AN OVERVIEW OF IRRIGATION

IN PAKISTAN

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FOREWORD

This brief paper has been prepared for the benefit of those readers who have interest in different aspects of irrigation in Pakistan. While all aspects are not covered in a brief presentation of this size, the author has attempted to bring out the principal features of irrigation in the country and the factors that impinge on its performance. Based on his vast experience of irrigation and drainage in Pakistan, the author has also highlighted those issues that have particular significance for the future of irrigation in Pakistan.

I hope that the readers, will find this 'overview' informative and thought provoking.

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AN OVERVIEW OF IRRIGATION IN PAKISTAN

1. Introduction

This paper presents an encapsulated overview of irrigation in Pakistan. It is intended for the benefit of those readers who wish to obtain reasonable familiarity with irrigation in Pakistan and its intimate relation to agriculture.

Although the many aspects relating to irrigation in Pakistan require a comprehensive treatment, this paper focuses on the role of irrigation in the context of agricultural development.

Following a brief overview of irrigation, bringing out the salient characteristics of the irrigation systems and the inherent constraints, the paper outlines the initiatives that have been taken over the years, and those in hand or proposed more recently in the Country's Five Year Development Plans, with the objective of realizing the potential for agricultural development.

The concluding part of the paper contains a treatment of the issues in the irrigation sector, which have been identified as having a significant import for the sustainable future development of irrigated agriculture.

2. Role of Irrigation in Pakistan

Irrigation plays a vital role in the Agriculture of Pakistan, which in turn is the most important sector of the economy, contributing 26% to the GDP and accounting for 75% of the foreign exchange earnings. Agriculture is otherwise important too, as is a scenario where the population is growing at a rate of over 3 percent per annum, it provides employment to 54 percent of the labor force with another 16 percent of the rural population dependent on activities related to it.

Out of the geographical area of the country of 79.4 m ha, the cultivated area totals 20.7 m ha, of which 16.2 m ha or 78 percent is irrigated. It is this irrigated area which accounts for 90% of the country's agricultural output. Irrigation is therefore the mainstay of the agricultural economy.

3. Irriaation in Pakistan

3.1 Need for Irriaation

The climate of Pakistan is arid to sub tropical. The natural precipitation in the country is however, very scanty[1]. Over half of the country receives less than 200 mm of annual rainfall, and rainfall in excess of 400 mm occurs over about 20 percent of the mountainous northern areas where rainfed agriculture is practiced in a small way. The precipitation, apart from being small, is distributed quite unevenly over the seasons and in a major part of the country this is concentrated in the 3 to 4 months of the summer monsoon.

As against the low precipitation, the lake evaporation, which is an index of evapotranspiration by the plants, ranges from 1800 mm to more than 2500 mm, annually.

Under these conditions, crops can only be raised by the provision of irrigation to meet essentially the entire crop water requirements- the contribution from rainfall being marginal.

3.2 Sources of Supply

The sources of surface water supply available to Pakistan are its rivers. Most of these rivers, in the western half of the country, are ephemeral streams that remain dry for most of the year. It is the Indus river and its tributaries with perennial flows, that constitute the main source of water supply.

The Indus and its tributaries, have their sources in the Himalayan mountains and the Hindu Kush, with a total drainage area of 399,000 sq. km, which is larger than that of the Ganges and Brahamaputra. The inflow to these rivers is mainly derived from snow and glacier melt and rainfall in the catchment areas. The tributaries of the Indus, originating in India but flowing into Pakistan are the Jhelum, Chenab, Ravi and Sutlej (with a major tributary Beas). Originating in Afghanistan, the other major tributary is the Kabul river.

Under the Indus Waters Treaty 1960, the flows of the three Eastern Rivers, (Sutlej, Beas and Ravi) have been allocated to India, whereas, with minor exceptions, Pakistan is entitled to all the waters of the Western Rivers (Indus, Jhelum and Chenab). The average annual inflow of the Western Rivers at the rim stations, as they enter the Indus Plains is 169.25 billion m^3 (BCM) or 137.2 MAF. This constitutes the main source of water supply for irrigation in the country.

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[1]. **Typical values of annual rainfall:** Lahore **493** mm, Faisalabad **348** mm, Multan 168 mm, Karachi **203** mm, Rawalpindi/Islamabad **960** mm.

In addition to the surface water, groundwater is another important source of water supply. Investigations have established the existence of a vast aquifer with an areal extent of 194,000 sq.km.(75000 sq. mi) underlying the Indus Plains which has been recharged in the geologic times from natural precipitation and river flows and more recently by the seepage from the canal systems. Although the quality of tho groundwater in the Indus Basin aquifer is highly variable, both areally and with depth, it is estimated that 49.8 BCM (40.4MAF) of groundwater, representing the recharge, could be withdrawn annually for beneficial uses.

3.3 History of Irrigation Development

There is evidence that irrigation, based in the flows of the Indus and its tributaries was practiced in the historic past but traces of it have now been lost.

Large scale irrigation development, essentially in the Indus Plains, was initiated with the British rule. Initial development consisted of inundation canals which functioned only during periods of high river flow providing water for summer (Kharif) crops, and some soil moisture for winter (Rabi) crops.

Controlled, year round irrigation began in 1859 with the completion of the Upper Bari Doab Canal, from the Madhopur Headworks on the Ravi River (now in India)[2]. This was followed with the development of several canals off-taking from headworks and barrages across the rivers Ravi, Sutlej, Chenab and Jhelum in the Punjab province and from the Kabul and Swat rivers in the North West Frontier Province. By the turn of the century, apart from the area served by the inundation canals, mostly in the Sindh Province, the culturable commanded area (CCA) of the canals with controlled inlets was around 2 million ha (5 million ac).

As irrigation development proceeded in the Punjab, it was realized that the flows of the individual rivers were not in proportion to the irrigable lands they could serve. The Triple Canal Project, comprising of the Upper Jhelum, Upper Chenab, and Lower Bari Doab canals (LBDC) was therefore developed from 1907 to 1915 to irrigate 1 million ha (2.6 million ac) by utilizing the flows of the Jhelurn and Chenab rivers and transferring their excess flows to the river Ravi for use in the LBDC. Another major project undertaken in the Punjab from 1922 to 1929 was the Sutlej Valley Project under which four barrages were constructed on the Sutlej river to feed eleven canals and serve an area now in Pakistan of 2.2 million ha (5.4 million ac). Another Barrage on the River Ravi was added in the Punjab during this period in 1929.

The first barrage on the Indus river named the Lloyd Barrage, was constructed at Sukkur in 1932 and while providing controlled supplies to the pre-existing inundation canals extended the irrigation command with new canals. Seven canals off-take from

[2]. The canal passing through Lahore, the Lahore Branch, is an off-take of this canal

this barrage that serve a commanded area of 2.95 million ha (7.3 million ac) in the Sindh province.

