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WATER RESOURCES MANAGEMENT IN PAKISTAN: THE CHALLENGES, CLIMATE CHANGE IMPLICATIONS AND WAY FORWARD

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By:

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ABSTRACT

The Indus Basin developed into the world's largest integrated canal network and the construction of large storages at Mangla, Tarbela and inter-river link canals are the major milestones in basin management. The Indus Basin Irrigation System (IBIS) in current regime reflects a situation in which the primary resource constraint on agricultural production is water. The system is designed to allocate the scarce resource over a large geographic area on equitable basis and the irrigation water delivery to the farmers is linked to the landholdings. The water demand has however increased tremendously over time due to population growth and agricultural development way beyond the system design. A host of issues facing Indus Basin are inadequate storage capacity, highly seasonal river flows, and increasing shortages during watering of Rabi crops and sowing of Kharif crops, inadequate transfer capacity of link canals, and extremely long lead times from reservoirs to the farmers fields. The use of groundwater tremendously increased facing an increasing danger of depletion and quality deterioration. The conjunctive use of canal and groundwater does not have corresponding planning and management at the command area level.

The Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers. While the science is still in its infancy, best estimates are that there will be fifty year of glacial retreat, during which time river flows will increase. This – especially in combination with the predicted flashier rainfall – is likely to exacerbate the already serious problems of flooding and drainage. But then the glacial reservoir will be empty, and there are likely to be substantial decreases in river flows – conceivably by 30 percent to 40 percent in the Indus Basin in one hundred years time. The emerging impacts of climate changes would add a new dimension to these issues which essentially call for more holistic, proactive, and integrated planning of the resource management.

SUMMARY AND CONCLUSIONS

The paper presents the water management framework in Indus basin system in the historical backdrop, current operational regime and the emerging challenges. It discusses the development of surface water resource base, resolving water sharing disputes and water allocation within the large basin in the context of system constraints and extensive groundwater development. The impending climate changes are perceived to have serious implications on river basin management due to more frequent extremes of floods and water scarcity.

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Irrigation in the Indus Basin has a long history dating back to the Indus civilization. The British rulers converted inundation canals to the regulated perennial and non-perennial canal systems. The main reason for this development included protection against famine, development of new lands for irrigated agriculture and to increase the state revenue. After the Independence of the sub-continent in 1947, dispute over sharing of Indus waters with India was finally resolved with the signing of Indus Waters Treaty in 1960. This was a major milestone in the basin management as major replacement works had to be constructed on three western rivers to feed the canal network off-taking from the eastern rivers which were earmarked for exclusive Indian use. The construction of two large storage dams at Mangla and Tarbela and 8 inter river link canals enabled basin management in more integrated manner, though it also had some negative impacts on water management regime and environment.

Another milestone in the history of Indus basin management was the signing of Water Accord in 1991 which resolved the longstanding dispute among the provinces of Pakistan over Indus water sharing. It provides the framework for water allocation to the provinces and main canal systems apportion water for future development and also defines the basis for sharing water shortages and surpluses among the Provinces.

The Indus basin irrigation system reflects a situation in which the primary resource constraint on agriculture production is water. The system is designed to allocate this scarce resource over a large geographic area on equitable basis and the irrigation water delivery to the farmers is linked to the land holdings. The water demand has however increased tremendously over time due to population growth and agricultural development way beyond the system design. The canals are resultantly providing only 40 to 50% of the crop water requirements and farmers have turned to groundwater for meeting the balance crop water requirements. The progressive groundwater development for conjunctive use signals an extremely important milestone in the context of basin management, as in some freshwater aquifers, groundwater is providing close to 50% of the crop water requirements.

The experience of Indus basin management has brought to fore a host of issues that include extremely long lead times from reservoirs to the farmers fields, inadequate storage capacity, highly seasonal river flows, increasing shortages during maturing of rabi crops and sowing of kharif crops, difficulty in predicting water losses in long dry reaches of rivers, and inadequate transfer capacity of link canals. The entitlements in the contiguous and complex canal irrigation network is another issue because the water right of main canals are established on historic basis which are not in keeping with the current requirements and the water entitlements within the secondary and tertiary canal system are not well-defined. The basin management is also confronted with increasing challenges due to built-up of water demand, particularly during the drought periods.

The Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers. While the science is still in its infancy, best estimates are that there will be fifty year of glacial retreat, during which time river flows will increase. This – especially in combination with the predicted flashier rainfall – is likely to exacerbate the already serious problems of flooding and drainage. But then the glacial reservoir will be empty, and there are likely to be substantial decreases in river flows – conceivably by 30 percent to 40 percent in the Indus Basin in one hundred years time. The emerging impacts of climate changes would add a new dimension to these challenges, which call for adequate knowledge base, strategic planning and proactive management initiatives.

INTRODUCTION

Irrigation in the Indus Basin has a long history dating back to the Indus civilization. The Indus river system comprises the main Indus and its major tributaries, the Kabul on the right bank and the Jhelum, the Chenab, the Ravi, the Beas and the Sutlej on the left bank. The Indus Basin Irrigation System Commands an area of 36.2 million acres and its tributaries on average bring about 152 MAF of water annually. This includes 143 MAF from the three Western Rivers and 8.4 from the Eastern Rivers. Most of the inflow, about 104 MAF, is diverted for irrigation, with 38 MAF flowing to the sea and about 10 MAF consumed by system losses.

The Indus Basin depends heavily on the glaciers of the Western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. Best estimates of glacier retreat are 50 years during which time river flows will increase. This especially in combination with predicted more flashier rainfall is likely to exacerbate already serious problems of flooding and draining, especially in the lower parts of the basin, in the next few decades. But then the glacial reservoirs will be empty, and there are likely to be dramatic decreases in river flows.

The Indus Basin developed into the world's largest integrated canal network and the main reason for this colonial era development included protection against famine, development of new lands for irrigated agriculture and increase in the revenue.

Agriculture is the single largest sector of the country's economy, directly sharing about 25% of the national GDP. Agriculture supports 60% of the population providing self employment to 40% (National Census 1998). Out of 21 million hectares (Mha) of agricultural land, 14.8 Mha is irrigated through its large scale irrigation systems, while 5 Mha is rain fed or flood based, with scattered well irrigation. About 65% of the average river inflows are diverted for agriculture and other uses through 43 main canals. The canal network is supported by two big reservoirs Mangla and Tarbela of 19.2 BCM live storage capacity and 14 inter-river link canals.

The surface water demand has however increased tremendously over time due to population and agriculture sector growth and therefore it contributes to 40% - 50% of the crop water requirement. Industrial and domestic requirements are met mostly from groundwater in the sweet water zone while river supplies are provided for both purposes in the saline groundwater areas. The progressive groundwater development for conjunctive use signals an extremely important milestone in the context of Indus Basin management, as in some fresh water aquifers, groundwater is providing close to 50% of the crop water requirements.

Pakistan has very little water storage capacity relative to other arid countries as United States and Australia have over 5000 cubic meters of storage capacity per inhabitant, and China has 2200 cubic meters and Pakistan has only 150 cubic meters storage capacity per capita. The dams of the Colorado and Murray-Darling rivers can hold 900 days of river runoff. South Africa can store 500 days in its Orange river, and India between 120 and 220 days in its major peninsular rivers. By contrast, Pakistan can barely store 30 days of water in the Indus Basin.

The Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers. While the science is still in its infancy, best estimates are that there will be fifty year of glacial retreat, during which time river flows will increase. This – especially in combination with the predicted flashier rainfall – is likely to exacerbate the already serious problems of flooding and drainage. But then the glacial reservoir will be empty, and there are likely to be substantial decreases in river flows – conceivably by 30 percent to 40 percent in the Indus Basin in one hundred years time. The emerging impacts of climate changes would add a new dimension to these

challenges, which call for adequate knowledge base, strategic planning and proactive management initiatives. Salient features of Indus Basin Irrigation System are given in Box-1:

BOX-1: Salient Features of Pakistan's Irrigation System

Total Area	:	197 Million Acres
Cultivated Area	:	51 Million Acres
Irrigated Area	:	34.5 Million Acres
Average Annual Surface Flow	:	144 MAF
Average Annual Canal Withdrawals	:	103 MAF
Average Annual Groundwater Pump-age	:	42 MAF
No. of Tubewells	:	1.0 Million
Total Length of Canals	:	58,500 Km
Average Depth of Water at Farm Gate	:	3.07 Feet per Acre
Reservoir Capacity (at the time of construction)	:	15.7 MAF
Reservoir Capacity (existing)	:	11.5 MAF
Length of Surface Drains	:	15100 Km
Length of Embankments	:	5000 Km

HISTORICAL PERSPECTIVE OF WATER SECTOR DEVELOPMENT

The Indus Basin Irrigation System comprises 3 major reservoirs, 16 barrages and two headworks, 12 inter river link canals (all in Punjab), and 44 canal systems (Figure-1). The Indus Basin Irrigation System commands an area of 16.68 Mha, is the largest contiguous irrigation system of the World.

