Khalid Mohtadullah, Chaudhry Ata-ur-Rehman & Chaudhry Muhammad Munir

WATER FOR THE 21ST CENTURY

P N C S

A Pakistan National Conservation Strategy Sector Paper

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Khalid Mohtadullah, Chaudhry Ata-ur-Rehman & Chaudhry Muhammad Munir

ENVIRONMENT &
URBAN AFFAIRS
DIVISION,
GOVERNMENT
OF PAKISTAN

IUCN
The World Conservation Union

The sector papers were commissioned from mid-1988 to mid-1990 and printed in 1992 and 1993

The Pakistan National Conservation Strategy was prepared by the Government of Pakistan (Environment and Urban Affairs Division) in collaboration with IUCN – The World Conservation Union

It was supported by the Canadian International Development Agency

Additional sector activities were supported by the United Nations Development Programme

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Editors: Tehmina Ahmed & Yasmin Qureshi
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ISBN 969-8141-07-3

Design: Creative Unit (Pvt) Ltd
Formatting: Umer Gul Afridi, Journalists' Resource Centre for the Environment
Printed in Pakistan by Rosette

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PREFACE

This monograph is one of the 29 sectoral and programme papers produced to support the preparation of the Pakistan National Conservation Strategy. The NCS is a comprehensive review of the state of the country's environment, and of government and corporate policies, the voluntary sector, community and individual practices, which support or hinder sustainable development. The objective of the NCS is to identify strategic initiatives to conserve the country's natural resources which are the base for lasting improvements in the quality of life.

Environmental impacts do not respect sectoral or administrative boundaries. Yet, conventional development planning is frequently focused on narrow performance criteria and associated financial requirements, ignoring huge costs on downstream ecosystems and economic activities dependent on them. These costs cannot be avoided and must be paid by society, the only questions are when and by which group.

To facilitate an understanding of such 'externalities', one of the first steps of the National Conservation Strategy was to undertake assessments of cross-sectoral impacts from the point of view of each major activity sector. In order to facilitate comparison, the reports were prepared according to common terms of reference. Subsequently, major programme areas that must be given priority in the transition to a sustainable society were identified. The list of economic, environment and programme areas is given overleaf.

A paper on each sector was produced by a well recognized expert supported by peer reviewers in related specialities. The key insights have been incorporated into the Strategy. Since the papers are the reference base of the strategy and contain special interest material, a decision was taken to publish them serially in the form of monographs. It is hoped they will be found useful by researchers of sustainable development in various facets of national life as well as by the interested lay reader.

The sectors are:

1. Economic sectors:

- Agriculture, forestry, livestock, fisheries.

- Mining, energy, industries, transport.
- Human settlements and recreation.

2. Environmental impact sectors:

- Soil degradation, loss of biodiversity, and over harvesting of renewable resources.
- Municipal and industrial discharges, environmental health effects, and misuse of water resources.
- Destruction of cultural heritage.

3. Programme areas:

- Incorporation of environment in education, communication, and research; enforcement of laws and regulations; improved administration; use of economic instruments to align market forces with sustainability; promotion of conservation ethics.
- Programmes to promote population planning, women in development, and regional equity.
- Creation of grassroots institutions, with participative management.

WATER FOR THE 21ST CENTURY

1. WATER: A RESOURCE AND ITS DEVELOPMENT

INTRODUCTION

Water is the source of life on earth, particularly freshwater which is essential for the well-being of people.

Water, like certain other natural resources, forms a closed cycle — it is 'recycled' by nature through various physical states back to a form which can be used by people. Usable freshwater comes from precipitation and snow. It finds its way into streams and rivers, and is called surface water; or it percolates through the soil to be stored underground as groundwater. While the latter is dependent on above-ground water supplies and is a secondary source of water, surface water has no such limitations.

Currently, agriculture is the most important user of water in our country. However, as Pakistani society develops, water for human consumption and sanitation, and for industrial development will also make substantial claims on this precious resource.

SURFACE WATER DEVELOPMENT

Prior to canal irrigation, agriculture was mostly limited to the regularly flooded riverine areas. The floods would recede, leaving fresh fertile silt and sufficient moisture in the soil to grow winter crops. As the pressure on land increased, human ingenuity devised ways and means to irrigate land distant from the river. Feroze Shah Tughlaq, in 1351, constructed an inundation canal — to channel riverwater during periods of high flow — off the Jamna River to irrigate areas in the Hisaar District of India. In 1568, Akbar improved this canal and in 1626, Shah Jehan extended it further by adding the Delhi and Rohtak branches. In 1633, Shah Jehan constructed another canal off-taking from Madhupur on the river Ravi to irrigate a part of the Bari Doab as well as the Shalimar Garden in Lahore. All these canals subsequently ceased to flow for one reason or another.

During the 19th century, efforts were made by the British Government to reconstruct some of these canals. By the end of the century, the rivers were controlled by headworks and canals carried water long distances inland to areas opened up for agricultural development.

At the time of Independence, the irrigation network consisted mainly of old established canal systems — with the exception of the Thal system, being developed for the perennial irrigation of 1.64 million acres. All these systems were dependent on daily water levels in the river Indus and its tributaries, as there were no dams to store surplus supplies for later use. With weirs and barrages to regulate river flow, the irrigation system covered a culturable area of 27 million acres, of which only 19.8 million acres were perennially supplied. In addition, 6 million acres were fed by inundation canals operating only during the Kharif (summer sowing) season when river levels were high.

Average canal head withdrawals at the time of Independence were 64 million acre-feet (MAF), excluding the 4 MAF taken from the Kabul, Swat and Kurram rivers in the North West Frontier Province (NWFP). Of this, over 10 MAF was being withdrawn from the three eastern rivers, the Sutlej, Beas and Ravi, whose headworks were located in Indian territory.

During the period 1947-60, while negotiations between Pakistan and India to resolve the Indus waters dispute were in progress, Pakistan undertook the construction of three inter-river link canals to ensure a continuous supply of water. These were the BRBD Link (1952), the Balloki-Suleimanki Link (1954), and the Marala-Ravi Link (1956). These link canals ultimately became part of the Indus Basin Replacement Plan.

Pakistan also constructed three barrages on the Indus River to convert the existing inundation canals into weir-controlled ones to ensure a more reliable water supply. These barrages were Kotri (1955), Taunsa (1958), and Gudu (1962) with a total canal command area (CCA) of 7.4 million acres, of which 0.87 million acres in the command of Kotri Barrage were made perennial. Irrigation was extended to some new areas as well, although the actual acreage was small. A number of small surface irrigation schemes were also constructed in the NWFP. The important canals were Pehur (1957-58), Marwat (1962-63), Warsak (1966-67), Tanda Dam (1968-69) and Third Lora (1968-69).

Under the Indus Waters Treaty 1960, certain construction was agreed upon to provide alternate water supplies to canals offtaking from the three eastern rivers. The present irrigation system thus consists of the three storage reservoirs at Mangla, Chashma and Tarbela — which became operational in 1967, 1971 and 1976 respectively — 16 barrages, 12 inter-river link canals, 2 syphons and 43 main canals as shown schematically in Figure 1. The total length of the main and link canals, branches, distributaries, etc. is about 35,000 miles. The system has 88,600 outlets. The length of farm channels and watercourses is about 1 million miles.

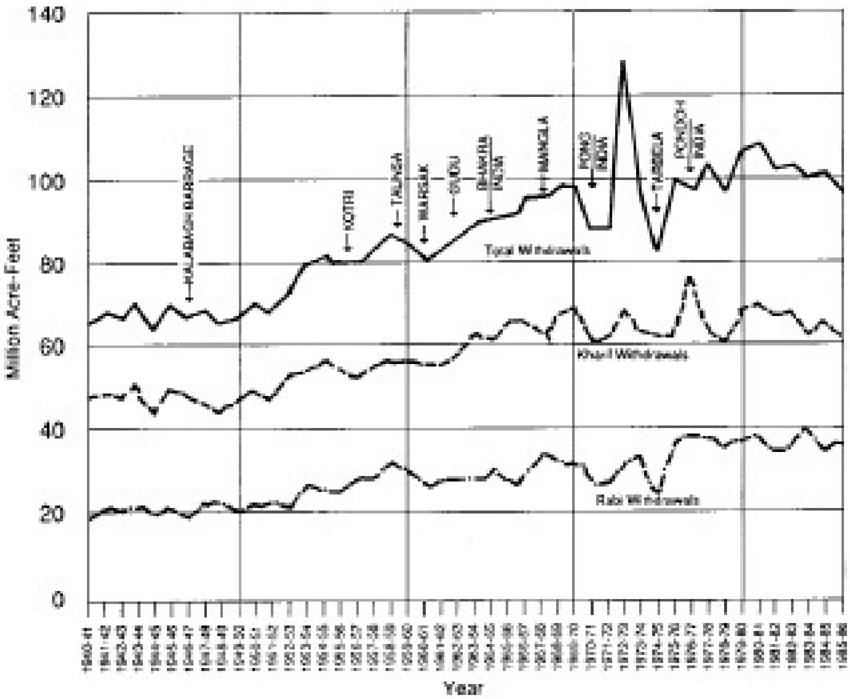
Hence the only significant development in the irrigation system in the last 40 years, apart from the development of the Thal canal and the conversion of inundation canals to weir control, has been the construction of the Tarbela and Chashma dams. Though the Mangla Dam provides storage, its major function is to provide water previously supplied by the eastern rivers. All these developments have served to improve control over the water supply, but there has been no significant addition of new land under irrigation.

Canal head withdrawals have continued to increase with progressive improvements in the system and with increasing irrigation demand. Total annual withdrawals are depicted graphically in Figure 2, on which important irrigation developments are also shown. Five-year average canal withdrawals, province-wise, are shown in Table 1.

