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CHAPTER: 1 IRRIGATION & ITS TYPES

Irrigation

Irrigation is defined as

> "It is the artificial application of water to the land or soil"

Uses of Irrigation

It has various uses such as

1. It is used to assist in the growing of agricultural crops, maintenance of landscapes, and during periods of inadequate rainfall.
2. Additionally, irrigation also has a few other uses in crop production, which include protecting plants against frost, suppressing weed growth in grain fields and preventing soil consolidation.
3. Irrigation systems are also used for dust suppression, disposal of sewage, and in mining.

Types of irrigation

Various types of irrigation techniques differ in how the water obtained from the source is distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. The modern methods are efficient enough to achieve this goal such as

1. Surface irrigation
2. Localized irrigation
3. Drip irrigation
4. Sprinkler irrigation
5. Center pivot irrigation
6. Sub irrigation

Fig. 1 Various types of Irrigation

Sources of Irrigation Water

Sources of irrigation water can be groundwater extracted from springs or by using wells, surface water withdrawn from rivers, lakes or reservoirs or non-conventional sources like treated wastewater, desalinated water or drainage water. A special form of irrigation using surface water is spate irrigation, also called floodwater harvesting. In case of a flood (spate) water is diverted to normally dry river beds (wadis) using a network of dams, gates and channels and spread over large areas. The moisture stored in the soil will be used thereafter to grow crops. Spate irrigation areas are in particular located in semi-arid or arid, mountainous regions. While floodwater harvesting belongs to the accepted irrigation methods, rainwater harvesting is usually not considered as a form of irrigation.

CHAPTER: 2 IRRIGATION IN INDO-PAK

Irrigation in Indo-Pak Sub-Continent

Controlled year round irrigation began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur Headworks (now in India) on Ravi River. Until that time, irrigation was undertaken through a network of inundation canals, which were functional only during periods of high river flow. These provided water for Kharif (summer) crops and some soil moisture for Rabi (winter) crops. The last inundation canals were connected to weir controlled supplies in 1962 with the completion of Guddu Barrage on Indus River. UBDC was followed by Sirhind Canal from Rupar Headworks on Sutlej in 1872 (also in India) and Sidhnai Canal from Sidhnai Barrage on Ravi in 1886. The Lower Chenab from Khanki on Chenab in 1892, and Lower Jhelum from Rasul on Jhelum in 1901 followed suit. Lower and Upper Swat, Kabul River and Paharpur Canals in NWFP were completed between 1885 to 1914. By the turn of the century, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable lands. Ravi River, serving a large area of Bari Doab, was deficient in supply while Jhelum had a surplus. An innovative solution was developed in the form of the Triple Canal Project, constructed during 1907–1915. The project linked the Jhelum, Chenab, and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi. The Triple Canal Project as a land-mark in integrated interbasin water resources management and also provided the key concept for the resolution of the Indus Waters Dispute between India and Pakistan in 1960.The Sutlej Valley Project, comprising of 4 barrages and 2 canals, was completed in 1933, resulting in the development of the unregulated flow resources of the Sutlej River and motivated planning for the Bhakra reservoir (now in India).

During the same period, the Sukkur Barrage and its system of 7 canals serving 2.95 million hectares of land in Lower Indus were completed. Haveli and Rangpur from Trimmu Headworks on Chenab in 1939 and Thal Canal from Kalabagh Headworks on Indus were completed in 1947. This comprised the system inherited by Pakistan at the time of its creation in 1947.

Irrigation in Pakistan

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without regard to irrigated boundaries. This resulted in the creation of an international water dispute in 1948, which was finally resolved by the enforcement of Indus Waters Treaty in 1960 under aegis of the World Bank. The treaty assigned the three eastern rivers (Ravi, Beas, Sutlej) to India, with an estimated total mean annual flow of 33 million acre feet (MAF) and the three western rivers (Indus, Jhelum, Chenab) to Pakistan with a transfer of irrigation supplies from the western rivers to areas in Pakistan formerly served by the eastern rivers as well as some development potential to compensate for the perpetual loss of the eastern waters. The Indus Basin Project including Mangla Dam, 5 barrages, 1 syphon and 8 inter-river link canals, was completed during 1960-71, while Tarbela Dam started partial operation in 1975-76. After partition, Kotri, Taunsa and Guddu Barrages were completed on the Indus River to provide

controlled irrigation to areas previously served by inundation canals. Also, three additional inter-river link canals were built prior to the initiation of Indus Basin Project.

