BE CIVIL ENGINEERING

PROJECT REPORT

AN INSIGHT INTO FUTURE HYDROLOGY OF KABUL RIVER BASIN: NOWSHERA FLOOD PERSPECTIVE

Project submitted in partial fulfillment of requirements for the degree of

BE Civil Engineering

PROJECT ADVISOR: Dr. Muhammad Amjad

SUBMITTED BY

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MILITARY COLLEGE OF ENGINEERING

NATIONAL UNIVERSITY OF SCIENCES & TECHNOLOGY, ISLAMABAD, PAKISTAN

2023

This is to certify that the

BE Civil Engineering Project entitled

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Has been accepted towards the partial fulfillment of requirements for BE Civil Engineering Degree

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Assistant Professor Dr. Muhammad Amjad

(Project Advisor)

Dedication

Dedicated to our parents who prayed for us since ever and our teachers without whose support this effort would never have been completed.

ACKNOWLEDGEMENT

All thanks and praise to Allah Almighty.

We bow our heads before **Almighty Allah** to provide us with opportunity and resources to give complete shape to our research work. There are several individuals whose contributions have been vital for the completion of this project. **Asst Prof Dr. Muhammad Amjad**, our project advisor, was the beacon of guidelines and the driving force behind this research. He contributed valuable ideas, invaluable guidance and enthusiastic encouragement throughout our research work. Also, we pay our gratitude to our faculty members and teachers for guiding and helping us whenever it was needed.

All Syndicate members

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ABSTRACT

Recent climate change impacts have been surfacing more frequently around the world, and under-developed countries like Pakistan are at increasingly worsening exposure to climate change-triggered hydrometeorological extremes. There has been an increased frequency of flooding events in most of the rivers including Kabul River. This study intends to investigate the hydrology of a periodically flooding region Kabul River Basin (KRB) during the recent past (2003-2022) and future (2023-2100) with the intention to contribute towards flood management in Nowshera region. The observed streamflow data of Kabul River at Nowshera and data of climatic parameters (temperature and precipitation) obtained from ERA5-Land for 2003-2022 were given as input to calibrate and validate HBV light hydrological software. Later, using the calibrated model, future simulations of streamflow were simulated on HBV light by giving climate projections of precipitation and temperature as input. The results indicate a much-increased frequency in the occurrence of mega and large floods in Kabul River in the near and far future, requiring a more elevated level of flood monitoring setup in the region. The findings of the study might be beneficial for water resources managers, development planners, and disaster management authorities in the KRB, especially in Nowshera that is highly susceptible to flooding in Kabul River.

CHAPTER 1

INTRODUCTION

1.1. Background

Over the long time, the changes in temperature and weather patterns are known as climate change. These changes may be brought on by natural processes, such as variations in the solar cycle. However, since the 1800s, human activity—particularly the combustion of fossil fuels like coal, oil, and gas—has been the primary cause of climate change. Fossil fuel combustion releases greenhouse gases that act as a blanket around the planet, trapping heat from the sun and raising temperatures.

1.1.1. Impact of climate change in Pakistan

Due to its varied geography and tropical climate, Pakistan experiences several climates- and weather-related natural hazards. In Pakistan, heat waves, droughts, river and flash floods, landslides, and cyclones or marine storms frequently occur. Climate change is predicted to worsen human vulnerability and increase the frequency and intensity of catastrophic disasters. It is expected that temperatures would rise significantly across the nation, especially in the snow-covered mountainous north. This will cause glaciers to melt more quickly, which will modify how the Kabul River flows downstream.

Pakistan is an agriculture country, and the average income of individual is far lower than that of other developed countries. Industrialization is in progress which is pulling mass population from rural areas into urban areas in search of jobs. Climate change has accelerated the rate of glacier melting, which ultimately increases downstream floods. Faster melting of glaciers, rising temperatures, changing weather with unpredictable rainfall are all changing the flow of the Kabul River, and this will increasingly affect activities related to farming, food production and livelihoods.

1.1.2. Intensity/frequency of floods in Pakistan

Climate change is not new in Pakistan and other nation has also faced severe storms and flood in the near past. One theory is based on the belief that it is normal to experience cyclones, storms, floods etc. and they will re-occur at a specific interval, while the others believe that its main reason is climate changes. It is backed by plenty scientific studies that have resulted in the widespread popularity of the belief. In both cases, however, this phenomenon has endangered the entire ecosystem and, as a result, for the countries as well. Globally, the occurrence of recurrent floods and droughts has increased, making Pakistan the seventh most vulnerable country in the world. According to the International Panel on Climate Change (IPCC), during the pre-industrial era the earth temperature has increased by 1 degree. In 2030–2050, this warming might reach 1.5°C under the business-as-usual scenario. By altering the regions of low- and high-pressure systems worldwide, the rise in temperature has an impact on the spatial-temporal distribution of air masses. Seasonal variation and stretches of exceptionally hot and cold weather are the outcome of this change. With temperatures surpassing 50 °C in Pakistan in June 2017 and 2020, the length of the summer season lengthened as a result.2 One of the deadliest results of seasonal changes, heat waves, was also experienced by the seaside metropolis of Karachi in 2015. Unexpectedly, the temperature in Karachi climbed to 43 ° C, and the hot, muggy conditions claimed the lives of almost 1,200 people. Unexpectedly, Karachi's temperature rose to 43 °C, and the sweltering weather claimed the lives of around 1,200 people. Along with the rest of the world, Pakistan has seen sea level rise at a pace of roughly 1.1 mm year.3 It will climb much more over the 21st century, according to projected scenarios. The Hunza River was blocked from flowing for around five months in 2010 due to large landslides that were caused by severe rainfall. In Pakistan, flooding occurs around every three to five years due to the interannual unpredictability of rainfall. Every four to five years between 1990 and 2010 saw tropical cyclones in the Indian Ocean. However, the frequency of cyclones gradually increased; in 2019, about two cyclones per year were reported with consequent losses. The need for water for consumption by people and animals likewise rises in a warmer environment. The irrigation system in Pakistan is dependent on local rainfall and glacier melting. Irrigation is heavily dependent on river tributaries. The storage capacity of big reservoirs has decreased because of increasing sedimentation brought on by recurrent floods, placing strain on groundwater supplies to supply additional water for crops.

1.2. **Problem Statement**

Pakistan, an agricultural country, has one of the largest and best-planned networks of rivers and canals, but unhappily, the system is not properly maintained, and as a result, millions of people who live in the river and canal basins endure floods in many parts of the country. In one of Pakistan's provinces, Khyber Pakhtunkhwa (KP), flooding is a common problem due to the occurrence of large rivers like the Swat and Kabul rivers and their tributaries. In the summer, the basin's average temperature rises to its peak level in July. During this period, the most snow melts, and there are also record-breaking monsoon rains, which caused the rivers to release their water rapidly. In the downstream areas, this causes frequent, severe floods. The Peshawar Valley, which includes the cities of Peshawar, Charsadda, Mardan, Nowshera, and Swabi, is among those most severely impacted by the flooding. Lower down the Kabul River is where Peshawar Vale is located. The greatest rainfall total for Peshawar since 1961 was reported there on July 29, 2010, when 274 mm fell there. The Pakistan Meteorological Department (PMD) noted that 80% of Peshawar received rainfall daily, which is five times the monthly normal (47 mm) in July. In KP, 3.8 million people were impacted by these flash floods, which killed up to 1156 people. Approximately 250,000 people were rendered homeless and at least 53 villages in the Nowshera area sustained significant damage. About 9,000 homes and 13,000 acres of crops were also devastated by the storm. Due to the Kabul River's heavy flood, which runs close to Nowshera, 89 educational institutions were also devastated. According to Du et al. (2015), dwellings are more susceptible to flood threats because of their improper structure and flood-prone location. Following agriculture as a very susceptible sector, according to the field survey, are housing (30%), livestock (13%) and other sectors (such as health, education, business, etc.) with a combined response rate of 17%. According to Khan and Rahman (2012), mitigation measures are activities or programs aimed at lessening how risks affect the human system. Structure-related and non-structure-related indicators are also included (Douben, 2006).

1.3. **Objectives**

The specific objectives of this study include:

- Setting up reliable hydrological simulations for Kabul River Basin for recent past.
- Providing an insight into the future hydrology of Kabul River Basin.

1.4. **Scope of study**

Introduction of new model based reliable data that would be easily accessible to all the stakeholders to study hydrological future insight of floods in Kabul River at Nowshera region on various sectors like agriculture, food security, water resources availability, transportation, health, education, and corporate etc.

The findings of this study could be beneficial for researchers and decision makers associated to the sectors such as water resources management, agriculture, and disaster management as well as for the experts concerned with the flood prediction in Kabul River.

CHAPTER 2

LITERATURE REVIEW

Studies conducted in various countries, especially neighboring countries, were examined during the out research. Different articles related to extreme events specifically in Pakistan were also examined to have certain degree of knowledge on the current development in this field. Few of the papers would be discussed in this section.

2.1. Climate Change and Past Flooding trends in Kabul River

The KRB on both sides of the DBL is highly concerned about flash floods. Urban areas will become more prone to seasonal flooding because of increased land usage due to population expansion. In RCP 4.5 flow scenarios, flood inundation will rise between (+17%) and (+31%), and in RCP8.5 scenarios, it will rise between (+26%) and (+50%) in comparison to historical records. If dams are not built in the future, these increases will be even greater. Flood reductions of between (-25%) and (-40%) for future planned dams are expected for the areas of Nowshera and Kheshgi, and between (-34%) and (-38%) for future planned dams under RCP 8.5 flow scenarios. The budget of the HKH's snowpack will be depleted despite an increase in water supply due to climate change. Rapid glacier melting in the upper KRB region (up to -20.3% under RCP4.5 and -21.6% under RCP8.5) is projected to be the cause of such an increase. Glaciers account for 3.3% of the KRB area, hence melting glaciers will result in higher low flows (Tarakay, 2021).

Catchments with a seasonal snowmelt regime, as well as a seasonal snowmelt and rainfall regime, had an increase in flood risk associated to annual maximum flood (AMF), annual maximum flood during spring (AMFsp), and POT3M. When the transition point occurred, the flood risk in the northern portion of the basin declined and rose towards the south, contrary to what was first seen, which was that the northern and northwestern regions of the KRB were more susceptible to flooding. In instance, the maximum one-day and maximum five-day precipitation rose with the extreme precipitation. The biggest contributing factor is the decline in annual and monsoon rainfall. The maximum five-day rainfall and a major reduction in forest area are the key factors contributing to the increased flood risk in the southern region of the KRB (Asif and Shao Feng, 2021). The hydrological cycle and water resource availability and management are both impacted by climate change and unpredictability. To assess potential flow changes in the Kabul River Basin for three future periods—the start of the century (2020), the middle of the century (2050), and the end of the century (2080)—the SWAT model was run with projected future climate data from three GCMs under two Representative Concentration Paths, RCP 4.5 and RCP 8.5. The average annual flow of the stream is anticipated to grow by 50 to 120% in the next years, whereas the forecasted yearly decline in precipitation is anticipated to be around 53 to 65% for the whole basin. Under RCP 4.5 and RCP 8.5, the mean annual temperature in this basin is predicted to rise by 2.2 and 2.8C, respectively. According to the study, there were seven different forms of land use: herbaceous vegetation (53.24%), agricultural (26.61%), permanent snow and ice (12.66%), forest (7.1%), bare land (0.31%), urban areas (0.01%), and water bodies (0.07%).

Using nine flood-causing factors—the drainage network, river flow, precipitation, slope, flow accumulation, soil, surface geology, flood depth, and land use—a forecast of flooded regions was produced in 2009 for the construction of spatial geodatabases. a GIS environment. The use of ANNs in flood hazard mapping and zonation was highlighted by the speaker. A variety of factors, such as high river discharge, encroachment on flood channels, and building activities in an active floodplain, often increase the risk of floods. Because there are so many currents and tiny surfaces present, the KRB displays special morphometric characteristics that lead to a substantial buildup of short-range flow. Floods are caused partly by rainfall and partly by the ability of a river to retain water flowing in its channel (Saeed et al., 2021).

To simulate rainfall, runoff, and flood inundation into the Kabul River basin, a 2D rainfall-runoff-inundation model was utilized. The largest flooded area along the major rivers Kabul and Swat demonstrated significant agreement between simulation and remote sensing. The investigation demonstrated that, for appropriate downstream flow prediction, model simulation may be able to supplement remote sensing, particularly over areas threatened by flash floods. In comparison to the situation without upstream inundation, the outlet flood peak was lowered to 35% and the peak was postponed by around 2.5 days when upstream flood inundation was considered (Takahiro, 2011).

Study and project water levels from 2011 through 2030 using historical trends. It is predicated on suppositional values. This study compelled the use of an ML method to water level forecasting so that engineers and decision-makers might employ preventive measures to handle severe events. The forecast was assessed by comparing it to the actual values, and it was discovered that ARMA had more accuracy than other modes based on the lowest AICI values. It has been determined that between 2011 and 2030, the Kabul River's water level will be just a little bit higher than 250 cu in. From January through August, the water level will progressively rise until it reaches a maximum of 250 cu in September. Once the monsoon season passes, the water level will return to its minimum value of 10 cu in the months of October to December until 2030 (Mohammed, 2017).

SPF and PMF calculations at a dam site where there is little access to flow data. A unit hydrograph was produced using the Snyder approach because there wasn't an observable hydrograph at the Kol dam site. The 2-day likely hydrograph of the greatest flood and the 2-day standard hydrograph of the project were calculated using the SPS and PMS values at the location of the Kol dam. Because the peak of the PMF hydrograph is much higher than the peak of the SPF hydrograph, it is advised that the design flood at Kol Dam be based on this peak in the absence of trustworthy rainfall and outflow data (Muhammad, 2017).

In the next 50 years, a 10% decrease in total annual precipitation is anticipated owing to climate change. Currently, surface water contributes 55.7 km3 to internally generated water from the Kabul basin, which is around 11.5 km3. Due to its phonological tuning and availability of reliable, geographical and temporal data, MODIS-NDVI was chosen for this investigation. From April through August, ETA in KRB often reaches its peak. The two months of June and July with the highest temperatures ever recorded in 2013 had ETAs of 78 and 74 mm, respectively. According to Fazlullah (2017), the average wind speed in 2013 was 2 m/s, with the highest wind speeds (2.5 m/s) occurring in December and January. Wind speed is a key factor in evaporative demand.