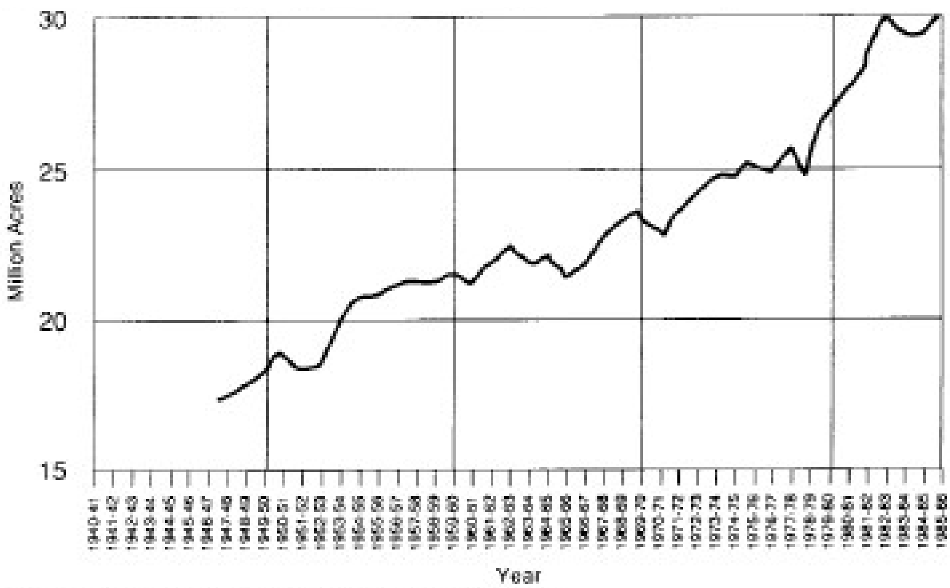
During the 10-year period ending in 1959-60, i.e., prior to the signing of the Indus Waters Treaty, canal head withdrawals had increased to an average of 78.6 MAF — an increase of about 23% over the 64 MAF withdrawn at the time of Independence. In the seven-year period ending 1966-67, i.e., prior to the completion of the Mangla Dam, withdrawals had further increased to an average of 87.7 MAF. After the completion of Mangla and prior to the commissioning of the Tarbela Dam in 1975-76, average canal withdrawals rose to 98.9 MAF. In recent years (1977/78-1985/86), withdrawals have averaged 100 MAF. Thus, since Independence overall canal head withdrawals have risen by 36 MAF or

FIGURE 2

WITHDRAWALS FROM INDUS BASIN CANALS IN PAKISTAN



DEVELOPMENT OF CANAL-IRRIGATED AREA



Source: Water Resources Management Directorate, WAPDA.

TABLE 1

AVERAGE CANAL HEAD WITHDRAWALS BY SEASON

PERIOD	PUNJAB		SINDH/BALOCH.		NWFP		TOTAL		WITHDRAWAL
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	TOTAL
	(million acre-feet)								
1967/68 – 1971/72	33.14	15.91	27.63	12.17	3.29	1.82	64.06	29.90	93.96
1972/73 – 1976/77	31.89	18.75	29.70	12.73	3.43	1.96	65.02	33.44	98.46
1977/78 – 1981/82	34.66	19.84	29.40	15.76	3.56	2.00	67.62	37.60	105.22
1982/83 – 1986/87	32.59	19.57	29.53	15.48	3.56	2.09	65.68	37.14	102.82

Source: Water Resources Management Directorate, WAPDA.

56%. Increases in withdrawals and storage capacity has gradually reduced freshwater flow to the sea. In recent years, from 1979 to 1986, discharge to the sea has averaged 20 MAF.

From the pre-Treaty period (1950/51-1959/60) to the post-Tarbela period (1975/76-1985/86), Kharif canal head withdrawals increased from 53 MAF to 67.4 MAF or by 27%. The Rabi (winter cropping) season supplies went up even more significantly, increasing by 46% from 25.6 MAF to 37.5 MAF. In quantitative terms, Kharif supplies increased by 14.4 MAF while Rabi supplies went up by 11.9 MAF. The Rabi season improvement is attributable to the storage reservoirs of Mangla, Chashma and Tarbela, with an initial overall live capacity of 15.472 MAF, since reduced to 14.377 MAF due to siltation. Storage releases of the three reservoirs have been between 14.1-17.2 MAF during the last five years. While the bulk of storage water is utilised during the Rabi season, supplies have also been available in the critically water-short periods of early and late Kharif, during the sowing and maturing periods of summer crops.

The development of surface water has not materially increased the extent of irrigated land; but greater control of water supplies and enhanced water diversion have boosted agricultural production. However, increased water supplies have also contributed to more waterlogging in some of the canal command areas.

GROUNDWATER DEVELOPMENT

Prior to canal irrigation, groundwater was found at shallow depths alongside rivers and streams; its depth below the surface increased with distance from the recharge source. During this period, groundwater at shallow depths was withdrawn for irrigation using a Persian-wheel powered by bullocks. With the development of diesel/electric power and pumping equipment, increasing amounts of groundwater was drawn-up, but more for municipal than for irrigation use.

In 1958, after detailed investigations into methods to combat waterlogging and salinity, the Water and Power Development Authority (WAPDA) adopted tubewell drainage in non-saline areas. Salt-affected soils were reclaimed and the effluent used to augment canal supplies, which helped increase cropping intensity. The success of conjunctive use of surface and groundwater triggered rapid development of private tubewells in the country. Tables 2 and 3 give the status of public and private tubewells and the groundwater being pumped annually for irrigation and drainage.

About two-thirds of private tubewells are diesel operated and the rest, electric powered. About 70% tubewells are located in the canal commands and utilised to supplement canal supplies for increased cropping intensity or to

TABLE 2

PUBLIC TUBEWELLS AND THEIR PUMPAGE

PROVINCE	TUBEWELLS[1]		PUMPAGE[2]		
	WAPDA	Irrigation Dept.	WAPDA	Irrigation Dept.	Total
	(number)		(million acre-feet)		
Punjab	9,465	1,565	4.25	0.09	4.34
Sindh	4,555	—	1.32	—	1.32
NWFP	491	—	0.13	—	0.13
Balochistan	—	—	—	—	—
Total	**14,511**	**1,565**	**5.70**	**0.09**	**5.79**

Sources: Ministry of Food and Agriculture. N.d. *Agricultural Statistics of Pakistan, 1990-91*. Islamabad: Government of Pakistan; SCARP Monitoring Organisation, WAPDA.

1. Upto June 1991.

2. 1990-91.

overcome water shortages in critical periods. Considering the role of both public and private tubewells, groundwater pumpage in the Indus plains increased from 3.34 MAF in 1959-60, to 30.40 MAF in 1976-77, to 43.8 MAF in 1990-91.

THE IRRIGATION SYSTEM AND ITS INEFFICIENCIES

Under existing irrigation facilities, the average availability of water (both surface and groundwater) at the farmgate is 104.82 MAF as detailed in Table 4.

But this system, which is almost a century old, is constrained in many respects; also, there are inherent problems with the system which are briefly described below.

Constant Flow

The water requirements of crops vary according to their stage of growth. Water needs are minimum in the early stages of growth and maximum during flowering and seed formation, dwindling as the crop comes to maturity. Much of Pakistan's irrigation system, on the other hand, from the barrages to the outlet heads has a continuous flow throughout the year. This may result in over- or under-irrigation, affecting crop yields because of soil moisture stress at critical demand periods. Constant irrigation also affects crops in areas with a high water-table or heavy rainfall.

TABLE 3

PRIVATE TUBEWELLS AND PUMPAGE

PROVINCE	TUBEWELLS[1]	PUMPAGE
	(number)	(MAF)
Punjab	290,091	33.54
Sindh	17,409	2.01
NWFP	6,065	0.70
Balochistan	15,163	1.75
Total	**328,728**	**38.00**

Sources: *Agricultural Statistics of Pakistan, 1990-91*.

1. Upto June 1991.

Note: Information about private tubewells has been derived from various sources which, in turn, have relied upon scanty/sampling data. Groundwater pumpage figures must, therefore, be regarded as broad estimates and, if anything, are likely to be somewhat on the higher side.

TABLE 4		
SUPPLY OF IRRIGATION WATER		
SOURCE	HEAD	FARMGATE
	(million acre-feet)	
Surface water		
Canal withdrawals	102.8[1]	61.7[2]
Conservation by OFWM[3]	—	2.3
Groundwater		
Public tubewells	5.8	4.93[4]
Private tubewells	38.0	36.10[5]
Total supply	**146.6**	**105.03**

1. Five-year average, from 1982-87.
2. 25% of canal head diversion upto watercourse head assumed lost, and 15% of canal head supply lost in watercourses. Thus overall loss is 40% from canal head to farmgate.
3. Presently about 10,297 watercourses improved under regular technology and 19,971 under accelerated programme. Savings are 126 acre-feet and 52 acre-feet per annum per watercourse respectively from the two improvements.
4. 15% loss upto farmgate.
5. 5% loss upto farmgate.

Excessive Water Loss

The irrigation system in Pakistan consists of two parts:

1. Main canals, branches, distributaries, and minors which are maintained by the government.
2. Watercourses and field ditches which are maintained collectively by the farmers.

Losses in Canals, Distributaries and Minors

Except for a few canals, most of the irrigation system in Pakistan is unlined. The delivery efficiency of canals/distributaries is about 75%. On this assumption, it is estimated that annually about 26 MAF water is lost in this part of the system.

Losses in Watercourses and Field Ditches

Beyond the outlet head, the conveyance network consists of, on average, 3 kilometres of main watercourses and about 30 kilometres of branch and farm ditches, providing irrigation to individual fields. The farmers operate and manage these watercourses with little or no professional guidance. The result is poor maintenance and excessive water loss in about 89,000 watercourses and field ditches in the country. This loss, estimated at 45%, amounts to about 35 MAF water affecting the groundwater table, as shown in Figure 3.

Losses in the Fields

It is estimated that about 27% or 12 MAF irrigation water is lost in the fields, because of flood irrigation methods and poorly levelled fields.

Lack of Drainage Facilities

During the design and planning of irrigation systems drainage schemes should have been built-in. A failure to do so has contributed to a rise in the water-table that has proved detrimental to the agro-economic structure of the country.