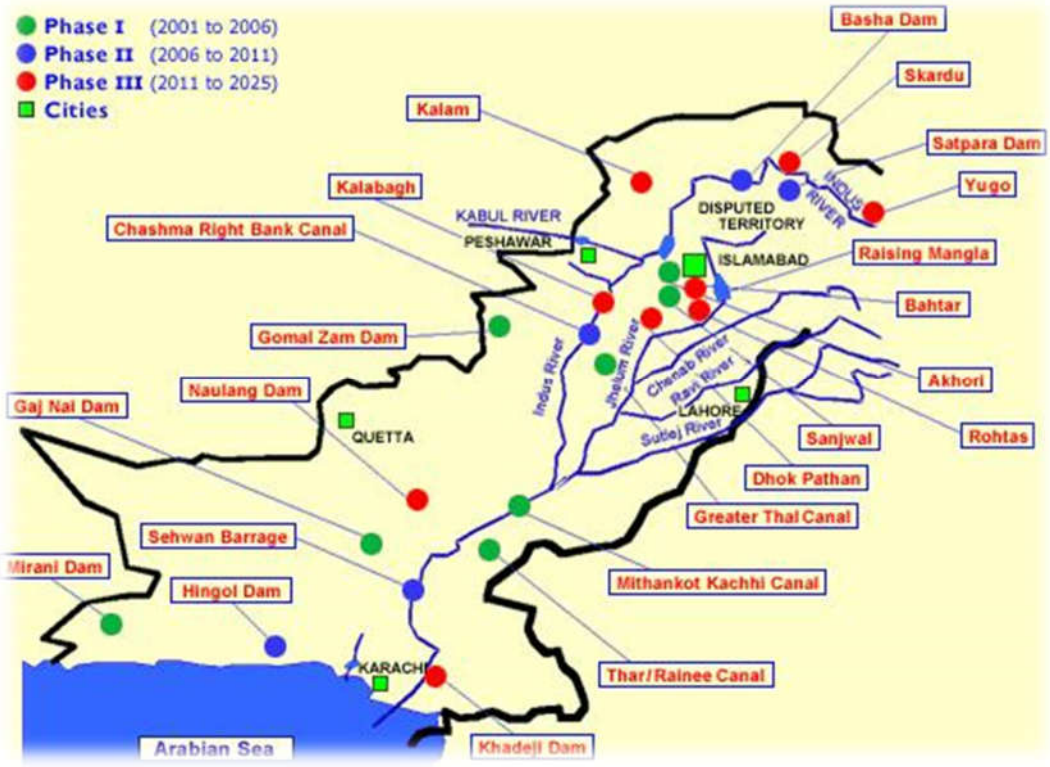

Fig.1 Pakistan Irrigation System

CHAPTER: 3 INDUS BASIN IRRIGATION SYSTEM

Indus Basin Irrigation System

Pakistan Indus Basin Irrigation System (IBIS) is the strong heart of the country's economy. Its creation is a tribute to the British irrigation engineers who created the original system (1847-1947) that Pakistan inherited in 1947 and to the Pakistani irrigation engineers and institutions (particularly the Water and Power Development Authority [WAPDA] and the provincial irrigation departments) who have spent the last 60 years adding new dams and barrages, building new link and branch canals, and modernizing and maintaining the world's most complex and extensive irrigation system. From the 1950s onward, the IBIS has also been the product of the generosity and intellectual input of a host of international experts and international institutions, particularly the World Bank. This paper starts with a review of what has been accomplished in order to put the IBIS into perspective and illustrate the magnitude of the effort put into building the present system. The paper's aim is to sketch the task ahead and develop a coherent national strategy for the preservation of the IBIS for the future.