After 1932, two more barrages were constructed in the Punjab, one on the river Chenab was completed in 1939 and the other on the Indus at Kalabagh was under construction at the time of the creation of Pakistan in 1947.

At the time of the independence of Pakistan, the total CCA for which the irrigation supplies were derived from weirs and barrages on the rivers was 10.9 million ha (27 million ac), whereas about 2.4 million ha (6 million ac) was fed from inundation canals. A number irrigation system at that time were extension of the systems originating in India or were dependent on supplies from headworks located in India.

In 1948, India unilaterally stopped the irrigation supplies flowing into Pakistan which created an International dispute. While Indo-Pakistan negotiation to resolve the wasters dispute were in progress, Pakistan on its own undertook the construction of 3 inter-river link canals to insure itself against the sudden stoppage of supplies by India. These links, constructed from 1952 to 1956, transferred the Chenab supplies to the Ravi and Sutlej rivers to feed the truncated systems and to make up for supplies appropriated by India.

After independence Pakistan also took up the construction of three new barrages on the Indus River to serve a CCA of 3 million ha (7.4 million ac). With the completion of these barrages by 1962 all the irrigation systems, with minor exceptions, were converted into weir controlled systems.

The dispute with India over the river waters, was resolved by the signing of the Indus Water Treaty in 1960 which provided that "Pakistan shall usee its best endeavors to construct and bring into operation, with due regard to expedition and economy, that part of a system of works which will accomplish the replacement from the Western Rivers and other sources, of water supplies for irrigation canals in Pakistan which on 15th August, 1947, were dependent on water supplies from the Eastern Rivers". The system of works were set forth in the Indus Basin Development Fund Agreement and comprised of two dams on the Jhelum and Indus, 9 inter-River Link canals, 3 Barrages and ancillary works.

The works under the Indus Water Treaty, as finally constructed, comprised of the Mangla Dam (reservoir capacity 6.58 BCM or 5.34 MAF), Tarbela Dam (reservoir capacity 11.59 BCM or 9.4 MAF), five Barrages, eight Inter-river link canals, linking the rivers Indus, Jhelum, Chenab, Ravi and Sutlej, a syphon under the Sutlej river and the remodelling of some existing barrages and link canals. With the exception of the Tarbela dam which became operational in 1976, all the works under the Treaty were completed during the period 1960-70. Although these works were regarded as 'replacement' works they also incorporated certain developmental aspects such as surface storage and hydro-power generation. The construction of the surface storages however, introduced, for the first time a measure of control on the natural river flows permitting inter-seasonal transfer of supplies and the inter-river link canals provided a flexibility in distributing the available supplies to different canal systems which now became a part of an integrated network. The Irrigation infrastructure, as developed is shown in the Schematic Diagram in Fig. 1 Indus Basin Irrigation Systems.

Since the creation of Pakistan, except for minor additions to the irrigation system, no major irrigation extension projects have been taken up until recently when the construction of the Chasma Right Bank Canal was started to serve a CCA of 230,000 ha (570,000 ac).

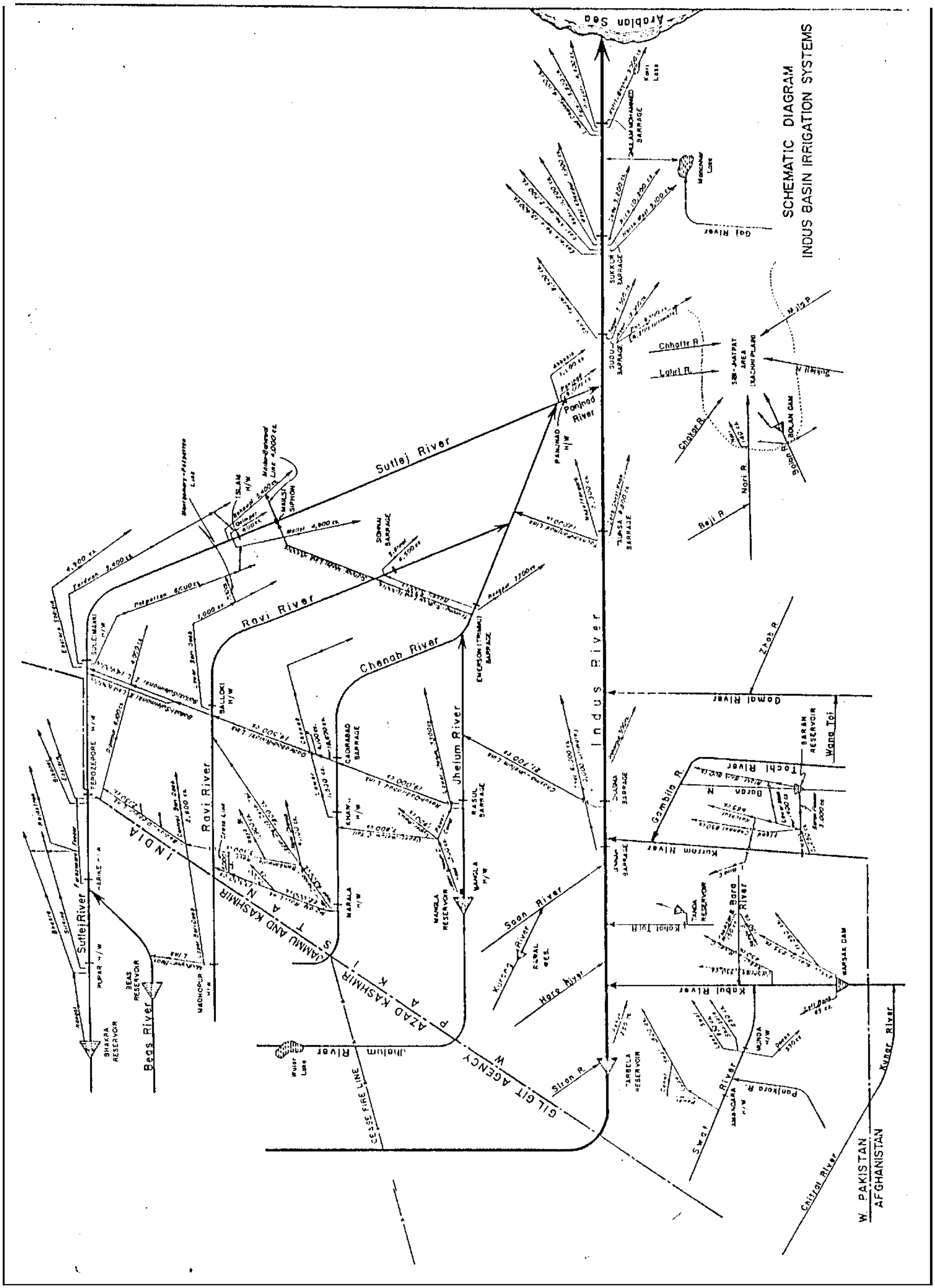
The surface irrigation system as it now exists covers the world's largest contiguous irrigated area (see Fig.2). It comprises of three storage reservoirs (Total original live capacity 18.99 BCM or 15.4 MAF), 16 Barrages, 12 inter river link canals, 2 syphons and 43 main canals. The total designed diversion capacity of main canals is 7250 cumecs (256,000 cusecs). The total length of the link canals, main canals branches and distributaries, is about 57000 km (35,500 miles). The system has 88,600 outlets for the irrigation of service areas. The length of the farm channels and water courses is about 1.6 million KM (one million miles). An irrigable area of 14.2 million ha (35 million ac) is served by the system.

