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Hydrology assessment of Kunar Sub basin

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Abstract: In Afghanistan, surface water resources mainly originate from snow, rain and glacial melt. Natural storage of snow precipitation in the higher attitude of the Hindu Kush Mountains represents 80% of Afghanistan's water resources. The average annual volume of ground and surface water resources of the country is estimated at around 69 BCM. Surface water resources account for 53 BCM of the total water resources potential and groundwater resources for the remaining 16 BCM in the country. In addition to its mountains, the country possesses many rivers, forests, lakes, and desert areas. The five major river systems are the Amu Darya, the Helmand basin, the Harirud-Murghab basin, North basin and the Kabul basin. Only the Kabul River, joining the Indus river system in Pakistan, leads to the sea. Many rivers and streams simply empty into arid portions of the country, spending themselves through evaporation without replenishing the four major systems; others flow only seasonally. The Kabul river basin which drains into the Indus Basin covers the drainage area of the South Eastern River which contributes 17.1 BCM average water in a year, around 35% of the total surface water resources of Afghanistan. Kunarsubbasin is located in Kunar province and it lays within the catchment of KRB.

Keywords: *KRB, Kunar basin, Hydrology, Precipitation, and snow*

INTRODUCTION

Hydrological assessment of river flow is becoming progressively prevalent, responding to numerous purposes such as the establishment of early warning of floods to initiate a suitable response (Hagget, 1998 and Parker, 1996). The streamflow regime is a dynamic force in river ecosystems. Stream flow control key habitat parameters such as flow depth, velocity, and fowvolume (King, 2010). The hydrologic system, which comprises of the rotation of water from the ocean to the atmosphere and back to the oceans, is a fundamental part of the global climate system (Critchfield, 2002). Hence, any change in the climate system may not only reason changes in the hydrologic system but also extra modification of the climate itself due to the new changes in the hydrologic system. Glaciers are very sensitive to climate change consequently they can be reflected as a good indicators of past climate changes (Nesje, 2000 and Critchfield, 2002). Afghanistan is a country which's about 85% of the population is involved in rain-fed agriculture, 98% of all water diverted from the rivers is used in agriculture and almost 60% of water diverted for use in irrigation is lost due to seepage and due to poor on-farm water management. In many cases, the same irrigation canal is also used for providing drinking water to the massive majority of the population (Fipps, 2006). Snowmelt during the late spring and summer is key to substituting water resources, mainly for major rivers in the east and northeast. The Hindu Kush's glaciers are melting due to rising temperatures caused by climate change. it reduces a natural water storage mechanism that safeguards against drought in the Amu Darya and Kabul River Basins. Higher evaporation amounts caused by high temperatures will considerably decrease water availability over the course of the century (USAID, 2019 and Bilal, 2017). Afghanistan has many water resources and its geography provides substantial occasions for their manipulation.Inadequate infrastructure and a lack of capacity limit Afghanistan's ability to store, manage, and develop its water resources. Afghanistan's 90% irrigation is managed through traditional, community-based Miraabsystem, which are self-regulating of broader national or regional arrangements and limited in their effectiveness (Favre, 2004). Afghanistan is covered by a relatively aggregate network of rivers although most of the smaller rivers only run with water during rainy periods or during the thaw. They are dry in summer. The most important rivers run from the central mountains in all directions (Tunnermeir and Houben, 2005). Afghanistan manages its surface waters through five basins, Kabul, Helmand, Harirud-Murghab, Northern, and Amu Darya. The Hindu Kush Mountains form the headwaters of all river basins. Most basins conclude their flows in low-lying deserts, wetlands, or inland lakes and seas. However, the Kabul River, which is a tributary of the Indus River, drains to the Arabian Sea (USAID, 2019 and Vincent, 2003). The source of most of Afghanistan's surface water is rainfall and winter snowfall at high altitudes. It is documented that long periods of summer drought limit the area under crop cover (Freitag, 1971). According to the European Union Emergency Humanitarian Aid (WUEHA), in a time frame of past 15 years, at least three periods of prolonged drought have prevailed in Afghanistan, thus with a frequency of 1 in 5 years. In recent years, however, there has been a marked tendency of this drought cycle to occur more frequently. Since 1960, the country experienced drought in 1963-64, 1966-67, 1970-72, and in 1998-2006. This situation has been intensified by decreasing rainfall amounts. Increased frequency of drought has been accountable for the failure of rain-fed crops which is estimated to constitute up to 80 percent of the cultivated land in Afghanistan and therefore this has large implications to the food security and livelihood of millions of farming households, especially those in the north, west and central regions of the country (CCDPWG, 2008). Almost 90% of Afghanistan's land area is enclosed in five major river basins. Kabul River basin lies in the north-eastern part of the country that flows west to east and joins the Indus River in Pakistan's northwest frontier province. Even though the Kabul basin encompasses only 12 percent of the area of the country (Favre and Kamal 2004 and Sediqi et, al, 2018). Over 35% of the population in the country lives and depends on the natural resources in the Kabul river basin. KRB has also the highest population growth rate in the country. Kabul, the capital of the country, and other important trade and commercial centers are located within the basin. The Kabul River flows in eastern Afghanistan and northwestern Pakistan. It is approximately 700 kilometers long, of which's 560 kilometers located in Afghanistan. The eastern part of the basin which is originated from Pakistan has higher elevations and covered by snow most of the year and the elevation variation is about (400-6,000 m). This part of the basin has significant potential to generate hydropower (Rasooli and Dongshik, 2015 and FAO, 2010). The major tributaries of the Kabul River consist of Logar, Panjshir, Kunar, Alingar, Bara and Swat rivers. The Kabul River is little more than a trickle for most of the year, but surges in summer due to melting 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 Chitral, Pakistan and after flowing south into Afghanistan it is met by the Bashgal river flowing from Nurestan. The Kunar meets Kabul near Jalalabad (Arfan, 2017). Theclimate in the KRB is semi-arid and strongly continental with large variations in the precipitation and temperature patterns. The average annual precipitation of the basin is 330 mm while the annual average temperature varies between 10 to 13°C. Almost all of the precipitation in the basin occurs during the winter. This precipitation in the upper mountainous area is in the form of a snowfall that sustains the river flow and groundwater recharge through snowmelt. Rivers run dry during the period when the snow has completely melted. No continuous water flow is perceived in the rivers flowing through the Kabul basin (Tunnermeier and Houben, 2003).

