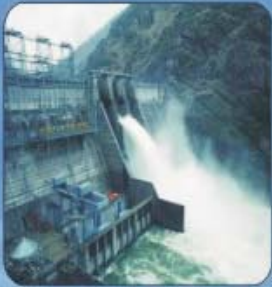


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# **Water Resources in the South: Present Scenario and Future Prospects**



Commission on Science and Technology  
for  
Sustainable Development in the South

3

COMSATS' Series of Publications on Science and Technology

# **Water Resources in the South: Present Scenario and Future Prospects**

November 2003



**Commission on Science and Technology for  
Sustainable Development in the South**

**COMSATS Headquarters**

4th floor, Shahrah-e-Jamhuriat, Sector G-5/2, Islamabad, Pakistan  
E-mail: [comsats@isb.comsats.net.pk](mailto:comsats@isb.comsats.net.pk), Website: [www.comsats.org.pk](http://www.comsats.org.pk)  
Ph: (+92-51) 9214515, (+92-51) 9204892 Fax: (+92-51) 9216539

## **PREFACE**

In order to deliberate upon the issues related to water resources, COMSATS organized a two-day meeting at its Headquarters on the 1<sup>st</sup> and 2<sup>nd</sup> November, 2001. The meeting, which was attended by eminent experts, scientists, researchers and engineers from COMSATS' member countries, focused on various crucial issues related to water-resources, and thought-provoking contributions were made during the course of the meeting.

The meeting had five technical sessions, and these sessions had a thematic sequence of topics, which included the areas of drought-preparedness and management, hydrological modeling, seawater pollution, ground-water salinity, recycling through bio-filters. In addition, various strategies for efficient management and sustainability of water-resources were discussed, and recommendations were made for potential implementation of these strategies.

This book is a selected compilation of the technical papers presented at the meeting. It is expected to be the first in a series of COMSATS' publications that we hope to bring out in the area of water-resources. This series may prove to be the right beginning in the streamlining of efforts aimed at solving water-related issues in our member countries. The references in the various articles of this book have been arranged in two systems: Numeric and Harvard Referencing Method.

I would like to thank Dr. Ishfaq Ahmad for his continued guidance and support to COMSATS over the years. He was instrumental in initiating activities related to water-resources at COMSATS, and his valuable suggestions enabled us to arrange this meeting. Our gratitude is also due to the speakers, participants and other individuals who made this meeting a success. Special credit is due to the team at COMSATS, who worked wholeheartedly in organizing this meeting and in making it a success. In this regard, special appreciation and accolades are due to Dr. M. M. Qurashi, the editor of this publication, whose unparalleled interest and direction make this a significant book vis-à-vis the importance of the subject. Last, but certainly not the least important, is the acknowledgement that is due to Mr. Salman Malik and Mr. Irfan Hayee for their valuable efforts and untiring contribution to the compilation and editing of this document.

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# **Management of Water- Resources in South Asia**

*Muhammad Hanif*

# MANAGEMENT OF WATER-RESOURCES IN SOUTH ASIA

## ABSTRACT

*The South Asian Region consists of Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and Maldives. The region has a high-altitude mountain terrain, sub-mountainous tracts, large flood-plains with a network of rivers and streams, deserts and large coastal areas. The South Asian Region has three distinct rainfall systems. Most of the rainfall is in summer (80%) and is brought by southwestern monsoon system. In winter, the rainfall is brought about by northeastern monsoon in Bangladesh / adjoining areas, and by western weather-system in Pakistan and other parts of the region. The winter rains are a very important source of water-supply for crops, as the water-scarcity peaks during this period.*

*Indus, Ganges and their tributaries mainly cover the sub continent. There are wide fluctuations in the river-flows during the year. The supplies peak up generally in the monsoon and during snowmelts (July- September) and the flows largely recede in the dry season, particularly in winter. A huge irrigation network , the world's largest, has been built on the rivers in the region. A water reservoir capacity of 248 MAF has been built in the region for a sustained production of crops. In addition, these reservoirs have provided an important opportunity in hydel power generation, fishing and ground-water recharge of the adjoining areas.*

*Groundwater is an important source of water supply. Large parts of the South Asian Region have a sweet-water aquifer. In all countries of the region, subsurface water is pumped through shallow wells or deep tubewells/ turbines, mainly for agricultural purposes. The total withdrawals of water from surface and subsurface are estimated at 772 MAF. About 90 % of the water-supplies in the region are used for agriculture and the remaining for households, industry and other purposes. Canals irrigation is mostly in the public sector and wells/tubewells are generally in the private sector.*

*The population of South Asia is 1.30 billion. The cropped area of the region is 204.8 million ha. Rice is the single predominant crop of the region, occupying 22.6% of the cropped area, followed by wheat in 14% area. Other important crops grown in the region are coarse grains, grown on 12.1% of area, pulses 10.5%, cotton 4.5%, oilseeds 4.5%, beans 3.8% and sugarcane 2.0%. The plantations such as tea, coconut and rubber, although having high commercial value, are grown on considerably smaller area.*

*About 40% of cropped area in this region is irrigated and 60% is dependent upon rains. Water requirements for the 8 important crop (grown on 74% of area) have been worked out at 1166 million-acre feet (MAF). Rice is the single largest irrigated crop (more than 90% irrigated) consuming 63 % of the water among these crops. In some countries, it is*

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## Management of Water-Resources in South Asia

*almost the only irrigated crop. Wheat is the second largest crop grown, both under rainfed and irrigated conditions. Water requirements have been estimated as: wheat 10%, coarse grains 7%, pulses 6% and sugarcane 6%. The water requirement for these five crops makes up 92% of the water requirements.*

*Prolonged dry weather, many a times, results in droughts in the region. The impact of drought is generally of universal nature, affecting vast areas in a country or the whole region. There were acute shortages of water in drought-hit areas. The crops were damaged and the pastures dried up; even drinkable water became a problem. Excessive mining of water in some areas lowered the water-table to dangerously low levels. There was massive human and livestock migration from these areas. The damage to the livestock-sector was colossal. It is proposed that the regional countries should put in place a system that forecasts droughts, assesses damages and provides relief-assistance to minimize the hardships of life. Some countries of the region have already started putting piped water-supplies and building communication-networks in these areas. The regional countries should take short and long-term measures to mitigate the affects of drought.*

*The reservoirs are useful, but there are growing concerns on building reservoirs in the countries of the region. These concerns are both national and international in character. There is a growing feeling that the reservoirs result in displacement of people/farming communities, create environmental problems and, many a times, lead to politicization of the issues. High initial capital-investment is another issue. Most of the reservoirs have watershed-management programs in the catchment areas. However, sometimes the catchment is in adjoining countries, which makes it impracticable to launch watershed programs. Once the reservoirs are built, the rapid sedimentation is a big issue and calls for appropriate policy and action plans.*

*Governments of the region need to make policies for conservation of water-resources that optimize use-efficiency. The countries of the region, in general, have agencies that have already done useful work in water-resources development, through construction of a network of water-structures such as reservoirs, dams, barrages, canals, link canals, lakes and ponds. The water-distribution systems have been geared to match water-requirements during the critical growth-stages of crops. De-silting of canals and minors and renovation of water-courses for improving water-delivery efficiency have been carried out in various parts of the region.*

*At farm level, programs have been undertaken to improve water-use efficiency, through precision land-leveling of uneven fields., sowing of crops on ridges and beds, use of pressurized irrigation-system for orchards, vegetables, floriculture and other high-valued crops. The cropping patterns are being adapted to minimize water-indent. All these works need to be furthered. Some countries of the region need to have a second look at their heavy dependence on mono-crop system of growing rice — a water-thirsty crop.*

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Figure - 1: Map of South Asia

*The statistics on subsurface water and from glacier melts, many a times, are inadequate or faulty and the countries of the region need to improve it for planning purposes.*

*Most of the rivers and creeks in their upper reaches have good-quality water. As water flows down-stream, the industrial and urban effluents load this water with heavy metals, injurious chemicals and biological pollutants. Cases of ill health, through pollution of drinkable water, have been reported in Pakistan and other countries. Iron and nitrate pollution has been noticed in Sri Lanka. The salinization of subsurface water, through intrusion of seawater, has been reported in India, Pakistan, Maldives and Sri Lanka in the coastal areas. This is an area that needs attention of the Governments in the region, in the context of appropriate legislation and implementation of sound environmental policies.*

*Over the last two decades, there is a growing participation of the farming communities in water resource development, distribution and on-farm water-management programs, in the countries of the region. Water-users' associations have been organized and actively involved in the planning and development programs of water-sector in agriculture. These farmers' organizations can be further involved in transforming agricultural/rural scenarios.*

*The studies carried out in countries of the region indicate that large O & M costs are being incurred on irrigation networks by maintaining them in public sector. At least part of this expenditure can be minimized through participation of farmers in maintenance of these canals. The subsidies on irrigation lead to an inefficient water-use. The Governments can have a second look on this issue.*

## **Management of Water-Resources in South Asia**

### **INTRODUCTION**

South Asian Region consists of Pakistan, India, Nepal, Bhutan, Bangladesh, Sri Lanka and Maldives. The map of the region is given in Figure-1. The region has high- altitude mountain terrains, sub–mountainous tracts, large flood-plains, with a network of rivers and streams, deserts and large coastal areas. The famous Indus and Gangetic civilizations thrived and prospered in this region.

Agriculture has been the main pursuit in the region since human civilization began. Land and water have been the primary resources for this activity since primeval times. Initially, the human settlements were built near the water-bodies, like rivers and lakes. Human beings learnt from experience that water is a basic input in raising crops. Agriculture continued to be mainly carried out under rain-fed conditions. Irrigated agriculture started much later.

As primary structures, wells and karezes (sub-surface irrigation ditches) are known to have been built in various parts of the world, including South Asia. These Structures helped an assured production of crops and also helped to raise farm-productivity. With expansion in human population, the land and water-resources came under pressure. The disasters, like drought, disease, insect hazards (locust and others), resulted in crop damages, many a times leading to famines. In addition, the process of degradation of land and water-resources, through salinization, water-logging, industrial effluents and other environmental hazards, is an on-going process and is a major threat to agriculture. There is a need for a judicious management of these scarce resources.

A number of efforts were initiated in the South Asian region, particularly during the last millennium, for the proper management/use of land and water-resources. This becomes more demanding at a time when large fertile tracts of agricultural land are falling victim to rapid industrialization, urbanization and other non-farm uses. Similarly, management of water-resources is of prime importance for fostering activities of agriculture sector on commercial lines.

### **SOUTH ASIAN SCENARIO**

#### **Population**

The population of the world in 1998 was 5.98 billion, Asia 3.63 billion and South Asia 1.30 billion. The population of South Asia was 21.7 % of the world population and 36.0 % of Asian population. The data is as in Table-1.1.

