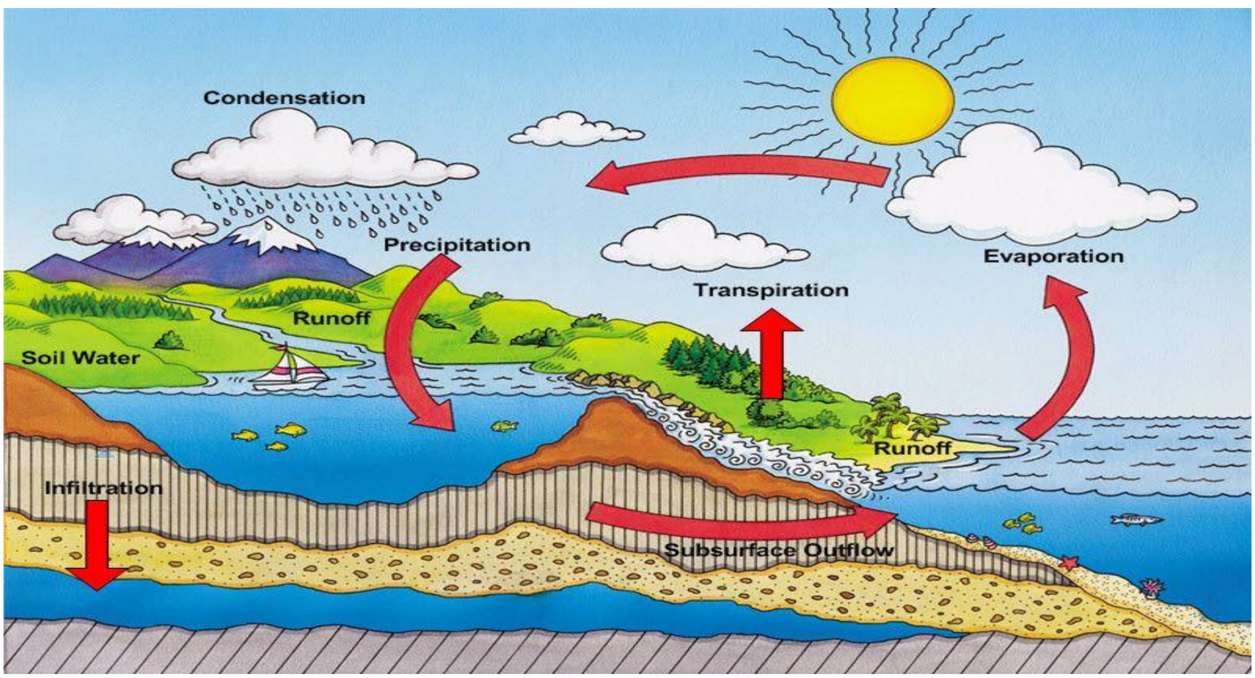
MODULE-1

Surface and Ground water Resources

HYDROLOGICAL CYCLE

Water can occur in three physical phases: solid, liquid, and gas and is found in nature in all these phases in large quantities. Depending upon the environment of the place of occurrence, water can quickly change its phase.

The Hydrologic Cycle, also known as the water cycle, is one cycle which forms the fundamental concept in hydrology. Hydrologic cycle was defined as "the pathway of water as it moves in its various phases to the atmosphere, to the earth, over and through the land, to the ocean and back to the atmosphere". This cycle has no beginning or end and water is present in all the three states (solid, liquid, and gas). A pictorial view of the hydrological cycle is given in Fig.



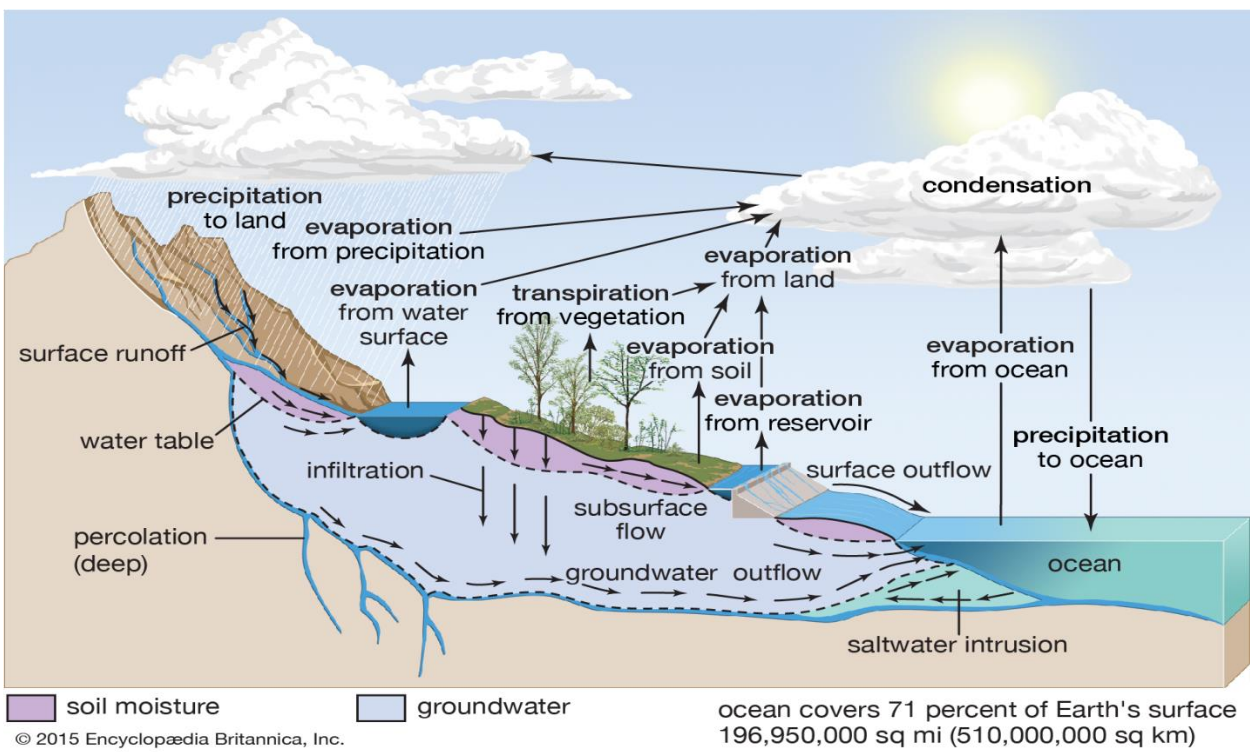
The hydrologic cycle can be visualized as a series of storages and a set of activities that move water among these storages. Among these, oceans are the largest reservoirs, holding about 97% of the earth's water. Of the remaining 3% freshwater, about 78% is stored in ice in

Antarctica and Greenland. About 21% of freshwater on the earth is groundwater, stored in sediments and rocks below the surface of the earth. Rivers, streams, and lakes together contain less than 1% of the freshwater on the earth and less than 0.1% of all the water on the earth.

Hydrologic cycle considers the motion, loss and recharge of the earth's water.it connects the atmosphere and two storages of the earth system: the ocean and the land sphere. The water evaporated from the earth and the oceans enter the atmosphere. Water leaves the atmosphere through precipitation and from the land through rivers and ground water flow. Water goes out of oceans only through evaporation. The water leaves land through Evotranspiration. Stream flow and ground water flow. Evaporation and precipitation processes take place in the vertical plane while stream flow and ground flow occur mostly in the horizontal plane.

Five Processes of the Hydrologic Cycle

1. Evapotranspiration: Evaporation+Transpiration
2. Condensation
3. Precipitation
4. Run-off
5. Infiltration



Evaporation

- Evaporation occurs when water changes from liquid state to gaseous state.
- Water is transferred from the surface to the atmosphere through evaporation, the process by which water changes from a liquid to a gas the sun's heat provides land, lakes rivers and oceans send up a steady stream of water vapor and plants also lose water to the air
- Approximately 80% of all Evaporation is from the oceans, with the remaining 20% coming from inland water and vegetation.

Transpiration

- The release of water vapor from plants into the atmosphere.
- As plants absorb water from the soil, the water moves from the roots through the stems to the leaves, once the water water reaches the leaves, some of it evaporates from the leaves, adding to the amount of water vapor in the air, this process of evaporation through plant leaves is called transpiration.

Condensation

- The opposite of evaporation. Condensation occurs when a gas is changed into a liquid.
- The Condensation is the process by which water vapor changes into water. Water vapour condenses to form dew, fog or clouds .condensation takes place due to cooling of air.
- As water rises higher in the atmosphere, it starts to cool and become a liquid again when large amount of water vapor condenses; it results in the formation of clouds.

Precipitation

- When the water in the clouds gets too heavy, the water falls back to the earth This is called precipitation. Precipitated water may fall into water bodies or on land it can then go to streams or penetrate into the soil.
- When the temperature and atmospheric pressure are right, the small droplets of water in clouds form larger droplets and precipitation occurs. The rain drops fall to Earth
- Different forms of Precipitation are.
  a.Rain

b.Hail

c.Sleet

d.Snow

Infiltration

- Flow of water from surface into the ground
- Returns to lithosphere by infiltration into the ground becoming soil water or ground water.
- Some precipitation seeps into the ground water and is stored in layers of rock below the surface of the earth.
- This process of precipitation seeping into the groundwater is called infiltration. This water stays there for varying amounts of time, Some water may evaporate into the hydrological cycle within days, while other water will stay in the ground for centuries or more.

Run off

- Returns to the hydrosphere by flowing as run-off from the land surface into streams, rivers, lakes and eventually the ocean.
- Most of the water which returns to land flows downhill as run-off. some of its penetrates and charges ground water while the rest becomes river flow .as the amount of ground

water increases or decrease, the water table rises or falls accordingly when the entire below the ground is saturated, flooding occurs because all subsequent precipitation is forced to remain on the surface.

- Flooding is very common during winter and early spring because frozen ground has no permeability, causing most rainwater and melt water to become run-off.

Global water Resources

- For proper control and use of water it is Essential to have an idea of availability of water resources of the world.
- World Oceans cover about 3/4th of Earth surface.
- The world's total water resources are estimated at 1.36x10^8 M ha-m.
- Which is enough to cover the earth with a layer of 3000meters depth. Of these global water resources, about 97.3% is in oceans as saline water and only 2.75% is available as fresh water at any time on the planet earth. About 77.2% of fresh water lies frozen in Polar Regions and another 22.4% is present as ground water and soil moisture, the rest is available in lakes, rivers, atmosphere and vegetation.

Distribution of water on earth

Saline water (oceans and sea)	- 97%
Fresh water	- 3.0%
Freshwater Resources	
Polar Ice caps	- 77.2%
Ground water and Soil Moisture	-22.4%
Lakes, swamp and Reservoirs	-0.35%
Atmosphere	- 0.04%
Rivers and Streams	- 0.01%

Scales for study of hydrologic cycle

From the point of view of hydrologic studies, two scales are readily distinct. These are the global scale and the catchment scale.

Global scale

From a global perspective, the hydrologic cycle can be considered to be comprised of three major systems; the oceans, the atmosphere, and the land sphere. Precipitation, runoff and evaporation are the principal processes that transmit water from one system to the other. This illustration earth (lithosphere), the oceans (hydrosphere), and the atmosphere. The study at the global scale is necessary to understand the global fluxes and global circulation patterns. The results of these studies form important inputs to water resources planning for a national, regional water resources assessment, weather forecasting, and study of climate changes. These results may also form the boundary conditions of small-scale models/applications.

Catchment Scale

While studying the hydrologic cycle on a catchment scale, the spatial coverage can range from a few square km to thousands of square km. The time scale could be a storm lasting for a few hours to a study spanning many years. When the water movement of the earth system is Considered, three systems can be recognized: the land (surface) system, the subsurface system, and the aquifer (or geologic) system. When the attention is focused on the hydrologic cycle of the land system, the dominant processes are precipitation, evapotranspiration, infiltration, and surface runoff. The land system itself comprises of three subsystems: vegetation subsystem, structural subsystem and soil subsystem. These subsystems subtract water from precipitation through interception, depression and detention storage. This water is either lost to the atmospheric system or enters subsurface system. The exchange of water among these subsystems takes place through the processes of infiltration, exfiltration, percolation, and capillary rise.

Time scales in hydrologic cycle

The time required for the movement of water through various components of the hydrologic Cycle varies considerably. The velocity of stream flow is much higher compared to the velocity of ground water. The time-step size for an analysis depends upon the purpose of study, the availability of data, and how detailed the study .The time step should be sufficiently small so that the variations in the processes can be captured in sufficient detail. But at the same time, it should not put undue burden on data collection and computational efforts.

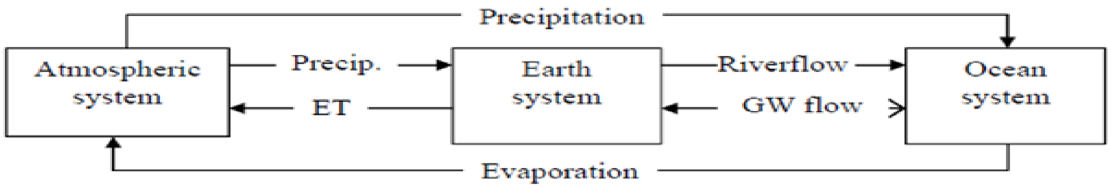


Fig. 1.2 A global schematic of the hydrologic cycle.

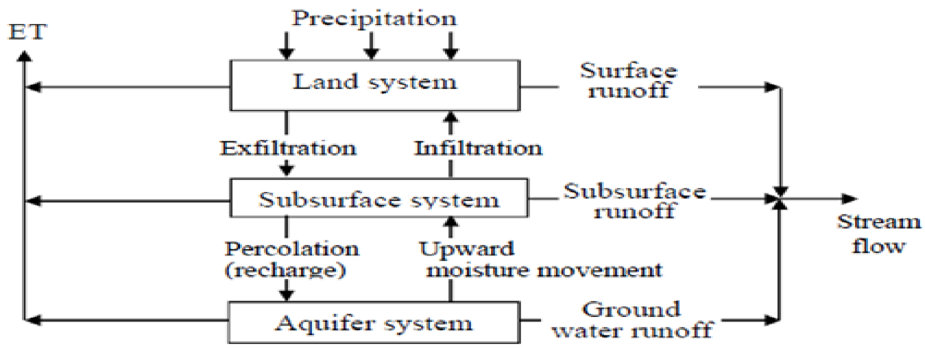


Fig. 1.3 A schematic of the hydrologic cycle of the earth system.

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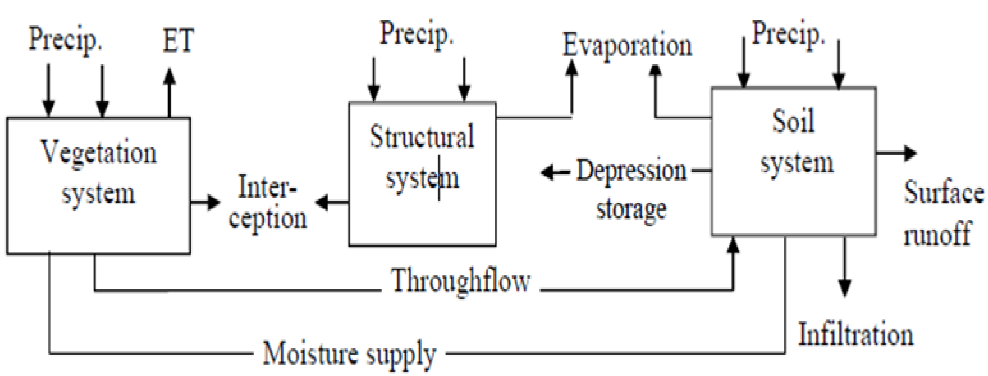


Fig. 1.4 A detailed schematic of the hydrologic cycle in the land system.

Indian Water Resources

India Physiography: India, with a geographical area of about 329 Million Hectares (M.ha), is a land of many mountains and rivers, some of them figuring amongst the mightiest rivers of the world. Physiographically, India may be divided into seven well defined regions. These are: the Northern Mountains comprising the mighty Himalayan ranges; the Great Plains traversed by the Indus, Ganga and Brahmaputra river systems; the Central Highlands, consisting of a wide belt of hills running east-west between the Great Plains and the Deccan plateau; the Peninsular Plateaus; the East Coast, a belt of land of about 100-130 km wide, bordering the Bay of Bengal; the West Coast, a narrow belt of land of about 10-25 km wide, bordering the Arabian Sea; and the islands, comprising the coral islands of Lakshadweep in Arabian Sea and Andaman and Nicobar group of islands in the Bay of Bengal.