Limited Control Capability in the System

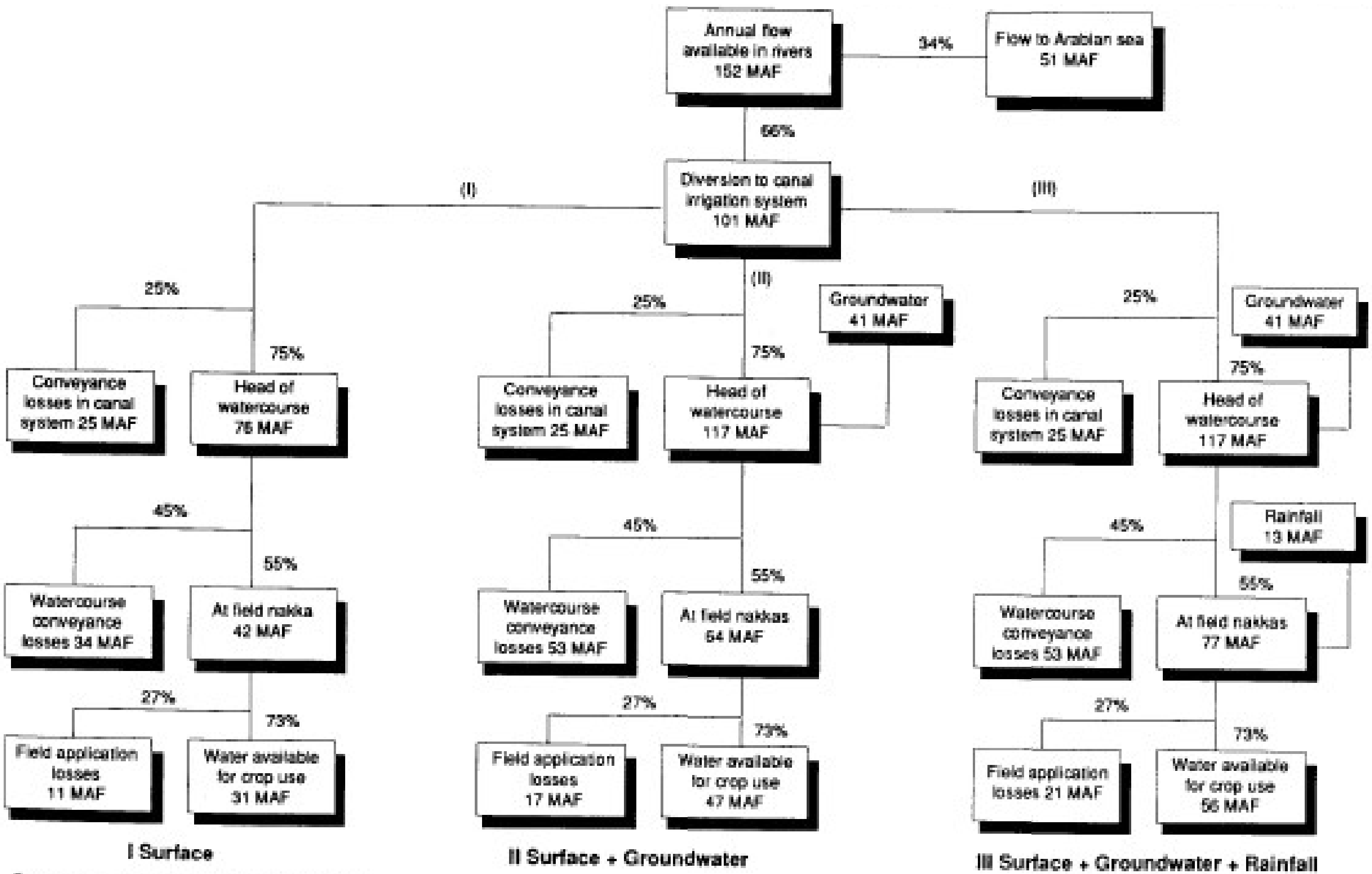
The irrigation system is based on run-of-the-river flows through barrage diversions. Structural capacity to regulate water supplies is limited to storage at Tarbela, Mangla and Chashma.

Poor Operation and Maintenance of the System

Proper maintenance of the irrigation system is a matter of considerable economic importance to Pakistan, as canal irrigation and its price relative to other inputs, can have considerable bearing on cropping patterns and total agricultural productivity. In the past, irrigation played a vital role in provincial revenues. Traditionally, the expenditure incurred remained within the receipt from

FIGURE 3

WATER AVAILABILITY IN THE INDUS BASIN



Source: Perspective Planning Division, WAPDA.

Note: Loss percentages adopted from Anon. 1979. *Operational Irrigation Evaluation of Pakistan Water Course Conveyance Systems.* Colorado State University Water Management Technical Report No. 52.

TABLE 5

THE IRRIGATION SYSTEM: OPERATION AND MAINTENANCE EXPENDITURE AND RECEIPTS

	YEAR					
	1980-81	1981-82	1982-83	1983-84	1984-85	1985-86
	(million rupees)					
Expenditure	1,144.4	1,417.0	1,537.5	1,902.9	2,202.4	2,453.4
Receipts	678.3	855.2	839.3	948.1	915.2	933.3
Subsidy involved	466.1	615.8	734.2	954.8	1,287.2	1,520.1

Source: Associated Consulting Engineers (ACE). 1990. Nation-wide study for improving procedures for assessment and collection of water charges, and drainage cess. Lahore.

irrigation, though this has proved impossible in recent years. At present, recoveries are so meagre that they do not cover normal operation and maintenance (O&M) expenses, as given in Table 5. Provincial governments, who do not have a sizeable potential for taxation, have been compelled to cut down on their provision for O&M costs. As allocations have not kept pace with increasing costs, deferred maintenance has resulted in deterioration of the system, endangering adequate and timely supplies of water.

2. WATER AND ITS INTERACTION WITH OTHER SECTORS

THE NATIONAL ECONOMY

Water is the main factor affecting agricultural development, the mainstay of Pakistan's economy accounting for over 23% of the gross domestic product (GDP), employing about 50% of the labour force and earning 70% of the export income (including raw and processed agricultural goods). Although agriculture's share in the GDP has declined over the years, due to the economy diversifying towards industry and infrastructure, it continues to remain the most important sector, providing a livelihood to over 70% of the rural population. Over the last decade (1978-88), agriculture has maintained an average growth rate of 3.3% per year, with a total value-added growth rate of 3.8% per year in the last five years (1983-88). The pattern of growth, however, remained uneven mainly due to fluctuations in the output of wheat and cotton.

TABLE 6

PROJECTED GROWTH RATES FOR THE AGRICULTURE SECTOR

	LONG TERM	SIXTH PLAN		SEVENTH PLAN
	1949-82	Target	Likely	Target
	(% per year)			
Major crops	3.4	3.6	2.3	4.0
Minor crops	3.1	7.0	3.6	5.5
Livestock	2.4	5.9	6.2	5.3
Fisheries	4.1	7.5	4.5	4.9
Forests	2.2	5.0	10.8	2.6
Total	**5.1**	**4.9**	**3.8**	**4.7**

Source: Planning Commission. 1988. *Seventh Five-Year Plan 1988-93 & Perspective Plan 1988-2003.* Islamabad: Government of Pakistan.

The National Commission on Agriculture (NCA) estimated that it should be possible to raise the growth rate from 3.8% to 5% per annum in the next 15 years. The main effort would have to focus on providing technology, credit and physical inputs to small-farm farmers. Projected targets for major crops appear in Table 6.

The Seventh Five-Year Plan projects an overall growth of 4.7% for the agriculture sector. This target takes into account the prospects of future demand, both at home and abroad, and the possibility of input substitution. The emphasis is on the production of crops projected to be in greater demand, including export demand, and accelerated oil-seed production to move towards self-sufficiency in this area. The agricultural sector is expected to account for 16.4% of the proposed increase in GDP to be achieved under the Seventh Plan.

THE HUMAN ELEMENT

Population Size and Growth

Since Independence, the population has increased from 34 million in 1951 to 103 million in 1987, as in Table 7. The present rate of population growth is estimated at 3.1% per year, but this is expected to decline over the coming years to around 2.6%.

Population and its growth impact on a country's socio-economic development, affecting the well-being of its people. Demographic characteristics such as the sex-age composition, labour force participation rates, and rural-urban ratios determine the structure of the labour force which, within a given level of capital stock and technology, determine the potential level of a country's output.

On the one hand, a growing population helps provide an adequate labour force. On the other hand, a very fast-growing population restricts the government's ability to implement socio-economic changes.

Since Independence the pattern of rural life has altered considerably. Dramatic structural changes have occurred, in that, there has been a large increase in the number of non-farm families, including livestock holders. Farm mechanization has displaced tenants and agricultural workers, though a growing and increasingly diversified rural sector has offered more opportunities for off-farm work. The most important factor in this change, however, has been economics.

TABLE 7

POPULATION GROWTH RATE

YEAR	POPULATION	INTER-CENSAL GROWTH RATE
	(million)	(% per annum)
1951	33.7	
1961	42.9	2.3
1972	65.2	3.7
1981	84.3	3.1
1987	102.5*	3.1
2003 (projected)	164.1	3.1

Source: *Seventh Five-Year Plan 1988-93*, *Vol. 1.* pp. 43,150.

* Estimated in 1987-88.

According to the 1981 census, a total of 5.92 million persons had migrated within the country, 87.6% from rural to urban areas. This has meant that the urban population has grown at a very fast rate. From 1972 to 1981, it grew at an annual rate of 4.4%, compared to a growth of 2.6% in the rural and 3.1% in the total population.

The above indicators, while running counter to theoretical expectations and the experience of other developing countries, reflect the seriousness of socio-economic pressures and their implications for public policy. Province-wise population projections for 1987 and 2003 are given in Tables 8 and 9.

The population growth has led to an increase in demand for all foods, with consumption patterns changing in the last 25 years. This has been in response to many influences, including changes in income level and distribution, urbanization, and a number of trade and pricing policies. The latter have influenced the absolute and relative price levels of various food commodities and encouraged the substitution of important diet items, e.g. vegetable ghee instead of butter oil.

TABLE 8

RURAL-URBAN POPULATION

	1961		1972		1981		1987 (Projected)		2003 (Projected)	
					(million)					
Rural	35.8	(77.48%)	48.72	(74.6%)	60.41	(71.7%)	71.50	(71.01%)	116.51	(71%)
Urban	10.4	(22.52%)	16.59	(25.4%)	23.84	(28.3%)	29.20	(28.99%)	47.59	(29%)
Total	**46.2**	**(100.00%)**	**65.31**	**(100.0%)**	**84.25**	**(100.0%)**	**100.07**	**(100.00%)**	**164.10**	**(100%)**

Source: Population Census Organisation, Federal Bureau of Statistics.

