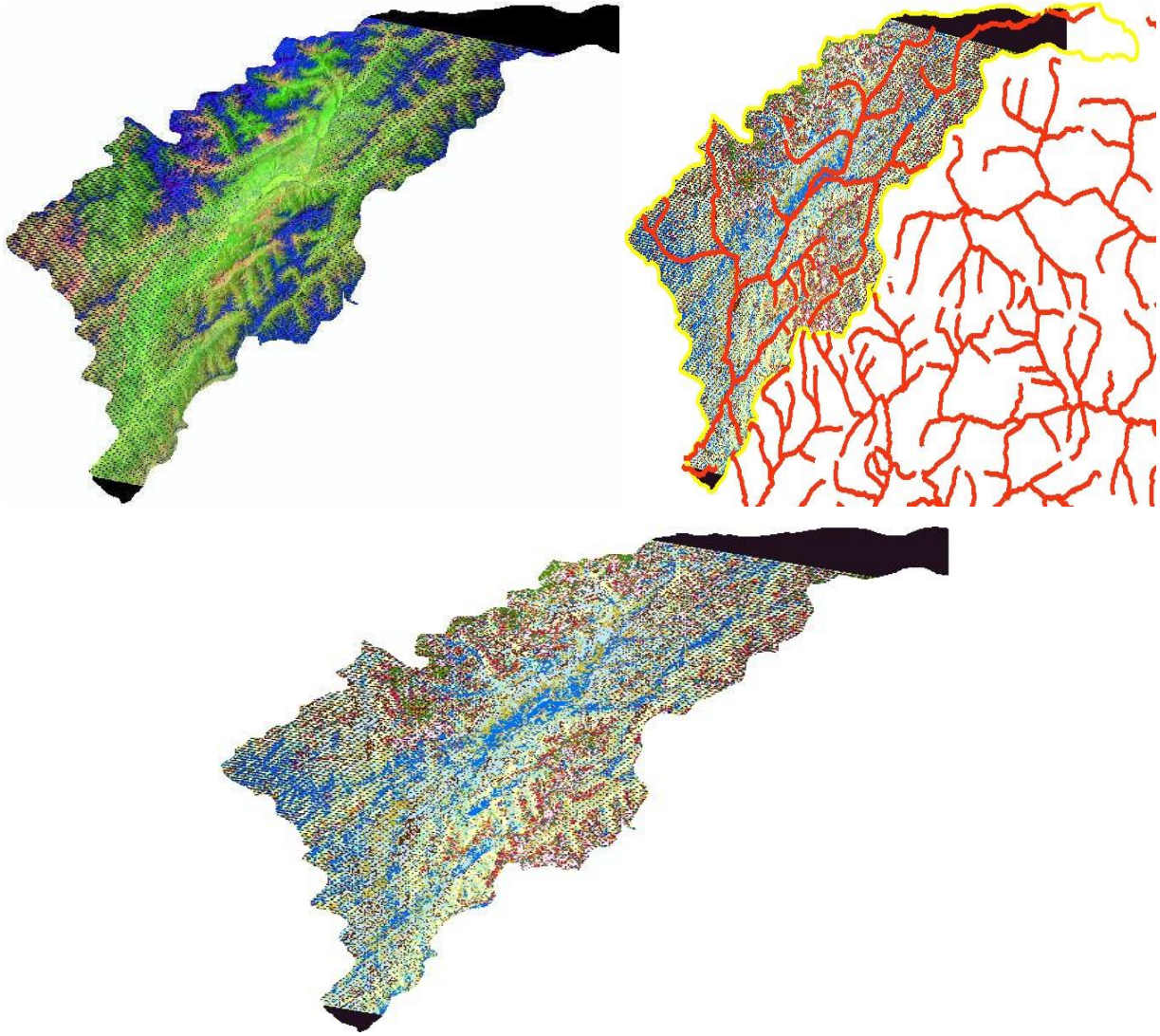


Figure 2. Land cover classification of Chitral (July 2010)

## Conclusion

Runoff estimation is mandatory to sustain the water resources but in this region the monitored data are limited. The present research tries to study the efficiency of HEC-HMS model in Chitral river basin. A sensitivity analysis will be carried out by adjusting different parameter values in both the HEC-HMS for watershed. After running the models repeatedly, the simulated streamflow results will be compared with monitored values in outlet of basin (where the discharge station is located) at each change of parameters. It is expected to complete the hydrological modelling in the month of January. Moreover, I will start learning new tools on snow glacier monitoring in Chitral.

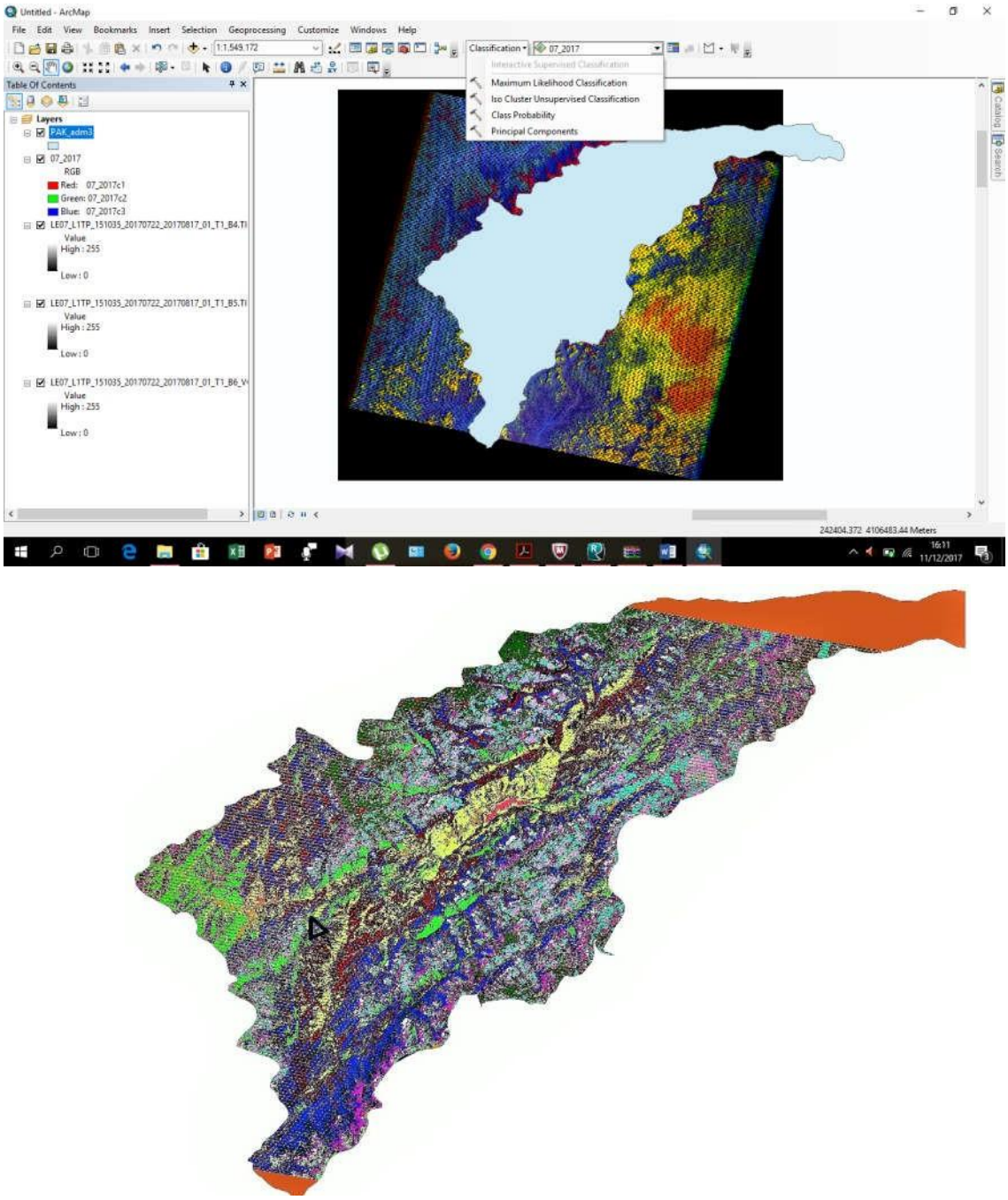



Figure 3. Land cover classification of Chitral (July 2017)

## Trainings on Project relevant activates

- Attended 4th CAWA Summer School on "Methods and Tools for the assessment and monitoring of Central Asian Water and Land Resources", 5-18 June 2017, Almaty, Kazakhstan.