Climate

The great mountain mass of Himalayas in the North and the ocean in the South are the two major influences operating on the climate of India. The Himalaya poses an impenetrable barrier to the influence of cold winds from central Asia and gives the sub-continent the elements of tropical type of climate. The oceans are the source of moisture-laden winds, giving India the elements of the oceanic type of climate. India has a very great diversity and variety of climate and an even greater variety of weather conditions. The climate ranges from extremes of heat to extremes of cold; from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall. The climatic condition influences to a great extent the water resources utilization in the country

Rainfall

Rainfall in India is dependent on the South-West and North-East monsoons, on shallow cyclonic depressions and disturbances and on violent local storms which form regions where cool humid winds from the sea meet hot dry winds from the land and occasionally reach cyclonic dimension. Most of the rainfall in India takes place under the influence of South West monsoon between June to September except in Tamil Nadu where it is under the influence of North-East monsoon during October and November. The average rainfall, i.e. total precipitation divided by the total land area, is about 1215 mm. However, there is considerable spatial variation in rainfall which ranges from less than 100 mm in the western Rajasthan to more than 2500 mm in North-Eastern areas.

Rivers of India: India is blessed with many rivers. Land slope determines the river to which the rain falling on an area will eventually flow. A river basin, also called catchment area of the river, is the area from which the rain will flow into that particular river. The shape and size of the river basin is determined by the topography. Following are the major river basins groups in India.

Indus system: This comprises the river Indus and its tributaries like the Jhelum, Chenab, Ravi, Beas and Sutlej. These originate in the North and generally flow in a West or South-West direction to eventually flow into Arabian Sea through Pakistan.

Ganga-Brahmaputra-Meghana system The main river Ganga and its tributaries like the Yamuna, Sone, Gandak, Kosi and many others; similarly main rivers Brahmaputra, Meghna and their tributaries. All these eventually flow into Bay of Bengal, through Bangladesh. Some of the tributaries of these rivers are larger than other independent rivers. e.g. Yamuna, a tributary of Ganga, has a larger catchment area than the Tapi, a small peninsula river.

Rivers of Rajasthan and Gujarat: Mahi, Sabarmati, Luni etc. These are rivers of arid regions, they carry relatively little flow, some of them flow to Arabian Sea through Gujrat while some are land-locked and their flow is lost through percolation and evaporation in the vast arid regions.

East Flowing Peninsular Rivers: The important membes of this group are :Damodar, Mahanadi, Brhamanai, Baitrani, Subarnarekha, Krishna-Godavari and Kaveri. The all flow in to Bay of Bengal at various places along the Eastern coast of India.

West Flowing Peninsular Rivers

Narmada and Tapi. These originate in Central India and flow in a Western direction to meet Arabian Sea south of Gujrat.

Western Coast Rivers

A large number of rivers in the Western Coast - i.e. coastal Maharashtra and Karnataka, and entire Kerala. These rivers are small in length but carry a significant amount of water due to very high rainfall in Western Ghats. They drain only 3 % of the India’s land area but carry 11 % of India’s water resources.

Major River Basins Of The Country

Name of the River	Origin	Length (Km.)	Catchment Area (Sq. Km.)
Indus	Mansarovar (Tibet)	1114 +	**321289 +**
a) Ganga	Gangotri (Uttar Kashi)	2525 +	**861452 +**

b) Brahmaputra	Kailash Range (Tibet)	916 +	**194413 +**
c) Barak and other rivers flowing into Meghna			**41723 +**
Sabarmati	AravalliHills (Rajasthan)	371	**21674**
Mahi	Dhar (Madhya Pradesh)	583	**34842**
Narmada	Amarkantak(Madhya Pradesh)	1312	**98796**
Tapi	Betul (Madhya Pradesh)	724	**65145**
Brahmani	Ranchi (Bihar)	799	**39033**
Mahanadi	Nazri Town(Madhya Pradesh)	851	**141589**
Godavari	Nasik (Maharashtra)	1465	**312812**
Krishna	Mahabaleshwar (Maharashtra)	1401	**258948**
Pennar	Kolar (Karnataka)	597	**55213**
Cauvery	Coorg (Karnataka)	800	**81155**
Total			**2528084**

Basin wise Surface Water Potential

Name of the River Basin	Average flow bcm/year
Indus (up to Border)	**73.31**
a) Ganga	**525.02**
b) Brahmaputra Barak and others	**585.6**
Godavari	**110.54**
Krishna	**78.12**

Cauvery	**21.36**
Pennar	**6.32**
East Flowing Rivers Between Mahanadi and Pennar	**22.52**
East Flowing Rivers Between Pennar and Kanyakumari	**16.46**
Mahanadi	**66.88**
Brahmani and Baitarni	**28.48**
Subernarekha	**12.37**
Sabarmati	**3.81**
Mahi	**11.02**
West Flowing Rivers of Kutch, Sabarmati including Luni	**15.1**
Narmada	**45.64**
Tapi	**14.88**
West Flowing Rivers from Tapi to Tadri	**87.41**
West Flowing Rivers from Tadri to Kanyakumari	**113.53**
Area of Inland drainage in Rajasthan desert	**Negligible**
Minor River Basins Draining into Bangladesh and Myanmar	**31**
Total	**1869.37**

Source of water

a.Surface water Resources

- Lakes
- Ponds
- Streams
- Rivers
- Storage Reservoir

b.Ground water Resources

- Open wells

- Tube wells
- Artisian well
- Springs
- Infiltration

Surface water Resources

- Surface water is any water that collects on the surface of the earth likes oceans,sea,lakes,river or wetlands
- On an average, India receives about 4000 Cubic Kilometers (1 Cubic Km is same as one billion cubic meters, abbreviated as bcm) of precipitation every year. Precipitation means rainfall and snowfall together.
- As explained above, this precipitation is not uniformly distributed over the entire land area and varies from less 100 mm in Rajasthan to more than 2500 in Assam. Of all the rain that falls on the land and mountains and forests, some evaporates back in to the atmosphere, some is percolates in the ground and some is used by the forests.
- The remaining that flows in to the rivers is less than 50% on the total precipitation. The total annual flow in the rivers is estimated as 1869 bcm.

1. Fresh water Lakes: Natural fresh water lakes account for about 0.26% of the freshwater Resources more than 50% of these lakes are found in Canada.

2.Wetlands:A part of freshwater resources is distributed in the globe as wetlands,marshes,lagoons,Swamps,bogs and mires these water bearing bodies play a very important role in maintaining the freshwater ecology as well as in the recharge of ground water.

3. Rivers

- Flowing water in rivers form one of the most important part of freshwater(surface)water resources sustaining human activity and ecology in the world.
- Even though this component forms a tiny fraction (0.006%) of fresh water resource, it form the core of human activity related to natural water use.
- A substantial part of the subject of engineering hydrology deals with river flow.

4. Reservoirs: Reservoirs are artificial lakes created by humans through construction of dams across rivers. Most of the water in these reservoirs estimated to be of the order of 4300 km^3, are used for beneficial purposes such as irrigation, drinking water, hydropower generation and industrial use.

Ground water Resources

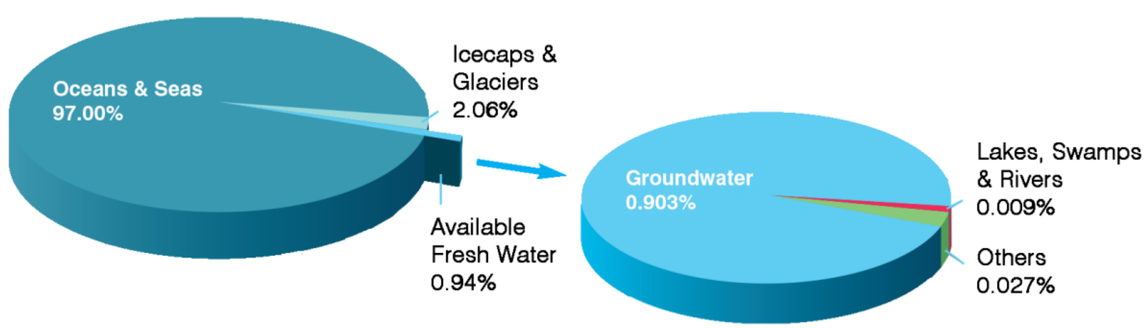
Ground water is the water Present Beneath the earth's Surface in soil pore spaces and in the fractures of rock formations.Ground water is that part of the subsurface water which occurs within the saturated zone of the earth's crust where all pores are filled with water. Ground water has also been referred to as that part of the subsurface water which can be lifted or which flows naturally to the earth's surface.

Groundwater is a very important natural resource and has a significant role in the economy. It is the main source of water for irrigation and the food industry. In general groundwater is a reliable source of water for the agriculture and can be used in a flexible manner: when it's dry and there is larger demand more groundwater can be extracted and when the rain fall meets the necessities, less groundwater will need to be extracted. Globally, irrigation accounts for more than 70% of total water withdraw (both surface and groundwater). Groundwater is estimated to be used for circa 43% of the total irrigation water use.

For the environment groundwater plays a very important role in keeping the water level and flow into rivers, lakes and wetlands. Specially during the drier months when there is little direct recharge from rainfall, it provides the environment with groundwater flow through the bottom of these water bodies and becomes essential for the wild life and plants living in these environment. Groundwater also plays a very relevant role in sustain navigation through inland waters in the drier seasons. By discharging groundwater into the rivers it helps keeping the water levels higher.

Groundwater is found almost everywhere and its quality is usually very good. The fact that groundwater is stored in the layers beneath the surface, and sometime at very high depths, helps protecting it from contamination and preserve its quality. Additionally, groundwater is a natural resource which can often be found close to the final consumers and therefore does not require large investments in terms of infrastructure and treatment, as it often is necessary when harvesting surface water. The most important about using groundwater is to find the right balance between withdrawing and letting the aquifer's level recover to avoid overexploitation and to avoid pollution of this crucial resource.

Groundwater importance water represents about 30% of world's fresh water. From the other 70%, nearly 69% is captured in the ice caps and mountain snow/glaciers and merely 1% is found in river and lakes. Groundwater counts in average for one third of the fresh water consumed by humans, but at some parts of the world, this percentage can reach up to 100%. In the illustration bellow an overview is given of Earth's water distribution.



The selection of ground water as a source of water supply, rather than the surface water sources, has following advantages:

- It is made available within a few hundred meters of the place where it is required for irrigation and where as surface water requires long conveying channel system.
- It is made available for areas where surface water is utilized for other uses.
- Yield from wells generally exhibit less fluctuations than surface stream flow in alternating wet and dry periods.
- Compared to surface water, it is relatively free from the effect of surface pollutants because it results from deep percolation of water infiltration in the soil.

Groundwater as a storage medium

Groundwater is a very important water resource for the following reasons:

- it is a reliable resource, especially in climates with a pronounced dry season
- it is a bacteriologically safe resource, provided pollution is controlled
- it is often available in situ (wide-spread occurrence)
- it may supply water at a time that surface water resources are limited

- it is not affected by evaporation loss, if deep enough there is a large storage capacity
- it can be easily managed

Disadvantages:

• It is a strongly limited resource; extractable quantities are often low as compared to surface water resources

• Groundwater recovery is generally expensive as a result of pumping costs

• Groundwater, if phreatic, is very sensitive to pollution

• Groundwater recovery may have serious impact on land subsidence or salinization especially in dry climates the existence of underground storage of water is of extreme importance. The water stored in the subsoil becomes available in two ways. One way is by artificial withdrawal (pumping) the other is by natural seepage to the surface water. The latter is an important link in the hydrological cycle. Whereas in the wet season the runoff is dominated by surface runoff, in the dry season the runoff is almost entirely fed by seepage from groundwater (base flow). Thus the groundwater component acts as a reservoir which retards the runoff from the wet season rainfall and smooths out the shape of the hydrograph.

Forms of subsurface water

1.Saturated zone

2.Aeration zone

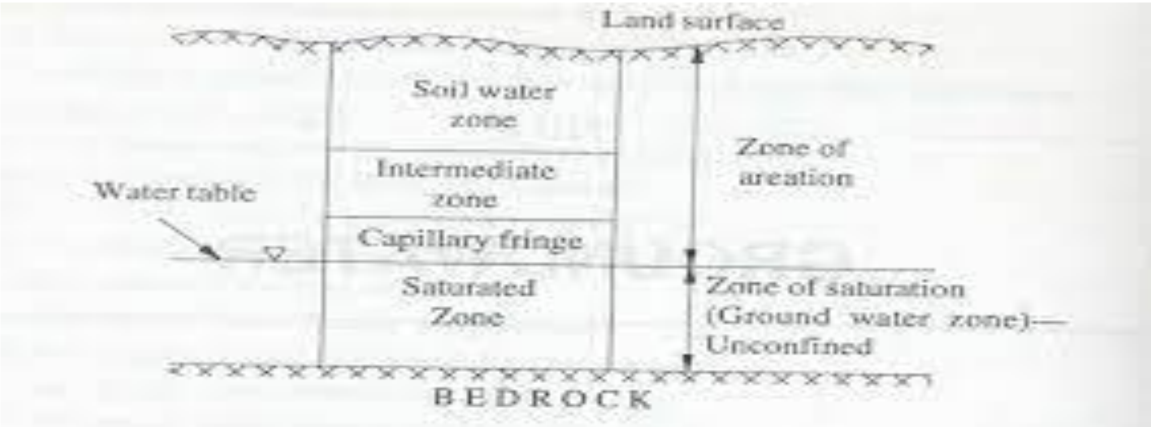


Fig. 9.1 Classification of subsurface water

1. Saturated Zone

- This zone also known as groundwater zone, is the space in which all the pores of the soil are filled with water.
- The water table forms its upper limit and marks a free surface, i.e. surface having atmospheric pressure**.**

2. Aeration zone

- In this zone, the soil pores only partially filled with water.
- The space between the land surface and the water table marks the extent of this zone of aeration has three sub-zones. Soil water Zone, Capillary fringe and intermediate zone

a.Soil water Zone

- This lies close to ground surface in the major root band of the vegetation from which the water is transported to the atmosphere by evapotranspiration.

b.capillary fringe

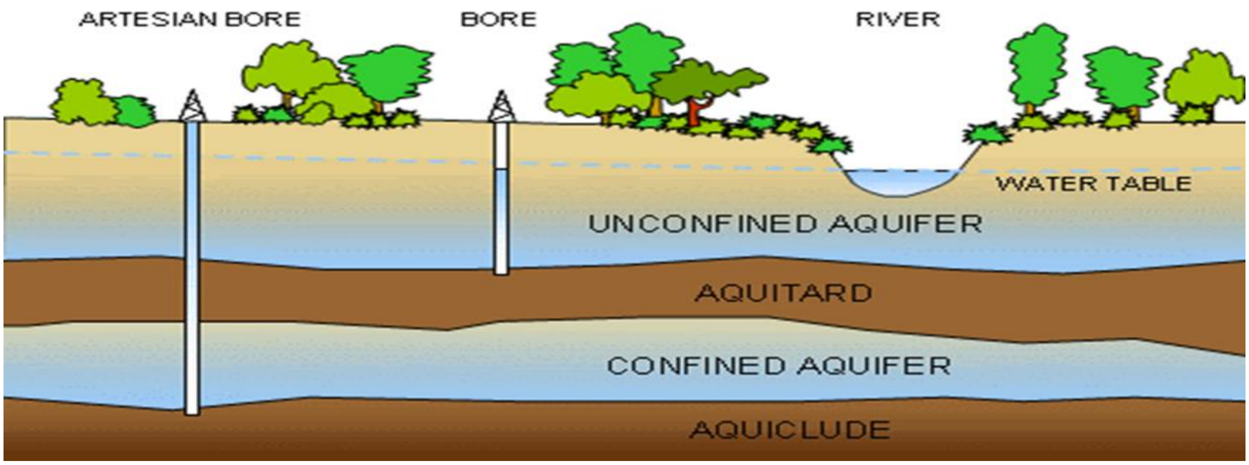
- In this sub zone water is held by capillary action, this subzone extends from the water table upwards to the limit of capillary rise.

c.intermediate zone

- This sub-zone lies between the soil water zone and the capillary fringe the thickness of the zone of aeration and its constituent subzones depend upon the soil moisture in the zone of aeration is of importance in agricultural practice and irrigation engineering.

Classification of saturated zone

- Aquifer
- Aquiclude
- Aquifuge
- Aquitard



1. Aquifer

- A Aquifer is a Saturated formation of Earth material which not only stores water but yields it in sufficient quantity.
- Thus an aquifer transmits water relatively easily due to its high permeability unconsolidated deposits of sand and gravel form good aquifers.

2. Aquitard

- It is a formation through which only seepage is possible and thus the yield is in significant compared to an aquifer.
- It is partly permeable; a sandy clay unit is an example of aquitard appreciable quantities of water may leak to an aquifer below it.

3. Aquiclude

- It is a geological formation which is essentially impermeable to the flow of water it may contain large amounts of water due to its high porosity .clay is an example of an aquiclude.

4. Aquifuge

- It is a geological formation which is neither porous nor permeable.

- There are no interconnected openings and hence it cannot transmit water massive compact rock without any fractures is an aquifuge

Types of Aquifer.