Surface water resources investigations in Afghanistan started in 1946. In 1964, the U.S. Agency for International Development (USAID) with the collaboration of the Water and Soil Survey Authority of Afghanistan, developed a plan for a nationwide network of stream-gaging stations; subsequently, 149 stations were installed in five river basins of the country. Unfortunately, as a result of war hydrological network has been destroyed. In 2007, the rehabilitation of the country's hydro-meteorological network started and 183 hydro-meteorological stations were installed. At present time, the hydrological data is being collected and is processed by NWARA. For the Hydrological of this study, data were collected from NWARA. Overall the hydro-meteorological data from four observation stations were available from 2008 to 2020 water years and historical data from 1959 to 1979 years.

Climate

The climate of Afghanistan is a dry continental climate. There is a great variation in climate due to the presence of rugged topography. The average temperatures vary from minus 10 °C in winter to 34 °C in summer. About 70 percent of precipitation occurs in winter (Middle of December to middle of March), much of which falls as snow in the central mountainous regions. Additional 30 percent precipitation falls in spring (Middle of March to Middle of June) and snowmelt runoff generally in spring and summer months. The rainfall is one of the direct water inputs for agriculture in Afghanistan. The Kunarbasin receives nearly 469 mm in the year. The monthly distribution of rainfall shows the rainy season from November to May with a high in February /March and remains dry during June to September. The monthly rainfall distributions of Kunarbasin at Nawabad station are shown in table 1 and figure 1.

Table 1: Monthly Rainfall Distributions of Provinces and Available Meteorological Stations (NWARA)

Month	Asmar (mm)	Chaghasarai (mm)	Nawabad (mm)
January	39	39	37
February	85	88	81
March	80	73	72
April	66	71	66
May	44	40	39
June	25	23	17
July	26	31	22
August	26	32	35
September	19	22	22
October	25	24	24
Nov	24	23	21
Dec	17	16	11
Total Annual	477	483	446

