# WATER BALANCE

## Achieving Sustainable Development through a Water Assessment and Management Plan

**The Case of Federally Administered Tribal Areas, Pakistan**

ASIAN DEVELOPMENT BANK

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# FOREWORD

The availability of adequate water is critical to sustain life and to generate economic activities in any area. However, the amount of water available and the amount of water needed are often off-balance. Erratic planning and deficient development initiatives, created despite a lack of basic information, rarely feature sustainability and often contribute to further degradation of watersheds.

While emphasizing the need for assessing precise water availability and its uses, this report consolidates the findings of an assessment of water resources and develops a management plan for sustainable use of the water resources in Bajaur, Khyber, and Mohmand agencies in the Federally Administered Tribal Areas (FATA) in Pakistan. It identifies basic concepts in water assessments, suggests various approaches for measuring availability of surface water and groundwater, pinpoints major users, and develops a water balance model. It also provides recommendations for using the water balance model as a critical planning tool for water resources development and suggests a way forward for expanding this tested approach.

This report also details the concepts, methods, data capture, and analyses needed for water assessment in micro watersheds and for strengthening management planning for water resources development. It is hoped that it will pave the way for similar studies in Pakistan and beyond. Identifying key interventions based on a robust water management plan is expected to improve awareness of the issue, decision making, and water infrastructure planning, and to sustain focused implementation.

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The author acknowledges the project staff members who contributed exhaustive surveys, data collection, and water availability assessments for that study, which led to this report.

# ABBREVIATIONS

| | | |
|---|---|---|
| FAD | – | FATA Agriculture Department |
| FATA | – | Federally Administered Tribal Areas |
| GIS | – | geographic information system |
| IWRM | – | integrated water resources management |
| PMD | – | Pakistan Meteorological Department |

# WEIGHTS AND MEASURES

| | | |
|---|---|---|
| ha | – | hectare |
| $km^2$ | – | square kilometer |
| m | – | meter |
| $m^3$ | – | cubic meter |
| $m^3$/sec | – | cubic meter per second |
| mm | – | millimeter |

# 1. BACKGROUND

1. Water is critical to all life forms in watersheds.[1] It is needed for human and animal consumption as well as for agriculture, forest, and rangeland management. Water shortages pose the greatest threat to watershed productivity.

2. By definition, a severe lack of water characterizes arid and semiarid watersheds. Precipitation plays a dominant role in water availability in arid areas. It is responsible for depositing water in a watershed, but evapotranspiration and surface runoff diminish this.

3. Rural communities living in arid watersheds are forced to draw their livelihoods from subsistence agriculture and from livestock raising. Farming systems in these areas generally rely upon infrequent and uneven precipitation, and such systems are characterized by low input, low output, and high risk.

4. Properly managed water resources are integral to improving socioeconomic conditions in such areas. However, achieving sustainable production from natural resources in arid and semiarid watersheds is difficult. Primarily, there is a trade-off between economic benefits and the detrimental impacts associated with using these natural resources. In addition, the competition for specific, limited resources requires use that minimizes watershed degradation and can provide economic returns.

5. In arid and semiarid watersheds, the demand for water resources often exceeds the available supply. In most instances, information on the amount of both demand and supply is simply not available. This lack of basic data on water resources leads to erratic planning, deficient initiatives, and unsustainable practices that further degrade watersheds. It is imperative to measure accurately the short-, medium-, and long-term water availability and to estimate demand prior to introducing planning interventions to enhance the natural resources base.

6. Most of Pakistan is classified as arid to semiarid, with insufficient rainfall to support crops, forests, and pastures. About 68% of the country has an annual rainfall of less than 250 millimeters (mm), 24% receives 250–500 mm, and only 8% exceeds 500 mm. Water availability is one of the key constraints to agricultural production and, consequently, in achieving sustainable development. Thus, better information on available water resources and their use is needed, which requires water budgeting through a water balance model showing total water input and output for a particular watershed.

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[1] A watershed is an area of land containing a common set of streams and rivers that all drain into a single larger body of water, such as a larger river, lake, or ocean.

7. Bordering Pakistan and Afghanistan, the Federally Administered Tribal Areas (FATA), comprising seven administrative agencies, shares the same climatic characteristics as most arid areas of Pakistan. During the implementation of the Asian Development Bank–funded FATA Rural Development Project in three agencies (Bajaur, Khyber, and Mohmand), a water assessment study was conducted to improve planning for water resources development and management.[2] The encouraging outcomes of the study paved the way for (i) believing that knowledge of water inputs and outputs should be a prerequisite for implementing any physical intervention, and (ii) disseminating results widely for possible replication in Pakistan and elsewhere.

8. This report builds upon the study for sustainable use of water resources in Bajaur, Khyber, and Mohmand. The study intended to assess surface water and groundwater potential, develop a water balance model, and prepare a water management plan. This report

(i) discusses concepts in water assessment;
(ii) summarizes the approach adopted in the study for measuring surface water and groundwater availability (i.e., input);
(iii) pinpoints major consumptive uses (i.e., output);
(iv) develops the water balance model, integrating geographic information system (GIS) use;
(v) identifies key infrastructure and related interventions; and
(vi) proposes a water management plan.

9. This report aims to disseminate knowledge on the concepts, methods, data capture, and analysis needed in micro watershed water assessments, and water resources development and management plans. It is expected to (i) stimulate discussion on key outcomes and impacts, (ii) lead further refinement, (iii) pave the way for initiating similar studies elsewhere, and (iv) help expand water resources development initiatives.

10. To achieve its objectives, the study adopted a multipronged, integrated approach. The project area was divided into 44 watersheds, and meteorological data for estimating surface runoff resulting from rainfall, groundwater recharge, and its extraction were examined. Agricultural, human, and livestock water consumption were estimated for the baseline case and future use. Since agriculture is the largest water consumer, a more detailed study estimated each crop's water requirements.

11. The study developed a project-area GIS to collect, store, manage, and report geographic, demographic, topographic, and other related information. Subsequently, GIS-based maps for topography, watershed demarcation, agroecological zones, land cover, isohyets, soil classification, and water resources were created.

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2 ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the Federally Administered Tribal Areas (FATA) Rural Development Project.* Manila.

12. Further, water balance models for average, dry, and wet precipitation conditions were separately crafted for each agency and watershed. The proposed water management plan is based on the integrated water resources management (IWRM) approach (Box 1). This plan focuses on watershed management, water infrastructure, and efficient water use.

### Box 1 Integrated Water Resources Management

"Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization."—*Agenda 21, Chapter 18*

Integrated water resources management "is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment." —*Global Water Partnership (GWP)*

The integrated water resources management approach promotes coordinated development and management of

- land and water,
- surface water and groundwater,
- the river basin and its adjacent coastal and marine environment, and
- upstream and downstream interests.

**Integrated water resources management is about reforming human systems to enable people to obtain sustainable and equitable benefits from those resources.**

*Source:* United Nations. 2006. *Water Monitoring: Mapping Existing Global Systems and Initiatives.* Background document, August. Prepared by the Food and Agriculture Organization on behalf of the UN-Water Task Force on Monitoring. Stockholm.

# 2. PROJECT AREA

13. The project area lies northwest of Khyber Pakhtunkhwa Province and constitutes the upper northern portion of FATA. It borders Afghanistan to the west, Lower Dir District to the northeast, Charsadda and Peshawar districts and Malakand Agency in the east, Orakzai Agency in the south, and Kurram Agency in the southwest. A major part of the project area is a series of mountain ridges, 450–475 meters (m) above sea level, and intervening valleys. The slopes are steep (80%) in the upper reaches but become moderate (13%) to near flat at the base. The area is drained by several rivers and streams that ultimately join the Indus River system. The natural country slope is from northwest to southeast.

14. The project area is composed of the three agencies of Bajaur, Khyber, and Mohmand with a population of about 2.2 million as of 2008, living in 1,206 villages or settlements within 6,162 square kilometers ($km^2$).

## 2.1 Bajaur Agency

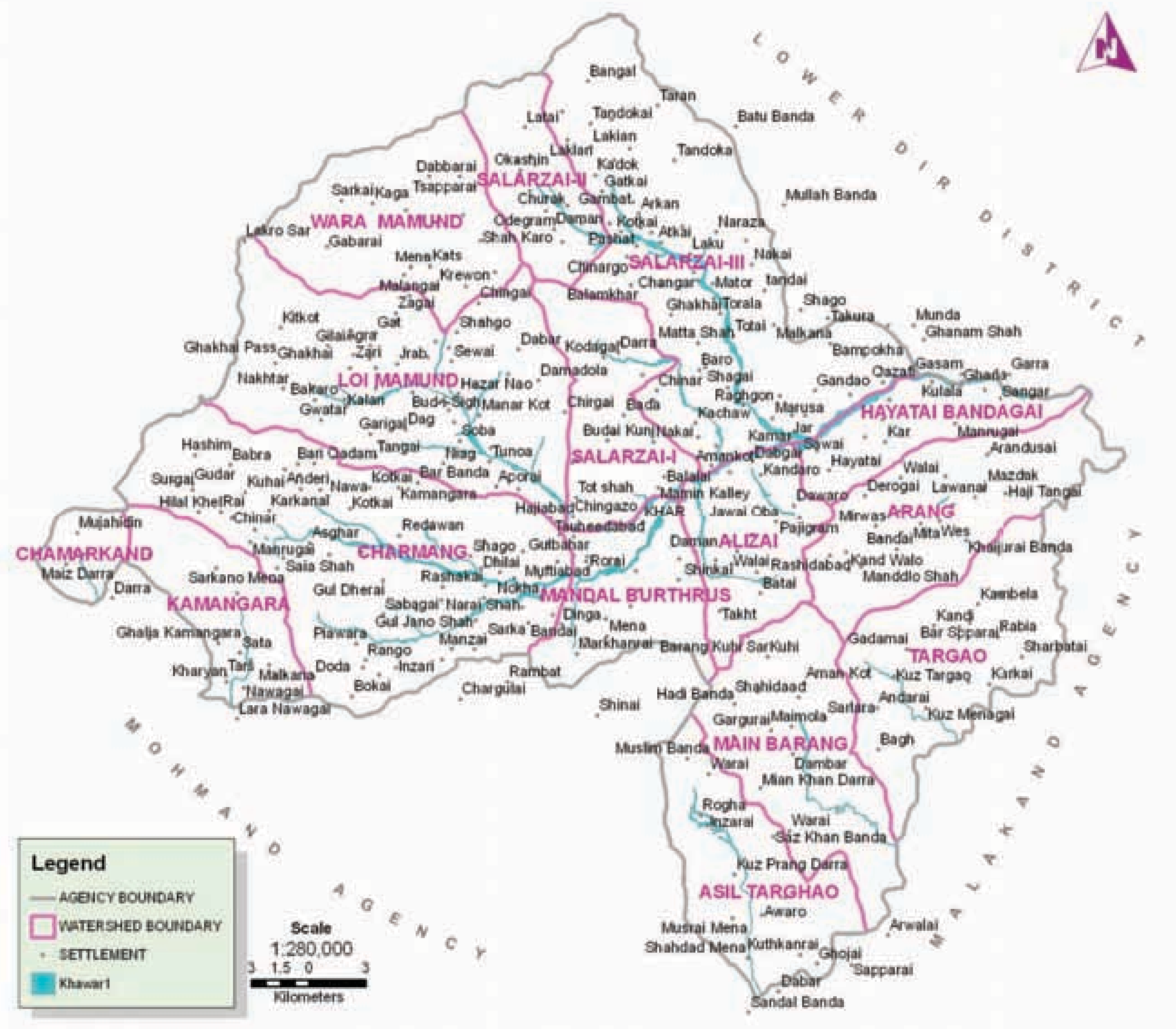
15. The northernmost agency of FATA, Bajaur (Figure 1) covers an area of 1,290 $km^2$ and was home to 900,000 inhabitants in 2008. With a comparatively high population growth of 4.33% and a male–female ratio of 1:1.05, its population density is 461 persons per $km^2$. Its elevation ranges from 762 m to 1,220 m above sea level, mostly open with varying gradients. The bordering hills rise to altitudes stretching from 2,475 m (i.e., Koimor in the south) to 3,202 m (i.e., Inkalsar in the northern Pakistan–Afghanistan divide).

