RESEARCH REVIEW International Journal of Multidisciplinary 2021; 6(4):85-93
ISSN: 2455-3085 (Online)
https://doi.org/10.31305/rrijm.2021.v06.i04.014
Double Blind Peer Reviewed/Refereed Journal
https://www.rrjournals.com/

Research Paper

GIS Based Flood Modeling of Laghman River

Sediqmal Mirwais

Teaching Assistant, Member of Civil Engineering Department, Laghman University

ABSTRACT

The research has shown that the reason of incensement of flood hazards is not the increment of frequency or magnitude of floods, but the intense use of flood terrains and limiting the river cross section by construction of (residential buildings, bridges etc.…) are the main reasons of hazardous floods creation. Respected to the thesis title and available data in our country, below are all the procedures which I have accomplished in my research. In this research GIS (Geographical Information system) has been used to specify flood hazard terrains according to hydraulic model in Laghman river territory which is of the most important parts of this research HEC-HMS software has been used for hydrologic modeling and for creation of flood hydrograph with frequency of (10,20,50) years for related catchment areas. Flow scheme for precipitation modeling is according to IDF (intensity duration frequency) curve which is developed from near station. HEC-RAS software has been used to simulate for cast flood on Laghman river. All mentioned models' document has been developed in ARC MAP-GIS environment using their related extensions HEC-GEO HMS and HEC-GEO RAS, digital elevation models with 5-meter accuracy has been studied and analyzed according to site coordinates. One dimensional steady flow analysis has shown that a major area in river territory is under the flood hazard and destruction which draws a huge damage to our compatriots. In this research I have found that in 37-kilometer length of river, 1.7 square kilometers of the areas in river terrain which are generally agricultural lands that are under flood hazard and destruction. Thus, I recommend flood prevention and control structures in this area in order to improve living condition of residents in this area. By this, flood hazards are being prevented and a residential area along Laghman river which is a joyful area is being built. Flood frequency in 50 years has been derived from Gamble method with respect to 20 years' flow from Tangi-e-Saidan hydrologic station.

Keywords: *Flood hazards, Frequency, Hydrologic Modeling, IDF, HEC-HMS, HEC-GEO HMS, HEC-GEO RAS*

Article Publication

Published Online: 15-Apr-2021

***Author's Correspondence**

Sediqmal Mirwais

Teaching Assistant, Member of Civil Engineering Department, Laghman University

elmitahqeeq[at]gmail.com

1. Introduction

Flood is one of the important natural hazards that causes more damage than all other hazards According to the World Disaster Report (2010), seismic events have killed the greatest number of people of all-natural hazards in recent years, averaging 50,184 people per year from 2000 to 2008, whereas flood events have affected the largest number of people, averaging 99 million people per year between 2000 and 2008.

Individual research has proven that limiting flood areas and river territory have causes improvement of flood and casualties. Urban and sub urban areas have the maximum potential of flood hazard. Afghanistan is a country which is limited with mountains that level of improvement of natural hazards such as earthquake, land slide, snow sliding; storm and flood are very high. With respect to its special climate Afghanistan is one of the flooded countries. Every year run off starts in different parts of Afghanistan from February because of milting of snow and rain falls and continuous to June. 21 out of 34 provinces in Afghanistan are vulnerable to floods the western region and central belt are at risk of floods. However the south west and few Northern provinces of Afghanistan (Herat, Ghor,Urozgan,Jozjan,Balkh and Faryab) can severely affected by both flood and drought. Laghman River is a 700-kilometer-long river that emerges in the Sanglakh Range of the Hindu Kush Mountains in Afghanistan and empties in the Indus River near Attock, Pakistan. It is the main river in eastern Afghanistan and is separated from the watershed of the Helmand by the Unai Pass. The Laghman river passes through the cities of Laghman and Jalalabad in Afghanistan before flowing into Khyber Pakhtunkhwa in Pakistan some 25 kilometers north of Durand Line border crossing at Torkham. The major tributaries of the Laghman river are the Logar, Laghman, Kunar, Alingar, Bara and Swat rivers. In this study, geographic information system (GIS) software was used in combination with hydrologic and hydraulic (H&H) modeling, to estimate the flood hazard of Laghman River from Unai Rage to Pol-e-Gulbagh, in this research maximum effort has been given to find sustainable and viable solutions to the above questions and risks, which areas are flooded? Having an urban development strategy for Laghman River. Besides tackling the most basic issues like water supply, sanitation and drainage, this strategy intends to consider the needs of the local population as well as the physical boundaries of sustainable urban development. Previous studies have shown that parts of this area are currently at high risk of being flooded. For a successful planning of Laghman River´s future development, it is thus essential to know, what impact severe storm events could have on the settlement. Based on this background, it is the main objective of this study to create a flood hazard zoning for Laghman River, outlining areas with frequent, rare and exceptional flood hazard. Furthermore, a framework of protection measures addressing the major flood related issues is developed. The following section gives an overview of the strategy that is applied to accomplish the study goals.

