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Hydrological Response and Water Balance Assessment of the Kabul River Basin Using SWAT

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Abstract: Human as well as the ecosystem is extremely vulnerable to address the demands of freshwater resources in the 21st century as per the changing climate. The future climate scenarios of 21st century show an overall intensification of the Water Resources of upper Kabul River Basin (KRB) with widespread changes expected in this region. To estimate the runoff of the water resources of KRB, this study aims at a research level due to the severe need of water resources, water and power development authority (WAPDA) and climate data from Pakistan meteorological department has been used. Soil and Water Assessment Tool (SWAT) is the main model used in this study, it is a semi distributed model. The model was calibrated and validated at Khairabad outlet gauge at Nowshera, with NSE values of 0.84 and 0.72, R^2 of 0.85 and 0.72, and PBIAS of 6.8% and 5.2% respectively, for the calibration and validation periods respectively, which shows that the model was satisfactory. Annual ET in 2000 was 159 m³/s, which is the same as in 2000, indicating an energy-limited regime, with mean annual streamflow dropping from 416 m³/s in 1993 to 159 m³/s by 2000 as ET/P increased from 26% to 45%, exhibiting progressive water stress during the drying period. The annual precipitation ranged between 541 and 1,089 mm with snowfall contributing between 26%–37% of the annual precipitation, which is very important in maintaining stream flow during spring and summer from the delayed snow melt in the Hindu Kush mountain range. As evident from the flow duration curve, the hydrology of KRB was highly flashy and very seasonal: Flows were high during the period of April to September (snowmelt and monsoonal), and low during the remaining months of the year. The findings give a quantitative hydrological baseline that is important for water resource management and flood preparedness in this strategically important transboundary basin.
Keywords: Water balance, Kabul river basin, Soil and Water assessment Tool (SWAT), streamflow.

I. INTRODUCTION

A. Background

Kabul River Basin has been suffering extreme nature events like melting of snow and rainfall causing destructive floods [1]. It is crucial to control the relationship between the precipitation and the resulting runoff, and finally, the water balance in order to manage the flood that might affect the people and their activities. However, there are certain difficulties associated with the nature of the hydrological data and modeling approach, and it raises concerns about the reliability of decisions, especially for various catchments such as KRB [2]. Climate change was expected to worsen the existing water resources stress and widen the gap between water supply and demand. For areas that experience imminent shortage in supply compared to demand of water resources, there are expected to be higher demands and reduced supplies of water due to increased warming conditions. The impact of climate change on water resources of the Kabul River Basin needs to be assessed. Such an assessment will help in determining the likely water supply and help in addressing the various problems that water managers normally face, including climate change.[3]

To meet this requirement, studies encourage using Arc SWAT Model to evaluate the impact of climate change on the accessibility of water resources in the Kabul River Basin, Scenario analysis using mathematical models can be used to evaluate the impact of climate change on the surface water system [4]. Population growth in the last century has resulted in adverse effects on the water resources because of climate change in the Kabul River basin, the consumption of nonrenewable energy sources has resulted in an increase in demand for water. Aquifers have depleted due to the rapid increase of groundwater utilization in response to the deteriorated surface water resources. For example, depletion of 4 meters in Paghman and central Kabul, and 2 meters in Shomali and Panjshir occurred. This depletion process has resulted in the depletion of shallow wells systems in the entire basin. Competition for water provisions, especially between city expansion and agricultural activities, is becoming more intense due to climate change.

CO2 and other greenhouses gases are responsible for causing global warming from 19th century. Due to changes in precipitation patterns and evapotranspiration, global warming affects water supplies and demands, especially those for the urban and agricultural uses. To minimize the impact of global warming on water resources it is necessary for the researchers and decision-makers to understand their interactions.However, the melting of the snow will be fastened owing to the increasing temperature in the summer season as a result of global warming and lack of storage capacity in the river basins. In the final stage, the groundwater resources will be progressively harassed to meet the increasing demands in each sub-area [5]

Hydrological modeling is necessary in understanding rainfall runoff relationship, but its efficiency is affected by numerous constraints and parameters. However, depending solely on a single statistical parameter to evaluate physically based models cannot be a sufficient assessment [6]. Therefore, a viable approach is needed to seizure the complexities of the hydrological conduct within the KRB.

To address these challenges, researchers have adopted a multisite calibration methodology that utilizes distinct sets of sensitive parameter values to account for the physio-climatic heterogeneity present in the basin. The reason behind choosing this model is because of the differences observed in hydrological behavior of the two parts of the river basin and thus this makes the model more accurate.

As far as the estimation of runoff is concerned, Soil and Water Assessment Tool (SWAT) has become an important instrument. By integrating the information about hydrological process, land uses, soil and climatic inputs, the tool facilitates simulation that provides a better understanding of the effects of climate changes. The use of this tool in the KRB will definitely lead to improved understanding of runoff estimation. The Kabul River Basin is of great importance for Afghanistan [7]. It serves as a vital water source for agricultural activities, providing sustenance for local communities. Furthermore, the importance of the basin is enhanced due to the fact that it serves as a means for hydroelectric power production, and hence meets some of the energy requirements of the nation. This clearly calls for an understanding of the impacts of climate change in order to formulate appropriate measures in order to protect the water resources from any form of degradation.

It is in view of the above factors that many researchers have carried out studies forecasting the future flow in the KRB until 2030 under RCP 4.5 and 8.5 scenarios, whereby the maximum reduction in the stream flow is projected to be between 5% and 8% in most KRB streams.

FIGURE 1: INCREASE IN FLOODS AND DROUGHTS DUE TO CLIMATE CHANGE [8]

Climate change is a major concern for the Kabul River Basin, causing more frequent floods and droughts. This has prompted researchers to look at the connections between rainfall and runoff, with the goal of developing infrastructure designs and water management strategies that can adapt to these changes. However, challenges with hydrological data and difficulties in modeling have raised concerns about the accuracy of the results. To address these challenges and improve the accuracy of runoff estimation, researchers plan to use the SWAT tool and a multisite calibration approach. This is necessary because the Kabul River Basin is vital to Afghanistan's ecology and economy. Understanding how climate change is affecting the basin is vital to ensuring its sustainability.

B. Scope and significance of work

The assessment of hydrological responses and water balance calculation is important for the reservoir operation as KRB has several important dams which serves as crucial sources of water resources for agriculture and hydropower. Working on water balance of KRB is very essential for the irrigation planning as the downstream part of KRB (Charsadda, Nowshera and Peshawar) is very fertile and dependent of good irrigation system for crops. The quantification of the hydrological responses provides a good foundation decision making for several sectors that are water dependent (including drought preparedness, flood management and ecosystem sustainability) in KRB.

C. Hydrology of Rivers

Water is critical for life on Earth, and understanding it is vital. Hydrology, the study of water, has emerged to help us grip the intricacies of water and its uses. This field investigates water's presence, distribution, movement, and properties within Earth's systems. It also examines the complex relations between water and the environment throughout the hydrological cycle.

Water is used in a number of different ways, including domestic, commercial, industry, agriculture, and energy. Water, once used, comes back into the natural water cycle. Cities generally depend on a source of water, such as a river, lake, or reservoir, close by to provide their supply of water. This study will focus on the water source in the Kabul River basin in Asia. There is a great benefit in being associated with other Asian river basins [5].

D. Application of runoff estimation for Water Resources Engineering

Planning for Water Supply: Calculations of the amount of water that runs off help plan the water supply system since it determines the availability of water. In addition, it is quite evident that the calculation of runoff helps in predicting and dealing with floods, thereby making proper use of the flood control measures. Water Resource Management: Issues of water movement and soil.

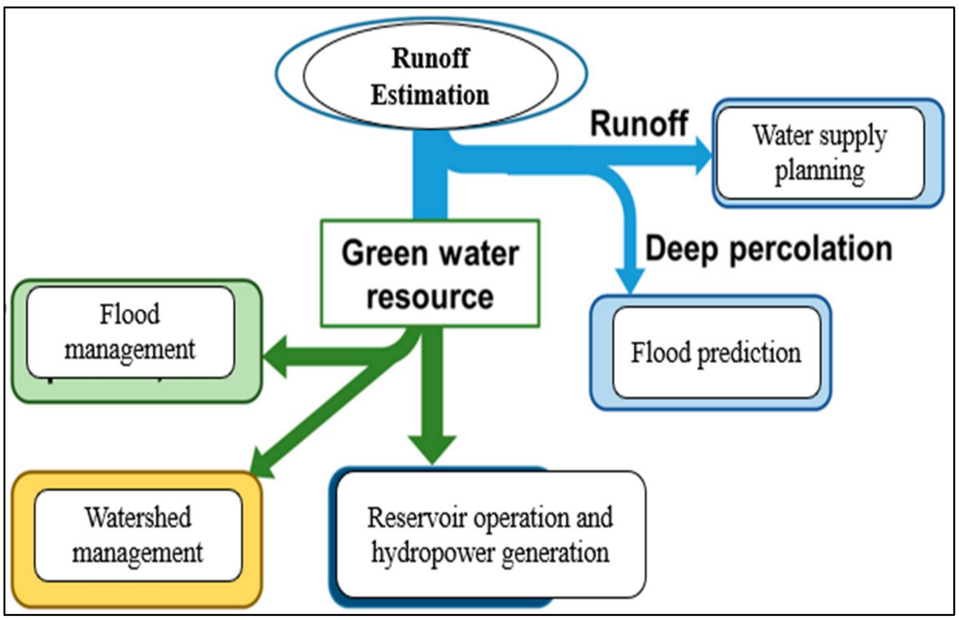

FIGURE 2: IMPORTANCE OF RUNOFF ESTIMATION FOR WATER RESOURCES ENGINEERING

E. Problem Statement

The rising instances of floods and droughts in the Kabul River Basin become an obvious pointer regarding the relevance of the runoff estimation. Secondly, it is important to say that the analysis of rainfall-runoff relations is necessary for the development of infrastructure projects. At the same time, there are certain uncertainties associated with hydrologic data and modeling which raise doubts about the validity of results obtained. It becomes important to overcome these issues using the multisite calibration approach and SWAT model. In view of the importance of the Kabul River Basin for Afghanistan and for the ecology of Pakistan and economy, the move to get an accurate runoff estimation becomes vital.

II. LITERATURE REVIEW

Hydrological modelling has emerged as an essential tool for understanding water balance dynamics and streamflow behavior across diverse climatic and physiographic settings, with physically based semi-distributed models such as SWAT demonstrating consistent applicability across catchments ranging from humid temperate to arid mountain environments worldwide [9], [10].