16. Bajaur has an extreme climate, with temperatures plunging below 0°C in December–January and reaching as high as 36°C in June–August. Summer lasts 6 months, from May to October, with temperatures from 23°C to 36°C. Winter and spring feature frequent rain, and average annual rainfall is about 738 mm. The Bajaur Stream and its tributaries drain northern Bajaur, while its southern parts drain directly into the Swat River. The Nawagai Stream drains Nawagai, while the Babukara, Charmung, Khatai, and Watalai streams drain the southern areas including Charmung, Mamund, Mandal, and Salarzai. All of these streams join the Bajaur Stream, which subsequently joins the Panjkora River south of Mian Killi.

## 2.2 Khyber Agency

17. Within the project area, Khyber (Figure 2) covers the largest area with 2,576 $km^2$. With an estimated population of 800,000 in 2008, it had a growth rate of 3.92% in 1998. The population density is 212 persons per $km^2$, with a male–female ratio of 1:1.09. It is a hilly tract with narrow strips of valleys. A series of mountain ranges converge in Khyber, starting from the Pamir Mountains and other

**Figure 1** Map of Bajaur Agency Showing Watersheds, Main Rivers, and Nullahs




*Source:* Developed by the Geographic Information System (GIS) Lab of the Federally Administered Tribal Areas (FATA) Rural Development Project.

offshoots of the Hindu Kush. The Kalauch, Karagah Ghar, Lacha Ghar, Morgah, Surghar, and Tor Ghar mountain ranges are located in the mostly barren Khyber.

18. Khyber has a severe climate with very cold winters and very hot summers. The temperatures range from 23°C to 45°C. December and January are the coldest months of the year. The average annual rainfall is 519 mm, and its hydrology is quite complex. A major part of Khyber is drained by the Bara River in the south, which originates in the Tirah Valley. After flowing a long distance, it terminates into the Kabul River south of Peshawar. The Bara River carries perennial flows from snowmelt and rainfall. High-flow months are April and May, with low flow in January. In 1979, the FATA Development Corporation constructed a weir on the Bara River, about 5 kilometers upstream of Jhansi Post to divert the river flow to the agriculture area in the Bara watershed. It supplies about 7.9 cubic meters per second ($m^3$/sec) of irrigation water to 18,219 hectares (ha) in Bara and Peshawar.

**Figure 2** Map of Khyber Agency Showing Watersheds, Main Rivers, and Nullahs


*Source:* Developed by the FATA Rural Development Project GIS Lab.

## 2.3 Mohmand Agency

19. Mohmand (Figure 3) is between Khyber (to the south) and Bajaur (to the north). It borders Peshawar and Charsadda districts and Malakand Agency in the east. It has an area of 2,296 km$^2$, drained by tributaries of the Kabul and Swat rivers. Its population was estimated at 510,000 in 2008, with a growth rate of 4.28% in 1998. The population density is 146 persons per km$^2$, with a male–female ratio of 1:1.10.

20. Mohmand has rugged mountains with barren slopes. The general slope of the area is from north to east with an average elevation of 1,450 m. Ilazai is the highest peak near the Pakistan–Afghanistan border; other prominent peaks are Silai and Yari sar. Perennial water is scarce. However, watersheds in Khawazi–Bazai, Qasim Khel, Umbar, and Upper Piandiali have reasonable surface flow. It is hot in the summer, from May to August, and cold in winter, from November to February. Rainfall is scant, and mostly received in the winter. The average annual rainfall is 422 mm.

**Figure 3** Map of Mohmand Agency Showing Watersheds, Main Rivers, and Nullahs


*Source:* Developed by the FATA Rural Development Project GIS Lab.

## 2.4 Socioeconomic Conditions

21. Livelihood opportunities in the project area are very limited. The local economy is chiefly pastoral. Comparing FATA development indicators with adjoining Khyber Pakhtunkhwa Province and national averages (Table 1) paints a bleak picture.

22. The majority of the population relies on livestock raising, farming, and local trading for their livelihoods. The industrial and mineral sectors are disorganized. Available poverty data are sketchy, but most residents live in poor conditions.

**Table 1 Comparison of Development Indicators**

| Indicator | Pakistan | Khyber Pakhtunkhwa | FATA |
|---|---|---|---|
| Literacy ratio (%) | 43.9 | 35.4 | 17.4 |
| Male literacy ratio (%) | 54.8 | 54.4 | 29.5 |
| Female literacy ratio (%) | 32.0 | 18.8 | 3.0 |
| Population per doctor (number) | 1,226 | 4,916 | 7,670 |
| Population per hospital bed (number) | 1,341 | 1,594 | 2,179 |
| Roads (kilometer per square kilometers) | 0.3 | 0.1 | 0.2 |

FATA = Federally Administered Tribal Areas.

*Note:* Literacy rates as of 1998. All other indicators as of 2003.

*Source:* Planning and Development Department, FATA Secretariat. 2008. *FATA Development Statistics.* Peshawar.

Two poverty indicators—daily caloric intake (2,350 calories per person) and monthly earnings ($12 per person)—reveal that 45% of the FATA population lives below the poverty line, one of the highest rates in Pakistan.[3]

23. The land-use pattern and climate indicate water scarcity across the project area. Farmlands are small, and farming practices are old-fashioned, with very low yields per ha. Most of the land is unproductive, as only 18% is cultivated, and less than 9% is covered with trees or vegetation. Rangelands are extensively used for grazing.

24. Women are involved in day-to-day household chores, including fetching water and collecting fodder and wood fuel. Safe drinking water is scarce, and health and education facilities are inadequate.

[3] Government of Pakistan. 2006. *Poverty Reduction Strategy Paper, 2005–2006.* Islamabad.

# 3. ASSESSING SURFACE WATER AVAILABILITY

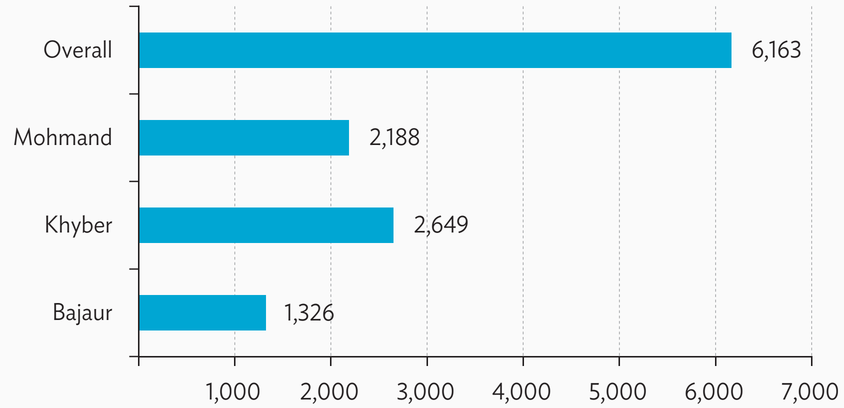
## 3.1 Project Area Zoning

25. To assess water availability and measure consumption, the study sectioned the project area into zones in terms of hydrology and climate.

### 3.1.1 Hydrological Zoning

26. The project area was divided into 44 watersheds, with 15 located in Bajaur, 14 in Khyber, and 15 in Mohmand. Longitude and latitude values demarcated each watershed. The largest watershed, with an area of 478 km$^2$, is in Khyber, while the smallest, at 17 km$^2$, is in Bajaur. Figure 4 shows the coverage of watershed areas by agency.

**Figure 4 Total Area of Watersheds by Agency** (square kilometers)




*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the Federally Administered Tribal Areas (FATA) Rural Development Project.* Manila.

### 3.1.2 Climatic Zoning

27. The climate in the project area varies from semiarid to subhumid, and from subtropical to temperate. Physiographic features, especially altitude, have a major impact on climatic conditions, as shown by the soil and vegetation in the area. The study classified 44 watersheds under three climatic zones: semiarid subtropical, subhumid subtropical, and subhumid temperate.

