



THEORY

Irrigation Water Resources: Irrigation, importance of irrigation, sources of irrigation water, Indus Basin Irrigation System, components of irrigation system, irrigation system management, warabandi, hill torrents.

Measurement of Irrigation Waters: Importance, units, methods.

Irrigation Methods: Surface, subsurface, sprinkler, drip, selection of irrigation method. Irrigation Scheduling: Components, soil water plant relationship, water requirements of crops, efficiencies.

PRACTICALS

Water measurement by velocity area method. Flow measurement using rectangular weir. Flow measurement using triangular weir. Flow measurement using trapezoidal weir. Determination of discharge coefficients.

BOOKS RECOMMENDED

1. Ahmad, N. 1993. Water Resources of Pakistan. Shahzad Nazir Publisher, Gulberg-III, Lahore, Pakistan.
2. Rafique, M. 2005. Irrigation and drainage practices. University of Agriculture, Faisalabad, Pakistan.
3. Siddiqui, I.H. 2003. Irrigation and drainage engineering. Royal Book Company, Karachi, Pakistan.



Irrigation and drainage, artificial application of water to land and artificial removal of excess water from land, respectively. Some land requires **irrigation** or **drainage** before it is possible to use it for any agricultural production; other land profits from either practice to increase production.

Agriculture: Backbone of economy

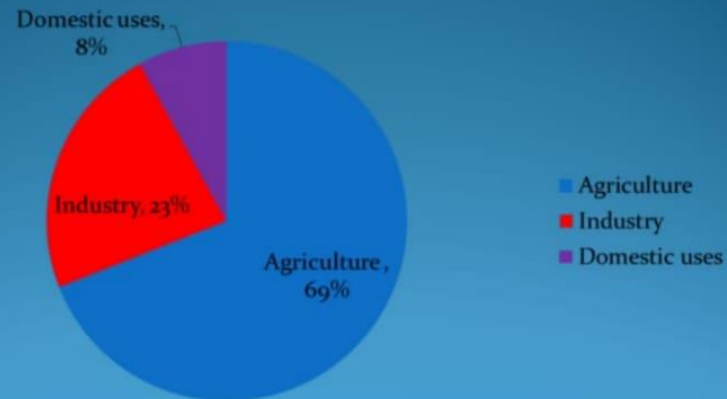
- ❑ Agriculture is the main player of the economy of Pakistan with 21% contribution to GDP and more than 45% contribution in labour force
- ❑ Pakistan's agriculture rely heavily on irrigation.
- ❑ Pakistan has the world's largest contiguous irrigation system
- ❑ Pakistan ranks 4th in the world as for as irrigated area (About 7%) is concerned. About 36 MA(About 75% of the cultivated area) in Pakistan is irrigated land.
- ❑ Pakistan has invested heavily in the irrigation sector. Allocated about \$ 8 billion in this sector upto the year 2011-12

Irrigation: Life blood of agriculture

12/5/2018

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Consumption Pattern of Water



Agriculture: Backbone of economy

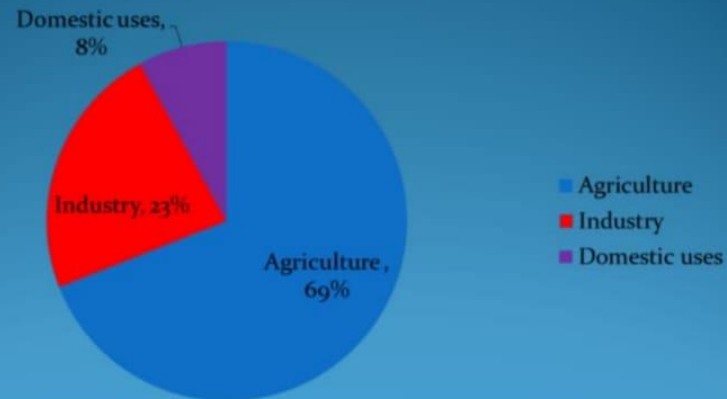
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Water Resources of Pakistan

Rainfall

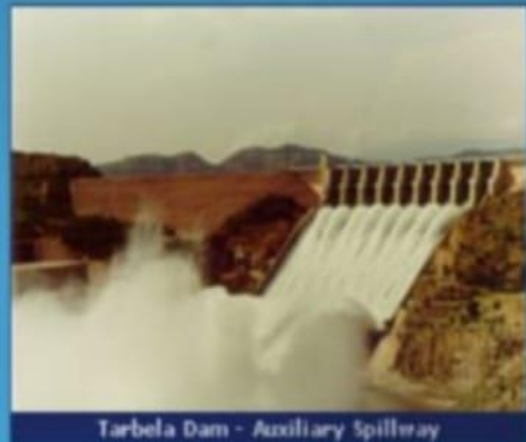
- Annual rainfall (125mm in South-East to 750mm North-West)
- Total water generated by rainfall is around 32 BCM
- Contribution to crops is 10-20%

Groundwater

- Exploitation of Groundwater is 59 BCM
- Over 9,00,000 private tubewells
- 40% of total supply at farm-gate

Surface Water Resources

- Total Inflow is 171 BCM
- Tarbela (10.38 BCM - 485 ft),
- Mangla (5.90 BCM - 380 ft)
- 48 Canals (61000 km), 19 Barrages
- 1,70,000 Watercourses (1.6 Million km)



Tarbela Dam - Auxiliary Spillway

Irrigation

Definition: irrigation is artificial application of water to soil for the purpose to access the crop production. It is supplied supplementary to water available from rainfall & ground water.

Types of irrigation – (classification)

1. Flood
2. Surface
3. Sub surface
4. Sprinkle
5. Drip irrigation.

Surface irrigation:

Water is applied directly to the soil from channel located at upper ridge of the field proper land preparation adequate control of water is necessary for uniform distribution of water border. The entire field is divided into strips separated by low ridge of the strip to lower in form of sheet guided by the low ridges. Border should have uniform gentle slope in direction of irrigation. Each strip is independently by turning stream of water at upper ridge. Suitability-suitable for close growing crops some row crop & orchards under favorable soil & topographic condition. Not recommended for extremely low or extremely high infiltration rate soils.

Advantage:

1. Easy construct & operate
2. Person can irrigation more compares to check basin.
3. If properly designed use uniform distribution & high water use efficiency.
4. Large streams can be effectively used.
5. If can provide excellent drainage (surface) if have proper outlet facility at the lower end.

Disadvantages:

1. Required precise land leveling
2. Required large irrigation streams.

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Check basin:

It is used in extreme condition of soil. It is well known method generally used for heavy soils with low infiltration rate or high permeable soil like deep sand. Used for orchards grain & folder production.

Disadvantages:

1. Labor requirement for land preparation is high.
2. Operation cost is more.
3. The ridges cause hindrances to implements by field operations.

Furrow method:

Furrow is preferably used for row crops like maize, sugarcane, potato, groundnut & other vegetable crops. Water is applied in small furrows between the row crops. Water infiltrates into soil & spreads within the root zone. Large as well as small sized streams can be effectively used for irrigation. It also aids for safe disposal of excess water i.e. facilitates drainage. Only $\frac{1}{5}$ to $\frac{1}{2}$ of land surface is in contact with water (wet). Thereby reducing the evaporation losses. Method is specially suited to crops like maize which are sensitive to water in contact with their roots. The cost of land preparation is reduced & there is no wastage of land under field channels. In clay or deep clay soils shadow furrows are made along with guiding ridges to take care of soil cracking behavior such furrows are called corrugated furrows.

Subsurface irrigation:

Water is applied below the ground surface by maintaining artificial water table at some depth depends upon the soil characteristic & root zone of crop. Water moves through capillaries within soil to meet plant requirement deep trenches & underground piper are the two ways for sub-surface irrigation.

Adaptability: Soils having low W.H.C. soil having very high-high infiltration rate. Soils surface method is not possible where sprinkle method of irrigation proves to be expensive.

Advantage:

- 1) Evaporative losses are minimum.

Disadvantage:

- 1) Salty water can not be used.

IRRIGATION

Irrigation is defined as the artificial application of water to the soil

Importance of water to plants

1. Plants contain 90% water which gives turgidity and keeps them erect
2. Water is an essential part of protoplasm
3. It regulates the temperature of the plant system
4. It is essential to meet the transpiration requirements
5. It serves as a medium for dissolving the nutrients present in the soil
6. It is an important ingredient in photosynthesis

1.2 Why Irrigation?

Factors that necessitate irrigation include;

- (i) Insufficient rainfall
- (ii) Non-uniform distribution of rainfall.

