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M.Sc. in Civil Engineering

MOHAMMAD SHAFIA HANIF

**REPUBLIC OF TURKEY**

**GAZİANTEP UNIVERSITY**

**GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES**

# IMPACT OF CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT IN PANJSHER SUB BASIN (AFGHANISTAN)

**M.Sc. THESIS**

**IN**

**CIVIL ENGINEERING**

**BY**

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**Supervisor**

**Asst. Prof. Dr. Ayşe Yeter GÜNAL**

**by**

**Mohammad Shafia HANIF**

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Name of the Student: Mohammad Shafia HANIF

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Prof. Dr. Mustafa GÜNAL
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This is to certify that we have read this thesis and that in our consensus opinion, it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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**Mohammad Shafia HANIF**

# ABSTRACT

**IMPACT OF CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT IN PANJSHER SUB BASIN (AFGHANISTAN)**

**HANIF, Mohammad Shafia**
**M.Sc. in Civil Engineering**
**Supervisor: Asst. Prof. Dr. Ayşe Yeter GÜNAL**
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**145 pages**

Effects of climate change on the water resources in the Panjsher sub basin significantly causing changes in quantity, type (rain or snow) and timing of precipitation and causing water scarcity on some parts of Panjsher sub basin. In order to focus on the assessment of the relationships between climate change, water availability, water demand and supply management are important. Hydrometeorological datas, ArcGIS and trend method analysis has used to find out how sensitive is the study area to climatic change also the impact of Climate Change on water quantity in the study area and the key elements and techniques for the Panjsher sub basin managements are studied. Water resources are important to both ecosystems and society. The effects of climate change on water quantity and water quality on the Panjsher sub basin is affecting many sectors, including human health, agriculture, energy production, ecosystems and infrastructure. By addressing key issues and technics for water resources management and having good regional data, information we can develop policies that make up scientific and human capacity to control and used the water in the best manner under effects of climate change.

**Key words:** Climate Change, Basin Management, Ecosystems, Infrastructure, Water Resources

## ÖZET

## İKLİM DEĞİŞİKLİĞİNİN VE SU KAYNAKLARI YÖNETİMİNİN PANJSHER ALT HAVZASINDAKİ ETKİLERİ (AFGANİSTAN)

**HANIF, Mohammad Shafia**
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**Danışman: Asst. Prof. Dr. Ayşe Yeter GÜNAL**
**Mart 2020**
**145 sayfa**

Panjsher alt havzasındaki iklim değişikliğinin, su kaynakları üzerinde etkileri belirli şekilde yağmur veya kar yağış miktarı, yağış zamanı değişiklikleri ve su kıtlığına sebep olmaktadır. Bu konuya odaklanmakmak için, İklim değişikliği, suyun mevcudiyeti, su talep-arz yönetimi çok önemlidir. Çalışma alanının iklim değişikliğine ne Kadar hassas olduğunu bulmak için Hidrometeorolojik verileriyla ArcGIS ve Trent yöntem analizi kullanılmıştır. Ayrıca iklim değişikliğinin Panjsher alt havzasındaki su miktarına etkileri, temel havza yönetim elemanları ve teknikleri çalışılmıştır. Su kaynakları hem toplum hem de ekosistemler için önemlidir. Su temini ve kalitesi üzerindeki iklim değişikliği etkileri başta enerji üretimi insan sağlığı, ziraat ve ekosistemler olmak üzere bir çok sektörü etkilemektedir. Su kaynakları yönetimi için temel konuları ve teknikleri adres gösterek ve bölgesel veri ve bilgi yardımıyla politikalar geliştirerek; bilimsel ve insan kapasitelerinin, iklim değişikliği etkilerine maruz kalan suyun, daha etkili kullanımı sağlanabilir.

**Anahtar Kelimeler:** İklim Değişikliği, Havza yönetimi, Ekosistemler, Altyapı, Su Kaynaklar

*To My Family*

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First and for most, I would like to praise Almighty Allah for giving me the strength opportunity, ability and knowledge to commence this thesis study and to preserve and complete it satisfactorily. Without his blesseing, this achievement would not have been possible.

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| **USAID** | United States Agency for International Development |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **NGO** | Non-governmental organization |
| **GCM** | Global climate model |
| **UNEP** | UN Environment Program |
| **WIR** | World Resources Institute |
| **IWRM** | Integrated Water Resources Management |
| **SWAT** | Soil and Water Assessment Tool |
| **FAO** | Food and Agriculture Organization of the United Nations |
| **USGS** | United States Geological Survey |
| **TRMM** | Tropical Rainfall Measuring Mission |

# CHAPTER 1

# INTRODUCTION

Water resources are important for ecosystems and society and we depend on a reliable and clean drinking water supply to maintain our health. We also need water for clean production of energy, agriculture, navigation and recreation. Many of these applications pollute water resources, which may increase as a result of climate change.

In many regions, climate change can lead to increased water demand while reducing water supplies. This changing balance will force water managers to meet the needs of growing communities, producers, energy producers, farmers, and sensitive ecosystems.

In some countries, water scarcity is less a problem than an increase in river levels or an increase in runoff, flooding. These can affect water quality and damage the infrastructure used to deliver or manage the water.

The impact of climate change on water quantity and quality will impress many sectors, including energy production, infrastructure, human health, agriculture and ecosystems.

The present thesis deals with main factors that causes climate change and its effects on the water resources especially in the Panjsher sub basin (Afghanistan). It clear that modeling alone is not enough to address these challenges.

Modeling is just one of several tools that can be used to support water resource management. By addressing key issues and technics for water resources management and having good regional data and information we can do develop policies that make up scientific and human capacity to control and used the water in the best manner under effects of climate change.

### 1.1 Background Study

Water resources is in danger by increase in population growth and climate change since last decades. The population of the world has increased three times, use of nonrenewable energy has increased by a factor of 30, and industrial production has increased 50 times. This means demand for water is increasing and resources with suitable quality are depleting because of urban, agriculture, and industrial uses [1].

Population of Panjsher river basin got two times more since 2000. Using of nonrenewable energy has increased respectively, means demand for water is increasing due to population explosion and climate change resulted ecological imbalancement and water fluctuations. By decreasing surface water supplies, ground water consumption have been quickly expanded during some drought seasons. For instance, drop of water level in the Shamali and Kabul river basin as whole and Panjsher sub basins as small scale has been realized. Nearly all shallow supply wells affected to the same degree in different areas of Panjsher sub basin especially in lower catchments. By adding another factor, climate change, the competition between urban development agriculture and water demands, is becoming more severe.

By increasing amounts of carbon dioxide and concentration of greenhouse gases, the average temperature of the earth's atmosphere rising since the 19th century. This is known as the global warming phenomenon. Global warming can have important effects on the water resources and water demands like urban and agricultural uses. Precipitation and evapotranspiration are two important hydrologic variables that can be altered by changing temperature. Understanding climate-water interactions can help researchers and policymakers alleviate the negative effects of global warming by introducing appropriate management scenarios [2].

Water resources are expected to be increasingly burdened by climate change, which is why the gap between water supply and water demand will widen. Generally, in warmer weather, water demand is expected to increase while water supply is expected to decrease. For example, agricultural consumption, which is the main demand for water supply, will decrease both due to falling rainfall and increasing evapotranspiration.

The effects of climate change can be particularly severe in water-stressed pools where water requirements are already approaching the available supply. To meet this need, this study assesses the impact of climate change on available water resources in Panjsher sub basin.

## 1.2 Problem Statement

In the Panjsher River sub basin, available land and water resources are not used efficiently to develop livelihoods and socio-economic conditions for residents. The system of land and water resources existing in the region is subject to rapid population growth and climate change, soil degradation and deforestation.
The impact of climate change on water resources in the Panjshir sub-basin leads to significant changes in volume, type (snow or rain) and timing of precipitation on the other hand, intensive population growth in the some parts of sub basin causing water scarcity. The most populated parts of Panjsher river sub basin such as first part of Kohistan widely consuming open channel waters with poor quality which is drastically caused so many sanitary problems and sicknesses.

The simulated decrease in groundwater level as a whole was huge in the western part of the central basin of Kabul. This area is very little charged with direct rainfall, and a dense population produces the most water. But all these models required field reliable and accurate data such as precipitation, temperature, stream flow runoff and evapotranspiration. Lack of reliable historical meteorological records, complex topography make modelling more difficult. That is to say the assessment of variations of the climate driving force for regional hydrology, the trends and impacts may be different on a watershed to watershed or from sub-basin to sub-basin scale. In order to focus on assessing the relationship between water availability, climate change and basin management, three research questions were identified.

How sensitive is the Panjsher sub basin to climate change relative to its water availability?

What is the impact of climate change on water quantity and quality in the study area?

What are the key elements and techniques for basin managements?

## 1.3 Limit Study

The first and foremost limitation of this study was the lake availability of reliable observed meteorological and hydrological data in terms of quantity and quality to be representative of all elevations in the Kabul river basin and its sub basins. After 2004, 29 Hydro meteorological stations installed across the Kabul river basin, due to insecurity and technical problems, some of these stations have not recorded properly and only few stations which are located in the plain areas of the basin records meteorological condition but cannot be representative of hilly and hillier areas of the basin. To fill this gap, Different methods have used and connect many historic events in the hydro metrological time of the region as well as receiving much broad local information.

## 1.4 Thesis Objectives

The overall goal of the thesis is to provide a better knowledge about the effects of climate change on Panjsher sub basin and its proper management, prevent further deterioration of rivers and improve the condition of water resources.

Superimpose the existing water infrastructure and present water demands in the basin on the natural hydrology based:

1. To quantify available water in the watershed.
2. Assessment of the impact of extreme climatic events on the provision of hydrological ecosystem services in the Panjshir low and medium flow basins:
3. To understand how sensitive is the sub basin to climate change?
4. Compare the current and future simulations of the Panjsher sub basin to assess the impact of climate change on water resources in the basin.
5. To understand how watershed resources are currently managed in Panjsher watershed basin and how the public is being engaged in watershed management.

## 1.5 Outline of Thesis

*Chapter One* imposed the background study with problem statements, Study objectives related to case study (Location, Climate, Land, Water resources) and terminology used.

*Chapter Two* express previous research carried out regarding the impacts of climate change on world water resources especially in South Asia. It also presents the importance of climate change effect on the hydrological ecosystem of Afghanistan.

*Chapter Three* introduces the river basin management and its necessary tools, techniques to manage. Climate and non-climate drivers and data challenges for river basing management.

*Chapter Four* consist of information about specification of case study area area including topography, Geology, land cover and, use condition, precipitation, temperature and stream flow in contrast with the past decades to depict obvious changes in water resources due to climate change.

*Chapter Five* describes the hydraulic and hydrological data gathering methods, data management, communication and use all through five deferent basin in Afghanistan.

*Chapter Six* shows dam seasibility study and analysis of water demand in Panjsher River and circumstances regarding hydraulic assets, sectorial demands and water availability, population grouth.

*Chapter Seven* includes result, discussions also conclusion and recommendations.

## 1.6 Case Study Area

In order to ensure adherence to the purpose and objectives of this thesis, following case study selection criteria has used to approach in the best manner:

1. Panjsher sub basin must be led by a conservation district designated as Water Planning Authority and should be analyzed by using most accurate data that can be recorded in different location alongside of the Panjsher valley.

2. Watershed cases must be geographically and demographically distinct in order to provide a broader range of perspectives on watershed management.

3. Panjsher sub basin and other Kabul river sub basins should be developed under the Water Protection Acts nationally and internationally.

### 1.6.1 Location

Panjsher sub basin is part of the Kabul river basin. It is located in the northeastern part of Afghanistan. It lies between 34 ° - 36 ° N latitudes and 69 ° - 70 ° E longitudes. Panjsher sub basin is part of Kabul river basin with the drainage area of 17700 $km^2$. Kabul river basin is divided into 8 sub-basins and 10 provinces. The upper catchment of the Kabul River reside of steep valleys in the Hindu Kush Mountains, which are located at an altitude of more than 7500 meters above sea level. The overall area of the Kabul River basin is divided into three different parts.

(1) The logar-maidan Kabul areas includes three river branches such as, the Maidan, Paghman and Qargha rivers, originates from upstream of Kabul.

(2**)** Panjsher- Ghorband area contain three tributaries such as, Ghorband, Salang and Shotul rivers.

(3) Lower Kabul comprises an area which is influenced by Panjsher and Maidan rivers in this distinct area. It comprises two large sub-catchment to the north and contains rivers such as, Kunar and Laghman rivers. Finally, all these tributaries and rivers joint in the Aba area of Nangarhar province and pass the border throughout the Pakistan territory.

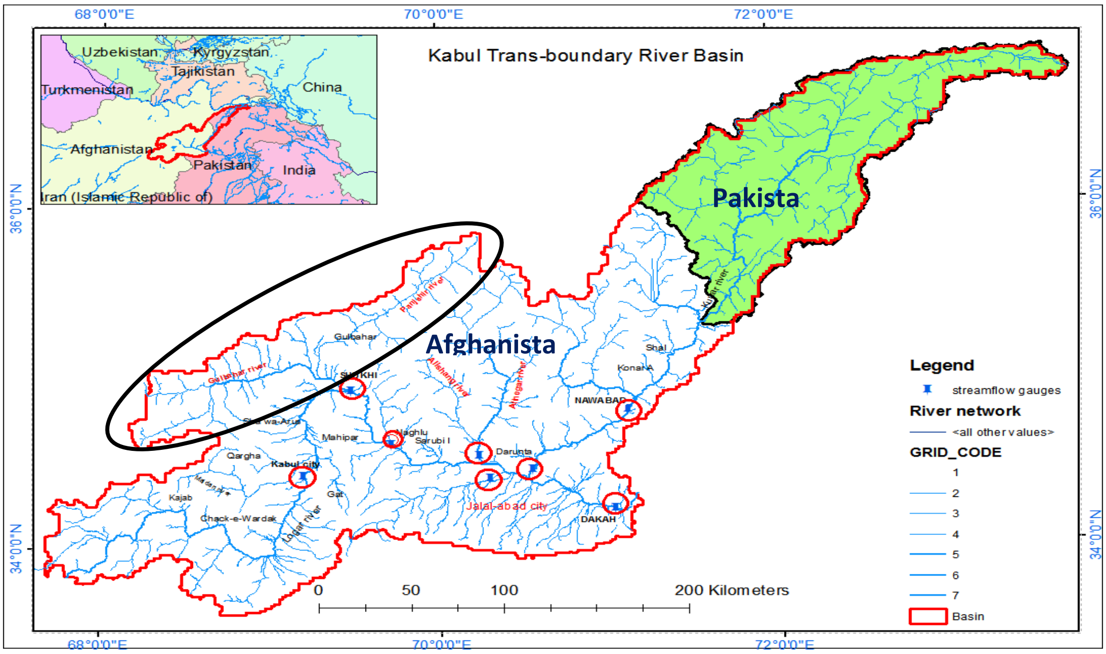



**Figure 1.1** Kabul river basin map

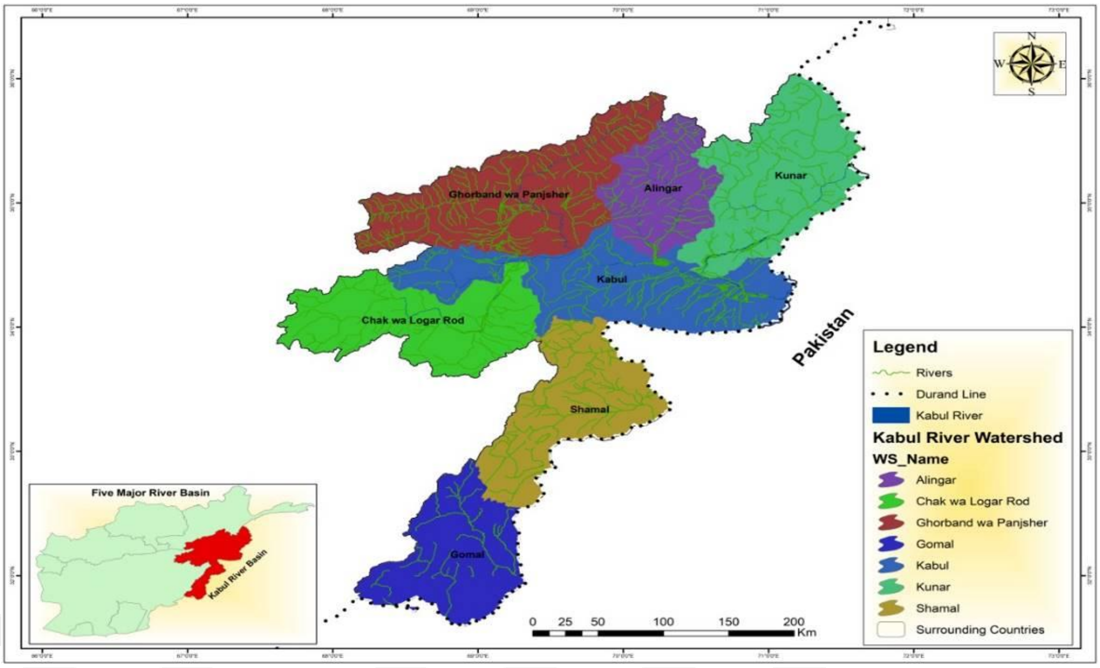



**Figure 1.2** Sub-divisions of Kabul River

### 1.6.2 Climate

Temperatures within the basin vary in response to topographic locations. The average annual temperature ranged between 12$^{o}$ C - 15$^{o}$ C and average temperature ranged between 4$^{o}$ - 5$^{o}$ C at Hindukush Mountains. Distribution of precipitation is uneven throughout the year and it ranges from about 680 mm per year in the highest mountains, 400 - 500 mm in the western part of the region and 320 - 450 mm in the middle part of the basin. The type of precipitation at high elevations is snow which constitutes the major portion of the runoff.

The Kabul River basin area has a semi-arid and sharply continental climate with strong temperature fluctuations day and night. It is characterized by hot summers and cold winters. The mean annual precipitation estimated (516 mm) figure 1.3 and the annual average temperature estimated (9°C) Figure1.4 Maximum precipitations occur during the winter season, including December, January and February. Minimum precipitations are expected to occur during the summer season, June, July and August.

The temperature and precipitation in the Kabul river basin differ from watershed to watershed, these climate elements depend on elevation. The maximum temperature measured (48°C) in the Kabul river basin in Nangarhar region, which is located in the plain area in the summer and minimum temperature (– 28°C) recorded in the Chatral valley in the high elevation which is located in the east part of the catchment.

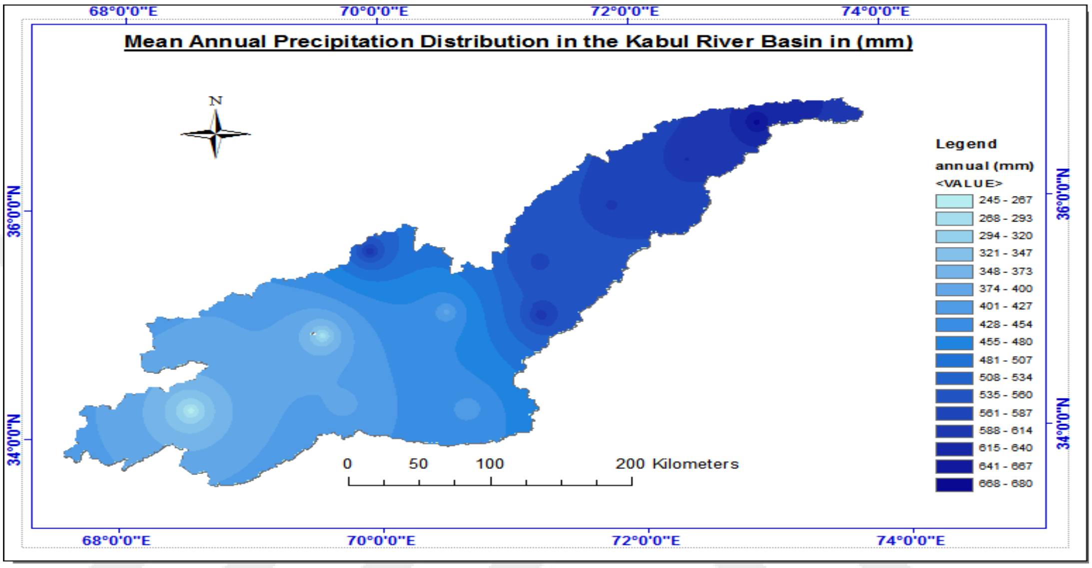



**Figure 1.3** The mean annual precipitation distribution in the Kabul river basin from (2007- 2017) Data sources: Tropical Rainfall Measuring mission.

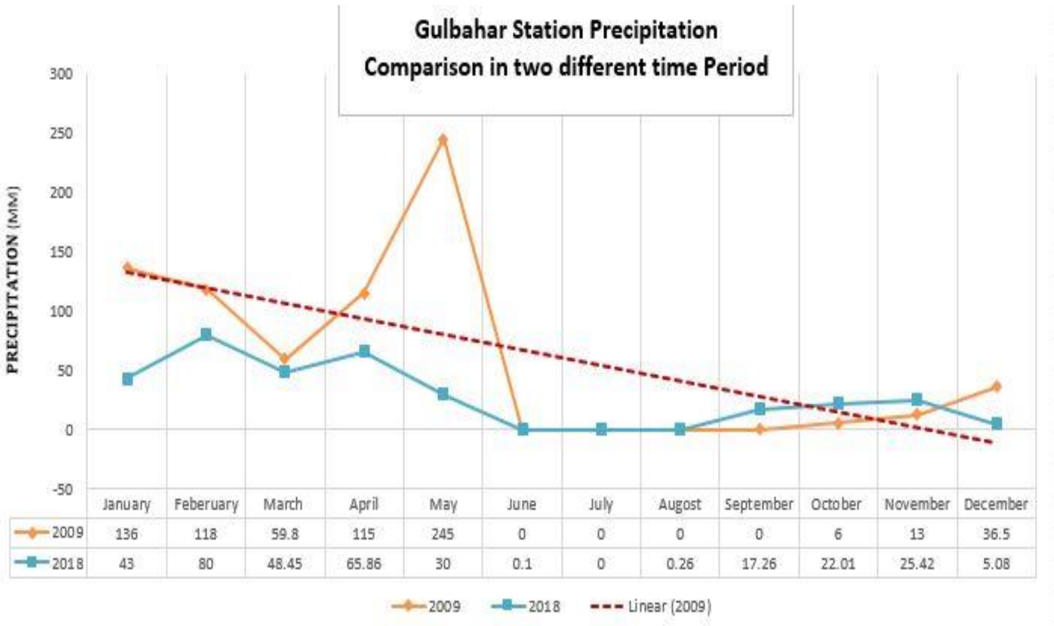



**Figure 1.4** Gulbahar Station precipitation Comparison in two different time period

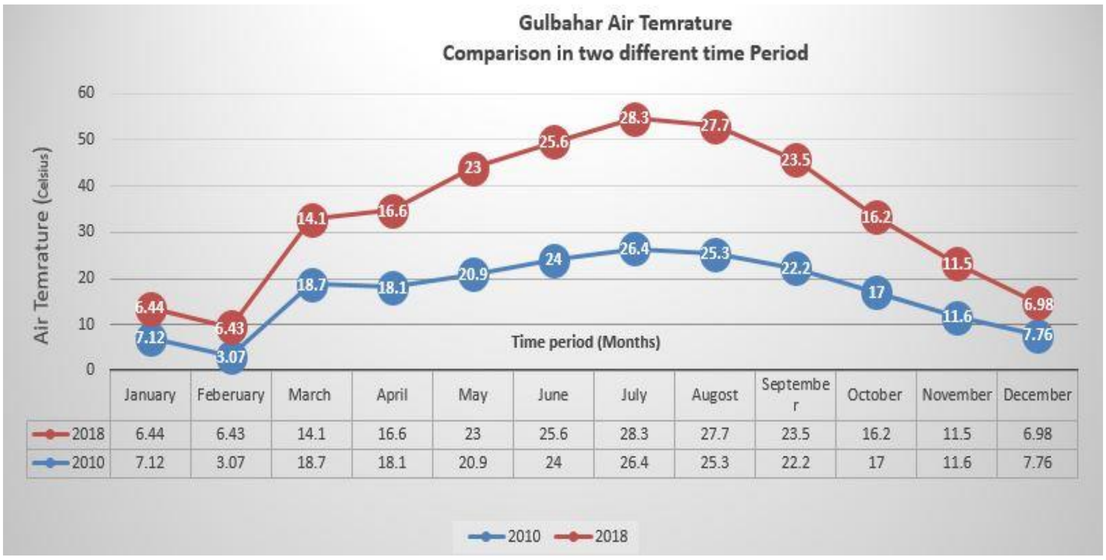



**Figure 1.5** Annual average temperature distribution in the Kabul river basin from (2007-2017)

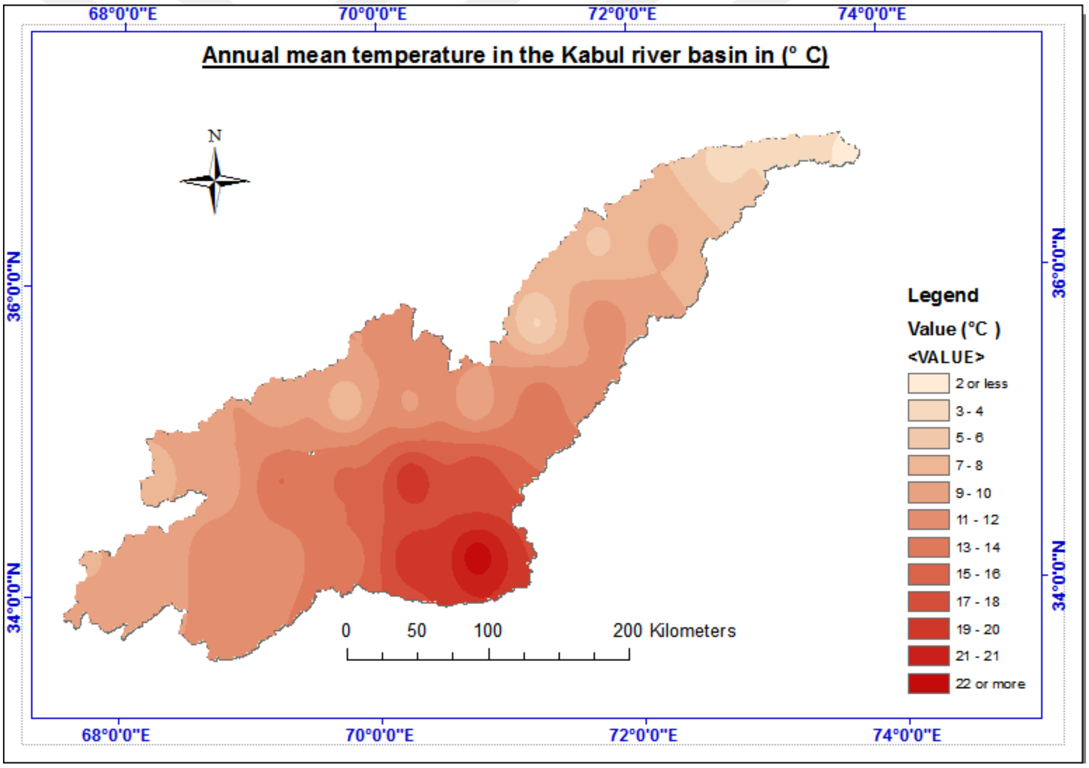



**Figure 1.6** Gulbahar Station temperature Comparison in two different time period

### 1.6.3 Land

The material of soils within the basin are weathered materials, wind deposits, and alluvial. Based on a general map developed by the Afghanistan Water Conservation Board and the United States Agency for International Development (USAID). The geology of the southern Panjsher Mountain province, which is located at the both side of the Panjsher River Basin, is Precambrian metamorphic schist and gneisses. The eastern part of basin, is dominated by multiple layers of sedimentary rocks, and Quaternary alluvium.

Land use in the Panjsher River Basin is displayed in figure 1.7. Most of the land in the Basin is used as mountain (75%), forest (8%), river (15%) and planted/cultivated areas (12%). The methods of irrigation are open furrow and surface irrigation systems. There are a complex of canals and ditches that distribute and provide water for irrigation along with the river from snows and mountain reservoirs.

**Figure 1.7** One of Panjsher River tributaries

### 1.6.4 Water Resources

Afghanistan is a landlocked country with a total area of about 652000 km$^2$. It is bordered by Tajikistan, Uzbekistan, Turkmenistan to the north, and China to the northeast, Iran to the west and Pakistan to the east. Afghanistan, according to its topography and water resources divided into five major river basins. These river basins are consisted in: (1) Kabul river basin, (2) Amu river basin, (3) Harrirud-Murghab river basin, (4) Helmand river basin and (5) North river basin. The map of all these river basins shown in figure 1.8.

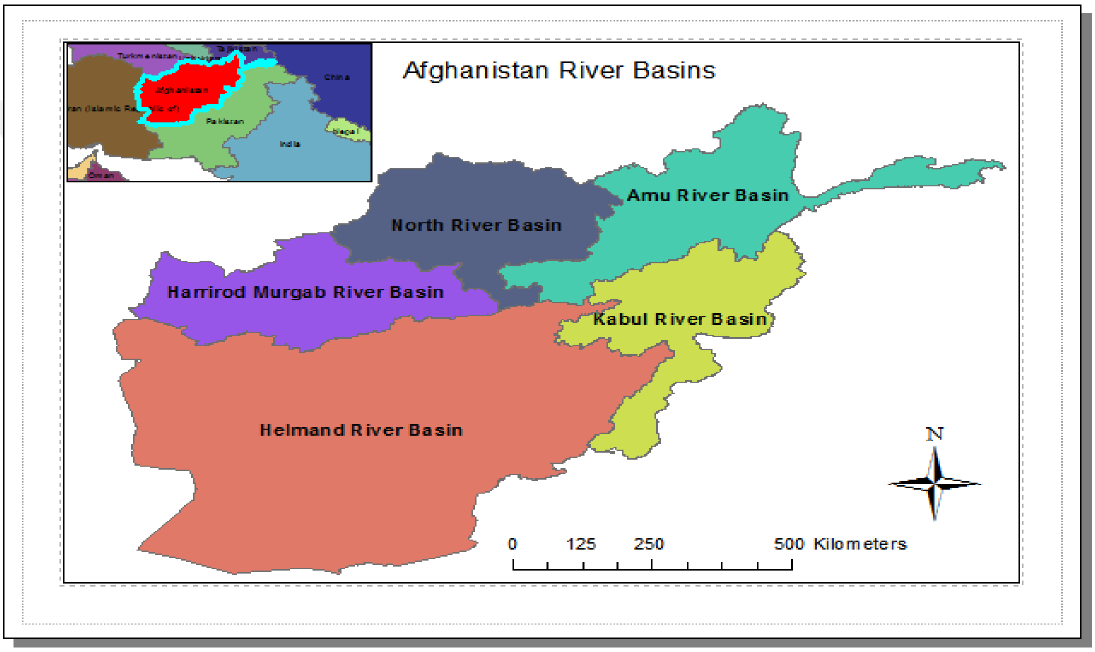



**Figure 1.8** Afghanistan basins map

The snowpack in the mountains at the western border of region constitutes the major runoff in the basin so water supply changes from year to year. Typically, more than 60 percent of the flow occurs between March and August and 20 percent between September and February. There are only lakes in the basin and their functions to control downstream natural water that are important. The reservoirs are using to store water to meet demand.

The peak runoff generally is during May and June due to snow melt while the peak demand for water usually is during July and August because of demand from the agricultural sector. Furthermore, there are some reservoirs and lakes that are used for recreation, fisheries and wildlife habitat, and flood control purposes. There are six aquifers inside of the basin, as described comprehensively in the final report of

JICA. The unconfined alluvial aquifer contains glacial silts to large boulders. The main sources of recharge for this aquifer are infiltration of surface water from the river, irrigation and the ditches and canals. The major use of this aquifer is for irrigation and domestic water. The snow pack in the mountains in the north and northeastern regions in the river basin constitutes the major runoff in the basin so water supply varies from year to year. In general, more than 72 percent of the runoff occurs between May and September and 40 percent occurs between Octobers to April [3].

A trans- Basin division also transports water from the Chatral valleys, Pakistan to the Kabul river basin. There are small reservoirs and lakes in the basin and their functions for generating electricity, irrigation and domestic water use are important.

The peak runoff generally is during June and July due to snow melt while the peak demand for water usually is during July and August because of demand from the Agriculture sector. Furthermore, there are some reservoirs and lakes are used for irrigation, domestic purposes. There are four aquifers in the Kabul area. The Paghman-Darulam area has two aquifers lying along the course of the Paghman River and the upper Kabul River.

The two other aquifers are located in the Logar sub basin. The main sources of recharge for this aquifer are infiltration of surface water from the river, irrigation and the ditches and canals. These aquifers are the main source of domestic water supply and supplemental for irrigation purpose.

Figure 1.9 the graphic shows the trend analysis of discharge over the period of time and the figure 1.10 shows the status compresian of river flow over months in tow different time scale from 1960 to 1980 and from 2005 to 2017.

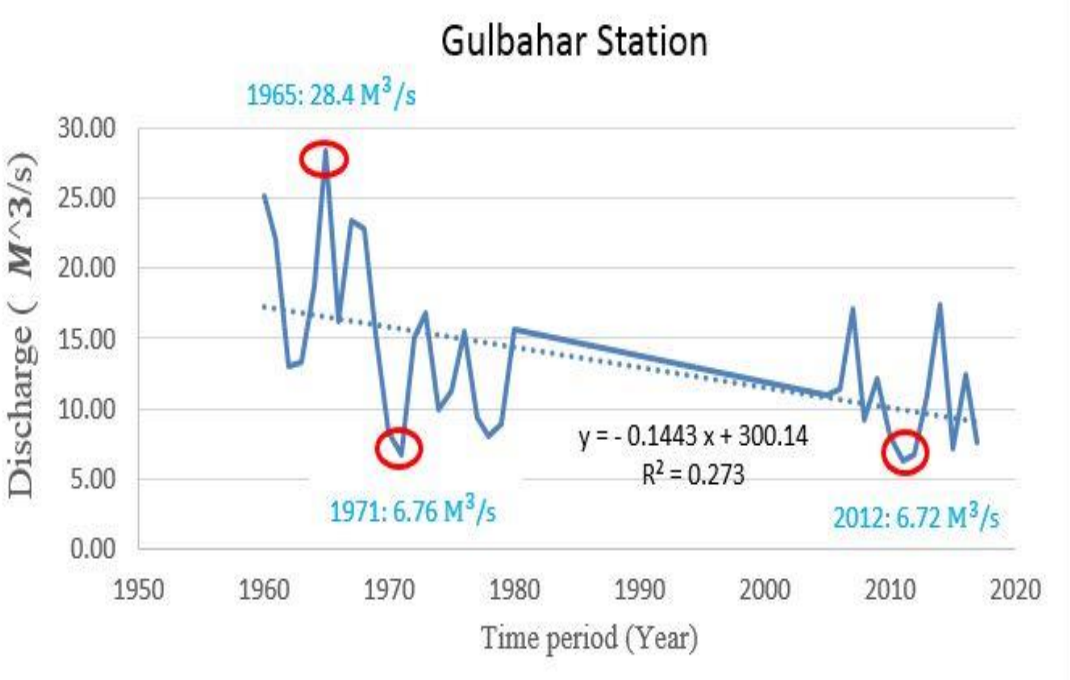



**Figure 1.9** Gulbahar station discharge scenario

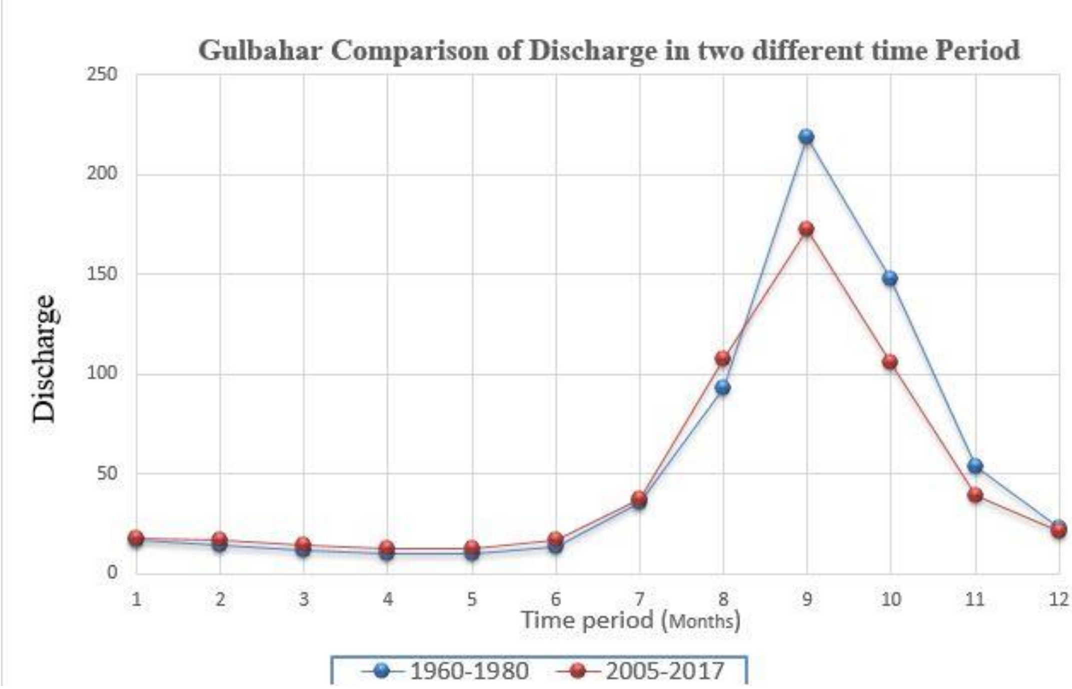



**Figure 1.10** Gulbahar Station Discharge Status

# CHAPTER 2

# CONCEPT OF CLIMATE CHANGE

The topic of climate change is one that has grown in importance over the last decade and has great consequences in the development discourse as well as on environmental research. Numerous literature and strong evidence points out that this phenomenon is a reality and that if policies do not shift to a more sustainable direction, it is imminent that the world will face scenarios of extreme climatic change with world-wide repercussions. The water cycle is expected to be altered in important ways by this phenomenon. The uneven distribution of this resource throughout the year will affect societies in numerous ways, as water is a central resource that supports human activities and ecosystems. The agriculture sector, among others, is extremely vulnerable to climate change due to the constraints, it can have on the hydrological cycle and the availability of water. The likelihood that already existing water related problems will worsen are high, therefore the clear next step is to adapt to future conditions [4].

Poverty is enduring in many aspects, with individuals lacking proper health, food, shelter and education. Although these issues are problems in themselves and require specific responses, global warming and its consequences are invasive and can aggravate different features of poverty. Although this topic has been discussed and dealt with in many levels, especially in international and political agendas, a very different reality is experienced in remote communities. At a global level, goals to react to climate change are clear, where key institutions such as the United Nations Framework for Convention on Climate Change (UNFCCC) and Intergovernmental Panel on Climate Change (IPCC) bring countries together to agree on reducing green-house-gasses emissions and to find new methods of adaptation. Likewise, NGOs and government institutions are increasingly combining efforts to improve local conditions to resist climate variations [5].

## 2.1 What Exactly is the Climate?

First we should know what is the difference between climate and weather. Weather is an element that we see every day, such as rain, temperature, snow and wind. weather can change hour after hour, day after day but Climate shows how the weather changes over a long period of time, usually over 30 years. This can be considered as average weather over a long period of time. Scientists managed to spread the world to another climate zone. These various interactions create a climate system.

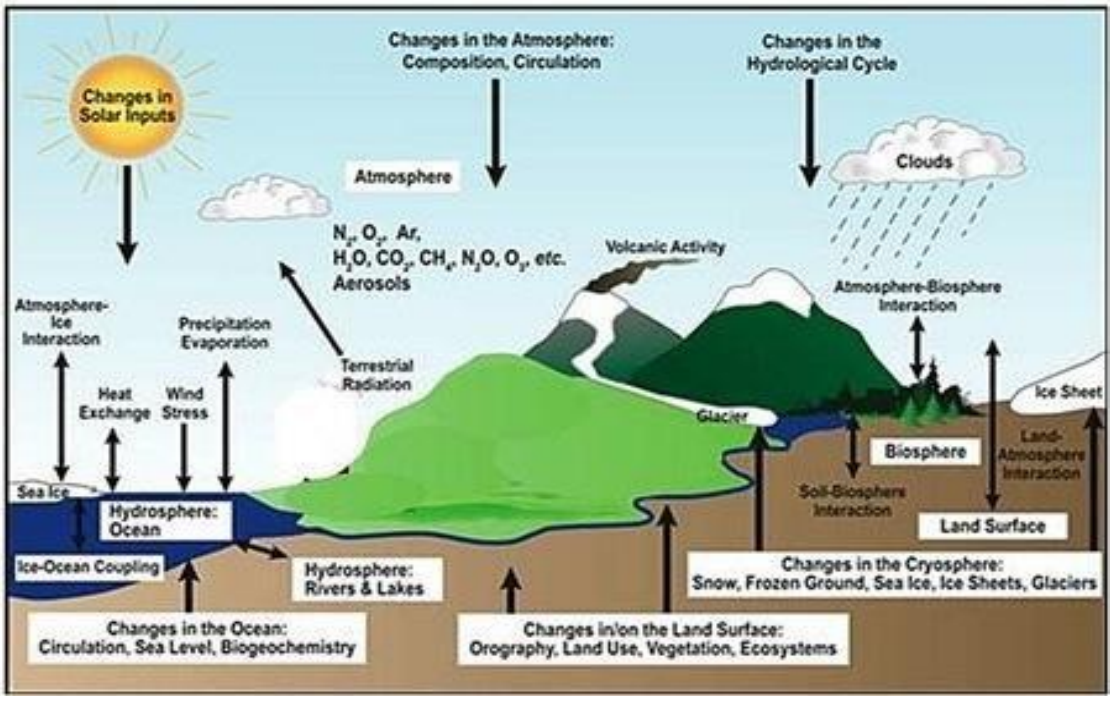


**Figure 2.1** Hydro meteorological cycle [6]

The difference between climate and weather is important. For instance, weather forecasts can be quite specific, but in the future it will take a little more than a couple of days. In contrast, climate forecasts focus on expected changes in average conditions, as individual days, weeks, months, or years are always opposed to a long-term trend.