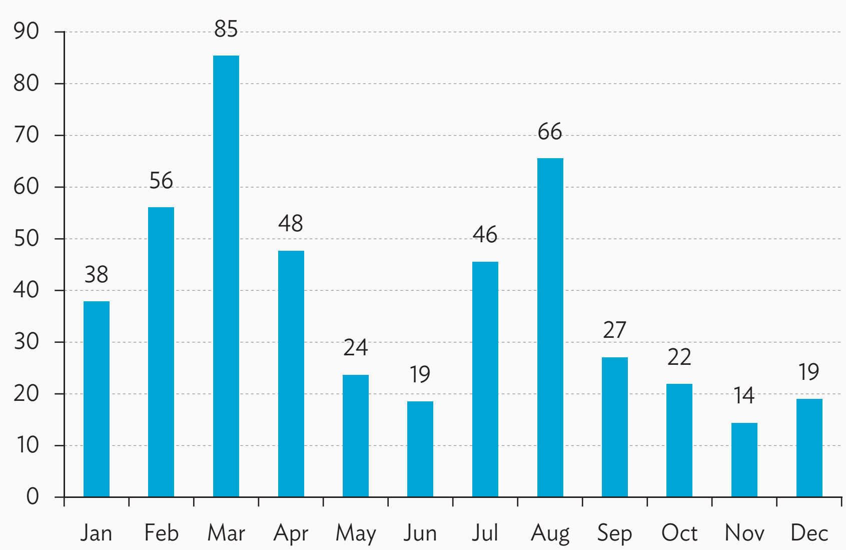
28. **Semiarid subtropical zone.** Twenty-eight of the 44 watersheds are categorized as semiarid subtropical zones: all 15 watersheds in Mohmand, 11 in Khyber, and 2 in Bajaur. This zone has more frequent, low-intensity, and longer-duration rains in winter. The mean annual temperature is 18°C–23°C. Winter temperatures are 8°C–12°C, and summer temperatures are 29°C–32°C. June and July are the hottest months, while December and January are the coolest. Frost occurs for a few days in December–February. Table 2 and Figure 5 use data from a nearby meteorological station at Peshawar, which has similar climatic conditions, at 359 m above sea level.

**Table 2 Average Rainfall and Temperature in Peshawar, 1978–2007**

| Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average rainfall (millimeters) | 38.0 | 56.0 | 85.0 | 48.0 | 24.0 | 19.0 | 46.0 | 66.0 | 27.0 | 22.0 | 14.0 | 19.0 | **463.0** |
| Average temperature (°C) | 10.9 | 13.0 | 17.3 | 22.9 | 28.7 | 33.0 | 32.2 | 30.9 | 28.8 | 23.6 | 17.4 | 12.4 | **22.7** |
| Average maximum temperature (°C) | 17.6 | 19.4 | 23.9 | 29.8 | 35.9 | 40.2 | 37.9 | 35.8 | 34.9 | 31.1 | 25.6 | 19.8 | **29.6** |
| Average minimum temperature (°C) | 3.9 | 6.4 | 11.0 | 16.2 | 21.4 | 25.7 | 26.8 | 25.8 | 22.7 | 16.3 | 9.5 | 5.0 | **16.2** |

*Source:* Pakistan Meteorological Department, 1978–2007.

**Figure 5 Monthly Average Rainfall Distribution in Peshawar, 1978–2007** (millimeters)




*Source:* Pakistan Meteorological Department, 1978–2007.

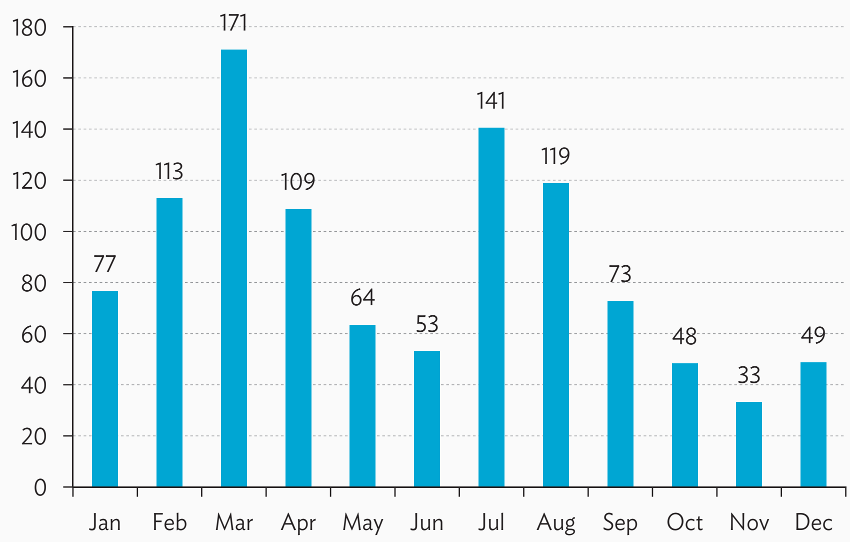
29. **Subhumid subtropical zone.** Thirteen watersheds are in the subhumid subtropical zone: 10 watersheds in Bajaur and 3 southern watersheds in Khyber. In Bajaur, rainfall is well distributed over the year. The average rainfall at Khar, Bajaur's headquarters, is 746 mm. Khar's mean annual temperature is 19.8°C, the mean winter temperature is 8.3°C, and the mean summer temperature is 30.7°C. During the winter, it snows on the mountains while the valleys frost. Without a rain gauge in Bajaur, and since it has similar climatic characteristics, rainfall data of the Saidu Sharif meteorological station were used for runoff estimation. Data from Saidu Sharif, at 961 m above sea level, are presented in Table 3 and Figure 6.

**Table 3 Average Rainfall and Temperature in Saidu Sharif, 1978–2007**

| Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average rainfall (millimeters) | 77.0 | 113.0 | 171.0 | 109.0 | 64.0 | 53.0 | 141.0 | 119.0 | 73.0 | 48.0 | 33.0 | 49.0 | **1,048.0** |
| Average temperature (°C) | 11.5 | 14.3 | 19.1 | 25.5 | 30.8 | 33.3 | 32.5 | 31.2 | 29.1 | 25.5 | 18.9 | 14.0 | **23.8** |
| Average maximum temperature (°C) | 13.9 | 15.4 | 19.4 | 26.3 | 32.2 | 36.3 | 34.3 | 32.8 | 31.7 | 27.7 | 22.1 | 16.5 | **25.7** |
| Average minimum temperature (°C) | 1.9 | 3.7 | 7.5 | 12.1 | 16.4 | 20.3 | 22.7 | 21.7 | 17.8 | 11.9 | 6.3 | 3.0 | **12.1** |

*Source:* Pakistan Meteorological Department, 1978–2007.

**Figure 6 Monthly Average Rainfall Distribution in Saidu Sharif, 1978–2007** (millimeters)




*Source:* Pakistan Meteorological Department, 1978–2007.

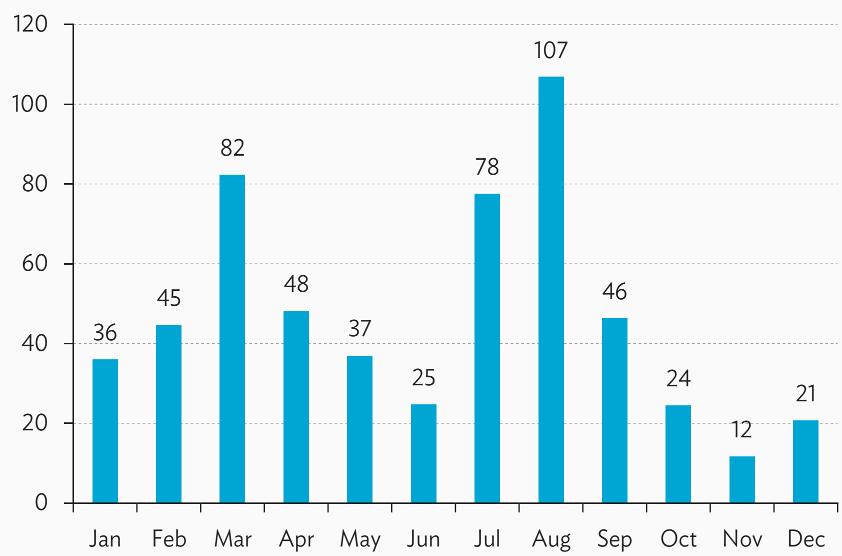
30. With its similar climatic characteristics, data from the Kohat meteorological station were used for the three southwestern Khyber watersheds, Malik Din Khel, Miri Khel, and Rajgah. Data from Kohat, at 1,068 m above sea level, are presented in Table 4 and Figure 7.

**Table 4 Average Rainfall and Temperature in Kohat, 1978–2007**

| Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average rainfall (millimeters) | 36.0 | 45.0 | 82.0 | 48.0 | 37.0 | 25.0 | 78.0 | 107.0 | 46.0 | 24.0 | 12.0 | 21.0 | **560.0** |
| Average temperature (°C) | 11.5 | 14.3 | 19.1 | 25.5 | 30.8 | 33.3 | 32.5 | 31.2 | 29.1 | 25.5 | 18.9 | 14.0 | **23.8** |
| Average maximum temperature (°C) | 18.1 | 20.5 | 25.7 | 32.6 | 38.2 | 40.6 | 38.4 | 36.9 | 35.4 | 32.6 | 25.9 | 21.5 | **30.5** |
| Average minimum temperature (°C) | 4.9 | 8.0 | 12.4 | 18.3 | 23.4 | 25.9 | 26.5 | 25.4 | 22.8 | 18.3 | 11.8 | 6.4 | **17.0** |

*Source:* Pakistan Meteorological Department, 1978–2007.

**Figure 7 Monthly Average Rainfall Distribution in Kohat, 1978–2007**
(millimeters)




*Source:* Pakistan Meteorological Department, 1978–2007.

31. **Subhumid temperate zone.** Three Bajaur watersheds, Salarzai-II, Salarzai-III, and Wara Mamund, are in the subhumid temperate zone. The mean temperature in October–February remains below 10°C. Without an observatory in this zone, the study could not measure rainfall and temperature data. It used Saidu Sharif station rain gauge data to estimate surface runoff. Significant rainfall (61%) occurs in February, March, April, July, August, and September.

32. Table 5 outlines the location of watersheds by climatic zone, agency, and gauging station where climatic data was accessed.