Apart from the improvements in surface irrigation, a significant feature impacting on the country's irrigation, has been the massive development of groundwater from the Indus Basin aquifer during the last **30** years. Initial development of groundwater, as a supplement to surface irrigation, was an outcome of the Salinity Control and Reclamation Projects (SCARPs) under which large capacity (*60* to 150 litlsec) tubewells were installed in the irrigated area to control waterlogging. Starting from 1963 over 11000 tubewells were installed upto 1985 in the SCARPs having useable groundwater. At the same time, the demonstration effect of the SCARP tubewells, spurred the development of groundwater in the private sector by the use of small capacity (30 litlsec) tubewells. From 1964 to 1989 the number of private tubewells jumped from 27,000 to 264,000 representing an average growth rate of 9.6% per annum. About 70% of these private tubewells are located in the canal commanded areas while the rest provide irrigation based on groundwater alone.

3.4 Irriaation supplies and their utilization

The flows in the Indus river and its tributaries vary from year to year, the 80 per probability values (flows which can be depended upon in 4 years out of 5) being 88%. 83% and 86% of mean annual flows for the rivers Indus, Jhelum and Chenab respectively. The flows are however characterized by a large seasonal variation, with 84 percent of the flow occurring during the summer cropping season of Kharif (April to Sept) and only 16 percent in the winter cropping season of Rabi (Oct to Mar). While it has been possible to utilize essentially all the low flows during Rabi, the highly

Figure - 1


SCHEMATIC DIAGRAM
INDUS BASIN IRRIGATION SYSTEMS
Arabian Sea
Indus River
Jhelum River
Chenab River
Ravi River
Sutlej River
Beas River
Panjnad River
Kabul River
Swat River
Soan River
Haro River
Siran R.
Kurram River
Tochi River
Gomal River
Zhob R.
Nari R.
Bolan R.
Chhattr R.
Lahri R.
Chakar R.
Beji R.
Gaj River
Kunar River
Chitral River
Panjkora R.
Gambila R.
Kohat Toi R.
Bara River
Wana Toi
Kurang River
GHULAM MOHAMMED BARRAGE
SUKKUR BARRAGE
GUDDU BARRAGE
TAUNSA BARRAGE
CHASMA BARRAGE
JINNAH BARRAGE
EMERSON (TRIMMU) BARRAGE
RASUL BARRAGE
QADIRABAD BARRAGE
SIDHNAI BARRAGE
MARALA H/W
KHANKI H/W
BALLOKI H/W
SULEIMANKI H/W
ISLAM H/W
PANJNAD H/W
FEROZEPORE H/W
MADHOPUR H/W
RUPAR H/W
HARIKE H/W
MANGLA H/W
MANGLA RESERVOIR
TARBELA RESERVOIR
BHAKRA RESERVOIR
BEAS RESERVOIR
RAWAL RES.
TANDA RESERVOIR
BARAN RESERVOIR
WARSAK DAM
BOLAN DAM
MAILSI SIPHON
SIBI-JHATPAT AREA (KACHHI PLAIN)
Manchar Lake
Kinjhar Lake
Wular Lake
INDIA
JAMMU AND KASHMIR
AZAD KASHMIR
W. PAKISTAN
GILGIT AGENCY
W. PAKISTAN
AFGHANISTAN
CEASE FIRE LINE
Sutlej River
Ravi River
Jhelum River

variable flows during the Kharif season, accompanied with flood peaks, cannot be utilized as effectively.

Over the years, there has been an increase in the diversion of the river flows for irrigation as the systems were developed or as the demand for irrigation water increased., Over different periods, the seasonal canal head withdrawals are shown in the Table below:

CANAL HEAD WITHDRAWALS
(Billion cubic Meters)

Period	Kharif Apr - Sept	Rabi Oct - Mar	Annual
1950-60 Pre-Treaty	**61.72**	**31.52**	**96.94**
1960-67 Pre-Manala	**74.21**	**31.46**	**108.14**
1967-75 Pre-Tarbela	**78.90**	**36.49**	**115.39**
1975-85 Post-Tarbela	**79.70**	**45.50**	**125.20**

A review of the last **11** years of System operations **(1976-87)** brings out that the total annual canal head diversions averaged **129.07** BCM **(104.63** MAF) or **71%** of total river inflows. However, the Rabi diversions amounted to **46.87** BCM **(38** MAF) against the Rabi inflows of **32.01** BCM **(25.95** MAF) which was possible due to the inter-seasonal transfer of supplies through the storage reservoirs, Tarbela, Mangla and Chasma augmented with regeneration. On the other hand the Kharif diversions of **82.20** BCM **(66.63** MAF) were only **55** percent of the inflows. During this period, the quantity of water that escaped to the sea averaged **42.97** BCM **(34.83 MAF)** annually.

