# WATER ENERGY NEXUS

By

**Dr. Izhar ul Haq[1]**

## SYNOPSIS

Pakistan has on the average about 145 MAF of surface flows per annum. Out of this on average 103 MAF is diverted for irrigation at various barrages, 10 MAF is the system loss and 32 MAF goes down the last barrage into sea every year. Mangla and Tarbela two mega Dams were built as a part of the replacement works of the Indus Basin Plan. Their storage capacity has reduced due to sedimentation. There are about 100 small to medium dams on tributaries but their storage capacity is small. Pakistan has presently storage capacity of 10% of annual flows against 40% World average. Construction of Kalabagh Dam is stalled due to non consensus of the provinces. Diamer Basha Dam, having the approval of Council of Common Interest and Political Consensus, is ready for construction since 2008 and is still awaiting the financing arrangement for construction. These are only a couple of mega storage sites on main river Indus. Pakistan must build storage dams not only for food self sufficiency but also for cheap hydropower and flood mitigation.

Pakistan has hydropower potential of 60,000 MW out of which it has exploited only 11%. The share of hydropower has reduced from 60% to 32% of the total power generated. The dependence on the imported fossil fuel (oil) has pushed the power tariff upwards. Pakistan has 18 small to medium hydel stations and only 3 stations greater than 1000 MW. The hydel power produced by Mangla and Tarbela has been the main stay in the economy of Pakistan. After Tarbela, the hydel power addition has been very little. About two dozen run of river hydel projects sites are under various stages of studies and construction. Diamer Basha multipurpose dam would not only produce 4500 MW but would have a cascading effect on all the d/s hydropower projects.

This paper describes the water availability, storage sites and hydropower potential in Pakistan. This also gives the generation capacity and future plans. Pakistan's salvation lies in building multi purpose storage and hydropower projects for self sufficiency in food, mitigation of flood losses and cheap environmentally clean hydropower.

## INTRODUCTION

Water and Energy has an eternal nexus. From the very onset of civilization man has been diverting water from the streams to turn the water mill wheel to grind cereals. There is no life without water and no civilization can flourish without energy. Older civilizations were mostly on banks of rivers and means of communication were boats. We need water not only for drinking, domestic purposes, growing food and fibre (irrigation) but also for industrial uses. Energy is required for processing the products at every stage in addition to the domestic and industrial use. Two thirds of the world area is water and

---

1. Advisor, WAPDA

only one third is land. Nature has created water cycle a renewable resource. Water evaporates from the sea due to heat energy and turns into precipitation which runs down the mountains converting potential energy into kinetic energy. Hydropower is one of the earliest forms of electricity man started using for domestic and industrial purposes.

As water is crucial to all dimensions of sustainable development, there are strong links between water and energy and their related targets. Integrating the different development goals into a coherent structure offers the best hope of delivering maximum sustainable benefits for the greatest number of people. Development goals for poverty reduction food security, energy and others can not be met without reliable water supplies. Economic loss from inadequate delivery of water and sanitation is estimated by WHO to be 1.5% of gross domestic product of the country while the economic loss from inadequate delivery of electricity is estimated to be many times more than this.

Hydel power stations more than 150 years old are still working around the world. Sir Ganga Ram built 1 MW hydel power station on Lower Bari Doab Canal to lift water to irrigate lands at higher elevation.

Pakistan has exploited only 11% of its hydropower potential and is storing only 10% of its annual average flows against 40% of World average. Egypt built high Aswan dam 120 MAF storage and survived seven years of drought. America built Hoover dam in thirties and quickly came out of world recession after World War 1. Brazil built Itaipu dam (14000 MW) and Venezuvela Guri dam 1020 MW in eighties which put these countries on the path of progress. China built Three Gorges Dam in the first decade of this century to store 33 MAF, produce 22500 MW, mitigate flood and better navigation. Pakistan built Mangla dam in sixties and Tarbela dam in seventies which brought the green revolution in Pakistan. All the developed countries have utilized their water resources to produce surplus food and export it which laid the base of industrialization.

Multi purpose (storage and power) mega dams are time and cost intensive. They require several years of planning, data collection and investigations before design and a number of years are required for construction. They require long term government policies. There are settlement issues of the displaced persons which need to be tackled carefully. High upfront costs are quickly paid back by the hydropower projects after which the energy is very cheap and pollution free. During the last decade of the $20^{th}$ century, certain vested interest lobbies had stalled the construction of large dams but world has again recognized that without building dams the progress is not possible and construction of dams has started again. Many large dams are being built in China, Iran, Turkey, Japan and India.

Pakistan has not built any large dam since 1975 after Mangla and Tarbela. Construction of Kalabagh dam has been held up for the last 27 years. Diamer Basha dam is ready for construction since 2008. It needs strong political commitment to construct these mega projects of national interest. Way forward is Pakistan needs to store water and produce food and cheap hydropower for its sustained growth.

## WATER AVAILABILITY IN PAKISTAN

Pakistan has one main basin, Indus Basin, which has the largest contiguous irrigation system. The other two small basins are Kharan and Makran basins both in Baluchistan province. **Figure-1** presents river system and the water basins of Pakistan. Indus basin receives surface water flows on the average 145 Million Acre Feet (MAF) (180 BCM) per annum. The rivers emanating from the World's highest mountains in the north of Pakistan pass through the four provinces and fall into sea in south. Main source of Indus Basin is river Indus and its tributaries which are fed by snow and glacier melt and rainfall. Kharan and Pishin are closed basins in which Pishin-lora, Mashkel, Rakhshan and Baddo streams discharge having a water potential of about 0.79 MAF / annum. Makran is located on the coast line of Baluchistan. Dasht, Shadi, Basal, Hingol, Porali & Hub are its water resources. Their combined annual mean flow is about 3.7 MAF. All its streams flow in a south westerly direction, discharging individually into the Arabian Sea.

Pakistan is located in Arid to semi Arid region. The rainfall in Pakistan is low and irregular with an average annual rainfall of 15 inches (375 mm). More than half of the country receives less than 8 inches (200 mm) of annual rainfall. Rainfall is mostly with Monsoon during the month of July / August. In winter rainfall is scanty with westerly disturbances. The annual evaporation is higher due to semi Arid region. The snow and glacier melt contribution is about 60 MAF / annum.

The population of Pakistan which was 30 millions at the time of independence in 1947 has increased to 180 million and is projected to touch 225 million in year 2025. The water availability per capita has reduced from 5650 cubic meters ($M^3$) in 1951 to about 1000 $M^3$ in 2013. **Figure-2** presents water availability Vs Population. Pakistan is just at the threshold of water scarce country. There is large seasonal and temporal variation in water availability. There are cycles of droughts and floods. Most of the water is received in about 100 days in a year. **Figure-3** presents water availability in upper Indus during the year. During Kharif the flows (80%) are in excess of the capacity to divert them to the land and a part of it goes to sea while in Rabi the flows are only 20%, less than half the requirement. This underscores the importance of storage of water for seasonal carry over. **Table-1** presents water availability for Indus river system.

## WATER REQUIREMENT

Pakistan has total area of 196 Million Acres (MA) out of which 77 MA is suitable for agriculture. Total cultivated area by irrigation as well as barani is 55 MA. There is still 22 MA which can be brought under plough if water is available. **Figure-4** presents land use map in Pakistan.

Pakistan built two large dams Mangla (1967) and Tarbela (1975), consequent to the Indus Water Treaty. Due to sedimentation their live storage capacity has reduced from 16 MAF to 11.26 MAF. Now after raising Mangla dam the storage has become 14.15 MAF. Pakistan did not build any large dam since 1975. Although it has built small dams like Mirani & Sabakzai in Baluchistan, Gomal Zam dam in South Waziristan and Satpara dam in Skardu. These dams provide water for local agriculture use.

Pakistan has one of the lowest water storage about 10% of average annual flows against 40% of world average. The water storage is only 100 days of average flows and about 150 $M^3$ per capita. **Figure-5** presents storage per capita in different semi Arid countries. The canal withdrawals are on decline because of sedimentation. Currently on average 32 MAF of water goes down the last barrage into sea. If conserved this water can meet our requirement. **Figure-6** presents the flows d/s of Kotri the last barrage from 1976 to 2013.

Presently ground water built over centuries is meeting the shortages. Over exploitation of this would create great environmental hazard. According to World Bank's "Country Water Resources Assistance Strategy", 2025, Pakistan's water demands for Agriculture, Municipal uses and Industry in 2010 aggregated to about 120 MAF 148 (BCM). The projected demand of 2025 would be over 140 MAF (173 BCM). **Figure-7** presents projected water demand in Pakistan. The primary source of supplying the demand would be major storages to harness the unregulated flows of the Indus river system.

**GRAIN PRODUCTION**

Before turn of century Pakistan had annual grain production of about 25 million tons (MT) and was able to meet its requirement. However with the increasing population, the current requirement is about 40 MT and would grow to 53 MT by 2025. The current production is 28 MT with consequent shortfall of 12 MT. **Figure-8** presents grain production and requirement. This deficit may increase to 25 MT by 2025 if no storage dam is built.

Due to persistent water stress during critical crop period, the cereal yields in Pakistan are the lowest among the producing countries. The essential agriculture input is the timely and adequate availability of water for meeting the crop needs. Due to depletion of storages the cotton crop sown in early Kharif in Sindh would also be badly effected.