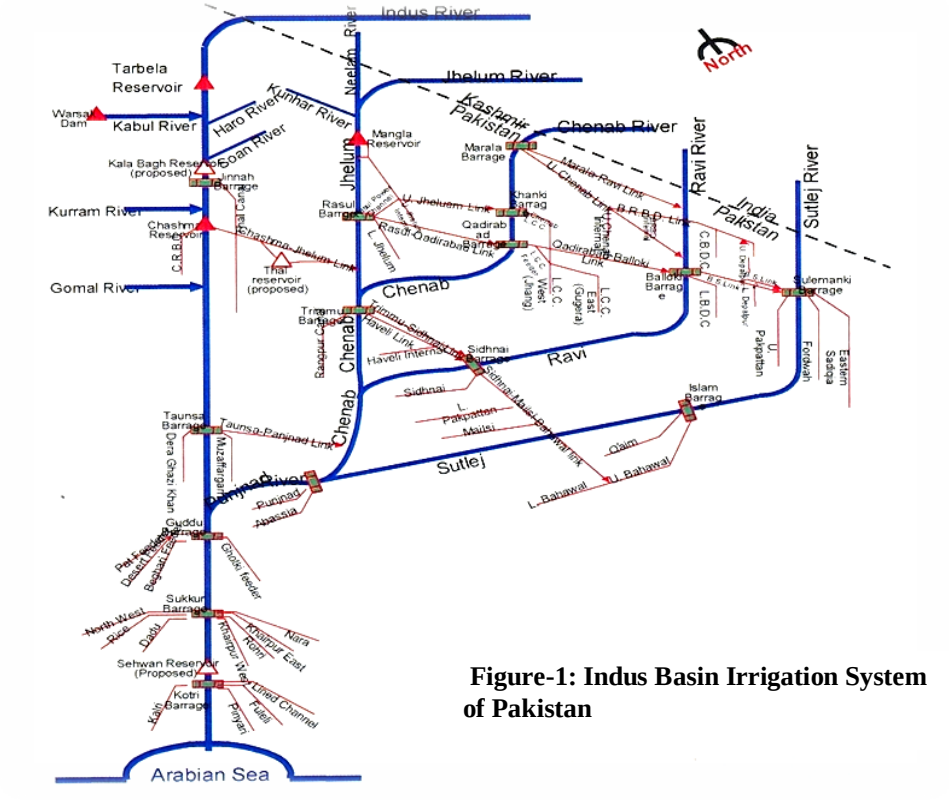


Figure-1: Indus Basin Irrigation System of Pakistan

Indus Basin Treaty 1960 and Accord 1991 are two major milestones accomplished. According to the Indus Water Treaty of 1960 signed between Pakistan and India under the World Bank auspices, the flow of 3 main western rivers are available to Pakistan, the Indus, Jhelum, and Chenab, while India has exclusive rights to waters of the eastern rivers Ravi, Beas, and Sutlej.

The Water Management Framework was based on the following considerations (Box-2) during 1947 to 1990:

BOX-2: Indus Basin Water Management Framework

- ✓ The primary resource constraint on agriculture is assured and timely supply of water.
- ✓ System design based on water allocation to a larger geographic area on equitable basis.
- ✓ Water allocation to the farmer is linked to the culturable land.
- ✓ After the construction of reservoirs Rabi water use is increased and some water allocated to non perennial channels.
- ✓ Historic water rights of the main canals are protected and adhoc water sharing arrangement was based on these 10 daily water allocations.
- ✓ Excess and shortages to be shared proportionate to the design allocations.

Link canal systems were constructed as a sequel to the signing of the Indus basin from the eastern rivers. The construction of Indus Basin works necessitated water management in an integrated manner requiring greater control on canal water regulation and enhanced water utilization in the basin.

Water Apportionment Accord 1991 supersedes all previous sharing arrangements and protects the existing uses of canal water in each province. It apportions the balance river supplies including flood surpluses and future storages among the Provinces and recognizes the need for constructing new storages where ever feasible on the Indus and other tributaries for planned future agricultural development. It also recognizes the need for certain minimum escapage to sea below Kotri to check sea intrusion and lays down the procedure for sharing shortages and surpluses wherein the record of actual average system uses for the period 1977-82 would form a guideline for future regulation pattern (Siddiqui, 2001).

THE ISSUES AND CHALLENGES

The sustainable management of a huge, inter-linked and very complex natural resource base is probably the single most challenging long-term task for Pakistan. Some of the challenges which were identified in World Bank Report June 2005 titled “Pakistan Water Economy Running Dry” are given in Box-3.

Box-3: Major Challenges of Water Sector Management

- Growing water shortages
- Progressive deterioration of irrigation infrastructure
- Lack of transparency and inequities in water distribution
- Degradation of the resource base
- Over-exploitation of groundwater
- Gaps in governance and trust
- Low water productivity
- Inadequate knowledge base

Pakistan water sector multi-facet challenges are as under;

i) **Water stress –** Pakistan is already one of the most water-stressed countries in the world, a situation which is going to degrade into outright water scarcity due to high population growth.

ii) **Very little additional water –** There is no feasible intervention which would enable Pakistan to mobilize appreciably more water than it now uses.

iii) **A high risk water environment –** Pakistan's dependence on a single river system means it has little of the robustness that most countries enjoy by virtue of having a multiplicity of river basins and diversity of water resources.

iv) **Large-scale degradation of the resource base –** There is abundant evidence of wide-scale degradation of the natural resource base on which the people of Pakistan depend. Salinity remains a major problem, with some aspects partially controlled but others – including the fate of the approximately 15 million tons of salt which are accumulating in the Indus Basin every year and the ingress of saline water into over-pumped freshwater aquifers–remains only dimly understood threats.

v) **Groundwater is now being overexploited in many areas, and its quality is deteriorating –** Over the past forty years, the exploitation of groundwater, mostly by private farmers, has brought enormous economic and environmental benefits. Groundwater now accounts for almost half of all irrigation requirements. Now, although, there is clear evidence that groundwater is being over-exploited, yet tens of thousands of additional wells are being put Into service every year, which is jeopardizing the sustainability of this precious resource.

vi) **Flooding and drainage problems are going to get worse –** The drainage problems are encountered due to flat topography and construction of roads and other infrastructure across the natural drainage lines. Similarly, the risk of flooding is increasing due to accretion of river beds, encroachments in the river flood plains and incidence of unprecedented floods as happened in case of flood 2010.

vii) **Climate change-** The Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers. While the science is still in its infancy, best estimates are that there will be fifty year of glacial retreat, during which time river flows will increase. This – especially in combination with the predicted flashier rainfall – is

likely to exacerbate the already serious problems of flooding and drainage. But then the glacial reservoir will be empty, and there are likely to be substantial decreases in river flows – conceivably by 30 percent to 40 percent in the Indus Basin in one hundred years time.

viii) **An inadequate knowledge base –** The Indus Basin is a single, massive, highly complex interconnected ecosystem, upon which man has left a huge footprint. The past twenty years should have been ones of massive investment in knowledge about this ecosystem. But the reverse has happened, and even the once-renowned Pakistan water planning capability has fallen into disarray.

ix) **Much of the water infrastructure is in poor repair –** Pakistan is extraordinary dependent on its water infrastructure, and it has invested in it massively. Due to a combination of age and what has aptly been called the "Build/Neglect/Rebuild" philosophy of public works, much of the infrastructure is in bad shape. This is true even for some of the major barrages, which serve millions of hectares and where failure would be catastrophic.

x) **The quality of project implementation is inadequate –** Pakistan is justifiably proud of its outstanding achievements in building the Indus Basin Replacement Works. In the intervening years, the quality of project implementation has declined substantially. Today, implementation of water sector projects in Pakistan is characterized by inefficiencies, completion delays, and time and cost overruns.

xi) **The system is not financially sustainable -** The current water rates are highly inadequate and these finance only 20 to 25% of the O&M cost of the irrigation infrastructure. This is one of the reasons for the declining health of the irrigation network.

xii) **Pakistan has to invest, and invest soon, in costly and contentious new large dams –** When river flow is variable, then storage is required so that the supply of water can more closely match water demands. Relative to other arid countries, Pakistan has very little water storage capacity that whereas the United States and Australia have over 5000 cubic meters of storage capacity per inhabitant, and China has 2200 cubic meters, Pakistan has only 150 cubic meters of storage capacity per capita. As a result of this constraint, the water availability during the crucial Rabi maturing and Kharif sowing seriously hampers the system capacity to meet the irrigation requirements which translates into lower yields.

xiii) **Poor governance and low trust –** Conceptually the simplest task for water managers in the Indus Basin is to move water in a predictable, timely manner to those who need it and have a right to it. Pakistan has among the best water engineers in the world. And yet this task is done less and less satisfactorily. As a result, deficit of trust prevails among the managers and the farmers.

xiv) **Water productivity is low –** Large parts of Pakistan have good soils, abundant sunshine, and excellent farmers. And yet crop yields, both per hectare and per cubic meter of water, are much lower than international benchmarks, and much lower even than in neighboring areas of India. The quality of water service plays an important role in this: yields from reliable, self-provided groundwater are twice those of unreliable and inflexible canal supplies.