2. Materials and Methods

2.1 Description of the Study area

Laghman is the one of the province of Afghanistan as well as its largest city, located in the eastern section of the country. According to a 2015 estimate, the population of the city was around 3,678,033 which includes all the major ethnic groups. Rapid urbanization had made Laghman the world's 64th largest city and the fifth fastest-growing city in the world.

Laghman is said to be over 3,500 years old, mentioned since at least the time of the Achaemenid Empire. The city is at a strategic location along the trade routes of South and Central Asia, and a key location of the ancient Silk Road. It has been part of the Achaemenids, Seleucids, Mauryans, Kushans, LaghmanShahis, Saffarids, Ghaznavids, and Ghurids. Later, it was controlled by the Mughal Empire until finally becoming part of the Durrani Empire in 1747. The city is located high up in a narrow valley between the Hindu Kush mountains. The Laghman is a 700-kilometre (430 mi) long river that emerges in the Sanglakh Range of the Hindu Kush mountains in Afghanistan and empties into the Indus River near Attock, Pakistan. It is the main river in eastern Afghanistan and is separated from the watershed of the Helmand by the Unai Pass. The Laghman River passes through the cities of Kabul and Jalalabad in Afghanistan before flowing into Khyber Pakhtunkhwa in Pakistan some 25 kilometers (16 mi) north of the Durand Line border crossing at Torkham. The major tributaries of the Laghman river are the Logar, Laghman, Kunar, Alingar, Bara and Swat rivers.

The Laghman river is little more than a trickle for most of the year, but swells in summer due to melting snows in the Hindu Kush Range. Its largest tributary is the Kunar River, which starts out as the Mastuj River, flowing from the Chiantar glacier in Brughil valley in Chitral, Pakistan and after flowing south into Afghanistan it is met by the Bash gal river flowing from Nuristan. The Kunar meets the Laghman near Jalalabad. In spite of the Kunar carrying more water than the Kabul, the river continues as the Laghman River after this confluence, mainly for the political and historical significance of the name.

The Laghman River is impounded by several dams. The Naghlu, Surobi, and Darunta dams are located in Kabul and Nangarhar provinces of Afghanistan. The Warsak Dam is in Pakistan, approximately 20 km northwest of the city of Peshawar.

The study area is 37km of Laghman River from Chaghar area with geographical coordinates (68.878714, 34.319411) to Pul-e-Gulbagh with geographical coordinates (69.128725, 34.434996).

2.2. Research Methods

In this research actual data will been used, maximum flood will be considered by both (statically and software) methods.

a) Collection of general and river information of Laghman River and its upper basin, like geological characteristics, physiography, metrology, hydrology, and geographical maps.
b) Using from collection of reports and pervious research and research findings for extracting information.
c) Considering sources and history of research for relevant research objective by collecting accomplished reports, internet-based searches and written books studies.
d) Collecting hydrological data and calculation of maximum amount of discharge with different return periods.
e) Drawing cross section lines in river path in GIS environment.
f) Making a readable file by HEC-RAS model.

g) Exporting file from GIS and importing the readable file into HEC-RAS.
h) Completion of required entering data for HEC-RAS.
i) Performing HEC-RAS model and determining water level in Crosse sections.
j) Making readable file by ARC View-GIS by HEC-RAS.
k) Presenting depth zoning in ARC View-GIS with extension HEC-GEO-HMS.
l) Presenting flood hazard zoning or flooded area in ARC GIS and final flood maps with different return period.
m) Final report.

2.3. Sources and use of data

This topic gives overview of the data as well as methods used for H&H modeling. Due to the lack of readily available data for H&H modeling, acquisition of accurate topographic and hydrologic data was found to be crucial for the fulfilling of the study goals. While in many countries, high-resolution digital elevation models (DEMs), long term rain data, reliable land use and soil type maps exist and can be obtained from public institutions, studies in developing countries often require a high degree of effort and different methods to obtain adequate data.

The three software solutions and the mathematical models used in this study are presented in this chapter in detail. ArcMap is used for all GIS related tasks, HEC-HMS for hydrologic- and HEC-RAS for hydraulic modeling. Arc Hydro, HEC-GeoHMS and HEC-Geo RAS serve as the interface between GIS and the H&H modeling. At the end of this section a brief literature review gives an overview about the applicability and limitations of the applied models.