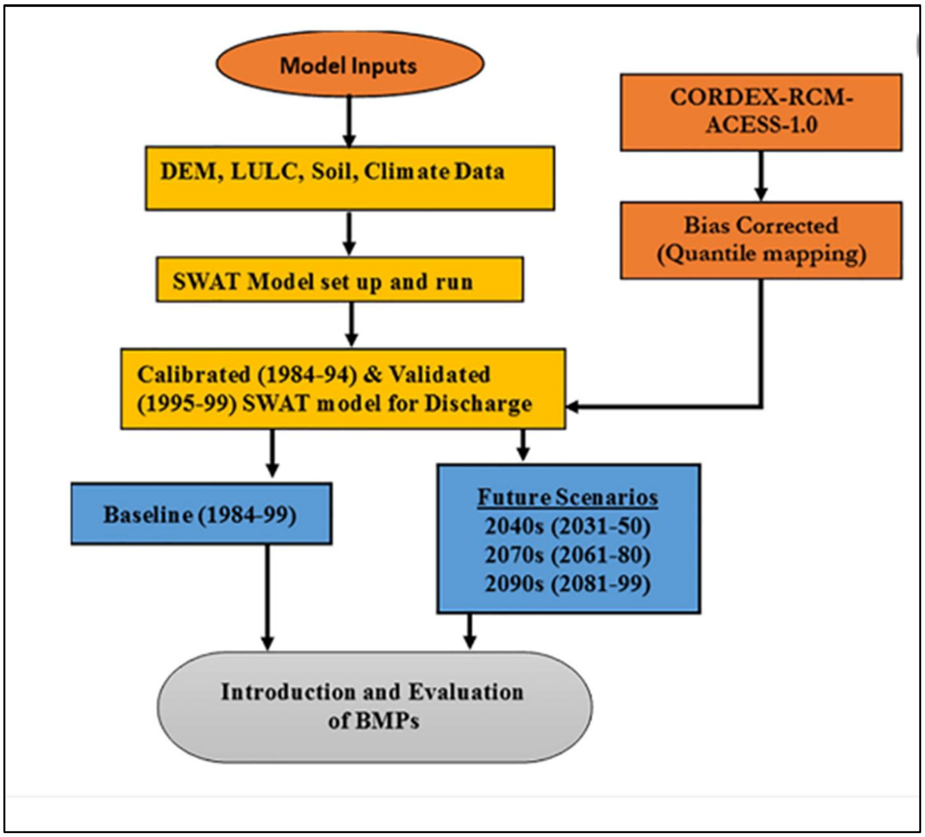

FIGURE 3: METHODOLOGY BY [11]

As per [12] freshwater availability have highlighted the increasing vulnerability of snow-dominated river basins to climate variability, (global reports) with studies projecting that declining snowpack and shifting precipitation regimes will substantially alter the seasonal timing and magnitude of streamflow in mountain-fed river systems throughout the 21st century.

Studies conducted by [13] across Afghan and Pakistani river basins have documented significant inter-annual and decadal variability in precipitation driven by the competing influences of the South Asian monsoon and mid-latitude western disturbances, with periods of prolonged drought such as 1999–2002 resulting in dramatic reductions in streamflow and groundwater recharge across the region . The SWAT model has been extensively evaluated across a wide range of international river basins and consistently demonstrated its capability to simulate water balance components including surface runoff, lateral flow, groundwater contribution, evapotranspiration, and snowmelt with satisfactory performance metrics when adequately calibrated against observed streamflow records [14]. SWAT, developed by the USDA, is normally used for global hydrological process simulations, often focusing on large river basins and land use management areas. Its ability to work across different time scales makes it suitable for simulating changes in water accessibility, quality, and climate. Extensive support tools and interfaces have elevated the versatility of SWAT for basin-scale analysis. However as per the study conducted by [15] challenges arise when using SWAT in heterogeneous basins with varying data inputs and spatial parameter variations. Manual calibration and sensitivity analysis can be time-consuming, particularly for composite catchments with numerous HRUs (Hydrologic Response Units). Water balance assessments of major South Asian river basins have demonstrated that evapotranspiration in semi-arid mountain catchments is predominantly energy-limited rather than water-limited, with actual ET remaining relatively stable across wet and dry years while precipitation variability is primarily expressed through changes in runoff and groundwater recharge rather than evaporative losses [7]. Despite these limitations, SWAT remains a valuable tool for simulating a wide range of hydrological processes and supporting various land and water management applications [16].

The use of SWAT in data-poor transboundary basins in Central and South Asia has brought into sharp focus the crucial need for the integration of data from various sources to account for spatial variability in precipitation input through the combination of ground-based observation data and grid-based climatic data like GPCC and CHIRPS [17], [18].

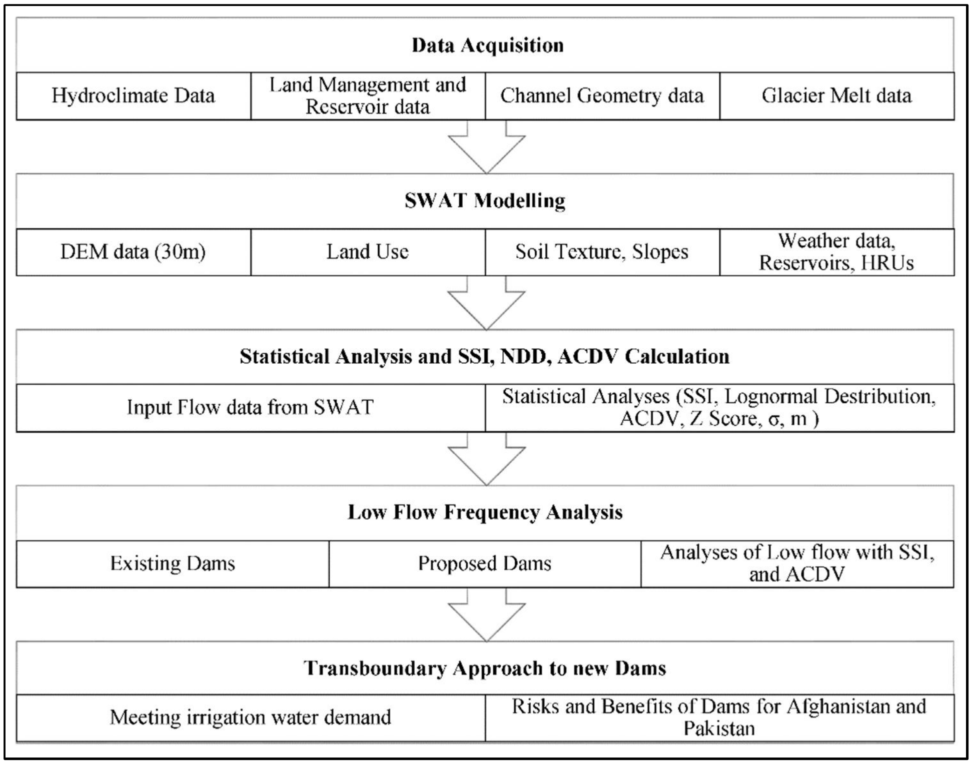

FIGURE 4: METHODOLOGY USED BY [16]

Climate change is the worlds on of the most pressing issue, with impacts on water resources that are uncertain and differ from place to place. The HKKH mountain region has an increased vulnerability since it serves as the source region for several big rivers as well as having an abundance of glaciers. Alterations in water flow in rivers can be attributed to the climate variations in the HKKH mountain region. There is an expectation of prolonged warming affecting the mountain's snow and ice supply [19].

Through the Soil and Water Assessment Tool (SWAT), this research investigates flood risks and cross-border water management within the Kabul River Basin. To assess the viability of a transboundary water management plan for the Kabul River Basin, researchers analyzed flood risks under various climate and dam management scenarios. Based on these results, they proposed a tailored agreement specifically for the Kabul River Basin [20].

The automated autoregressive integrated moving average (ARIMA), a machine learning tool, was used in this article's statistical methodological analysis to predict the Kabul River's River flow. The water flow of KRB will rise during 2019 and 2020. Until 2030, the water level will remain at a maximum of 250 cumecs and a minimum of 10 cumecs. [21] .

III. METHODOLOGY

A. Study Area

The Kabul River Basin (KRB) is a transboundary system shared between Afghanistan and Pakistan, extending across eastern Afghanistan and the Chitral region. As shown by research work of [22], [23] and GIS work of this study it covers an area of about 91297 km² and is fed by several major tributaries, including the Panjshir, Kunar, Swat, and Kalpani rivers. For hydrological point of view, KRB is often divided into three main sub-basins the Upper Kabul (including Kabul and Maidan Wardak), the Panjshir system (covering Logar, Panjshir, Parwan, and Kapisa), and the Lower Kabul (including Charsadda, Swat, and Nowshera). The Kabul River originates from the Sanglakh range of the Hindu Kush in Afghanistan and plays a vital role in sustaining agriculture and livelihoods for millions of people across both countries. It also contributes roughly 10-12% of the total annual flow to the Indus River system, making it an important component of the regional water balance. The KRB before Nowshera (outlet) propagates as a tributaries named as Swat River and main KRB tributary which passed through main and populated districts of Khyber

Pukhtunkhwa (District Khyber, Mohmand, Peshawar, Charsadda) helping the agriculture and groundwater recharge. The details of main bridges on KRB is as follows. On the upstream near the Warsak dam KRB passes under the Mechani Pull which is near to the border with Mohmand agency.

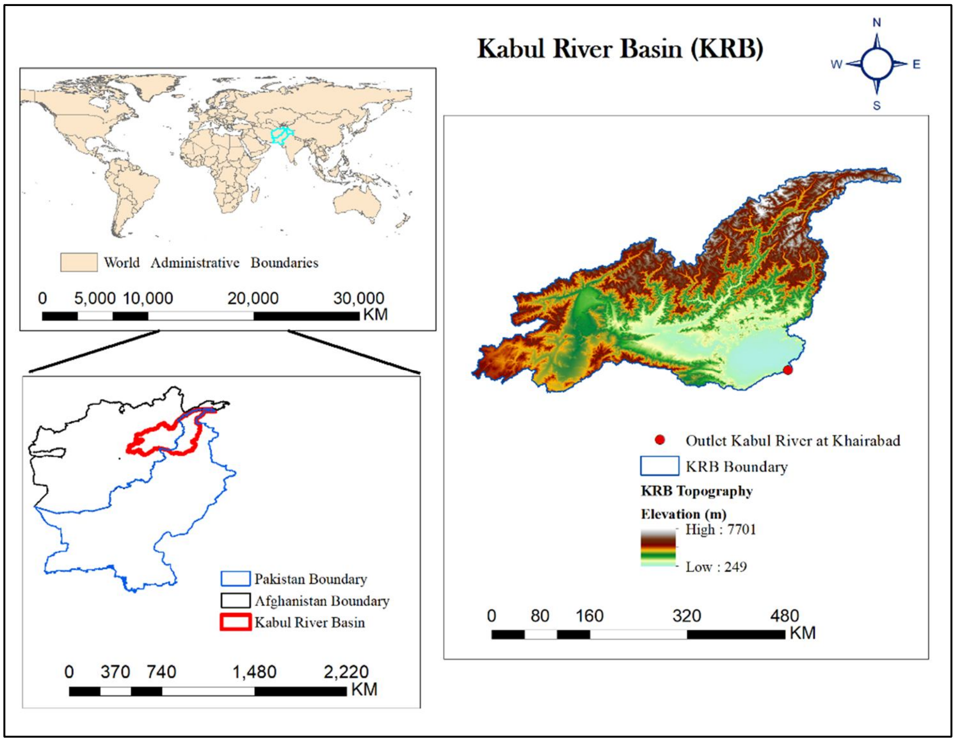

FIGURE 5: STUDY AREA

Other bridges includes Nowshera Bridge (GT Road Bridge) which is a 500m long prestressed concrete bridge constructed over the fast-flowing Kabul River at Nowshera for the Communication and Works Department of the KP government. Nowshera Railway Bridge the iron road and railway bridge across the river at Nowshera was opened on 1 December 1903. The upper Kabul basin, receiving less rainfall and no snowmelt, contributes 2.6% of the average annual flow of the basin. The Panjshir sub-basin on the other hand generates nearly 15% of the annual flow. In shabqadar tehsil of district charsadda, the bridge is in Hajizai which also serves as the boundary of District Peshawar and Charsadda, after that on downstream it passes under Sardaryab bridge, with similar two bridges in parallel on Swat river are Monda headworks (Monda region with irrigation canals of Sadar Garhi few Kilometers away from Matta Mughal Khel) and Khiali bridge few kilometers away from the Sardaryad bridge. Kabul River is of prime importance for the locality. It supports agricultural, urban areas, and industries and incorporates a diversity of topography, including plains and mountains. However, it affected with issues like population increase, water stress, and effects of climate change.