Future Projections for Water Demand

There is a gap of crop water requirement and the water availability from canal irrigation networks due to system design (Haq, 1998; Haq and Khan 2002). The introduction of

contiguous canal irrigation networks and inter-river link canals caused the problem of water-logging and salinity at a colossal scale. This scenario of drainage problem coupled with water demand in Upper Indus System changed due to over-exploitation of fresh groundwater through private tubewells. Limited and unreliable canal supplies have prompted the mushroom private tubewells growth in the canal irrigated area. A decrease in the groundwater recharge and the unreliability of rainfall has promoted their installation in rain fed areas. About 35% of the command areas have saline groundwater especially in the Lower Indus Basin, with limited use of groundwater. Water-logging continues to be a major threat in those areas.

Pakistan is one of the most water stressed countries in the world, a situation which is going to degrade into outright water scarcity due to high population growth (Table-1). Pakistan's dependence on a single river system means it has little of the robustness which most countries enjoy by virtue of having a multiplicity of river basins and diversity of water resources. There is no feasible intervention which would enable Pakistan to mobilize appreciable more water that it now uses.

Table-1: Future Water Requirements

Sr #	Description	Year 2000	Year 2025	Additional Water Requirement (MAF)
A.	**Population (Million)**	131.51	208.66	
		Existing Uses (MAF)	**Requirement (MAF)**	
B.	**Non-Agricultural Sector**			
	Water Supply and Sanitation	4.5	10.5	6.0
	Industry	2.2	3.5	1.3
	Environmental Protection	1.3	1.7	0.4
	Total	8.0	15.7	7.7
C	**Agriculture Sector Requirement**			
	At Canal Heads	105.0	142.0	37.0
D	Total (B+C)	113.0	157.7	44.7
				Source: GOP, 2004

Resource Base and Water Uses

Agriculture is the largest sector contributing directly 25% to GDP and generating over 70% of total foreign exchange earnings of Pakistan. About 95% of Indus Basin water is used for agriculture. At the same time, deprivation from access to water is a major barrier in the livelihood and an obstacle to poverty alleviation. To over come the food and fiber shortage for the growing population more land has been brought under cultivation. The land resources of Pakistan are given in Table-2.

Table-2: Land Resources of Pakistan

Province	Gross Command Area Mha	Culturable Command Area Mha
Punjab	9.96	8.52
Sindh	5.74	4.86
NWFP	0.59	0.45
Balochistan	0.40	0.33
Total:	**16.69**	**14.16**
		Source: GOP, 2008

The surface water through canal irrigation network provides almost 50% of crop water requirement. The surface water resources of Pakistan are given in Table-3:

Table-3: Indus Basin Surface Water Resources

(BCM)

Western Rivers			Eastern Rivers			Indus Basin		
Kharif	**Rabi**	**Annual**	**Kharif**	**Rabi**	**Annual**	**Kharif**	**Rabi**	**Annual**
142.87	28.88	171.75	15.29	3.18	18.47	158.16	32.07	190.23
								Source: GOP, 2010

The surface water resource availability in the Indus Basin has declined due to reduction in Eastern river flows which are now 1.33 BCM as compared to18.47 on the basis of long term average 1937 – 2010 and now on annual basis the surface water resources are 173 BCM.

Sustainable groundwater use requires the extraction from the aquifer on a long term basis which is less than an equal to the recharge of the groundwater reservoir. Groundwater Budget for the Indus Basin is given in Table-4.

Table-4: Groundwater Budget of the Indus Basin

Parameter	Volume (BCM)
Recharge Component	
Recharge from Rainfall	13.53
Recharge from Irrigation System	51.80
Return flow from Groundwater	10.00
Recharge from River	3.70
Total	**79.03**
Discharge Component	
Groundwater extraction	51.80
Non-beneficial evaporation	5.35
Groundwater outflow	4.06
Groundwater mining	1.84
Non-beneficial ET losses	16.02
Total	**79.07**
	Source: GOP, 2010

Groundwater Management

The extent and quality of groundwater is dispersed in Pakistan and the main source of recharge to groundwater is canal irrigation system and therefore it becomes a contentious issue among the provinces in establishing water rights when surface and groundwater are combined. The water entitlement of groundwater cannot be established in the absence of groundwater regulatory framework. The groundwater use depends on the potential of user to abstract groundwater i.e. investment on groundwater abstraction and viz-a-viz the type of tubewell and the quality of groundwater. Groundwater is not only used by the farmers but there are urban and rural domestic and industrial users and their entitlements have to be defined aswell. In the absence of sufficient data of monitoring groundwater abstraction, tubewell ownership, capacity and utilization factor, it is difficult to impose groundwater entitlements.

In an integrated system, the surface water supply cannot be isolated from the net availability of different water resources and the demand pattern of different water users. The actual requirements of agriculture, the variability of surface inflows and the storage have influenced the operational concepts and targets which are now different from and perhaps even in conflict with design allocations in terms of volume and timings. During periods of water stress difficulty in setting the supply targets becomes obvious as IRSA could not agree and implement water distribution without administrative interference (Ministerial Committee in 1994 and Presidential Orders in 2001-02) – (Habib, 2004).

River Flow Trends

The Indus Basin depends heavily on the glaciers of the western Himalayas snow and rain, holding the water and releasing it into the rivers which feed the plain. The climatic change is affecting these western glaciers, and the findings of IPCC indicate that in the coming years, there will be high glacial melting and deicing of mountain caps. In the beginning there will be 20

to 40% increase in Indus flows and after 50 years, there will be glacial retreat and flows will drop down to 30 to 40%. The available river flow data of Indus Basin System from 1937 to 2006 shows that maximum annual flows were 226 BCM in 1950-51 and minimum flows were 99.40 BCM in 2001-02. The western and eastern river flows in BCM are depicted in Figure-2 and average river flows in BCM are shown in Table-5.

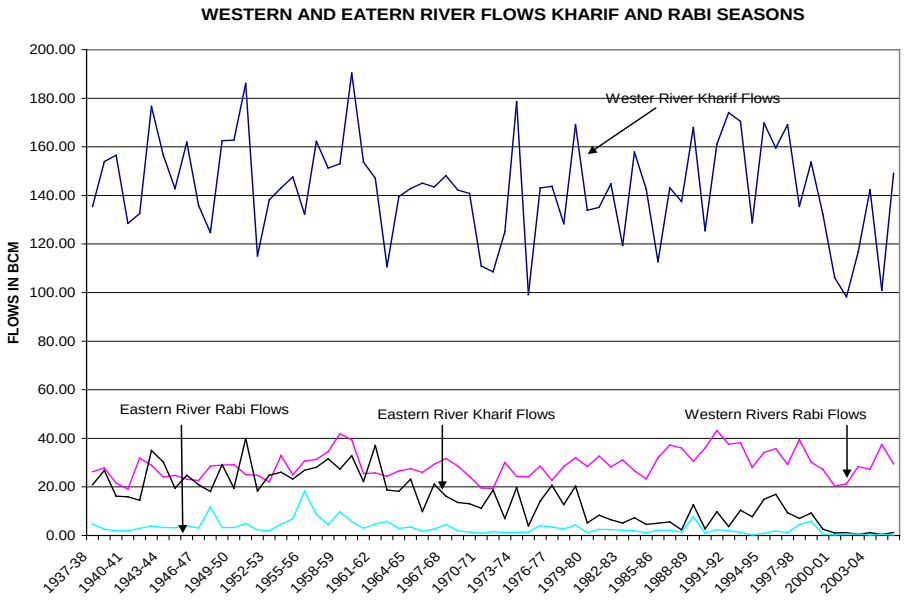


Figure-2: Western and Eastern River Flows during Kharif and Rabi Season

Table-5: River Flows (BCM) at Rim Stations in Pakistan

Period	Western Rivers			Eastern Rivers			Total Indus Basin		
	Kharif	Rabi	Annual	Kharif	Rabi	Annual	Kharif	Rabi	Annual
Pre Independence 1937-47	148.08	25.03	173.11	22.48	3.16	25.64	170.55	28.19	198.74
Pre Treaty 1947-60	151.47	30.34	181.81	26.60	6.62	33.22	178.08	36.96	215.05
Pre Mangla 1960-67	140.33	26.42	166.75	21.49	3.47	24.96	161.80	29.89	191.69
Pre Tarbela 1967-75	131.68	25.25	156.94	12.93	1.78	14.71	144.61	27.03	171.64
Post Tarbela Wet Period 1975-2000	146.35	31.88	178.23	8.99	2.45	11.44	155.35	34.33	189.67
Dry period + 25% Storage Loss 2000-2006	118.94	27.36	146.29	0.94	0.40	1.33	119.87	27.75	147.62
Total Post-Tarbela 1975-2006	141.05	31.00	172.05	7.43	2.05	9.48	148.48	33.05	181.53
Long-Term Average 1937-06	142.87	28.88	171.75	15.29	3.18	18.47	158.16	32.07	190.23
Source: WAPDA, 1960-2006									

The canal water availability was ensured with the development of canal irrigation network and construction of Mangla, Chashma and Tarbela reservoirs. During the pre-independence period

the Kharif canal uses were 54.76 BCM and Rabi period were 22.82 BCM. After the independence of Pakistan and pre Mangla period (1960-67), the average canal uses during Kharif were 70.44 BCM and during Rabi were 31.90 BCM. After the commissioning of reservoirs, the canal flows increased to 79.45 BCM in Kharif and 44.41 BCM in Rabi season. However, with the onset of drought and gradual storage loss of reservoirs by 25% during the period from the year 2000 to 2006, there was 1.25 BCM drop in Kharif canal flows whereas Rabi canal flows dropped to 31.78 BCM touching a level of pre Mangla period. The canal withdrawal statistics in BCM of Indus Basin System and the baseline water entitlements for Indus Basin System are indicated in Figure-3 and Table-5.

