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## Introduction

Under Partnerships for Enhanced Engagement in Research (PEER), cycle 5, awarded project is to develop the integrated surface and groundwater modeling for the trans-boundary (Pakistan upstream and Afghanistan downstream) Kabul River Basin (KRB) with Satellite Enhanced Snowmelt Flood and Drought Predictions. In this project the advanced NASA satellite data will apply to track snow, snow melting, floods, surface water coverage, and droughts over the KRB.

“Groundwater model” is a representation in computer software of a regional scale hydrogeological system:

- Based on a complete description of the natural system (geometry, material properties, recharge etc.)
- including proposed changes
- to predict water levels, pzometric well heads and flows in space and time

The groundwater modelling of Kabul river basin is created as above conditions.

## Aim and objectives

The objectives of the project are to develop a numerical groundwater model flow that will Help to:

- Determine sustainable yields from the Kabul river basin aquifer.
- Predict the response of the aquifer system to potential groundwater use scenarios.
- Predict the response of the aquifer system climatic variability, risk of over extraction and
  Impact on the available yield.

## Description of Study area

The study area is part of the Kabul Basin, which is considered the geologic valley formed by the Paghman Mountains to the west and the Kohe Safi Mountains to the east (fig.1).The study area is limited by three sub basins which are Central Kabul, logar and Chakari (fig.1). The mentioned area is conspired as the drainage of Kabul River, Logar River, and Chakari River.

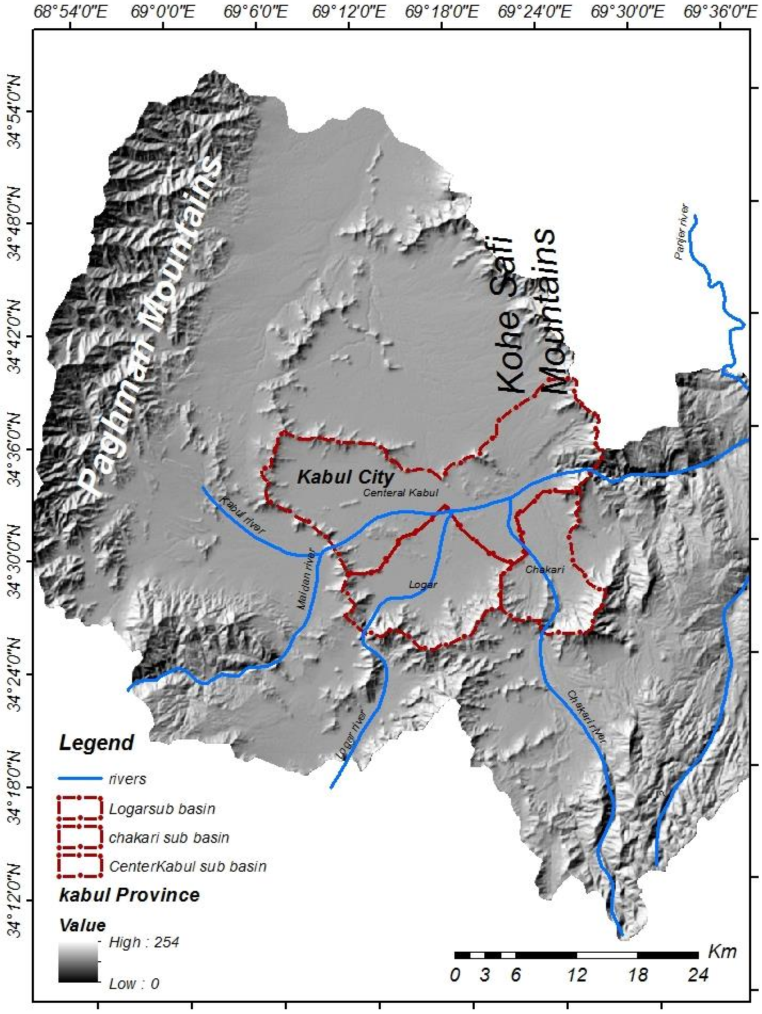



Figure 1. The Study area with major geographic features and sub basins

## Climate

Climate recordkeeping in Afghanistan was interrupted around 1980 as a consequence of war and civil strife. Few climatic data were available for Kabul; most records were not available until 2003 or later, and the record for most direct observations includes gaps of about 20 years or more. Table 1 presents mean monthly temperature, precipitation, and estimated evapotranspiration for Kabul from historical records (Böckh, 1971). Average annual precipitation is low in the Kabul Basin; between 1957 and 1977 it was 330 mm/yr (Tunnermeir and Houben, 2003). Evaporation rates are high relative to annual total precipitation—approximately 1,600 mm/yr—and thus net groundwater recharge by precipitation in the Kabul Valley is generally near zero on an annual basis. Mean monthly precipitation (table 1) historically was highest in the spring (February to April, 58 to 84 mm), moderate in the late fall and winter months (November to January, 21 to 33 mm), and very low in the summer months (June to October, 1 to 5 mm). Regional evaporation has been calculated to range from 140 to 220 mm per month during the growing season (April to September).

Table 1. Mean monthly temperature, precipitation, and estimated evapotranspiration for Kabul

[mm, millimeters; °C, degrees Celsius; –, not applicable or not calculated]

| Month | Air temperature[1] 1957-1977 (°C) | Air temperature[3] 1961-1991 (°C) | Air temperature[3] 2003-2007 (°C) | Evaporation[2] 1957-1963 (mm) | Precipitation[1] 1957-1977 (mm) | Precipitation[4] 2003-2006 (mm) |
|---|---|---|---|---|---|---|
| January | -2.5 | -1.9 | -0.9 | 50 | 33 | 43.4 |
| February | -1 | -0.3 | 4.9 | 70 | 58 | 47.8 |
| March | 6.5 | 6.6 | 9.5 | 120 | 64 | 79.1 |
| April | 12 | 13.3 | 15.2 | 140 | 84 | 31.1 |
| May | 17 | 17.8 | 19.5 | 180 | 25 | 28.9 |
| June | 22 | 23 | 23.3 | 210 | 1 | 0.8 |
| July | 24.5 | 25.1 | 25.9 | 220 | 5 | 6.5 |
| August | 23.5 | 24.4 | 24.9 | 210 | 1 | 0.6 |
| September | 19 | 20 | 21.4 | 150 | 2 | 5.4 |
| October | 12 | 13.7 | 14.6 | 130 | 2 | 1.8 |
| November | 5 | 12 | 7.8 | 80 | 21 | 29.2 |
| December | -0.2 | 1.2 | 3.5 | 50 | 34 | 49.4 |
| Annual average monthly | 11 | 13 | 14 | 133 | 28 | 27 |
| Annual total | – | – | – | 1,610 | 330 | 330 |

[1]Approximated from graphs in Houben and Tunnermeier (2005).

[2]As reported in Böckh (1971).

[3]Food and Agriculture Organization, Afghanistan (2001).

[4]Fahim Zaheer, written comm., AGROMET, Afghanistan, 2008.

## Geomorphology and topography

The study area is part of the Kabul Basin as previously mentioned, because of that the most properties of study area such as geomorphology, geology and topography checked out in relation to the Kabul Basin. The landforms within the Kabul Basin are typical of an arid to semiarid, tectonically active region. All adjacent sub basins except for the Central Kabul and Logar sub basins are separated by prominent bedrock outcrops (fig 2). The central plains of the sub basins are local depositional centers for sediments derived from the surrounding surficial deposits and bedrock outcrops. The central plains gently slope up to the adjacent mountains and hills to form piedmonts. Alluvial fans have developed on the flanks of the mountains surrounding the sub basins and on the interbasin ridges. The alluvial fans generally grade from coarse material near the source to finer material at the distal edges (Broshears and others, 2005). Physical weathering induced by extreme temperature fluctuations has produced pronounced breaks in slope at the edges of the subbasins (Houben and Tunnermeier, 2005). This continuing weathering process maintains the steep, rugged mountain slopes.

The topography of the Kabul Basin is strongly influenced by regional and local tectonic activity and by fluvial processes. The basin is bounded by mountain ranges; the highest range, reaching 4,400 m in altitude, is the Paghman Mountains to the west of the study area. The Kohe Safi range to the east of the study area is as high as 3,000 m, and most of the range slopes out of the study area to the east. The central plains of the subbasins are generally flat, rising gradually to the surrounding bedrock outcrops. Altitudes of the central plains range from around 1,800 m in the Central Kabul and Logar subbasins to 2,200 m in the Paghman and Upper Kabul subbasin. Perennial and ephemeral stream channels have dissected the valley-fill sediments. Active stream channels are generally narrow and shallow, rarely exceeding 10 m in width and 5 m in depth. Some isolated topographic depressions in the Central Kabul and Logar subbasins act as catchments for surface-water runoff and are the sites of playa lakes or ephemeral marshes (Houben and Tunnermeier, 2005).

## Geology

The Kabul Basin is part of the tectonically active Kabul block in the transgressional plate-boundary region of Afghanistan (Wheeler and others, 2005). A generalized geohydrologic section of the Kabul Basin is presented in figure 3 to illustrate the general structure and major geologic and hydrologic features. The western edge of the Kabul block is defined by the Paghman fault within the Chaman fault system (Ruleman and others, 2007). The Paghman fault trends north-northeast and is evident in the continuous fault scarp and piedmont alluvium along the western boundary of the Kabul Basin. The Paghman fault marks a transition from primarily left-lateral strike-slip movement on the Chaman fault to apparent left-lateral oblique-thrust faulting and dip-slip displacement on the Paghman fault. The eastern boundary of the Kabul Basin is marked by a few discontinuous linear fault scarps displaying normal dip-slip movement (Ruleman and others, 2007). Geomorphic evidence, such as left-lateral displacement of active stream channels, shows that movement on the Paghman fault has been sustained throughout much of Quaternary time (Ruleman and others, 2007).

The Kabul Basin can be described as a valley-fill basin-and-range setting where the valleys are filled with Quaternary and Tertiary sediments and rocks, and the ranges are composed of uplifted crystalline and sedimentary rocks (Bohannon and Turner, 2007; Lindsay and others, 2005). Quaternary sediments are typically less than 80 m thick in the valleys (Böckh, 1971). The underlying Tertiary sediments have been estimated to be as much as 800 m thick in the city of Kabul (Broshears and others, 2005; Japan International Cooperation Agency, 2007a; Houben and Tunnermeier, 2005) and may be more than 1,000 m thick in some areas of the valley (Böckh, 1971; John San Felipo, U.S. Geological Survey, written commun., 2007).

Most surficial geologic maps of the region are based on Afghan and Soviet mapping efforts (Abdullah and Chmyriov, 1977). The Quaternary and Tertiary sediments and rocks have been classified by Böckh, 1971; Bohannon and Turner, 2007; Houben and Tunnermeier, 2005; and Lindsay and others, 2005. Böckh (1971) divides the sediments into younger and older basin deposits. The younger deposits, the Reworked Loess Series, are described as reworked loess, gravel and sand, and talus. The gravel and sand were deposited mainly in the river channels. The Reworked Loess Series is as thick as 80 m in the Kabul Basin. The older deposits are the Lataband Series, the Kabul Series, and the Butkhak Series. The Lataband Series includes gravels and conglomerates ranging in thickness from several meters to several hundred meters. Houben and Tunnemeier (2005) describe the Lataband Formation as Quaternary terrace sediments of middle and younger Pleistocene age overlying conglomerates. In the central parts of the subbasins, the Kabul Series is described as at least 200 m thick. The series consists of marls, clays, siltstones, and fine-grained sandstones. Two boreholes drilled in the Logar subbasin penetrated 130 m of Kabul Series sediments. The Butkhak Series consists of the oldest known sedimentary deposits in the Kabul Basin, which are red silts, sandstones, clays, and conglomerates.

The geologic map of Bohannon and Turner (2007) shows Late Pleistocene loess in the centers of the subbasins, grading to Late Pleistocene conglomerate and sandstone and (or) Late Pleistocene-Holocene conglomerate and sandstone toward the bedrock outcrops. An exception to this transition is the western boundary, where the deposits at the contact between the alluvium-filled basins and the outcrops of the Paghman Mountains are Middle Pleistocene conglomerate and sandstone, Late Pleistocene loess, or Late Pleistocene-Holocene conglomerate and sandstone.

The surrounding mountains are primarily composed of Paleoproterozoic gneiss and Late Permian through Late Triassic sedimentary rocks (Bohannon and Turner, 2007). The interbasin ridges, composed of metamorphic core-complex rocks, are Paleoproterozoic gneiss. Basement rocks in the Kohe Safi, to the east of the Kabul Basin, are Paleoproterozoic gneiss and migmatite of the Sherdarwaza Series and low-grade schist and quartzite of the Walayati Series. The basement is overlain by Permian to Jurassic shelf or platform carbonate rocks of the Khengil Group (R.G. Bohannon, written commune. 2008). The Khengil and basement rocks are overthrust by schist mélange, which has been called the Kotagai Series, in the northern Kohe Safi range, and they are underthrust by mélange in Kabul River gorge (R.G. Bohannon, written common. 2008). The mélange is tectonically overlain by large slabs of peridodite in the northern Kohe Safi. Early Cretaceous gabbro and monzonite intrusions are present in the Paghman Mountains. The composition of the rocks beneath the valley-fill sediments is not well known, but is probably similar to the predominant Sherdarwaza bedrock surrounding and within the Kabul Basin.