The world has a population of 43% engaged in agricultural discipline. However, Asian involvement in agriculture is 53% and South Asia 56%; Bhutan and Nepal have more than

Table - 1.1: Population (million)

Category	Total	Agricultural	% in Agriculture
World	5,978.40	2,575.50	43.08
Asia	3,634.30	1,956.50	53.83
South Asia	1,309.40	735.70	56.18
Bangladesh	126.90	72.00	56.74
Bhutan	2.10	1.90	90.48
India	998.10	553.20	55.43
Maldives	0.3	0.08	26.67
Nepal	23.4	21.8	93.16
Pakistan	140.0	78.0	55.71
Sri Lanka	18.6	8.7	46.77

Source: FAO Production Year Book, 1999

90% of their population in agriculture sector. The Maldives, on the other side has less than the South Asian %age population engaged in agriculture sector.

### Land

The cropped area of the world is about 1512 million ha. The cropped area in Asia is 557.6 million ha and South Asian cropped area is 204.8 million ha. This makes 12.6 % of the world-cropped area and 36.7 of the Asian cropped area. The cropped area in South Asia is 40% irrigated (82.6 million ha) and 60 % rainfed (122.2 million ha). The per-head cropped

Table - 1.2: Area Profile of South Asian Countries

Category	Land Area	Cultivated Area	Irrigated Area	Per-head Cropped area
Unit	(000) Ha	(000) Ha	(000) Ha	Ha
World	13,048,407	1,511,964	271,432	0.25
Asia	3,085,414	557,633	191,171	0.15
South Asia	412,917	204,810	82,631	0.16
Bangladesh	13,017	8,774	3,844	0.07
Bhutan	4,700	160	1	0.08
India	297,319	169,500	59,000	0.17
Maldives	30	3	-	0.01
Nepal	14,300	2,968	1,135	0.13
Pakistan	77,088	22,050	18,000	0.16
Sri Lanka	6,463	1,888	651	0.1

Source: FAO Production Year Book, 1999.

## Management of Water-Resources in South Asia

area in the world is 0.25 ha and in Asia only 0.15 ha. The cropped area per head is 0.16 ha in South Asia. The detailed data is as in Table-1.2.

### Important Crops in South Asia

The cultivated area in South Asia is 204.8 million ha. Extrapolating through a cropping intensity of 130 % from Indian cropping pattern (largest crop-machine in the region) for the South Asian region, the cropped area works out to be 266 million ha.

Eight important crops grown in the region are rice, occupying 22.6% of the cropped area, wheat 14%, coarse grains 12.1%, pulses 10.5%, cotton 4.5%, oilseeds 4.5%, beans 3.8% sugarcane 2.0%, and other crops 26 % of the cropped area. The data is shown in Table-1.3.

Table - 1.3: Area under important crops in South Asia (million ha)

Country	Wheat	Rice	Coarse grains	Cotton	Sugar cane	Pulses	Oil seeds	Beans	Total
Bangladesh	0.85	10.50	0.00	0.00	0.17	0.67	0.50	0.00	12.69
India	27.40	44.80	29.40	9.00	4.15	25.30	10.50	9.90	160.45
Nepal	0.64	1.52	1.10	0.00	0.00	0.30	0.00	0.04	3.60
Pakistan	8.30	2.40	1.80	3.00	1.10	1.71	0.90	0.25	19.46
Sri Lanka	0.00	0.82	0.00	0.00	0.00	0.05	0.00	0.03	0.90
<b>Total</b>	<b>37.19</b>	<b>60.04</b>	<b>32.30</b>	<b>12.00</b>	<b>5.42</b>	<b>28.03</b>	<b>11.90</b>	<b>10.22</b>	<b>197.10</b>

### Water Requirements of Important Crops

In South Asia, the crops are grown both under irrigated and rainfed conditions. It is little difficult to work out the exact requirement to be supplemented to the crops through the irrigation-network, in addition to rains. However, in the background of requirement of crops in Pakistan, the water requirements have been worked out for the 8 important crops at 1166 million-acre feet (MAF). About 63.6 % are required for rice alone; wheat 9.8 %, coarse grains 6.8%, pulses 5.7 %%, sugarcane 5.9 %. The water-requirement for these five crops makes 92 % of the water requirements depicted in the following Table-1.4.

## COUNTRY PROFILE

The water resource profile of the South Asian Countries is as follows:

### BANGLADESH

The cultivated area of Bangladesh is 8.8 million ha. The country has a high density of

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Table - 1.4: Water Requirements of Important Crops

Crops	Area	Water Requirements	Total	% Share
<i>Unit</i>	<i>Million ha</i>	<i>Acre inches*</i>	<i>MAF</i>	
Wheat	37.19	15	114.9	9.8
Rice	60.04	60	741.8	63.6
Coarse grains	32.3	12	79.8	6.8
Cotton	12.00	16	39.5	3.4
Sugarcane	5.42	60	67.0	5.7
Pulses	28.03	10	69.3	5.9
Oilseeds	11.90	12	29.4	2.5
Beans	10.22	12	25.3	2.2
<b>Total</b>	<b>197.1</b>	<b>29</b>	<b>1166.9</b>	<b>100</b>

*\* By Pakistan standard*

population of 834 inhabitants per km<sup>2</sup>. The average holding per farm household in 1983 was 0.9 ha. Nearly 24 per cent of farm households own less than 0.2 ha and another 46 per cent own up to 1.0 ha. Agriculture is mainly carried out under conventional subsistence-farming practices. Rice is the main crop, occupying an area of 10.5 million ha, which makes 90 % of the area under cereal crops. Other important crops grown in the country are pulses, oilseeds, jute and sugar cane. Recently a plan has been prepared to introduce and expand cotton-production in the country to meet domestic requirements and to sustain the exports of garments and other textile made ups.

Bangladesh has a tropical monsoon climate. About 80 per cent of the total rainfall occurs in the monsoon and the average annual rainfall over the country is 2320 mm. Being a deltaic country, cyclone cause heavy damage to the agricultural economy and structures. Floods, cyclones and droughts are a common feature of the climate pattern in Bangladesh. There are wide annual variations in rainfall and temperature throughout the country.

Ganges, Brahmaputra and Meghna, and their tributaries cover the flood plains of Bangladesh. The total dam capacity is 17.3 MAF. In addition, there are three barrages across the Teesta, Tangon and Manu rivers that are used as diversion structures for irrigation purposes only. In 1990, the total water withdrawal for agricultural, domestic and industrial purposes was estimated at about 12.4 MAF. ,of which agriculture makes 86%, the domestic industrial sectors make 14%. The requirement of navigation and fisheries is estimated at 8.5 MAF. Approximately 73 per cent of the total water-withdrawal comes from groundwater.

## **Management of Water-Resources in South Asia**

In Bangladesh, irrigation through major canals covers only 6 per cent of the total irrigated area, the remaining being classed as minor irrigation consisting of low lift pumps, shallow tube-wells, deep tube-wells. Government's main emphasis in Bangladesh is the expansion of small-scale irrigation.

At present, irrigation is practiced for rice (71 per cent) and wheat (9 per cent), which together occupy 80 per cent of the irrigated land. Irrigation is mainly used in the dry season.

Because of its low-lying topography, about 22 per cent of the area of the country are flooded each year. Flood control and drainage are used to reduce the depth of flooding or eliminate, through 'controlled flooding' high and untimely floods in order to provide greater security for crop production.

Water-management and flood-protection occupy a pivotal position in the planning process of Bangladesh. The major emphasis in Bangladesh is on the following issues:

- Improving use efficiency of existing facilities with an effective O&M;
- De-Silting of rivers and channels;
- Integrated flood control / drainage;
- Participation of water-users in the planning and design of new irrigation/drainage projects.

## **BHUTAN**

Bhutan is a Himalayan country with a rugged mountain terrain. Climate ranges from hot and humid subtropical conditions in the south to the incessant ice and snow in Himalayas.

The only dam in the country is the Chukka hydropower dam. Most rivers are deeply incised into the landscape, a fact that greatly limits the possibilities for run-of-the-river irrigation. The total water-withdrawal was estimated at 16.2 thousand-acre feet in 1987.

The cultivated area in Bhutan is 160 thousand ha. Out of this, about 1 thousand ha are irrigated and rest is dependent upon rains. The irrigated area is mostly under rice crop.

The irrigation-management strategy mainly focuses on:

- Sustainable improvements in water-delivery and use-efficiency;
- Diversifying the range of irrigation from mono-cropped rice system to multi-crop system;
- Increasing the role of water-users and the private sector, and to reduce recurrent government investments in irrigation schemes.

## INDIA

The total cultivable area of India is estimated at 169.5 million ha, or about 57 per cent of the land area. The cropping intensity is 130 per cent. The major cereals grown in India are wheat, rice, and coarse grains. Ninety one per cent of the farmers have land holdings less than 4 ha. The average farm size is estimated at 1.57 ha.

The rainfall in India is brought about by the monsoon system and western disturbances. The average rainfall is 1170 mm. There are places, which get world's highest rainfall of 12,500 mm. On the other extreme, there are places like Rajasthan, Gujarat, Saurashtra and Kutch, which get less than 150-mm rainfall. Most of these areas have undergone extensive drought conditions, with massive human and livestock migration. This called for an intervention from the Government to address the drudgeries of masses in these areas. Temperature variations are also marked.

The major sources of water in India are rainfall and the glacier melts. The total surface flow, including groundwater is 1570 MAF. Out of this 587 MAF are utilized. The total water-storage capacity constructed up to 1996 was of the order of 212 MAF. In 1990, the total water-withdrawal was estimated at 425 MAF, of which 92 per cent was for irrigation purposes.

India has the largest irrigated area of the world, size of the irrigated area is 59 million ha. Irrigation is mainly concentrated in the north of the country, along the Indus and Ganges rivers.

Uttar Pradesh (22 per cent of the irrigated area), Rajasthan (9 per cent) Madhya Pradesh (9 per cent) and Punjab (8 per cent) Liberal subsidies on electricity and its abundant supplies has helped to foster both production and productivity of crops. This situation has resulted in huge inefficient use of water at the farm.

The average overall water-use efficiency in canal irrigation systems is estimated at 40 per cent. Water-rates are uniform throughout the state in Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh and West Bengal. However, in Bihar, Haryana, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Tripura and Uttar Pradesh, the rates vary within the state from region to region or project to project.

The water-rates are higher for storage-systems than for flow-diversion schemes. Similarly, the rates for canal-lift irrigation are generally higher (double) than flow-irrigation when water lifting is undertaken by the Government bodies. The development of sprinkler and drip-irrigation is likely not to pick up in various states of India particularly in view of free or subsidized electric tariff. However, India is providing subsidy to promote drip irrigation.

## **Management of Water-Resources in South Asia**

A number of Indian states in recent years are cutting down or partially withdrawing subsidies. This is likely to promote the efficient use of pressurized irrigation systems. However since India does not have compulsion from the donor-agencies, it may take considerable time before the efficient use of water accelerates. The area under drip-irrigation is mainly concentrated in Maharashtra, Andhra Pradesh and Karnataka. The drip-irrigation is mainly followed on high-value horticultural crops/orchards.

Drainage works have been undertaken on about 5.8 million ha, which is 12 per cent of the irrigated area. In addition, 3.1 million ha are affected by salinity and about 0.24 million ha by alkalinity. These figures however seem gross under estimates.