Food and Fibre Requirements

Domestic demand for agricultural products depends upon agricultural prices, population size and national income. Agricultural prices for most commodities are close to international prices and are likely to stay at current levels in real terms throughout the period to the year 2000. Hence prices in Pakistan for the period 1988-2000 have been assumed constant, though in some cases, this may result in over-estimation of domestic demand — this should be acceptable in order to build a margin of safety in demand and supply projections.

The technique for agricultural demand projections, under constant price assumptions, has five steps: (1) decide upon the national population growth rate and the real GNP to be used in this analysis; (2) use these to project population and GNP figures for 1992-93 and 1999-2000; (3) derive future increase in per capita income from these figures; (4) compute figures for the income elasticity of demand for each of the commodities of concern; and (5) use the income

TABLE 9

PROJECTED PROVINCE-WISE POPULATION FOR 1987 AND 2003

PROVINCE	1981 CENSUS		1987 PROJECTIONS		2003 PROJECTIONS	
	Rural	Urban	Rural	Urban	Rural	Urban
			(million)			
Islamabad	0.136	0.204	0.11	0.31	0.21	0.47
Punjab	34.241	13.051	40.70	15.82	66.30	25.79
Sindh	10.786	8.243	12.58	10.16	20.42	16.63
NWFP	9.396	1.665	11.20	2.03	18.20	3.35
Balochistan	3.655	0.677	4.31	0.88	7.10	1.35
FATA	2.199	—	2.60	—	4.28	—
Total	60.413	23.840	71.50	29.20	116.51	47.59
Total	**84.26**		**100.7**		**164.10**	

Source: Economic Advisor's Wing, Finance Division. N.d. *Economic Survey 1986-87.* Islamabad: Government of Pakistan.

elasticity and growth in per capita income to compute per capita consumption in the terminal years 1992-93 and 1999-2000. This is then multiplied by the terminal year population to produce the demand estimate.

The NCA made projections using an estimated GNP growth rate of 5.6% per annum for 1988-2000, and a population growth rate estimated at 3.0% in the Sixth Plan period. But these projections assumed that a major effort to reduce the population growth rate to 2.5% by the year 2000 would be made.

Country and province-wise crop demand and production projections are shown in Table 10. Crop production targets for the year 2000 which emerge from the proposed strategy include:

1. Self-sufficiency in food grains based on demand projections.
2. Maximising agricultural exports based on an assessment of export possibilities, and potential barriers to Pakistan's agricultural exports.
3. Maintaining at least 90% self-sufficiency in sugar production, and increased self-sufficiency in oil-seeds production from the present 37% to about 50%.
4. Expanding the high-value fruit and vegetable sector at a rate of 7% per annum, which is one and a half times the growth rate of the rest of the crop sector. This would be largely for domestic consumption, but also for export as fast as market possibilities emerge.

The targets for wheat, rice and cotton do not present insurmountable problems. The institutional infrastructure is well developed and the supporting policies are in place. The necessary technology has also been developed — what is now required is its wide dissemination. The prospects of expanding the yield and production of sugar cane in Sindh are particularly promising.

Accelerating the pace of fruit and vegetable production would be a major challenge. But an essential element of the strategy would be to diversify and improve income and employment in this sector and to increase exports. The most important requirement would be to improve the marketing infrastructure for horticultural products, promote domestic processing of surplus produce and find export markets for both fresh and processed fruits, and fruit juices.

One measure necessary to avoid undue burden on the balance of payments, is careful management of the fast-increasing demand for the import of edible oil and sugar. Promoting the use of refined oil rather than vegetable ghee, would save money which would otherwise be spent on unnecessary processing.

SOCIO-ECONOMIC DEVELOPMENT

The traditional indicators by which the success or failure of an agriculture plan or policy is normally judged — the rates of agricultural growth, production indices of main crops or earnings from agricultural exports — are not enough. Constant improvement in, and maintenance of, the rural infrastructure is also necessary. This facilitates the process of rural diversification and is an essential component of a longer term strategy. This is also necessary if the tide of urbanization is to be stemmed and a higher rate of agricultural development achieved.

Incremental income has largely accrued to groups with higher income, which have the financial means and the political power to acquire them. The single most important factor responsible for this state of affairs is the breakdown in the implementation of programmes and policies. The ultimate aim of economic development is to improve the well-being of society as a whole, and to ensure that the benefits of economic progress are distributed fairly across the entire community. Despite considerable efforts to improve the socio-economic condition of depressed areas, there are still many regions with a high concentration of low-income households; these include Balochistan, the NWFP, the Northern Areas and the Federally Administered Tribal Areas (FATA). Socio-economic indices show that these less developed regions are much lower than the national average in all respects.

TABLE 10

PROJECTED DOMESTIC DEMAND AND PRODUCTION OF AGRICULTURAL COMMODITIES

PROVINCE/ YEAR	WHEAT	RICE BASMATI	RICE OTHER	COTTON	SUGAR REFINED	OIL EDIBLE	MAIZE	MILLET/ SORGHUM	PULSES	MEAT	MILK	FRUIT	VEGE- TABLES
(million tonnes)													
PUNJAB						**Production**							
1993	9.27	0.63	1.66	0.94	1.16	0.38	0.84	0.40	0.37	0.81	9.40	2.83	2.65
2000	11.60	1.16	1.88	1.18	1.63	0.58	1.12	0.63	0.41	1.24	13.02	4.42	4.53
						Domestic Demand							
1993	8.32	0.42	0.95	0.50	1.31	0.83	0.92	0.40	0.51	0.97	9.33	2.74	2.59
2000	10.31	0.59	1.12	0.69	1.81	1.12	1.24	0.63	0.60	1.49	13.02	4.22	4.40
SINDH						**Production**							
1993	3.71	0.30	0.67	0.38	0.47	0.15	0.34	0.16	0.15	0.33	3.76	1.13	1.06
2000	4.63	0.47	0.75	0.47	0.65	0.23	0.45	0.25	0.16	0.50	5.20	1.77	1.81
						Domestic Demand							
1993	3.33	0.17	0.38	0.20	0.52	0.33	0.37	0.16	0.21	0.39	3.73	1.11	1.04
2000	4.12	0.24	0.45	0.28	0.72	0.45	0.50	0.25	0.24	0.60	5.20	1.69	1.76
BALOCHISTAN						**Production**							
1993	0.84	0.07	0.15	0.09	0.11	0.04	0.08	0.04	0.04	0.08	0.85	0.26	0.24
2000	1.05	0.11	0.17	0.11	0.15	0.06	0.10	0.06	0.04	0.12	1.18	0.40	0.41
						Domestic Demand							
1993	0.75	0.04	0.09	0.05	0.12	0.08	0.09	0.04	0.05	0.09	0.84	0.25	0.24
2000	0.93	0.06	0.10	0.07	0.17	0.10	0.12	0.06	0.06	0.14	1.18	0.38	0.40
NWFP						**Production**							
1993	2.15	0.17	0.39	0.22	0.27	0.09	0.20	0.10	0.09	0.19	2.18	0.66	0.62
2000	2.69	0.27	0.44	0.28	0.38	0.14	0.26	0.15	0.10	0.29	3.02	1.03	1.05
						Domestic Demand							
1993	1.93	0.10	0.22	0.12	0.31	0.20	0.22	0.10	0.12	0.23	2.16	0.64	0.60
2000	2.39	0.14	0.26	0.16	0.42	0.26	0.29	0.15	0.14	0.35	3.02	0.98	1.02
FATA						**Production**							
1993	0.43	0.04	0.08	0.05	0.06	0.02	0.04	0.02	0.02	0.04	0.44	0.13	0.13
2000	0.53	0.06	0.09	0.06	0.08	0.03	0.06	0.03	0.02	0.06	0.60	0.21	0.21
						Domestic Demand							
1993	0.39	0.02	0.05	0.03	0.06	0.04	0.05	0.02	0.03	0.05	0.43	0.13	0.12
2000	0.48	0.03	0.06	0.04	0.09	0.06	0.06	0.03	0.03	0.07	0.60	0.20	0.21
PAKISTAN						**Production**							
1993	16.38	1.29	2.93	1.65	2.05	0.66	1.47	0.70	0.65	1.43	16.60	5.00	4.67
2000	20.48	2.05	3.32	2.07	2.87	1.02	1.98	1.10	0.71	2.18	23.00	7.80	8.00
						Domestic Demand							
1993	14.70	0.74	1.67	0.88	2.30	1.46	1.62	0.70	0.90	1.70	16.47	4.83	4.57
2000	18.20	1.03	1.78	1.22	3.19	1.94	2.18	1.10	1.05	2.63	23.00	7.46	7.76

Source: National Commission on Agriculture, Ministry of Food and Agriculture. 1988. *Report of the National Commission on Agriculture.* Islamabad: Government of Pakistan.

3. THE POTENTIAL FOR DEVELOPMENT

SURFACE WATER POTENTIAL

The flow of the Indus River and its tributaries constitute the main source of surface water for the country. Inflow to the Indus River system is derived from snow, glacier melt and rainfall, primarily upstream of the Indus plains. Under the Indus Waters Treaty 1960, the flow of three eastern rivers, the Sutlej, Beas and Ravi, have been allocated to India and storage reservoirs have already been constructed: Bhakra on the Sutlej in 1964; Pong and Pandoh on the Beas in 1972 and 1977 respectively; and an under-construction reservoir on the Ravi. Once this is completed, there will be no significant flow from the eastern rivers into Pakistan, except for occasional flood flows towards the end of the monsoon season. Currently, inflows into Pakistan have averaged 5.18 MAF in the Kharif and 1.67 MAF in the Rabi season.

Water from the three western rivers, the Indus, Jhelum and Chenab — except for specified limited use in occupied Kashmir and India — is available to Pakistan. The flow is measured at three rim stations: at Kalabagh on the Indus (which includes the flow of the Kabul River and its tributaries), at Mangla on the Jhelum, and at Marala on the Chenab. These rim stations include most of the tributary inflows and are above the existing canal system except for the Swat, Kabul and Kurram River canals in the NWFP.