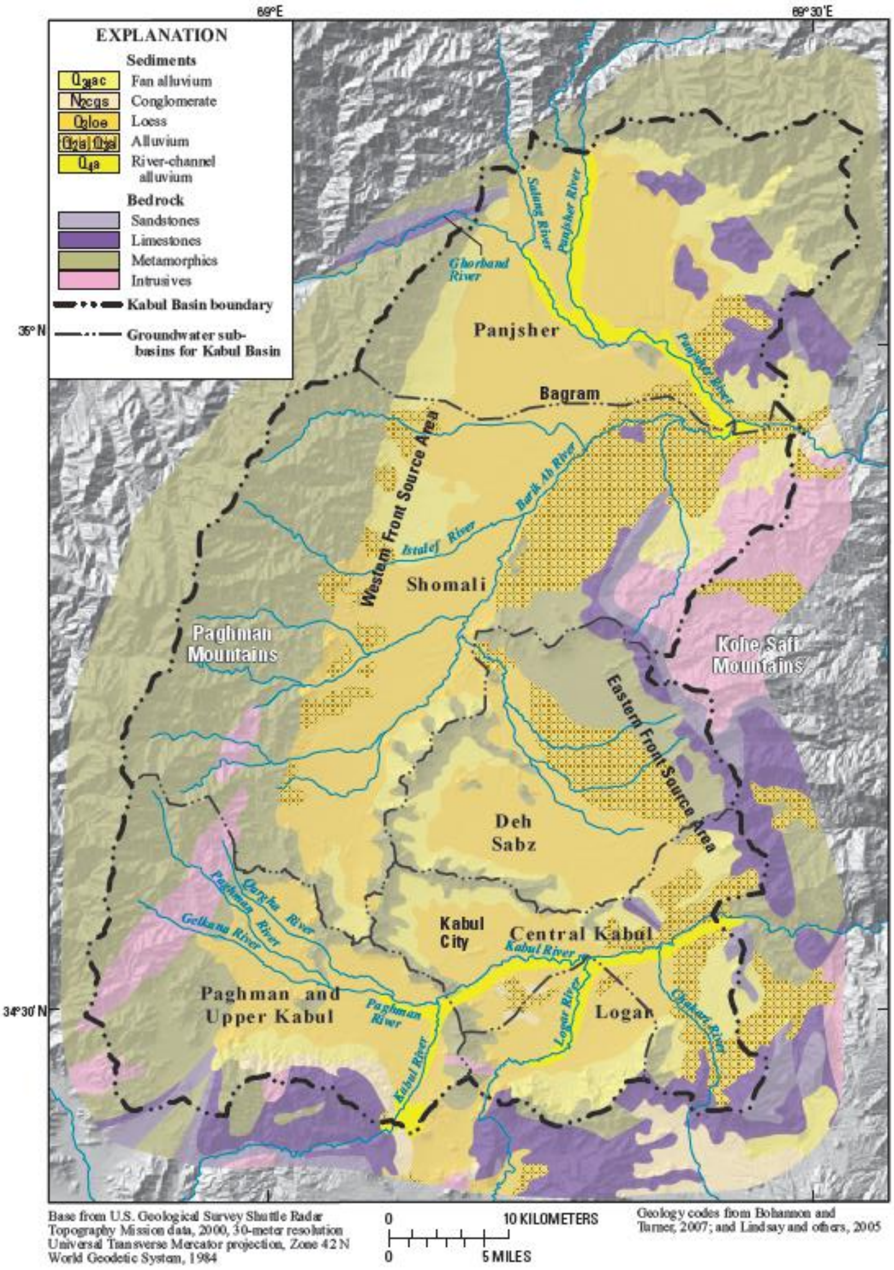



Figure 2. Generalized surficial geology and topography of the Kabul Basin,

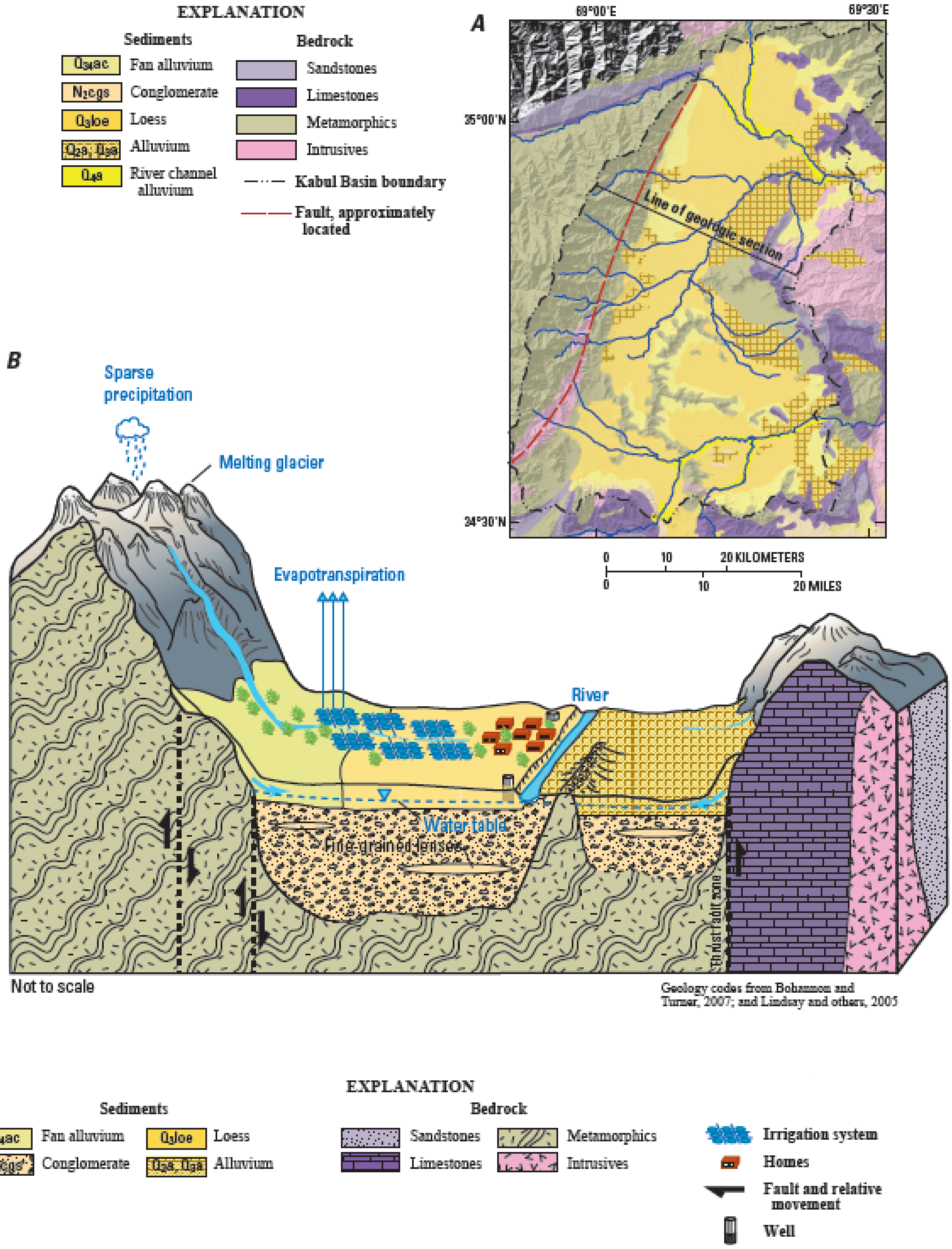



Figure 3. Planar view (A) and generalized hydrologic cross section (B) of the Kabul Basin,

## Hydrology

The study area (fig. 2) is within the Kabul River basin. The Kabul River enters the study area from the south, flows north about 21 km to the city of Kabul, and then flows east, leaving the study area through a steeply cut valley in the Kohe Safi Mountains. The Paghman River flows eastward from the Paghman Mountains and enters the Kabul River in the city of Kabul near the point where the Kabul River begins to flow east. The Logar River, a large tributary to the Kabul River, enters the study area from the south through a steeply cut valley and flows northward for about 28 km. The Logar River enters the Kabul River at the eastern edge of the city of Kabul, about 17 km downstream of the mouth of Paghman River. The Chakari River enters the study area from the south, flows northward for about 35 km, and enters the Kabul River about 6 km downstream from the mouth of the Logar River. General characteristics of the Kabul, Logar River Basins are provided by Favre and Kamal (2004). Most water flows into and out of the Kabul Basin in the major rivers. Because of the limited extent of unconsolidated sediments where the major rivers enter or leave the study area at steeply cut valleys, groundwater inflow or outflow at the margins of the Kabul Basin (fig.2) is likely to be much less than the groundwater flow in the sub basins.

Within and adjacent to the Kabul area, 12 stream gages (fig. 4) were operated for various periods from 1959 until 1980 that seven stream gages are related to the study area. General characteristics of the sub basin watersheds, including mean runoff, and mean runoff per unit area, and periods of record, are provided in table 2. Historical streamflow records are available from data reports (German Water Economy Group of Afghanistan and Ministry of Agriculture of the Kingdom of Afghanistan, 1967).

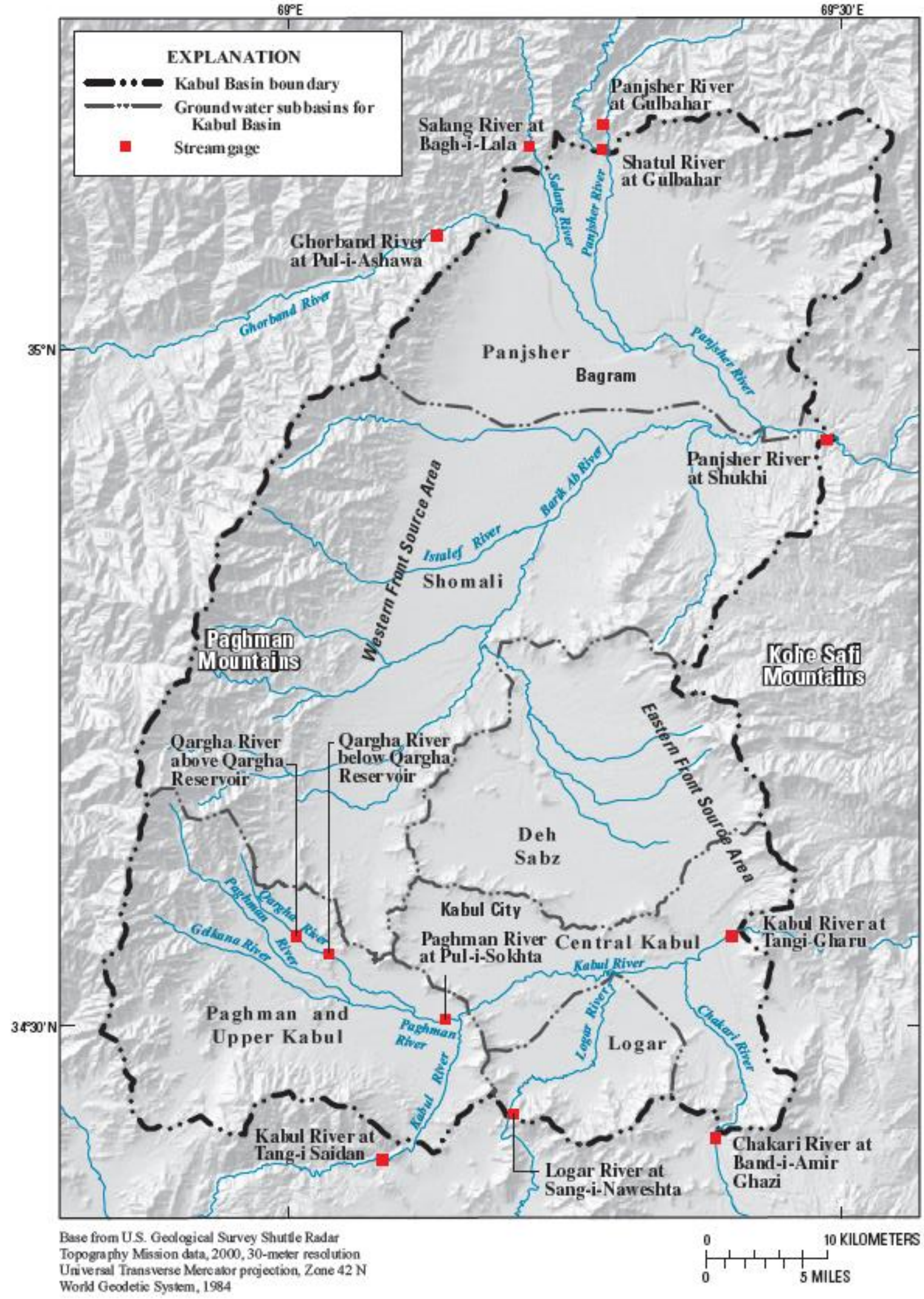



Figure 4.Location of historical stream gages in the Kabul Basin.

**Table 2.** Historical streamgages and general watershed characteristics in the Kabul Basin study area.

[Streamgages shown on figure 4; Latitude and longitude are given in decimal degrees. Runoff, in meters per second; $km^2$, square kilometers]

| Streamgage | Latitude | Longitude | Mean annual runoff | Drainage[1] area, $km^2$ | Runoff, $km^2$ | Drainage[2] area, $km^2$ | Runoff, $km^2$ | Period of record |
|---|---|---|---|---|---|---|---|---|
| Kabul River at Tangi Saidan | 34.40 | 69.08 | 4.05 | 1,625 | 0.002 | 1,663 | 0.002 | 10/01/1961 – 09/30/1980 |
| Qargha River above Qargha Reservoir | 34.57 | 69.02 | 0.33 | 70 | 0.005 | 20.79 | 0.016 | 04/16/1963 – 09/30/1980 |
| Qargha River below Qargha Reservoir | 34.55 | 69.03 | 0.22 | 115 | 0.002 | 43.21 | 0.005 | 10/01/1964 – 09/30/1980 |
| Paghman River at Pul-i-Sokhta | 34.50 | 69.13 | 0.72 | 500 | 0.001 | 424 | 0.002 | 03/01/1963 – 09/30/1980 |
| Logar River at Sang-i-Naweshta | 34.43 | 69.20 | 9.63 | 9,735 | 0.001 | 11,461 | 0.001 | 10/01/1961 – 09/30/1980 |
| Chakari at Band-i-Amir Ghazi | 34.42 | 69.38 | 0.31 | 395 | 0.001 | 302 | 0.001 | 05/26/1965 – 09/30/1980 |
| Kabul River at Tang-i-Gharu | 34.57 | 69.40 | 15.4 | 12,850 | 0.001 | 14,556 | 0.001 | 10/01/1959 – 09/30/1980 |
| Panjsher River at Gulbahar | 35.17 | 69.28 | 54.5 | 3,565 | 0.015 | 3,538 | 0.015 | 10/01/1959 – 09/30/1980 |
| Shatul River at Gulahar | 35.15 | 69.28 | 3.89 | 205 | 0.019 | 202 | 0.019 | 05/30/1967 – 03/06/1980 |
| Ghorband River at Puli-Ashawa | 35.08 | 69.13 | 23.1 | 4,020 | 0.006 | 4,032 | 0.006 | 10/01/1959 – 02/04/1980 |
| Salang River at Bagh-i-Lala | 35.15 | 69.22 | 10.1 | 485 | 0.021 | 435 | 0.023 | 10/01/1961 – 02/29/1980 |
| Panjsher River at Shukhi | 34.93 | 69.48 | 92.6 | 10,850 | 0.008 | 10,857 | 0.009 | 10/01/1966 – 09/30/1980 |

[1] Drainage area reported by previous studies.