Indian irrigation is dominated by the public sector. The O&M of most schemes require public sector involvement. India adopted a national water-policy in 1987 for the planning and development of water-resources. It emphasizes the need for river basin planning. Water allocation priority has been given to drinking water, followed by irrigation, hydropower, navigation and industrial or other uses in the order. All the states are required to develop their state water-policy within the framework of the national water-policy and, accordingly, set up a master plan for water-resources development.

All rivers in their upper reaches have good quality of water. Like elsewhere, the deterioration in quality of water starts downstream through domestic, industrial and agricultural pollutants. These pollutants also affect groundwater. The mining of groundwater in drought-hit states has resulted in lowering of water-table in large number of Indian States to very low levels. This is mainly because of the conditions of non-recharging of water in current drought conditions that forced a large number of the farming communities to migrate from water-starving areas to water sanctuaries. Indian policy of providing heavy subsidy on electric tariff has also been responsible for this situation.

## **MALDIVES**

The total cultivated area of Maldives is estimated at 3000 ha. Permanent crops as coconut and aeronaut are grown on an area of 2000 ha and annual field-crops as maize, sorghum, cassava, onion and chilies are grown on an area of 1000 ha.

The islands have a tropical climate with two monsoons, which are:

- The southwest monsoon from May to September;
- The northeast monsoon from November to March.

The precipitation is uniformly distributed between April - December. The January – March is a dry period. The mean annual rainfall is 1883 mm. The islands do not have any rivers. Rainwater is collected through water-harvesting on a small scale and used for drinking



purposes. Maldives finds it extremely difficult to obtain suitable drinkable water. Three desalination plants are in operation, with a total production of 1000 m<sup>3</sup>/d.

## NEPAL

Nepal is a land locked Himalayan State located entirely in the Ganges basin. The cultivable area of Nepal is estimated at 2.96 million ha. One third of this area is in the Terai plain, 8 per cent in the Siwalik, 48 per cent in the mountain and hill region and 10 per cent in the high Himalayas. Agriculture contributed 40 per cent of GDP in 1996 and employed more than 93 per cent of the economically active population of the country. The main agricultural exports are rice, pulses and jute.

The mean annual rainfall is 1500 mm. There are two rainy seasons in Nepal: one in the summer (June to September) when the southwest monsoon brings more than 75 per cent of the total rainfall, and the other in winter (December to February) accounting for less than 25 per cent of the total. The summer monsoon-rain first falls in the southeast of the country and gradually moves westwards with diminishing intensity. This results in more rainfall in the east of the country. During winter, rainfall is brought about by westerly disturbances.

All rivers in Nepal drain into the Ganges River. The country is divided into five river basins, which are from west to east. The seasonal distribution of flow is extremely variable. The flows in rivers, both from rains and snow-melt greatly recede during January – March period. This situation improves during July – August period as snowmelt and rainfall picks up.

The surface-water resources produced internally are estimated at 168 MAF water. The groundwater-resources have not been fully assessed. The Terai and some parts of the Siwalik valley have sweet-water aquifers. A rough estimate is made by assuming a groundwater-resource equivalent to ten per cent of surface-water, i.e. approximately 17 MAF. This makes Nepal one of the Asian countries with the highest level of water-resources per inhabitant.

The total dam-capacity of Nepal is 69 thousand-acre feet. This is a small fraction of the potential dam-capacity of 117 MAF. The irrigated area in Nepal is 1.14 million ha. Irrigation is mainly done by flooding. Ninety one per cent area is dependent on surface-water and 9 per cent on groundwater. The Department of Irrigation is responsible for the management of the irrigation programs. The main irrigated crop is paddy in summer, followed by wheat crop in winter.

## Management of Water-Resources in South Asia

### PAKISTAN

Rainfall activity over Pakistan occurs mainly in two distinct periods, namely summer (June to September, the monsoon season) and winter (December to March). More rains fall during the monsoon season than during the winter season.

The annual flow of water in the Indus River system, on an average, is 140 MAF. The flow during summer is 118 MAF (84%) and in winter is 22 MAF (16). Indus is the Main River contributing 65% of water supplies, with Jhelum giving 17% and Chenab 19%. In the light of Indus-Basin Water-Treaty, Pakistan has built a series of link canals to divert water from the western rivers, to provide water to the Southern Punjab. Pakistan has built a reservoir capacity of 18 MAF water to cater for the needs during periods of scarcity, mainly winter crops. About 4 MAF capacity has already been reduced through sedimentation. The alluvial plains of Pakistan have a sweet-water aquifer of 50 MAF. Out of this, 40 MAF is being exploited through 600,000 tubewells mainly in private sector. The availability of water in Kharif is 77 MAF and Rabi 56 MAF, making total water supplies at 133 MAF.

Under On-Farm Water-Management Program, 45 thousand watercourses have been improved, out of a total of 120 thousand watercourses. A follow-up program, pursuant to improvement of watercourses to improve water-use efficiency was carried out at farmer's fields. Technologies are disseminated to Farmers on laser-leveling of fields, sowing of crops on beds and furrows, zero tillage, inter-cultural practices and balanced application of fertilizers. This helps to raise the productivity of crops and living standards of the farming community. The pressurized irrigation system e.g. sprinkler and trickle irrigation system, were introduced for high-value crops viz. orchard and vegetables. This system is particularly good for areas with an uneven topography, particularly in rainfed areas. The initial investment is very high/prohibitive and poor farming-communities, especially in drought hit Balochistan and other places, cannot afford such a high capital investment. Another problem with the pressurized irrigation system is that most of the materials are imported. Local initiatives have been taken recently, which are of infinitesimal nature. There is a need for inducting the private-sector in this area, assuring competitive and cost-effective supplies of the pressurized-irrigation materials to the interested farmers.

Rod Kohis are hilly valleys, where hill-torrents move at a rapid pace and result in soil erosion and damage to standing crops. Primarily, the structures in these areas are built to slow down the speed of the torrents. Research is underway to investigate practices and package of technology to minimize the farm-losses to soil and crops.

As water-resources are under high pressure, the Ministry of Food and Agriculture is in the process of promoting cropping pattern/production practices that minimize the requirements of irrigation-water, without compromise on farm-productivity/profitability.

A flow of 10 MAF is required to maintain ecology in the deltaic region and to avoid intrusion of sea water. There was not much water available for the purpose during the drought encountered over the last three years. As a result, the seawater intruded, causing damage to farmlands.

## **SRI LANKA**

Sri Lanka receives rainfall mainly through two monsoons. The rainfall-intensity varies markedly across the island. Based on rainfall, several agro-climatic regions (wet zone, intermediate zone, dry zone and arid zone) can be recognized. There is considerable variation around the mean annual rainfall of 2000 mm. The highest rainfalls are in the central highlands.

Groundwater resources have been extensively used. Sri Lanka's largest aquifer extends over 200 km in the northwestern and northern coastal areas. There are about 15000 tube-wells in the country. The quality of the groundwater is generally fairly good and relatively constant throughout the year. However, in some parts of the country (northern and northwestern coastal areas) excessive concentrations of iron and nitrates (due to agro-chemicals and fertilizers) have been reported. Furthermore, due to uncontrolled extraction of groundwater for domestic and agricultural uses, intrusion of brackish water has occurred in the coastal areas.

Groundwater is an important source of water for irrigation and domestic use. It is increasingly used as drinking water, especially in small towns and rural areas. The total water-demand is estimated to be 9.3 MAF. Of this, 90 per cent is for agriculture, 7 per cent for domestic purposes and 3 per cent for industrial purposes.

The total cultivated area of Sri Lanka is 1.9 million ha. Out of this 0.7 million ha are irrigated and rest is dependent upon rains. Of this cultivated area, 1 million ha are under permanent crops such as tea, rubber and coconut. Annual crops viz. paddy, sugar cane, maize, green gram, green chilies and cowpeas, are grown on 0.9 million ha. The irrigation systems in Sri Lanka are designed mainly for paddy (0.8 million ha) cultivation. Other irrigated crops are chilies (15000 ha), sweet potato, banana and green gram.

In Sri Lanka, irrigation-schemes can be classed as minor, medium or major, depending on the area they serve. Minor schemes provide facilities for less than 80 ha. In 1995, they served about 200 000 ha. Medium schemes provide facilities for areas of 80-400 ha. In 1995, they served 61 000 ha. Major schemes provide facilities for more than 400 ha. In 1995, they served 309 000 ha.

## **Management of Water-Resources in South Asia**

Storage schemes have two purposes: storage and flood control. Water is impounded in these tanks by building dams across valleys, and then released when required to service downstream areas.

Diversion weirs, commonly called anicuts, are constructed in perennial streams in the wet zone, to convey water to the fields below. In the wet zone, flood-control and drainage schemes have been incorporated into the irrigation-system mainly in the lower reaches of rivers. In the coastal areas, saltwater exclusion schemes have been commissioned where water salinity affects the agriculture. Flood bunds and pumps are the main features in flood-protection schemes, whereas gated regulators are adopted in saltwater-exclusion schemes.

Lift-irrigation schemes, with mechanically or electrically operated pumps, have been introduced recently to irrigate the highlands. It is estimated that around 1000 ha are irrigated by groundwater-wells.

In 1980, an attempt was made to establish a water-tax. However, this attempt failed because of the political unrest in the 1980s. Irrigation development, O&M and rehabilitation have been predominantly state activities. The participation of water-users has been adopted in irrigation schemes in recent years. A Water Resources Council has been established in Sri Lanka, to oversee the implementation of the action-plan of water management.

## **ISSUES AND OPPORTUNITIES FOR SOUTH ASIA**

### **Climate**

The climate is the biggest factor affecting availability of water. The South Asian Region has two distinct rainfall systems. In summer, the southwestern system brings rainfall to this region. In winter, Bangladesh and adjoining areas of India get rainfall from the North Eastern monsoon system. Pakistan and other parts of the region get rainfall from the western weather system. La-Nina (dry spell) and El-Nino (wet spell) are the two distinct phenomena that effect the availability of water extraordinarily. The details are as follows:

*a. La-Nina:* This is a situation of low or no rainfall resulting in drought. The South Asian Region suffered from this phenomenon during last 3-4 years resulted in a drought in the region, severely affecting the economy of the countries in the region.

The effects of drought are of universal nature, affecting vast areas in a country or the region. There were areas in the region, particularly in arid and semi-arid climate, where there was acute shortage of water. In these areas, the crops were damaged. The pastures dried up. Even drinking water became a problem. There was massive human and livestock

migration. The damage to the livestock was substantial. A large number of crops, especially in rainfed area were damaged, affecting the GDP. The farmers' incomes were also affected and the ambit of poverty widened.

The farmers in these areas, where feasible, pumped excessive quantities of water from the sub-surface, disturbing the ecosystem. This lowered the water-table depth to dangerously low levels, as there was no recharging system available to recoup the aquifer. This chain of events led to a vicious cycle of poverty. The countries of the region are massively involved in mitigating the effects of drought from the destitute and poverty stricken masses in the affected areas. The following short and long-term measures are proposed for drought hit areas:

#### *Short-Term Measures*

- The Governments should assess the extent of damage/likely damage and declare affected areas as calamity-hit, to cope with the extra-ordinary situation.
- The Governments should provide a relief package, providing food for the human being and feed/fodders for the animals.
- Vaccination programs may be carried out for livestock.
- The elite animals of good breeds of livestock may be taken to sanctuaries, to avoid the risk of loss of such breeds.
- Governments may provide credit-line, to enable the farmers to buy seeds, fertilizers, bullocks, farm machinery and farming inputs.