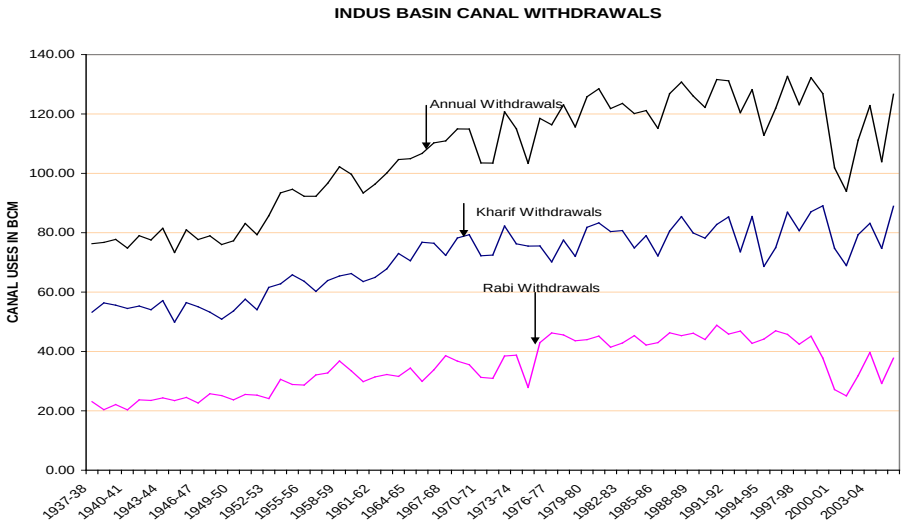


Figure-3: Indus Basin Canal Withdrawals below Rim Station

Table-5: Canal Withdrawals below Rim Stations in Pakistan Indus Basin

Period	Kharif	Rabi	Annual
Pre-Independence 1937-47	54.76	22.81	77.57
Pre-Treaty 1947-60	59.92	28.67	88.59
Pre-Mangla 1960-67	70.45	31.89	102.34
Pre-Tarbela 1967-75	76.08	34.78	110.86
Post-Tarbela Wet Period 1975-2000	79.44	44.42	123.86
Dry period + 25% Storage Loss 2000-2006	78.29	31.78	110.07
Total Post Tarbela 1975-2006	79.22	41.97	121.19
Long Term Average 1937-06	70.78	34.83	105.62
Average System Uses 1977-82	79.30	43.75	123.05
Water Accord Allocation 1991	91.86	43.55	135.41
IRSA Existing Arrangement	82.55	44.75	127.29
Source: GOP, 2010			

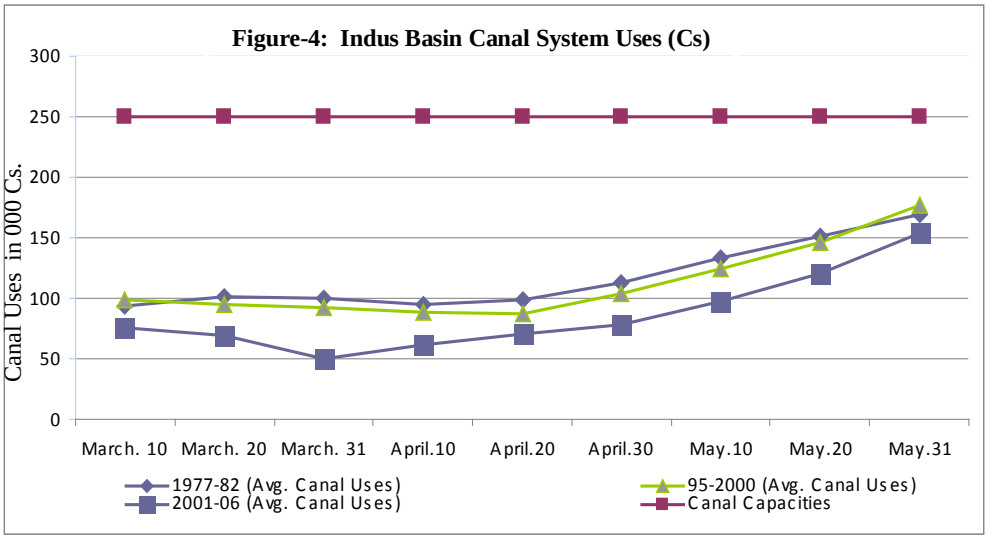
LINK CANALS AND WATER MANAGEMENT

The function of Indus Basin link canals is to transfer water between two rivers by connecting their respective barrages and to carry water from the Indus, Jhelum and Chenab rivers to feed the main canal systems. Link canals as conveyance channels are the most critical regulatory devices in the Indus Basin. Main Canal indents and crop water requirements usually determine the link canals transferring water from Jhelum and Chenab to Ravi and Sutlej and from the Indus river towards the Punjab are given in Table-6.

Table-6: Average lead time from Tarbela and Mangla reservoirs to the main canal headworks and respective farm fields

Average Lead Time From Tarbela Reservoir to Headworks and Farm Fields		
Location	**Lead Time From Tarbela to Canal H/W (Days)**	**Lead Time from Tarbela to Farm field (Days)**
Kalabagh	**2**	**3-5**
Taunsa	**4**	**5-7**
Panjnad	**6**	**7-9**
Sukkur	**9**	**10-12**
Kotri	**14**	**15-18**
Average Lead Time from Mangla Reservoir to Headworks and Farm Fields		
Location	**Lead Time From Mangla to Canal H/W (Days)**	**Lead Time from Mangla to Farm field (Days)**
Rasul	**1**	**2-4**
Qadirabad	**2**	**3-5**
Balloki	**4**	**5-7**
Suleimanki	**5**	**6-9**
Source: GOP, 2010		

In the context of transfer of water to critical headworks locations for Balloki Headworks, Sidhnai Barrage and Punjab Headworks, during early Kharif period, water storage is exhausted in the Mangla and Tarbela reservoirs, the western rivers flow transfer capacity through link channels is less than the off-taking channel capacity at these headworks. The available canal supplies during March – May (1995-2000) with respect to canal capacities and average system uses were quite low, and the same were extremely low during the same period in 2001-06 (Figure-4) which has major impact on Kharif crop sowing (cotton).



Water Entitlements

The operation of an irrigation system is as important as its design and is one of the most challenging management exercise. The irrigation channels are designed to be operated at or near full supply capacity. Operational flows significantly below the design capacity leads inequities in distribution of water. In water scarce environment, when channels are closed and rotations instituted, pronounced inequities have been observed to exist among channels with respect to the relative length of time of channel closure. The main problem area in the secondary canals has been suboptimal operational planning and its ineffective monitoring.

The Water Accord 1991 establishes water sharing among the provinces and the share of main canal systems on the basis of historic water rights and there are different water entitlements stages depending on the season, flood supplies, future development of storages and the actual water availability. There are well established rules for distributing water to each distributary and their outlets. At the watercourse, warabandi establishes each farmer's right to his turn to take whatever water is flowing in the delivery channel. However, there is no fixed entitlement of water for the Province, Irrigation Canal Systems or water entitlement for the farmer. There is no ownership concept or entitlement of water to the farmer. The delivery of water is fluctuating to the canal system depending upon the surface water availability in the rivers and storage dams and the farmers do get fluctuating supplies of water. The supply of water to the canal system and the farmers by default is linked to the land holding. There is no mechanism to ensure and arrange delivery of water to the farmers on demand and in terms of volume which will form the basis of entitlement or ownership of surface water delivered through canal system.