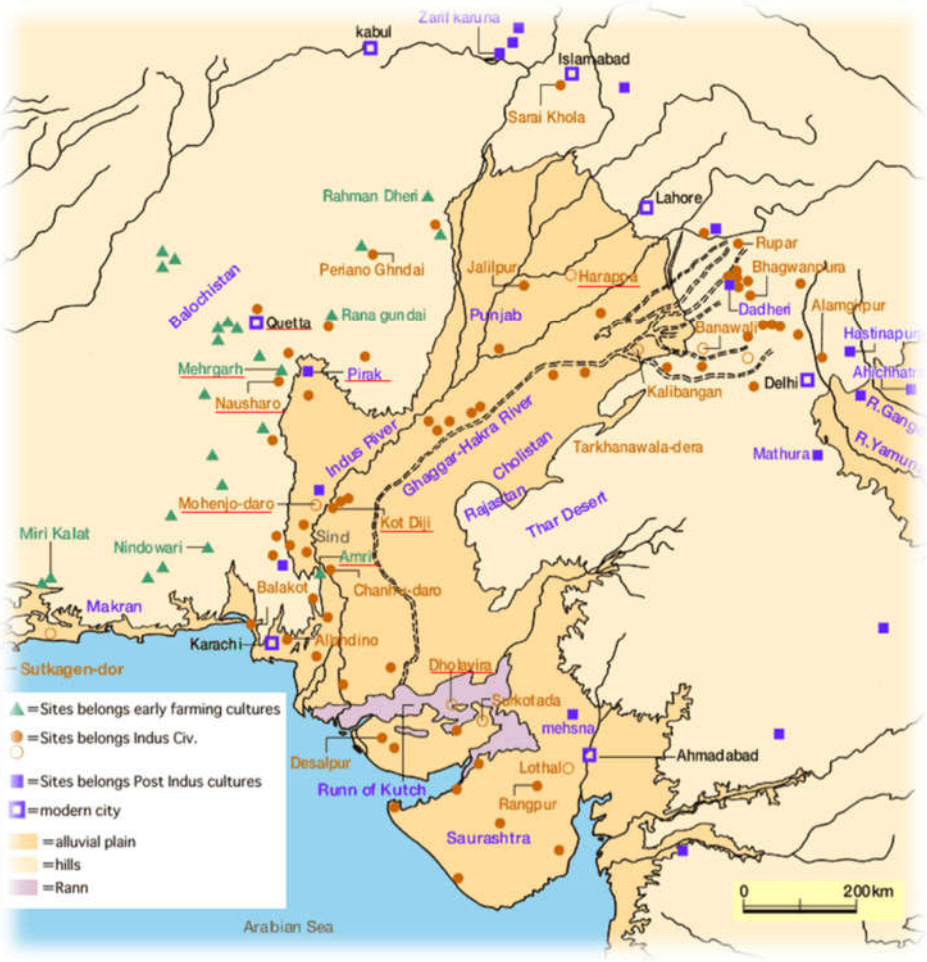

Fig 3 Indus basin

History of Indus Valley

The Indus Valley Civilization (IVC) was a Bronze Age civilization (3300-1300 BCE; mature period 2600-1900 BCE) that was located in the northwestern region of the Indian subcontinent, consisting of what is now mainly modern-day Pakistan and northwest India.

Fig. 4 Indus Valley

The Indus Valley is one of the world's earliest urban civilizations, along with its contemporaries, Mesopotamia and Ancient Egypt. At its peak, the Indus Civilization may have had a population of well over five million. Inhabitants of the ancient Indus river valley developed new techniques in metallurgy and handicraft (seal carving) and produced copper, bronze, lead, and tin. The civilization is noted for its cities built of brick, roadside drainage system, and multistoried houses.

The Indus Valley has been the host to one of the most ancient civilization of human history, the Indus Valley Civilization. After the extinction of the Indus Civilization, new settlements especially in doabs grew slowly. New irrigation systems started to evolve. Inundation canals and small dams were constructed and population grew all around this area. In order to reduce the occurrence of low irrigation water supply the British authorities, towards the middle of the last century, started modernizing and expanding the irrigation system of the Indus Basin.

