WATER-RESOURCES SITUATION IN PAKISTAN: CHALLENGES AND FUTURE STRATEGIES

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ABSTRACT

Pakistan, once a water-surplus country, is now a water deficit country. The rainfall is neither sufficient nor regular, to meet the growing needs of water. About 70 per cent of the annual rainfall occurs in the months of July to September. The surface water resources of Pakistan mainly consist of flows of the Indus River and its tributaries, which bring in about 138 million acre feet (MAF) of water annually. The Indus River alone provides 65% of the total river flows, while the share of Jhelum and Chenab is 17 and 19% respectively. The months of peak-flow are June to August during the monsoon season. The flow during the Kharif (Summer) is 84% and during Rabi (Winter) season is 16%. The alluvial plains of Pakistan are blessed with extensive unconfined aquifer, with a potential of over 50 MAF, which is being exploited to an extent of about 38 MAF by over 562,000 private and 10,000 public tubewells. In Balochistan (outside the Indus Basin), out of a total available potential of about 0.9 MAF of groundwater, over 0.5 MAF are already being utilized, thereby leaving a balance of about 0.4 MAF that can still be utilized, though some aquifers are already over exploited. The Indus River System, as such, will not be able to continue self-reliance in agricultural production. Due to enormous amounts of sediments brought in by the feeding rivers, the three major reservoirs – Tarbela, Mangla and Chashma – will lose their storage capacity, by 25% by the end of the year 2010, which will further aggravate the water-availability situation.

This paper takes stock of the present situation of water-resources, present needs and future requirements, the challenges imposed, and suggests short, medium, and long-term strategies to cope with the situation.

The suggested short-term strategies include starting a mass-awareness campaign, propagation of high-efficiency irrigation systems, changes in cropping-patterns, identification of feasible surface-water storage sites and dams, and activation of water-user organizations. The medium-term strategies suggest giving priority to lining of distributaries, minors and watercourses in saline groundwater areas, construction of small dams and installation of tubewells in technically feasible areas, improving flood and drought-forecasting methods, and a much wider application of conjunctive water-use approach and propagation of high-efficiency irrigation systems. Institutional reforms for better co-ordination and a wider formulation of a national water-policy are other priority areas under the medium-term strategic plan. Long-term strategies include formulation of a regulatory framework on groundwater abstraction, construction of large storage dams, better flood and drought-forecasting mechanisms and resolving water-distribution problems between provinces. It is recommended that a National Commission on Water, supported by an experts panel, be created to steer the formulation of the strategies and ensure the implementation of the strategies proposed.

INTRODUCTION

Water is essential for sustaining quality of life on earth. This finite commodity has a direct bearing on almost all sectors of economy. In Pakistan its importance is more than ordinary due to the agrarian nature of the economy. The share of agricultural sector in the Gross Domestic Product (GDP) of Pakistan is about 24 %. Since agriculture is the major user of water, therefore sustainability of agriculture depends on the timely and adequate availability of water. The increasing pressures of population and industrialisation have already placed greater demands on water, with an ever-increasing number and intensity of local and regional conflicts over its availability and use. Historically, the high aridity index of the country is adding further to the significance of water in developmental activities in Pakistan.

Though, once a water-surplus country with huge water-resources of the Indus River System, Pakistan is now a water-deficit country. At present, the annual per capita water- availability in Pakistan is about 1,100 cubic meter (m^3); below 1,000 m^3, countries begin experiencing chronic water stress (Population Action International, 1993). Table-1 gives the comparison of per-capita water-

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Table - 1: Per Capita Water-Availability in Selected Countries (m^3)			
COUNTRY	**1955**	**1990**	**2025**
China	4,597	2,427	1,818
Mexico	11,396	4,226	2,597
Philippines	13,507	5,173	3,072
Iraq	18,441	6,029	2,356
USA	14,934	9,913	7,695
Pakistan	2,490	1,672	837
Source: Population Action International, 1993			

availability in some selected countries of the World, including Pakistan.

The situation in Pakistan indicates that the country is nearing conditions of chronic water-stress. Meanwhile, the gap between demand and supply of water has increased to levels creating unrest among the federating units. The extended drought during recent years reduced fresh-water supplies of the country, which has highlighted the importance of development of new sources and adopting water-conservation measures for extremely judicious use of the finite quantity of water.

WATER-RESOURCES

Figure-1 is a map of Pakistan showing the river system with dams and barrages and the irrigated areas.

The water-resources of Pakistan include surface water, rainfall, and groundwater. The extent of availability of these resources is location-specific. A brief description of water-resources of Pakistan is given in the following sections.

Surface Water-Resources

Surface water-resources of Pakistan are mainly based on the flows of the Indus River and its tributaries. The Indus River has a total length of 2900 kilometres (Km) and the drainage-area is about 966,000 sq. Km. Five major tributaries joining its eastern side are Jhelum, Chenab, Ravi, Beas and Sutlej; besides, three minor tributaries are the Soan, Harow, and Siran, which drain in mountainous areas. A number of small tributaries also join the Indus towards its western side. The biggest of such tributaries is River Kabul.