The existing Indus Basin System has strong links with the past in water and land ownership concepts, planning as well as management operations. The water allocations to the main canals irrigated areas have a wide range, from 0.19 to 1.17 l/s/ha (2.47 to 17 cusecs per 1000 acres) for a period of six months during the summer (non-perennial systems) or for the full year (perennial irrigation). These allocations were made between 1882 and 1971 during the design of different canal systems (RAP 1979, Bhatti and Kijine 1990, Kuper 1997). Water allocations vary within the secondary canals, which are influenced by many factors like water demand, groundwater quality, political objectives, level of technology (SCARP Tubewells) and proximity to the river area and rainfall. The time based schedule of water distribution at watercourse level among the farmers exists since the development of canal irrigation networks. The system has been found practicable and appropriate to ensure equitable distribution of scarce resources.

Some drawbacks have been identified in the systems which include progressively increasing water losses along the watercourse not accounted for in the warabandi schedule.

CLIMATE CHANGE

Climate change threatens all countries, with developing countries the most vulnerable. Estimates are that they would bear some 75 to 80 percent of the costs of damages caused by the changing climate. Even 2°C warming above preindustrial temperatures—the minimum the world is likely to experience—could result in permanent reductions in GDP of 4 to 5 percent for South Asia. Most developing countries lack sufficient financial and technical capacities to manage increasing climate risk. They also depend more directly on climate-sensitive natural resources for income and well-being. And most are in tropical and subtropical regions already subject to highly variable climate.

Climate change is posing a potential threat to the economics of developing countries. Global warming and the associated changes in precipitation, extreme weather events, glacier melt, floods and droughts, are causing considerable impacts on water resources management and development of developing countries like Pakistan. Global warming is having a severe impact on the amount of snow and ice, which has serious implications for downstream water availability in both short and long term.

Global warming and the associated changes in precipitation, unexpected and extreme weather events, glacier melt and sea level rise, among others, are causing considerable impacts, direct and indirect, on various socioeconomic and environmental sectors such as water, agriculture, health, biodiversity / ecosystems and land resources, and are increasingly threatening already stressed livelihoods, thus hindering the development process.

Extreme events have increased in temperate and tropical Asia, including floods, droughts, forest fires, and tropical cyclones. On the other hand, decreases in agricultural productivity and aquaculture due to thermal and water stress, sea-level rise, floods and droughts, and tropical cyclones would diminish food security in many countries of arid, tropical, and temperate Asia. Runoff and water availability may decrease in arid and semi-arid Asia while human health would be threatened by possible increased exposure to vector-borne infectious diseases and heat stress. Sea-level rise and an increase in the intensity of tropical cyclones would displace tens of millions of people in low-lying coastal areas of temperate and tropical Asia. Increased intensity of rainfall would increase flood risks.

Climate change would increase energy demand, decrease tourism's attraction, and adversely affect transportation in some regions of Asia. It would also exacerbate threats to biodiversity due to land-use and land-cover changes and population pressure. Pole ward movement of the southern boundary of the permafrost zones of Asia would result in a change of thermokarst and thermal erosion with negative impacts on social infrastructure and industries.

Besides being highly vulnerable, the adaptive capacity of human systems is low in the developing countries of Asia particularly (IPCC, 2007). This is due to high levels of poverty, fragile natural resource based economies, and low resilience to changing conditions.

Climate Change - The Perspective

Climate change impacts the hydrologic landscape and influences the water supply and demand scenario. Most climate scientists agree that global warming will result in an intensification, acceleration or enhancement of the global hydrologic cycle, and there is some observational evidence that this is already happening. In many places, Climate-related events have become more frequent and more extreme. In developing countries extreme floods can result in many deaths, while in developed countries they can result in billions of dollars in damages. More intense droughts in the past decade, affecting an increasing number of people, have been

linked to higher temperatures and decreased precipitation but are also frequently a consequence of the mismanagement of resources and the neglect of risk management.

Changes in flow and inputs of chemical and biological waste from human activity have altered the water quality and ecological functioning of many of the world's rivers. Global warming is expected to have substantial effects on energy flows and matter recycling through its impact on water temperature, resulting in algal blooms, increases in toxic cyanobacteria bloom and reductions in biodiversity. In areas of increasing water stress groundwater is an important buffer resource, capable of responding to increased water demands or of compensating for the declining availability of surface water. Dealing with risk and uncertainty has long been a routine challenge for water resources managers and policy-makers across sectors and the world. However, issues like climate change and demographic dynamics have made the risks greater and the task more complex. Risk management is now much more important – indeed essential – for analysis and decision-making.

Current water management practices may not be robust enough to cope with the impacts of climate change on water supply reliability, flood risk, health, agriculture, energy and aquatic ecosystems. In many locations, water management cannot satisfactorily cope even with current climate variability, so that large flood and drought damages occur. As a first step, improved incorporation of information about current climate variability into water-related management would assist adaptation to longer-term climate change impacts. Climatic and non-climatic factors, such as growth of population and damage potential, would exacerbate problems in the future. (*very high confidence*) Source: IPCC 2008.

Climate change. There is evidence that the global climate is changing and that some of the change is human-induced. The main impacts of climate change on humans and the environment occur through water. Climate change is a fundamental driver of changes in water resources and an additional stressor through its effects on external drivers. Policies and practices for mitigating climate change or adapting to it can have impacts on water resources, and the way we manage water can affect the climate.

Public policy, so far dominated by mitigation, could benefit from a better balance between mitigation and adaptation. Carbon is a measure of the anthropogenic causes of climate change – water is a measure of its impacts. The international community also has to balance investing for tomorrow's likely problems of greater climate variability and global warming against investing for today's problems of climate variability to prevent losses from droughts and floods.

While both are vital, focusing on today's problems can also create greater resilience for dealing with the problems of tomorrow. glacier meltwater, the general conclusion is that global trends are not present or cannot be detected at this stage, although climate change-related trends are evident in some regions. Groundwater resources have been heavily used for human supply and agriculture for many years. While many groundwater abstraction schemes access fossil water (water unrelated to current conditions), renewable groundwater resources depend on highly variable recharge volumes.

It is thus realistic to expect future recharge regimes to reflect changes in the driving hydrologic processes (such as precipitation and evapotranspiration) that might result from anticipated climate changes. It is increasingly clear that the assumption of statistical stationarity is no longer a defensible basis for water planning. Among the consequences of a changing hydrologic cycle is its interaction with the terrestrial carbon cycle. The terrestrial biosphere may have taken up roughly 25% of anthropogenic carbon emissions during the last century; it is unclear how long this can continue.

Climate Change in the Global Water Cycle

Most climate scientists agree that global warming will result in an intensification, acceleration or enhancement of the global hydrologic cycle, and there is some observational evidence that this is already happening. While trends in precipitation have been noted in some parts of the world, in other areas precipitation patterns have remained about the same within the period of observed data. Changes have been observed in snow cover extent and snow water equivalent and in the frequency with which precipitation falls as snow. More than 15% of the world's population live where water resources availability depends heavily on snowmelt from ephemeral snowpacks or perennial glaciers. Despite the evidence of temperature changes, there is little evidence of detectable changes in evaporation and evapotranspiration.

Climate change is being superimposed on an already complex hydrologic landscape, making its signal difficult to isolate, and yet making its influence felt throughout the water supply, demand and buffering system. Data limitations in record length, continuity and spatial coverage contribute to the uncertainty, while natural climate variability and multiyear variability associated with large-scale atmospheric circulation patterns influence the interpretation of many trends in ways that are not yet fully understood.

Despite the limitations of global datasets, many studies have shown changes in runoff and stream flow. Many have focused on low (drought) or high (flood) extremes, except in regions extremely affected.

Evolving Hazards and Emerging Opportunities

Water-related hazards can be naturally occurring or anthropogenic. Hazards can result from too much water (floods, erosion, landslides and so on) or too little (droughts and loss of wetlands or habitat) and from the effects of chemical and biological pollution on water quality and in-stream ecosystems. The natural variability of water resources and changes, whatever the cause, can provide opportunities for management strategies to respond to potential climate change threats by implementing more resource-sustainable policies and practices.

In many places climate-related water events have become more frequent and more extreme. In developing countries extreme floods can result in many deaths, while in developed countries they can result in billions of dollars in damages. More intense droughts in the past decade, affecting an increasing number of people, have been linked to higher temperatures and decreased precipitation but are also frequently a consequence of the mismanagement of resources and the neglect of risk management. The increased exposure to potential climate change hazards has led to more awareness of water resources management.

Changes in flow and inputs of chemical and biological waste from human activity have altered the water quality and ecological functioning of many of the world's rivers. Global warming is expected to have substantial effects on energy flows and matter recycling through its impact on water temperature, resulting in algal blooms, increases in toxic cyanobacteria bloom and reductions in biodiversity. In areas of increasing water stress groundwater is an important buffer resource, capable of responding to increased water demands or of compensating for the declining availability of surface water.

Leaders in the water sector – in water supply and sanitation, hydropower, irrigation and flood control – have long been aware that water is essential to sustainable development, but they do not make the decisions on development objectives and the allocation of human and financial resources to meet them. These decisions are made or influenced by leaders in government, the private sector and civil society, who must learn to recognize water's role in obtaining their objectives.