Flood risk maps could occasionally need to be updated using Earth observation (EO) data. The Kabul River and the Swat River provide a constant threat of flooding to the Charsadda District of KP. The dimensions of the people, buildings, agriculture, transportation, and infrastructure were taken into consideration while assessing exposure, susceptibility, and risk. With the use of PRA instruments, thorough field surveys were carried out. To acquire the most accurate findings, key informant interviews and focus groups (FGDs) were done for social mapping, risk mapping, historical profiles, seasonal calendars, transect walks, and direct observation Several GIS methodologies were used to analyze the data from these analyses. Due to its position and the absence of disaster planning initiatives, it demonstrates that UC Agra is extremely susceptible to flood dangers. To avert additional erosion and harm to the barrier, the plantation and a few weak breaches need to be repaired (Asif and Shao Feng, 2018).

Massive deforestation has occurred in KPK, AJK, and Gilgit-Baltistan due to a lack of watershed management attention. delayed flood embankment maintenance, improper provincial flood management Floods are caused in large part by a lack of storage facilities. On the weak points of the flood levees, there was no machinery, enough supply of stone, sandbags, etc. Routes for evacuation, emergency shelters, and war rooms were poorly prepared. Budgetary resources are insufficient for the upkeep of new flood works as well as current flood control facilities (Hashim and Talat, 2011).

The Kabul River basin's three regions—Central, Northern, and Eastern—each have three different climatic traits. The temporal area of rainfall analyzed by the spectral analysis approach was used to ascertain the periodicity of precipitation in various seasons. The notion of Thornthwaite was used to categorize the climate. Due to the high temperatures, summer and the beginning of autumn were considered dry; yet the eastern half had quite substantial rainfall. A summer monsoon from South Asia arrived together with the appearance of summer spectral peaks in the eastern region. Weather maps over the summer and fall revealed that the South Asian summer monsoon, which mostly functioned in the eastern region, was the major source of moisture (Jamal et al., 2017).

For the Upper Kabul watershed in Afghanistan, the SRM is used to calculate streamflow. 2009 calibration and 2011 validation serve as the SRM's baselines. 5.6 m3 s-1 and 5.7 m3 s-1, respectively, were the estimated and observed average flows for 2009; in 2011, these values were 1.31 m3 s-1 and 1.33 m3 s-1. With volume differences of 0.5% and 0.903, respectively, and noticeably high R2s of 0.904 and 0.903, the model performs well. 2.4%. The yearly flow will rise by 17.4% with a 1oC rise in air temperature and a 10% increase in precipitation. Like this, yearly flow increases by 47.3% when temperature and precipitation are both raised by 2°C. The findings show that SRM may be successfully used in more sub-watersheds in the Upper Kabul basin.

Utilizing gridded climate data from the early 2000s, the study tried to quantify how the effects of climate change have affected the KRB's water supply. The study was carried out for the two chosen future time periods of the near future (2011-2030) and the far future (2031-2050). four GCMs combined with RCP 4.5. According to analysis of future climatic time series, under the RCP 4.5 and RCP 8.5 scenarios in both the near and long future, the overall temperature increase for the whole basin would be in the range of 3-5 _C. There are several major discoveries associated with the hydrological regime change, including the following: (i) higher annual mean discharge with more variability (SD values: 218 for baseline, 289 for RCP 4.5, and 284 for RCP 8.5, in the near future and 219, 240, and 359 for the baseline, RCP 4.5, and RCP 8.5, respectively, under the far-off scenario; (ii) more frequent extreme events of greater magnitude, for example, annual maximum values of 5,000 m3/s and 6,000 m3/s are anticipated to occur more frequently in the near and more distant futures compared to the baseline period (Hashmi, 2020).

To build a five-century history of precipitation for the Kabul River basin, we used seven tree-ring chronologies from the Hindu Kush Mountains. The reconstruction's trend analyses showed that there had been a variety of changes: no trend in the highest amount of precipitation, a statistically significant but modestly increasing trend in the median amount of precipitation, and lastly a large and considerable decline in annual precipitation. The outcome is concerning because it confirms that the water cycle is becoming more intense at a time when the basin is expected to experience higher rainfall and flooding. Decisions about basin-wide water management must take climatic variability at different time scales into consideration when dealing with flood and drought threats; tree-ring-based reconstructions are an invaluable source of data to meet this need (Nasrullah and Nguyen, 2022).

This study used the WRF model over the KRB to forecast excessive rainfall in 2010 and replicate the flood that occurred that year. To assess the efficacy of the model performance, the data should be contrasted with other satellite and remote sensing datasets that are currently accessible. Extreme occurrences over the KRB might be simulated by WRF. In the difficult terrain of the HKH region, comparable future occurrences may be predicted using the WRF model with the appropriate physical parameterization techniques, horizontal resolution, and nested domain (Fahmida and Dars, 2017).

2.2. Simulation of Discharges using various software's

To analyze gross soil loss and the geographical distribution of soil loss rates under different land uses, this study combines the RUSLE model with GIS approaches. by causing 57% of the entire yearly average soil loss. If all the forest in the Kunar basin is turned into arid terrain, the study's prediction would come true. According to Ahmed (2013), the Boyce, Renfro, Williams, and Maner method's projected values are in the same range as the sediment supply ratios for the sediment measurement sites in the basin.

The findings of this investigation revealed that the basin's peak flow rose (17.5%) over time. Due to numerous droughts, mean flow has decreased (-4.6%). This implies that increased floods may be a problem for irrigation. A combined dataset with gap duration analyses produced a more credible result than utilizing a single dataset alone for flood return period forecasts, according to flood recurrence analyses. The study also aids researchers by specifying the degree of flow change at each station, which is helpful for calibrating or cross validating their models using later period data and simulations using early period data (Hafiz Asim, 2020).

This study estimated flood design quantiles for "in situ analysis" in a changing environment and examined its implications for flood management in the Kabul River Basin (KRB), Pakistan, using a shape parameter-informed Bayesian framework for a generalized extreme value (GEV) model. These studies' findings looked at how the KRB's precipitation regime has changed. To identify patterns in annual maximum floods, the non-parametric Mann-Kendall rank (MK) test was performed. The Bayesian derived parameters are estimated using a differential evolutionary Markov chain (DE-MC), which integrates several realizations from the posterior distributions of the parameters (Asif et al., 2019).

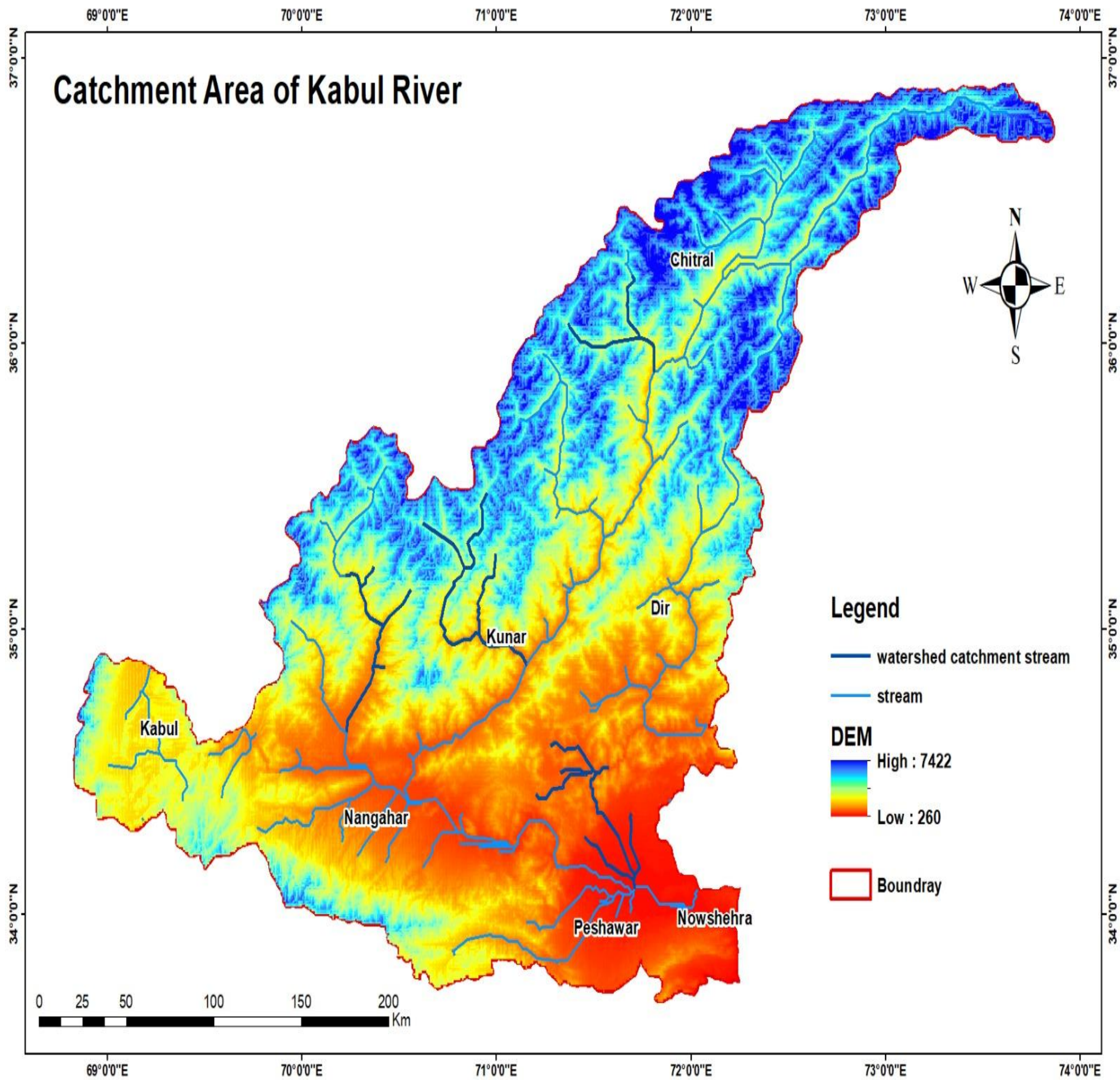
Using a shape parameter-informed Bayesian framework for a generalized extreme value (GEV) model, this study computed flood design quantiles for "in situ analysis" in a changing environment and explored its implications for flood management in the Kabul River Basin (KRB), Pakistan. The results of this research examined the evolution of the precipitation regime in the KRB. The non-parametric Mann-Kendall rank (MK) test was used to find trends in yearly maximum floods. A differential evolutionary Markov chain (DE-MC), which incorporates numerous realizations from the posterior distributions of the parameters, is used to estimate the Bayesian-derived parameters (Asif et al., 2019).

CHAPTER 3

MATERIALS AND METHODS

3.1. Study Area

Pakistan's coordinates are 23° 35' N to 37° 05' N and 60° 50' E to 77° 50' E. It is in South Asia. Kabul River Basin, with a case study on the Nowshera region, is the field of research chosen for this essay. Located in Pakistan, the 40,064 km2 Kabul River Basin (KRB) stretches from 71° 1′ 55° to 72° 56° east to 33° 20′ 9° to 36° 50′ 0° north. The Kabul River rises in Afghanistan at the foot of the Hindu Kush Mountains' Unai Pass, then runs for 700 km to the east until emptying into Pakistan's Indus River. A total of 87,499 km2 comprise the basin. From 249 m.a.s.l. to 7603 m.a.s.l., the elevation in the watershed varies greatly. Largely in the north are high mountains. Precipitation and temperature typically radically differ across the basin. About 13 C is the average temperature. Up to 1600 mm of precipitation can be found in the northern mountains and highlands. The KRB's contribution to floods is examined in this study. The major source of the flooding issue is when the Kabul River enters Pakistan. Thus, it is essential for Pakistan to gather knowledge about the basin's future hydrology to plan for prospective flood and drought occurrences and to create successful adaptation methods. The future hydrology of the Kabul River Basin from Pakistan's perspective has been studied using a variety of data sources. These consist of satellite images, past rainfall and streamflow information, climate models, and hydrological models. The whole Kabul River Basin and its principal tributaries, the Swat River, Panjshir River, and Kunar River, are included in the research region under observation. In 2010, one of the worst floods to hit the Kabul River Basin in recent memory happened, having severe impact on millions of people in Pakistan and Afghanistan. The flood was brought on by significant rainfall in the basin's upper levels, which overflowed numerous rivers, notably the Kabul River. It is anticipated that future floods and droughts in the Kabul River Basin would become more frequent and more severe based on the data and models now in use. As temperatures, precipitation patterns, and extreme weather events are predicted to alter due to climate change, these occurrences are likely to get worse. Therefore, it is essential that Pakistan create effective adaptation plans, such as early warning systems, flood preparedness measures, and water resource management plans, to lessen the effects of upcoming flood and drought disasters.