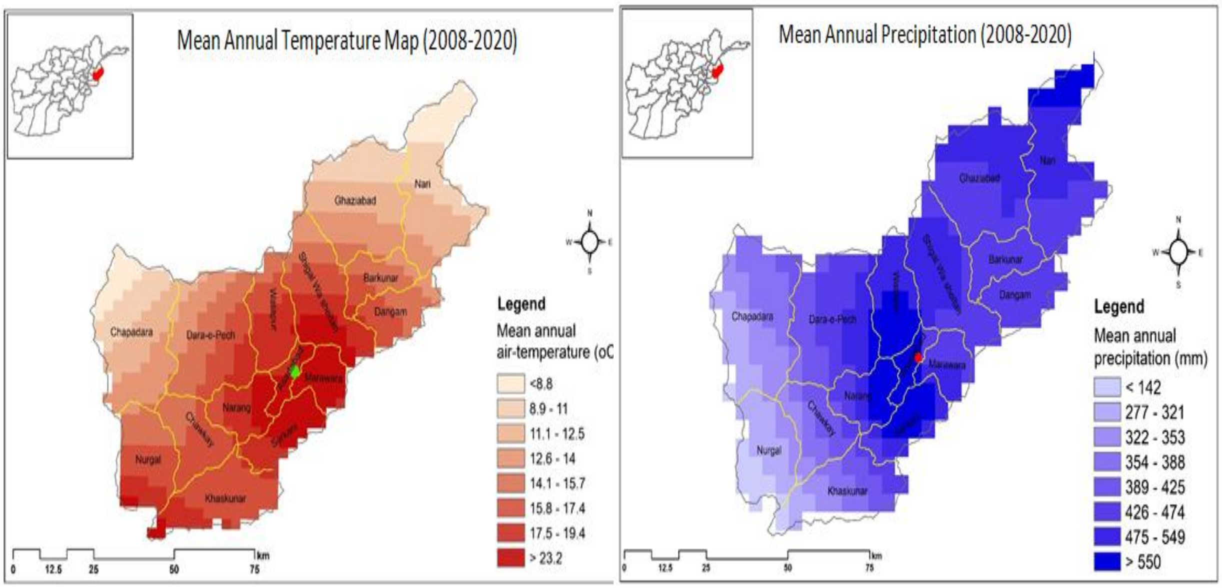

Figure 1: Mean annual temperature and precipitation distribution

In the figure, 2 climate graph of the study area is shown. In cold winters (December up to the middle of March) with significant snowfall and dry summer is the dominant characteristic of the climate. The study region receives an average annual precipitation of 469 mm, almost all of the precipitation occurs during the October to June period. The hydro-meteorological stations observed data showing relativity high temperatures during July about 40°C, and low temperatures in winter during January 2°C, and the annual average temperature was recorded 20°C (Figure 2).

The higher portion of the basin receives a significantly high amount of precipitation in the form of winter snow while the downstream areas to somewhat receive less precipitation. During dry session, snow and glacial melt contribute to the stream flow and causing significant of river flow happened in May to October.

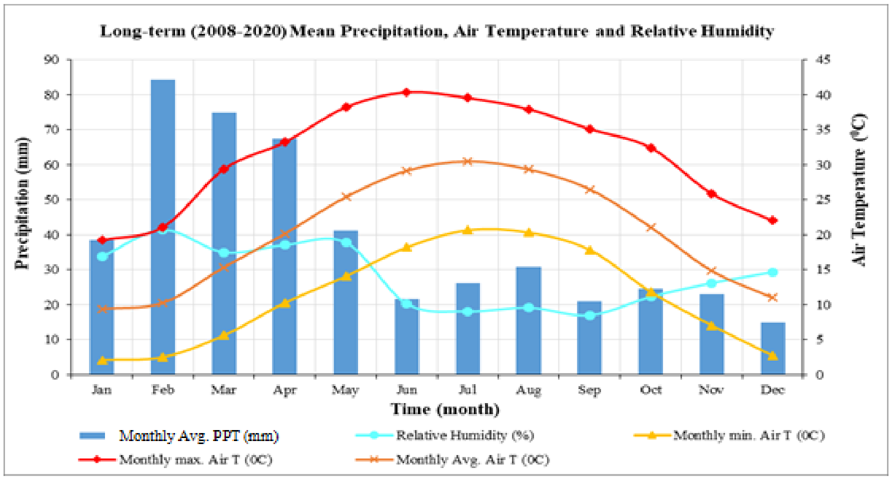

Figure 2: Climate graph in the Kunar sub-basin

Precipitation and Potential Evapotranspiration

The potential evapotranspiration (PET) for the study area is calculated based on the Penman-Monteith method (Allen et al. 1998). In Figure 3, long-term precipitation and potential evapotranspiration are compared, as the figure indicates a high amount of potential for evapotranspiration in the area (1,270 mm/annual); the precipitation exceeds the potential evapotranspiration during the first months of the year (January to April) and decreases for the remaining period. Although, the potential evapotranspiration is still increasing. Generally, during six months of a year PET is higher than precipitation (May – October)