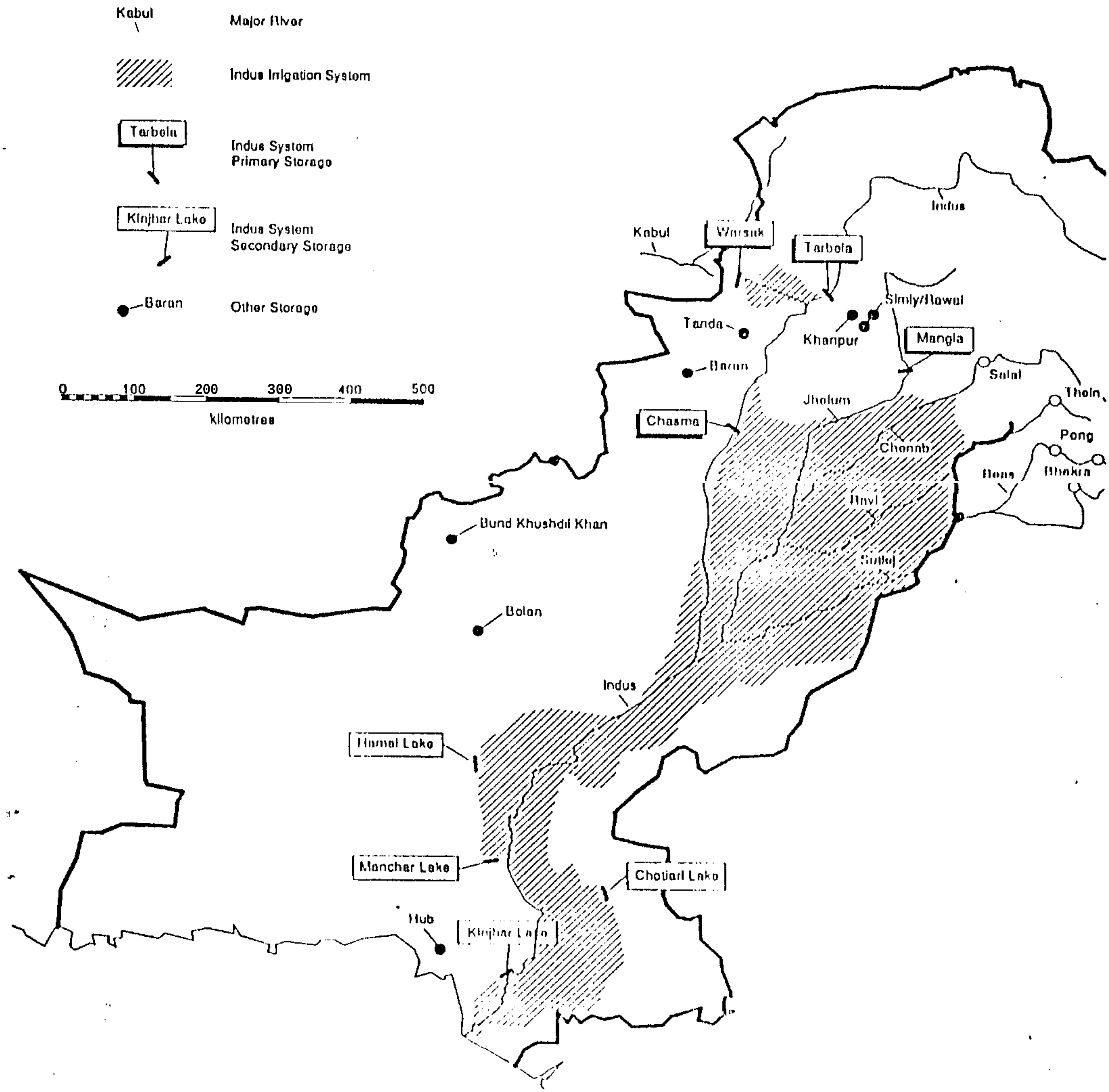
Considering the highly variable nature of the Kharif flows, further capture of surface waters for enhancing dependable irrigation supplies is now greatly limited. Potential increases in irrigation supplies would have to depend on the construction of surface storages.

Out of the annual potential of useable groundwater estimated as **49.84** BCM **(40.4** MAF), the groundwater pumpage in **1984-85** was found to be **10.80** BCM **(8.76** MAF) from the SCARP tubewells and **39.35** BCM **(31.90** MAF) from the private tubewells. Thus, if anything, there is now a tendency for over exploitation.

In the present scenario therefore, the water resources, available for irrigation have been largely appropriated.

Figure - 2

Indus Irrigation System and Surface Storage



3.5 Irrigation System Characteristics

Irrigation systems in Pakistan have been developed mainly over the vast Indus Plains, which covers an area of 207,000 sq.km (80,000 sq mi.) and extends for nearly 1600 km from the lower Himalayan foot hills to the Arabian sea. The un-dissected nature of the terrain in the Indus Plains with its gentle slopes has permitted the construction of large Irrigation systems in which, form a single river diversion the irrigation water is conveyed over long distances. While this may have been cost effective, the sheer size of the systems is an impediment in the effective operation of the systems, as in some system it takes several days before the diverted water reaches the farthest extremities.

All the irrigation systems, in the Indus Plains, have been developed on the run-of-the river flows and it was only with the construction of Mangla and Tarbela dams and the Chasma Barrage that a small measure of regulation has been provided over the natural river flows, Dependence on the run-of-the river, implies that the supplies that can be diverted for irrigation are subject to variation depending on the flow conditions. This basic design feature has also meant that only the systems which first appropriated the small winter flows have the benefit of perennial irrigation supplies whereas the other systems must depend on summer supplies only, although year round cropping is possible and practiced. Out of the total irrigated area of 14.2 million ha (35 million ac) commanded by the Indus system, 60% is perennial and the remaining is entitled to irrigation supplies only during the Kharif season. The present annual cropping intensity over the systems is about 103% (against the theoretical maximum of 200% for the two cropping seasons). Cropping intensities however, vary from system to system, from a low of 29% in a non-perennial command to a high of 150% in a perennial command.

A basic design feature of the irrigation system has been to spread the irrigation water over as large an area as possible to expand the settlement opportunities. In most of the major perennial systems, the entitlement of water from the irrigation outlet, termed as water allowance, was fixed as 200 litlsec for 1000 ha (3.0 cs per 1000 ac) of CCA (equivalent to 1.8 mm/day over the irrigable area). As this water would be insufficient to irrigate all of the irrigable areas, cropping intensities were, in design, restricted to around 25% in Rabi and 50% in Kharif or a total annual of 75%. While in some perennial systems somewhat higher water allowance were permitted, the non perennial canals were allowed more copious supplies with water allowance going up to 1300 litlsec for 1000 ha (19 cs/1000 ac) for rice cultivation.

The irrigation systems, typically consist of the main canal from which the water is distributed to branch canals. Secondary channels, called distributaries take off from the main and branch canals. The distributaries and their smaller branches called minors are the main arteries for releasing, through outlets, the irrigation water to small irrigation service areas (averaging 160 ha) called 'chaks'. The outlets are free draining structures which have a capacity fixed in proportion to the service area. As the outlet discharge is a function of water surface elevation in the supply channel, it becomes difficult to achieve equity in water distribution, the basic design objective, due to the variations in discharge and the changes in the channel regime caused by siltation.

The distribution of water from the outlets, having mostly a capacity of 30 to 90 lit/sec, to the group of farmers in the 'chak' is done on a rotation called 'warabandi'. In the 'warabandi', which is generally of seven days, each farmer receives the entire outlet discharge (successfully along the tertiary channel), at fixed times and for a period in proportion to the size of the holding. The framing of the 'warabandi' is left to the farmers, but where they do not agree, it is prescribed by the officials of the Irrigation Department.

The hydraulic design of the earthen channels to satisfy the regime condition (obviating silting or scour) places a restriction on their operation. Standing instructions require that the channels should be operated within a narrow range of discharge - usually between 80 to 110 percent of design. Under conditions of low water availability, therefore the channels have to be operated in rotation, greatly increasing the irrigation intervals.