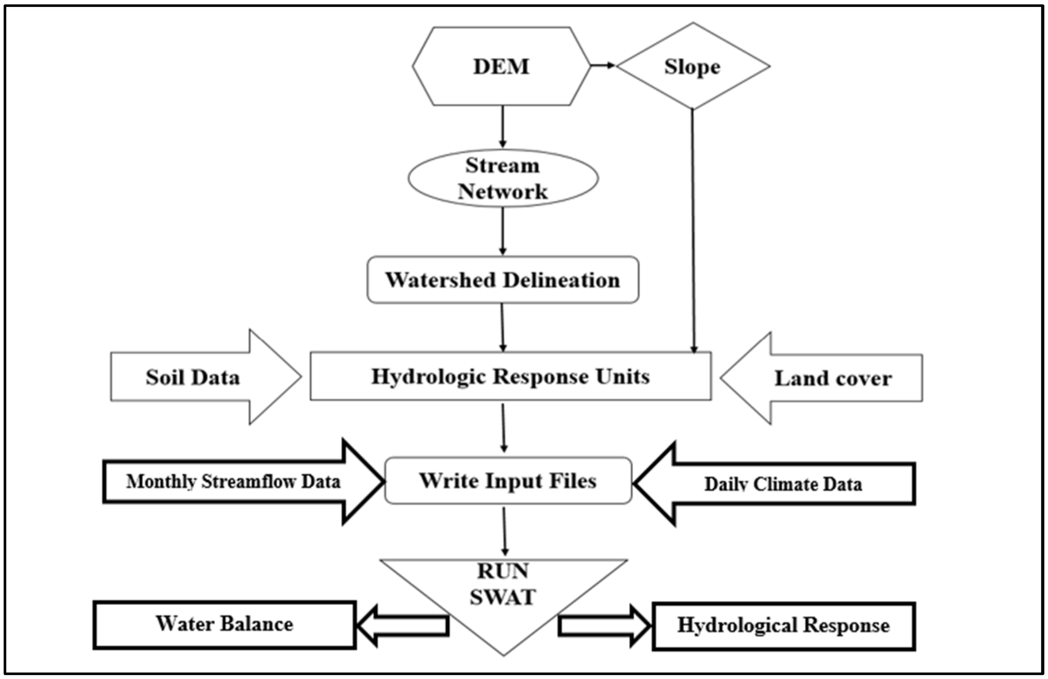

FIGURE 6: METHODOLOGY SCHEME

B. DEM Processing and Watershed Delineation

A Digital Elevation Model (DEM) is used as the primary topographic input to derive the stream network and delineate the watershed boundary of the KRB. Slope is extracted alongside the DEM and used in the subsequent classification of hydrological response units. The stream network was generated by applying a flow accumulation threshold, and the watershed was delineated into 30 sub basins with the outlet defined at the Nowshera gauge station (Khairabad Bridge) on the Kabul River in Pakistan.

C. Hydrological Response Units

Hydrological Response Units (HRUs) were defined by overlaying three spatial datasets soil data, land cover classification, and slope within each delineated subbasin. Each unique combination of soil type, land use, and slope class was assigned as a distinct HRU, allowing the model to account for spatial heterogeneity in hydrological processes such as infiltration, runoff generation, and evapotranspiration at a sub-subbasin scale.

D. Model Input Preparation

All required input files were compiled and written into the SWAT project directory. Daily climate data including precipitation, maximum and minimum temperature were formatted and assigned to the nearest subbasin centroids. Monthly observed streamflow records at the Nowshera gauge station (Khairabad bridge) for the periods 1991–2000 and 2010–2015 is prepared for use in model calibration and validation respectively. The model results are obtained for 1993-2000 as two years are taken as warp up period in arc SWAT.

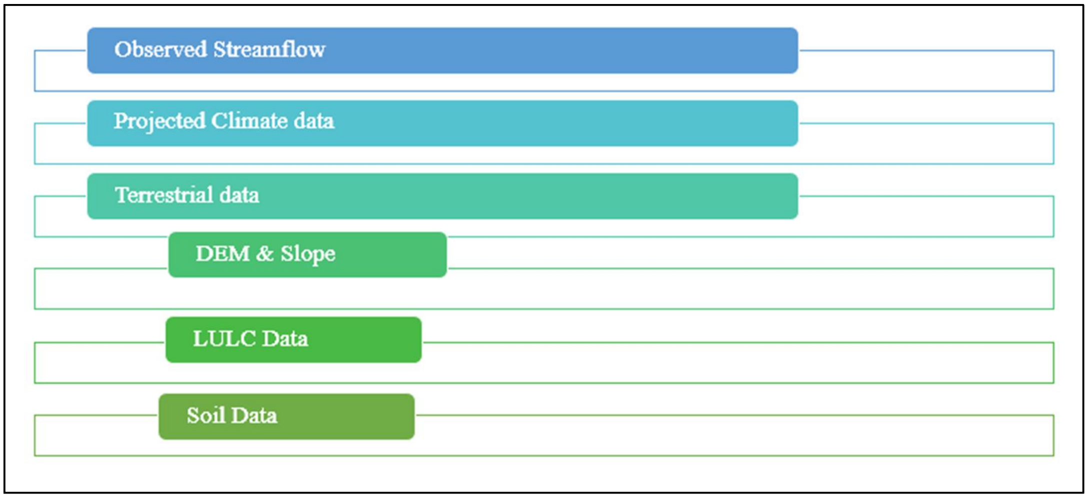

FIGURE 7: DATA DETAILS FOR WATER BALANCE STUDY ON KRB

E. SWAT Model Execution and Calibration

The SWAT model was run on a monthly time step with a two-year warm-up period. Sensitivity analysis was conducted using SWAT-CUP with the SUFI-2 algorithm to identify the most influential parameters controlling streamflow simulation. Calibration was performed for the period 1991–2000 and validation for 2010–2015 by iteratively adjusting sensitive parameters within physically acceptable ranges. Model performance was evaluated using NSE, R^2, PBIAS, P-factor, and R-factor.

F. Water Balance and Hydrological Response Analysis

Following successful calibration, SWAT outputs were extracted and processed in R to assess two primary objectives. Water balance components including precipitation, actual and potential evapotranspiration, snowmelt, percolation, groundwater recharge, and soil water storage were aggregated at monthly and annual scales and analysed for seasonal and inter-annual patterns. Hydrological response was characterised through flow duration curves, seasonal boxplots, annual streamflow trends, and a suite of hydrological indices including mean flow, Q10, Q50, Q90, coefficient of variation, baseflow index, and flashiness index, providing a comprehensive quantitative picture of the KRB flow regime.

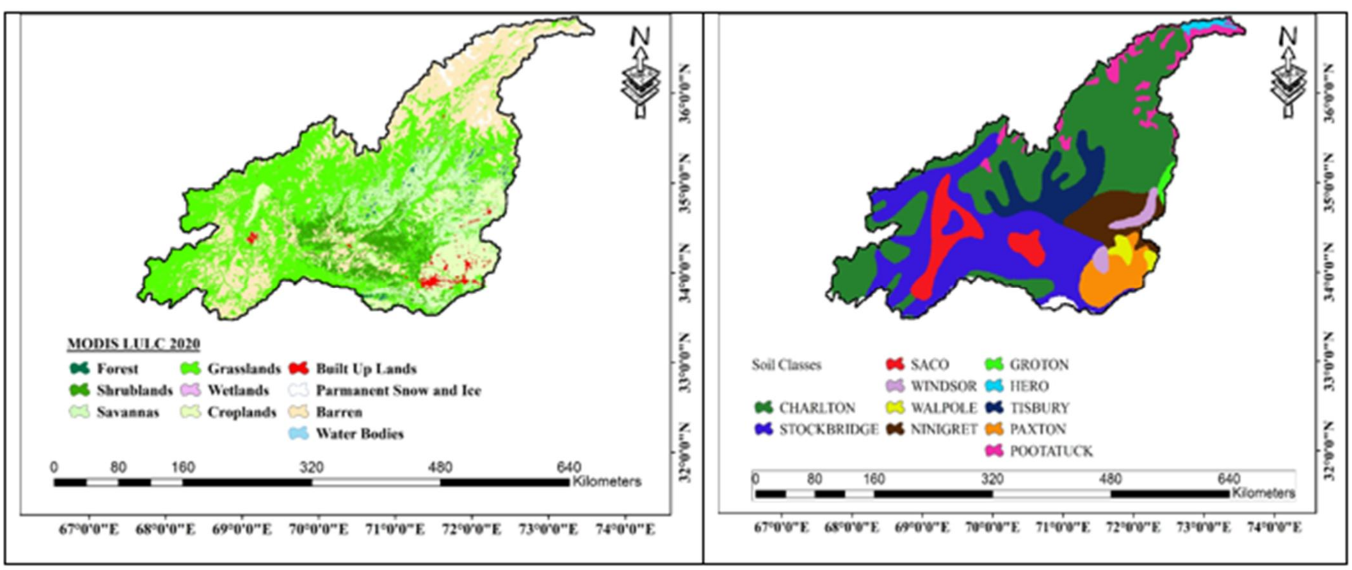

Figure 8: Swat Input Main Datasets, Lulc Map On The Left, Soil Map On The Right (Obtained From Fao Website) And Dem Used For Watershed Delineation Is Already Shown In Study Area In Figure 5

Streamflow data at Khairabad Nowshehra Bridge is taken from Water and Power Development Authority (WAPDA). The observed data is on monthly scale from 1981 to 2010. The Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) DEM of **30-meter resolution** is used in this research. The DEM data is obtained from U.S. Geological Survey data site. (https://earthexplorer.usgs.gov/). Landsat-8 collection is used for LULC maps and analysis is retrieved from U.S. Geological Survey data site. *(https://earthexplorer.usgs.gov/)*. Soil Data is retrieved from FAO website (https://www.fao.org/soils-portal) and then extract by mask command is used to extract the study area.