History

The first canals were constructed some five or six centuries ago and extended under the Mughal Emperors. The early canals were inundation channels and delivered water to the fields when rivers were in high flow during the summer. They tended to be unpredictable in operation and subjected both to frequent breaches and serious siltation problems. The next stage in the evaluation of the Irrigation System was construction of perennial canal shaving permanent head works. These head works either did not extend across the entire stream or allowed the floods to pass over their crests. The first evidence of perennial irrigation on any of the Indus rivers dates back to early seventeenth century when a 80 Km long canal was constructed by the Mughal Emperor Jahangir (reigned 1605-27) to bring water from the right bank of the Ravi to the pleasure gardens of Sheikhupura near

Lahore. The irrigation system which exists today was stated in the nineteenth century under the British administration. In the early 19th century, there were numerous inundation canals leading from the Indus River and its tributaries. The more important of these were the Upper and Lower Sutlej canals, the Shahpur canals, the Chenab canals and the Indus canals in Punjab and Bahawalpur. In the Sindh, where the Indus River flows more or less on a ridge, conditions were particularly favorable for inundation canals. Among Sindh's 19th century canals were the Desert, the Begari, the Sukkur, the Fuleli, the Pinyari and the Kalri canals. From the middle of the 19th century onwards, a large number of inundation canals were remodeled and fitted with permanent head works and new canals with weir controlled supply were constructed for the Sindh, Punjab and NWFP areas. The first permanent head works constructed in 1887 was the Marala Barrage, which started supplying water to the Upper Chenab Canal in 1915. In 1889, a project was prepared for the irrigation of part of the Rechna Doab. The project envisaged the diversion of the Chenab waters by means of a weir at Khanki. The project was sanctioned in 1890 and the Chenab Canal, now called the Lower Chenab Canal, was opened in 1892.

A similar scheme was sanctioned for the irrigation of the area between the Chenab and the Jhelum (Chaj Doab) from a weir at Rasul on the Jhelum River. Construction was started in 1897and the Jhelum Canal, now called the Lower Jhelum Canal was opened in 1901.After World War-I, the Sukkur Barrage Project, the first barrage constructed on the Indus River was started in 1923 and was commissioned to irrigation in 1932. During 1921 the Sutlej Valley Project was sanctioned for the development of the Punjab, Bikaner (now in India) and Bahawalpur states areas. The Project consisting of four (4) weirs on the Sutlej River at Ferozepur, Sulemanki, Islam and Panjnad and 11 canals were completed by 1933.The Trimmu Barrage, located below the junction of the Jhelum and the Chenab Rivers was started in 1837 and completed in 1939, was the last barrage completed prior to World War II. At the time of independence the Kalabagh Barrage (Jinnah), Kotri Barrage on the Indus River and the Bhakra Dam in India on the Sutlej River were under construction.

Fig.5 Indus River

Triple Canal Project

The Triple Canal Project was sanctioned in 1905 and became the first project to transfer water from one river to another. The Triple Canal Project involved the diversion of the available waters in the Jhelum River across the Chaj and Rechna Doabs. The project consisted of a feeder canal from the Jhelum River at Mangla to the Chenab River above Khanki (Upper Jhelum Canal), a feeder canal from Marala on the Chenab River to the Ravi River above Balloki (Upper Chenab Canal) and construction of a barrage (level crossing) on the Ravi River at Balloki to divert the transferred water into the new Lower Bari Doab Canal (LBDC). The Triple Canal Project Chenab Canals are primarily feeder or link canals but they also provide considerable irrigation enroot in the Upper parts of the Chaj and Rechna Doab.