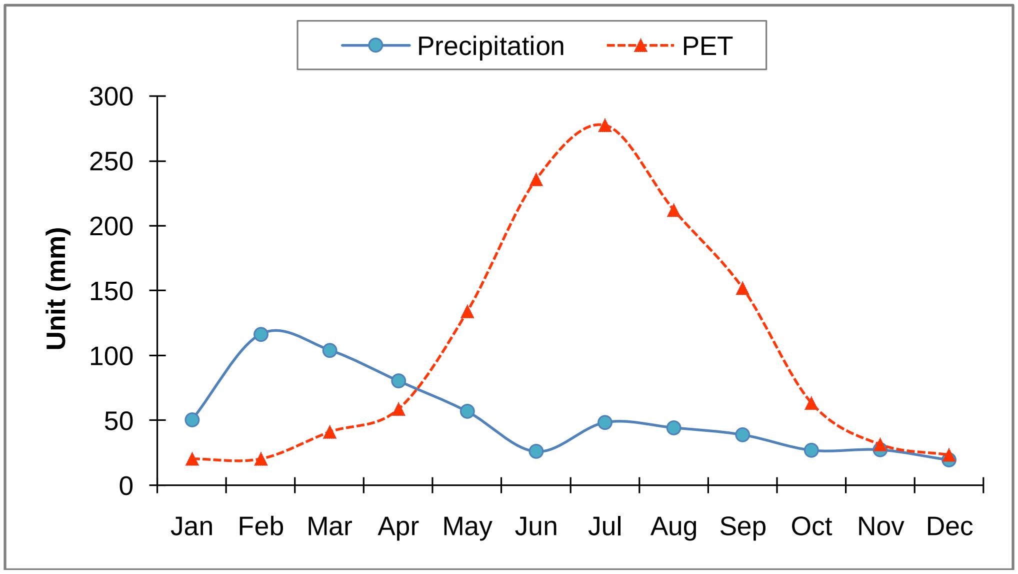

Figure 3: Long-term average precipitation and potential evapotranspiration (2009-2018)

Kunar River

Kunar River is located in Kunar province and it lays within the catchment of KRB. The catchment area of Kunar River is nearly 19,036 km2 at Asmar Hydrological Station and 25,133 km^2 at Pul-i-kama

Station. Hydrologialcal data available from 1959 to 1979 and (2008 to 2020), the annual average flow of this river is 14.2 BCM and the minimum was recorded 12.2 BCM. The maximum river discharge in Kunar River at Pul-i-Kama stations is observed at 2,350 m^3/sec in 1973.

Table, 2 indicates the mean monthly runoff volume in the upstream stations (Nawabad) and downstream area Pul-i-kama station. The mean annual runoff volume of 16.0 BCM at the Nawaband is available in a normal year and 14.2 BCM surface water at the Pul-i- Kama station. The below figure illustrates the compression of the long-term mean monthly flow of the two stations. It is observed that overall the river flow decreases at the Pul-i-kama Station and the highest reduction is observed during the peak irrigation period (April to August).

Table 2: Monthly Flow of Kunar River (Source: NWARA)

Months	Mean runoff at Nawabad (MCM)	Mean runoff at Pul-i-Kama (MCM)	Changes (MCM)
Oct	743	648	-95
Nov	606	488	-119
Dec	497	440	-56
Jan	434	399	-35
Feb	380	343	-37
Mar	615	483	-132
Apr	1,251	916	-335
May	1,951	1,754	-197
Jun	2,835	2,698	-137
Jul	3,231	2,941	-290
Aug	2,361	2,070	-290
Sep	1,123	1,037	-85
Total	16,026	14,218	-1,808

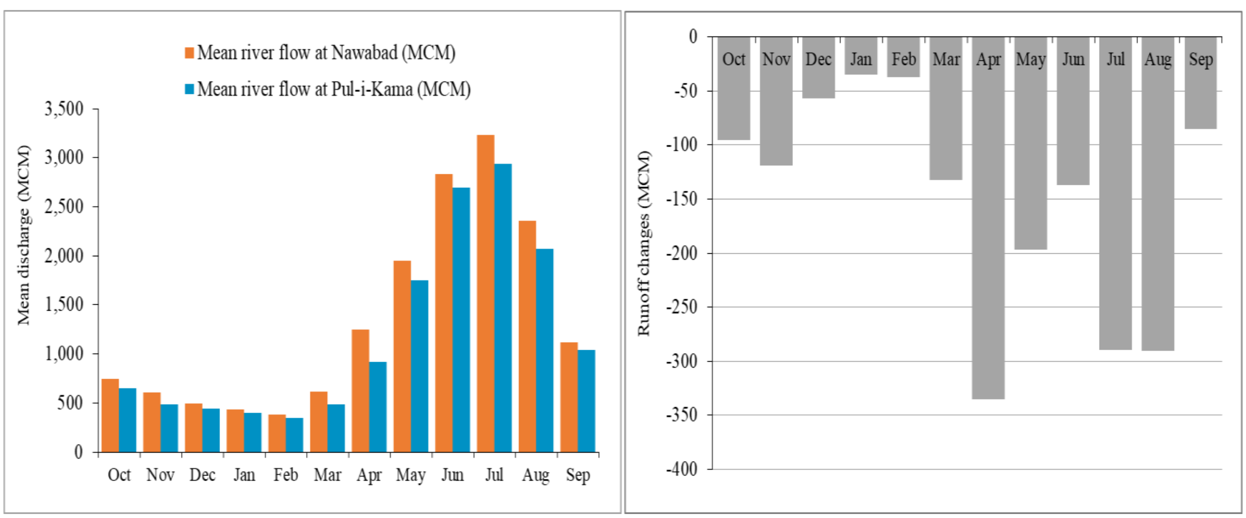

Figure 4: Mean monthly hydrograph of Kunar River at Nawabad and Pul-i-Kama Stations

In Figure 4, 5 the discharge hydrographs during the 2008 to 2020 water years are analyzed. The figures show that river flow at Nawabad Station records high flow with the maximum peak discharge of 3,232 m_3/sec during the high flow season in 2019. Similarly, in Pul-i-Kama hydrological station 1,709 m3/sec maximum discharge is observed during 2018 year.