The sun also controls our climate. Sunlight provides energy that warms the earth. Without an earthly atmosphere and certain gases, the climate would be completely different than it is now. Our atmosphere prevents the release of heat into space. If not, the planet would indeed be a very cold place. Some gases let in solar energy, but prevent it from returning into space, such as greenhouse. This is why it is called the greenhouse effect. Gases responsible for this changes, such as water vapor, carbon dioxide and methane, are known as greenhouse gases. Scientists have explained the effect of greenhouse gases on heat detection more than 150 years ago. They found that without the greenhouse effect, the earth would be 300 ° C colder, making it unsuitable for most life forms. Greenhouse gases store Earth's heat so efficiently that changes affect Earth's temperature. According to the International Panel on Climate Change, they have described climate change as any variability over time, whether as a result of human activities or as a result of natural changes. Greenhouse gases such as carbon dioxide (methane ($CH_4$)) and nitrous oxide ($N_2O$) in the atmosphere have increased significantly as a result of human activities. Greenhouse gases reduce heat radiation and return to space, causing global warming. Prior to industrialization, and until 1750, the concentration of carbon dioxide remained roughly constant for thousands of years according to the established values for the coverage of icy cores. Carbon dioxide is the most important greenhouse gas produced by mankind. The global concentration of carbon dioxide in the atmosphere increased from about 280 ppm to industrialization to 397 ppm in 2005, and the carbon dioxide concentration increased by 1.9 ppm annually.

Changes in the greenhouse gases in the atmosphere affect the balance of the climate system. Measuring the effect of radiation can be expressed by the influence of a factor on changing the energy balance in the Earth's atmosphere or the amount of energy that enters or leaves it. Since we left the last ice age about 11,000 years ago, the Earth's climate has remained relatively stable with an average global temperature of around 14° C, allowing complex ecosystems to thrive and support a wide range of life on Earth.

However, our climate has changed rapidly in the past century. This is not just a temporary system error. Data show that a long-term change in our climate is occurring at an unusual rate. But how can we determine whether or not these changes are normal?

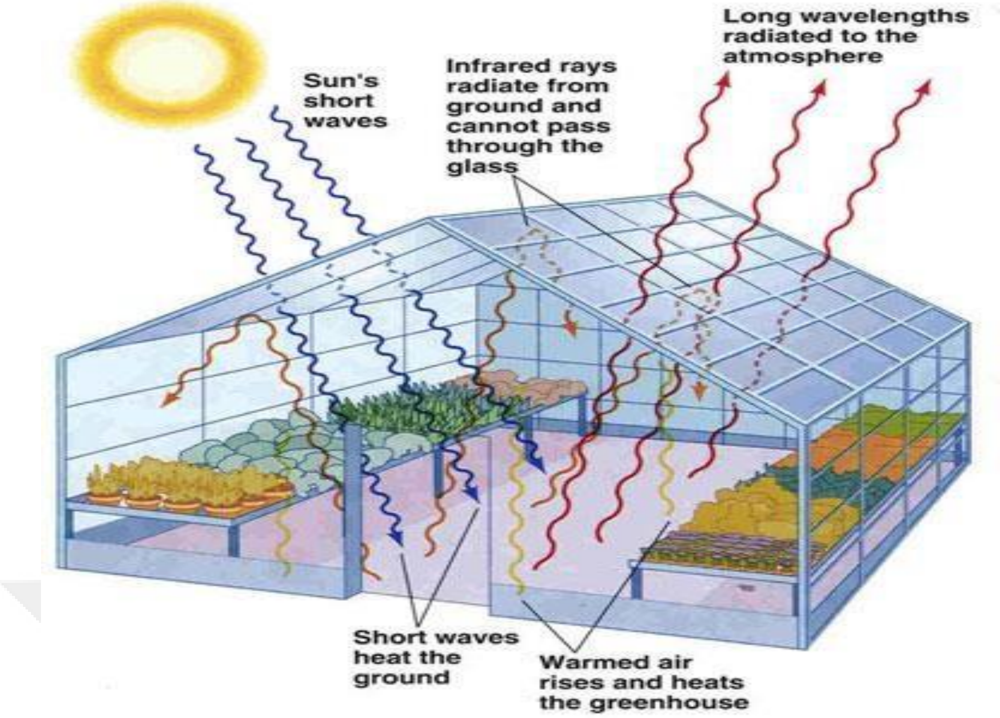



**Figure 2.2** The greenhouse effect [7]

There are many factors that can cause a warming climate. For example, more energy from the sun, and greater natural phenomena. Scientists have dismissed the sun and natural changes in our climate as the main causes of recent global warming. There is strong evidence that much of this warming is associated with an increase in the number of greenhouse gases, such as water vapor, carbon dioxide and methane that occur naturally in the atmosphere. However, human activity directly increased the amount of carbon dioxide, methane and some other greenhouse gases. This means that if we do not change our behavior, greenhouse gases will heat our planet at 1.4-5.8 ° C over the next hundred years. This is expected by a group of eminent international experts. How do we know that the climate is changing?

There are a large number of global temperature measurements near the Earth's surface, by which we can achieve a global average until 1860. All temperatures have been appearing higher in the past few years than at any time during the instrument period, which takes into account even Measurement errors and data gaps. Average annual global average temperatures on Earth and at sea fluctuate greatly from year to year, but there is a clear major trend, a rise in temperature until 1940, a slight downward trend from 1940 to 1975, and an increase of about 0.5 ° C in the period since 1975 and it appears today. Three independent types of temperature measurement - the air temperature measured in the terrestrial climate, on ships at

night, and the sea surface temperature - all show good agreement between 1900 and the past decades when the earth's temperature rose faster than sea temperature.
Temperatures were also measured in the atmosphere; over the past 50 years, with the help of weather sensors and satellite remote sensing since 1979. Global warming occurred in the middle troposphere, about 5 km above the surface. Although data in tropical regions according to the data from sensors on meteorological balloons are scarce, the temperature in the tropical central troposphere has apparently changed slightly over the past 235 years, which models do not predict. This discrepancy and its consequences are the subject of ongoing research.

The complex topography with different natural conditions like high-altitude and arid areas and the mesoscale weather systems of different influences of the central Asia region need to be taken into account in Afghanistan. The Global Climate Models (GCMs) typically perform poorly over the region, a fact that needs to be taken into consideration when discussing and judging climate change projections. Importantly, the GCMs, and to a lesser extent Regional Climate Models, tend to overestimate the precipitation for the arid and semi arid regions in the north.
The regional climate change model suggests that in general in the arid region of Central and South East Asia, the average annual temperature would rise and average annual precipitation would decrease as shown in the figures below. This could result in an increase in crop water requirements and other demands while the basin will have less annual river flow. However no quantitative data is available for this kind of analysis.

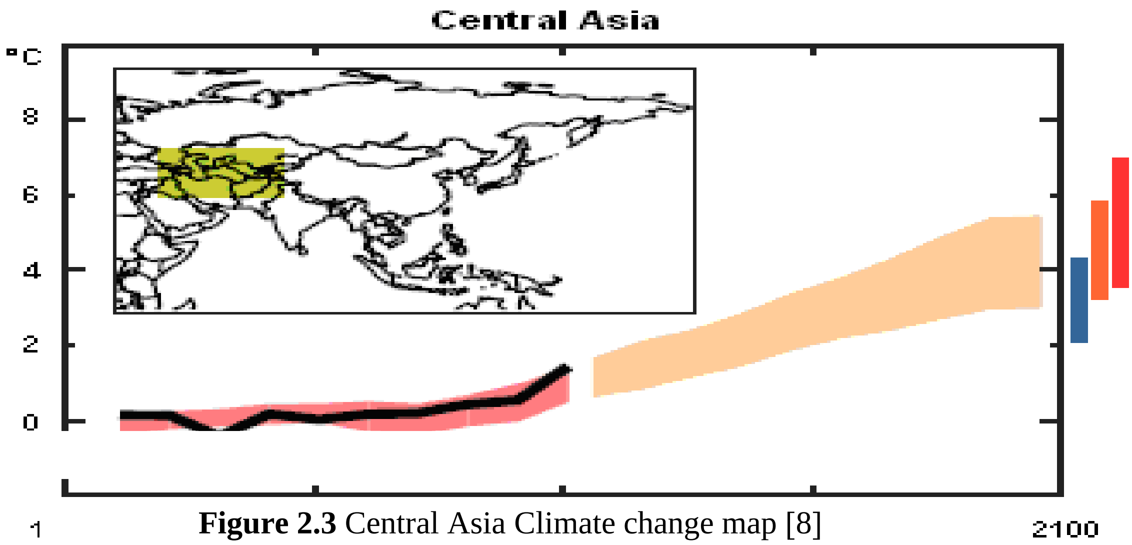



**Figure 2.3** Central Asia Climate change map [8]

Climate change could have a major impact in Afghanistan since the rivers are fed by snow and glaciers. Therefore, we have carried out sensitivity analysis to address the issue of climate change regimes and with a sequence of dry flow in the model.

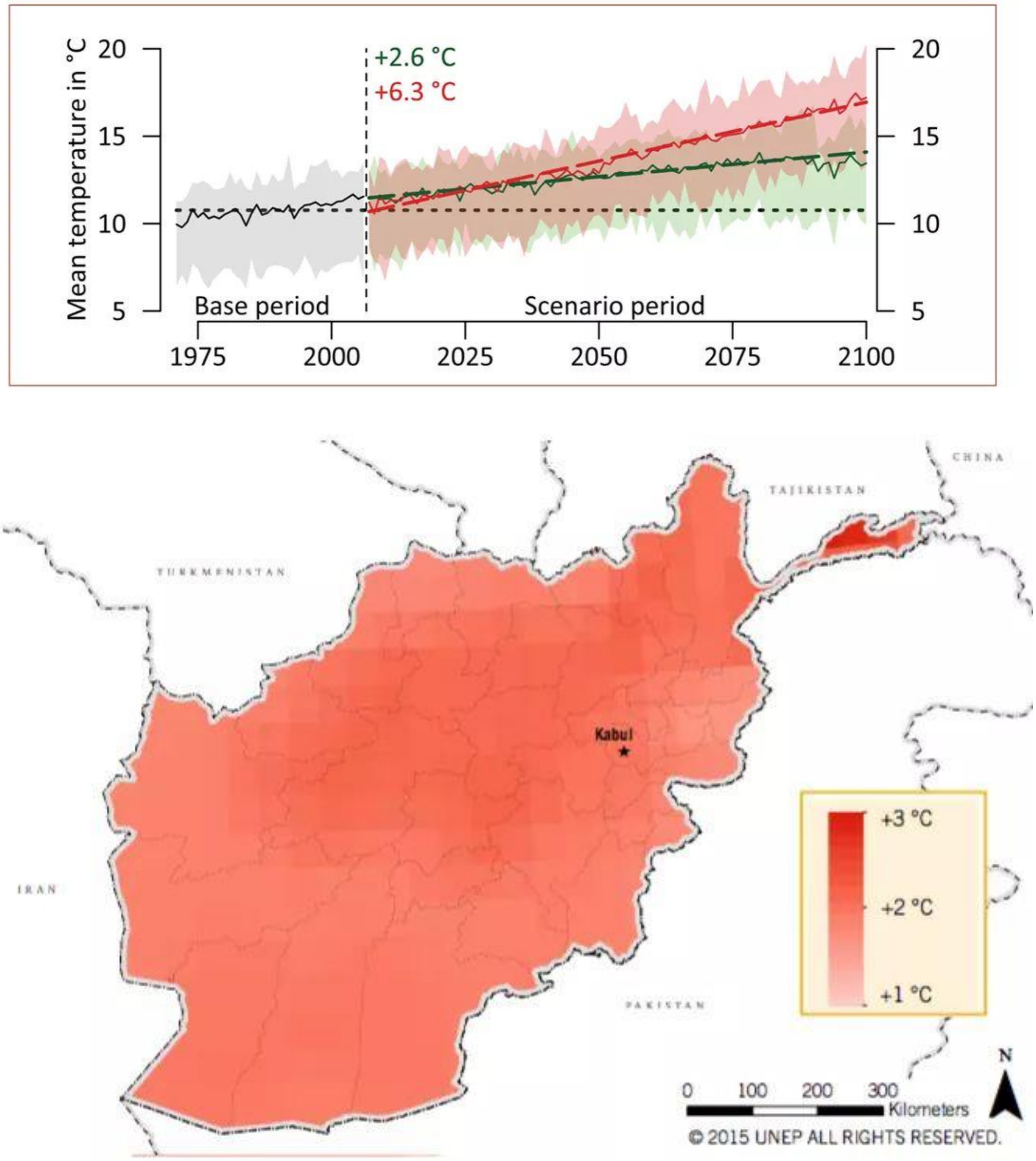



**Figure 2.4** Afghanistan temperature change scenario [9]

### 2.2 Changes in Earth’s Orbit

The orbital plane is the effect of slow changes in the tilt of the Earth's axis and the shape of its orbit on climate. These orbital changes change the total amount of sunlight reaching Earth at multitudes to 25%. It is known that global temperatures change dramatically over a hundred thousand years when the climate changes from ice ages to interglacial temperatures. The measurements were obtained on the basis of the icy cores that had been drilled from the Greenland Ice Sheet and analyzed by the British Antarctic Service and others as part of the European program. The actual measurement indicates the deuterium concentration in the air bubbles, and this may be due to an increase in the local temperature of 9 ° C between the depth of the last ice age 20,000 years ago and the current interglacial period. The cause of fluctuations between glaciers and the glacial climate are likely to be subtle differences in Earth's orbit and the tilt of the axis around the sun [10].

### 2.3 Energy from the Sun

In addition to the long-term changes associated with Earth's orbit, there are two main natural components that could change the global climate: changes in the energy we receive from the sun and the effects of volcanoes. Shown here is the amount of energy the sun absorbs on Earth. There are several estimates for this amount; as shown here due to the slope, the annual solar cycle is clearly visible, as is the increase between 1900 and 1960, with little or no change later. Sun exposure was estimated in 1978 using indirect data and less reliable than that measured by satellite. Based on the climate model in the Hadley Center, we can estimate the increase in global temperatures that could cause a change in solar radiation. This appears on the right scale and is one or two tenths of a degree. This may explain at least part of the global increase in temperatures observed at the beginning of the twentieth century. However, current climate models include changes in solar energy, and the attribution analysis, which attempts to understand the causes of past climate changes by comparing modeling with observed changes, does not show any significant exposure to the sun. Instead, these analysis show that greenhouse gases have recently been attributed to greenhouse gases, even if these analyzes consider the potential extent of climate response to solar changes using models [11].

## 2.4 Change in Volcanic Aerosol

When the pressure in volcanoes from the molten rock below the surface of the earth becomes very high, the stones, usually accompanied by lava or gases, escape through a crack or hole in the earth's crust. "Volcano" is a term used for both surface runoffs and conical mountains that result from a flood of lava, stone, and ash. Volcanoes inject gas into the atmosphere. When the energy is high enough, this gas is released into the atmosphere and forms small particles of sulfate aerosols that can last for several years. It reflects part of the solar radiation that would warm the surface of the earth and thereby cool the planet. The amount of volcanic aerosols in the atmosphere is very different. Although energy volcanoes were relatively common in the late nineteenth and early twentieth centuries and there have been a large number of energy volcanoes since the 1960s, there was a time in the 1940s and 1950s when the atmosphere was relatively devoid of volcanic aerosols. The degree of cooling of the climate by volcanic aerosols will be low during this time. This unusually low volcanic cooling could have contributed to temperatures being relatively high in the 1940s compared to previous decades. As with solar energy, the optical depth was estimated indirectly through volcanic aerosols. As with solar energy, the optical depth from volcanic aerosols was estimated indirectly until about 1983 and is therefore less specific.

## 2.5 Emissions: Carbon Dioxide, $CO_2$

Carbon dioxide is the most harmful greenhouse gas. Its concentration in the atmosphere is highest and it is currently responsible for more than half of the improved greenhouse effect. At present, annual carbon dioxide emissions are over 23

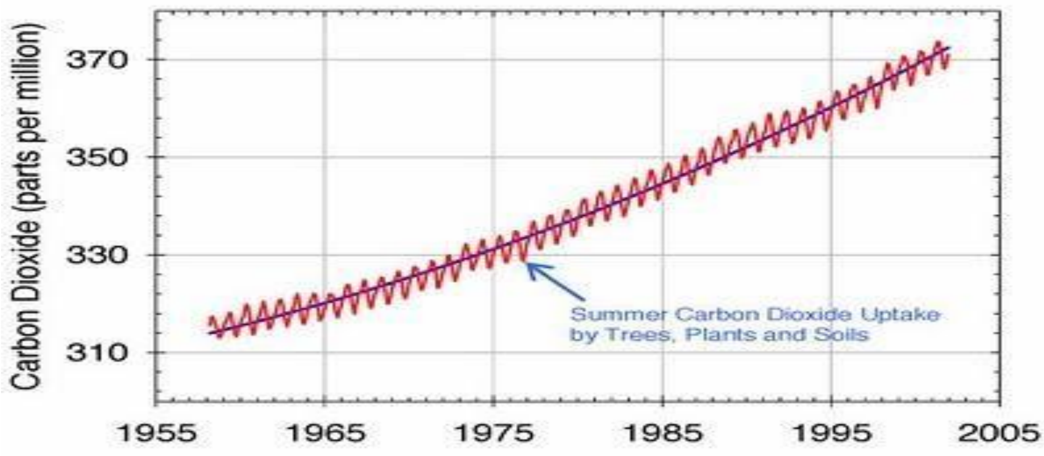



**Figure 2.5** World carbon dioxide increase scenario [12]

billion tons and the carbon dioxide concentration in the troposphere is higher. Carbon dioxide ($CO_2$) is released into the the atmosphere when burning fossil fuels (oil, natural gas, coal), solid waste, trees and wood products as well as other chemical reactions. The concentration of carbon dioxide in the air rises rapidly in fossil fuels. Until 1960 the carbon dioxide content was around 315 ppm (parts per million). The carbon dioxide concentration in the atmosphere is around 390 ppm. This increase in atmospheric carbon dioxide is mainly due to the activities related to the industrial revolution. 65% of the emissions from the combustion of fossil fuels come from deforestation, meadow diversion, forests and forest ecosystems.

Climate change is caused by greenhouse gas emissions. 63% of all greenhouse gases emitted are carbon dioxide ($CO_2$), 24% methane and 10% laughing gas ($NO_2$). Therefore, carbon dioxide emissions are the main cause of global warming. $CO_2$ inevitably results from the combustion of fuels such as oil, natural gas, diesel, biodiesel, gasoline, bio-gasoline and ethanol. Over the past 50 years, $CO_2$ emissions have risen sharply and continue to increase by almost 3% per year, see figure 2.6 below.

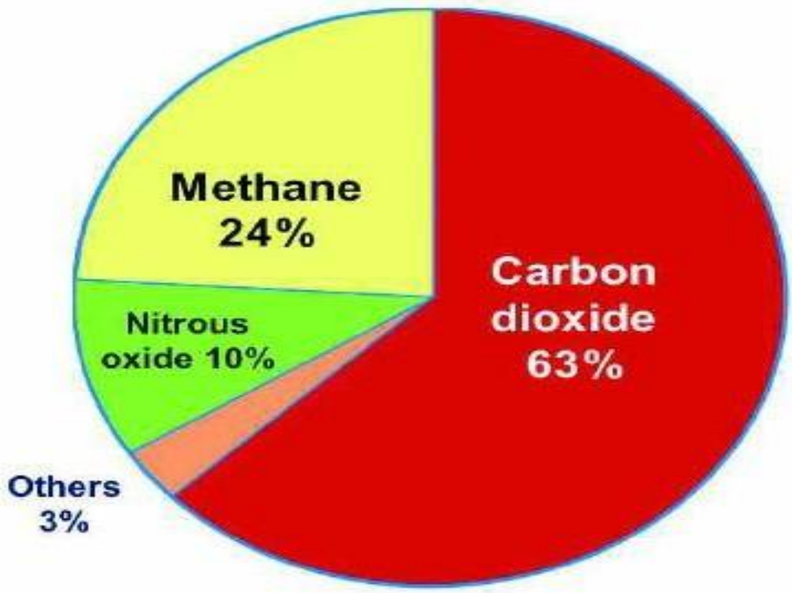



**Figure 2.6** Global warming scenario [13]

### 2.6 Emissions: Methane, $CH_4$

Many scientists believe that methane that is released into the atmosphere is one of the so-called greenhouse gases that lead to global warming. Indeed, methane is the second most harmful greenhouse gas generated by human activity. It is estimated that it accounts for one fifth of all the effects of global warming. Landfills, burning fossil fuels, and agriculture, especially livestock and rice, release methane into the air.

### 2.7 Emissions: Nitrogen Oxides, $NO_2$

Nitrogen oxides interact with water vapor in the atmosphere and form nitric acid, an element of acid rain. Nitrogen oxides increase the ozone in the lower atmosphere and contribute to smog in large cities. The contribution of forestry to total national nitrogen dioxide emissions is less than five percent. Nitrogen oxides interact with hydroxyl radicals or with ultraviolet radiation and form ozone in the lower atmosphere, which is poison and greenhouse gas. They also form an aerosol that increases cloud formation. The overall effect of cloud formation is likely to be a cooling off. Nitrogen oxides can also react in the atmosphere with the formation of nitric acid, which can lead to acidification in lakes and forests

### 2.8 Steam

Water has two important properties that influence the Earth's radiation budget. Water vapor is one of the most important greenhouse gases. In addition, clouds (water drops and ice crystals) reflect and increase the whiteness of the atmosphere, which leads to the reflection of incident solar radiation. The presence of atmospheric water vapor increases significantly with increasing temperature due to evaporation. This leads to positive feedback, since an increase in greenhouse gases further increases the global temperature. These notes are faced with an increased reflection of clouds. Most theories claim that the combination of reflection and heat detection leads to a clean cooling effect. Condensation and evaporation add or remove water vapor from the atmosphere. These processes make up the largest part of the energy transfer between atmosphere and earth and are called latent heat flows. These processes make up the largest part of the energy transfer between atmosphere and earth and are called latent heat flows. These rivers do not have a direct impact on temperature, but are very important for the water cycle. Figure 2.7 shows that the carbon cycle is the process by which carbon passes through air, soil, plants, animals and fossil fuels. The atmosphere contains a large amount of carbon in the form of carbon dioxide ($CO_2$). Green plants transfer carbon dioxide to organic molecules (glucose, which is food) during a process known as photosynthesis. Hence the food of every heterogeneous organism.

Animals do the opposite of plants - they release carbon dioxide back into the air, just like the product of breathing to produce food, but most of the carbon in the air comes from heterozygotes (photosynthesis). Analysts also release carbon dioxide into the air when the dead organic substance is destroyed. Decomposition is important because without it all of the carbon on this planet will eventually return to the food web. Carbon is also stored in fossil fuels such as coal, oil and natural gas. When burned, carbon dioxide is released back into the air. Volcanoes and fires also release large amounts of carbon dioxide into the atmosphere. Carbon dioxide can decompose in water, some of which then returns to the atmosphere.

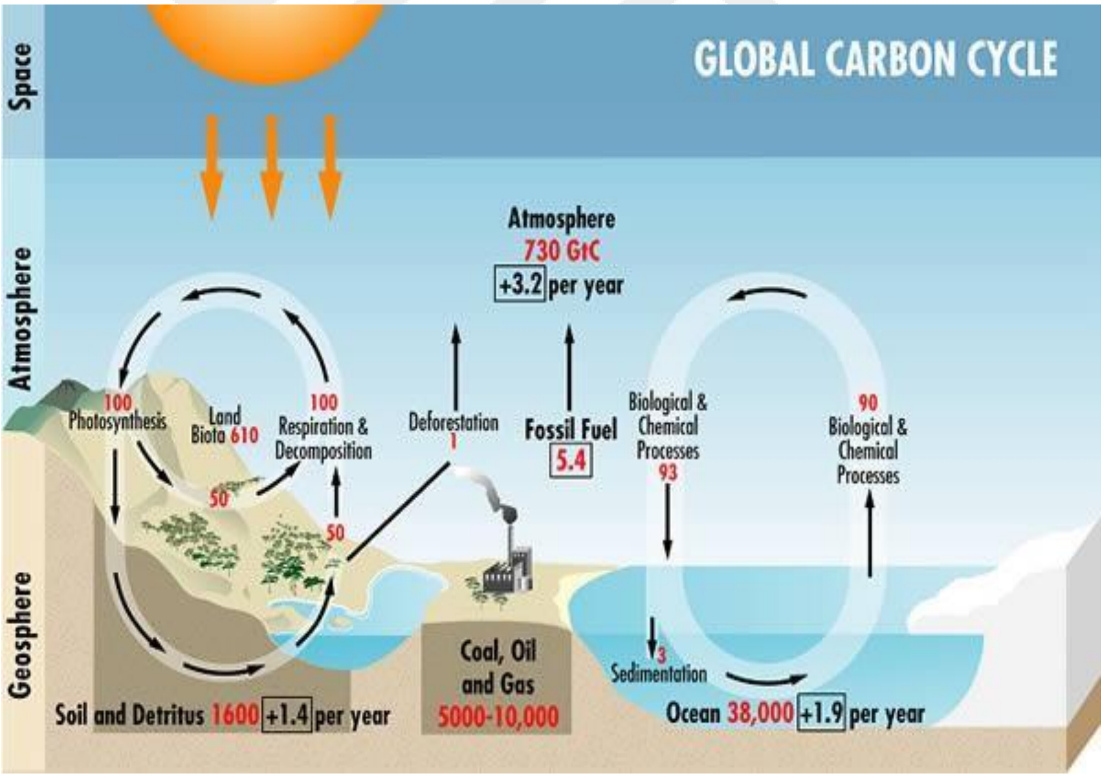



**Figure 2.7** Global carbon cycle [14]

### 2.9 Drivers of CO2 Emissions, Population and Energy Use

The main factors which have caused the rise in $CO_2$ emissions shown in the previous figures are twofold: (a) growth in population and (b) growth in energy-intensive over the years in consideration of standard of living, with increased ownership of goods, more services and greater travel.

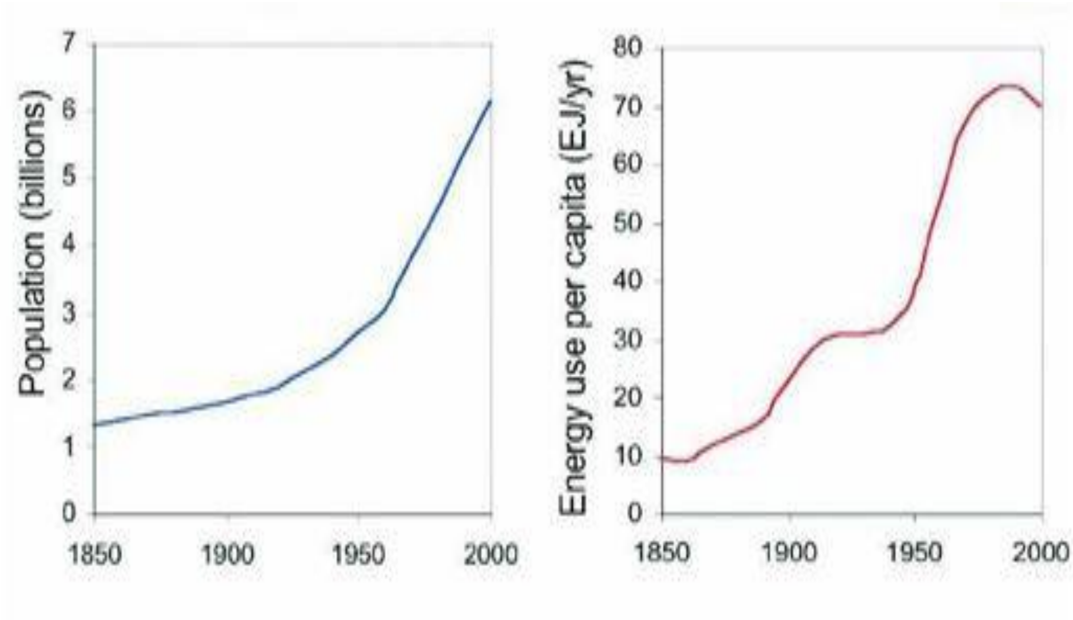



**Figure 2.8** Population and energy consumption scenarios

Direct carbon dioxide emissions. When we use energy from fossil fuels, power generation (whether gasoline in cars, heating our homes with natural gas, or lighting our homes with electricity) generates greenhouse gases. In 2000, the average family produced 12.4 tons of carbon dioxide from their home operations and about 11.7 tons from cars. Indirect carbon dioxide emissions: The entire remaining energy consumed in the economy, which, as mentioned above, is not directly attributable to the consumer, leads to indirect greenhouse gas emissions. When we buy a new product, this product has great energy in its manufacture, packaging and delivery. Even when we visit an air-conditioned shop, stay in a hotel on vacation or work in a heated office building, these and other activities cause indirect CO2 emissions. Man-made greenhouse gases dominate the change in climate impacts: a) tropical changes that cause changes in the amount and distribution of sunlight are large but are effective for very long periods of time b) variation in sunlight c) volcanic aerosols [15].

Therefore, the human or anthropogenic drive includes carbon dioxide and other greenhouse gases. The figure shows that all man-made greenhouse gases dominate climate change.

### 2.10 Aspects of Climate Change

The awareness of the extent to which change of climate can affect the environment, society, and economy is increasing. Due to the increase in the concentration of greenhouse gases, especially carbon dioxide, long-term climate change is observed at the continental, regional and oceanic levels. This includes changes in the amount and time of precipitation, arctic temperatures, the nature of the wind, and aspects of extreme weather such as heavy rains, drought, and heat.

The precipitation pattern is not evenly distributed throughout the world and is determined by atmospheric circulation patterns and the presence of moisture. These two factors are temperature dependent, so the nature of the precipitation may change due to changes in temperature. Changes include precipitation type, amount, intensity and frequency. Precipitation has increased in eastern North America, northern Europe and decreased in the Mediterranean, most of Africa, and southern Asia. Increasing global average air and ocean temperature can change the type of precipitation during the winter season. The pattern of precipitation is changing from snow to rain in Northern regions and mountainous area so that heavy precipitation events have increased even in places where total rain amounts have decreased. All these changes are associated with increasing global temperature since warmer air can hold and carry more water vapor [16].

Population growth will also lead to a decrease in water quality as the volume of wastewater increases, as well as an increase in industrial and agricultural pollution. These factors will further burden the way institutions use this resource to sustain life. Climate change is likely to exacerbate this pressure and make it difficult to manage water across borders.

According to the Intergovernmental Panel on Climate Change, climate change will have a number of consequences for water, including:

- An increase in precipitation in some regions, while in other regions there is a decrease in precipitation;

- Increase in average runoff and water availability in some regions, while in other regions, runoff decreases;
- Increased risk of floods and droughts due to a corresponding increase in rainfall and variability;
- increased melting of glaciers;
- Reducing food security and increasing vulnerability to farmers;
- negative impact on the functioning and functioning of the existing water infrastructure; and
- Significant impact on water quality, especially with regard to sediment content, chemical composition, total organic carbon content and microbial quality.

Climate variability has always played a role in society's relationship with fresh water, and ecological systems have always changed. Climate variability will change the functioning of shared water systems in hydrological, environmental, economic and social relations and will require joint adaptation measures. As climate change will have local effects, water management, including laws, policies and regulations at the national and local levels, will play a vital role in supporting adaptation efforts. Although about 300 transboundary agreements have been registered, 60 percent of the 263 watercourses in the world (158 transboundary river basins) currently do not have a basis for joint management.

### 2.10.1 Global Climate Change and its Vulnerability

Global warming is generally defined as the steady rise in average temperatures of the Earth's atmosphere, caused by the release of greenhouse gasses. Effects of this climate phenomenon are globally manifested in the rise of sea levels and the disruption of the hydrological cycle (mainly in the amount and patterns of precipitation), all of which have other subsequent consequences on ecosystems. Among these, likely effects include the frequent occurrence of extreme weather (heat waves, cold spells), changes in agricultural yields and the deterioration of ecosystems and extinction of species due to shifting temperatures.

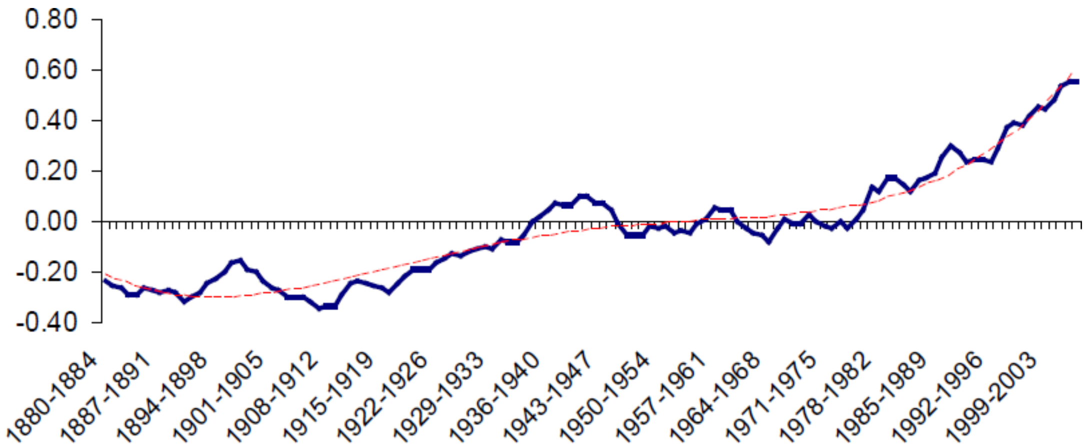


**Figure 2.9** Global temperature variation [17]

### 2.11 Impact of Climate Change in Afghanistan

The massive amounts of water stored in the mountains of Afghanistan and their importance for future generations is extremely important to follow climatic studies to predict their evolution. The study carried out by whole the available facilities and knowledge but in consideration of just 32 years data records, Trends analysis of climate and some other methods used.

The information can be generalized to most glaciers in this region, although with some small differences in humidity, cloud cover, and atmospheric circulation. According to the results, temperature in Afghanistan has increased by approximately 0.10°C/decade.The projections indicate that this warming will continue throughout the 21st century and will do so increasingly at higher elevations. His predictions show that Afghan territories may experience a substantial warming of 3-5 °C by the end of the 21st century.

As mentioned before, 22% of its glacier area has already been lost since 1970 due to this significant increase. Based on IPCC scenarios for 2050 and 2080, tropical glacier-models indicate that glaciers will continue to retreat, some disappearing in the next few decades. Such simulations have also pointed out that even if some glaciers do not completely disappear, their change in seasonal stream flow will significantly affect the water availability.It is important to point out that climate variations in this region increase the probabilities of floods, landslides and droughts. The IPCC also has related glacier retreat to such events that increase temperatures between 1°C and 2°C above average.

### 2.11.1 $CO_2$ Emissions in Afghanistan

The excess carbon dioxide in the atmosphere accelerates the greenhouse effect. Carbon dioxide from renewable energies does not increase the total amount of carbon dioxide in the atmosphere. This is due to the fact that the emitted carbon dioxide will eventually be replenished in the forest as the forests grow. As shown in Figure 2.10, $CO_2$ emissions in Afghanistan have increased in recent years. In 2008, carbon dioxide emissions reached 73 million tons. The increase in carbon dioxide emissions was due to the fact that this year the low hydropower production was offset by coal and peat power plants.

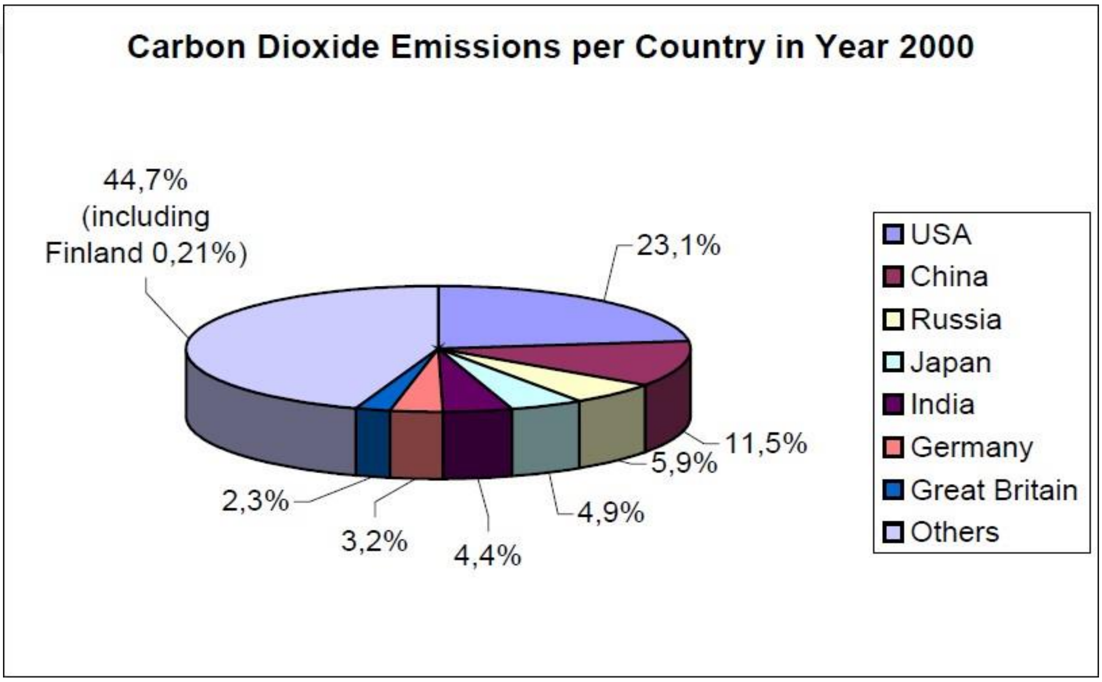



**Figure 2.10** Carbon Dioxide Emission in big country [18]

Climate change poses many dangers, and water is at the center of its consequences, as this will exacerbate the uncertainty and severity of hydrological variability. For example, regardless of the hydrological regime, the effects of climate variability and change on coastal areas (especially in East Asia, the Pacific, and South Asia) are expected to be significant in terms of rising sea levels on the coast and an increase on land. Until recently, almost the entire water industry assumed that the best basis for planning and managing infrastructure is based on historical records of the hydrological variability of this basin. However, the basic assumption that recent knowledge provided effective guidance for the future was that stationarity was declared “dead” due to anthropogenic climate change.

Climate change poses additional challenges for water management in Afghanistan, while most impacts will vary from basin to basin. Effects such as increased intensity and variability of precipitation are widespread and increase the risk of floods and droughts. These uncertainties and risks require even greater cooperation. Other problems in transboundary basins include:

• Risks of conflicts upstream and downstream due to the distribution of water between neighboring countries;

• Excessive use of groundwater as a result of increased production for agricultural purposes and drinking water supply;

• pollution of drinking water sources as a result of pollution from local sources, such as urban wastewater treatment and old industrial enterprises in the Central Asia, as well as in Southeast Europe; and heavily modified and man-made waters and pollution from diffuse sources (such as agriculture, urban areas) in Western and Central Europe.

## 2.12 Climate Change Standards

Hydrological ecosystem services are under great pressure worldwide due to the climate and global change. In the past two decades, various criteria and classifications for climate change have been developed to assess and quantify these problems. The Intergovernmental Panel on Climate Change (IPCC) was founded in 1988. It was launched by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to prepare assessments of all aspects of climate change and its impacts, and to develop realistic response strategies based on available scientific information. Today, the Intergovernmental Panel on Climate Change is mandated to assess changes, their potential impacts, and scientific, technical, and socio-economic information related to understanding the scientific foundations of human climate risks on a comprehensive, objective, open, and transparent basis. Adjustment and reduction options. "The reports of the Intergovernmental Panel on Climate Change should be policy-neutral, although they should objectively take into account scientific, technical and socio-economic factors that are relevant to the application of a particular policy." Through the Intergovernmental Panel on Climate Change, climate experts from all over the world summarize the latest climate data every five to seven years and report to the world's political leaders [19].

Water cycle and freshwater ecosystems, the water cycle can be explained as the continuous movement of water above and above the earth's surface. Over time, the water constantly changes its state between liquid, steam and ice. It also connects the global water cycle and connects the Earth's atmosphere, land and oceans. In addition, water offers important functions that contribute to the conservation of life on earth, including energy exchange, erosion, transport of biologically active chemicals and climate regulation.