The operation of the systems is based on a continuous supply diverted at the headworks and is in no way related to the crop water requirements. The supply is stopped for a period of 4 weeks or more in the winter for silt removal from the channels and for repairs to canal structures. The supply has also to be interrupted during periods of high river flows to avoid the entry of highly silt laden waters into the canal system. The supplies that can be run into a system are also subject to change depending upon the available river flows. The water in transit in the large irrigation systems is also not subject to prompt regulation, when the irrigation demand drops following widespread rainfall, as no appropriate escapages are provided. Under these circumstances, breaches in canals take place as the farmers tend to block their outlets.

Due to the inadequacy of the surface irrigation supplies and the variability in them associated with the river diversions which is further aggravated in the distribution system, the farmers have turned more and more to the use of groundwater, wherever it can be tapped, but without a full awareness of the hazard represented by the groundwater quality.

3.6 Physical and Environmental Constraints

There are few physical constraints for agriculture production in the irrigation systems of the country. The climate is favorable for year round cropping and the soils are deep and well suited for irrigation. The lack of natural drainage in the flat Indus Plains however, causes local flooding after heavy rainstorms in many parts of the irrigated areas. Although most of the irrigated areas adjoining the rivers have been protected by levees they are still prone to flooding by the infrequent high floods that cause breaches in the levees or if they have to be deliberately breached to protect the barrages or towns.

The only constraint for agricultural production in the irrigated areas which has been of great concern is waterlogging and salinity. In the absence of any natural sub-surface drainage, the seepage from the irrigation systems has caused the water table to rise (by as much as 25 to **30** meters at places) creating waterlogged conditions. Soil salinity occurring naturally or caused by high water tables has also continued to affect large areas. Although a major programme of Salinity Control and Reclamation has been undertaken over the last **30** years high water table (within **1.5** meters of the surface) affects **13%** of the area during the driest part of the year and **30%** following the rains. Surveys in the recent past have indicated that, while there has been improvement over the past, there are still large areas which are affected by soil salinity. Recent salinity appraisals indicate that 28% of the area was affected by surface salinity (in the top soil), but when the soil profile to a depth of 2 meters **(6ft)** was examined the **39%** of profiles were found to be affected by salinity, sodicity or both.

3.7 Management of Irrigation Systems

With the exception of small irrigation systems, mostly in the NWFP Province, which were privately constructed and are administered by the Civil authorities, and local systems outside the Indus Plains depending on hill torrents, all other irrigation systems in the country are controlled by the Irrigation Departments of the Province independently of the Agriculture Departments. The Federal Government, through the Water and Power Development Authority (WAPDA), is responsible for making the releases of water from the storage reservoirs in accordance with the provincial requirements with due regard to the likely seasonal availability of supplies.

The provincial share in the available supplies was determined until recently by historical precedent and on an ad-hoc basis for Tarbela releases. Although in 1945 an agreement was drafted on priorities for sharing by the Punjab and Sindh of the waters of the Indus and its tributaries for the existing and projected canals, it lost its relevance following the Indus Water Treaty with India in **1960.** The subject of establishing the share of the provinces in the surface supplies was examined by a succession of Committees and Commissions without resolution for over 40 years. It was only in **1991,** that the four provinces agreed to their respective shares in the water of the Indus River System. To oversee the implementation of the accord on a continuing basis the Indus River System Authority with Federal and Provincial representation has been created.

Water allocations of the systems have been established as they were constructed and in later developments priorities had been fixed for various systems for sharing the supplies. In the normal course, the irrigation officers responsible for the O&M of parts of the system place an indent for the supplies but the actual releases that are made are determined by the supplies (to be shared by different systems) following the principle of equitable distribution. In the allocation process, however, no consideration is paid to the crop water needs or to the relative availability of ground water even in cases where the groundwater pumpage is controlled by the Irrigation Department.

Management of the Irrigation systems by the Irrigation Departments is in effect an administration of the systems as the age old rules and procedure continue to be applied without regard to the changed conditions.

Although the Irrigation Departments have the responsibility for the O&M of the drainage systems - surface and sub-surface, (in addition to flood control measures), the irrigation operations are handled independently even in cases where the groundwater is pumped by the department and added to the canal supplies at the outlet for equitable distribution.

The maintenance of the irrigation systems upto the outlet is the responsibility of the Irrigation Departments but the upkeep of the tertiary channels in the outlet 'chak' is left to the farmers.

For carrying out their responsibilities, the Irrigation Departments are provided with funds from the Non Development Budgets of the Provinces. For special repairs, allocations from the Annual Development Program are made as required. There is a charge for the supply of irrigation water by crops which is assessed on the areas of the crops harvested by each irrigator. The revenue from water charges (and from drainage cess where levied) reverts to the provincial exchequer.

In a broad perspective, the management of the irrigation systems is characterized by a situation in which the Irrigation Departments are isolated from the beneficiaries and make the system run as best as possible with little regard to the basic objective of crop production.

3.8 Performance of Irriaation Systems

There are no criteria established in the country to assess the performance of the irrigation systems either from the point of view of the efficiency with which the systems are operated and the waters are utilized or in terms of their contribution to agricultural output. Under these conditions, only indirect indicators can be used.

In so far as systems' operation is concerned, IIMI's work [3] has indicated that supplies in the systems studied are characterized by unreliability and inequity with chronic shortages at the tail ends. Studies have also indicated that in almost all irrigation Systems the supplies are unrelated to crop water requirements, there being periods

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[3]. **Bhutta** M.N **and Vander Velde, E.J. Equity of water distribution along secondary canals in Punjab, Pakistan. Irrigation and Drainage Systems** *6:* **161-177, 1992**

of shortages and surpluses. While the shortages impact on crop yields, the surpluses represent not only a waste of a resource but also create drainage problems.

There is evidence that the systems have been falling in disrepair, for want of adequate and timely maintenance, as major projects for the rehabilitation of a large number of canals had to be taken up from 1988. According to an inventory prepared by the Irrigation Departments, a total of 39,661 km of canals required rehabilitation. Similarly the large number of public irrigation tubewells installed under the SCARPs have shown a marked decline in their discharges and those that had outlived their lives have not been regularly replaced. (The deficiency in public tubewells, may however, have been made up by the private tubewells).

If the countries agricultural production, which is heavily dependent on irrigation, is taken as an index of irrigation performance, then for the past, Annual Growth Rates for agriculture, over successive five year periods, can be looked at. These are shown in the Table below.

Period	Growth Rate-Percent per Annum
1950 - 1955	1.0
1955 - 1960	2.1
1960 - 1965	3.8
1970 - 1975	0.8
1975 - 1980	3.9
1980 - 1985	3.2

1990) are shown in the Table below, and compared to those attained in other countries.