Based on 64 years of historic data, from 1922/23-1985/86, the average annual inflow of the western rivers at the rim stations amounted to 137.27 MAF. The flow varies from year to year: the maximum was 186.79 MAF (36% above the average) in 1959-60 and the minimum 100.31 MAF (26.9% below average) in 1974-75. The flow varies markedly during the Kharif and Rabi seasons also. Kharif inflows average 115.18 MAF or over five times the Rabi inflows of 22.06 MAF. The characteristics of river inflows are shown in Table 11. Of the three western rivers, the largest flow is contributed by the Indus with an annual mean of 89.22 MAF. The corresponding values for the Jhelum and the Chenab rivers are 22.55 MAF and 25.48 MAF respectively.

TABLE 11

WESTERN RIVERS INFLOW

ITEM	KHARIF	RABI	ANNUAL
	(million acre-feet)		
Mean	115.24	22.03	137.27
Median	116.20	21.66	137.64
Minimum	80.64	15.74	100.31
Maximum	154.74	34.09	186.79
3 out of 5 years	110.10	20.38	132.22
4 out of 5 years	101.28	18.76	123.59

Source: Water Resources Management Directorate, WAPDA.

After estimating inflows from hill torrents and other water sources below the rim stations, river gains and losses and flow below Kotri, the average surface water flow of the western rivers available for development is 130 MAF, as detailed in Table 12.

GROUNDWATER POTENTIAL

Pakistan's groundwater resources have been extensively investigated during the last 25 years. The investigations have established the existence of a vast aquifer underlying the Indus plains, recharged in the past by natural precipitation and river flow, and more recently by seepage from the canal system. Other small aquifers have also been identified in the inter-montane valley alluviums.

The Indus plains aquifer is composed of unconsolidated alluvial deposits of fine to medium sand, silt and clay. Fine grain deposits are generally discontinuous so that the sand, making up 65-75% of the alluvium, forms a unified aquifer under water-table conditions. Although the quality of groundwater in the Indus Basin aquifer is highly variable, there are large areas underlain with usable water, both plentiful in quantity and at an accessible depth. It represents a water source of significant importance for agriculture. Within the canal command area of 40.7 million acres, it is estimated that about 20.1 million acres is underlain by groundwater with salt concentrations of less than 1,500 ppm, and another 4.8 million acres with salinity between 1,500-3,000 ppm. Outside the canal command area, in the riverine stretches and the area below the Himalayan foothills groundwater is usable, although aquifer characteristics are not as uniformly favourable. The extent of such areas is around 5 million acres.

Groundwater availability has been investigated in all 12 valleys of Balochistan and in most of the promising parts of the NWFP. Investigations are also being carried out in the remaining areas in Cholistan and Tharparkar. These investigations have established the presence of small isolated aquifers, whose usable groundwater is limited in potential and whose extraction will require deeper and costlier well installations and hence, higher pumping costs.

Groundwater which can be withdrawn from

TABLE 12

PROJECTION OF INDUS WATER BASIN AVAILABILITY

DESCRIPTION	MEAN	IN 4 OUT OF 5 YEARS 80% Probability
	(million acre-feet)	
1. Western rivers: rim station inflows	137.27[1]	123.59[1]
2. Eastern rivers: contribution	2.0[2]	1.5
3. Used above rim stations	5.5	5.5
4. Total inflow (1+2+3)	144.77	130.59
5. Losses & gains below rim stations (inclusive of inflows)	(—) 10.0[3]	(—) 8.0
6. Outflow to sea	(—) 5.0	(—) 3.0
7. Net available for utilization (4-5)	129.77	119.59
8. Average post-Tarbela canal withdrawals		
Current (1986-87)	104.15[4]	99.80[5]
CRBC	2.11	2.11
Pat feeder	1.53	1.53
9. Balance available (6-7)	21.98	16.15
10. Authorised use by India out of the western rivers	(—) 2.0	(—) 2.0
11. Actual potential available (8-9)	19.98	14.15

Source: Water Resources Management Directorate, WAPDA.

1. Mean value derived from 64 years (1922/23-1985/86) data.
2. Five-year average (1980/81-1984/85) 6.8 MAF minus 2 MAF for Thein Reservoir & 2.8 MAF for further developments in India (assumed).
3. Post-Mangla average 1966/67-1985/86.
4. Post-Tarbela average 1977/78-1985/86, including ungauged civil canals of the NWFP.
5. 80% probability derived from 64 years (1922/23-1985/86) data.
6. 80% probability of 97.3 MAF from gauged & 2.5 MAF from ungauged canals based on 10 years (1967/77-1985/86) data.

BOX 1

GROUNDWATER DEPTH

PROVINCE	BELOW SEA LEVEL 1978	1987
	(feet)	
Punjab	13.0	13.1
Sindh/Balochistan	8.7	8.4
NWFP	15.5	15.2
Pakistan	11.5	11.4

BOX 2

ESTIMATED GROUNDWATER

PROVINCE	COMMAND AREA	OTHER AREAS
	(feet)	
Punjab	29.0	7.4
Sindh/Balochistan	3.9	3.0
NWFP	0.4	0.3
Total	**33.3**	**10.7**

year to year and put to beneficial use is neither unlimited nor permanent in nature, and has to be recharged. Its development is further restricted in situations where fresh groundwater overlies saline groundwater, as the saline water is drawn upwards.

The groundwater potential, therefore, can be defined as the net annual recharge averaged over a few years in an area underlain by usable groundwater and favourable aquifer characteristics. Changes in groundwater level indicate that under present pumpage conditions it has, more or less, attained stability. (See Box 1).

Keeping this in mind, the estimated usable potential (upto 3,000 ppm) is about 44 MAF of groundwater of which 33.3 MAF is in the canal command area and 10.7 MAF in riverine and other areas. (See Box 2).

The annual groundwater potential of areas outside the Indus Basin, established so far, is 0.74 MAF in the 12 valley basins of Balochistan, 0.48 MAF in the Potowar Plateau in the Punjab and 0.19 MAF in the NWFP, making a total of 1.41 MAF.

Although groundwater is a supplementary source of irrigation water, the quality of the pumped water is inferior to riverwater due to the absence of silt and the presence of dissolved salts. Unrestricted groundwater use is a potential hazard, leading to water quality degradation. Groundwater pumpage also adds significantly to the farmer's cost of production.

WATER REQUIREMENTS IN THE FUTURE

Gauging future water needs depends on how irrigated agricultural areas are to be expanded to meet national requirements. The historical expansion of irrigated areas is given in Table 13.

The future food and fibre requirements of the country can be met partly through increased yields per acre and partly through an expansion in irrigated areas. It is estimated that a 1% compound growth would be acceptable. Keeping this in view and assuming 2.75 feet per acre as water requirement at the farmgate, the cropped area and water requirement for the year 2000 would be 45.96 million acres and 126.40 MAF respectively, as given in Table 14.

4. ENVIRONMENTAL IMPACT OF DEVELOPMENT OF THE WATER SECTOR

RISE IN THE GROUNDWATER TABLE

Nature tends to move towards an equilibrium; and this is also true for the groundwater table. When agriculture was limited to the *barani* (rain-fed) and *sailaba* (riverine) areas, and to some extent to land irrigated by Persian-wheel wells, the water-table was in a state of dynamic equilibrium. But with the development

TABLE 13

GROWTH IN IRRIGATED AREA

YEAR	PAKISTAN	PUNJAB	SINDH	BALOCHISTAN	NWFP
			(million acres)		
1960-61	25.71	—	—	—	—
1965-66	28.36	—	—	—	—
1970-71	26.16	—	—	—	—
1975-76	33.39	22.98	7.79	1.03	1.59
1980-81	36.50	25.87	7.52	1.30	1.81
1985-86	38.68	27.95	7.47	1.26	2.00

Source: Ministry of Food and Agriculture. N.d. *Agricultural Statistics of Pakistan, 1987-88.* Islamabad: Government of Pakistan.

TABLE 14

ESTIMATES OF FUTURE IRRIGATED AREAS AND THEIR WATER REQUIREMENT

PROVINCE	PERIOD		
	1990-91	1995-96	2000-01
Punjab			
Irrigated area (million acres)	29.62	31.14	32.72
Water requirement at farmgate (million acre-feet)	81.46	85.64	89.98
Sindh			
Irrigated area (million acres)	8.57	9.01	9.46
Water requirement at farmgate (million acre-feet)	23.57	24.78	26.02
Balochistan			
Irrigated area (million acres)	1.32	1.39	1.46
Water requirement at farmgate (million acre-feet)	3.63	3.82	4.02
NWFP			
Irrigated area (million acres)	2.10	2.21	2.32
Water requirement at farmgate (million acre-feet)	5.78	6.08	6.38
Pakistan			
Irrigated area (million acres)	41.61	43.75	45.96
Water requirement at farmgate (million acre-feet)	114.44	120.32	126.40

of an extensive irrigation system, thousands of miles of unlined conveyance channels were dug. A new and extensive source of groundwater recharge was introduced — water from the conveyance system.

But failure to develop discharge channels, to balance the new recharge, has disturbed the hydrological balance and set in motion the problem of a rising water-table. The water-table has risen at different rates varying from half a foot to over two feet per year, depending upon the imbalance between recharge and discharge. Hydrographs from observation wells depict the rising water-table, as shown in Figure 4.

WATERLOGGING AND SALINITY

A rising water-table, in the absence of drainage channels, has been discharged through evaporation from the soil surface and transpiration from plants. Uneven land surfaces were affected by patchy waterlogging and acted as sinks. Where evaporation was less than recharge, swamps appeared which gradually grew larger to provide enough surface area to attain a new hydrological balance. Slightly higher areas became shallow swamps choking root aeration. As mineralised water evaporated, salts accumulated in the soil profile and on the surface.