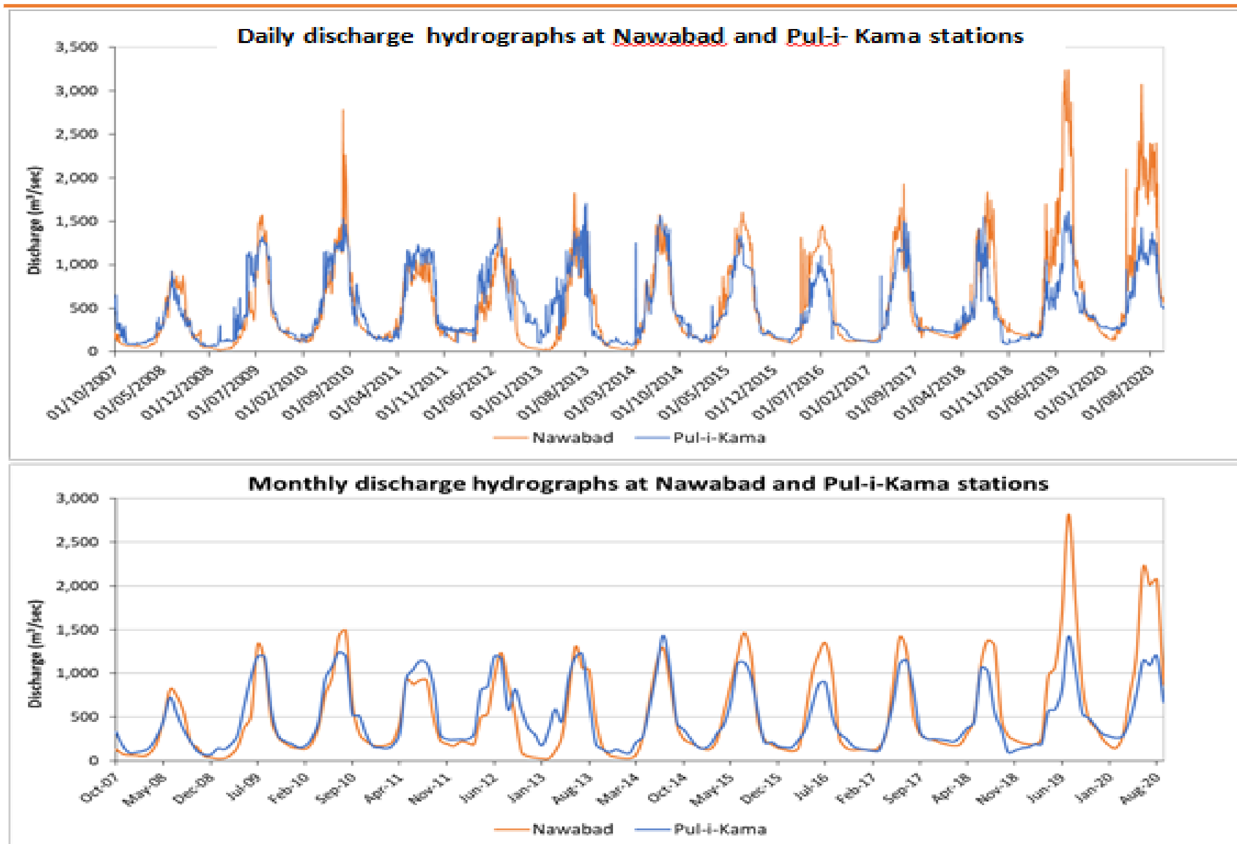

Figure 5: Daily and mean monthly hydrographs of Kunar River at Nawabad and Pul-i-Kama tations (2008-2020) water years

Flood Frequency Analysis

The Gumbel's distribution model was used for flood frequency analysis using the annual maximum discharge of Kunar River at Nawabad hydrological station in the upstream area for the period of 2008 to 2020 water years. Gumbel's distribution model is one of the statistical approaches that is mostly used to analyze flood data. The results from the Gumbel's distribution using return periods (T) of 2yrs, 3yrs, 5yrs, 20yrs, 25yrs, 50yrs, 100yrs and 500yrs; the expected estimated discharges obtained are: 1497 m3 /sec, 1905 m3 /sec, 2360 m3 /sec, 3497 m3 /sec, 3653 m3 /sec, 4188 m3 /sec, 4720 m3 /sec and 5948 m3 /sec.