**STORAGE REQUIREMENT**

Existing storages have lost about 5.123 MAF of useable capacity uptill 2013. After raised Mangla, the live storage capacity has increased to 14.15 MAF. The planned storages are Diamer Basha Dam 6.4 MAF, Kalabagh Dam 6.1 MAF, Kurram Tangi 0.7 MAF, Munda dam about 1 MAF and Akhori dam 6 MAF. Both Diamer Basha and Kalabagh Dams are ready for construction. Construction work has been started on Ist Phase of Kurram Tangi. Feasibility of Munda Dam is being revised. Feasibility of Akhori Dam was completed nine years back. One mega dam would only replenish the storage capacity lost. In addition to building at least two mega dams, Pakistan has to build storages wherever possible to meet the growing demand. **Table-2** presents average canal withdrawals and corresponding storage required. **Figure-8** presents projected sedimentation and live storage capacity through 2025.

**ENERGY**

Energy is the most crucial issue in the World. Pakistan is also an energy deficient country and relies on imported fossil fuels. The country is facing electric power crises since a decade. The power shortage has forced hundred of Industries to shut down operations, affecting industrial production and the livelihood of thousand, of families. Due to rising demand, the gap between supply and demand is increasing.

**HYDEL POWER**

Hydel Power supplies about 7,15,000 MW or 19% of World electric power. Some countries have abundance of natural hydropower resources, while others have fossil fuels. Pakistan is endowed with large renewable hydropower energy source.

After resolution of water dispute with India, Indus Water Treaty was signed in 1960. Water & Power Development Authority (WAPDA) was created in 1958 to implement the Indus Basin Plan. According to the Treaty, the three Eastern river Bias, Sutlej and Ravi were given to India and three Western rivers Chenab, Jhelum and Indus were given to Pakistan. Two dams Mangla in 1967 and Tarbela in 1975 were built to store water and transfer via link canals to replace the water of three rivers stopped by India. Although the main objective and priority was irrigation but power houses; 1000 MW on Mangla and 3478 MW on Tarbela were installed. These two power houses have been the main stay of Pakistan's economy. The stored water and released by Mangla for irrigation from 1967 to 2012 is 209.56 MAF and by Tarbela from 1975 to 2013 is 305.06 MAF. This brought green revolution and food self sufficiency in the country. In addition Mangla produced upto year 2013, 204 B KWH of electricity and Tarbela produced upto year 2013, 413.705 B KWH of electricity for domestic and industrial use of Pakistan.

Indus river flows in a narrow gorge, descends from about 3000 m at line of control to less than 300 meters at Kalabagh site before it debouches and widens into the plains. Although there are only a few large storage sites Shyok dam (5 MAF) on river Shyok, Katzara on river Indus (10 Km d/s of Skardu), Diamer Basha Dam (6.4 MAF), Tarbela Dam already built and Kalabagh Dam (6.1 MAF). There are a number of run of the river sites: Tungus, Yulbo, Bunji, Dasu, Pattan and Thakot on main river Indus and many on the tributaries. **Figure-9** presents the Hydropower potential of Indus river basin. Pakistan has hydropower potential of more than 60,000 MW out which only 6900 MW about 11% has been exploited. **Table-3** gives hydropower potential of Pakistan, while **Table-4** gives the hydel stations in operation in Pakistan. **Figure-10** gives hydropower potential of Jhelum river, while **Figure-11** gives hydropower potential of Swat basin.

Montreal Engg. Co. (MONENCO) prepared ranking study of hydropower potential of Northern Areas of Pakistan and prepared feasibility study of the number one ranked, Diamer Basha Dam Project in 1981-84.

**DIAMER BASHA DAM**

The feasibility study of Diamer Basha Dam was revised upgraded and detailed engineering design was produced from 2002 to 2008. It is 272 m high Roller Compacted Concrete (RCC) Dam. The project is ready for implementation. Land is being acquired and site infrastructure offices, residential colonies, rest houses, hospitals and roads are near completion. The moment funds are arranged, the dam construction would be started. In addition to 6.4 MAF of live storage, it has installed capacity of 4500 MW. It would produce more than 18 billion electric unit annually and would have cascading effect on the d / s projects. Due to the regulated flows, Tarbela, Ghazi Barotha and Chashma would produce about 2 billion additional units. Dasu, Pattan and Thakot would also produce additional hydropower. Diamer Basha would entrap more than 80% of the sediment load for about 35 years. This would enhance the life of Tarbela dam by 35 years and similarly for all the d/s projects.

## DASU HYDROPOWER PROJECT

Located on river Indus 70 KM d/s of Diamer Basha is ready for construction. It is 242 m high RCC dam. It has small reservoir of about 1 MAF and installed capacity of 4320 MW. World Bank has assured to finance the Phase-I: Dam and two tunnels with six power units of installed capacity each 360 MW

## GENERATION CAPACITY AND SOURCES

The total installed capacity of Pakistan is about 22,000 MW and that of PEPCO formerly WAPDA is 20,800 MW which is spread over all Pakistan except Karachi which is supplied by KESC . Out of PEPCO total 20,800 MW, Hydel power is 6900 MW which is about 32%, the rest is thermal power from Gas, oil coal and nuclear. Before the turn of the century the hydel power was 50% of the total, now it is less than 32%. Couple of years back, major part of the thermal power was being produced from gas. Due to dwindling of the gas supply, now the stress is on imported oil. Because of the increase in oil prices, the cost of production has gone high and it weighs heavily on the foreign exchange resources. **Table-5** gives generation capacity of Pakistan in 2013 while **Table-6** gives generation sources of Pakistan. **Figure-12** gives the future demand and supply position. **Table-7** gives the planned generation mix. We have to increase the hydel power share by year 2025 from 32% to more than 40% to contain the tariff rise. Due to decreasing supply of gas its share shall go down from 41% to 25%. We have to exploit our indigenous coal deposit and increase its contribution as coal is cheaper than imported oil. Share of nuclear power and alternate resources; Wind and solar would also increase.

**Table-8** gives the storage releases and energy produced by Mangla dam from 1967 to 2013. It has recovered its cost many times since its start. **Table-9** gives the benefits of Tarbela dam. It has released 322.3 MAF of stored water and produced 413.7 Billion units since its starts in 1975. Its total benefits from water and power alone upto 2013 are11.629 B rupees which is 6 times its cost.

## CONCLUSIONS & RECOMMENDATIONS

- Pakistan has 145 MAF of average annual surface flows.
- After river diversions it has still 32 MAF annual flows for future development.
- Pakistan needs to build consensus for storage of water.
- It must store about 20 MAF by building 3 mega storage projects on river Indus.

- ❖ The three mega storage projects would help to produce cheap electricity contain power tariff raise and have cascading effect on d / s projects.

- ❖ Pakistan has 60,000 MW of hydropower potential.

- ❖ In addition to storage projects, it must build run of the river projects as dozens of sites are available for these.

- ❖ Hydropower would be helpful for peaking and meeting daily load variations.

**REFERENCES**

1. MONTREAL, Canada (1984) “Hydroelectric Inventory Ranking and Feasibility Studies for Pakistan”.

2. NEAC, (2004) “Diamer Basha Dam – Feasibility Report”.

3. Diamer Basha Consultants 2008 “Diamer Basha Dam – Design Report”.

4. Izhar ul Haq (2005) “Hydropower potential, Development & Problems in Pakistan PGES Ist National Seminar on Geotech Aspects of Hydropower Projects”.

5. Riaz Nazir Tarar (2011) “Pakistan Need for storages for different uses”, Pakistan Engineering Congress 71$^{st}$ Annual Session Proceedings Vol-71.

6. WAPDA Presentations to various delegates.

7. WAPDA (2013) “Annual Report (2012-2013).

8. World Bank (2005) “Pakistan Country Water Resources Assistance Strategy, Water Economy running Dry.

**Table-1 Surface Water Availability for Indus River System**

| Sr. No. | Source | Post-Tarbela *Availability (MAF) |
|---|---|---|
| **I** | **Western Rivers** | |
| 1. | Indus at Kalabagh | 90.3 |
| 2. | Jhelum at Mangla | 22.8 |
| 3. | Chenab at Marala | 26.5 |
| 4. | Sub-total (1+2+3) | 139.6 |
| 5. | NWFP Diversions Above Kalabagh | 5.0 |
| **6.** | **Total (I)** | **144.6** |
| **II** | **Eastern Rivers Run-off Within Pakistan** | **3.8** |
| **III** | **Total (I+II)** | **148.4** |
| **IV** | **Present Utilization** | **102.0** |
| **V** | **Escapage Below Kotri** | **31.5** |

*Average from 1976-2008

**Table-2 Estimated Average Canal Withdrawals and Corresponding Storage Availability Through 2025**

| Period | Average System Canal Withdrawals / Demands (MAF) | Average Storage Availability (MAF) | Remarks |
|---|---|---|---|
| 1960-67 | 88 | - | Pre-Mangla |
| 1967-71 | 95 | 5.3 | Pre-Chashma |
| 1971-77 | 95 | 6.0 | Pre-Tarbela |
| 1977-82 | 105 | 15.7 | Post-Tarbela |
| 1982-91 | 104 | 14.4 | Pre-Accord |
| 1991-2010 | 100 | 12.5 | Post-Accord |
| 1976-2008 | 102 | 13.4 | Post-Tarbela |
| 2010-2020 | 107 (121) | 13.5 | Post-Raised Mangla |
| 2020-2025 | 117& (125) | 19.0 | Post-Diamer Basha |