G. Historical Climate data

Due to the transboundary nature of the Kabul River Basin and the limited accessibility of hydro-meteorological records from the Afghanistan side, the availability of long-term climate observations was restricted. Therefore, only seven meteorological stations (Chitral, Cherat, Dir, Drosh, Parachinar, Peshawar and Saidu Sharif) with relatively reliable records were used for the development, calibration, and validation of the SWAT model, representing one of the main limitations of this study. The available climatic records covered the period from 2010 to 2025 and provided the basis for describing the spatial variability of temperature and precipitation across the basin. To improve the spatial representation in areas where observed data were scarce, annual maximum temperature information for South Salang, Kabul, and Paghman stations was supplemented from published literature [20], [21]. These additional values were used solely for map preparation and interpolation purposes, while the SWAT simulations relied on the available daily observations.

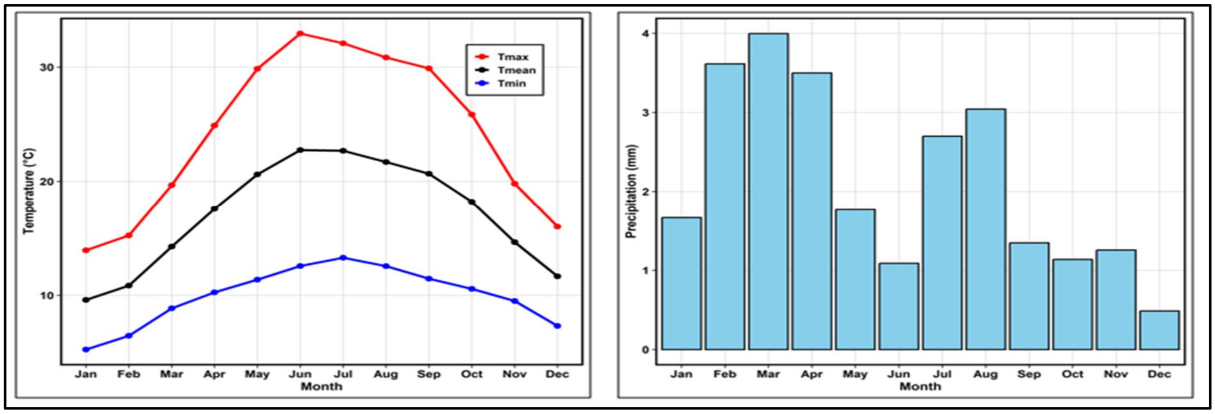

Figure 9: Monthly Variation In Observed Climate Data For Selected Stations

The graph of temperature indicates a typical seasonality pattern for the continental climate of the KRB, where the mean temperature is seen to go from about 10°C in January to a high of 23°C in June-July months; and maximum temperature in summer exceeds 33°C and minimum temperature in winter is close to 3°C, indicating the typical large variation in temperature both diurnally and seasonally found in high elevation interior basins of the Hindu Kush region. The precipitation graph indicates a two-peaked seasonality, with the first peak occurring between February-March with an average value of about 4 mm, which is brought about by the passage of westerly disturbances providing winter-spring precipitation for the basin, a second peak in July-August due to monsoon penetration, and a dry spell from September to December where average monthly precipitation does not exceed 1.5 mm.

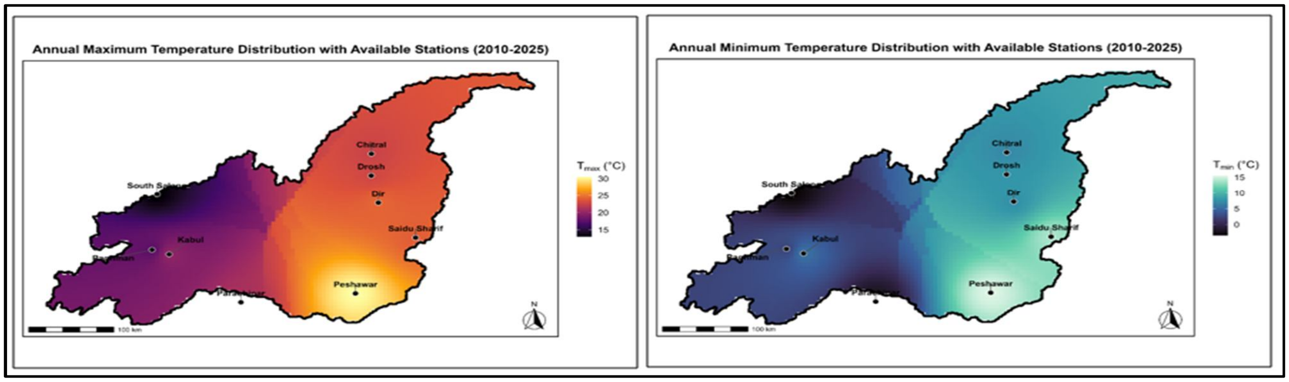

FIGURE 10: Spatial Variation In Temperature Data For Selected Stations

As depicted in Figure 9 showing the spatial variation of average maximum and minimum temperature in the region, there is a distinct difference between the lowlands and mountains in the basin. The higher temperature value close to 30 °C can be seen in the plain areas of Peshawar, Charsadda, and Nowshera shown in the yellow and orange zones. The region of Sedu Sharif is characterized by average temperature less than 25 °C, while those situated in Dir, Drosh, and Chitral are in the intermediate temperature zone ranging from 20 to 30 °C. It is evident that there is a temperature difference due to the impact of topographical and altitude differences on the climate of the region. In contrast, low temperatures are found in the higher elevation areas of Afghanistan, namely South Salang, Kabul, and Paghman, where temperatures stay less than 20 °C.

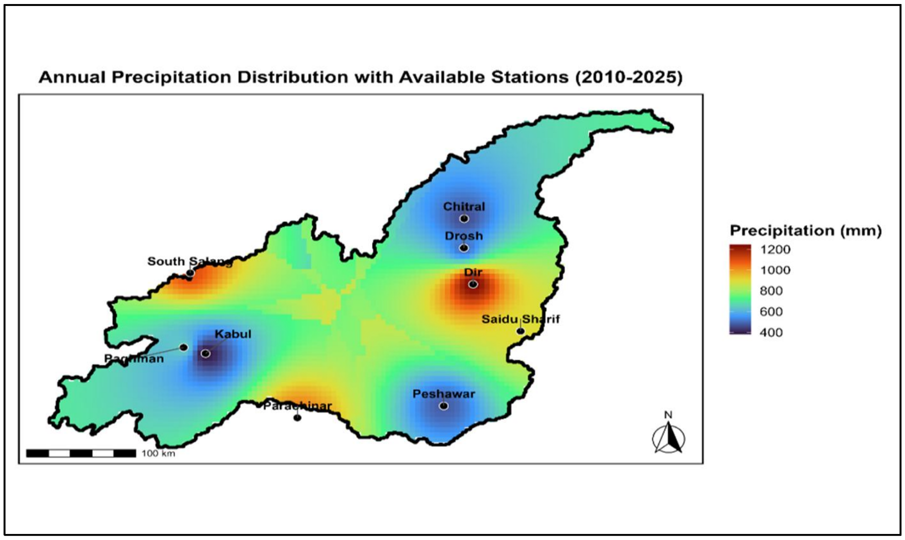

FIGURE 11: Spatial Variation In Observed Precipitation For Selected Stations

The annual precipitation map of the Kabul River Basin during the period of 2010-2025 indicates that the precipitation regime is highly heterogeneous with the highest precipitation levels registered in the region of Dir and Saidu Sharif, which is located at the eastern part of the river basin and has a precipitation level more than 1,200 mm, probably due to the orographic effect of monsoons when passing through the mountain ranges of the Hindu Kush and Swat. The central and western parts of the basin have moderate precipitation levels, which are between 400-800 mm. The northern parts of Chitral and Drosh have an intermediate level of precipitation.

IV. RESULTS AND DISCUSSION

The hydrological response and water balance characteristics of the KRB were estimated from the output of the calibrated SWAT model at monthly time scale for the simulation period (1993 to 2000 having two years as a warm up period). The Water Balance and Hydrological response analysis was done on the basis of the outlet data of the sub basin (sub basin 29), which was obtained from the output files of HRU, Sub-basin and reach. Monthly and annual water balance parameters such as precipitation, stream flow, evapotranspiration, potential evapotranspiration, soil water storage and snowmelt have been assessed in order to evaluate the inter-annual variability of the KRB. In order to analyze and interpret the results, different statistical, temporal trends, seasonality and inter-relationships of the hydrological parameters have been evaluated using different tables and graphs. This analysis was performed in order to estimate the important hydrological processes governing the water resources and runoff generation of the KRB.

A. Sensitivity Analysis

The most important and useful parameter in hydrological modeling as per the literature is CN2 and it is mainly used to surface runoff generation. In sensitive analysis it can be checked whether the model is giving good performance on 10% increase or decrease from the original value. After simulation and checking the model outputs it is realized from the trend and a specific plot which is called dotty plot. The dotty plot in SWAT-CUP shows how the objective functions like NSE is changing (increasing or decreasing) with the change in a parameter value. Another improvement thing in sensitivity analysis is checking the T test values and P test values and eliminating unimportant parameters accordingly.

Table 1: Swat Parametrization Detail From Sensitivity Analysis

Parameter Name	Description	Min Value	Fitted Value	Max Value
V__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	0	657.3	5000
R__ALPHA_BF.gw	Baseflow alpha factor (days)	0	1.0	1
V__SHALLST.gw	Concentration of nitrate in groundwater contribution to streamflow from subbasin (mg N/l	0	649.3	5000
R__ESCO.bsn	Soil evaporation compensation factor	0	0.2	1
R__EPCO.bsn	Plant uptake compensation factor	0	0.9	1
R__GW_REVAP.gw	Groundwater "revap" coefficient	0.02	0.2	0.2
R__CN2.mgt	SCS runoff curve number	35	55.4	98
R__OV_N.hru	Manning's "n" value for overland flow	0.01	0.2	30
R__SLSOIL.hru	Slope length for lateral subsurface flow	0	0.1	150
R__SLSUBBSN.hru	Average slope length	10	10.0	150
v__PLAPS.sub	Precipitation laps rate	-0.2	0.0	0.2
v__TLAPS.sub	Temperature laps rate	-10	-8.5	10
v__SURLAG.bsn	Surface runoff lag tim	10	2.0	15
v__SFTMP.bsn	Snowfall temperature	-20	-4.6	20
r__SOL_AWC(1).sol	Available water capacity of the soil layer	0	0.5	1
R__SMTMP.bsn	Snow melt base temperature	-20	5.3	20
R__SMFMX.bsn	Maximum melt rate for snow during year (occurs on summer solstice)	0	3.6	20
R__SMFMN.bsn	Minimum melt rate for snow during the year (occurs on winter solstice)	0	19.6	20

The t-stat is the ratio of the coefficient of parameters to their standard error, serving as an indicator of the accuracy with which the regression coefficient is measured. In case the coefficient exceeds the standard error, it means that the parameter is sensitive. P-values, which are obtained using t-distribution student's table depending on the t-stat values computed, give additional information. The high p-value means that the parameter sensitivity is low, and the low p-value indicates a high sensitivity of the parameter. It will help to reveal the most important parameters which are significant for correct model calibration and prediction.