**Table 5 Watershed Locations**

| Climatic Zone | Agency | Watersheds | Gauging Station (PMD) |
|---|---|---|---|
| Semiarid subtropical | Khyber | Bara, Bazar Valley, Dand, Kuki Khel, Landi Kotal, Murda Mulagori, Shilman, Spinpokh-Shamsai, Shpora, Zakha Khel | Peshawar |
| | Mohmand | Ekka Ghund-I, Ekka Ghund-II, Ekka Ghund-III, Khawazai-Baizai, Lakarao, Lower Haleemzai, Lower Pandiali, Lower Prang Ghaar, Qasim Khel, Safi, Shinwari, Umbar, Upper Haleemzai, Upper Pandiali, Upper Prang Ghaar | |
| | Bajaur | Chamarkand, Kamangara | |
| Subhumid subtropical | Bajaur | Arang, Asil Targhao, Charmang, Hayatai Bandagai, Loi Mamund, Main Barang, Mandal Burthrus Alizai, Salarzai-I, Targao | Saidu Sharif |
| | Khyber | Malik Din Khel, Miri Khel, Rajgah | Kohat |
| Subhumid temperate | Bajaur | Salarzai-II, Salarzai-III, Wara Mamund | Saidu Sharif (PMD) |

PMD = Pakistan Meteorological Department.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

## 3.2 Surface Water Assessment

33. The study assessed surface water by estimating surface runoff from rainfall as well as stream flow generated from perennial sources like snow and glaciers. It used long-term hydrometeorological data of watersheds. When data were not available, it carried out regionalized analyses and extrapolated results from adjoining areas with similar hydrometeorological conditions. Random short-term measurements verified these results.

34. Rainfall is the primary source of runoff in the project area. Several major streams flow toward low-lying areas, but these streams do not have rain-gauging stations. Rainfall data were necessary to estimate runoff.

35. There are seven rain gauges in the project area. The FATA Agriculture Department (FAD) maintains four of these, while the Pakistan Meteorological Department (PMD) maintains three. Five rain gauges are in Khyber, one is in Bajaur, and one is in Mohmand. The FAD rain gauges measure rainfall data for 17–26 years on a monthly basis. The study could not use these data, however, because the analysis required daily, not monthly, rainfall data. The three PMD rain gauges have daily rainfall data over a 15-month period, but these were also insufficient for a reliable runoff estimate.

36. Since the Kohat, Peshawar, and Saidu Sharif meteorological stations have long-term daily rainfall data, the study used these to estimate runoff from watersheds, with aerial adjustments. The study derived aerial adjustment factors from isohyetal maps generated from normal monthly rainfall data of gauges within and around the project area.

## 3.3 Estimation of Surface Runoff from Rainfall

37. The study used the curve number method developed by the Natural Resources Conservation Service (formerly Soil Conservation Service) of the United States to estimate the surface runoff from rainfall. This method takes into account various factors affecting runoff, including soil type, vegetation, forest cover, density of vegetation, and wetness degree of the watershed represented by a curve number. The study employed a computer model to calculate the runoff from rainfall. It used daily rainfall data over 30 years (1978–2007) for analysis and for rationalizing surface runoff from each watershed. The average, wet, and dry periods were filtered from the data produced. Annual rainfall events, generating average, maximum, and minimum surface runoff from watersheds, were designated for each watershed.

38. The results for the three agencies revealed a wide variation in surface water generated during average, dry, and wet years. In Bajaur, surface runoff from watersheds varied from 2.7% to 15.9% during average years, 7.8% to 24.2% during wet years, and 0% to 2.2% during dry years. The minimum runoff was estimated in the Asil Targhao watershed and the maximum in Hayatai Bandagai.

39. In Khyber, surface runoff varied from 1.9% to 18.7% during average years, 4.9% to 33.3% during wet years, and 0% to 2.43% during dry years. The maximum runoff was estimated in the Landi Kotal watershed and the minimum in Spinpokh Shamsai.

40. In Mohmand, surface runoff varied from 5.7% to 21.1% during average years, 14.1% to 43.2% during wet years, and 0.16% to 1.45% during dry years. The maximum runoff was estimated in the Lower Pang Ghar watershed and the minimum in Lower Haleemzai.

## 3.4 Snowmelt Runoff

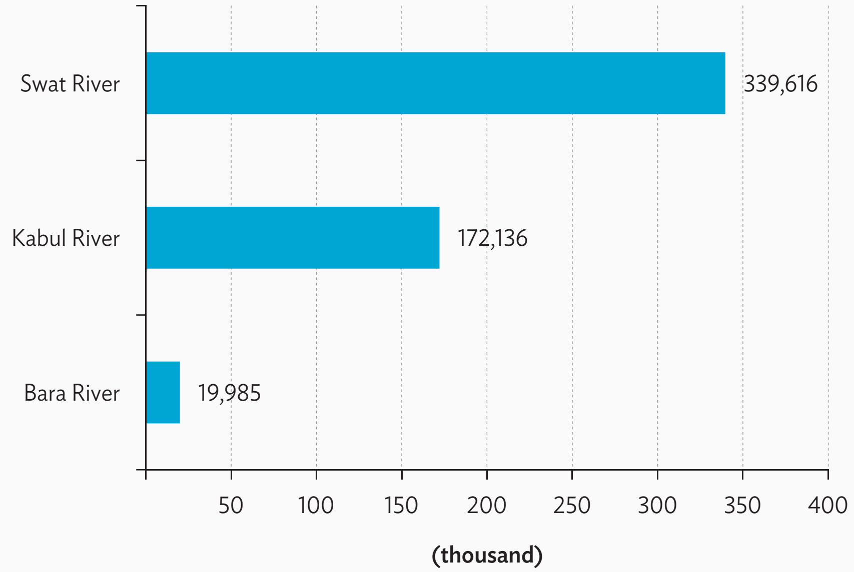
41. Several rivers and their tributaries in the project area have perennial flow from snowmelt. These include the Bara, Kabul, and Swat rivers. These rivers run through deep narrow gorges and are sources of irrigation (Table 6) for more than 500,000 ha of culturable command area (Table 6 and Figure 8).

**Table 6** Irrigation Data by River

| River | Irrigation Scheme | Discharge ($m^3$/sec) | Length (m) | CCA (ha) |
|---|---|---|---|---|
| Bara | Sangu Branch in KP | 0.28 | 1,225 | 548 |
| | Shekhan Branch in KP | 0.45 | 1,541 | 1,218 |
| | Bara River Canal in Khyber | 7.90 | 2,680 | 18,219 |
| Kabul | Warsak Gravity Canal | 9.91 | 93,908 | 55,473 |
| | Warsak Left Bank Canal | 1.27 | 28,041 | 11,604 |
| | Warsak Lift Canal | 5.61 | 662,635 | 40,337 |
| | Kabul River Canal | 12.74 | 115,610 | 4,440 |
| | Joe Sheikh Canal | 9.91 | 54,223 | 56,596 |
| | Banda Mohib Canal | 1.30 | 15,285 | 3,124 |
| | Zakha Lift Scheme | 0.20 | 2,133 | 562 |
| Swat | Fatehpur Canal | 0.99 | 22,451 | 1,400 |
| | Nipki Khel Canal | 4.25 | 38,770 | 10,264 |
| | Upper Swat Canal System | 1.42 | 446,557 | 159,555 |
| | Lower Swat Canal System | 50.01 | 34,102 | 134,420 |
| | Doaba Canal System | 9.91 | 44,636 | 33,977 |

CCA = culturable command area, ha = hectare, KP = Khyber Pakhtunkhwa, m = meter, $m^3$/sec = cubic meter per second.
*Source:* Khyber Pakhtunkhwa Irrigation Department.

**Figure 8** **Total Culturable Command Area per River** (hectare)




*Source:* Khyber Pakhtunkhwa Irrigation Department.

## 3.5 Proposed and Existing Dams in the Project Area

42. The FATA Development Authority identified 18 dams in the project area that are at various stages of implementation. Of these, 13 are storage dams for irrigation or other purposes, 2 are for groundwater recharge, and 3 for drinking water supply. In addition, the multipurpose Munda Dam is in Mohmand. Apart from these dams, the study identified 57 potential sites for constructing small dams for various purposes. The FATA Rural Development Project constructed five dams in these sites.

## 3.6 Surface Water Availability and Proposed Interventions

43. The study calculated surface water availability at the rim station[4] of each watershed, taking into account the surface runoff generated from rainfall and snowmelt, and net water used for irrigated agriculture. Based on net availability of surface water, the study proposed various interventions, such as storage-cum-recharge dams and storage ponds, for effective utilization of available water resources in the project area.

### 3.6.1 Bajaur Agency

44. In the 15 watersheds of Bajaur, the total surface water available for the average year is 291.8 million cubic meters ($m^3$), of which 87.5 million $m^3$ is used for irrigation. The study determined that more than 70% (204.2 million $m^3$) of available water flows out of the agency. Of this, 63% (128 million $m^3$) is from perennial sources, and 37% (76 million $m^3$) is from rain runoff. The net water available varies from a maximum of 50.6 million $m^3$ in the Salarzai-III watershed to a minimum of 0.3 million $m^3$ in the Chamarkand watershed (Table 7).

45. A significant part of this discharge could be utilized for irrigation, drinking water, and other purposes within the agency. To utilize this surface water for productive purposes, the study proposed constructing 14 recharge-cum-delay action and storage dams in Bajaur (Table 7).

### 3.6.2 Khyber Agency

46. The study estimated that in the 14 watersheds of Khyber, the total surface water available is 802.5 million $m^3$. Less than 50% (385.3 million $m^3$) is used for irrigation, while most of the water (417 million $m^3$) flows out of the agency and drains into the Indus River system. The net water availability ranges from a high of 140.7 million $m^3$ in the Zakha Khel watershed to a low of 0.6 million $m^3$ in the Spinpokh Shamsai watershed.

[4] A rim station is a specific location on a stream where the discharge of a catchment area is measured.

**Table 7 Surface Water Availability and Proposed Interventions in Bajaur, 2008**

| Watershed | Net Available Surface Water (million cubic meters) | Proposed Interventions: Recharge, Delayed Action, and Storage Dams (No.) | Proposed Interventions: Surface Ponds (No.) |
|---|---|---|---|
| Chamarkand (B-1) | 0.3 | 0 | 12 |
| Targao (B-2) | 4.8 | 1 | 7 |
| Main Barang (B-3) | 2.0 | 1 | 7 |
| Alizai (B-4) | 7.9 | 1 | 7 |
| Hayatai Bandagai (B-5) | 5.9 | 1 | 7 |
| Kamangarai (B-6) | 1.9 | 0 | 12 |
| Arang (B-7) | 34.8 | 2 | 5 |
| Mandal Burthrus (B-8) | 4.1 | 0 | 12 |
| Asil Targhao (B-9) | 1.5 | 0 | 12 |
| Salarzai-III (B-10) | 50.6 | 3 | 5 |
| Charmang (B-11) | 39.0 | 2 | 5 |
| Loi Mamund (B-12) | 37.2 | 2 | 5 |
| Wara Mamund (B-13) | 6.8 | 1 | 7 |
| Salarzai-I (B-14) | 4.0 | 0 | 12 |
| Salarzai-II (B-15) | 3.4 | 0 | 12 |
| **Total** | **204.2** | **14** | **127** |

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

47. While identifying and assessing the substantial rain runoff (69 million $m^3$) in these watersheds, the study stressed the need for its effective utilization. Only a small amount of perennial water flowing through the Malik Din Khel, Rajgah, and Zakha Khel watersheds is used for irrigation. Most of the water is irrigating the Bara watershed downstream. The study recommended constructing 15 small dams in these three watersheds and 9 dams in other watersheds (Table 8).