2.3.1. DEM (Digital Elevation Model):

Digital elevation model (DEM) is a digital model or 3D representation of a terrain's surface. Digital elevation models (DEM) are a superset of both digital terrain models (DTM) and digital surface models (DSM). Thus, it can be concluded that, there are two kinds of DEM:

- Digital Terrain Model (DTM)
- Digital Surface Model (DSM)

Remote sensing generally captures the surface height, so the top of the tree canopy or buildings is returned, not the bare ground elevation (DSM). If this data is corrected to remove elements which extrude above the terrain height, you are left with a DTM. The DEM could be acquired through techniques such as photogrammetry, LiDAR, IfSAR, land surveying, etc.

In aspect of file rendering and presentation there are two kinds of DEM:

- **Raster:** Raster is the representation of the land surface, which is built up from grid of squares, also known as a height map when representing elevation.
- **Vector (TIN): TIN** (Triangulated Irregular Network) is the representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (x, y, and z) that are arranged in a network of non-overlapping triangles. An advantage of using a TIN over a rasterized digital elevation model (DEM) in mapping and analysis is that the points of a TIN are distributed variably based on an algorithm that determines which points are most necessary to an accurate representation of the terrain. Data input is therefore flexible and fewer points need to be stored than in a raster DEM, with regularly distributed points. A TIN may be less suited than a raster DEM for certain kinds of GIS applications, such as analysis of a surface's slope and aspect. A DTM can be formed from a DEM. A DEM can be interpolated from a TIN.

“DEM” used in this research project is provided by ‘MAIL” Ministry of Agriculture, Irrigation and Livestock. In 2010 the US & NATO missions in Afghanistan captured “DEM” for whole Afghanistan. This “DEM” was captured by satellites of US Army and “USGS” United States Geological Survey using LiDAR Technique. The cell size is (30,30) which means the resolution of DEM is 30 meters & the “DEM” type is “DSM”. A copy of this DSM was provided for “IRoA” Islamic Republic of Afghanistan’s Government. Afghanistan government removed surface objects (such as buildings, tress, etc.) on the “DSM” to develop a “DTM” for whole area of country. Although Afghanistan government developed a DTM, but it needs very much corrections and manipulations. Using this “DEM” and Imagery, Afghanistan government started to create and develop land cover and Soil Type datasets.

LiDAR is a surveying method that measures distance to a target by illuminating that target with a laser light. The name LIDAR, sometimes considered an acronym of Light Detection and Ranging (sometimes Light Imaging, Detection, And Ranging), was originally a portmanteau of light and radar.