## 2.13 Ecosystems and their Interconnectedness through the Water Cycle

According to the Convention on Biological Diversity, an “ecosystem” is a dynamic complex of communities of plants, animals and microorganisms and their non-living environment, which interact as a functional unit. The Millennium Ecosystem Assessment of 2005 identified ten categories of ecosystems: marine, coastal, inland waters, forests and dry lands, as well as island, mountain, polar, cultural and urban ecosystems. Inland waters include permanent waters within the coastal region and in areas where the environment dominates, as well as the use of permanent, seasonal or temporary floods. Inland or freshwater ecosystems typically consist of rivers, lakes, floodplains, reservoirs and wetlands. The WWF also includes rivers, their sources, tributaries, deltas, lakes and groundwater / aquifers in its description of the "ecological regions", which it defines as a large land or water unit with a geographically different unit.

Freshwater ecosystems have a major impact on the water cycle and, consequently, water supply for various human purposes, including irrigation, energy and transportation. Therefore, the water cycle is not only the movement of water between all parts of the earth in its various forms (vapors, liquids and ice), but also the relationship between water and the wider biological environment (atmosphere). Generally two elements of the water cycle are recognized. Blue water is all water that is controlled by physical processes such as evaporation and precipitation. "Green water" is water that is affected by biological processes such as complete evaporation through vegetation using the water stored in the soil.  In fact, the water cycle on earth connects ecosystems, and these ecosystems inturn control the water cycle.

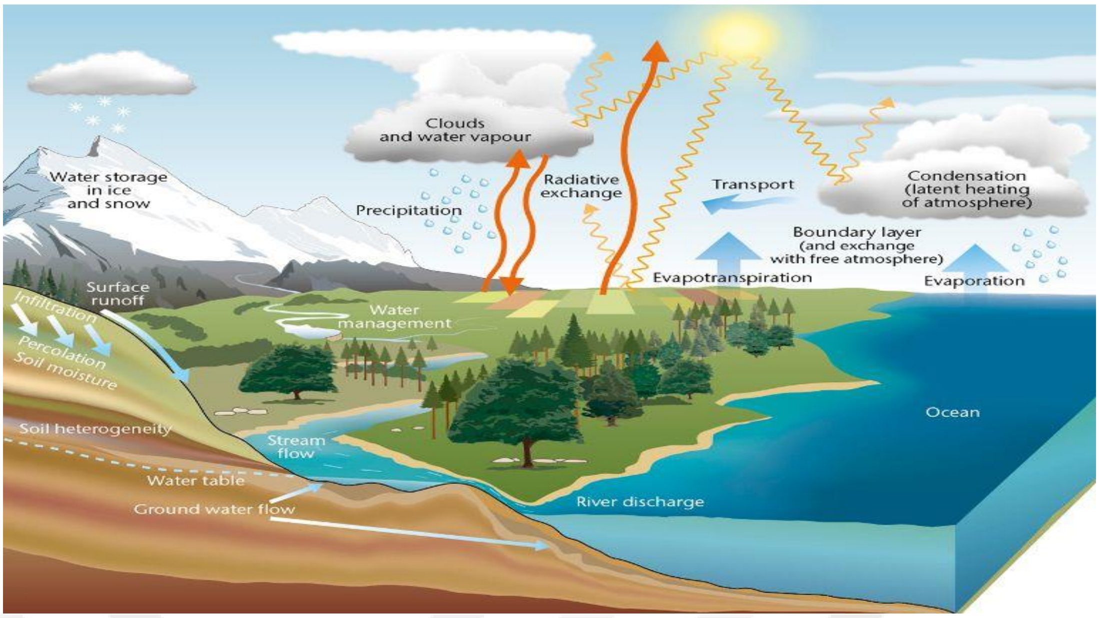



**Figure 2.11** Water cycle [20]

Ecosystems differ widely in the degree of rainfall and are therefore a source of renewable drainage points from the earth's surface, which are formed as part of the water cycle. This is particularly evident in forest ecosystems, mountains and droughts. Forests are associated with more than half of the world's rainfall and provide about half of the world's runoff. In general, ongoing hydrological studies of forests show that forest ecosystems are the main users of water. Because natural and artificial forests use more water than most alternative land coverings (including agriculture and grazing), it is known that even partial deforestation speeds up water drainage, increases downstream water flow, and can increase the risk of flooding during the rainy season. It can also lead to dry conditions where forests use water to sweat, especially at daytime temperatures, and water retention in the soil is reduced by picking leaves.

Perhaps the most important contribution of forests to the hydrological balance of water catchment ecosystems is maintaining water quality. This is achieved by minimizing soil erosion at the site, reducing sediments in bodies of water (wetlands, ponds, lakes, streams and rivers) and collecting / filtering other water pollutants in forest waste and their growth.

### 2.13.1 Freshwater Ecosystems and Adaptation

The effects of climate change, along with other factors of global change, affect the international community's ability to address global economic, social and social priorities. Given the importance of water to the effects of climate change, its management is essential to reduce vulnerability. Ecosystems play an important role in the water cycle and thus in the provision and use of water for people, including irrigation, energy and transport.

1. Adaptation

According to the IPCC adaptation means adapting natural or artificial systems to actual or predicted climate impacts that reduce damage or take advantage of opportunities. Adaptation is primarily associated with reducing the exposure of biological systems to impacts climate change by increasing their sustainability. Correction takes place in a series of link scales and can either anticipate changes or be a reaction to these changes.

A) Weakness

According to the Intergovernmental Panel on Climate Change, vulnerability to climate change is the extent to which the system is weak or unable to cope with the adverse effects of climate change, volatility and extreme events. This can be determined by examining the level of exposure to water stress and climate variability, and the level of sensitivity and adaptation in a community or ecosystem. The impact is determined by the degree, type and speed of climate change in the region. The effects of climate change depend primarily on geography. For example, droughts can hit communities in semi-arid regions even more. Sensitivity is the extent to which climate-related factors negatively or positively influence a community (or group). This mainly depends on the livelihoods, the most important livelihoods and the effects of climate change on these resources.

B) Adaptability

In the context of both social and natural systems, resilience can be understood as the ability of a system to adapt to climate change, mitigate potential damage, take advantage of opportunities or bear consequences. Adaptability means the ability to eliminate weaknesses (sensitivity, sensitivity and reaction) and to increase stability.

C) Stability

When it comes to the effects of climate change, vulnerability and sustainability are factors. According to the IPCC, sustainability indicates the degree of disruption that can be overcome before a system changes its structure and behavior, for example before it crashes. To strengthen resilience to climate change, the social and economic dimensions of development must be brought together and the environment restored and managed. The environment in particular is key to climate resilience, and well-functioning catchment areas, pristine plains and beaches provide ecosystem services (such as water storage, flood management and coastal protection) that reduce exposure to the serious effects of climate change (such as droughts and floods). (And coastal flooding).

2. Adaptation to the ecosystem

Human well-being depends not only on one, but often on many interconnected ecosystem services. Climate change can have a negative impact on the service portfolio of an ecosystem, for example by separating water management and food security services. This means that if ecosystem services are lost or deactivated, the services used by humans are also lost. The deterioration of the ecosystem often leads to a reduction in human benefit [21].

### 2.13.2 Water scarcity and Climate Change

The climate is expected to change further in the future, although there are still many uncertainties that will affect natural and human systems such as forests, fisheries, water, human settlements and human health. The surface temperature of the earth has risen by about 1° C in the last 100 years, and the temperature has risen faster in the past fifty years. Heat and water are closely related, and in recent decades, warming trends have changed the water cycle, and disruptions in the water cycle can lead to water shortages in the region. Water scarcity refers to the relative water scarcity in a water supply system that can lead to consumption restrictions. The deficit is the extent to which demand exceeds available resources and can occur due to droughts or human acts such as population growth, water abuse and unequal access to resources.

Drought is a common climatic feature characterized by a temporary lack of water compared to natural supplies over a long period of the season, a year or several years. The term is relative because dehydration varies in degree, duration, and severity. According to the World Resources Institute (WRI), the world's water networks are exposed to enormous threats. There are currently over a billion people living in arid regions and up to 3.5 billion people may be deprived of water by 2025. Pollution increases freshwater deterioration and coastal aquatic ecosystems. Climate change is ready to change the structure of precipitation, accelerate the melting of glaciers, change the water supply, and exacerbate floods and droughts in different parts of the world.

Worldwide water consumption is increasing due to economic growth. In most countries, with the exception of some industrialized countries, water consumption has increased in recent decades due to population and economic growth, lifestyle changes and the expansion of water supply systems. The main source is water consumption for irrigation. Irrigation accounts for about 70% of all water withdrawals worldwide and more than 90% of water consumption. Water is exposed to a variety of pressures, including water pollution, water scarcity and flooding. Significant changes in water also affect formation and water flow.

Central and South Asia are subject to rapid local and global social and ecological changes. All indicators point to an increase in water and environmental scarcity, which has a negative impact on current and future sustainability. The pressure on water scarcity is heterogeneous across South Asia and in the water use sectors. It is suggested that the risk of water shortage be addressed through preparedness rather than a crisis approach and the importance of local governance at the river basin level.

Climate change is increasing pressure on water resources in parts of the world where drainage is low, including the Mediterranean, parts of Europe, Central and South America and South Africa. In other parts of the world it suffers from water stress, especially in South and East Asia. Climate change increases runoff, but in reality this may not be very helpful as increases usually occur during the rainy season and additional water may not be available during the dry season. Future population growth will further burden the available water resources in many countries and around the world. The way countries around the world use water has become more important every day. Climate change will increase water temperature and the possibility of floods, droughts and water scarcity in the coming years. There are many signs that bodies of water that are already under stress are very vulnerable to the effects of climate change and that climate change can hamper attempts to bring some bodies of water back to normal. Preparing for climate change is a major challenge for the management of the world's water resources. The Water Framework Directive is the first part of European environmental legislation regarding hydromorphological pollution and water impacts.

This requires action in cases where the hydrophorological pressure affects the environmental conditions and the ability to achieve the WFD goals. The WFD should be implemented as part of the river basin management process [22].

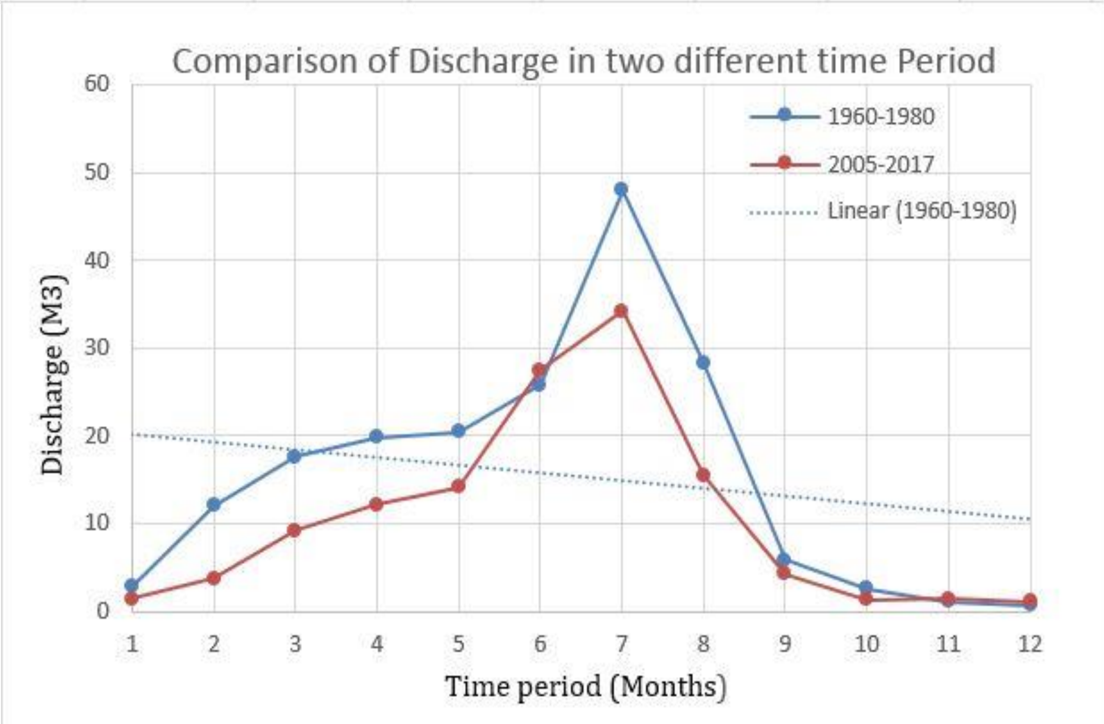



**Figure 2.12** Gulbahar Station discharge under effect of climate change

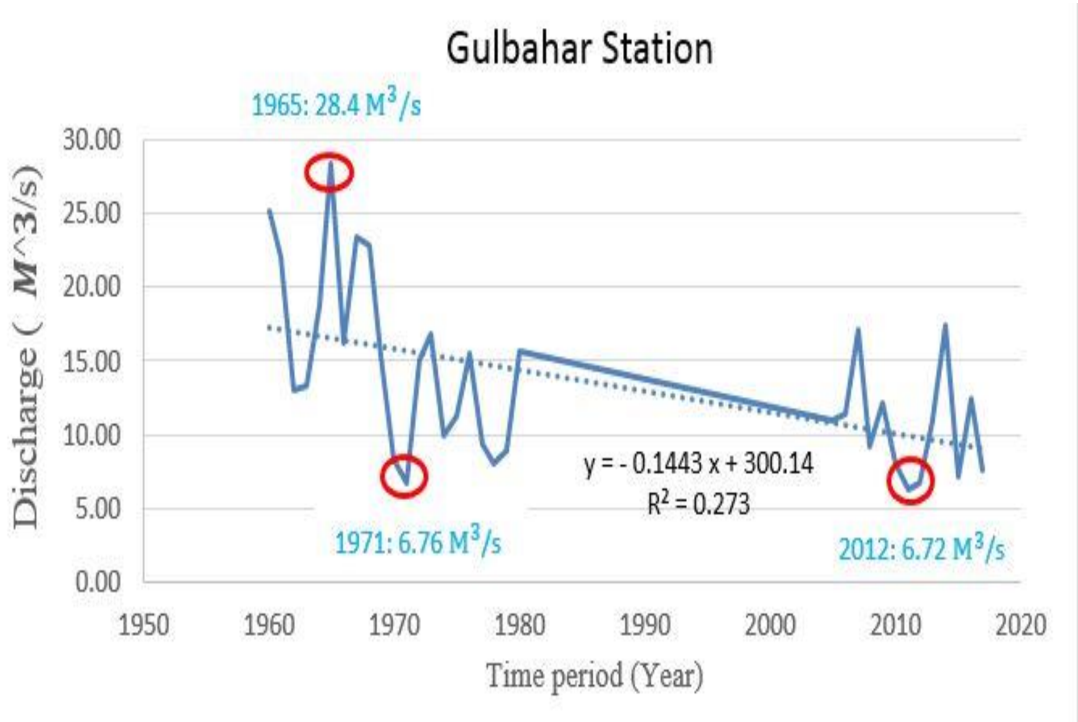



**Figure 2.13** Panjsher River discharge scenario over time period

# CHAPTER 3

# CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT

Afghanistan is characterized by uneven natural geographical distribution of water resources and precipitation, water availability and poor water supply stability. This can be exacerbated by climate change, which can affect the quantity and reliability of water and thereby undermine the existence of civilization in terms of health, food security, energy and the environment. In addition, current water management practices may not be adequate to deal with the effects of climate change. Therefore, information on current climate changes should also be included in water management by improving mitigation strategies that address this problem in a wider context, possibly including environment and human health.

Since the water cycle reaction is exacerbated by any climate change that is compounded by the fact that Afghanistan is already experiencing water shortage in some regions, this is a bad situation. In addition, the ability to adapt to these changes is weak, so this threat must be urgently included in our policy today.

The catchment areas, also called catchment areas, are functional and geographical areas that combine various environmental processes and human influence on the landscape. Integrated assessments recognize the interdependence of the resources and components that make up the watershed. Because of their complexity, managers and planners traditionally manage catchment areas to optimize only one or more resources. A more holistic approach is needed that affects river basin resources and other components, while emphasizing the importance of maintaining the sustainable use of all river basin resources. Recently, the need for a comprehensive climate assessment and analysis for quantifying and evaluating ecological systems has been increasingly recognized. Integrated assessment takes into account several types of land use and at the same time implements the concept of sustainability through community-based watershed management [23].

The catchment areas are often subject to multiple uses, including recreation, agriculture, habitat management, mining, forestry and development. In order to understand the interaction of catchment areas in assessing the catchment area, the physical, biological, social and economic components of this catchment area must be accurately understood.

It is a management process that promotes the coordinated development and management of water, land and related resources to maximize economic and social well-being without compromising the sustainability of vital systems. In order to adequately understand the design of catchment areas in a developing country, it is important to understand all the components that are involved in the evaluation and implementation of the coastal monitoring program. The principles of governance in Afghanistan are fragmented and there is no integration between people, resources and development. This chapter explains the technology and guidelines for the concept of pool management in the face of climate variability.

### 3.1 Effects of Climate Change on Water Resources

Climate change is currently a scientifically based fact, and an intergovernmental panel of experts on climate change recognized it as a threat to sustainable development. It is defined as a trend or constant change in climate that includes properties such as temperature, precipitation, humidity and wind speed. Climate change can be identified by changing the mean and / or variability of its properties.

The properties of the atmosphere, oceans, ice and land surface describe the climate system. Exposure to the sun, natural (e.g. volcanic) and human activities are key elements of climate change [24].

The climate system remains in balance when the energy of the sun is balanced by radiation from the surface of the Earth back into space. Greenhouse gases, water vapor, carbon dioxide, methane, laughing gas and other artificial compounds emit part of this energy back to the surface of the earth.

Aerosols, on the other hand, which are composed of organic and black carbon, sulfates, nitrates and dust, have a cooling effect on the system, reflecting solar radiation. For example, an increase in the concentration of greenhouse gases “tilts” this balance and directs large amounts of radiated energy back to the earth’s surface. Conversely, an increase in aerosol concentration due to the reflection of solar energy back into space will lead to a cooling effect. Due to the time scales associated with climate processes, restoring balance can take centuries. Climate variability and imbalance have affected global water resources in recent decades, making Afghanistan one of the most vulnerable countries due to its low infrastructure and water management capacity [25].

### 3.1.1 Pollution of Water Resources

Pollution is observed in both surface water and groundwater resources. Surface water is polluted by uncontrolled domestic waste and sewage disposal. Raw industrial effluents and the more widespread use of chemical fertilizers may play a large role in the future and should also be addressed now. In Afghanistan especially in Kabul groundwater quality suffers from wastewater leaching into the underground from unsanitary open pits and leakage from septic tanks. While being costly, interventions to deal with water resource degradation will be unavoidable to maintain long term sustainability.

## 3.2 Critical Issues

Sustainable water resource use is a key factor for long lasting development. Currently a strongly unsustainable situation exists in the Panjsher sub basin with the upper catchments degrading, groundwater levels dropping and pollution of water sources has increased. Sustainable water management would be a prerequisite to the long-term viability of both urban and rural communities in the basin.

There are a number of issues that are becoming increasingly critical in the Afghanistan river basins especially in Panjsher sub basin:

1. Drinking water supply for urban centers in need of a stable year-round water supply of high quality.
2. Flood control with the need for low level in reservoirs before the flood season
3. Hydropower with the need for timely flow (peak needs in winter)
4. Irrigation water with a need for timely flows (peak needs in summer)
5. Industry with the need for process water and discharging of effluents and pollutants
6. Environmental requirements with a need for environmental flows to maintain wetlands, water quality, fish populations, ecosystem services and recreation

potential.

7. Groundwater recharge is essential for sustainable supply
8. Climate change or climate variations with potential impacts on glacier flow. Climate change is not well understood in the Kabul River basin which leads to the need for robust and resilient planning

From a purely economic perspective, most public institutions are still relatively weak while the underlying legal/regulatory environment is equally fragile. This, in turn, has greatly inhibited private investment, particularly with respect to the extensive but largely undeveloped mineral resources in the country.

### 3.3 Water Availability and Scarcity

Surface water availability in the Panjsher River is dependent on seasonal runoff resulting from snowmelt, rain and catchment base flow. Suitability of the water, in addition, depends on the state of the water courses with regards to pollution levels and respective usability for different purposes. Availability is generally high in spring and summer when snowmelt in the upper catchments leads to runoff of melt water. With catchment degradation the runoff characteristics of the rivers may become increasingly extreme which can lead to increased floods (numbers and intensities) in the summer months and increased droughts after the snowmelt season due to decreased retention potential of the upper catchments.

With the continued and expanding use of groundwater, levels are gradually dropping. Between 1965 and 2015, over a period of 50 years, the groundwater table in Kabul as whole has dropped more than 40m and it exacerbated unexpectedly in the recent years. Low water availability is not only a quantitative problem but also a timing problem. The timely availability of water in a basin to some extent can be controlled by dams and reservoirs which store the water and release it with a delay and a different flow regime depending on dam size and operation schedule. Conflicts may arise not only based on water quantity demanded by competing stakeholders but also by different timing needs. Hydropower production for example needs reservoirs as full as possible at any time and discharges the water based on electricity consumption needs. Irrigation water users on the other hand need timely water supply only during the growing season. Flood control would require the reservoirs to be as empty as possible to provide flood retention [26].

### 3.4 Solutions for River Basin Management

The problems associated with river basin management can include a range of conflicts, policies, strategies and control measures that vary from different actors, from interests to communities, taxes and can function from one level to another depending on the driver or government problem. It improves management capabilities and management solutions; the term "management requests" is accepted. Participating in the millennium abandonment are the six main types of responses that are used in managing surveillance:

• Institutions (both formal and informal) and legal norms are not the answer, but create leadership for the management response. Requirements for legal instruments are very different from functional enforcement systems.

• Property rights are a personal way of regulating the use and overuse of environmental goods and regulation. There is the possibility of options, for example Quote, taxes, sub-payments or additional payments.

• Social and regulatory powers related to strengthening awareness-raising and awareness-raising campaigns, strengthening indigenous and social relations, social rights, disobedience and protests.

• Certificates of technological approval for the hardware of products, devices and software (procedures, procedures, processes) in order to reduce human resumes to those concerned, receive compensation claims, treat them anthropogenically or support minority conditions.

• Cognitive denial of claims through behavioral knowledge. As for options, the acquisition and use of knowledge (for example, through observation programs), adaptive management approaches, as well as legitimation and our own traditional and scientific conditions.

Another solution is development projects which have been identified in the Kabul River basin. The project options are listed in the table below, and an overview is shown in the figure below.


**Figure 3.1** Water resources management [27]

**Table 3.1** Panjsher River capacity

| Scheme | River | Purpose | P (MW) | $S_t$ ($Mm^3$) | $S_l$ ($Mm^3$) | Q ($Mm^3$/a) | C (MUS$) |
|---|---|---|---|---|---|---|---|
| Gulbahar Dam | Panjsher | Irrigation, hydro.p domestic | 116 | 490 | 405 | 1725 | 1,437 |
| Baghdara-I | Panjsher | Hydro.p | 165 | 1.9 | 1.8 | 3022 | 475 |
| Baghdara-II | Panjsher | Hydro.p | 244 | 400 | 275 | 3022 | 547 |

The listed dams cater for different and mostly mixed purposes. We have generally concentrated on larger schemes with a significant influence on the basin hydrology and with potentially large benefits. For example water supply and sanitation schemes for small towns have not been dealt with individually, but were grouped under rural water supply. Equally small hydropower projects are not included in the investment analysis. According to the ESHA (2004) hydropower schemes that produce less than 10 MW are considered small. We have used this limit to exclude the smaller schemes, which have negligible influence on the total hydropower production in the basin. Among the projects three of them is located on the Panjsher river path [28].

Primary needs related to the dams include:

- Reservoir use
    - Water for human consumption as domestic water
    - Waterford agricultural use through irrigation
    - Water for energy production through hydropower
- Downstream use
    - Water for downstream domestic users
    - Water for irrigation
    - Water for industrial users
    - Water for the environment through maintaining an environmental flow component
    - Floodwater control through flood retention

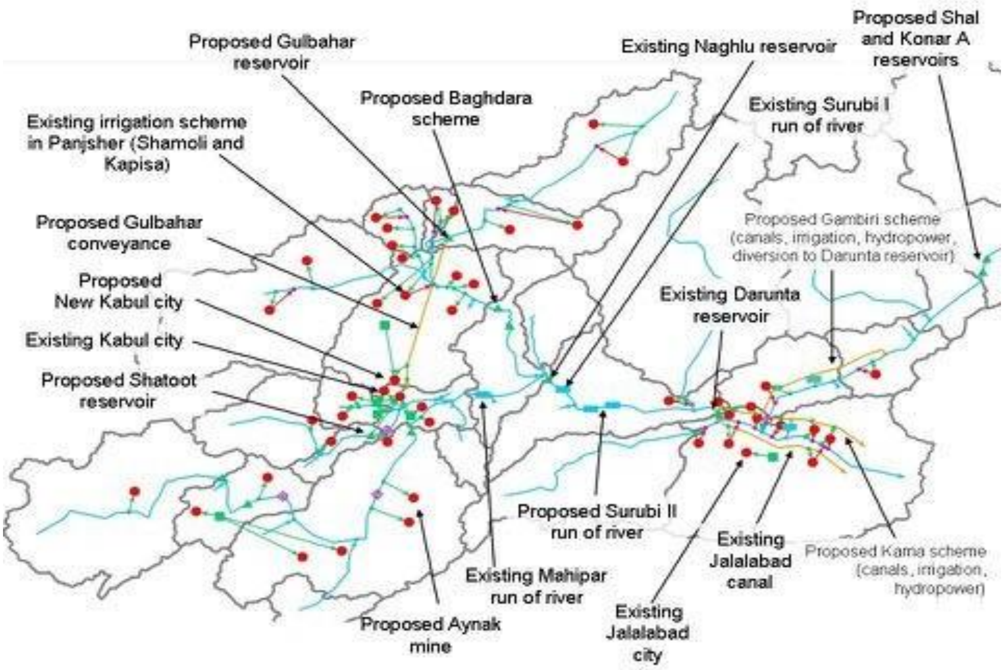



**Figure 3.2** Gulbahar station

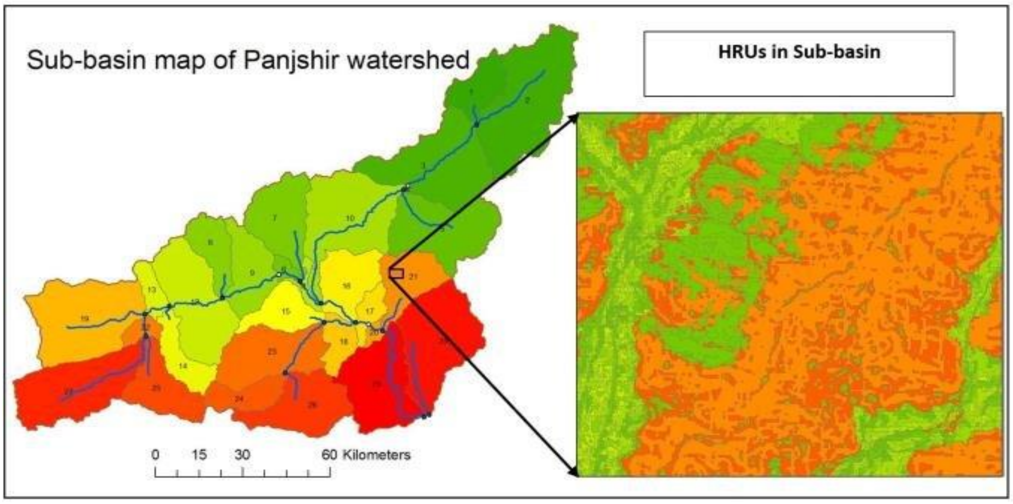



**Figure 3.3** Panjsher sab basin

Future targets in the Panjsher sub basin aim to conserve water resources and to provide water in sufficient quantity, quality, and timing for all of the actual and potential water users in the basin. The aim will largely be met by construction of several dams in the different path of the river which in combination can provide the required water storage and flood retention capacity. In addition, water resources conservation, especially through reduction of pollution of surface- and groundwater resources, will be an important issue.

### 3.5 How Will Climate Change Effect Water Resources?

Climate change will have an interconnected consequences on the water cycle. The spatial distribution of precipitation due to its temporary occurrence is likely to change. At higher temperatures, the amount of precipitation that turns into snow changes and affects the time and amount of ice melting. Evaporation also increases, leading to drier soils. A change in $CO_2$ concentration also affects the total evaporation of vegetation, which can increase water loss. Longer periods of drought can be caused by drier soils, which also alter the land cover and thus affect the drainage response in the catchment area to rainfall. In addition, this affects the recharge of groundwater, which changes the amount of seepage. This change, therefore, changes the contribution of groundwater flow [29].

In addition to the amount of water, quality is also changing. Extreme rainfall leads to increased runoff, which discharges pollutants from urban areas and farms into the receiving waters. It also poses a physical risk to water infrastructures, such as dams and water supply and wastewater treatment systems, as pollutants are overloaded and treatment is difficult. On the other hand, a decrease in the flow of electricity and the volume of the reservoir will increase the concentration of pollutants. In addition, an increase in water temperature can affect the environment, which may depend on a cooler environment.

The effects of climate change, combined with other factors of global change, affect our ability to address global economic, social and social priorities. About 700 million people in 43 countries are currently suffering from water shortages due to the effects of climate change on fresh water. It is estimated that by 2025, 1.8 billion people will live in absolute waters in countries or regions, and two-thirds of the world's population can live in water-related conditions. It is believed that rising water temperatures and extreme changes, including floods and droughts, affect water quality and exacerbate many forms of water pollution. These impacts will negatively affect ecosystems, human health, the reliability of the water supply system and operating costs. As floods, droughts and other effects of climate change on water become more frequent or more intense, economies and livelihoods will decrease.

### 3.6 The State of our Water Resources

Our water resources with varying spatial and temporal distribution are under constant pressure due to important factors such as population growth, increased demand and climate change. Despite the fact that less than 1% of the world's fresh water (or about 0.007% of all water on Earth) is easily accessible for direct human use, the depletion of this invaluable resource continues regardless of the future. As governments continue to be unable to provide water, coupled with growing poverty and inequality, 1.1 billion people (about one in six people on earth) do not have access to improved water sources.

Transboundary water management, especially in arid and semi-arid regions, is becoming increasingly complex at the transboundary level due to the collective effects of anthropogenic changes in the upper reaches and climate change. Climate change raises doubts about transboundary water management practices and creates a number of uncertainties. The main goal is to develop measures for the sustainable use of shared water resources, as Afghanistan has transboundary water resources, most of which do not have an agreement with cropped countries.

### 3.7 Afghanistan River Basins

Water resources endowment in Afghanistan is significant on an annual per capita basis, with five major river basins: Kabul, Panj-Amu, Hari Rod-Murghab, Northern and Helmand, with numerous key rivers contributing to the total yield. However, measurements show that there is considerable seasonal variability in rainfall-runoff causing frequent periods of local and widespread drought and flood. Hence, the need for infrastructure investment for development of storage and delivery systems is vital for securing long term water supplies and retaining floodwaters to support economic development and poverty reduction.

Key to Afghanistan's economic development and poverty reduction efforts is an increase in significant scale investments in effective and sustainable water resources development and management. The river basin perspective and integrated water resources management approaches have been adopted by the Afghanistan government for water resources development since 2002. This is reflected in the new water law of 2009 and the institutional structure of the Ministry, which at sub national level is subdivided into basin agencies.

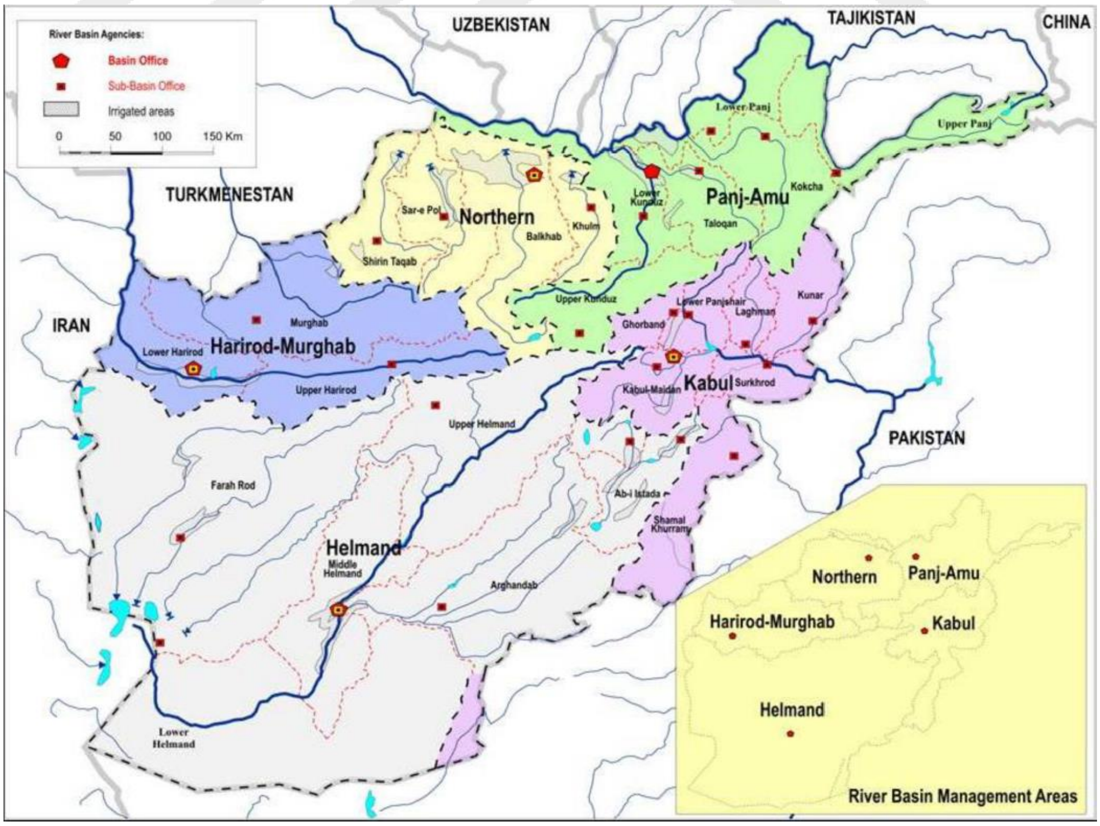



**Figure 3.4** Afghanistan Water resources

To achieve the desired results for ware resources management, there are key considerations and issues to be addressed as a matter of course, including;

- Balancing and phasing the priorities and benefits of rehabilitation and small water sector projects with quick yield focus, with those of longer term yielding medium and larger projects implementation;
- Analysis and prioritization of projects and preparation of implementation plans to an internationally acceptable standard within a multi-sectorial basin framework;
- Improve effectiveness of coordination across water-related sector institutions to ensure shared-vision planning, development, and management of water across related institutions;
- Enhance the technical, managerial and human resourced development capacity for integrated water resources management and project preparation.

### 3.7.1 Physical Characteristics

Afghanistan is a landlocked state with a total area of 652000 km². Borders on Turkmenistan, Uzbekistan, and Tajikistan in the north, China in the northeast, Pakistan in the east, and Iran in the west. The country has a sharply continental climate, and the severity of winter is exacerbated by the high altitude of most of the country. Winter and spring are seasons with different weather conditions, and most of the annual precipitation falls from November to May. Summer is warm to very hot with little rainfall or lack of flow or lack of flow, with the exception of rivers and streams feeding on melting snow and glaciers.

Monsoon influence can occur in the easternmost part of Afghanistan. It is also the easternmost country, where the influence of the Mediterranean Sea is felt, where most of the depression occurs, which causes winter precipitation and cause erratic rainfall in spring. Snowfall is concentrated in the central mountains and the higher ranges in the northeast.

Overall the weather pattern with regards to precipitation is highly variable throughout the basin. The average Whole basin discharge is about 19,900 $Mm^3$ and just Panjsher sub basin discharge is about 118 $Mm^3$ annually. An overview of the hydro-meteorological conditions and of the snow coverage is given in the figures below, as well as an overview of the principal sub-basin.

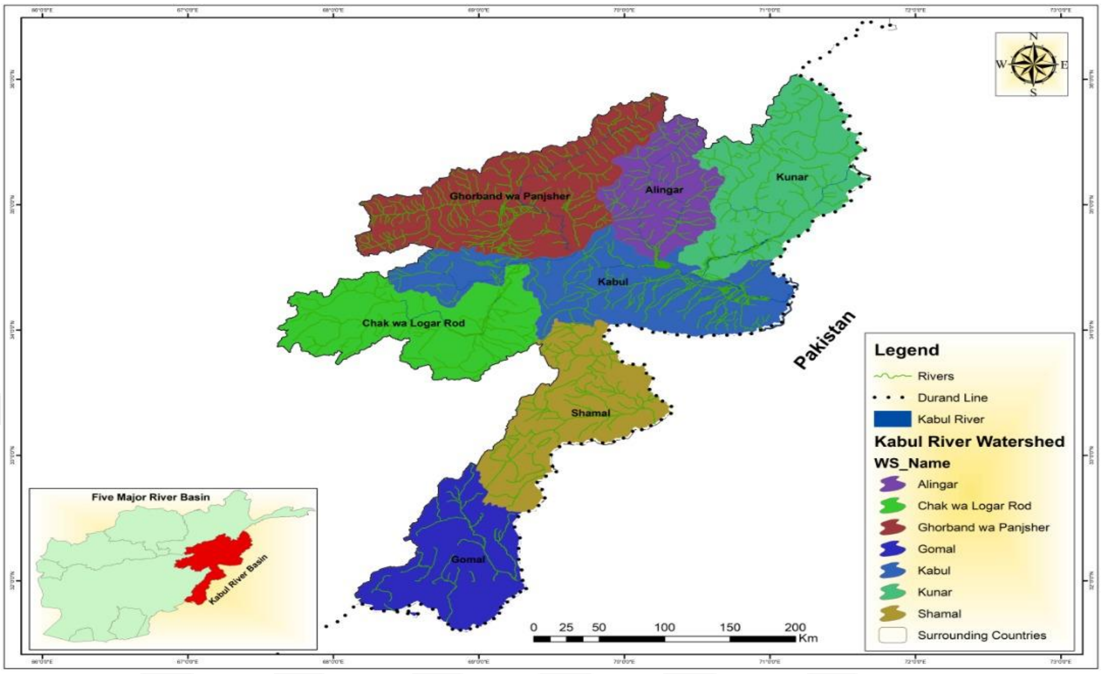



**Figure 3.5** Kabul River Physical characteristics

### 3.8 The Kabul Basin is Divided into the following Eight Sub-basins

The Medium Kabul sub basin, contains three small rivers, the Maidan, Paghman, and Qargha, which all originate upstream of Kabul city. These rivers join at different confluences throughout Kabul city and flow through the center of Kabul city. The Maidan River is formed by numerous small streams west of Kabul city. The River changes its name to Kabul River before it enters the city and flows across the city where it is joined by the Paghman and Qargha tributaries and then flows further until Naghlu dam where it flows into the Panjsher River. The main water projects and users of the Kabul River are Qargha reservoir, Shatoot irrigation and water supply to Maidan Shar and Tangi Saidan.

When the Maidan River reaches Kabul city it has little or no water due to high water withdrawal for irrigation. The annual average flow is approximately 140 $Mm^3$ at Maidan, 490 $Mm^3$ at Tangi Gharu, and 3,400 $Mm^3$ at Naghlu.

The Logar watershed drains hilly and dry sub basin south of the city of Kabul.

a) The Logar catchments comprises approximately 75% of the drainage area of the Logar-Kabul sub basin. There is modest but important areas for agriculture along the Logar valleys and in the river upstream of Kabul.

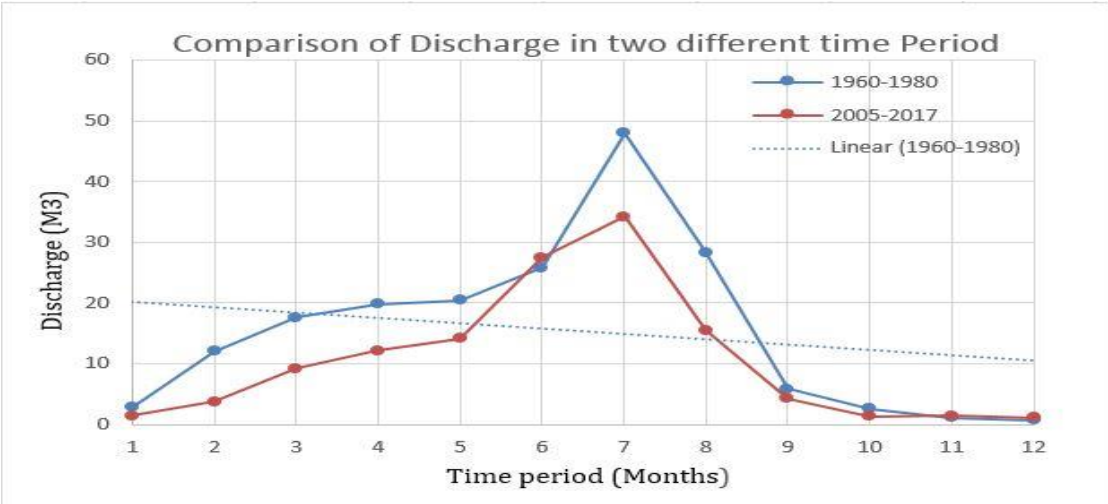
b) The main water users are a) Chak e Wardak dam for hydro power production b) narrow strips of irrigated land along the river and c) Kole Hasmat Khan wetland South of Kabul.

c) The average annual flow is 230 $Mm^3$ at Kajab and 300 $Mm^3$ at Sangi Naweshta.