[2] Drainage area calculated by this study.

Böckh (1971) collected discharge data at eight stations within the city of Kabul during the 1963 water year (a water year is defined as October 1 through September 30) and evaluated streamflow gains and losses to the underlying aquifer. Böckh's (1971) analysis, presented in tables 3-1 to 3-7 includes the locations of stream gages and annual and monthly discharges at the eight stations (fig 5).

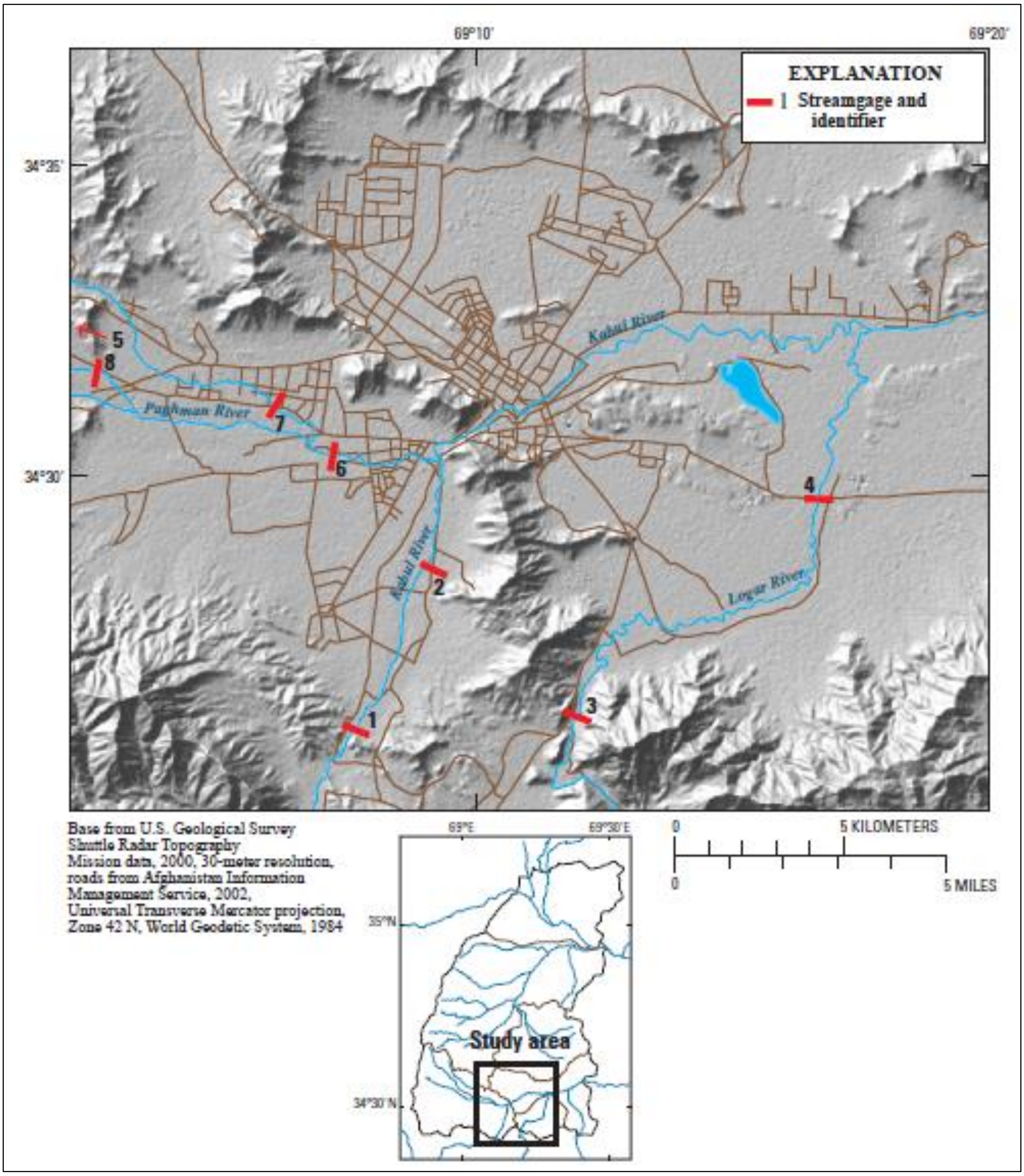



Figure 5. Location of stream gages at which runoff and water losses are provided by Böckh (1971). Stream gage numbers and locations are based on map plates from Böckh (1971).

Table 3-1. Discharge between stream gages 1 and 2.

| Year | Month | Discharge, in cubic meters per second | | |
|---|---|---|---|---|
| | | Streamgage 1 | Streamgage 2 | Water gain or loss (-) |
| 1962 | October | 0.65 | [1]0.26 | 0.39 |
| | November | 1.17 | [1]0.35 | 0.82 |
| | December | 1.84 | 0.74 | 1.10 |
| 1963 | January | 2.81 | 1.59 | 1.22 |
| | February | 2.07 | 1.09 | 0.98 |
| | March | 1.70 | 0.75 | 0.95 |
| | April | 6.55 | 5.20 | 1.35 |
| | May | 22.50 | 17.20 | 5.30 |
| | June | 6.56 | 5.05 | 1.51 |
| | July | 0.64 | 0.26 | 0.38 |
| | August | 0.59 | 0.17 | 0.42 |
| | September | 0.51 | 0.18 | 0.33 |
| Annual mean | | 3.97 | 2.74 | 1.23 |

[1] Computed from discharge at Streamgage 1.

Table 3-4. Discharge between stream gages 3 and 4.

| Year | Month | Discharge, in cubic meters per second | | |
|---|---|---|---|---|
| | | Streamgage 3 | Streamgage 4 | Water gain or loss (-) |
| 1962 | October | 5.78 | [1]4.58 | -1.20 |
| | November | 12.00 | [1]12.5 | 0.50 |
| | December | 15.80 | [1]16.7 | 0.90 |
| 1963 | January | 16.00 | 17.60 | 1.60 |
| | February | 14.80 | 16.00 | 1.20 |
| | March | 12.90 | 13.90 | 1.00 |
| | April | 8.40 | 7.85 | -0.55 |
| | May | 20.50 | 21.40 | 0.90 |
| | June | 2.11 | 0.57 | -1.54 |
| | July | 1.89 | [1]0.55 | -1.34 |
| | August | 1.62 | [1]0.41 | -1.21 |
| | September | 1.78 | [1]0.39 | -1.39 |
| Annual mean | | 9.47 | 9.37 | -0.10 |

[1] Discharge diverted to the Kabul River was added.

**Table 3-2.** Annual discharges and losses for stream gages 1 and 2, 1963 water year.

| | Discharge, in millions of cubic meters | | |
|---|---|---|---|
| | Streamgage 1 | Streamgage 2 | Water loss |
| River | 96.5 | 71.1 | 25.4 |
| Channels | 27.5 | 14.3 | 13.2 |
| Total discharge | 124.0 | 85.4 | 38.6 |

**Table 3-5.** Annual discharges and losses for stream gages 3 and 4, 1963 water year.

| | Discharge, in millions of cubic meters | | |
|---|---|---|---|
| | Streamgage 3 | Streamgage 4 | Water loss |
| River | 231.8 | 227.0 | 4.8 |
| Channels | 67.7 | 65.5 | 2.2 |
| Total discharge | 299.5 | 292.5 | 7.0 |

**Table 3-3.** Discharge differences between stream gages 1 and 2 for selected periods.

| Periods | Discharge, in cubic meters per second | | | | | |
|---|---|---|---|---|---|---|
| | Streamgage 1 | | Streamgage 2 | | Water loss | |
| | River | Channel | River | Channel | River | Channel |
| April - June | 10.70 | 1.20 | 8.41 | 0.73 | 2.29 | 0.47 |
| July - November | 0.08 | 0.63 | 0.00 | 0.25 | 0.08 | 0.38 |
| December - March | 1.15 | 0.97 | 0.42 | 0.63 | 0.73 | 0.34 |
| Annual Mean | 3.10 | 0.87 | 2.25 | 0.49 | 0.85 | 0.38 |

**Table 3-6.** Discharge differences between stream gages 3 and 4 for selected periods.

| Periods | Discharge, in cubic meters per second | | | | | |
|---|---|---|---|---|---|---|
| | Streamgage 3 | | Streamgage 4 | | Water gain or loss (-) | |
| | River | Channel | River | Channel | River | Channel |
| October - November | 5.94 | 2.95 | 6.90 | 1.64 | 0.96 | -1.31 |
| December - March | 13.30 | 1.60 | 12.80 | 3.30 | -0.50 | 1.70 |
| April - May | 11.80 | 2.60 | 11.00 | 3.60 | -0.80 | 1.00 |
| June - September | 0.15 | 1.70 | 0.18 | 0.30 | 0.03 | -1.40 |
| Annual mean | 7.43 | 2.04 | 7.28 | 2.09 | -0.15 | 0.05 |

**Table 3-7.** Discharge between stream gages 5, 7, and 8, and 6.

| Year | Month | Discharge, in cubic meters per second | | | | | |
|---|---|---|---|---|---|---|---|
| | | Streamgage 5[1] | Streamgage 7[2] | Streamgage 8[3] | Sum of streamgage 5, 7, and 8 | Streamgage 6[4] | Water gain or loss (-) |
| 1962 | October | 0.03 | 0.00 | 0.00 | 0.03 | 0.00 | -0.03 |
| | November | 0.03 | 0.00 | 0.00 | 0.03 | 0.01 | -0.02 |
| | December | 0.03 | 0.00 | 0.00 | 0.03 | 0.29 | 0.26 |
| 1963 | January | 0.04 | 0.13 | 0.00 | 0.17 | 0.37 | 0.02 |
| | February | 0.04 | 0.11 | -- | 0.15 | 0.15 | 0.00 |
| | March | 0.02 | 0.05 | 1.12 | 0.19 | 0.22 | 0.03 |
| | April | 0.10 | 0.00 | 1.06 | 1.16 | 0.67 | -0.49 |
| | May | 1.92 | 0.26 | 3.61 | 5.79 | 3.77 | -2.02 |
| | June | 0.37 | 0.00 | 0.06 | 0.43 | 0.07 | -0.36 |
| | July | 0.19 | 0.00 | 0.05 | 0.24 | 0.01 | -0.23 |
| | August | 0.10 | 0.00 | 0.02 | 0.12 | 0.00 | -0.11 |
| | September | 0.05 | 0.00 | 0.02 | 0.08 | 0.01 | -0.08 |
| Annual mean | | 0.24 | 0.05 | 0.41 | 0.70 | 0.46 | -0.24 |

[1] Paghman River plus channel.

[2] Qargha (Karga) River.

[3] Cheltan River plus channel.

[4] Paghman River which is downstream of streamgages 5, 7, and 8.

In 2005, two stations that record stage and discharge measurements were reestablished in the study area: Logar River at Sang-i-Naweshta, Kabul River at Tang-i-Gharu (fig. 4). For the stations Logar River at Sang-i-Naweshta and the Kabul River at Tang-i-Gharu, either not enough discharge measurements were made to develop a discharge rating, and (or) the stage data are missing periods needed to compute daily streamflow for the complete year.

## Streamflow Statistics

Streamflow in the study study area is extremely variable seasonally and annually as well as spatially. More than half of total annual streamflow occurs in the spring as the result of snowmelt. Two types of floods occur in the Kabul study area. The spring flood is the result of several factors, including snow and rain on snow during spring snowmelt. The less common type of flood is caused by rains during late spring, summer, and fall. Occasionally, monsoons extend into Afghanistan from the Indian Subcontinent and cause summer rainstorms. Long periods of no flow occur on most of the smaller rivers, and occasionally no-flow periods occur on the larger rivers.

Statistics are available for each stream gage include the maximum, minimum, and mean monthly discharges for mentioned period. Monthly mean values were calculated as the average of the daily values for one month for one specific year; months for which all daily values were not available. The maximum monthly mean discharge is the maximum of all the monthly mean values for a specific month during a specified period of years. Similarly, the minimum monthly mean discharge is the minimum of all the monthly mean values for a specific month during a specified period of years. The mean monthly discharge values are the means of the monthly mean discharges for each month during the respective periods of record for the stations.

The stream gages on rivers in the southern portion of the study area (Kabul River at Tang-i-Saidan, Qargha River above Qargha Reservoir, Paghman River at Pul-i-Sokhta, Logar River at Sang-i-Naweshta, and Kabul River at Tang-i-Gharu) have recorded the highest monthly runoff values during April and a large variability in the mean monthly values for April and May. The flows at Qargha River below Qargha Reservoir and Chakari River at Band-i-Amir Ghazi are exceptions because the stations are below dams, and the monthly flows reflect reservoir releases. The runoff from the southern part of the study area is generally from the melting of the snow cover on the eastern slopes of the Paghman Mountains to the west and the northern slopes of the Dasht-i-Nawur Mountains to the south. In 2007, glaciers covered about 66 km2 of the Panjsher River drainage area, but there are no glaciers in the drainage area of the Kabul River that flows into the study area. The Hindu Kush Mountains are much higher than the Paghman or Dasht-i-Nawur Mountains, which have no glaciers. Therefore, more snow accumulates in the Hindu Kush Mountains, and it melts about 2 months later. The larger snow accumulation results in an average annual runoff per square kilometer of 0.020 m3/s for the northern stations compared to 0.004 m3/s for the southern station.

Extensive and highly permeable aquifers or glaciers in the headwaters of streams generate a relatively stable supply of water, resulting in a relative stable flow. These streams also tend to have large recession indices. The recession index is the time it takes for streamflow discharge to decrease across one log cycle of a flow-duration curve plotted on a semi log graph with time. Conversely, streams that do not have a stable supply of water or lose flow as they cross highly permeable aquifers, provide a less reliable supply of water, and tend to have small recession indexes. The indices for the stations Qargha River above Qargha Reservoir indicating a more stable water supply.