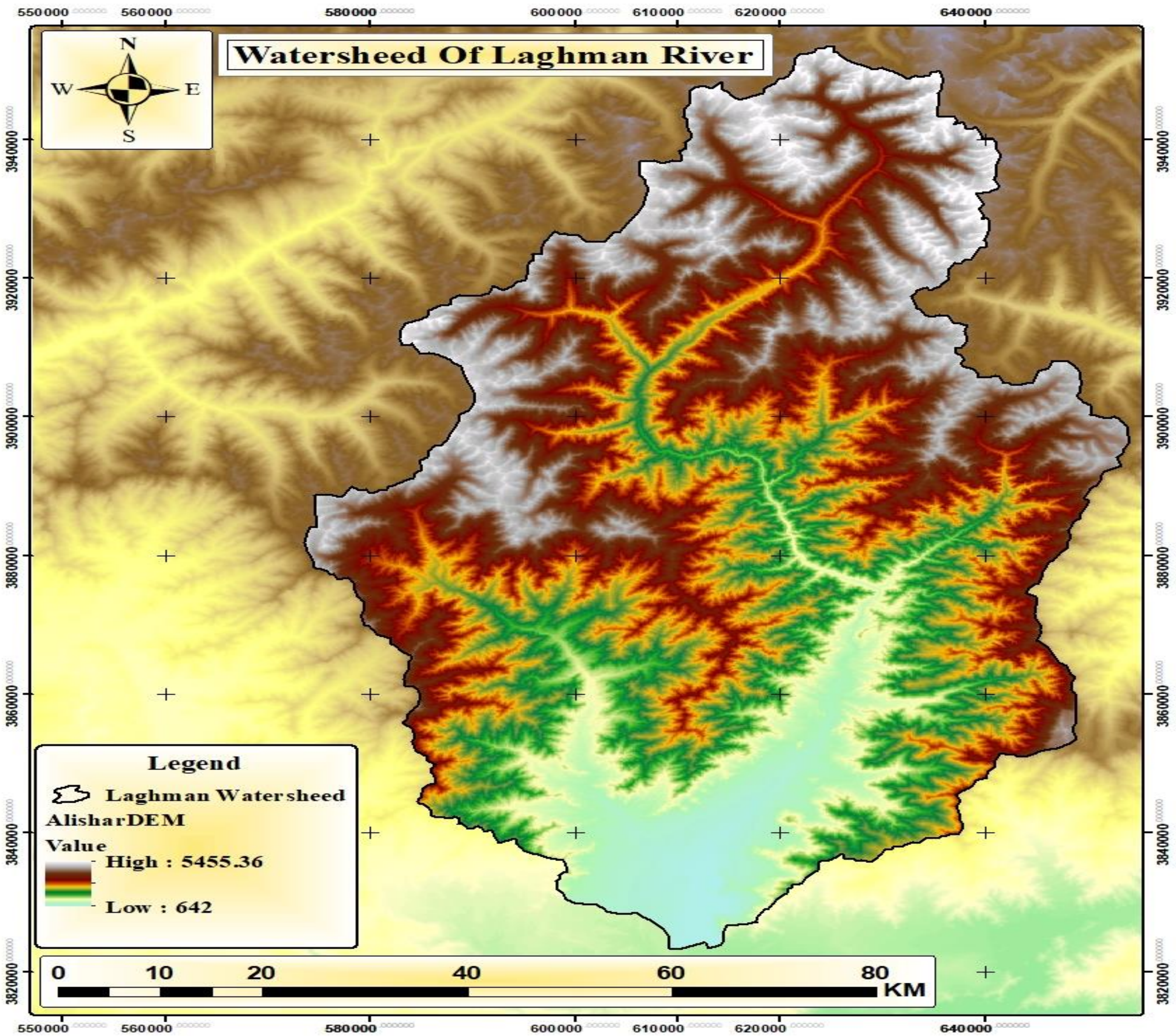

Figure 1: DEM of Laghman Watershed

2.3.2. Satellite Imagery

Satellite imagery consists of images of Earth or other planets collected by satellites. Imaging satellites are operated by governments and businesses around the world. Satellite imaging companies sell images under license. Images are licensed to governments and businesses (such as Apple Maps and Google Maps) or open-licensed (such as Open Street Maps). Satellite Imageries used for this project was captured by US Government's Organizations (USGS) in 2012's ending quarter. The cell size of this dataset is (0.0000516666* 0.0000516666) which means it approximately represents a (5 m) resolution.