When it comes to SWAT calibration in the Kabul River Basin (KRB), some key parameters from various groups are selected for ensuring correct simulation of the hydrological processes. Among the parameters from the groundwater group we should mention GWQMN (threshold depth of water in the shallow aquifer required for return flow to occur), ALPHA_BF (baseflow alpha factor), SHALLST (concentration of nitrate in groundwater contribution to streamflow) and GW_REVAP (groundwater "revap" coefficient). The fitted value of GWQMN is equal to 657.3 mm.

B. Calibration and validation

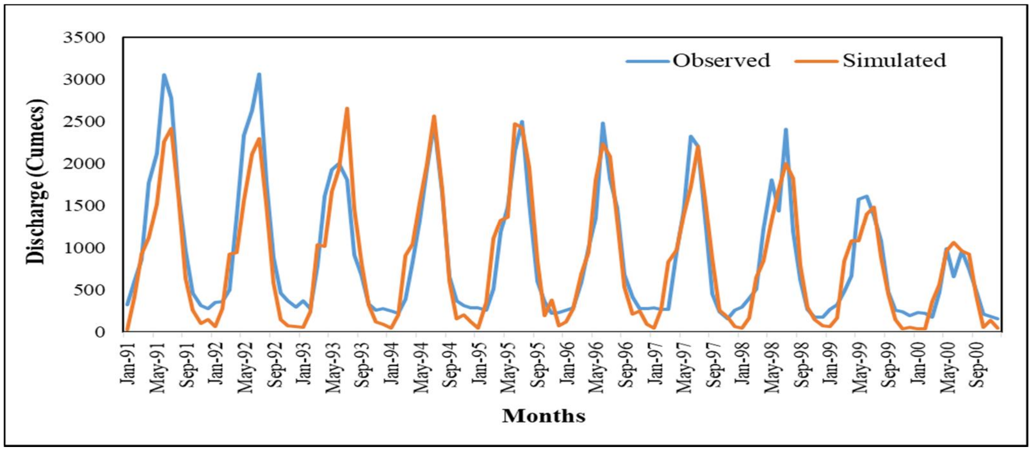

FIGURE 12: CALIBRATION RESULTS OF SWAT MODEL ON MONTHLY BASIS

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The calibration plot of KRB at the monthly level demonstrates high consistency of the model-simulated monthly flow with the observed one for the period from 1991 to 2000; thus, the model-simulated flow follows the seasonal pattern of the observed flow for all ten years. In particular, the summer peaks caused by snowmelt and monsoon rainfalls are captured fairly well, and two lines rise and fall synchronously during the majority of years. Nash-Sutcliffe Efficiency of 0.84 and R^2 of 0.85 suggest that the model explains about 85% of variability of the observed flow, which is a relatively good result for such a transboundary river basin as the KRB. The value of PBIAS equal to 6.8% indicates a minor underestimation of the total amount of flows, which is acceptable, because the maximum allowable PBIAS value for monthly simulation is ±10%. The value of P-factor, which is an indicator of model performance inside the uncertainty band, is 0.83, meaning that 83% of observed data points are within the 95% prediction uncertainty band, and R-factor (the average width of the uncertainty band) is 1.33.

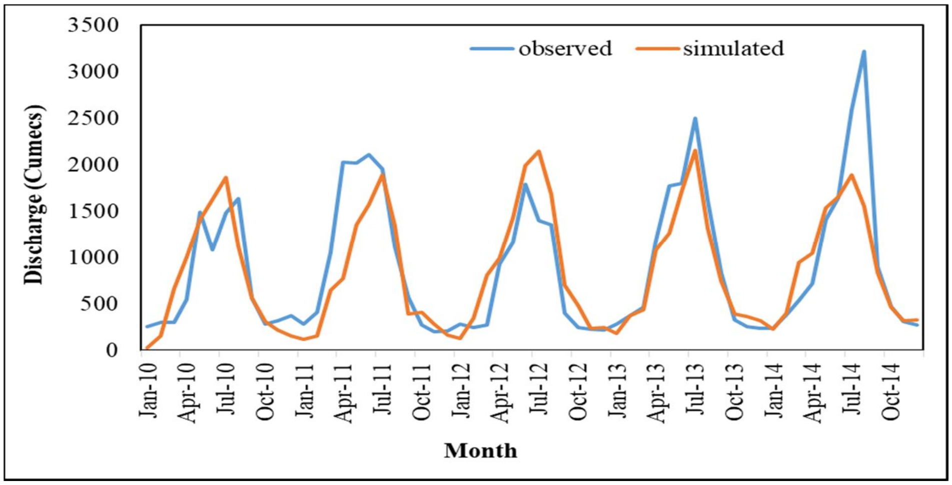


Figure 13: VALIDATION OF SWAT MODEL ON MONTHLY BASIS

Figure 6.16 represents the validation plot of KRB model on a monthly basis from 2010 to 2014. From the figure, it can be noted that the SWAT model still provides satisfactory results during the process of validation in the independent period. The simulated flow follows the seasonal pattern of the observed flow during all years in the period. However, it has been observed that the model fails to simulate the peak flows of 2014. The figure shows that during the peak flow, there is an obvious underestimation by the model of observed peaks that go above 3,200 cumecs. During 2014 peak, the simulated flows are about 1,900 cumecs, which shows that the model has difficulty simulating flows that have not been included during the calibration stage. The value of NSE and R^2 has declined slightly from 0.84 and 0.85 to 0.72, which is the usual behavior of hydrological models. The slight drop in the performance of the model should be considered normal because in this case, the model is no longer optimised for that period. The value of PBIAS of 5.2% shows that the model is still underestimating total flow volume like the PBIAS of calibration stage of 6.8%. The value is within the acceptable ±10% threshold limit. The value of P-factor reduces from 0.74 during calibration stage to 0.68, meaning 68% of the observed values lie within the uncertainty band. The value is slightly below the recommended 0.70 threshold but still acceptable. The value of R-factor has increased to 1.43 from 1.28 during calibration stage.

TABLE 2: ANNUAL WATER BALANCE

Year	P (mm)	ET (mm)	PET (mm)	Snow (mm)	Mean Q (m^3/s)	ET/P (%)
1993	659	275	395	200	416	41.8
1994	950	298	430	245	341	31.4
1995	1089	285	405	285	397	26.2
1996	870	307	464	256	324	35.3
1997	860	295	467	232	308	34.3
1998	810	287	454	214	289	35.5
1999	625	276	509	199	226	44.2
2000	541	243	497	156	159	44.8

The precipitation dynamics show a pronounced trend of increase followed by steady decrease from the highest value of 1,089 mm in 1995 to 541 mm in 2000, which means an overall decrease of almost 50% of water supply between the two extremities, while snowfall dynamics show an almost identical trend, decreasing from 285 mm to 156 mm, which can be explained by the high dependence of snowfall on the precipitation dynamics in the basin with dominating Hindu Kush topography. Even though there were significant fluctuations in precipitation, there were no such fluctuations in the actual ET; on the contrary, ET stays constant and varies in a narrow range from 243 mm to 307 mm during the whole study period, which means that ET in KRB is energy-limited and not affected by water availability in any way. Unlike the actual ET, PET shows a consistent trend of increasing from 395 mm in 1993 to 509 mm in 1999-2000, which means that the atmosphere demands more water because of increasing temperature towards the end of the record. The mean annual streamflow in the studied basin is also decreasing from 416 m³/s in 1993 to 159 m³/s in 2000, which means the decrease of more than 60% and confirms the high sensitivity of river flow to inter-annual changes in precipitation with insignificant contribution from groundwater and soil moisture stores. The ratio of ET/P grows significantly from 26% in 1995 (the year of maximum precipitation) to almost 45% in 2000 (the year of minimum precipitation).

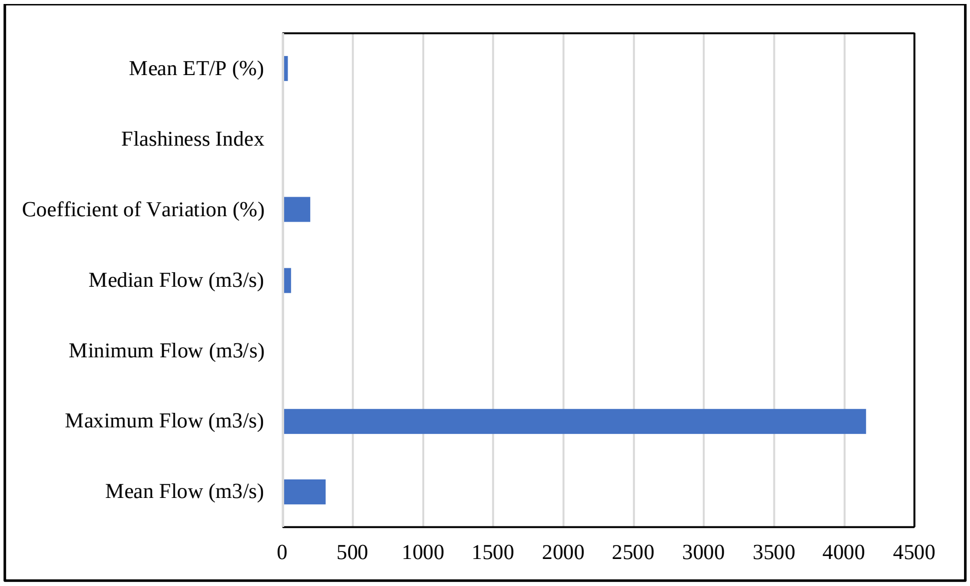


FIGURE 14: HYDROLOGICAL RESPONSE INDICES

Indices for the hydrological response for the Kabul River Basin show the presence of highly variable and flashy flow pattern with extreme flows at different times of the year. The average monthly flow at around 307 m3/s is quite lower than the highest value of flow of about 4,155 m3/s showing that the Kabul River Basin has high flow peaks that probably occur due to snowmelt and monsoon precipitation in the spring and summer, respectively, and also low flow levels approaching zero, thus experiencing extremely low flow levels in winter. The high coefficient of variation of about 110% also demonstrates that there is high variability in flows, meaning monthly flows vary by more than the mean itself throughout the year, which is characteristic of rivers influenced by snow and monsoonal precipitation in Hindu Kush mountains. A median flow being much lower than the average flow shows that there is a positively skewed distribution of monthly flows where only a few months have high peak values while the others have moderate discharges. Both the flashiness index and the average ET/P ratio are quite low at around 36%, although they both carry some significance – the low flashiness despite high variation from the minimum to maximum flow levels means that although peak flows are high, the changes in flows are gradual and not abrupt as expected with the combined effect of snowmelt and groundwater storage in the basin.