## Contribution in Papers/Conferences:

- **2** Journal papers are submitted; **1** Conference paper; Very good performance

# Mr. Muhammad Zahir

**Centre for Climate Research and Development (CCRD), COMSATS UNIVERSITY, Islamabad, Pakistan**


## Underground water modelling

Mr. Zahir has selected underground water modelling and is using MODFLOW which is a popular opensource groundwater flow model distributed by the U.S. Geological Survey. Growing interest in surface and groundwater interactions, local refinement with nested and unstructured grids, karst groundwater flow, solute transport, and saltwater intrusion, has led to the development of numerous MODFLOW versions. For achieving desire result the following data will be need for the calibration of models, now we are collecting data from different institutes, and also we will go to field for data collection and evidence of groundwater or surface water problems. Some data regarding temperature, humidity and rainfall is collected from PMD, Islamabad

- Water table elevation of the study area
- Surface water elevation
- Type and extent of recharge areas ➢ Rate of recharge data
- Type and extent of discharge areas
- Rate discharge Data ➢ River or Basin size
- Tube wells Data
- Pumping Data
- Rain fall Data
- Topography
- Geological Data
- Types of aquifers
- Aquifer thickness and lateral extent
- Aquifer boundaries

After getting all required information model will be calibrated during study period; validated and daily, monthly and annual stream flow will be measured. The monthly or daily discharge data will be collected from different departments for the 17 years (200-2017). Further the climatological data comprising of min and max temperatures, precipitations, wind speeds and the sunshine hours will be collected from Pakistan Meteorological Department. SRTM 90 m Digital Elevation Model (DEM) will downloaded from internet source. Results are expected by end of January and will be shared as received.

## Trainings on Project relevant activates

- Attended 4th CAWA Summer School on "Methods and Tools for the assessment and monitoring of Central Asian Water and Land Resources", 5-18 June 2017 in Almaty, Kazakhstan.
- Training on HEC-RAS and HEC-HMS at NUST and NARC, Islamabad. **Contribution in Papers/Conferences:**
- **2** Journal papers are submitted; **1** Conference paper; Very good performance

## Dr Toqeer Ahmed

**Centre for Climate Research and Development (CCRD), COMSATS UNIVERSITY, Islamabad, Pakistan**

1. As part of team members of Hydrologic and hydraulic sub group, data on temperature, humidity and rainfall of Chitral was collected from PMD, Islamabad and sent to Mr. Alamgeer for further processing /working on Hydrologic and hydraulic modelling.
2. As part of team members of ground water modelling Ground water modelling (MODFLOW) was learnt during the trainings and installation was performed and meetings were conducted at *Climate Change*, Alternate Energy and *Water* Resources Institute (CAEWRI), NARC for support. Accordingly, data collection is in process.
3. Both Peer reviewed and grey literature available online is in progress. Currently working on data collection on the following:

   Water table elevation; Surface water elevation; Type and extent of recharge areas; Rate of recharge data; Type and extent of discharge areas; Rate discharge Data; River or Basin size; Tube wells Data; Pumping Data; Rain fall Data; Topography; Geological Data; Types of aquifers; Aquifer thickness and lateral extent; Aquifer boundaries
4. After collection of data in the Month of Jan 2018, MODFLOW will be applied to assess the river flow and ground water situation. Depending on availability of data, MODFLOW will be run and outcome will be shared.

**Trainings on Project relevant activities**

- Training on MODFLOW at Lanzhou China and NUST, Islamabad.
- Training on HEC-RAS and HEC-HMS at NUST and NARC, Islamabad.
- Training on GIS and RS at Almaty, Kazakhstan

**Contribution in Papers/Conferences:**

- **2** Journal papers are submitted; **1** Conference paper; Very good performance

## Mr. Alamgeer Hussain

### Flood Hydraulic Modelling of Chitral River Using HEC-RAS and GIS

**Abstract:**

Flood hydraulic modeling of Chitral River basin from Chiantar glacier source of Chitral River to Osiak Drosh village near Afghanistan boarder using unsteady flow analysis in HEC-RAS

environment. 2015 flood discharge data of Yarkhun, Laspur, Torkhow, Garamchasma and Karimabad streams couple with 30 meter digital elevation model (DEM) with appropriate upstream and downstream boundary conditions. The observed and simulated flood and stage hydrograph are compared at five streams. The performance statistic discloses that simulated flood flow in close agreement with observed flow. The hydrological modeling can be used for flood forecasting in lower part of chitral river basin.

***Keywords:*** Hydraulic modeling, unsteady simulation, Flood and stage hydro graph, HEC RAS

## 1. Introduction

Hydraulic modeling of river associated with selected design flood is an important exercise related to both land planning and river basin management. Determining the extent of inundation requires the processing of large quantities of hydraulic and spatial data, which is typically accomplished through numerical modeling. However, delineation of the inundated floodplain zones on topographic maps, which is largely done manually, can be a time-consuming and tedious process. A numerical model that has enjoyed wide application in floodplain delineation work during the past 35 years is the Hydrologic Engineering Center's HEC-RAS model (USACE 1991).

HEC-RAS is an integrated system of software, designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface (GUI). Separate analysis components, data storage, management capabilities, graphics and reporting facilities (Brunner, G. W 1995). The HEC-RAS system contains one and two dimensional river analysis components for: (1) Steady flow water surface profile computations: (2) Unsteady flow simulation: (3) movable boundary sediment transport computations: and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines (Bates, 1996). The current version of HEC-HAS supports steady and unsteady flow water surface profile calculations, sediment transport / mobile bed computations and water quality analysis. In this study we used unsteady flow simulation for Chitral River Basin

### Chitral River Basin

The drainage of chitral river basin (Figure 1) in about 11400 km2 is one of the tributary of Kabul River Basin second largest river of Pakistan. Chitral River also called Kunar River. The mean annual runoff of river for 34 year record (1964-67, 1969-98) is 8670 $Mm^3$ $_{the}$ maximum discharge was record 1585$m^3$/s on 16$^{th}$ July 1973 and minimum recorded discharge was 46$m^3$/s on 10$^{th}$ March 1964. The river is snow and glacier fed (Shakir, A. S., & Ehsan, S. 2016 and Khalid et al. 2013).

The source of Chitral River is Chiantar glacier yarkhun valley, from its source to the place where it enters Afghanistan, has various names; First of all during its journey through the cast and long valley of Yarkhun, it is called the **Yarkhun River.** At Mastuj it is joined by the **Laspur River** which is its first main tributary and drains the huge section of the northern face of Shandur Hindu Raj range. From here it is given the name of **Mastuj River** and continues to be such till it reaches a place called **Gankorini,** four miles above Chitral town. During this course it collects numerous hill torrents and steams on both bank and also **Torkhow River** on the right bank. The Torkhow River drains the regions of Torkhow and Mulkhow. At Gankorini it is joined by the **Lotkoh River** and from here onwards it becomes the **Chitral River** till it enters Afghanistan at Arandu. On its way, the Chitral River is joined by many streams and side valleys such as Jughoor gole, Ayun Gole, Kalashgum, Shishi Kuh and Ashuret. The main valley as a whole from Broghil to the border of Afghanistan is about 320 kilometers long. The average width of the valley would be not more than 5/6 kilometers. The valley floors rise gradually from 3377 feet at Arandu to 12270 at Showar Shur in Broghil (BOS-P&DD and UNICEF, 2014).

**Flood Situation of Chitral River Basin**

Flood and flash are one of killing hazard of chitral river basin. Flood intensity has been increase during last two decade due climate change. The 2010 and 2015 floods are devastating disaster in history of chitral district. Flood, flash flood and GLOF during year of 2015, alone caused major devastation to chitral district. A total of 1,486 houses were damaged displacing a population of 307,500 people, furthermore 30 schools,10 powerhouses, 13 bridges, and 154 water supply schemes are also damages as well as 3,225 acres of standing crops were washed and 81 irrigation channel were badly damages(PDMA,2015).

The villages are settled along both sites of Chitral River from Yarkhun to Arandu. Due to recent flood 2015, where significant damages were caused, the ambiguity still exist about area surrounding the river and flood potential risk associated with them. The potential of flood to the loss of property and life in the area near the river is one of big problem that need to be examined.