#### *Long-Term Measures*

- Governments should undertake to build up water-supply schemes in the desert/affected areas, through arranging pipeline supplies in remote water-deficit areas.
- Build up a network of roads, to facilitate the movement of goods and relief supplies in the drought-stricken areas.
- The scientists should come up with a package of crop-production practices and technologies that are low water-requiring, particularly crop-varieties that have less thirst for water.

*b. El-Nino:* This is a situation of high rainfall, often resulting in floods. The effects of floods are localized in nature and show a corridor effect, around the inundating creeks and rivers. The coverage of floods is not of the same large dimension as in droughts. The floods are quite common in the countries of the region and damage standing crops, households, farms, irrigation structures and communication links. The opportunities for a solution to this type of situation are proposed as follows:

## **Management of Water-Resources in South Asia**

- On short-term basis, the Governments may provide relief to the affectees and take other appropriate measures, as reported earlier.
- On long-term basis, the Governments should plan for mitigating the effects of floods, through building of structures and reservoirs to pond the water overflowing from the banks of rivers and creeks. Sri Lanka has successfully diverted floods through building such structures.

## **River System**

The region has a network of rivers and streams in almost all the countries. The rainfall and the snowmelt from the glaciers are the two sources of water-supply in these rivers.

There is a wide fluctuation in the river-flows during wet and dry seasons of the year. The supplies peak up generally in monsoon and during snowmelts (July- September) while the flows recede in dry season, particularly in winter. This situation calls for a judicious management of water-resources for raising crops during periods of scarcity, particularly winter crops. The rivers need to be tamed through construction of control-structures and water-reservoirs to offset the shortages in times of scarcity.

## **Water-Reservoirs**

To tame the rivers, there is a necessity to build up water-reservoirs on the river systems. A large number of such reservoirs have already been built in various countries of the region, with a reservoir capacity of 248 MAF. These reservoirs are useful for a regular supply of water during periods of scarcity, for sustained production of crops.

In addition, these reservoirs have provided an important opportunity in hydel-power generation, fishing and a ground-water recharge of the adjoining areas. The situation has helped to raise farm-incomes and eradicate poverty.

The region has a huge potential for building additional storage-capacity. However, there are inter-country conflicts on building of these reservoirs. Even within countries, many a times, there are problems in construction of these reservoirs. There is a growing feeling that the reservoirs result in displacement of people/farming community, create environmental problems and, some times, lead to politicization of the issues. High initial capital investment is another issue. Most of the reservoirs have watershed-management programs in the catchment areas. However, sometimes the catchment is in adjoining countries, which makes it impracticable to launch watershed programs. Once the reservoirs are built, the rapid sedimentation is a big issue and calls for appropriate policy and action plans.

## **Groundwater**

The groundwater involves aspects of quantity and quality of subsurface water for human use and agricultural purposes. The South Asian Region has a good sweet-water aquifer. In addition, it has a large brackish subsurface-water profile.

Almost in all countries of the region, the supplementation of canal-water irrigation through subsurface water supplies is quite common. This water is pumped through shallow wells or deep tubewells or turbines for industrial, potable and agricultural purposes. A large number of these irrigation-programs are in both public and private sector. Some countries of the region have already handed over the public-sector tubewells to the benefiting water-users.

Recharging of the subsurface water-aquifer is highly important to keep the pumping of water continued from this subsurface layer. However, the countries of the region in some areas have suffered in water-recharging programs on the following accounts:

- a. Drought affected the rainfall and water-balance.
- b. Subsidies in some countries on electric tariff and irrigation-equipment promoted in efficient use. There is a need to minimize/withdraw these subsidies, to optimize water-use efficiency and to ensure that (inefficient) mining of water does not continue.

Water recharging is important for the countries of the region, especially in the arid and semi-arid areas where water depth has been lowered substantially, in much case to 40-50 feet deep. In some places, the farmers have been mining fossilized water from depths of 800-1000 feet. This water has been used to grow crops which unfortunately did not fetch good prices in some years, inflicting huge losses to the farm economy. This is a classical case of onion-production in Balochistan, Pakistan. Such situations are quite common in other countries of the South Asian Region. Governments of the region need to make policies for conservation of water-resources that optimize use efficiency.

## **Institutional Development**

There is a need to assure that proper institutions are in place to carry out the various activities concerning water-resource development, distribution and on farm water management.

### *a. Water-Resources Development*

The countries of the region in general, has already established, agencies that have complete water-mapping of surface-water available in various parts of their country. These agencies have already done useful work in water-resources development, through

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## **Management of Water-Resources in South Asia**

construction of a network of water-structures, such as reservoirs, dams, barrages, canals, link canals, lakes and ponds. These agencies in the regional countries, in many cases have information on potential sites to meet a century's requirements of building water-reservoirs.

The estimation of subsurface water and water-supplies from glacier-melts, however, have not been adequately quantified in some countries and this need to be carried out for better planning and utilization of water resources. The responsible institutions for development of resources need to be strengthened through providing financial and technical backstopping.

### *b. Water Distribution-System*

A number of the countries of the region have established a scientific water-distribution system to meet requirements of water for crops. The drought over the last 3-4 years has given very good learning experiences on judicious water-use system. The Agricultural and Irrigation Departments were able to develop schedules for water-distribution system, depending upon crop-needs. This has helped to mitigate the ill affects of water-supplies, without much effect on productivity of crops. One classical example is the wheat crop of 21 million tons in Pakistan during 1999-2000 and 19 million tons in 2000-01, despite a water shortage of 40% during the early period of wheat crop and 60-70% during earring and grain formation stages. At the beginning of the wheat-crop season, Pakistan Irrigation Department, in consultation with Agricultural Departments, was able to rotate the water-supply in canals. In spring 2001, when shortages further worsened, the canal-supply was restricted to areas that had subsurface brackish water, so that farming/ rural communities may get drinking water. The strategy has helped Pakistan. Despite a very bad year, Pakistan has sufficient stocks of wheat for domestic consumption. It has already exported 0.7 million tons of wheat and has in pipeline, a supply of additional one million tons of wheat for export. This is a lesson repeated in some other countries of the region also that a judicious management of water-resources can help to avert disasters in agricultural sector, particularly crops.

### *c. Water Conservation*

The Governments should aim at conserving the soil and water-resources to maximize the efficiency of use.

## **Water Delivery-System**

The studies carried out by various institutions in Pakistan show that the water-losses in delivery from canal to watercourse outlets are about 40 % on an average. An equal amount of water is lost in the century-old watercourses. There is a need to minimize these losses in water-delivery through:

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- Desilting of canals and minors.
- Renovation of water-courses, through brick lining and earthing improvement.

Pakistan and other countries of the region that are conscious of this situation have already launched on-farm water management programs, in the context of their farming situations. The countries of the region need to take up crash water-management programmes, so as to quickly renovate water-delivery system, to improve efficiency of delivery.

### **On Farm Programs**

A large number of fields are so uneven that the result is unequal distribution of water applied, patchy germination and poor crop-stands. There is a need for improving water-use efficiency at the farm, to maximize productivity of crops. The following programmes are being followed in Pakistan and some other countries of the region, to optimize water at the farm:

- Precision leveling of land, in uneven fields.
- Sowing of crops on ridges and beds.
- Use of pressurized-irrigation systems for orchards, vegetables, floriculture and other high-valued crops.

Some countries of the region have used subsidies to promote use of drip and trickle-irrigation systems. This generally leads to more efficient utilization of the scarce farm-resources.

### **Cropping Patterns**

South Asia mainly grows crops with high water-requirements such as rice and sugarcane. Out of a total cultivated area of 204.8 million ha area under crops in South Asia, 60.04 million ha are under rice crop alone. This far exceeds the area under any other crop. Some countries have almost one irrigated crop, rice. Another high water-requiring crop is sugarcane that covers 5.42 million ha in the region.

As drought is a frequent visitor to this region, it is advisable that regional agricultural institutions may focus on promoting cropping-patterns that minimize water-use for agricultural purpose. In Pakistan, the crop-substitution program includes persuading farmers not to grow rice in cotton zone. Similarly, the sowing of sugarbeet is being promoted to replace high water-requiring sugarcane.

Scientists in Pakistan are now focussing on reducing the sowing time of cotton from 150 days to 120 days. The curtailment in growing period will help to save one irrigation. The scientists also need to focus on other crops and should try to replace long period cultivars with short duration cultivars.

## **Management of Water-Resources in South Asia**

### **Water Pollution**

Most of the rivers and creeks in their upper reaches have good-quality water. As water flows downstream, the industrial and urban effluents load this water with heavy metals, injurious chemicals and biological pollutants. The quality of ground-water is also deteriorating rapidly. Cases of ill effects of such industrial effluents have been reported in Pakistan and other countries of the region. In Sri Lanka, the pollution with iron and nitrates has been reported. The salinization of subsurface water, through intrusion of seawater, has been reported in some countries of the region in coastal areas. This is an area, that needs the attention of the Governments in the region, in the context of appropriate legislation and implementation of sound environmental policies.

### **Participation of the Farming Communities**

Over the last two decades, in the countries of the region, there is a growing involvement of the farming communities in water-resource development, distribution and on-farm-water management programs. Water users' associations have been organized and are actively involved in the planning and development programs of the water-sector in agriculture. These farmer organizations can be further involved in transformation of agricultural rural scenarios.

### **Pricing of Water**

The studies carried out in countries of the region indicate that large O & M costs are being incurred on irrigation-networks by maintaining them in public sector. At least part of this expenditure can be minimized through participation of farmers in maintenance of these canals. The studies carried out by IWMI in Pakistan and other countries of the region indicate a successful experiment. It has been demonstrated that farmers can maintain canals and water-distribution systems, quite efficiently. This can be followed up further. The rebate on electric tariff and installation of tube-wells generally leads to their inefficient use. All such concessions and subsidies need to be withdrawn, for conservation of water-resources and their efficient utilization.

### **ACKNOWLEDGEMENT**

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# **Water-Resources Situation in Pakistan: Challenges and Future Strategies**

*M.A. Kahlowan and Abdul Majeed*

## **WATER-RESOURCES SITUATION IN PAKISTAN: CHALLENGES AND FUTURE STRATEGIES**

### **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 article takes stock of the present situation of water-resources, present needs and future requirements and 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*

## Water-Resources Situation in Pakistan: Challenges and Future Strategies

*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%. Agriculture is the major user of water, and 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<sup>3</sup>); below 1,000 m<sup>3</sup>, countries begin experiencing chronic water stress (Population Action International, 1993). Table-1 gives the comparison of per-capita water-availability upto the year 2025 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.