- Any geological formation that is water bearing is called as an aquifer.
- Such rocks may readily transmit water to wells and springs.
- Based on the nature and distribution of water bearing zones, Aquifers could be classified in to two types. They are

a.Unconfined

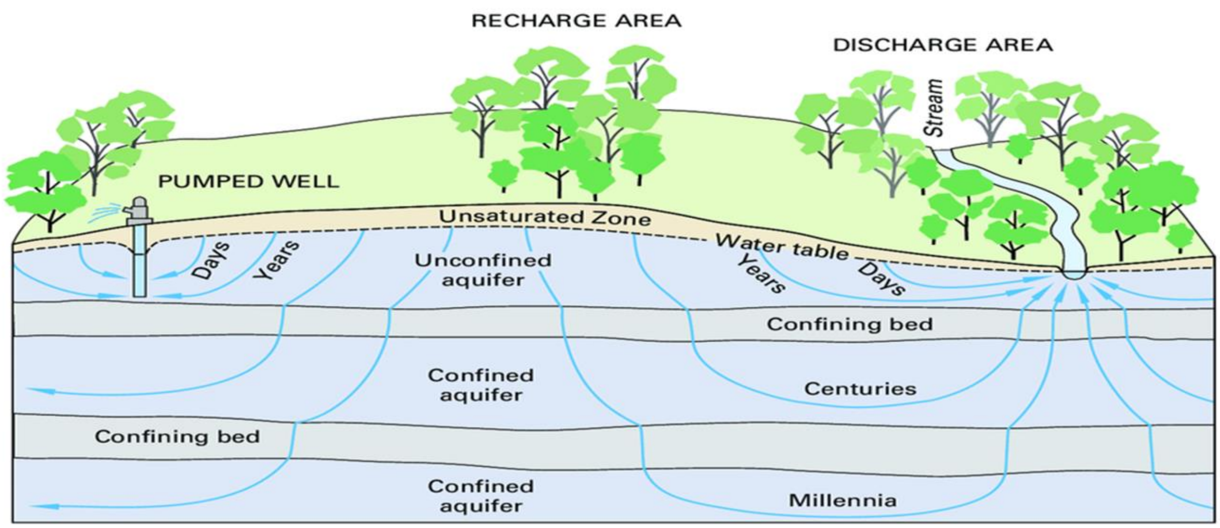
b.confined

1. Un confined aquifer

- It is also known as water table aquifer.is one in which a free water surface exists.
- An unconfined aquifer have water table forms upper surface of the zone of saturation .
- An aquifer where the water table is the upper surface limit and extends below till the impermeable rock strata is called the unconfined aquifer. This aquifer is directly accessible to the atmosphere

2. Confined Aquifer

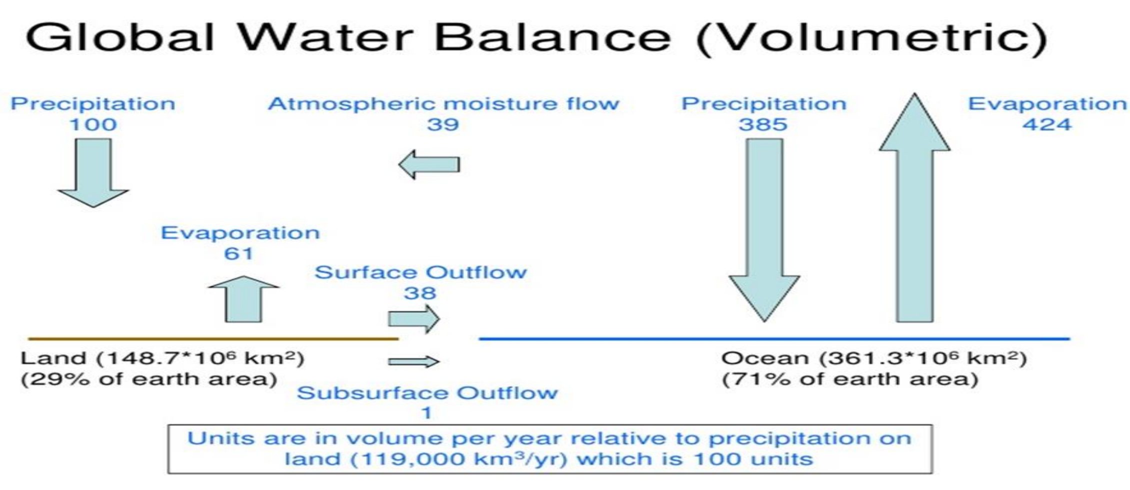
- When an aquifer is sandwiched between two impermeable layers it is known as a confined aquifer.
- It is also known as a pressure aquifer or an artesian aquifer .
- Confined aquifers are completely filled with water and they do not have a free water table and the aquifer will be under pressure.
- Recharge of this aquifer takes place only in the area where it is exposed at the ground surface.
- The imaginary surface to which water rises in walls tapping an artesian aquifer is known as piezometric surface.



Water Balance

The water balance is an accounting of the inputs and outputs of water. The water balance of a place, whether it is an agricultural field, watershed, or continent, can be determined by calculating the input, output, and storage changes of water at the Earth's surface. A water balance diagram will help organization to understand water use and may help you to reduce water costs.

Global water balance, schematic, and not-to-scale. Water stocks are in million km3 and water flows are in million km3 A-1. The key sources for this figure are Berner and Berner (1996), Seiler and Gat (2007), UNEP (2008), and World Business Council for Sustainable Development—WBCSD (2005)



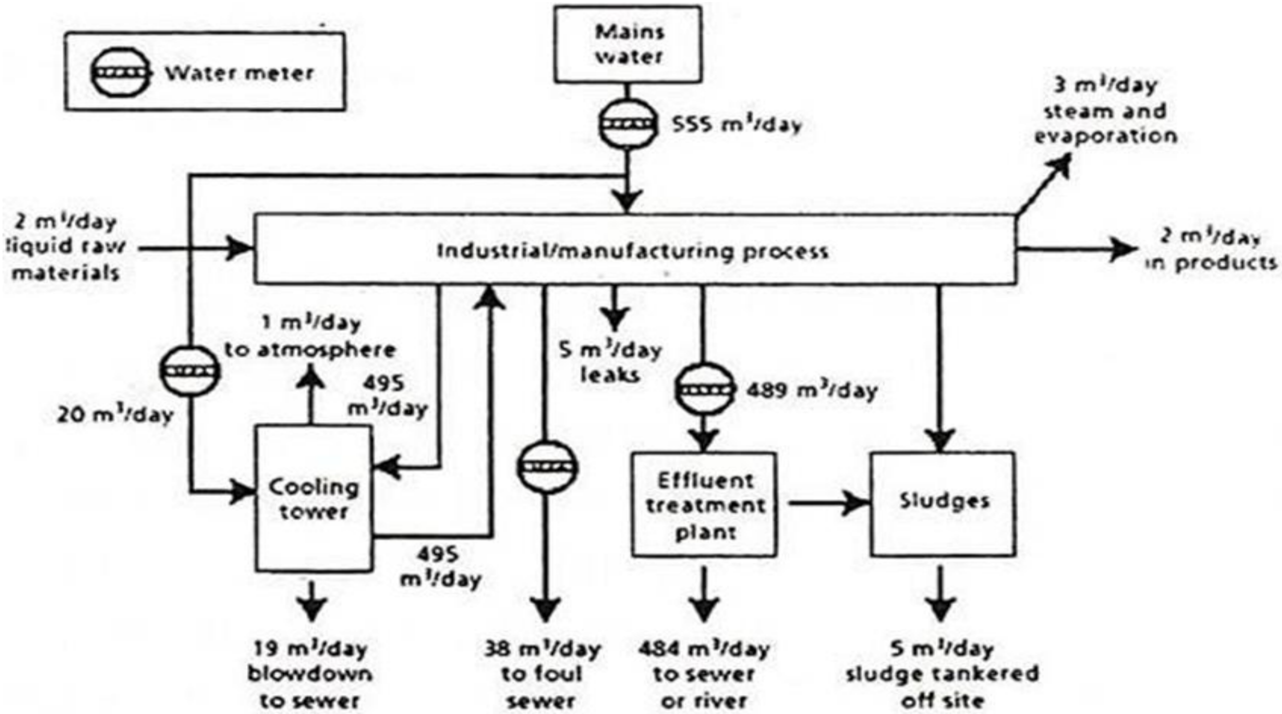


Fig.6.5

Components of Water Balance

i. Precipitation (P):

Precipitation is any product of the condensation of atmospheric water vapour that is pulled down by gravity and deposited on the Earth's surface.

ii. Actual Evapotranspiration (AE):

Evaporation is the phase change from a liquid to a gas releasing water from a wet surface into the air above. Similarly, transpiration is represents a phase change when water is released into the air by plants. Evapotranspiration is the combined transfer of water into the air by evaporation and transpiration. Actual evapotranspiration is the amount of water delivered to the air from these two processes. Actual evapotranspiration is an output of water that is dependent on moisture availability, temperature and humidity.

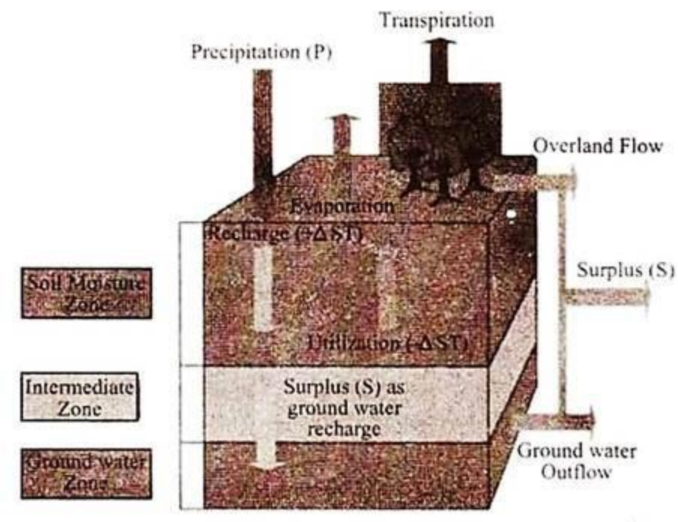


Fig. 6.3: The soil water balance (After Strahler & Strahler, 2006)

iii. Potential Evapotranspiration (PE):

The environmental conditions at a place create a demand for water. Especially in the case for plants, as energy input increases, so does the demand for water to maintain life processes. If this demand is not met, serious consequences can occur. If the demand for water far exceeds that which is actual present, dry soil moisture conditions prevail. Natural ecosystems have adapted to the demands placed on water.

iv. Soil Moisture Storage (ST):

Soil moisture storage refers to the amount of water held in the soil at any particular time. The amount of water in the soil depends on soil properties like soil texture and organic matter content. The maximum amount of water the soil can hold is called the field capacity. Fine grain soils have larger field capacities than coarse grain (sandy) soils. Thus, more water is available for actual evapotranspiration from fine soils than coarse soils. The upper limit of soil moisture storage is the field capacity; the lower limit is 0 when the soil has dried out.

v. Change in Soil Moisture Storage (ÄST):

The change in soil moisture storage is the amount of water that is being added to or removed from what is stored. The change in soil moisture storage falls between 0 and the field capacity.

Heneral water balance equation is

$P=Q+E+\Delta S$,	$P-R-G-E-T=\Delta S$
Where,	where,
P=Precipitation	P=Precipitation
Q=Runoff	R=surface Runoff
E=Evapotranspiration	G=Infiltration
ΔS=Change in storage	E=Evaporation
	T=Transpiration
	ΔS=Change in storage

In its simplest form, this equation reads

Inflow=out flow+change in storage

The water balance method has four characteristic features

1.A water balance can be expressed for any subsystem of the hydrological cycle, for any size of area and for any period of time.

2.A water balance can serve to check whether all flow and storage components involved have been considered quantitatively.

3.A water balance can serve to calculate one unknown of the balance equation, provided that the other components are known with sufficient accuracy.

4. A water balance can be regarded as a model of the complete hydrologic process under study, which means it can be used to predict what effect the changes imposed on certain components will have on the other components of the system or subsystem.

Human Influence on the Water Balance

Human activity has the potential to indirectly and directly affect water quantity and the natural flow regime of a river system. Indirect impacts to the hydrologic cycle can result from land-use changes. Direct impacts can result from water diversions, withdrawals and discharges, and from dams (flow regulation and water storage).

Human interferences in the water resource system

Man's attitude towards nature and development

Human action has influenced to a very large extent the present state of the environment.
The driving force which led to these actions is simply that humans needed to survive and feed, clothe and house themselves. About the way in which they interfered in their environment, however, it is important to realize what their attitude towards the environment was. Did they look upon the environment as something separate from them or did they consider themselves as being an integral part of the environment? This attitude very much depends on culture and religion.

Human interferences

Man influences the hydrological cycle in several ways, either to protect himself against the Water, or to try to make use of the water. The next main activities can be distinguished:

- Flood protection,
- Irrigation,
- Drainage,
- Groundwater withdrawal,
- Water supply,
- Sanitation,
- Flow regulation,
- Power generation,
- Navigation.

Unfortunately there are also a number of unproductive interferences of man, such as:

• Discharge of wastes,

• Discharge of polluted water,

• Pollution of aquifers,

• Discharge of cooling water from industrial and thermal plants.

Man tries to control the water resource system through hydraulic structures. These structures are designed taking into consideration the risk of failure acceptable for the Specific case.

The renewable water resources.

These are defined as the average manual flow of rivers and recharge of aquifers generated from precipitation. It distinguishes between the natural situation (natural renewable resources), which corresponds to a situation without human influence, Natural renewable water resources are the total amount of a country's water resources (internal and external resources), both surface water and groundwater, which is generated through the hydrological cycle. The amount is computed on a yearly basis. Renewable water resources are computed on the basis of the water cycle. They represent the long-term average annual flow of rivers (surface water) and groundwater

Non- on the human time-scale and thus can be considered non-renewable. The computation of the actual renewable water resources of a renewable water resources are groundwater bodies (deep aquifers) that have a negligible rate of recharge country takes account of possible reductions in flow resulting from the abstraction of water in upstream countries

Actual renewable water resources. These are defined as the sum of internal renewable resources (IRWR) and external renewable resources (ERWR), taking into consideration the quantity of flow reserved to upstream and downstream countries through formal or informal agreements or treaties and possible reduction of external flow due to upstream water abstraction. Unlike natural renewable water resources, actual renewable water resources vary with time and consumption patterns and, therefore, must be associated to a specific year.

Exploitable water resources

Not all natural freshwater, surface water or groundwater is accessible for use. exploitable water resources (manageable water resources or water development potential) considers factors such as: the economic and environmental feasibility of storing floodwater behind dams or extracting groundwater; the physical possibility of catching water which naturally flows out to the sea; and the minimum flow requirements for navigation, environmental services, aquatic life.

Water scarcity

- Water scarcity is the lack of sufficient available water resources to meet the demands of water usage within a region. It already affects every continent and around 2.8 billion people around the world at least one month out of every year.
- More than 1.2 billion people lack access to clean drinking water.
- Water scarcity involves water stress, water shortage or deficits, and water crisis.
- While the concept of water stress is relatively new, it is the difficulty of obtaining sources of fresh water for use during a period of time and may result in further depletion and deterioration of available water resources. Water shortages may be caused by climate change, such as altered weather patterns including droughts or floods, increased pollution, and increased human demand and overuse of water.
- A water crisis is a situation where the available potable, unpolluted water within a region is less than that region's demand.
- Water scarcity is being driven by two converging phenomena: growing freshwater use and depletion of usable freshwater resources.
- Water scarcity can be a result of two mechanisms: physical (absolute) water scarcity and economic water scarcity, where physical water scarcity is a result of inadequate natural water resources to supply a region's demand, and economic water scarcity is a result of poor management of the sufficient available water resources.
- According to the United Nations Development Programme, the latter is found more often to be the cause of countries or regions experiencing water scarcity, as most countries or regions have enough water to meet household, industrial, agricultural, and environmental needs, but lack the means to provide it in an accessible manner.

- Despite water being an existential need for humans, it’s also one of the most under prioritized but over abused commodity. Water is central to our lives but has not been the central point of focus in our planning while we rapidly evolve into an urban society.

Water scarcity in India.

The world’s oldest civilization grew around the Indus and the Ganges and is still thriving. But not for long. Post-independence, due importance was given to harnessing the power of water by way of controlling and storing of water through large Dams. That was the need of the hour. However, our cities and towns have subsequently grown without planning for water need vs water availability. In 1951, the per capita water availability was about 5177 m3. This has now reduced to about 1545 m3 in 2011

Reasons behind water scarcity in India

- The water scarcity is mostly man made due to excess population growth and mismanagement of water resources. Some of the major reasons for water scarcity are:
- Inefficient use of water for agriculture. India is among the top growers of agricultural produce in the world and therefore the consumption of water for irrigation is amongst the highest. Traditional techniques of irrigation causes maximum water loss due to evaporation, drainage, percolation, water conveyance, and excess use of groundwater. As more areas come under traditional irrigation techniques, the stress for water available for other purposes will continue. The solution lies in extensive use of micro-irrigation techniques such as drip and sprinkler irrigation.
- Reduction in traditional water recharging areas. Rapid construction is ignoring traditional water bodies that have also acted as ground water recharging mechanism. We need to urgently revive traditional aquifers while implementing new ones.
- Sewage and wastewater drainage into traditional water bodies. Government intervention at the source is urgently required if this problem is to be tackled.
- Release of chemicals and effluents into rivers, streams and ponds. Strict monitoring and implementation of laws by the government, NGOs and social activists is required.