Rivers in Pakistan have individual flow characteristics, but all of them generally start to rise in the spring and early summer, with the monsoon rains and snow melting on the mountains and have a combined peak discharge in July and August. The flows are minimum during winters e.g., during the period November to February, mean monthly flows are only about one tenth of those in summer. Besides the major rivers, there are numerous small rivers and streams, which are only seasonal with flow depending on rain fall and carry practically no water during the winter months. and carry practically no water during the winter months. The 77-year record of the Indus River (1922-23 to 1999-2000) indicates that the watersheds of the Indus River yield

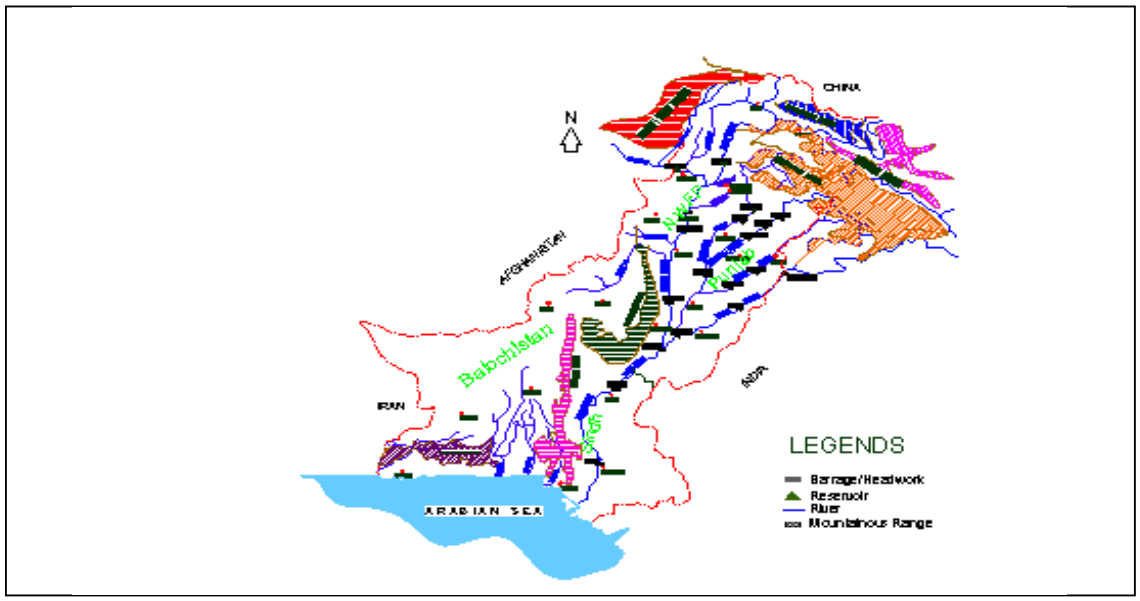


Figure - 1: Indus River System

Table-2: Inflows in Western Rivers (in MAF)			
	Kharif	**Rabi**	**Total**
Maximum (Year)	154.7 (1959-60)	35.1 (1990-91)	186.8 (1959-60)
Minimum (Year)	71.5 (1999-2000)	15.7 (1971-72)	97.7 (1971-72)
Mean (77 Years)	115.9	22.8	138.7
Source: WAPDA and IRSA reports			

about 138.7 MAF of water annually, see Table-2.

Table – 2(a)	
Province	**Water Development Potential (MAF)**
Punjab	2.7
NWFP	7.3
Balochistan	7.86
Sindh	0.78

It is worth mentioning that the Indus River alone provides 65% of total river flows, while the share of Jhelum and Chenab is 17 and 19 % respectively. The months of peak-flow are June to August, which is the monsoons period in the sub-continent. Flows for Kharif and Rabi crop seasons are 84 and 16 % respectively. Thus, it becomes all the more important to store as much water as possible during the high-flow period, for use during low-flow period. Under such circumstances, the availability and integrated management of storage-reservoirs in the country becomes very important.

After the Indus Basin Treaty between India and Pakistan (1960), the availability of water to Pakistan is limited to the three western rivers, namely Indus, Jhelum and Chenab, while India is entitled to divert flows of Ravi, Beas and Sutlej. This treaty also provided for the construction of a number of link canals, barrages and dams on the Indus and its two tributaries, Jhelum and Chenab, transferring at least 20 MAF of water for the irrigation of areas that were cut off from irrigation-systems of rivers Ravi, Sutlej and Beas after the Indus Basin Treaty.

During the current century, the Indus Basin has developed the largest contiguous irrigation-system in the world. The system includes Indus River and its major tributaries, 3 major reservoirs (Tarbela, Mangla and Chashma), 19 barrages/headworks, 12 link canals, 45 canal commands and some 99,000 watercourses. The total length of the canal-system is, 58,450 Km, with 88,600 watercourses, farm channels and field ditches running another 160,000 Km in length.

Hill torrents in the hilly areas of the country provide another source of surface water, which has not been developed to its full potential. There are 14 distinguishable hill-torrent areas in all the four provinces of Pakistan, with a total potential of about 19 MAF at about 1,200