From general observation and discussion of the flows with Hanif Ashoor (Ministry of Energy and Water, oral comm., 2006) the stream flows in the vicinity of the city of Kabul are reported to have been zero or intermittent during May 2006.

## Hydrogeology

### Hydraulic properties

The surficial and bedrock geology of the Kabul Basin was fairly well known and has recently been reinterpreted by Bohannon and Turner (2007) and Lindsay and others (2005). The geology in the study area was grouped into eight major hydro geologic zones (fig. 3) on the basis of general hydraulic conductivity and storage characteristics (table 4). The categories were Quaternary fan alluvium and colluvium (sand and gravel) (K1); river channel sediments (K2); loess (K3); unconsolidated conglomerates (K4); upper (K5) and lower (K6) Neogene sediments consisting of semi-consolidated fine-grained sediments and gravel; sedimentary rocks including sandstone, siltstone, limestone, and dolomite (K7); and all metamorphic and igneous rocks (K8). The hydraulic properties of the primary unconsolidated aquifer sediments in the Kabul Valley are generally high, on the order of 10s of meters per day. Hydraulic characteristics of the Quaternary and recent sediments (table 4) have been determined from aquifer tests (Böckh, 1971) and have been evaluated in other investigations (Houben and Tunnermeier, 2005; Niard, 2007). The geohydrology parameter categories used in the model were based on general hydraulic characteristics of sediments or rocks.

Table 4. Hydraulic parameters and generalized hydraulic characteristics of sediment and rock aquifers in the Kabul Basin
[m/d, meters per day; – not known or available]

| Sediment or rock unit | Hydraulic conductivity (m/d[1]) | Geologic codes[2] | Conceptual model | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Model layer(s) | Horizontal hydraulic conductivity (m/d) | Parameter code | Vertical hydraulic conductivity (m/d) | Parameter code | Porosity[3] |
| Fan alluvium and colluvium | – | $Q_{34}$ac | 1 | 50 | K1 | 5 | K1v | 0.28 |
| River channel sediments | 388.8 | $Q_4$a | 1 | 100 | K2 | 10 | K2v | 0.3 |
| Loess | 34.56 | $Q_3$loe | 1 | 20 | K3 | 2 | K3v | 0.28 |
| Unconsolidated conglomerates | – | $Q_3$a | 1 | 3 | K4 | 0.3 | K4v | 0.28 |
| Upper Neogene | 8.64 | $N_2$cgs | 1,2 | 1 | K5 | 0.1 | K5v | 0.1 |
| Lower Neogene | – | $N_2$cgs | 3 | 3 | K6 | 0.3 | K6v | 0.1 |
| Sedimentary rocks | – | all sedimentary rock codes | 4 | 0.1 | K7 | 0.1 | K7v | 0.01 |
| Metamorphic and igneous rocks[2] | – | all metamorphic and igneous codes | 4 | 0.01 | K8 | 0.01 | K8v | 0.01 |

[1] Reported by Böckh (1971).

Also, the deep layer of aquifer (Neogene aquifer) investigation was conducted by Japan International Cooperation Agency (JICA) under the direction supervision of Ministry of Mines. The investigation started from June, 2006 and completed in March, 2011. Original deep layer of aquifer investigation plan was formulated out based on the prerequisite that the depth of Neogene Aquifer should be around 600m.

Therefore, the original deep aquifer investigation included 6 wells of depth (600m class), 4 wells on middle test well (400m class), and also 4 wells of shallow test well (200 m class). But the deep aquifer investigation plan revised and finally fixed as follows: 3 wells of deep test well (600m class), 2 wells of middle test well (400m class) and 2 well of shallow test well (200m class), 1 well of super deep test well (1,000m) class and one new observation well (450m). From 9 wells, 7 of them are located in lower Kabul Basin. The wells locations are shown in figure 6. Table 5- 1 and 5-2 shown the results of the neogene aquifer investigation by JICA.

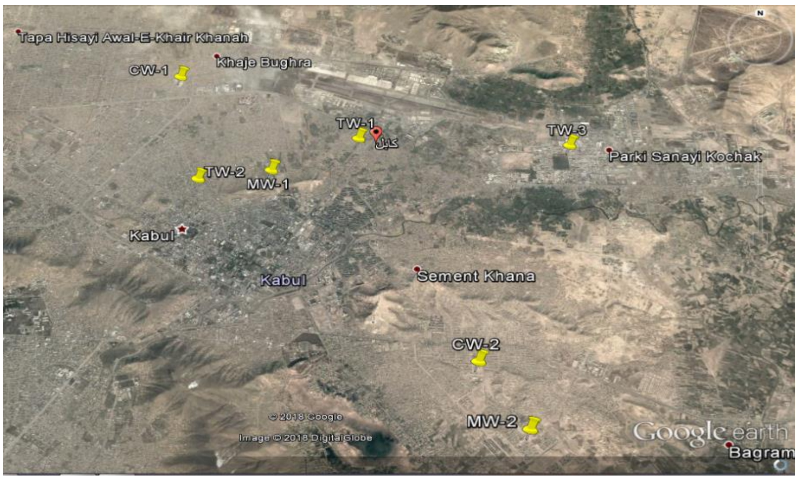



Figure 6. The location of well on neogene aquifer in the study area

Table 5-1 Neogene aquifer properties by JICA investigation

| Well No. | Coordinates | | Well Depth (m) | Screen location |
|---|---|---|---|---|
| | Easting | Northing | | |
| TW-1 | 69° 12' 10.6" | 34° 33' 11.8" | 640 | 500-590 m |
| TW-2 | 69° 10' 07" | 34° 32' 36" | 575 | 444-534m |
| MW-1 | 69° 11' 2.9" | 34° 32' 43.6" | 218.3 | 191-212m |
| CW-1 | 69° 09' 46.9" | 34° 34' 09.2" | 167 | 131-161 |
| MW-2 | 69° 13' 58.7" | 34° 39' 13" | 498 | 428-490m |
| CW-2 | 69° 13' 28.61" | 34° 30' 16.14" | 232 | 192-226m |
| TW-3 | 69° 14' 55" | 34° 33' 06" | 570 | 480-562m |

Table 5-2. Hydraulic Conductivity and Transmissivity of each well (Parameters of Neogene aquifer)

| Well No. | Cooper-Jacob Method | | Chaw Method | |
|---|---|---|---|---|
| | K (m/day) | T (m2/day) | K (m/day) | T (m2/day) |
| TW-1 | 0.16 | 14.78 | 0.12 | 10.9 |
| TW-2 | 0.13 | 11.9 | 0.08 | 7.77 |
| MW-1 | 0.049 | 1.03 | 0.042 | 0.9 |
| CW-1 | 0.35 | 10.5 | 0.38 | 11.59 |
| MW-2 | 0.11 | 7.10 | 0.05 | 3.4 |
| CW-2 | 0.12 | 3.60 | 0.1 | 3.13 |
| TW-3 | 0.23 | 18.96 | 0.21 | 17.79 |
| Average | 0.16 | 9.7 | 0.14 | 9.05 |

Three wells place in the study area, so base on those study parameters considered as below table 6.

Table 6. Hydraulic conductivity and transmissivity of well (parameters of neogene aquifer) in the study area.

| Well No. | Cooper-Jacob Method | | Chaw Method | |
|---|---|---|---|---|
| | K (m/day) | T (m2/day) | K (m/day) | T (m2/day) |
| MW-1 | 0.049 | 1.03 | 0.042 | 0.9 |
| MW-2 | 0.11 | 7.1 | 0.05 | 3.4 |
| CW-2 | 0.12 | 3.6 | 0.1 | 3.13 |
| Average | 0.093 | 3.91 | 0.064 | 2.47667 |

## Hydrogeological current status

Groundwater extraction by varied usages, potentiometric surface water and groundwater level trend were descripted here.

### Groundwater extraction

Water use in the Kabul Basin can be grouped into two major categories—combined municipal and domestic use, and agricultural irrigation. The amount of water used for industrial purposes is unknown but is probably much less than that used for other purposes. Water for municipal and domestic use is generally supplied by community or individual wells, which are concentrated in the more populated areas. Water use for agricultural purposes has been estimated to be at least an order of magnitude greater than that for domestic use (Uhl, 2006). Agricultural use is seasonal, generally from May through September, and is concentrated in the northern and western areas of the basin.

#### Municipal and Domestic

The city of Kabul operates municipal supply and distribution systems in parts of the city. The municipal systems are supplied primarily by groundwater from supply wells, and secondarily by surface water obtained from the Qargha Reservoir in the upper Paghman River watershed. In rural areas, domestic water generally is supplied by shallow dug or driven wells, but also may be supplied by deeper wells, karezes, springs, or surface-water sources.

The per person rate of water use in the study area is not known and most likely differs considerably from rural to urban areas. Estimated per person water-use rates reported for Kabul include 40 L/d (Niard, 2007), 50 L/d (Afghanistan Ministry of Energy and Water, written commun. 2005), and 60 L/d in winter to 110 L/d in summer (Böckh, 1971). Estimated per person water use in rural areas is thought to be lower than previous estimates, generally about 20 to 30 L/d. In 2006, municipal groundwater withdrawals in the city of Kabul were reported to be approximately 40,000 m3/d from a few pumping centers in the city (Mr. Djallazada, Ministry of Urban Development, oral commun. 2007). Low estimated rates of water use, such as 11 L/d by Uhl (2006), may be realistic for domestic use in the more rural areas; however, in rural areas individuals also provide water to livestock and small gardens, and the total per person use rate for both domestic and livestock uses might be close to rates for more urban areas. With increasing security and an improving standard of living, future per person water-use rates may be greater than current rates.

If the per person water-use rate is assumed to be 25 L/d (0.025 m3/d), the Kabul municipal-supply system serves about one million people in the city. Shallow wells equipped with hand pumps supply local domestic water needs in many urban and rural areas throughout the Kabul Basin. The Ministry of Urban Development indicates that municipal groundwater withdrawals in the city of Kabul were expected to increase to 120,000 m3/d in 2009 with the installation of additional planned wells. The total population in the Kabul Basin was estimated to be approximately 3.5 million in 2002 (Afghan Information Management System, written commun. 2006) with about 66 percent of the population (2.3 million) in the Kabul district which includes the city of Kabul. The population is anticipated to increase by approximately 20 percent by the year 2012 (Mr. Rashid Fahkri, Central Statistics Office Afghanistan, written commun. 2007).

Between 1997 and 2005, the Danish Committee for Aid to Afghan Refugees (DACAAR) installed approximately 1,500 shallow wells (with a median depth of 22 m) in the Kabul Basin with about 1,000 of these wells in the three sub basins of the city of Kabul (Safi and Vijselaar, 2007). Of the DACAAR wells with status reported, about 25 percent in the city of Kabul were reported as dry or inoperative, whereas about 20 percent in the larger Kabul Basin were reported as dry or inoperative. Water levels have declined by about 10 m since 1982 in the city of Kabul's intermountain aquifers because of increased water use (Safi, 2005). Increasing water use has reduced groundwater levels, which in turn have led to dry wells. During recent droughts, more than 25 percent of shallow wells have gone dry (Safi, 2005).

So, the statistics indicate that Kabul citizens will in general tend to use less water per capita than those in a fully developed European city for the following reasons:

– Limited access to modern water using appliances

– General use of earth latrines rather than flush toilets in traditional properties

– Lack of sewerage system to take away liquid waste in large volumes

– Large household sizes hence more efficient use of water for food preparation etc.

The study area cover some districts of Kabul city (fig 7). The mentioned districts are described in table 7. According to Statistical Yearbook from the Central Statistics Organization (CSO) for 2017-018 year, the final population of study is 2421363 person.

Based on the" Reference: JICA_EIDJR09108 Sector 3 Water, the per capita water supply and consumption is calculated as table 8.

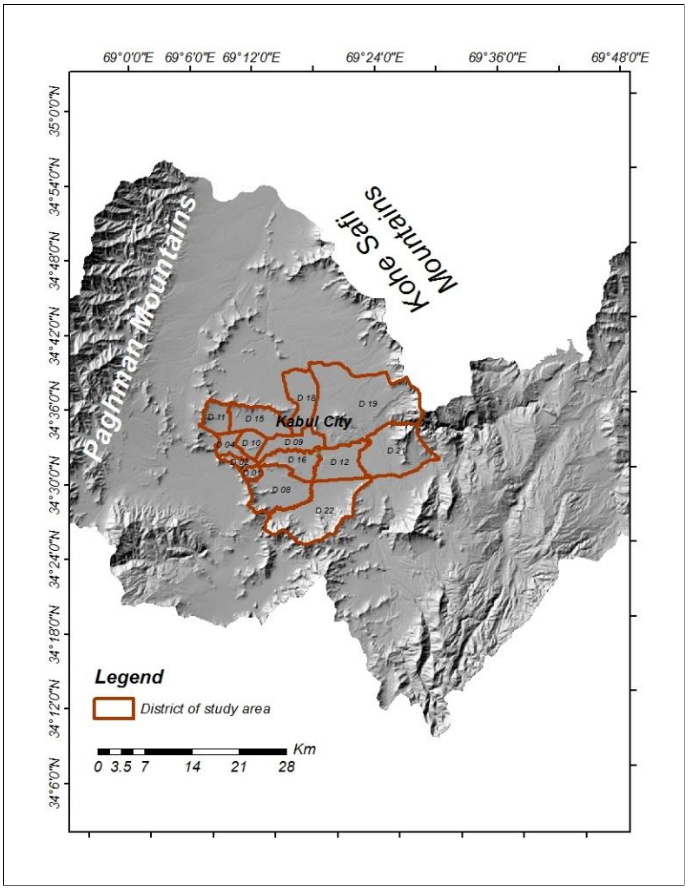



Figure 7. The districts of Kabul city in the study area

Table 7. Estimated population of study area by district year 2017-2018

| No | District | Total | Area مساحت KM2 |
|---|---|---|---|
| | | | |
| 01 | No 1 | 105195 | 4.7 |
| 02 | No 2 | 128111 | 6.8 |
| 03 | No 22 | * | 79.0 |
| 04 | No 4 | 330115 | 11.6 |
| 05 | No 21 | * | 63.9 |
| 06 | No 19 | * | 141.4 |
| 07 | No 18 | * | 33.9 |
| 08 | No 8 | 335481 | 48.4 |
| 09 | No 9 | 290205 | 24.5 |
| 10 | No 10 | 355939 | 13.0 |
| 11 | No 11 | 278580 | 17.4 |
| 12 | No 12 | 51310 | 34.8 |
| 13 | No 15 | 381091 | 32.1 |
| 14 | No 16 | 165336 | 25.2 |
| Total | | 2421363 | |
| • No data | | | |

Table 8. Estimated per capita water consumption of study area by JICA

| | *2010/Short-term (LCD)* | *2015/Mid-term (LCD)* | *2030/Long-term (LCD)* |
|---|---|---|---|
| ***Kabul*** | *60* | *100* | *120* |
| ***Other Cities in the Basin*** | *50* | *80* | *100* |
| ***Rural area*** | *25* | *40* | *60* |

Agricultural

With the exception of the urban area of Kabul and the city of Jalalabad in the Lower Kabul sub-basin, the Kabul river basin is predominately rural and sparsely populated. Population growth rates are quite modest except Kabul. The population is concentrated along river courses and in the adjacent valleys where space and water are accessible for irrigating the summer crop. Consequently the construction of new storage reservoirs is likely to involve extensive resettlement and compensation of people displaced by the reservoirs.