**Table - 1: Per Capita Water-Availability in Selected Countries (m<sup>3</sup>)**

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*



Figure - 1: Indus River System

## 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

## Water-Resources Situation in Pakistan: Challenges and Future Strategies

**Table - 2: Inflows in Western Rivers (in MAF)**

	<b>Kharif</b>	<b>Rabi</b>	<b>Total</b>
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
<i>Source: WAPDA and IRSA reports</i>			

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

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 sites. Out of this, almost 60 per cent can be developed for crop production. This

**Table - 2(a): Provincial Water Developmental Potential**

<b>Province</b>	<b>Water Development Potential (MAF)</b>
Punjab	2.7
NWFP	7.3
Balochistan	7.86
Sindh	0.78

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



## Water-Resources Situation in Pakistan: Challenges and Future Strategies

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 target, on the surface, may not look so demanding, as the country is bestowed with enough fertile

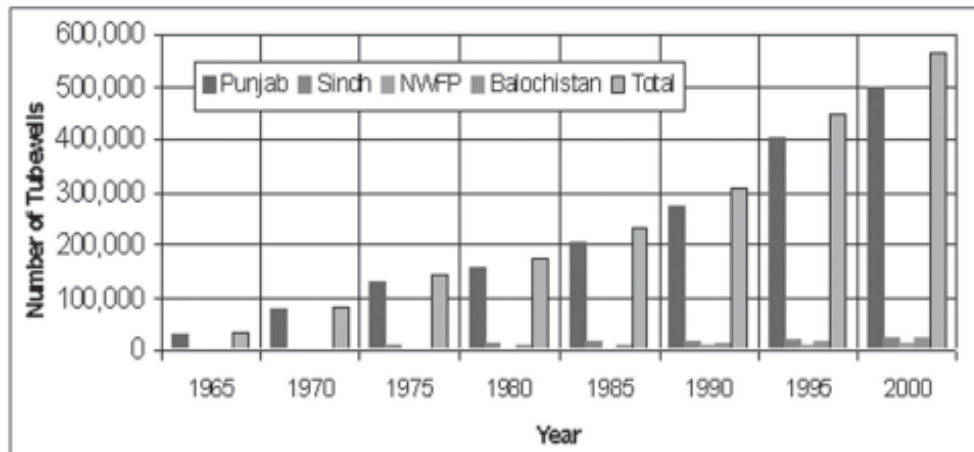


Figure - 2: Growth in Number of Tube Wells

**Table - 3: Agricultural Water Demands (MAF)**

<b>Crops</b>	<b>1990</b>	<b>2000</b>	<b>2025</b>
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
<b>Total with Losses @70%</b>	<b>168.32</b>	<b>188.28</b>	<b>261.14</b>

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<sup>3</sup> per annum. The corresponding industrial water-demand is considered negligible when compared with the domestic and agricultural demands.

### **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<sup>3</sup> 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

**Table - 4: Water Demand for Domestic Use**

<b>Year</b>	<b>1990</b>	<b>2000</b>	<b>2025</b>
Population (Million)	110	140	260
Water Demand (MAF)	4.1	5.2	9.7

## Water-Resources Situation in Pakistan: Challenges and Future Strategies

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

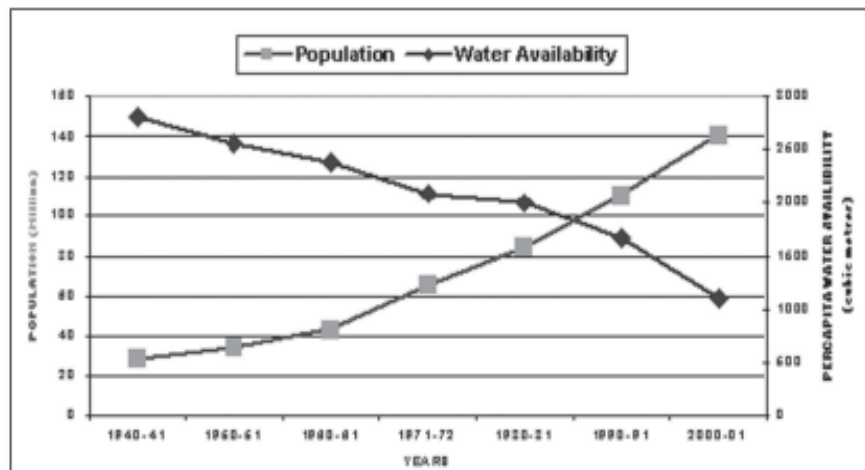
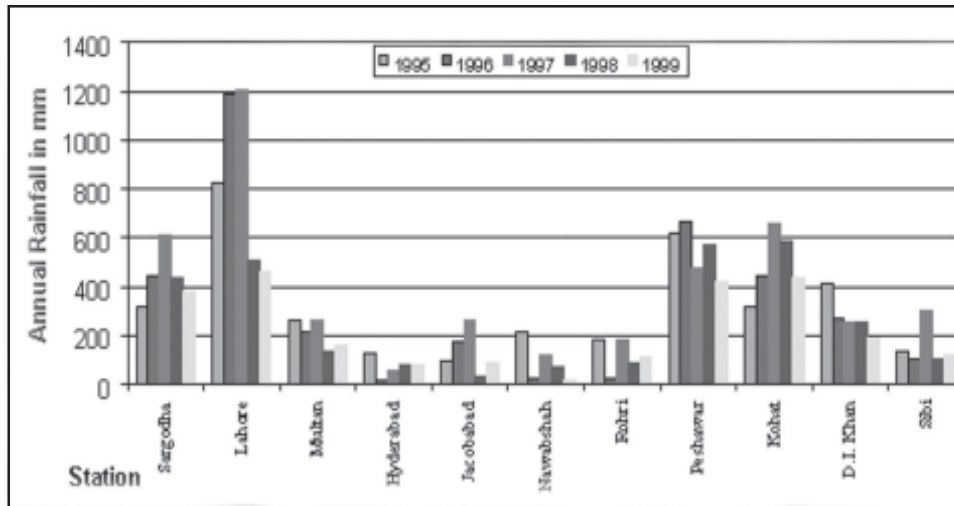


Figure - 3: Per-Capita Water-Availability

### 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



Source: Pakistan Meteorological Department rainfall data

Figure - 4: Rainfall over Irrigated Areas

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 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 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-

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Table - 5: Reduction in Capacities of Major Reservoirs

Reservoir	Year Commissioned	Live Storage Capacity			Decrease	
		(MAF)			(%)	
		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
<b>Total</b>		<b>15.7</b>	<b>13.6</b>	<b>11.7</b>	<b>13</b>	<b>25</b>

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

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

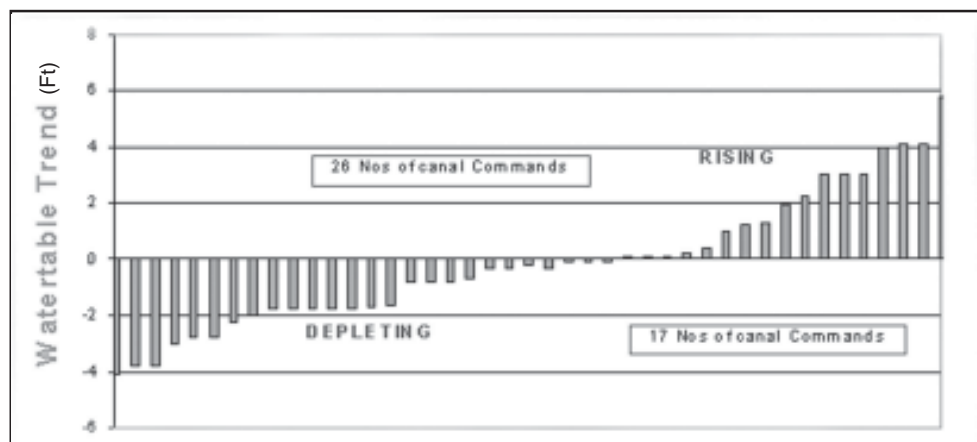


Figure - 5: Water-Table Trends in Canal Commands

groundwater-use, floods during the summer and 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, 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),

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

<b>Year</b>	<b>&lt;1.5 m</b>	<b>1.5-3.0 m</b>	<b>&gt;3.0 m</b>
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
<b>Average</b>	<b>13.50</b>	<b>37.40</b>	<b>49.10</b>
<i>Source: SMO unpublished data</i>			

## Water-Resources Situation in Pakistan: Challenges and Future Strategies

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 though 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.

### 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

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)

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.

**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 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.



## **Water-Resources Situation in Pakistan: Challenges and Future Strategies**

- 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

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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-Storage 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

## **Water-Resources Situation in Pakistan: Challenges and Future Strategies**

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.

## **Water-Resources Situation in Pakistan: Challenges and Future Strategies**

*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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# **Efficient and Sustainable Irrigation-Management in Pakistan**

*Illahi B. Shaikh*



# EFFICIENT AND SUSTAINABLE IRRIGATION-MANAGEMENT IN PAKISTAN

## ABSTRACT

*Pakistan, with a Geographical area of 796,101 square kilometers, possesses large rivers, like Indus which, along with its 5 tributaries, namely Chenab, Jhelum, Ravi, Kabul and Sutlej, forms one of the mightiest River-Systems of the world. The River-System comprises 2 storage reservoirs, 19 large river headworks, 43 Canal Systems measuring 58,000 kilometers, some 1.6 million kilometers of water-courses and field Irrigation Channels. Pakistan has big rivers like Indus, Chenab, Ravi, Jhelum and Sutlej, where discharges in summer season vary from 100 thousand Cusecs to 1,200 thousand Cusecs (3 thousand to 34 thousand cumecs) and can cause tremendous loss to human lives, crops and property.*

*In order to manage the huge Irrigation-System, Planning has been made, in consultation with four Provincial Irrigation Departments and Government of Pakistan, to establish Provincial Irrigation and Drainage Authorities and Farmer Organizations, which are under way. Due to limited capacity of storage at Tarbela and Mangla Dams on river Indus and Jhelum, with virtually no control on Chenab, Ravi and Sutlej, devastating problems are faced between July and October in the event of excessive rainfall in the catchments. This chapter discusses, in detail, the irrigation-network in Pakistan and the efforts to establish Irrigation and Drainage Authorities, Farmer Organizations, etc, for efficient and sustainable management of irrigation in Pakistan.*

## INTRODUCTION

Pakistan, with a Geographical area of 796,101 square kilometers, possesses large rivers, like Indus which, along with its 5 tributaries, namely Chenab, Jhelum, Ravi, Kabul and Sutlej, forms one of the mightiest River-Systems of the world. The River-System comprises 2 storage reservoirs, 19 large river headworks, 43 Canal-Systems measuring 58,000 kilometers, some 1.6 million kilometers of water-courses and field Irrigation-Channels. Pakistan has big rivers like Indus, Chenab, Ravi, Jhelum and Sutlej, where discharges in summer season vary from 100 thousand Cusecs to 1,200 thousand Cusecs (3 thousand to 34 thousand cusecs) and can cause tremendous loss to human lives, crops and property. Due to limited capacity of storage at Tarbela and Mangla Dams on river Indus and Jhelum, with virtually no control on Chenab, Ravi and Sutlej, devastating problems are faced between July and October in the event of excessive rainfall in the catchments (see Figure-1).