- Lack of on-time de-silting operations in large water bodies that can enhance water storage capacity during monsoon. It is surprising that the governments at state levels has not taken this up on priority as an annual practice. This act alone can significantly add to the water storage levels.
- Lack of efficient water management and distribution of water between urban consumers, the agriculture sector and industry. The government needs to enhance its investment in technology and include all stakeholders at the planning level to ensure optimization of existing resources.

Urban nightmare

- The problem has been compounded with increased concretization due to urban development that has choked ground water resources. Water is neither being recharged nor stored in ways that optimizes its use while retaining the natural ingredients of water. In addition, the entry of sewage and industrial waste into water bodies is severely shrinking the availability of potable water. Marine life is mostly lost in these areas already. This is the genesis of a very serious emerging crisis. If we do not understand the source of the problem we will never be able to find sustainable solutions.
- The demand for water continues to grow while the collection, storage, regeneration and distribution has become over stressed. The story repeats itself across urban centers in India.

Solutions to overcome water scarcity problems

- A simple addition of a ‘water free’ male urinal in our homes can save well over 25,000 liters of water, per home per year. The traditional flush dispenses around six liters of water per flush. If all male members including boys of the house use the ‘water free urinal’ instead of pulling the traditional flush, the collective impact on the demand for water will reduce significantly. This must be made mandatory by law and followed up by education and awareness both at home and school.

- The amount of water that is wasted during dish washing at home is significant. We need to change our dish washing methods and minimize the habit of keeping the water running. A small step here can make a significant saving in water consumption.
- Every independent home/flat and group housing colony must have rain water harvesting facility. If efficiently designed and properly managed, this alone can reduce the water demand significantly.
- Waste water treatment and recycling for non-drinking purposes. Several low cost technologies are available that can be implemented in group housing areas.
- Very often, we see water leaking in our homes, in public areas and colonies. A small steady water leak can cause a loss of 226,800 liters of water per year! Unless we are aware and conscious of water wastage we will not be able to avail the basic quantity of water that we need to carry on with our normal lives.

MODULE-2

Water Resources Planning and Management

INTRODUCTION

The main sources of water supply are surface and ground water which have been used for a variety of purposes such as drinking, irrigation, hydroelectric energy, transport, recreation etc. Often, human activities are based on the "usual or normal" range of river flow conditions. However, flows and storage vary spatially and temporally; and also they are finite (limited) in nature i.e., there is a limit to the services that can be expected from these resources. Rare or "extreme" flows or water quality conditions outside the normal ranges will result in losses to river-dependent, human activities. Therefore, planning is needed to increase the benefits from the available water sources. The purpose of water resources planning and management activities is to determine

(i) How can the renewable yet finite resources best be managed and used?

(ii) How can this be accomplished in an environment of uncertain supplies and uncertain and increasing demands, and consequently of increasing conflicts among individuals having different interests in the management of a river and its basin?

NEED FOR PLANNING AND MANAGEMENT

Planning and management of water resources systems are essential due to following factors:

(1) Severity of the adverse consequences of droughts, floods and excessive pollution. These can lead to

a. Too little water due to growing urbanization, additional water requirements, in stream flow requirements etc. Measures should be taken to reduce the demand during scarcity times

b. Too much water due to increased flood frequencies and also increase in water requirements due to increased economic development on river floodplains

c. Polluted water due to both industrial and household discharges

(2) Degradation of aquatic and riparian systems due to river training and reclamation of floodplains for urban and industrial development, poor water quality due to discharges of pesticides, fertilizers and wastewater effluents etc.

(3) While port development requires deeper rivers, narrowing the river for shipping purposes will increase the flood level

(4) River bank erosion and degradation of river bed upstream of the reservoirs may increase the flooding risks

(5) Sediment accumulation in the reservoir due to poor water quality

Considering all these factors, the identification and evaluation of alternative measures that may increase the quantitative and qualitative system performance is the primary goal of planning and management policies.

SYSTEM COMPONENTS

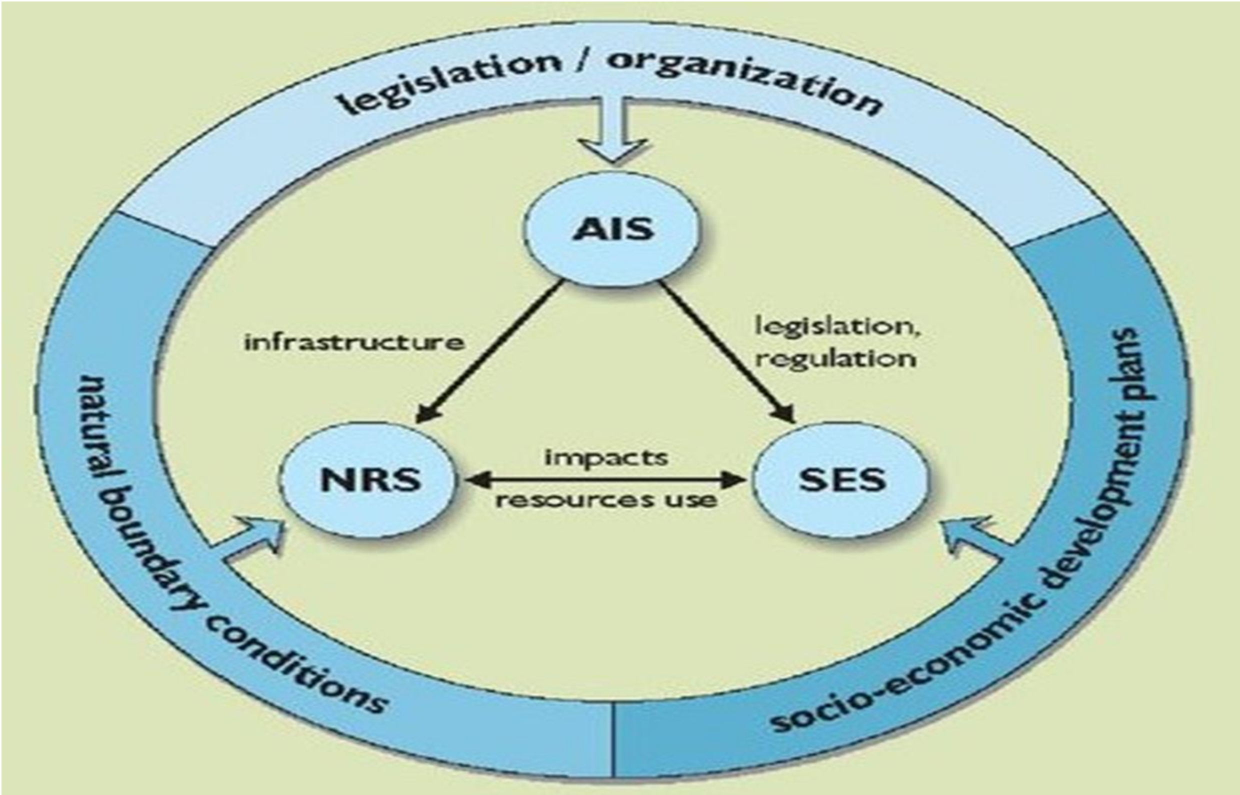
Water resources management involves the interaction of three interdependent subsystems:

1. Natural river subsystem in which the physical, chemical and biological processes takes place

2. Socio-economic subsystem, which includes the human activities related to the use of the natural river system

3. Administrative and institutional subsystem of administration, legislation and regulation, where the decision, planning and management processes take place

Inadequate attention to one subsystem can reduce the effect of any work done to improve the performance of the others.



System planning Scales

Spatial Scales for planning and management

- Watersheds or river basins are usually considered logical regions for water resources planning and arrangement. If the impacts of decisions regarding water resources management are contained within the watershed or basin.
- How land and water are managed in one part of a river basin can affect the land and water in other parts of the basin. For example, the discharge of pollutants or the clearing of forests in the upstream portion of the basin may degrade the quality and increase the variability of the flows and sedimentation downstream.
- The construction of a dam or weir in the downstream part of a river may prevent vessels and fish from travelling upstream.
- To maximize the economic and social benefits obtained from the entire basin, and to ensure that these benefits and accompanying costs are equitably distributed, planning and management is often undertaken on a basin scale.

- While basin boundaries make sense from a hydrological point of view, they may be inadequate for addressing particular water resources problems that are caused by events taking place outside the basin. What is desired is the highest level of performance, however defined, of the entire physical, socio-economic and administrative water resource system.
- To the extent that the applicable problems, stakeholders and administrative boundaries extend outside the river basin, the physically based ‘river basin’ focus of planning and management should be expanded to include the entire applicable ‘problem-shed’.

Temporal Scales for Planning and Management

- Water resources planning requires looking into the future. Decisions recommended for the immediate future should take account of their long-term future impacts.
- These impacts may also depend on economic, demographic and physical conditions now and on into some distant future. The question of just how far into the future one need look, and try to forecast, is directly dependent on the influence that future forecast has on the present decisions. What is most important now is what decision to make now.
- Decisions that are to be made later can be based on updated forecasts, then-current information and planning and management objectives. Planning is a continuing sequential process.
- Water resources plans need to be periodically updated and adapted to new information, new objectives, and updated forecasts of future supplies, demands, costs and benefits .
- The number and duration of within-year time periods explicitly considered in the planning process will be dependent in part on the need to consider the variability of the supplies and demands for water resources and on the purposes to be served by the water resources within the basin.
- Irrigation planning and summer season water recreation planning may require a greater number of within-year periods during the summer growing and recreation season than might be the case if one were considering only municipal water supply planning ,for example.
- Assessing the impacts of alternatives for conjunctive surface and groundwater management or for water quantity and quality management, require attention to processes that take place on different spatial and temporal scales.

Planning and Management Approaches

Two approaches which lead to an integrated plan and management policy are

- From the top down or the command and control approach
- From the bottom up or the grass-roots approach

Top down approach

- Water resources professionals prepare integrated, multipurpose “master”development plans with alternative structural and non-structural management options.
- There is dominance of professionals and little participation of stakeholders. In this approach, one or more institutions have the ability and authority to develop and implement the plan.
- However, nowadays, since public have active participation in planning and management activities, top-down approaches are becoming less desirable or acceptable.

Bottom up approach

- In this approach there is active participation of interested stakeholders – those affected by the management of the water and land resources. Plans are being created from the bottom up rather than top down.
- Top down approach plans do not take into consideration the concerns of affected local stakeholders. Bottom up approach ensures cooperation and commitment from stakeholders.
- The goals and priorities will be common among all stakeholders by taking care of laws and regulations and by identifying multiple alternatives and performance criteria.
- Trade-offs is made between conflicting goals or measures of performance.

Planning and management Aspects

1. Technical aspects

It is first necessary to identify the characteristics of resources in the basin, including the land, the rainfall, the runoff, the stream and river flows and the groundwater Technical aspects of planning involves

- Predicting changes in land use/covers and economic activities at watershed and river basin levels

- Estimation of the costs and benefits of any measures being and to be taken to manage the basin's water resource including engineering structures, canals, diversion structures etc.
- Identification and evaluation of alternative management strategies and also alternative time schedules for implementing those measures.

2. Economic and Financial aspects

- Water should be treated as an economic commodity to extract the maximum benefits as well as to generate funds to recover the costs of the investments and of the operation and maintenance of the system.
- Water had been treated for long as a free commodity. Revenues recovered are far below the capital cost incurred.
- Financial component of any planning process is needed to recover construction costs, maintenance, and repair and operation costs.
- In management policies, financial viability is viewed as a constraint that must be satisfied; not as an objective whose maximization could result in a reduction in economic efficiency, equity or other non-monetary objectives

3. Institutional aspects

- Successful project implementation needs an enabling environment. National, provincial and local policies, legislation and institutions are crucial for implementation of the decisions.
- The role of the government is crucial since water is (i) not a property right (ii) a resource that often requires large investment to develop and (iii) a medium that can impulse external effects.
- The main causes of failure of water resources development project are insufficient institutional setting and lack of a sound economic evaluation and implementation.

Analysis for Planning and Management

Analyses for water resources planning and management generally comprise several stages. The explicit description of these stages is referred to as the analytical (or conceptual) framework. Within this framework, a set of coherent models for the quantitative analysis of measures and strategies is used. This set of models and related databases will be referred to as the computational framework.

The purpose of the analyses is to prepare and support planning and management decisions. The main phases of the analytical framework therefore correspond to the phases of the decision process. Such a decision process is not a simple, one-line sequence of steps. Inherent in a decision-making process are factors causing the decision makers to return to earlier steps of the process. Part of the process is thus cyclic.

Two types of cycling Steps

- Comprehension cycles and
- Feedback cycles.

A comprehension cycle improves the decision-makers' understanding of a complex problem by cycling within or between steps.

Feedback cycles imply returning to earlier phases of the process.

They are needed when:

• Solutions fail to meet criteria.

• New insights change the perception of the problem and its solutions (e.g., due to more/better information).

• Essential system links have been overlooked.

• Situations change (political, international, societal developments).

The three elementary phases of that framework are:

• Inception

• Development

• Selection.

During each phase the processes have a cyclic component (comprehensive cycle). Interaction with the decision makers, or their representatives, is essential throughout the process. Regular reporting through inception and interim reports will improve the effectiveness of the communication. The first phase of the process is the

1. Inception phase

- Here the subject of the analysis (what is analysed under what conditions) and its object (the desired results of the analysis) are specified.
- Based on this initial analysis, during which intensive communication with (representatives of the) decision-makers is essential, the approach for the policy analysis is specified.
- The results of the inception phase are presented in the inception report, which includes the work plan for the other phases of the analysis process (project).

2. Development phase

- In the development phase tools are developed for analysing and identifying possible solutions to the WRM problems.
- The main block of activities is usually related to data collection and modelling.
- Various preliminary analyses will be made to ensure that the tools developed for the purpose are appropriate for solving the WRM problems.
- Individual measures will be developed and screened in this phase, and preliminary attempts will be made to combine promising measures into management strategies.
- The development phase is characterized by an increased understanding of the functioning of the water resources system, starting with limited data sets and simplified tools and ending at the levels of detail deemed necessary in the inception phase.
- Scanning of possible measures should also start as soon as possible during this phase. The desired level of detail in the data collection and modelling strongly depends on what is required to distinguish among the various measures being considered.
- Interactions with decision makers are facilitated through the presentation of interim results in interim reports.

3. Selection Phase

- The purpose of the selection phase is to prepare a limited number of promising strategies based on a detailed analysis of their effects on the evaluation criteria, and to present them to the decision-makers, who will make the final selection.
- Important activities in this phase are strategy design, evaluation of strategies and presentation.
- The results of this phase are included in the final report.
- Although it is clear that analyses are made to support the decision-making process, it is not always clear who will make the final decision, or who is the decision maker.
- If analyses are contracted to a consultant, careful selection of the appropriate coordinating agency is instrumental to the successful implementation of the project.
- It is always advantageous to use existing line agencies as much as possible. Interactions with the decision-makers usually take place through steering commissions (with an interdepartmental forum) and technical advisory Post-Planning and Management Issues Once a plan or strategy is produced, common implementation issues include seeing that the Plan is followed, Modified,As appropriate, over time.

What incentives need to be created to ensure compliance?

How are the impacts resulting from the implementation of any decision going to be monitored, assessed and modified as required and desired?

Who is going to be responsible?

Who is going to pay, and how much?

Who will keep the stakeholders informed?