Post-Independence Pre-water Treaty

Partition of the Punjab Province left the Bhakra Dam, the headworks of the old Upper Bari DoabCanal at Madhopur and those at Ferozepur on the Sutlej in India. Pending final settlement of the Indus Water Dispute, it became urgent for Pakistan to secure a supply of water for the Upper bari Doab and the Sutlej Valley. Thus the 164 Km Bombanwala-Ravi-Bedian Dipalpur Link and Balloki-Suleimanki Link I were constructed between 1951 and 1954 and the 101 Km Marala-Ravi Link was built between 1954 and 1965, all to bring additional water from the Chenab River to the east. The Pakistan Government continued the work which had been planned by the British Administration and completed the Kalabagh Barrage in 1947, the Kotri Barrage in 1955 and the Guddu barrage in 1963.After independence, the Lower Sindh Inundation Canals were converted into weir-controlled canals to command cultivable area of 809,400 ha (2 million acres) and to serve a local cultivable commanded area of 1.13 million ha (2.8 million acres) of land, with the construction of the Kotri Barrage at Kotri (1947-1955).

Similarly, the Guddu Barrage built (1953-1962) at the head of Upper Sindh Inundation Canals system, converted the Upper Sindh Inundation Canals into a controlled perennial canals system for the irrigation of 1.13 million ha of land. The Taunsa Barrage built (1953-1958) on the Indus provided weir-controlled irrigation supplies to cultivable commanded area of 687,970 ha. This barrage is multipurpose and also provides bridges for road and railway and head regulator for the Taunsa-Panjnad Link-Canals. In 1954, the World Bank put forward a proposal for the equitable distribution of the water resources available to India and Pakistan.

Indus Water Treaty

The proposal has three essential features:

1. The waters of the three western rivers “the Indus, the Jhelum and the Chenab” were to be allocated to Pakistan, and the waters of the three eastern rivers, the Ravi, the Beas and the Sutlej to India. Requirements of the areas within Pakistan, hitherto fed by the eastern rivers, would in future be met by waters to be transferred from the western rivers by means of a system of replacement works. It was estimated that some 17,300 million m3

(14 million acre feet) would be required, ultimately, to replace the water designated for use in India.

2. India would make a contribution to the cost of the replacement works.
3. During the construction phase, India would limit her withdrawals from the eastern rivers in proportions to match Pakistan's capacity to replace. It took eight years of negotiations before an agreement was reached and a Treaty signed on 19 September 1960.To compensate Pakistan for the loss of the water of the eastern rivers, six friendly countries and the World Bank together with Pakistan and India agreed to provide funds to enable a system of replacement works to be constructed which would transfer water from the western rivers to the areas that were dependent on supplies from the eastern rivers.

CHAPTER: 4 SALIENT FEATURES OF BARRAGES IN INDUS BASIN IRRIGATION SYSTEM

Barrages over Indus Ravi

Taunsa Barrage

Year Of completion	1958
Location	River Indus,20 km south east of Taunsa city
Design discharge	750,000 cusecs
Length	4436ft
No. Of Bays	53
No. of Under-sluices	12
Crest Level	--
Off-taking canals	4

Fig. 6 Taunsa Barrage

Gazi Barotha Barrage

Year Of completion	2005
Location	River Indus
Design discharge	500,000 cusecs
Length	170560 ft
Off-taking canals	1

Fig.7 Gazi Barotha Barrage

Jinnah Barrage

Year Of completion	1946
Location	River Indus, Kala bagh Mianwali District
Design discharge	950,000 cusecs
Length	3360 ft.
No. Of Bays	42
Off-taking canals	1

Fig. 8 Jinnah Barrage

Chashma Barrage

Year Of completion	1967-1971
Location	River Indus,25 km south west of Punjab
Design discharge	11,76,000 cusecs
Length	3536 ft.
No. Of Bays	52
No. of Under-sluices	11
Crest Level	--
Off-taking canals	2

Fig.9 Chashma Barrage

Guddu Barrage

Year Of completion	1962
Location	River Indus, near Kashmore
Design discharge	12,00,000 cusecs
Length	3840 ft.
No. Of Bays	64
Off-taking canals	5