COMPARATIVE YIELDS OF CROPS
AVERAGE FOR 1985 TO 1990
Tons per Hectare

Country	Wheat	Rice (Paddy)	Maize	Seed Cotton	Sugarcane
Pakistan	1.77	2.40	1.34	1.63	39.59
India	2.09	2.29	1.33	0.56	59.20
Mexico	4.15	-	1.69	2.90	-
Egypt	-	5.93	-	2.39	90.55
Philippines	-	2.66	-		-
Thailand	-	2.05	-	-	-
U.S.A.	2.31	6.24	6.97	1.85	80.75
Japan		6.16		-	-
Turkey	1.85	-	4.03	2.20	-

4. Development Initiatives

4.1 Past Efforts

From 1955, development efforts in the country have been undertaken under successive, Five-year Development Plans except for a 3 years break from 1975 to 1978. Upto the start of the Seventh Five-Year Plan in 1988, the developments pertaining to Irrigation are summarized below.

On the physical side, the developments in the irrigation systems, have been brought out in the section 3.3. History of Irrigation Development. These have consisted of the provision of controlled inlets to the existing canals and the creation of the major

.irrigation infrastructure following the Indus Waters Treaty. The development of irrigation in new areas took place on a small scale only, as this was forestalled by the lack of a decision on the provincial shares in the river waters.

Starting from 1960, the greatest emphasis was placed on waterlogging and salinity control in the irrigated areas. For this purpose major sub-surface drainage projects were undertaken involving the pumpage of groundwater through large capacity tubewells. Initially the projects were planned for the fresh groundwater areas and the pumped water was used as an irrigation supplement to achieve higher cropping intensities. BY 1989, over 12,500 tubewells had been installed and their contribution to irrigation had gone up to 1I.2 BCM (9.05 MAF) per year.

Sub-surface drainage of saline groundwater areas was also undertaken in a small way, with local arrangements for the disposal of the saline effluent into the canals or rivers, and a start was made on a major outfall drain to sea to cater to the drainage needs in the Sindh Province,

The planning of a major surface storage for irrigation and hydro-power generation on the Indus was also completed, but political controversies forestalled its execution.

On the institutional side, a major change was introduced when, with the amalgamation of the provinces into the One Unit in 1958, WAPDA was created to undertake all water and power development activities and the irrigation operations were centralized under the One Unit. While WAPDA continued as a Federal Organization, with its functions unchanged, the irrigation operations reverted to the four provinces on their recreation in 1970.

The past policies in the Water Sector continued to emphasize water development and massive exploitation of groundwater in the Public Sector, but from the mid 70s attention was directed to water conservation to make a better use of the available supplies.

4.2 Seventh Five Year Plan

The country's Seventh Five Year Plan covers the last 5 years extending to June 1993.

In the Agriculture Sector, the Plan envisaged a growth rate of 4.7 percent per year "mainly by vertical expansion which will effectively override the constraint on area expansion imposed by the available irrigation supplies". In the water sector the elements underpinning the Plan were

- Progressive addition to irrigation supplies from new surface water sources and groundwater exploitation;

- Conservation of existing irrigation supplies and their effective management; and

- Increasing the productivity of land through the control of waterlogging and programmes of drainage and soil reclamation.

No increases in existing canal withdrawal were foreseen during the Plan and the 11.5% addition to the irrigation supplies at the farm gate amounting to 15.5 BCM (12.9 MAF) was to be derived mainly from groundwater development 7.0 BCM (5.7 MAF) and water conservation 6.0 BCM (4.9 MAF). The balance represented supplies from small irrigation developments.

In the total public outlay in the Water Sector amounting to Rs. 28.6 billion ($ 1.14 billion) the Plan allocated the largest share to Drainage and Reclamation (47%), the other main components being : Irrigation (30%), On-farm Water management (13%). with Flood Control and other items accounting for the rest.

The Plan carried through the basic change in policy introduced during the Sixth Plan, to leave the development of usable groundwater to the private sector and provided for the transfer of the public irrigation tubewells in SCARPs to the farmers or for replacement by them with smaller tubewells. On the institutional side, the Plan recognized the need to upgrade the operations of the Provincial Irrigation Departments. The outstanding issues, were regarded to be: financing mechanisms (such as sector loans) which could ensure adequate and timely financial allocation for the many projects in the reclamation program; allocation of river water to the provinces, and recovery of full O&M costs.

With the Plan coming to an end, its evaluation has been undertaken by concerned agencies to provide a frame work for the Eight Five Year Plan. According to the report on Agriculture and Water Sector, by a Committee appointed by the Government, the Crop Sector is estimated to have grown at the rate of 4.3% against the target of 4.5% per year. Comparison of the annual growth rates of different crops, with the Plan targets, however revealed that the Plan failed to achieve the targets for all the major crops except cotton as shown in the table below:

SEVENTH PLAN - PERFORMANCE OF CROP SUB-SECTOR

Growth Rates, Percent per annum.

CROPS	PLANNED	ESTIMATE
Wheat	3.9	2.6
Rice	5.1	(-) 0.2
Basmati	9.0	3.1
Other varieties	3.6	(-) 1.7
Maize	6.0	(-) 0.5
Sugarcane	4.6	(-) 0.1
Cotton	4.7	5.5

On the water side, the Committees on Agriculture and Water, has noted that during the Seventh Plan the projected increase in water availability was likely to be achieved, and although a significant development for the future of irrigation took place with the signing of the Water Accord, specifying the respective provincial shares in the surface waters, the following constraints were being experienced in attaining sustainable irrigated agriculture.

* Irrigation systems water management inefficiencies
* Lack of drainage and anti salinity measures
* Shortage of resources for the improvement, modernization and expansion of the irrigation system.
* Wastage of huge surplus flood flows to the sea due to lack of timely policy decisions in developing surface storage.
* Irrigation system inability to function as demand based system.
* Inadequate diversion capacity of the canals particularly in the Punjab and NWFP.

4.3. Eighth Five Year Plan

The countries Eighth Five Year Development Plan, is on the anvil and with its approval is likely to go into effect from July 1, 1993.

Although the form and content of this Plan are subject to approval, an important step in its formulation was 'that for the first time the Agriculture and Water Sectors were considered together by the constitution of a Committee on Agriculture and Water for the Eighth Five Year Plan. Apart from the review of elements impacting on agricultural production, the Committee was required to recommend the objectives, policies and strategies for agriculture and water resources development during the Eight Plan, keeping in view the countries need for food and raw materials and exportable surpluses. The Committee was also required to consider the policy and institutional aspects and the program outlines.

The Committee has upheld the objectives of agricultural development, declared by the Government, to be social equity, self reliance, enhanced productivity, export orientation, and sustainable agriculture. These have to be accomplished through a strategy whose elements comprise of i) higher growth rates (exceeding population growth) ii) increasing productivity, iii) institutionalizing reforms, institutional development and bringing economic and social equity iv) focus on the small farmer, and v) achieving full employment through agro-based industries.

The Committee has highlighted main strategic issues and an Agenda for action, the main elements of which, under the relevant heads recognized, are given below:

Organization and Manaoemenf

1. Defining the Federal and Provincial roles in agriculture and irrigation and delegating greater powers to the provinces.

2. Development of more effective linkages and interactions between the numerous agencies based on a study of existing institutional structures and mandates.