Water is essential for achieving sustainable development and the Millennium Development Goals. Properly managing water resources is an essential component of growth, social and economic development, poverty reduction and equity, and sustainable environmental services – all essential for achieving the Millennium Development Goals. Water is linked to the crises of climate change, energy and food supplies and prices, and troubled financial markets. Unless their links with water are addressed and water crises around the world are resolved, these other crises may intensify and local water crises may worsen, converging into a global water crisis and leading to political instability.

Effective policy and legal frameworks are necessary to develop, carry out and enforce the rules and regulations that govern water use and protect the resource. Water policy operates within a context of local, national, regional and global policy and legal frameworks that must all support sound water management goals. Legitimate, transparent and participatory processes can effectively mobilize input for designing and implementing water resources policy and create a strong deterrent to corruption.

Although water is often described as a 'gift of nature', harnessing and managing it for the wide variety of human and ecological needs entail financial costs. While there may appear to be many financing options for water resources development, governments still have only three basic means of financing them: tariffs, taxes and transfers through external aid and philanthropy.

Policy-makers need to make political decisions on socially and environmentally acceptable trade-offs among different objectives and on the bearers of the costs of such compromise.

Climate Change Impacts on Indus River Basin

Pakistan is a natural resource based economy with more than a quarter of its land area (22.2 million ha.) under agricultural use. Due to its highly diverse physiographic and climatic conditions, it is classified into eleven geographical, ten agro-ecological, and nine major ecological zones. This unique geographical placement exposes the country to multiple threats from glacial melt, natural disasters and droughts, to sea level rise. Pakistan also has low forest cover (4.5%), with a deforestation rate as high as 0.2- 0.4 % per annum. Furthermore, the country has a highly fragile economic base. In 2007, Pakistan's Human Development Index (HDI) ranked it 0.572 (141 out of 182 countries). Per capita gross domestic product (GDP) ranked it 125th in the world and wealth is distributed highly unevenly. In fact, one-quarter of the population in Pakistan is classified as poor.

The Indus River Basin is of major importance to the economies of several countries of South Asia. It consists of six main rivers (the Indus, Jhelum, Chenab, Ravi, Sutlej, and Kabul rivers) originating from glaciers in the Western Himalayas and provides irrigation to more than 16 million hectares of agricultural land and generates up to 13 giga Watts of electricity through hydropower plants in Pakistan, India, and Afghanistan. Glacial retreat and changes in precipitation patterns from anthropogenic climate changes are expected to alter significantly river basin behavior and jeopardize hydropower generation and irrigated agriculture production. Initial short-term increases in water flow may endanger the sustainability of downstream infrastructure. Expected long-term reduction in water flows will reduce power generation potential and irrigation supply, with dramatic impacts on overall agriculture yields of these countries, consequently altering people's livelihoods. This will be particularly catastrophic for Pakistan where an estimated 50 % or more of river run-off flowing into the Indus Basin Irrigation System originates from glacial melt (Archer, 2001).

Moreover, the Indus Basin Irrigation System supports the irrigation of 75% of the country's cultivated areas and 34% of the countries' electric generation capacity. Similarly, loss in

hydropower generation capacity may directly induce the carbonization of the power sector (countries returning to thermal power plants to make up for reduced hydropower potential). A resulting increase in greenhouse gas emissions would contribute further to atmospheric global warming and subsequent glacial melt.

Field observations, satellite imagery, and historical hydrologic records have been used to investigate the reduction of the Western Himalayan glaciers, but results fail to accurately document and sometimes even contradict climate impacts. Even with relative consensus on global warming, and recorded increases in overall regional temperature, uncertainties remain regarding glacier melt and climate impacts in the Western Himalayas. Consequently, predictive downstream impacts (in terms of both timeframe and intensity) are not sufficiently reliable to inform decision-makers.

The development and introduction of climate adaptive measures would help reduce some of the potentially adverse climate impacts on food production and environmental degradation, and build a level of climate resilience in target watersheds to begin to address extreme events, climate variability, and disaster scenarios.

It becomes crucial to have a better understanding of global warming impacts on water, energy, and transport projects at the regional, national, and downscaled project levels to inform future risk management development planning and introduce adaptive infrastructure design criteria. Without an acceptable level of precision, developing member countries will not be able to develop meaningful adaptation strategies and lower-risk investment portfolios without addressing knowledge gap in the thematic areas mentioned.

Table-7: Indus Basin and the Different Portions of Different Countries

Countries	**Area of Basin in Country**	
	(Km^2)	**(%)**
Pakistan	597,700	52.48
India	381,600	33.51
China	76,200	6.69
Afghanistan	72,100	6.33
Chinese Control, claimed by India	9,600	0.84
Indian Control, claimed by China	1,600	0.14
Nepal	10	0.00
Total Basin Area:	**1,138,810**	**100**
		Source: UNEP, 2002

The inventory of glaciers in the Northern Areas of Pakistan described in PARC (2005) identified 5218 glaciers with a total area of 15,040.8 km^2 or 11.7% of the total area.

Table-8: Glacier Inventory in the Northern Area of Pakistan

Basins	No. of Glaciers	Glacier Area (Km^2)	Ice Reserves (Km^3)
Swat	233	223.55	12.221
Chitral	542	1903.67	258.817
Gilgit	585	968.10	83.345
Hunza	1050	4677.34	808.794
Shigar	194	2240.08	581.268
Shyok	372	3547.84	891.801
Indus	1098	688.00	46.381
Shingo	172	36.91	1.009
Astor	588	607.03	47.931
Jhelum	384	148.18	6.943
Total:	**5218**	**15040.80**	**2738.510**
			Source: PARC, 2005

Indus Basin's climatology is dominated by distinct summer and winter precipitation patterns. During summers, monsoon circulation, because of differential heating of sea and land and from subtropical jet stream, bestows rainfall over the plains of Kashmir, Punjab and Khyber Pakhtunkhwa (formerly known as NWFP), after striking ridges of the Himalayas and Karakorum. Sometimes, monsoon depressions are so strong that its impacts are recorded at Biafo glacier to much higher elevations (Wake 1979). During winters, depressions flowing in the westerlies are conspicuous. Westerly air masses borrow moisture from the Mediterranean, Caspian and Black seas and deliver precipitation over the HKH range, in both snowfall and rainfall forms. Western depressions are the biggest sources of nourishment for HKH glaciers in the winters, which ultimately keep the Indus River system flowing in summers. Furthermore, Archer and Fowler (2005*)* have found teleconnections between El Niño Southern Oscillation (ENSO) and the westerly depression over the HKH and reports that the HKH has received below normal precipitation in ENSO years.

Winiger et al. (2005) estimate that about 50% of the total annual runoff in the Indus River irrigation systems in Pakistan depends on snow and glacial melt from the eastern Hindu Kush, Karakoram, and western Himalayas. According to estimates of Hewitt (1989), snow and ice melt water supplies 75% of the flow of the Kabul River at Warsak, 80% of the Swat River, 85% of the main Indus River at Tarbela reservoir, and 65% of the Jhelum River at Mangla reservoir. Archer (2003) indicates these flows are primarily controlled by winter precipitation and the energy inputs during summer.

Precipitation and temperature have shown different trends in different locations of the Indus Basin and different studies come to different conclusions. Precipitation in the Northern areas of Pakistan seems to have increased while temperature has shown different trends in different seasons. There seems to be more rainfall than snow. In the Kabul River Basin, it is indicated that mean annual temperature is increasing. Mean rainfall over the same period has decreased slightly, mainly due to decreases in spring precipitation. This combination of factors has led to a

prolonged drought in recent years. In the Western Himalayas, decreasing annual precipitation and warming trend overall is observed, leading to drier conditions in the areas. However, a trans-boundary assessment of the trends is missing as all analyses focus on areas within a single country. There is no general agreement of the processes.

In terms of impact of climate change on river flows, there is no indication at present of changing flows in the main stem of the Upper Indus River. A decreasing trend is observed on Kabul River and in the lower stretches of the Indus Basin at Kotri Barrage. There is no conclusive answer in the case of glacier dynamics. In general, glaciers are retreating with the exception of some glaciers in the Central Karakorum.

Climate change projections are inconclusive for this scale. In general, an increase in temperature is expected and in most areas, a decrease of precipitation. To make these projections useful for planning purposes, there is a need to reduce the uncertainties and increase the spatial scale.

Precipitation Regime

Rasul et al. (2010) analyzed the precipitation pattern based on data collected at stations of the meteorological network of Pakistan Meteorology Department (PMD) and pointed out that dominant wet season in the Upper Indus Basin extends from December to May reaching the maxima around March/April, while the peak used to be in February/March in earlier years. From December to mid-March, precipitation falls in the form of snow and afterwards, rainfall dominates although some spells of snowfall have been recorded until early May (up to 3,000 m above mean sea level). They have investigated that the solid precipitation maxima has shifted towards the end of winter i.e. instead of January, heavy snow falls in February.