The Ghorband sub basin is formed by the Ghorband River flowing until its confluence with the Panjshir River. The average annual flow at Ghorband River is 730 $Mm^3$ at Pule Ashawa, after the confluence with the Panshir River the river is referred to as Panshir River.

The Panjshir River Basin consists of the Panjshir River and its tributaries Salang and Shotul. The upper part of this watershed consists of steep mountain valleys in the Hindu Kush Mountains, which are located at an altitude of more than 6000 meters above sea level and remain covered with snow all year round.

The southern part of the Panjshir watershed opens to the broad and gentle fertile plain of Shamali, where some of the most important irrigated areas of the basin are located [30].



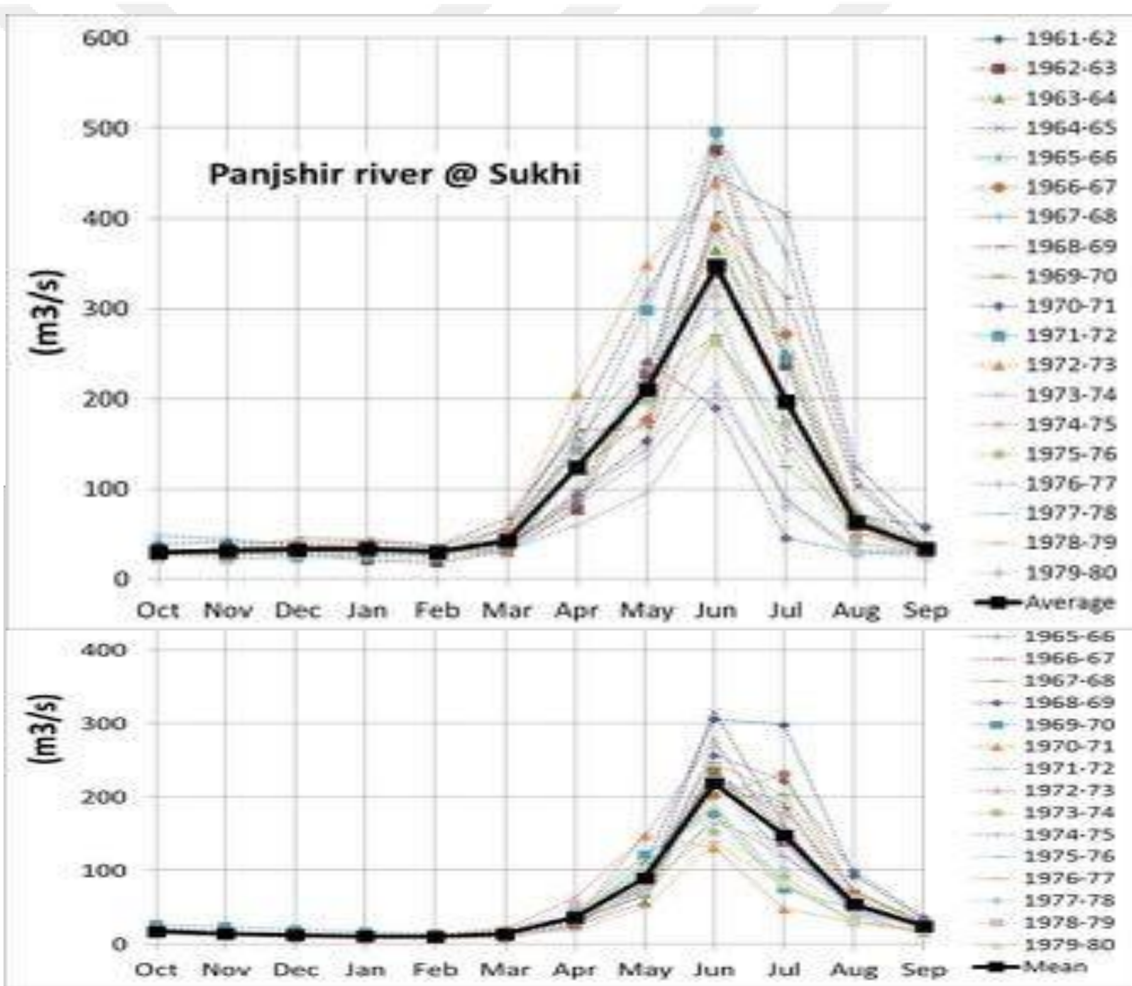




**Figure 3.6** Panjsher River discharge graph

Although the catchment area of the Panjshir River in Shokhi is about 84 percent less than the Upper Kabul River, its average annual flow is six times larger. Average annual Capacity of Panjshir River is 1,710 Mm3 at Gulbahar.

Below their confluence, the Panjshir and Ghorband Rivers together are named Panshir River and flow down to the Naghlu dam. The combined flow is 3,080 Mm3 observed at Sokhi.

The Laghman Sub Basin includes the Alishang and Alingar rivers, which after their confluence are referred to as Laghman River. The Laghman River, drains into the Kabul River at Darunta dam where the valley begins to widen. The average annual flow is 1,850 $Mm^3$.

The Kunar Sub Basin is formed by the Valley of the Kunar River. The river originates from the Karakoram Range south of Wakhan corridor in Pakistan. This a glacier fed river and it maintains a high flow in the summer. Due to the high flow, several projects are proposed in the Kunar sub basin. The average annual flow is 12,130 $Mm^3$ at Asmar and 14,830 $Mm^3$ at Pul e Kama (see figure below). The present water users are Konari irrigation, Gambiri irrigation, Sigi irrigation and Kama irrigation along the river.

The Lower Kabul Sub Basin extends downstream from the Naghlu basin and after confluence of the Ghorband, Panshir, Medium Kabul and Logar Sub Basins and flows to the Pakistan border. The Lower Kabul Sub Basin has the Laghman and Konar Rivers as tributaries. It consists of two large catchment areas to the north or left edge of the main river trunk.

a) There are many small tributaries on the right bank, including Surkhrud near Jalal-Abad, which is the only large city in the Lower Kabul basin with a population of about 120000 people.

b) When the main tribe of the river continues east, the valley expands to a wide plain, which includes the second largest and second largest agricultural region in the Kabul River Basin

c) In the Lower Kabul area three dams and reservoirs have been under construction, mainly for hydropower purpose. Naghlu dam and Sarobi dam just below the confluence of Upper Kabul and Panjshir Rivers and further below Darunta dam, just upstream form Jalalabad City. The latter dam also has an important irrigation function.

d) The current runoff in the lower basin comes mainly from two large mountain lower basins, namely Laghman and Konar, whose high-altitude snow and glacier zones are located almost 6500 meters above sea level.

e) With the exception of the highlands in the north, the climate of this lower region is influenced by the southwest monsoon, which is supplemented by several frosts or frosts several days a year.

f) The average annual flow is 6,000 $Mm^3$ at Darunta and is 19,900 $Mm^3$ at Dakah before the Pakistan border.

The lower eastern part of the basin to the border with Pakistan includes huge but rapidly shrinking forests (11,800 km2), which make up almost 93 percent of the country's forest area. The area of pastures (32,700 km2) is limited to about 13 percent of the total area of the country, as is agriculture with rain products (1,140 km2), which is only 3.5 percent of the total agricultural area in the country in which it rains. Irrigated land in a basin with intensive cultivation of one or two plants per year is currently estimated at 4,100 km2, which corresponds to almost 25 percent of the approximately 15,600 km2 of irrigated land in Afghanistan. Four hydroelectric power stations operating in the Kabul River Basin (Mahipar, Naghlu, Sarobi and Darunta) form the core of the country's hydropower system.

### 3.9 The Need for River Basin Management

The planning and management of water resources in river basins is becoming increasingly complex. River basin managers must balance the often competing needs of different sectors (household water use, agriculture, industry, ecosystems) by maintaining or restoring water in communities and ecosystems throughout the catchment in terms of both availability and water quality.

River basin managers should also consider the effects of external factors, such as land and water development, climate change and variability, which are especially important for developing countries, population growth, and the rapid and often uncontrolled development of cities and agriculture. Wetlands are particularly vulnerable to the aforementioned pressures and, despite their importance for the watershed and livelihoods, continue to deteriorate. Floods and droughts can disrupt the functioning of society and the ecosystem and take measures before preparation, during (emergency measures) and, if necessary, after the natural disaster has been restored and reduced. In addition, upstream and downstream impacts, often across administrative boundaries, need to be taken into account and requires collaboration and coordination between local institutions, communities and academics

- The River Basin Management Plan (RBMP) ideally consists of the following components:
- interdisciplinary characteristics taking into account the biophysical and socio-economic status and trends, as well as related factors and pressure factors, analysis of interest groups, as well as institutional and political context; Given that initiatives in other sectors, such as agricultural development, land use planning, nature conservation, etc., can affect the river basin, it is important to assess where each sector comes from in terms of its planning and management cycle. Start with a gradual integration and synchronization process.
- The completion of the management plan marks the transition from the planning phase to the implementation phase. Agreed decisions must be implemented. Progress and remoteness from goals can be controlled and lead to a review of the implementation strategy based on the knowledge gained, the results achieved (through the implementation of measures), possible changes in priorities and observed trends in the state of the system.
- Based on the characteristics of the system, a description of the problem is established, which also leads to a set of agreed priorities and goals, ideally together with quantitative and measurable goals based on a set of criteria and indicators.
- A number of management options and solutions that are ideally prepared for implementation and related to budget requirements•

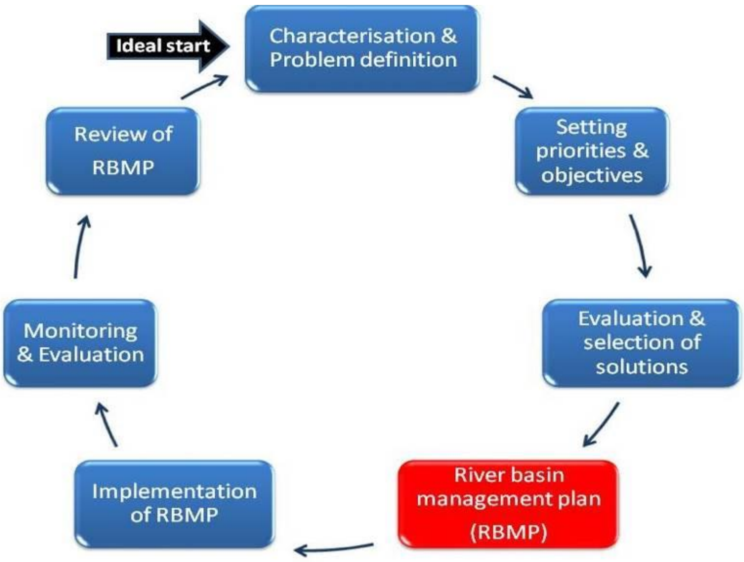



**Figure 3.7** River basin management plan

River basin management is a continuous process and must adapt to a changing environment. Each control cycle is followed by the following, and ideally over time it becomes a spiral when it comes to more efficient water management. The spiral adjustment process makes it possible to cope with external factors of change, such as climate change, population growth, economic growth, upper water development, wetland management, healthcare, etc., as well as contribute to the inclusion and personal responsibility of decision makers and stakeholders.

• Previous catchment planning strategies usually focused on only one discipline, often one-sided and downward. The topics discussed are only part of the problems that arise in the watershed, and are not related to the complexity and interaction between physical, biological, geomorphological and geochemical processes. Many management approaches focus on the short-term needs of decision-makers and political decision-makers, and do not take into account the long-term sustainability of the resource. Planning agencies traditionally deal with current issues and do not pay attention to prevention. Land use plans and river basins do not take into account specific areas and resources, as different management and planning agencies are not coordinated. Politicians and social planners have existed in some areas of environmental management and protection in the past. Planning strategies should focus on integrating management skills, disciplines and institutions

• The integration of water quality management, sustainable development, economic prosperity and a growing population is a challenge in developing countries in the 21st century. The need for integrated management is increasing as current surveillance indicates ongoing deterioration of the catchment area. Water quality management has several goals, interactive and dynamic characteristics, and the tasks associated with managing these characteristics are often contradictory. Lack of common knowledge and financial sources leads to inadequate management and misuse of natural resources. Due to increasing water scarcity and a growing population, integrated management is required to conserve resources in catchment areas. The management of land and resources in the Panjsher Basin is very fragmented, and planning is not based on a holistic or integrated approach. There is no agency responsible for land and water management, and these agencies are part of several government ministries and departments in Afghanistan [31].

### 3.9.1 Water Management Adaptation to Climate Change

The most important and applicable practices have therefore been those of water management, which have helped deal with rain excess and shortage. Rain is perhaps among the most perceived dangers of climate change as it causes more frequent and intense floods and droughts. These problems have direct effects on crops, affecting food security and the most basic source of income for peasants.

Communities of this river basin share a vulnerable position due to their socio-economic conditions. As mentioned before, the capability to adapt to internal or external shocks and stresses will increase a person's resilience with tangible/intangible assets or capabilities. Among the tangible assets provided by the institutions, we find the construction of infrastructure (e.g. reservoirs, channeled tubes, technical irrigation, and terraces).

According to the research performed, this community has fallen behind using the technologies installed and has not continued with soil and water conservation practices. According to interviews, peasants have either stopped using the infrastructure because of its deterioration, their lack of knowledge or economic resources, and/or because they do not feel they are necessary. First of all, peasants have mentioned that irrigation tubes have broken and that nobody has taken responsibility or initiative to repair them. Because such infrastructure is used by a number of peasants, collective action is needed but there is little coordination. A peasant expressed himself saying: “things belong to everyone and they belong to no one”, referring to the fact that when things benefit peasants, they are present, but when they break nobody takes responsibility. This means that peasants have continued to use traditional irrigation practices where tubes have been broken and have not learned the importance of water conservation. Other families have stopped using technical irrigation because they do not have the resources to repair such tools. In the majority of cases, peasants do not need such advanced practices as they have subsistence farming and do not need to irrigate large areas [32].

To set up better rules for pasturing and organization to divide tasks. This community has developed a number of committees responsible for different tasks, among which we find: irrigation, potable water and livestock. These have been essential for managing water resources and taking care of vegetation and forestation. Once strong rules were set up, members had to pay high fines for uncontrolled grazing, excessive irrigation or absence to community meetings and activities. This kept forestation and soil conservation practices in good conditions as frequent maintenance was done and the community set up a self-controlled system. Their achievements have been so remarkable that their experience has become exemplary for similar development projects. Among the topics dealt with, we see soil conservation, resource management, disaster risk reduction and livestock keeping.

### 3.10 Effects of Water Management Practices

Poverty is pervasive and can affect several aspects of rural life, all of which are further affected by climate change. As there are several factors that can contribute to a community’s development, it is hard to choose which ones are affected by changes in water management. Among the factors that this research has chosen, we find: economic benefits, access to safe water and the amount of climate related disaster. These were chosen because information was obtainable from interviews and conversations with peasants and technicians and a clear comparison could be made between the two communities. Conclusions were based on interviews and information was obtained for the community of Nejrab.

Economic benefits, the efficient use of water leads to an increased irrigation capacity; which can lead to a higher crop output. Similarly, the growth and preservation of grasses can improve.

Livestock fattening. In the interviews, peasants were asked about their agricultural sources of income and how they improved their economic conditions. Because there has been no previous records on the production or productivity levels of Panjsher River their improvements in crop output can only be based on the information collected in interviews and their general opinions on their sense of improvement.

### 3.10.1 Access to Safe Water

Projects in this river basin have also looked at giving peasants access to safe water. If water is managed correctly, then it should be accessible and in good condition. Afghanistan Government have included plans to increase water availability by building reservoirs, channeled tubes, and technical irrigation systems. Although has not implemented in Shamali regions yet.

New administration have emphasized their efforts on projects mostly in matters of water management. When asked about their sources of water, they mentioned different reservoirs or ground water for irrigation and for drinking.

On the other hand evidences has shown less responsibility and coordination when taking care of reservoirs and channeled, hydraulic structures this is reflected, First of all, because peasants have not shown ownership of the installed infrastructure; they are often damaged and water is wasted. When asked about their sources of water for irrigation and for drinking, only half of them use different sources; the other half use it indiscriminately. According to several respondents, this happens because the water that comes from the reservoir for drinking is not treated correctly and/or regularly with chlorine. Although certain rules and assignations have been made to regularly apply chlorine, peasants have stopped trusting water from this source because in several occasions children have gotten sick from waterborne diseases.

## 3.11 The Data Challenge for River Basin Management

The implementation of river basin management places high demands on human resources and information and requires targeted quantitative management of water resources. Data on water volume (drought and flooded areas discharges) and water quality (pollutant emissions, environmental quality and bacteriological quality) are often scarce. Knowing of the problems faced by individual catchment areas and an understanding of the relevant administration response to these problems should be based on reliable information. This includes not only basic data for monitoring status and pressure, but also analysis tools to interpret and determine what measures and tools should be used, where and when. A key issue for politicians is obtaining reliable and relevant information for decision making. This information may be provided by the scientific community, but may also come from public opinion. In addition, research community tools are only used inappropriately in the operational management of water resources. However, in most less developed countries, data on the functions, processes, and values of river basins are scarce, and management decisions often have to be made without comprehensive information. Expert knowledge and data (measured, modeled or estimated) are often available from global data sets or international research projects, but they are not sufficiently accessible and are used to make managerial decisions. Existing data and knowledge are often not systematically stored. In the absence of data, the role of qualitative data sources based, for example, on the opinions of experts or traditional knowledge, is important, and the observed quantitative data may be unreliable. There are a number of problems that subjects experience when trying to effectively implement plans and strategies. Cross-border planning and implementation remain a major challenge. This is due to practical difficulties in working in different countries, especially if there are no intergovernmental agreements on cooperation on these issues or if no strategy has been agreed at the national level.

**Table 3.2** Strategies to cope with data challenges.

| **Key Implementation Gap** | **Elaboration of the Implementation Gap** | **Suggested Solution** |
|---|---|---|
| **Administrative gap** | Geographical "mismatch" between hydrological and administrative boundaries. | Requirement for instruments to reach effective size and appropriate scale. |

| | | |
|---|---|---|
| **Information gap** | Information asymmetry (quantity, quality, type) between various participants involved in water policy, voluntarily or not. | Requirement for instruments for revealing and sharing data. |
| **Policy gap** | Sectorial fragmentation of water-related tasks between ministries and government. | Requirement for mechanisms to create multidimensional systemic approaches and for political leadership and participation. |
| **Capacity gap** | Insufficient scientific, technical and infrastructural potential of local participants for the development and implementation of water policies (size and quality of infrastructure, etc.) and related strategies. | Requirement for instruments to build local capacity. |
| **Funding gap** | Unstable or inadequate income undermines the effective implementation of water responsibility at the subnational level, intersect oral policies and necessary investments | Requirement for shared financing mechanisms. |
| **Objective gap** | Various reasons that hinder the adoption of convergent goals, especially in the absence of motivation (this | Requirement for instruments to align objectives. |

| | | |
|---|---|---|
| | refers to problems that reduce political will to play a key role in organizing the water sector) | |
| **Accountability gap** | Difficulty in ensuring transparency of practice in different districts, mainly due to lack of user commitment, lack of care, awareness or participation. | Institutional quality tools are needed for tools to strengthen local integrity frameworks, for tools to improve citizen participation |

While the aforementioned focuses primarily on the problems that the state faces as a water resources manager, it is also necessary to focus on key implementation gaps in order to attract stakeholders as part of adaptive water policy. The civil society review identified the following issues:

1. Weak industry ties within the government;

2. National plans are not translated into local plans.

Public uncertainty over who is responsible for what in the government

1. Weak institutional authority;

2. An international focus on financial agreements and economic benefits, rather than social and environmental issues;

3. Lack of public access to relevant and timely information; and

4. Citizens are not able to effectively participate in decision-making processes.

In response to the aforementioned challenges, management reforms aimed at improving decentralized decision-making need to be promoted. This means that at the cross-border level there is a great need for agreements between states and interest groups for cross-border cooperation in the field of adaptation.

Tools are widely defined as classic “software” models and decision support tools as “something (tangible or intangible) to support operational and strategic measures in implementing IWRM”. Therefore, an instrument can be everything that consists of a policy or protocol, method or technology, device, device or program. In recent decades, a large number of tools for RBM have been developed. The following are selected tools that are not exhaustive.

### 3.12 GIS-Based Watershed Classification

In the modern literature, three principles of a managed integrated management approach have been recognized. These principles were discussed in the literature and agreed upon in the early 1990s. These three principles are: (1) the environmental process; (2) community involvement; and (3) coordinating agencies and groups. The principles of this study are aimed at integrated water management and leading hydrological relations.

The first principle states that the management of interconnected resources must take into account environmental processes and maintaining environmental quality. Management focuses on continuous improvement of resources based on reliable scientific data, including monitoring of information collected through the watershed. Ecological processes should be monitored to preserve productive soil and water resources for both humans and biota.

An integrated approach should also include active community participation in natural resource management and take into account public awareness and participation. The participation of stakeholders leads to more efficient use and management of water resources, as well as to obtaining benefits such as cash income, nutrition and interaction with the family. Community participation leads to the formation of a natural resource system and a transition to healthier management practices. Strong community participation provides an opportunity not only to learn about natural resources, but also to protect them and improve the quality of life.

The latter principle emphasizes the importance of coordinating the strategies and actions of government leaders, non-governmental organizations and municipal resources.

Federal authorities value community-based conservation approaches and have implemented appropriate recovery strategies. When coordinating responsibilities and goals, agencies and groups can formulate governance structures that help implement integrated resource management. They may also provide support and add information that might not otherwise be available to other agencies. Water consumption. Recently, integrated watershed and resource management has been recognized as a more coordinated and unified approach to water management in the Caribbean. Management issues extend to developing countries and focus on concepts such as land management, erosion control, deposition, floods and water.

Water for people (municipal, industrial, sanitary, etc.), (2) water for food and rural development (irrigation, etc.) And (3) water for nature (environment and ecosystems). These three categories of water are useful for integrating water management into various land uses and practices.

Hydrological connections. An integrated approach to catchment management to study water in catchment areas explores the hydrological relationship within the system. This section describes three relationships that provide guidelines for a watershed management approach.

People management. Hydrological connections are associated with human management and development in the watershed. The Center for the Protection of Watersheds represents eight categories of underwater catchments, depending on the type of water resource and intensity of land use with the underwater catchment area. Categories relate the use and condition of electricity to human values, such as an impenetrable surface. Although each type of water resource has unique management features, it is useful to distinguish between them and apply similar management methods and tools for underwater catchments in the same category. The distinction between different waters [33].

### 3.13 Watershed-Based Planning

When assessing a catchment and developing a plan, it is useful to consider the catchment configuration and related terminology. The catchment is most often defined as the territory that contributes to runoff to a specific drainage point along the waterway. The total area of land drained by the river and its tributaries is called the catchment area. The catchment or hydrographic basin is topographically separated from neighboring basins by geographical units, such as a ridge or mountain. The catchment zones come in all shapes and sizes and can be broken down into smaller administrative or geographical units called catchment zones. These units are of a size that can be managed in accordance with units and land use practices within specific underwater catchment areas, and appropriate plans for each underwater watershed can be created accordingly. Figure 4 shows the concept of several planning units in larger water for planning purposes, watersheds and sub watersheds can be classified according to specific land use practices and water resources within their delineated boundaries.

A specific catchment can have any number of separate underwater catchments that are delimited within their boundaries, and the classification of a local catchment is most effective for identifying and correctly identifying stressors and resources in a particular system. The implementation of catchment planning for each block can be structured in accordance with the size, landscape features, distance from the coast and current land use, as well as the impact of these users on the catchment area. The classification of watercourses in the context of the catchment area determines the local impact of land use practices and the combined impact of human activities on biota and environmental conditions. Classification of catchment areas at the local level under the catchment sites allows for detailed management that takes into account specific goals for each catchment area [34].

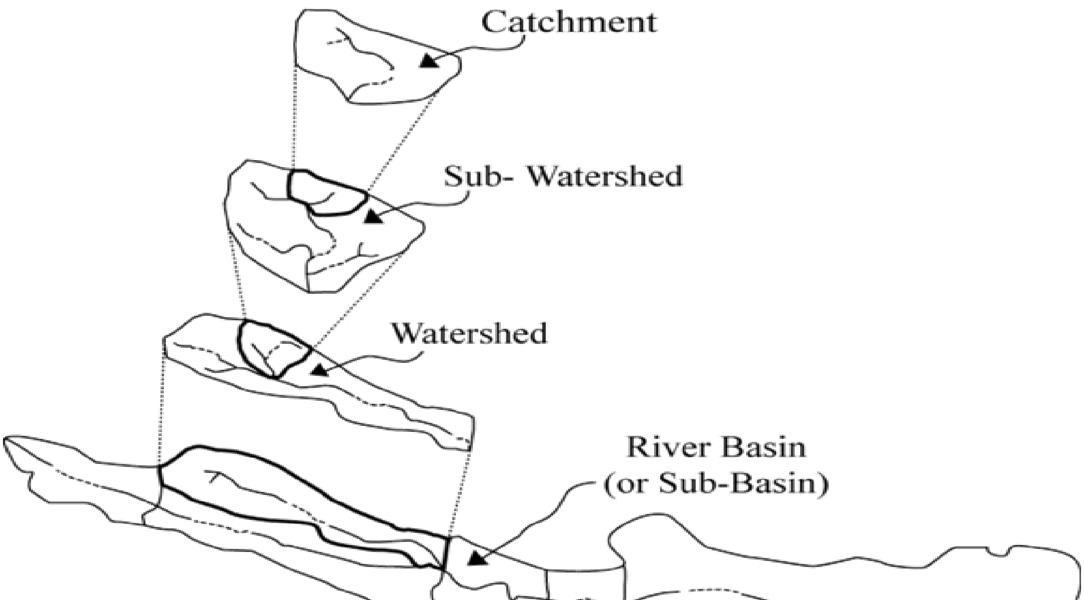



**Figure 3.8** Watershed-based planning

### 3.14 Panjsher Sub basin Watershed

The topographic catchment of the Panjshir basin is seriously dynamic and consists of environmental, biological, hydrological and cultural sub regions. These regions are constantly interacting with each other. To understand the problems and threats to water supply and natural resources in the catchment, it is important to understand the components that make up the various regions. The topographic profile of the Panjshir basin can be divided into many classification zones. Panjshir river basin watershed the catchment components are interconnected by water flows, mountain fronts flows through low local areas, and various subsidiary farms land next to these flows. The lowlands are located between the mountains on both sides of the river, they also have relatively flat land for agriculture and community development. Spring-loaded electrical systems at appropriate levels also look like freshwater wetlands due to the topography of the region. In these regions, there are currently more durable streets and road structures, as well as apartments with integrated water supply systems.

The mountainous regions are hilly and narrow, and piped water systems and a truck are usually required to access the water. The natural distribution area contains water sources such as groundwater recharge and sensitive spring water flows, which are directly dependent on landscape changes within the catchment. In mountainous areas, municipalities have been established with water supply systems (natural drainage and communal systems) that connect road, pedestrian and sewer networks, as well as agricultural land and waterways. These changes in the landscape lead to soil erosion and vegetation and the morphology of natural water systems.

The boundary of the Panjshir basin can be determined using various boundaries. The basins were defined by agreed geographic boundaries, which are considered official boundaries of protected areas. The Panjshir basin can also be defined, usually using reef lines. The location of the bay can also be described based on the cultural identification of certain places and landscape features. This work identifies the Panjshir basin in accordance with the government-established reserve boundaries.

If the watershed problems are of serious concern to the local community, there is a degree of distrust among the interested parties, or a high level of conflict is expected regarding the proposed measures, civic participation processes with a distributed approach to decision-making may be the best.

The success of the distributed management approach to decision-making in watershed management largely depends on the actual release of the state from power. A local process, such as integrated watershed management, tends to fail if community members feel that they do not have the authority to develop and implement solutions at the local level. However, in the distribution of powers for water management, great care must be taken so that local communities and organizations can effectively solve complex local water problems. Distributed water policy should not lead to a deterioration of water resources management, nor to the fact that the state could simply distance itself from responsibility for protecting water resources. Therefore, it is necessary to ensure an appropriate balance between interaction and power between the government and public actors before water policy can be effectively implemented at the local level [35].

### 3.14.1 The Benefits of Public Engagement in Watershed Decision Making

Why should the public participate in river basin management planning? What is the potential value of opening up opportunities for opinions on very complex water issues? Industry and government agencies believe that avoiding participatory processes that involve the public is faster and cheaper, which can be time consuming and resource-intensive. In situations where urgent solutions are needed, such as a crisis, such as widespread flooding, there is no incentive to spend time effectively engaging the public. In many cases, public involvement processes that lead to long decision-making times encourage decision-makers to avoid future public involvement processes in order to expedite decision-making.

Another common belief is that many solutions require a high level of understanding and technical knowledge. The public may not be prepared enough to make a significant contribution to solving very complex issues or political decisions. There is also skepticism regarding the wisdom of opening the door to large members of the public. Isn't the common good better served if only knowledgeable stakeholders are involved?

Industry may also be reluctant to engage the public in decision making to gain a competitive advantage. Concern over the impact of open debates on the company's activities and policies has led many companies to engage the public at a lower level, for example, in communicating with the public or consulting. Interaction processes can create serious political threats to government agencies and lead to further split within the community, in contrast to beneficial partnerships and cooperation. Some fear that open processes may lead to a softening of decisions and priorities aimed at those dominant stakeholders that do not reflect the values of the wider community.

Even the coals of the public do not dare to take part in the engagement. Public involvement processes are often used by industry and governments as a political tool to enlist the support of an unpopular decision or policy. Despite all the fears of not involving the public in decision-making processes, there are a number of important reasons for cooperation in decision-making on the management of watersheds. In principle, the participation of those affected by decisions is consistent with the principles of democracy. Public participation provides a practical place to resolve disputes and fosters public debate on complex issues [36].

# CHAPTER 4

# CASE STUDY

Panjshir literally "Five Lions" also written, is one of the thirty-four provinces of Afghanistan, located in the north-east of the country. The province is divided into seven districts and consists of 512 villages. As of 2018, about 1 million people live in Panjshir province. Bazarak serves as the provincial capital. According to the report, more than 700,000 people in Panjshir province live outside this province, especially in the city of Kabul in Afghanistan.

Panjsher became an independent province in 2004 from the neighboring province of Parwan. It is surrounded by Badakhshan and Nuristan in the east, Takhar and Baghlan in the north, Parwan in the west and Laghman and Kapisa in the south.

**Figure 4.1** Panjsher-Bazarak distract

## 4.1 Physical Description

Panjshir is 2 km north-east of Kabul between the two southern branches of the Hindu Kush, parallel to the northeast to the southwest along the Hindu Kush, with its sub-valleys extending from the north to the south and from the south to the north and reaching the Panjshir general valley Connects. Its surface height is 6,000 meters above sea level.

The Panjshir River originates from the Hindu Kush Mountains near the Association Road and flows southeast. Panjshir River passes through long narrow valise, its path receives several other branches such as Ghorband and Shotul then joins Kabul River about 2 km east of Kabul. Panjshir is one of the permanent rivers of Afghanistan and its length is 320km. Panjshir has a strategic geo position. Connected with seven provinces of the country (north with Takhar, north with Baghlan, west with Parwan, south with Kapisa, south with Laghman, east with Nuristan and northeast with Badakhshan).

The province has more than two large valleys and dozens of small valleys, most of which are opposite one another, and each valley is subdivided into several sub-valleys, further enhancing its strategic importance. Panjshir has high mountains and some glaciers, which generally store snow in winter, and during the heat of these snowstorms are melted and many springs and lakes flow through them all into the roaring Panjshir River. The abundance of springs, lush meadows, beautiful and enduring waterfalls in the province's highlands make it possible to live in and provide a natural bedrock for guerrilla warfare.

The Panjshir River originates from the Hindu Kush Mountains, from the Kotel tributaries of the Wachar Association and the Kotel Khawak, descending from more than three thousand meters in height, with 19 other deputies flowing from the Valleys to the corridors. It flows east-south-west and flows straight to the south at the bottom of the stone corridor. It flows through the Nilab Bridge in Gulbahar, slowing its course, and there the Shuttle, Nejrab, Ghorband and Narrow Sea waters on the mountain range. Afterwards, it reaches the Noglu valley and joins the Kabul River. This river reaches 320 km from the source of the Tabernacle of Dronta.

In June the Panjshir River is the main source of glaciers and snow dunes, starts from the intense heat of the sun to the watering of the valleys, the main river and its inland deputy irrigate the Millennium pastures, Water as their conduit has fallen to low levels except for a few villages and small settlements.

The Parwan Canal Project, a public utility project, is made famous by water from the Panjshir River by passing a siphon pipe over the Ghorband River. The operation of a power plant for the city of Charikar and the cultivated land promotes 4800 hectares of land around Charikar in vegetable production and its products are sent not only for local consumption but also for export to cable markets.

Above the Panjshir River in 1975, a feasibility study of the dam section of the Panjshir Corridor and its preliminary work was started. Regrettably, due to the war, this large hydroelectric power station project has been stopped and the plan for technical and economic studies of the project has been resumed in 2008 by the Ministry of Energy and Water. It will irrigate about 60,000 hectares of existing farmland, and the construction of a water tunnel from the dam to irrigation canals will solve the irrigation problem of Kapisa and Parwan's new ten-green Kabul farmland.

The only source of water in the vast plain behind Bagram Airfield and in the area of Koh Safi District, which is vibrant and refreshing and adds to the beauty of this area, is the roaring river of Panjsher.

Panjsher, Kapisa, Parwan Provinces Their climate is topographically winter Most of their areas are affected by the cold cyberlands, and in their mountains the snow reaches one meter and with hot summers and rainfalls.

### 4.2 Topography

Topography Figure 4.2 shows the location of Panjshir Fan. “Panjshir Fan” is the abbreviated name given to the “Panjshir River Fan”, on blue and pink color which is a large composite alluvial fan created by flow of Panjshir, Ghorband and Salang rivers. This fan is located to the northeast of Charikar in Parwan Province. “Panjshir River Fan” is the name created in the master plan report of KMAMP, because, judging from its topography, it is obvious that the Panjshir River has more significant influence to create it than the other two rivers.

However, the fan will be called “Sayad Fan” in accordance with a recommendation of the Steering Committee that the fan be named “Sayad Fan” after the location name.

"Panjshir Fan" is now also used by people concerned in the Kabul new city development, for referring to the area of groundwater development for the new city, that is, the investigation area (or study area) of this feasibility study which is located in the lower part of the large composite fan. In this thesis, "Panjshir River Fan" is used to refer to the overall composite fan and "Panjshir Fan" is used as a synonym of the investigation area. In 2011, the area on the right bank of the Ghorband River was mainly investigated.

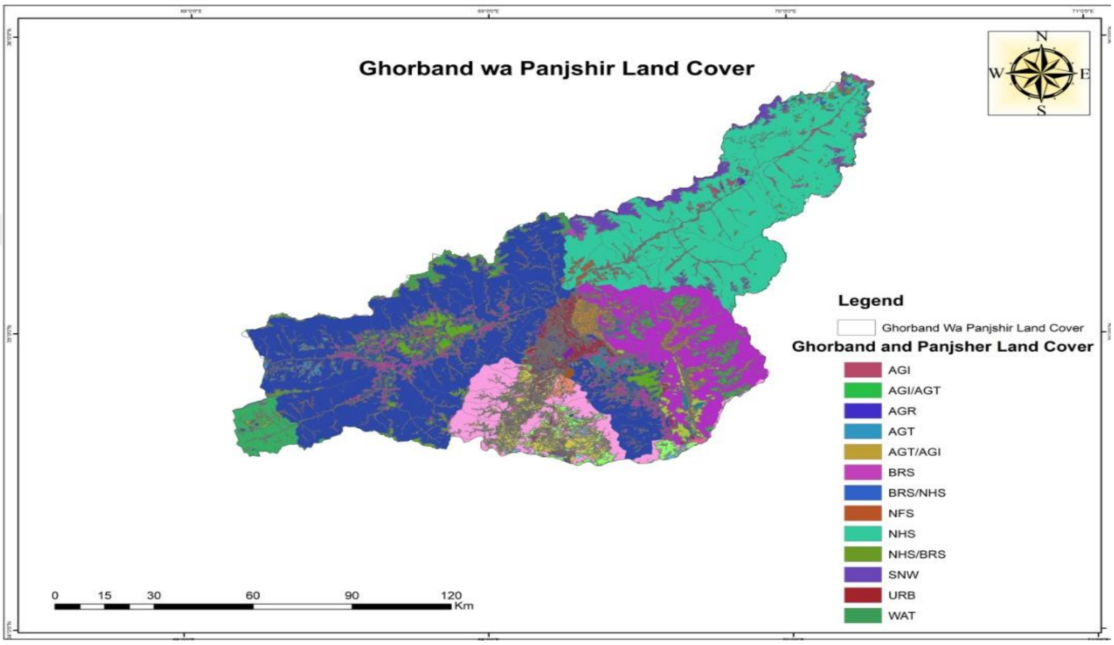



**Figure 4.2** Panjsher Topography map

### 4.3 Geology and Soils

In the Panjshir fan area, Pleistocene thick alluvial fan deposits cover the land and make terraces. Sediment below Terraces and Present River bed Gravel layer an alluvial terrace plane is usually a sedimentation surface of alluvial materials consisting mainly of gravel.

Accordingly, gravel widely distributes in the Panjshir River Fan, which deduced geological sections in the study area developed mainly based on the results of vertical electric sounding (VES) and test well drilling. As understood gravel with sand spreads generally more than 60m to 80m below ground in the area. At some portions, bedrock or clay layer might underlie it in a depth starting from 25m to 45m below ground. Higher terrace was made in older age.

There is much time difference of creation between the low land Tr-1 and Tr-3, and the highest TR-7. The former terrace gravel is unconsolidated, whereas the latter gravel is semi-consolidated. Here we call the former the “younger gravel” and the latter the “older gravel”. Depth of the younger gravel might be 25m to 45m or more. Present riverbed consists mainly of unconsolidated gravel. Clay/silt layer A few ten centimeters of clayey thin layers are seen on the surface or in the shallow depth in the test pits excavated on the riverside of Tr-1 terrace. Some fine material layers are found in well logs.

The naturally flowing conditions at two test wells and small springs with the "dancing sand" on the Ghorband river side show the presence of artesian condition. This implies that relatively impervious layer spreads in the gravel layer in some extent. The surface of swampy land in the lowland is covered with peaty clayey soil with thickness less than one meter. The soil has many grass bodies and contains sands. Reworked loess covers Tr-7 terrace. It is a mixture of silt and clay, and originally brought with wind. It is also intercalated in the older gravel. The thickness of the loess layer is a few meters on the Tr-7 terrace scarp at Qalae Belant [37].

The SWAT model requires different soil textural and physic-chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density and organic carbon content for different layers of each soil type.
In this study, soil dataset obtained from FAO/UNESCO-ISWC (FAO/UNESCO-ISWC, 1998) with the resolution of 90*90 meter and projected based on UTM, then applied in SWAT in Hydrological Respond Unite.

Younger Gravel (TP-8)

Older Gravel (Sayad)

Conglomerate of Older Gravel (Sayad)


Older Gravel with Loess Layers (Qalae Beland)


**Figure 4.3** Geology and soils specification of the Panjsher Sub-basin

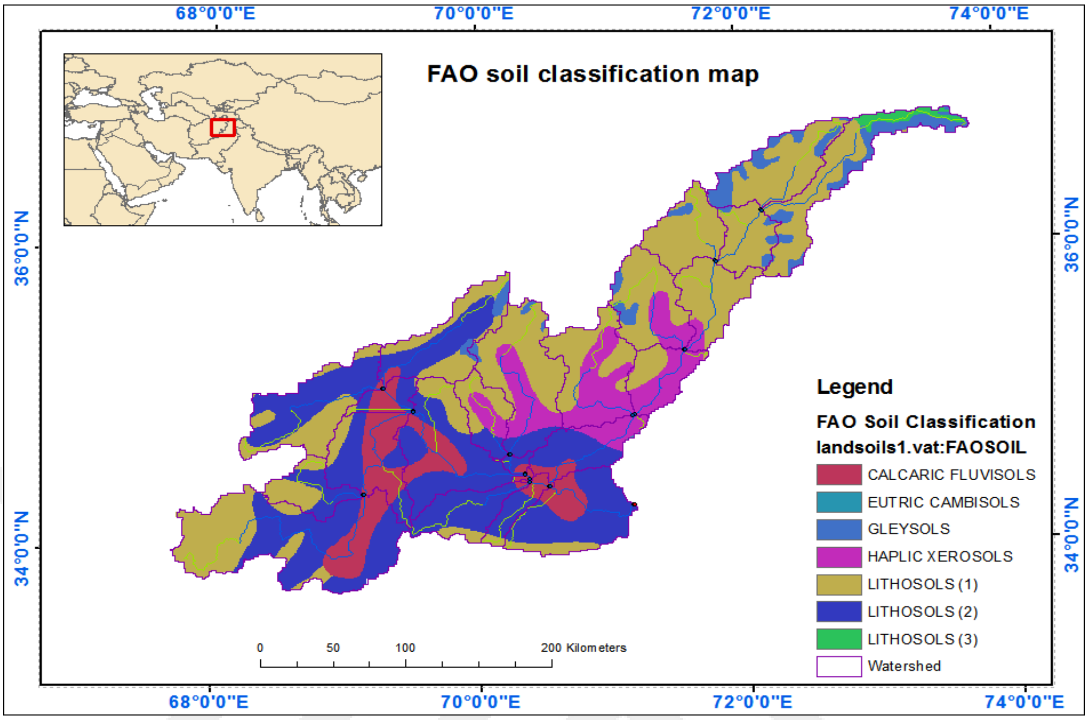



**Figure 4.4** Soil classification map

## 4.4 Population

Panjsher last known population is ≈ 158 500 (year 2018). This was 0.454% of total Afghanistan population. In this year, Panjsher population density was 42 p/km². If population growth rate would be same as in period 2006-2018 (+1.46%/year), Panjsher population in 2020 would be 163 219. To analyze water availability in the catchment or reviver basin, population data is important. I have find population raster data as Lands can raster data set of 2000 and 2005 from Professor SATO Keisuke. The LandScan global population database has developed by Oak Ridge National Laboratory for the United States Department of defense. Today this dataset widely use all over the globe for the purpose of research and academic investigations. Arc GIS 2012 has applied for zonal statistic and extraction of the population in my study area. The Identifying population growth rate is a crucial element for long term sustainability analysis.