### 3.6.3 Mohmand Agency

48. Like the other two agencies, Mohmand has phenomenal outflows because of underutilization of water resources within its boundaries. The study found that 64% of surface water remains untapped and flows out of the agency. The surface water available for an average year in its 15 watersheds is 174.6 million $m^3$, of which 36% (63 million $m^3$) is utilized and 64% (111.6 million $m^3$) is drained. The net water availability ranges from 17.2 million $m^3$ in the Lower Prang Ghar watershed to 1.8 million $m^3$ in the Ekka Ghund-III watershed (Table 9).

49. The study recommended construction of 19 small dams for tapping available water resources in its 15 watersheds (Table 9).

**Table 8 Surface Water Availability and Proposed Interventions in Khyber, 2008**

| Watershed | Net Available Surface Water (million cubic meters) | Proposed Interventions | |
|---|---|---|---|
| | | Recharge, Delayed Action, and Storage Dams (No.) | Surface Ponds (No.) |
| Spinpokh-Shamsai (K-1) | 0.6 | 1 | 9 |
| Jamrud (K-2) | 14.4 | 1 | 9 |
| Bazar Valley (K-3) | 28.4 | 2 | 8 |
| Bar (K-4) | 40.7 | 2 | 8 |
| Mulagori (K-5) | 2.2 | 0 | 17 |
| Shilman (K-6) | 3.9 | 1 | 9 |
| Shpora (K-7) | 1.4 | 0 | 17 |
| Landi Kotal (K-8) | 7.7 | 1 | 9 |
| Zakha Khel (K-9) | 140.7 | 6 | 4 |
| Malik Din Khel (K-10) | 77.7 | 4 | 7 |
| Rajgah (K-11) | 87.6 | 5 | 7 |
| Murda Dand (K-12) | 1.4 | 0 | 17 |
| Kuki Khel (K-13) | 4.6 | 1 | 9 |
| Miri Khel (K-14) | 5.9 | 0 | 17 |
| **Total** | **417.2** | **24** | **147** |

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

**Table 9 Surface Water Availability and Proposed Interventions in Mohmand, 2008**

| Watershed | Net Available Surface Water (million cubic meters) | Proposed Interventions | |
|---|---|---|---|
| | | Recharge, Delayed Action, and Storage Dams (No.) | Surface Ponds (No.) |
| Lower Pandiali (M-1) | 4.0 | 1 | 12 |
| Lower Prang Ghar (M-2) | 17.3 | 3 | 7 |
| Lower Haleemzai (M-3) | 2.6 | 0 | 19 |
| Khawazai Bazai (M-4) | 9.9 | 1 | 12 |
| Upper Prang Ghar (M-5) | 15.7 | 3 | 7 |
| Ekka Ghund-I (M-6) | 8.2 | 2 | 9 |
| Qasim Khel (M-7) | 5.2 | 1 | 12 |
| Ekka Ghund-II (M-8) | 4.3 | 1 | 12 |
| Upper Piandiali (M-9) | 8.0 | 1 | 12 |
| Upper Haleemzai (M-10) | 2.8 | 1 | 10 |
| Ekka Ghund-III (M-11) | 1.8 | 0 | 19 |
| Safi (M-12) | 5.5 | 1 | 12 |
| Lakarao (M-13) | 5.5 | 1 | 12 |
| Shinwari (M-14) | 4.5 | 1 | 12 |
| Umbar (M-15) | 16.3 | 2 | 9 |
| **Total** | **111.6** | **19** | **176** |

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

50. Table 10 summarizes proposed interventions in each agency.

**Table 10 Proposed Interventions by Agency** (Number)

| Agency | Recharge, Delay Action, Storage Dams | Surface Ponds |
|---|---|---|
| Bajaur | 14 | 127 |
| Khyber | 24 | 147 |
| Mohmand | 19 | 176 |
| **Total** | **57** | **450** |

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

# 4. ASSESSING GROUNDWATER

51. The groundwater potential in the project area largely depends on rainfall. The irrigation systems consist mostly of shallow wells, dug wells (i.e., open wells with motorized pumping), and tube wells. Unregulated groundwater abstraction, through unplanned tube wells and dug wells, has considerably lowered the water table while putting groundwater aquifers under extreme stress in most of the watersheds.

## 4.1 Geology and Groundwater Availability

52. **Bajaur Agency.** Southern Bajaur consists of metamorphic rocks, such as schist, while the rest of the area consists of igneous rocks like granodiorite and diorite. Alluvial deposits from the Quaternary Period are found in major valleys. The lithological sequence is usually a clay top layer underlain by gravel, sand, and a clay bottom layer. The water level in wells is 5–45 meters (m) deep. The Irrigation and Hydel Power Department's strata charts revealed that groundwater occurs under unconfined conditions. The alluvial plain catchment covers an area of 371 $km^2$ and receives precipitation of 700–1,000 mm per year.

53. **Khyber Agency.** Eastern Khyber has extensive outcrops of massive grey limestone with sand and clay beds made up of carboniferous formation, slate phyllite, and schist with minor limestone and quartzite beds. Near Warsak, on the boundary with Peshawar, the valley has a granite intrusion. Khyber is mountainous without a well-developed alluvial plain. Lithological data collected during the study peg the depth of the groundwater table at 55–70 m.

54. **Mohmand Agency.** Mohmand's geology consists of schist and phyllite with interbedded metamorphosed limestone. Unconsolidated alluvial deposits are found as valley fill in the terraces. The groundwater table is at 60–150 m.

## 4.2 Methodology Adopted

55. **Collecting basic data.** As a fundamental requirement in groundwater assessment, the study calculated basic measurements like discharge, static water level, and drawdown at 328 water points in 44 watersheds spread over the project area. The information collected was used to determine (i) depth of the water table, (ii) type and depth of the aquifer, (iii) volume of water drawn, and (iv) operating hours of every water point.

56. **Documenting subsurface lithology.** The project and the Irrigation and Hydel Power Department carried out an electric resistivity survey. The study used the resultant subsurface lithological data to establish the subsurface strata and geometry of aquifer material.

57. **Assessing depth of groundwater table.** The study observed water points in each watershed to obtain previous and existing groundwater conditions as well as the decrease and increase in the water table. The minimum depth of the water table was 5.24 m in the Salarzai-III watershed at Bajaur, while the maximum was 150.33 m in the Lakarao watershed at Mohmand.

58. **Preparing well inventory.** The study inventoried 607 tube wells, 1,649 dug wells, and 154 spring-based water supply schemes in 44 watersheds. These are operated either by government departments or by the communities. These water points are used for irrigation and/or drinking. There are also 73,425 open wells being used for irrigation and drinking.[5]

59. **Estimating groundwater recharge.** Scant rainfall in 44 watersheds mostly turns into surface flow that goes into various streams and rivers. The geology and high country slope do not allow high quantities of seepage. There is some seepage through rivers and perennial streams, but the contribution by nonperennial streams is negligible. Groundwater occurs generally in two aquifers: alluvial and limestone. Summer rains are high intensity, of short duration, and mostly drain out of the watersheds. On the other hand, winter rains are low intensity, of long duration, and generate less runoff, which recharges the groundwater.

60. Using United States Bureau of Reclamation criteria, the study estimated recharge at 5%–10% of total rainfall. In Bajaur, the volume of annual groundwater recharge is 116.32 million $m^3$ for average years, 98.65 million $m^3$ for dry years, and 191.99 million $m^3$ for wet years. In a typical dry year, the minimum recharge is 0.65 million $m^3$ in the Chamarkand watershed, and the maximum recharge is 18.56 million $m^3$ in the Loi Mamund watershed.

61. In Khyber, the study estimated the annual recharge at 85.41 million $m^3$ for average years, 46.58 million $m^3$ for dry years, and 146.06 million $m^3$ for wet years. In a typical dry year, the minimum recharge is 0.49 million $m^3$ in the Murda Dand watershed, and the maximum is 8.12 million $m^3$ in the Bara watershed.

62. In Mohmand, the annual recharge volume is 65.47 million $m^3$ for average years, 41.62 million $m^3$ for dry years, and 132.60 million $m^3$ for wet years. In a typical dry year, the minimum recharge was estimated at 1.07 million $m^3$ in the Ekka Ghund-III watershed, and the maximum is 6.51 million $m^3$ in the Khwaizai Bezai watershed. Table 11 provides a summary of groundwater recharge estimates for typical average, dry, and wet years.

63. **Estimating groundwater abstractions.** The study estimated the average annual groundwater abstraction in the project area at 299.95 million $m^3$. The highest abstraction (127.92 million $m^3$) is in Bajaur, followed by Khyber (91.25 million $m^3$) and Mohmand (80.77 million $m^3$). This estimate came from

[5] Planning and Development Department, FATA Secretariat. 2008. FATA Development Statistics, Peshawar; Irrigation and Power Department, Public Health Engineering Department, and Local Government and Rural Development Department data.

**Table 11 Groundwater Recharge and Return Period by Agency**

| Item | Bajaur | | | Khyber | | | Mohmand | | |
|---|---|---|---|---|---|---|---|---|---|
| | Average | Dry | Wet | Average | Dry | Wet | Average | Dry | Wet |
| Recharge (million $m^3$) | 116.32 | 98.65 | 191.99 | 85.41 | 46.58 | 146.06 | 65.47 | 41.62 | 132.60 |
| Return period (years) | 17 | 1 | 30 | 19 | 1 | 30 | 18 | 1 | 30 |

Source: Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project*. Manila.

data collected from 328 water points, including at least one sample each of tube wells, dug wells, open wells, and springs in each watershed. The first round of assessments for groundwater abstractions was revalidated and cross-checked with the estimated consumptive water use by irrigation, people, and livestock.