Agriculture in the Kabul river basin is generally limited to land along the river valleys with access to the river for irrigation (fig 8). The exceptions are the broad plan stretching southward from the Ghorband and Panjshir rivers, the lower Logar valley, areas adjacent to Kabul, and the wide valley of the Kabul River east of Jalalabad. These areas represent the greatest potential in the Kabul River basin for intensive cultivation of high-value crops. These large contiguous agricultural areas are also close to the primary transport routes and the largest economic centers.

Figure 8. Irrigation Channel in the Logar Valley – Photo via Google Earth

If water supply is reliable throughout the summer season, irrigated agriculture is intensive, intermittent irrigation is practices where access is more uncertain, both within the season and from year to year. There is also a relatively small area of rain-fed agriculture. The existing and potential irrigated areas within the Kabul River basin total approximately 352,000 hectares. Potential irrigated areas in the Upper Kabul basins and around are summarized in the table 9.

Table 9. Irrigated Land Areas

| Irrigated Area | River | Total area (hectares) |
|---|---|---|
| **Logar-Upper Kabul** | | |
| Chak Wardak | Logar | 3,750 |
| Tangi Wardag | Logar | 26,000 |
| Lower Logar | Logar | 10,500 |
| Upper Kabul | Upper Kabul | 28,740 |
| East of Kabul | Recycled wastewater from Kabul | 37,330 |

[Source Scoping Strategic Options for Development of the Kabul River Basin; World Bank]

At the low irrigation efficiency (30 percent) the water diversion requirement is about 13,636 m3/hectare at an improved efficiency of approximately 45 percent the diversion requirement is approximately 9,131 m3/hectare.

Ground water for Kabul is currently taken from the lower Logar and Upper Kabul aquifers at an estimated extraction rate of 90,000 m3/day. Based on an irrigation requirement of 10,000 m3/hectare the impact from extraction of the two aquifers is around 3,000 hectares or roughly 10% of the current irrigated area in the Lower Logar and Upper Kabul areas.

Based on Pell Frischmann and partners hydrological study in Kabul river basin several aquifers supplying water for Kabul City requirement fig 9. Also the current abstraction of aquifers was determined by JICA study as a table 10.

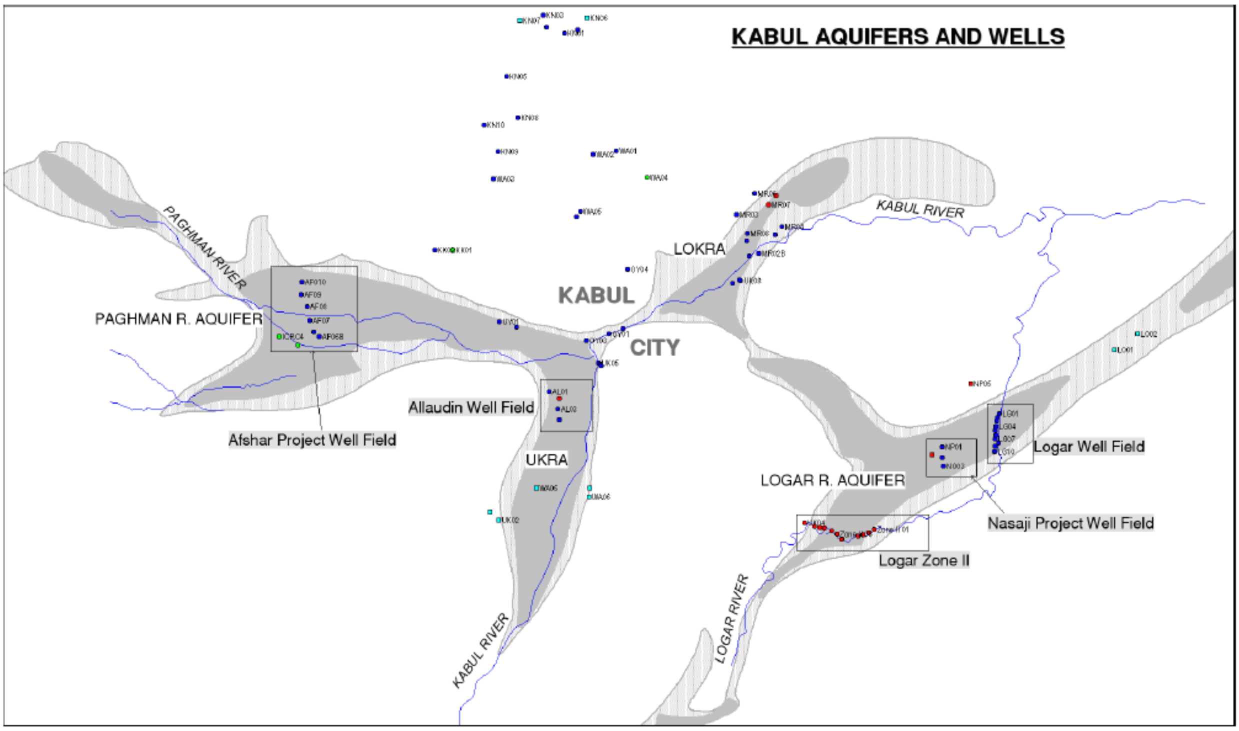



Figure 9. Aquifers supplying water for Kabul City

Table 10. Current abstraction within the Kabul city by aquifers

| Aquifer | Current abstraction m3/day |
|---|---|
| Lower Logar (Logar R Aquifer) | 33750 |
| Allaudin and Upper Kabul | 8630 |
| Asfer (paghman River) | 10000 |
| Lower Kabul(Lokra) | 10000 |
| Total | 62380 |

[Sources: Availability –JICA EID09108 Final Report Sector 05 Water Supply and Sewerage; Table 1.8, Page 1-6. Abstraction – AUWSSC data]

Two aquifers is placed within the study area as Lower Logar and Lower Kabul. from the JICA Study 2009 for the Kabul city water demand (fig 10) Current/Proposed Abstraction m3/day and Water Supply Potential Yield m3/day was calculated as table11.

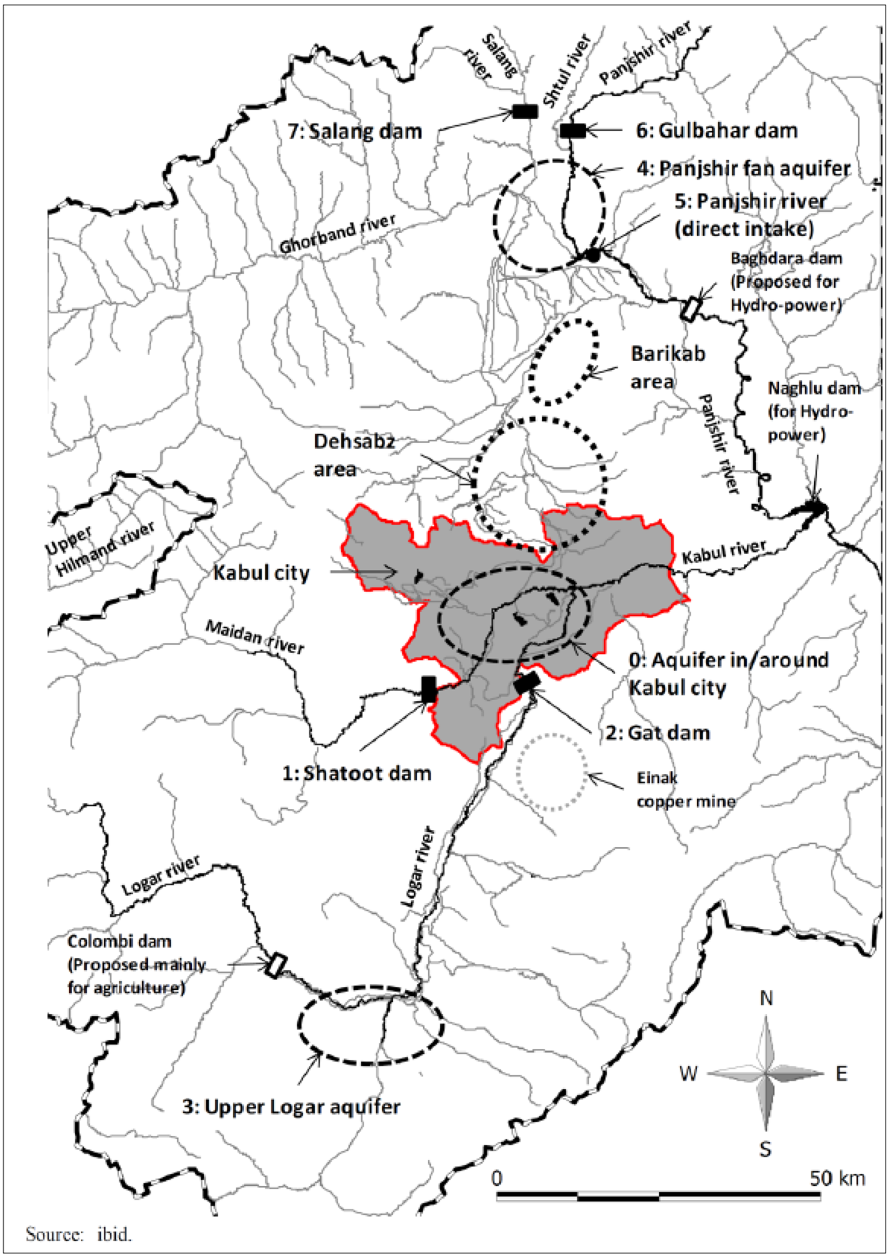



Figure 10. the Kabul city boundary and rivers situation

Table 11: Summary current abstraction and Water Supply Potential

| Type | Location | Current/Proposed Abstraction $m^3$/day | Potential Yield $m^3$/day | Remarks |
|---|---|---|---|---|
| **Current** | | | | |
| Ground water | Lower Logar river aquifer | 33,750 | 67,500 | Current abstraction excluding STP |
| Ground water | Allaudin and Upper Kabul | 8,630 | 34,200 | Current abstraction |
| Ground water | Asfer (Paghman river) | 10,000 | 10,000 | Current abstraction |
| Ground water | Lower Kabul (Lokra) | 10,000 | 10,000 | Current abstraction |
| Ground water | Shallow private wells | 50,000 | | Estimated extraction from local private wells |
| | **Total** | **112,380** | **121,700** | Current proposal under Extension of Kabul Water Supply II program |
| **Medium Term 10-15 Years** | | | | |
| Ground water | Lower Logar river aquifer | 60,000 | 67,500 | Extraction increased to max |
| Ground water | Allaudin and Upper Kabul | 15,000 | 15,000 | Extraction reduced due to Shatoot dam |
| Ground water | Asfer (Paghman river) | 10,000 | 10,000 | Max extraction |
| Ground water | Lower Kabul (Lokra) | 10,000 | 10,000 | Max extraction |
| Surface Water | Shatoot Dam | 266,000 | 266,000 | Design treated water flow |
| Ground water | Middle Logar Aquifer | 50,000 | 173,000 | 35,000 $m^3$/day required for Aynak |
| Ground water | Upper Logar Aquifer | 50,000 | 173,000 | Medium extraction rate could be increased |
| | **Total** | **461,000** | **714,500** | |
| **Long Term 30 Years** | | | | |
| Ground water | Lower Logar river aquifer | 60,000 | 67,500 | |
| Ground water | Allaudin and Upper Kabul | 15,000 | 15,000 | |
| Ground water | Asfer (Paghman river) | 10,000 | 10,000 | |
| Ground water | Lower Kabul (Lokra) | 10,000 | 10,000 | |
| Surface Water | Shatoot Dam | 266,000 | 266,000 | |
| Ground water | Middle Logar Aquifer | 50,000 | 173,000 | |
| Ground water | Upper Logar Aquifer | 50,000 | 173,000 | |
| Ground water | Panjshir fan aquifer | 160,000 | 573,000 | Single transfer main from Panjshir |
| | **Total** | **621,000** | **1,287,500** | |

Groundwater level trends

Groundwater levels in the Kabul River Basin have fallen dramatically as a result of below-normal precipitation since about 1998. The mean annual precipitation from 1956 to 1983 was 312 mm (World Meteorological Organization, 2004). In 2001, only 175 mm of precipitation was reported for Kabul (International Water Management Institute, 2002). The below-normal precipitation has continued with the exceptions of only the years 2004–2005 and 2006–2007, when it was near normal in the Kabul Basin. Banks and Soldal (2002) reported declines of 4–6 m in the water table in Kabul during the drought period of the last 3–4 years (1998 to 2002) and of up to 10 m in some areas. They further state that the largest declines are probably a result of the effects of withdrawals superimposed upon climatic trends. The water level at the BGR project house in Kabul has declined from 2–3 m below land surface in 1965 to 9.5 m in 2004 (Houben and Tunnemeier, 2005), a drop of 6–7 m in 40 years.