Total rainfall during a year may be adequate to raise a crop, however it may not be evenly distributed over the crop growth period

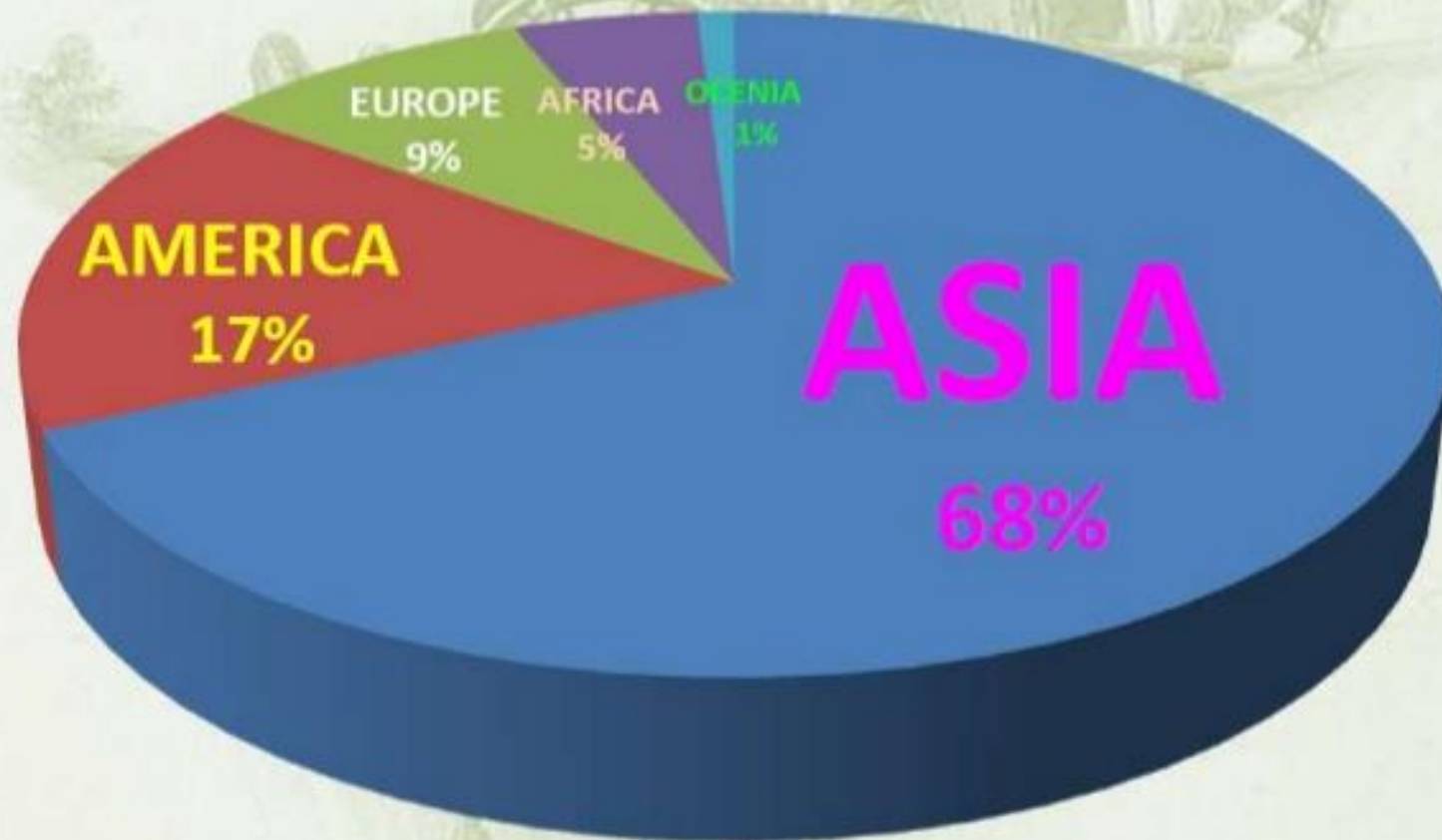
- (iii) Control of water supply.

Irrigation enables water to be applied to the crops as and when required thereby increasing the yield per unit area,

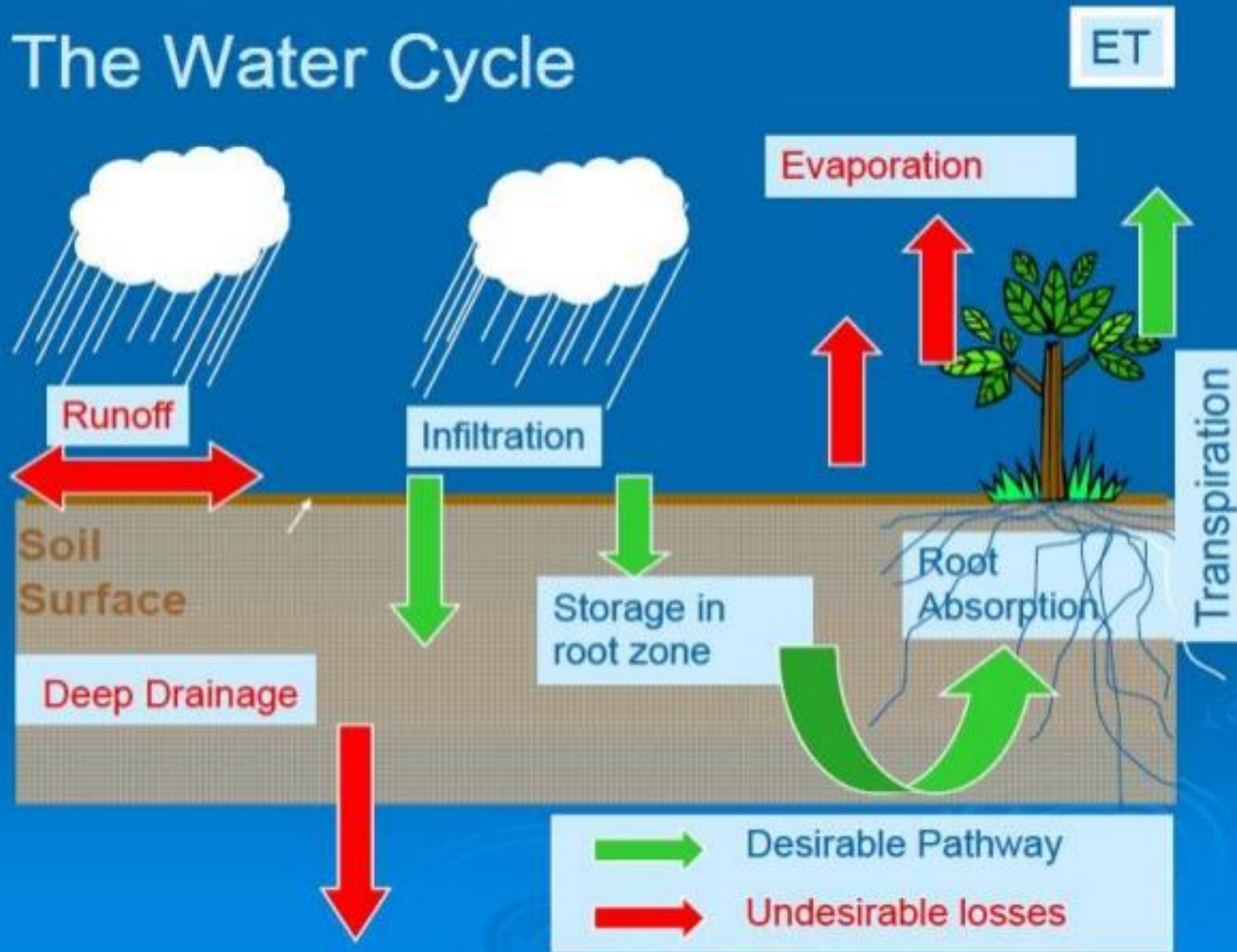
- (iv) Growing of cash crops.

The growth of cash crops e.g. flowers, sugarcane, rice, etc. may be preferred as they bring better returns. Such crops may require abundant supply of water and frequent watering to maturity, which cannot be met from natural rainfall during the crop growth period. This makes irrigation essential.

PERCENTAGE OF IRRIGATION IN THE WORLD



The Water Cycle



Pakistan Water Resources:

- Ice Caps & Glaciers
- Rivers and Canals
- Lakes
- Rain water
- Underground sweet water
- Underground Saline water
- Sea water