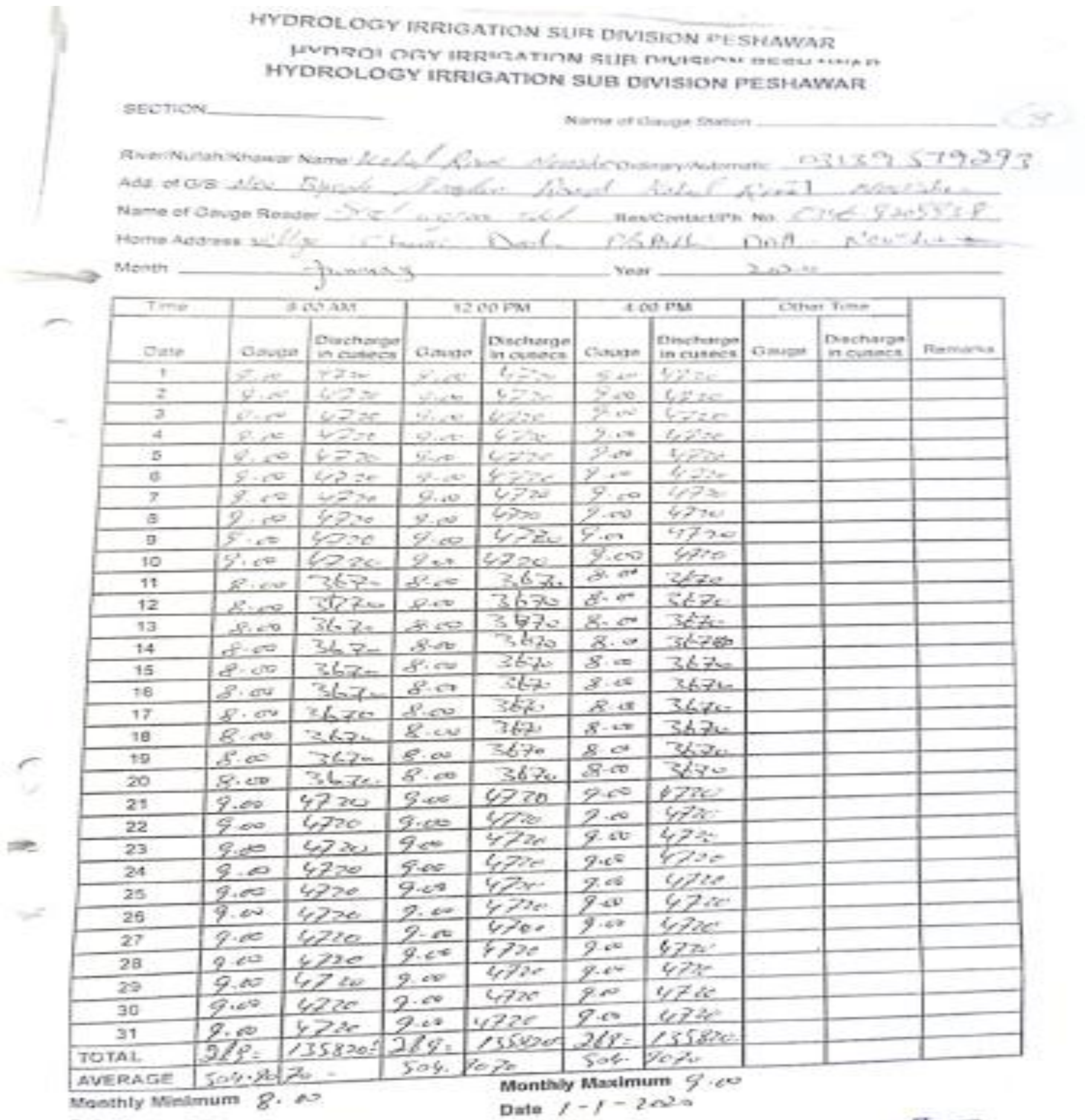


<u>Figure 3.1 Watershed map of Kabul River basin along with its elevation distribution into 8 bands</u>

3.2. Data Collection

3.2.1. Observed Data

Data Collection was done from the Hydrology Irrigation Department Peshawar. This data gives the daily discharge of Kabul River at the Nowshera KASHTI Bridge.



HYDROLOGY IRRIGATION SUB DIVISION PESHAWAR

HYDROLOGY IRRIGATION SUB DIVISION PESHAWAR
HYDROLOGY IRRIGATION SUB DIVISION PESHAWAR

SECTION ______ Name of Gauge Station ______

River/Nullah/Khawar Name ______ Ordinary/Automatic ______

Add. of G/S ______

Name of Gauge Reader ______ Res/Contact/Ph. No. ______

Home Address ______

Month January Year 2020

Time	8:00 AM		12:00 PM		4:00 PM		Other Time		
Date	Gauge	Discharge in cusecs	Gauge	Discharge in cusecs	Gauge	Discharge in cusecs	Gauge	Discharge in cusecs	Remarks
1	9.00	4720	9.00	4720	9.00	4720			
2	9.00	4720	9.00	4720	9.00	4720			
3	9.00	4720	9.00	4720	9.00	4720			
4	9.00	4720	9.00	4720	9.00	4720			
5	9.00	4720	9.00	4720	9.00	4720			
6	9.00	4720	9.00	4720	9.00	4720			
7	9.00	4720	9.00	4720	9.00	4720			
8	9.00	4720	9.00	4720	9.00	4720			
9	9.00	4720	9.00	4720	9.00	4720			
10	9.00	4720	9.00	4720	9.00	4720			
11	8.00	3670	8.00	3670	8.00	3670			
12	8.00	3670	8.00	3670	8.00	3670			
13	8.00	3670	8.00	3670	8.00	3670			
14	8.00	3670	8.00	3670	8.00	3670			
15	8.00	3670	8.00	3670	8.00	3670			
16	8.00	3670	8.00	3670	8.00	3670			
17	8.00	3670	8.00	3670	8.00	3670			
18	8.00	3670	8.00	3670	8.00	3670			
19	8.00	3670	8.00	3670	8.00	3670			
20	8.00	3670	8.00	3670	8.00	3670			
21	9.00	4720	9.00	4720	9.00	4720			
22	9.00	4720	9.00	4720	9.00	4720			
23	9.00	4720	9.00	4720	9.00	4720			
24	9.00	4720	9.00	4720	9.00	4720			
25	9.00	4720	9.00	4720	9.00	4720			
26	9.00	4720	9.00	4720	9.00	4720			
27	9.00	4720	9.00	4720	9.00	4720			
28	9.00	4720	9.00	4720	9.00	4720			
29	9.00	4720	9.00	4720	9.00	4720			
30	9.00	4720	9.00	4720	9.00	4720			
31	9.00	4720	9.00	4720	9.00	4720			
TOTAL	289.-	135820.-	289.-	135820	289.-	135820.			
AVERAGE	504.90	70.-	504.	9070	504.	9070			

Monthly Minimum 8.00 Monthly Maximum 9.00

Date 11-1-2020 Date 1-1-2020

4381.29

Signature of G/R Signature of Sub Engineer Sub Divisional Officer

Figure 3.2 Observed Data

3.2.2. ERA5 - Land Data

The fifth-generation reanalysis data (ERA5-Land) released by the European Centre for Medium-Range Weather Forecasts (ECMWF) is a global dataset that provides high-resolution (with a spatial resolution of ~10 km) information on land surface conditions covering a wide range of variables related to land processes such as temperature, precipitation, soil moisture, humidity, etc. ERA5-Land is a faction of state-of-the-art fifth-generation reanalysis of ECMWF namely ERA5.

ERA5-Land data is archived at Climate Data Store (CDS) of Copernicus (https://cds.climate.copernicus.eu/#!/home). For this study, monthly averages of temperature and precipitation for ERA5-Land were obtained from CDS. The data, in its origin, is a continuous gridded data that spanned over Pakistan for the period of 1950-2022.

3.2.3. CORDEX Climate Projections

Coordinated Regional Downscaling Experiment, known as CORDEX (https://cordex.org/), archives climate projections data for different spatial segments (domains) of the globe such as “South Asia”, “Middle East North Africa”, etc. Climate data projections are available for various regional circulation models (RCMs) while the data for these RCMs is downscaled from Global Circulation Models (GCMs) having relatively coarser spatial resolution. This study utilized climate projections (for RCP 8.5) obtained from RCMs having mean resolution of ~0.44 (i.e., ~45 km) over Middle East North Africa (MENA) domain.

3.3. Data Processing

3.3.1 Digitizing the Observed Data

We got daily water flowing data at Nowshera from irrigation department in PDF form as shown below:

Hydrology Irrigation Sub Division 8

2282

SECTION

Name of Gauge Station

River/Nullah/Khawar Name: Kabul River new bridge Mardan Road Nowshera

Location: Mardan Road Nowshera

Name of Gauge Reader: Syed Anwar Shah Res/Contact/Ph.No. 0344-9209339

Home Address: village [illegible] Pabbi distt Nowshera

Month: August (8) Year: 2021

Time	8:00 AM		12:00 PM		4:00 PM		Other Time		Remarks
Date	Gauge	Discharge in Cusecs	Gauge	Discharge in Cusecs	Gauge	Discharge in Cusecs	Gauge	Discharge in Cusecs	
1	20-5	77403	20-5	77403	20-5	77403			
2	20-00	73320	20-00	73320	20-00	73320			
3	19.5	68873	19-5	68873	19.5	68873			
4	18-00	55781	18-00	55781	18-00	55781			
5	18-00	55781	18-00	55781	18-00	55781			
6	18-00	55781	18-00	55781	18-00	55781			
7	17-5	51600	17-5	51600	17-5	51600			
8	17-00	47619	17-00	47619	17-00	47619			
9	17-00	47619	17-00	47619	17-00	47619			
10	17-00	47619	17-00	47619	17-00	47619			
11	17.00	47619	17-00	47619	17-00	47619			
12	17-00	47619	17-00	47619	17-00	47619			
13	17-00	47619	17-00	47619	17-00	47619			
14	17-00	47619	17-00	47619	17-00	47619			
15	17-00	47619	17-00	47619	17-00	47619			
16	17-00	47619	17-00	47619	17-00	47619			
17	16-5	43657	16-5	43657	16-5	43657			
18	16-00	39859	16-00	39859	16-00	39859			
19	16-00	39859	16-00	39859	16-00	39859			
20	16-00	39859	16-00	39859	16-00	39859			
21	16-00	39859	16-00	39859	16-00	39859			
22	16-00	39859	16-00	39859	16-00	39859			
23	15-00	32655	15-00	32655	15-00	32655			
24	15-00	32655	15-00	32655	15-00	32655			
25	15-00	32655	15-00	32655	15-00	32655			
26	15-00	32655	15-00	32655	15-00	32655			
27	15-00	32655	15-00	32655	15-00	32655			
28	15-00	32655	15-00	32655	15-00	32655			
29	15-00	32655	15-00	32655	15-00	32655			
30	15-00	32655	15-00	32655	15-00	32655			
31	15-00	32655	15-00	32655	15-00	32655			
TOTAL	516	1051615	516	[illegible]	516	[illegible]			
AVERAGE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			

Monthly Minimum Discharge

Date 1-9-2021

Signature of G.R.

Monthly Maximum Discharge

Date

Signature of Sub Engineer

Sub Divisional Officer

Figure 3.3 Observed Data

Making sure that the data is logically organized and simple to use is crucial when transferring visual data into an Excel sheet. To do this, the data may need to be arranged into columns and rows, given labels and headings, and subjected to calculations that can be used to alter the data. Digitalize data in form of excel sheet as shown in screen shots

YEAR	MONTH	DISCHARGES
2021	JAN	6634
	FEB	7245
	MAR	15854
	APR	39165
	MAY	51585
	JUNE	55745
	JULY	56347
	AUG	45978
	SEP	28454
	OCT	21056
	NOV	9834
	DEC	11547

Figure 3.4 Observed Data on Excel Sheet

The data can be utilized to run applications once it has been translated to an Excel format. To do this, the Excel sheet must be imported into the software application that will be used to analyze the data. Users should be able to input data from Excel into the software programs, where they can then analyze and alter the data.

3.3.2. Reading and Processing ERA5-Land Data

ERA5-Land monthly averages for precipitation and temperature, obtained from CDS, processed to get an R-compatible format (i.e., ". Rdata") and were trimmed for Kabul River Basin.

To run hydrological model to simulate surface runoff, the precipitation and temperature datasets of ERA5-Land were given input (as a "ptq" file) to HBV Light. Similarly, "EVAP" file was prepared by processing ERA5-Land temperature data into potential ET data using "thorn Waite" package of R-statistical language.

3.3.3 Reading and Processing CORDEX Climatic Projections

The climate projections data (originally in ".nc" format) over MENA was processed to R-compatible format and trimmed for Kabul River Basin. The data contained daily estimates for two parameters (total precipitation and 2m-temperature) for the period 2023-2100. Later, the daily precipitation and temperature data was converted into monthly data to make it compatible for HBV Light.

A "ptq" file to be given as input to HBV Light was prepared using climate projections for precipitation and temperature along with "EVAP" file generated by using temperature data.

3.4. Hydrological Modeling

3.4.1. Introduction to HBV Lite

HBV light is a new version of the HBV model developed by the Swedish Meteorological and Hydrological Institute (SMHI). It provides an easy-to-use version of Windows for research and education. The basic equations for HBV light are consistent with the SMHI-version of HBV-6, but instead of using initial states, the new version uses a warm-up period. In the original version, only the integer value is allowed in the MAXBAS routing parameter. To keep the program as simple as possible, several functions included in the HBV-6 software have not been implemented in the HBV light software. The HBV-light version offers two options that do not exist in the HBV-6 version. The first is the option to include the observed groundwater level in the analysis, and the second is the option to use a different response routine with a delay parameter.

Mandatory input files required for runoff simulations are:

1. PTQ file (ptq.txt) that contains time series of daily precipitation [mm/day], temperature [ºC] and observed runoff [mm/time].

2. The evaporation-file (EVAP.txt) which contains values for potential evaporation [mm/time].

The total period for simulation is required to be split into calibration and validation periods and saving the results for both the periods is optional. For each of the two periods, the detailed results-files contain data for input, as well as the resulting output variables; the output variables include the time series of simulated runoff (Qsim), simulated rain (Qsim_rain), and simulated snow (Qsim_snow), among the other variables. Whereas the summary (of the results) files contain:

1. Annual water balance (mm/year), which includes the sums of simulated runoff, observed runoff, precipitation, and other variables like evapotranspiration.

2. Goodness of fit, which includes coefficient of determination, model efficiency or Nash-Sutcliffe Efficiency (NSE), Kling-Gupta Efficiency (KGE), mean difference etc.