According national disaster management authority (NDMA) and Pakistan meteorological department (PMD) annual report, each year more death and damages occur due to flooding in chitral district than any other weather related hazards owing climate change impact with more melting of glaciers and snow couple with thunder rains. The flood risk of chitral river basin are undermined and absence of information about flood zones and their risk can leads government official unable to create awareness and preparedness in community about the future flood.

Scenario base flood risk mapping is very important for local government, organizations to developed future flood plan and mitigation measures in flood plan area as well as will helpful for sustainable development like construction of hydropower plants and other critical infrastructures like bridges and houses. By executing of extreme flood modeling (2015) for Chitral River basin. It was determined the element at risk and identify the high hazardous zones and calculating the time arrival information of flood, which is very important for local community for early evacuation from hazardous area of flood.

The objective of this research project was to perform hydraulic modeling using unsteady flow analysis of chitral river basin on extreme flood scenario (2015) from Yarkhun (source of river) to Osiak village. This study was performed using hydrological engineering centre and river analysis system (HEC-RAS) couple with geographical information system (Arc GIS). The hydraulic flood modeling was done on peak flow rate of 2015 flood of Chitral River. The River floodplain was mapped on the flow rates of 1985.7 $cm^3$, which is historically extreme flood of district chitral.

Digital elevation model (DEM) of 30 meter acquired from USGS was used to develop, analyze and create flood zonation maps. ESRI's Arc Map was used for pre-processing of DEM data and conversion of tiff to float as well as river centre line were automatically extract from DEM using hydrology tool. The data was import into HEC-RAS where development of geometrical data and execution of unsteady flow analysis were carried out. The results of floodplains were import into Arc Map for further analysis like calculation of element at risk, flood exposures and layout of flood hazard maps.

## 2. Methods

Three tier methodologies were used to creating floodplain map for Chitral river basin. Pre-processing of data (filtering of data), development of model (Processing) and post-processing (validation of results). Work flow diagram shows the detail of these steps. Pre-processing step is preparation and filtering of data which carried out in arc GIS environment. The processing step was entirely done with

HEC RAS platform using river and elevation data prepared in previous step. The final step is include analysing the results from HEC-RAS model with Arc Map. This study is about Chitral River, but the procedure used in study is replicable in any other river system.

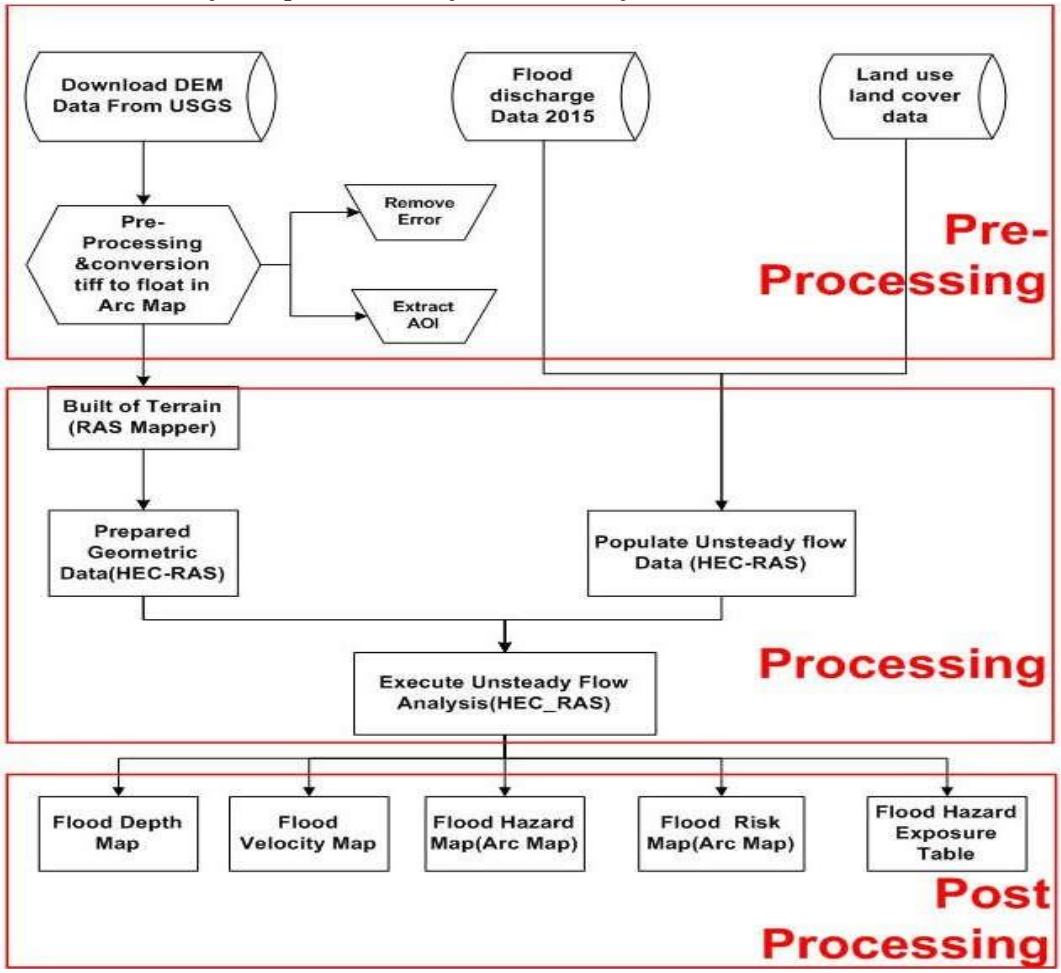



Figure: 2 Work flow Diagram of Research

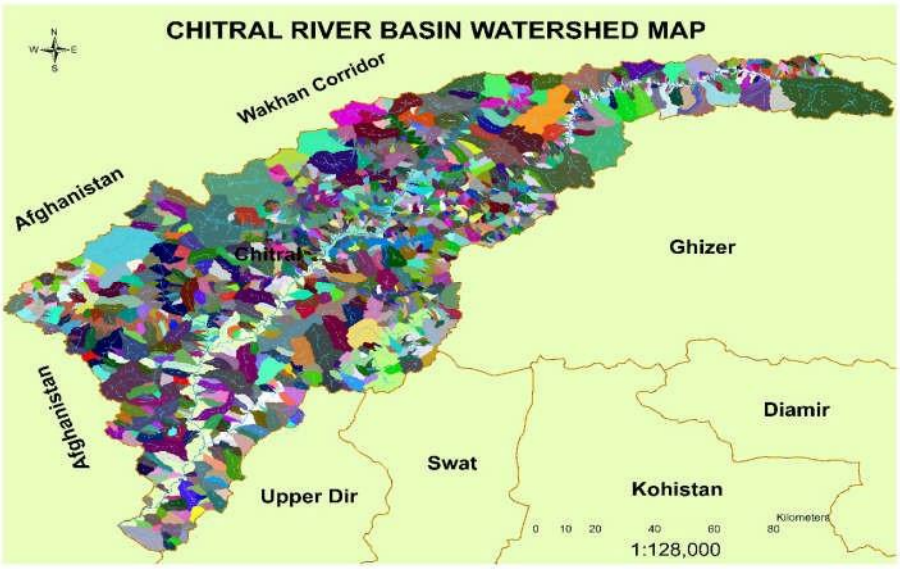



Figure: 3 Chitral River Basin Watershed Map

**Pre-Processing**

Pre-processing steps consist of data acquiring, filtering and remove the error. Chitral river basin boundary shape file was extract through watershed delineating process in Arc Map using hydrology (tool figure 3).The shape file was used as area of interest (AOI) to download the 30 meter digital elevation model (DEM) from United States Geological Survey (USGS). Land use land cover map of Chitral District was acquired from CCS Support Unit of IUCN–The World Conservation Union has been used for calculation manning roughness value in flood plain of Chitral River. The land use land cover maps were developed by IUCN based on national land cover classification system (Figure 4). Manning roughness value were assigned based on researches done by Kalyanapu et al. (2009) and Arcement and Schneider, 1990 methodologies. This manning roughness values has been used during creation of 2D mesh or 2D flow area. 2015 Flood discharge data from 15 July to 2 august was acquired from Aga Khan Rural Support Programme (AKRSP) (Table 1).