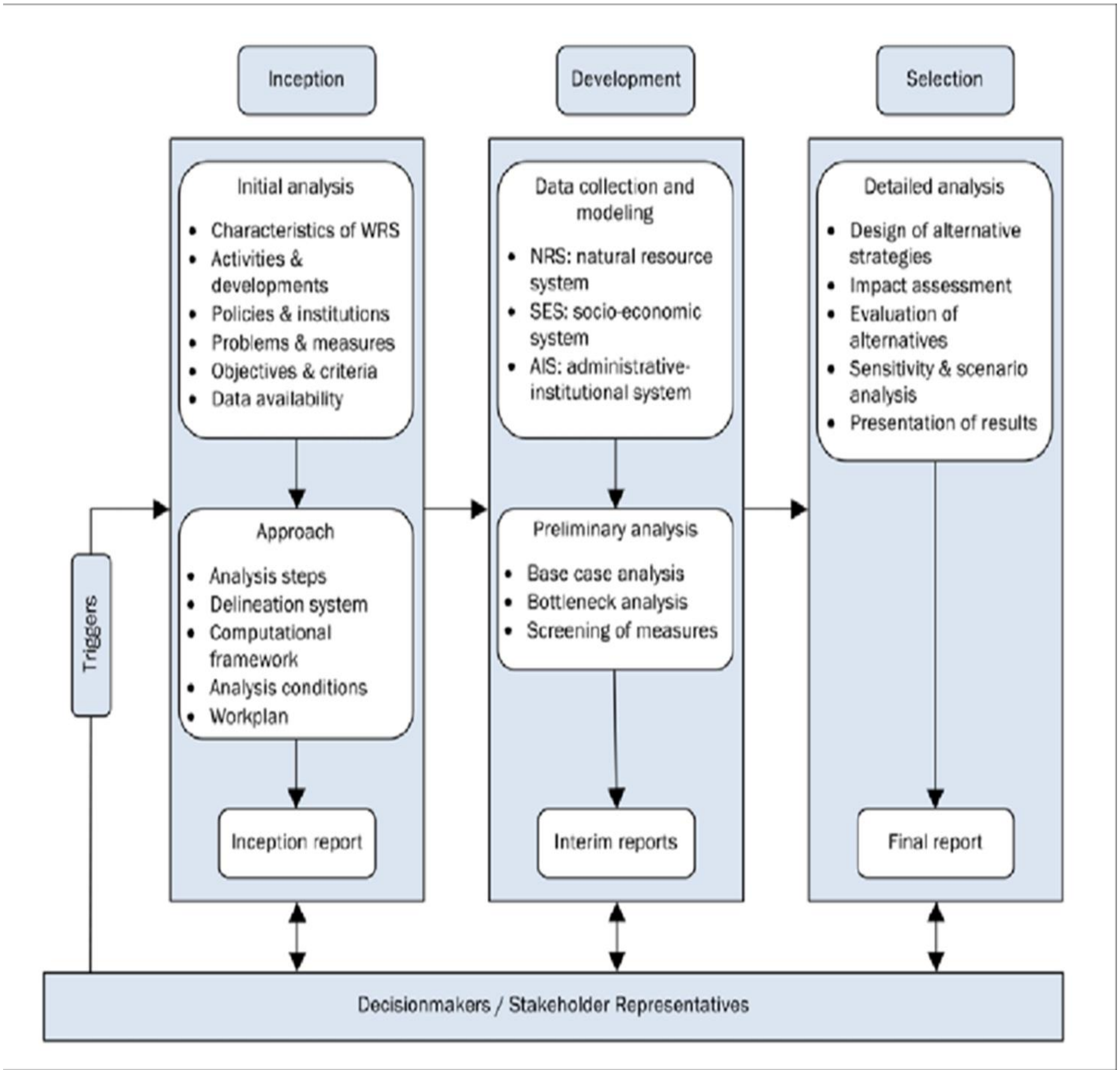
Who will keep the plan current?

How often should plans and their databases be updated?

How can new projects be operated in ways that increase the efficiencies and effectiveness of joint operation of multiple projects in watersheds or river basins – rather than each project being operated independently of the others?

These questions should be asked and answered, at least in general terms, before the water resources planning and management process begins. The questions should be revisited as decisions are made and when answers to them can be much more specific.

Typical analytical frame work water resources studies



Models for Impact Prediction and Evaluation

- The process of planning has undergone a significant transformation over the past several decades, mainly due to the continuing development of improved computational technology, and various water resource simulation and optimization models together with their associated databases and user-friendly interactive interfaces.
- Planning today is heavily dependent on the use of computer-based impact prediction models. Such models are used to assist in the identification and evaluation of alternative ways of meeting various planning and management objectives.
- They provide an efficient way of analysing spatial and temporal data in an effort to predict the interaction and impacts, over space and time, of various river basin components under alternative designs and operating policies.

Models can assist planning and management at different levels of detail.

- Some are used for preliminary screening of alternative plans and policies, and as such do not require major data collection efforts.
- Screening models can also be used to estimate how significant certain data and assumptions are for the decisions being considered, and hence can help guide additional data collection activities.
- At the other end of the planning and management spectrum, much more detailed models can be used for engineering design. These more complex models are more data demanding, and typically require higher levels of expertise for their proper use.
- The integration of modelling technology into the social and political components of the planning and management processes in a way that enhances those processes continues to be the main challenge of those who develop planning and management models.

Adaptive Integrated policies

- First issue is to address the product desired.
- Report should contain a discussion of the water resources management issues and options.
- List of strategies for addressing existing problems
- Desire to keep more options open for future generations

- Desire to be adaptive to new information and to respond to surprises.

Models developed for predicting the economic as well as ecologic interactions and impacts due to changes in land and water management and use could be used to address questions such as:

- What are the hydrological, ecological and economic consequences of clustering or dispersing human land uses such as urban and commercial developments and large residential areas?
- Should large intensive developments be best located in upland or valley areas?
- To what extent can riparian conservation and enhancement mitigate upland human land use effects? How do the costs of upland controls compare with the costs of riparian mitigation measures?
- What are the economic and environment quality tradeoffs associated with different areas of various classes of land use such as commercial/urban, residential, agriculture and forest?
- Can adverse effect on hydrology, aquatic ecology and water quality of urban areas be better mitigated through upstream or downstream management approaches?
- Is there a threshold size for residential/commercial areas that yield marked ecological effect?
- Mitigating flood risk by minimizing floodplain developments coincides with conservation of aquatic life in streams. What are the economic costs of this type of risk avoidance?
- What are the economic limitations and ecological benefits of having light residential zones between waterways and commercial, urban or agricultural lands?
- What are the economic development decisions that are irreversible on the landscape?

Post planning and management Issues

Once a plan or strategy is produced, a common implementation issues include:

- How are the impacts resulting from the implementation of any decision going to be monitored, assessed and modified as required and desired?
- Who will keep the stakeholders informed?

- Who will keep the plan current?
- How often plans and their data bases should be updated?
- How can new projects be operated in ways that increase the efficiencies and effectiveness of joint operation of multiple projects in watersheds or river basins rather than each project being operated independently of the others?

These questions should be asked and answered, at least in general terms, before the water resources planning and management process begins. The questions should be revisited as decisions are made and when answers to them can be much more specific.

MODULE-3

Integrated water resources management

Introduction

International conference or ministerial meeting involved with sustainable development will result in recommendations for more and better “Integrated water resources management” (IWRM). Governments are repeatedly urged to introduce or extend IWRM, as a vital component of their sustainable development agenda.

Integrated water resources management is a logical and intuitively appealing concept. Its basis is that the many different uses of water resources are interdependent. High irrigation demands and polluted drainage flows from agriculture mean less freshwater for drinking or industrial use; contaminated municipal and industrial wastewater pollutes rivers and threatens ecosystems; if water has to be left in a river to protect fisheries and ecosystems, less can be diverted to grow crops. Unregulated use of scarce water resources is wasteful and inherently unsustainable.

Integrated management means that all the different uses of water resources are considered together. Water allocations and management decisions consider the effects of each use on the others. They are able to take account of overall social and economic goals, including the achievement of sustainable development.

Management emphasizes that we must not only focus on development of water resources but that we must consciously manage water development in a way that ensures long term sustainable use for future generations.

Integrated water resources management is therefore a systematic process for the sustainable development, allocation and monitoring of water resource use in the context of social, economic and environmental objectives. It contrasts with the sectoral approach that applies in many countries. When responsibility for drinking water rests with one agency, for irrigation water with another and for the environment with yet another, lack of cross-sectoral linkages leads to uncoordinated water resource development and management, resulting in conflict, Waste and unsustainable systems.

Definition of IWRM

IWRM is defined by the Global Water Partnership (GWP-2000) as ‘A process which promotes the coordinated development and the management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems’.

Introduction to Integrated Approach

Issues

- Resources under pressure
- Population under water pressure
- Impact of pollution
- Water governance crisis

Challenges

- Securing water for people
- Securing water for food production
- Protecting vital ecosystems
- Managing Risks
- Developing other Job Creating activities
- Creating popular awareness and understanding
- Ensuring collaboration across sectors and boundaries

Development

The development of IWRM was particularly recommended in the final statement of the ministers at the international conference on water and environment in 1992 (so called the Dublin principles)

- This concept aims to promote changes in practices which are considered fundamental to improved water resource management.

The IWRM rests upon three principles that together act as the overall framework

Integrating the three E's

1. **Social Equity:** Ensuring Equal access for all users,means all people must have access to water of adequate quantity and quality participation in water management by all stakeholders best way to ensure equity.
2. **Economic Efficiency:** Efficiency in water use is core principles of IWRM; water must be used with maximum possible efficiency by bringing the greatest benefit to the greatest numbers of users possible with available financial and water resources.
3. **Ecological sustainability:** to achieve ecological sustainability, current water use should be managed in such a way that it does not affect future generations.
   Note: Sustainability Meaning: Ability to maintain

Principles

WRM is based on four principles –the Dublin principles

1. Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.

- Water sustains life in all its forms and is required for many different purposes, functions and services. Therefore holistic management has to involve for the demands placed on the resources and the threats to it.
- Creating water sensitive political economy requires co-ordinated policy making at all levels from national ministries to local government or community.
- There is also a need for mechanics which ensure that economic sector decision makers take water costs and sustainability into account when making production and consumption choices.

2. Water development and management should be based on a participatory approach, involving users, planners and policymakers at all levels.

- Water is a subject in which everyone is a stakeholder. Real participation only takes place when stakeholders are part of the decision-making process.

- Participation also occurs if democratically elected or otherwise accountable agencies or spokespersons can represent stakeholder groups.

3. Women play a central part in the provision, management and safeguarding of water.

- Women play a key role in the collection and safeguarding of water for domestic and –in many cases – agricultural use, but that they have a much less influential role than men in management, problem analysis and in the decision-making process related to water resources.
- In developing the full and effective participation of women at all levels of decision-making, consideration has to be given to the way different societies assign particular Social, economic and cultural roles to men and women. There is a need to ensure that the water sector as a whole is gender aware, a process which should begin by the implementation of training programmes for water professionals and community or grass root mobilizers.
- The women's views, interests and needs shapes the development agenda as much as men's and that development agenda support progress towards more equal relations between women and men.

4. Water has an economic value in all its competing uses and should be recognized as an economic good.

- Within in this principle it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price.
- Managing water as an economic good is an important way of achieving efficient and equitable use and of encouraging conservation and protection of water resources.

Implementation of integrated water resource management

An IWRM Implementation is focused on three basics and aims at avoiding a fragmented approach of water resources management by considering the following aspects.

1. **Enabling Environment:** A proper Enabling environment is essential to both ensure the rights and assets of all stakeholders (Individuals as well as public and private sector organizations and companies) and also protects public assets such as an intrinsic environmental values.

2. **Role of Institutions:** Institutional development is critical to the formation and implementation of IWRM policies and programmes.Failure to match responsibilities authority and capacities for action are all major sources of difficulty with implementing IWRM.
3. **Management instruments:** the management instruments for IWRM are the tools and methods that enable and help decision-makers to make rational and informed choices between alternative actions.

Some of the cross-cutting conditions that are also important to consider when implementing IWRM are:

- Political will and commitment
- Capacity development
- Adequate investment, financial stability and sustainable cost recovery
- Monitoring and Evaluation

IWRM should be viewed as a process rather than a one shot approach.

- There is no correct administrative model
- The art of IWRM lies in selecting, adjusting and applying the right mix of these tools for a given situation
- IWRM has no fixed beginnings or endings.

Development Objectives

Elements of an integrated water legislation frame work

- National Provincial and local water and policies determine stakeholders play their respective roles in the development and management of water resources.
- Basin organizations put up by law have a strong mandate.
- Laws and water policies spell out rules responsibility and accountability of public and private sectors.
- Water management framework should be a part of an existing national administration system.
- Basin and national water policy management plans should be harmonized.

Assessment of the institutional/organizational frame work

Process and tools:

Assessment of the institutional framework requires a process to come from an identified present water resources management situation to a desired integrated water resources management situation.

The steps in this process are

- Identification of the present situation
- Formulation of a desired IWRM situation
- Formulation of interventions to arrive at the desired IWRM situation and establishment of a monitoring system to see whether the interventions are being carried out properly and whether they really contribute to the achievement of the IWRM goals.

Step-1

- The present situation on water resources use and management should be well known before any intervention directing to IWRM can be made.
- Understanding the water situation is a prerequisite for assessment and analysis of the institutional frame work and the water use conflicts between stakeholders.
- It is essential to have a basic document on the present water management to start the institutional assessment process; such a document will represent an expert's opinion and will not necessarily be complete.
- Accurate and representing the opinions, desires and aspirations of all stakeholders.

Important aspects to be dealt with are

- Water availability and water use
- Stake holders
- Physical conditions

- Socio Economic conditions
- Legal framework
- Institutional framework
- Policies and the trends and financial situation

This report serves as a general background document for the following steps and has to be disseminated accordingly.

Physical conditions

The assessment of the physical conditions concentrates and use of the water (quantitative, and qualitative)it Requires information the

a.Climate and meteorology

b.hydrology and hydrogeology

c.Aquatic Ecosystems

d.availability and capacity of storage facilities.

Stakeholders and interest Groups

Stake holders are people or groups of people with interest the stakeholders are considered as private body.

Assessment of institutional framework in IWRM the stakeholders can be classified as follows

- Water users –consumptive and non-consumptive uses
- Water polluters agriculture,industry, domestic etc.
- Water managers organizational and operational level
- Water policy and low makers constitutional level
- Society general interests represented by government
- Specific interests represented by NGOS.

Inventory of water problems

The water use flow diagram can be most useful to put the registered problems in this stage the inventory of water problems limits itself to those generally known and the registered water problems by the main stakeholders.

Step-2: Stakeholder selection

Stake holders inventory will be made in step one

- These stake holders will be the obvious operations of water services,co-ordination bodies and policy and law makers

For further process a selection of stakeholders has to be made to avoid duplication.

An independent team id formed to identify and select relevant stakeholders from the categories.

- Water policy makers
- Water mangers
- Water service providers
- Water using agencies
- Water using groups
- Water users and other potential interests holders at constitutional, organizational and operation levels.

These stakeholders will be approached for the department interviews.

Step-3: Stakeholder interviews

Experts carry out an elaborate procedure of interviewing the selected stakeholders applying the guidelines for interviews. These guidelines are in the format of a questionnaire, which contain questions relating to the stakeholders interviewed and their perception of the existing situation and what they consider to be the desired IWRM situation during this interview.

- Previously overlooked stakeholders can be identification through the identification of parties that negatively influence the implementation of the stakeholder's duties.

A different set of questions under the issues in the matrix is used for all three functional levels. They are organized under the headings

- Stakeholders
- Awareness
- Policy
- Legal framework
- Institutional framework
- Financial arrangements
- Human resource development
- Management information systems and decision support systems

Second part of the interview aim to

Obtain a description of the stakeholder's concept for improvement of the existing water resources situation, towards more integrated water resource management.

The following aspects and principles should be included

- Equitable and socially acceptable water distribution
- Efficient and economically sustainable water use
- Delegation, decentralization and other evolution of authority
- Integrated planning
- Participation of stake holders
- Private sector participation
- Environmental protection

Step-4: Analysis of stakeholder's opinions

The outcome of all the interviews will be collected and an inventory will be made of agreements between the different stakeholders on the present situations the problems and constraints and the steps to be taken to come to a better water management

- The results of the interviews are described in a report
- These stakeholders should also be invited to the workshops that follow in the process.

Step-5: Workshop-1 problem Identification

It is important that all the relevant Stakeholders recognize their problems and those of others hence

1. The first workshop to which all the relevant stakeholders are invited deal with the assessment of the existing water resource management situation and problem identification according to the perception of stakeholders.

2. The purpose of the first workshop is to obtain common understanding between all different stakeholders of what the real problem and which should be addressed.

3. The analysis report which is formulated in the analysis of step 4 will be used as a reference and will be improved in accordance with the outcome of the workshop.

4. The agreed set of problems by the stakeholders will be then be used as an input for the further stages on formulation of a desired IWRM situation and necessary interventions.

5. End result of this workshop should be a selection of a very fruitful method to arrive at a set of most important problems.

Step-6: workshop-2 Formulations of desired IWRM situation and interventions

The second workshop one or three months after the first workshop

- It will elaborate extensively on the principles of integrated water resources management and it will further result in the formulation of a desired water resources management situation in that specific river basin and set of inventions that will be needed to achieve that
- This workshop outcome provides directions for constitutional, organizational and operational interventions
- The outcome should be seen as an input for national policy and decision makers.

Step-7: Preliminary sub basin report

Based on the foregoing steps the experts will draft a preliminary country document comprising.

- Assessment of existing water management situation
- Complete problem inventory
- Desired water resources management situation
- Proposed set of general and specific interventions needed to reach the desired situation.

Step-8

The draft country /basin/sub basin report is disseminated and a through procedure for collecting comments from the different stake holders at the different levels is followed.

Step-9: Final country basin report

Experts draft a final sub basin/basin report which is offered to the government and financing agencies for endorsement and inclusion into the strategy in to specific water related projects for the specific country.

Step-10 Monitoring Procedure

A monitoring procedure is developed to see whether the interventions are taking place and whether the envisaged results are achieved

Types and forms of private sector Involvement

The Private sector is morally bound to do invests in environmental protection as a response to regulation, legislation and specific incentives

- The private sector plays an important role in financing water resource management through investments in service delivery in water supply and sanitation.