3.4.2. Preparing input for HBV Lite

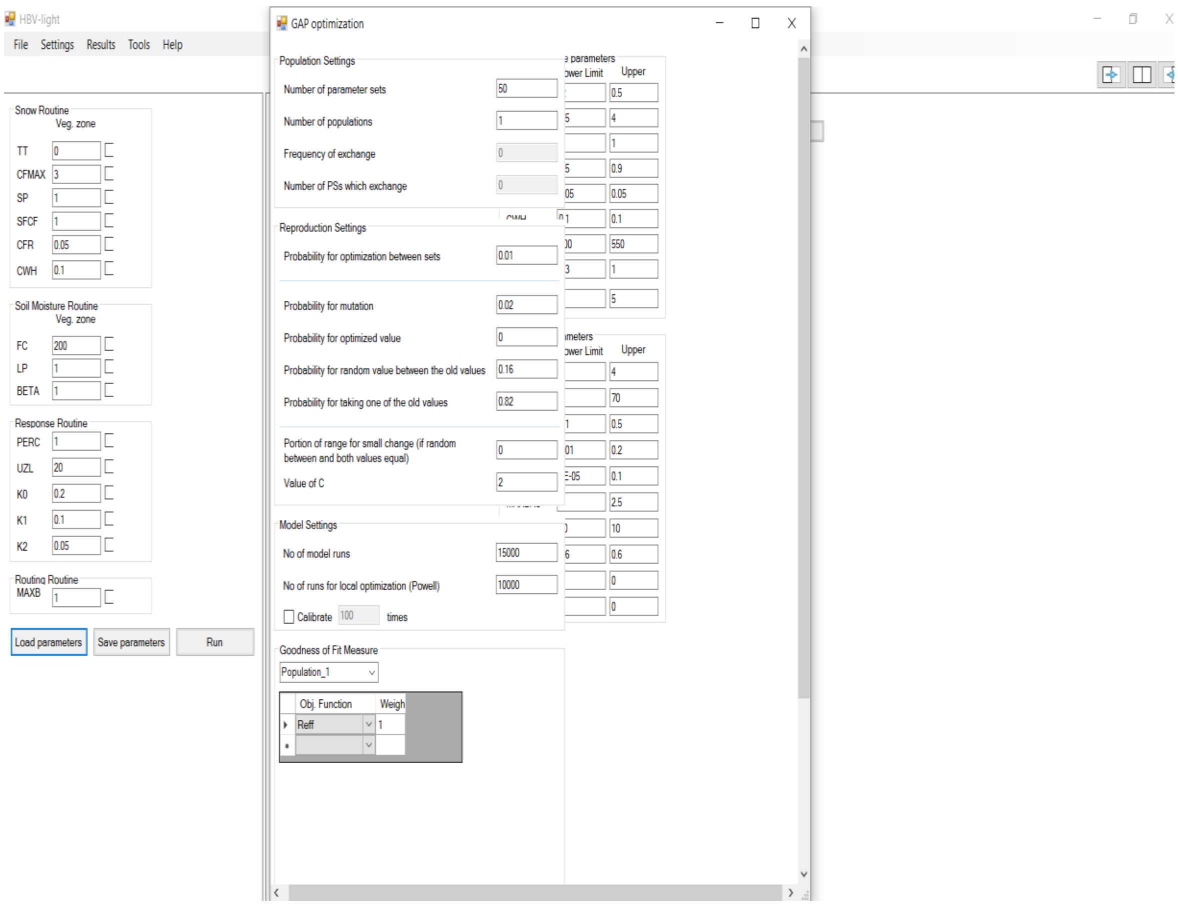


Figure 3.5a **Calibration: Parameter optimization**

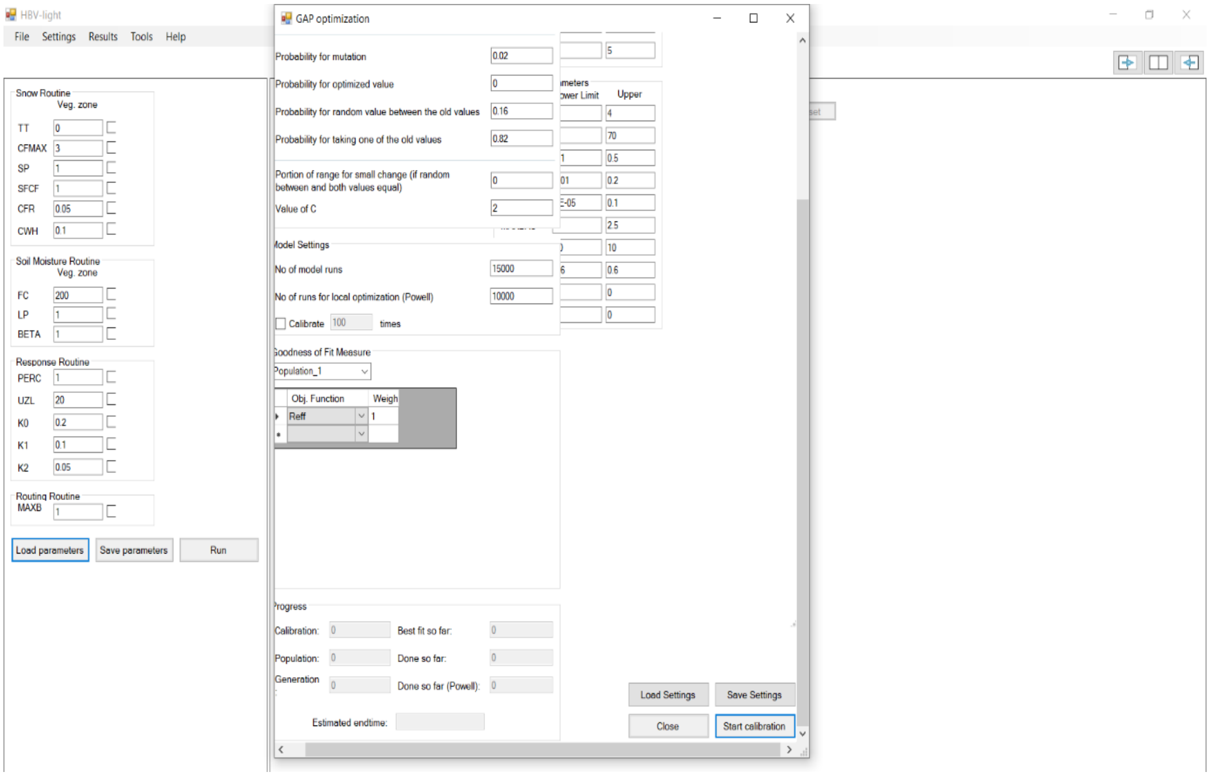


***Figure 3.5b* Calibration: Parameter optimization**

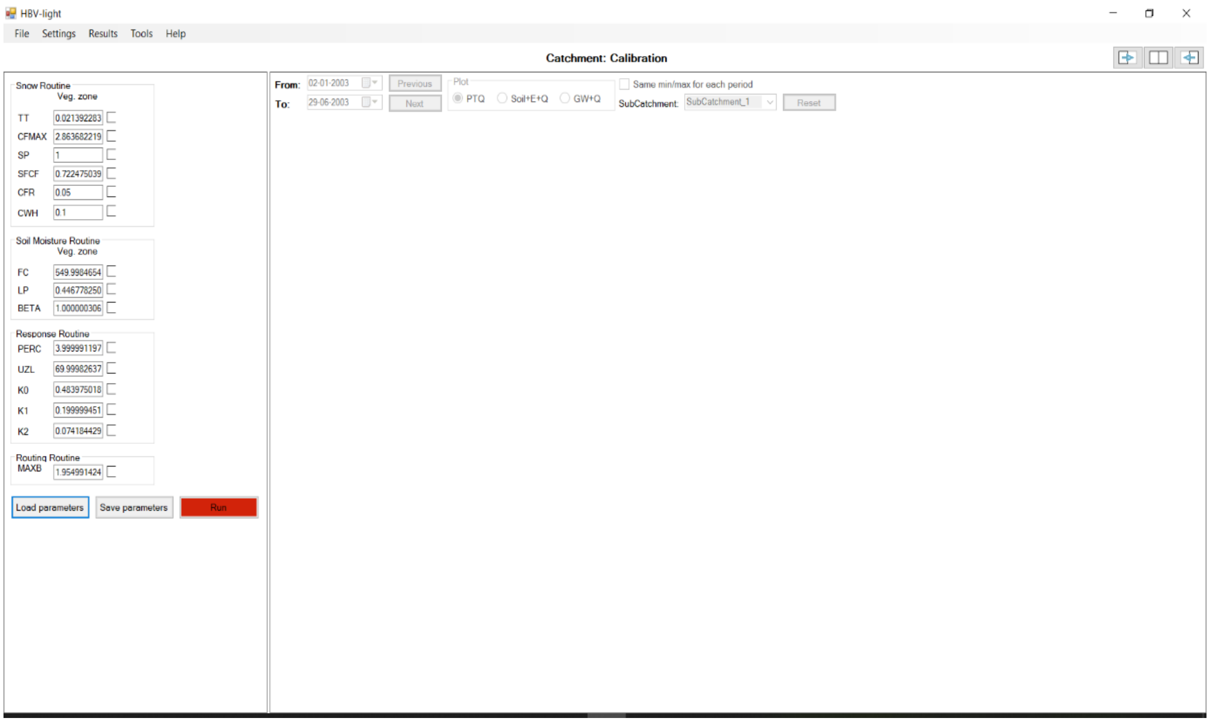


***Figure 3.5c* Calibration: Parameter loading**

3.4.3. Training and Calibration of model for 15 years

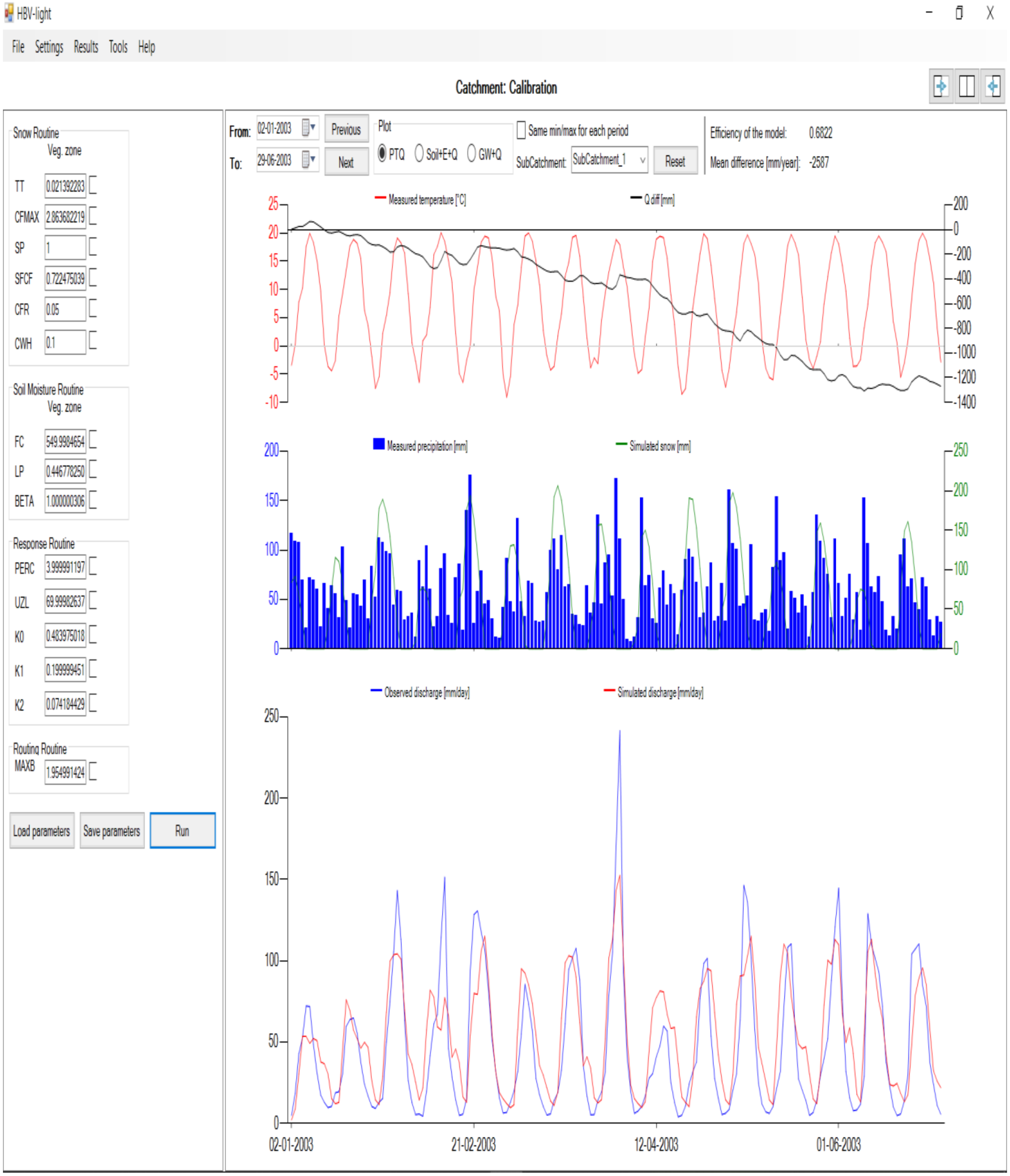


Figure 3.5d Calibration: Model run

3.4.4. Validation of model for 5 years

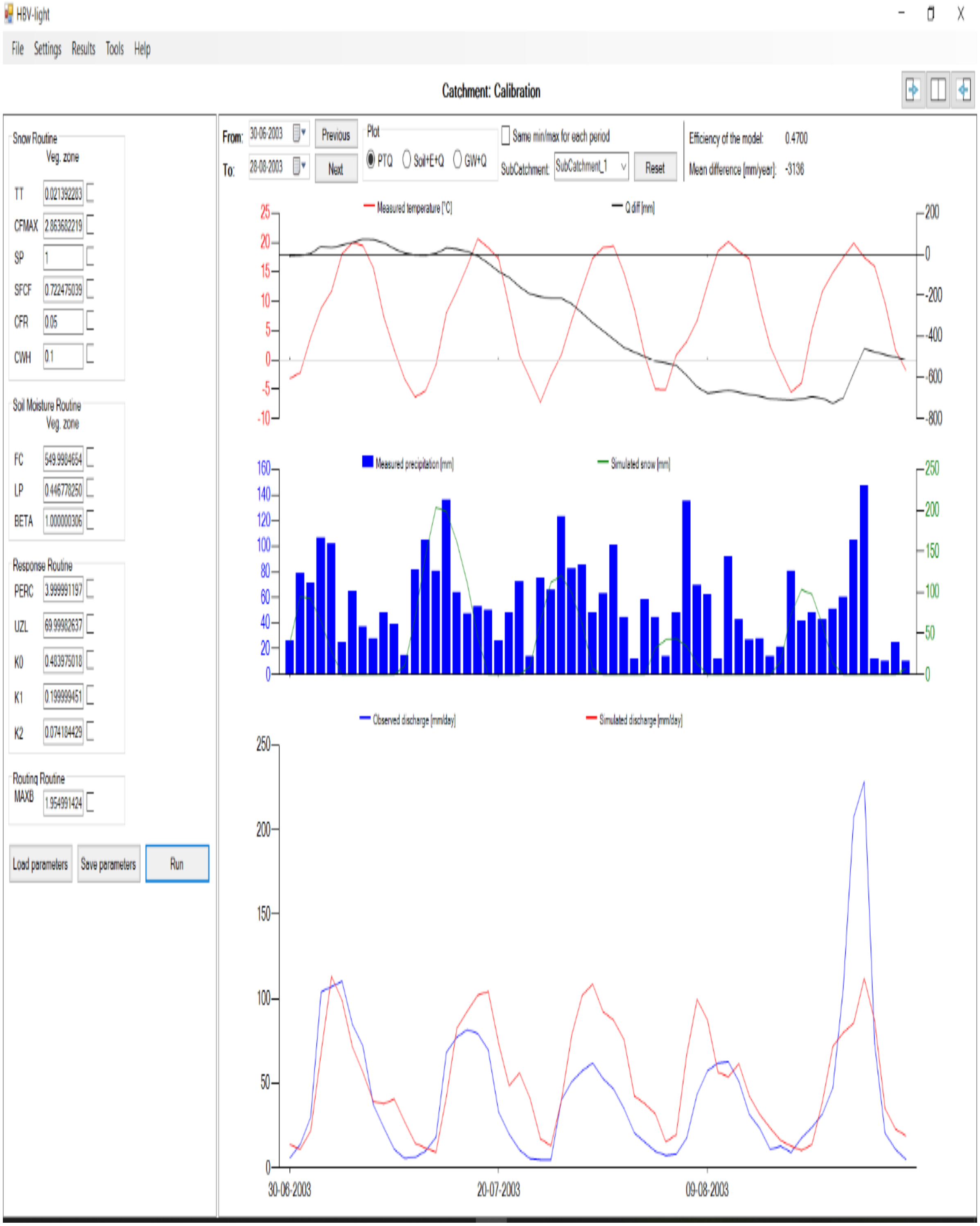


Figure 3.5e **Validation: Model run**

3.4.5. Simulation of Past and Future for 78 years

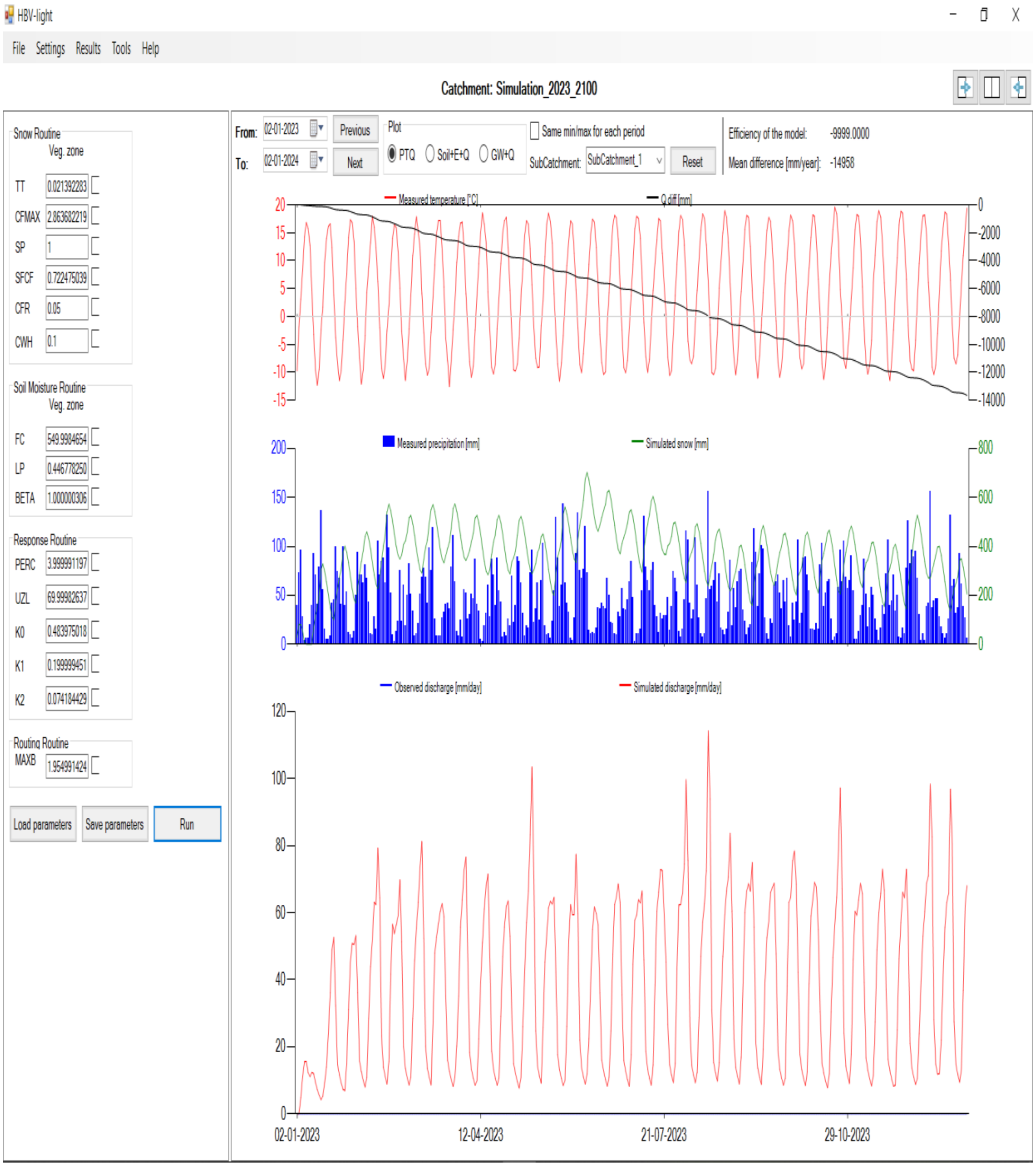


Figure 3.5f **Simulation: Model run**

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Input Data