Fig.10 Guddu Barrage

Sukkur Barrage

Year Of completion	1932
Location	River Indus, near Sukkur city
Design discharge	15,00,000 cusecs
Length	4490 ft.
No. Of Bays	54
No. of Under-sluices	12
Crest Level	177
Off-taking canals	7

Fig.11 Sukkur Barrage

Kotri Barrage

Year Of completion	1955
Location	South west of Karachi near Hyderabad
Design discharge	750,000 cusecs
Length	3000 ft.
No. Of Bays	44
No. of Under-sluices	--
Crest Level	48 S.P.D
Off-taking canals	4

Fig.12 KotriBarrage

Barrages over River Ravi

Balloki Barrage

Year Of completion	1914
Location	River Ravi
Design discharge	140,000 cusecs
Length	1644 ft.
No. Of Bays	35
No. of Under-sluices	--
Crest Level	625 S.P.D
Off-taking canals	2

Fig.13 Balloki Barrage

Sidhnai Barrage

Year Of completion	1965
Location	River Ravi
Design discharge	167,000 cusecs
Length	712 ft.
No. Of Bays	15
No. of Under-sluices	4
Crest Level	454 S.P.D
Off-taking canals	2

Fig.14 Sidhnai Barrage

Barrages over Jehlum River

Rasool Barrage

Year Of completion	1968
Location	River Jehlum, 72 km from Mangla Dam
Design discharge	876,000 cusecs
Length	3209 ft.
No. Of Bays	42
No. of Under-sluices	6
Crest Level	703 S.P.D
Off-taking canals	2

Fig.15 Rasool Barrage

Barrages over Satluj River

Sulemanki Barrage

Year Of completion	1927
Location	River Satluj
Design discharge	309,000 cusecs
Length	2220 ft.
No. Of Bays	24
No. of Under-sluices	16
Crest Level	560 S.P.D
Off-taking canals	3

Fig.16 Sulemanki Barrage

Islam Barrage

Year Of completion	1927
Location	River Chenab
Design discharge	300,000 cusecs
Length	1650 ft.
No. Of Bays	29
No. of Under-sluices	4
Crest Level	435.5 S.P.D
Off-taking canals	2

Fig.17 Islam Barrage

Mailsi Syphon

Year Of completion	1965
Location	River Satluj near Mailsi
Design discharge	429,000 cusecs
Length	1601 ft.
No. Of Bays	24
No. of Under-sluices	--
Crest Level	415.5 S.P.D

Fig.18 Mailsi Syphon

Barrages over Chenab River

Maralla Headwork

Year Of completion	1968
Location	River Chenab, near Sialkot City
Design discharge	11,00,000 cusecs
Length	4472 ft.
No. Of Bays	66
No. of Under-sluices	13
Crest Level	800 S.P.D
Off-taking canals	2

Fig.19 Marala Headwork

Khanki Headwork

Year Of completion	1889
Location	River Chenab, Gujrat District
Design discharge	750,000 cusecs
Length	4000 ft.
No. Of Bays	48
No. of Under-sluices	56
Crest Level	726.5-727 S.P.D
Off-taking canals	1

Fig.20 Khanki Headwork

Qadirabad Barrage

Year Of completion	1967
Location	River Chenab, Mandi Bahaudin
Design discharge	900,000 cusecs
Length	3373 ft.
No. Of Bays	50
No. of Under-sluices	5
Crest Level	684.5 S.P.D
Off-taking canals	1

Fig.21 Qadirabad Barrage

Trimmu Barrage

Year Of completion	1939
Location	25 km from Jhang city
Design discharge	645,000 cusecs
Length	2856 ft.
No. Of Bays	47
No. of Under-sluices	L=5, R=6
Crest Level	Main Weir: 477.5 S.P.D Under Sluice: 472 S.P.D
Off-taking canals	3

Fig.22 Trimmu Barrage

Punjnad Barrage

Year Of completion	1929
Location	River Chenab
Design discharge	700,000 cusecs
Length	2856 ft.
No. Of Bays	47
No. of Under-sluices	--
Crest Level	325 S.P.D
Off-taking canals	2