3. Bringing agriculture and irrigation together at the provincial level by placing them under one Secretary.

4. Undertaking integrated agricultural developments in canal commands, on the pattern of Command Water Management Projects.

Policy Issues

1. Most remunerative use of available resources, in different agro-ecological zones - to be established through research based on an adequate data base.

2. Incentives may be given to farmers to improve production technologies, and agricultural prices and subsidies should keep the interest of the farmer alive.

Water Sector

1. Increasing crop productivity by at least 25% during the Plan to overcome the anticipated shortage of water availability (only 10.1 BCM likely to be developed against the requirement of 19.7 BCM to meet crop targets).

2. Undertaking early construction of 9-12 BCM storage reservoir(s).

3. Making more effective use of water resources, and gradually moving towards demand base operations by providing sub-storages.

4. Rationalizing water rates structure to make irrigation self financing.

5. Developing cost effective strategies to control Water Logging and Salinity.

institutional Development

1. Developing more effective linkages between education, research, extension and the farmers.

Preliminary proposals developed in Water Sector for the Eighth Plan, follow the past pattern, giving a high priority to Drainage and Reclamation, with a larger effort to be directed on the termination of the SCARP irrigation tubewells and transferring the responsibility of ground water development in the areas served by them to the private sector. Pertaining to irrigation, apart from the extension of irrigation to small areas, the programme of the rehabilitation of canals is intended to be carried through, with the likely addition of canal lining to conserve seepage losses. Also, the Watercourse Improvement Programme, is likely to be accelerated by improving 10,000 water courses. Command Water Management Projects, involving improvements to the irrigation systems, as a component of institutional development for integrating irrigation and agricultural are foreseen as an additional item.

5. Problems of Irrigated Agriculture and Issues

Despite the massive development of the surface and groundwater resources in the country the performance of the agriculture sector, based as it is on irrigation, has been faltering. Non-water inputs may have contributed to growth but is not clear to what extent their impact was constrained by the pattern of the largely uncontrolled irrigation supplies. The persisting low crop yields, showing no signs of progressive increase. reflect on the performance of irrigation, when it is considered that irrigation is intended to provide an insurance against the vagaries of nature.

The recent (1990) Water Sector Investment Planning Study (WSIP) examined the future agricultural production scenarios for a population of 148 million in 1999-2000 and 207 million in 2012-213, (growing from 107 million in 1989) and estimated the deficits in crop production that were likely if no investments were made in the water sector and the crop yields followed the historical trend, and those that would still persist if an investment of Rs. 105 billions ($4billion) was made upto the year 2000. In relation to the requirements these deficits are shown in the table below.

CROP PRODUCTION DEFICITS
PERCENT OF REQUIREMENT

CROPS	Year 1990-2000		Year 2012 - 2013	
	Without Investment	With Investment	Without Investment	With Investment
Wheat	20	7	30	18
Rice	38	21	40	29
Sugarcane	20	3	36	23
Cotton	19	(48)	24	(31)
Oil seeds	63	63	61	57
All fruits	39	42	49	43

Note: Figures in parentheses reflect surplus.

The figures in the above table are indicative of a backslide in agriculture, and point to need for a larger growth in crop yields, for which potential still exists. The WSIP study has estimated that if the crop yields are not increased, the additional water requirements at farm gate necessary to eliminate production deficits would be 29.2 BCM (23.7 MAF) by 1999-2000 and 84.8 BCM (68.8 MAF) by 2012-2013. With the limited potential now left for harnessing additional water supplies from the surface or groundwater resources, the most pressing problem is to increase the production per unit of water.

Another problem which must be faced is the maintenance of the production base for irrigated agriculture. While measures have been taken to reclaim and protect the lands from the adverse effects of waterlogging and salinity, these problems still afflict large areas. Satisfactorily solutions have yet to be found for removing the salts from the system.

Maintaining the operating efficiency of the irrigation and drainage systems, is yet another problems which has implications for their sustainability.

In this broad perspective, the issues in irrigation sector, which have been identified as having significant import for the future development of irrigated agriculture are treated below.

5.1 Relation of Irriaation and Aariculture

Although irrigated agriculture is a unified subject, water and agriculture are treated as separate entities both for the purposes of planning and for management of the affairs pertaining of them. At the Federal level, there are separate Ministries and at the Provincial level separate Departments, and there is a lack of effective mechanism for coordination. The provincial Irrigation Departments are responsible for the operation and maintenance of the irrigation systems and for the distribution of the irrigation supplies at their convenience, with the beneficiaries having no say. Their jurisdiction ends at the 'outlet' or the point where water use begins. The Agriculture Departments too do not have any tract with irrigation. The result is that irrigation, or rather the use of water for agricultural production at the field level remains the most neglected area.

At the level of the outlet 'Chak' where the water distribution system and the sharing of the waters is a communal subject, no viable institutions have existed and it is only recently under the On-farm Water Management Programmes that the formation of Water Users Associations is being encouraged. The role of these Associations has been limited to the improvement of the watercourses and their maintenance, and even in these areas their success has been highly questionable. No viable mechanism is being developed under which the farming communities could inter-act with the Irrigation Department in matters pertaining to irrigation water supplies.

With a closer relationship between Water and Agriculture institutionally, and by relating water to agriculture requirements, it should be possible to realize substantial improvement in the agricultural productivity.

5.2 Manaaement and Distribution of Supplies

Adequacy and timeliness of irrigation water supplies has been regarded as a critical issue for the irrigated agriculture of Pakistan. Although a number of inflexibilities are built into the irrigation systems many possibilities have been suggested for moving in the direction of a demand-based systems.

Considering that the Indus Basin is a single hydrologic unit and realizing that the rivers and the canals form an integrated network, Kirmani [4] has provided a rationale for Integrated Comprehensive Management of the Basin's resources. In terms of surface water distribution, it implies the coordinated use of the storages and the variable river supplies, more in accord with the requirements of the different canal commands taking into consideration the availability of tubewell supplies and the potential for over pumping from the groundwater reservoir during periods of shortage. Without affecting the water rights of the canal systems (although these could well be reexamined) the flexibility in operations can result in more profitable use of the waters in different systems.

In the past there had been a tendency to maximize the canal withdrawals, ostensibly, to establish historic water rights but now that the Water Accord has been reached, and the shares of the provinces in the surface waters have been fixed, the time is ripe for each province to give serious thought to: how to make the most of the waters.

5.3 Improving Water Use Efficiency

It is estimated that about 25% of the surface supplies diverted from the rivers into the canal systems are lost through seepage and evaporation, and only 75% is delivered at the outlets. However, recent investigations have revealed that the water losses in the tertiary water distribution system below the outlet are of a very large order, the delivery efficiencies averaging 55%. At the farm further losses are encountered in irrigation application by the traditional irrigation methods of basin flooding over imperfectly levelled lands. Application efficiencies have been found to average 70%. This implies that only about 30% of the water diverted at the headworks, is beneficially available for the crops. While it may be difficult to avoid the losses in the main canals, there is considerable scope for conserving the large losses below the outlet. The on-going programme of On-Farm Water Management, involving the improvement of the main water courses and their partial lining is a move in this direction, but its efficiency needs to be established considering that the improvements are not extended to the farmers distribution channels.