TABLE 3: MONTHLY CLIMATOLOGY

MON	P (mm)	ET (mm)	PET (mm)	Snow (mm)	Q (m3/s)
1	57.98	5.77	10.01	1.54	44.17
2	87.67	6.83	8.81	4.52	103.54
3	113.49	15.27	19.03	16.71	247.27
4	90.4	21.22	27.36	27.11	392.62

5	54.68	29.62	41.6	41.89	589.89
6	36.69	36.68	61.97	46.16	656.27
7	85.03	45.03	69.78	40.7	699.43
8	88.19	43.27	66.17	22.81	486.07
9	46.76	29.11	51.51	7.87	206.43
10	34.4	17.4	36.24	0.84	64.8
11	48.48	10.38	20.19	0.63	60.94
12	37.59	7.51	14.39	1.28	29.69

The monthly climatology of the Kabul River Basin reveals a strongly seasonal hydrological regime driven by the interplay of winter precipitation, spring snowmelt, and summer monsoon inputs. Precipitation is relatively well distributed across the year with a primary peak in March (113 mm) associated with western disturbances bringing winter-spring rainfall, a secondary pulse in July August (85–88 mm) from monsoon incursions, and a pronounced dry period from September to December when monthly totals drop below 50 mm. Snowmelt builds progressively from near zero in winter to a peak of 46 mm in June, directly driving the sustained rise in streamflow from March onward and explaining why peak discharge of 699 m³/s occurs in July — well after the March precipitation peak as the accumulated snowpack releases its stored water through spring and early summer. Actual ET tracks the seasonal temperature cycle closely, rising from just 6 mm in January to a peak of 45 mm in July as energy availability increases, while PET reaches its maximum of 70 mm in July, and the growing gap between PET and actual ET from May onward indicates increasing atmospheric water demand that the basin cannot fully satisfy during drier months. Streamflow exhibits a sharp unimodal seasonal pattern, rising from a winter low of just 30 m³/s in December to the July peak of 699 m³/s before declining rapidly through the post-monsoon season, with the entire high-flow period concentrated between April and September a six-month window that carries the overwhelming majority of the basin's annual water yield.

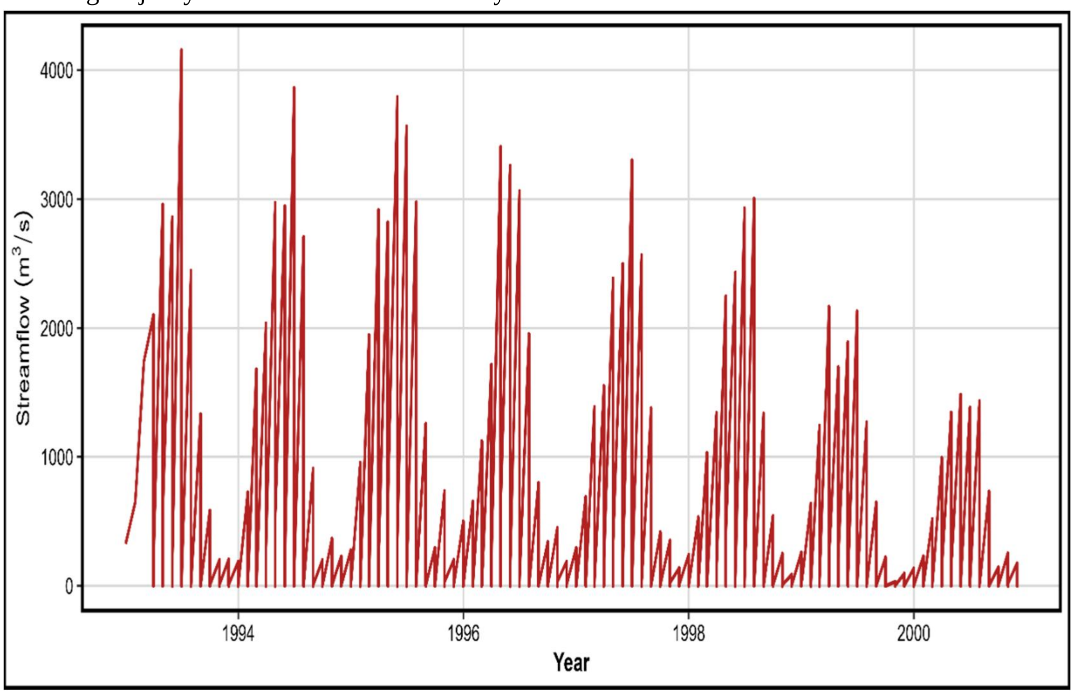


FIGURE 15: MONTHLY STREAMFLOW HYDROGRAPH OF THE KRB OVER 1993–2000

The monthly streamflow hydrograph of the Kabul River Basin over 1993–2000 displays a clear and consistent seasonal pulse pattern, with sharp annual peaks recurring every summer driven by the combined contribution of snowmelt and monsoon rainfall, while flows drop to near-zero during the dry winter months confirming the strongly seasonal and episodic nature of discharge in this snow-and-monsoon-fed basin. The highest peak of approximately 4,200 m³/s occurs in 1993, and while subsequent years maintain a broadly similar seasonal rhythm, there is a visible downward trend in peak magnitudes from the mid-1990s onward, with the 1999–2000 peaks rarely exceeding 1,500 m³/s — consistent with the declining precipitation trend identified in the annual water balance analysis. The progressively narrowing and lower peaks toward the end of the record, combined with the increasingly sharp recession limbs, suggest a reduction in snowpack contribution and overall water availability in the latter years, pointing to a drying signal in the basin that has direct implications for downstream water security.

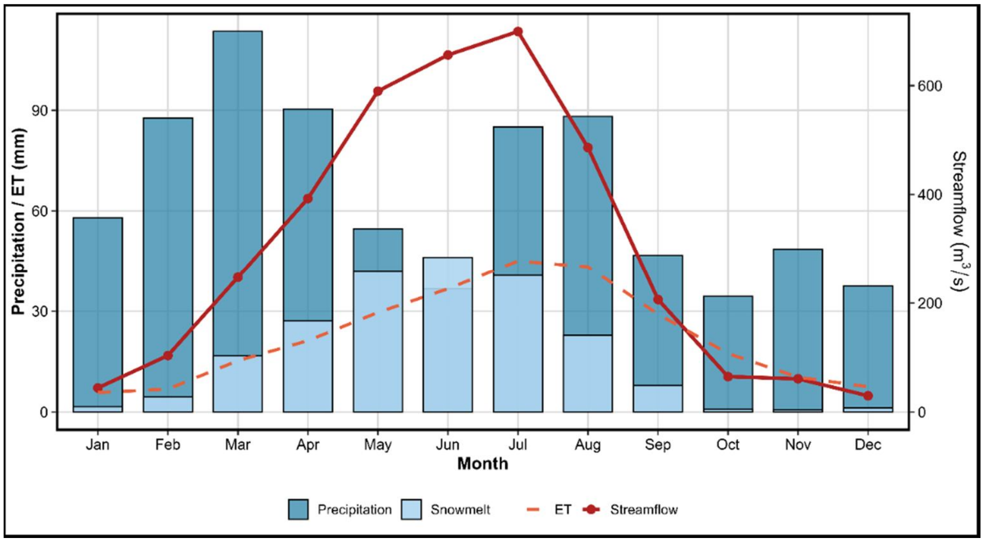


FIGURE 16: MEAN MONTHLY CLIMATOLOGY

In fact, the mean monthly climatology diagram very well illustrates the water balance equation with the four components of it. First of all, precipitation is observed to reach the maximal value in March – about 100 mm because of western disturbance, then there is another pulse of the monsoon causing relatively high precipitation values till July-August, while the component of snow melt – light blue part of the bars – increases from zero in winter to the maximal values in May-June due to melting of snow pack from the Hindu Kush. The stream flow, following the delayed response to the two previous components of the equation, reaches its maximum in July (about 700 m³/s), well after the maximum in precipitation in March. This fact confirms that the storage of snow pack and its subsequent slow release is the main driver of maintaining the stream flow at the level exceeding the value achieved by precipitation only. ET follows the energy cycle of temperature and achieves its maximum in July-August together with precipitation. Then, starting from September and up to December, the four components fall down to almost zero values at once, marking the end of the wet period.

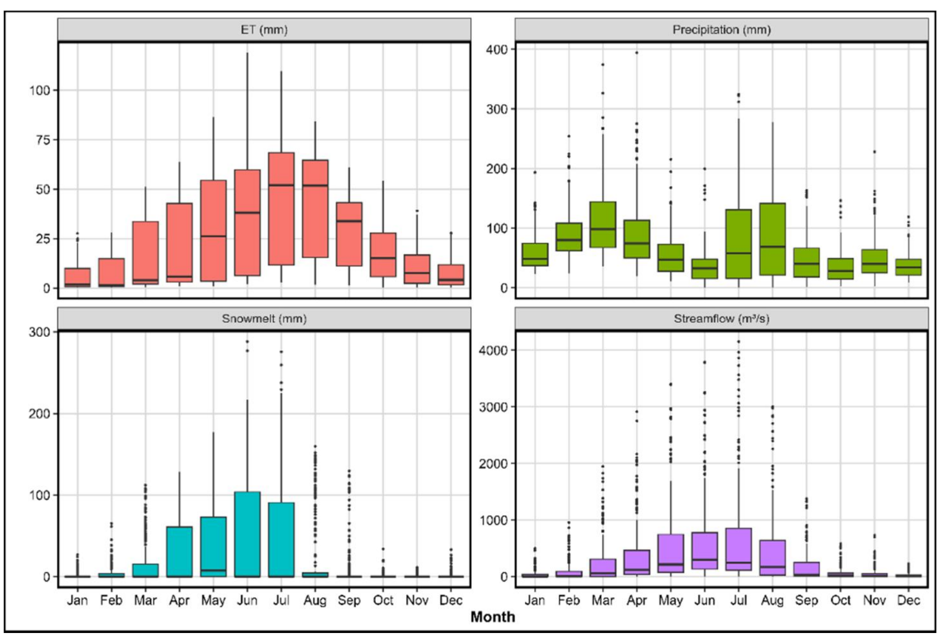


FIGURE 17: SEASONAL VARIABILITY OF HYDROLOGY

The seasonal boxplot in four panels presents a full range of monthly variation of major hydrological indicators within the KRB basin, presenting the central tendency of each component along with its distribution. In the case of ET (top left), one can see a unimodal distribution with the peak in June-July and relatively small interquartile ranges for medians that equal 50-65 mm, which proves that there is a steady energy-based evapotranspiration with insignificant interannual variation during summer months, while in winter months it equals to nearly zero with the outliers showing anomalously warm years. In turn, precipitation (top right) demonstrates a bimodal pattern with medians in February-March due to western disturbances and again in July-August due to monsoon inflows, however, the width of boxes is considerable and numerous outliers can be found mainly in March and July, exceeding 300 mm – that proves that precipitation in KRB is rather sporadic rather than steady annual process. Concerning snowmelt (bottom left), it is seen only in April-July period with the largest variation in June-July, where outliers exceed 200-250 mm, while all other months equal nearly zero; this plot is a good evidence of snow-based nature of hydrology during these months in the Hindu Kush basin. Finally, the streamflow (bottom right) reflects the same pattern as snowmelt with the largest medians and distribution in May-July, but the extremely large upper whiskers and many outliers in these months exceeding 4,000 m³/s prove that extreme peaks of flow are caused by the combination of snowmelt and monsoon precipitation, while nearly zero medians in October-February prove the severity of low flow regime.