**Figures in ( ) depict estimated demand**

## Table-3 Hydropower Potential of Pakistan

# PAKISTAN'S HYDROPOWER POTENTIAL

| Sr. No. | River/ Tributary | Power (MW) |
|---|---|---|
| A | Hydropower Projects above 50 MW | |
| 1 | Indus River | 39558 |
| 2 | Tributaries of Indus in Gilgit-Baltistan | 1698 |
| 3 | Tributaries of Indus in Khyber-Pakhtunkhwa | 4028 |
| | Sub Total (1-3) | 45284 |
| 4 | Jhelum River | 4341 |
| 5 | Kunhar River | 1455 |
| 6 | Neelum River & its Tributaries | 1769 |
| 7 | Poonch River | 462 |
| | Sub Total (4-7) | 8027 |
| 8 | Swat River & its Tributaries | 2297 |
| 9 | Chitral River & its Tributaries | 2285 |
| | Sub Total (8-9) | 4582 |
| | Total A | 57893 |
| B. | Hydropower Projects below 50 MW | |
| 1 | On Tributaries | 1591 |
| 2 | On Canals | 674 |
| | Total B | 2265 |
| | TOTAL (A+B) | 60,158 |

2

**Table-4 HYDEL STATIONS IN OPERATION**

| S# | Project | Storage Capacity (MAF) | Installed Capacity (MW) | Energy Generation (GWh) | Commercial Operation Date |
|---|---|---|---|---|---|
| 1. | Renala | RoR | 1.1 | 3 | 1925 |
| 2. | Rasul | RoR | 22 | 49 | 1952 |
| 3. | Dargai | RoR | 20 | 97 | 1952 |
| 4. | Kurram Garhi | RoR | 4.0 | 14 | 1958 |
| 5. | Chichoki | RoR | 13.2 | 43 | 1959 |
| 6. | Warsak | RoR * | 243 | 1050 | 1960-81 |
| 7. | Shadiwal | RoR | 13.5 | 31 | 1961 |
| 8. | Nandipur | RoR | 13.8 | 50 | 1963 |
| 9. | Mangla | 4.46 | 1000 | 4687 | 1967-94 |
| 10. | Chitral | RoR | 1.0 | 4 | 1975-1982 |
| 11. | Tarbela | 6.78 | 3478 | 14937 | 1977-93 |
| 12. | Chashma | 0.37 | 184 | 987 | 2001 |
| 13. | Ghazi Barotha | RoR | 1450 | 6574 | 2003-04 |
| 14. | Khan Khwar | RoR | 72 | 306 | 2012 |
| 15. | Allai Khwar | RoR | 121 | 463 | 2013 |
| 16. | Jinnah | RoR | 96 | 688 | 2013 |
| 17. | Gomal Zam | 0.89 | 17.4 | 91 | 2013 |
| 18. | Satpara | 0.053 | 17.36 | 105 | 2007-2013 |
| 19. | Jabban Unit No.3 & 4 | RoR | 11 | 10 | 2013 |
| 20. | Duber Khwar | RoR | 130 | 595 | 2013 |
| | **Total** | **10.61** | **6908.36** | **30784** | |

**Table-5 Generation Capacity of Pakistan 2013.**

| Type of Generation | Name Plate / Installed Capacity (MW) | Dependable Capacity (MW) | Availability (MW) | |
|---|---|---|---|---|
| | | | Summer | Winter |
| Hydro | 6928 | 6928 | 6928 | 2300* |
| GENCOs | 4785 | 3536 | 2736 | 3178** |
| IPPs (incl Nuclear) | 9009 | 8300 | 7000 | 7578** |
| **Total:** | **20722** | **18764** | **16664** | **13056** |

**Table-6 Generation Sources of Pakistan 2013**

| **Generation Sources June, 2013** | | |
|---|---|---|
| **1.** | **HYDRO** | |
| • | WAPDA | 6733 |
| • | IPPS | 195 |
| • | Sub Total | 6928 |
| 2. | **THERMAL** | |
| • | Ex-WAPDA GENCOS | 4785 |
| • | IPPS | 8359 |
| • | NUCLEAR | 650 |
| • | Sub-Total | 13794 |
| • | Grand Total: | 20,722 |

**Table-7 Planned Generation mix of Pakistan.**
**(1967-68 to 2012-13)**

| Type of Generation | March, 2013 | | Upto 2019-20 | |
|---|---|---|---|---|
| | **Capacity (MW)** | **%age** | **Capacity (MW)** | **%age** |
| Hydro | 6928 | 32% | 16344 | 40.6% |
| Thermal (Gas) | 8450 (5117*) | 41 (25)% | 9975 | 24.8% |
| Thermal (Oil) | 4528 | 22% | 5116 | 12.7% |
| Thermal (Coal) | 150 | 1% | 2350 | 5.9% |
| Nuclear | 665 | 3% | 2345 | 5.9% |
| Wind / Solar | 0 | 0% | 2000 | 5% |
| Imports | 79 | 0.4% | 2079 | 5.2% |
| **Total:** | **20,800** | | **40,209** | |

**Table 8 Storage releases and Energy produced by Mangla Dam.**

| Year | Storage Releases (MAF) | Total Generation (MKWh) |
|---|---|---|
| 1967-68 to 1999-2000 | 152.34 | 141,633.63 |
| 2000-01 | 4.13 | 2,799.95 |
| 2001-02 | 3.54 | 3,398.89 |
| 2002-03 | 5.57 | 5,363.17 |
| 2003-04 | 5.23 | 5,058.94 |
| 2004-05 | 3.89 | 4,218.53 |
| 2005-06 | 4.97 | 5,442.94 |
| 2006-07 | 4.17 | 6,150.91 |
| 2007-08 | 5.57 | 4,687.33 |
| 2008-09 | 5.51 | 4,797.43 |
| 2009-10 | 5.22 | 4,772.40 |
| 2010-11 | 4.29 | 6,107.63 |
| 2011-12 | 5.13 | 4,799.25 |
| 2012-13 | 4.47 | 4,713.19 |
| **Total:** | **214.03** | **203944.19** |

**Table 9 Benefits of Tarbela dam**

| Year July-June | WATER | | POWER | | Total Benefits (Rs. Million) (3) + (5) | Remarks |
|---|---|---|---|---|---|---|
| | Release (MAF) | Benefits (Rs. Million) | Generation (MKWH) | Benefits (Rs.Million) (31 Rs.0.30/- Per unit) | | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1975-76 | 3.33 | 666.00 | - | - | 666.00 | **NOTE:** Upto FY 1991-92 the benefit of water releases have been worked out at acre foot, from 1992-93 to 1996-97 at the rate of |
| 1976-77 | 9.07 | 1814.00 | 138.30 | 41.49 | 1855.49 | |
| 1977-78 | 10.00 | 2000.00 | 3367.20 | 1010.16 | 3010.16 | |
| 1978-79 | 8.71 | 1742.00 | 3726.00 | 1010.16 | 3010.16 | |
| 1979-80 | 9.91 | 1982.00 | 4123.00 | 1236.90 | 3218.90 | |
| 1980-81 | 10.63 | 2126.00 | 4128.80 | 1236.64 | 3364.64 | |
| 1981-82 | 11.33 | 2266.00 | 4200.50 | 1260.15 | 3526.15 | |
| 1982-83 | 9.12 | 1824.00 | 5228.20 | 1558.46 | 3392.46 | |
| 1983-84 | 9.18 | 1836.00 | 7450.80 | 2235.24 | 4071.24 | |
| 1984-85 | 9.24 | 1848.00 | 7253.94 | 2176.18 | 4024.18 | |
| 1985-86 | 9.76 | 1952.00 | 7993.59 | 2398.08 | 4350.08 | |
| 1986-87 | 9.98 | 1996.00 | 8121.23 | 2436.37 | 4432.37 | |
| 1987-88 | 7.52 | 1504.00 | 9402.64 | 2820.79 | 4324.79 | |
| 1988-89 | 11.12 | 2224.00 | 10378.22 | 3113.47 | 5337.47 | |
| 1989-90 | 7.32 | 1464.00 | 9981.50 | 2994.45 | 4458.45 | |
| 1990-91 | 6.19 | 1238.00 | 11356.00 | 3406.80 | 4644.80 | |
| 1991-92 | 5.93 | 1186.00 | 11765.00 | 3529.50 | 4715.50 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1992-93 | 6.31 | 1893.00 | 13955.00 | 4186.50 | 6079.50 | thereafter from 1996-97 at the rate of Rs.900 per acre foot. |
| 1993-94 | 9.41 | 2823.00 | 12956.26 | 3886.88 | 6709.88 | |
| 1994-95 | 5.39 | 1617.00 | 14765.19 | 4429.56 | 6046.56 | |
| 1995-96 | 8.17 | 2451.00 | 14922.36 | 4476.71 | 6927.71 | |
| 1996-97 | 9.15 | 8235.00 | 14230.17 | 4269.05 | 12504.05 | |
| 1997-98 | 8.66 | 7794.00 | 15084.90 | 4525.47 | 12319.46 | |
| 1998-99 | 9.04 | 8136.00 | 16377.84 | 4913.35 | 13049.35 | |
| 1999-00 | 8.71 | 7837.20 | 14747.64 | 4424.29 | 12261.49 | |
| 2000-01 | 8.69 | 7820.10 | 12811.24 | 3843.37 | 11663.47 | |
| 2001-02 | 8.21 | 7385.40 | 13495.05 | 4048.52 | 11433.92 | |
| 2002-03 | 8.66 | 7797.60 | 14676.69 | 4403.01 | 12200.61 | |
| 2003-04 | 8.36 | 7522.20 | 15119.76 | 4535.93 | 12058.13 | |
| 2004-05 | 8.10 | 7292.70 | 12308.00 | 3692.40 | 10985.10 | |
| 2005-06 | 9.12 | 8207.10 | 15822.97 | 4746.89 | 12953.99 | |
| 2006-07 | 8.50 | 7647.30 | 16131.60 | 4839.48 | 12486.76 | |
| 2007-08 | 7.64 | 6879.60 | 14937.63 | 4481.29 | 11360.89 | |
| 2008-09 | 9.28 | 8350.20 | 13964.97 | 4189.49 | 12539.69 | |
| 2009-10 | 7.80 | 7020.90 | 13902.03 | 4170.61 | 11191.51 | |
| 2010-11 | 7.52 | 6765.30 | 16002.69 | 4800.81 | 11566.11 | |
| 2011-12 | 7.23 | 6508.80 | 14109.12 | 4232.74 | 10741.54 | |
| 2012-13 | 7.99 | 7198.20 | 14769.02 | 4430.71 | 11628.98 | |
| **Total:-** | 322.28 | 166852.6 | 413705.05 | 123991.9 | | |