Lakes



Glaciers



Sea water



Canals



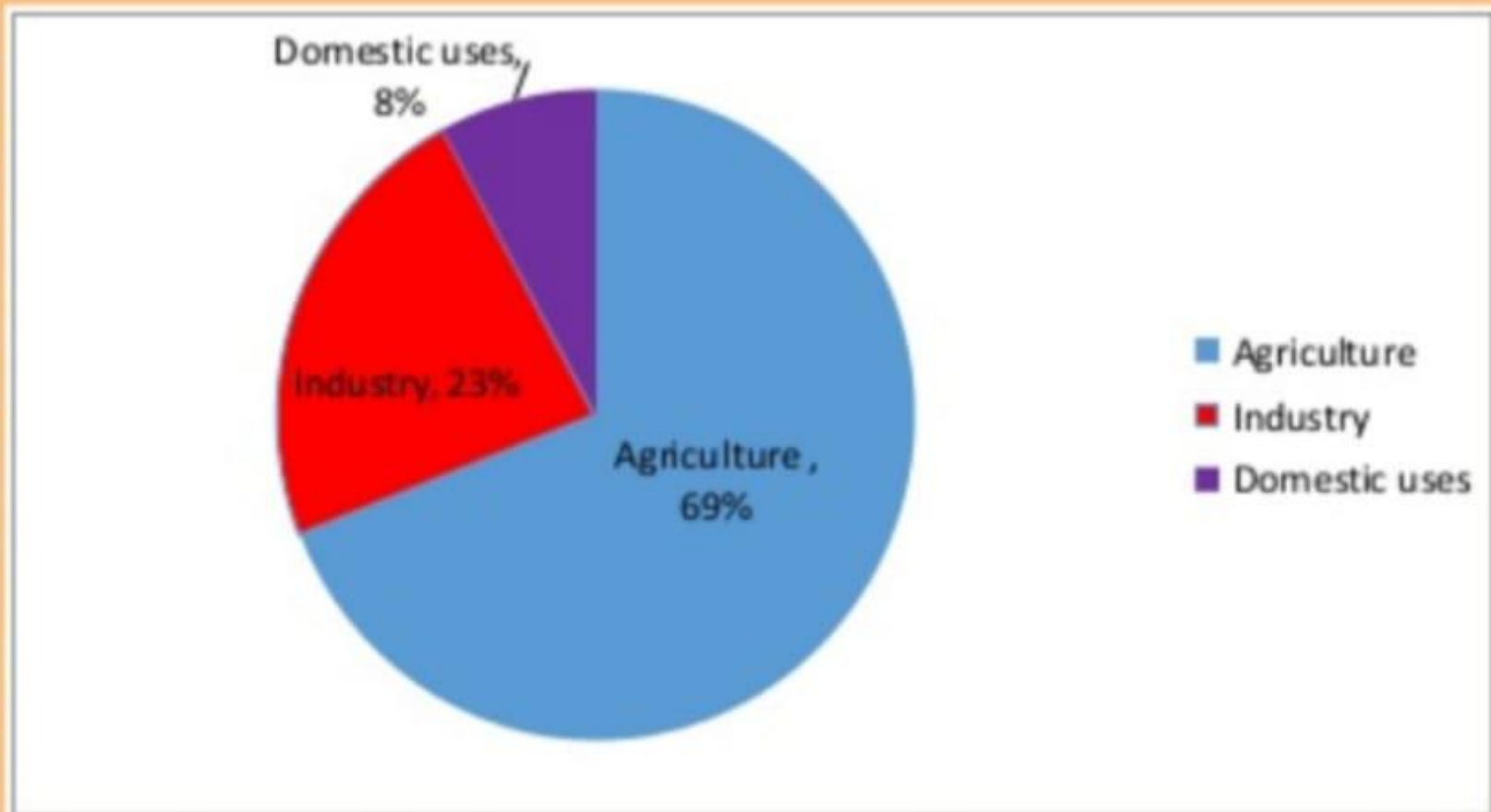
Rivers



Water Use and Consumption

Out of the **169,384** billion m³ of water which were withdrawn in 2000, 69% were used for agricultural purposes, leaving 8% for domestic and another 23% for industrial use. By far most water is used for irrigated agriculture, emphasizing the particular significance of agriculture in the country. The sector contributes about 25% of the Pakistan's GNP (2000-2001). The country still has the world's largest contiguous irrigation system. In 1999-2000, the total irrigated area in Pakistan was 181,000 km².

Water is also essential for power generation in Pakistan, since about 29% is generated through hydropower.



Macro Level Water Management

- Dams for irrigation and power production
- Rivers
- Barrages for water storage
- Canals for water transportation
- Irrigation channels

Environmental Impact Challenges:

1. Ecological systems around major rivers is destroyed
2. Floods
3. Habitat for migratory birds is threatened.
4. Some animal and bird species disappeared.
5. Amphibian species are at the verge of extinct. Crocodiles etc.



Micro Level Water Management

- Public water supply system for Domestic use.
- Irrigation channels.
- Industrial use e.g. tanning of hides, chemical plants, fertilizer companies etc.

Environmental Impact Challenges:

1. Scarcity of public water supply systems.
2. Direct pumping of underground water.
3. Lowering of underground water table
4. Waste water management.
5. Waste water treatment.



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Environmental Impacts:

1. Due to water storage in dams, ecosystem around rivers is destroyed.
2. Dams result in to massive floods in summer when glaciers melt.
3. Floods in two rainy seasons due to dam overflow.
4. Reduction in life of dams by earth filling.
5. Glaciers are melting due to global warming which is also causing unusual floods.
6. Water table in urban areas is dropping quickly.
7. Due to lining of water channels underground water table is dropping.
8. Water bodies in Pakistan are habitat to migratory birds in winter.
9. Millions of cubic meters of water is wasted to flow to the oceans.

Suggestions:

1. Small dams at the tail of river should be planned.
2. Restoration of rivers to their natural flow.
3. Water supply companies should only be permitted to extract ground water.
4. Only licensed water extraction should be allowed to industries.
5. No lining of water channels near urban areas so that underground water table recharge.
6. Water bodies in Pakistan are habitat to migratory birds should be monitored.
7. Water storage to stop wastage of water.
8. Modern methods of irrigation should be adopted.
9. Education of masses about water conservation.
10. Local production and lowering of technical equipment.

What is irrigation system of Pakistan?



LARGEST **IRRIGATION SYSTEM** OF THE WORLD

The world's largest **irrigation network** is present in **Pakistan**. It serves 14.4 million hectares of cultivated land. The **irrigation system** is fed by water from the Indus River. Mar 5, 2017

What are 4 types of irrigation techniques?

The four methods of irrigation are: Surface. Sprinkler. Drip/trickle. Subsurface.

What is the best source of irrigation water?



The main sources for irrigation water are **groundwater** from wells, surface water, drainage ponds, rain and **municipal** water. Drilled wells are a clean source of water for **many** greenhouse operations however, the water yield from drilled wells is usually limited.

What are modern methods of irrigation?



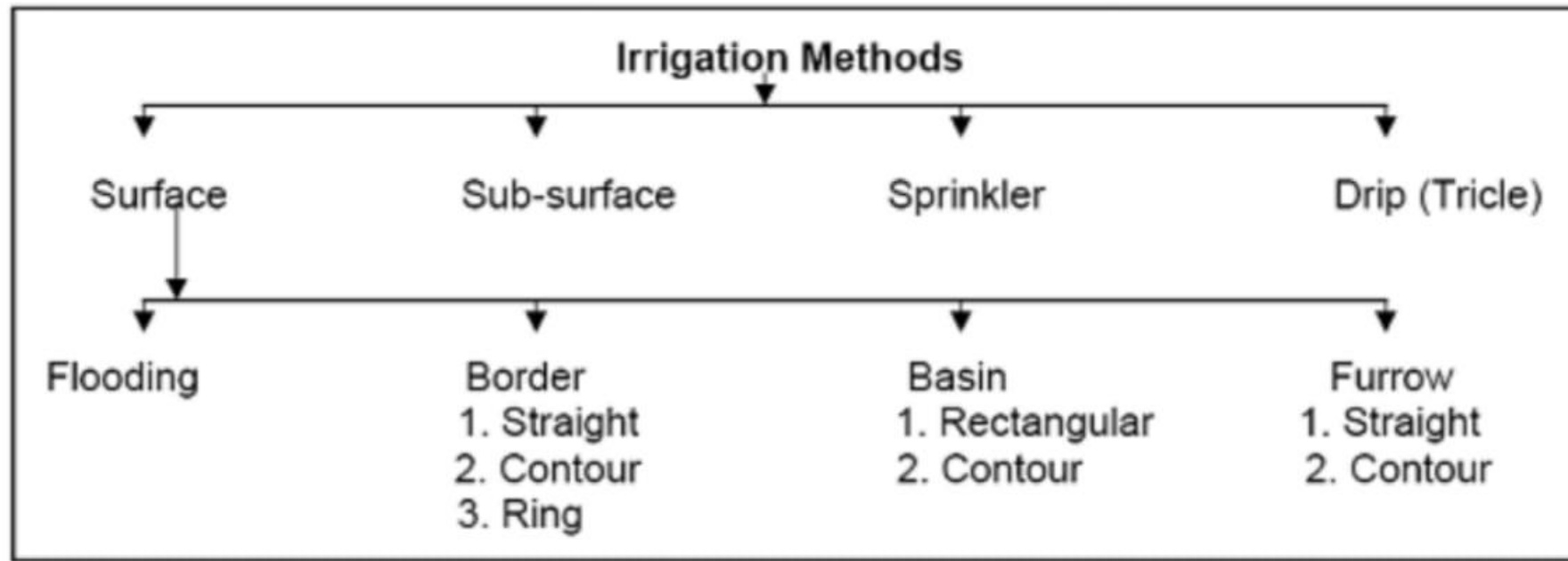
Drip System of **Irrigation**. The most commonly used **method of irrigation** these days is the drip **method**. They lay the pipes in rows near the crops or plants. These plastic pipes have holes in them.

What are man made sources of water?



Dams, **wells**, **tube wells**, canals are man-made sources of water. Natural sources of water: oceans, **rivers**, lakes, rainwater, streams, ponds and springs are natural sources of water. 2)

Surface Water: Water on the surface of the earth like oceans, **rivers**, lakes, ponds, and streams are called surface water. Aug 2, 2018



There are three principle methods of irrigation viz. surface, sub surface and aerial, overhead or sprinkler irrigation.

A. Surface irrigation: There are four variations under this method viz.

- (1) Flooding,
- (2) Bed or border method (Saras and flat beds),
- (3) Basin method (ring and basin) and
- (4) Furrow method (rides and furrows, broad ridges or raised beds)

Flooding: It consist of opening a water channel in a plot or field so that water can flow freely in all directions and cover the surface of the land in a continuous sheet. It is the most inefficient method of irrigation as only about 20 percent of the water is actually used by plants.

The rest being lost as a runoff, seepage and evaporation. Water distribution is very uneven and crop growth is not uniform. It is suitable for uneven land where the cost of leveling is high and where a cheap and abundant supply of water is available. It is unsuitable for crops that are sensitive to water logging the method suitable where broadcast crops, particularly pastures, alfalfa, peas and small grains are produced.

Adaptations:

- (1) An abundant supply of water
- (2) Close growing crops
- (3) Soils that do not erode easily
- (4) Soils that is permeable
- (5) Irregular topography
- (6) Areas where water is cheap.