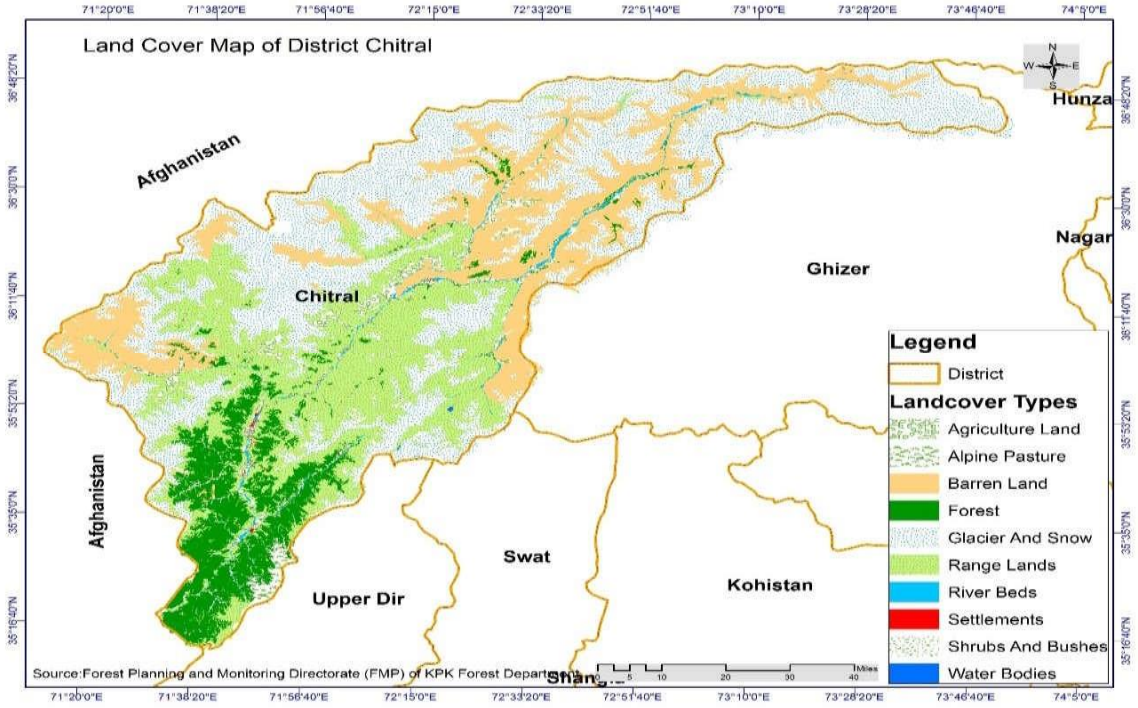



Figure: 4 land cover map Chitral River Basin

Table: 1 Discharge of Sub Stream of Chitral River ($M^3/S$) 2015 flood(AKRSP)

| Sub stream | Location | X | Y | *15-Jul-* | *16-Jul-* | *17-Jul* | *18-Jul-* |
|---|---|---|---|---|---|---|---|
| Laspur River | Istordeni | 36.255996° | 72.512694° | 176.6 | 176.9 | 176.9 | 177.2 |
| Yarkhun) | Mastuj | 36.287696° | 72.512215° | 920.3 | 932.6 | 933.3 | 935.3 |
| Lotkhow | Bumbagh | 36.243166° | 72.172232° | 435.8 | 436.2 | 437.1 | 437.6 |
| Karimabad | Momi | 36.035898° | 71.724155° | 155.4 | 155.4 | 155.6 | 155.9 |
| Garamchasma | Andakhti | 36.017330° | 71.721476° | 256.2 | 256.4 | 256.8 | 257.0 |
| ***Total flow*** | | | | 1944.3 | 1957.6 | 1959.8 | 1963.1 |

| *19-Jul* | *20-Jul* | *21-Jul-* | *22-Jul-* | *23-Jul-* | *24-Jul-* | *25-Jul-* | *26-Jul-* | *27-Jul-15* |
|---|---|---|---|---|---|---|---|---|
| 177.3 | 177.3 | 177.3 | 177.3 | 178.0 | 178.1 | 178.9 | 179.8 | 177.1 |
| 935.4 | 935.8 | 935.7 | 937.0 | 937.8 | 936.3 | 937.0 | 937.1 | 935.5 |
| 439.8 | 439.8 | 439.8 | 439.6 | 439.4 | 440.1 | 442.8 | 443.1 | 439.8 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 156.7 | 158.8 | 159.3 | 159.9 | 160.4 | 162.0 | 163.0 | 166.0 | | 161.1 |
| 258.0 | 259.5 | 259.5 | 260.0 | 262.1 | 263.5 | 264.0 | 263.6 | | 261.1 |
| 1967.3 | 1971.0 | 1971.6 | 1973.8 | 1977.7 | 1980.0 | 1985.7 | 1989.6 | | 1974.5 |
| ***28-Jul*** | ***29-Jul*** | ***30-Jul*** | ***31-Jul-*** | ***1-Aug-*** | ***2-Aug-*** | ***3-Aug-*** | ***MAX*** | ***MIN*** | ***MEAN*** |
| 176.6 | 176.0 | 176.3 | 176.2 | 175.7 | 175.1 | 175.3 | 179.8 | 175.1 | 177.0 |
| 934.7 | 934.1 | 932.8 | 930.4 | 920.2 | 915.1 | 915.2 | 937.8 | 915.1 | 931.6 |
| 439.2 | 439.0 | 438.1 | 436.8 | 436.2 | 435.8 | 435.5 | 443.1 | 435.5 | 438.6 |
| 159.3 | 158.5 | 157.1 | 156.8 | 155.3 | 155.0 | 155.0 | 166.0 | 155.0 | 158.3 |
| 260.0 | 259.8 | 259.0 | 258.8 | 258.4 | 257.5 | 257.0 | 264.0 | 256.2 | 259.4 |
| 1969.9 | 1967.5 | 1963.3 | 1959.1 | 1945.7 | 1938.5 | 1938.0 | 1990.8 | 1936.8 | 1964.9 |

**Processing**

The digital elevation data in float type was import in to RAS Mapper window to create terrain surface. Terrain surface was used to create geometrical data in geometric window of HEC-RAS. Computational mesh was created for 2D modeling in HEC-RAS. The mesh was generated with computation point spacing of DX 300 and DY 300. The mesh contain 6115 cells with max cell (2993) cover 674784.10 (sq ft), Minimum cell 48880.36(sq ft) and average cell 100955 (sq ft). The manning values was set 0.04 for entire chitral river due mostly cover with barren land and Rocky Mountains. Total five upstream location were marked at yarkhun stream, Laspur, Torkhow, Garamchasma and Karimabad (Lotkhow) and downstream area were marked at Osiak Drosh village (Figure 5).

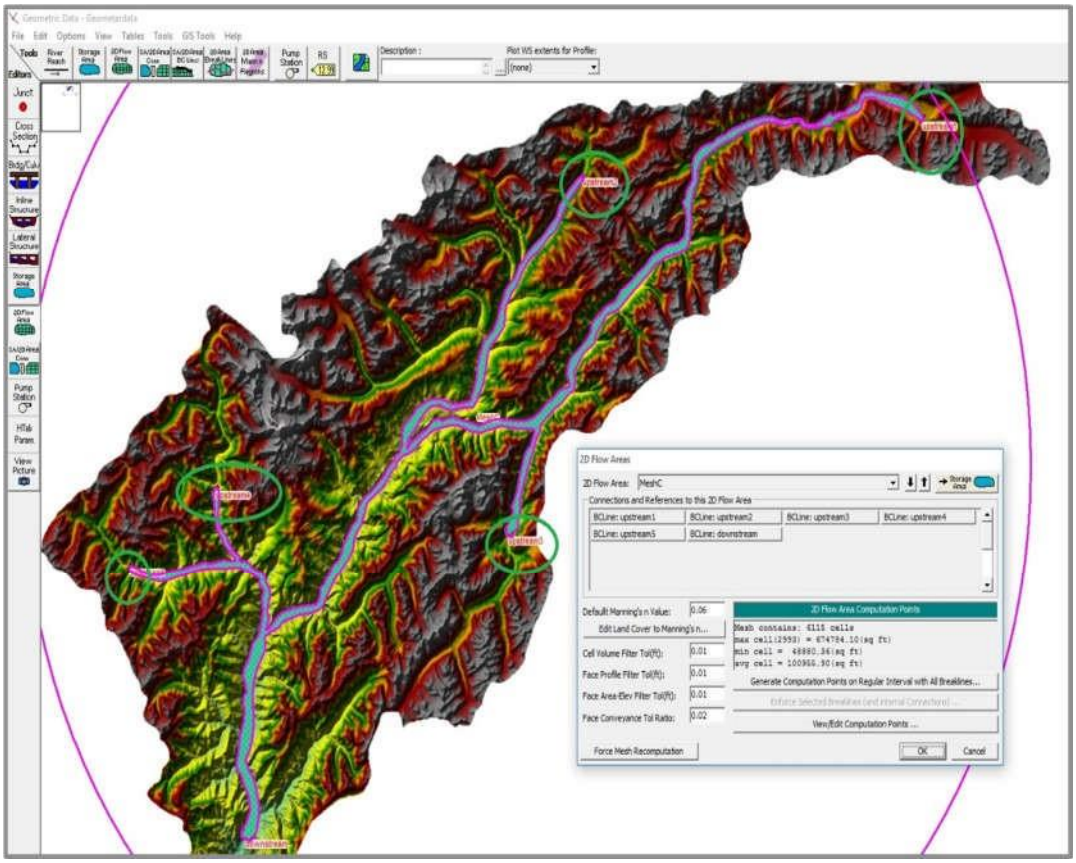


Figure: 5 Shows the Geometric network of Stream of Chitral River basin

After the completion of geometrical data peak flood scenario was developed based on discharge data from 15 July to o3 august 2015(Table 1). Flood discharge data was populated for all