FIGURE 18 which shows the log-scale flow duration curve for the Kabul River Basin shows an extremely steep and concave nature of flow duration, suggesting that there is a highly variable and flashy flow regime where high flows are very intensive but last for only a short period of time and low flows are highly constrained – a typical sign for snow-monsoon-based basins in Hindu Kush. High levels of flows, greater than 10 m³/s, continue to exist relatively sustainably until the 75% exceedance probability, after which a steep decline occurs towards near-zero and ultimately negative levels of flows at the highest exceedance probabilities, implying that for nearly 25% of the time there is practically no water flow in the river – which most probably corresponds to the dry winter period found during the seasonal analysis of flows. The negative levels of flows at the 95% and higher exceedance probabilities are a SWAT artifact, not a real phenomenon; however, the steep nature of the curve at the exceedances greater than 75% suggests clearly that KRB has a very constrained low-flow regime.

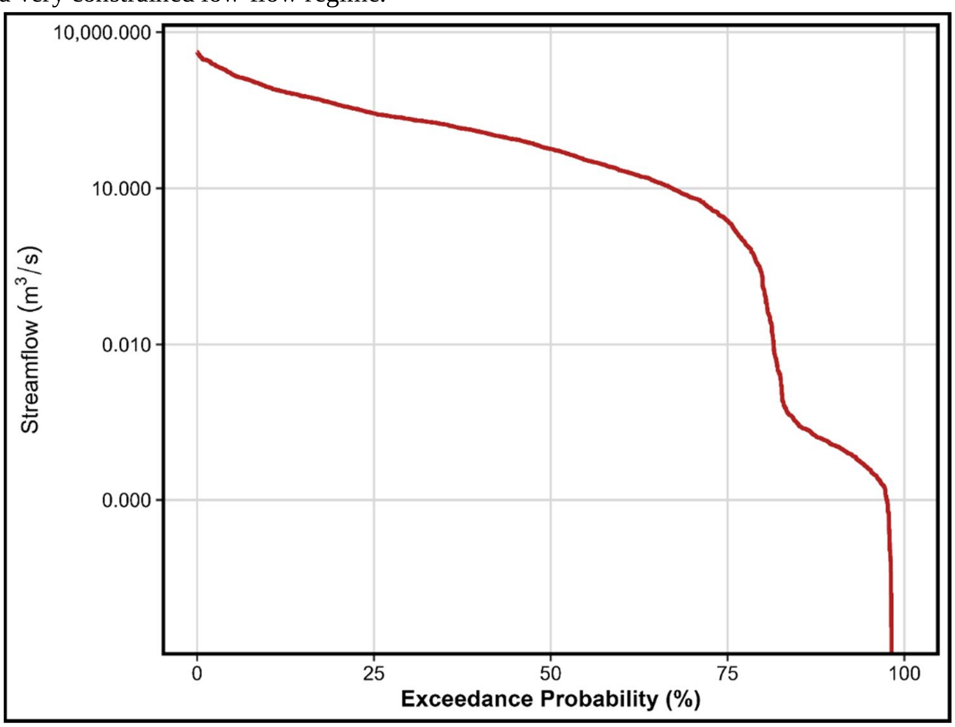


FIGURE 18: FLOW DURATION CURVE

Pearson correlation heatmap as shown in FIGURE 19 which reflects the relationships between the important hydrological parameters within the KRB, the strongest of which is the perfect positive correlation between percolation and groundwater recharge ($r = 0.95$). It demonstrates that aquifer recharge in the KRB takes place almost exclusively due to the percolation process rather than direct precipitation

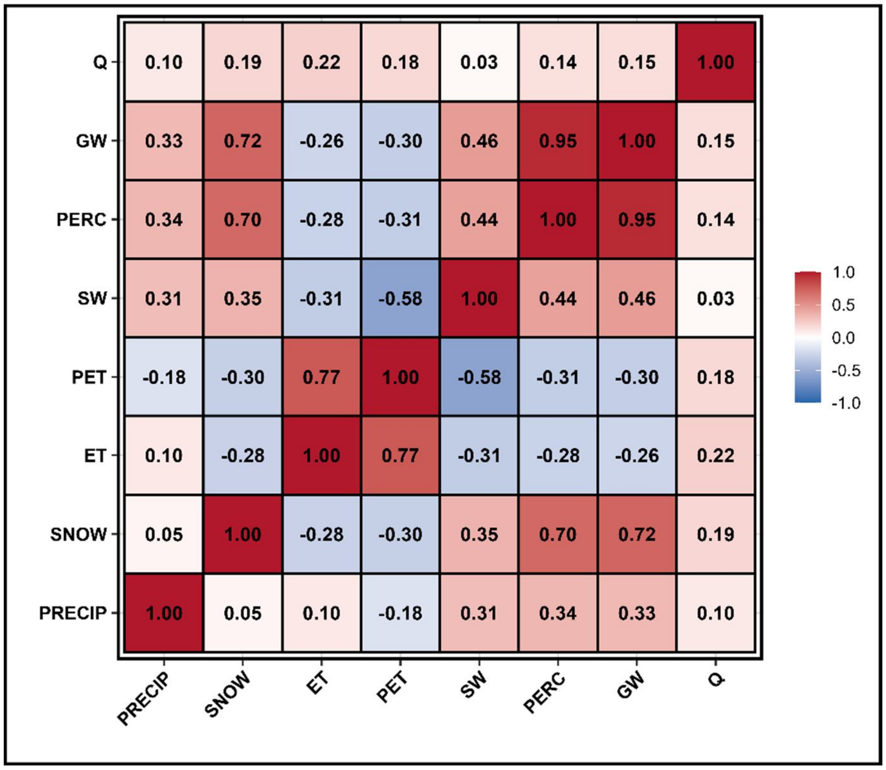


FIGURE 19: PEARSON CORRELATION HEATMAP

As follows from Pearson's coefficient value, the snowmelt is positively correlated both with percolation (r = 0.70) and with the groundwater recharge (r = 0.72), which means that this variable plays an essential part in providing the subsurface water storage and recharging along with the surface runoff generation. Expectedly, the ET and PET demonstrate a strong positive correlation (r = 0.77), however, both are negatively correlated with soil water (ET r = −0.31; PET r = −0.58), percolation, and groundwater recharge, showing that in periods of high evapotranspiration demand there is a competition for water that limits its availability for percolation. SW (soil water) is positively correlated with percolation (r = 0.44) and groundwater recharge (r = 0.46), which means that the initial moisture content has a considerable influence on the process of percolation of water to deeper layers, and the strong negative correlation between soil water and PET (r = −0.58) indicates that the soil water is most intensively depleted in hot weather. The precipitation is surprisingly poorly correlated with most of the variables, including streamflow (r = 0.10) and snowmelt (r = 0.05), which seems to be paradoxical but actually demonstrates the dominance of the snowmelt over the precipitation in terms of runoff generation, which is characteristic for the snow-dominated basins. Precipitation usually falls in snow form during the winter season and contributes to discharge generation when melts during summer months. Finally, the Q (streamflow) shows weak and moderate positive correlation with ET (r = 0.22), PET (r = 0.18), and snowmelt (r = 0.19).

V. CONCLUSIONS

The SWAT model was satisfactorily calibrated and validated for its suitability to represent the water balance of the Kabul River Basin, having attained the NSE coefficient values of 0.84 and 0.72, respectively. The water balance analysis showed that the KRB is a precipitation-driven, snow-dominated system with the annual precipitation varying from 541 to 1,089 mm during the study period and the snowmelt being a significant component of spring and summer streamflow, and representing around 26–37% of the total annual precipitation on the study years. Despite large inter-annual precipitation variations, actual ET within the basin remained relatively stable (243–307 mm/year), supporting the concept that evapotranspiration in this basin is not water-limited, but rather energy-limited, and the increasing trend in PET in the final portion of the record suggests an increased demand for water by the atmosphere, probably related to warming. A decrease in mean annual streamflow from 416 m³/s in 1993 to 159 m³/s in 2000 (more than a 60% drop) followed the observed decrease in precipitation and snowfall, and the ratio of ET/P increased from 26% to nearly 45% during that period, reflecting increasing water stress as the basin dried.

Therefore, the flow duration curve and the seasonal boxplots were used to confirm that the hydrology of KRB is highly variable and flashy, with most flow times during summer being dominated by high flows, whereas winter months flow times are essentially all low-flows, and many are close to zero, indicating a very seasonal regime that is almost entirely driven by the seasonal pulse of inputs from snowmelt and monsoons.Our research work correlation analysis showed that percolation and groundwater recharge are tightly coupled ($r = 0.95$) and closely tied to snowmelt, while direct precipitation had surprisingly weak control on streamflow, consistent with the strong storagedelayed release dynamic characteristic of high-elevation snow-fed basins in the wider Hindu Kush region. Together, these results present a quantitative hydrological baseline for the KRB that is necessary for understanding the availability and vulnerability of water resources in the basin to climate variability as well as those hydrological processes that will need to be accurately represented in future assessments of climate change impact.

VI. RECOMMENDATIONS

We need to look at the SWAT simulation for a longer time period than we are doing now. The time period we are looking at is from 1993 to 2000. We should look at the years after 2010 because that is when we started to see changes in how people are using the land glaciers are melting and rain and snow are falling in the Hindu Kush-Himalayan region. This will help us understand what is happening with water over a long time period.The SWAT results we have now show that there is no snow falling and no snow melting. This tells us that we need to make sure the snow settings in the model are correct. We need to look at things like the temperature at which snow melts. The water in the streams is very sensitive to the amount of rain that falls as we found out in this study. So for work we should use computer models that give us better information about what will happen to the water in the streams under different scenarios. We need to look at how the snow will melt and how the water will be used by plants and people in the Kabul River Basin, which includes Afghanistan and Pakistan. This will help us know how much water will be available in the future.We also found out that the amount of rain that falls does not directly affect the water in the streams much as we thought. This means we need to look at the melting of glaciers as another factor that affects the water in the streams. We should add this to our computer models so we can get an understanding of what is happening in the Kabul River Basin especially in the areas where there are a lot of glaciers.To get information we need to have more weather stations in the area to measure the rain and other weather conditions. We can also use satellites to get this information. This is especially important in Afghanistan where we do not have a lot of weather stations.The Kabul River Basin is shared by Afghanistan and Pakistan so we need to work to monitor the water and make decisions about how to use it. The computer model we developed can help us make these decisions and plan for things like floods and how to use the water in the reservoirs like the ones at Warsak and Sardaryab.Finally we should use our model to look at how the water in the streams will be affected by climate change and changes in how the land's used. This will give us an understanding of what will happen to the water in the Kabul River Basin and help us make good decisions, about how to manage the water.

REFERENCES

[1] Ahmad Shukran Sahaar, "Erosion mapping and sediment yield of the Kabul river basin, Afghanistan - ProQuest." Accessed: May 05, 2023. [Online]. Available: https://www.proquest.com/openview/8764166ee2341728375d671806852314/1?pq-origsite=gscholar&cbl=18750

[2] A. Aziz, "Rainfall-runoff modeling of the trans-boundary Kabul River Basin using integrated flood analysis system (IFAS)," Pak. J. Meteorol. Pak., 2016, Accessed: Feb. 28, 2023. [Online]. Available: https://scholar.google.com/scholar_lookup?title=Rainfall- .%2C+Lahore+%28Pakistan%29.+Pakistan+Meteorological+Dept.%29&publication_year=2016

[3] M. T. Bromand, "IMPACT ASSESSMENT OF CLIMATE CHANGE ON WATER RESOURCES IN THE KABUL RIVER BASIN, AFGHANISTAN".