Advantages:

- (1) Can be used on shallow soils
- (2) Can be employed where expense of leveling is great
- (3) Installation and operation costs are low
- (4) System is not damaged by livestock and does not interfere with use of farm implements.

Disadvantages:

- (1) Excessive loss of water by run of and deep percolation
- (2) Excessive soil erosion on step land.
- (3) Fertilizer and FYM are eroded from the soil.

Basin irrigation: This method is suitable for orchids and other high value crops where the size of the plot to be irrigated is very small. The basin may be square, rectangular or circular shape. A variation in this method viz. ring and basin is commonly used for irrigating fruit trees. A small bund of 15 to 22 cm high is formed around the stump of the tree at a distance of about 30 to 60 cm to keep soil dry. The height of the outer bund varies depending upon the depth of water proposed to retain. Basin irrigation also requires leveled land and not suitable for all types of soil. It is also efficient in the use of water but its initial cost is high.

Advantages:

- 1) Varying supply of water
- 2) No water loss by run off
- 3) Rapid irrigation possible
- 4) No loss of fertilizers and organic manures
- 5) Satisfactory

Disadvantages:

- 1) If land is not leveled initial cost may be high
- 2) Suitable mainly for orchids, rice, jute, etc.
- 3) Except rice, not suitable for soils that disperse easily and readily from a crust.

Furrow method (rides and furrow, broad ridges, counter furrow etc.): Row crops such as potatoes, cotton, sugarcane, vegetable etc. can be irrigated by furrow method. Water is allowed to flow in furrow opened in crop rows. It is suitable for sloppy lands where the furrows are made along contours. The length of furrow is determined mostly by soil permeability. It varies from 3 to 6 meters. In sandy and clay loams, the length is shorter than in clay and clay loams. Water does not come in contact with the plant stems. There is a great economy in use of water. Some times, even in furrow irrigation the field is divided into beds having alternate rides and furrows. On slopes of 1 to 3 percent, furrow irrigation with straight furrows is quite successful. But on steeper slopes contour furrows, not only check erosion but ensure uniform water penetration.

Adaptations:

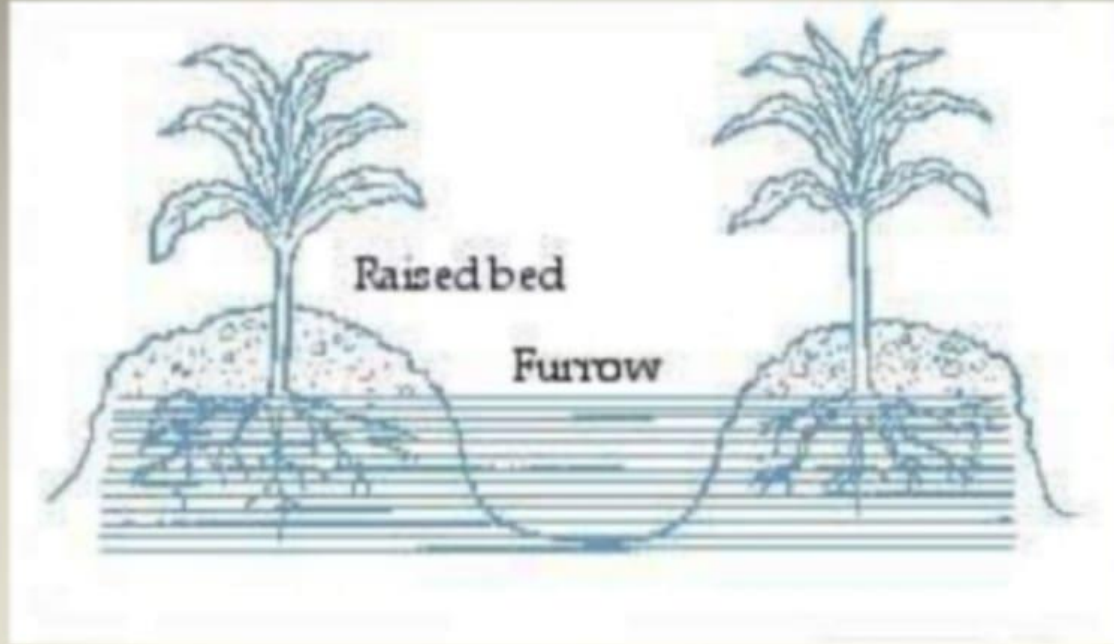
- 1) Medium and fine textured soils.
- 2) Variable water supply
- 3) Farms with only small amount of equipment.

Advantages:

- 1) High water efficiency
- 2) Can be used in any row crop
- 3) Relatively easy in stall
- 4) Not expensive to maintain
- 5) Adapted to most soils.

Disadvantages:

- 1) Requirement of skilled labour is more
- 2) A hazard to operation of machinery
- 3) Drainage must be provided.





B. Subsurface method:

Subsurface irrigation or sub-irrigation may be natural or artificial. Natural sub surface irrigation is possible where an impervious layer exists below the root zone. Water is allowed in to series of ditches dug up to the impervious layer, which then moves laterally and wets root zone.

In artificial sub surface irrigation, perforated or porous pipes are laid out underground below the root zone and water is led into the pipes by suitable means. In either case, the idea is to raise the water by capillary movement. The method involves initial high cost, but maintaince is very cheap. There is a risk of soil getting saline or alkaline and neighboring land damaged due to heavy seepage.

C. Drip or trickle irrigation:

It involves slow application of water to the root zone. The drip irrigation system consist of

- 1) Head
- 2) Main line and sub line
- 3) Lateral lines
- 4) Drip nozzles.

The head consists of a pump to lift water and produce the desired pressure (about 2.5 tmosphere) and to distribute water through nozzles. A fertilizer tank for applying fertilizer solution directly to the field along with the irrigation water and filter which cleans the suspended impurities in irrigation water to prevent the blockage of holes and passage of drip and nozzles

Mains and sub mains are normally of flexible material such as black PVC pipes. Laterals or drip lines are small diameter flexible lines (usually 1 to 1.25 cm diameter black PVC tubes) taking off from the mains or sub mains. Laterals are normally laid parallel to each other. Lateral lines can be up to about 50 meters long and are usually 1.2 cm diameter black plastic tubing. There is usually one lateral line for each crop row. By laying the main line along the center line of the field, it is possible to irrigate either side of the field alternately by shifting the laterals. A pressure drop of 10 percent is permitted between the ends of lateral.

Drip nozzles are also known as emitters or valves and are fixed at regular intervals in the laterals. These PVC valves allow water to flow at the extremely slow rates, ranging from 2 to 11 liters per hour and they are of different shapes and design.

The spacing between laterals is controlled by the row-to-row spacing of the crop to be irrigated. Drip laterals laid on soil surface are buried underground at the depth of 5 to 10 cm.

Advantages:

- 1) The losses by drip irrigation and evaporation are minimized
- 2) Precise amount of water is applied to replenish the depleted soil moisture at frequent intervals for optimum plant growth.
- 3) The system enables the application of water fertilizers at an optimum rate to the plant root system.
- 4) The amount of water supplied to the soil is almost equal to the daily consumptive use, thus maintaining a low moisture tension in soil.

Disadvantages:

The initial cost of the drip irrigation for large-scale irrigation is its main limitation. The cost of the unit per hectare depends mainly on the spacing of the crop. For widely spaced crops like fruit trees, the system may be even more economical than sprinkler.

D. Sprinkler or overhead irrigation:

This method consists of application of water to soil in the form of spray, somewhat as rain. It is particularly useful for sandy soils because they absorb water too fast. Soils that are too shallow, too steep or rolling can be irrigated efficiently with sprinklers.

This method is suitable for areas having uneven topography and where erosion hazards are great.

In sprinkler irrigation, water is conveyed under pressure through pipes to the area to be irrigated where it is passed out through or sprinklers the system comprises four main parts

- i. Power generator
- ii. Pump
- iii. Pipeline and
- iv. Sprinkler

The power generator may be electrical or mechanical. A centrifugal pump may be used for suction lift up to 37 to 50 cm. A piston type pump is preferable where water is very deep. The pipe consists of two sections, the main line and the laterals.

The main line may be permanently buried underground or may be laid above ground, if it is to be used on a number of fields. The main pipes are usually made of steel or iron.

The laterals are lightweight aluminum pipes and are usually portable. The sprinkler nozzles may be single or double, revolving or stationery and mounted on riser pipes attached to riser. Each sprinkler head applies water to circular area whose diameter depends up on the size of water, which varies from $\frac{1}{4}$ to $\frac{3}{4}$ inch per hour is determined by selecting the proper combination of nozzles.

Adaptations:

- 1) A dependable supply of water
- 2) Uneven topography
- 3) Shallow soils.
- 4) Close growing crops.

Advantages:

- 1) It ensures uniform distribution of water
- 2) It is adaptable to most kinds of soil.
- 3) It offers no hindrance to the use of farm implements
- 4) Fertilizers material may be evenly applied through sprinklers. This is done by drawing liquid fertilizer solution slowly in to the pipes on the suction side of the pump so that the time of application varies from 10 to 30 minutes.
- 5) Water losses are reduced to a minimum extent
- 6) More land can be irrigated
- 7) Costly land leveling operations are not necessary and
- 8) The amount of water can be controlled to meet the needs of young seedling or mature crops.