five streams of chitral river basin. The flow hydrograph was set for each stream with specific discharge data from 15 July to 03 august 2015(Figure 6). Normal depth of downstream was set 0.01. Finally unsteady flow analysis was executed, which generated flood depth, Velocity, WSE surfaces and flood time arrival surface.

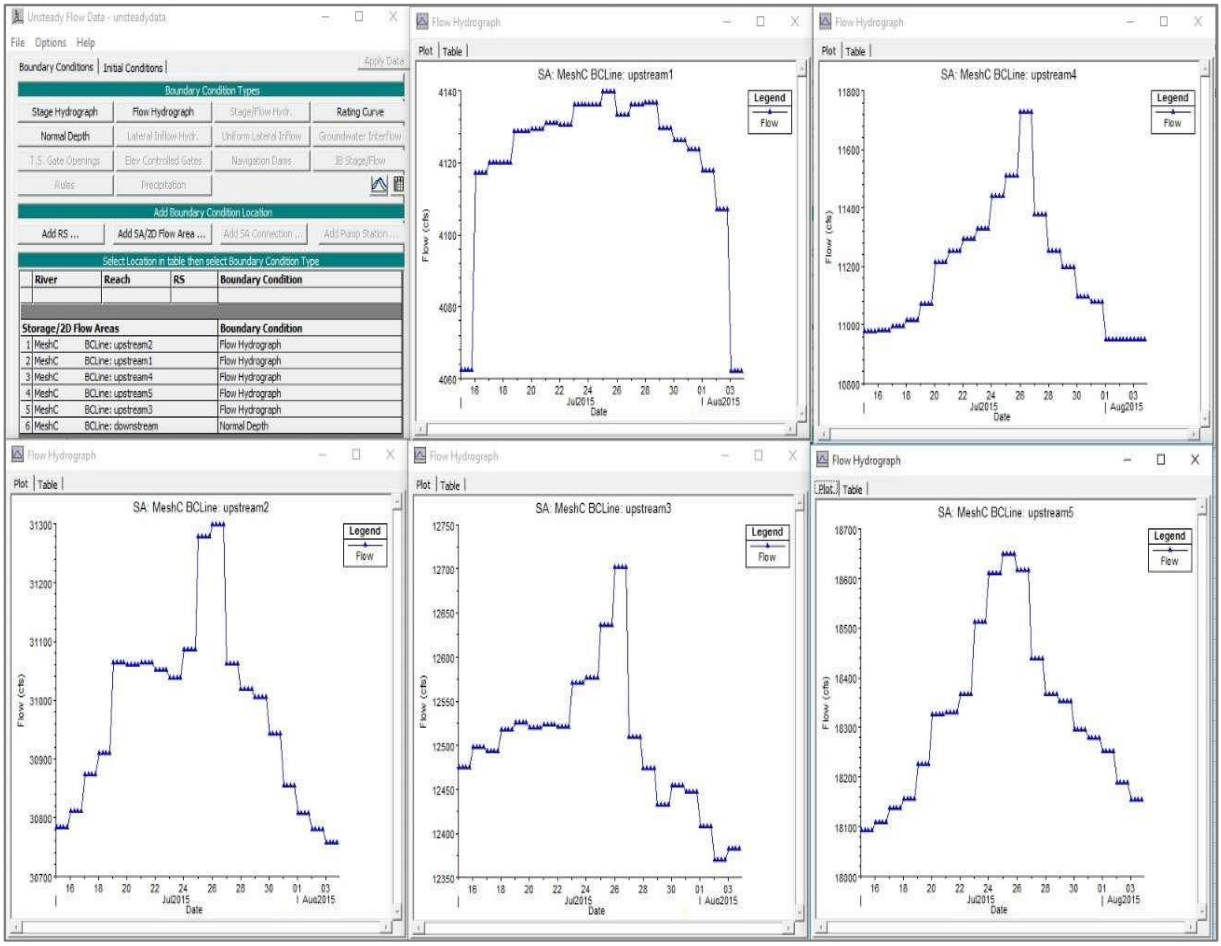



Figure: 6 Shows Flow Hydrograph of five Streams of Chitral River basin

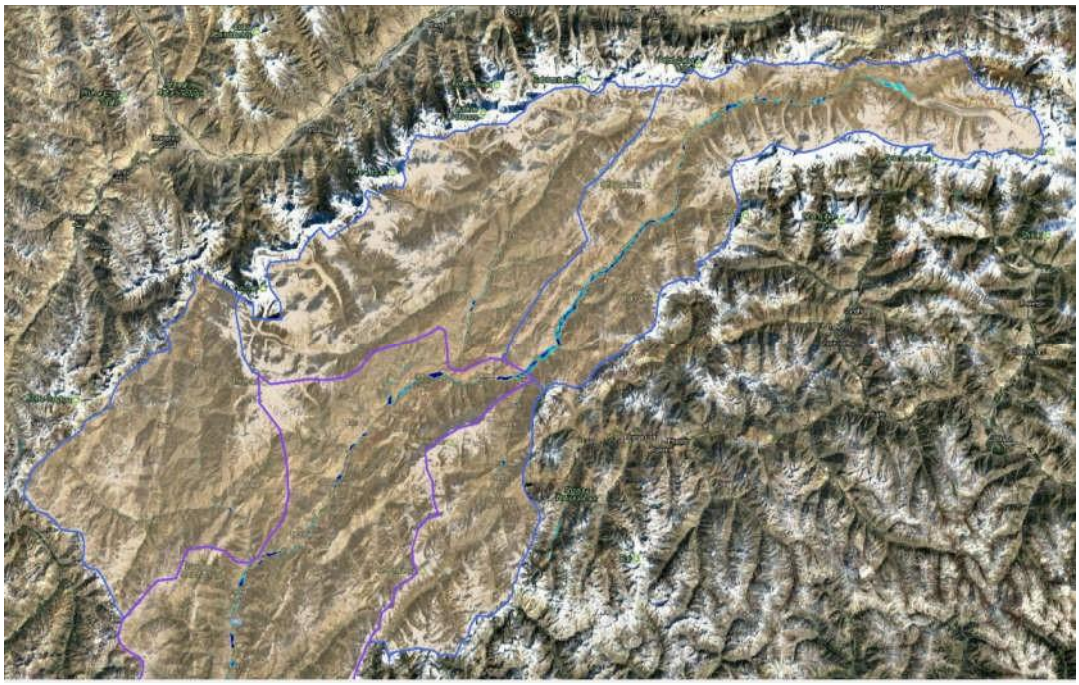
**Post –processing.**

Final step of hydraulic modeling was analysed the flood depth, velocity and time arrival information and validated with the actual flood heights and velocity of five streams (Yarkhun stream at Mastuj, Laspur stream at Istordeni, Torkhow stream at Bumbagh, Karimabad stream at Momi and Garamchasma stream at Andakhti villages) acquired from field during 2015 flood in chitral district in RAS Mapper platform. Risk map was developed and flood exposure was calculated in Arc Map environment.