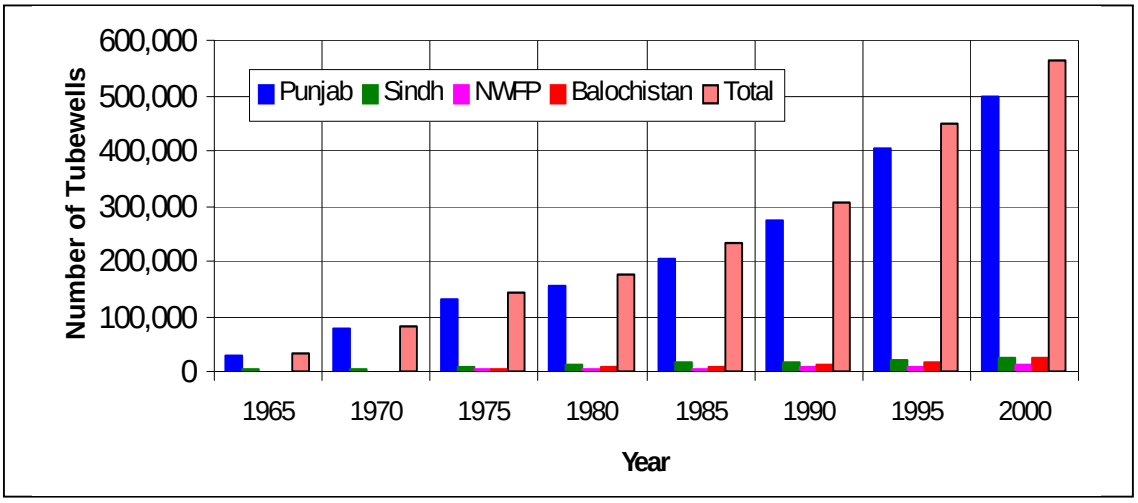


Figure- 2: Growth in Number of Tube wells

sites. Out of this, almost 60 per cent can be developed for crop production. This water offers excellent opportunity to irrigate almost 6 Million acres of culturable wasteland in the hill torrent areas. Province-wise development potential of the hill torrents is shown in Table - 2(a).

Rainfall

About 70 per cent of the annual rainfall occurs in the months of June to September. This causes the loss of most of the run-off in the lower Indus plains to the sea. The mean annual rainfall distribution in Pakistan has a broad regional variation. It ranges between 125 mm in Balochistan (South East) to 750 mm in the Northwest.

Rainfall is neither sufficient nor regular. The intensity of rainfall and the volume of downpour are much more than can be utilized readily. A large part of the rainfall, therefore, either floods the riverine areas and/or villages/cities near the rivers and causes consequential miseries and damages, or flows into the sea without any economic benefit to the country.

In the Sindh plains, high-intensity rainfall occurs during July and August and its intensity continues to decrease from coastal areas towards central parts of the Sindh. The southern Punjab and northern Sindh are the areas of very low annual rainfall-less than 152 mm. The areas above the Salt Range, including the districts of Jhelum, Rawalpindi, Attock and Mianwali, receive high rainfall, above the average of 635 mm per year.

The winter rains are generally widespread. Northern and northwestern area of NWFP and the northern areas of Balochistan receive comparatively high order of rainfall during winter. The magnitude of the annual rainfall over nearly 21 million hectares (Mha) of Indus Plains and Peshawar valley averages about 26 MAF. The present contribution of rain to crops in the irrigated areas is estimated at about 6 MAF.

Groundwater Resources

Most of the groundwater resources of Pakistan exist in the Indus Plain, extending from Himalayan foothills to Arabian Sea, and are stored in alluvial deposits. The Plain is about 1,600 Km long and covers an area of 21 Mha and is blessed with extensive unconfined aquifer, which is fast becoming the supplemental source of water for irrigation. The aquifer has been built due to direct recharge from natural precipitation, river flow, and the continued seepage from the conveyance-system of canals, distributaries, watercourses and application-losses in the irrigated lands during the last 90 years. This aquifer, with a potential of about 50 MAF, is being exploited to an extent of about 38 MAF by over 562,000 private tubewells and about 10,000 public tubewells. Figure-2 shows the province-wise growth of tubewells for extracting water since 1965.

In Balochistan, groundwater, extracted through dug wells, tubewells, springs and karezes, is the main dependable source of water for irrigation of orchards and other cash crops. This is because almost all the rivers and natural streams are ephemeral in nature, with seasonal flows only. It is estimated that, out of a total available potential of about 0.9 MAF, 0.5 MAF is already being utilized, thereby leaving a balance of 0.4 MAF that can still be utilized. This, however, creates misconception, as the aquifers are not continuous but are limited to basins due to geologic conditions. It is pointed out that, in two of the basins (Pishin-Lora and Nari) groundwater is being over-exploited, beyond its development potential, creating mining conditions and causing a huge overdraft of groundwater that is threatening to dry up the aquifers in the long term.

WATER REQUIREMENTS

Agricultural Demands

Pakistan is a country, which is required to double its annual food production every 15 years, in order to maintain its status-quo in meeting requirements of food. This

Table - 3: Agricultural Water Demands (MAF)

Crops	1990	2000	2025
Wheat	26.27	28.8	56.91
Rice	18.78	22.24	16.68
Cotton	13.68	15.71	19.35
Sugarcane	11.35	13.41	13.93
Other Crops	28.93	30.59	46.74
Total with Losses @70%	168.32	188.28	261.14

target, on the surface, may not look so demanding, as the country is bestowed with enough fertile and productive lands and sufficient freshwater-resources. Despite the availability of these basic resources, unfortunately the country has to import large quantities of food commodities every year. With the current population of about 140 million people growing at the rate of almost 2.5% per annum, the country would have to feed 120 million additional mouths by the year 2025. Table-3 shows the production and water-requirements of some major crops needed to maintain self-sufficiency in these food grains, which may be compared with Table-2.

Domestic and Industrial Needs

Table - 4 shows the domestic present and future domestic requirements, based on a per-capita demand of 46 m^3 per annum. The corresponding industrial water-demand is considered negligible when compared with the domestic and agricultural demands.