## 4.5 Digital Elevation Model

Topography was defined by DEM that describes the elevation of entire the points and the area at the specific resolution. DEM with resolution of 30m*30m (as show in Fig 4.5, was downloaded from SRTM (Shuttle Radar Topography Mission) website on September 2019. The data sets are mosaicked and projected in UTM projection using GIS10.2. The DEM was applied in the SWAT model to delineate the watersheds and to analyze the drainage patters of the land surface terrain. Sub basin parameters such as slope gradient, slope length, and stream network characteristics such as primary, secondary streams and rivers which were derived from the DEM.

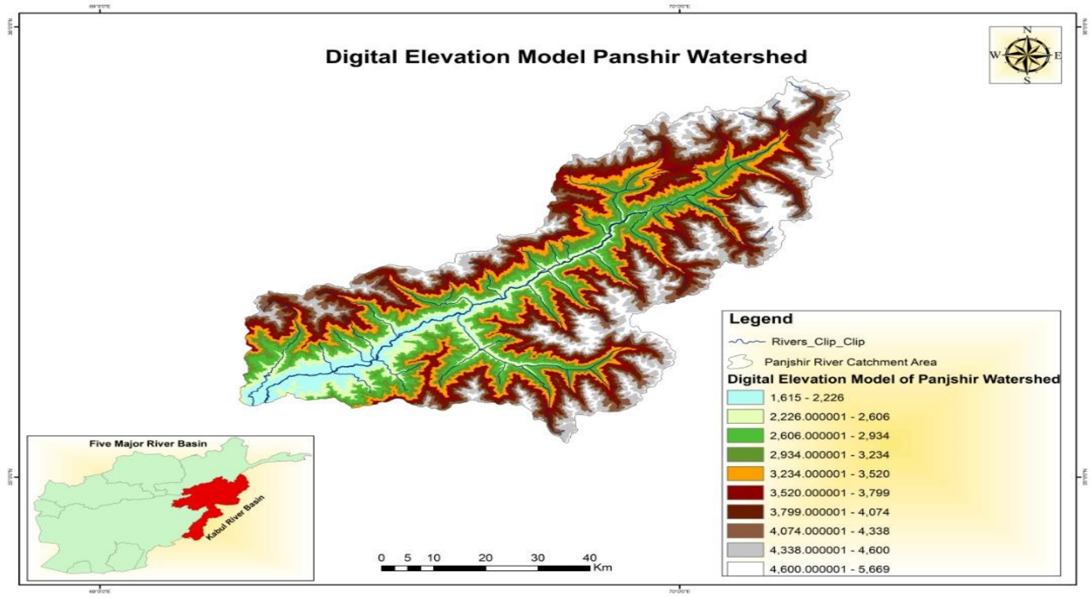



**Figure 4.5** Panjsher digital elevation model

## 4.6 Hydraulic and Hydrologic Data

The hydraulic and hydrologic data were collected by the Afghanistan Government with little coordination, with different bases and datum planes. By invasion of Soviet Union the data collection stopped and during the cold and Afghan civil war lots of hydraulic structures damaged. With the end of war and constitution of new government the hydraulic infrastructures rehabilitated and some of the dada collector stations restarted again.

After year 2005 the Afghanistan water and power ministry activated most of the data collection stations. So that fortunately we have more than ten year complete overall hydrological and metrological data in the databases of Afghanistan.

### 4.7 Meteorological Data

Lack of a sufficiently dense network of weather station for measuring precipitation and temperature in the Kabul river basin was the main obstacle for my researches. Since 1980 till 2005 there is a gap of meteorological records in the study area due to insecurity and civil war. From 2006 up to now, Ministry of Energy and Water of Afghanistan resume its jobs with financial cooperation of World Bank installed 31 meteorological stations in the Kabul river basin, but the majority of these stations due to insecurity and technical problem do not record properly. In my field trip to Afghanistan on October, 2014, only obtain 8 Hydro-meteorological stations data from 2008 to 2012 in an area of greater than 65202 $Km^2$.

This is far below the World Meteorological Organization (WMO) standard of one station for 100 to 250 $km^2$ of area for the mountainous region. There are no weather stations in the high altitude of 3000 meters above sea level in this basin, however the majority of the basin area is over 2500 meters above sea level, where the majority of precipitation occurs as snow in the winter season and early in spring.
However, all these 8 stations are located in the most flat and plain area of the basin. On the other hand, these stations due to security problem cannot operate regularly.

Even these existing stations which are operating after 2006, are full of errors and missing records during the months and years of their records. The detailed method for Hydro- meteorological data filling and screening and comparison of observed precipitation from two sources, MoEW and MAIL and TRMM stations for data quality assessment will describe in the chapter three [38].

### 4.8 Data Processing and Comparing

Regression-based approaches and normal-ratio methods for reconstructing precipitation and temperature data were used to bridge the gaps in a series of meteorological data at 8 stations that were received for my research area from the Ministry of Water Resources, Ministry of Energy and Water Resources. Kabul, Afghanistan. The presented method is characterized by a dynamic choice of reconstruction of stations and the communication period, which may precede or follow the missing data, as a result of which each type of gap is considered as a specific approach.

Determine the best set of stations and the time period that minimizes the estimated recovery error for the gap. This provides a potentially better adaptation to time-dependent factors that influence station relationships.

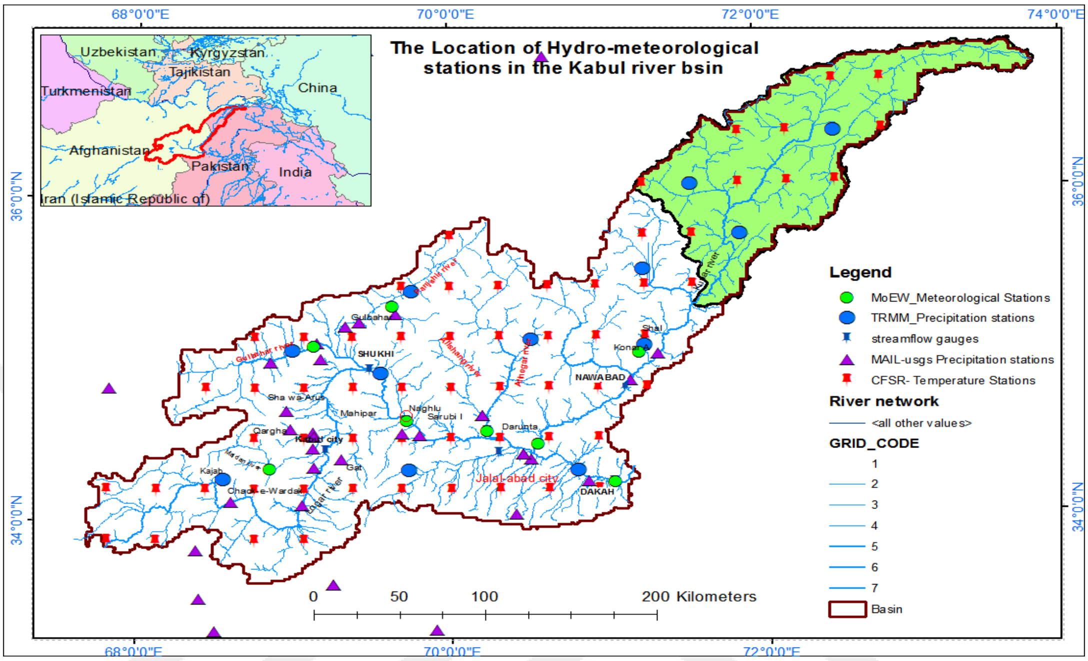



**Figure 4.6** Hydro-meteorological stations from five sources in the Kabul river Basin

### 4.8.1 Comparison of Precipitation Records Based on Different Data Sets

Three precipitation data sets are compared over the Kabul river basin. These data sets include four Precipitation stations from the Ministry of Energy and Water (MoEW), four precipitation stations products from the Ministry of Agriculture, Irrigation and Livestock (MAIL), and four gauges-only precipitation products from the Tropical Rainfall Measuring Mission(TRMM) as shown in figure 4.7 The main objectives of this comparison were consistency analysis, among these three observed and non-observed data set and selection of best data source for the SWAT model application. Plotting method has been applied in the four different areas of the basin with different climate patterns. Quantitatively, the differences in monthly precipitation records in these three data sets are significant. The differences in annual precipitation between MAIL and TRMM are less than 5%, in these four blocks [39].

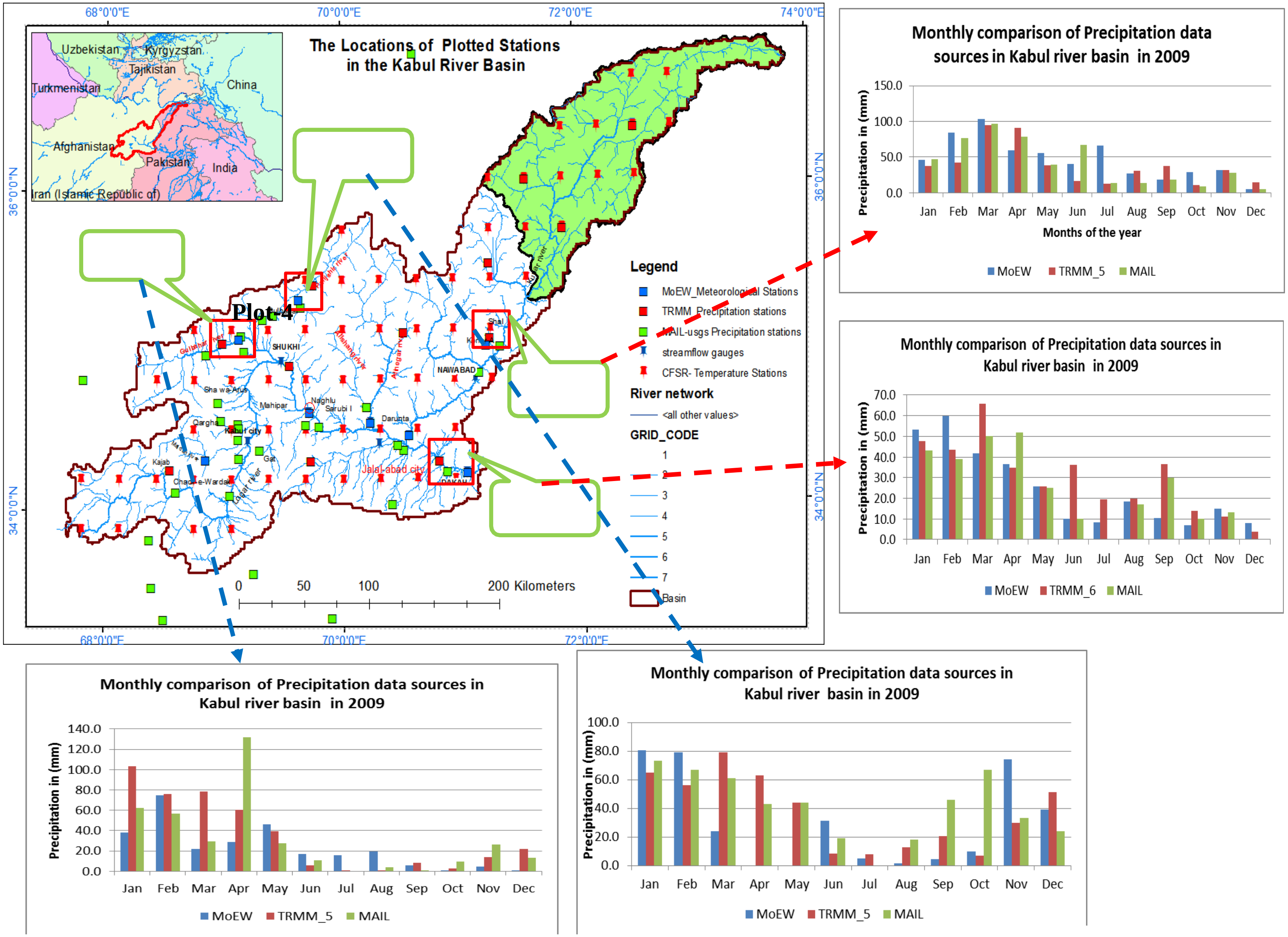



**Figure 4.7** Comparison of precipitation records based on three different data (2009) [40]

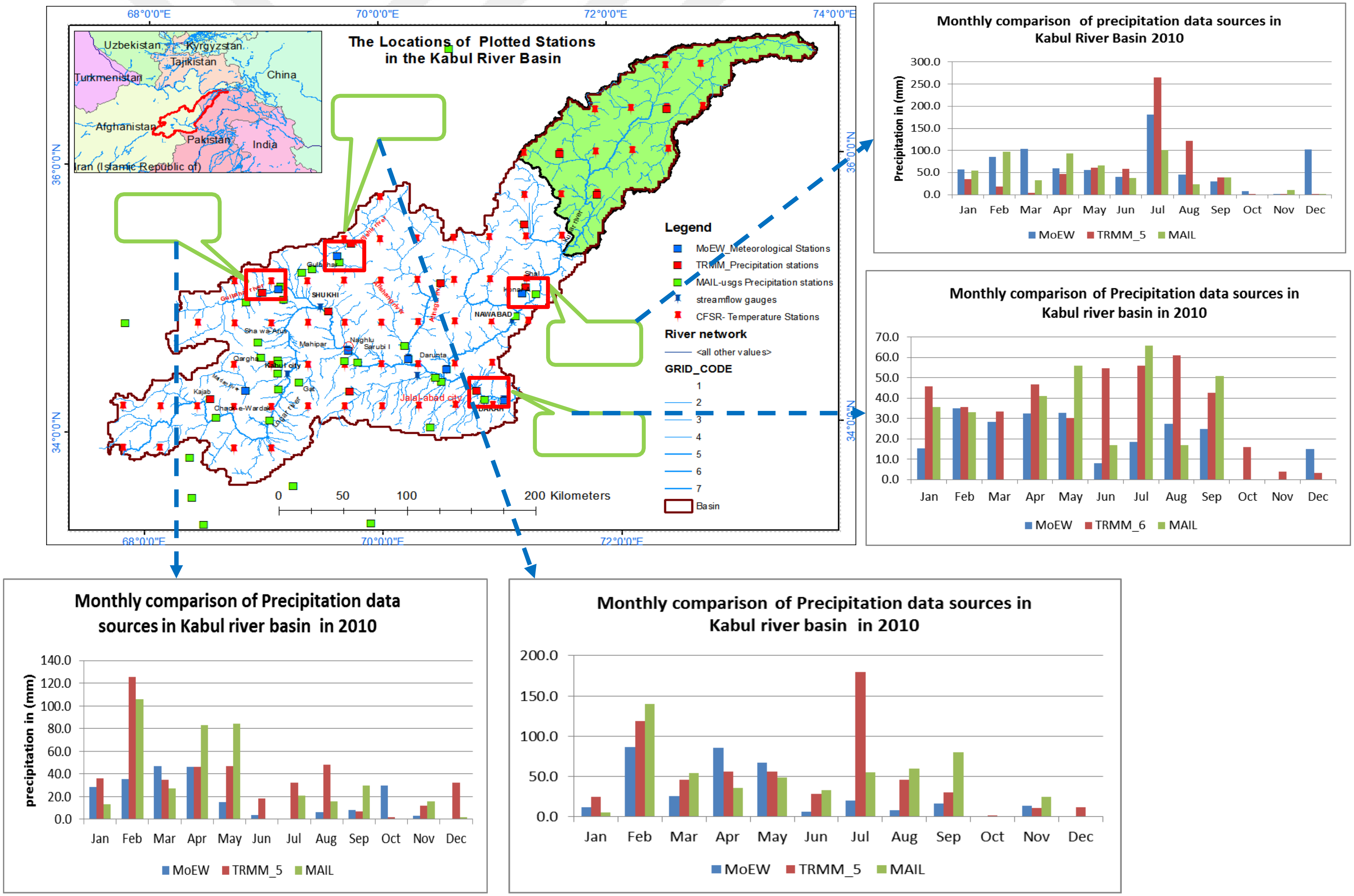



**Figure 4.8** Comparison of precipitation records based on three different data sets (2010)

### 4.8.2 Tropical Rainfall Measuring Mission (TRMM)

TRMM, a tropical rainfall measurement mission, was launched on November 28, 1997, using the H-11 rocket of the Tanegashima Space Center of the National Space Development Agency of Japan (NASDA). This satellite was developed as a joint project between Japan and the United States. TRMM is the first space mission to measure precipitation (NASDA, 2001), which combines TIR and MW sensors. The MW channel carefully measures the tiny amounts of microwave energy that is emitted and scattered by the Earth and its atmospheric components. TRMM also works with active radar. The TRMM satellite rotates around the Earth at an angle of 35 ° to the equator. TRMM covers an area of the earth's surface that extends far beyond the tropics and covers stripes between 38 ° north latitude and 38 ° south latitude. TRMM makes this data available almost in real time, as well as in formats with a delay in the quality of research. TRMM precipitation products have a spatial resolution of 0.25 ° and a time resolution of 3 hours. Twelve station points were selected for this study, and TRMM 3B42 version 7 was downloaded and used to fill in the gaps in the soil data, compared with the soil sediment records for quality assessment and the applied daily TRMM data in the SWAT model for annual availability assessment water [41].

### 4.8.3 Land cover data set

The 1981-1996 land cover dataset, uploaded from the Global Land Cover Fund (GLCF) with a resolution of 1 km, was used to determine the base level of land use and land cover. For comparison, a land cover data set based on MODIS of 0.5 km (2001-2010) was also added. All land use and land cover classes were grouped into seven main categories according to their hydrological properties. These include pastures, meadows, mixed forests, wastelands, arable land, settlements and water. Land use is a key factor in assessing the hydrological model of total net catchment evaporation. Changes in land use at the basin level from 1981 to 2010, estimated using the SWAT model. Changes in the distribution of land between settlements, pastures, pastures, mixed forests and agriculture, land and land cover, and changes in land use can be caused by population growth and the cost of housing. Analysis of two land cover data sets and comparison of them uses, Arc SWAT 2012 suggest that, urbanization dominates land use changes in patterns. Urban areas increased from 11215 hectares in 1982 to 14692 hectares by 2010 which shows 31% increase, Rangeland and mixed forest shown a decrease in the area of 22 percent, - 56 percent respectively. Water body, grassland, cropland and barren saw decreases in the area of 17 percent, 12 percent, 183 percent and 84 percent in the Kabul river basin respectively [42].

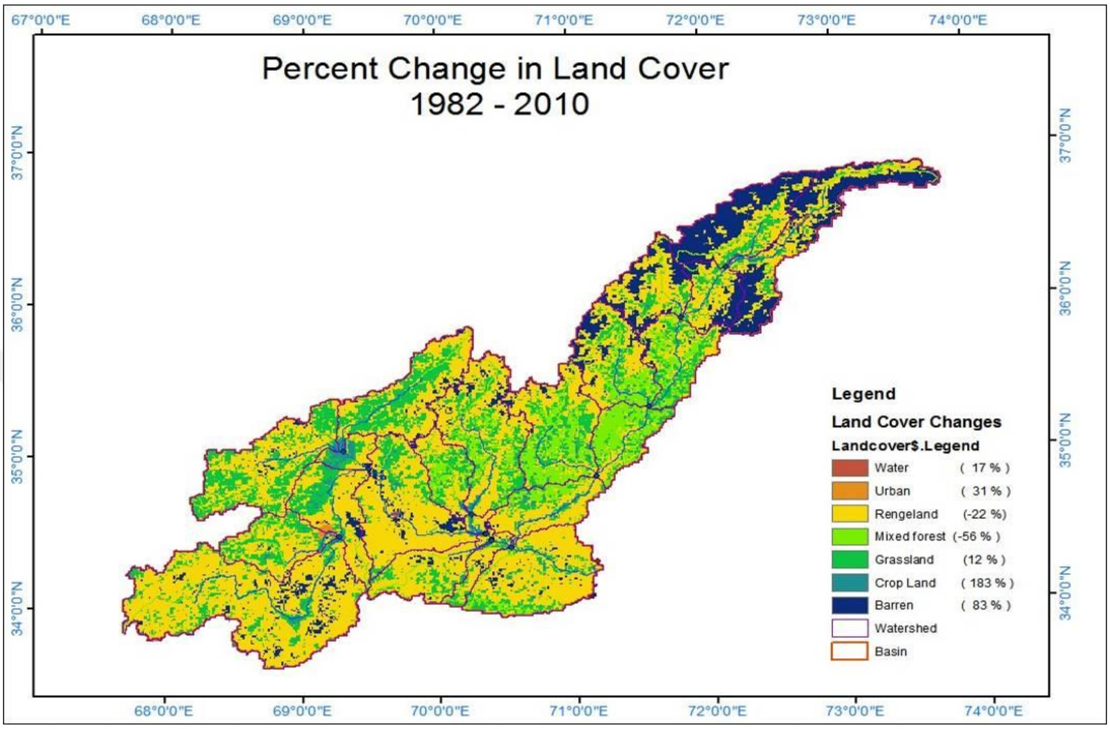



**Figure 4.9** Kabul River basin Land Cover

# CHAPTER .5

# METHODOLOGY

To conduct an assessment of the sub basin of the Panjshir region based on a research for thesis writing, the following methods has been used:

1. GIS methods
2. Field methods and statistics
3. Trent analysis method

According to water managers or planners, we first need to identify a number of “good” and “bad” environmental aspects. Then these indicators can be used to display the quality of the environment and varies over time. The service area classification is used to divide Kabul's sub-basin areas based on the functions described below.

## 5.1 GIS Methods

The landscape data’s for the Panjsher catchment was created using the GIS layer database. Land use and land cover classification levels have been verified and compared with historical documents and current catchment area characteristics. Soil and geological data were compared with published journal articles, human structures in the Panjshir catchment were previously mapped, and all these characteristics were compared with aerial photographs and local knowledge of the area. Delimitation of the watershed. In order to be able to effectively assess the Panjshir basin, we will first focus on defining the boundaries of the underwater catchments that flow into the Panjshir basin.

All catchment areas that contributed to the Panjshir basin were delimited, and all drainage entrances were examined. Various sources of information are used to delimit the individual catchment basins of the Panjshir basin.

Digital Roth topographic quadrangles are also used to define watersheds and watersheds according to the contours and landscape layout. River networks obtained from the DEM also went through a physical tour of the stream and checking the direction and location of the drainage and river on the ground.

Due to the poor quality of the data set for the river system, one of the main tasks of this work was to verify and map the river system throughout the catchment. River mapping included the physical passage of each stream, the marking of its position using a global positioning system (GPS) and transmitting longitude and latitude data by coordinating altitude data. Land use data, such as location structure, location, type and use of the surrounding landscape, were also recorded when measuring each river. Sub watershed classification.

With the help of GIS, all delimited catchment areas that contributed to the formation of the Panjshir basin were divided into physical and geographical areas. The drainage area from the mouth of each power system to the farthest catchment area for each of these partial catchment areas was designed for 1-10 km along the length of the channel upstream. Then, the proportion was determined in low-lying, mountainous transitional and highland areas. The following three categories were developed to classify underwater catchment areas.

**5.2 Field Methods**

Field studies were carried out at each observation site to characterize and classify water, the soil layer, the channel, and the fault inside and along the stream. These parameters are important for understanding the structure, settings and dynamics of individual stream properties of locations.
River flow. The output of each current was measured at each location in the sample. The global flow sensor is used to measure current speed. A flow sensor is used to measure the average speed over a cross section in a stream, so that the tape measure is initially strong throughout the stream. Since the speeds vary in the cross section of the stream, the stream is divided into additional sections along with the tape measure on the insert and the average speed measured in each section. In this study, most streams were wide enough to sample two or three-speed subsections in a stream. Depth 0.6 represents the center of speed for the vertical profile.

Once the measured average velocity is then multiplied by the area of the subsection, which corresponds to the flow for this subsection (Q = VxA). After calculating the flow rate of each subsection, all subsections are added to get the total expense or expense.

Measuring the speed and volume of a stream in a stream is critical to understanding the amount of water passing through the stream channel and the speed at which water moves. These flow properties can then be related to the concentration and transport rate of nutrients in the flow channel

### 5.3 Trend Analysis Method

Precipitation and temperature data shows a long-term change of data or some pattern changes in the given temporal scale series. Hence, to describe a trend of a time series Mann-kendall trend test is used to see whether there is a decreasing or increasing trend or not. Mann-kendall statistics (S) is one of non-parametric statistical test used for detecting trends of climatic variables.

It is the most widely used method since it is less sensitive to outliers (extraordinary high values with in time series data) and it is the most robust as well as suitable for detecting trends in precipitation. Different software such as SPSS, XLSTAT and Microsoft excel can be used for trend analysis test. The Mann-Kendall test statistic is calculated according to:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}\left(X_j-X_k\right) \tag{5.1}$$

$$\operatorname{sgn}(x)=\begin{cases}1 & \text{if} \quad x>0\\ 0 & \text{if} \quad x=0\\ -1 & \text{if} \quad x<0\end{cases} \tag{5.2}$$

The mean of S is E[S] = 0 and the variance σ is

$$\sigma^2=\left\{n\left(n-1\right)\left(2n+5\right)-\sum_{j=1}^{p}t_j\left(t_j-1\right)\left(2t_j+5\right)\right\}/18 \tag{5.3}$$

Where p is the number of the tied groups in the data set and tj is the number of data points in the jth tied group. The statistic S is approximately normal distributed nprovided that the following Z-transformation is employed:

$$Z = \begin{cases} \frac{S-1}{\sigma} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \frac{S+1}{\sigma} & \text{if} \quad S > 0 \end{cases} \tag{5.4}$$

The statistic S is closely related to Kendall's τ as given by:

$$\tau = \frac{S}{D} \tag{5.5}$$

Where

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{j=1}^{p} t_j(t_j - 1)\right]^{1/2} \left[\frac{1}{2}n(n-1)\right]^{1/2} \tag{5.6}$$

**5.4 Data Collection Methodology**

The development of a logical technical framework that can support decision-making on mitigating and adapting to the effects of climate change in the context of the basin and upstream evolution requires careful analysis and assessment of key elements, including, but not limited to, features of the watershed, hydro climatic conditions, anthropogenic activities, the development of characteristic basins, the presence / absence of a water agreement between neighboring countries and the availability and accessibility of data. To achieve the goals and achieve the goal, the following list shows the main components that must comply with the recommended methodology.

1. Identify the data needed
2. Data collection and management
3. Basin development level
4. Impacts of upstream development on lower basin flow regime
5. Analysis of meteorological data

6. Impacts of climate change
7. Base flow contribution to total runoff
8. Sensitivity of irrigation water demand

### 5.4.1 Data

To conduct proper analysis and achieve the goals and the overall goal of the work, it is necessary to collect the following list of data:

1. Hydrological data, such as runoff time series, isolated discharge hydrographs, inflow to dams, and releases from reservoirs. This affects different gauging stations.

2. Meteorological data such as precipitation, temperature, humidity, wind speed, hours of sunshine, evaporation and possible total evaporation. Different weather stations are taken into account.

3. Existing, under construction and planned dams, irrigation systems, fish farms, water intakes and public water supply.

4. Storage capacities of existing, under construction and designed reservoirs.

   I. Water abstraction for existing, under construction and planned irrigation projects, fish farms and public water supply systems.

   II. The effectiveness of all irrigation systems.

   III. Topographic data, including soil type and land use intravenously aquifers and their properties against related quality documents and data.

### 5.4.2 Data Collection and Management

The data collected is divided into three main groups. These groups include river records, meteorological parameters and hydraulic structures, such as dams, irrigation and water intake, as well as other useful data, such as Google km / km and form files.

River data: Daily rivers between 1960 and 2017 are observed at the Gulbahar Hydro meteorological Station and at nearby stations.

Meteorological data: meteorological data such as precipitation and average air temperature have been collected. Data includes monthly precipitation and data on average air temperature from 4 meteorological to the basin. The Afghan Ministry of Water and Energy has provided interpolated daily climate data such as rainfall (P), minimum (Tmin), maximum (Tmax), average air temperature (Tmean), radiation and humidity from 2005 to 2017.

Waterworks. Data was collected on existing and under construction dams, including storage tanks and schedules in which plumbing was carried out or construction was planned. Irrigation and water abstraction: data were collected on existing, under construction and investigated / planned water abstraction systems, including project sites, as well as current and projected total irrigation water requirements (TIWR). The data also includes the periods in which the projects were posted on the network or the implementation of which is planned. Data comes from various international sources.

### 5.4.3 Data Storage Systems

Data in various formats, such as spreadsheets, Word documents, and scanned documents, was collected either from official sources, or from published documents, or downloaded from websites. In some cases, documents had to be translated from Persian into English. In this study, extensively develop a database to achieve and process data.

A Microsoft Excel add-in that is used to extract and save data directly from spreadsheet files. A geodatabase for storing and managing geospatial data for the Arc GIS application has also been developed.

**Data collection:** Data gathering is the most important step toward the hydrologic modelling, demand evaluation and climate change assessment. In this study, the following datasets are collected and used to estimate potential water availability, sectorial water demand and climate change impact assessment in the Kabul river basin:

1. Digital Elevation Model (DEM) downloaded from NASA website,
2. Poor and incomplete daily and monthly hydrological and meteorological data were collected from the Department of Water Resources (DWR), Ministry of Energy and Water (MoEW) and Ministry of Agriculture, Irrigation and livestock (MAIL), Kabul, Afghanistan,
3. Daily precipitation obtained from Tropical Rainfall Measuring Mission

(TRMM) in NASA,

4. daily temperature downloaded from (CFSR) website,
5. Land cover raster obtained from USGS,
6. Soil dataset downloaded from FAO/UNESCO website,
7. Population raster obtained from Prof. SATO Keisuke,
8. Climate scenarios, B1, A1B and A2 and climate change models daily data, such as precipitation and temperature downloaded from, CCCMA CGCM3.1, MIROC3.2(meres), GFDL CM2.1 and CNRM-CH3 websites [43].

### 5.5 Dynamic Method for Gap filling

Multiple linear regression approach, using a set of surrounding stations as regressors is the most conventional method, suitable for gap filling of the precipitation and temperature records,

The approach to selecting stations and determining the best connection times for reconstruction and target stations can be summarized in figure 5.1

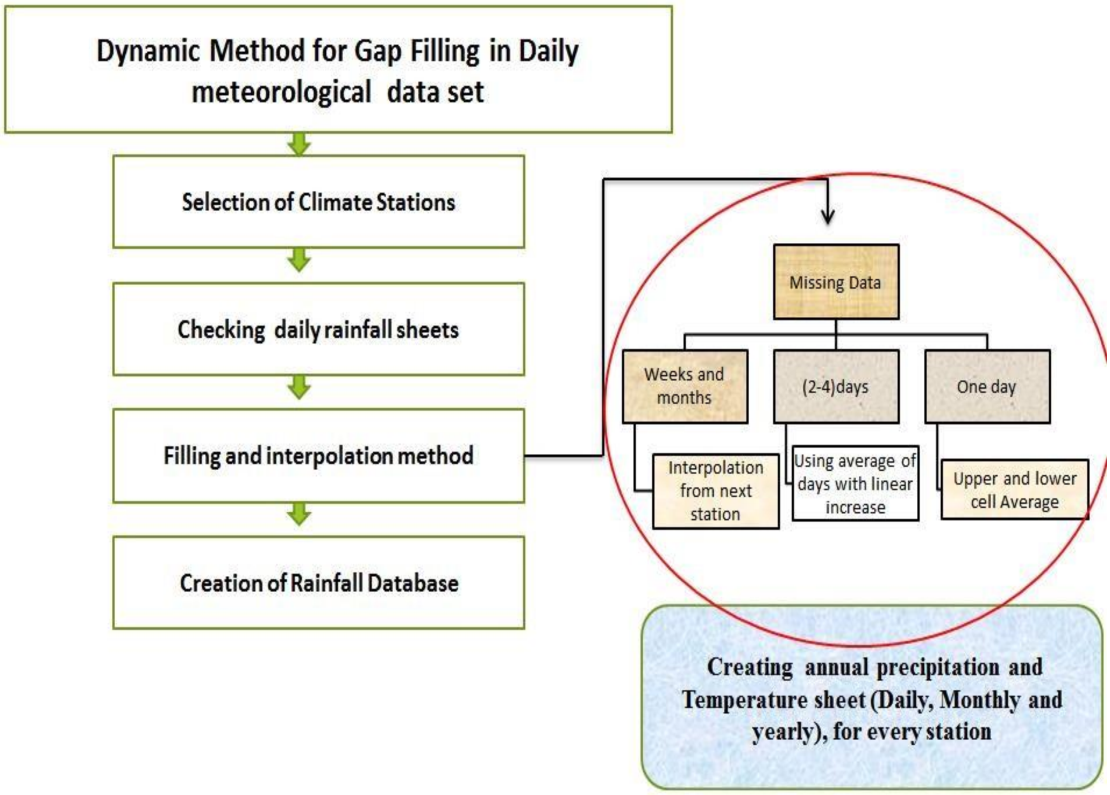



**Figure 5.1** Dynamic Method for Gap Filling

- Analysis of the target station to identify a period without gaps of sufficient length contiguous to the gap to be filled preceding and or following the gap.
- Identification of two groups of stations (high gaped stations and low gaped stations) for data reconstruction in the neighborhood of the target station.
- Selection of the period to be considered (before or after the gap).
- Identification of the subset of stations, in the period previously identified, giving the best correlation with the target station for the specific gap to be filled

### 5.5.1 Normal Ratio Method

Normal Ratio Method is the most traditional method used to fill in the gaps in precipitation and temperature records, especially when the coefficient method is used when the normal annual rainfall at the index station differs by more than 10% from the level at the interpolation station. This method has been used in various places around the world. This method is one of the easier methods for predicting missing values. Repeated calculations, however, make it troublesome if the number of data records is very large.

## 5.6 ArcGIS software

Integrated with ArcGIS, showed that, it can simulate even small rivers, calculate the flow of partial watersheds and efficiently analyze basin productivity in low data conditions. An essential aspect of the software is that the simultaneous use of surface and groundwater was taken into account in the modeling process. It also helps determine the best management techniques for the useful and distribution of water between different sectors.

The model was applied in a low flow. Despite the scarcity of data, the model shows its usefulness in the analysis of pelvic indicators. The analysis shows that the availability of water in the lower part of the Panjshir River is insufficient for domestic and industrial use.

It has also been shown that the rainy season increases water quantity compared to very or little water supply during the dry season. This inequality in water availability makes the community continue to depend on water resources between basins. Based on the results, options should be considered for new storage systems or replenishment of artificial aquifers for storing excess water in the rainy season and improving the reliability of the dry season.

# CHAPTER 6

# PANJSHER DAM FEASIBILITY STUDY

Afghanistan has been experiencing rapid population growth, for instance Kabul population has increased from around 2 million in 2001 to nearly 6 million in 2019, which is mainly due to the inflow of people from rural areas and refugees from neighboring countries. However, the improvement of infrastructures in Kabul is quite incomplete to cope with such a rapid population growth, and consequently, the city is facing a number of challenges such as shortage of housing and fresh water supply, deterioration of public hygiene, heavy traffic jams and urban sprawl. In order to tackle such challenges, urban development in an orderly and efficient manner is urgently required.

It is fundamental and a significant challenge to secure domestic and industrial water supply to the new city in order to materialize the development of the Kabul Metropolitan Area. A feasibility on the Gulbahar Dam and the Bagh-Dara Dam on the Panjsher River is as the medium-term or long-term water sources can also be examined together with the development of the Panjshir Fan Aquifer in order to establish the most optimal water resource development plan for the Kabul New City.

The objectives of this chapter is to conduct the Feasibility Study on the availability of the Panjshir Fan Aquifer under climate change effects and to review the Feasibility Study on the Gulbahar Dam currently being prepared by the Afghan Ministry of Energy and Water.

## 6.1 Site Study

The Kabul River receives four large tributaries, such as Logar, Panjshir, Alingar and Kunar in the territory of Afghanistan, and then flows into Pakistan territory. One of the four tributaries, the Kunar River, originates in the territory of Pakistan. The total catchment area of the Kabul River is 94,000 $km^2$, of which more than 57% lies in Afghanistan.

The Kabul River Basin in Afghanistan occupies only 12% of the country's land territory, but accommodates 35% of the national population. The basin includes the Kabul urban area, which is one of the biggest generators of economic growth in the country. This enhances the importance of the Kabul River Basin in Afghanistan. Due to the three decades long war, however, water resources in the river basin have been developed only at the primary level. Afghanistan definitely has the right to exploit a reasonable amount of water for its development.

Panjsher sub basin is one of the most important tributaries of Kabul river basin with the catchment area of 17700 $km^2$ that has flowing within four cities of Afghanistan.

The Panjshir Fan is located at about 60-80 km north of Kabul City in the alluvial fan along the Panjshir and Ghorband rivers. The abundant surface water and widely extended alluvial fan promise high groundwater potential. Direct water intake of surface water without storage even under drought conditions is possible only downstream of the Panjshir Fan. Direct river water intake upstream of the Panjshir Fan is impossible due to much irrigation water demand in the downstream areas including the fan area.

Finally, the Panjshir Fan Aquifer was preferred to the surface water source because of less treatment cost. From the following reasons the fan aquifer development was considered to be more suitable for early development than the storage options:

- Generally, dam projects take a longer period for implementation mainly due to resettlement issues.
- The total cost including operation and maintenance cost of the fan aquifer development is less.

### 6.2 Data Preparation

Data preparation is the process of cleaning and transforming raw data prior to processing and analysis. It is an important step prior to processing and often involves reformatting data, making corrections to data and the combining of data sets to enrich data.

A crucial element in the development of a water resources management project is having reliable hydrometrological data. The data collection is also needed to avoid major river floods; flash floods; snowmelt floods; and water management information. Collecting hydro meteorological data manually; using automated gages utilizing telephone, radio, and satellite; and by remote sensing using radar, satellites, and aircraft are the main technical process of data collection.

### 6.3 Critical Period

Critical period is the period which demand is more than the supply. In other words, it is the sequence of years with the lowest annual flows. In my analysis, I have 32 years data which is very time consuming to use graphical mass curve method to find the critical period. Therefore, I used analytical solution of mass curve to find the most critical years. I found 3 years of critical period from my 32 years of data, then from these 3 years I calculated the volume of the critical period as maximum of column (∑St-∑Dt $m^3$) $M^3$ in table 6.1,the volume according to critical period is found as **118758045.2$m^3$.**

∑St is the total coming water to the reservoir and (∑Dt) the cumulative amount of water demand. So, whenever the demand is somehow equal to supply or more than it these years called critical periods.