## 4.3 Groundwater Budget

64. The study based the groundwater budget estimate on the amount of recharge to and discharge from the aquifer. Table 12 presents the current and projected groundwater budget for a typical dry year. Figure 9 illustrates the increase in drawdown by year.

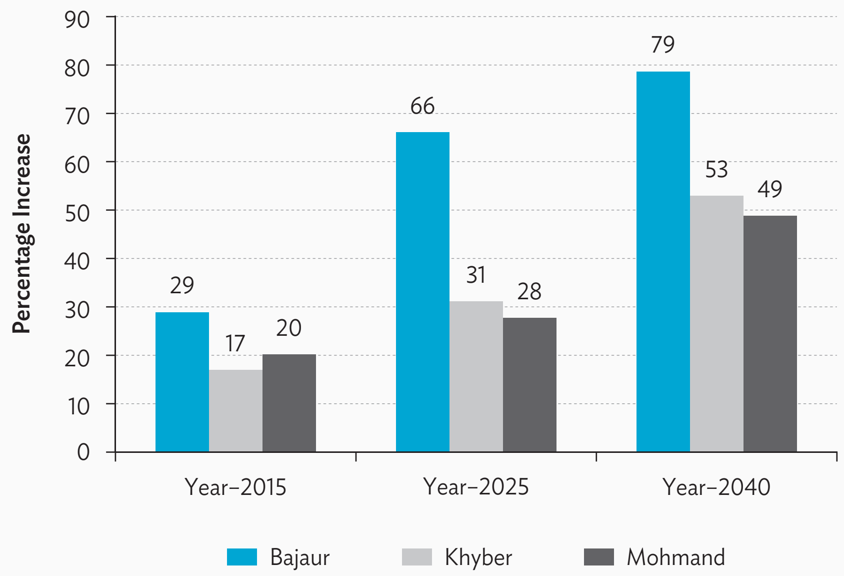
**Table 12 Groundwater Budget for Typical Dry Year by Agency**

| Agency | Year | Recharge (million $m^3$) | Discharge (million $m^3$) | Change in Storage (million $m^3$) | Increase/ Decrease (m/yr) | Increase in Drawdown by Year (%) |
|---|---|---|---|---|---|---|
| Bajaur | 2008–2009 | 98.65 | 127.92 | (29.27) | (0.23) | Present |
| | 2015 | 98.65 | 136.39 | (37.74) | (0.29) | 28.92 |
| | 2025 | 98.65 | 161.34 | (62.69) | (0.48) | 66.11 |
| | 2040 | 98.65 | 210.66 | (112.01) | (0.87) | 78.67 |
| Khyber | 2008–2009 | 46.58 | 91.25 | (44.67) | (0.30) | Present |
| | 2015 | 46.58 | 98.83 | (52.25) | (0.35) | 16.96 |
| | 2025 | 46.58 | 115.09 | (68.51) | (0.47) | 31.13 |
| | 2040 | 46.58 | 151.42 | (104.84) | (0.71) | 53.02 |
| Mohmand | 2008–2009 | 41.62 | 80.78 | (39.16) | (0.35) | Present |
| | 2015 | 41.62 | 88.70 | (47.08) | (0.42) | 20.23 |
| | 2025 | 41.62 | 101.75 | (60.13) | (0.53) | 27.73 |
| | 2040 | 41.62 | 131.14 | (89.52) | (0.79) | 48.86 |

( ) = negative, m = meter, $m^3$ = cubic meter.

Source: Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project*. Manila.

**Figure 9** Increase in Drawdown by Year (%)




*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project*. Manila.

65. The study estimated the watershed groundwater budget for average, dry, and wet years. In a typical dry year, groundwater is not expected to be available. However, during a typical average year—which will probably occur once every 17 years—the water table in 17 watersheds is almost static under recharge and discharge conditions (Table 13).

## 4.4 Key Findings and Recommendations

66. **Worsening recharge–abstraction balance.** The groundwater situation in the project area appears bleak, particularly during dry years. In most of the watersheds, groundwater abstraction is significantly higher than the recharge-to-groundwater aquifers. This results in lowering of the water table in those watersheds. In all three agencies, recharge exceeds discharge by 50%–64% during wet years, but wet years only occur once every 30 years.

67. In Bajaur, the average annual abstraction is 10% more than the recharge in a typical average year and 30% more in a dry year. During wet years, the recharge to aquifers is 50% more than the discharge. The situation is worse in Khyber where, in dry years, the abstraction is almost double the recharge. It gets better during average years, with the discharge 7% more than the recharge, and in wet years, with the recharge exceeding the discharge by about 60%. Mohmand is under stress during dry years, with abstraction exceeding the recharge by 94%, and during average years, with abstraction exceeding the recharge by 23%. During wet years, the recharge is 64% higher than abstraction.

**Table 13  Groundwater Budget of Watersheds with Static Water Table in Average Years**

| Agency | Watershed | Recharge | Discharge | Change in Storage | Increase/ Decrease |
|---|---|---|---|---|---|
| | | (million $m^3$) | | | |
| Bajaur | Charmang | 10.94 | 10.96 | (0.02) | 0.00 |
| | Alizai | 4.34 | 4.43 | (0.09) | (0.02) |
| | Mandal Burthrus | 4.67 | 4.93 | (0.26) | (0.03) |
| | Salarzai-II | 4.63 | 4.88 | (0.25) | (0.15) |
| | Salarzai-III | 16.77 | 18.64 | (1.87) | (0.17) |
| | Loi Mamund | 21.16 | 24.10 | (2.94) | (0.07) |
| | Wara Mamund | 12.15 | 14.40 | (2.26) | (0.09) |
| Khyber | Shpora | 2.06 | 3.21 | (1.15) | (0.10) |
| | Malik Din Khel | 12.33 | 12.37 | (0.04) | 0.00 |
| | Mulagori | 2.13 | 2.63 | (0.49) | (0.06) |
| | Bara | 12.36 | 13.35 | (1.00) | (0.02) |
| | Jamrud | 8.25 | 8.35 | (0.10) | 0.00 |
| Mohmand | Lower Prang Ghaar | 3.95 | 4.00 | (0.05) | 0.00 |
| | Qasim Khel | 2.82 | 3.24 | (0.42) | (0.04) |
| | Safi | 6.32 | 10.41 | (4.08) | (0.08) |
| | Upper Pandiali | 3.59 | 3.77 | (0.18) | (0.02) |
| | Umbar | 6.41 | 6.91 | (0.50) | (0.02) |

( ) = negative, $m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

68. **Heavy reliance on groundwater.** The lack of surface water sources leads to increased reliance on groundwater for drinking and irrigation purposes. Low rainfall, coupled with intensive groundwater abstraction, contributes to the alarming depletion of the aquifer in most of the watersheds. The study predicted that this trend of groundwater abstraction is unlikely to improve for various reasons, including (i) the ease of construction and proximity of groundwater pumping facilities, (ii) reliability and continuity of good-quality water, and (iii) increasing human and livestock consumption. In this context, the study recommended construction of recharge dams, particularly in watersheds experiencing excessive abstraction.

69. **Proposed interventions.** The study expected that only 17 of 44 watersheds will have groundwater equilibrium to a certain extent. These are potential areas for limited interventions for groundwater extraction, but construction of recharge dams to enhance groundwater recharge is preferable. In the remaining 27 watersheds, new groundwater-pumping facilities should be provided only after recharge dams are constructed.

70. Considering the projected water demand in 2025 and 2040, recharge dams should be an essential component of groundwater projects in the area in the next few years. Groundwater fluctuations should also be monitored periodically to inform planning and management of water resources.

# 5. ASSESSING WATER CONSUMPTION

71. Developing the water balance model for average, dry, and wet precipitation conditions for each watershed in the project area required estimates of current and projected water consumption. The study analyzed data on the major users of water—agriculture, people, and livestock—to estimate current and future water needs in the area.

## 5.1 Water Consumption by Agriculture

72. Like most of Pakistan, agriculture is the biggest water user in the project area. The study carried out detailed estimates of agriculture requirements, including actual water demand for each crop.

73. The study used climatic data collected from meteorological stations in Kohat, Peshawar, and Saidu Sharif. The reference evapotranspiration was estimated using Food and Agriculture Organization methodology with CROPWAT.[6] The study used agricultural data from FATA Development Statistics and satellite imagery to assess the crop area. Evapotranspiration of each crop was multiplied with the crop area for estimating monthly and annual crop water requirements.

74. Of the total geographic area (616,309 hectares [ha]) in Bajaur, Khyber, and Mohmand agencies, the crop area is 18%, and the irrigated area is 36% of the crop area (Table 14).

**Table 14 Crop and Irrigated Areas** (ha)

| Agency | Total Area | Cropped Area | Irrigated Area |
|---|---|---|---|
| Bajaur | 129,035 | 71,600 | 20,030 |
| Khyber | 257,654 | 19,954 | 11,000 |
| Mohmand | 229,620 | 21,410 | 9,418 |
| **Total** | **616,309** | **112,964** | **40,448** |

ha = hectare.

*Source:* Planning and Development Department, FATA Secretariat. 2008. *FATA Development Statistics.* Peshawar.

[6] J. Doorenbos and W. Pruitt. 1977. *Irrigation and Drainage Paper No. 24 (FAO-24).* Rome: Food and Agriculture Organization. CROPWAT is a decision support tool developed by the Land and Water Development Division of the Food and Agriculture Organization. See FAO. CROPWAT 8.0. http://www.fao.org/nr/water/infores_databases_cropwat.html (accessed May 2013).

75. Key crops grown in the project area include wheat, maize, tomato, onions, and other vegetables. The cropping intensity is 120.0% in Bajaur, 119.5% in Khyber, and 94.0% in Mohmand. The average water duty for the irrigated area is 200 acres per cubic foot per second. The total crop area in three agencies is 112,964 ha. The estimated monthly crop water consumption is detailed in Table 15.