Table - 4 : Water Demand for Domestic Use			
Year	**1990**	**2000**	**2025**
Population (Million)	110	140	260
Water Demand (MAF)	4.1	5.2	9.7

MAJOR CHALLENGES

Water Scarcity

The population growth and per-capita water-availability since 1940-41 is shown graphically in Figure-3. Currently the same is about 1,100 m^3 per person, a drop of over 60% in sixty-year periods. Average canal-water supplies to the Indus Basin canal commands are around 104 MAF. Out of this, around 38 MAF are available during the Rabi-season. The shortage of water during the current Rabi-season (2001-2002) would be over 40 per cent from that of the normal year. This shortage of water not only affected the Rabi-season crops (area and productivity) but would also affect the plantation of cotton crop, especially in the Sindh province, as the crop is planted much earlier than in Punjab.

- The key issues related to water availability include the following:
- Annual and seasonal variability in availability of surface water and impact of global warming
- Seawater intrusion due to low flows below Kotri, resulting in ecosystem degradation
- Reduction in capacity of storage reservoirs due to sedimentation
- Increase in domestic and industrial demands and consequent reduction in supplies for irrigation
- Poor delivery-efficiency in irrigation and municipal water supply systems, and
- Deterioration of water-quality due to disposal of untreated urban sewage and/or agricultural drainage effluent
- Depleting groundwater tables, due to over exploitation

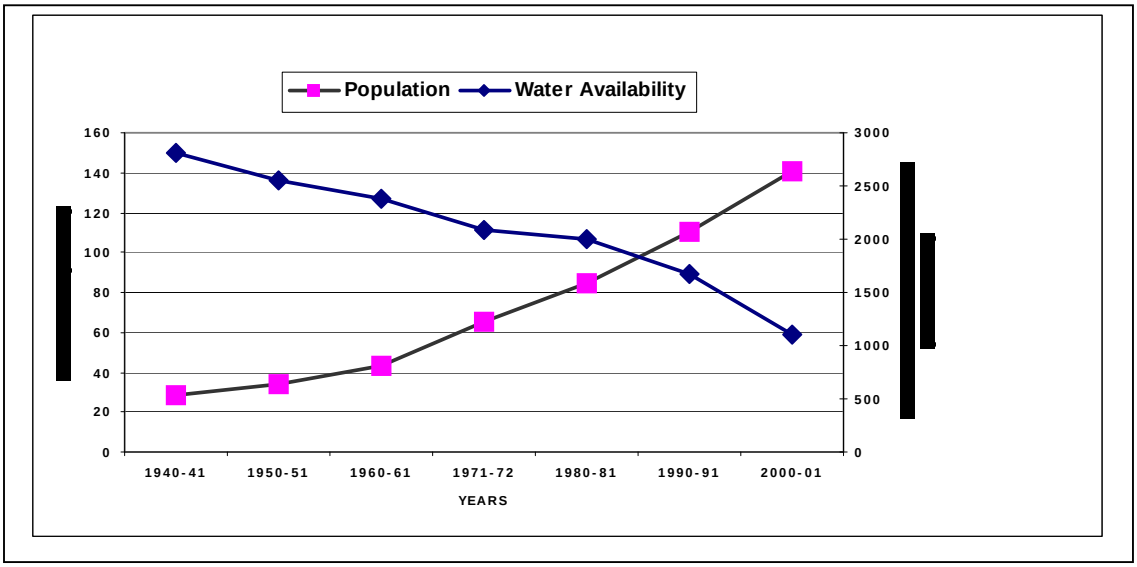
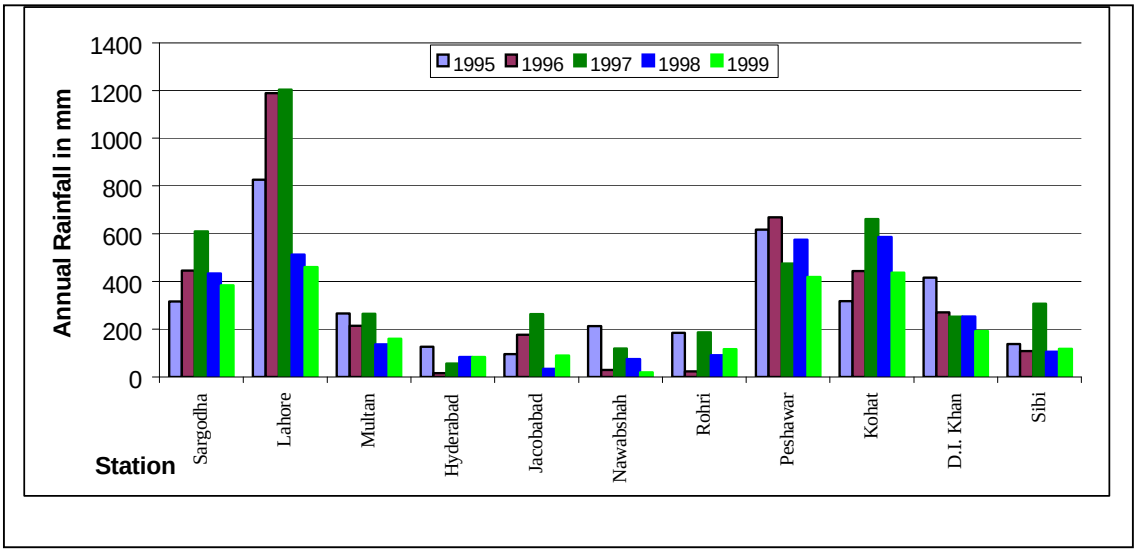