Comparing water-table contours measured by the 1965 German Geological Mission (Houben and Tunnemeier, 2005) to those reported by Broshears and others (2005) for Central Kabul, it is evident that water levels have dropped from 1,794–1,791 m ASL to 1,785–1,780 m ASL in about 40 years. Recent (2007) water levels indicate that groundwater levels are rising in response to lessening of the early 2000s drought, however, water levels are declining in other areas of the Kabul River Basin.

Also groundwater-level hydrographs for the sub basins of the Kabul Basin are provided by Akbari and others from 2004 to 2013 (2007). The net of monitoring wells are distributed in two sub basins of the Kabul basin; the central Kabul and Lugar sub basins. The locations and ground-surface elevations for the wells in the original monitoring network were established in World Geodetic System 1984 (WGS 84) coordinates by differential global positioning system (GPS) measurements (Broshears and others, 2005; Akbari and others, 2007). The locations and ground-surface elevations for the five wells added to the monitoring network after 2007 were located using standard GPS receivers. Well location information, along with other well characteristics, is presented with each well hydrograph in the Appendix 1.

Logar Sub basin

The depth to water on the western bank of the Logar River (Logar aquifer) is reported to be between 30 to 80 centimeters (cm) in the lower flat-lying area and between 1.5 and 2 meters (m) in the higher regions (elevations) during the period of investigation (2003–2005). Böckh (1971) reported that the water levels on the eastern bank of the Logar River ranged from around 5 to 10 m below land surface and that the depth to water fluctuated between 1 and 2 m in response to pumping for irrigation. The large difference between the depth to water on the west and east banks of the Logar River were attributed to differences in land-surface elevation. The Kabul aquifer generally has depths to water that range from 2 to 12 m and water-level fluctuations up to 5 m. Water levels in 1965 were from 2 to 5 m below land surface. The depth to water in the Paghman aquifer is very shallow near the center of the basin and increases towards the valley sides. Depth-to-water measurements made in 1962–1963 indicate a water level of 19 m below land surface near the confluence of the Cheltan and Paghman streams.

The Logar sub basin includes urban population centers and rural, agricultural land. Nine monitoring wells in the Logar sub basin (fig 11) ranged in total depth from 25 to 79.1 m. The surficial geology at the wells varied from Quaternary loess to Quaternary conglomerate and sandstone. Depth-to-water measurements under static conditions ranged from a minimum of 1.5 m (1,783.4 m above sea level) adjacent to the Logar River during May 2005 to a maximum of 10.2 m (1,781.1 m above sea level) during the fall of 2004 and 2006 at a well not in the vicinity of any streams or rivers. Seasonal water-level fluctuations from fall 2005 through spring 2006 ranged from about 1.3 to 4 m in the Logar sub basin. Water-level increases of up to 3.9 m from October 2004 until June 2006 were measured in a well along the Logar River. Many of the wells along the Logar River are municipal water-supply wells that are frequently pumped. Taking this into account, there does appear to be a strong seasonal recharge component that can be correlated to times of peak flow during winter and spring in the Logar River. Depth to water in one well rose from 9.3 m (1,783.3 m above sea level) in early January 2005 to 5 m (1,787.5 m above sea level) in May 2005. This change in water level corresponded to near-normal winter and spring precipitation and corresponding flow in the Logar River.

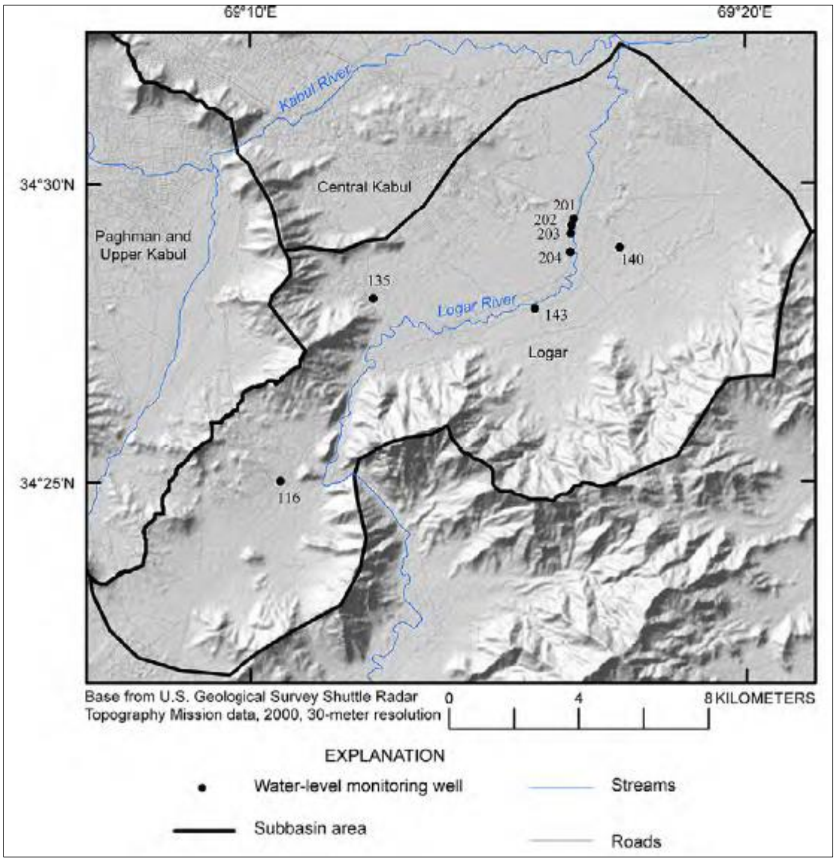



Figure 11. Location of wells in the Logar Sub basin.

Central Kabul Sub basin

The Central Kabul sub basin includes the primary population center of Afghanistan (city of Kabul) in the western part of the sub basin and more rural lands in the eastern part of the sub basin. Twenty-four monitoring wells in the Central Kabul sub basin ranged in total depth from 6.6 to 160 m (fig 12). One well was located on an outcrop of gneiss; at all other well sites, the surface geology consisted of Quaternary loess, fan alluvium and colluvium, or conglomerate and sandstone. Depth-to-water measurements under static conditions ranged from a minimum of about 2.5 m (1,790 m above sea level) during June 2005 to a maximum of about 23 m (1,778 m above sea level) during January and February 2006. Monitoring wells that have water levels not affected by pumping have seasonal fluctuations from 0.5 to 3 m. The water level in the supply well on the grounds of the Afghanistan Geological Survey building had a seasonal fluctuation of about 2 m. In general, it appears the wells near the Kabul River had increasing water levels during the monitoring period, and wells that are distant from the river had decreases in water level. The water-level summary plot for Well 208 shows a recovery of approximately 9 m from a dynamic water-level measurement in March 2005 to a static water-level measurement in early April 2005. The water-level measurement in this well in late April 2005 recorded a drop of about 8 m because of pumping. Larger water-level fluctuations caused by pumping were recorded in the Khair Khana wells; pumping-induced drawdown was up to 25 m.

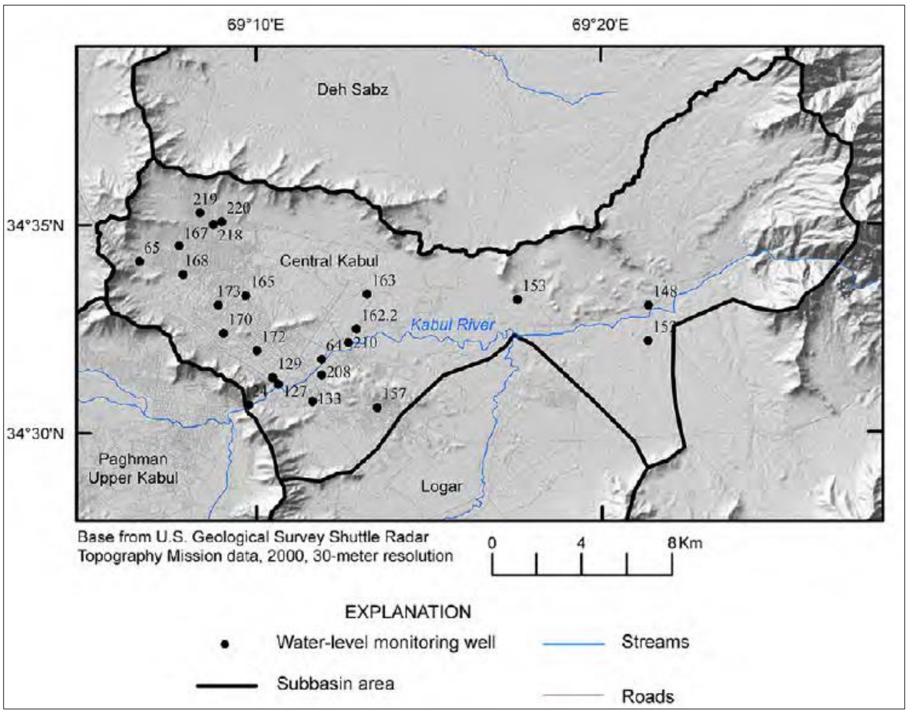



Figure 12. Location of wells in the Central Kabul Sub basin.

Broshears and others (2005) present a water-table map showing generalized directions of groundwater flow for five sub basins of the Kabul Basin; the map was based on AGS water-level data collected from July 2004 through November 2004. Akbari and others (2007) present further analysis based on data from the AGS water-level network through March 2007 and selected water-level hydrographs by sub basin. In Central Kabul sub basin, water-table altitudes range from 1,785 to 1,775 m ASL. The depth to groundwater along most stream channels is less than 15 m. The horizontal groundwater gradients are steep near mountain-front recharge areas and decrease towards the centers of the basins. A comparison of water levels from Akbari and others (2007) to water levels reported by Myslil and others (1982) indicates that water levels have declined more than 10 m in upslope areas and 5 to 6 m in the city of Kabul. Shallow lakes and marshes that were present in the city of Kabul in 1980 are now dry.

The water-table map based on data of net monitoring wells from 2004 up to now will be create. So that the unit hydrograph map will prepare for the study area base on monitoring wells water table.

The unit hydrograph will be show that the water table in which year has minimum fluctuations. The determination month data will be used to provide a water table map. Unfortunately the update water table data of monitoring well in the study area do not exist up to time of report prepare. But, based on exist data from 200 to 2013 regional water table was create by Thomas. Mack 2013 fig 13.

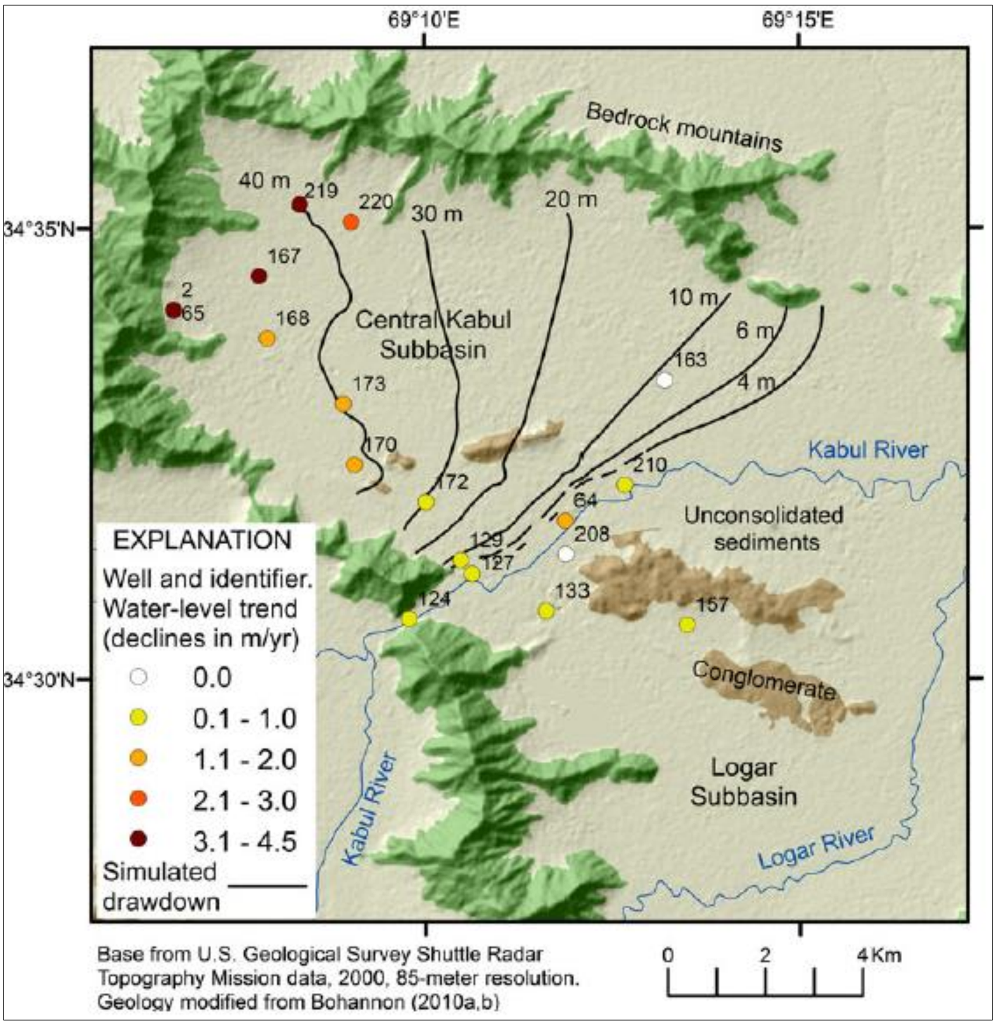



Figure. 13 .Groundwater-level trends, decrease in meters per year, from September 2008 to 2012

## MODEL CONSTRUCTION

The code selected for this study is MODFLOW-2000 (McDonald and Harbaugh, 1988). MODFLOW-2000 is a 3-dimensional, finite-difference, block-centered, saturated groundwater flow code which is supported by boundary conditions packages to handle flow the processes such as lateral recharge and discharge, and extraction and injection via wells. MODFLOW is well documented and is the most widely accepted groundwater flow code.

GMS is a comprehensive MODFLOW interface that was used in this exercise that provides tools for every phase of groundwater simulation including site characterization, model development, post-processing, calibration and visualization. Using GMS, models can be defined and edited at conceptual model level or on a cell-by-cell basis at the grid level. In addition to MODFLOW, GMS has interfaces to solute transport and particle tracking models (MODPATH, MT3DMS, RT3D, and VS2D). MODFLOW-2000 requires a rectangular grid made up of rows and columns.