Pakistan comprises four major administrative units; Punjab, Sindh, North West Frontier Province and Balochistan, besides the Federally Administered Tribal Areas. Pakistan's

## **Efficient and Sustainable Irrigation-Management in Pakistan**

population as estimated in 2001 is 140 million. The population growth-rate is estimated at 2.1%. The overall density of population is 174.63 per kilometers. However, there is large regional variation in population-density. Pakistan is a country with a very diverse social and geographic landscape, comprising high mountains in the north, to desolate plateaus, fertile plains, sandy deserts, coastal beaches and mangrove forests in the south. It has the largest share of the highest mountain-peaks in the world and has more glaciers than any other land outside the North and South Poles. Pakistan's glacial area covers some 13,680 sq.km, which represents an average of 13 per cent of mountain-regions of the upper Indus-Basin.

### **THE IRRIGATION NETWORK**

The Irrigation system of Pakistan is the largest integrated irrigation network in the world, serving 34.5 million acres (13.96 million ha) of contiguous cultivated land. The system is fed by the waters of the Indus River and its tributaries. The salient features of the system are three major storage reservoirs, namely, Tarbela and Chashma on River Indus, and Mangla on River Jhelum, with a present live-storage of about 15.4 BM<sup>3</sup> (12.5 MAF), 19 barrages; 12 inter-river link canals and 43 independent irrigation canal commands (Figure-2). The total length of main canals alone is 58,500 Km. Water courses comprise another 1,621,000 Kms.

Diversion of river waters into offtaking canals is made through barrages, which are gated diversion weirs and a system of link canals (Figure-2). The main canals, in turn, deliver water to branch canals, distributaries and minors. The water-courses get their share of water through outlets in the irrigation channels. Distribution of water from a watercourse is effected through a time-schedule or "warabandi", under which each farm gets water for a specified period once a week. The time-share of "wari" is proportionate to the farm area owned by a farmer under the command of the water-course.

The system draws an average of 106 MAF (131 BM<sup>3</sup>) of surface-water each year for irrigation. Supplemented by an annual groundwater pumpage of some 50 MAF, the average depth of water available at the farmgate is 3.07 feet per acre. Approximately 3 million individual farms, with an average size of about 12 acres (5 ha), benefit from this system.

### **WATER AVAILABILITY & UTILIZATION**

Pakistan has a diverse agro-ecological setting and is divided into three hydrological regions; (a) the Indus- Basin, which is the major source of Pakistan's water, (b) the Kharan desert in west Balochistan, with inland drainage and (c) the arid Makran coast along the Arabian Sea in the southern part of Balochistan. The deserts in the south (Thar and Cholistan) have no water-resources. Most of the Indus-Basin has been formed as a result of alluvial deposits brought by rivers from the mountainous ranges in the north. The flows in the

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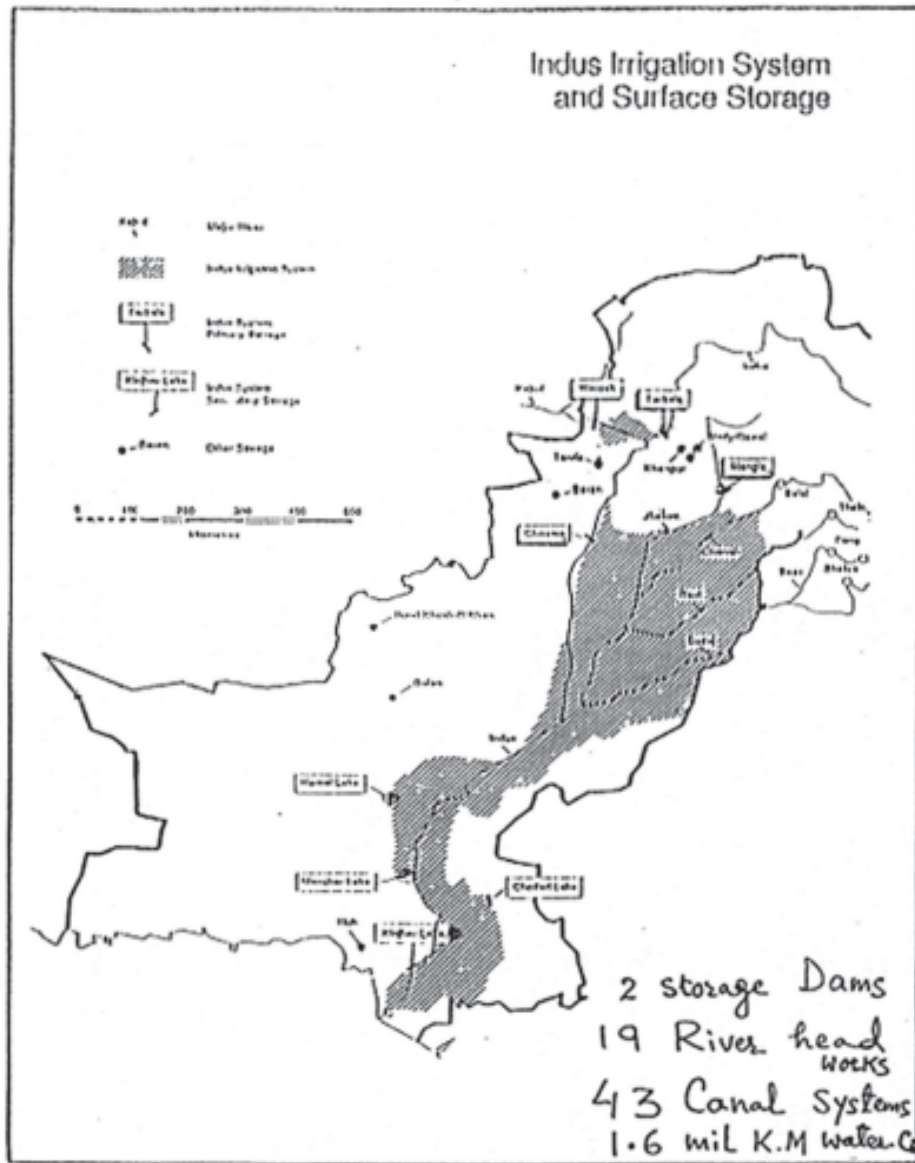


Figure - 1: Indus Irrigation-System and Surface-Storage

## **Efficient and Sustainable Irrigation-Management in Pakistan**

Indus River are from glacial snow melt, as well as rainfall outside the Indus Plains. Under the Indus- Water Treaty (1960), the flows of the three eastern rivers, the Sutlej, Beas and Ravi, have been allocated to India and water from the three western rivers, the Indus, Jhelum and Chenab is available for Pakistan.

The flow of the Indus River and its tributaries constitutes the main source of surface-water for the country. Based on 74 years of historic data from 1992-93 to 1996-97, the average annual inflow of the western rivers at the rim-station amounts to 140 million acre feet MAF (173 BM<sup>3</sup>). The flow varies from year to year; the maximum was 186.79 MAF (230 BM<sup>3</sup>) in 1959-60 and the minimum was 86 MAF (106 BM<sup>3</sup>) in 1999-2000. This presents a variation of more than 65% in the annual average-flows.

The groundwater storage-capacity in Pakistan is estimated to be around 55 MAF (67.8 BM<sup>3</sup>). The hydrogeological conditions are mostly favourable for pumping by tube-wells. It is estimated that 15,504 large-capacity public tube-wells and 469,546 private tube-wells of low capacity are currently installed in the country. Thus, the groundwater pumpage in the Indus-basin has increased from 33.4 MAF (41 BM<sup>3</sup>) in 1959 to about 50 MAF (62 BM<sup>3</sup>) in 1999-2000. Quality of groundwater is variable, with about 79% of the area in Punjab and 28% in Sindh as fresh groundwater suitable for irrigation. However, indiscriminate pumping, without proper monitoring, and lack of knowledge about the chemistry and hydrodynamics of the aquifer has already contributed to the pollution of the aquifers in certain pockets.

At the time of independence of Pakistan in 1947, about 64 MAF of water was being utilized annually in the irrigation canals in the country. With the construction of more barrages, link canals, and storage dams, water-use has increased to an average of 106 MAF (131 BM<sup>3</sup>). Per-capita availability of water has gone down from 5,104 cubic meter in 1950 to around 1,200 cubic meter currently- Out of the 35,040 MAF flowing to the sea, a total of about 20 MAF (25 BM<sup>3</sup>) can be used for future development through construction of multi-purpose storages, remodeling of canals and irrigation extension schemes. There is little potential for increase in water availability for Pakistan from surface or groundwater sources. However, the 9th Five-Year Plan envisages that about 4.32 MAF can be made available through conserving measures and installation of tube-wells in fresh groundwater areas.

Currently, 97% of the fresh water in Pakistan is used in the agriculture-sector and only 3% is available for domestic and industrial use. The competitive demands from different sectors has not yet emerged as a key issue in Pakistan but is likely to become a major issue in the future. A review of growth trends shows that as the income of a country increases, the use of water by different sector changes dramatically, and the water needs of the industrial and domestic sector changes dramatically and the water needs of the industrial and domestic sector grow rapidly until in high-income countries water requirements are 47% of the available water. In the immediate future, Pakistan needs to review strategies for