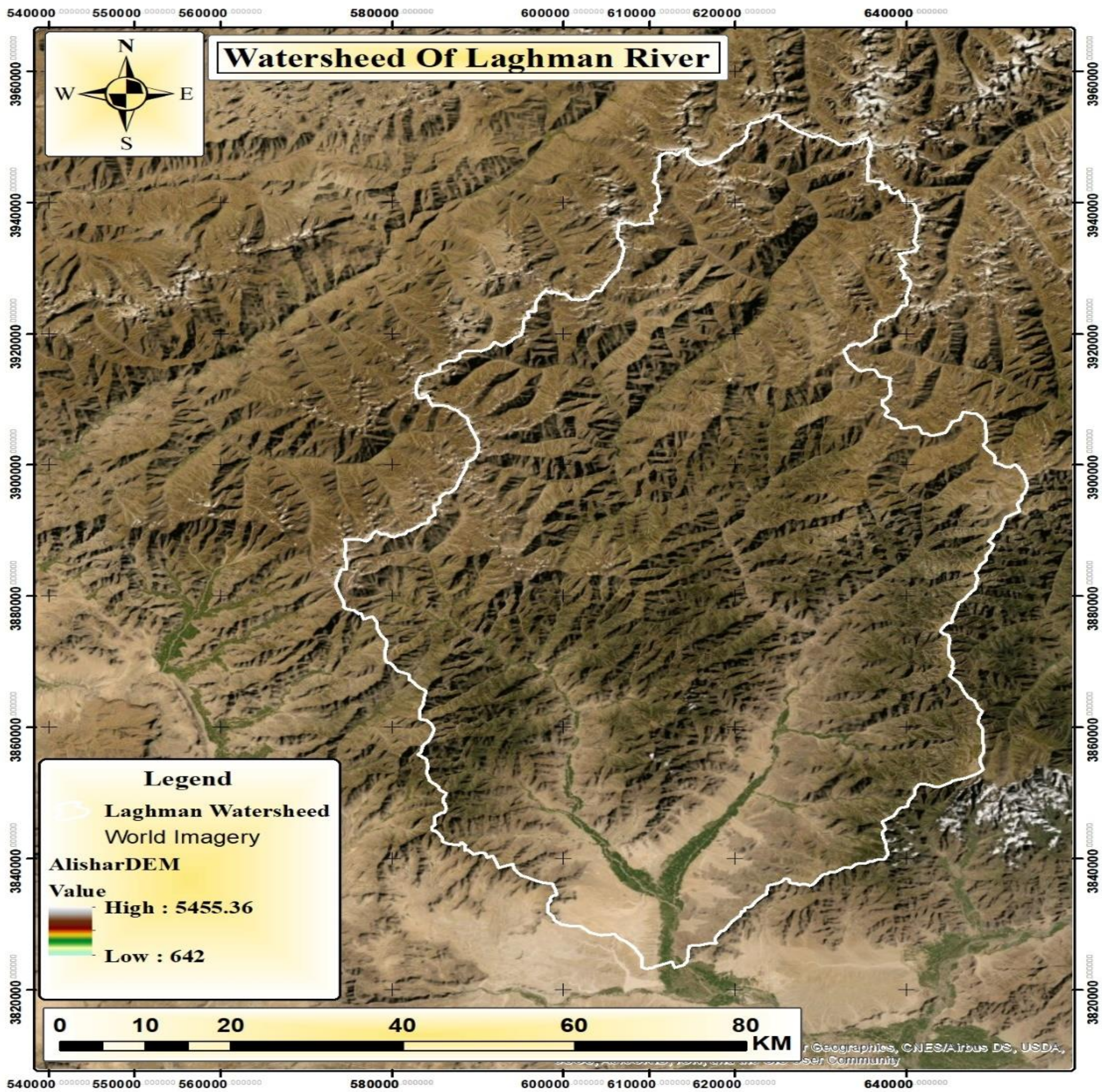

Figure. 2: DEM of Laghman from Chaghar to Pol-e-Gulbagh

2.3.3. Land Cover

Land cover is the physical material at the surface of the earth. Land covers include grass, asphalt, trees, bare ground, water, etc. As stated in 3.1.1, Afghanistan government started to develop a country-wide land cover dataset in early years which the source was "2010 & 2013"'s datasets. land cover for this project was developed for agricultural purposes by "MAIL". Researcher, (Mahdi Noor); has developed the "MAIL" datasets and classified it using GIS; based on USDA's (United States Department of Agriculture) TR-55 – Technical Release 55 & "NLCD" (National Land Cover Department of United States) Manual.

This classification; classifies LC's into four major groups of (Water, Residential, Forest, Agricultural groups.