The motives for growing involvement of the large and international private sector are

Financial: Government passes on the cost and work of raising funds.

Expertise: Private companies, if large or international, bring essential know how in some technical and economic fields.

Risk-Sharing: Private companies are typically more willing to take large risks than public authorities.

The main types of private involvement in water service provision are found

Full divesture: Transfer of all public assets through sales, in which case the private sector obtains full responsibility of the water supply network facilities and operations.

Joint ventures: Partial transfer of assets through share sales resulting in shared ownership and operating responsibilities between private and public sector.

Concessions: assets remain in public ownership but use of the system to by private sector for the duration of 20-25 years.

- Private sector can collect amount return fee collection or other form of payment

BOOTS (Build Operate Own and Transfer)/BOO

Build operate and own –schemes where contracts for the construction of particular infrastructure project is required and where ownership is handed to a public organization after a specified number of years.in the BOO case ownership remains in the hands of the private sector

Leasing-The water system remains in public ownership, but it leased to private operators

Contracting out-The least controversial form of Private sector involvement. A water understanding sub-contracts certain functions to private forms.

E.g meter reading Even when water services are provided by the private sector

- The government still has a key role in providing a clear regulating framework and ensuring that the poor are served and users are protected from excessive costs.

Module-4

Water Governance and Water Policy

Water Governance

Water governance refers to the political, social, economical and administrative systems that influence water use and management

- Essentially, who gets, what water, when and how and who has the right to water and related services, and their benefits.
- Water governance determines the equity and efficiency in water resource and services allocation and distribution, and balances water use between socio-economic activities and ecosystems.

Governing water Includes: -

1) The formulation of water laws.

2) Establishment and implementation of water Policies

3) Legislation and institutions

4) Clarification of the roles and responsibilities of government

5) The Involvement of private sector & civil Society.

Legal framework of water in India

The Existing legal Frame work:

The existing legal Institutional and decision making frame work for water law in India, both at the national and state level is embodied in the nine major acts at the national and state level.

The national legistations as applicable to water are:

1) Water prevention & control of pollution Act1974.

2) Air prevention and control of pollution Act 1973

3) Environment protection Act 1986.

4) Forest conservation Act 1980 and amended in 1988

5) Public liability Insurance Act 1991

6) Environment Assessment Development of projects, 1994

The ministry of environment and Forest is the nodal agency in the administrative structure of the central government for planning promotion and co-ordination and overseeing the implementation of environment legislation and programs and regulatory functions like environment clearance

1. Water prevention and control of pollution Act 1974

- An Act to provide for the prevention and control of water pollution and the maintaining or restoring of wholesomeness of water for the establishment, with a view to carrying out the purpose aforesaid, of boards for the prevention and control of water pollution, for conferring on and assigning to such boards powers and functions relating there to and for matters connected there with.
- The Act was amended on 1988 and finally updated in the year 2003
- The aim of the Act is to deal with a variety of environmental issues, including waste on land, water pollution, abandoned mines, noise pollution and the prevention of atmospheric pollution.

2) Air prevention and control of pollution Act 1973

- An Act to provide for the prevention, control and abatement of air pollution, for the establishment, with a view to carrying out the aforesaid purposes of boards powers and functions relating there to and for matters connected there with.
- “Air pollutant” means any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment
- The act was amended on 1981

3) Environment protection Act 1986.

- An act to provide for the protection and improvement of environment.
- "Environment" includes water, air and land the inter-relationship which exists among and between water, air and land human beings, other living creatures, plants, micro-organism and property.
- Environmental pollutant means any solid or gaseous substance present in such concentration as may be, or tend to be, injurious to environment.

4) Forest conservation Act 1980 and amended in 1988

- An Act to provide for the conservation of forests
- It extends to the whole of India except the state of Jammu and Kashmir.
- It shall be deemed to have come into force on the 25th day of October 1980.
- Whoever contravenes or abets the contravention of any of the provisions of section 2,shall be punished with simple imprisonment for a period which may extend to 15days

5) Public liability Insurance Act 1991

- An act to provide for public liability insurance for the purpose of providing immediate relief to the persons affected by accident occurring while handling any hazardous substance and for matters connected there with or incidental there to.

6) Environment Assessment Development of projects, 1994

- Enacted in the year 1994
- This assessment concentrates all the environmental consequences of plan policy or program

Existing Legal framework of for water:

Priority areas and water rights

Groundwater Law

Groundwater governance comprises the promotion of responsible collective action to ensure control protection and socially sustainable utilization of ground water resources for the benefit of humankind and dependent ecosystems?

But, In India the existing groundwater law is inappropriate because of following reasons

- Traditionally groundwater has been treated as a land property, where the access is to private land owners alone.
- Such a property do not relate to hydrological, ecological or equity concerns at all. Hence access to groundwater is highly inequitable, which depend up on land ownership and economies' capacity to draw.

Need of legal framework for ground-water rights existing legal frame work for ground water is as follows:- (why there should be reframing of ground water law)

- The existing groundwater rights are under totally land owners regime
- There is no limit to the volume of groundwater a landowner may draw.
- In such a legal framework only landowners can own groundwater in India
- All landless tribal's Community rights but who may have over land but not private ownership
- It also implies that rich land lords can be water lords and indulge in openly Selling as much water as they wish.

Recommendations

To ensure proper of water it is rights should be and equitable recommended separated from distribution that water land rights.

Areas where legal sanction is needed

1) Where there is over exploitation of ground water

2) Where there are disputes between two parties regarding the exploitation of water.

3) Where there is environmental degradation due to over exploitation

4) Where there is ground water pollution

Tank Water Bodies

In many parts of India, irrigation has traditionally been tank based

In major irrigation system, Irrigation canals covers only 367 of the agricultural land. Remaining 64% is rain fed ground water irrigated and natural or artificial tank Irrigated crop lands.

- Despite this crucial dependence on tanks and wells, India has witnessed the negligence and destructions of thousands of tanks and gross misuse of ground water.
- There is a need to reform the appropriate legal structure that will support local controls and provides incentives for sustainable and equitable use of water tanks.

Recommendations

It is proposed to make detailed study of the customary and statutory laws of the concerning use of tank and wetland wasters water's in rural areas.

- These laws provided various strategies through which common resources could be utilized for common good. The aim of the study would be to devise appropriate legal strategies for the preservation of tanks its management and for equitable use of its resources.
- The neglect of tank and ground water law is directly related to the emphasis on Construction of dams, since these have been conceived as the main scientific alternative for Irrigation and food production.
- The appropriate legal framework for dams will turn the attention to the development of tank and groundwater laws.

Indian National Water Policy.

National water policy is formulated by the ministry of water resources of the Government of India; to govern the planning and development of water resources and their optimum utilization.

- The first national water policy adopted was in September 1987. It was reviewed and updated in 2002 and later in 2012.

The Need for a National water policy.

1. Water is a Prime natural resource, a basic human need and a precious national asset planning and development resources -need to be governed by national perspectives.

2. India has more than 18% of the world's population, but has only

- 4% of renewable water resources
- 2.4%. of land area.

3. There are further limits on utilizable quantities of water owing to uneven distribution over time and space. [Water does not respect stale boundaries]

4. In addition, there are challenges of flood and draught, growing population Rising need climate change, miss management wastage, inefficient use and also pollution.

5. Water, like air is one of the most basic requirements for life. If a national law is considered necessary on subjects such as the environment forests, wildlife, and biological diversity, etc. Then a national law on water is even more necessary

6. Under the Indian constitution water is primarily a state subject, but it is an increasingly important national concern in the context of:

a) The right to water being a part of the fundamental right to life.

b) The perception of a water crisis because of the mounting pressure on a finite resource

c) The inter use and inter-state conflicts that this leads to, and the need for a national concensus on water - sharing principles and on the arrangements for minimizing conflicts and settling them quickly without resort to adjudication to the extent possible.

d) The threat to this vital resource by the massive generation of waste by various uses of water and the severe pollution and contamination caused by it.

e) The equity Implications of the distribution use and control of water, equity as between uses, users sectors, states, countries and generations.

7. Different state governments tend to adopt different positions on the rights of different States over the waters of a river basin. A national statement of the general legal position and principles that should govern such cases in a desirable way should be required i.e. as nation water polity. Hence a National water policy is necessary.

The Nature and scope of a National water law

1. The proposed national water law is not intended to centralise water management or to change the center -state relations in any way. It is a frame work of law i.e.an umbrella statement of general principles governing the exercise of legislative or executive powers by the center, the states and the local governance Institutions

2. The law is to be justiciable in the sense that the laws passed and the executive actions taken by the central and state governments and the developed functions are exercised in the nation Any deviations from this can be challenged in a court of law.

3. No administrative machinery or institutional structure is predicting at the center under this framework hence no penal provisions are expected.

Other key Issues

1. Lack of awareness

- Lack of framework awareness about the law and policy framework is still a major issue in rural India

2. Lack of participation

- The lack of public participation in law and policy making process is a collateral impact of general awareness.
- Mostly, law and policy making process follow a top to bottom approach where people are. at the receiving end having no role to play in framing of norms and regulations. This situation is worse in rural areas where people cannot read and write. A lot of efforts needs to be put to make a bottom- to - top approach work in law and policy making process.

- Hence idea of participation is also important from the angle of implementation of various policies.

3. Gender and caste Discrimination

Gender and caste are two important factors to be given adequate attention in the law and policy framework related to water and sanitation

- Women and lower caste people are quite often neglected sections. Even though women can play crucial and effective role in water resource management and development they are mostly no where in the picture of framing and implementation of various policies and schemes.
- The emerging legal framework also by implications excludes women, for Instance. The participatory irrigation management laws allows only the land owners or occupiers to become members of water user's associations (WUAS) consequently, women are excluded from the key decision making process.
- Caste is also a crucial determining factor. Even though caste discrimination has been prohibited by law, it is still prevalent in rural areas. Lower caste people usually has to wait till the higher caste people finishes fetching water and they also have to face some times abusive language and degrading treatment.

Hence, more actions are needed from the side of the government to eliminate these antique in human practices.

Irrigation Management Transfer policies and Irrigation Management Activities and Institutions

Definitions

"An Irrigation system is a system of physical structures such as dams, canals, gates, pumps and others that capture water from a natural source and distribute it to farmers to use for watering crop plants".

Irrigation Management activities are:

1. Water distribution: Capturing and distributing water in an irrigation system.

2. Maintenance: Repairing and maintaining the physical features or structures of the irrigation system.

3. Resource Mobilization (act of movement): Raising the resources needed for operations and maintenance

4. Conflict Resolution: Resolving conflicts among users and system managers are over the above three items. Irrigation management institutions include the rules and organizations concerned with these four activities.

Irrigation Management Policy

Government irrigation management policy includes those rules and principles that defines institutions - rules and organizations Irrigation management policies thus define

Water distribution rules: The rules defining the proper distribution of irrigation water to users

Resource Mobilization rules: The process a for mobilization of resources for operations and maintenance of the system, including requirements for the payment of irrigation fees and for contributing labor.

Conflict Resolution Rules: The rules regarding how conflicts are to be settled.

System Managers: The persons or organizations responsible for operations and maintenance for resource mobilization, and for conflict resolution

These items are defined in government policy for all government managed irrigation systems.

There are more important policy provisions rather than this single document

Irrigation management transfers.

Irrigation Management Transfer (IMT) can be defined as the transfer of some on all irrigation management responsibilities for an irrigation system from a government agency to one or more private (local) persons or organizations"

- Management transfer need not be total but could be limited to specific parts of Irrigation systems or to specific management functions.

- Irrigation management transfer activities are the programs and individual efforts designed to implement IMT policies.

Dimensions for classifying Irrigation Management

Transfer policies and activities.

The definition of IMT includes transfer of responsibilities from a government agency to private persons or organizations.

This suggests that two of the needed traits Characteristics are: -

- Definition of the persons or organizations to whom the responsibilities are to be transferred.
- The responsibilities to be transferred from the government agency to the private person.

Transfer of responsibilities should be to water user associations (WUAS) or some form or other.

The reasoning is that,

a) **water users -** farmers have the proper set of motivations to handle irrigation management activities efficiently and effectively
    - The rights and powers, particularly those over water distribution in the board Sense to be transferred

Since IMT involves two parties the government agency and the private organizations and persons resources should be mobilized for the operation and maintenance for any irrigation system.

Other Issues

1) Change in systems and requirements for resource mobilization for the government agency.

2) Changes in systems and requirements for resource mobilizations for the private persons and organizations.

The means by which IMT is to be implemented

The following seven elements as them key dimensions for the classification of IMT policies and activities:

1. Persons or organizations to whom responsibilities are transferred

2. Responsibilities transferred

3. Rights and powers transferred

4. Change in agency recourse mobilization

5. Change in resource mobilization for the private persons or organizations.

6. Changes in conflict resolution institutions.

7. IMT implementation in any one of classification, it may not be necessary to make use of all of these dimensions

Water user Allocations (WUAS)

WUA (Is an Association of water Origin of WUAS users like, Irrigators, farmers etc.)

Two aspects of the origin are particularly relevant to performance

1. The age of the organizations

2. Whether the impetus for organizing was internal or external.

WUAS originating from internal initiatives are often found in small scale, farmer managed irrigation systems.

By laws of the WUAS

By laws are normally required before a WuA;can be registered as a legal entity, and before it can be allowed to operate.

The issues that such by laws address includes

1. Basic facts about and objectives of the WOA.
2. Criteria for becoming a member of WUA
3. Number of farmers required for the establishment of a WUA.
4. The WUA as a legal entity
5. Structural organizations and internal arrangement
6. Operations and maintenance
7. Water charges.
8. Rights and obligations of members.
9. Interpreting and amending the bylaws.
10. Liquidation of the WUA and
11. Establishment of a federation of WUAS

Criteria for becoming a member of the WUA

Most by laws restrict membership to the registered landowners in the hydraulic unit who are engaged on a full-time basis in farming.

- But it in some countries like Nepal extends the right to become a member to both owners and tentants, where membership of WUA is open to farmers having lands or tenancy rights.
- In some cases multiple users of water can become members of the WUA
  Eg: not only irrigators, but also livestock owner’s fisherman.
- In many cases, women appear to be almost absent from water user's groups or associations. The only women who can potentially participate in water user's groups are either widows or single mothers with no adult male living in the house hold.

- On occassion special arrangements are made to provide for the representation of the disadvantaged such as tail - Enders female heads of farms or small famers. i,e Representatives from the head and tail end of the irrigation system.

Role of water Allocation

- Water allocation is the process of sharing a limited natural resource between different regions and competing users.
- It is a process made necessary when the natural distribution and availability of water fails to meet the needs of all water users in terms of quantity, quality, timing of availability
- In simple terms, it is the mechanism for determining who can take water, how much they can take, from which location, when and for what purpose.

Ten golden rules of basin water Allocation.

Rule1: In basins where water is becoming stressed, it is important to link allocation planning to broader Social environmental and economic development planning.

Rule 2: Successful basin allocation processes depend on the existence of adequate institutional capacity.

Rule 3: The degree of complexity in an allocation plan should reflect the complexity and challenges in the basin.

Rule 4: Considerable care is required in defining the amount of water available for allocation.
Rule 5: Environmental water need a foundation on which basin allocation Planning should be built.

Rule 6: The water needs of certain priority purposes should be met before water is allocated among other users.

Rule 7: in stressed basins, water efficiency assessments and objectives should be developed in or alongside the allocation plan.

Rule 8: Allocation plans need to have a Clear and equitable approach for addressing Variability between years.

Rule 9: Allocation plans need to incorporate flexibility in recognition of uncertainty over the medium to long term.

Rule 10: a clear process is required for converting regional water shares into local and individual water entitlements, and for clearly defining annual allocations.

Water Reforms in India

Reform - make something better, to improve something or to remove the faults.

The Mihir shah Committee suggested a reform strategy for the country's water Sector.

- The report a 21st century institutional Architecture for India's water Reforms, made several recommendations based on its diagnosis of the ailing sector.
- The reform agenda was a proposed restructuring of the central water commission (CNC) and Central around water board of India (CAWB)

Scope of Reform

India's water Sector faces challenges. Some of the problems in the water sector identified by the committer are:

1. The efficiency in public irrigation schemes is as low as 35%,. There is a huge gap between potential created and potential utilised in the irrigation Sector.
2. There is no scope for further development of the surface water in the country in view of the fact that in India highly developed rivers are facing severe water stress.
3. Managing water today is no longer about only developing new sources through means such as.
    - Construction of Reservoirs.
    - Digging Wells
    - Laying canals and pipelines.

But it is allocating the limited water amongest various competitive uses.

India's Draft National Water Policy 2012

- Ministry of water resources, Government of India in Jan 2012, released a draft National water policy for the consideration and opinion of state governments and other stake holders.