Figure - 3: Per-Capita Water-Availability

- Salt-water intrusion, due to up-welling from underlying saline aquifer
- Deteriorating performance of public tubewells, resulting in increased pumping costs

thousands of livestock heads died due to damage to the rangelands and fodder crops. The catastrophe exposed the serious limitations in our water-development, management, and utilization systems and



Source: Pakistan Meteorological Department rainfall data

Figure - 4. Rainfall over Irrigated Areas

Drought

Frequency of occurrence of droughts has increased in recent years. The Drought phenomenon (dry year) has been observed to occur in 4 out of 10 years, instead of 3 out of 10. The precipitation during the years 1997-2000 has been exceptionally low as in this period the precipitation over most of the country has been less than 50% of the normal, causing severe loss to agricultural production. The rainfalls have been showing a generally decreasing trend since 1997, which was the peak-year (Figure-4). The effect of the continued low rainfalls over most of the country since the last three years has resulted in low river flows and drought conditions. Not only precious human lives were lost, but also

policies, which calls for a comprehensive strategy/policy on water to streamline the problems of water- resources of the country in the near and far future.

The recent long drought-conditions have affected 75 out of 106 districts in Pakistan. Estimates show that, between November 1999 and July 2000, 143 humans and 2.48 million livestock died. The loss has been more pronounced in the arid areas of Balochistan and Sindh. In addition, increased incidence of malnutrition, diarrhea, respiratory infections, measles, malaria, school drop-outs, and permanent dislocation of families have been observed. The drought has also been responsible for seawater intrusion in deltaic areas, migration of cattle due to worsening

Table - 5: Reduction in Capacities of Major Reservoirs

Reservoir	Year Commissioned	Live Storage Capacity (MAF)			Decrease (%)	
		Starting	2000	2010	2000	2010
Mangla	1967	5.3	4.5	4.2	15	21
Tarbela	1974	9.7	8.8	7.3	9	25
Chashma	1971	0.7	0.3	0.2	57	71
Total		**15.7**	**13.6**	**11.7**	**13**	**25**

Source: Three Years Development Programme (2001-04), Planning Commission, GoP

state of range and wetlands, and depletion and deterioration of groundwater reservoirs. The effect on agricultural crops has been tremendous: the total loss is estimated to be about Rs. 50 billion, including the total loss of crops in 3 Million hectares of Barani (rain-fed) areas.

Inadequate Storage and Sedimentation

Sedimentation in the three major reservoirs – Tarbela, Mangla, and Chashma – is going to decrease their storage capacities by over 40% by the end of the year 2010. In this situation, their capability to continue supplies to the irrigation-system need to be re-assessed and appropriate solutions found. The estimated loss of the storage-capacity of the three major reservoirs till 2010 is given in Table-5.

Groundwater Over-draft and Water logging and Salinity

The continued abstraction of groundwater has resulted in over-pumping and consequent lowering of water table in many areas. Prominent areas among these are Lahore, parts of Balochistan and some densely populated urban areas of the Punjab and Sindh. Efforts to recharge the depleting aquifers need to be undertaken immediately.

Figure-5 shows the water-table in canal commands as bars, to illustrate rising or lowering trend. It is clear from the figure that, in 26 canal commands, water-table is fulling, with various degrees of depletion. Depletion is generally in those canal-commands where water-allowance is lower and crops are heavily dependent on tubewell irrigation. The figure further shows rising trend in 17 canal-commands with various rising levels. The rise in water-table seems to be high for those canal-commands that have higher water allowance. Most of these canals are in Lower Indus Basin where heavy investment in drainage has been done during the past 15 years. The reasons could be very low rate of groundwater-use, floods during the summer nd mis-management of water. However, the overall picture shows depletion of carelessly used groundwater resources, which would be cared for till it is too late. It also indicates that there is a need to find appropriate water-allowance for canals, which will be required for the sustainability of groundwater. If surface canal supplies are not increased, the groundwater will not be available in future.

Waterlogging and salinity in Pakistan emerged as a consequence of the mismanagement of irrigated agriculture, flat topography, seepage from unlined earthen canals, inadequate provision of drainage and the use of poor-quality drainage-effluent. The menace still persists and the situation is becoming serious due to the problem of disposal of drainage-effluent. From 1978 to 1998, the area with water-table above 1.5 m ranged from 9.0 to 18.3%, and similar variations were observed between 1.5 and 3.0 m and below 3.0 m (Table-6).

The magnitude of the salinity/sodicity problems can be gauged from the fact that, at one stage, the area of productive land being lost due to salinity was at a rate of about 40,000 ha per year. A countrywide survey conducted by WAPDA during 1977-1979 showed the true status of soil-salinity in the canal commands. In this, covering 16.72 Mha,