### Conceptual model

The conceptualization of the flow of groundwater in the study area was based on the considerable quantity of available information on all aspects of the hydrogeology of the area.

The steps adopted in the development of the flow concept included definition of aquifers and confining units, identification of sources and sinks for groundwater, and delineation of the hydrogeological boundaries encompassing the study area: Essentially, groundwater recharges, the groundwater flow path, the hydraulic head distribution, connectivity of layers and the permeability variation within the aquifer.

Extent (Model Domain and spatial discretization)

The Kabul River Basin is in a "basin and range" setting, approximately 20 km wide and about 35.5 km long, where the valley is filled with quaternary and tertiary sediments and the ranges are composed of uplifted crystalline and sedimentary rocks. The table 12 show the study area boundary in model.

Table 12. The study area boundary in model

<table>
<tr><td></td><td></td><td>TOP</td><td></td><td></td></tr>
<tr><td></td><td></td><td>3831600</td><td></td><td></td></tr>
<tr><td>LEFT</td><td>509700</td><td></td><td>543300</td><td>RIGHT</td></tr>
<tr><td></td><td></td><td>3810000</td><td></td><td></td></tr>
<tr><td></td><td></td><td>BOTTOM</td><td></td><td></td></tr>
</table>

The model was aligned with the primary axis of the basin where the lateral model boundary coincides with the major drainage divides forming the mountains that define the valley (fig 14). The model was simulated with a horizontal cell size of 400 by 400 m in the row and column direction (fig. 15). The model was subdivided vertically into just one layer to about 500 m from the ground surface.

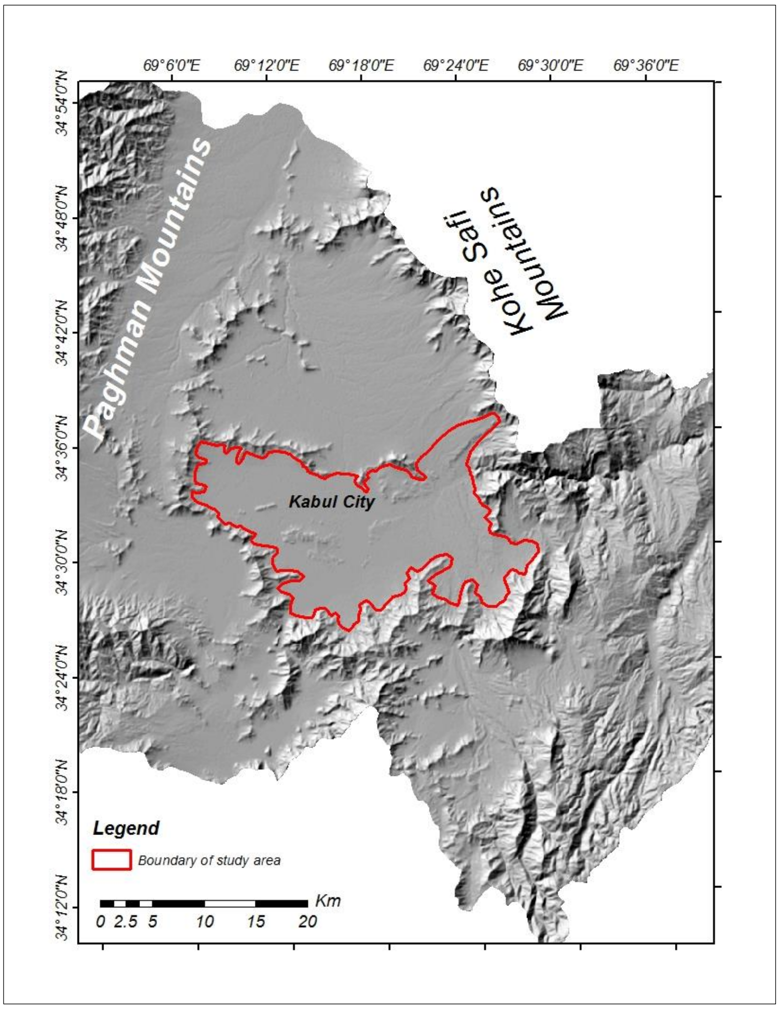



Figure 14. The Boundary of study area in model

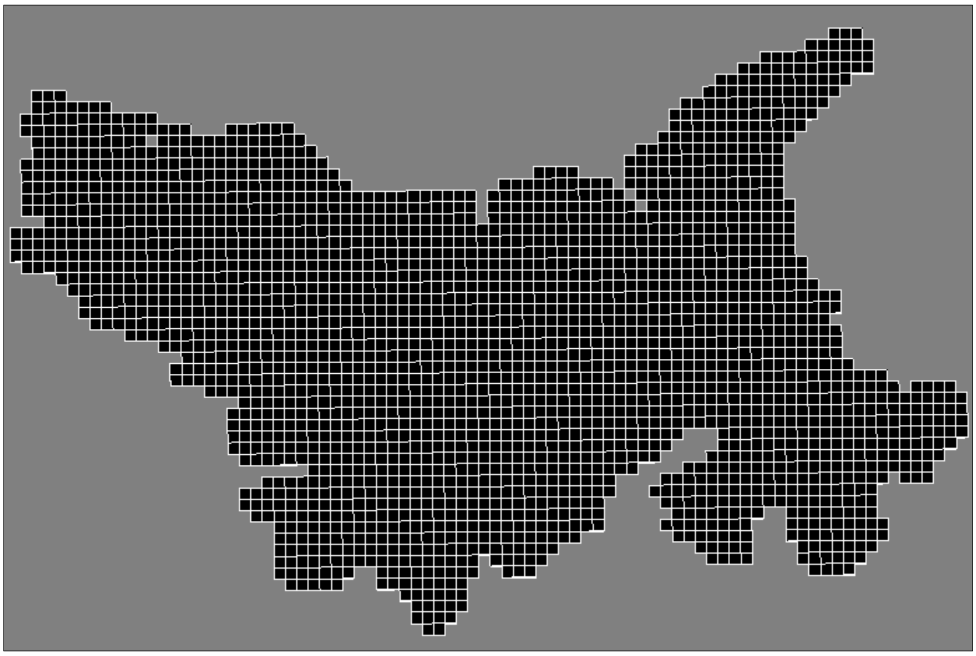


Figure 15. The Gridding of the study area in model

Boundary condition

The modelled area is considered a closed hydrogeological system. To represent this limitation, model boundary conditions was used to account for the flow to and from areas beyond the extent of the model area. The perimeter of the model is bounded by no-flow boundaries.

Ground surface elevations layer

The ground surface elevation was interpolated from regional ground surface elevation data obtained from GIS land topography coverage (DEM) using the GMS software by the Kriging technique. The fig.16 show the Landsat 8 imagery of the study area that obtained from USGS web site. Also, the fig 17 show the topographic condition of aquifer in GMS model.

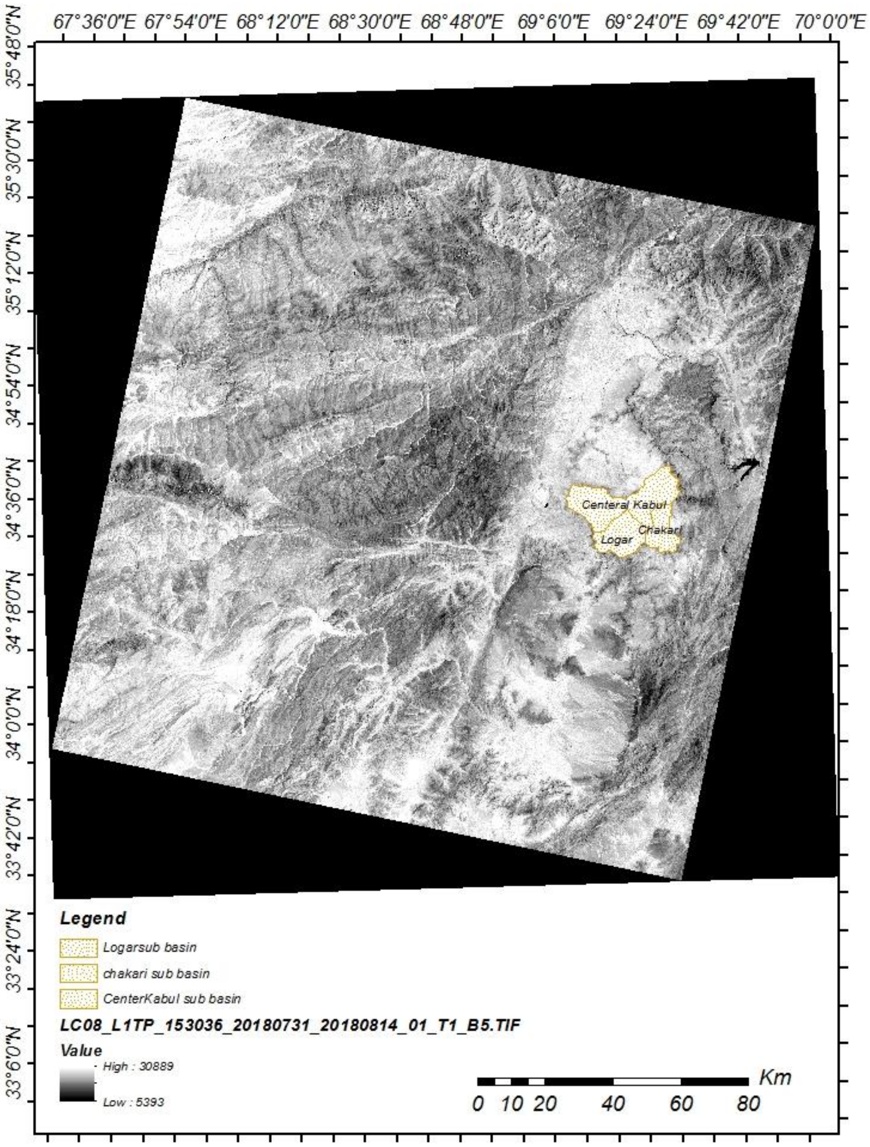



Figure 16. The Landsat 8 imagery of the study area

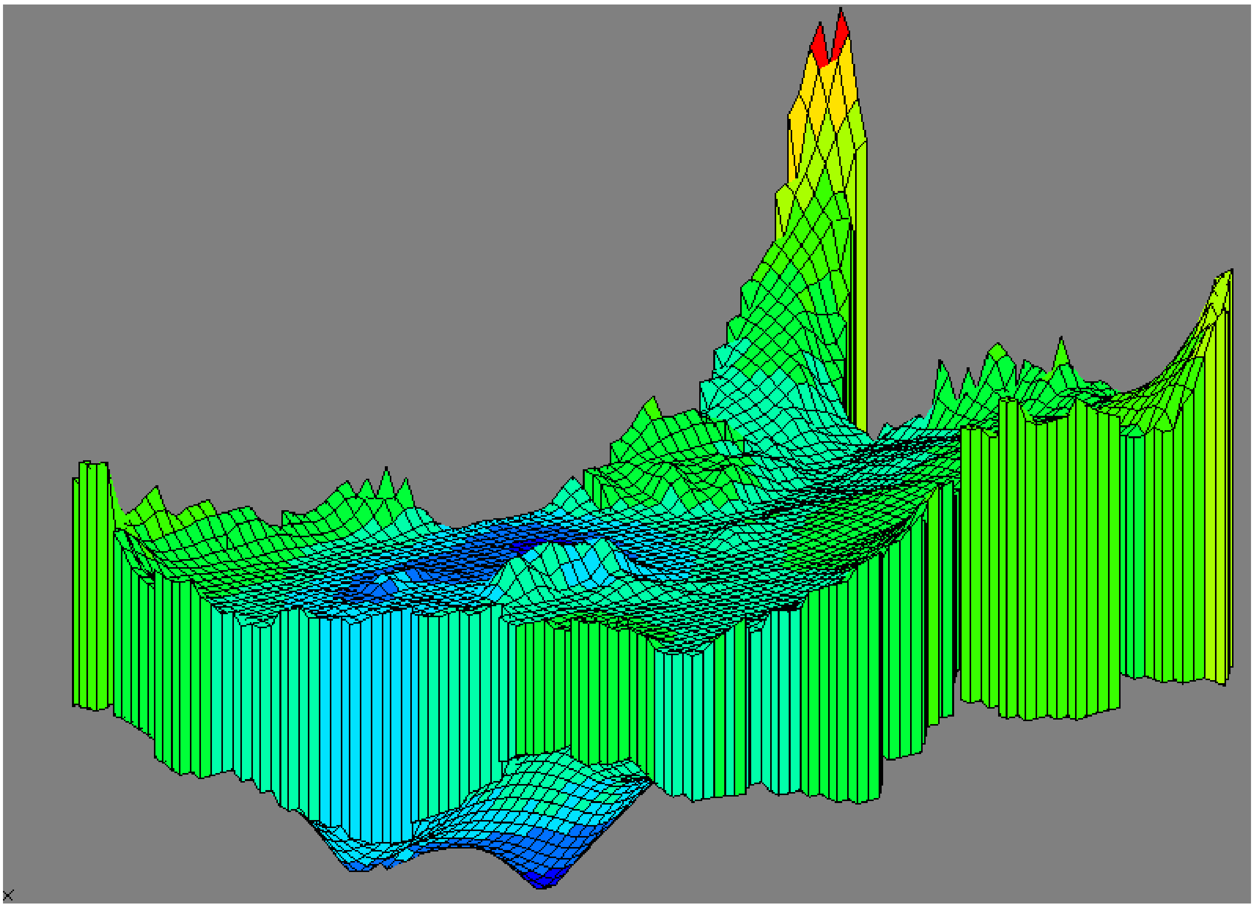


Figure 17. The topographic condition of aquifer in GMS model

Bed rock layer

Model layer represent Quaternary, Neogene and recent sediments together in the valley-bottom, sub basin areas. The generalized valley section (fig. 3) provides a general profile of the basin where Quaternary sediments are typically less than 80 m thick in the valley, the underlying tertiary (Neogene) sediments are as much as about 500 m thick (Homilius, 1969), Although the thickness of aquifer is varies, but in modelling, aquifer was considered as one layer to 500m height from ground level.