Disadvantage:

- 1) The initial cost is rather very high.
- 2) Any cost of power to provide pressure must be added to the irrigation charges.
- 3) Wind interferes with the distribution pattern, reducing spread or increasing application rate near lateral pipe.
- 4) There is often trouble from clogged nozzle or the failure of sprinklers to revolve.
- 5) The cost of operations and maintaince is very high. Labour requirement for moving a pipe and related work approximately nearly one hour per irrigation.
- 6) It requires a dependable constant supply of water free slit and suspended matter and
- 7) It is suitable for high value crops

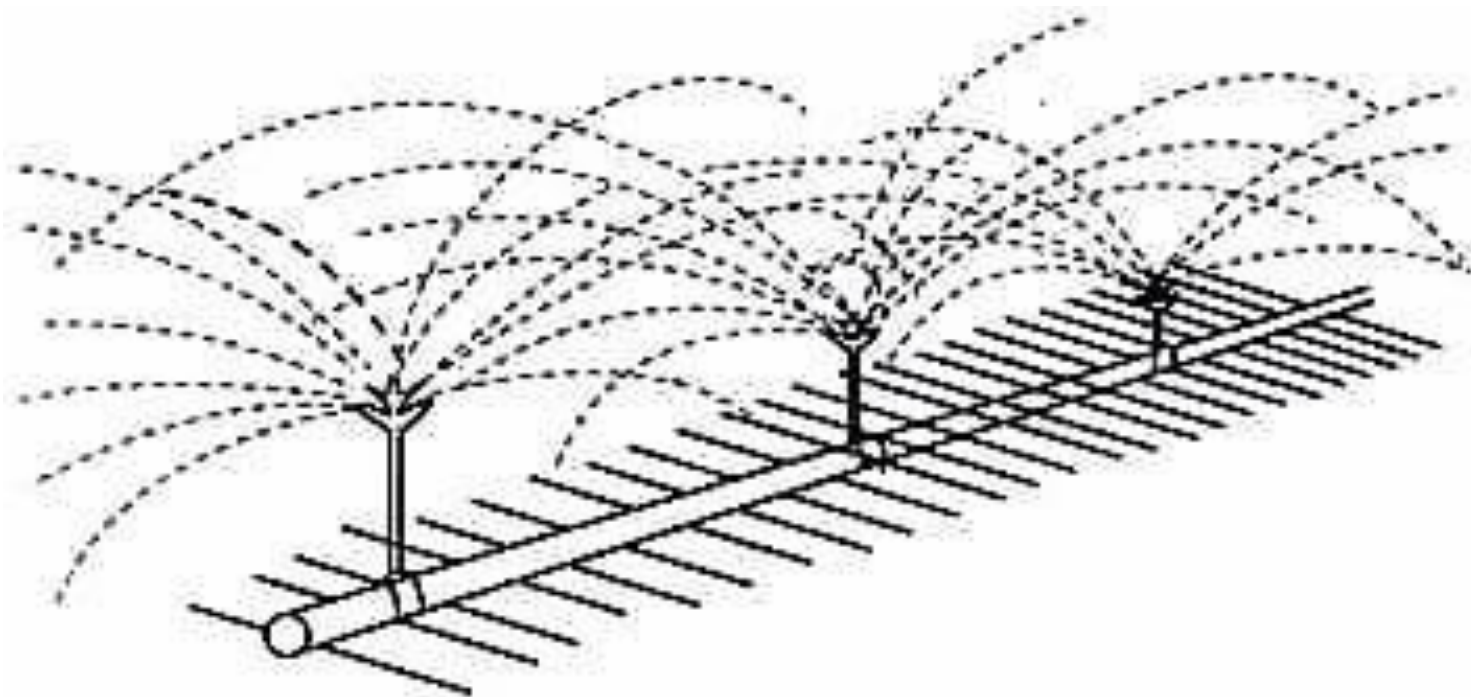
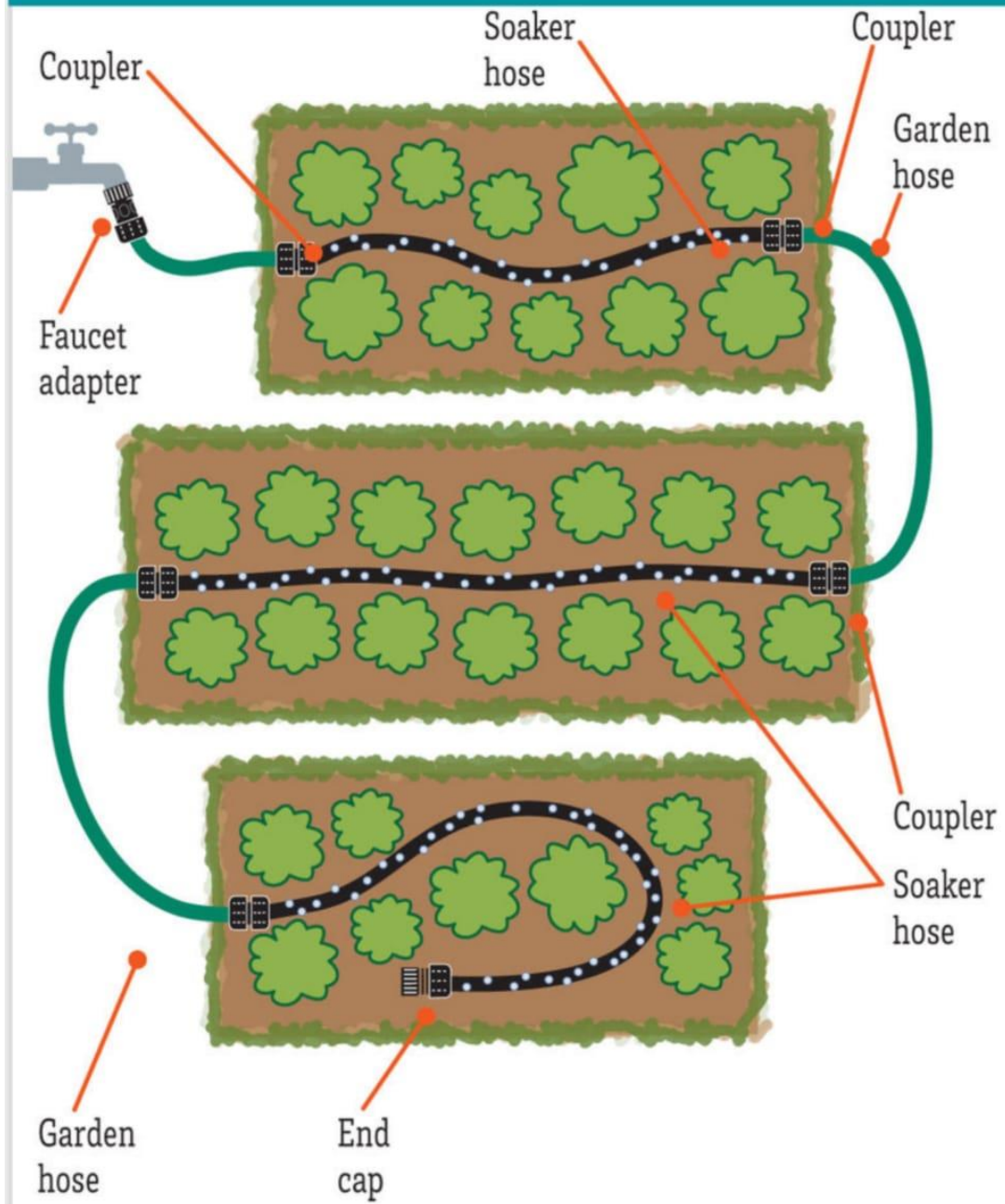


Fig. 6.6. Sprinkler irrigation

Dig Deeper

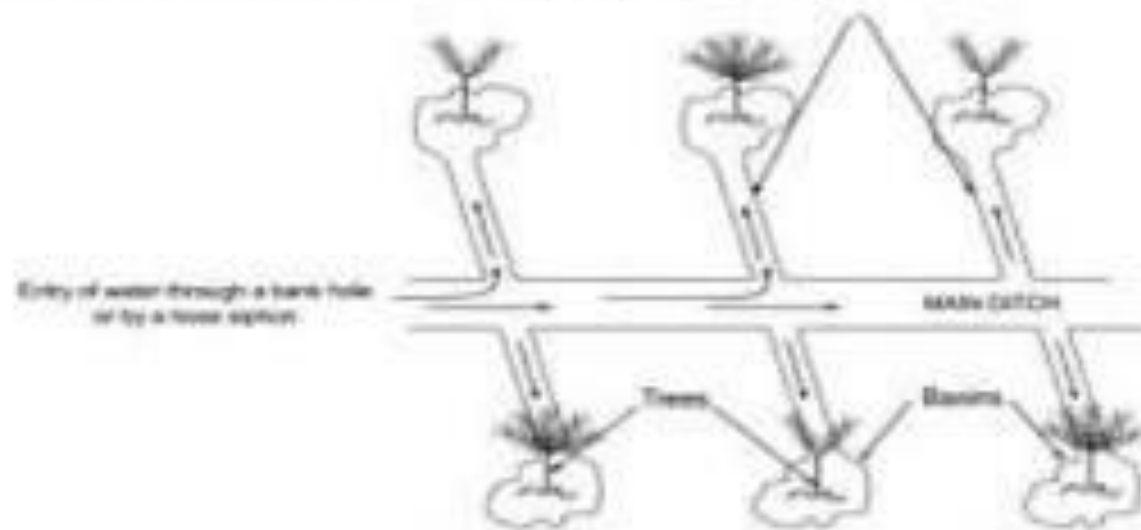


Sprinkler irrigation system

- This system prevent the seepage losses and to have controlled irrigation.
- Many seed farms and nurseries are being successfully raised under this system.
- 30-40% water is saved under this system.