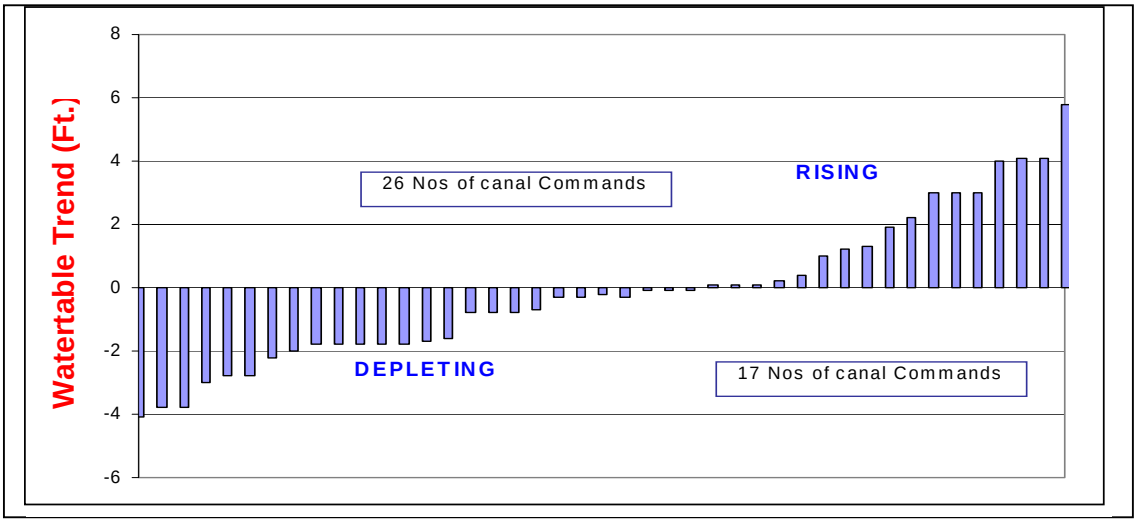


Figure-5. Water-Table Trends in Canal Commands

Table - 6: Area Under Various Water-Table Depths (% of CCA)

Year	<1.5 m	1.5-3.0 m	>3.0 m
1978	11.90	39.50	48.60
1982	13.50	43.20	43.30
1986	13.00	41.00	46.00
1988	9.00	38.20	52.80
1990	13.20	36.20	50.60
1992	18.30	32.60	49.10
1993	16.20	35.70	48.10
1994	12.00	36.00	52.00
1995	12.30	36.90	50.80
1996	10.40	40.10	49.50
1997	17.20	33.20	49.60
1998	14.70	36.60	48.70
Average	**13.50**	**37.40**	**49.10**

Source: SMO unpublished data

both surface and profile salinity/sodicity was established through chemical analysis. About 25% of the area was affected by surface-salinity. Province-wise position of surface-salinity is shown in Table-7. Comparisons with past surveys have indicated that the land affected by surface-salinity decreased from 42% in the early 1960's to about 25% in 1977-79 (WAPDA, 1980), primarily due to increased irrigation-water supply from surface and groundwater sources and management measures taken by the Government of Pakistan.

Low System-Efficiency and Productivity

As the irrigation system of Pakistan consists of the perennial rivers, a network of inundation and link canals, distributaries, watercourses and irrigated fields, an appreciable percentage of the water is lost through seepage and evaporation. A number of studies have been conducted to estimate water-losses in earthen canals, and watercourses. Conveyance- losses in canals and watercourses are around 25 per cent and 30 per cent, respectively. The application losses in fields are around 25-40 per cent. These losses are high, due to application of old irrigation-practices by the farmers. The overall irrigation-efficiency in the irrigated areas is estimated to be hardly 30%. Similarly, in Balochistan, where groundwater is a precious and depleting resource, irrigation to apple orchards exceeds the requirements by over 100%. This is a huge loss of water, even through part of it is recoverable by pumping in fresh- water areas only, but a major part is lost to saline aquifers and due to high evaporation.

Table - 7: Province-Wise Soil Salinity Status (% of Area Surveyed)

Province	Survey Period	Salt Free S1	Slightly Saline S2	Moderate Saline S3	Strongly Saline S4
NWFP	1977-79	78	8	2	2
	1971-75	75	10	4	2
Punjab	1977-79	84	7	4	3
	1953-65	72	15	5	6
Sindh	1977-79	50	19	10	18
	1953-54	26	28	17	27
Balochistan	1977-79	74	17	5	4
	1953-54	69	15	7	9
Pakistan	1977-79	72	11	6	8
	1953-75	56	20	9	13

Source:(WAPDA 1980)

Table - 8: Changes in Water-Quality in SCARP Areas

Project	Data Period	Percent Change in Water Quality		
		Usable Water	Marginal Water	Hazardous Water
SCARP I	1962-89	-8	4	4
SCARP II	1975-88	-3	1	2
SCARP III	1969-86	-10	6	4
SCARP IV	1970-85	-10	11	-1
SCARP V	1976-86	-6	8	-2
SCARP VI	1976-89	-18	8	10
SCARP VIII	1979-89	-29	14	15
Shahpur	1977-87	-6	6	0
Peshawar	1979-88	1	-2	1
Mardan	1979-88	5	-5	0
Khairpur	1965-88	-4	6	-2
Bannu	1978-88	1	4	-5
North Rohri	1977-88	-6	5	1
South Rohri	1979-88	-5	5	0
Ghotki	1978-88	-2	2	0
Larkana	1976-88	7	-7	0
Shikarpur	1976-88	-1	1	0
Sukkur	1975-88	-5	-3	8

Water-Quality Deterioration

The surface and ground-water quality is deteriorating day by day. The indiscriminate discharge of industrial and domestic wastewater into open water-bodies and groundwater is the main threat to the country's water-reserves. The absence and non-implementation of legislative measures and standards has been the root cause of the deterioration in water-quality observed over the year. The issue is becoming very serious, as many aquifers and open water-bodies, like lakes, rivers and streams, are being increasingly contaminated by pollution from industrial, agricultural and municipal wastes. According to estimates, pollution in River Ravi, due to sewage disposal from the city of Lahore, claims the lives of over 5,000 tonnes of fish every year.