**Table 15 Estimated Crop Water Consumption, Base Year 2008** (million $m^3$)

| Agency | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bajaur | 14.7 | 10.4 | 7.2 | 1.5 | 1.8 | 1.9 | 3.7 | 11.6 | 15.1 | 11.6 | 14.5 | 10.8 | **104.6** |
| Khyber | 5.8 | 6.2 | 4.6 | 2.3 | 2.6 | 6.3 | 11.0 | 10.4 | 5.1 | 3.1 | 6.6 | 5.8 | **69.6** |
| Mohmand | 7.2 | 7.4 | 4.4 | 0.5 | 0.6 | 5.0 | 9.9 | 10.5 | 5.8 | 4.0 | 5.8 | 6.7 | **67.8** |
| **Total** | **27.6** | **24.1** | **16.2** | **4.3** | **4.9** | **13.1** | **24.5** | **32.5** | **26.0** | **18.7** | **26.8** | **23.3** | **242.0** |

$m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

## 5.2 Water Consumption by People and Livestock

76. To estimate the current population using the growth rate suggested by FATA Development Statistics in 2008, 1998 census data for population and 1996 data for livestock were used. Figures for per capita water consumption by people and livestock used data from the Soan Valley Development Program,[7] since the valley has a similar climate and topography.

77. **Human water consumption.** Using 2008 as a base year, the total annual human water consumption in the project area was estimated at 46.56 million $m^3$ (Table 16). Agency estimates were 19.06 million $m^3$ for Bajaur, 16.83 million $m^3$ for Khyber, and 10.66 million $m^3$ for Mohmand.

**Table 16 Estimated Human Water Consumption, Base Year 2008** (million $m^3$)

| Agency | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bajaur | 1.7 | 1.4 | 1.7 | 1.7 | 1.7 | 1.7 | 1.8 | 1.8 | 1.6 | 1.4 | 1.2 | 1.3 | **19.1** |
| Khyber | 1.5 | 1.2 | 1.5 | 1.5 | 1.5 | 1.5 | 1.6 | 1.6 | 1.4 | 1.3 | 1.1 | 1.1 | **16.8** |
| Mohmand | 0.9 | 0.8 | 1.0 | 0.9 | 1.0 | 1.0 | 1.0 | 1.0 | 0.9 | 0.8 | 0.7 | 0.7 | **10.7** |
| **Total** | **4.1** | **3.4** | **4.2** | **4.1** | **4.3** | **4.2** | **4.4** | **4.4** | **3.9** | **3.5** | **3.0** | **3.1** | **46.6** |

$m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

[7] Pakistan Poverty Alleviation Fund. 2007. *Soon Valley Development Program Report.* Naushehra.

78. **Livestock water consumption.** Using 2008 as a base year, the total annual livestock water consumption in the project area was estimated at 3.13 million $m^3$ (Table 17). The annual total per agency is estimated at 0.94 million $m^3$ for Bajaur, 1.16 million $m^3$ for Khyber, and 1.02 million $m^3$ for Mohmand.

**Table 17 Estimated Livestock Water Consumption, Base Year 2008** (million $m^3$)

| Agency | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bajaur | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | **0.9** |
| Khyber | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | **1.2** |
| Mohmand | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | **1.0** |
| **Total** | **0.2** | **0.2** | **0.2** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.3** | **0.2** | **3.1** |

$m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

79. The total annual water consumption is summarized in Table 18. As illustrated in Figure 10, agriculture is the biggest consumer with 83% total consumption, followed by human consumption at 16%, and livestock consumption at 1%.

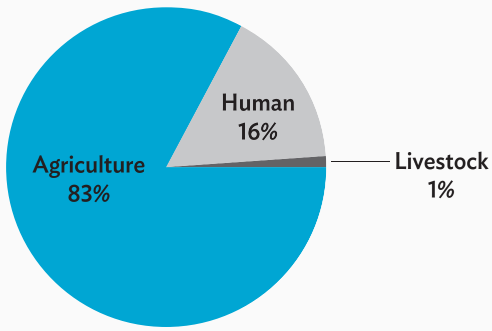
**Table 18 Annual Water Consumption** (million $m^3$)

| Category | Bajaur | Khyber | Mohmand | Total |
|---|---|---|---|---|
| Agriculture | 104.62 | 69.63 | 67.77 | 242.02 |
| Human | 19.06 | 16.84 | 10.66 | 46.56 |
| Livestock | 0.94 | 1.16 | 1.03 | 3.14 |
| **Total** | **124.62** | **87.63** | **79.46** | **291.71** |

$m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

**Figure 10 Distribution of Annual Water Consumption, Base Year 2008**




*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

## 5.3 Projected Water Consumption

80. The study estimated the average annual growth rate for the human population at 4.17% and at 5.00% for livestock. The increase in crop area was estimated at 0.6%.[8] The study used these growth rates to estimate water requirements in 2015, 2025, and 2040 (Table 19). Since the population growth rates of people and livestock are higher than the estimated increase in crop area, there is no compatibility between projected water consumption for people, livestock, and agriculture.

**Table 19 Projected Water Consumption** (million $m^3$)

| | Bajaur | | | Khyber | | | Mohmand | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Human | Livestock | Agriculture | Human | Livestock | Agriculture | Human | Livestock | Agriculture |
| 2008 | 19.06 | 0.94 | 104.62 | 16.84 | 1.16 | 69.63 | 10.66 | 1.03 | 67.77 |
| 2015 | 25.64 | 1.33 | 109.10 | 22.03 | 1.64 | 72.61 | 14.30 | 1.45 | 70.67 |
| % increase | 34.50 | 40.65 | 4.28 | 30.88 | 40.65 | 4.28 | 34.08 | 40.65 | 4.28 |
| 2025 | 39.19 | 2.16 | 115.83 | 32.36 | 2.67 | 77.10 | 21.74 | 2.36 | 75.04 |
| % increase | 105.56 | 129.12 | 10.72 | 92.24 | 129.12 | 10.72 | 103.80 | 129.12 | 10.72 |
| 2040 | 74.01 | 4.49 | 126.73 | 57.62 | 5.55 | 84.35 | 40.76 | 4.90 | 82.09 |
| % increase | 288.20 | 376.40 | 21.14 | 242.26 | 376.40 | 21.14 | 282.30 | 376.40 | 21.14 |

$m^3$ = cubic meter.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

[8] Planning and Development Department, FATA Secretariat. 2008. *FATA Development Statistics.* Peshawar.

# 6. WATER BALANCE MODEL

81. The study developed a water balance model for three climatic conditions (i.e., average, dry, and wet) in the project area, for each agency, and for each watershed. It based the model on the estimated amount of water volume available and consumption by agriculture, people, and livestock. The model took into account inflows (i.e., rainfall and perennial flows) and outflows (i.e., runoff from rainfall, evapotranspiration, and infiltration) to estimate surface water availability (Box 2). To estimate groundwater, the study equated recharge and discharge volumes to compute change in storage.

**Box 2 Water Balance**

In hydrology, a water balance equation can be used to describe the flow of water in and out of a system. A system can be one of several hydrological domains such as a column of soil or a drainage basin. The water balance components can be grouped into components corresponding to zones in a vertical cross section in the soil, forming reservoirs with inflow, outflow, and storage of water. The general water balance reads:

**Inflow = outflow + change of storage**

82. While developed on a worksheet with simple computations, the model required a wide range of data for reliable estimates of runoff from rainfall, recharge to groundwater, and evaporation losses, as well as measurements of perennial flows, existing groundwater abstraction rates and volume, and utilization of water by various users.

83. The study estimated the net available surface water and groundwater in the 44 watersheds for dry, average, and wet years. Table 20 shows that in dry and average years, there is no potential for additional exploitation of groundwater in any of the agencies. The groundwater abstraction rate (i.e., discharge) exceeds the recharge in all agencies even in average years. Aquifers are being depleted, and the water table is lowering.

84. However, in 17 watersheds (7 in Bajaur, 5 in Khyber, and 5 in Mohmand), there is some groundwater potential, as the water table is almost static under discharge and recharge conditions during a typical average year. During wet years, the recharge exceeds discharge in all agencies, but the probability of a wet year occurs only once every 30 years.

**Table 20 Project Area Water Balance Model** (million m³)

| Agency | Year | Average Rainfall (mm) | Inflow: Net Perennial Flows | Inflow: Estimated Rainwater Volume | Outflow: Estimated Runoff | Outflow: Losses[a] | Outflow: Recharge to Groundwater | Outflow: Total Outflow | Net Available Surface Water[b] | Estimated Groundwater Use | Change in Groundwater Storage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bajaur | Dry | 552 | 128 | 757 | 3 | 655 | 99 | 757 | 131 | 128 | (29) |
| | Average | 678 | 128 | 931 | 76 | 738 | 117 | 931 | 204 | 128 | (11) |
| | Wet | 1,185 | 128 | 1,626 | 236 | 1,194 | 196 | 1,626 | 364 | 128 | 68 |
| Khyber | Dry | 261 | 0 | 715 | 5 | 663 | 47 | 715 | 5 | 91 | (45) |
| | Average | 530 | 0 | 1,452 | 170 | 1,197 | 85 | 1,453 | 170 | 91 | (6) |
| | Wet | 923 | 0 | 2,528 | 636 | 1,746 | 146 | 2,528 | 636 | 91 | 55 |
| Mohmand | Dry | 236 | 112 | 533 | 3 | 489 | 42 | 533 | 115 | 81 | (39) |
| | Average | 407 | 112 | 906 | 100 | 740 | 65 | 906 | 212 | 81 | (15) |
| | Wet | 843 | 112 | 1,907 | 422 | 1,353 | 133 | 1,907 | 534 | 81 | 52 |

( ) = negative, $m^3$ = cubic meter, mm = millimeters.

[a] Losses include evapotranspiration from vegetation and trees.

[b] Net available surface water is net perennial flows plus estimated runoff.

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

# 7. WATER MANAGEMENT PLAN

85. The economy of the project area is largely agriculture based. Surface water utilization is low, and dependence on groundwater is extremely high, leading to severe environmental degradation. In all three agencies, groundwater recharge is lower than water abstraction in a typical dry year. This water deficit ranges from 30% in Bajaur to 93% in Mohmand. This calls for the development of a water management plan, which suggests optimal water utilization and proposes interventions for increasing groundwater recharge.

86. The study proposed a water management plan following the integrated water resources management (IWRM) approach, focusing on (i) watershed management, (ii) water infrastructure, and (iii) efficient water use. The water management plan emphasized a shift from groundwater to surface water utilization, and increasing groundwater recharge while considering future demand, environmental degradation, and the shrinking natural resources base.

87. Cognizant that water is critical to the local economy, the study emphasized careful management and sustainable use of scarce resources, taking into account their regeneration mechanisms. The proposed plan encompassed four key areas: (i) water resources management, (ii) watershed management, (iii) agriculture improvement, and (iv) water monitoring.