Figure-1 River System and Water Basin of Pakistan

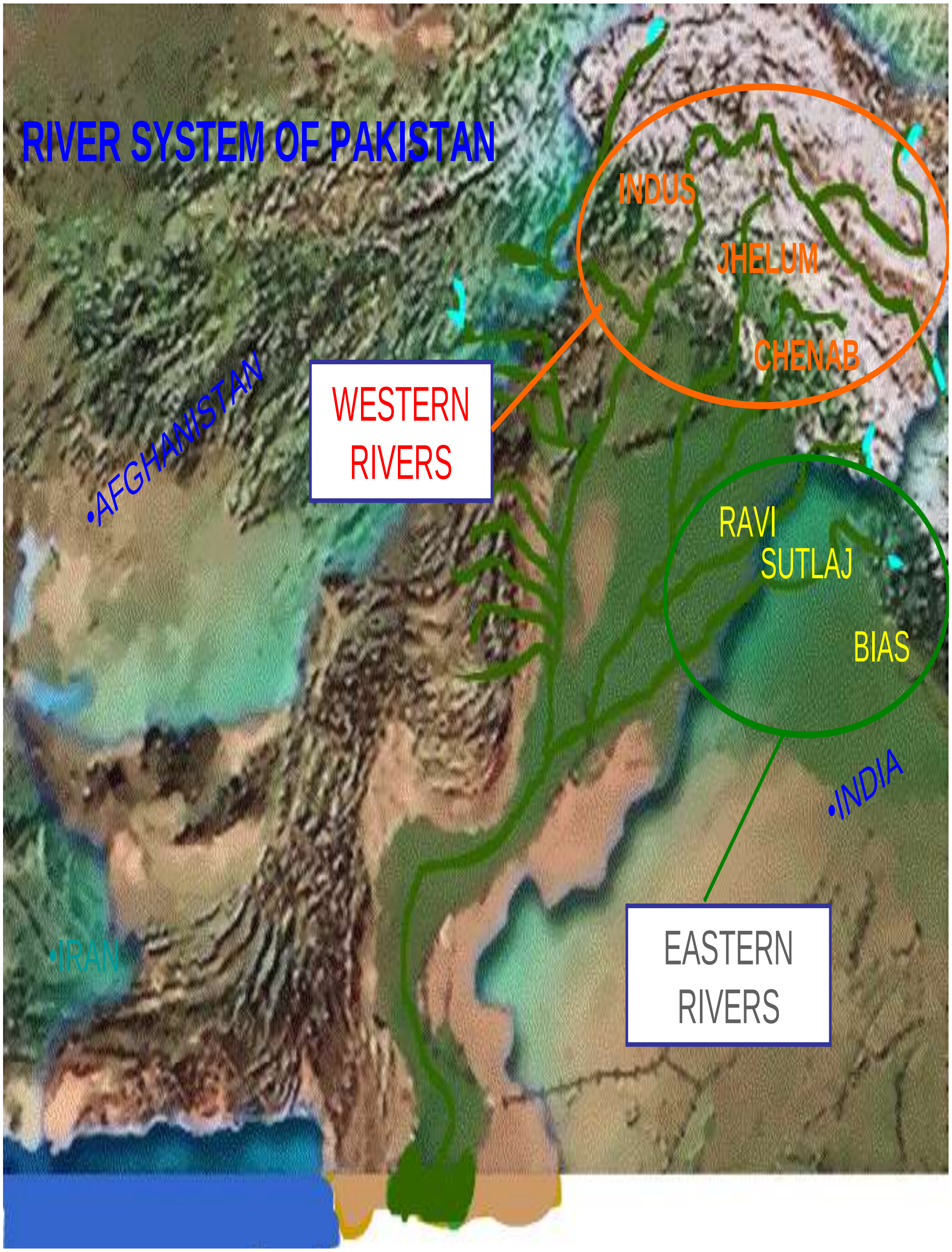
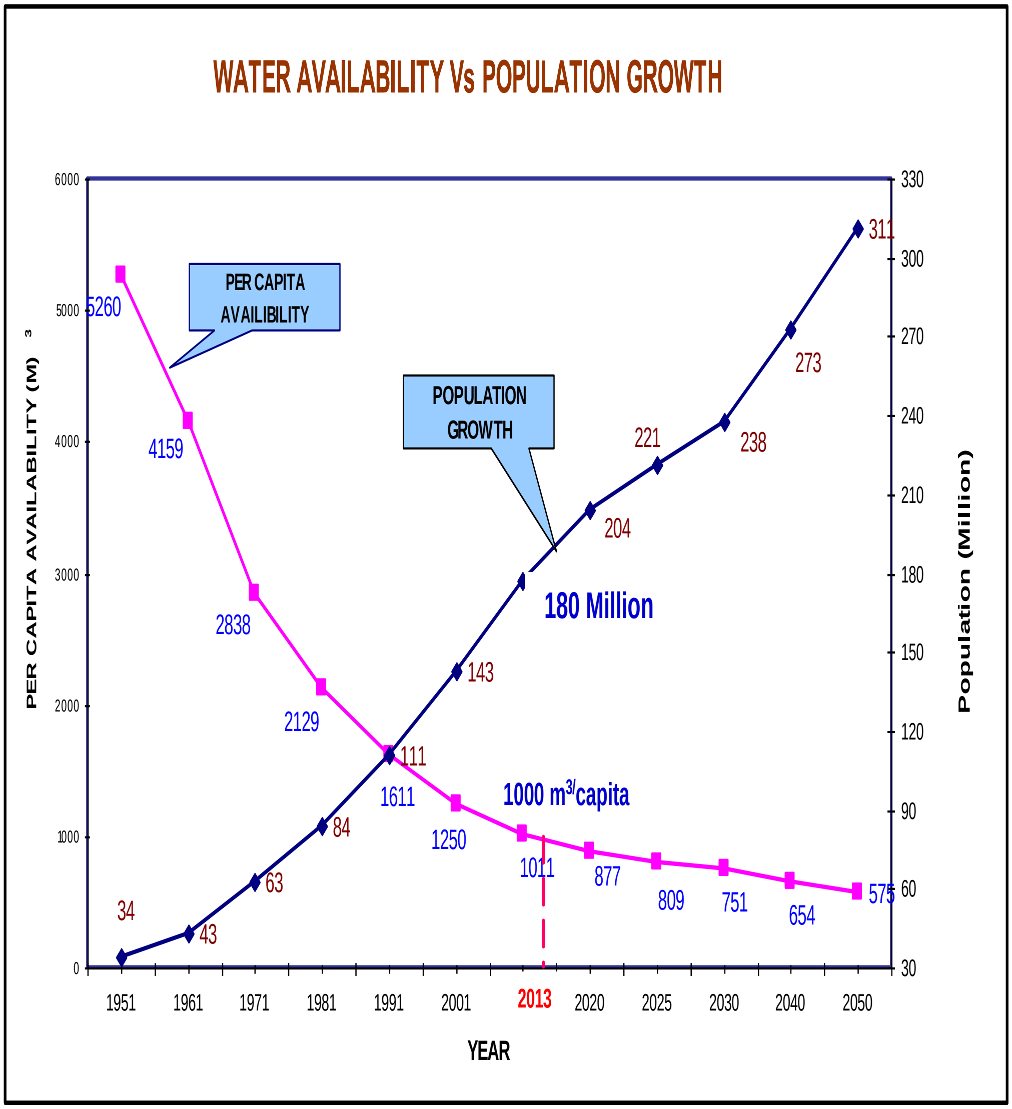