On the basis of data available from monitoring studies undertaken in the Salinity Control and Reclamation Projects (SCARP) has indicated a general deterioration of groundwater quality, though little change has been observed in surface water quality. Table-8 shows the change in water quality in SCARP areas. The table indicates appreciable increase in the areas under hazardous water, with corresponding decrease in the areas under usable water-quality.

WATER MANAGEMENT-STRATEGIES

A three-pronged approach towards formulation of strategies to meet the growing scarcity of water needs is proposed. The general approach involves:

a. Tapping of existing un-utilised resources and development of new and unexplored water-resources.
b. Management of water-resources, to achieve the goal of maximum production per unit of water used.
c. Improving the institutional set-up and better governance of water-resources institutions and infrastructure.

Based on the above approach, the following strategies are suggested. These strategies are grouped as short-term, medium-term and long-term.

Short-Term Strategies (Time frame- 3 years)

These strategies are suggested for management of existing water-resources with the main aim to formulate a framework for dealing with drought, during the immediate two crop seasons. Some of the suggested actions for short-term may continue during the medium and long-term strategies. Following are the details of the suggested strategies:

Awareness Campaigns: Most of the problems associated with the water-sector have risen from illiteracy and lack of knowledge and understanding of water-conservation practices and high-efficiency irrigation-systems among users at large. An extensive social awareness campaign is required, using mass-media and a village-to-village campaign of extension services. Moreover, effective extension-service mechanism must be developed to transfer new and efficient irrigation methods, technologies, and practices to farmers.

Increasing On-Farm Application Efficiencies: Precision land-levelling increases field-application efficiencies in plain areas, where basin irrigation is practiced. Efforts to introduce laser-guided land-levelling with cost-effective locally developed technology should be encouraged. Similarly, farmers in upland areas, with undulating topography, should be encouraged to use high-efficiency irrigation-systems, like trickle, bubbler, and sprinkler, to conserve water. For this, demonstration plots on cost-sharing basis need to be established in the entire country.

Improving Conveyance Efficiencies: Earthen improvement of distributaries, minors and watercourses, with installation of concrete control-structures, should be undertaken to enhance conveyance-efficiencies, which are presently around 55 per cent.

Motivation To Farmers And Industrialists: To motivate the farmers for adoption of the high-efficiency irrigation-systems, incentives/ subsidies and soft loans may be given. The local industries may be encouraged to manufacture components of the systems, for which tax holidays may be given.

Improved Surface Irrigation Methods: In plain areas, where row and grain crops like cotton, wheat and maize are grown; bed and furrow-irrigation methods should be made mandatory for adoption by farmers, to increase the application-efficiency of water.

Changes In Cropping Patterns And Crop Varieties: To conserve water, meet water shortage, and match water-requirements with supplies, appropriate changes in cropping patterns may be considered. This would require change over from high-delta to low-delta crops, capable of giving higher returns to the farmers. Similarly, growing drought and salt-resistant crop varieties is another option that can be considered.

Reduction In Cultivation Areas: To reduce the chances of crop-failures, due to anticipated water shortage, planned reduction in cultivation areas to match water-availability may be propagated in a very timely fashion.

Regulation Of Groundwater: To reduce and control the over-extraction of groundwater resulting in mining, groundwater use must be regulated and properly priced through appropriate legislation and its strict implementation. Subsidies given to users of groundwater in stressed areas, in particular, may be withdrawn.

Undertaking Skimming Wells Projects: In areas where fresh water is overlying saline water, it would help if skimming-well technology were used to pump out fresh water, without disturbing the underlying saline layer. For this, it would be necessary to undertake an investigation exercise to delineate such areas.

Identifying New Water-Storages Sites: To tap the surface water going to waste, identification of possible surface water storage sites for small and large dams should be done on top priority bases. WAPDA and provincial irrigation departments should be asked to complete this task as soon as possible.

Rejuvenation Of Depleting Aquifers: Due to ever increasing number of depleting fresh water aquifers, there is a need to rejuvenate them. Various artificial recharge measures should be tried/experimented upon, in areas where depletion of aquifers is becoming a serious problem like in Pishin Lora and Nari basin in Balochistan and Lahore area in the Punjab. Appropriate methods of artificial recharge should be identified.

Identification Of Focal-Point Organisation: A focal point organisation must be identified to monitor the progress of the implementation of strategies and their effect on overall water availability for crop use, drinking and other purposes.

Involvement of Water-User Organisations: Water User Organisations (WUOs) in irrigated areas are very effective to motivate the farmers to solve the problems related to water use because of their presence at grass root level. Their involvement in the planning, execution and management of all water-resources development projects should be ensured for sustained operation and maintenance of the projects.

Providing Farmers With Information On Water-Requirements: Dissemination of information to farmers regarding actual crop water requirements of various crops in major agro-climatic zones should be undertaken on top priority basis to avoid over and under irrigation. This will help in controlling wastage of water and overcoming problems like waterlogging and salinity.

Medium-Term Strategies (Time Frame – 3 to 7 years)

Lining Of Conveyance System: Lining of canals, distributaries and watercourses is an important option to reduce water-losses and increase water-availability at the farm gate. However, since the system conveyance-loss can be recouped in good-quality aquifers by pumping, preference should be given to lining of distributaries, minors and watercourses in saline groundwater areas.

Construction Of Storage Reservoirs: To harness and utilize water currently going waste, small dams/storage reservoirs need to be constructed. These storages could be at appropriate sites in the Northern Areas or downstream of Tarbela. WAPDA and provincial irrigation departments have already identified most of the sites and the construction of dams for development of water-reservoirs is included in their medium and long-term plans.