Table-9: Areal Snow Cover (Km^2) based on MODIS Imagery, March 2000 to April 2010 for Upper Indus Basin

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	NA	NA	74532	62157	32840	24004	13088	10452	13496	23677	35975	55244
2001	37581	47586	65903	59414	31920	22642	14578	9254	20682	17126	48307	51501
2002	56224	63605	66148	68596	52315	31175	13930	10261	20734	18816	28960	35329
2003	52781	69924	77710	68947	60388	38915	14729	12097	17892	36179	40285	36716
2004	56363	75231	61734	57831	52984	25129	23165	13493	16807	40441	43448	35835
2005	78462	89297	65977	70831	59353	44571	23475	11921	11315	24282	31814	41205
2006	44587	71482	63392	67599	43421	26591	12498	11285	13887	11446	32406	53996
2007	52768	53411	-	57154	35905	23940	16696	16763	16712	16926	20087	38662
2008	47987	64919	87718	55661	42083	22566	10693	13798	13338	25931	30668	38300
Source: Rasul et al., 2010												

In addition to snow and glacier melt, monsoon precipitation provides the necessary water resources. Monsoon precipitation falls in summer from July to September. It not only caters to the peak power supply demands, but also fulfils the highest water demands of field crops and gathers the reserves to meet the requirements of low flow periods in next 4-5 months. Being an agro-based economy, Pakistan is highly sensitive to any shock wave in the form of weak monsoon or mismanagement of available water resource. Deviation of precipitation in summer (monsoon season) during 2001 to 2007 has been shown in the above figure against the long-term average. It is more or less similar to the annual pattern, which depicts that the Southern

half has become slightly wetter than normal while the Northern half has had reduced precipitation and has become drier than its long term average.

Winter brings plenty of snow over the Northern mountains, which melts in early summer and sustains the river flows for power generation and irrigation before the onset of the summer monsoon. In addition to solid precipitation over hilly areas, winter rain bearing systems yield substantial rainfall in sub-mountainous and low elevation plains, including arid plains of Balochistan. Generally, the Northern half gets about five times more precipitation in winter than the Southern half.

Hydrological Regime

They further observed summer temperature reductions and positive trend in winter precipitation implying reduced ablation and increased accumulation of Karakoram glaciers. These observations are consistent with the observed thickening and expansion of glaciers in the Upper Indus basin also discussed by Hewitt (2005). In the main Indus River, Ali et al. (2009) identified neither a significant change in flow on the basis of the inflow into Tarbela (1961 – 2004) and at Kalabagh (1922 – 2002) nor of the Jhelum River measured at Mangla (1922 – 2004). An increasing trend was observed for the flow of Chenab measured at Marala (1922 - 2004) and a significant decreasing trend in the flow of Kabul River at Nowshera (1961 - 2004).

Climate Change – Issues

Issue 1:	Scarcity of automatic weather and hydrological stations in the glacierized areas
Issue 2:	Lack of basin and transboundary modelling excercises
Issue 3:	Lack of basin wide data on glacier status and dynamics
Issue 4:	Large uncertainties in precipitation projections
Issue 5:	Absence of a climate policy and National Adaptation Programme

Recent Trends of Climate Change in Pakistan

Recent trend of climate change in Pakistan based on last 70 years climate data compiled by Pakistan Meteorological Department in Technical Report No.PMD-22/2009 indicates:

a) Rise in mean daily temp of 0.6 to 1.0 degree centigrade in arid coastal areas and arid Western / North-Western Mountains.

b) 10 – 15% decrease both in winter and summer rainfall in coastal belt.

c) 18 – 32% increase in rainfall in monsoon zone (sub-humid and humid areas).

d) Further decrease of 5% in relative humidity over and plains of Baluchistan.

e) 3 – 5% decrease in cloud cover over central and southern Pakistan resulting in increase in sunshine.

f) Monsoonal Zone of Pakistan (a region that receives almost 65% of total monsoon rains) has shifted 80 – 100 Km from North East (KPK + Kashmir) towards North West (KPK + North West Punjab), therefore, the possibility of occurrence of heavy rainfall events during monsoon season, in the future, would be very likely over North West Pakistan instead of North East. Subsequently, the areas along western rivers (Indus and Kabul) would be extremely vulnerable to flood episodes as experienced during this season.

g) This trend will give rise to increase in frequency of extreme events such as heavy rains, flash floods, dust / thunderstorms, hailstorms, heat waves, density, persistence of fog etc.

Table-10: Some Recent Precipitation Related Extremes in Pakistan

2010	▪ Heavy rains during July, 2010 leading towards a major flood in most parts of Pakistan bringing in its wake huge devastation to life and property. ▪ A Cyclone named Phet of Cat-4, the second strongest storm ever to develop in the Arabian Sea after Gonu, had a landfall along Makran Coast west of Karachi during June, 2010 and brought serious damages in its wake.
2009	▪ Karachi received 208 mm of rain on July 18 & 19. Heaviest prior rainfall event recorded at Karachi was 207 mm on July 01, 1977. The normal rainfall at Karachi for the periods 1961 – 1990 is 85.5 mm.
2007	▪ Record heat wave gripped Pakistan during June, 2007. 48°C temperature was recorded on June 9 at Lahore, a record repeated after 78 years. earlier it was recorded on June 8, 1929. ▪ Two super cyclones namely Gonu (02A) of Cat-5 and Yemyin (03B) of Cat-1 developed in the Arabian Sea during June 2007 and hit Makran Coast and adjoining countries. The history of the Arabian Sea at least during the previous century shows no such events occurring twice in a month.
2001	▪ 620 mm rainfall in Islamabad during 10 hours in the month of July (on 23rd of July); it caused flooding in Lai Nullah.
1998 – 2001	▪ History's worst drought gripped southern parts of Pakistan and parts of surrounding countries.
1996	▪ 438 mm rain in Lahore in 72 hours in August 1996 the wettest month on record.
1992	▪ Previous century's worst flood in Jhelum river.
Source: Global Change Impact Studies Centre, Islamabad	

Climate Change Related Policies

In order to be a progressive nation, safeguard its ecological integrity and ensure sustainable development, Pakistan has shown a very strong commitment to play an effective role in global efforts aiming to mitigate and adapt to climate change. Pakistan has been actively participating in the global dialogue since the historic Rio Earth Summit in 1992. The country has also effectively contributed to global dialogue on climate change, sustainable development and conservation and is a signatory to a number of conventions and protocols, including the United Nations Framework Convention on Climate Change (UNFCCC).

Pakistan entered into Kyoto Protocol on 11 January 2005 and has since become eligible to benefit from carbon financing opportunities under the Clean Development Mechanism (CDM). Pakistan formulated the National Operational Strategy for CDM in February 2006, which offers tremendous incentives to investors to generate carbon credits for reducing carbon emission

from potential sectors. Pakistan has also participated in all international climate change related negotiations, including Conference of Parties (COP) to UNFCCC, Meeting of Parties (MOP) to the Kyoto Protocol and meetings of subsidiary bodies.

WAY FORWARD

The Indus Basin Irrigation System reflects a situation in which the primary resource constraint on agriculture production is water. Pakistan has very little water storage capacity and can barely store 30 days of water in the Indus Basin. When river flow is variable, then storage is required in order the supply of water can more closely match water demands. Growing shortfall in water availability compare to demand will continuously increase in future at the basin level. Holistic policies for water resources development and management are required to sustain growth in the context of resource limitation. Development of 15 to 20 MAF of water and interventions for improving water availability through water conservation are imperative.

Pakistan water resource sector has to be developed and make significant investments. There is a need of further intensification of canal water supply and land development to meet the future needs of population growth. The conjunctive surface and groundwater management would require water from additional storage reservoirs, and to have alternative water management regulatory framework / Institutional setup and use of new technologies in irrigation to improve water productivity.

Water has always played a key role in economic development, and economic development has always been accompanied by water development. Investment in water management has been repaid through livelihood security and reductions in health risks, vulnerability and ultimately poverty. While most of the old challenges of water supply, sanitation and environmental sustainability remain, new challenges such as adaptation to climate change, rising food and energy prices, and ageing infrastructure are increasing the complexity and financial burden of water management.

Population growth and rapid economic development have led to accelerated freshwater withdrawals. As population continues to grow and demand for food intensifies, pressure on water from agricultural activities are expected to increase, although at a slower pace. Agriculture is also facing competition for water from other sectors, and its allocation is decreasing in water-scarce areas, especially around urban centers. Competition for water and shortcomings in managing it to meet the needs of society and the environment call for enhanced societal responses through improved management, better legislation and more effective and transparent allocation mechanisms.