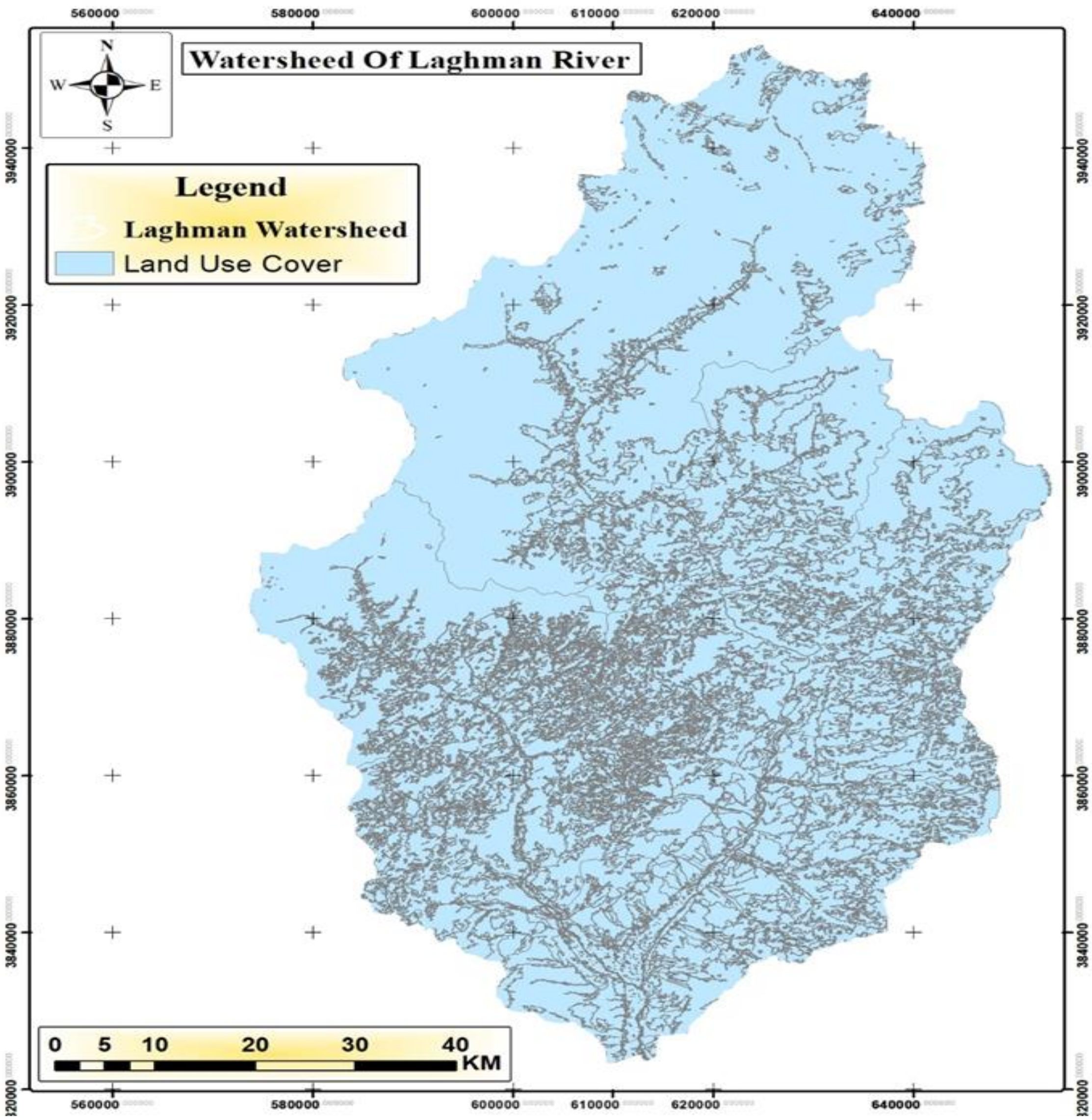

Figure. 3: Land use cover of Laghman Watershed

2.3.4. Soil Type

Soils were originally assigned to hydrologic soil groups based on measured rainfall, runoff, and infiltrometer data. Since the initial work was done to establish these groupings, assignment of soils to hydrologic soil groups has been based on the judgment of soil scientists. Assignments are made based on comparison of the characteristics of unclassified soil profiles with profiles of soils already placed into hydrologic soil groups. Most of the groupings are based on the premise that soils found within a climatic region that are similar in depth to a restrictive layer or water table, transmission rate of water, texture, structure, and degree of swelling when saturated, will have similar runoff responses. The classes are based on the following factors:

- Intake and transmission of water under the conditions of maximum yearly wetness (thoroughly wet)
- Soil not frozen
- Bare soil Surface
- Maximum swelling of expansive clays

Same as 3.1.3, soil type dataset for this research project was developed “2010 & 2013”’s datasets by “MAIL” which was not developed for hydrologic uses. Researcher, (Mahdi Noor); has developed the “MAIL” datasets and classified it using GIS. Hydrologic Soil Groups classifications are based on USDA’s (United States Department of Agriculture) TR-55 – Technical Release 55 & USDA’s Natural Resources Conservation Service (NRCS), National Engineering Handbook, Part 630, Chapter 7 (Hydrologic Soil Groups). This classification; classifies soils into four groups (A, B, C, D).

2.3.5. TIN

TIN (Triangulated Irregular Network) dataset is developed from 5 meters DEM which was provided by "MAIL". Although it's possible to convert the raster to TIN directly in ArcMap software, but after consulting with hydrologists and GIS Experts; The researcher decided to use the recommended and better technique. First the raster the data was converted to Point, then it was converted to TIN. This technique increases the accuracy and resolution of resulting TIN.