4.1.1. ERA-5 Land Precipitation and Temperature Data

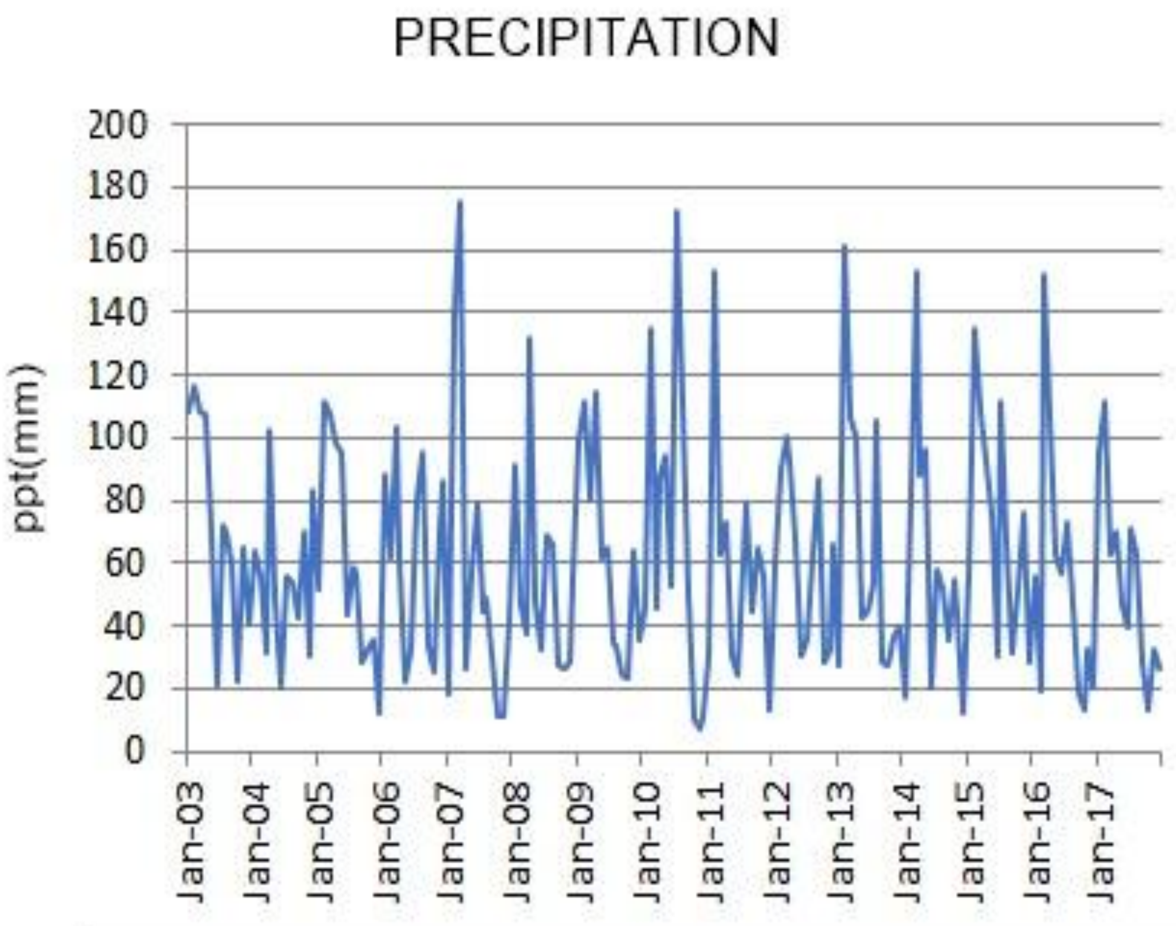


Figure 4.1a ERA5-Land Precipitation data

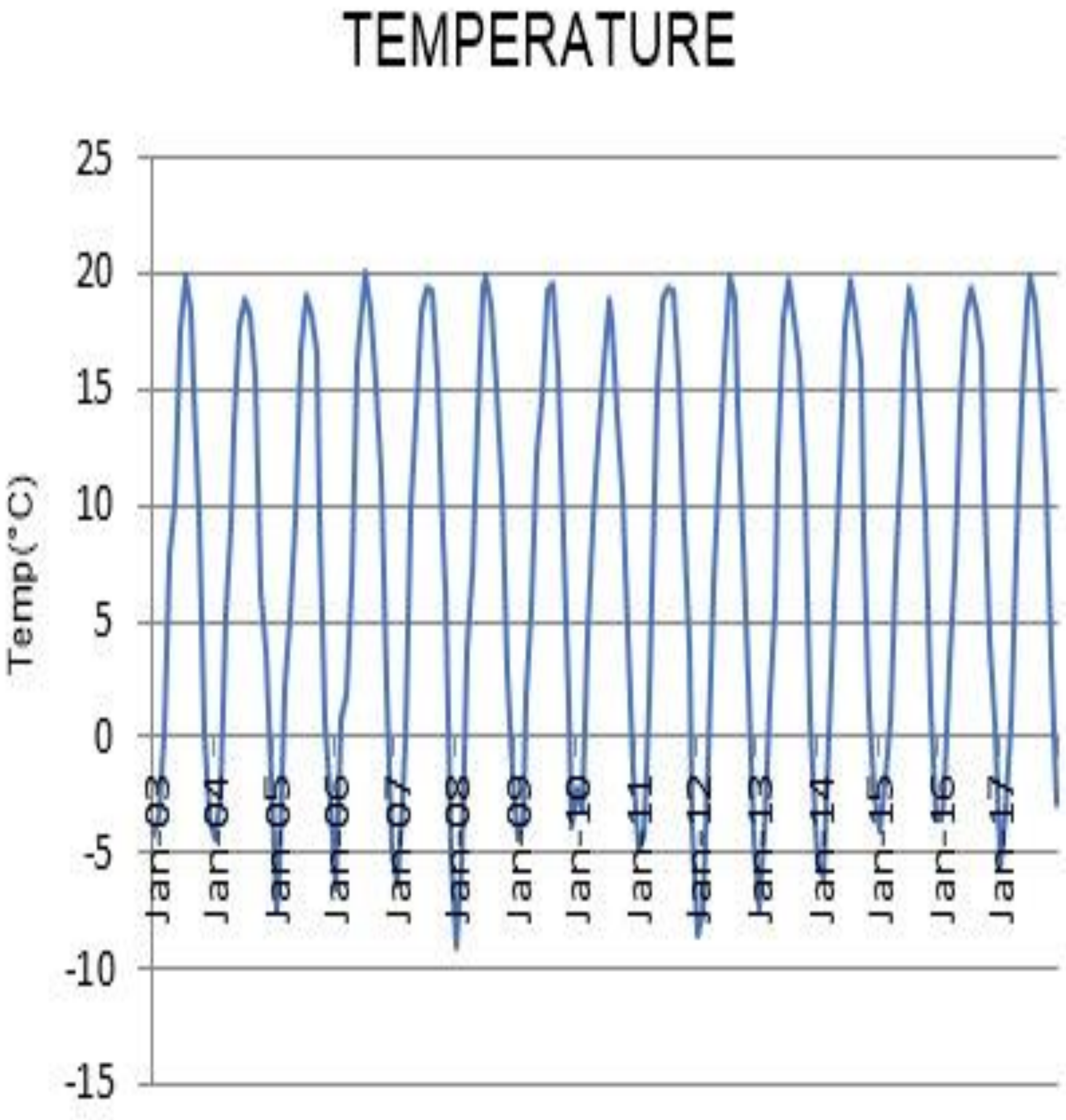


Figure 4.1b ERA5-Land Temperature data

Trends of simulated temperature is showing that, temperature of KRB will be increased in future due to environmental changes. The global mean surface temperature is predicted to increase by 0.3–0.7◦C for the near future 2016–2035 as compared to 1986–2005. A warmer atmosphere can hold more moisture. In fact, for every degree of warming the atmosphere can hold around 7% more moisture. More moisture can then mean that more rainfall comes in short, intense downpours. This can increase the risk of flash flooding.