Identification Of Fresh Groundwater Areas: To decide on where to implement the strategy regarding preferential lining of the conveyance-system, installation of new tubewells, and regulation of groundwater, it is necessary that fresh groundwater areas be identified and mapped with regard to water-table depth, potential, and quality.

Institutional Improvements: Lack of co-ordination between line-departments at the provincial and federal level has been one of the stumbling blocks in successful and effective implementation of various strategies and projects in the water-sector. Institutional reforms for better co-ordination and management should be undertaken.

Finding And Developing New Resources: Glaciers and winter snowfall in the northern areas form an important and extensive potential source of water in the Indus River System. Experiments to harness this resource in a sustainable and environment friendly fashion, limited studies should be undertaken.

High-Efficiency Irrigation Systems: As a continuation of the short-term strategy, the high- efficiency irrigation-systems technology should be propagated and spread all over the country. The farmers will bear the full cost of systems to cover a much wider range of crops and agro-climatic zones.

Rejuvenation Of Aquifers: Application of the identified aquifer-rejuvenation methods will be done on a wide scale, besides developing efficient methods for recycling of groundwater.

Developing Drought-Forecasting Mechanism: The country is deficient in drought-forecasting methods and techniques. Models should be developed to predict the incidence of droughts for better preparedness and to plan ahead in the event of any drought calamity.

Developing Conjunctive Use Methodologies: The saline groundwater extensively available in various parts of Pakistan should be made use of, through developing conjunctive use methodologies and change of crops, etc.

Corporate Farming And Consolidation Of Land Holdings: The land-holdings in the irrigated areas are increasingly becoming fragmented, due to inheritance laws, etc., which hampers adoption of new and modern technologies. Popularising the concept of corporate farming and consolidation of land holdings is an important area for consideration.

Undertaking Watershed-Management: The heavy amount of sediment loads brought in by the feeding-streams in our reservoirs must be checked. For this, undertaking watershed-management works in catchments of existing reservoirs and planning such activities in new project as well as projects in pipeline may be ensured.

Controlling Evaporation-Losses From Reservoirs: The methods to control evaporation-losses from open water-bodies, which are huge due to the arid climate over

most of the country should be developed and the most economical methods adopted on our reservoirs.

Formulating A National Water-Policy: Despite heavy dependence on water for its economy, the country still does not have a national water-policy. This policy will be formed to form the basis for future planning, development, and utilisation of water-resources. The present document with little more work can provide the essential elements of such a policy.

Long-Term Strategies (Time Frame – beyond 7 years)

Regulatory Framework On Groundwater: Uncontrolled abstraction of groundwater has played havoc in terms of quantity and quality in the arid areas of Balochistan and parts of Punjab and Sindh. This needs to be checked through a stringent regulatory framework on groundwater-abstraction.

Construction Of Storage Reservoirs: This policy/strategy on construction of storage dams, wherever feasible, should continue to be vigorously followed on long-term basis. Sites with the possible inter-provincial conflicts should be given priority.

Improved Forecasting Of Droughts And Floods: The forecasting mechanisms for floods and droughts should be strengthened and improved, for saving precious life and property.

Resolving Water-Distribution Issues: The mechanism of water-distribution among provinces and on the field in the irrigated areas should be resolved amicably, to suit the ground situations.

Continuation Of Activities Suggested Under Medium-Term Strategies: A number of activities under the medium-term strategies will be continued during the long-term strategic plan. These are: undertaking the watershed-management activities, rejuvenating aquifers, propagation of high-efficiency irrigation systems, etc.

CONCLUSIONS & RECOMMENDATIONS

Pakistan's water-resources have been diminishing at an alarming rate, as can be concluded from the above-stated facts. The quality of water is also deteriorating with time. To improve the situation, the suggested strategies need to be implemented in an organized and coordinated way, through concerted efforts including better water-management at the field level and good-governance and institutional arrangements. The following overall recommendations are put-forth for implementation of the proposed strategies.

i) A focal-point organization at the federal-level should be identified. This organization is suggested to be the Pakistan Council of Research in Water-Resources, which has the mandate to undertake Research and Development activities in water-resources at the national level. The Council may be given the additional mandate to provide the necessary coordination between the various federal and provincial planning and executing agencies, besides providing the advisory role for implementing the proposed strategy.

ii) The planning and execution of mega-projects in the water-sector would continue to be done by WAPDA. The WAPDA continue to be the key organization for implementing the component related with the operation and maintenance of existing storage reservoirs and development of additional main reservoirs in the Indus River System.

iii) The provincial governments and its various Research and Development departments and agencies, like the On-Farm Water Management Project, the extension directorates of the Agricultural Department, will play a major role in the execution of the activities related with high-efficiency irrigation systems and lining of minors and watercourses, etc. The Irrigation Department will look after the execution of water-development projects of local and regional level like small dams and reservoirs, karez management, harnessing spring-water, groundwater regulation, and stream-flow diversions, etc.

iv) A committee of senior officers, at policy level, is suggested to oversee the detailed design and implementation of the proposed strategy as outlined in the previous paragraphs. This committee should consist of representatives of the key institutions of four ministries viz. PCRWR, Federal Flood Commission,

Pakistan Meteorological Department, Ministry of Food, Agriculture and Livestock, and the representatives of provincial irrigation and agriculture departments. The committee should hold regular quarterly meetings, to review the progress of implementation of the strategy.

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