Key Items in the Draft Policy Include

- Since 2012 draft is, the are review of 2002 draft, here priorities are given for water allocation.
- The Center would like water budgeling and auditing to be made mandatory and for each state government to put a regulator for water allocation, water use efficiency and physical and financial sustainability of water resources, with a mechanism to establish water tariff system and fix the criteria for water charges.
- The draft is made to change the current attitude towards water recharging, both among the government agencies as well as the public, especially the farming communities.
- Currently, heavy underpricing of electricity leads to wasteful use of both electricity and water which this draft also hopes to reverse.
- The water related services should be transferred to community and/or private sector with appropriate public private partnership model .
- The draft policy calls for a boliation of all forms of water subsides to the agricultural and domestic sectors, but subsides and incentives should be provided to private industry for recycling and reasing treated effluents.

Module -5

Water Harvesting and Conservation

What is Water Harvesting?

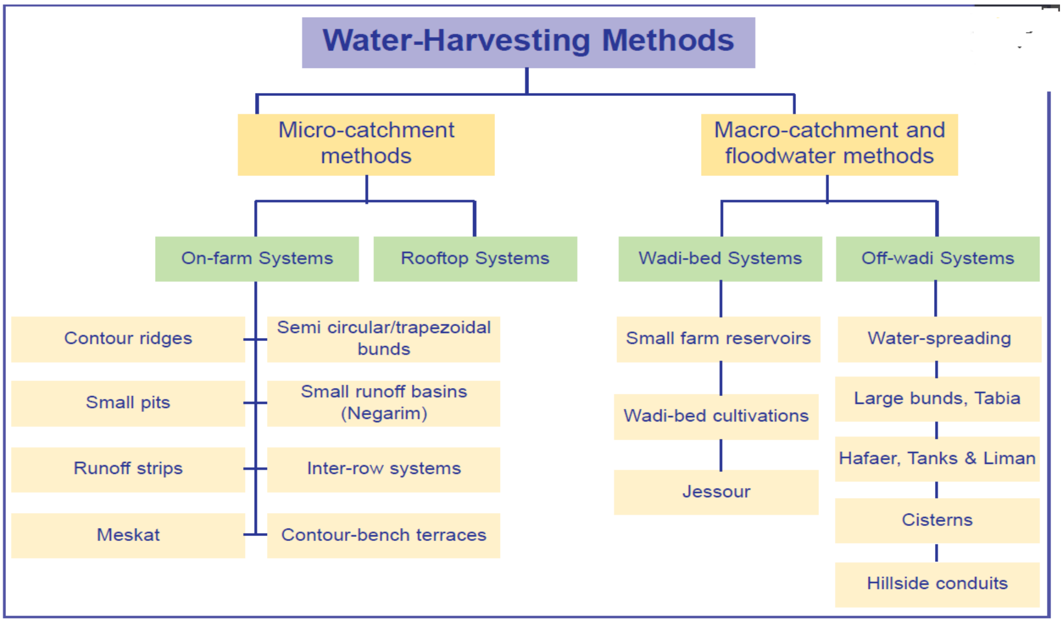
Water harvesting is based on the principle of depriving part of the land of its share of rain, which is usually small and non-productive, and adding it to the share of another part. This brings the amount of water available to the latter area closer to crop water requirements and thereby permits economic agricultural production. For example, an area of four hectares in an arid zone receiving 150 mm of annual rain cannot normally produce an economic crop. If two hectares forming one half of the area add their share of 150 mm of rain to the other half, then the latter will have a total of 300 mm. This amount may be enough to support drought-resistant crops. Furthermore, if three hectares of the land contribute their quantity of rain to the remaining one hectare, this quarter would have a total of 600 mm, i.e. its own 150 mm share of rain and the shares of the other three hectares (450 mm). If well distributed, this may be enough to support quite a wide range of crops. Of course, in reality, only a portion of this water may be diverted easily and at low cost. Such concentration of rainwater is called water harvesting, which may be defined as "the process of concentrating precipitation through runoff and storage, for beneficial use."

Water harvesting may occur naturally or by intervention. Natural water harvesting can be observed after heavy storms, when water flows to depressions, providing areas for farmers to cultivate. Water harvesting by intervention involves inducing runoff and either collecting or directing it, or both, to a target area for use. Besides being applied to agriculture, water harvesting may be developed to provide drinking water for humans and animals as well as for domestic and environmental purposes.

Components of Water Harvesting Systems The main components of water harvesting systems are: Catchment area: the part of the land that contributes some or all its share of rainwater to a target area outside its boundaries. The catchment area can be as small as a few square meters or as large as several square kilometres. It can be agricultural, rocky or marginal land, or even a rooftop or a paved road. Storage facility: the place where runoff water is held from the time it is collected until it is used. Storage can be in surface reservoirs, subsurface reservoirs such as cisterns, in the soil profile as soil moisture, and in groundwater aquifers. Target area: where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is the human being or the enterprise and its needs.

Overview of Water-Harvesting Systems

As water harvesting is an ancient tradition and has been used for millennia in most dry lands of the world, many different techniques have been developed. Most of these are for irrigation purposes, while others are to conserve water for human and animal. The same techniques some- times have different names in different regions and others have similar names but, in practice, are completely different. Water- harvesting methods are classified in several ways, mostly based on the type of use or storage, but the most commonly used classification is based on the catchment size.



Micro-catchment Systems

Micro-catchment systems are those in which surface runoff is collected from a small catchment area with mainly sheet flow over a short distance. Runoff water is usually applied to an adjacent agricultural area, where it is either stored in the root zone and used directly by plants, or stored in a small reservoir for later use. The target area may be planted with trees, bushes, or with annual crops. The size of the catchment ranges from a few square meters to around 1000 m^2 Land catchment surfaces may be natural, with their vegetation intact, or cleared and treated in some way to induce runoff, especially when soils are light. Non-land catchment surfaces include the rooftops of buildings, courtyards and similar impermeable structures.

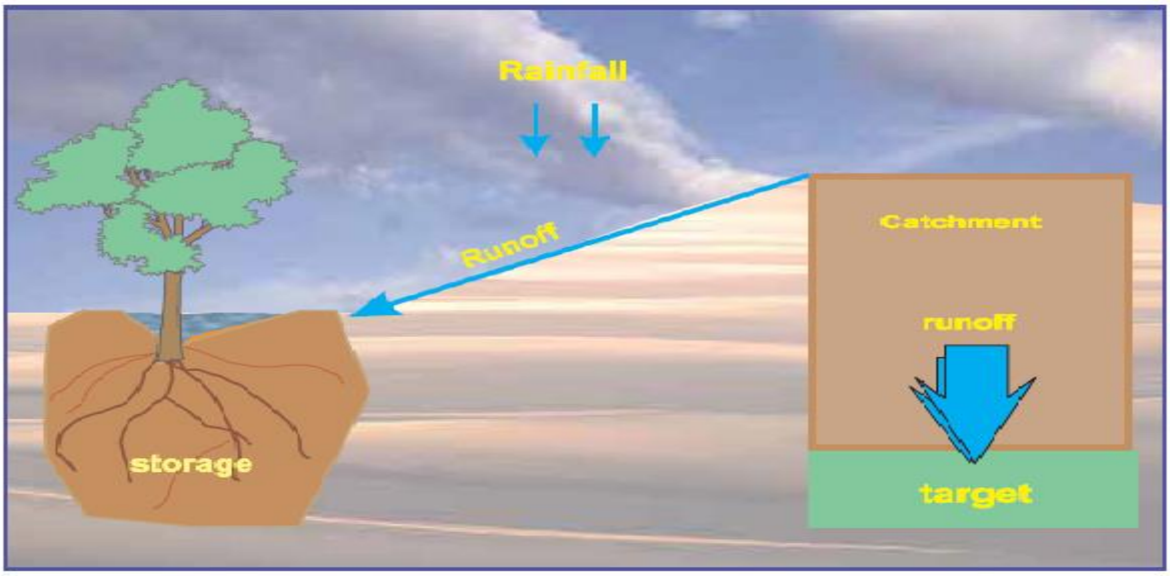


Diagram of micro-catchment water-harvesting systems

On-Farm Systems

On-Farm micro-catchment systems are simple in design and may be constructed at low cost, making them easily replicable and adaptable. They have higher runoff efficiency than macro-catchment systems and do not usually need a water conveyance system. They allow soil erosion to be controlled and sediments to be directed to settle in the cultivated area. Suitable land-based micro-catchment techniques exist for any slope or crop. However, these systems generally require continuous maintenance with a relatively high labour input. Unlike macro-catchment systems, the farmer has control within his farm over both the catchment and the target areas. All the components of the system are constructed inside the farm boundaries. This is an advantage from the point of view of maintenance and management, but because of the loss of productive land it is only in the drier environments, where cropping is most risky, that farmers are willing to allocate part of their farm to a catchment. The most important land-based micro catchment or on-farm water-harvesting systems in the dry areas of WANA are described below.

1. Contour ridges

These are bunds or ridges constructed along the contour line, usually spaced between 5 and 20 m apart. The first 1–2 m above the ridge is for cultivation, whereas the rest is the catchment. The height of each ridge varies according to the slope's gradient and the expected depth of the Runoff water retained behind it. Bunds may be reinforced by stones if necessary. Ridging is a simple technique that can be carried out by farmers. Ridges can be formed manually, with an animal-driven implement, or by tractors with suitable implements. They may be constructed on a wide range of slopes, from 1% to 50%. The key to the success of these systems is to locate the ridge as precisely as possible along the contour. Otherwise water will flow along the ridge, accumulate at the lowest point, eventually break through and destroy the whole down slope system.

Design of Small Water Harvesting Structures

There are many ways of harvesting water. All these methods basically fall under three main categories viz.:

- Surface water collection
- Ground water collection
- Augmentation of ground water recharge

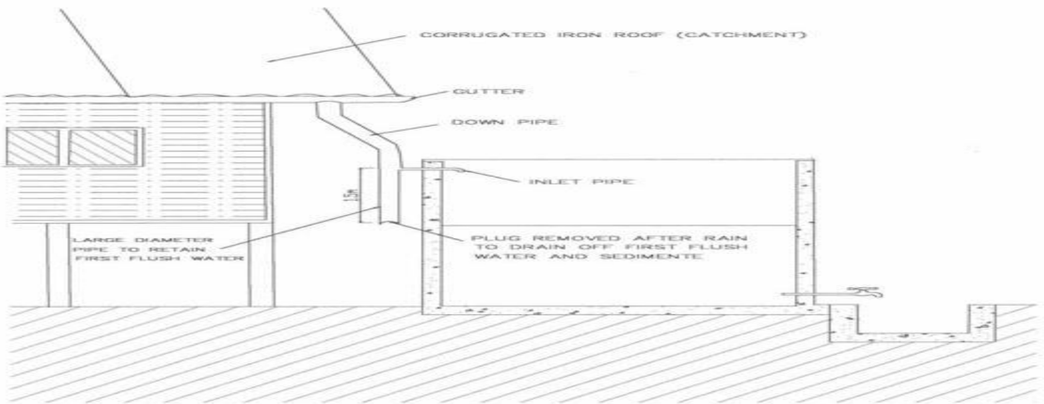
The methods which are particularly useful in augmenting drinking water availability especially in the rural areas and which can be easily adopted at a moderate cost with the involvement of the local people are discussed in the following below

ROOF TOP HARVESTING

Rain water may be harvested in areas, having rainfall of considerable intensity, spread over the larger part of the year e.g. the Himalayan areas, northeastern states, Andaman Nicobar, Lakshadweep islands and southern parts of Kerala and Tamil Nadu. This is an ideal solution of water problem where there is inadequate groundwater supply and surface sources are either lacking or insignificant. Rain water is bacteriologically pure, free from organic matter and soft in nature.

In this system, only roof top is the catchment (see Figure A). The roofing should be of galvanized iron sheets (G.I.), aluminium, clay tiles, asbestos or concrete. In case of thatch-roof, it may be covered with waterproof LDPE sheeting. For collection of water, a Drain is provided (Gutter) along the edge of the roof. It is fixed with a gentle slope towards down pipe, which is meant for free flow of water to the storage tank. This may be made up of G.I. sheet, wood, bamboo or any other locally available material. The down pipe should be at least 100 mm diameter and be provided with a 20 mesh wire screen at the inlet to prevent dry leaves and other debris from entering it.

Figure A: Typical Roof Top Harvesting Structure



Design Example

If, for example, 40 lpd (q) is agreed upon and a dry period of 80 days (t) is normally not exceeded, a storage volume of 16 m3 would be required for a family of 5 members (n). [V = 80 (t) × 5 (n) × 40 (q) = 16,000 litres or 16 m3]

The required catchment area (i.e. the area of the roof) can be determined by dividing the volume of the tank by the accumulated average rainfall volume (in litres) per unit area (in m2) over the preceding wet months and multiplying this with the runoff coefficient, which can be set at 0.8 for galvanized iron or tiled roofs. Experience shows that with the water storage tanks next to their houses, people use between 20-40 litres of water per person per day (lpd). However, this may rise in time as people relax their water use habits because of easy access. This contrasts with a maximum of l0 lpd consumption levels under similar environments with people fetching water from distant sources. Together with the community/ family, a decision must be taken on how the water will be used or what affordable service level can be provided.

PERCOLATION TANK

Percolation tanks are artificially created surface water bodies, submerging a land area with adequate permeability to facilitate sufficient percolation of impounded surface runoff to recharge the ground water. These have come to be recognized as a dependable mode for ground water recharge in the hard rock terrain covering two-third of the country. The hard rock areas with limited to moderate water holding and water yielding capabilities often experience water scarce situations due to inadequate recharge, indiscriminate withdrawal of ground water and mismanagement. These are quite popular in the states of Maharashtra, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Karnataka and Gujarat. The percolation tank is more or less similar to check dams or nala bund with a fairly large storage reservoir. A tank can be located either across small streams by creating low elevation check dams or in uncultivated land adjoining streams, through excavation and providing a delivery canal connecting the tanks and the stream.

General Guidelines

(i) Percolation tanks should normally be constructed in a terrain with highly fractured and weathered rock for speedy recharge. In case of alluvium, the boundary formations are ideal. However, the permeability should not be too high that may result in the percolated water escaping in the downstream as regenerated surface flow.

(ii) The aquifer to be recharged should have sufficient thickness of permeable vadose zone to accommodate recharge. The Vadose zone should normally be about 3 m below the ground level to minimize the possibility of water logging.

(iii) The benefited area should have sufficient number of wells, hand pumps etc. A minimum well density of 3 to 5 per square kilometres is desirable. The aquifer zone should extend up to the benefited area.

(iv) Submergence area should be uncultivated as far as possible.

(v) The nature of the catchment is to be evaluated based on Stranger's Table for classification under Good, Average and Bad Category. It is advisable to have the percolation tank in a good/ average catchment.

(vi) Rainfall pattern based on long-term evaluation is to be studied so that the percolation tank gets filled up fully during monsoon (preferably more than once).

(vii) Soils in the catchment area should preferably be of light sandy type to avoid silting up of the tank bed.

(viii) The location of the tank should preferably be downstream of runoff zone or in the upper part of the transition zone, with a land slope gradient of 3 to 5%.

(ix) The yield of a catchment area is generally from 0.44 to 0.55 MCM/sq.km in a low catchment area. Accordingly, the catchment area for small tanks varies from 2.5 to 4 sq.km and for larger tanks from 5 to 8 sq.km.

(x) The size of percolation tank is governed more by the percolating capacity of the formation under submergence rather than the yield of the catchment. Therefore, depending on the percolation capacity, the tank is to be designed. Generally, a percolation tank is designed for a storage capacity of 2.25 to 5.65 MCM. As a general guide the design capacity should normally not be more than 50 percent of the total quantum of utilizable runoff from the catchment.

(xi) While designing, due care should be taken to keep the height of the ponded water column about 3 to 4.5 m above the bed level. It is desirable to exhaust the storage by February since evaporation losses become substantial from February onwards. It is preferable that in the downstream area, the water table is at a depth of 3 to 5 m below ground level during the post monsoon period, implying that the benefited area possesses a potential shallow aquifer.

(xii) Construction-wise there is not much difference between a percolation tank and a minor irrigation tank, except for providing outlets for surface irrigation and the depth of the cut-off trench. The cut-off trench is to be provided below the earthen bund with depth limited to one fourth of the height between bed level and full storage level

Design Aspects

The design of percolation tanks involves detailed consideration of the following aspects:

(i) The catchment yield is to be calculated for long-term average annual rainfall, using Stranger's Table. Table A-3.1 of Appendix-III gives the yield from 1 hectare of Catchment for different values of monsoon rainfall.

(ii) The design of the dam is to be done on the basis of

(a) the topographical setting of the impounded area, to calculate the height and length of the dam wall, its gradient, width and the depth of the foundation, taking into account the nature of the underlying formation;

(b) Details of the cut-off trench, to reduce seepage losses;

(c) Height of stone pitching on the upstream slope to avoid erosion due to ripple action and on the downstream slope from rain by suitable turfing;

(d) Upstream and downstream slopes to be moderate so that shear stress is not induced in the foundation beyond a permissible limit; and

(e) Stability of the dam.

(iii) Percolation tanks are normally earthen dams with masonry structures only for the spillway. Construction materials consist of a mixture of soil, silt, loam, clay, sand, gravel, suitably mixed and laid in layers and properly compacted to achieve stability and water tightness. The dam is not to be over-tapped, by providing adequate length of waste weir and adequate free board.