4.2. Calibration Period

4.2.1. Observed and Simulated Discharges for 2003-2017

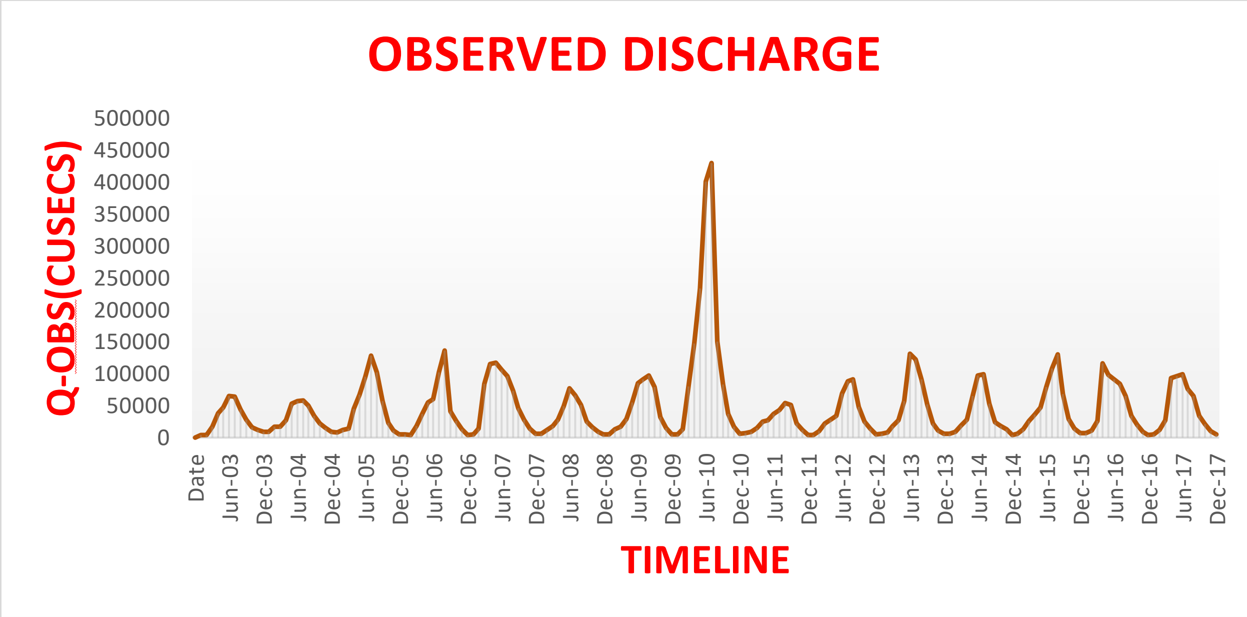


Figure 4.2a Observed discharge for 2003-2017

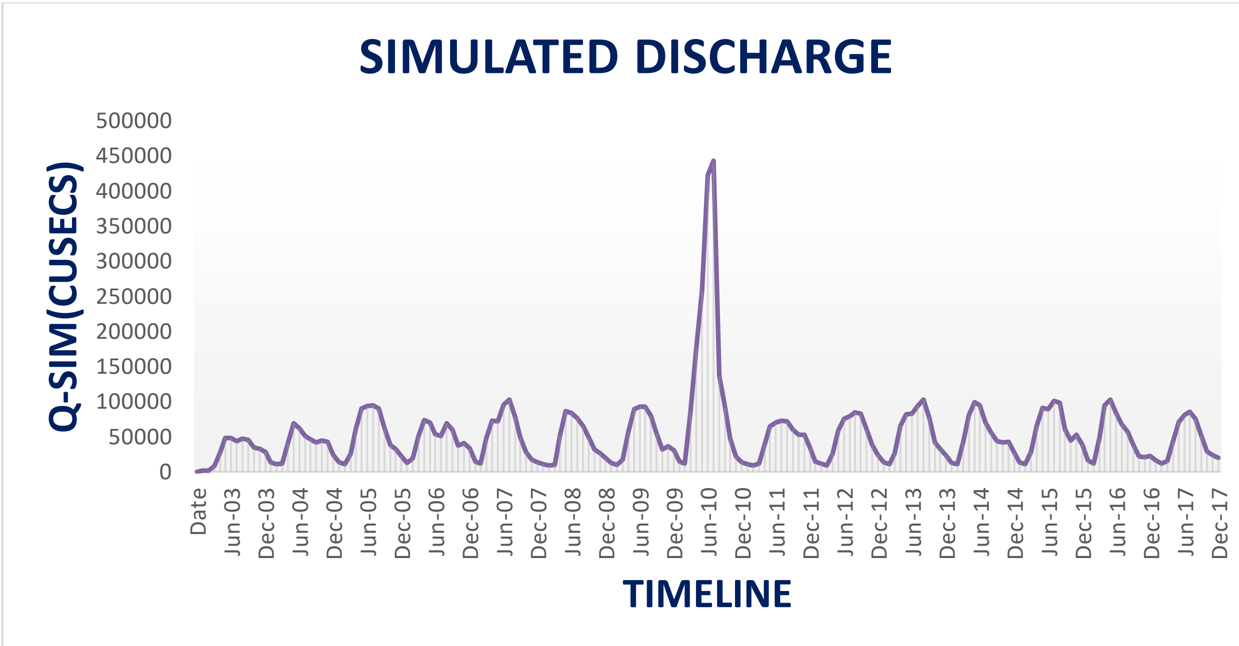


Figure 4.2b Simulated discharge for 2003-2017

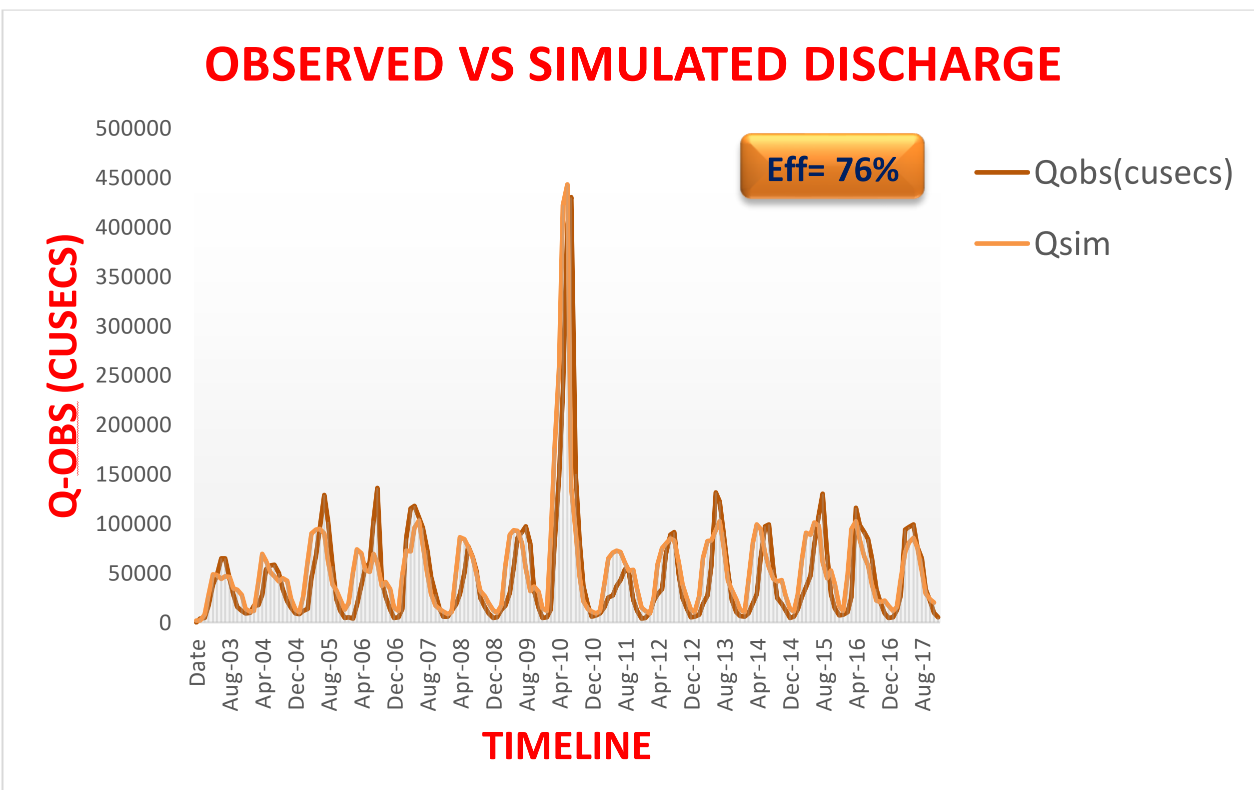
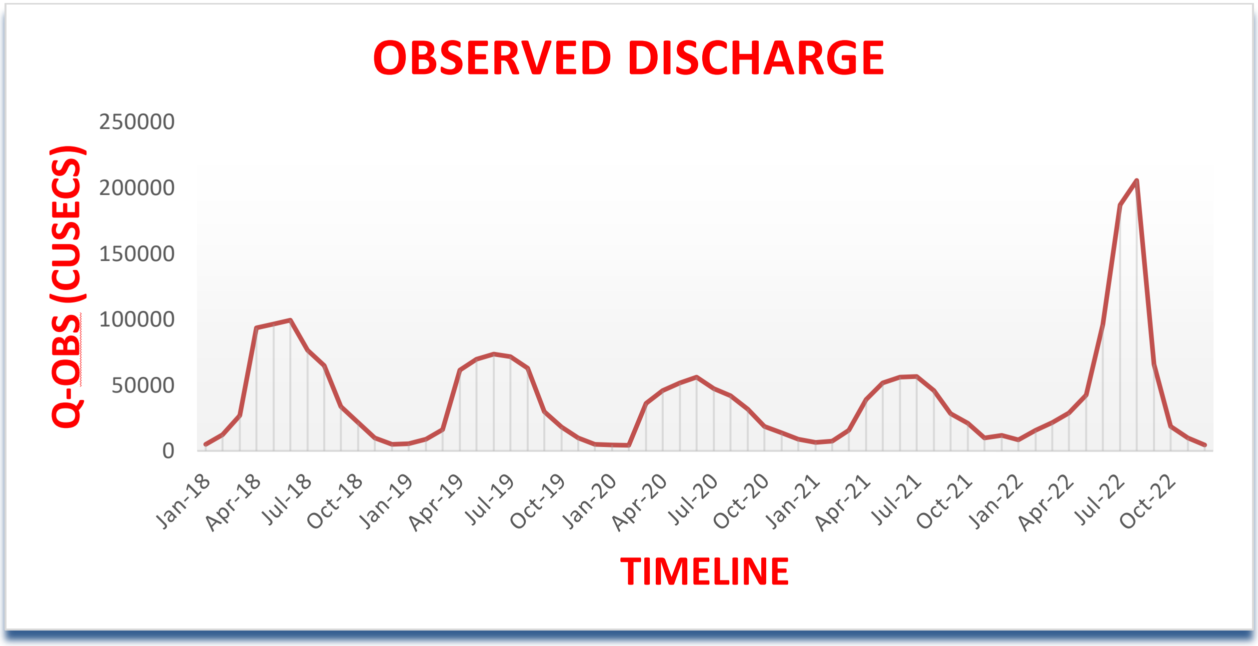
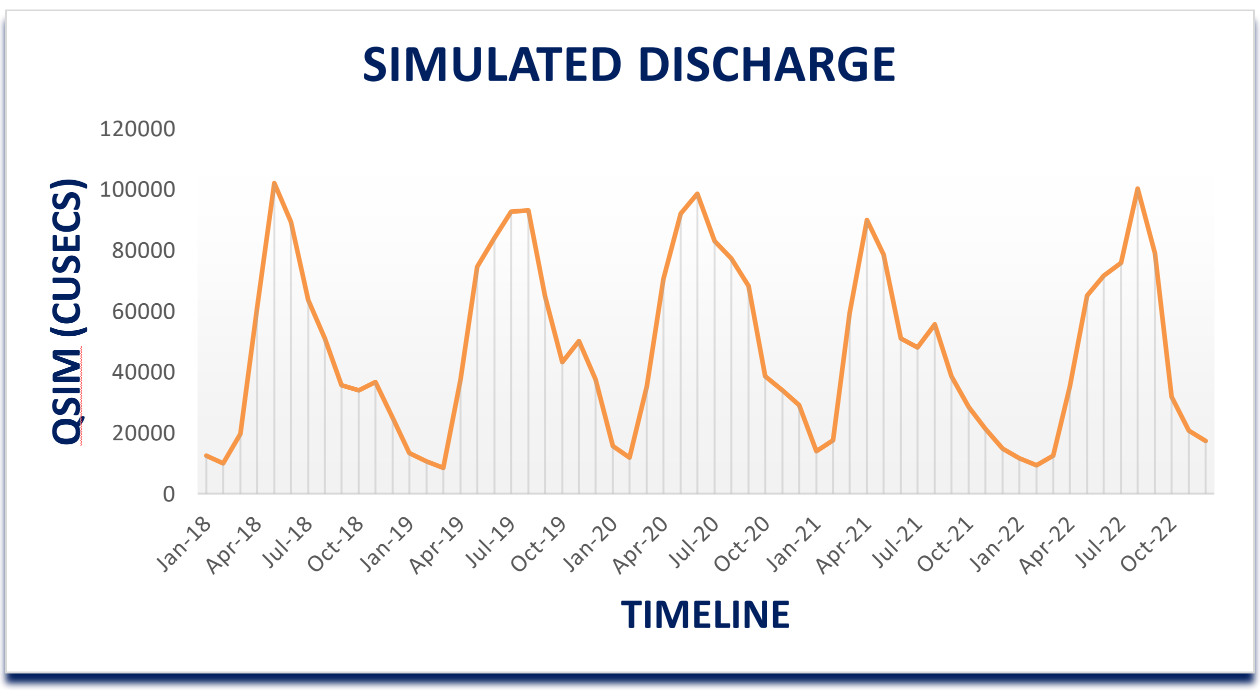