The water-table exhibits an annual cycle of rise and fall. It is at its lowest point in the period prior to the monsoons (April-June). Recharged through Kharif season irrigation and the rains, it rises to its highest point in October, when it is closest to the land surface before declining again. High water-table conditions after the monsoon, though transitory, interfere with the cultivation of Rabi crops. Its position in April-June is particularly critical, as this level persists throughout the year and is used as an index for waterlogging. The extent of waterlogged area, where the water-table remains within five feet of

TABLE 15

AREA WITH WATER-TABLE WITHIN 1.5 METRES DEPTH

PROVINCE	1979		1984		1985		1986		1987	
	(million acres)									
I. Pre-Monsoon (April-June)										
Punjab	3.012	(12%)	1.945	(8%)	1.218	(5%)	1.898	(8%)	2.377	(10%)
Sindh	2.934	(21%)	2.881	(20%)	3.025	(21%)	3.133	(22%)	—	—
NWFP	0.072	(5%)	0.128	(10%)	0.096	(7%)	0.094	(7%)	—	—
Balochistan	0.127	(34%)	0.109	(29%)	0.116	(31%)	0.136	(36%)	—	—
Pakistan	6.145	(15%)	5.063	(13%)	4.455	(11%)	5.261	(13%)	—	—
II. Post-Monsoon (October)										
Punjab	4.324	(81%)	4.255	(17%)	2.983	(12%)	3.195	(13%)	—	—
Sindh	7.300	(51%)	8.221	(58%)	8.286	(58%)	8.417	(59%)	—	—
NWFP	0.084	(7%)	0.175	(13%)	0.139	(10%)	0.150	(11%)	—	—
Balochistan	0.373	(100%)	0.373	(100%)	0.373	(100%)	0.373	(100%)	—	—
Pakistan	12.081	(30%)	13.024	(32%)	11.781	(29%)	12.135	(30%)	—	—

Source: SCARP Monitoring Organisation, WAPDA.

Note: The area and percentages refer to the gross canal-command area of 40.506 million acres.

FIGURE 4

HYDROGRAPHS FROM OBSERVATION WELLS

Source: SCARP Monitoring Organisation, WAPDA.

TABLE 16

SURFACE SALINITY

PROVINCE	SLIGHTLY SALINE	MODERATELY TO STRONGLY SALINE
	(million acres)	
NWFP	0.12	0.06
Punjab	1.76	1.81
Sindh	2.57	3.89
Balochistan	0.15	0.07
Total	**4.60**	**5.83**

Source: Planning Division (Water), WAPDA.

the land surface throughout the year, over the period 1978-87 is given in Table 15.

In a WAPDA survey, covering 41.3 million acres, both surface and profile salinity was established through chemical analysis of the soil. In terms of surface salinity, an area of 5.83 million acres is moderately to strongly saline and 4.6 million acres is slightly saline. The province-wise extent of surface salinity is shown in Table 16.

Soil profiles were examined to a depth of six feet and salinity, sodicity or both affected 38% of the soils: 11% were saline, 3% sodic, while 24% were saline-sodic. The province-wise distribution of salinity/sodicity in the soil profile is shown in Table 17.

An increased water supply has affected agricultural development: some areas have been lost to production and, in others, yields have become depressed due to increased salinity and constant wetness.

Communication Infrastructure

Communication infrastructure is invariably affected in waterlogged areas because of the reduced load-bearing capacity of the soil. Infrastructure has then to be built on higher ground, resulting in increased capital outlay and O&M costs.

Road and rail systems generally run across natural drainage lines and bridges across these waterways are generally missing or inadequate. This is because drainage channels are not recognised for what they are or because of financial constraints. The result is that surface run-off during the rainy season or water flow during floods is impeded, damaging communication links and increasing recharge, further accentuating the problem of waterlogging. Burrows and pits along roadsides are ugly, form stagnant ponds, act as recharge sources and reduce the load-bearing capacity of the road's foundation. Thus poorly designed cross-drainage works in the physical infrastructure of communication systems are, indirectly, increasing the waterlogging problem.

Health Hazards

There is inadequate research and information on the health aspects of waterlogging and salinity. Waterlogged areas, i.e., swamps can act as breeding places for mosquitoes and other insects. Potable water in the rural areas is obtained mostly through Persian-wheel wells, polluted by increased run-off during the monsoons, as these areas have no water-absorbing capacity. Sewage flow from villages is hampered and the swamps become disposal ponds, further polluting the environment.

Disregarding the importance of environmental impact assessments of irrigation projects and its links to health can have serious consequences.

TABLE 17

SOIL PROFILE

PROVINCE	SOIL PROFILE		
	Saline	Saline/Sodic	Sodic
		(per cent)	
NWFP	11	7	2
Punjab	7	14	5
Sindh	17	42	2
Balochistan	26	38	1
Total	**11**	**24**	**3**

Source: Planning Division (Water), WAPDA.

An example is the Chashma-Jhelum link, an unlined canal with a capacity of 27,000 cubic feet per second, constructed near Adikot by cutting through an area of highly porous sandy soil. This caused immense damage to Chan village and the surrounding area. Several houses collapsed and ponds appeared. The latter became mosquito breeding spots and a hazard to health.

SALT BALANCE

Extensive canal irrigation together with waterlogging and salinity has effected the salt balance of the Indus Basin. The average annual salinity of the western rivers at the rim stations is about 131 ppm, and at outflow near Kotri, 243 ppm. Assuming 138 MAF as inflow and 5 MAF as outflow under complete development of water resources, the salt retained in the basin would be around 20 metric tonnes per year.

A programme of drainage and reclamation was started by WAPDA in 1958. Non-saline groundwater drainage projects were implemented first. Nearly 6 MAF groundwater is being pumped up by public tubewells. The demonstrative effect of these projects triggered private tubewell development, that now pumps up 38 MAF groundwater per year.

The use of groundwater for irrigation has increased the amount of salt infiltrating the soil to far more than what was being dumped by canal water. A study for SCARP-I indicated that nearly 2 tons of salt per acre per year was being dumped. Part of this salt is accumulating in the soil and in the long run is likely to endanger the productivity of agricultural land.

Disposal of Saline Effluent

Saline effluent can be disposed of in three ways:

1. Through drains and rivers.
2. Through evaporation ponds.
3. Through canals.

All these methods are being used, subject to their technical and economic feasibility. However, they all have long-term adverse effects on the environment. Water discharged into rivers and canals is ultimately going to find its way, through headworks, into downstream canals leading to further salt accumulation. Ponds are a short-term measure also, as they fill up with salt and become unusable. Besides this, ponds pollute the groundwater reservoir; and land under the pond is permanently lost to agriculture and other uses.

ENERGY WASTAGE

The rapid proliferation of private tubewells have also caused some problems. While properly designed and matched equipment from known manufacturers is being used in the public sector, hundreds of small manufacturers are producing the equipment used in private sector. Recent studies have indicated that this equipment is substandard and has a low energy efficiency. Part of this problem is because substandard material is cheap and readily available; and in part due to a lack of technical advice regarding efficiency, resulting in unnecessary energy losses. At present over 250,000 private tubewells with a utilization capacity of 15% are being used; improved performance, assuming a 20-year life, could lead to an estimated energy saving of around 9.86 x 10e kilowatt-hour.

REAPPEARANCE OF WATERLOGGING

When planning drainage and reclamation measures, certain assumptions regarding surface water supply and the amount to be drained are made. However either due to poor operation and maintenance of drainage systems or a greater surface water input than envisaged during planning, or both, imbalances between supply and drainage occur. Consequently, waterlogging reappears in areas already provided with drainage measures.

GROUNDWATER POLLUTION

Groundwater in the Indus Basin is of variable quality. It is non-saline near sources of recharge, i.e., rivers and major canals; and saline as depth and distance from the recharge source increases. Sub-surface drainage measures, first used in non-saline areas are now being gradually extended into the saline zones. Large-scale withdrawal of groundwater is creating differential heads, and may result in the lateral and vertical movement of saline water into fresh water zones — which, if not managed, could pollute the non-saline aquifer zones permanently.

SURFACE WATER POLLUTION

Water supply and sewer systems are neither efficient nor adequate in any of the industrial cities, e.g., Karachi, Lahore, Peshawar, Faisalabad, Hyderabad, Gujranwala, Sialkot and Rawalpindi. Sewage, in most cases, is carried by open surface-flow drains which ultimately discharge into a stream, a river or the sea, affecting surface water.

Both small industries — mechanical and auto workshops, hosiery and carpet looms, spice and grain-grinding mills — scattered within residential areas, and medium- and large-scale industries located in planned industrial estates, do not pre-treat their effluent. It is simply discharged into a nearby channel. But the waste waters of the textile, plastic, tanning, food and metal-processing industries contain toxic chemicals used in processing the raw material that needs different treatment from municipal discharges.

Karachi's industrial estates discharge their waste into the Lyari and Malir rivers, which flow into the Arabian Sea, without any of this effluent being treated. A sewage treatment plant of 20 million gallons per day (MGD), located in the Sindh Industrial Trading Estate, carries out primary treatment of domestic sewage only. This is discharged into the Lyari, which receives about one-half of the city's total waste water. The Lyari River itself empties into Manora Channel which is not easily flushed. Karachi's port and fish harbour, and five saltworks are located in this channel; the effluent has begun to pose a serious threat to the marine environment as the channel water is contaminated not only with bacteria but with toxic chemicals, including lead.

In other parts of the country, industrial effluents are discharged into natural streams, irrigation channels, seepage drains or onto adjoining agricultural land, with the result that water is polluted and fertile land lost.

The industrial and municipal wastes of Lahore are discharged into the Ravi River without treatment; the industrial complexes of Kala Shah Kaku, Muridke and Mandiala pump their water directly into Deg Nullah. Severe damage to land, underground water, aquatic and animal life and to the local people's health has been reported.

The municipal and industrial wastes of Faisalabad cannot be separated, as industries are sited in residential areas. The mixture is discharged onto open land. The local textile, soap and vegetable oil industries have separate ponds for the discharge of their waste. In Jaranwala, municipal and industrial waste water is discharged into a seepage drain. The same is the case with Gujranwala, where the seepage drain/distributary passes through the city.

The Bhed and Aik Nullahs receive the industrial and municipal wastes of Sialkot. In Rawalpindi and Islamabad, wastes are discharged into Leh Nullah, which finally discharges the pollutants into the Soan River. Multan's textile, tannery, fertilizer and vegetable oil industry discharge waste indiscriminately into seepage drains or onto land. A small sewage treatment plant only partially disposes of the mixture of industrial and municipal waste received by it.

SHORTAGE OF IRRIGATION WATER

Water is not as plentiful as needed and an allocation criteria, adopted a century ago, is still generally followed: water is distributed among the canal commands not on the basis of demand but to attain a cropping intensity that is as low as 75% per year. Thus the supply of surface water has not improved noticeably.