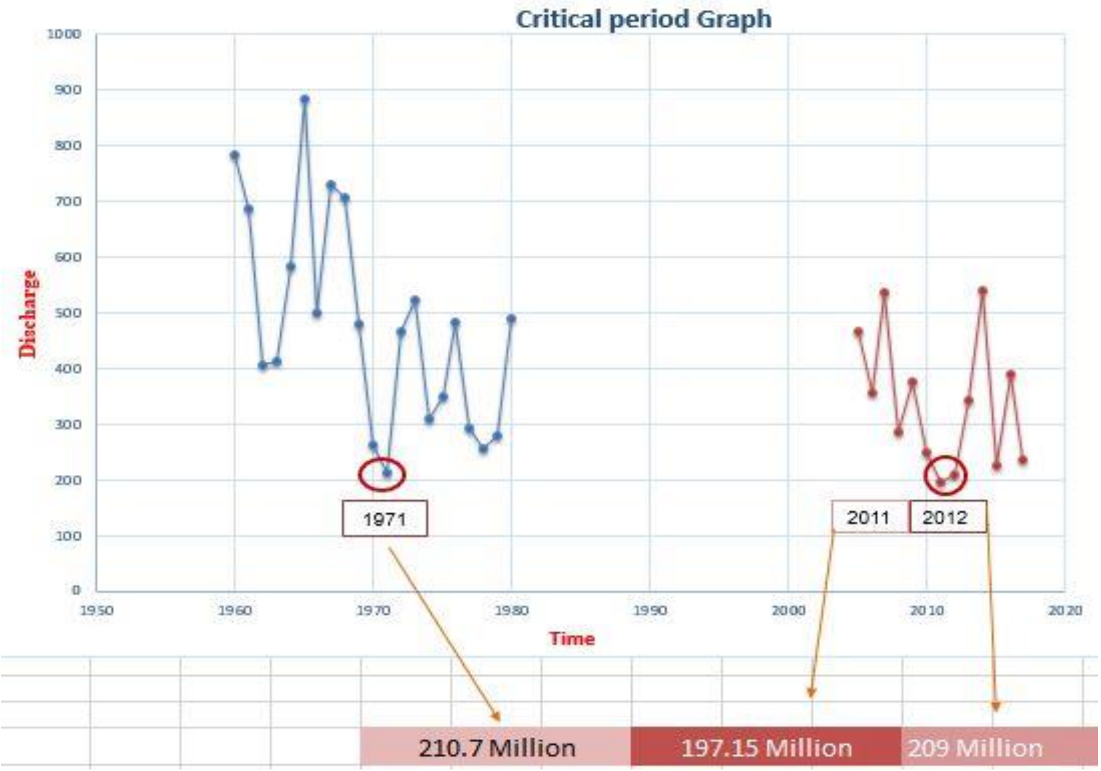



**Figure 6.1** Gulbahar station critical year's analysis

**Table 6.1** Excel sheet, yearly available water in passing through the Gulbahar station

| Time | ∑St (m3)Yearly |
|---|---|
| 1960 | 783846720 |
| 1961 | 685298880 |
| 1962 | 407566080 |
| 1963 | 411583680 |
| 1964 | 584366400 |
| 1965 | 882912960 |
| 1966 | 499037760 |
| 1967 | 728688960 |
| 1968 | 705464640 |
| 1969 | 479390400 |
| 1970 | 262025280 |
| 1971 | 210703680 |
| 1972 | 465730560 |
| 1973 | 523454400 |
| 1974 | 309744000 |
| 1975 | 349453440 |
| 1976 | 482578560 |
| 1977 | 292014720 |
| 1978 | 256478400 |
| 1979 | 277473600 |
| 1980 | 489214080 |
| 2005 | 466130940.4 |
| 2006 | 355438539.2 |
| 2007 | 534669952.9 |
| 2008 | 285403746.6 |
| 2009 | 375046875.9 |
| 2010 | 248732488.7 |
| 2011 | 197150838.6 |
| 2012 | 209054729.8 |
| 2013 | 342888182.7 |
| 2014 | 539405607.8 |
| 2015 | 225026423 |
| 2016 | 389483433.4 |
| 2017 | 235324612.2 |
| = | 197150838.6 |

## 6.4 Reservoir Capacity

Storage reservoirs have much larger capacities than distribution reservoirs. Generally, the supply to storage reservoirs show large variations while outflow is relatively constant. Designing the capacity of a storage reservoir involves determination of the critical period, i.e., the sequence of years with lowest annual flows. Therefore, it is aimed to deliver at least the safe or firm yield from the reservoir. In case of lack of stream gaging records, synthetic data including maximum flows and droughts must be generated. The methods used for determining the capacity of a storage reservoir are as follow:

a) Mass curve (Ripple diagram) method
b) Sequent-peak analyses
c) Operation studies
d) Optimization analysis and stochastic models

### 6.4.1 Mass Curve Analysis

A mass graph is a graph of the accumulated inflow, outflow (i.e. demand) versus time. Define hourly requirements for all 24 hours for typical days (maximum, average, and minimum) from previous records and it's shown by million $m^3$ below.

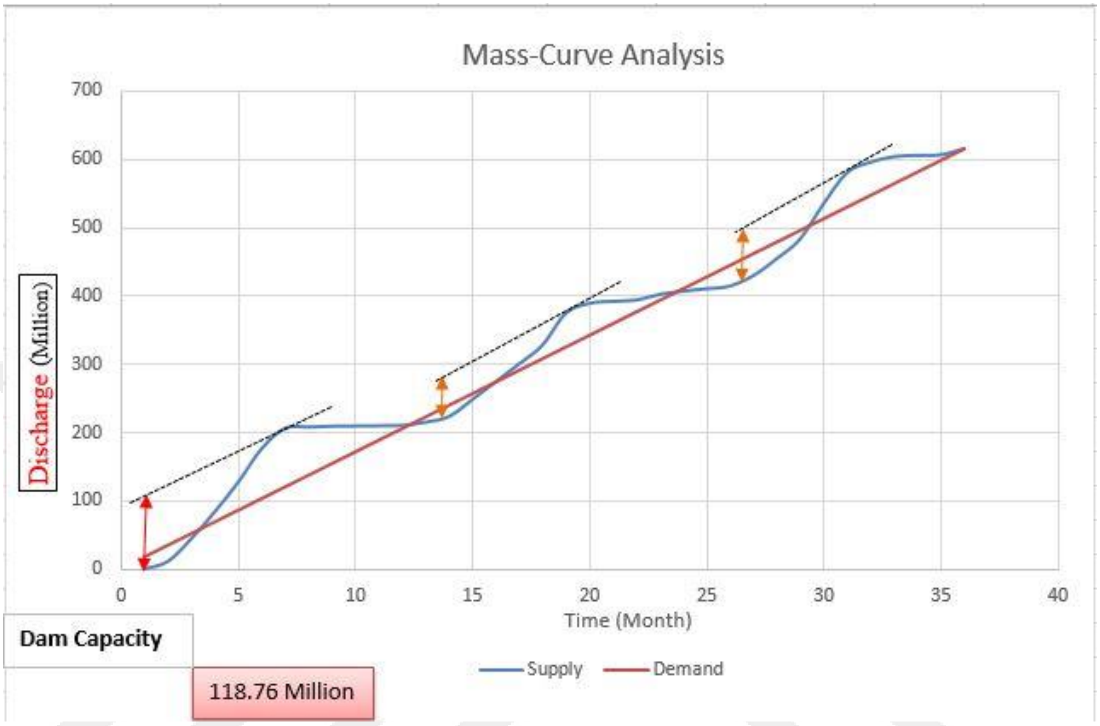



**Figure 6.2** Gulbahar Station mass-curve analysis

**Table 6.2** excel sheet, water demand and dam capacity using mass-curve analysis

| Years | Months | Discharge | ∑St(m3) | Months# | Demand | ∑Dt (m3) | ∑St-∑Dt (m3) |
|---|---|---|---|---|---|---|---|
| 1971 | October | 155520 | 155520 | 1 | 17136368.01 | 17136368 | -16980848 |
| | November | 11041920 | 11197440 | 2 | 17136368.01 | 34272736 | -23075296 |
| | December | 33177600 | 44375040 | 3 | 17136368.01 | 51409104 | -7034064.03 |
| | January | 39657600 | 84032640 | 4 | 17136368.01 | 68545472 | 15487168 |
| | Feberuary | 43286400 | 1.27E+08 | 5 | 17136368.01 | 85681840 | 41637199.9 |
| | March | 49248000 | 1.77E+08 | 6 | 17136368.01 | 1.03E+08 | 73748831.9 |
| | April | 30067200 | 2.07E+08 | 7 | 17136368.01 | 1.2E+08 | 86679663.9 |
| | May | 1814400 | 2.08E+08 | 8 | 17136368.01 | 1.37E+08 | 71357695.9 |
| | June | 1140480 | 2.1E+08 | 9 | 17136368.01 | 1.54E+08 | 55361807.9 |
| | July | 336960 | 2.1E+08 | 10 | 17136368.01 | 1.71E+08 | 38562399.9 |
| | Augost | 336960 | 2.1E+08 | 11 | 17136368.01 | 1.89E+08 | 21762991.9 |
| | Septembe | 440640 | 2.11E+08 | 12 | 17136368.01 | 2.06E+08 | 5067263.87 |
| 2011 | October | 4838679 | 2.16E+08 | 13 | 17136368.01 | 2.23E+08 | -7230425.43 |
| | November | 8233056 | 2.24E+08 | 14 | 17136368.01 | 2.4E+08 | -16133737.4 |
| | December | 24951763 | 2.49E+08 | 15 | 17136368.01 | 2.57E+08 | -8318342.87 |
| | January | 26042075 | 2.75E+08 | 16 | 17136368.01 | 2.74E+08 | 587363.956 |
| | Feberuary | 26300469 | 3.01E+08 | 17 | 17136368.01 | 2.91E+08 | 9751464.52 |
| | March | 27791257 | 3.29E+08 | 18 | 17136368.01 | 3.08E+08 | 20406353.3 |
| | April | 46949760 | 3.76E+08 | 19 | 17136368.01 | 3.26E+08 | 50219745.3 |
| | May | 14083757 | 3.9E+08 | 20 | 17136368.01 | 3.43E+08 | 47167134.7 |
| | June | 3090528 | 3.93E+08 | 21 | 17136368.01 | 3.6E+08 | 33121294.7 |
| | July | 1878615 | 3.95E+08 | 22 | 17136368.01 | 3.77E+08 | 17863541.4 |
| | Augost | 8352929 | 4.03E+08 | 23 | 17136368.01 | 3.94E+08 | 9080102.39 |
| | Septembe | 4637952 | 4.08E+08 | 24 | 17136368.01 | 4.11E+08 | -3418313.62 |
| 2012 | October | 3652212 | 4.12E+08 | 25 | 17136368.01 | 4.28E+08 | -16902470 |
| | November | 3773088 | 4.15E+08 | 26 | 17136368.01 | 4.46E+08 | -30265750 |
| | December | 15323737 | 4.31E+08 | 27 | 17136368.01 | 4.63E+08 | -32078381.3 |
| | January | 25002766 | 4.56E+08 | 28 | 17136368.01 | 4.8E+08 | -24211982.8 |
| | Feberuary | 28878455 | 4.84E+08 | 29 | 17136368.01 | 4.97E+08 | -12469895.7 |
| | March | 51840000 | 5.36E+08 | 30 | 17136368.01 | 5.14E+08 | 22233736.3 |
| | April | 45515520 | 5.82E+08 | 31 | 17136368.01 | 5.31E+08 | 50612888.3 |
| | May | 15375577 | 5.97E+08 | 32 | 17136368.01 | 5.48E+08 | 48852097.1 |
| | June | 8121600 | 6.05E+08 | 33 | 17136368.01 | 5.66E+08 | 39837329.1 |
| | July | 1934886 | 6.07E+08 | 34 | 17136368.01 | 5.83E+08 | 24635847.2 |
| | Augost | 733368.8 | 6.08E+08 | 35 | 17136368.01 | 6E+08 | 8232848.01 |
| | Septembe | 8903520 | 6.17E+08 | 36 | 17136368.01 | 6.17E+08 | 0 |
| | | | | | | | |
| | | | | | | Max: | 86679664 |
| | Demand = | | 1.7E+07 | | | Min: | -32078381 |
| | | | | | Dam Capacity = | | 118758045 |

### 6.4.2 Sequent Peak Analyses

Since my data is very large, graphically determining storage capacity using a sequential burst algorithm can be time consuming. The analytical solution for the sequential peak algorithm, which is well suited for computer applications, can be formulated as follows:

$$V_t = D_t - S_t + V_{t+1} \quad (6.1)$$

$$\text{If, } D_t - S_t + V_{t+1} > 0 \quad (6.2)$$

$$V_t = 0 \quad \text{Otherwise}$$

Where $V_t$ is the required capacity at the end of specific period t, $D_t$, outflow and $S_t$, inflow during period t, $V_{t+1}$ is the required storage at the end of the preceding month. The maximum all calculated values of $V_t$ is the required reservoir storage capacity for the specified inflows and outflow. In my thesis I used the result from this analysis which is shown in Table 6.3, which gives the result of **2047948924** m$^3$ as my dam storage capacity.

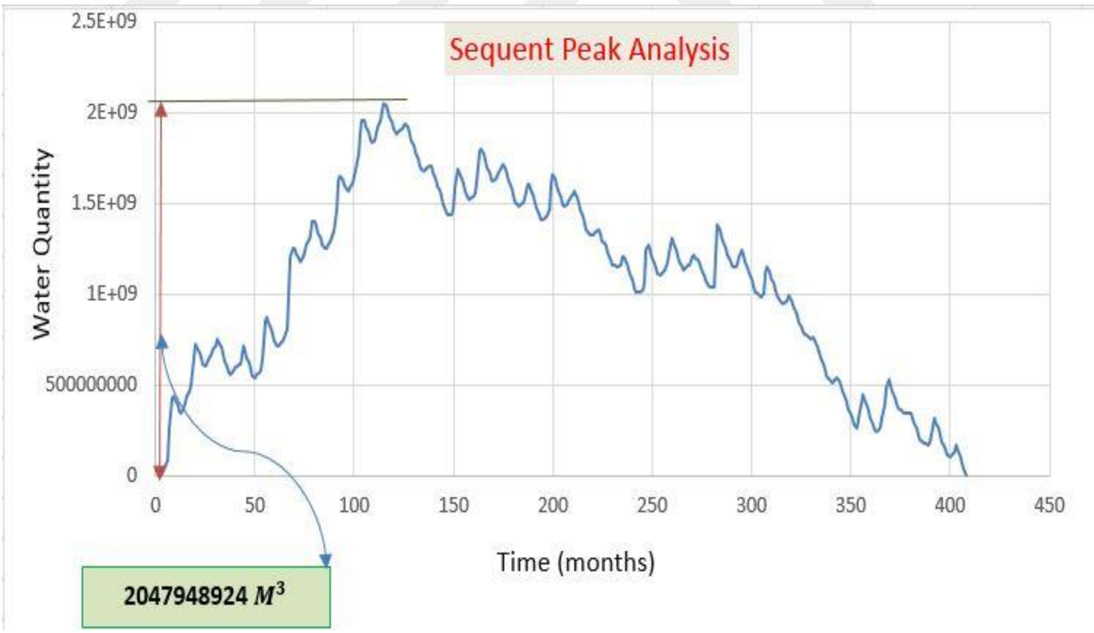



**Figure 6.3** Gulbahar station Sequent Peak Analysis

**Table 6.3** excel sheet, water demand and dam capacity using sequent peak analysis

| Time | | month | Vt | St-Dt (m3) | ∑.St-Dt (m3) |
|---|---|---|---|---|---|
| 1960 | October | 1 | 26055826 | -26055826.4 | -26055826.4 |
| | November | 2 | 10250853 | 15804973.6 | -10250852.8 |

| | | | | | |
|---|---|---|---|---|---|
| | December | 3 | 0 | 22284973.6 | 12034120.8 |
| | January | 4 | 0 | 18656173.6 | 30690294.4 |
| | February | 5 | 0 | 20988973.6 | 51679268 |
| | March | 6 | 0 | 33430573.6 | 85109841.6 |
| | April | 7 | 0 | 179878573.6 | 264988415.2 |
| | May | 8 | 0 | 159920173.6 | 424908588.8 |
| | June | 9 | 0 | 12176173.6 | 437084762.4 |
| | July | 10 | 16802386 | -16802386.4 | 420282376 |
| | August | 11 | 47783013 | -30980626.4 | 389301749.6 |
| | September | 12 | 79437559 | -31654546.4 | 357647203.2 |
| 1961 | October | 13 | 89422986 | -9985426.4 | 347661776.8 |
| | November | 14 | 61694812 | 27728173.6 | 375389950.4 |
| | December | 15 | 33448238 | 28246573.6 | 403636524 |
| | January | 16 | 1313664.8 | 32134573.6 | 435771097.6 |
| | February | 17 | 0 | 30838573.6 | 466609671.2 |
| | March | 18 | 0 | 37577773.6 | 504187444.8 |
| | April | 19 | 0 | 144368173.6 | 648555618.4 |
| | May | 20 | 0 | 71532973.6 | 720088592 |
| | June | 21 | 17657746 | -17657746.4 | 702430845.6 |
| | July | 22 | 38892453 | -21234706.4 | 681196139.2 |
| | August | 23 | 70598839 | -31706386.4 | 649489752.8 |
| | September | 24 | 103342026 | -32743186.4 | 616746566.4 |
| 1962 | October | 25 | 121025692 | -17683666.4 | 599062900 |
| | November | 26 | 98999918 | 22025773.6 | 621088673.6 |
| | December | 27 | 76196545 | 22803373.6 | 643892047.2 |
| | January | 28 | 50541971 | 25654573.6 | 669546620.8 |
| | February | 29 | 25146598 | 25395373.6 | 694941994.4 |
| | March | 30 | 4416824 | 20729773.6 | 715671768 |
| | April | 31 | 0 | 39132973.6 | 754804741.6 |
| | May | 32 | 19394386 | -19394386.4 | 735410355.2 |
| | June | 33 | 53381733 | -33987346.4 | 701423008.8 |
| | July | 34 | 87291319 | -33909586.4 | 667513422.4 |
| | August | 35 | 121926666 | -34635346.4 | 632878076 |
| | September | 36 | 156691612 | -34764946.4 | 598113129.6 |
| . | ... | | | | |
| . | | | | | |
| . | | | | | |
| 2015 | October | 373 | 1.648E+09 | -28802510.27 | 399961571.5 |
| | November | 374 | 1.672E+09 | -23958898.4 | 376002673.1 |
| | December | 375 | 1.685E+09 | -13275594.14 | 362727079 |
| | January | 376 | 1.694E+09 | -8344105.11 | 354382973.9 |
| | February | 377 | 1.701E+09 | -7087940.686 | 347295033.2 |
| | March | 378 | 1.701E+09 | -474458.6583 | 346820574.5 |

| | | | | | |
|---|---|---|---|---|---|
| | April | 379 | 1.705E+09 | -3952114.4 | 342868460.1 |
| | May | 380 | 1.705E+09 | -267098.6583 | 342601361.5 |
| | June | 381 | 1.73E+09 | -24948178.4 | 317653183.1 |
| | July | 382 | 1.76E+09 | -29449674.14 | 288203508.9 |
| | August | 383 | 1.79E+09 | -30748182.53 | 257455326.4 |
| | September | 384 | 1.82E+09 | -29864338.4 | 227590988 |
| | October | 385 | 1.852E+09 | -31744848.34 | 195846139.6 |
| | November | 386 | 1.865E+09 | -12976594.4 | 182869545.2 |
| | December | 387 | 1.872E+09 | -6707800.594 | 176161744.7 |
| | January | 388 | 1.869E+09 | 2493799.406 | 178655544.1 |
| | February | 389 | 1.879E+09 | -10061398.81 | 168594145.2 |
| 2016 | March | 390 | 1.86E+09 | 19532436.83 | 188126582.1 |
| | April | 391 | 1.78E+09 | 79969069.6 | 268095651.7 |
| | May | 392 | 1.727E+09 | 52455017.47 | 320550669.1 |
| | June | 393 | 1.756E+09 | -28506476 | 292044193.1 |
| | July | 394 | 1.79E+09 | -33841358.27 | 258202834.9 |
| | August | 395 | 1.823E+09 | -33530318.27 | 224672516.6 |
| | September | 396 | 1.857E+09 | -33797612 | 190874904.6 |
| | October | 397 | 1.89E+09 | -32809491.43 | 158065413.2 |
| | November | 398 | 1.919E+09 | -28643679.2 | 129421734 |
| | December | 399 | 1.938E+09 | -19790711.56 | 109631022.4 |
| | January | 400 | 1.946E+09 | -8178551.561 | 101452470.8 |
| | February | 401 | 1.931E+09 | 15962345.03 | 117414815.9 |
| 2017 | March | 402 | 1.917E+09 | 13706289.73 | 131121105.6 |
| | April | 403 | 1.882E+09 | 34442317.6 | 165563423.2 |
| | May | 404 | 1.912E+09 | -29196327.05 | 136367096.2 |
| | June | 405 | 1.945E+09 | -33541004 | 102826092.2 |
| | July | 406 | 1.979E+09 | -33835254.53 | 68990837.63 |
| | August | 407 | 2.014E+09 | -34547385.63 | 34443452 |
| | September | 408 | 2.048E+09 | -34443452 | 1.508E-05 |
| | | **35516626.4** | **2.048E+09** | Storage Capacity | **2047948924** |

### 6.5 Environmental and Social Considerations

In general, it is concerned that the multiple developments in one basin may cause combined or cumulated impacts to the environment of the basin. Considering the issue, possibility of the combined impacts of Panjshir Fan Aquifer and either of the two dam projects are also assessed based on the respective impacts.

No significant impacts are expected on social and natural environment. On the other hand, impacts by the two dam projects are significant; especially, they require relocation of a large number of houses.

Hydrological impact to the basin is also expected for both projects. Gulbahar Dam will cause larger impacts and would alters the hydrological condition of the Panjshir River significantly because downstream irrigation is one of the purposes of the Gulbahar Dam.

In spite of the possibility of large environmental impacts, hydrological change as well as the other environmental impacts has not been studied enough to meet the possibility of combined impacts by the Panjshir Fan Aquifer and the dam projects are basically not expected, because the impacts of the Panjshir Fan Aquifer to the basin are limited.

However, the impacts by the dams such as those on water quality, flora and fauna may spread to the basin including the Panjshir Fan Aquifer. Since the possibility and extent are not clear at this moment, it is necessary to study the impacts based on broad scale survey results before deciding on the dam project.Although the impact of the Gulbahar Dam to the basin will be significant, not only adverse impacts but also positive effects are expected.

Especially, it is expected that the irrigation water from the Gulbahar Dam will increase the recharge of the Panjshir Fan Aquifer and cause positive effects on the water intake at the Panjshir Fan Aquifer [44].

## 6.6 Population Growth and Water Demand Based on Lifestyle

Projected Population water demand by 2045, compared under three scenarios, first with basic life style 80 liters per day with loss index in the summer season, second with intermediate lifestyle 120 liters per day like China and Mexico, thirdly, to advanced lifestyle like Japan 200 litter per day.

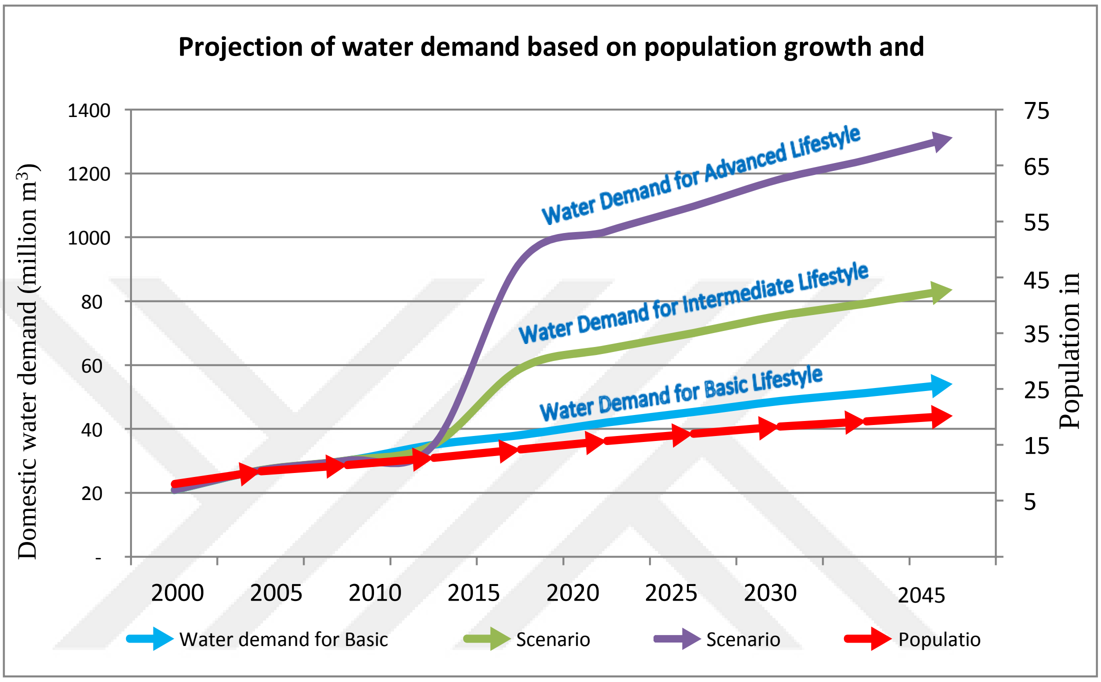



**Figure 6.4** Projection of water demand based on population growth [45]

## 6.7 Land Cover Analysis

In this study, two land use data sets have been used, GLCF (Global Land Cover Facility) and MODIS based global land cover data sets have been applied in SWAT model for land cover changes.

All land use and land cover classes were grouped into seven categories according to their hydrological characteristics. These include mixed forests, arable land, pastures, meadows, wastelands, settlements and water. The overall result of the analysis showed in Table 6.4.

**Table 6.4** Land Cover distribution

| Number | Land cover/ land use | Land cover / land use area (Thousand hectare) | | Percent of Changes (1982- 1992 to 2000-2010) |
|---|---|---|---|---|
| | | (1982 – 1992) | (2000 – 2010) | |
| 1 | Water | 9.1 | 7.8 | -14.3 |
| 2 | Urban/ Built up | 11.3 | 14.6 | 29.2 |
| 3 | Rangeland | 3652.5 | 2848.6 | -22.0 |
| 4 | Mixed forest | 448.3 | 195.7 | -56.3 |
| 5 | Grassland | 1413.8 | 1586.6 | 12.2 |
| 6 | Cropland / Irrigated Area | 94.2 | 264.1 | 180.4 |
| 7 | Barren | 891 | 1602.8 | 79.9 |

According to the output of land cover analysis, cropland or irrigated land shows 180 % increased after 20 years, if we project the land cover changes, in contrast to the two data sets, and projection of irrigation, land could be significant, for projection of irrigated area by 2045 the cropland assumed 496 (thousand hectare).

Projected sectorial water demand by 2045, Assuming a high growth scenario for 2045, where,

1. Agriculture production in the Kabul river basin is increased, maintaining the irrigation infrastructure along the river valleys in upstream, midstream and downstream and achieving a maximum river water, plus extension of irrigated land due to the implementation of MAIL policy for land improvement and irrigation extension from 264000 to 496000 hectares in the Kabul basin.

2. The population in the Basin has grown to almost 22 million in 2045 based on statistical analysis. Domestic water demand evaluates as developed country, 200 liters per day per person.

3. Environmental flow demands stay the same with 1.3 indices in the summer season due to increasing temperature to (4-3°C) by mid- century.

The projected water demand and water availability under rapid population growth and climate change condition seriously moving in unexpected directions. The future sectorial water requirement expected to increase 63% more than today's demand and available water resources will decline 14 % compared to current available water resources. Also, it is mentionable that, the monthly stream flow regime changed based on increasing temperature and deceasing snowfall in the winter season under A2 climate change scenario. Projected sectorial water demand and future available water compared in the below Figure 6.4.

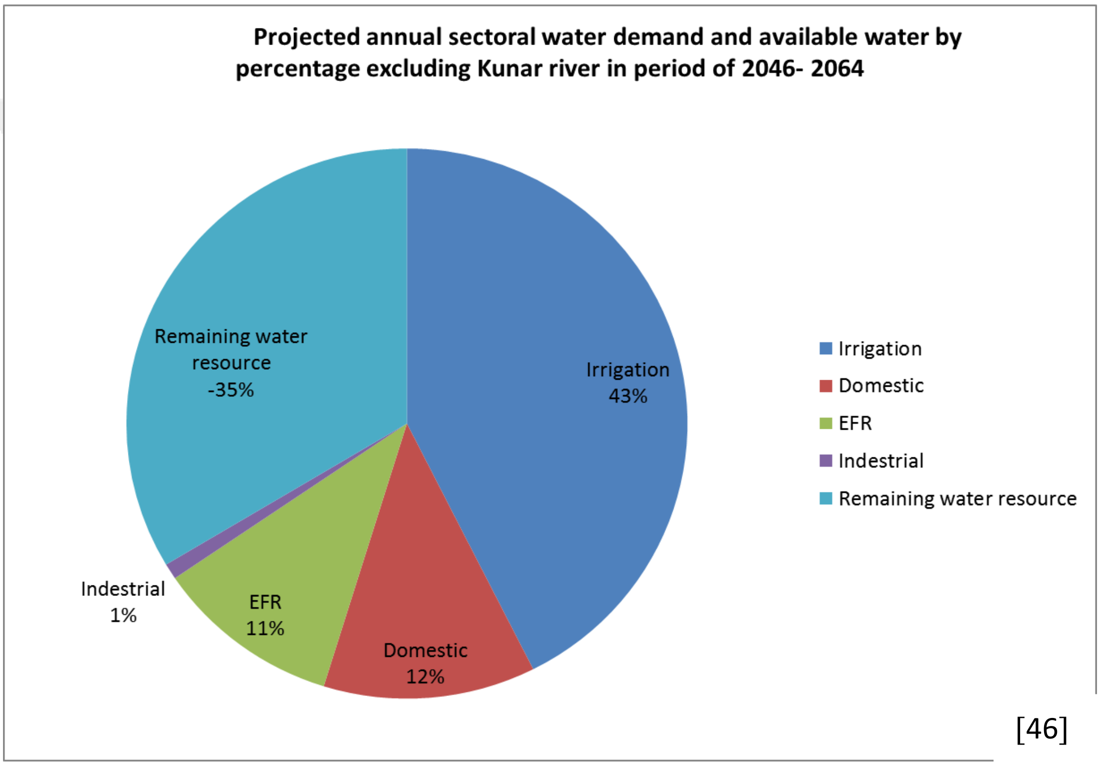



**Figure 6.5** Projected annual sectorial water demand and available water resources

### 6.8 Feasibility Outcome

The scenario analysis simulates conditions for the year 2030 and includes various possible combinations of new schemes:

- Gulbahar dam, a multipurpose scheme on Panjshir River

- Baghdar dam, a hydropower scheme on Panjshir River for which two options were evaluated, Baghdara A2, with negligible storage and Baghdara D1 with considerable storage

The schemes in the year 2030 are represented by developed conditions with the reservoirs partly filled as it would occur under routine operation. The new schemes are assumed to be operational and generating revenues, resulting in a return of investment. Incurred Operation and Maintenance costs and capital costs are being annualized.

Parameters considered in the scenario modelling and analysis include:

- Different flow scenarios (hydrological conditions reflecting future uncertainties). To characterize the monthly and inter-annual variability in stream flow the median flow as well as two mild variations are simulated.

- Irrigation condition alterations have been considered through sensitivity runs in order to assess the effects of different irrigation efficiencies.

- Different priorities for water allocation of the different schemes as well as their combinations were used to test different development options. This includes priority shifts between domestic water supply, hydropower generation, irrigation water supply and filling the reservoirs.

- A plant factor for depicting the actual productive time of the power generating assets considering maintenance needs and downtimes. Considering data availability, the analysis had to make a number of assumptions and simplifications as described in the respective report sections. In addition, only those investment options for which sufficient data (feasibility studies) were available have been considered. The main aspects that would benefit from an update include:

- Inclusion of specific investments for which feasibility study results become available;
- New findings regarding potential changes in catchment hydrology, i.e. runoff, based on anthropogenic activities and climate change;
- Political aspects that have an influence on the water utilization in the basin, i.e. that would impact on priorities;
- External factors that can have an influence on the basin, with power transfer into- or from other basins as well as power transfer to Pakistan being the most likely scenarios;
- Global aspects that could lead to changes on the food or energy market
- Price changes.

It should be noted that due to the complexity and uncertainty involved in the future development of the basin the scenarios were tested under operational conditions. Depending on what assets will finally be implemented and in what sequence as well as with what management and priorities, it will be important to conduct detailed studies for the finally agreed assets where their interaction with already existing assets, mainly during the construction and commissioning phase, is assessed in detail. The main aspects here include flow requirements during early construction (river diversion and closure) as well as impounding of the reservoir.

Flood related information, especially with regards to socioeconomic impacts of flood events, is not available in the basin and has respectively not been included in the investment plan. It is recommended that a respective study that uses flood modelling to derive flood risk zones under different discharge events and also studies socioeconomic impacts of flood events is conducted and that the results will be used to update the river basin investment plan by considering flood retention as a potential priority for the reservoirs. Providing flood retention would require reservoirs being as empty as possible which is contrary to the other sectors' needs of having full reservoirs, considering the operation of the investment assets that will finally put in place, it is recommended that a detailed study is carried out to optimize the assets with regards to their agreed function within the overall river basin system.

A time series of climate data on annual precipitation anomalies in Afghanistan and the vicinity of Afghanistan-2004 shows that severe droughts are generally characterized by three consecutive dry years. During the last century there were three of such sequences, around 1900, around 1970 and again by the end of the 20th century. The sequence of the 1970s occurred during the period for which hydrologic data are available. We have used the actual data of these years to analysis the water supply with new water supply projects under serious drought conditions. This also provides an indication of conditions that could potentially occur more frequently as a result of climate change.

- The dry conditions were chosen as three consecutive dry years in three strategic locations in the basin. These conditions were identified using the stream flow data at these three locations:

- Flow of the Panjshir River at Gulbahar, which will be used to examine the new reservoir Gulbahar: the driest observed sequence is 1975-76 to 1977-78.
- Flow of the Maidan River at Maidan, which will be used to examine the new reservoir Shatoot: the driest observed sequence is 1976-77 to 1978-79.
- Flow of the Konar River at Asmar, which will be used to examine the new reservoirs Shal and Konar A: the driest observed sequence is 1961-62 to 1963-64.
- The sequence identified for each station is represented in the figure below.

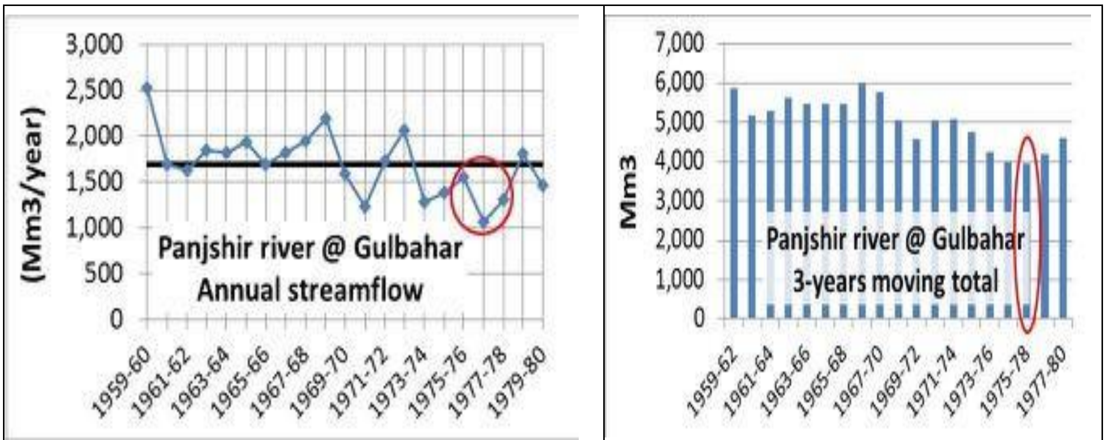



**Figure 6.6** Panjsher river annual streamflow

# CHAPTER 7

# CONCLUSION

Afghanistan is a country with a water-based development. Most of Afghanistan's people earn a living through agriculture and livestock. With increasing population and increasing urbanization in the country, as well as industrial development, water resources management is a vital asset.

Water resources in all countries of the world, especially Afghanistan, are affected by climate change and population growth, as well as poor water resources management and pollution. As a result of the research found that, Effects of climate change on the water resources in the Panjsher sub basin significantly causing changes in quantity, type (rain or snow) and timing of precipitation and causing water scarcity on some parts of Panjsher sub basin.

The effects of climate change on water quantity and water quality on the Panjsher sub basin is affecting many sectors, including human health, agriculture, energy production, ecosystems and infrastructure.

Futher more it shows that the Panjshir water sub-basin has a good energy production and economic development potential and is affected by climate change causing unbalanced river currents, time, quantity and type of rainfall resulting in significant financial and human losses. Losing its capacity and economic importance is still continuing.

Practical measures should be taken to build small irrigation dams along the river stream, construction of retaining walls, gabions on vulnerable sides of the river and to plant seedlings to absorbe seasonal rainfall and regular water management for operating welfare and growth aslo to provide economic benefits to residents.

The results propose a ranking of the development options based on water supply priority, net benefit considerations and best options for hydropower production and increased agricultural benefits.

The results also provide an implementation plan, showing which investments to implement in which order under different funding scenarios. Based on the methodology used in the analysis, the recommended solutions are robust under different stream flow conditions that represent potential future changes in the regional climate.

The main findings are:

- Securing the supply of domestic water to the existing Old Kabul city is a priority for any investment in the basin. Projection of the population, consumption rate and connection rate have shown that less than 30% of the demand from the connected population of the city can be satisfied in year 2030 with the supply from neighboring aquifers.
- The net benefit of Gulbahar is relatively small as well, which is due to its high investment cost and the relative small amount of water allocated to domestic water supply. Should it be possible technically to convey more than 100 $Mm^3$/year from Gulbahar to Old and New Kabul city, substantial greater benefits could be generated at Gulbahar for a little reduction in benefit from agriculture and hydropower, Moreover, additional domestic supply from Gulbahar would improve the reliability of the domestic water coverage under extended drought.
- Along the Panjshir and Kabul river: there is a cascading effect with the chain Gulbahar, Baghdara D1, Naghlu, Surubi I and Surubi II since the electricity production get successively increased.
- The combination of Baghdara D1 and Konar A, which are both reservoirs dedicated to electricity production, has the highest potential for increase the electricity production during winter.
- Gulbahar: as mentioned in point 3, if possible technically, the supply of domestic water to New and Old Kabul city should be greater than 100 $Mm^3$/year. Possible values are 150 $Mm^3$/year to secure further the supply under normal hydrologic conditions.

# CHAPTER 8

# RECOMMENDATIONS

Finally, while additional studies are recommended as stated above, this should not delay by the academicians in implementation of the Investment Plan and parallel researches. I therefore recommend that the government and NGOs to undertakes the following steps:

1. Prepare Investment Plans for sub basins in order to determine the total infrastructure needs and priorities for the whole country.

2. Based on the agreed development priorities, and the funding commitments from the donor, the appropriate set of infrastructure options can be decided upon.

3. The Gulbahar Dam Project has two critical issues, the possibility of existence of quaternary faults and the large number of relocation houses. The Afghan side should conduct a further survey on the active faults.