➤ **Basin flooding**

- ✓ This method is used frequently to irrigate the plantations. It is a special type of check flooding method.
- ✓ Each plant is enclosed by circular channels which is called basin. Basins are connected to small field ditches.
- ✓ Ditches are fed from the main supply channel.



IRRIGATION METHODS

1. Surface 2. Sub-surface 3. Pressurized irrigation

Criteria for selection of irrigation method

- ✓ Water supply source
- ✓ Topography
- ✓ Quantity of water to be applied
- ✓ The crop
- ✓ Method of cultivation

IRRIGATION METHODS AND DESIGNS

• 3.1 IRRIGATION METHODS

- a) **Surface Irrigation:** Just flooding water. About 90% of the irrigated areas in the world are by this method.
- b) **Sprinkler Irrigation:** Applying water under pressure. About 5 % of the irrigated areas are by this method.
- c) **Drip or Trickle Irrigation:** Applying water slowly to the soil ideally at the same rate with crop consumption.
- d) **Sub-Surface Irrigation:** Flooding water underground and allowing it to come up by capillarity to crop roots.



SPRINKLER IRRIGATION



- Pressurized irrigation through devices called sprinklers.
- Pakistan is fast heading towards a situation of water shortage with increasing population.
- The surface water availability per capita was 5650 cubic meters in 1951, which reduced to 1400 in 2000.
- The minimum water requirement to avoid being a "water short country" is 1000 cubic meters.
- In the year 2012 Pakistan will have reached the stage of "acute water shortage".
- Sprinklers are usually located on pipes called laterals.
- Water is discharged into the air and hopefully infiltrates near where it lands.

- Is irrigation a good idea for small farms?

For small farms, getting access to water for irrigation is less of a problem than stretching the supply of available water. Use of irrigation systems is increasing on small- and medium-sized farms and in greenhouse operations.

- Which countries lead in irrigated agriculture?

Four countries—India, China, the U.S., and Pakistan—account for more than half of the world's irrigated land. Many nations, including China, Egypt, India, Indonesia, and Pakistan, rely on irrigated land for more than half of their domestic food production.

- Can we win the salt and drainage battles, or is irrigation doomed to decline?

In theory, most salt problems can be solved, but in reality, most remain unsolved. Engineers have devised many techniques to control waterlogging and the accompanying salt buildup, but practically speaking, we have just started to manage waterlogging, salinity, and drainage.

- Will the increasing water requirements of our urban areas affect the availability of water for agricultural irrigation?

Without a doubt, cities will continue to require more water, leaving less for agriculture. Unknown, however, is the amount of water that ultimately will be reallocated and the effect of that reallocation on food production, farmers, and small communities.

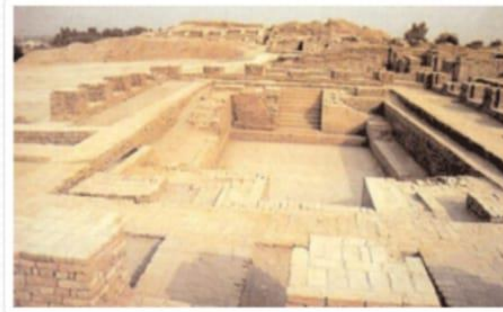
- Can agriculture continue to irrigate?

In large part, the answer lies in agriculture's ability to do more with less water and energy. As water becomes increasingly scarce, getting more benefit from every drop will be the key.

Crops which are benefited under Sprinkler Irrigation System :-

| <u>Crops</u> | <u>Water Saving (%)</u> | <u>Yield increase (%)</u> |
|--------------|-------------------------|---------------------------|
| Chilli | 33 | 24 |
| Cotton | 36 | 50 |
| Fenugreek | 29 | 35 |
| Gram | 69 | 57 |
| Jowar | 55 | 34 |
| Maize | 41 | 36 |
| Onion | 33 | 23 |
| Sunflower | 33 | 20 |
| Wheat | 35 | 24 |

INDUS BASIN IRRIGATION SYSTEM OF PAKISTAN



Pakistan, a country of enchanting landscapes offers a combination of beaches, mountains, beautiful deserts and valleys. Its vast farm lands are sustained by the Indus Basin Irrigation System (IBIS), the largest contiguous irrigation system in the world. The IBIS irrigates 45 million acres of farm land which produces wheat, rice, fruits, vegetables, sugarcane, maize and cotton in abundance for local use as well as for export.

This report provides the historical context in which the IBIS was developed. It discusses the economic impact of the IBIS on Pakistan, and provides recommendations for some current problems related to insufficient drainage and inefficient farming practices.

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- Pakistan's 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)

- ④ 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.

The Indus Basin: The First Decade 1947-1957

- Pakistan at this time was overwhelmingly rural. There was a magnificent canal irrigation system based on the River Indus and its five tributaries (the Jhelum, Chenab, Ravi, Sutlej, and Beas), but it was plagued by its seasonal nature and lack of surface storage (nearly half the flows went to sea unused in the summer, with less than 2 feet/acre left for the irrigated land).

LAND USE IN PAKISTAN

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Current Problems and Recommendations

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5. Group small farms into larger units for cooperative farming using the latest irrigation and farming techniques and modern agricultural practices.
6. Increase the production of beans, lentils and edible oil seeds to reduce their imports.
7. Develop pastures for cattle farming and increase milk and meat production.
8. Big land holdings more than five thousand acres of area should be made available for cooperative farming.
9. The level and standard of research should be enhanced in the existing agricultural universities of Pakistan.

- The irrigation system during the 1950s (largely inherited pre-1947) consisted of 10 barrages (Thal, Jinnah, Taunsa, Guddu, Sukkur, Kotri, Trimmu, Dipalpur, Suleimanke, Islam, and Panjnad) and 35,000 miles of canals. India had started depriving Pakistan of water from the three eastern rivers, i.e., the Ravi, Sutlej, and Beas from March 1948.

Treaty Between Pakistan and India

In 1947, the Indian sub continent was partitioned by the British into two independent states – Pakistan and India. After the partition a commission was set up to resolve any issue that may emerge as a consequence of the partition. The matter of utilization of water resources of Indus Basin was raised by Pakistan. The boundary commission, chaired by Sir Cyril Radcliff, awarded control barrages (situated very close to the border) to India, while 90 percent of irrigated land lay in Pakistan.

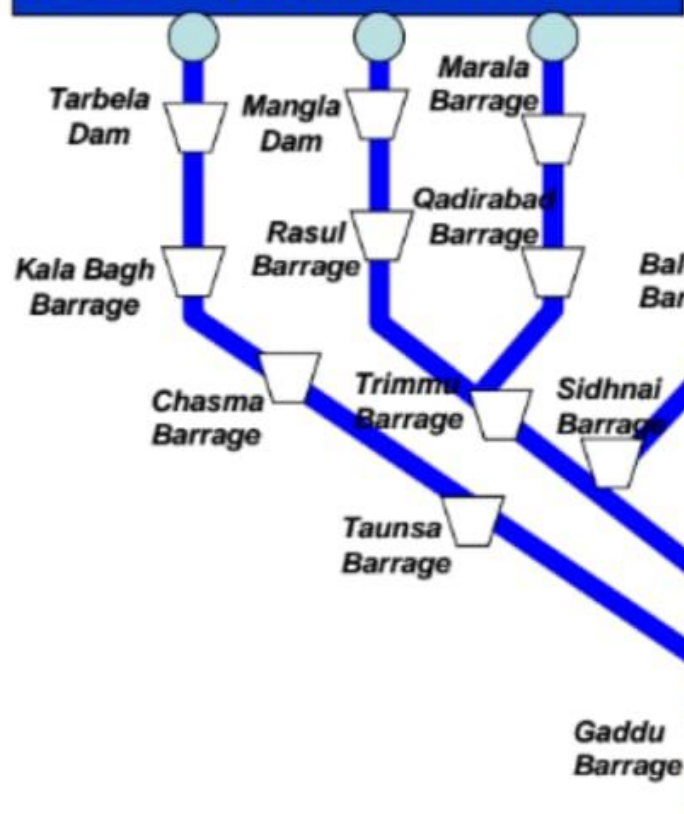
After a protracted negotiation of ten years through facilitation of the World Bank, the Indus Basin Treaty was signed by India and Pakistan in 1960 for distribution of water resources in the Indus Basin. According to the terms of the treaty India was given the exclusive use of the waters of the eastern rivers namely Ravi, Sutlej and Beas. Pakistan was not given its full historic share and was allocated only 75 percent of its legitimate share of the waters in Indus Basin. Consequently, Pakistan agreed to embark upon a gigantic project nicknamed as “Indus Basin Replacement Works”. The extensive undertaking involved the construction of two major dams, five barrages and eight link canals.

- This combination, together with Pakistani and international funding, enabled the entire Indus Basin Replacement Works to be completed by the early 1970s.