Figure 4.2c Observed vs Simulated discharge for 2003-2017

4.3. Validation Period



<u>Figure 4.3a Observed discharge for 2018-2022</u>



<u>Figure 4.3b Simulated discharge for 2018-2022</u>

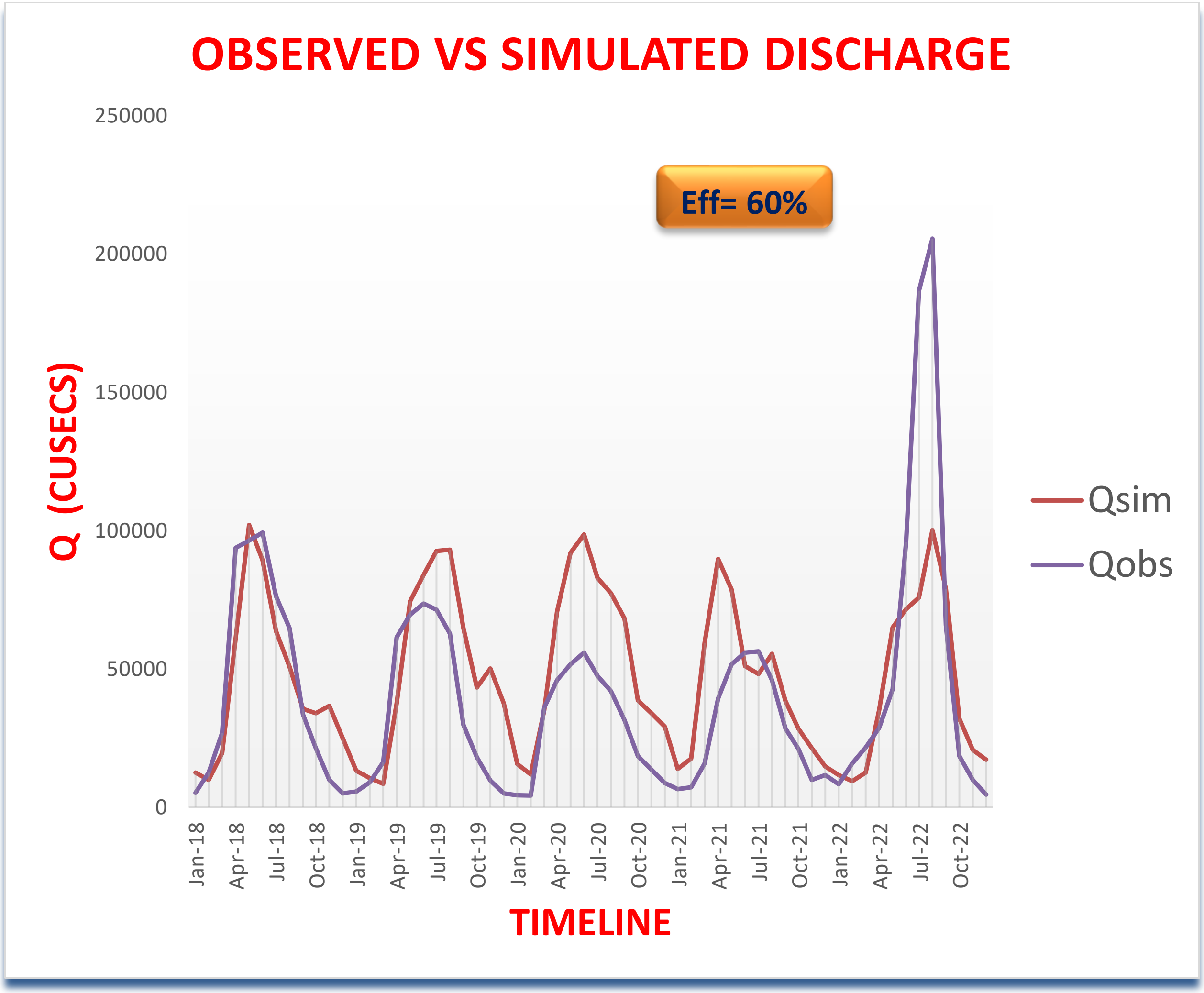


Figure 4.3c Observed VS Simulated discharge for 2018-2022

4.4. Climate Projections

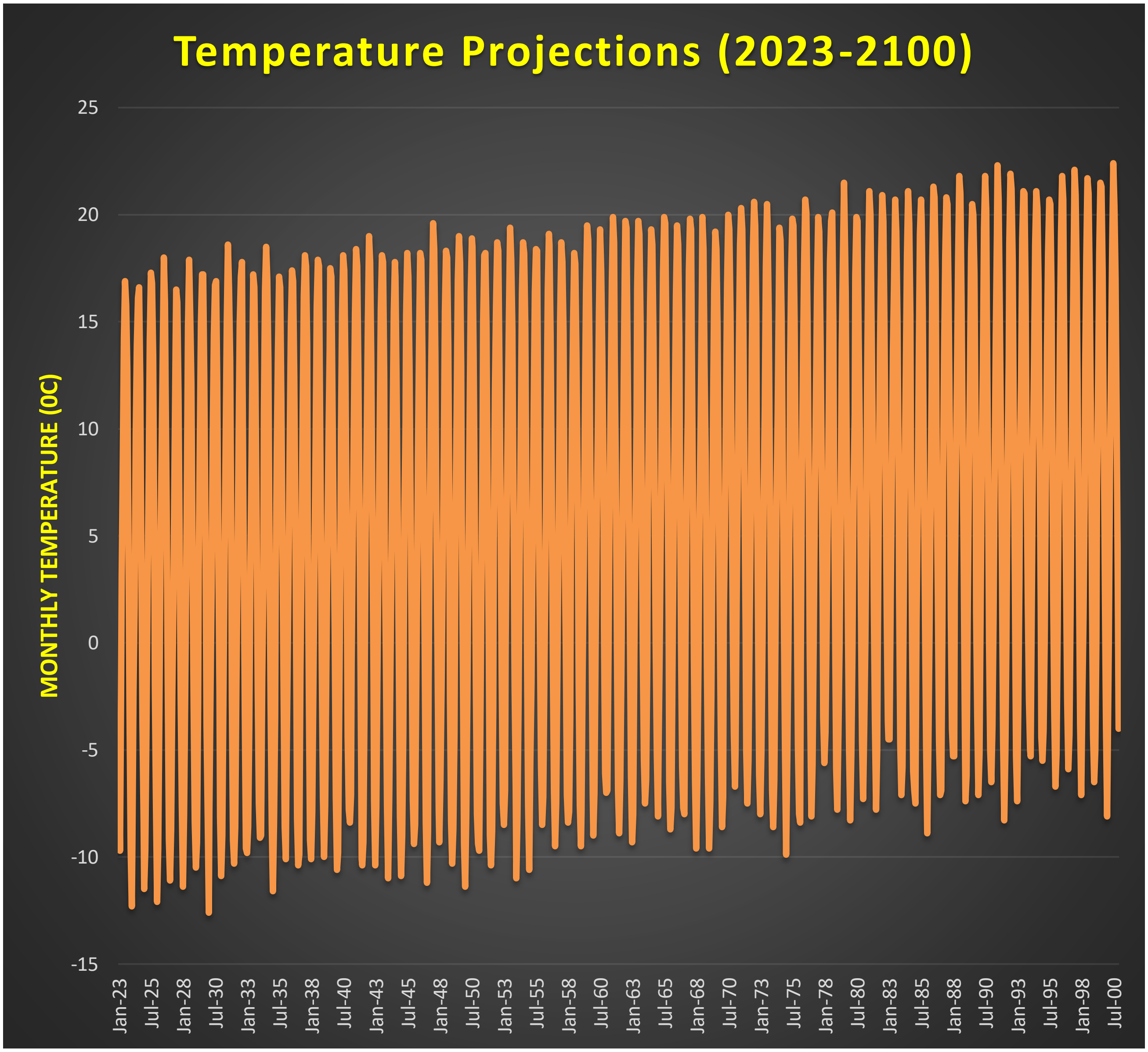


Figure 4.4a Simulated Temp data for 2023-2100

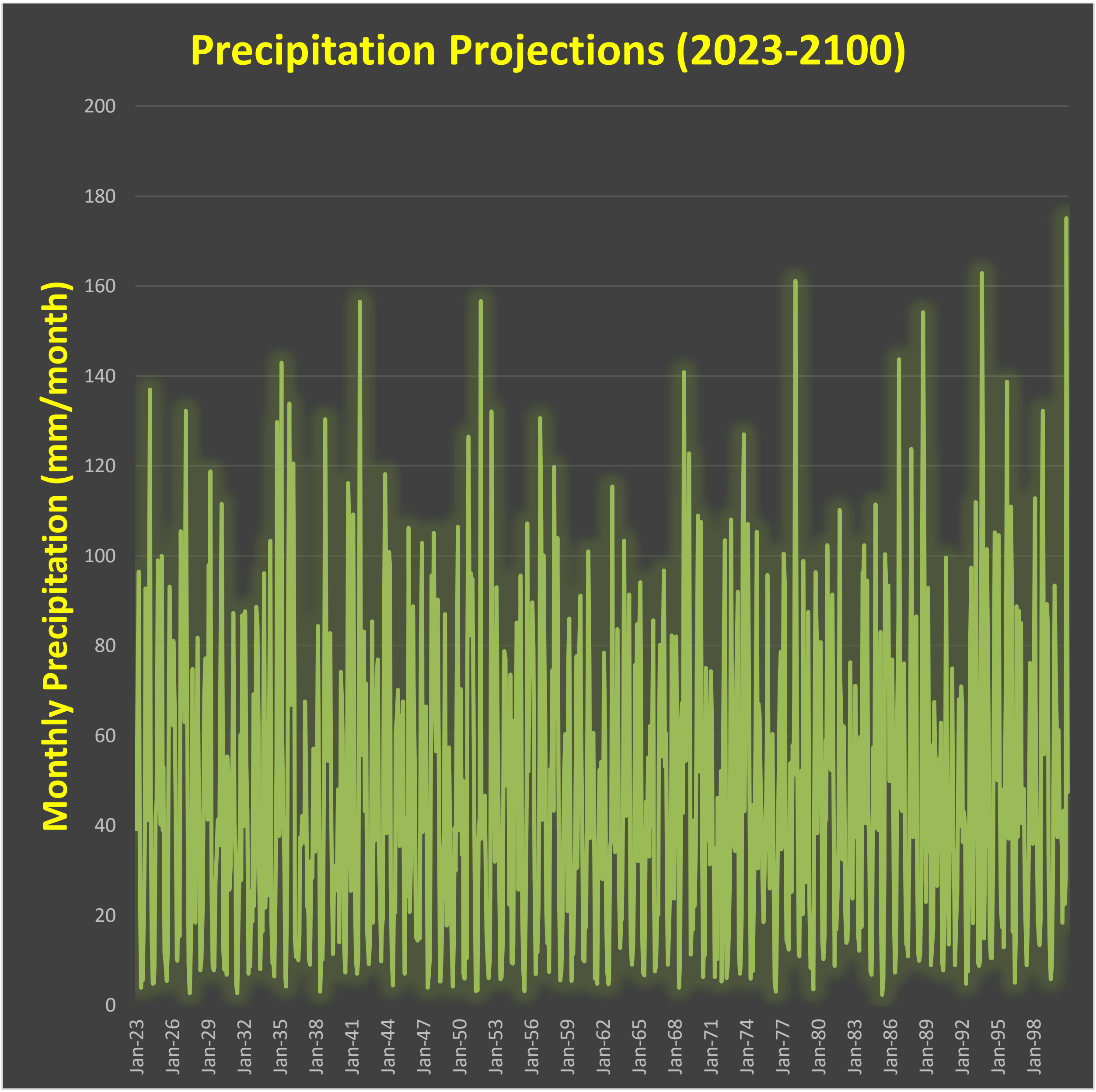


Figure 4.4b Simulated Precipitation data for 2023-2100

Trends of simulated Precipitation is showing that, Precipitation of KRB will be increased in future. The main impacts of heavy precipitation may include crop damage, soil erosions, and an increase in flood risk due to high rainfalls which in turn can lead to injuries/deaths and other flooding-related effects on health. Perhaps the most prominent reasoning is that rising global surface temperatures have increased evaporation rates and added water vapor to the atmosphere.