Figure-2

# WATER AVAILABILITY vis-a-vis POPULATION




**Source:**

**Population:** Population Census Organization Pakistan

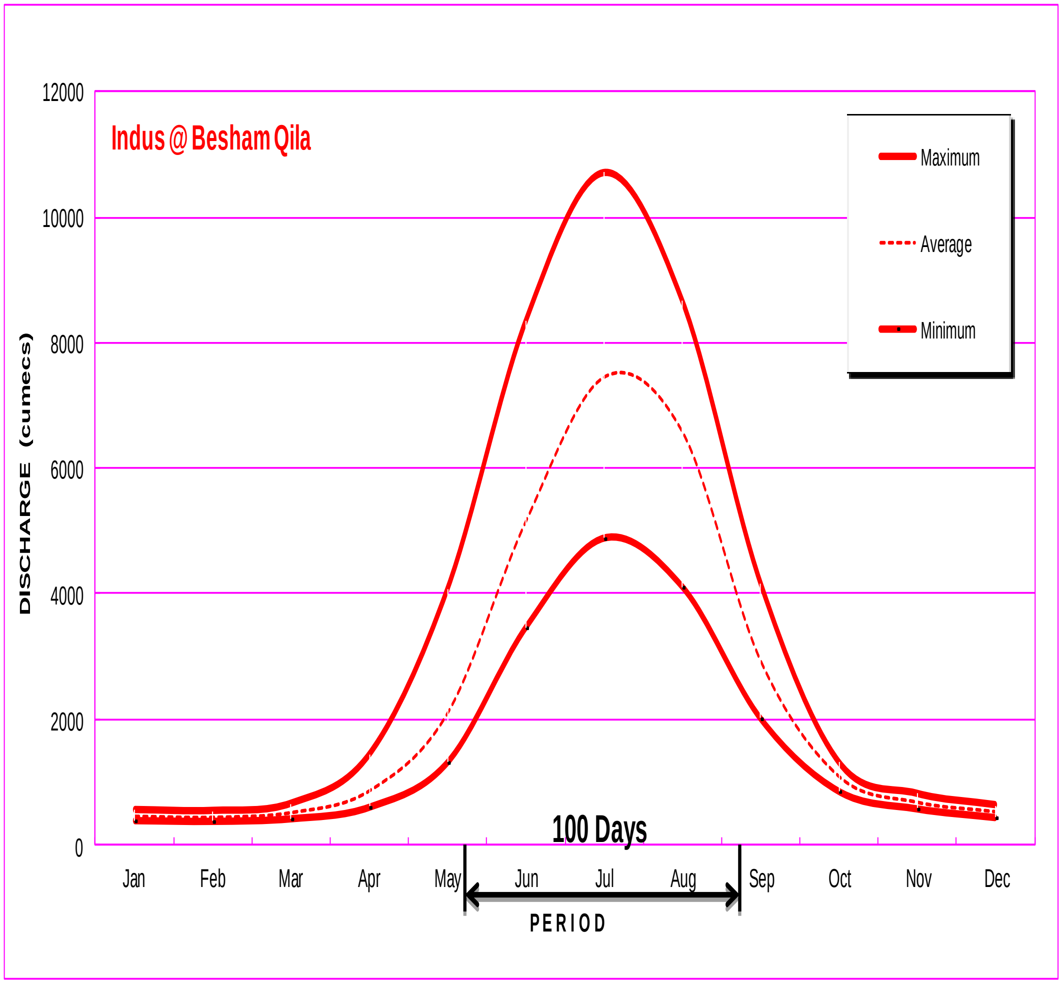
**Water Availability:** 180 BCM

6

Figure-3

# UPPER INDUS BASIN WATER VARIABILITY

## 1961 - 2012

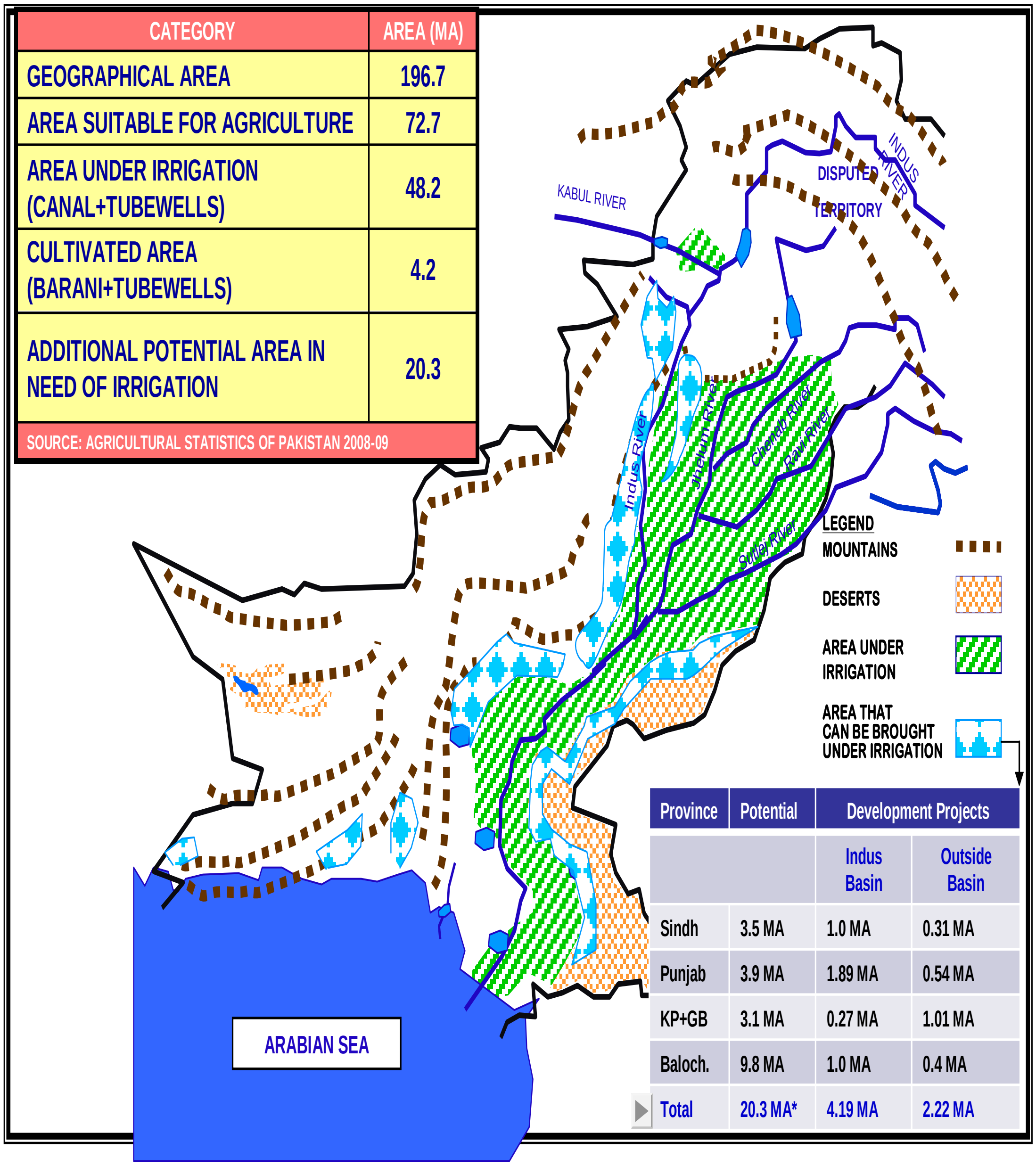



- **Availability – 100 days, 80% of inflow, rest 20% comes in the rest of the year**
- **Variability - Minimum 92 MAF (113.5 BCM) to Maximum 180 MAF (222.1 BCM)**
- **Uncertainty**

Figure-4

# LAND USE IN PAKISTAN

| CATEGORY | AREA (MA) |
|---|---|
| GEOGRAPHICAL AREA | 196.7 |
| AREA SUITABLE FOR AGRICULTURE | 72.7 |
| AREA UNDER IRRIGATION (CANAL+TUBEWELLS) | 48.2 |
| CULTIVATED AREA (BARANI+TUBEWELLS) | 4.2 |
| ADDITIONAL POTENTIAL AREA IN NEED OF IRRIGATION | 20.3 |
| SOURCE: AGRICULTURAL STATISTICS OF PAKISTAN 2008-09 | |




| Province | Potential | Development Projects | |
|---|---|---|---|
| | | Indus Basin | Outside Basin |
| Sindh | 3.5 MA | 1.0 MA | 0.31 MA |
| Punjab | 3.9 MA | 1.89 MA | 0.54 MA |
| KP+GB | 3.1 MA | 0.27 MA | 1.01 MA |
| Baloch. | 9.8 MA | 1.0 MA | 0.4 MA |
| Total | 20.3 MA* | 4.19 MA | 2.22 MA |