Fig.23 Punjnad Barrage

Barrages over River Ravi

Balloki Barrage

Year Of completion	1914
Location	River Ravi
Design discharge	140,000 cusecs
Length	1644 ft.
No. Of Bays	35
No. of Under-sluices	--
Crest Level	625.5 S.P.D
Off-taking canals	2

Fig.24 Baloki Barrage

Sidhnai Barrage

Year Of completion	1965
Location	River Ravi
Design discharge	167,000 cusecs
Length	712 ft.
No. Of Bays	15
No. of Under-sluices	4
Crest Level	454 S.P.D
Off-taking canals	2

Fig.21 Sidhnai Barrage

CHAPTER: 5 SALIENT FEATURES OF OFF-TAKING CANALS FROM THE BARRAGES OF PAK

Above Rim Station

Barrage Names	Rivers	Year Of Completion of Barrage	Area Irrigated $(km)^2$	Canals	Year of Completion	Discharge (cusecs)
Amandra	Swat	1915	1557	Upper Sawat Canal	1915	96
Munda	Swat	1885/1917		Lower Sawat Canal	1885	55
Warsak	Swat	1890/1962		Warsak Canal (L & R)	1962	14
				Kabul River Canal	1890	13

Below Rim Station

Barrage Names	Rivers	Year Of Completion of Barrage	Area Irrigated (km)^2	Canals	Year of Completion	Discharge (cusecs)
Jinnah	Indus	1947	26900	Thal Canal	1949	311
Chashma	Indus	1971	28317	Chashma Jehlum Link	1970	614
				CRBC		142
Taunsa	Indus	1959	21237	Taunsa Punjnud Link	1970	340
				Muzafargarh Canal	1959	235
				DG khan Canal	1959	249
Guddu	Indus	1962	25485	Ghotki Feeder	1962	241
				Desert Pat Feeder	1962	365
				Pat Feeder Canal	1962	235
				Begari Canal	1962	439
Sukkur	Indus	1932	42475	Nara Canal	1932	379
				Khairpur East Canal	1932	76
				Rohri Canal	1932	317
				Khairpur West Canal	1932	54
				North West Canal	1932	144
				Rice Canal	1932	289
Kotri	Indus	1954	25485	Akram Wah Link Canal	1955	116
				Fuleli Canal	1955	391
				Pinyari Canal	1955	408
				Kalri Canal	1955	255
Rasul	Jehlum	1967	24069	Rasool Qadirabad Link	1967	538
				Lower Jehlum Canal	1901	150

				LJC Feeder		154
				Rasool Power Canal		101
Marala	Chenab	1968	31148	Marala Ravi Link	1956	623
				Upper Chanab Canal	1912	467
Khanki	Chenab	1892	29732	Lower Chenab Canal	1892	326
Qadirabad	Chenab	1967	25485	Qadirabad- Balloki Link and LCC Feeder	1967	527
Trimmu	Chenab	1939	18406	Trimu Sidhnai Link Canal	1965	311
				Haveli Canal	1939	183
				Rangpur Canal	1939	77
Balloki	Ravi	1965	63712	Baloki Sulemanki Link	1954	524
				Lower Bari Doab Canal	1913	198
Sidhnai	Ravi	1965	4709	Sidhnai Mailsi Link	1965	286
				Mailsi Bahawal Link	1965	110
				Sidhnai Canal	1886	127
Sulemanki	Sutlej	1928	9911	Easter Sadiqia Canal	1927	139
				Fodwah Canal	1927	95
				Upper Pakpattan Canal	1927	169
Islam	Sutlej	1928	10987	U & L Bahawal Canal	1927	132
				Qasim Canal	1927	213
Punjnad	Chenab	1932		Panjnad Canal	1335	231
				Abbasia Canal	1338	65
Ghaza Barrage	Indus	2002		Ghazi Barotha Power Channel	2002	132

REFERENCES

1. http://www.wapda.gov.pk/
2. http://www.scribd.com/
3. http://uetblogs.com/groups/civil-engineers/
4. http://www.tbl.com.pk/
5. http://irrigation.punjab.gov.pk/