Table 3: Maximum discharge and return period based on Gamble method

Return period (years)	**2**	**3**	**5**	**20**	**25**	**50**	**100**	**500**
Max Discharge (m3/sec)	1,497	1,905	2,360	3,479	3,653	4,188	4,720	5,948

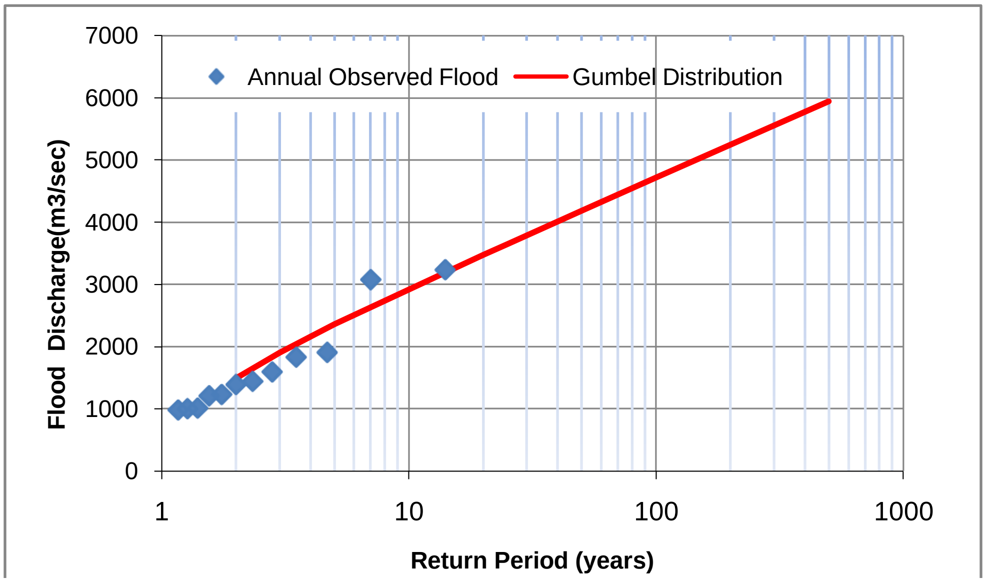

Figure 6: Maximum discharge and return period based on Gamble probability distribution function at Nawabad station, Kunar River

The comparison of stream flow hydrograph in two periods (1977 – 1979) and (2008 – 2020) at Nawabad hydrological station is presented in (Figure,7). The river hydrograph within the two periods gives a sharp difference in the flow regime of the river. The annual flow during the meting season in June and July months has reduced. For the rest of the months, the change of flow regimes is similar comparing to (1977 – 1979) period.

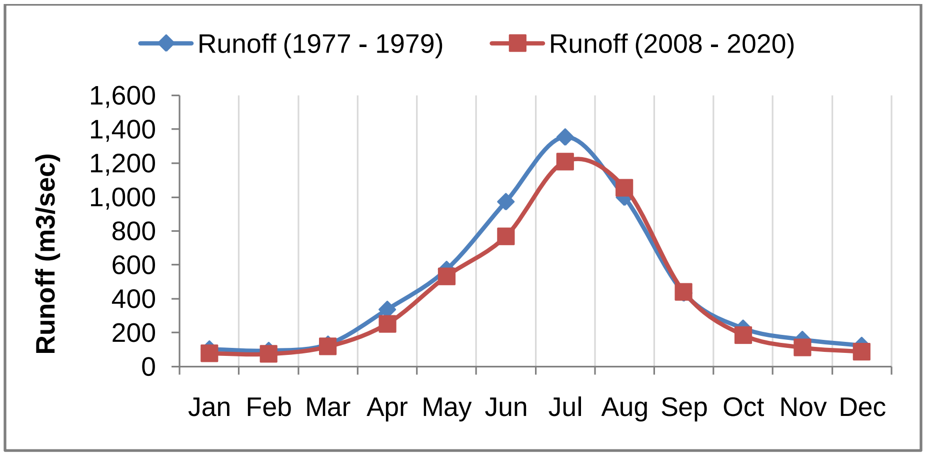

Figure 7: Kunar river basin at Nawabad Station, flow runoff duration characteristics

Table 4: River flow and percent probability equaled or exceedance

No	Time Exceedance (day)	Runoff 1977 - 1979 (m^3/sec)	Runoff 2008 - 2020 (m^3/sec)
1	36	1,247	1,357
2	73	876	1,043
3	109	561	734
4	146	388	468
5	182	253	286
6	219	170	194
7	255	140	159
8	292	116	135

No	Time Exceedance (day)	Runoff 1977 - 1979 (m^3/sec)	Runoff 2008 - 2020 (m^3/sec)
9	328	100	121
10	365	84	98

In Table river discharge and exceedance, time is shown. It is obvious that the river flow is averagely available throughout the year (365 day) is 98 m3/sec, year as well as during 50 percent of the year there is 286 m3/sec water is available in the river as normal river flow. The 886 m3/sec river discharge can be denoted as high flow threshold and 144 m3/sec for low flow during a year.