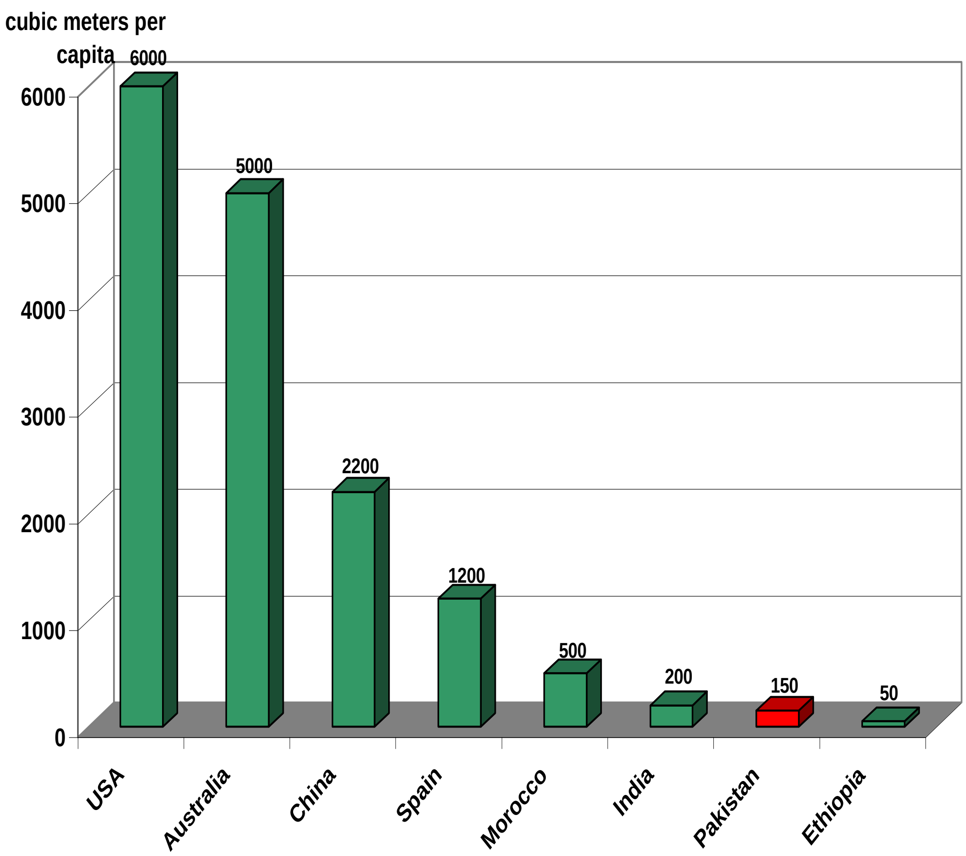
* Remaining 13.9 MA can be irrigated through hill torrents management & flood management channels