4.5. Hydrological Simulations for Future

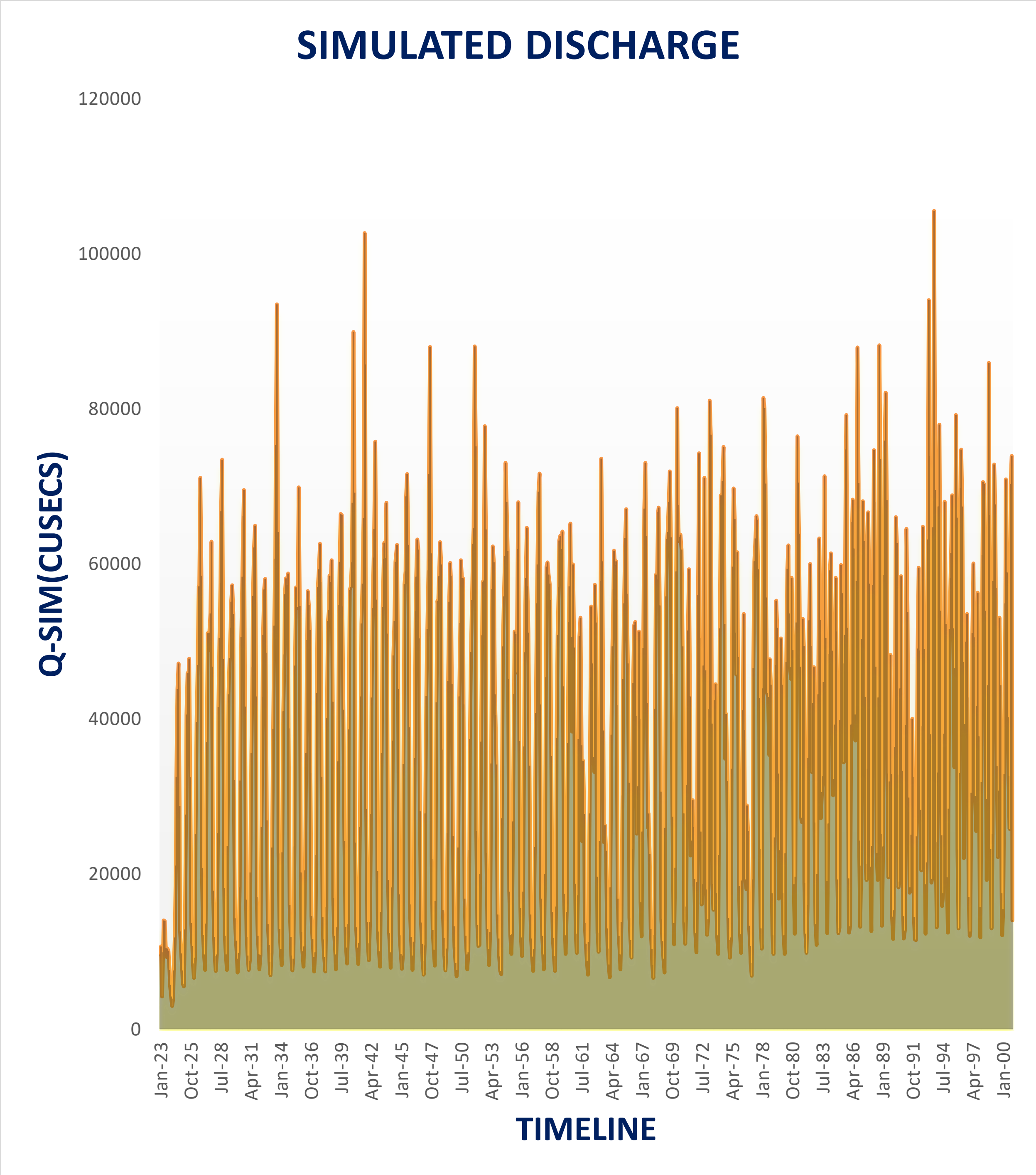


Figure 4.5a Simulated discharge obtained from HBV for 2023-2100

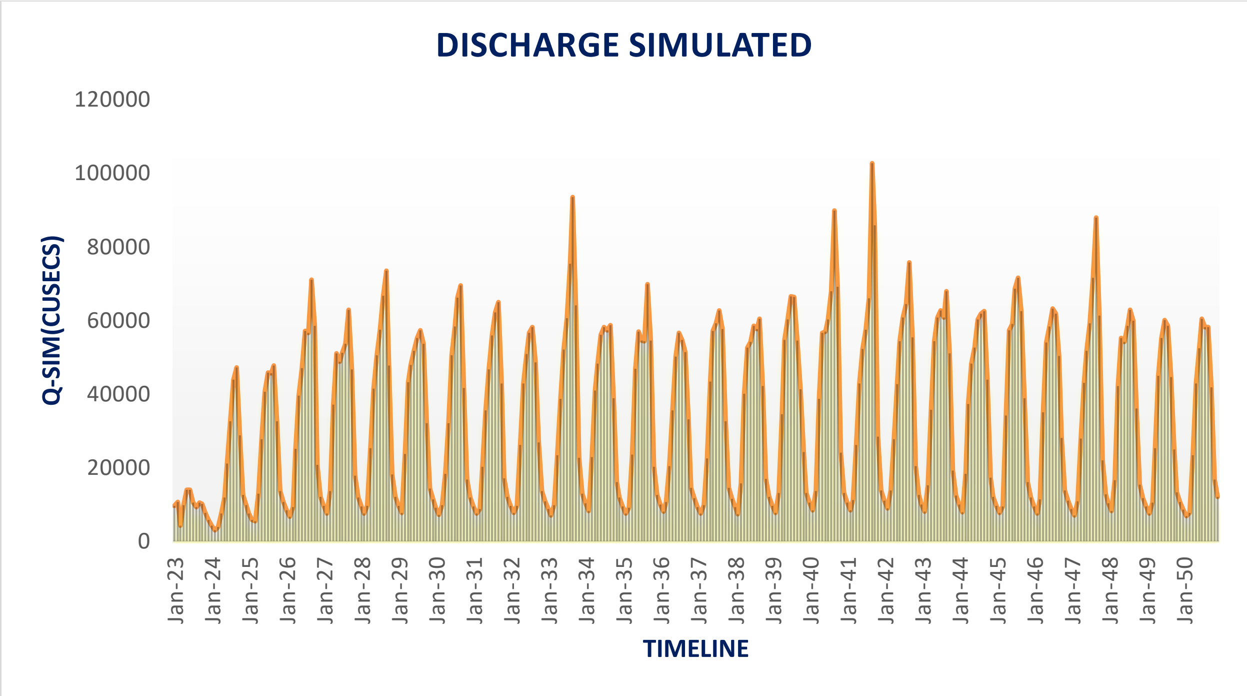


Figure 4.5b Simulated discharge obtained from HBV for 2023-2050

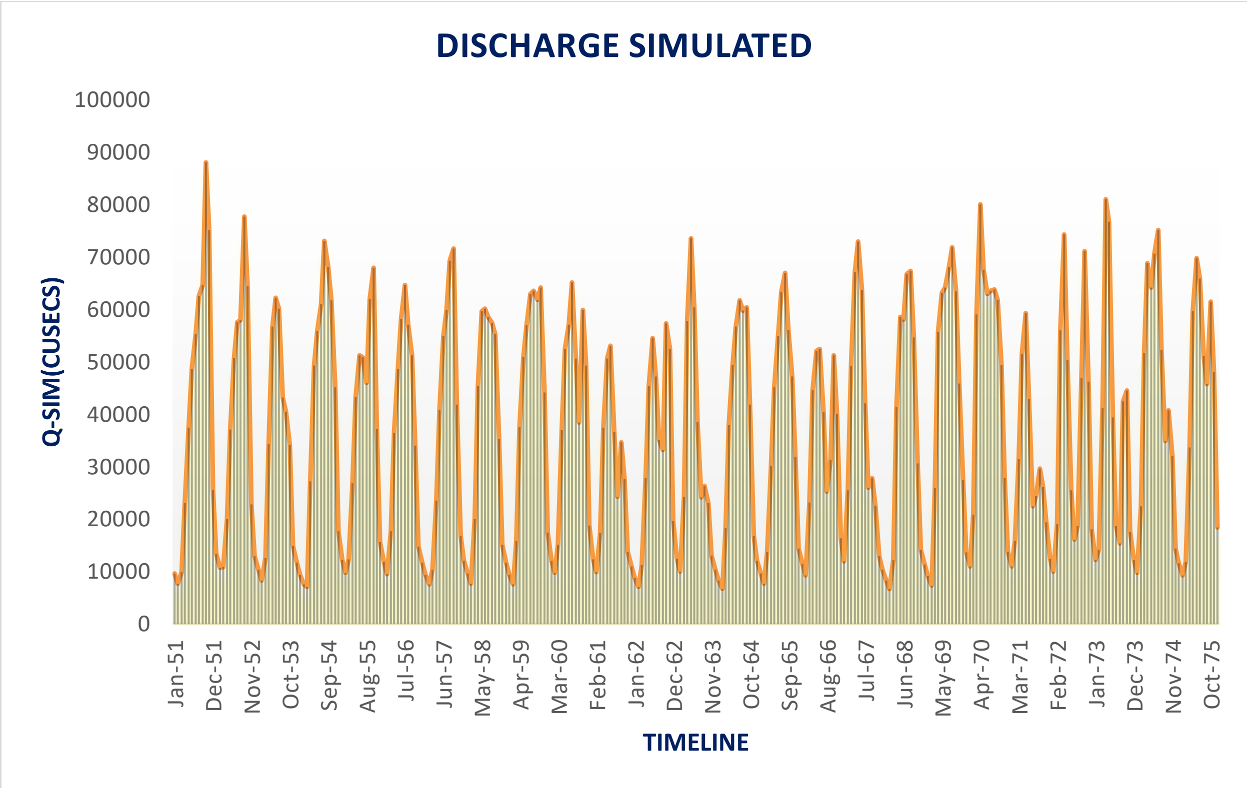


Figure 4.5c Simulated discharge obtained from HBV for 2051-2075

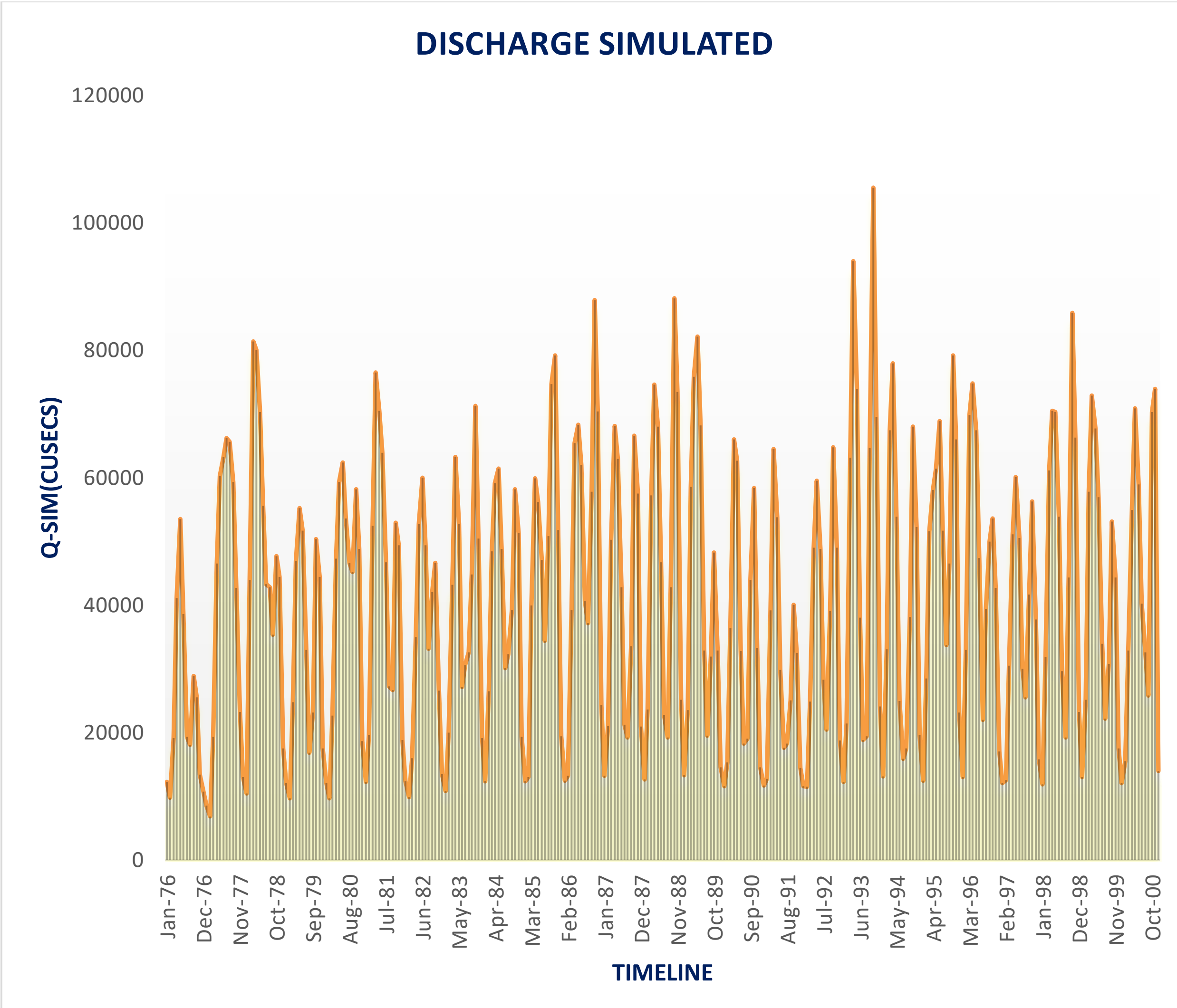


Figure 4.5d Simulated discharge obtained from HBV for 2076-2100

Based on Simulated Discharge data, we came to know that in the future the flood intensity will be increased. Highest floods in KRB with discharges above are likely to be in years 2033, 2042, 2051 and 2093. This increase in frequency and intensity of floods is due to climatic changes over time i.e., increase in temperature resulting in glacier melt and thus increase in water levels, increase in precipitation causing floods.

CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1. Summary

Each extreme weather event may not be regarded because of climate change, but the scientists agree on the fact that the unprecedented pace of climate change is, at least, causing the increased frequency of occurrence of extreme weather events in the recent decades. The purpose of this study is to predict the flood events by simulation in Kabul River Basin. This prediction is based on the precipitation and temperature data of the area. This data became the basis of input on which ERA-5 Land software is trained. Hydrological simulations of 78 years i.e., till 2100, are made by ERA-5 based on calibrated and validated data. Data used for the calibration is of years 2003-2017 i.e., 15 years and data used for the validation is of years 2018-2022 i.e., 5 years. ERA-5 using this data gave the simulated Precipitation and temperature data along with the simulated discharges of years 2023-2100.

5.2. Conclusions

This study revealed substantial changes in the hydro climatology of the basin for the near and distant future. ERA-5 Land simulations show an increase in mean annual temperature, precipitation, and streamflow. The low elevations and densely populated areas i.e., Nowshera in its lower reaches are seriously threatened by frequent high floods. The results and analysis that are presented in our study indicate the hydrological consequences of projected climate changes in the basin by 2100. The study revealed that temperature and precipitation will increase in the future due to climate change that results in the melting of glaciers and thus an increase flash and premature floods in the Kabul River basin. This will have devastating effects on the downstream areas i.e., Nowshera. There will be an increase in the intensity and frequency of floods on the Kabul River, so this study will be useful for various departments involved in flood mitigation and flood control measures.

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