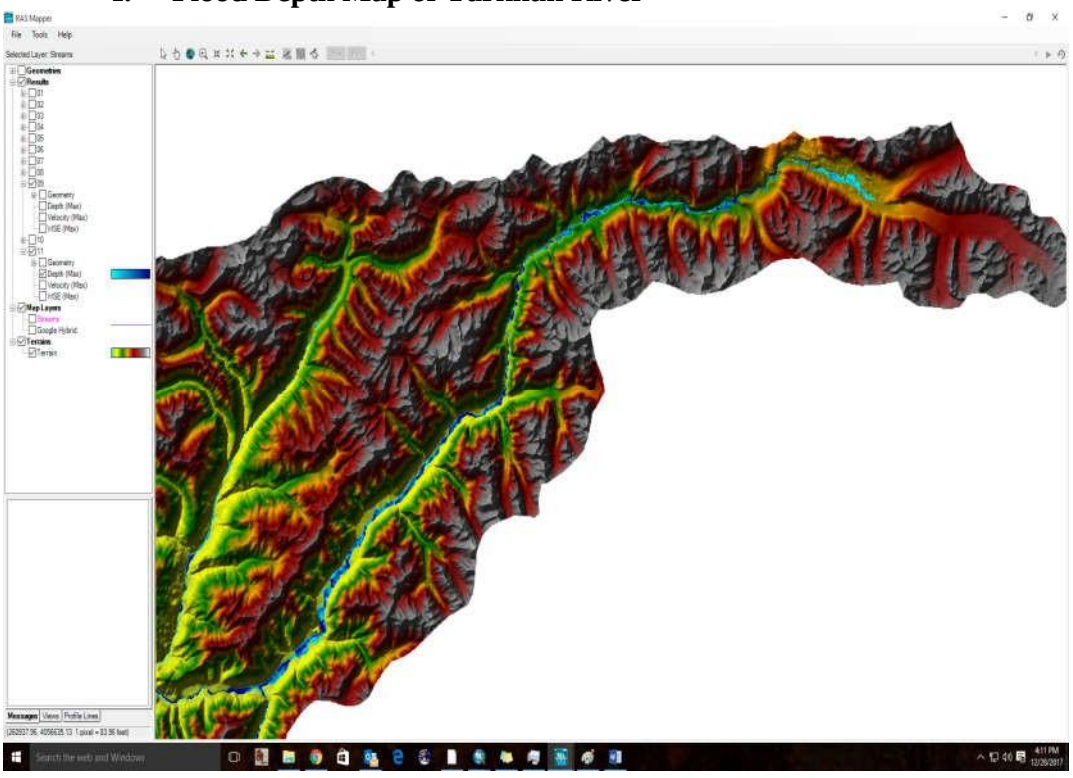
**Results and Discussions**

The objective of river hydraulic modeling of chitral river basin using HEC-RAS was to produced peak floodplain map of 2015 (Figure 7-11) and identified the element at risk like road and bridges (Table 2) were also identified through overlay process of floodplain polygon with road and bridge shape file. The flood affected area along the Chitral River was measured through intersection of flood polygon with land use land cover shape file of chitral district (Table 3).