[4] M. S. Iqbal, M. M. M. Islam, and N. Hofstra, "The impact of socio-economic development and climate change on E. coli loads and concentrations in Kabul River, Pakistan," Sci. Total Environ., vol. 650, pp. 1935–1943, Feb. 2019, doi: 10.1016/j.scitotenv.2018.09.347.

[5] R. Quraishi, "Impact Assessment of Climate Change and Mitigation and Adaptation Methods on Water Resources in Kabul River Basin," vol. 9, no. 9, 2018.

[6] S. M. Akhtar and J. Iqbal, "Assessment of emerging hydrological, water quality issues and policy discussion on water sharing of transboundary Kabul River," Water Policy, vol. 19, no. 4, pp. 650–672, Aug. 2017, doi: 10.2166/wp.2017.119.

[7] A. azzam Zhang, "Application of hydrological model to assess river flow in the transboundary cryosphere and data-scarce watershed, a case study: Chitral-Kabul River Basin (C-KRB) in Pakistan | Water Supply | IWA Publishing." Accessed: Jan. 25, 2023. [Online]. Available: https://iwaponline.com/ws/article/22/4/3842/86267/Application-of-hydrological-model-to-assess-river

[8] S. Stavropoulos, G. N. Zaimes, E. Filippidis, D. C. Diaconu, and D. Emmanouloudis, "MITIGATING FLASH FLOODS WITH THE USE OF NEW TECHNOLOGIES: A MULTI-CRITERIA DECISION ANALYSIS TO MAP FLOOD SUSCEPTIBILITY FOR ZAKYNTHOS ISLAND, GREECE," J. Urban Reg. Anal., vol. 12, no. 2, Jul. 2020, doi: 10.37043/JURA.2020.12.2.7.

[9] A. Arnold, H. Rhinane, A. Kaoukaya, Y. Kharchaf, and O. A. Bachir, "Arnold, J.G., et al. (1998) Large Area Hydrologic Modeling and Assessment Part I: Model Development 1. Wiley Online Library, Hoboken.," J. Geogr. Inf. Syst., vol. 3, no. 4, Art. no. 4, 1998, doi: 10.4236/jgis.2011.34024.

[10] J. K. Sang, P. M. Allen, J. A. Dunbar, J. G. Arnold, and J. D. White, "Sediment Yield Dynamics during the 1950s Multi-Year Droughts from Two Ungauged Basins in the Edwards Plateau, Texas," J. Water Resour. Prot., vol. 7, no. 16, pp. 1345–1362, Nov. 2015, doi: 10.4236/jwarp.2015.716109.

[11] A. Pandey, K. C. Bishal, P. Kalura, V. M. Chowdary, C. S. Jha, and A. Cerdà, “A Soil Water Assessment Tool (SWAT) Modeling Approach to Prioritize Soil Conservation Management in River Basin Critical Areas Coupled With Future Climate Scenario Analysis,” Air Soil Water Res., vol. 14, p. 11786221211021395, Jan. 2021, doi: 10.1177/11786221211021395.

[12] T. P. Barnett, J. C. Adam, and D. P. Lettenmaier, “Potential impacts of a warming climate on water availability in snow-dominated regions,” Nature, vol. 438, no. 7066, pp. 303–309, Nov. 2005, doi: 10.1038/nature04141.

[13] S. Ijaz, Q. Hameed, A. Ahsan, and M. A. Butt, “Flood Frequency Analysis of Chenab River for Predicting Peak Flows during Late Monsoon Period,” Adv. Remote Sens., vol. 8, no. 1, pp. 1–29, Mar. 2019, doi: 10.4236/ars.2019.81001.

[14] W. N. Adger, N. W. Arnell, and E. L. Tompkins, “Successful adaptation to climate change across scales,” Glob. Environ. Change, vol. 15, no. 2, pp. 77–86, 2005.

[15] V. Escamilla-Rivera, S. Cortina-Villar, R. A. Vaca, D. Golicher, J. Arellano-Monterrosas, and J. Honey-Rosés, “Effects of Finer Scale Soil Survey and Land-Use Classification on SWAT Hydrological Modelling Accuracy in Data-Poor Study Areas,” J. Water Resour. Prot., vol. 14, no. 2, pp. 100–125, Feb. 2022, doi: 10.4236/jwarp.2022.142007.

[16] Y. M. Taraky et al., “The Role of Large Dams in a Transboundary Drought Management Co-Operation Framework—Case Study of the Kabul River Basin,” Water, vol. 13, no. 19, Art. no. 19, Jan. 2021, doi: 10.3390/w13192628.

[17] W. Yang, J. Zhang, P. Hua, and P. Krebs, “Global framework for flood risk management under climate change and urbanization,” Innov. Geosci., vol. 1, no. 1, p. 100009, 2023, doi: 10.59717/j.xinn-geo.2023.100009.

[18] [18] K. C. Abbaspour, E. Rouholahnejad, S. Vaghefi, R. Srinivasan, H. Yang, and B. Kløve, “A continental-scale hydrology and water quality model for Europe: Calibration and uncertainty of a high-resolution large-scale SWAT model,” J. Hydrol., vol. 524, pp. 733–752, May 2015, doi: 10.1016/j.jhydrol.2015.03.027.

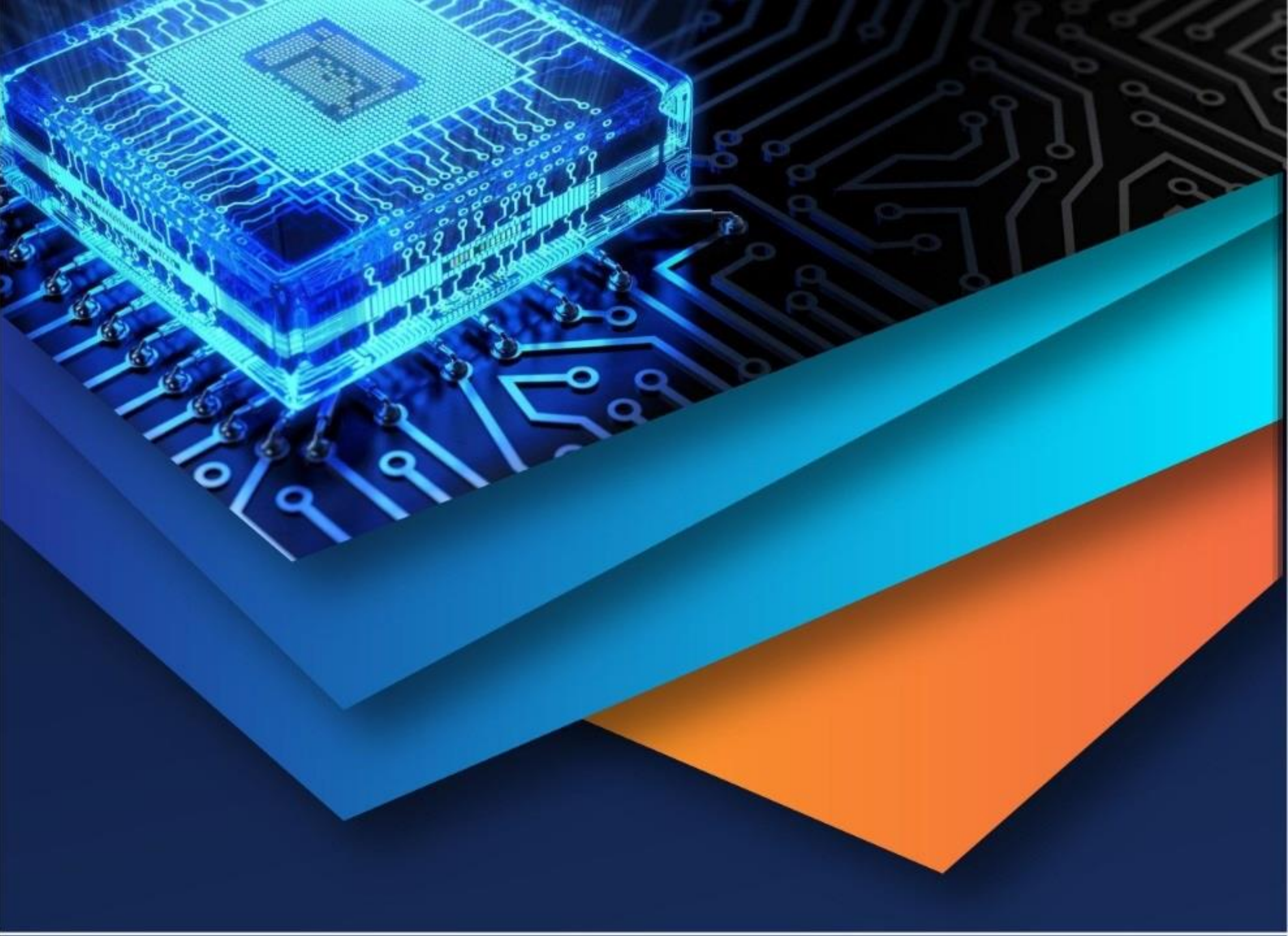
[19] S. A. A. Bokhari, B. Ahmad, J. Ali, S. Ahmad, H. Mushtaq, and G. Rasul, “Future Climate Change Projections of the Kabul River Basin Using a Multi-model Ensemble of High-Resolution Statistically Downscaled Data,” Earth Syst. Environ., vol. 2, no. 3, pp. 477–497, Dec. 2018, doi: 10.1007/s41748-018-0061-y.

[20] Y. M. Taraky, “Flood Risk Management with Transboundary Conflict and Cooperation Dynamics in the Kabul River Basin,” Water, vol. 13, no. 11, p. 1513, May 2021, doi: 10.3390/W13111513.

[21] M. Irfan, “(PDF) Assessment of temporal flow variability of the kabul river (2017) | Muhammad Arfan | 3 Citations.” Accessed: Aug. 09, 2023. [Online]. Available: https://typeset.io/papers/assessment-of-temporal-flow-variability-of-the-kabul-river-26wpmr2kp1

[22] A. Azzam, W. Zhang, M. A. Shahid, and A. Elbeltagi, “Application of hydrological model to assess river flow in the transboundary cryosphere and data-scarce watershed, a case study: Chitral-Kabul River Basin (C-KRB) in Pakistan,” Water Supply, vol. 22, no. 4, pp. 3842–3862, Jan. 2022, doi: 10.2166/ws.2022.016.

[23] M. S. Iqbal, Z. H. Dahri, E. P. Querner, A. Khan, and N. Hofstra, “Impact of Climate Change on Flood Frequency and Intensity in the Kabul River Basin,” Geosciences, vol. 8, no. 4, Art. no. 4, Apr. 2018, doi: 10.3390/geosciences8040114.



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