Challenges include wise planning for water resources, evaluation of availability and needs in watersheds, possible reallocation or storage expansion in existing reservoirs, more emphasis on water demand management, better balance between equity and efficiency in water use, inadequate legislative and institutional frameworks and the rising financial burden of ageing infrastructure. Water management choices should emerge from informed consultation and negotiation on the costs and benefits of all options after considering basin interconnectedness, relationships between land and water resources, and the consistency and coherence of decisions with other government policies. The uneven distribution of water resources over time and space and the way human activity is affecting that distribution today are fundamental sources of water crises in many parts of the world.

Drivers and policies outside the water sector have more impact on water management than do many policies championed and implemented by water-related ministries. Identifying trade-offs and synergies between water and other policy sectors can enhance policy impacts in all sectors and avoid some adverse effects on water. Leaders in the water domain can inform the

processes outside their domain and manage water resources to achieve agreed socioeconomic objectives and environmental integrity. Examples of win-win situations abound – whether created by governments, communities or businesses – that point to promoting deliberate cooperation between water and non-water actors and integrating water issues into external decisions.

International organizations, notably the UN system, can provide support and expertise to governments, help civil society build capacity and catalyse leadership in the private sector. Water and water systems must be managed to achieve social and economic development objectives and to sustain development. Water resources, properly managed, are critical to the survival and well-being of individuals. They can ensure equity and security in water and sanitation for families, businesses and communities. And they can ensure adequate water for food, energy and the environment as well as protection from floods and droughts.

Decision-making on water requires seeking synergies and selecting appropriate trade-offs. It also requires distinguishing between short-term 'fire-fighting' – responding to the urgent issues of the day – and long term strategic development. Developing multipurpose water schemes and reusing water wherever feasible can lessen the need for trade-offs by enabling the same volumes of scarce water to deliver multiple outcomes. The challenges are great, but unsustainable management and inequitable access to water resources cannot continue. We might not have all the information we would like to have before acting, but we do know enough now to begin to take significant steps. Actions must include increased investment in water infrastructure and capacity development.

Groundwater Management

At present, the water demand of agriculture, livestock, rural and urban households, industry and non-agriculture infrastructure has gone far beyond the originally planned surface water supply. The population growth and urbanization are two important factors upsetting the self-sufficient rural canal colony model (The Canal and Drainage Act 1873). In this context, the use of groundwater tremendously increased facing an increasing danger of depletion and quality deterioration. The agriculture sector is the major user of groundwater. The conjunctive use of canal and groundwater does not have corresponding planning and management at the command area level.

Groundwater has become a vital and major part of the overall water resources in the Indus Basin irrigation system. The groundwater use is however reaching to the sustainable limits. The fast growing cities and industries looking for large increases in water supply are adding to the challenge. An effective monitoring and management system that encourages the private management sustainability of this water source is needed. Punjab must intensify its efforts to put in place an effective framework for groundwater management. The experience in this regard suggest to follow a phased and incremental implementation strategy with initial focus on groundwater monitoring and gradual shift to groundwater management in a phased manner. The awareness raising campaign is also very important for sensitizing the stakeholders about groundwater issues, self-regulation, groundwater monitoring and management interventions. It is relevant to point out that the upcoming institution of Farmers Organizations can play an effective role for management of groundwater in their respective areas.

Integrated Water Resources Management (IWRM)

Strengthening IWRM and water management capacity is needed to deal with both the existing and emerging water challenges taking into account the issues like climatic changes, groundwater use, water quality, pollution, urbanization and industrialization, licensing access to water etc. A continuum for decision making in water resources management is to be prepared,

identifying the fundamentals of IWRM implementation by addressing the resource condition and allocation issues at the basin level.

The distinct elements for progressing IWRM and to address the resource conditions and allocation issues as shown below:

Box-4: IWRM Fundamentals

- ✓ How much water (surface and groundwater) is available
- ✓ What are the risks / opportunities annunciated with these resources – climate change / pollution / new dams
- ✓ What is its quality
- ✓ Who is authorized to use it and under what conditions will this authorization be changed
- ✓ Who will have policy and decision making responsibility for an integrated approach for water management that will take into account all the competing issues and sectors

Source: Donald 2008

Institutional and Policy Reforms

In water sector, the role of Government is coordination and policy formulation. IRSA coordinates and oversees the distribution of water of the Indus and its tributaries among provinces. Any proposed development in the water sector has to be reviewed by IRSA to ensure conformity to the Water Accord. Implementations of agriculture and irrigation activities were mostly non-collaborative with a very little interaction among respective stakeholders. There is no overall single agency, which is responsible for coordinating water resources development as well as approving inter-sectoral water allocations either at federal or provincial level. A comprehensive strategy and a framework for the water sector is required within which competing demand for water and scarce financial resources can be assessed and service delivery improved.

Holistic institutional and policy reforms to improve the management and maintenance of the Indus Basin Irrigation System to ensure its long-term physical and financial sustainability, water resources management reforms to make inter-intra- province water allocation and distribution more transparent, service delivery reforms to improve the quality efficiency and accountability and reforms to improve water use efficiency and on-farm productivity are required.

Climate Change

The Indus Basin depends heavily on the glaciers of the western Himalayas which act as a reservoir, capturing snow and rain, holding the water and releasing it into the rivers which feed the plain. It is now clear that climate change is already affecting these western glaciers. While the science is still in its infancy, best estimates are that there will be fifty year of glacial retreat, during which time river flows will increase. This – especially in combination with the predicted flashier rainfall – is likely to exacerbate the already serious problems of flooding and drainage. But then the glacial reservoir will be empty, and there are likely to be substantial decreases in river flows – conceivably by 30 percent to 40 percent in the Indus Basin in one hundred years time. The emerging impacts of climate changes would add a new dimension to these challenges, which call for adequate knowledge base, strategic planning and proactive management initiatives.

A Task Force on Climate Change was set up by the Planning Commission of Pakistan in October 2008 with the view to take stock of country's situation in relation to climate change; to contribute to the formulation of a climate change policy that would assist the government in

achieving sustained economic growth by appropriately addressing climate change threats so as to ensure water security, food security and energy security of the country; and to recommend policy measures for promoting large scale adaptation and mitigation efforts, raising awareness of various stakeholders; and enhancing the capacities of relevant national institutions.

The final report of the Task Force has been issued in February 2010, which describes Pakistan's vulnerability to climate change due to impacts on various socio-economic sectors. It recommends a number of adaptation and mitigation measures based on the initial available assessment of different sectors and reviews the country's implicit ongoing and planned responses. It also provides recommendations on issues such as much needed capacity building, needs for international cooperation and Pakistan's position in international negotiations on future climate change regime. It is hoped this report will serve as a seminal document, providing a base for further work and helping the Planning Commission and the Ministry of Environment in the formulation of National Climate Change Policy and National Adaptation Programs of Action (NAPA).

The National Climate Change and Action Plan 2011-15 by Ministry of Environment, Government of Pakistan towards climate change, adaptation and mitigation action plans is given in Box-5.

Box- 5: National Climate Change Strategies

- Providing incentives for adoption of more efficient irrigation techniques
- Developing local rain harvesting measures
- Enhancing public awareness to underscore the importance of conservation and sustainable use of water resources
- Ensuring that water allocations are made according to changes in sectoral demands caused by climate change
- Protecting groundwater through management and technical measures like regulatory frameworks, water licensing, artificial recharge especially for threatened aquifers, and adopt integrated water resources management concepts
- Developing wastewater recycling and its reuse in agriculture, artificial wetlands and groundwater recharge
- Protecting and conserving water 'catchment' areas, and reservoirs from degradation, silting and irrigation system contamination
- Encourage active participation of farmers in water management alongwith line-departments
- Distributing water among provinces as far as possible according to crop sowing timing
- Addressing sea water intrusion into Indus deltaic region by allocating required water flow downstream Kotri, and taking measures to preserve the ecology of dry-river reaches of Eastern rivers
- Development of contingency plans for short-term measures to adapt to water shortages that could help to mitigate drought
- Exploring the possibility of trans-boundary joint watershed management of catchment areas with neighboring countries
- Safeguarding Pakistan's rights on trans-boundary water inflows according to international norms and conventions
- Promoting integrated watershed management practices in uphill watersheds
- Legislating and enforcing laws and regulations required for efficient water resources management, conservation and groundwater regulatory framework
- Legislating and implementing the draft National Water Policy to address the water related vulnerabilities induced by climate change
- Legislating and enforcing laws related to industrial and domestic waste management
- Declaring glaciated areas as 'protected areas' to protect HKH Glaciers.
- Preparing a comprehensive inventory of all water resources, including surface and groundwater, in order to support an efficient water management system in the country
- Strengthening the present hydrological network to monitor river flows and flood warning systems
- Ensuring effective planning and management of irrigation water
- Developing and extending technologies and techniques of domestic and drinking water saving as well as sea water utilization
- Enhancing national capacities for monitoring temporal changes in glaciers, snow cover, and meteorological parameters
- Enhancing country's water storages capacities
- Ensuring the early rehabilitation, remodeling and up-gradation of existing irrigation infrastructure in the country, which can sustain the climate change related expected extreme weather events
- Developing infrastructure to harness the hill torrents potential

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