Structures on Indus River System

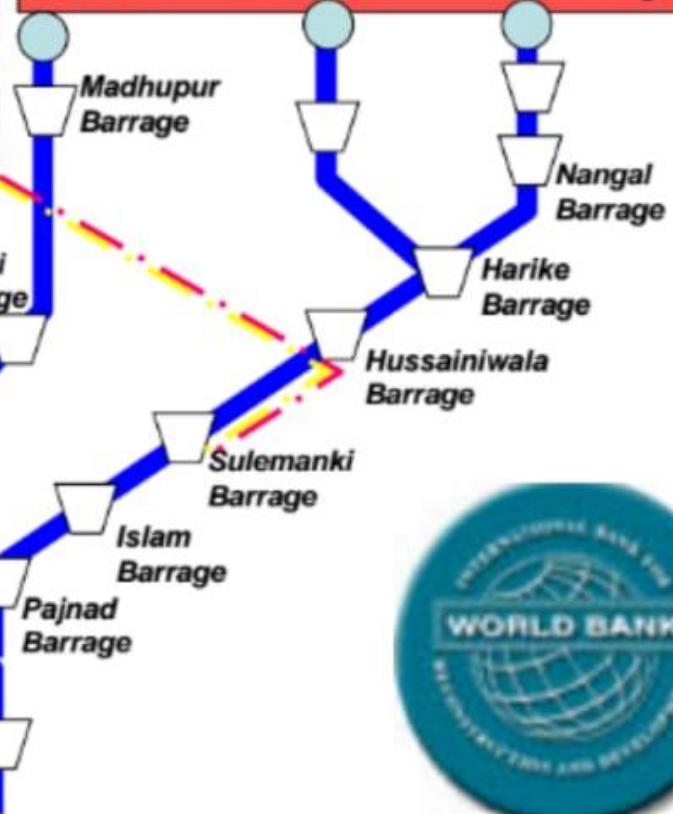
WESTERN RIVERS

Indus Jhelum Chenab



EASTERN RIVERS

Ravi Beas Sutlej



The Indus Basin Replacement Works (1960-80)

- The total replacement cost of the infrastructure is currently estimated at more than \$60 billion,⁵ and of these, the two major dams (Tarbela and Mangla), a syphon-cum-barrage (Mailsi), five barrages (Chashma, Rasul, Qadirabad, Marala, and Sidnai), and eight major link canals were built under the Indus Basin Replacement Works.

Water Ability of the IBIS

There are three main sources of water availability in the Indus Basin:

A. The average annual flow of Western Rivers of Indus Basin is approximately 142 million acre feet (MAF). About 104 MAF of this water is diverted for irrigation purposes and about 35 million acre feet outflows to the Arabian Sea.

B. Rain Water:

Another source of water is the rain fall. Irrigated areas of Indus Basin receive on average 40 million acres feet of water annually.

C. Ground Water:

The third source of water is the ground water. It provides approximately 40 percent of crop water requirements of the country.

according to treaty Pakistan will use of western rivers and india will use of eastern rivers. The first reservoir “mangla dam” was built in 1967 and the second reservoir “tarbela dam” completed in 1974

IBIS Investments in the Last Decade 2000-2010

- ④ The last decade has seen the initiation and completion of a number of important projects relating to the Indus Basin, financed in large part by the Government of Pakistan itself. These include:
 1. The Mangla Dam Raising Project 2003-2010 (raising the Mangla Dam 30 feet and thereby adding an additional 2.9 MAF to its existing capacity of 6 MAF at an original cost of Rs 63 billion)

4. The Raineer Canal Project for Sindh, covering Ghotki, Khairpur, and Sukkur 2002-2012 (creating a new CCA of 0.41 million acres at a cost of Rs 19 billion).

2. The Greater Thal Canal Project in Punjab 2002-2010 (creating a new culturable command area [CCA] of 1.5 million acres at a cost of Rs30 billion)
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Irrigation & Drainage Practices

Lect 2.

- Irrigation (Importance of water to plants.)
- The water cycle.
- Percentage of irrigation.
- Why irrigation

Lecture 3

- Pakistan water resources.
- Water use & consumption.
- Macro Level water management.
- Micro Level water management.
- Environmental impacts
- Suggestions.
- 5 Q/Answers.

Lect 4

- Irrigation methods
- Flooding
 - Advantages
 - Disadvantages

Lecture 5

- Basin
 - Advantages
 - Disadvantages
- Furrow methods
 - Detail Advantages
 - Disadvantages

Lecture 6

- Subsurface methods
 - Detail
- Drip methods
 - Advantages
 - Disadvantages

Lecture 7

- Sprinkler method
 - Advantages & Disadvantages
- Sprinkler irrigation system.
- Rainfall flooding.
- Irrigation methods
 - Criteria for selection of irrigation method
- Irrigation methods & design.
- Sprinkler irrigation.
- 5 Q/Answers.
- course completed

Lect 8

- Indus Basin irrigation system
- Pak. Indus Basin who have.
- Indus basin first decade.
- the irrigation system
- Treaty b/w Pak. & India.
- Indus Basin replacement work
- Water quality of the IBIS

Lect 9

- Current problems & recommendations. IBIS.
- Land use.
- Structures on Indus River system

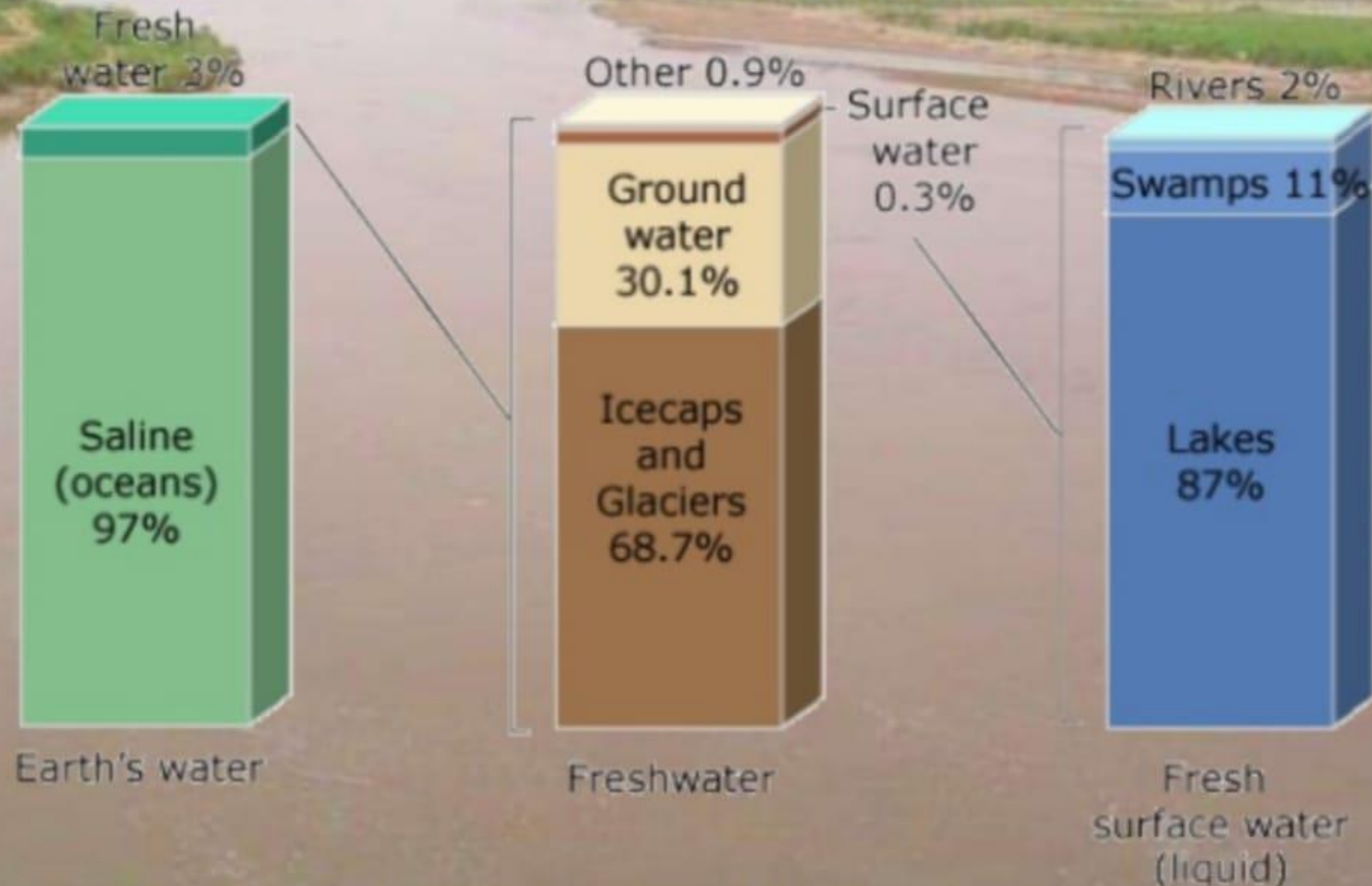
IRRIGATION

Issues

- ⌚ Supply driven rather than demand led distribution of water without consideration of cropping pattern
- ⌚ Inequity of irrigation water both inter and intra provincial level and watercourse level
- ⌚ Deferred operation and maintenance of centuries old irrigation system
- ⌚ System losses as high as 55%
- ⌚ Slow and lackluster approach for watercourse improvement and lining
- ⌚ Lack of water conservation and application techniques at the farm level

- Water covers 71% of the earth's surface
- Water moves continually through a cycle of evaporation, precipitation and runoff
- Essential for all forms of life.