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## APPENDIX

**Table A.1** Sequent Peak Analysis for water quqantity calculation

| Time | | St (m3) | Dt(m3) | Dt-St (m3) | Vt | Vt-1 |
|---|---|---|---|---|---|---|
| 1960 | Oct | 9460800 | 35516626 | 26055826.4 | 26055826 | 0 |
| | Nov | 51321600 | 35516626 | -15804973.6 | 10250853 | 3E+07 |
| | Dec | 57801600 | 35516626 | -22284973.6 | 0 | 1E+07 |
| | Jan | 54172800 | 35516626 | -18656173.6 | 0 | 0 |
| | Feb | 56505600 | 35516626 | -20988973.6 | 0 | 0 |
| | Mar | 68947200 | 35516626 | -33430573.6 | 0 | 0 |
| | Apr | 2.15E+08 | 35516626 | -179878574 | 0 | 0 |
| | May | 1.95E+08 | 35516626 | -159920174 | 0 | 0 |
| | Jun | 47692800 | 35516626 | -12176173.6 | 0 | 0 |
| | Jul | 18714240 | 35516626 | 16802386.4 | 16802386 | 0 |
| | Aug | 4536000 | 35516626 | 30980626.4 | 47783013 | 2E+07 |
| | Sep | 3862080 | 35516626 | 31654546.4 | 79437559 | 5E+07 |
| 1961 | Oct | 25531200 | 35516626 | 9985426.4 | 89422986 | 8E+07 |
| | Nov | 63244800 | 35516626 | -27728173.6 | 61694812 | 9E+07 |
| | Dec | 63763200 | 35516626 | -28246573.6 | 33448238 | 6E+07 |
| | Jan | 67651200 | 35516626 | -32134573.6 | 1313665 | 3E+07 |
| | Feb | 66355200 | 35516626 | -30838573.6 | 0 | 1E+06 |
| | Mar | 73094400 | 35516626 | -37577773.6 | 0 | 0 |
| | Apr | 1.8E+08 | 35516626 | -144368174 | 0 | 0 |
| | May | 1.07E+08 | 35516626 | -71532973.6 | 0 | 0 |
| | Jun | 17858880 | 35516626 | 17657746.4 | 17657746 | 0 |
| | Jul | 14281920 | 35516626 | 21234706.4 | 38892453 | 2E+07 |
| | Aug | 3810240 | 35516626 | 31706386.4 | 70598839 | 4E+07 |
| | Sep | 2773440 | 35516626 | 32743186.4 | 1.03E+08 | 7E+07 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1962 | Oct | 170832960 | 35516626 | 17683666.4 | 1.21E+08 | 1E+08 |
| | Nov | 57542400 | 35516626 | -22025773.6 | 98999918 | 1E+08 |
| | Dec | 58320000 | 35516626 | -22803373.6 | 76196545 | 1E+08 |
| | Jan | 61171200 | 35516626 | -25654573.6 | 50541971 | 8E+07 |
| | Feb | 60912000 | 35516626 | -25395373.6 | 25146598 | 5E+07 |
| | Mar | 56246400 | 35516626 | -20729773.6 | 4416824 | 3E+07 |
| | Apr | 74649600 | 35516626 | -39132973.6 | 0 | 4E+06 |
| | May | 16122240 | 35516626 | 19394386.4 | 19394386 | 0 |
| | Jun | 1529280 | 35516626 | 33987346.4 | 53381733 | 2E+07 |
| | Jul | 1607040 | 35516626 | 33909586.4 | 87291319 | 5E+07 |
| | Aug | 881280 | 35516626 | 34635346.4 | 1.22E+08 | 9E+07 |
| | Sep | 751680 | 35516626 | 34764946.4 | 1.57E+08 | 1E+08 |
| 1963 | Oct | 6039360 | 35516626 | 29477266.4 | 1.86E+08 | 2E+08 |
| | Nov | 26438400 | 35516626 | 9078226.4 | 1.95E+08 | 2E+08 |
| | Dec | 51321600 | 35516626 | -15804973.6 | 1.79E+08 | 2E+08 |
| | Jan | 52876800 | 35516626 | -17360173.6 | 1.62E+08 | 2E+08 |
| | Feb | 48470400 | 35516626 | -12953773.6 | 1.49E+08 | 2E+08 |
| | Mar | 45100800 | 35516626 | -9584173.6 | 1.4E+08 | 1E+08 |
| | Apr | 34992000 | 35516626 | 524626.4002 | 1.4E+08 | 1E+08 |
| | May | 1.31E+08 | 35516626 | -95379373.6 | 44689263 | 1E+08 |
| | Jun | 11482560 | 35516626 | 24034066.4 | 68723330 | 4E+07 |
| | Jul | 1010880 | 35516626 | 34505746.4 | 1.03E+08 | 7E+07 |
| | Aug | 2203200 | 35516626 | 33313426.4 | 1.37E+08 | 1E+08 |
| | Sep | 751680 | 35516626 | 34764946.4 | 1.71E+08 | 1E+08 |
| 1964 | Oct | 1736640 | 35516626 | 33779986.4 | 2.05E+08 | 2E+08 |
| | Nov | 29030400 | 35516626 | 6486226.4 | 2.12E+08 | 2E+08 |
| | Dec | 45619200 | 35516626 | -10102573.6 | 2.01E+08 | 2E+08 |
| | Jan | 50284800 | 35516626 | -14768173.6 | 1.87E+08 | 2E+08 |
| | Feb | 50544000 | 35516626 | -15027373.6 | 1.72E+08 | 2E+08 |
| | Mar | 90201600 | 35516626 | -54684973.6 | 1.17E+08 | 2E+08 |
| | Apr | 2.49E+08 | 35516626 | -213833774 | 0 | 1E+08 |
| | May | 55728000 | 35516626 | -20211373.6 | 0 | 0 |
| | Jun | 7257600 | 35516626 | 28259026.4 | 28259026 | 0 |

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|---|---|---|---|---|---|---|
| | Jul | 2592000 | 35516626 | 32924626.4 | 61183653 | 3E+07 |
| | Aug | 1114560 | 35516626 | 34402066.4 | 95585719 | 6E+07 |
| | Sep | 907200 | 35516626 | 34609426.4 | 1.3E+08 | 1E+08 |
| 1965 | Oct | 4691520 | 35516626 | 30825106.4 | 1.61E+08 | 1E+08 |
| | Nov | 39657600 | 35516626 | -4140973.6 | 1.57E+08 | 2E+08 |
| | Dec | 51321600 | 35516626 | -15804973.6 | 1.41E+08 | 2E+08 |
| | Jan | 48470400 | 35516626 | -12953773.6 | 1.28E+08 | 1E+08 |
| | Feb | 56764800 | 35516626 | -21248173.6 | 1.07E+08 | 1E+08 |
| | Mar | 73612800 | 35516626 | -38096173.6 | 68776184 | 1E+08 |
| | Apr | 2.32E+08 | 35516626 | -196467374 | 0 | 7E+07 |
| | May | 2.41E+08 | 35516626 | -205798574 | 0 | 0 |
| | Jun | 80611200 | 35516626 | -45094573.6 | 0 | 0 |
| | Jul | 35251200 | 35516626 | 265426.4002 | 265426.4 | 0 |
| | Aug | 9486720 | 35516626 | 26029906.4 | 26295333 | 265426 |
| | Sep | 9745920 | 35516626 | 25770706.4 | 52066039 | 3E+07 |
| 1966 | Oct | 17936640 | 35516626 | 17579986.4 | 69646026 | 5E+07 |
| | Nov | 57542400 | 35516626 | -22025773.6 | 47620252 | 7E+07 |
| | Dec | 68947200 | 35516626 | -33430573.6 | 14189678 | 5E+07 |
| | Jan | 65836800 | 35516626 | -30320173.6 | 0 | 1E+07 |
| | Feb | 62985600 | 35516626 | -27468973.6 | 0 | 0 |
| | Mar | 69465600 | 35516626 | -33948973.6 | 0 | 0 |
| | Apr | 1.09E+08 | 35516626 | -73865773.6 | 0 | 0 |
| | May | 31881600 | 35516626 | 3635026.4 | 3635026 | 0 |
| | Jun | 5391360 | 35516626 | 30125266.4 | 33760293 | 4E+06 |
| | Jul | 2980800 | 35516626 | 32535826.4 | 66296119 | 3E+07 |
| | Aug | 2203200 | 35516626 | 33313426.4 | 99609546 | 7E+07 |
| | Sep | 4484160 | 35516626 | 31032466.4 | 1.31E+08 | 1E+08 |
| 1967 | Oct | 13789440 | 35516626 | 21727186.4 | 1.52E+08 | 1E+08 |
| | Nov | 41472000 | 35516626 | -5955373.6 | 1.46E+08 | 2E+08 |
| | Dec | 52358400 | 35516626 | -16841773.6 | 1.3E+08 | 1E+08 |
| | Jan | 58320000 | 35516626 | -22803373.6 | 1.07E+08 | 1E+08 |
| | Feb | 61171200 | 35516626 | -25654573.6 | 81114104 | 1E+08 |
| | Mar | 61430400 | 35516626 | -25913773.6 | 55200330 | 8E+07 |

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|---|---|---|---|---|---|---|
| | Apr | 1.56E+08 | 35516626 | -120003374 | 0 | 6E+07 |
| | May | 1.93E+08 | 35516626 | -157846574 | 0 | 0 |
| | Jun | 59097600 | 35516626 | -23580973.6 | 0 | 0 |
| | Jul | 20088000 | 35516626 | 15428626.4 | 15428626 | 0 |
| | Aug | 6791040 | 35516626 | 28725586.4 | 44154213 | 2E+07 |
| | Sep | 5287680 | 35516626 | 30228946.4 | 74383159 | 4E+07 |
| 1968 | Oct | 23483520 | 35516626 | 12033106.4 | 86416266 | 7E+07 |
| | Nov | 56246400 | 35516626 | -20729773.6 | 65686492 | 9E+07 |
| | Dec | 66873600 | 35516626 | -31356973.6 | 34329518 | 7E+07 |
| | Jan | 72316800 | 35516626 | -36800173.6 | 0 | 3E+07 |
| | Feb | 69984000 | 35516626 | -34467373.6 | 0 | 0 |
| | Mar | 1.18E+08 | 35516626 | -82419373.6 | 0 | 0 |
| | Apr | 1.47E+08 | 35516626 | -111449774 | 0 | 0 |
| | May | 1.08E+08 | 35516626 | -72828973.6 | 0 | 0 |
| | Jun | 35769600 | 35516626 | -252973.6 | 0 | 0 |
| | Jul | 3551040 | 35516626 | 31965586.4 | 31965586 | 0 |
| | Aug | 1270080 | 35516626 | 34246546.4 | 66212133 | 3E+07 |
| | Sep | 2721600 | 35516626 | 32795026.4 | 99007159 | 7E+07 |
| 1969 | Oct | 16951680 | 35516626 | 18564946.4 | 1.18E+08 | 1E+08 |
| | Nov | 47174400 | 35516626 | -11657773.6 | 1.06E+08 | 1E+08 |
| | Dec | 68947200 | 35516626 | -33430573.6 | 72483758 | 1E+08 |
| | Jan | 72057600 | 35516626 | -36540973.6 | 35942785 | 7E+07 |
| | Feb | 73612800 | 35516626 | -38096173.6 | 0 | 4E+07 |
| | Mar | 84758400 | 35516626 | -49241773.6 | 0 | 0 |
| | Apr | 80092800 | 35516626 | -44576173.6 | 0 | 0 |
| | May | 27475200 | 35516626 | 8041426.4 | 8041426 | 0 |
| | Jun | 5832000 | 35516626 | 29684626.4 | 37726053 | 8E+06 |
| | Jul | 855360 | 35516626 | 34661266.4 | 72387319 | 4E+07 |
| | Aug | 803520 | 35516626 | 34713106.4 | 1.07E+08 | 7E+07 |
| | Sep | 829440 | 35516626 | 34687186.4 | 1.42E+08 | 1E+08 |
| 1970 | Oct | 5391360 | 35516626 | 30125266.4 | 1.72E+08 | 1E+08 |
| | Nov | 44841600 | 35516626 | -9324973.6 | 1.63E+08 | 2E+08 |
| | Dec | 45100800 | 35516626 | -9584173.6 | 1.53E+08 | 2E+08 |

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|---|---|---|---|---|---|---|
| | Jan | 51062400 | 35516626 | -15545773.6 | 1.37E+08 | 2E+08 |
| | Feb | 47433600 | 35516626 | -11916973.6 | 1.26E+08 | 1E+08 |
| | Mar | 46656000 | 35516626 | -11139373.6 | 1.14E+08 | 1E+08 |
| | Apr | 15992640 | 35516626 | 19523986.4 | 1.34E+08 | 1E+08 |
| | May | 1140480 | 35516626 | 34376146.4 | 1.68E+08 | 1E+08 |
| | Jun | 388800 | 35516626 | 35127826.4 | 2.03E+08 | 2E+08 |
| | Jul | 3473280 | 35516626 | 32043346.4 | 2.35E+08 | 2E+08 |
| | Aug | 440640 | 35516626 | 35075986.4 | 2.71E+08 | 2E+08 |
| | Sep | 103680 | 35516626 | 35412946.4 | 3.06E+08 | 3E+08 |
| 1971 | Oct | 155520 | 35516626 | 35361106.4 | 3.41E+08 | 3E+08 |
| | Nov | 11041920 | 35516626 | 24474706.4 | 3.66E+08 | 3E+08 |
| | Dec | 33177600 | 35516626 | 2339026.4 | 3.68E+08 | 4E+08 |
| | Jan | 39657600 | 35516626 | -4140973.6 | 3.64E+08 | 4E+08 |
| | Feb | 43286400 | 35516626 | -7769773.6 | 3.56E+08 | 4E+08 |
| | Mar | 49248000 | 35516626 | -13731373.6 | 3.42E+08 | 4E+08 |
| | Apr | 30067200 | 35516626 | 5449426.4 | 3.48E+08 | 3E+08 |
| | May | 1814400 | 35516626 | 33702226.4 | 3.82E+08 | 3E+08 |
| | Jun | 1140480 | 35516626 | 34376146.4 | 4.16E+08 | 4E+08 |
| | Jul | 336960 | 35516626 | 35179666.4 | 4.51E+08 | 4E+08 |
| | Aug | 336960 | 35516626 | 35179666.4 | 4.86E+08 | 5E+08 |
| | Sep | 440640 | 35516626 | 35075986.4 | 5.21E+08 | 5E+08 |
| 1972 | Oct | 570240 | 35516626 | 34946386.4 | 5.56E+08 | 5E+08 |
| | Nov | 1451520 | 35516626 | 34065106.4 | 5.9E+08 | 6E+08 |
| | Dec | 17547840 | 35516626 | 17968786.4 | 6.08E+08 | 6E+08 |
| | Jan | 29808000 | 35516626 | 5708626.4 | 6.14E+08 | 6E+08 |
| | Feb | 37843200 | 35516626 | -2326573.6 | 6.12E+08 | 6E+08 |
| | Mar | 75686400 | 35516626 | -40169773.6 | 5.72E+08 | 6E+08 |
| | Apr | 1.39E+08 | 35516626 | -103414574 | 4.68E+08 | 6E+08 |
| | May | 1.39E+08 | 35516626 | -103932974 | 3.64E+08 | 5E+08 |
| | Jun | 17625600 | 35516626 | 17891026.4 | 3.82E+08 | 4E+08 |
| | Jul | 4769280 | 35516626 | 30747346.4 | 4.13E+08 | 4E+08 |
| | Aug | 1944000 | 35516626 | 33572626.4 | 4.47E+08 | 4E+08 |
| | Sep | 103680 | 35516626 | 35412946.4 | 4.82E+08 | 4E+08 |

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|---|---|---|---|---|---|---|
| 1973 | Oct | 2047680 | 35516626 | 33468946.4 | 5.15E+08 | 5E+08 |
| | Nov | 23068800 | 35516626 | 12447826.4 | 5.28E+08 | 5E+08 |
| | Dec | 42768000 | 35516626 | -7251373.6 | 5.21E+08 | 5E+08 |
| | Jan | 49507200 | 35516626 | -13990573.6 | 5.07E+08 | 5E+08 |
| | Feb | 48729600 | 35516626 | -13212973.6 | 4.93E+08 | 5E+08 |
| | Mar | 1.01E+08 | 35516626 | -65830573.6 | 4.28E+08 | 5E+08 |
| | Apr | 2.05E+08 | 35516626 | -168992174 | 2.59E+08 | 4E+08 |
| | May | 44582400 | 35516626 | -9065773.6 | 2.49E+08 | 3E+08 |
| | Jun | 3343680 | 35516626 | 32172946.4 | 2.82E+08 | 2E+08 |
| | Jul | 1918080 | 35516626 | 33598546.4 | 3.15E+08 | 3E+08 |
| | Aug | 1010880 | 35516626 | 34505746.4 | 3.5E+08 | 3E+08 |
| | Sep | 622080 | 35516626 | 34894546.4 | 3.85E+08 | 3E+08 |
| 1974 | Oct | 2928960 | 35516626 | 32587666.4 | 4.17E+08 | 4E+08 |
| | Nov | 21850560 | 35516626 | 13666066.4 | 4.31E+08 | 4E+08 |
| | Dec | 46137600 | 35516626 | -10620973.6 | 4.2E+08 | 4E+08 |
| | Jan | 55468800 | 35516626 | -19952173.6 | 4E+08 | 4E+08 |
| | Feb | 55209600 | 35516626 | -19692973.6 | 3.81E+08 | 4E+08 |
| | Mar | 59097600 | 35516626 | -23580973.6 | 3.57E+08 | 4E+08 |
| | Apr | 57542400 | 35516626 | -22025773.6 | 3.35E+08 | 4E+08 |
| | May | 5417280 | 35516626 | 30099346.4 | 3.65E+08 | 3E+08 |
| | Jun | 5495040 | 35516626 | 30021586.4 | 3.95E+08 | 4E+08 |
| | Jul | 311040 | 35516626 | 35205586.4 | 4.3E+08 | 4E+08 |
| | Aug | 25920 | 35516626 | 35490706.4 | 4.66E+08 | 4E+08 |
| | Sep | 259200 | 35516626 | 35257426.4 | 5.01E+08 | 5E+08 |
| 1975 | Oct | 518400 | 35516626 | 34998226.4 | 5.36E+08 | 5E+08 |
| | Nov | 11430720 | 35516626 | 24085906.4 | 5.6E+08 | 5E+08 |
| | Dec | 27216000 | 35516626 | 8300626.4 | 5.69E+08 | 6E+08 |
| | Jan | 43804800 | 35516626 | -8288173.6 | 5.6E+08 | 6E+08 |
| | Feb | 47692800 | 35516626 | -12176173.6 | 5.48E+08 | 6E+08 |
| | Mar | 63244800 | 35516626 | -27728173.6 | 5.2E+08 | 5E+08 |
| | Apr | 1.13E+08 | 35516626 | -77494573.6 | 4.43E+08 | 5E+08 |
| | May | 35510400 | 35516626 | 6226.400206 | 4.43E+08 | 4E+08 |
| | Jun | 4432320 | 35516626 | 31084306.4 | 4.74E+08 | 4E+08 |

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|---|---|---|---|---|---|---|
| | Jul | 648000 | 35516626 | 34868626.4 | 5.09E+08 | 5E+08 |
| | Aug | 1555200 | 35516626 | 33961426.4 | 5.43E+08 | 5E+08 |
| | Sep | 388800 | 35516626 | 35127826.4 | 5.78E+08 | 5E+08 |
| 1976 | Oct | 311040 | 35516626 | 35205586.4 | 6.13E+08 | 6E+08 |
| | Nov | 13556160 | 35516626 | 21960466.4 | 6.35E+08 | 6E+08 |
| | Dec | 34992000 | 35516626 | 524626.4002 | 6.36E+08 | 6E+08 |
| | Jan | 43027200 | 35516626 | -7510573.6 | 6.28E+08 | 6E+08 |
| | Feb | 46915200 | 35516626 | -11398573.6 | 6.17E+08 | 6E+08 |
| | Mar | 64022400 | 35516626 | -28505773.6 | 5.88E+08 | 6E+08 |
| | Apr | 1.74E+08 | 35516626 | -138406574 | 4.5E+08 | 6E+08 |
| | May | 92016000 | 35516626 | -56499373.6 | 3.93E+08 | 4E+08 |
| | Jun | 8190720 | 35516626 | 27325906.4 | 4.21E+08 | 4E+08 |
| | Jul | 4484160 | 35516626 | 31032466.4 | 4.52E+08 | 4E+08 |
| | Aug | 622080 | 35516626 | 34894546.4 | 4.86E+08 | 5E+08 |
| | Sep | 518400 | 35516626 | 34998226.4 | 5.21E+08 | 5E+08 |
| 1977 | Oct | 1658880 | 35516626 | 33857746.4 | 5.55E+08 | 5E+08 |
| | Nov | 25479360 | 35516626 | 10037266.4 | 5.65E+08 | 6E+08 |
| | Dec | 43545600 | 35516626 | -8028973.6 | 5.57E+08 | 6E+08 |
| | Jan | 56505600 | 35516626 | -20988973.6 | 5.36E+08 | 6E+08 |
| | Feb | 59097600 | 35516626 | -23580973.6 | 5.13E+08 | 5E+08 |
| | Mar | 47433600 | 35516626 | -11916973.6 | 5.01E+08 | 5E+08 |
| | Apr | 53395200 | 35516626 | -17878573.6 | 4.83E+08 | 5E+08 |
| | May | 3240000 | 35516626 | 32276626.4 | 5.15E+08 | 5E+08 |
| | Jun | 570240 | 35516626 | 34946386.4 | 5.5E+08 | 5E+08 |
| | Jul | 362880 | 35516626 | 35153746.4 | 5.85E+08 | 6E+08 |
| | Aug | 388800 | 35516626 | 35127826.4 | 6.2E+08 | 6E+08 |
| | Sep | 336960 | 35516626 | 35179666.4 | 6.56E+08 | 6E+08 |
| 1978 | Oct | 466560 | 35516626 | 35050066.4 | 6.91E+08 | 7E+08 |
| | Nov | 10964160 | 35516626 | 24552466.4 | 7.15E+08 | 7E+08 |
| | Dec | 28252800 | 35516626 | 7263826.4 | 7.23E+08 | 7E+08 |
| | Jan | 35510400 | 35516626 | 6226.400206 | 7.23E+08 | 7E+08 |
| | Feb | 41472000 | 35516626 | -5955373.6 | 7.17E+08 | 7E+08 |
| | Mar | 47952000 | 35516626 | -12435373.6 | 7.04E+08 | 7E+08 |

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|---|---|---|---|---|---|---|
| | Apr | 42768000 | 35516626 | -7251373.6 | 6.97E+08 | 7E+08 |
| | May | 7283520 | 35516626 | 28233106.4 | 7.25E+08 | 7E+08 |
| | Jun | 3214080 | 35516626 | 32302546.4 | 7.57E+08 | 7E+08 |
| | Jul | 22576320 | 35516626 | 12940306.4 | 7.7E+08 | 8E+08 |
| | Aug | 14541120 | 35516626 | 20975506.4 | 7.91E+08 | 8E+08 |
| | Sep | 1477440 | 35516626 | 34039186.4 | 8.25E+08 | 8E+08 |
| 1979 | Oct | 596160 | 35516626 | 34920466.4 | 8.6E+08 | 8E+08 |
| | Nov | 11067840 | 35516626 | 24448786.4 | 8.85E+08 | 9E+08 |
| | Dec | 26438400 | 35516626 | 9078226.4 | 8.94E+08 | 9E+08 |
| | Jan | 34214400 | 35516626 | 1302226.4 | 8.95E+08 | 9E+08 |
| | Feb | 34992000 | 35516626 | 524626.4002 | 8.96E+08 | 9E+08 |
| | Mar | 37584000 | 35516626 | -2067373.6 | 8.94E+08 | 9E+08 |
| | Apr | 89683200 | 35516626 | -54166573.6 | 8.39E+08 | 9E+08 |
| | May | 33436800 | 35516626 | 2079826.4 | 8.42E+08 | 8E+08 |
| | Jun | 751680 | 35516626 | 34764946.4 | 8.76E+08 | 8E+08 |
| | Jul | 207360 | 35516626 | 35309266.4 | 9.12E+08 | 9E+08 |
| | Aug | 7957440 | 35516626 | 27559186.4 | 9.39E+08 | 9E+08 |
| | Sep | 544320 | 35516626 | 34972306.4 | 9.74E+08 | 9E+08 |
| 1980 | Oct | 570240 | 35516626 | 34946386.4 | 1.01E+09 | 1E+09 |
| | Nov | 10860480 | 35516626 | 24656146.4 | 1.03E+09 | 1E+09 |
| | Dec | 30326400 | 35516626 | 5190226.4 | 1.04E+09 | 1E+09 |
| | Jan | 39398400 | 35516626 | -3881773.6 | 1.04E+09 | 1E+09 |
| | Feb | 46656000 | 35516626 | -11139373.6 | 1.02E+09 | 1E+09 |
| | Mar | 72057600 | 35516626 | -36540973.6 | 9.87E+08 | 1E+09 |
| | Apr | 2.15E+08 | 35516626 | -179100974 | 8.08E+08 | 1E+09 |
| | May | 69206400 | 35516626 | -33689773.6 | 7.75E+08 | 8E+08 |
| | Jun | 3784320 | 35516626 | 31732306.4 | 8.06E+08 | 8E+08 |
| | Jul | 1088640 | 35516626 | 34427986.4 | 8.41E+08 | 8E+08 |
| | Aug | 259200 | 35516626 | 35257426.4 | 8.76E+08 | 8E+08 |
| | Sep | 388800 | 35516626 | 35127826.4 | 9.11E+08 | 9E+08 |
| 2005 | Oct | 7257600 | 35516626 | 28259026.4 | 9.39E+08 | 9E+08 |
| | Nov | 31207680 | 35516626 | 4308946.4 | 9.44E+08 | 9E+08 |
| | Dec | 45748800 | 35516626 | -10232173.6 | 9.33E+08 | 9E+08 |

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|---|---|---|---|---|---|---|
| | Jan | 51477120 | 35516626 | -15960493.6 | 9.17E+08 | 9E+08 |
| | Feb | 53161920 | 35516626 | -17645293.6 | 9E+08 | 9E+08 |
| | Mar | 66899520 | 35516626 | -31382893.6 | 8.68E+08 | 9E+08 |
| | Apr | 1.24E+08 | 35516626 | -88899373.6 | 7.8E+08 | 9E+08 |
| | May | 73353600 | 35516626 | -37836973.6 | 7.42E+08 | 8E+08 |
| | Jun | 4446144 | 35516626 | 31070482.4 | 7.73E+08 | 7E+08 |
| | Jul | 2025105 | 35516626 | 33491521.88 | 8.06E+08 | 8E+08 |
| | Aug | 1632124 | 35516626 | 33884502.53 | 8.4E+08 | 8E+08 |
| | Sep | 4505328 | 35516626 | 31011298.4 | 8.71E+08 | 8E+08 |
| 2006 | Oct | 5963272 | 35516626 | 29553354.14 | 9.01E+08 | 9E+08 |
| | Nov | 22281696 | 35516626 | 13234930.4 | 9.14E+08 | 9E+08 |
| | Dec | 49498839 | 35516626 | -13982212.3 | 9E+08 | 9E+08 |
| | Jan | 42642581 | 35516626 | -7125954.24 | 8.93E+08 | 9E+08 |
| | Feb | 40638857 | 35516626 | -5122230.74 | 8.88E+08 | 9E+08 |
| | Mar | 78520877 | 35516626 | -43004251 | 8.45E+08 | 9E+08 |
| | Apr | 46195488 | 35516626 | -10678861.6 | 8.34E+08 | 8E+08 |
| | May | 19782813 | 35516626 | 15733813.5 | 8.5E+08 | 8E+08 |
| | Jun | 20044800 | 35516626 | 15471826.4 | 8.65E+08 | 8E+08 |
| | Jul | 16638968 | 35516626 | 18877658.66 | 8.84E+08 | 9E+08 |
| | Aug | 10033548 | 35516626 | 25483078.01 | 9.1E+08 | 9E+08 |
| | Sep | 3196800 | 35516626 | 32319826.4 | 9.42E+08 | 9E+08 |
| 2007 | Oct | 1505032 | 35516626 | 34011594.14 | 9.76E+08 | 9E+08 |
| | Nov | 8210592 | 35516626 | 27306034.4 | 1E+09 | 1E+09 |
| | Dec | 25889899 | 35516626 | 9626727.045 | 1.01E+09 | 1E+09 |
| | Jan | 35562240 | 35516626 | -45613.5998 | 1.01E+09 | 1E+09 |
| | Feb | 40350034 | 35516626 | -4833407.89 | 1.01E+09 | 1E+09 |
| | Mar | 2.18E+08 | 35516626 | -182449670 | 8.26E+08 | 1E+09 |
| | Apr | 1.97E+08 | 35516626 | -161240366 | 6.64E+08 | 8E+08 |
| | May | 5866281 | 35516626 | 29650345.11 | 6.94E+08 | 7E+08 |
| | Jun | 1437005 | 35516626 | 34079621.6 | 7.28E+08 | 7E+08 |
| | Jul | 447997.9 | 35516626 | 35068628.46 | 7.63E+08 | 7E+08 |
| | Aug | 374836.6 | 35516626 | 35141789.76 | 7.98E+08 | 8E+08 |
| | Sep | 302745.6 | 35516626 | 35213880.8 | 8.33E+08 | 8E+08 |

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|---|---|---|---|---|---|---|
| 2008 | Oct | 5734173 | 35516626 | 29782453.5 | 8.63E+08 | 8E+08 |
| | Nov | 9600768 | 35516626 | 25915858.4 | 8.89E+08 | 9E+08 |
| | Dec | 23603923 | 35516626 | 11912703.82 | 9.01E+08 | 9E+08 |
| | Jan | 35535484 | 35516626 | -18857.4708 | 9.01E+08 | 9E+08 |
| | Feb | 58990345 | 35516626 | -23473718.4 | 8.78E+08 | 9E+08 |
| | Mar | 73579355 | 35516626 | -38062728.4 | 8.4E+08 | 9E+08 |
| | Apr | 70396992 | 35516626 | -34880365.6 | 8.05E+08 | 8E+08 |
| | May | 1974101 | 35516626 | 33542525.76 | 8.38E+08 | 8E+08 |
| | Jun | 1498176 | 35516626 | 34018450.4 | 8.72E+08 | 8E+08 |
| | Jul | 1725770 | 35516626 | 33790856.08 | 9.06E+08 | 9E+08 |
| | Aug | 1403861 | 35516626 | 34112765.76 | 9.4E+08 | 9E+08 |
| | Sep | 1360800 | 35516626 | 34155826.4 | 9.74E+08 | 9E+08 |
| 2009 | Oct | 1460717 | 35516626 | 34055908.98 | 1.01E+09 | 1E+09 |
| | Nov | 8208000 | 35516626 | 27308626.4 | 1.04E+09 | 1E+09 |
| | Dec | 20359742 | 35516626 | 15156884.46 | 1.05E+09 | 1E+09 |
| | Jan | 28980232 | 35516626 | 6536394.142 | 1.06E+09 | 1E+09 |
| | Feb | 31052160 | 35516626 | 4464466.4 | 1.06E+09 | 1E+09 |
| | Mar | 51764748 | 35516626 | -16248122 | 1.05E+09 | 1E+09 |
| | Apr | 1.47E+08 | 35516626 | -111912014 | 9.34E+08 | 1E+09 |
| | May | 74237388 | 35516626 | -38720762 | 8.95E+08 | 9E+08 |
| | Jun | 5320512 | 35516626 | 30196114.4 | 9.25E+08 | 9E+08 |
| | Jul | 1939819 | 35516626 | 33576807.05 | 9.59E+08 | 9E+08 |
| | Aug | 2048516 | 35516626 | 33468110.27 | 9.92E+08 | 1E+09 |
| | Sep | 2246400 | 35516626 | 33270226.4 | 1.03E+09 | 1E+09 |
| 2010 | Oct | 1423092 | 35516626 | 34093534.79 | 1.06E+09 | 1E+09 |
| | Nov | 7788096 | 35516626 | 27728530.4 | 1.09E+09 | 1E+09 |
| | Dec | 26110637 | 35516626 | 9405988.981 | 1.1E+09 | 1E+09 |
| | Jan | 33426766 | 35516626 | 2089859.949 | 1.1E+09 | 1E+09 |
| | Feb | 40083429 | 35516626 | -4566802.17 | 1.09E+09 | 1E+09 |
| | Mar | 50544000 | 35516626 | -15027373.6 | 1.08E+09 | 1E+09 |
| | Apr | 54734400 | 35516626 | -19217773.6 | 1.06E+09 | 1E+09 |
| | May | 14866374 | 35516626 | 20650252.21 | 1.08E+09 | 1E+09 |
| | Jun | 1086048 | 35516626 | 34430578.4 | 1.12E+09 | 1E+09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Jul | 1780704 | 35516626 | 33735922.4 | 1.15E+09 | 1E+09 |
| | Aug | 13079566 | 35516626 | 22437059.95 | 1.17E+09 | 1E+09 |
| | Sep | 3809376 | 35516626 | 31707250.4 | 1.2E+09 | 1E+09 |
| 2011 | Oct | 4838679 | 35516626 | 30677947.69 | 1.23E+09 | 1E+09 |
| | Nov | 8233056 | 35516626 | 27283570.4 | 1.26E+09 | 1E+09 |
| | Dec | 24951763 | 35516626 | 10564863.82 | 1.27E+09 | 1E+09 |
| | Jan | 26042075 | 35516626 | 9474551.561 | 1.28E+09 | 1E+09 |
| | Feb | 26300469 | 35516626 | 9216157.829 | 1.29E+09 | 1E+09 |
| | Mar | 27791257 | 35516626 | 7725369.626 | 1.3E+09 | 1E+09 |
| | Apr | 46949760 | 35516626 | -11433133.6 | 1.29E+09 | 1E+09 |
| | May | 14083757 | 35516626 | 21432868.98 | 1.31E+09 | 1E+09 |
| | Jun | 3090528 | 35516626 | 32426098.4 | 1.34E+09 | 1E+09 |
| | Jul | 1878615 | 35516626 | 33638011.69 | 1.37E+09 | 1E+09 |
| | Aug | 8352929 | 35516626 | 27163697.37 | 1.4E+09 | 1E+09 |
| | Sep | 4637952 | 35516626 | 30878674.4 | 1.43E+09 | 1E+09 |
| 2012 | Oct | 3652212 | 35516626 | 31864414.79 | 1.46E+09 | 1E+09 |
| | Nov | 3773088 | 35516626 | 31743538.4 | 1.5E+09 | 1E+09 |
| | Dec | 15323737 | 35516626 | 20192889.63 | 1.52E+09 | 1E+09 |
| | Jan | 25002766 | 35516626 | 10513859.95 | 1.53E+09 | 2E+09 |
| | Feb | 28878455 | 35516626 | 6638171.228 | 1.53E+09 | 2E+09 |
| | Mar | 51840000 | 35516626 | -16323373.6 | 1.52E+09 | 2E+09 |
| | Apr | 45515520 | 35516626 | -9998893.6 | 1.51E+09 | 2E+09 |
| | May | 15375577 | 35516626 | 20141049.63 | 1.53E+09 | 2E+09 |
| | Jun | 8121600 | 35516626 | 27395026.4 | 1.55E+09 | 2E+09 |
| | Jul | 1934886 | 35516626 | 33581740.21 | 1.59E+09 | 2E+09 |
| | Aug | 733368.8 | 35516626 | 34783257.63 | 1.62E+09 | 2E+09 |
| | Sep | 8903520 | 35516626 | 26613106.4 | 1.65E+09 | 2E+09 |
| 2013 | Oct | 3181471 | 35516626 | 32335155.43 | 1.68E+09 | 2E+09 |
| | Nov | 3672000 | 35516626 | 31844626.4 | 1.71E+09 | 2E+09 |
| | Dec | 6806926 | 35516626 | 28709699.95 | 1.74E+09 | 2E+09 |
| | Jan | 12186581 | 35516626 | 23330045.76 | 1.77E+09 | 2E+09 |
| | Feb | 14256000 | 35516626 | 21260626.4 | 1.79E+09 | 2E+09 |
| | Mar | 88245058 | 35516626 | -52728431.7 | 1.73E+09 | 2E+09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Apr | 1.25E+08 | 35516626 | -89124013.6 | 1.64E+09 | 2E+09 |
| | May | 80441466 | 35516626 | -44924839.4 | 1.6E+09 | 2E+09 |
| | Jun | 2739744 | 35516626 | 32776882.4 | 1.63E+09 | 2E+09 |
| | Jul | 3181471 | 35516626 | 32335155.43 | 1.66E+09 | 2E+09 |
| | Aug | 2240826 | 35516626 | 33275800.59 | 1.7E+09 | 2E+09 |
| | Sep | 1296000 | 35516626 | 34220626.4 | 1.73E+09 | 2E+09 |
| 2014 | Oct | 3051871 | 35516626 | 32464755.43 | 1.76E+09 | 2E+09 |
| | Nov | 5486400 | 35516626 | 30030226.4 | 1.79E+09 | 2E+09 |
| | Dec | 26379871 | 35516626 | 9136755.432 | 1.8E+09 | 2E+09 |
| | Jan | 45778065 | 35516626 | -10261438.1 | 1.79E+09 | 2E+09 |
| | Feb | 54524571 | 35516626 | -19007945 | 1.77E+09 | 2E+09 |
| | Mar | 76708986 | 35516626 | -41192359.4 | 1.73E+09 | 2E+09 |
| | Apr | 1.16E+08 | 35516626 | -80665453.6 | 1.65E+09 | 2E+09 |
| | May | 1.28E+08 | 35516626 | -92578341.3 | 1.56E+09 | 2E+09 |
| | Jun | 75945600 | 35516626 | -40428973.6 | 1.52E+09 | 2E+09 |
| | Jul | 4230813 | 35516626 | 31285813.5 | 1.55E+09 | 2E+09 |
| | Aug | 1759215 | 35516626 | 33757410.92 | 1.58E+09 | 2E+09 |
| | Sep | 1263168 | 35516626 | 34253458.4 | 1.62E+09 | 2E+09 |
| 2015 | Oct | 6714116 | 35516626 | 28802510.27 | 1.65E+09 | 2E+09 |
| | Nov | 11557728 | 35516626 | 23958898.4 | 1.67E+09 | 2E+09 |
| | Dec | 22241032 | 35516626 | 13275594.14 | 1.69E+09 | 2E+09 |
| | Jan | 27172521 | 35516626 | 8344105.11 | 1.69E+09 | 2E+09 |
| | Feb | 28428686 | 35516626 | 7087940.686 | 1.7E+09 | 2E+09 |
| | Mar | 35042168 | 35516626 | 474458.6583 | 1.7E+09 | 2E+09 |
| | Apr | 31564512 | 35516626 | 3952114.4 | 1.71E+09 | 2E+09 |
| | May | 35249528 | 35516626 | 267098.6583 | 1.71E+09 | 2E+09 |
| | Jun | 10568448 | 35516626 | 24948178.4 | 1.73E+09 | 2E+09 |
| | Jul | 6066952 | 35516626 | 29449674.14 | 1.76E+09 | 2E+09 |
| | Aug | 4768444 | 35516626 | 30748182.53 | 1.79E+09 | 2E+09 |
| | Sep | 5652288 | 35516626 | 29864338.4 | 1.82E+09 | 2E+09 |
| 2016 | Oct | 3771778 | 35516626 | 31744848.34 | 1.85E+09 | 2E+09 |
| | Nov | 22540032 | 35516626 | 12976594.4 | 1.87E+09 | 2E+09 |
| | Dec | 28808826 | 35516626 | 6707800.594 | 1.87E+09 | 2E+09 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Jan | 38010426 | 35516626 | -2493799.41 | 1.87E+09 | 2E+09 |
| | Feb | 25455228 | 35516626 | 10061398.81 | 1.88E+09 | 2E+09 |
| | Mar | 55049063 | 35516626 | -19532436.8 | 1.86E+09 | 2E+09 |
| | Apr | 1.15E+08 | 35516626 | -79969069.6 | 1.78E+09 | 2E+09 |
| | May | 87971644 | 35516626 | -52455017.5 | 1.73E+09 | 2E+09 |
| | Jun | 7010150 | 35516626 | 28506476 | 1.76E+09 | 2E+09 |
| | Jul | 1675268 | 35516626 | 33841358.27 | 1.79E+09 | 2E+09 |
| | Aug | 1986308 | 35516626 | 33530318.27 | 1.82E+09 | 2E+09 |
| | Sep | 1719014 | 35516626 | 33797612 | 1.86E+09 | 2E+09 |
| 2017 | Oct | 2707135 | 35516626 | 32809491.43 | 1.89E+09 | 2E+09 |
| | Nov | 6872947 | 35516626 | 28643679.2 | 1.92E+09 | 2E+09 |
| | Dec | 15725915 | 35516626 | 19790711.56 | 1.94E+09 | 2E+09 |
| | Jan | 27338075 | 35516626 | 8178551.561 | 1.95E+09 | 2E+09 |
| | Feb | 51478971 | 35516626 | -15962345 | 1.93E+09 | 2E+09 |
| | Mar | 49222916 | 35516626 | -13706289.7 | 1.92E+09 | 2E+09 |
| | Apr | 69958944 | 35516626 | -34442317.6 | 1.88E+09 | 2E+09 |
| | May | 6320299 | 35516626 | 29196327.05 | 1.91E+09 | 2E+09 |
| | Jun | 1975622 | 35516626 | 33541004 | 1.95E+09 | 2E+09 |
| | Jul | 1681372 | 35516626 | 33835254.53 | 1.98E+09 | 2E+09 |
| | Aug | 969240.8 | 35516626 | 34547385.63 | 2.01E+09 | 2E+09 |
| | Sep | 1073174 | 35516626 | 34443452 | 2.05E+09 | 2E+09 |
| | | | | | | 2E+09 |
| | | | | Max :=> | 2.05E+09 | |