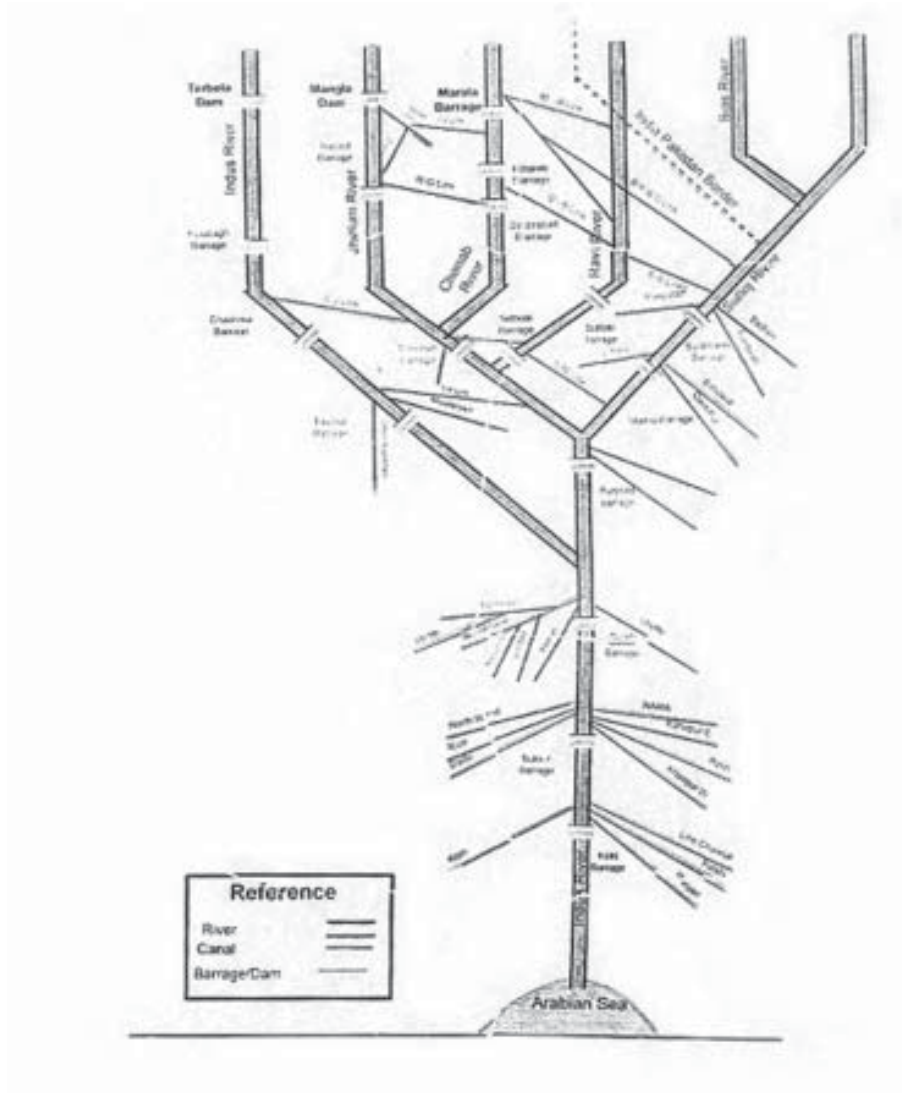


Figure - 2: Schematic Diagram Indus-Basin Irrigation-System

## **Efficient and Sustainable Irrigation-Management in Pakistan**

reallocation of water from irrigation to domestic and industrial use to harvest economic benefits. The rate of return of a cubic meter of water used for agriculture is less than 10% of return on municipal and industrial use. Conservation measures in agriculture can therefore help in increasing the productivity of water.

### **IRRIGATION AND WATER-MANAGEMENT ISSUES**

Water-resources development and management has acquired new dimensions in Pakistan. A host of factors constrain the performance of irrigation, which are multi-faceted and multi-dimensional. The major constraints facing the irrigation management broadly include; Physical Constraints, Financial Inadequacies, Institutional Issues and Environmental Problems. The Physical Constraints have been caused by the agricultural development beyond the system design capacities, scarcity of irrigation water, lack of storages, and gradual deterioration of the network due to the overstressing and aging. The main Financial Issues include inadequate maintenance funding, rise in maintenance expenditure of public tube-wells, and flood works, as well as escalating expenditures on establishment, stagnation of abiana rates, and a widening gap between the expenditure and cost recovery. The Institutional Issues have emerged because the changes in the institutional set-up have lagged behind the changes that have taken place in the resource-base and socio-economic context over the years. On the Environmental Front, the main problems are waterlogging and salinity, salt-imbalance, and increasing pollution of water-bodies.

A small fraction of the population pays tax; agricultural income tax has never been imposed on full-scale basis, despite its potential to generate resources for the country. The revenue from abiana (water tax) is also not collected seriously and there is massive leakage in the system. There is a legal framework in place for the organization of Water User Association (WUA), as the Punjab (1981) and Sindh (1982) Water-User Association Ordinances provide for such associations at the water-course level, while the Punjab Irrigation and Drainage Authority Act (1997) and the Sindh Irrigation and Drainage Authority (1997) provides for establishing Farmers Organizations (FOs) at distributary and minor levels. Despite this, the WUAs do not feel empowered to undertake the responsibility of operating and maintaining their watercourses or have any autonomy in the management of their water-resources. Similarly, a uniform policy exists for the water supply and sanitation sector, but it is not fully implemented. The National Environmental Quality Standards exist, but these are not enforced seriously.

The Indus-Basin Irrigation System was installed almost a hundred years ago and, now, its efficiency has come down to such an extent that more than 50 per cent of the irrigation-water is lost in transit and during application to the crops. The quantum of wastage of precious irrigation-water is not only the limiting factor for expansion of the irrigated area and realizing the maximum benefits per unit of already irrigated land, but it also has aggravated the severity of the twin menace of waterlogging and salinity. Crop-yields on

average Pakistani farms are considerably lower than the average yields attained by many other countries of the world, under similar agro-climatic conditions. The mounting pressure of population has furthered the importance of conservation and better management of the scarce resource. Thus, the low productivity of irrigated agriculture and ever-increasing pressure of population present a major threat to the country's food- security in the future. Therefore, this underscores the dire need to save every drop of water wasted in the irrigation-system and at the farm-level, through active participation of the end-users.

The importance of water for Pakistan can not be under-estimated, particularly for irrigated agriculture in the country. In Pakistan, irrigated agriculture covers 16.2 million hectare (74%) out of the total cultivated area of 22 million hectare. Irrigated agriculture uses 97% of the available water and provides over 90% of agricultural, produce; it accounts for 25% of GDP, earns 70% of the export revenue and employs 50% of the work-force directly and another 20% indirectly. Although the share of agriculture in GDP has declined over the years, it is still the largest single contributor to GDP. However, despite its importance, the level and growth of agricultural production falls short of its real potential. The sustainability of irrigated agriculture is threatened by continuous deterioration of the irrigation infrastructure.

The need for improvement and up-gradation of the irrigation system has become imperative. Indeed, over the last three decades, some damages have occurred due to floods, causing stoppage of irrigation-water to large areas, with huge economic losses. Recent surveys have revealed that numerous important hydraulic structures are in a precarious state and the need for rehabilitation is urgent. Besides rehabilitation, the system also needs overall improvements to allow efficient operation and equitable water-delivery, in order to cater for the enhanced water-demand and to meet the challenges of 21st century.

In order to address the sustainability issues, a number of policy-interventions have been proposed. While the main thrust of the policy-framework remains on institutional reforms, other policy interventions like Global Water Law, Dis-investment of Fresh Groundwater Tube-wells, Groundwater Regulatory Framework, Optimizing Irrigation-Water Allocations and Alternative Rate Mechanisms, are also proposed for optimizing the overall Irrigation Management. A sectoral strategy and National Water Policy are also being formulated, to have a historic approach for development and management of the water sector.

At the moment, the irrigation and drainage system of Pakistan suffers from a number of fundamental problems, notably;

- Unsatisfactory planning and programming of public expenditure on drainage;
  - Delays in Implementation;
  - Unsatisfactory planning, funding and execution of operation and maintenance (O&M);
  - Deteriorating capabilities of key-institutions;
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## **Efficient and Sustainable Irrigation-Management in Pakistan**

- Lack of public participation;
- Inadequate investment in drainage;
- Poor monitoring of drainage projects and infrastructure, and
- Inadequate investment in research on drainage, and lack of application of research-results to policy and planning.

### **FARMERS' PARTICIPATION IN CANAL-IRRIGATION AND WATER-USERS ASSOCIATIONS**

Nature has blessed this country with the World's largest and most integrated system of irrigation. This network was installed almost a hundred years ago and now its efficiency has been reduced to such an extent that more than 50 per cent of the irrigation-water is lost in transit and during application to the crops. The quantum of wastage of precious irrigation-water is not only the limiting factor for expansion of the irrigated area and realizing the maximum benefits per unit of already irrigated land, but also has aggravated the severity of the twin menace of waterlogging and salinity. Water-Users Organizations were not a part of the agricultural system in Pakistan till the late 1970s. With the onset of the On-Farm Water- Management (OFWM) Pilot Projects, their involvement was experimented upon, at times when it was considered a politically explosive and socially vulnerable issue, and it proved successful. Under various OFWM Programs, efforts were exerted to involve them at tertiary levels of the irrigation-system and, by now, they are contributing 55 per cent of the cost of the civil works on the watercourse. The usefulness of farmers' participation in other countries fostered the testing of some pilots on their participation at secondary levels of the system. A few pilot-surveys have been conducted so far and the results have shown that the WUA's participation can play a promising role in the operation and maintenance of the already deteriorating irrigation-systems, not only in improving productivity but also in sustaining the environment. Their performance will, nevertheless, hinge upon effective organizational efforts, imparting necessary training to them, proper recognition and adequate legislative support from the government, as well as commitment from operating agencies.

The Government has recently taken strategic initiatives to address the longstanding issues of irrigation-management that had been reflecting on the performance of the sector. The new strategies primarily focus on better governance, decentralization, participatory management and sustainability. Under the institutional reforms agenda, Provincial Irrigation Departments (PIDAs) are being transformed into Provincial Irrigation and Drainage Authority (PIDA). The responsibilities of management would be decentralized at canal command level to Area Water Boards (AWBs), while most of the existing functions at the distributary / minor level would be performed by the Farmers Organizations (FOs). The focus of most of the above activities would initially be on pilot AWB and pilot FOs on the System. Subsequently, the reforms package will gradually be extended to other AWBs and FOs, on the basis of the results of monitoring and learning- experience of the pilot

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programmes. The Government has enacted the legal framework and the reform agenda is under implementation, to varying degrees in all Provinces.

The strategy consists of the following interlinked parts:

- Restructuring the Provincial Irrigation Departments (PIDs), to form Public Utilities (PUs) around canal commands;
- Actively promoting formation and development of Farmers Organizations (FOs);
- Strengthening federal agencies, notably the Water and Power Development Authority's (WAPDA's) Water Wing, so as to better implement their federal responsibilities; and
- Formalizing water markets and individual water-property rights.

PIDAs have been established in all the four provinces; one Area Water Board (AWB) in each province has been notified. Also, Punjab and Sindh have notified rules and regulations for FOs. Other provinces are in the process of doing the same; 30 FOs have been registered in Punjab. Formation of 23 FOs have been completed, following by registration in Sindh Province under PIDA Act.

NWFP has designated the existing Northern Irrigation Circle Mardan as Area Water Board, Swat Canals (Pilot) and its Members have already been notified. The On-Farm Water-Management of the Agriculture Department have already constituted a FO in 31 Lora Canal scheme in Lakki Marwat district and they are busy in forming FOs in Peshawar and Charsadda areas.

The Farmers' Organization for K.K. Bund Irrigation Schemes, in Balochistan, have been registered. FOs registration for rehabilitation of Lasbella Canal is being processed.

The issues of physical / financial sustainability of irrigation and drainage network is assuming increasingly critical proportions. The specific policy-interventions, which are under consideration, include the following:

- i) Drainage cess and / or other appropriate measures, including cost-sharing by non-agricultural beneficiaries, to finance the O&M cost of drainage infrastructure.
- ii) Mechanisms for financing the O&M costs of flood-works, which may inter-alia include transfer (or cost sharing) of non-irrigation flood-infrastructure to the local bodies / other relevant beneficiaries and/or charging flood-cess, etc.
- iii) Redefining water-rates and alternate rate-mechanisms to enhance the incomes and to rationalize assessment costs. For a start, flat-rate assessment could be introduced in pilot FOs.
- iv) Redefining water-rates for water-use by non-agricultural users.