Distribution of Earth's Water



OPTIONS FOR IMPROVING IRRIGATION WATER PRODUCTIVITY

Technical

- Land leveling to apply water more uniformly
- Efficient sprinklers to apply water more uniformly
- Furrow and bed cultivation to save water
- Drip irrigation to conserve water

OPTIONS FOR IMPROVING IRRIGATION WATER PRODUCTIVITY

Managerial

- Better irrigation scheduling
- Improving canal operations for timely deliveries
- Applying water when most crucial to a crops yield
- Water-conserving tillage and field operation methods
- Better maintenance of canal, watercourses and equipment
- Recycling drainage water

OPTIONS FOR IMPROVING IRRIGATION WATER PRODUCTIVITY

Institutional

- Establishing water users organizations for better management of water
- Fostering rural infrastructure for private sector dissemination of efficient technologies
- Better training and extension efforts

OPTIONS FOR IMPROVING IRRIGATION WATER PRODUCTIVITY

Agronomic

- Selecting crop varieties with high yields per cubic meter of transpired water
- Inter-cropping to maximize use of soil moisture
- Better matching crops to climate conditions and the quality of water available
- Crop rotations to maximize output under condition of soil and water salinity
- Selecting drought-tolerant crops where water is scarce or unreliable
- Breeding water-efficient crop varieties

1.4 Advantages and Disadvantages of Irrigation.

Advantages

The advantages of irrigated agriculture include;

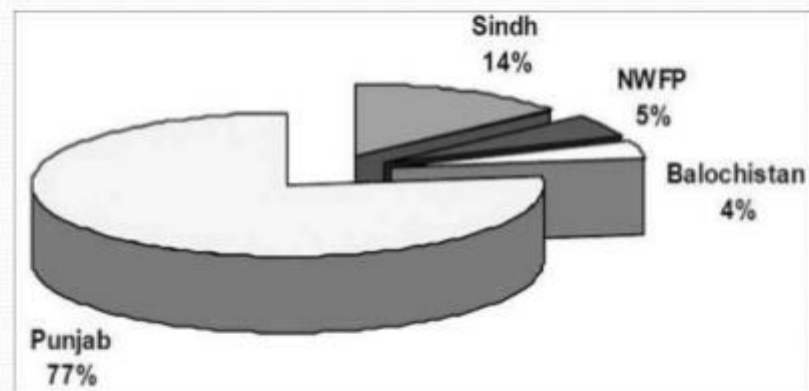
- It increases the area of land brought under cultivation.
- It improves crop yield over rainfed agriculture three or four fold.
- Allows for the greater cropping intensity.
- It results in improved economic security for the farmer.
- Reduces risks associated with drought hence farmers can easily use high yield seed varieties, increase the use of fertilizers, pesticides, pesticides and mechanization. They can also control the timing of delivery of their products to the market and also the labour demands.
- It allows for the introduction of more valuable crops to farmers.

Disadvantages

The disadvantages of irrigated agriculture include

- Over irrigation leads to water logging of the soil and this reduces yields.
- Increased possibility of ground water pollution as a result of increased use of chemicals and fertilizers.
- Due to the presence of water in open channels, there is an increased possibility of having several water borne diseases e.g malaria, bilharzias, etc.
- It is complex and expensive undertaking; most of the time requiring donor funding yet most of them are not self sustaining in the long run.

Provincial-wise irrigated area



Punjab

- Punjab has 56 % of total population of Pakistan. Total irrigated area is 14.41 million hectares.
- Out of total 45 canals in Indus basin system there are 23 canals in Punjab.

Balochistan

- Balochistan is the largest landmass in Paskistan. Balochistan receives very low rainfall annually.
- This area is very dry so the inhabited have used a unique way of gathering water called Karez.
- In this method groundwater is tapped by a tunnel
- Karez run under the ground and then it is exposed on the surface.



Importance of Irrigation management

- To the development of nation through proper management of water resources for the purpose of crop production and other activities such as industrialization, power generation etc., which in turn provides employment opportunities and good living condition of the people.
- To store the regulate the water resources for further use or non-season use
- To allocate the water with proper proportion based on area and crop under cultivation. (Balanced equity in distribution)
- To convey the water without much loss through percolation and seepage (Efficiency in use)

Lakes

- Natural depressions of land.
- Lakes are supplied with water by
 - ❖ rainfall that falls directly on the surface of lakes.
 - ❖ By water run-off from adjacent land.
- Lakes loses water via
 - ❖ Evaporation.
 - ❖ Through percolation from the bottom of the lake to the groundwater.
- The amount of irrigation water required must be less than the quantity of water available in lakes

The Jhelum

Reservoirs

- **Amount of water in a reservoir depends on**
 - ❖ **River discharge**
 - ❖ **Height of the dam**
 - ❖ **Area of the reservoir**
- **On-stream storage**
- **Off-stream storage**

Pumping from a Lake or Reservoir

- **Water can be taken from lakes or reservoir via**
 - ❖ **Direct diversion**
 - ❖ **Concrete or steel pipe**
 - ❖ **Pumps**

Indus river from
Karakouram highway

What is difference between **Barrage** and **Headworks**?

- The **head works** are built on river or water course between two banks at the same level of river to control water, distribute it through canals for irrigation or other purpose of supplying water.
- **Barrage** is made in similar way but main difference is that barrage is designed in such a way so that it could increase the water level and serve as a storage. Electricity can be produced at a barrage after construction of hydro power plants but could not be at a head work.

Salient Features of Main Rivers - **Indus River**

| | |
|-----------------------|--|
| Origin | <ul style="list-style-type: none">-One of the largest rivers of the world and the main river of the Indus valley;-Originates near lake Mansarowar on north of Himalayas range in the mountain of Kailash Parbat in Tibet at an elevation of 18,000 ft.; |
| Length | 925 miles/1,489 Km above Tarbela |
| Catchment Area | 1,80,000 Sq.miles/2,88,000 Sq.km |

| | |
|--------------------------|---|
| Tributary Rivers | Twenty seven (27) major tributaries above Guddu Barrage |
| Largest Tributary | Shyoke river (400 miles/640km) , catchment area (12,600 Sq.miles/20,160 Sq.km) |
| Dams on the River | Tarbela |
| Barrages on River | Kalabagh, Chashma, Taunsa, Guddu, Sukkur, Kotri |

What is duty and Delta?



Duty and Delta are very basic definitions used in the calculation of irrigation water demand of the crops. To put it simple, **Duty** is the area of land that can be irrigated with a unit volume of water supplied across the base period where as **delta** is the depth of water required to raise a crop over a unit area.

How many gates are there in Sukkur Barrage?



PakistanPaedia - Sukkur Barrage. Sukkur, located on the Indus River, is an important commercial and industrial city of Sind province. Sukkur is famous for its Sukkur Barrage, a **60 gates** barrage, made of yellow stone and steel, across the Indus, which controls one of the largest irrigation systems in the world. Jun 25, 2006

Which is the smallest dam of Pakistan?



Warsak Dam is the Smallest dam of Pakistan.

Warsak Dam is defined as the mass concrete gravity dam. It is located on the **Kabul River** around 20 km northwest of the city of Peshawar in Khyber Pakhtunkhwa province of Pakistan.

Warsak Dam known as the smallest dam of Pakistan.

Which is the oldest barrage of Pakistan?



Sukkur **Barrage** (Sindhi: سکر بئراج, Urdu: سکھر بیراج) is a **barrage** on the River Indus near the city of Sukkur in the Sindh province of **Pakistan**. The **Barrage** was built during the British Raj from 1923 to 1932 and was named Lloyd **Barrage**.

Which is the longest canal of Pakistan?



It was built as an excavated channel off the left bank of the **Indus River** into the course of the old **Nara River**. The canal runs from above the **Sukkur Barrage** through the Khairpur, Sanghar, Mirpurkhas and **Tharparkar** Districts to the **Jamrao Canal**. Nara is the longest canal in Pakistan, running for about 226 mi (364 km).

Which is the largest barrage in Pakistan?



The **Barrage** was built during the British Raj from 1923 to 1932 and was named Lloyd **Barrage**. The Sukkur **Barrage**, is the pride of **Pakistan's** Irrigation system as it is the **largest** single Irrigation network of its kind in the world.

Cont.....

- The Sukkur Barrage, is the pride of Pakistan's Irrigation system as it is the largest single Irrigation network of its kind in the world.
- The introduction of barrage-controlled irrigation system resulted in more timely water supplies for the existing cultivated areas of Sindh Province of Pakistan.

Cont.....

- It is the largest barrage of Pakistan and was built during British rule.
- It was known as Lloyd Barrage.
- Sukkur Barrage was constructed in 1932 on the Sukkur, River Indus. It is among the few large barrages in the world, and has a maximum design discharge of 1.5 million cusecs.
- The maximum flood level height of Sukkur Barrage is 30 feet.

5-SUKKUR BARRAGE



Cont.....

- ✓ The dam is 148 meter high above riverbed. Construction started in 1968 and completed in 1976 at cost of \$1,497 million. Total capacity of the dam is 13.69 cubic kilometers spread over the construction area of 168,000 km².

Cont.....

- ✓ It is one of the world's largest **earth and rock filled** Dam and greatest water resources development project , which was completed in **1976** as a component part of **Indus Basin Project**. The Dam is built on Pakistan's largest river i.e **INDUS**.
- ✓ *It is also considered as the biggest Dam of the world after **Syncrude Tailings Dam (Canada)**.*

1-Tarbela Dam



Dams

- A barrier constructed across a waterway to control the flow or raise the level of water.
- A **dam** is a barrier that impounds water or underground streams. The reservoirs created by **dams** not only suppress floods but provide water for various needs to include irrigation, human consumption, industrial use, aquaculture and navigability.
- A dam is also the basic key element for hydropower generation.