50

Figure-5

S-5

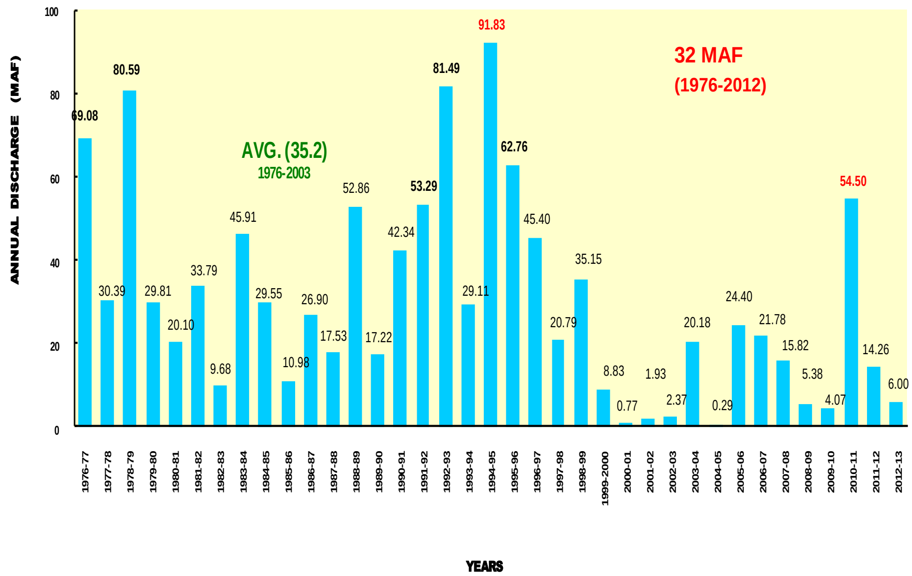
# STORAGE PER CAPITA IN DIFFERENT SEMI-ARID COUNTRIES




*Source: World Bank analysis of ICOLD data*

Figure-6

# ESCAPAGE BELOW KOTRI (MAF) TO SEA

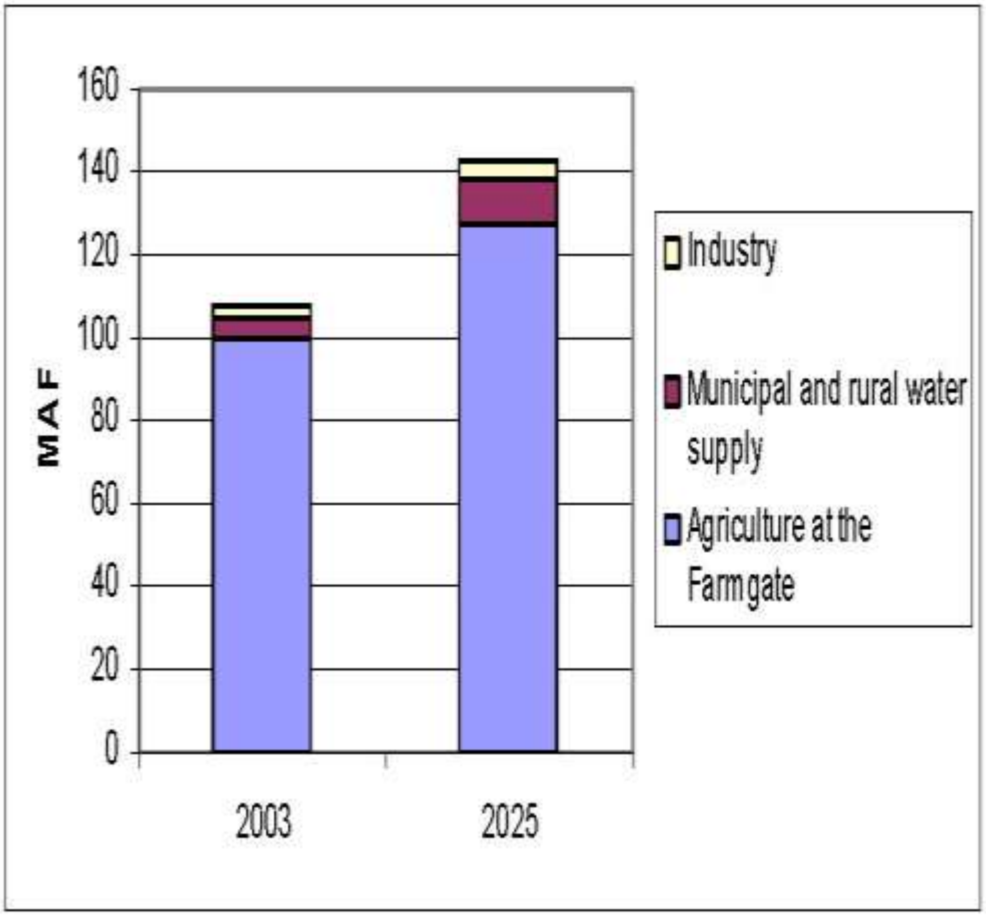



**Source: WRMD WAPDA based on data supplied by Govt. of Sindh**

Figure-7

S-13

# PROJECTED DEMANDS FOR WATER




*Source: Hasan 2005 (World Bank Study)*

Figure-8

S-11

## PAKISTAN
## GRAIN PRODUCTION REQUIREMENT AND PRODUCTION

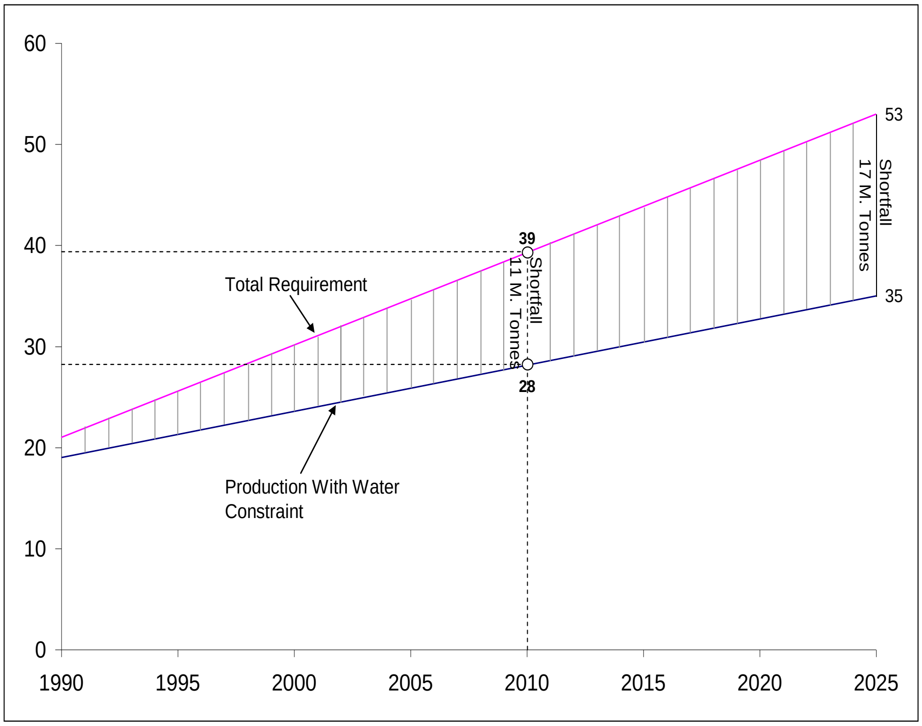


Figure-9

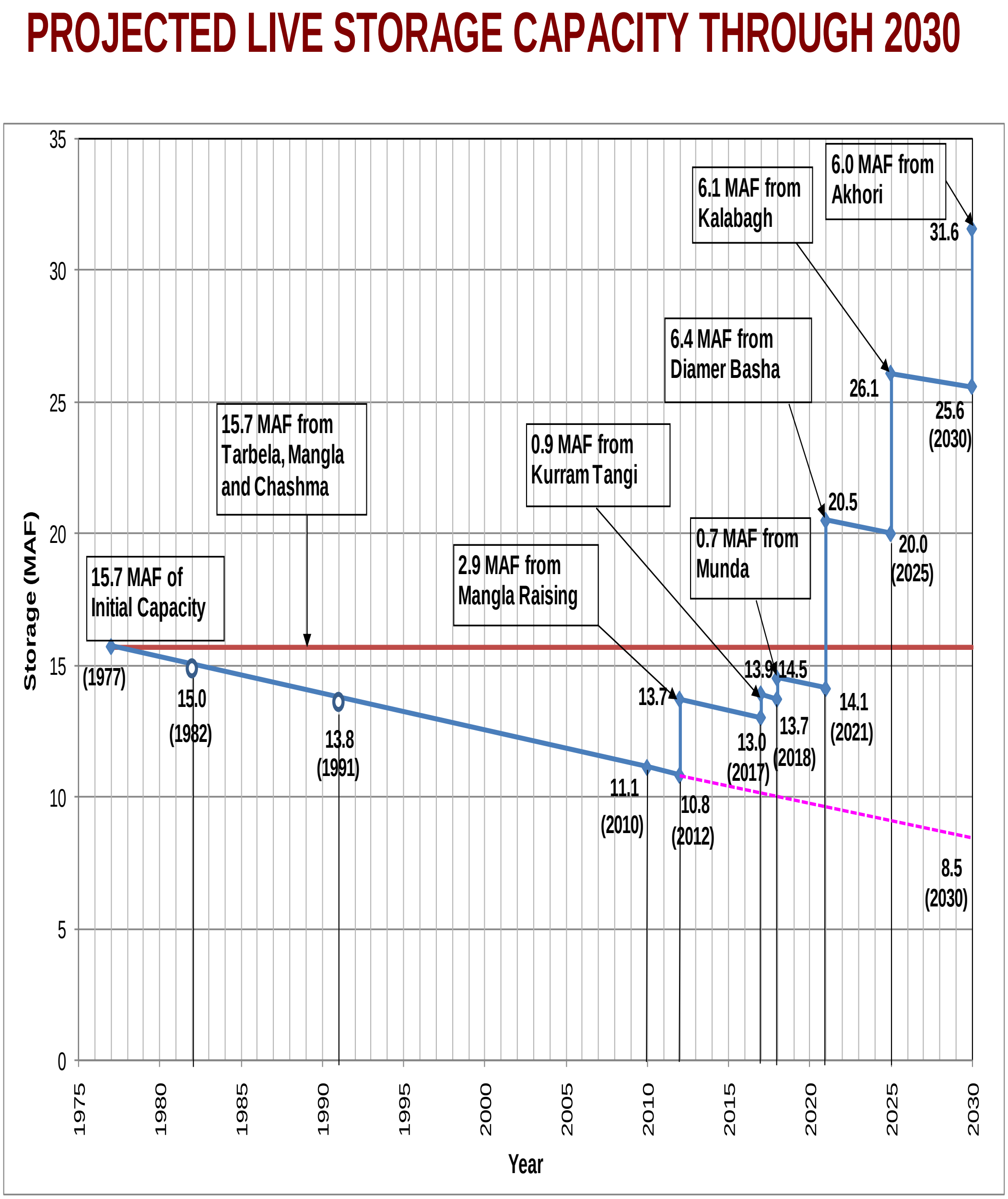
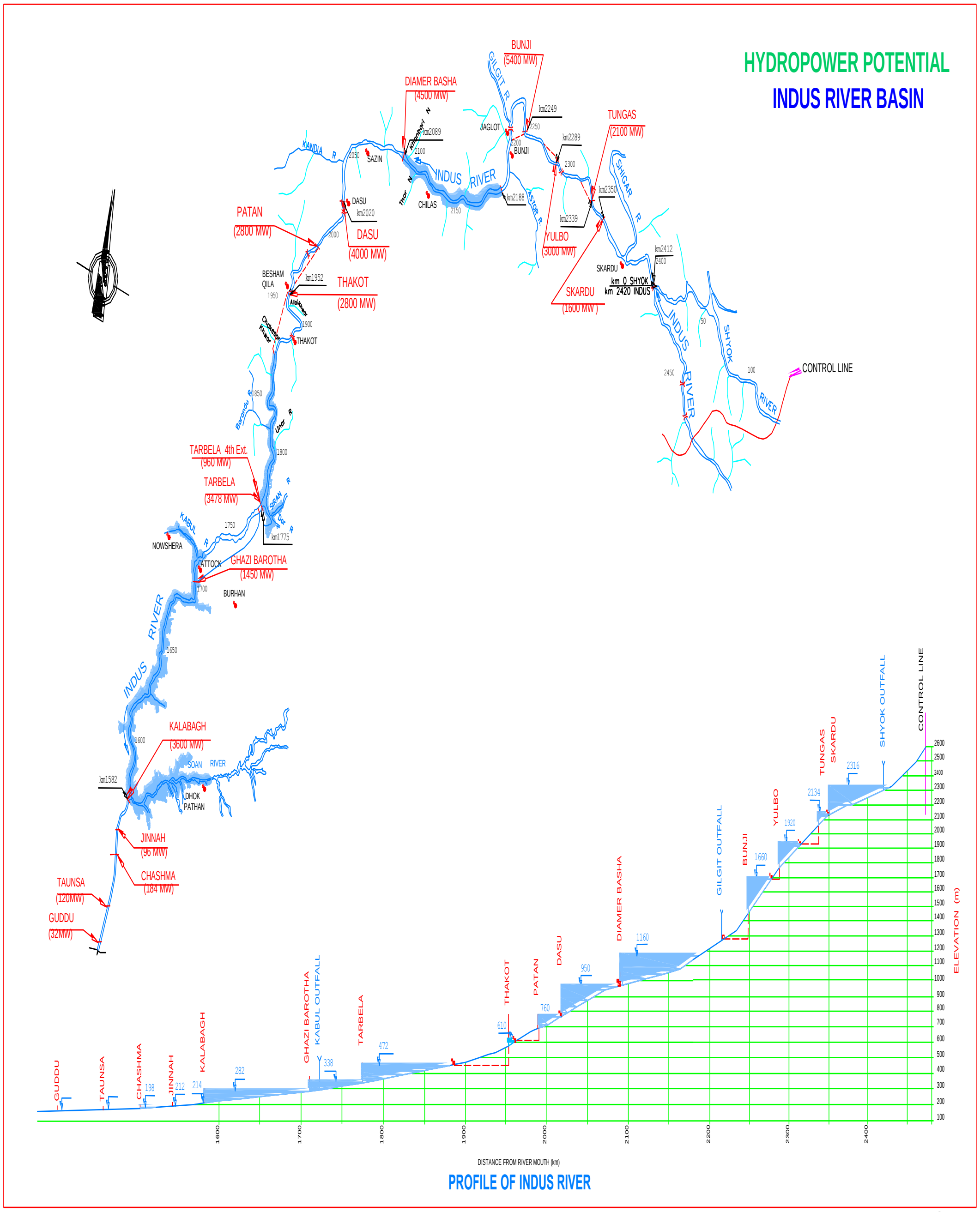

PROJECTED LIVE STORAGE CAPACITY THROUGH 2030
Storage (MAF)
Year
15.7 MAF of Initial Capacity
15.7 MAF from Tarbela, Mangla and Chashma
2.9 MAF from Mangla Raising
0.9 MAF from Kurram Tangi
6.4 MAF from Diamer Basha
0.7 MAF from Munda
6.1 MAF from Kalabagh
6.0 MAF from Akhori
(1977)
15.0 (1982)
13.8 (1991)
11.1 (2010)
10.8 (2012)
13.7
13.0 (2017)
13.9
14.5
13.7 (2018)
14.1 (2021)
20.5
20.0 (2025)
26.1
25.6 (2030)
31.6
8.5 (2030)

Figure-10



HYDROPOWER POTENTIAL
INDUS RIVER BASIN
BUNJI (5400 MW)
DIAMER BASHA (4500 MW)
TUNGAS (2100 MW)
PATAN (2800 MW)
DASU (4000 MW)
THAKOT (2800 MW)
YULBO (3000 MW)
SKARDU (1600 MW)
TARBELA 4th Ext. (960 MW)
TARBELA (3478 MW)
GHAZI BAROTHA (1450 MW)
KALABAGH (3600 MW)
JINNAH (96 MW)
CHASHMA (184 MW)
TAUNSA (120MW)
GUDDU (32MW)
INDUS RIVER
SHYOK RIVER
CONTROL LINE
PROFILE OF INDUS RIVER
DISTANCE FROM RIVER MOUTH (km)
ELEVATION (m)