Tubewells in the canal command areas have, to a significant extent, introduced an element of flexibility in the water supply. Supplemental

TABLE 18

WATER SUPPLY AND IRRIGATED AREA

	AVERAGE PER YEAR			
	1960-61	1967-68	1977-78	1985-87
Farmgate availability of water (MAF)	52.52	68.54	89.44	102.32
Water supply growth rate (%)	—	3.9	2.7	1.6
Irrigated area (million acres)	25.71	30.86	35.14	39.80
Land growth rate (%)	—	2.7	1.3	1.5
Feet per acre	2.04	2.22	2.55	2.57

Source: *Report of the National Commission on Agriculture*, Table XVII.2.

water taken from tubewells has progressively increased. Table 18 shows the rate of increase since 1960-61. This, however, has slowed down in recent years.

Soils in the CCA are fertile, and the climate is suitable for year-round cropping. Cropping intensities have, however, remained low due to the shortage of irrigation water. Low delta crops, which dominate the cropping pattern in most canal commands, are conducive to increasing soil salinity. At the same time, it is hard to spare irrigation water to leach salts from the soil. Hence, areas where natural leaching through rainfall does not occur continue to suffer from salinity and sodicity problems.

INEQUITABLE DISTRIBUTION

The irrigation system in the Indus Basin is mostly a run-of-river system, operating on gravity flow. Controls have been provided in the main and branch canals through proportionate distributors. Outlets which draw water from distributary channels have also been designed to share the shortages proportionately. However, this entire distribution system depends on a full supply in the channels. The continual degradation of unlined distributaries is affecting the conveyance system. The tail reaches generally suffer, even during periods of excess water from the river, resulting not only in inequitable distribution but decreased agricultural production.

Studies have shown that conveyance losses in the watercourses further accentuate the inequitable distribution of water. Losses in a watercourse are unevenly distributed, with the head farms getting a disproportionately low share of the losses relative to the tail farms. This is due to the physical nature of the system: the distance from the watercourse is a crucial variable, but the operation of what is called the *warabandi* system of water distribution is also important.

PROBLEMS OF THE RIVERINE AREA

The *sailaba* areas have always attracted cultivators, even before the advent of canal irrigation, as water is not a problem. During the summer the rivers rise, spill over and inundate a part of or all the area. The extent of inundation depends upon the intensity and frequency of floods. Floods also cause widespread damage to life and property in the region. During winter, as the waters recede, riverine areas become available for cultivation. Most Rabi crops in these areas mature without any further irrigation, as the saturated soil contains adequate moisture, from the floods and from seepage from the nearby river. Crop yields are quite high and in some areas more or less at par with those under canal irrigation. Due to flood hazards, summer crops in these areas are not grown on as large a scale as Rabi crops. Nevertheless land is cultivated, wherever possible, with the help of tubewells, or dug-wells at high spots within or around the area.

The diversion of the three eastern rivers by India, under the Indus Waters Treaty of 1960, has meant that the sailaba areas of these rivers have almost gone out of cultivation. Spill irrigation along the western rivers has been adversely affected by the Mangla and the Tarbela dams on the Jhelum and Indus rivers respectively, as by the link canals. India has also constructed the Salal Dam on the river Chenab. Although this is a purely hydro-electric project, it is assumed that the dam will control peak floods and regularise river flow, adversely affecting spill cultivation. Since these areas contribute an appreciable amount to the national economy, it is imperative to find alternate means of irrigation to maintain, and possibly develop, the agriculture of these areas.

PROBLEMS WITH RESERVOIRS

River Channel Degradation

Reservoirs hold back and retain all bed material and a portion of the suspended matter normally carried by the river. The sediment-free water discharged degrades downstream river beds as the water picks up a new load of sediment. As the finer material is washed away, the river bed becomes paved with heavier non-movable material and bed erosion is stopped. The resulting changes in channel profile need to be studied to determine if the new configurations pose a threat to downstream river banks or man-made structures.

This reduced silt flow is thought to have played a part in the deterioration of the mangrove ecosystem in the Indus Delta.

Human Displacement

A reservoir formed by a major dam extends many miles upstream. The reservoir area is generally barren but there may be many isolated communities farming pockets of adjacent land.

For the reservoir to come into use, these villages, their agricultural land and civic facilities have to be submerged. In some instances, the inhabitants of the affected settlements are relocated on land in the immediate vicinity. In other cases, however, people may have to be resettled in areas at some distance from their previous homes. The problems of people and their land becomes delicate in some regions, especially those governed by tribal customs and traditions.

Planning a successful resettlement programme is a lengthy and complicated process that requires attention. However, the relatively long construction time gives ample time for the establishment of equitable procedures and policies.

FISHERIES

Pakistan's marine environment seems to have undergone considerable change over the last 200 years. As the course of the Indus River gradually shifted south-east of Karachi, the old river channels became filled with sea water, with high salinities and reduced nutrients. The food chains in the originally estuarine creeks changed, leading to the disappearance of filter- and detritus-feeding organisms such as oysters, clams and mussels.

Diversion of the Indus waters for irrigation has further degraded the coastal environment. Mangrove swamps, once in abundance along the coastline, have shrunk considerably in area — an estimated 1% of the original 250,000 hectares survive today. These forests have tremendous importance as fish and shellfish nurseries; the diversion of the Indus must surely have adversely affected fish landings in this region. Decreased discharge has meant that cultivation of red rice at Keti Bunder in the Indus Delta has had to be abandoned. A drastic decrease in the sediment load reaching the sea has led to erosion of the coastline, raising turbidity levels along the coast.

The coastal environment of Pakistan is, therefore, not conducive to the healthy growth of mangroves or to the establishment of oyster reefs.

5. ACHIEVING SUSTAINABLE USE

Water must remain available in quantity and quality to sustain agricultural development on a permanent basis. The many factors responsible for reducing the availability of water should be kept in view and a brief description of each is given below.

CONTROL OF CONVEYANCE LOSSES

Losses from the canal system are estimated to be about 26%, a major part of which goes to groundwater recharge. Lining the canals would be valuable, especially in areas underlain by saline groundwater, as this would perform the twin functions of expanding the water supply and reducing system losses, particularly where the canal traverses highly permeable soils. However, it is unlikely that cost-effective methods would be available in the near future. A start can be made by:

1. Lining the smaller canals, i.e., the minors and distributaries using conventional techniques.
2. Through policy decisions, so that no future canal system in the country would be unlined.
3. Making efforts to line the existing system wherever possible at the time of canal remodelling, etc.

Efforts to control conveyance losses in the watercourses have already been undertaken through the On-Farm Water Management programmes e.g., lining of 10-30% of Sarkari Khal and earthen improvements of the remaining part. It has not been possible, so far, to shift the entire financial burden of this improvement onto the private sector.

Hence not only has the pace of improvement been slow, but the maintenance of improved watercourses has not been very effective, with the danger that the work done may deteriorate and become ineffective. The need is:

1. To shift the entire burden of improvement and maintenance onto the private sector through legislation, i.e., the Canal Act.
2. To make Water Users' Associations more effective.

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER

Nearly 44 MAF of groundwater is being pumped for its conjunctive use with surface water. This uncontrolled development may deplete the groundwater — in 14 of 45 canal commands the water-table is declining, indicating overuse. Also such large-scale sub-surface movement of groundwater may result in brackish groundwater laterally moving into less saline groundwater zones. It is very difficult to predict the optimum level of development of groundwater. There is a need to monitor the trend, both regularly and extensively.

INSTALLATION/REPLACEMENT OF TUBEWELLS

Since the development of groundwater has almost reached its limit, the potential for the installation of tubewells in new groundwater areas is limited. Presently, it may be appropriate, as well as timely, to lay more stress on the development of riverine areas, and also develop techniques to skim shallow freshwater layers in saline groundwater areas.

RESERVOIR SEDIMENTATION

Storage reservoirs are created to regulate riverwater supply and transfer flow, by holding water, from one season to another. Since rivers deposit silt in the reservoir, the storage capacity decreases over time, reducing the dam's ability to ensure a sustained supply of water on a predetermined basis. In order to maintain a continuous supply, two actions are required:

1. To reduce silt inflow through watershed management.
2. To continuously add new storage facilities to makeup for lost capacity.

At present, the live capacities of Tarbela and Mangla reservoirs is 14.64 MAF. In the next 50 to 100 years, this will be reduced to nil. In the almost 13 years that have passed since Tarbela was constructed, no additional storage capacity has been added.

TREATMENT OF INDUSTRIAL/ DOMESTIC WASTE

Not only are industries polluting rivers and streams, but in the long run they may also pollute the groundwater reservoir. If treatment of industrial waste water is made compulsory, then the cost of production by our already inefficient industries would increase further. The extra cost would be passed on to the consumer and more difficulties would be faced in competing on an international level. This, however, does not mean that the status quo should be maintained. This problem should dealt with in a phased manner and the following suggestions are being made:

1. Due consideration should be given to siting similar industries together. The effluent could then be collectively treated, reducing water pollution.
2. Treatment of industrial waste water can be taken up in phases. Highly polluted 'black water' containing chemicals should be separated from the less polluted 'grey water' used for washing, by discharging the effluent into separate channels. Black water should be tackled in the first phase of the programme.
3. New factories should have pollution control equipment as an integral part of their plant. Older industries should be encouraged to install primary and secondary treatment units in gradual stages.
4. The 'polluter pays' principle should be implemented, if the existing Factories Act is found to be lacking in waste water discharge standards.
5. Solid wastes need to be removed on site: through still tanks located within the factory premises. This would avoid the waste being disposed of in sewage drains, which are often choked because of low flow velocities in flat gradients.

MONITORING WATER QUALITY

Irrigation water is largely surface water. Riverwater quality needs to be continually monitored at strategic diversion points, i.e., at headworks and barrages to avoid damage to the cultivated areas. In order to pinpoint channels carrying polluted water, the major drains of big industrial cities should also be monitored before outfall into the river.

LAND CONSERVATION

Land is an important natural resource which must be protected against the effects of development activities which reduce or degrade it — such as water. Though water is the source of life for the land, its careless use may result in the deterioration of the land.