**Table A.2** Monthly mean water discharge ($m^3$/sec)

(1960-1980) & (2005 - 2017)

| River | | Panjshir | | | | | Code | 1-8.L00 | | | | Elevation | | | 1625 m+m.s.l | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | | Tang-i-Gulbahar | | | | | Code | 1-8.L00-5A | | | | Drainage arae | | | 3565 Km2 | |
| Gage | | Staff/Recorder | | | | | Latitude | 35.15932778 | | | | Longitude | | | 69.28868330 | |
| Year | Monthly Mean Water Discharge ( $m^3$/sec) | | | | | | | | | | | | Yearly summary | | | |
| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Min | Mean | Max | Runoff($Mm^3$) |
| 1960 | 17.3 | 15.4 | 12.2 | 9.58 | 10.1 | 16.2 | 37.8 | 110.0 | 306 | 298 | 93.5 | 33.5 | 8.00 | 80.2 | 461 | 2536 |
| 1961 | 20.3 | 16.1 | 12.4 | 9.64 | 8.07 | 9.15 | 25.4 | 92.4 | 235 | 138 | 52.8 | 27.7 | 6.00 | 54.0 | 368 | 1703 |
| 1962 | 17.7 | 14.7 | 10.5 | 8.82 | 7.84 | 8.48 | 24.3 | 57.8 | 238 | 153 | 48.6 | 29.5 | 51.7 | 51.7 | 351 | 1630 |
| 1963 | 17.9 | 13.4 | 9.70 | 7.44 | 7.57 | 11.7 | 27.4 | 75.6 | 316 | 162 | 41.3 | 13.6 | 6.70 | 58.6 | 394 | 1848 |
| 1964 | 12.3 | 10.5 | 9.74 | 7.78 | 7.46 | 12.6 | 40.8 | 99.7 | 226 | 191 | 54.1 | 21.6 | 6.70 | 57.8 | 390 | 1828 |
| 1965 | 15.4 | 13.4 | 12.9 | 11.9 | 11.7 | 15.2 | 38.4 | 90.5 | 202 | 231 | 68.5 | 28.2 | 10.0 | 61.6 | 300 | 1252 |
| 1966 | 22.3 | 18.1 | 14.8 | 10.7 | 10.6 | 14.4 | 39.0 | 80.7 | 228 | 120 | 60.0 | 25.1 | 9.4 | 53.6 | 335 | 1694 |
| 1967 | 16.6 | 13.0 | 10.4 | 9.22 | 12.9 | 14.1 | 35.5 | 77.1 | 219 | 184 | 72.3 | 30.5 | 7.20 | 58.0 | 358 | 1830 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1968 | 17.2 | 12.9 | 13.6 | 13.3 | 12.2 | 23.4 | 37.1 | 64.2 | 246 | 203 | 73.9 | 26.3 | 9.44 | 61.9 | 412 | 1959 |
| 1969 | 19.9 | 16.8 | 16.8 | 13.4 | 11.6 | 19.1 | 37.8 | 88.8 | 257 | 222 | 99.4 | 36.3 | 11.0 | 75.5 | 424 | 2210 |
| 1970 | 27.1 | 24.3 | 19.3 | 17.2 | 14.1 | 14.4 | 41.9 | 121.0 | 178 | 74.6 | 48.9 | 0.27 | 12.3 | 50.7 | 350 | 1602 |
| 1971 | 15.0 | 12.0 | 8.59 | 7.24 | 7.18 | 11.1 | 34.5 | 148.0 | 131 | 48.1 | 30.3 | 17.4 | 6.08 | 39.2 | 321 | 1241 |
| 1972 | 13.4 | 12.0 | 11.3 | 8.84 | 10.0 | 12.4 | 21.1 | 70.9 | 271 | 155 | 50.0 | 25.0 | 8.00 | 55.2 | 385 | 1740 |
| 1973 | 17.4 | 15.5 | 13.5 | 11.7 | 12.5 | 20.3 | 62.9 | 146.0 | 280 | 138 | 44.5 | 22.4 | 7.48 | 65.5 | 473 | 2067 |
| 1974 | 19.3 | 15.2 | 12.2 | 10.2 | 10.0 | 12.7 | 33.1 | 82.0 | 152 | 91.2 | 31.5 | 18.2 | 7.48 | 40.7 | 292 | 1284 |
| 1975 | 13.7 | 11.5 | 10.0 | 9.32 | 9.20 | 10.7 | 31.4 | 66.4 | 174 | 119 | 52.2 | 22.6 | 7.48 | 44.3 | 335 | 1397 |
| 1976 | 16.7 | 14.8 | 11.9 | 11.3 | 10.9 | 12.9 | 38.6 | 99.2 | 164 | 138 | 46.4 | 23.7 | 8.53 | 49.0 | 327 | 1554 |
| 1977 | 15.7 | 11.8 | 10.6 | 10.8 | 11.2 | 12.2 | 19.1 | 49.8 | 138 | 80.2 | 30.6 | 16.5 | 9.74 | 33.9 | 338 | 1070 |
| 1978 | 13.2 | 11.7 | 11.1 | 9.55 | 9.18 | 12.6 | 41.4 | 137 | 221 | 103 | 44.4 | 22.0 | 7.83 | 53.0 | 418 | 1397 |
| 1979 | 14.6 | 11.6 | 11.0 | 10.0 | 10.5 | 13.3 | 53.6 | 81.4 | 223 | 175 | 61.9 | 23.6 | 10.0 | 57.7 | 477 | 1819 |
| 1980 | 18.0 | 16.1 | 15.4 | 13.9 | 13.0 | 13.7 | 38.4 | 108 | 189 | 82.8 | 31.1 | 20.5 | 11.0 | 46.7 | 220 | 1476 |
| Mean | 17.19 | 14.32 | 12.28 | 10.56 | 10.37 | 13.84 | 36.17 | 92.7 | 219 | 148 | 54.1 | 23.1 | 6.00 | 54.7 | 477 | 1673 |
| | | | | | | | | | | | | | | | | |
| 2007 | 16.8 | 15 | 14.2 | 12.4 | 12.5 | 16.37 | 37.73 | 107 | 172 | 105.86 | 39.4 | 21.58 | 8 | 47.9 | 400 | 1499 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2008 | 18.96 | 16.78 | 14.45 | 12.00 | 11.34 | 15.41 | 24.46 | 72.68 | 106.53 | 70.90 | 31.22 | 17.43 | 11.00 | 34.35 | 120 | 1086.7 |
| 2009 | 17.50 | 15.91 | 14.81 | 11.68 | 10.93 | 13.35 | 23.63 | 106.48 | 188.38 | 158.43 | 27.72 | 17.67 | 10.00 | 50.54 | 286.0 | 1600.4 |
| 2010 | 16.84 | 14.00 | 13.94 | 13.50 | 14.10 | 20.57 | 41.61 | 108.25 | 160.97 | 143.09 | 72.16 | 26.53 | 12.00 | 53.80 | 228.0 | 1704.4 |
| 2011 | 17.78 | 15.37 | 13.03 | 11.62 | 11.67 | 15.16 | 27.82 | 102.92 | 193.13 | 110.83 | 24.26 | 18.94 | 10.20 | 46.93 | 226.0 | 1481.6 |
| 2012 | 12.26 | 11.56 | 10.33 | 10.34 | 11.18 | 19.91 | 47.99 | 60.63 | 140.90 | 118.74 | 46.32 | 34.01 | 8.54 | 43.64 | 190.0 | 1270.0 |
| 2013 | 17.57 | 14.08 | 12.65 | 11.63 | 11.91 | 16.34 | 30.81 | 100.46 | 166.47 | 57.18 | 30.09 | 17.31 | 10.00 | 40.54 | 335.0 | 1200.4 |
| 2014 | 15.40 | 13.37 | 10.29 | 8.40 | 9.30 | 13.08 | 32.53 | 123.23 | 209.33 | 100.00 | 39.06 | 17.70 | 8.00 | 49.31 | 270.0 | 1558.8 |
| 2015 | 18.05 | 18.57 | 14.41 | 13.14 | 13.81 | 24.17 | 62.38 | 131.58 | 225.97 | 113.39 | 34.81 | 19.07 | 11.90 | 57.44 | 400.00 | 1814.6 |
| 2016 | 23.13 | 22.26 | 17.81 | 16.12 | 14.70 | 18.12 | 44.04 | 140.81 | 195.05 | 116.60 | 53.42 | 24.30 | 13.90 | 57.20 | 229.00 | 1811.1 |
| 2017 | 21.12 | 23.84 | 20.49 | 15.68 | 16.07 | 17.60 | 42.03 | 130.24 | 139.75 | 69.44 | 35.22 | 22.88 | 14.30 | 46.20 | 196.8 | 1462.3 |
| Mean | 17.86 | 16.57 | 14.22 | 12.41 | 12.50 | 17.37 | 37.73 | 107.73 | 172.65 | 105.86 | 39.43 | 21.58 | 8.00 | 47.99 | 400 | 1499.0 |

**Table A.3** Monthly min, max, avg of air temprature (C0) recorded at authomatic hydrometeorology stations over 15 minute

| Year | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 2008 | | | | | | | | | | | | | 11.4 | 35.0 | 23.6 | 19.3 | 36.0 | 28.1 |
| 2009 | -3.8 | 10.2 | 3.22 | -3.7 | 12.7 | 3.81 | 4.30 | 21.2 | 11.7 | 3.80 | 20.2 | 11.6 | | | | | | |
| 2010 | 0.60 | 15.5 | 7.12 | -4.6 | 12.2 | 3.07 | 11.7 | 24.5 | 18.7 | 9.00 | 26.4 | 18.1 | 11.6 | 32.5 | 20.9 | 15.5 | 33.5 | 24.0 |
| 2011 | -0.6 | 14.0 | 5.21 | -0.8 | 10.6 | 3.99 | 0.30 | 25.5 | 11.8 | 5.70 | 29.6 | 16.7 | 12.3 | 34.4 | 24.2 | 17.0 | 35.8 | 27.5 |
| 2012 | -7.5 | 10.7 | -0.1 | -11 | 7.60 | -1.4 | -2.9 | 23.9 | 7.91 | 8.30 | 23.7 | 15.7 | 10.3 | 30.7 | 19.9 | 16.9 | 31.4 | 24.5 |
| 2013 | -5.6 | 9.90 | 1.38 | -0.9 | 12.4 | 4.57 | -1.1 | 21.5 | 11.3 | 6.80 | 23.4 | 15.0 | 9.10 | 32.0 | 21.7 | 15.6 | 36.3 | 26.3 |
| 2014 | -3.4 | 12.7 | 4.52 | -4.0 | 12.2 | 3.54 | 0.10 | 18.2 | 8.34 | 6.50 | 26.6 | 15.3 | 10.2 | 31.7 | 19.2 | 15.2 | 34.9 | 25.6 |
| 2015 | -2.7 | 15.3 | 4.83 | -3.2 | 18.1 | 6.26 | -0.6 | 25.5 | 9.69 | 5.30 | 29.4 | 17.1 | 11.1 | 30.9 | 21.1 | 15.6 | 35.7 | 25.0 |
| 2016 | -0.7 | 17.9 | 6.25 | -0.5 | 28.5 | 9.42 | 2.80 | 23.9 | 11.2 | 6.30 | 29.1 | 15.5 | 10.4 | 32.8 | 22.7 | 13.7 | 35.4 | 26.1 |
| 2017 | -3.6 | 15.5 | 2.51 | -5.4 | 18.1 | 4.22 | -0.2 | 23.8 | 10.4 | 11.3 | 32.3 | 19.5 | 12.5 | 32.7 | 22.9 | 17.1 | 37.4 | 27.2 |
| 2018 | -0.5 | 15.9 | 6.44 | -1.9 | 19.5 | 6.43 | 5.3 | 29.4 | 14.1 | 3.2 | 27.1 | 16.6 | | | | 17.9 | 34.8 | 25.6 |
| Summary | -7.5 | 17.9 | 4.14 | -11 | 28.5 | 4.39 | -2.9 | 29.4 | 11.5 | 3.20 | 32.3 | 16.1 | 9.10 | 35.0 | 21.8 | 13.7 | 37.4 | 26.0 |

| Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 18.1 | 38.0 | 29.0 | 19.9 | 36.4 | 27.3 | 15.0 | 32.5 | 23.2 | 11.3 | 30.7 | 20.4 | | | | 1.00 | 13.5 | 7.06 | 1.00 | 38.0 | 22.6 |
| | | | | | | | | | | | | | | | | | | -3.8 | 21.2 | 7.58 |
| 16.5 | 37.5 | 26.4 | 14.5 | 36.8 | 25.3 | 12.3 | 33.6 | 22.2 | | | | 3.40 | 20.8 | 11.6 | -1.0 | 19.0 | 7.76 | -4.6 | 37.5 | 16.8 |
| 19.7 | 37.4 | 28.4 | 19.2 | 38.1 | 27.8 | 16.4 | 34.0 | 23.4 | 7.40 | 31.5 | 17.4 | 4.90 | 20.7 | 12.1 | -4.7 | 15.5 | 6.46 | -4.7 | 38.1 | 17.1 |
| 17.9 | 35.6 | 27.8 | 19.9 | 36.7 | 27.3 | 10.3 | 32.7 | 22.4 | 8.30 | 25.8 | 17.1 | 2.30 | 19.2 | 11.6 | -6.1 | 13.3 | 4.98 | -11 | 36.7 | 14.8 |
| 17.4 | 37.6 | 28.3 | 18.6 | 36.6 | 26.7 | 17.0 | 31.6 | 24.0 | 7.40 | 31.1 | 18.8 | 4.40 | 17.9 | 10.5 | -6.3 | 17.1 | 6.46 | -6.3 | 37.6 | 16.2 |
| 17.8 | 37.3 | 27.9 | 15.6 | 35.9 | 26.6 | 17.0 | 32.1 | 24.5 | 5.90 | 31.1 | 17.0 | 3.70 | 21.6 | 10.4 | -0.3 | 17.1 | 7.66 | -4.0 | 37.3 | 15.9 |
| 17.4 | 36.7 | 27.7 | 17.6 | 36.1 | 26.8 | 13.1 | 31.5 | 22.6 | 6.60 | 32.9 | 19.0 | | | | | | | -3.2 | 36.7 | 18.0 |
| 20.5 | 37.4 | 28.2 | 18.3 | 35.8 | 26.6 | 15.3 | 33.8 | 24.9 | 11.1 | 30.4 | 19.1 | 5.20 | 24.7 | 12.5 | 2.70 | 22.3 | 10.2 | -0.7 | 37.4 | 17.7 |
| 20.2 | 37.3 | 28.5 | 16.0 | 37.0 | 27.0 | 13.8 | 33.3 | 24.0 | 9.00 | 31.3 | 19.1 | 1.60 | 25.9 | 11.4 | -2.1 | 17.2 | 6.54 | -5.4 | 37.4 | 16.9 |
| 20.9 | 37.4 | 28.3 | 20.9 | 36.2 | 27.7 | 12.7 | 32.8 | 23.5 | -9.6 | 26.9 | 16.2 | -8.7 | 20.6 | 11.5 | -7.6 | 18.7 | 6.98 | -9.6 | 37.4 | 16.7 |
| 16.5 | 38.0 | 28.1 | 14.5 | 38.1 | 26.9 | 10.3 | 34.0 | 23.5 | -9.6 | 32.9 | 18.2 | -8.7 | 25.9 | 11.4 | -7.6 | 22.3 | 7.13 | -11 | 38.1 | 16.4 |

Monthly max, total of precipitation (mm) recorded at automatic hydrometeorology stations over 15 minute

| Year | Jan | | Feb | | Mar | | Apr | | May | | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total |
| 2008 | | | | | | | | | 0.00 | 10.00 | 0.00 | 0.00 |
| 2009 | 0.00 | 136 | 0.0 | 118 | 0.00 | 59.8 | 0.00 | 115 | 0.00 | 24.5 | 0.00 | 0.83 |
| 2010 | 0.00 | 36.6 | 0.00 | 118 | 0.00 | 36.3 | 0.00 | 41.6 | 0.00 | 53.85 | 0.00 | 3.39 |
| 2011 | 0.00 | 9.1 | 0.00 | 195 | 0.00 | 80.8 | 0.00 | 50.7 | 0.00 | 17.49 | 0.00 | 0.00 |
| 2012 | 0.00 | 84.6 | 0.00 | 81.1 | 0.00 | 103 | 0.00 | 65.2 | 0.00 | 25.9 | 0.00 | 0.00 |
| 2013 | 0.00 | 44.7 | 0.00 | 163.3 | 0.00 | 102 | 0.0 | 64.0 | 0.00 | 2.53 | 0.00 | 5.55 |
| 2014 | 0.00 | 4.9 | 3.17 | 110.2 | 2.06 | 155.8 | 9.06 | 100.8 | 15.28 | 72.20 | 0.66 | 1.20 |
| 2015 | 1.52 | 67.6 | 5.20 | 183.0 | 3.56 | 86.3 | 5.84 | 61.2 | 1.15 | 25.3 | 0.00 | 0.00 |
| 2016 | 3.23 | 76.5 | 0.01 | 2.9 | 2.45 | 136.2 | 8.06 | 121 | 21.65 | 49.8 | 5.7 | 21.1 |
| 2017 | 0.00 | 109 | 0.00 | 150 | 1.95 | 25.14 | 5.01 | 25.3 | 0.00 | 1.33 | 0.19 | 0.74 |
| 2018 | 1.39 | 43 | 2.12 | 80 | 2.41 | 48.45 | 3.66 | 65.86 | | | 0.10 | 0.10 |
| Mean | 3.23 | 61.3 | 5.20 | 120.1 | 3.56 | 83.4 | 9.06 | 71.1 | 21.65 | 28.3 | 5.69 | 2.99 |

| Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.00 | 0.00 | 13.0 | 0.00 | 36.5 | | |
| 0.00 | 7.25 | 0.00 | 3.13 | 0.00 | 1.67 | 0.00 | 3.03 | 0.00 | 31.7 | 0.00 | 46.7 | 0.00 | 548 |
| 0.00 | 28.45 | 0.00 | 14.49 | 0.00 | 10.34 | 0.00 | 0.00 | 0.00 | 13.44 | 0.00 | 0.00 | 0.00 | 357 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.45 | 0.00 | 72.42 | 0.00 | 38.8 | 0.00 | 0.0 | 0.00 | 470 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 24.9 | 0.00 | 2.1 | 0.0 | 10.4 | 0.00 | 74.0 | 0.00 | 472 |
| 0.00 | 3.50 | 0.00 | 4.39 | 0.00 | 2.90 | 0.00 | 13.50 | 0.00 | 19.2 | 0.00 | 36.0 | 0.00 | 461 |
| 2.64 | 4.10 | 0.00 | 0.00 | 0.00 | 0.00 | 2.22 | 7.90 | 1.90 | 33.8 | 0.00 | 0.00 | 15.28 | 491 |
| 13.39 | 18.50 | 0.00 | 0.20 | 0.00 | 0.87 | 0.00 | 3.32 | 0.00 | 58.0 | 0.00 | 8.8 | 13.39 | 513 |
| 0.00 | 0.00 | 11.4 | 11.4 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 6.94 | 0.00 | 3.81 | 21.65 | 429 |
| 7.89 | 12.59 | 0.10 | 0.90 | 0.10 | 0.30 | 4.91 | 12.04 | 1.25 | 12.53 | 0.78 | 3.57 | 7.89 | 354 |
| 0.00 | 0.00 | 0.15 | 0.26 | 5.50 | 17.26 | 4.11 | 22.01 | 2.13 | 25.42 | 0.88 | 5.08 | 5.50 | 308 |
| 13.39 | 6.76 | 11.37 | 3.16 | 5.50 | 5.88 | 4.91 | 12.9 | 2.13 | 23.9 | 0.88 | 19.5 | 21.7 | 440 |

Monthly min, max, avg of relative humidity (%) recorded at authomatic hydrometeorology stations over 15 minute

| Year | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 2008 | | | | | | | | | | | | | 7.00 | 87.0 | 27.3 | 7.00 | 51.0 | 17.7 |
| 2009 | 17.0 | 100 | 65.2 | 15.0 | 100 | 59.4 | 9.00 | 97.0 | 43.6 | | | | | | | | | |
| 2010 | 11.0 | 100 | 41.1 | 25.0 | 100 | 55.7 | 8.00 | 91.0 | 27.9 | 10.0 | 100 | 41.3 | 6.00 | 100 | 39.1 | 9.00 | 76.0 | 27.7 |
| 2011 | 5.00 | 100 | 33.0 | 13.0 | 100 | 65.6 | 5.0 | 100 | 45.7 | 6.00 | 100 | 35.8 | 6.00 | 100 | 24.7 | 7.00 | 58.0 | 18.7 |
| 2012 | 8.00 | 100 | 61.0 | 24.0 | 100 | 65.6 | 12.0 | 100 | 48.8 | 10.0 | 100 | 48.4 | 7.00 | 100 | 33.0 | 10.0 | 68.0 | 24.9 |
| 2013 | 21.0 | 100 | 56.1 | 13.0 | 100 | 62.9 | 9.0 | 100 | 52.7 | 8.00 | 100 | 48.5 | 5.00 | 88.0 | 25.9 | 7.0 | 90.0 | 24.2 |
| 2014 | 9.00 | 100 | 44.6 | 14.0 | 100 | 54.0 | 14.0 | 100 | 56.4 | 7.00 | 100 | 40.1 | 10.0 | 100 | 46.2 | 9.00 | 92.0 | 22.8 |
| 2015 | 15.0 | 100 | 54.4 | 16.0 | 100 | 64.9 | 16.0 | 100 | 52.3 | 5.00 | 100 | 38.0 | 5.00 | 100 | 31.5 | 9.00 | 66.0 | 22.1 |
| 2016 | 9.00 | 100 | 50.9 | 5.00 | 95.0 | 29.1 | 14.0 | 100 | 63.9 | 11.0 | 100 | 51.0 | 8.00 | 100 | 32.9 | 7.00 | 95.0 | 26.3 |
| 2017 | 12.0 | 100 | 63.2 | 13.0 | 100 | 61.3 | 7.00 | 100 | 42.0 | 7.00 | 77.0 | 27.7 | 5.00 | 100 | 29.1 | 6.00 | 71.0 | 17.9 |
| Summary | 5.0 | 100 | 52.2 | 5.0 | 100 | 57.6 | 5.00 | 100 | 48.2 | 5.00 | 100 | 41.3 | 5.00 | 100 | 32.2 | 6.00 | 95.0 | 22.5 |

| Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 7.00 | 67.0 | 20.4 | 9.00 | 79.0 | 25.1 | 7.00 | 78.0 | 24.3 | 8.00 | 76.0 | 24.2 | | | | | | | 7.00 | 87 | 23.2 |
| | | | | | | | | | | | | | | | | | | 9.00 | 100 | 56.1 |
| 7.00 | 100 | 30.7 | 8.00 | 100 | 43.8 | 9.00 | 83.0 | 27.9 | | | | 5.00 | 65.0 | 24.6 | 7.00 | 76.0 | 22.2 | 5.00 | 100 | 34.7 |
| 7.00 | 69.0 | 18.6 | 7.00 | 81.0 | 30.6 | 8.00 | 100 | 34.0 | 6.00 | 100 | 41.9 | 19.0 | 100 | 53.2 | 8.00 | 73.0 | 29.6 | 5.00 | 100 | 35.9 |
| 6.00 | 71.0 | 20.2 | 8.00 | 79.0 | 26.7 | 9.00 | 100 | 37.9 | 6.00 | 92.0 | 29.6 | 8.00 | 100 | 29.7 | 18.0 | 100 | 53.2 | 6.00 | 100 | 39.9 |
| 6.00 | 83.0 | 24.3 | 8.00 | 84.0 | 30.6 | 5.00 | 76.0 | 28.3 | 6.00 | 100 | 29.6 | 9.00 | 100 | 40.9 | 12.0 | 100 | 46.5 | 5.00 | 100 | 39.2 |
| 5.00 | 90.0 | 22.7 | 6.00 | 78.0 | 21.6 | 5.00 | 75.0 | 22.5 | 6.00 | 100 | 39.4 | 11.0 | 100 | 44.5 | | | | 5.00 | 100 | 37.7 |
| 10.0 | 100 | 32.2 | 6.00 | 86.0 | 25.1 | 8.00 | 68.0 | 25.7 | 6.00 | 100 | 33.7 | | | | | | | 5.00 | 100 | 38.0 |
| 6.00 | 75.0 | 23.5 | 9.00 | 77.0 | 24.4 | 6.00 | 72.0 | 19.8 | 6.00 | 67.0 | 20.6 | 3.00 | 100 | 33.4 | 11.0 | 100 | 33.1 | 3.00 | 100 | 34.1 |
| 5.00 | 82.0 | 25.5 | 6.00 | 70.0 | 22.1 | 7.00 | 59.0 | 18.7 | 7.00 | 77.0 | 21.1 | 10.0 | 100 | 37.4 | 5.00 | 100 | 38.9 | 5.00 | 100 | 33.7 |
| 5.00 | 100 | 24.2 | 6.00 | 100 | 27.8 | 5.00 | 100 | 26.6 | 6.00 | 100 | 30.0 | 3.00 | 100 | 37.7 | 5.00 | 100 | 37.2 | 3.00 | 100 | 37.3 |

Monthly min, max, avg of wind speed (m/sec) recorded at automatic weather station over 1 hour

| Year | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 2011 | | | | | | | | | | | | | | | | | | |
| 2012 | | | | | | | | | | | | | | | | | | |
| 2013 | 0.04 | 7.26 | 1.42 | 0.00 | 6.08 | 1.54 | 0.02 | 7.61 | 1.91 | 0.44 | 8.17 | 2.18 | 0.39 | 8.44 | 2.41 | 0.42 | 7.63 | 2.67 |
| 2014 | 0.38 | 3.62 | 1.26 | 0.43 | 3.88 | 1.46 | 0.06 | 5.97 | 1.66 | 0.33 | 6.76 | 1.86 | 0.38 | 7.19 | 2.10 | 0.43 | 6.49 | 2.64 |
| 2015 | 0.22 | 5.13 | 1.37 | 0.05 | 7.66 | 1.55 | 0.29 | 4.94 | 1.62 | 0.42 | 5.38 | 1.80 | 0.37 | 6.38 | 2.21 | 0.46 | 6.28 | 2.64 |
| 2016 | 0.08 | 4.77 | 1.35 | 0.47 | 4.67 | 1.47 | 0.12 | 6.46 | 1.63 | 0.12 | 6.67 | 1.72 | 0.43 | 5.81 | 2.09 | 0.41 | 6.14 | 2.22 |
| 2017 | 0.01 | 5.10 | 1.06 | 0.00 | 7.82 | 1.25 | 0.05 | 7.23 | 1.52 | 0.03 | 10.3 | 1.97 | 0.04 | 10.9 | 2.18 | 0.03 | 11.4 | 2.65 |
| 2018 | 0.02 | 7.31 | 1.26 | 0.01 | 5.90 | 1.17 | 0.11 | 9.18 | 1.56 | 0.08 | 7.86 | 1.77 | 0.01 | 9.16 | 1.91 | 0.02 | 9.96 | 2.54 |
| Mean | 0.01 | 7.31 | 1.29 | 0.00 | 7.82 | 1.40 | 0.02 | 9.18 | 1.65 | 0.03 | 10.3 | 1.88 | 0.01 | 10.9 | 2.15 | 0.02 | 11.4 | 2.56 |

| Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| | | | | | | | | | | | | | | | | | | | | |
| | | | 0.06 | 10.1 | 2.47 | 0.03 | 8.80 | 1.94 | 0.02 | 7.88 | 1.67 | 0.04 | 8.99 | 1.51 | 0.03 | 6.57 | 1.28 | | | |
| | | | 0.28 | 7.03 | 2.62 | 0.31 | 6.36 | 2.03 | 0.36 | 6.42 | 1.77 | 0.06 | 3.85 | 1.46 | 0.40 | 5.05 | 1.35 | 0.00 | 8.44 | 1.94 |
| 0.30 | 6.34 | 2.58 | 0.37 | 7.14 | 2.45 | 0.33 | 7.01 | 2.03 | 0.42 | 5.80 | 1.58 | 0.51 | 4.59 | 1.29 | 0.34 | 4.09 | 1.37 | 0.06 | 7.19 | 1.86 |
| 0.42 | 7.26 | 2.62 | 0.39 | 5.97 | 2.25 | 0.32 | 8.38 | 1.95 | 0.38 | 6.65 | 1.60 | 0.25 | 6.45 | 1.46 | 0.38 | 5.60 | 1.32 | 0.05 | 8.38 | 1.87 |
| 0.37 | 6.87 | 2.57 | 0.27 | 5.97 | 2.07 | 0.34 | 5.50 | 1.90 | 0.34 | 5.09 | 1.49 | 0.33 | 5.54 | 1.35 | 0.45 | 5.91 | 1.32 | 0.08 | 6.87 | 1.76 |
| 0.02 | 12.6 | 2.65 | 0.00 | 9.50 | 2.19 | 0.00 | 9.13 | 1.84 | 0.02 | 7.78 | 1.45 | 0.03 | 7.54 | 1.31 | 0.05 | 5.68 | 1.19 | 0.00 | 12.6 | 1.77 |
| 0.12 | 10.6 | 2.79 | 0.02 | 12.1 | 2.42 | 0.01 | 9.34 | 1.94 | 0.01 | 7.75 | 1.40 | 0.02 | 6.41 | 1.34 | 0.03 | 5.24 | 1.07 | 0.01 | 12.1 | 1.76 |
| 0.02 | 12.6 | 2.64 | 0.00 | 12.1 | 2.35 | 0.00 | 9.34 | 1.95 | 0.01 | 7.88 | 1.57 | 0.02 | 8.99 | 1.39 | 0.03 | 6.57 | 1.27 | 0.00 | 12.6 | 1.83 |

**Table A.4** Kawak monthly max, total of precipitation (mm) recorded at automatic hydrometeorology stations sver 15 minute

| Year | Jan | | Feb | | Mar | | Apr | | May | | Jun | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total |
| 2008 | | | | | | | | | | | | |
| 2009 | | | | | | | | | | | | |
| 2010 | | | | | | | | | | | | |
| 2011 | | | | | | | | | | | | |
| 2012 | | | | | | | | | | | | |
| 2013 | 0.00 | 7.77 | 0.54 | 9.49 | 2.04 | 60.2 | 2.35 | 59.7 | 2.01 | 24.6 | 3.02 | 11.0 |
| 2014 | 0.00 | 1.1 | 0.01 | 10.3 | 2.27 | 88.3 | 2.06 | 67.2 | 1.90 | 32.4 | 0.88 | 3.31 |
| 2015 | 2.18 | 36.4 | 5.15 | 137.9 | 2.30 | 48.0 | 2.01 | 71.9 | 1.78 | 42.4 | 1.64 | 5.90 |
| 2016 | 0.53 | 13.0 | 0.00 | 2.7 | 1.25 | 35.8 | 2.20 | 80.7 | 1.67 | 27.0 | 1.0 | 15.4 |
| 2017 | 5.02 | 68.6 | 2.96 | 64.6 | 1.64 | 62.0 | 1.62 | 81.5 | 2.17 | 19.2 | 0.13 | 0.47 |
| 2018 | 0.31 | 3.4 | 1.24 | 78.3 | 2.09 | 68.0 | 2.01 | 59.4 | 2.52 | 92.8 | 0.10 | 1.50 |
| 2019 | 0.53 | 49.8 | 0.41 | 17.6 | 1.24 | 23.0 | | | | | | |
| Mean | 5.02 | 25.7 | 5.15 | 45.8 | 2.30 | 55.0 | 2.35 | 70.1 | 2.52 | 39.7 | 3.02 | 6.2 |

| Jul | | Aug | | Sep | | Oct | | Nov | | Dec | | Annual | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total | Max | Total |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| 0.00 | 0.00 | 0.00 | 0.63 | 0.00 | 0.00 | 0.90 | 7.06 | 0.52 | 14.9 | 0.56 | 24.3 | 3.02 | 220 |
| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.53 | 1.51 | 25.7 | 1.02 | 23.4 | 0.00 | 0.00 | 2.27 | 252 |
| 1.13 | 14.43 | 0.60 | 2.82 | 0.00 | 1.03 | 2.67 | 18.99 | 3.21 | 53.5 | 0.00 | 8.9 | 5.15 | 442 |
| 0.00 | 0.00 | 1.70 | 1.82 | 0.77 | 2.10 | 0.00 | 0.00 | 0.88 | 7.85 | 0.52 | 2.27 | 2.20 | 189 |
| 0.13 | 0.35 | 0.13 | 1.16 | 0.88 | 7.73 | 0.31 | 1.58 | 0.22 | 1.66 | 0.11 | 2.02 | 5.02 | 311 |
| 0.00 | 0.00 | 0.00 | 0.00 | 1.11 | 6.07 | 1.92 | 19.49 | 2.86 | 32.5 | 3.36 | 5.40 | 3.36 | 367 |
| | | | | | | | | | | | | | |
| 1.13 | 2.5 | 1.70 | 1.1 | 1.11 | 2.9 | 2.67 | 12.1 | 3.21 | 22.3 | 3.36 | 7.1 | 5.15 | 297 |
| | | | | | | | | | | | | | |

Khawak monthly min,max,avg Of Air temprature (C0) recorded at authomatic hydrometeorology stations over 15 minute

| Year | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 2008 | | | | | | | | | | | | | | | | | | |
| 2009 | | | | | | | | | | | | | | | | 4.50 | 27.1 | 14.7 |
| 2010 | -4.7 | 7.70 | 1.27 | -11 | 3.80 | -2.0 | -6 | 18.9 | 4.5 | -4.2 | 25 | 9.72 | 5.57 | 23 | 16.6 | 8.40 | 29.1 | 18.7 |
| 2011 | -12 | 8.80 | -3.4 | -11 | 4.50 | -2.3 | -6.2 | 18.6 | 4.68 | -4.0 | 25.4 | 9.79 | 5.50 | 28.3 | 16.5 | 8.40 | 29.1 | 19.7 |
| 2012 | -17 | 3.60 | -6.0 | -17 | 3.10 | -7.0 | -11 | 16.2 | 0.22 | 2.20 | 18.5 | 9.54 | 3.70 | 23.6 | 12.5 | 9.20 | 25.2 | 16.4 |
| 2013 | -15 | 7.10 | -3.8 | -8.1 | 8.00 | -0.7 | -6.1 | 15.3 | 5.50 | -2.3 | 19.5 | 8.42 | -0.1 | 25.7 | 13.9 | 8.80 | 30.6 | 19.2 |
| 2014 | -13 | 8.70 | -3.2 | -12 | 9.10 | -2.6 | -6.1 | 12.7 | 2.00 | -0.7 | 20.2 | 7.89 | 3.00 | 23.5 | 12.9 | 8.90 | 28.5 | 18.1 |
| 2015 | -12 | 6.80 | -2.7 | -12 | 7.70 | -1.8 | -9.3 | 11.8 | 1.07 | -0.2 | 20.9 | 9.09 | 4.40 | 24.2 | 13.6 | 8.60 | 28.4 | 17.2 |
| 2016 | -11 | 9.20 | -1.1 | -11 | 15.4 | 0.76 | -2.8 | 17.2 | 5.81 | 0.30 | 23.0 | 8.97 | 6.50 | 25.2 | 15.7 | 9.90 | 29.1 | 19.2 |
| 2017 | -17 | 6.80 | -4.8 | -13 | 4.90 | -2.9 | -11 | 13.4 | 1.64 | -3.6 | 22.3 | 8.78 | 3.90 | 25.4 | 15.7 | 7.90 | 30.3 | 19.4 |
| 2018 | -9 | 10.8 | -0.9 | -10 | 8.70 | -1.0 | -2.4 | 21.8 | 6.24 | 0.8 | 22.3 | 10.7 | 2.70 | 25.7 | 12.0 | 9.50 | 27.1 | 18.3 |
| Summary | -17 | 10.8 | -2.7 | -17 | 15.4 | -2.2 | -11 | 21.8 | 3.39 | -4.0 | 25.4 | 9.15 | -0.1 | 28.3 | 14.1 | 4.50 | 30.6 | 18.0 |

| Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| | | | | | | | | | | | | | | | | | | | | |
| 9.40 | 29.4 | 19.7 | 10.6 | 29.1 | 20.2 | 6.50 | 27.1 | 16.4 | -0.3 | 24.5 | 9.56 | -9.2 | 16.0 | 2.74 | -10 | 6.30 | -2.3 | -10 | 29.4 | 11.6 |
| 11 | 28.7 | 21 | 12.5 | 30 | 21.8 | 6.5 | 28 | 16 | -0.7 | 21 | 9.5 | -6.5 | 16 | 4.2 | -9.0 | 8.90 | -1.3 | -11 | 8.90 | -0.7 |
| 12.5 | 29.7 | 21.0 | 13.5 | 30.9 | 21.8 | 7.00 | 28.7 | 17.0 | -0.7 | 21.8 | 10.1 | -6.5 | 16.3 | 4.32 | -11 | 9.90 | -0.8 | -12 | 30.9 | 9.87 |
| 12.4 | 28.5 | 20.4 | 12.4 | 30.3 | 20.8 | 4.80 | 29.1 | 16.0 | 0.00 | 27.2 | 12.4 | -3.9 | 12.6 | 3.68 | -12 | 11.6 | -1.0 | -17 | 30.3 | 8.17 |
| 10.6 | 32.7 | 21.8 | 12.0 | 30.9 | 20.6 | 8.50 | 28.8 | 18.2 | 0.80 | 25.4 | 10.2 | -2.6 | 12.1 | 4.64 | -13 | 11.5 | -1.3 | -15 | 32.7 | 9.72 |
| 11.8 | 31.8 | 21.2 | 9.50 | 29.4 | 19.9 | 8.80 | 27.3 | 17.5 | 0.20 | 24.8 | 10.4 | -3.6 | 13.5 | 3.78 | -7.1 | 11.0 | 0.00 | -13 | 31.8 | 8.99 |
| 13.7 | 30.0 | 21.3 | 9.20 | 29.7 | 19.8 | 6.20 | 25.9 | 15.4 | 1.50 | 23.6 | 11.9 | -6.2 | 14.1 | 3.37 | -12 | 12.8 | -0.4 | -12 | 30.0 | 8.98 |
| 12.8 | 31.0 | 21.4 | 11.7 | 28.2 | 19.9 | 9.20 | 27.2 | 17.6 | 1.90 | 23.3 | 11.3 | -2.6 | 17.7 | 5.76 | -5.9 | 14.7 | 3.26 | -11 | 31.0 | 10.7 |
| 13.1 | 30.5 | 22.0 | 11.1 | 30.3 | 20.2 | 7.70 | 27.7 | 16.2 | 2.30 | 22.9 | 12.0 | -4.3 | 19.4 | 5.38 | -11 | 9.20 | -1.2 | -17 | 30.5 | 9.37 |
| 11.8 | 30.7 | 21.8 | 10.1 | 29.3 | 20.3 | 7.00 | 27.0 | 16.4 | 0.10 | 21.1 | 9.30 | -3.7 | 14.6 | 4.10 | -7.9 | 9.50 | 0.2 | -10 | 30.7 | 9.78 |
| 9.40 | 32.7 | 21.2 | 9.20 | 30.9 | 20.4 | 4.80 | 29.1 | 16.7 | -0.7 | 27.2 | 10.8 | -9.2 | 19.4 | 4.20 | -13 | 14.7 | -0.5 | -17 | 32.7 | 8.65 |

Kawak monthly min, max, avg of relative humidity (%) recorded at authomatic hydrometeorology stations over 15 minute

| Year | Jan | | | Feb | | | Mar | | | Apr | | | May | | | Jun | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| 2008 | | | | | | | | | | | | | | | | | | |
| 2009 | | | | | | | | | | | | | | | | 11.0 | 89.0 | 41.2 |
| 2010 | 16.0 | 95.0 | 52.0 | 15.0 | 100 | 69.1 | 7.5 | 95 | 45 | 6.2 | 92 | 38.7 | 7.5 | 83.2 | 33 | 5.9 | 56 | 25 |
| 2011 | 6.00 | 97.0 | 45.7 | 14.0 | 98.0 | 59.5 | 8.00 | 96.0 | 46.8 | 6.00 | 93.0 | 39.4 | 8.00 | 84.0 | 32.4 | 6.00 | 55.0 | 26.1 |
| 2012 | 15.0 | 97.0 | 53.6 | 23.0 | 96.0 | 59.1 | 16.0 | 100 | 61.1 | 7.00 | 100 | 49.4 | 9.00 | 94.0 | 43.5 | 11.0 | 87.0 | 39.3 |
| 2013 | 11.0 | 100 | 46.1 | 8.00 | 100 | 53.7 | 6.00 | 100 | 50.4 | 8.00 | 100 | 51.3 | 7.00 | 89.0 | 37.3 | 5.00 | 78.0 | 31.0 |
| 2014 | 14.0 | 100 | 48.0 | 12.0 | 100 | 51.8 | 11.0 | 100 | 60.4 | 10.0 | 100 | 47.5 | 9.00 | 100 | 49.6 | 11.0 | 82.0 | 33.2 |
| 2015 | 11.0 | 100 | 58.4 | 25.0 | 100 | 68.0 | 23.0 | 100 | 58.5 | 8.00 | 100 | 43.2 | 7.00 | 100 | 41.1 | 6.00 | 72.0 | 32.7 |
| 2016 | 10.0 | 100 | 51.6 | 9.00 | 100 | 37.3 | 13.0 | 100 | 58.1 | 6.00 | 100 | 54.0 | 7.00 | 95.0 | 38.9 | 7.00 | 89.0 | 34.5 |
| 2017 | 20.0 | 100 | 63.2 | 20.0 | 100 | 61.0 | 13.0 | 100 | 55.7 | 8.00 | 100 | 44.6 | 5.00 | 86.0 | 37.2 | 6.00 | 54.0 | 27.4 |
| Summary | 6.00 | 100 | 52.3 | 8.00 | 100 | 57.4 | 6.00 | 100 | 55.9 | 6.00 | 100 | 47.0 | 5.00 | 100 | 40.0 | 5.00 | 89.0 | 33.2 |

| Jul | | | Aug | | | Sep | | | Oct | | | Nov | | | Dec | | | Annual | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg | Min | Max | Avg |
| | | | | | | | | | | | | | | | | | | | | |
| 8.00 | 56.0 | 27.2 | 5.00 | 49.0 | 25.0 | 4.00 | 74.0 | 26.8 | 7.00 | 95.0 | 36.4 | 9.00 | 97.0 | 47.6 | 3.9 | 99 | 28.3 | 4.00 | 97.0 | 34.0 |
| 7.5 | 55.5 | 24.9 | 6.4 | 45 | 25.3 | 4.8 | 85.3 | 27 | 6.8 | 95.3 | 45.2 | 3.00 | 60.0 | 28.7 | 5.00 | 100 | 27.4 | 3.00 | 100 | 44.3 |
| 7.00 | 41.0 | 22.6 | 7.00 | 62.0 | 24.8 | 6.00 | 92.0 | 29.9 | 7.00 | 94.0 | 44.3 | 13.0 | 100 | 61.2 | 7.00 | 98.0 | 38.3 | 6.00 | 100 | 39.2 |
| 6.00 | 65.0 | 28.7 | 8.00 | 49.0 | 26.4 | 5.00 | 100 | 36.1 | 5.00 | 100 | 31.0 | 6.00 | 100 | 38.1 | 11.0 | 100 | 48.3 | 5.00 | 100 | 42.9 |
| 8.00 | 58.0 | 26.2 | 9.00 | 82.0 | 30.5 | 5.00 | 49.0 | 20.9 | 4.00 | 100 | 28.4 | 6.00 | 100 | 40.3 | 10.0 | 100 | 51.9 | 4.00 | 100 | 39.0 |
| 6.00 | 68.0 | 25.5 | 4.00 | 46.0 | 22.7 | 5.00 | 77.0 | 22.7 | 5.00 | 100 | 39.5 | 6.00 | 100 | 42.6 | 6.00 | 96.0 | 34.5 | 4.00 | 100 | 39.8 |
| 13.0 | 100 | 35.7 | 7.00 | 74.0 | 28.1 | 8.00 | 63.0 | 31.7 | 7.00 | 100 | 32.1 | 13.0 | 100 | 57.3 | 7.00 | 100 | 43.8 | 6.00 | 100 | 44.2 |
| 5.00 | 73.0 | 28.0 | 7.00 | 46.0 | 25.1 | 4.00 | 70.0 | 24.0 | 6.00 | 70.0 | 24.1 | 5.00 | 100 | 37.3 | 6.00 | 100 | 38.2 | 4.00 | 100 | 37.6 |
| 6.00 | 55.0 | 26.7 | 6.00 | 55.0 | 23.7 | 4.00 | 75.0 | 25.8 | 3.00 | 80.0 | 23.0 | 5.00 | 100 | 35.3 | 9.0 | 97 | 46.8 | 3.00 | 100 | 39.2 |
| 5.00 | 100 | 27.6 | 4.00 | 82.0 | 25.8 | 4.00 | 100 | 27.2 | 3.00 | 100 | 32.3 | 3.00 | 100 | 43.2 | 5.00 | 100 | 41.1 | 3.00 | 100 | 40.0 |