The comparison of stream flow hydrograph in two periods (1968 – 1979) and (2008 – 2020) at Pul-i-Kama hydrological station, the outlet of the Kunar sub-basin is presented in (Figure 8). The river flow increases. Besides, the river hydrograph within two periods differs in their flow regime of the river. The maximum annual flow has decreased compared to the historical period, and during snow melt period, significantly during (March to July) which shows earlier snow melt. For the rest of the months the change of flow regimes is similar comparing to (1968 – 1979) period.

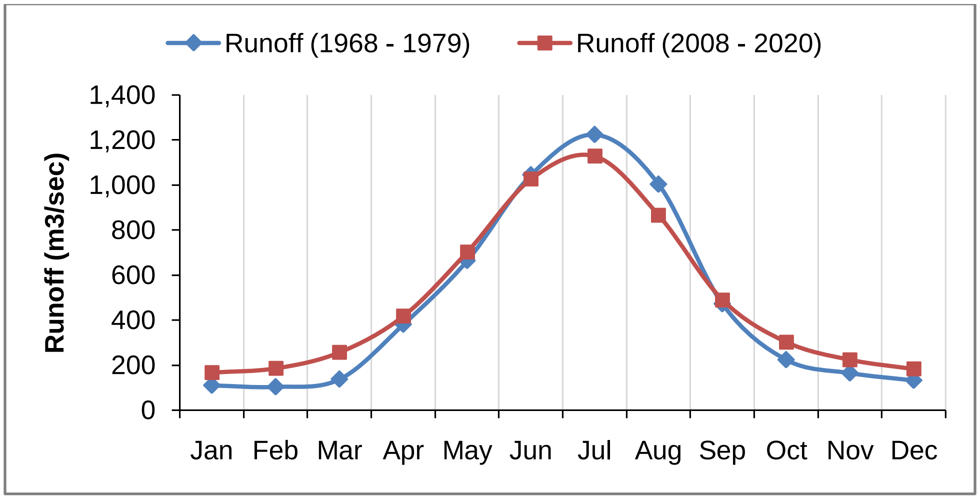

Figure 8: driver hydrograph at Pul-I Kama station (1968-1979, 2008-2020)

Table 5: River flow and percent probability equaled or exceedance

No	Time Exceedance (day)	Runoff 1968 - 1979 (m3/sec)	Runoff 2008 - 2020 (m3/sec)
1	36	1,183	1,118
2	73	928	891
3	109	649	656
4	146	430	484
5	182	259	349
6	219	180	247
7	255	143	213
8	292	118	175
9	328	106	157
10	365	87	120

In Table 5, river discharge and exceedance time is shown. It is obvious that the river flow is averagely available throughout the year (365 days) is 120 m3/sec, year as well as during 50 percent of the year there is 349 m3/sec water is available in the river as normal river flow. The 798 m3/sec river discharge can be denoted as high flow threshold and 191 m3/sec for low flow during a year.

Snow Cover Analysis

The MODIS snow-covered data in the study area from (2001 – 2016) was aggregated to monthly average time series, the variation of the snow-covered area is shown in the below figure. The minimum snow-covered area is observed in August when only 16 percent of the total basin area is covered by snow. During September the snow-covered area starts increasing till November, in February average up to 83 percent of the basin is covered by snow.

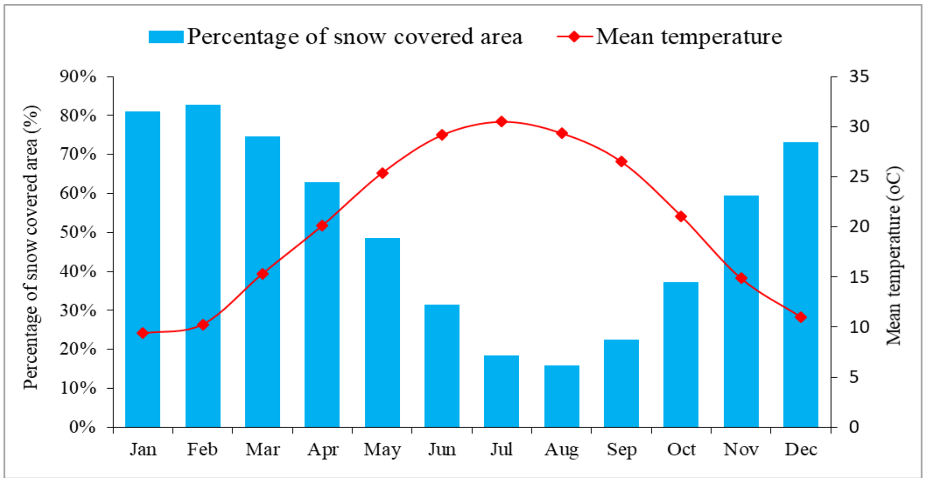

Figure 9: Long-term average monthly snow coverage percentage and mean air-temperature

The study area snow cover analysis indicated that the catchment area receives extensive snow precipitation during the year, the snow cover peaks in the winter (November to February) and starts melting during spring and low precipitation period which feeds the downstream river which is the life-line of thousands of people in Afghanistan and outside the country.