Water development efforts since the turn of the century have resulted in waterlogging and salinity in millions of acres of fertile land. This does not mean that water use must be abandoned, but that there is need for a new equilibrium: for efficient drains to take away excess water. Because of Pakistan's flat topography, a surface drainage system is not efficient. It is proposed that:

1. Special agencies, equipped with adequate machinery, be developed to maintain and operate surface and sub-surface drainage systems.
2. Pumped drainage should be gradually introduced. This can help in the design of surface drainage for steeper slopes.

Construction of 'diversion structures' such as barrages and weirs on rivers have constricted waterways and raised the bed level of rivers. Similarly, construction of reservoirs have stoppered certain river channels, constricting flow and encouraging encroachments. The result is that flood waters play havoc with both agriculture and human life. Central measures taken to date to control flooding have been inadequate. It is, therefore, proposed that:

1. National flood protection plans be prepared and implemented in a methodical manner for sufficiently long reaches of the river.

2. All constrictions and encroachments be removed and this be enforced through legislation.
3. All communication lines, i.e., roads and rails be provided cross-drainage works to allow the unobstructed passage of water.
4. All future road/rail projects and feasibility reports must include detailed hydrological data and provision for cross-drainage works.
5. Riverine forests must be encouraged to stabilise river channels.

The sub-surface drainage of lands affected by saline groundwater is a serious problem. This water cannot be discharged into the existing drainage system as it will eventually degrade the quality of riverwater. Presently, it is being dumped in evaporation ponds covering thousands of acres of land. Not only is this land permanently lost, but the saline water gradually affects adjoining land. In addition, these ponds are temporary in nature, as the accumulating salt raises the bed level and makes gravity flow into the pond difficult. These ponds need to be connected to the sea through drains and disposal channels.

SOILS AND THEIR OPTIMAL USE

Waterlogging and salinity, commonly known as the cancer of the earth, have devoured the fertility of the soils of the Indus Basin, largely due to the working of the world's largest man-made irrigation system. However, WAPDA's SCARP programmes, coupled with the digging of innumerable private tubewells have substantially reduced this problem. A recent country-wide salinity survey by WAPDA has indicated that soil salinity has fallen from 42% to 26%.

Soils affected by salinity/sodicity in various land capability classes is given in Box 3. The bulk of saline soils are found in lands which, though within the CCA, have never been cultivated. Even the 979,751 acres of saline/sodic soils within Class III and iV land are, at best, only marginal.

Also, in view of the fact that water is a limited resource, priority must be given to those soils that have the potential of maximum return per acre-foot of water applied. On this basis it is apparent that Class I soils should be fully utilised and cropping intensity enhanced to the optimal level; after this, Class II and III soils should be utilised, depending upon the availability of water.

BOX 3

SOIL AFFECTED BY SALINITY/ SODICITY

LAND CAPABILITY CLASSES	SALINE/SODIC AREA* (acres)
Class I	—
Class II	1,980,000
Class III	622,445
Class IV	357,306
Class V & VI (not represented)	
Class VII & VIII	480,000

Source: *Report of the National Commission on Agriculture*, Table XVII.1.

* Out of a surveyed area of 33.5 million acres.

ENERGY CONSERVATION

Tremendous energy is wasted due to sub-standard, low-efficiency pumping equipment and oversize prime movers. It is therefore proposed that:

1. All manufacturers of pumping equipment be registered, and their designs be checked and approved.
2. Technical guidance be provided to tubewell users to use suitably sized prime movers.

6. POLICY ISSUES AND RECOMMENDATIONS

WATER — A LIMITED RESOURCE

The main source of irrigation water is river flow, of which more than 50% is lost before the farmgate. After allowing for losses in the river channels and for flow below Kotri, the average amount of water available is 130 MAF. If this entire amount could be diverted, the supply at the farmgate would still be 71 MAF only. Groundwater, which is a secondary source created by seepage loss, would supply about 44 MAF at best. Therefore, the maximum supply at the farmgate, under present conditions, would be 115 MAF against the requirement of 120 MAF projected for 1995-96 and 126 MAF for the year 2000. It is, therefore, obvious that water is very limited and is not enough to meet the future food requirements of the country. In the years to come, more emphasis needs to be given to the development and conservation of surface water. In the last 20 years since 1966-67, canal diversions have increased at an average rate of 0.5 MAF per year, i.e., less than one half per cent per year. This growth rate is extremely low and needs to be increased. By the year 2000, all available surface water will have to be exploited through the construction of reservoir facilities to fully regulate river flow and to replace storage capacity lost to sedimentation. A considerable portion of surface water lost through seepage is being recovered through pumping. However, in areas underlain by saline groundwater, this loss must be prevented through appropriate technology.

WATER PER CAPITA

Pakistan's water resources are not only finite but exhaustible and no viable technology is available to generate additional water. Water availability will improve, but only in the medium-term while demand will continue to grow as the population increases. The gap between demand and supply will widen at an increasing rate.

Water is required for municipal and industrial use as well. While there are no exact estimates of the quantum of water required for these functions it goes without saying that with a growing population, increasing urbanization and industrialization, water requirements will grow considerably.

One way of judging the adequacy or otherwise of a country's water resources is to assess the per capita water availability. The per capita water requirement per year has been estimated, by Malik, at 1,000 metres. Water availability for each person in Pakistan will drop from 1,160 metres per year in 1978 to 970 metres by the year 1990. It may improve slightly to 980 metres per year by the year 2000, depending on development of additional potential. Given the investment and implementation implications, the per capita availability will further drop to 780 metres per year by the year 2010, and continue to fall sharply thereafter.

7. CONCLUSIONS

Even if every drop of surface water is safely conveyed to the farmers, the projected water requirements of the country cannot be met on a sustained basis. Hence, stress must be laid on:

1. Optimum output per unit water through optimal use of other inputs and supporting services.
2. Maximising the rational management, conservation and efficient use of water, through improved water use efficiency by accelerating on-farm and command area management programmes.
3. Use of modern techniques such as sprinkle or drip irrigation, wherever economically viable.
4. Recycling municipal and industrial waste water after appropriate treatment.
5. Introduction and installation of shallow pumping or skimming in saline groundwater areas.
6. Reducing the population growth rate through an effective family planning programme.
7. Gradual reduction in the per capita consumption of cereals and the introduction of nutritious foods into the diet, improving the health of the common person.
8. Priority should be accorded to Class I soils in order to maximise the return per acre-foot of water applied. Class II and Class III soils should be utilised after the Class I soils have been fully utilised.

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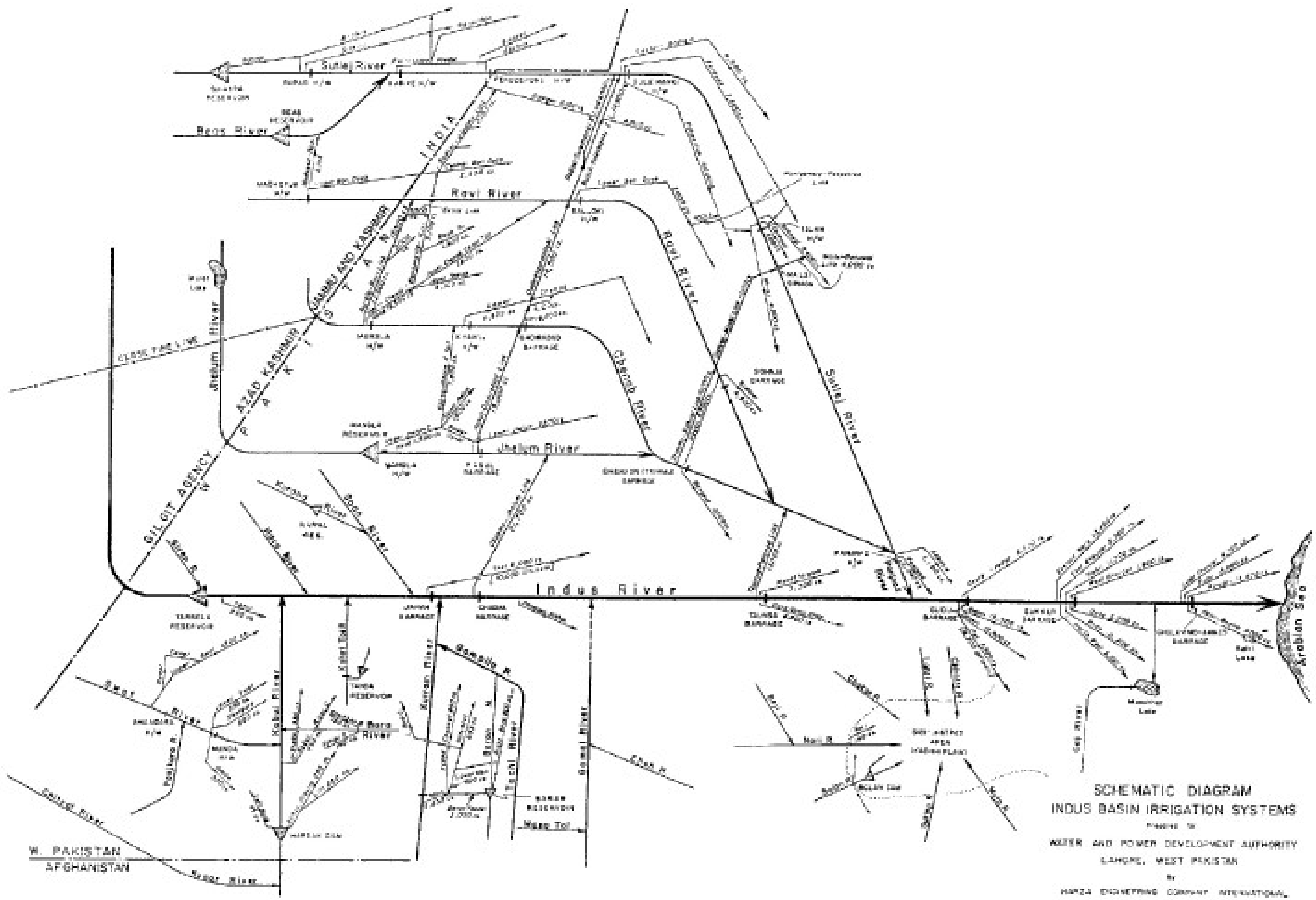
FIGURE	1

SCHEMATIC DIAGRAM OF THE INDUS BASIN IRRIGATION SYSTEMS



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