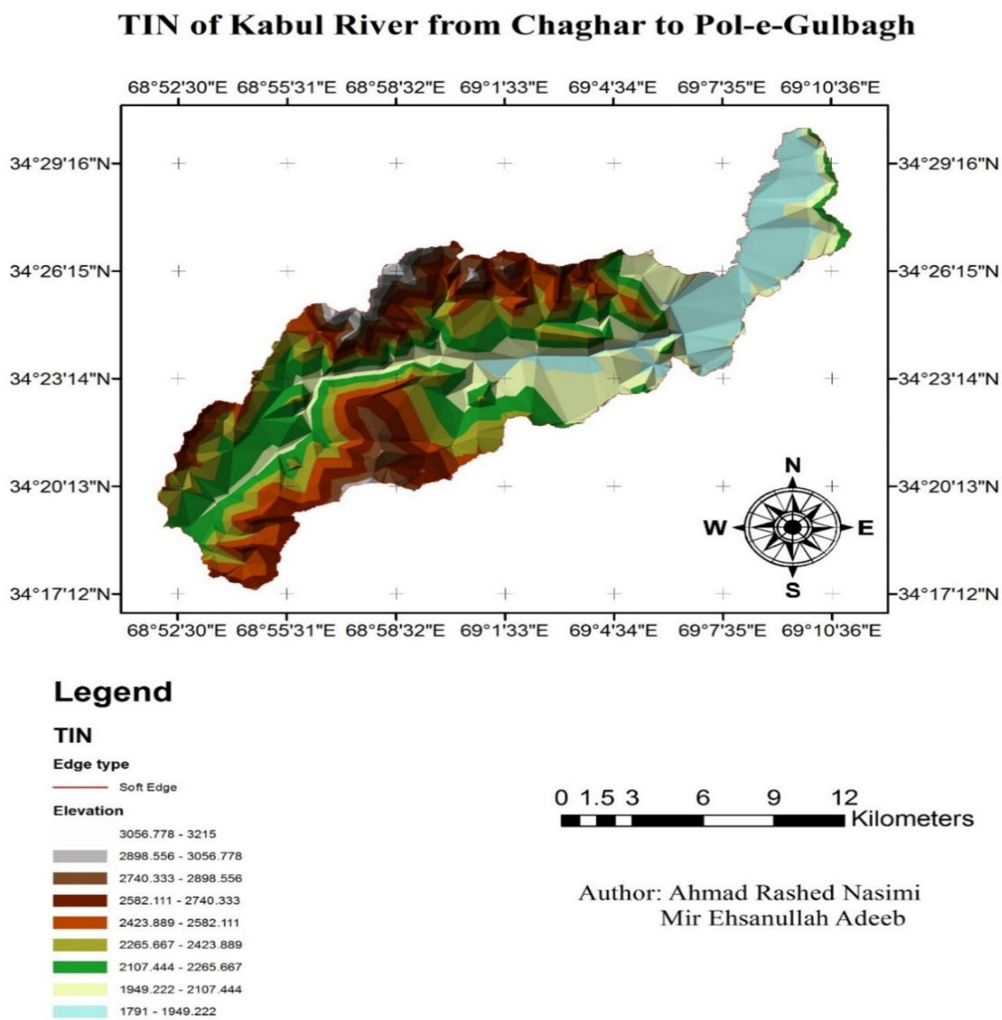

Figure. 4: TIN of Kabul River from Chaghar to Pol-e-Gulbagh

2.3.6. Discharge

Discharge data is provided by "MEW" (Ministry of Energy and Water)'s "WAPIKA" Department. This data is collected from "Tangi-e-Sayedan" Hydrometric station which is located in "Gulbagh" District of Laghman Province. Discharge data is used for Gumbel Distribution, to calculate maximum flow (flood). As the recorded data in early years is between (2007-2015), (8 years); is not enough for calculating a Gumbel distribution, thus the data which is recorded between (1962 – 1980) for 18 years is used for this project. Usually, gap filling is done for quasi circumstances, but; as it needed a wide and full discussion, and was not compatible and permitted according Laghman University's Undergraduate rules, the researcher (Mahdi Noor) was inevitably neglected from discussion. The coordinates of discharge point is, "Lat, Long" (34.434996 N, 69.128725 E) with approx. drainage area is (1400 Km2).

Yearly summary				
Year	Min	Max	Mean	Runoff(Mm3)
1962	0.2	25.7	2.8	88.3
1963	0.2	30.7	2.23	70.3
1964	0.3	34.3	5.62	177.7
1965	0.3	37.4	7.95	250.9
1966	0.12	21.8	4.12	129.8
1967	0.12	87.2	6.03	189.9
1968	0.41	57.8	6.89	217.5
1969	0.02	32.2	3.58	112.9
1970	0.03	11.5	1.51	47.5
1971	0.03	10.8	1.14	35.73
1972	0.02	58.2	5.8	183.6
1973	0.06	47	5.45	171.5
1974	0.11	18.5	1.79	56.5
1975	0.2	32	3.24	102.2
1976	0.06	65.6	5.32	168
1977	0.01	28.4	1.84	57.7
1978	0.042	57.8	2.32	73.2
1979	0.3	35.5	2.82	89
1980	0.2	60.8	6.72	213

Table. 1: Annual discharge of Laghman river

2.3.7. Rainfall

Rainfall data of Laghman watershed “Tangi-e-Saydan” stations is provided by “MEW” (Ministry of Energy and Water)’s WAPEKA Department. The data from WAPEKA has been compared with ArcSWAT (Soil and Water Assessment Tool) developer organization and Texas A&M University global weather data which is available at (http://globalweather.tamu.edu) and 2-year and 24hours Rainfall has been derived.

2.3.7. IDF Curve

IDF (Intensity Duration Frequency) Curve data is used for runoff modeling at HEC-HMS Software, Meteorological Models, Frequency Storm. The IDF curve of “Kabul” province is calculated by “USACE – AED” (United States of America, Army Corps of Engineers – Afghanistan Engineering District) which is named (AED Design Requirements – Hydrology Studies) and was published at (January, 2010 – Version 1.6). (AED Design Requirements) is the only available public hydrologic manual and reference for engineers in Afghanistan up to now.