Conclusion

Afghanistan has many water resources and its geography provides significant opportunities for their exploitation. Insufficient infrastructure and a lack of capacity, limit Afghanistan’s ability to store, manage and develop its water resources. 90% of Afghanistan’s irrigation today is managed through traditional, community-based mirabsystem, which are independent of broader national or regional arrangements and limited in their efficiency. Afghanistan is covered by a relatively dense network of rivers although most of the smaller rivers only run with water during rainy periods or during the melting. They are dry in summer. The most important rivers run from the central mountains in all directions. Afghanistan surface waters are divided in to five basins, Kabul, Helmand, Harirud-Murghab, Northern, and the Amu Darya. The Hindu Kush Mountains form the headwaters of all river basins. Most basins conclude their flows in low-lying deserts, wetlands, or inland lakes and seas. At the country level surface water resources mainly originate from snow, rain, and glacial melt. Natural storage of snow precipitation in the higher attitude of the Hindu Kush Mountains represents 80% of the country's water resources. Almost 70 percent of precipitation occurs in winter (Middle of December to middle of March), much of which falls as snow in the central mountainous regions. Additional 30 percent precipitation falls in spring (Middle of March to Middle of June) and snowmelt runoff generally in spring and summer months. The monthly distribution of rainfall shows the rainy season from November to May with a high in February /March and remains dry during June to September. The Kunar basin receives an average annual precipitation of 469 mm, almost all of the precipitation occurs during the October to June period. The hydro-meteorological stations observed data shows relativity high temperatures during July about 40°C, and low temperatures in winter during January 2°C, and the annual average temperature was recorded 20°C. The higher portion of the basin receives a significantly high amount of precipitation in the form of winter snow while the downstream areas to somewhat receive less precipitation. During the dry session, snow and glacial melt contribute to the stream flow and causing significant of river flow that happened in May to October. The mean annual runoff volume of 16.0 BCM at the Nawabad is available in a normal year and 14.2 BCM surface water at the Pul-i- Kama station. It is observed that overall the river flow decreases at the Pul-i-kama Station and the highest reduction is observed during the peak irrigation period (April to August). The discharge hydrographs during the 2008 to 2020 water years are analyzed. The analyzed show that river flow at Nawabad Station records high flow with the maximum peak discharge of 3,232 m3/sec during high flow season in 2019. Similarly, in Pul-i-Kama hydrological station 1,709 m3/sec maximum discharge is observed during the 2018 year. The results from the Gumbel's distribution using return periods (T) of 2yrs, 3yrs, 5yrs, 20yrs, 25yrs, 50yrs, 100yrs, and 500yrs; the expected estimated discharges obtained are: 1497 m3 /sec, 1905 m3 /sec, 2360 m3 /sec, 3497 m3 /sec, 3653 m3 /sec, 4188 m3 /sec, 4720 m3 /sec and 5948 m3 /sec. The FDC during 2008 – 2020 is slightly higher, especially in the high flow and medium flow period compared to the low flow period where the increase of the river flow is less significant. The river hydrograph within the two periods gives a sharp difference in the flow regime of the river. For the rest of the months, the change of flow regimes is similar comparing to 1977 – 1979 period. The comparison of flow duration curve in two periods 1968 – 1979 and 2008 – 2020 at Pul-i-Kama hydrological station, the outlet of the Kunar sub-basin, and a comparison of stream flow hydrograph in the same periods is analyzed. The river hydrograph within two periods differs in their flow regime of the river. The maximum annual flow has decreased compare to the historical period, and during snow melt period, significantly during (March to July) which shows earlier snow melt. The rest of the months the change of flow regimes is similar comparing to 1968 – 1979 period. The minimum snow-covered area is observed in August when only 16 percent of the total basinarea is covered by snow. During September the snow-covered area starts increasing till November, in February average up to 83 percent of the basin is covered by snow. The study area snow cover analysis indicated that the catchment area receives extensive snow precipitation during the year, the snow cover peaks in the winter (November to February) and starts melting during spring and low precipitation period which feeds the downstream river which are the life-line of thousands of people in Afghanistan and outside the country.

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