## 7.1 Water Resources Management

88. Water resources management aims for water conservation and sustainable development, while considering water availability and its competing uses. The study recommended implementing four physical interventions to achieve a balance between demand and availability:

(i) water conservation schemes through lining of channels and provision of pipe irrigation,
(ii) small storage ponds,
(iii) small recharge-cum-delay action and storage dams, and
(iv) drinking water supply schemes.

89. **Water conservation schemes.** The study suggested water conservation interventions as key measures to improve water conveyance efficiency. Tube-well water conveyed through earthen channels for irrigation results in about 30% water loss, and several studies have assessed the losses incurred in unlined watercourses (Box 3). Lining channels and introducing pipe irrigation with valve control would reduce conveyance losses to less than 10% and would make more water available at the end.

**Box 3 Estimated Water Losses in Unlined Channels**

| | |
|---|---|
| 33%–37% | Water and Power Development Authority (WAPDA). 1996. *Final Report on Monitoring and Evaluation of the On-Farm Water Management (OFWM)-III Project.* Lahore. |
| 39% | Punjab Economic Research Institute. 1993. *Evaluation of OFWM Program in Punjab.* Lahore. |
| 35%–45% | Government of the Punjab. 1984. *Report of the Expert Committee on Irrigation Problems of the Punjab.* Chandigarh. |
| 36%–48% | WAPDA. 1994. *First Time-Scaled Evaluation Report of OFWM Program, World Bank-Financed OFWM-I and II Projects.* Lahore. |

90. The FATA Rural Development Project completed lining 90 surface irrigation schemes. The water management plan recommended lining 1,180 more channels in the next few years. These are expected to

(i) reduce water losses,
(ii) reduce pumping costs and operation and maintenance expenditures,
(iii) increase the irrigated area,
(iv) increase agricultural production, and,
(v) ensure sustainability and equity in irrigation systems.

91. **Water ponds.** Water ponds are generally constructed to collect rainwater for drinking purposes. These also help recharge aquifers. The project constructed more than 83 water ponds through community organizations. The study recommended construction of 370 more ponds.

92. **Small dams.** The study found reasonable potential for constructing small dams to recharge groundwater and store surface water for irrigation and consumption. Surface water is underutilized, and almost all watersheds have potential for small dams.

93. The study recommended integration of recharge dams in all future groundwater schemes. These small dams are low-cost gravity structures. In watersheds where water for storage was available, the study proposed small dams for irrigation. The water management plan identified 52 sites for small dams in addition to the five dams constructed under the project.

94. **Drinking water supply schemes.** Fetching drinking water takes a huge toll on time and energy, especially on women who have to travel long distances to do so. The situation worsens in the hot summer and cold winter months. The study prioritized the construction of drinking water schemes, with emphasis on tapping surface water. Where surface water schemes were not feasible, the study recommended groundwater-based schemes for watersheds that have potential for abstraction and where recharge-enhancing facilities could be constructed. The project constructed 938 drinking water schemes, mostly from surface flows.

## 7.2 Watershed Management

95. Degradation of watersheds is largely due to deforestation and overgrazing. This degradation leads to flash floods, soil erosion, low recharge, and decrease in grazing potential. Conservation; optimal utilization; proper management; and regulation of rangelands, forests, and watersheds are important to sustain the availability of resources and to maintain environmental equilibrium. It is critical to integrate watershed management in future development plans to keep the existing natural resources base intact. Watershed management consists of forest and rangeland management, and check dams.

96. **Forest and rangeland management.** Forest and rangelands regulate water balance and improve the environment, and they mitigate floods and erosion caused by heavy rains. Livestock survive by grazing on rangelands and forests. Overexploitation of forest and rangelands drastically reduced vegetation cover. The study recommended the adoption of forest and rangeland improvement practices in the project area, including

(i) afforest and enrichment plantation on a regular basis,
(ii) promoting community-based forest management practices,
(iii) building the capacity of tree farmers on farm forestry,
(iv) afforesting with soil and water conservation practices,
(v) optimizing the number of livestock on the basis of available grazing area,
(vi) eradicating poisonous and useless plants,
(vii) reseeding natural nutritious grasses like Dhaman or Kala Dhaman to replace the low-caloric species,
(viii) dry forestation of appropriate species using dry zone afforestation techniques,
(ix) introducing water-harvesting techniques to enhance vegetation cover, and
(x) introducing controlled and deferred grazing.

97. **Check dams.** Check dams stop the movement of sediment in streams, thus mitigating erosion. They also replenish aquifers. Check dams are constructed in gabions, with concrete, or with earth-fill materials. Planting trees and shrubs together with constructing check dams on mountain slopes reduce the flow of sediment and control erosion. The project constructed 135 check dams, and the water management plan proposed constructing 680 more check dams.

## 7.3 Agriculture Improvement

98. Agricultural development is solely dependent upon water availability and its optimized use. The water assessment study had two critical findings: (i) surface flows are underutilized, and (ii) groundwater is overexploited. Until water is sufficient, the study recommended changing the cropping pattern and adapting improved farm practices for increased agricultural production (Table 21).

**Table 21 Present and Proposed Cropping Pattern**

| Agency | Present | Proposed |
|---|---|---|
| Bajaur | Wheat–maize–wheat | Wheat–tomato–onion–off-season vegetables |
| Khyber | Wheat–maize–vegetables | Wheat–onion–off-season vegetables |
| Mohmand | Wheat–sorghum–wheat | Wheat–onion–tomato–off-season vegetables |

*Source:* Water Assessment Study (2010) cited in ADB. 2006. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the Islamic Republic of Pakistan for the FATA Rural Development Project.* Manila.

99. Improved farm practices—including precision land leveling, efficient extension services, and efficient irrigation systems like drip and sprinkler systems—are key measures to enhance output and reduce losses. The study proposed integrating these on-farm measures into water and agriculture projects.

## 7.4 Water Monitoring

100. For appropriate water resources planning and management, it is imperative to measure surface water flows, groundwater levels, and rainfall on a regular basis. Development and management of surface and groundwater resources largely depend on data collected through a network of rain gauges, stream gauges, and piezometers.

101. There are no discharge measurement facilities at any of the rivers and streams in the project area. The FATA Agriculture Department (FAD) installed four rain gauges and the Pakistan Meteorological Department (PMD) installed three rain gauges in the project area. Five of these are in Khyber, one is in Bajaur, and one is in Mohmand. The four FAD gauges are not useful because they do not record daily data and are not of standard specifications, unlike the PMD gauges. The FATA Development Authority and the PMD are installing rain gauges, but these are expected to provide insufficient rain data for the entire project area. Thus, there are no arrangements for groundwater monitoring, despite heavy reliance on this source of water for irrigation and drinking purposes.

102. The study recommended installing 3 weather stations and 11 rain gauges in the project area. It recommended installing 50 stream gauges at various locations on rivers and major streams for discharge measurements. It also recommended installing 44 electronic data loggers with water level indicators, 15 portable water level indicators, and 15 piezometers for groundwater monitoring.

# 8. CONCLUSION

103. Water availability has a tremendous impact on water resources development and socioeconomic sustainability, particularly in arid and semiarid areas. A thorough assessment of water availability and demand is essential in preparing any water resources development and management plan.

104. According to Agenda 21,[9] water resources assessments identify potential sources of freshwater supply, dependability and quality of water resources, and human activities that affect those resources. The study under the project carried out detailed analysis to estimate surface runoff from rainfall and snowmelt; groundwater recharge and extraction; and water consumption by agriculture, people, and livestock in the project area.

105. Following the IWRM approach, the study identified interventions for sustainable use of natural resources in the project area. Proposed interventions include increased utilization of surface water with recharge-cum-delay action and storage dams, small ponds, and check dams for watershed improvement as well as drinking water supply schemes. It also proposed lining irrigation channels, controlling grazing of rangelands, and improving agriculture practices.

106. Climatic data on rainfall and evaporation, watershed topography, vegetation cover, and soil type and soil conditions are critical to estimate rainfall runoff in a watershed. Defining watershed boundaries is also critical to ensure the watershed area drains at the defined rim station. If a discharge-measuring gauge exists at the rim station, the gauge data could be used to verify the estimated runoff with the observed flows, thus ensuring reliability of the estimates. Random flow measurements are essential to enhance reliability of estimates in the absence of existing gauging facilities.

107. In the absence of rain- and evaporation-measuring facilities in a watershed, correlation with data from an adjacent watershed with similar climatic conditions yields reasonable estimates. However, installing a climate station must be included in the management plan if a development intervention is proposed or anticipated in that watershed. The climate station should have, at a minimum, a rain gauge and an evaporation pan. At least one discharge-measuring gauge at the rim station must be included in the management plan. The climate and gauging stations should be installed at the early stage of feasibility study preparation. Actual observed data would help verify the estimated runoff and make adjustments as required.

[9] Agenda 21 is a nonbinding, voluntarily implemented action plan adopted by all participating nations at the United Nations Conference on Environment and Development held on 13 June 1992 in Rio de Janeiro, Brazil, for developing a plan of action to confront and overcome environmental, health, and social issues facing the planet.

108. Groundwater and surface water assessment in this report is based on the historic data. However, the looming climate change may significantly affect rainfall patterns and intensities as well as temperature variations, which could seriously impact the water availability in the medium to long term. Therefore, integrating the hydrological forecasting with the climate change modeling for FATA is recommended. This will not only provide better forecasts but also make policy makers and water users aware of the scarcity of water and its judicious use.

109. The study helped coordinate ongoing FATA projects, by ensuring that interventions implemented in one project are not redundant with similar interventions in other projects. The study also provided a basis for planning prior to making investment decisions for water resources development and management in similar watersheds.

## Water Balance

**Achieving Sustainable Development through a Water Assessment and Management Plan**
**The Case of Federally Administered Tribal Areas, Pakistan**

If water is to be managed in a sustainable way, the planners and managers must know how much there is and how much of it is needed, particularly in arid and semi-arid regions. The report provides the guidance, methods, data, and analyses needed to assess water availability and needs in micro watersheds. It shows how to prepare short-, medium-, and long-term water investment and management plans on the basis of volume of surface and groundwater within a watershed and the needs of agriculture, people, and livestock. It offers a practical approach based on real-life assessments that have helped planners decide on investments to develop and manage water.

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