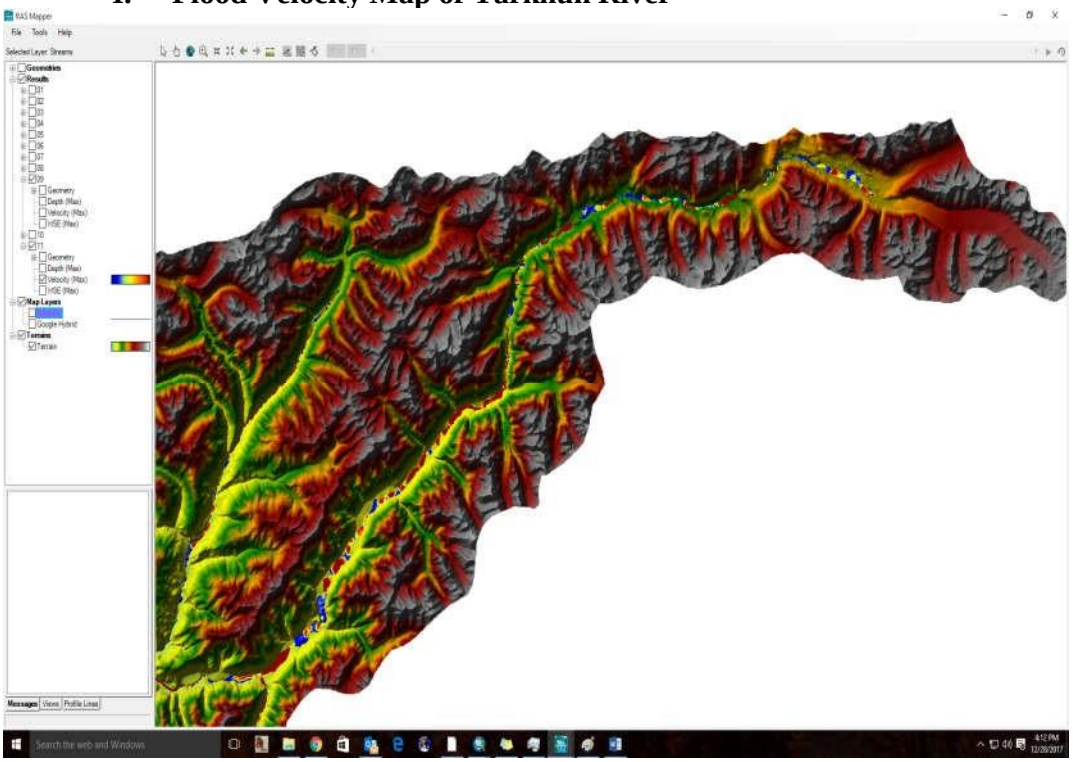
## Floods maps of Chitral River Basin



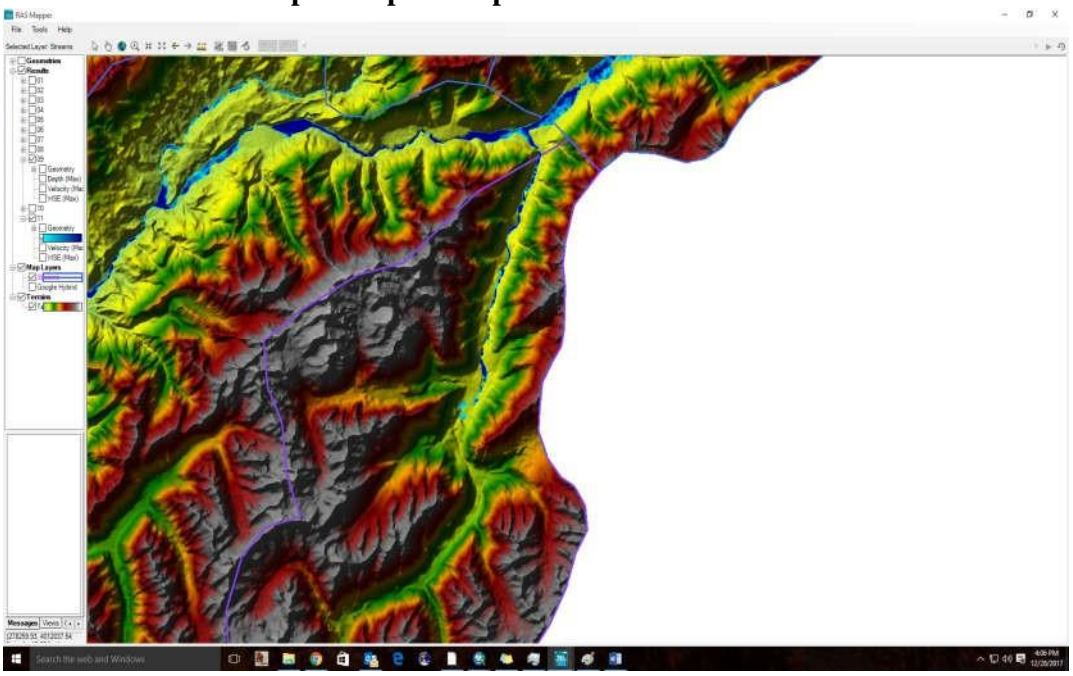
### I. Flood Depth Map of Yarkhun River



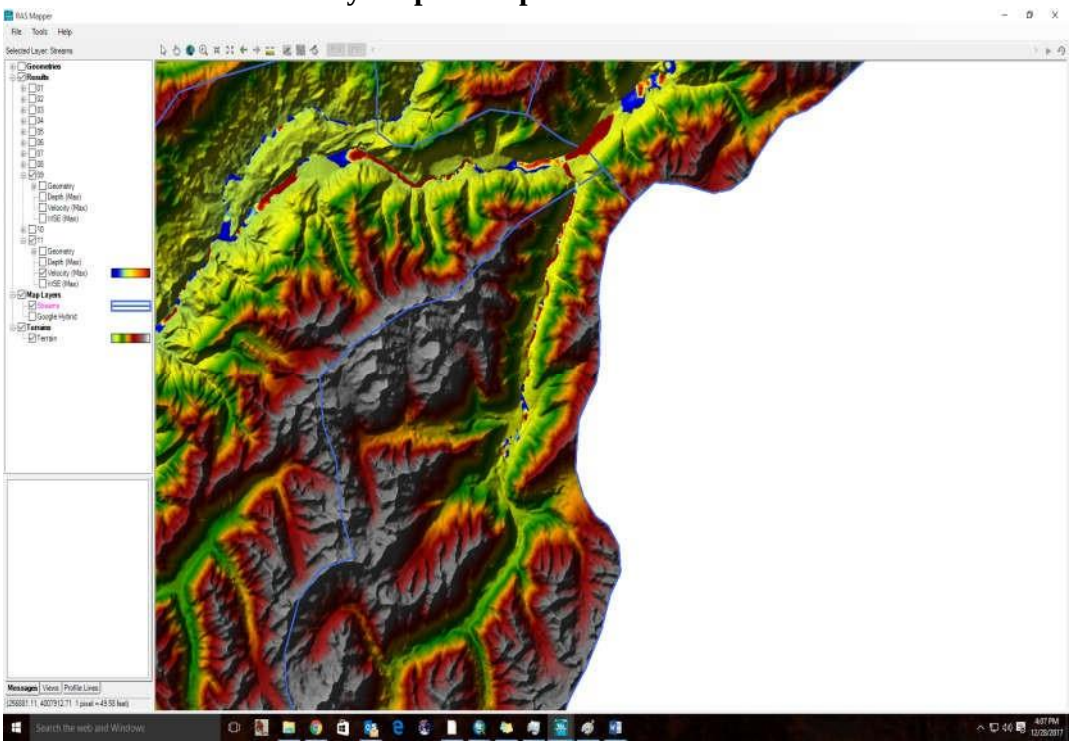
## I. Flood Velocity Map of Yarkhun River



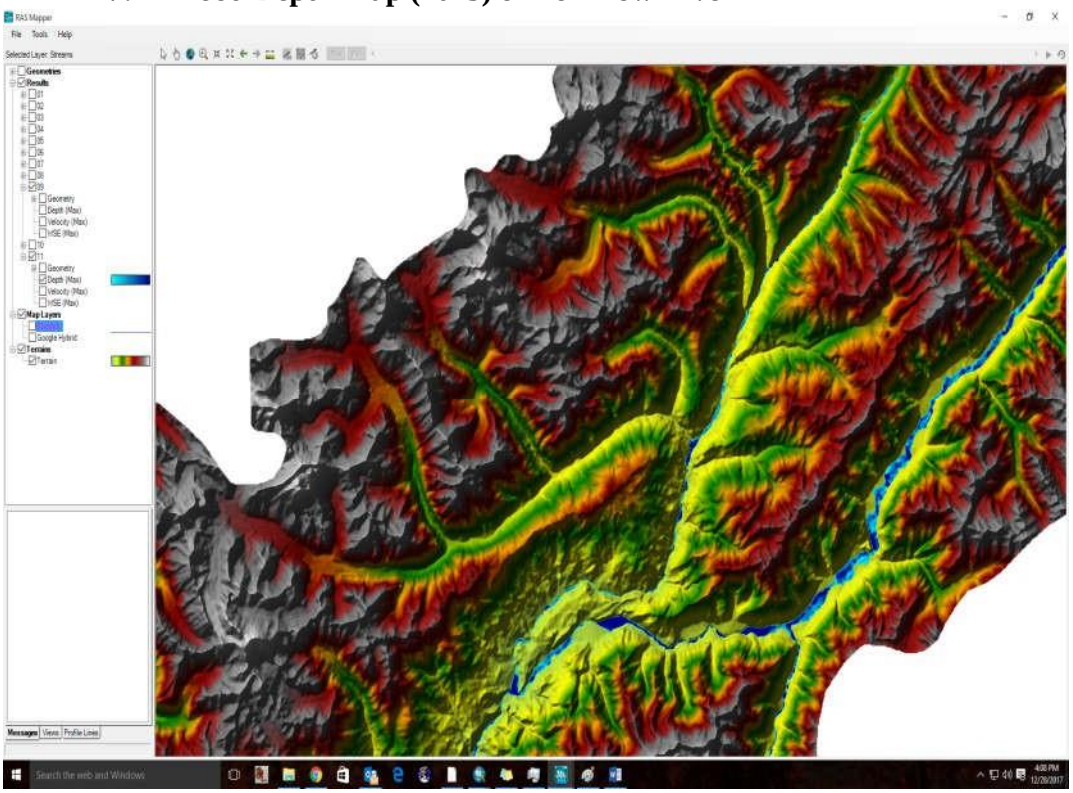
## II. Flood Depth Map of Laspur River



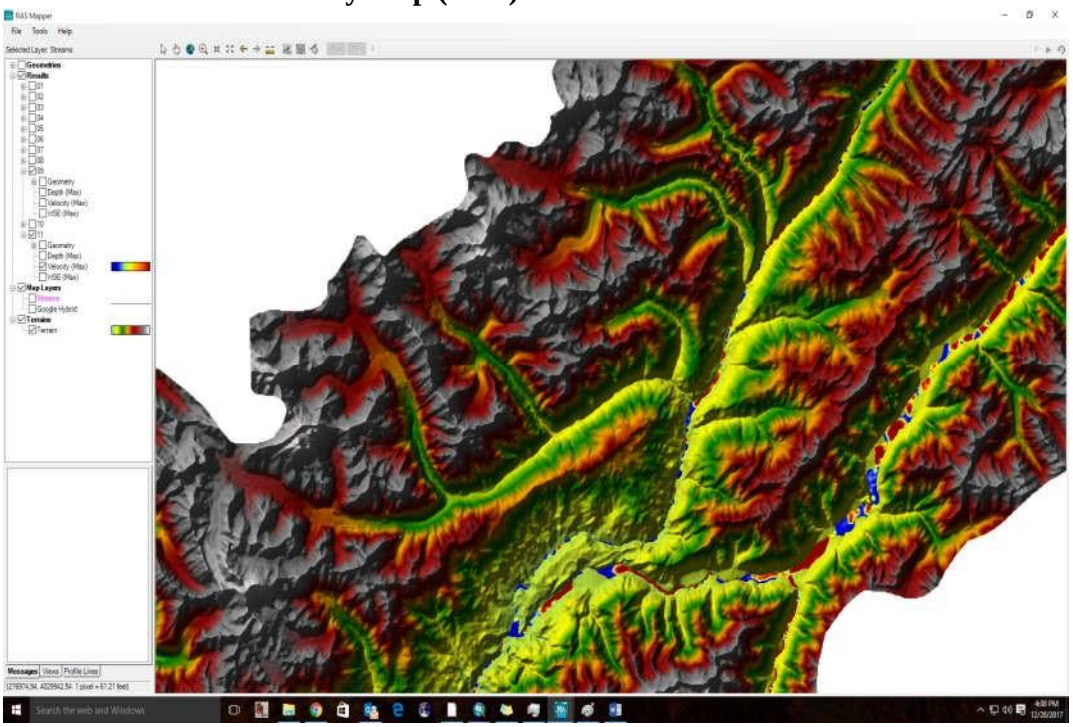
## III. Flood Velocity Map of Laspur River