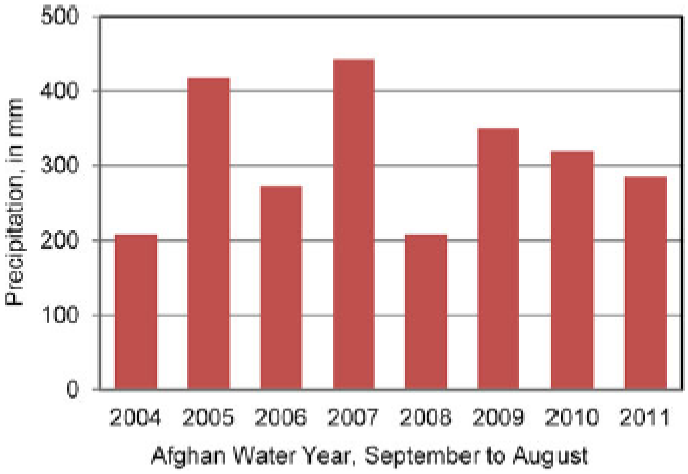
Recharge

Recharge in the system includes direct infiltration of precipitation, leakage from the major rivers flowing through the basin, leakage from tributary perennial streams that drain adjacent upland areas. Recharge to the aquifer was from river leakage, leakage in irrigated areas, and from direct infiltration during the winter months. For simulated model leakage due to irrigated area was presented in before section.

Climate recordkeeping in Afghanistan was interrupted around 1980 as a consequence of war and civil strife. Few climatic data were available for Kabul; most records were not available until 2003 or later, and the record for most direct observations includes gaps of about 20 years or more. The mean monthly temperature, precipitation, and estimated evapotranspiration for Kabul from historical records (Böckh, 1971). Average annual precipitation is low in the Kabul Basin; between 1957 and 1977 it was 330 mm/yr (Tunnermeir and Houben, 2003). Evaporation rates are high relative to annual total precipitation—approximately 1,600 mm/yr—

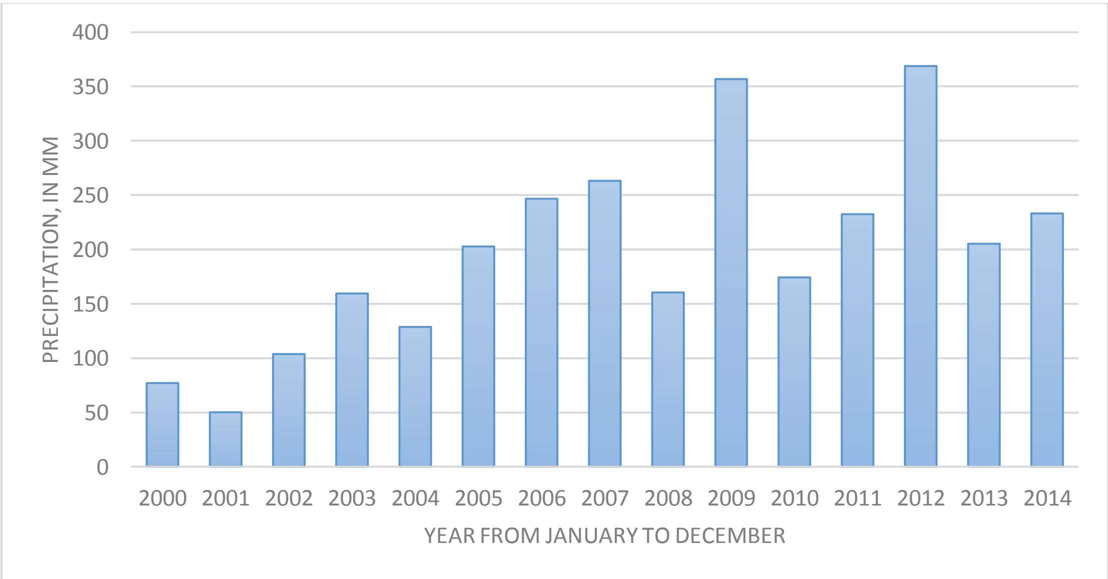
and thus net groundwater recharge by precipitation in the Kabul Valley is generally near zero on an annual basis. Also, by data received from the Kabul Airport station, the annual precipitation was calculated between September 1, 2003, and August 31, 2011 table13.

Table 13. , the annual precipitation was calculated between September 1, 2003, and August 31, 2011




Finally remotely sensed data obtained from the global weather web site station Kabul with Longitude 69.0625, Latitude 34.50130081 coordinate to compere the precipitation measurement data between January 2000 to December 2014 table 14. Further of the total weather data is presented in appendix 2. Thus recharge by precipitation about 20% of total annual value is considered in the model.

Table 14. , the annual precipitation was calculated between 2000 to 2014



Leakage to aquifer due to Major River was calculated for period of simulation and were used. Base on result of “Sustainability of Water Supply at Military Installations, Kabul Basin, Afghanistan project “ by T.J. Mack, M.P. Chornack, and I.M. Verstraeten year 2012, recharge rate for Southern sub basin areas of Kabul basin by rivers and direct recharge on sub basin surfaces were calculated as table 15.

Table15. Recharge rate by rivers in the study area, year 2012

| Flow | Drainage area, in Km2 | Recharge rate, in m3/day |
|---|---|---|
| Kabul River at Tangi Saidan | 1663 | 303903 |
| Logar River | 11461 | 690416 |
| Chakari River | 302 | 25744 |
| Direct recharge on sub basin surfaces | 780 | 891429 |

## Knowledge gap and limitations

The knowledge gaps are summarized below.

1. The uncertainty due to lack of accurate information is high.
2. The bedrock PROPERTISE is not accurately defined, for example the boundary between aquifer layers is not determine. There is limited distribution of hydraulic property data on the aquifer.
3. The number of monitoring well is not good enough. Also the dispersion of them are not inappropriate.
4. Discharge data from stream gages is low and there is no long term data.
5. Update groundwater abstractions are not exist accurately.
6. There is not enough information on hydraulic properties for the chakary sub basin.
7. It is very difficult to collect information due to the administrative problems in Afghanistan.

References

Akbari, M.A., Tahir, M., Litke, D.W., and Chornack, M.P., 2007, Groundwater levels in the Kabul Basin, Afghanistan, 2004–07: U.S. Geological Survey Open-File Report 2007–1294, 46 p.

Akbari, M.A., Chornack, M.P., Coplen, T.B., Emerson, D.G., Litke, D.W., Mack, T.J., Plummer, L.N., Verdin, J.P., and Verstraeten, I.M., 2008, Water resources availability in Kabul, Afghanistan: AGU 2008 Fall Meeting, San Francisco, Calif., December 15–19, 2008, Session NS22 Geoscientific Data for the Revitalization of Afghanistan [ABSTRACT NS22A-04, available online at http://nh.water.usgs.gov/Publications/abstracts/Kabul-AGU-Mack.pdf]

Banks, David, and Soldal, Oddmund, 2002, towards a policy for sustainable use of groundwater by non-governmental organizations in Afghanistan: Hydrogeology Journal, v. 10, p. 377–392.

Böckh, E.G., 1971, Report on the groundwater resources of the city of Kabul, report for Bundesanstalt für Geowissenschaften und Rohstoffe [unpublished]: BGR file number 0021016, 43 p.

Bohannon, R.G., and Turner, K.J., 2007, Geologic map of quadrangle 3468, Chak Wardak-Syahgerd (509) and Kabul (510) quadrangles, Afghanistan: U.S. Geological Survey Open-File Report 2005–1107–A. 1 sheet.

Broshears, R.E., Akbari, M.A., Chornack, M.P., Mueller, D.K., and Ruddy, B.C., 2005, Inventory of groundwater resources in the Kabul Basin, Afghanistan: U.S. Geological Survey Scientific Investigations Report 2005–5090, 34 p.

The Central Statistics Organization, 2017, Afghanistan Statistical Yearbook, 2017-18,

Democratic Republic of Afghanistan, Ministry of Irrigation and Water Resources, Institute of Water Resources Development, 1985, Hydrological Yearbook 1979–1980, Part (I and II), rivers of Indus and Helmand Basin (Kabul, Khuram, Helmand and Ghazni), 131 p.

https://earthexplorer.usgs.gov

Favre, R., and Kamal, G.M., 2004, Watershed atlas of Afghanistan: Afghanistan Information Management Service, Kabul, Afghanistan, 183 p.

German Water Economy Group of Afghanistan and Ministry of Agriculture of the Kingdom of Afghanistan, 1967; Democratic Republic of Afghanistan, 1977a and1977b; Democratic Republic of Afghanistan, 1981 and 1985).

Https;//globalweather.tmu.edu

Hall, D.K., Riggs, G.A., and Salomonson, V.V., 2000, updated daily, MODIS/Terra Snow Cover Daily L3 Global 500m Grid V004, January to March 2003: Boulder, Colo., U.S.A., National Snow and Ice Data Center, Digital mediaHamid, M.H., 2002, Kabul city water supply networks: Note to Norwegian Church Aid, based on data held by Central Authority for Water Supply and Sewerage, February 21, 2002.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, the U.S. Geological Survey modular groundwater-flow model—User guide to modularization concepts and the groundwater flow process: U.S. Geological Survey Open-File Report 00–92, 121 p.

Hill, M.C., Banta, E.R., Harbaugh, A.W., and Anderman, E.R., 2000, MODFLOW-2000, the U.S. Geological Survey modular groundwater model—User guide to the observation, sensitivity, and parameter-estimation process and three post-processing programs: U.S. Geological Survey Open-File Report 00–184, p. 209.

Homilius, Joachim, 1969, Geoelectrical investigations in east Afghanistan, Geophysical Prospecting, vol. 17, issue 4, p. 468–487.

Houben, Georg, and Tunnermeier, Torge, 2005, Hydrogeology of the Kabul Basin, Part I—Geology, aquifer characteristics, climate and hydrology: Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany, p. 45.

International Water Management Institute, 2002, Current drought situation in Afghanistan: accessed February 28, 2005, at,

http://www.iwmi.cgiar.org/droughtassessment/files/pdf/Drought2000inAfghanistan.pdf

Japan International Cooperation Agency (JICA), 2007a, the study on groundwater resources potential in Kabul Basin, in the Islamic Republic of Afghanistan: 3rd Joint Technical Committee, Sanyu Consultants, Inc., Kabul, Afghanistan, p. 20.

Japan International Cooperation Agency (JICA), 2007b, the study on groundwater resources potential in Kabul Basin, in the Islamic Republic of Afghanistan: 4th Joint Technical Committee, Sanyu Consultants, Inc., Kabul, Afghanistan, p. 12.

Japan International Cooperation Agency (JICA), 2009, the Study for the Development of the Master Plan for the Kabul Metropolitan Area; Final Report, Sector Report 3: Water esources, Chapter 3.

Japan International Cooperation Agency (JICA), Final Report Sector 05 Water Supply and Sewerage; Table 1.8, Page 1-6. Abstraction – AUWSSC data.

Kevin C. Vining and Aldo V. Vecchia, 2014, Estimated Monthly Streamflows for Selected Locations on the Kabul and Logar Rivers, Aynak Copper, Cobalt, and Chromium Area of Interest, Afghanistan, 1951–2010, Report 2014–5157

Lashkaripour, G.R., and Hussaini, S.A., 2008, Water resources management in Kabul River basin, eastern Afghanistan: The Environmentalist, v. 28, no. 3, p. 253–260.

Myslil, Vlastimil, Eqrar, M.N., and Hafisi, M., 1982, Hydrogeology of Kabul Basin (translated from Russian): sponsored by the United Nations Children’s Fund and the Ministry of Water and Power, Democratic Republic of Afghanistan, p. 47.

Mohammad R. Taher, Michael P. Chornack, and Thomas J. Mack ., 2013, Groundwater Levels in the Kabul Basin, Afghanistan, 2004–2013 ; U.S. Geological Survey Open- File Report 2013-1296.

Niard, Nadege, 2007, Hydrogeology of the Kabul Basin, Part III—Modeling approach, Conceptual and numerical models: Federal Institute for Geosciences and Natural Resources (BGR), Hannover, Germany, p. 103.

Frischmann, P., House, B, Park, P, Lane, R., 2010, Afghanistan resource corridor development; water strategy final Kabul river basin report, version 4.0.

Rutledge, A.T., 1998, Computer programs for describing the recession of groundwater discharge and for estimating mean groundwater recharge and discharge from streamflow records—update: U.S. Geological Survey Water-Resources Investigations Report 98–4148,

Robert E. Broshears, M.amin Akbari, Michael P. Chornack, David K. Muller, and Barbara C. Ruddy, 2005, Inventory of Ground-Water Resources in the Kabul Basin, Afghanistan, Report 2005-5090.

Safi, Hassan, 2005, Report on groundwater balance deficiency and contamination in Kabul City: DACAAR, Kabul, Afghanistan, unpublished document, p. 7.

Safi, Hassan, and Vijselaar, Leendert, 2007, Groundwater monitoring, Evaluation of groundwater data: DACAAR, Kabul, Afghanistan, p. 99.

Thomas J. Mack, M. Amin Akbari, M. Hanif Ashoor, Michael P. Chornack, Tyler B. Coplen, Douglas G. merson, Bernard E. Hubbard, David W. Litke, Robert L. Michel, L. Niel Plummer, M. Taher Rezai, Gabriel B. Senay, James P. Verdin, and Ingrid M. Verstraeten., 2009, Conceptual Model of Water Resources in the Kabul Basin, Afghanistan: U.S. Geological Survey, Reston, Virginia: 2010.

T.J. Mack, M.P. Chornack, and I.M. Verstraeten, 2012, Sustainability of Water Supply at Military Installations, Kabul Basin, Afghanistan

Thomas J. Mack, Michael P. Chornack, Sarah M. Flanagan, and Ann T. Chalmers, 2014, Hydrogeology and Water Quality of the Chakari Basin, Afghanistan, report 2014-5113.

Uhl, V.W., 2006, Afghanistan—an overview of groundwater resources and challenges: Ground Water, v. 44, no. 5, pp. 626–627.

U.S. Army Corps of Engineers, 2002, Water resources areal appraisal of Afghanistan: U.S. Army Engineer Research and Development Center, 52 p.

World Meteorological Organization, 2004, Weather information for Kabul, accessed on December 10, 2007, at http:/www.worldweather.org/115/c00219.htm