Inefficiencies also occur in the distribution of irrigation supplies. Equity in water distribution, the stated objective, has been difficult to achieve or is being violated.

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4. **Kirmani, S.S. Comprehensive Water Resources** Management - **A** Pre requisite **for Progress in Pakistan's Irrigated Agriculture. Working Paper for Consultative** Meeting on WSIP.

Studies have indicated that outlets in the head reaches of the distributaries commonly draw 3 to 6 times greater shares of total supplies than do the tail outlets. The main causes of this inequity are the changes in channel physical conditions due to low levels of maintenance and unauthorized withdrawals. Combined with the operational constraints or interventions, the variability and unreliability are the two main obstacles to efficient use of canal water.

Although groundwater, wherever available, is being depended upon more and more for conjunctive use its availability at time of need again is not reliable, as the electrically driven public or private tubewells are subject to frequent and unscheduled power shut-downs.

Inefficiencies in water use at the farm are compounded by the lack of knowledge of the farmers on proper water management practices. Recommendations have been made in the past for providing an extension service to advise farmers on appropriate irrigation methods (including land levelling), watercourse improvement, water use practices with tubewell waters of different qualities and methods for reclaiming salt affected soils. These recommendations have yet to be implemented.

5.4 Sustainability Issues

The sustainability issues that confront irrigated agriculture in Pakistan are related to the maintenance of the productive base and the maintenance of the viability of the Irrigation and Drainage Systems, as treated below.

5.4.1 Maintainino the Productive Base

As brought out in Section 3.6 Physical and Environmental Constraints, waterlogging and soil salinity is quite widespread in the irrigated areas. The Committee on Agriculture and Water Sector for the Eighth Plan notes that:

> 'At present about 20% of the cultivated land in CCA is affected by waterlogging to varying degrees, and even greater amount suffers from sodicity. An additional 1.2 mha of land is affected by excessive sodicity. It has been estimated that despite three decades of investment, the water table was as high as zero to 1.5 meter in more than 1.58 mha of irrigated land and 1.5 to 3 meter in 5 mha. All the land under 0-1.5 m water table and 1.46 mha with 1.5-3.0 m water table has been designated as disastrous areas.'
>
> ' The total salt affected area in CCA is 3 mha and outside CCA is 2.65 mha. Most of it, especially in sweet ground water areas, is reclaimable'.

Apart from the soil salinity that is naturally occurring or that which may have been the result of rising water tables, recent work by IIMI [5] has brought out a disturbing finding - the unrestricted use of groundwater, which is generally of an inferior quality is causing secondary soil salinization insidiously. This could have far reaching effects as large areas depend on groundwater.

Over the years, massive investments have been made to control the water table by the installation of large well fields to pump out the excess waters, and more recently through the provision of costly tile drains. While these measures have shown positive results, their long term effectiveness is greatly dependent upon the efficiency with which their operation and maintenance is sustained. This brings in the issues related to O&M funding and cost recoveries treated in the next section.

Related to the maintenance of the productive base and intimately connected to the waterlogging and salinity problems is the question of maintaining the salt balance in the system. Presently there is no mechanism for the removal of the salts from the greater part of the system. There is only a small area in the south from which the salt, mobilized by drainage, could be transported to the sea through the outfall drain under construction. In the rest of the country the current practices of disposing the saline effluents into canals or rivers or into evaporation ponds results in the re-distribution of the salts and induces salinity problems for downstream water users. This is expected to have adverse long term consequences. The sustainability of the system would therefore depend on finding a satisfactory solution of the salt balance problem.

5.4.2. O&M of the Irriaation and Drainaae Svstems

The major Irrigation Systems Rehabilitation Projects that have been taken up recently for 22,483 km of canals and 3194 km of drain at a cost of $ 380 million (Rs.9.5 billion) clearly point to the degree to which the physical condition of the irrigation and drainage systems had deteriorated for want of adequate and timely maintenance. These projects would take care of only 60% of the canals needing rehabilitation. In the face of these figures it is not difficult to imagine how the operations of the system many have been affected. There have been other factors too that have been impinging on the efficiency of canal operations which create concerns for the sustainability of the system. In the Punjab, which has the largest irrigation system, the state of affairs was so grim that motions were brought forth in the Provincial Assembly in October 1992 regarding "complete lawlessness on canals, tail shortages and depressed feelings of the farmers about the actual performance of the system" [6].

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5. Kijne, J.W and Vander Velde, E.J: Salinity in Punjab Watercourse Commands and Irrigation System Operations in Advancements in IIMI's Research 1989-91. IIMI, 1992.

6. Report of Standing Committee for Irrigation and Power Department, Punjah Provincial Assembly .

Apart from the need to operate the systems to achieve the stated objectives (a major task in itself, in the face of social and political pressures) the maintenance of the irrigation and drainage facilities at their full operating efficiency deserves particular attention. This is a subject closely related to level of O&M funding and cost recoveries from the beneficiaries.

Although, at the instance of the World Bank, the O&M allocations have been increased in recent years these have been much lower than the sums demanded by the Irrigation Departments. During the last four years the actual O&M expenditures have been 18 to 39% short of the targets set by the World Bank.

The inadequacy of the O&M funding is related in part to the recoveries effected from the beneficiaries in the form of water charges (and Drainage cess were levied). For the year 1992-93, the Committee on Agriculture and Water Sector for the Eighth Plan has brought out that the revenue receipts in relation to the O&M expenditures were estimated to be 56% for the Punjab, 40% for Sindh, 16.6% for NWFP and only 7.7% for Baluchistan. The Committee has therefore proposed a progressive increase in water charges to close the gap. This should be possible, when it is considered that the water rates per acre of crops constitute a very small proportion of the net income form the corp (Based on rough estimates, water rates constitute 1.6%. 2.6%, 2.4% and 1.4% of the net income for Paddy, Cotton, Wheat and Sugarcane)

interrelated to the level of charges, is the question of assessment and recovery. A recent study [7] has brought out that leakages occur from under-recording of areas under cultivation and recording of higher rated crops as lower ones. For the year 1990-91 the estimated recoveries in the Punjab were only 75% of potential, 74% in Sindh and 64% in Baluchistan, compared with 98% in NWFP.

In addition to adequate funding supported by recoveries from the beneficiaries the effective operation of the irrigation and drainage systems for their sustainability, would require that standards of operating efficiency are established and maintained.

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7. **Nation wide Study for Improving Procedures for Assessment and Collection of Water Changes and Drainage Cess. Ministry of Water and Power, 1990**