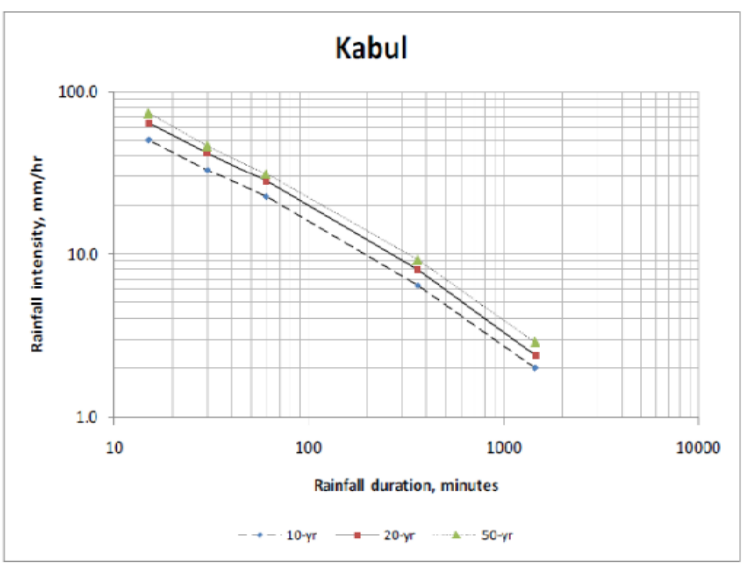

Figure. 5: IDF curve for Kaul province

3. Result

For the creation of the flood hazard zoning, hydrologic and hydraulic modeling of the relevant watercourses in combination with a detailed analysis of Laghman River´s hydro geomorphology was conducted. The usage of GIS in combination with H&H modeling is nowadays state of the art for the determination of flood risk areas. Using GIS for the processing and the display of geospatial data largely simplifies the time-consuming preparation and interpretation of model data a physical model of all watersheds that are relevant for Laghman river is created with the ArcMap extension hec-geo hms using a 5-meter resolution digital elevation model (dem).

4. Conclusion

The first and objective of this research project was to derive a maximum runoff value for Laghman from Chaghar to Pol-e-Gulbagh area which has been derived from HEC-HMS (90 m3/sec), & (113 m3/sec) as Gumbel Distribution's result (Both for 50 years return period). Gumbel's Distribution Method's result (113 m3/sec) has been used as calibrated data considering its standard error value (4.652) and its coefficient of variation which is (51.1%). Collected runoff from approx. (208 km2) of area has been used to simulate flood on (37 kilometers) of river and its banks was starting from "Chaghar" end point upto "Pol-e-Gulbagh" near point. The analysis on HEC-RAS & HEC-Geo RAS shown, 37 kilometers of river have (1.88 km2) channel area, which is being covered on flood time and when the flood reaches to its maximum value, then its overflows to banks and covers (5.59 km2) area with river channel. After deduction of channel area, it results as (3.71 km2). This means, (3.71 km2 which is equal to 371.0 hectares) areas around river channel are directly under flood hazard. By increasing boundary areas, water surface level increases and it may cause overfill and overflow which ravages more areas by flood. This may lead to significant damages and flood hazards and it should be considered when the boundary area is being specified. This is the reason which many countries do not permit building construction in such populated areas with a legal pretext or they permit with special conditions.

References

1. HEC (Hydrologic Engineering Center) (2000): HEC-HMS Technical Reference Manual, U.S. Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.
2. HEC (Hydrologic Engineering Center) (2016): HEC-HMS User´s Manual, Version 4.2, U.S. Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.
3. HEC (Hydrologic Engineering Center) (2016, CPD-69): HEC-RAS Hydraulic Reference Manual, Version 4.1, U.S. Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.
4. HEC (Hydrologic Engineering Center) (2016, CPD-68): HEC-RAS User´s Manual, Version 5.0, U.S. Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.
5. HEC (Hydrologic Engineering Center) (2013): HEC-GeoHMS User´s Manual, Version 10.3, U.S. Army Corps of Engineers Hydrologic Engineering Center, Davis, CA.
6. HEC (Hydrologic Engineering Center) (2012, CPD-83): HEC-Geo RAS User´s Manual.
7. NRCS (Natural Resources Conservation Service) (1987): Soil Mechanics Level 1, Module 3, USDA Textural Soil Classification, Study Guide, United States Department of Agriculture.
8. NRCS (Natural Resources Conservation Service) (1986): Technical release number 55. (TR55), Urban hydrology for small watersheds, U.S. Department of Agriculture, Washington, DC.
9. NRCS (Natural Resources Conservation Service) (2004): National Engineering Handbook, Part 630-Hydrology, Chapter 1,4,6, U.S. Department of Agriculture, Washington, DC.
10. AED Design Requirements: Hydrology Studies (Provisional) January 2010, Version 1.6.
11. Chin, D.A. (2006): Water-Resources Engineering, 0-13-148192-4, Pearson Prentice Hall, New Jersey.
12. IFRC (International Federation of Red Cross and Red Crescent Societies) (2016): World Disasters Report 2016, Imprimerie Chirat, Lyon, France, Available at : http://www.ifrc.org/wdr2016 (Accessed December 2016).
13. Herman, L.K. (1942): The unit hydrograph method, In Physics of the Earth, IX, Hydrology, O.E. Meinzer, ed., National Research Council, McGraw-Hill, New York.
14. K, Subramanya. (2008): Engineering Hydrology, Third Edition, 13-978-0-07-064855-5, Tata McGraw-Hill, West Patel Nagar, New Delhi.