## **Efficient and Sustainable Irrigation-Management in Pakistan**

- v) Adequate O&M funding for proper upkeep of the existing irrigation-infrastructure. Revision of yardsticks, enhanced allocations and shifting of resources from SCARP tube-wells to canals operations.
- vi) Need to reassess the impact of the increase in investment vis-à-vis O&M requirements and the increases in “abiana” to sustain such investments.

The following points regarding institutional and environmental issues are now under active consideration of the Government:

- i) Willingness to invest in social mobilization and capacity-building of the upcoming new institutions (i.e AWBs and FOs) is absolutely essential for the success of the ongoing institutional reforms. For the new entities to be sustainable, the upcoming FOs would require technical assistance and support for quite some time, which may account for about 20-30% of the Investment Costs.
- ii) There is pressing need to take steps for expediting the capacity-building process for the upcoming FOs if the targets, for formation of FOs and transitioning of the management responsibilities to them, are to be met.
- iii) In order to optimize integrated resource-management, comprehensive and holistic interventions for rationalizing existing canal-water allowance need to be undertaken. Appropriate policy also needs to be developed, to address the emerging environmental issues in order to preserve the water-quality and land-base for sustainability of the irrigated agriculture.

## **CONCLUSIONS**

Owing to scarcity of water, proper management of water-resources is essential for the Agriculture Sector, which is the largest user (97%) of water. The development of Pakistan's economy strongly depends on its ability to properly operate and manage its water-resources. The efficient and effective use of all water- resources in Pakistan requires formulation and implementation of an appropriate water-sector policy. The Ministry of Water and Power is formulating a National Water Policy to face the challenges of water-scarcity. The overall objective is to utilize the available water-resources to meet the socio-economic and environmental needs for sustainable development in the country.

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# **Optimal Utilization of Water-Resources at Mangla Reservoir**

*Qamar-uz-Zaman Chaudhry*

# OPTIMAL UTILIZATION OF WATER-RESOURCES AT MANGLA RESERVOIR

## ABSTRACT

*Pakistan has an agro-based economy, but most parts of the country are arid or semi-arid. As such, a large part of the agricultural activity depends on irrigation water, which mostly comes from two main reservoirs, namely, Tarbela and Mangla. Optimal utilization of the available capacities of these reservoirs, therefore, becomes an important issue.*

*At the time of the dam-design, the Probable Maximum Flood (PMF) value calculated for the dam was 26 lac cusecs. Now, Pakistan Meteorological Department (PMD) has eighty years of data, analysis of which suggests that the present PMF value of 26 lac cusecs is much on the higher side and should be revised downward to around 16 lac cusecs. This revision can allow raising of the present Maximum Conservation Level (MCL) of Mangla by 15-20 ft, which can be accomplished at a fraction of the original cost. The storage capacity of the dam would be increased by about 1 million acre ft.*

## INTRODUCTION

Mangla Dam was built on the river Jhelum in 1960 mainly to replace waters of the three eastern rivers allocated to India under the Indus Water Treaty.

The catchment area of the Jhelum river is about 12,870 sq. miles. Of this, 3,605 sq. miles area (about 28%) is located at an elevation higher than 10,000 ft above Mean Sea Level (MSL). The area above 4,000 ft constitutes about 82% of the total area. The basin is bounded in the north by the great Himalayan Mountains and contains whole of the Kashmir valley.

The climate of the Jhelum basin can be divided into four seasons. These are winter (December-February), the hot weather (March-May), the summer monsoon (June-September) and the transition (October-November). During winter season, precipitation over major portion of the basin is in the form of snow. In April, May and June, the snowmelt gives rise to high sustained river flows at Mangla, which normally reach their maximum in June. During the summer monsoon season, precipitation is concentrated in the southern and western portions of the basin and features intense rainstorms. It is these rainstorms, which usually gives rise to major floods.

Any proposal to carry out the structural raising of Mangla dam deserves special attention because it could boost the dam's irrigation and power potential. Besides socio-economic and geotechnological considerations, the two major issues involved in the decision-making

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### **Optimal Utilization of Water-Resources at Mangla Reservoir**

process relate to: (i) the availability of water in the system, and (ii) the magnitude and volume of the highest possible flood or the probable maximum flood (PMF).

A correct assessment of these two factors will determine whether the structural raising of the dam is at all needed and, if so, then exactly how much. Hydrologists appear divided on the issue of water-availability. Some believe a 40-ft raising of the dam is not commensurate with the water-potential of the dam. They argue that, during quite a few seasons, the Dam's filling even up to the present conservation-level of 1,202ft had not been possible. They fear that an increase in the dam's capacity could increase the number of water-deficient years, as well, and thus make the project uneconomical.

### **WATER AVAILABILITY & RE-EVALUATION OF PMF**

The inflow at Mangla constitutes around 70% of snow-melt water and spring water, plus around 30% rainfall. Dam filling under the increased capacity shall necessitate more than normal snowfall during winter, followed by more than normal rainfall during summer. Such occasions would be relatively few. Thus, the water-availability for the increased capacity (built at such high cost) remains doubtful.

The second most important factor to be considered in the context of raising the capacity of Mangla dam is the accurate assessment of the magnitude and volume of the highest possible flood, called the PMF. It is customary to express the PMF in terms of its peak (discharge) value, even though its volume is equally important. Essentially, it is on the PMF-value that the Maximum conservation-level of the reservoir is fixed and the detailed dam-operating procedure is formulated.

In the case of Mangla reservoir, a great deal has gone wrong with regard to the PMF. As it exists today, Mangla PMF is grossly over-estimated and we have under-utilized the dam's capacity right from the beginning. PMF study of the Mangla dam was carried out by two international companies. The first study was done in 1959 by M/S Binnie<sup>1</sup> and its UK Partners, in association with M/S Harza of USA, while second study was carried out alone by M/S Harza<sup>2</sup>, in 1992.

### **DISCUSSION ON VARIOUS STUDIES**

Before commenting on the two studies, it is necessary that a few basic and simple elements regarding the concept of the PMF are brought out. PMF occurs as a result of the heaviest possible precipitation, technically called the probable Maximum precipitation (PMP). The PMP is caused by the extremely rare combination of the most rain-producing meteorological factors, which may act together to produce such an imaginably high rainfall, the equal of which has never occurred before. Thus, the starting point in computing PMF is the estimation of the PMP, which, in turn, calls for an in-depth understanding of those

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meteorological factors that are necessary to cause PMP. In Pakistan, the essential causes of the heaviest rainfall are the low-pressure weather-systems, which originate in the Bay of Bengal during monsoon season and then move across India, to arrive in the vicinity of the Mangla catchment. Turning of these monsoon depressions (towards the catchment) and their intensification, etc, is caused by another weather-system called the westerly waves. Cause of the extremely heavy rainfall in Mangla catchment develops when, on an extremely rare occasion, the position of the arriving intense monsoon-depression (to the south) and that of the intense westerly waves (to the north) get mutually juxtaposed along a North – South axis. The first step in computing PMP is to look for a past event in which the “heaviest-ever” recorded rainfall and thus the run-off had occurred. Then the actual rainfall is further enhanced (theoretically) by assuming the situation of saturated atmospheric condition to release more (additional) rain. Such precipitation (rain) is then converted into run-off, to compute the PMF, using any standard rainfall / run-off model like, for example, HEC Model.

Now, turning to the Mangla PMF study, it appears that the foreign consultants did not possess full understanding of the local rain-producing meteorological factors. The British and American Meteorologists live and deal with the temperate region and its atmospheric environment, while Pakistan is located in the region which becomes meteorologically tropical during summer and temperate during winter. This regional characteristic causes much more complex weather-systems, which are not easily comprehended by the visiting meteorologists of European or American origin. It further appears that this lack of knowledge of the foreign consultants forced them to play safe by aiming at a very high value of the PMF, with safety margin comparable to the one normally adopted in USA for Hurricane-related rainfall.

In achieving such a high value of PMF, they violated the very basic procedure of PMF computation. As indicated earlier, the first step in the PMP/PMF computational procedure is to select the past event of the heaviest rainfall, which in case of Mangla, up till that time, was the event of the year 1929. The consultants of the study, however, selected an event, which was relatively insignificant in terms of rainfall and flood intensity. This was the flood of 1956. However, strangely enough, despite selecting one of the lowest storms, they produced the highest PMF value. This was done by multiplying the actual storm rainfall with an additional multiplication factor called the Wind Maximization Factor, which was actually not applicable to Mangla storms (since the wind-factor is applicable to the coastal belt only and not as far inland as Mangla).

PMF value of 26 lac cusecs was computed by M/S Binnie<sup>1</sup> and Partners and M/S Harza. Against this, the highest flood actually experienced at Mangla over a period of more than 80 years is less than 11 lac cusecs, which occurred in 1992. The figure of 26 lac cusecs for PMF resulted in fixing the maximum conservation level of the dam at 1,202ft. (Crest level of the dam is around 1,232ft and the level in case of PMF could be taken to 1,228ft).

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## **Optimal Utilization of Water-Resources at Mangla Reservoir**

Thus, around 26ft of the useable space was kept empty for the PMF situation. A feeling that 26 lacs of the PMF (as against 11 lacs actually experienced so far) was on the higher side prompted WAPDA to revise the study. However, strangely enough, the revision was again awarded to none but M/s Harza (which was already co-author of the first study). This was done early in 1992. No wonder that, in this revised study also, the PMF of Mangla again reached close to the previous value of 26 lac cusecs. On the face of it, the previous PMF value got confirmed through the revised study and thus the situation with regard to the water-conservation in the reservoir remained unchanged. Flaw in the entire exercise stemmed from the decision to award the revised study to M/S Harza, which was in no position to prove its (own) earlier study wrong. Indeed, Harza is a good international firm having long-standing association with WAPDA, but this did not deny WAPDA the right to an independent check of its work through some other national / international firm, since quite a few companies of equally good repute are available at the international level.

In 1995, Pakistan Met. Deptt., in one of its detailed studies conducted by its Director, Mr. Abdul Majid, strongly pointed out flaws in this overestimated Mangla PMF value of 26 lac cusecs. Some conservative estimates suggest that this under-utilization of Mangla Dam has caused a loss of about Rs. 20 billion<sup>3</sup> to the national exchequer so far.

## **CONCLUSIONS**

The gist of what has been stated above is that an independent study of the Mangla PMF needs to be done, through a firm not involved in the earlier studies. Involvement of Pakistan Meteorological Department must be ensured in the study, since the subject of PMF is a hydro-meteorological subject directly related to the technical function of Pakistan Meteorological Department.

On the basis of the various studies<sup>4,5</sup>, the present author is of the firm view that the PMF value is most likely to range between 15 lac and 17 lac cusecs. This shall allow a raising of Mangla's present maximum conservation level to 15ft above the present level of 1,202 ft. The first 6 ft can be raised without any structural change, while the remaining raising can be achieved either by raising the emergency spillway (present level 1208 ft) or just by putting gates on it. This can be done at a fraction of the cost of rupees 50 billion needed for raising the Dam upto 40 ft. In view of the water-availability constraint, the option of raising the level, on the basis of revised PMF, should be exercised first. It shall be much more beneficial to use the available funds in the construction of some new dams, rather than raising the Mangla dam too much, without first utilizing the dam's available potential.

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