Figure-11

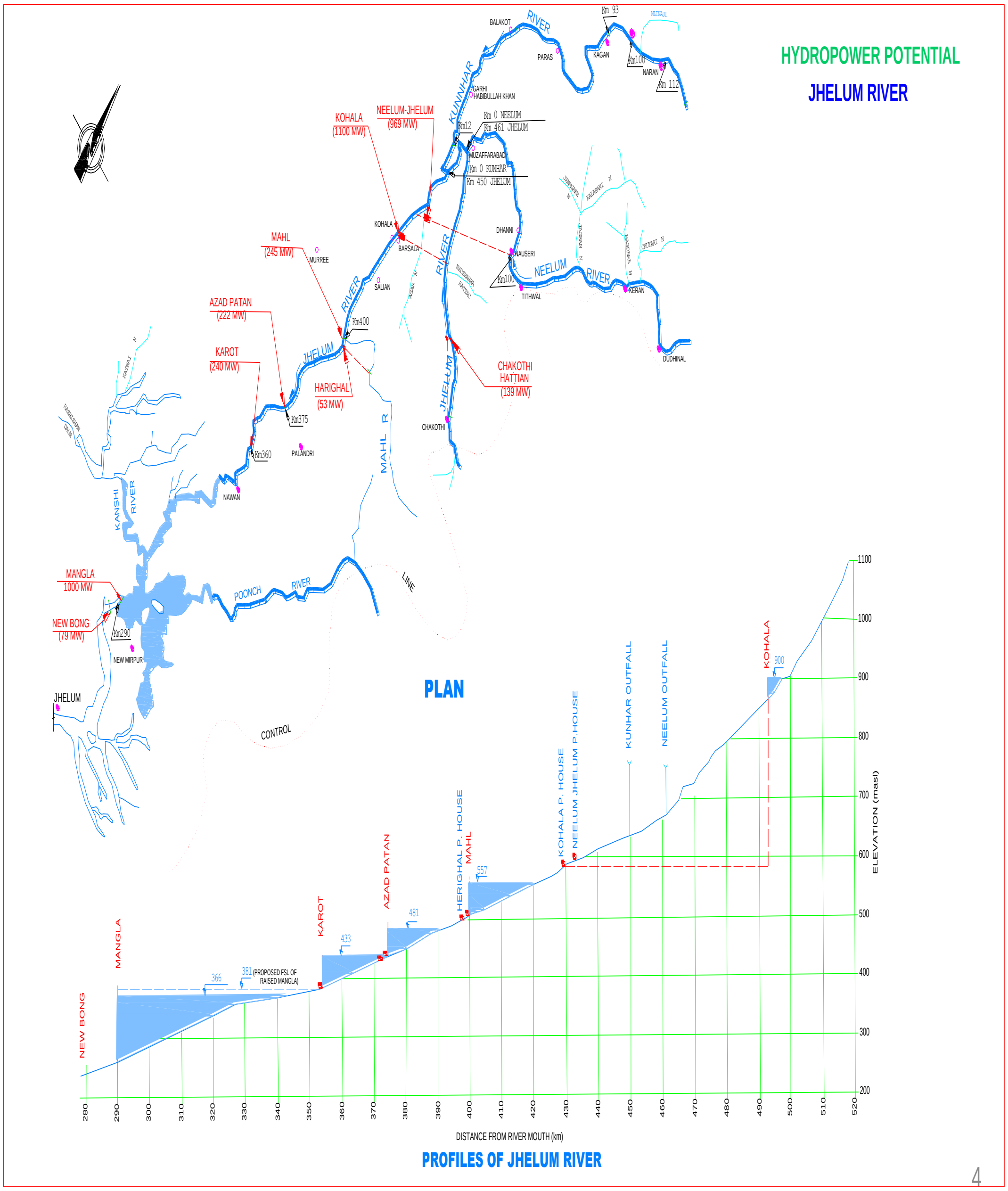

HYDROPOWER POTENTIAL
JHELUM RIVER
PLAN
PROFILES OF JHELUM RIVER
DISTANCE FROM RIVER MOUTH (km)
ELEVATION (masl)
MANGLA
1000 MW
NEW BONG
(79 MW)
KAROT
(240 MW)
AZAD PATAN
(222 MW)
MAHL
(245 MW)
HARIGHAL
(53 MW)
KOHALA
(1100 MW)
NEELUM-JHELUM
(969 MW)
CHAKOTHI
HATTIAN
(139 MW)
KUNHAR OUTFALL
NEELUM OUTFALL
KOHALA P. HOUSE
NEELUM JHELUM P.HOUSE
HERIGHAL P. HOUSE
(PROPOSED FSL OF
RAISED MANGLA)

Figure-12

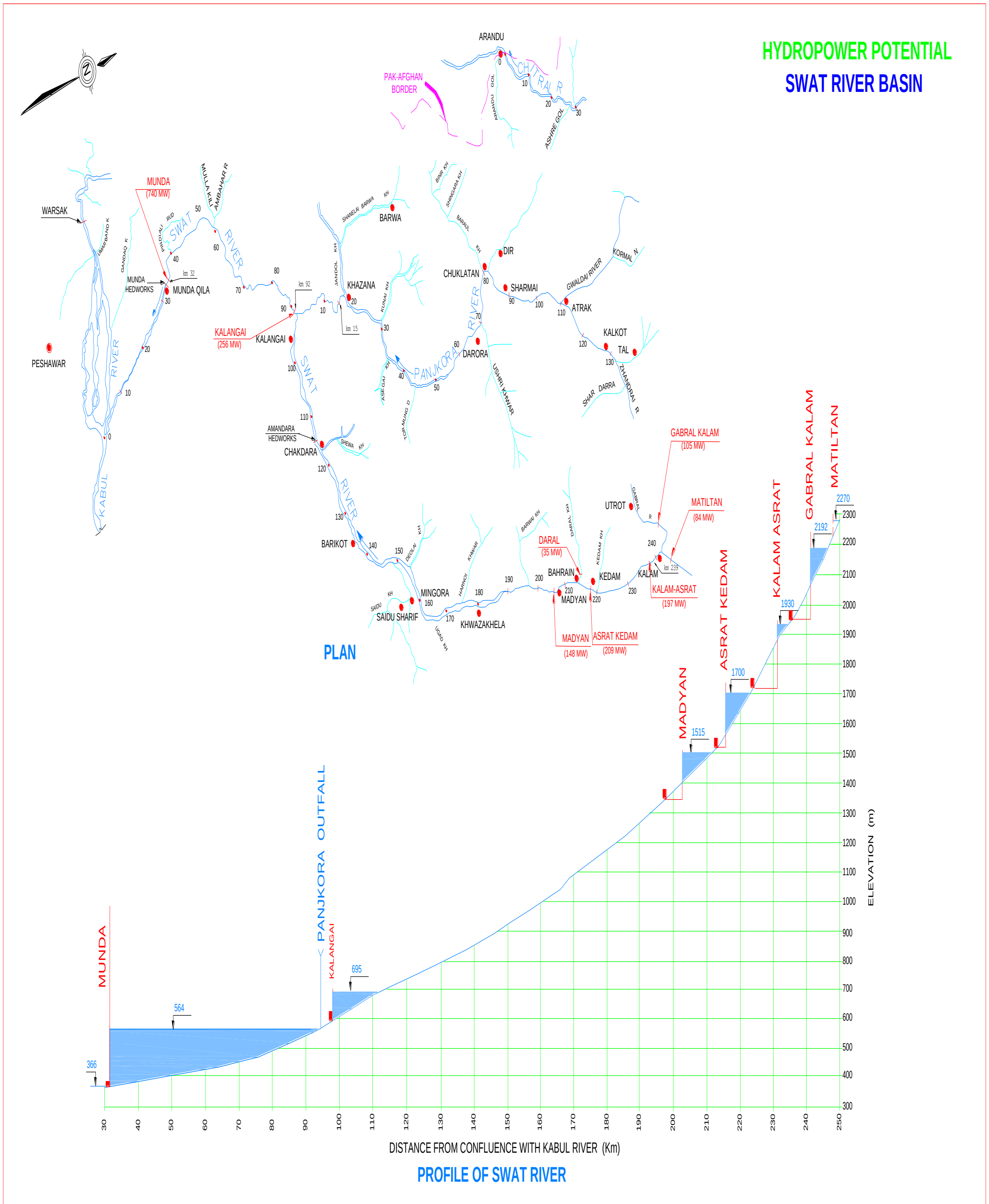

HYDROPOWER POTENTIAL
SWAT RIVER BASIN
PLAN
MUNDA (740 MW)
KALANGAI (256 MW)
GABRAL KALAM (105 MW)
MATILTAN (84 MW)
DARAL (35 MW)
KALAM-ASRAT (197 MW)
MADYAN (148 MW)
ASRAT KEDAM (209 MW)
PAK-AFGHAN BORDER
PESHAWAR
WARSAK
MUNDA QILA
KALANGAI
CHAKDARA
BARIKOT
MINGORA
SAIDU SHARIF
KHWAZAKHELA
BAHRAIN
MADYAN
KEDAM
KALAM
UTROT
DIR
SHARMAI
ATRAK
KALKOT
DARORA
KHAZANA
BARWA
CHUKLATAN
ARANDU
SWAT RIVER
PANJKORA RIVER
KABUL RIVER
PANJKORA OUTFALL
ELEVATION (m)
DISTANCE FROM CONFLUENCE WITH KABUL RIVER (Km)
PROFILE OF SWAT RIVER

Figure-13

# FUTURE DEMAND & SUPPLY POSITION (X-WAPDA DISCOs)

## (Normal plan as on June, 2013)