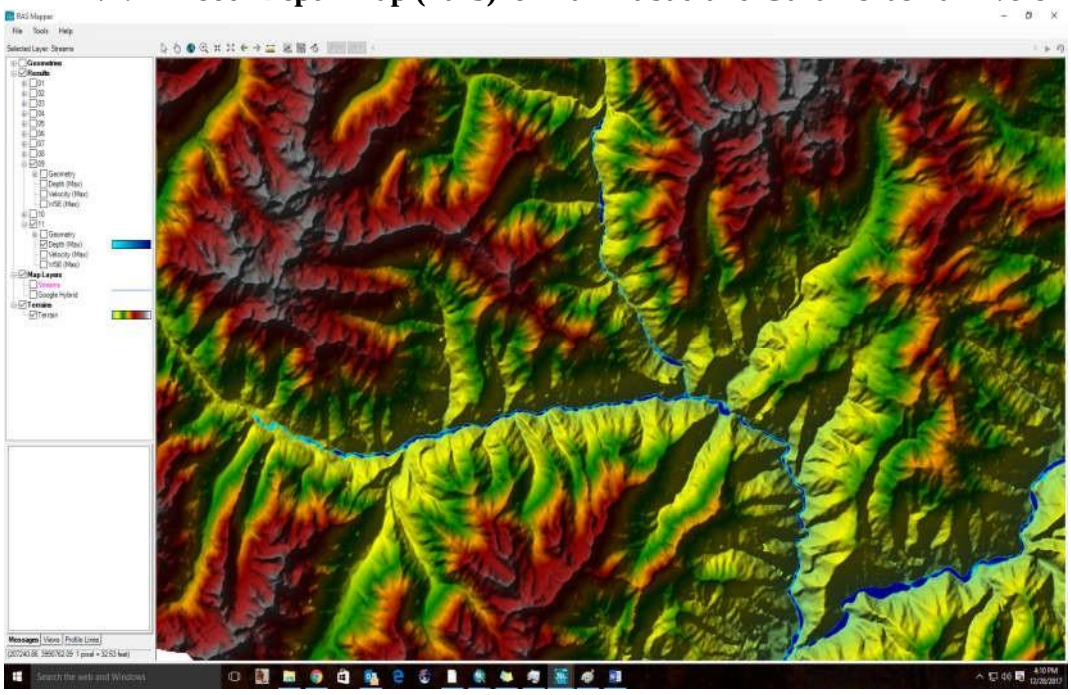
## IV. Flood Depth Map (2015) of Torkhow River



## V. Flood Velocity Map (2015) of Torkhow River



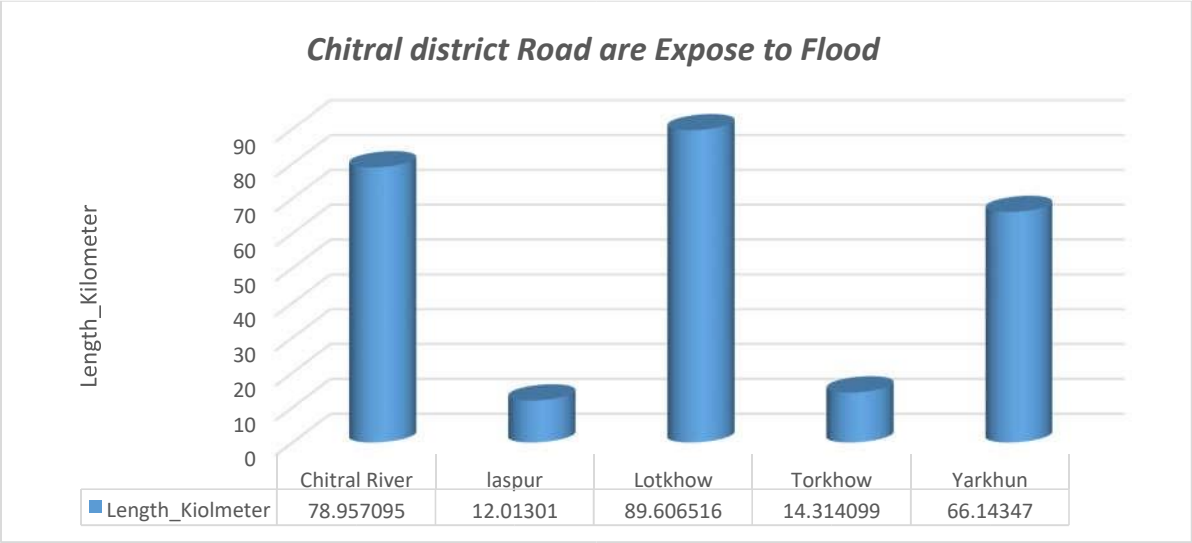
## VI. Flood Depth Map (2015) of Karimabad and Garamchasma Rivers



## VII. Flood Velocity Map (2015) of Karimabad and Garamchasma Rivers

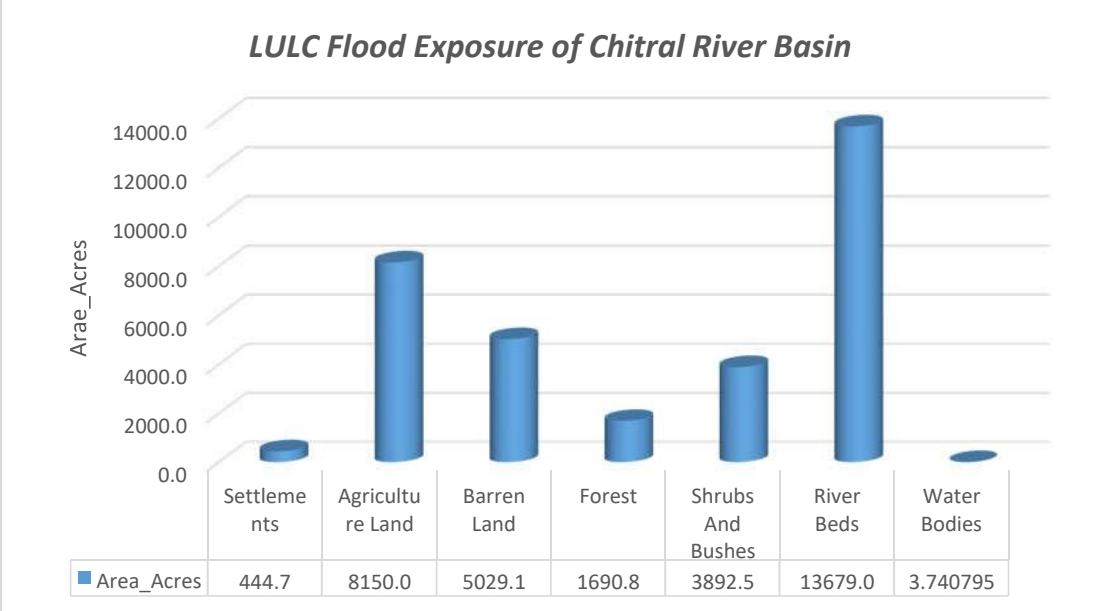
## VIII. Flood road exposure of Chitral District

| Provinces | District | Road Name | Length Kilometer |
|---|---|---|---|
| khyber pakhtunkhwa (KP) | Chitral | Chitral River | 78.957095 |
| khyber pakhtunkhwa (KP) | Chitral | Laspur | 12.01301 |
| khyber pakhtunkhwa (KP) | Chitral | Lotkhow | 89.606516 |
| khyber pakhtunkhwa (KP) | Chitral | Torkhow | 14.314099 |
| khyber pakhtunkhwa (KP) | Chitral | Yarkhun | 66.14347 |



## IX. Land use land cover flood exposure of Chitral River Basin

| FID | Provinces | District | LULC Flood Exposure | Area Acres | Hectares |
|---|---|---|---|---|---|
| 2 | khyber pakhtunkhwa (KP) | Chitral | Settlements | 444.7 | 180.0 |
| 1 | khyber pakhtunkhwa (KP) | Chitral | Agriculture Land | 8150.0 | 3298.2 |
| 3 | khyber pakhtunkhwa (KP) | Chitral | Barren Land | 5029.1 | 2035.2 |
| 4 | khyber pakhtunkhwa (KP) | Chitral | Forest | 1690.8 | 684.3 |
| 6 | khyber pakhtunkhwa (KP) | Chitral | Shrubs And Bushes | 3892.5 | 1575.3 |
| 7 | khyber pakhtunkhwa (KP) | Chitral | River Beds | 13679.0 | 5535.7 |
| 8 | khyber pakhtunkhwa (KP) | Chitral | Water Bodies | 3.740795 | 1.513846 |
| Total flood exposure | | | | 32889.9 | 13310.1 |




### Source of uncertainty

After completing the hydraulic analysis of Chitral River and its floodplain, effort were made to reduce the error in data and result through validating with round data. The main limitation is resided in digital elevation model which is 30 meter. It is the base topography on which analysis was performed. Unavailability of updated land use land cover data is gap to calculate the actual river floodplain

roughness value. It is possible to delineate the highly accurate flood zonation using high resolution digital terrain data set with updated land use land cover data of chitral district. **Reference**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**Trainings on Project relevant activates**

- Training on HEC-RAS and HEC-HMS at NUST and NARC, Islamabad.
- Training on GIS and RS at Almaty, Kazakhstan

**Contribution in Papers/Conferences:**

- **1** Conference paper; Very good work on Flood modelling; Very Good performance