(iv) A waste weir is provided to discharge surplus water when the full pond level is reached. Maximum permissible discharge from the catchment is to be calculated using the formula approved by the competent authority based on local conditions. In the absence of such a formula, Inglis, or Dicken's formula may be used based on the observed or design discharge and catchment areas for local culverts under road or railway bridges. Once the discharge is known the length of the waste weir is decided depending on the maximum flood discharge and permissible flood depth the crest of Waste weir.

(v) Finally, measures indicated for the protection of catchment areas of rock dams hold good in the case of percolation tanks also.

(vi) The percolation tanks in a watershed may not have enough catchment discharge though a high capacity tank is possible as per site conditions. In such situations stream from nearby watershed can be diverted with some additional cost and the tank can be made more efficient. Such an effort was made in Satpura Mountain front area at Nagadevi, Jalgaon district, Maharashtra. The existing capacity of the tank of 350 TMC was never utilized after its construction. This could however be filled by stream diversion from adjacent watershed.

DESIGN OF FARM POND

Farm ponds are small tanks or reservoirs constructed for the purpose of storing water essentially from surface runoff. Farm ponds are useful for irrigation, water supply for the cattle, fish production etc. The design and construction of farm ponds require a thorough knowledge of the site conditions and requirements. Some sites are ideally suited for locating the ponds and advantage of natural conditions should always be taken. Types of Ponds Depending on the source of water and their location with respect to the land surface, farm ponds are grouped into four types.

These are (1) Dugout ponds (2) Surface ponds (3) Spring or Creek fed ponds and (4) Off-stream storage ponds. Dugout Ponds are excavated at the site and the soil obtained by excavation is formed as embankment around the pond. The pond could either be fed by surface runoff or groundwater wherever aquifers are available. In case of dugout ponds, if the stored water is to be used for irrigation, the water has to be pumped out. Surface water ponds are the most common type of farm ponds. These are partly excavated and an embankment is constructed to retain the water. Generally a site which has a depression already is chosen for this pond construction. Spring or creek fed ponds is those where a spring or a creek is the source of water supply to the pond. Construction of these ponds, therefore, depends upon the availability of natural springs or creeks. Off-stream storage ponds are constructed by the side of streams which flow only seasonally. The idea is to store the water obtained from the seasonal flow in the streams. Suitable arrangements need to be made for conveying the water from the stream to the storage ponds. Components of a Farm Pond: Figure below shows a typical layout of a farm pond. The pond consists of the storage area, earthen dam, mechanical spillway and an emergency spillway. The mechanical spillway is used for letting out the excess water from the pond and also as an outlet for taking out the water for irrigation. The emergency spillway is to safeguard the earthen dam from overtopping when there are inflows higher than the designed values.

Soil and Water Conservation Engineering Department of Soil & Water Conservation Engineering Design of Farm Pond the design of farm ponds consists of

(1) Selection of site

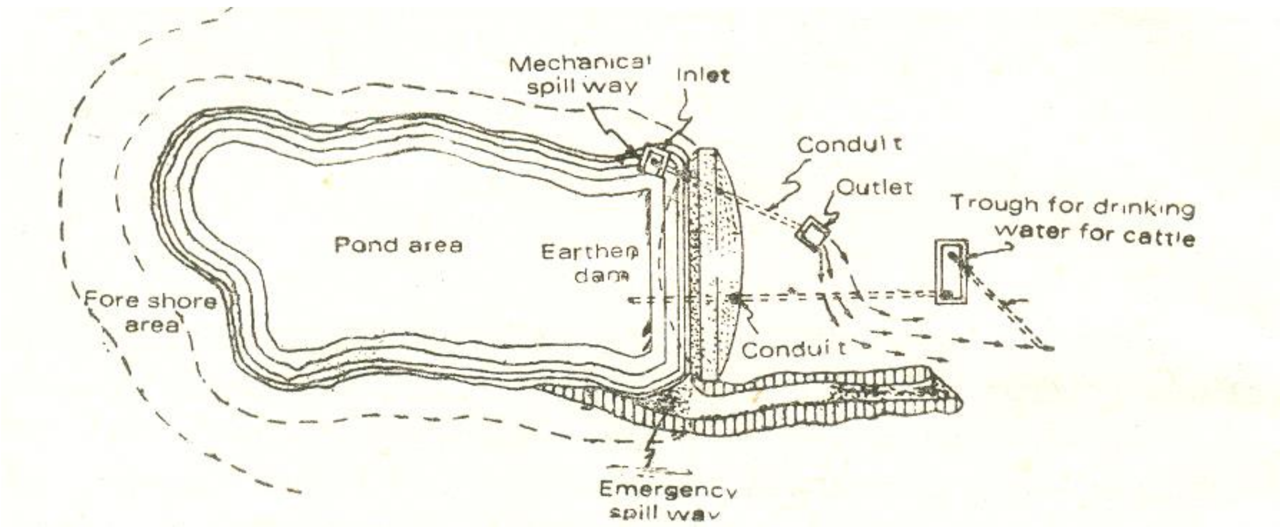
(2) Determination of the capacity of the pond

(3) Design of the embankment

(4) Design of the mechanical spillway

(5) Design of the emergency spillway

(6) Providing for seepage control from the bottom



Selection of site Selection of suitable site for the pond is important as the cost of construction as well as the utility of the pond depend upon the site. The site for the pond is to be selected keeping in view of the following considerations:

1. The site should be such that largest storage volume is available with the least amount of earth fill. A narrow section of the valley with steep side's slopes is preferable.
2. Large areas of shallow water should be avoided as these will cause excessive evaporation losses and also cause water weeds to grow.
3. The site should not cause excessive seepage losses.
4. The pond should be located as near as possible to the area where the water will be used. When the water is to be used for irrigation, gravity flow to the areas to be irrigated is preferable.

Techniques of Rain Water Harvesting in Urban and Rural Areas

What is Rain Water Harvesting?

a. Conscious collection and storage of rain water for drinking, domestic purposes and irrigation is termed as rain water harvesting.

b. It is a process of artificially enhancing ground water recharge at a rate exceeding natural rate of recharge by putting proper structures.

Rain water harvesting in urban area and rural area:

Roof top rain water/run-off harvesting through Rain water harvesting through

• Recharge Pit • Gully plug • Recharge Trench • Contour bunding • Tube well • Check dam/Nala bund • Recharge well • Percolation tank • Recharge shaft • Dug well recharge • Sub surface dyke (U.G.C.D)

Why to harvest rainwater?

a. To conserve surface water run-off during monsoon and to augment ground water table.

b. To improve quality of ground water.

c. To save energy in lifting water: 1m rise in water level saves 0.4kWh of energy.

d. To reduce soil erosion

e. Prevention of sea water ingress in coastal areas.

f. Decrease in choking of storm water drains and Flooding of roads

g. To create a culture of water conservation

Salient features of Ground water recharge techniques:

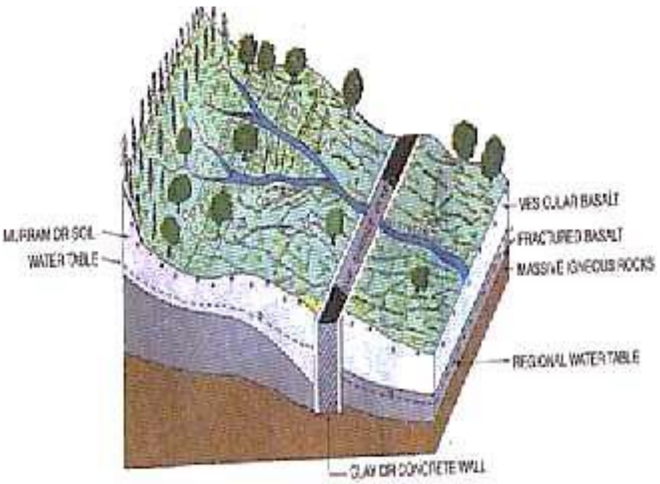
Quantum of water to be recharged is large. Space available for recharge is also in plenty. Therefore, surface spreading techniques are common for rural ground water recharge. Watershed is considered as a unit

Techniques for Ground water recharge in rural areas

1. Gully Plug

Built along hilly slopes across gullies/ small streams using locally available stones, clay etc.

- Better selection where slope breaks so as to have some storage behind
- Prevents soil erosion and conserves soil moisture



Contour Bund

These are suitable in low rain fall areas by constructing bunds on sloping grounds all along the Contour of equal elevation

- Flowing water is intercepted before it attains erosive velocity by keeping suitable spacing between bunds
- Effective method to conserve soil moisture in watershed for long duration
- Spacing between two bunds depends on slope, area and permeability of soil

Check Dam/Nala Bund

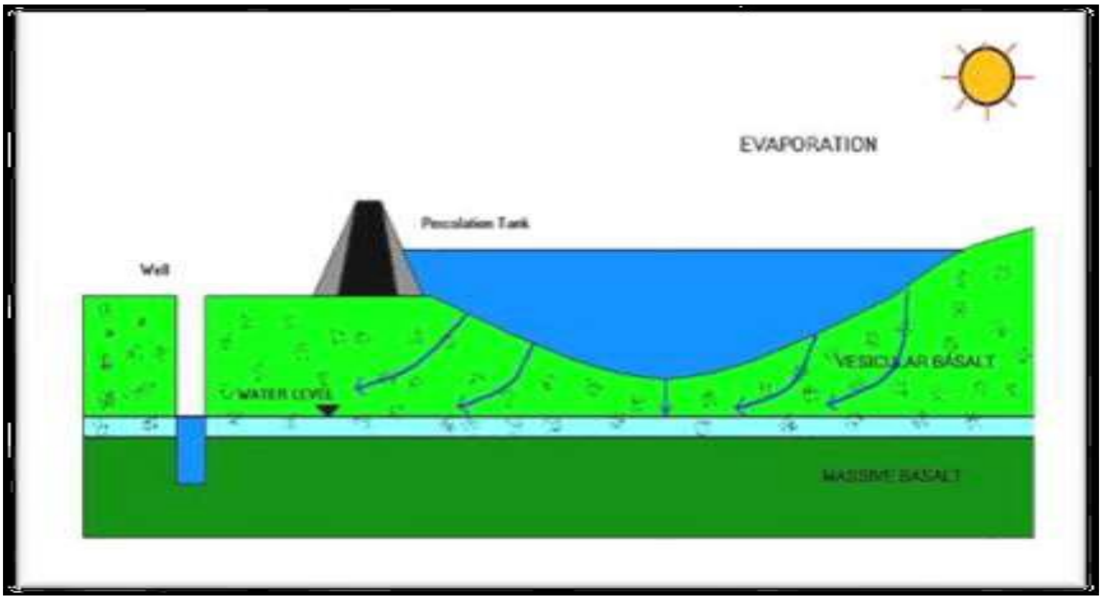
Constructed across streams with gentle slopes.

- Should have sufficient thickness of permeable bed
- Water confined within the bank of stream
- Height not to exceed 1.5 to 2 meter in general
- Excess water flows above wall May be constructed with masonry/ concrete
- Downstream water cushion chamber required to prevent scouring.

Percolation tank

To be constructed on highly fractured and weathered rocks having lateral continuity downstream with number of wells

- It's a water body created by submerging highly permeable land so that surface run-off percolates and recharges ground water storage
- Normally having storage capacity of 0.1-0.5 MCM.
- Designed to provide water column of 3-4.5m.
- They are mostly earthen dams with masonry spillway.



Recharge Shaft

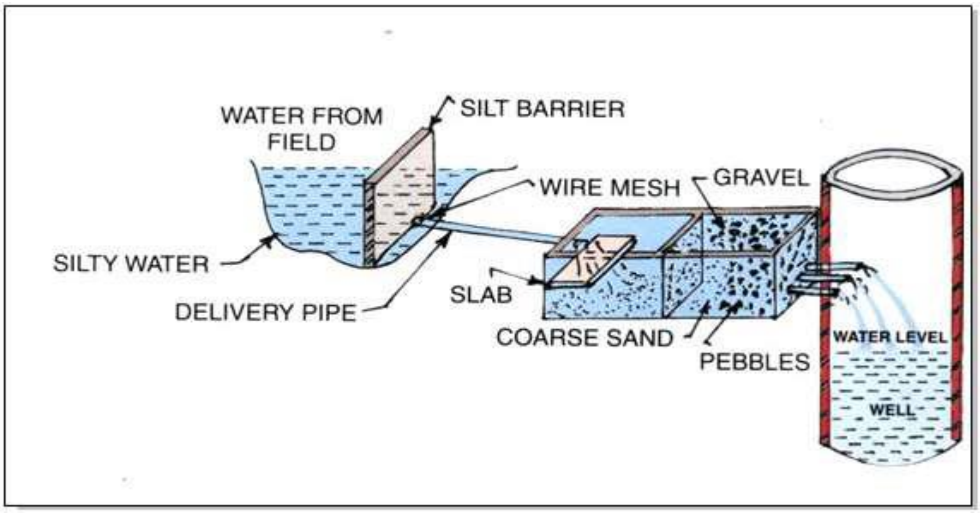
In rainy season, village tanks are filled up but water does not percolate due to siltation in the tanks and this water gets evaporated after some months.

- By constructing recharge shafts in tanks, this water can be recharged to ground water.
- Diameter: 0.5-3.0m, Depth: 10.0- 15.0m, Depending upon the availability of water Top of shaft is kept at half of full supply depth of tank.
- Shaft is filled with filter material like boulders, gravel and coarse sand.
- Shaft should end in more permeable strata, below the top impermeable strata.
- Most efficient and cost effective technique to recharge unconfined aquifer.

Dug-Well Recharge

Existing and abandoned dug wells may be utilized as recharge structure after cleaning and desalting the same.

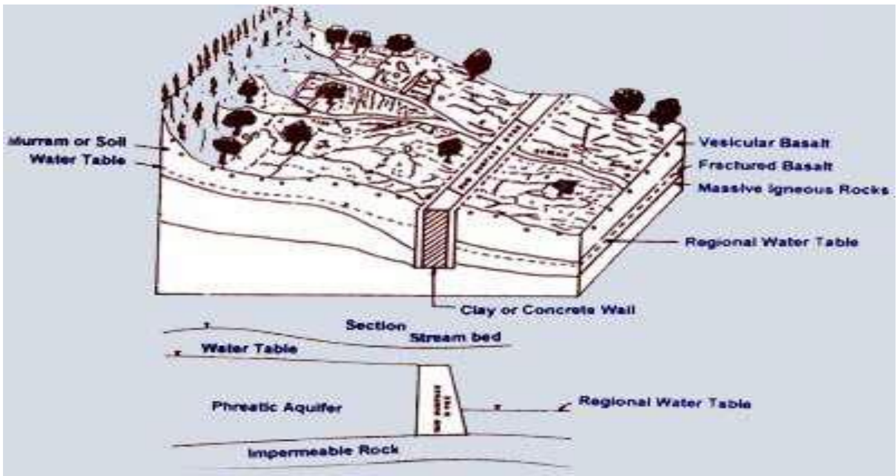
- The recharge water is guided through a pipe from desalting chamber to the bottom of well or below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.
- Recharge water should be silt free and for removing the silt contents, the runoff water should pass either through a desalting chamber or filter chamber.
- Periodic chlorination should be done for controlling the bacteriological contaminations



Sub-surface Dyke

Sub surface dyke or under-ground dam is a subsurface barrier across stream which retards the base flow and stores water upstream below ground surface. By doing so, the water levels in upstream part of ground water dam rises saturating otherwise dry part of aquifer.

- The site where sub-surface dyke is proposed should have shallow impervious layer with wide valley and narrow out let.



Salient features of Ground water recharge techniques for urban areas:

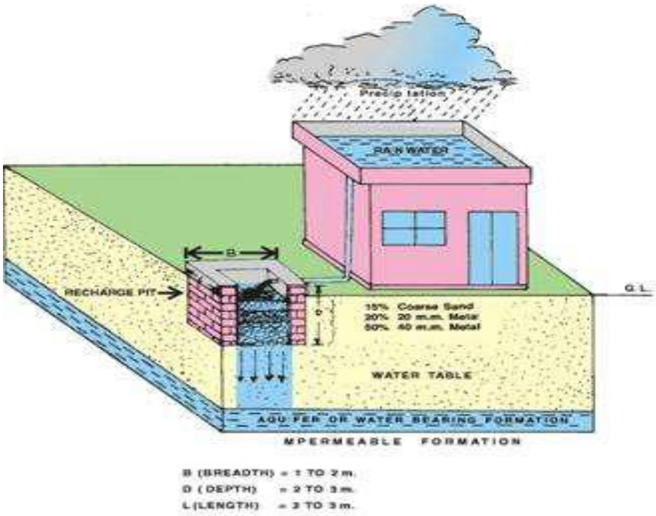
- The collection and recharge system in urban areas needs to be designed in such a way that it does not occupy large space.
- Rain water available from rooftop of building,

1. Recharge Pit

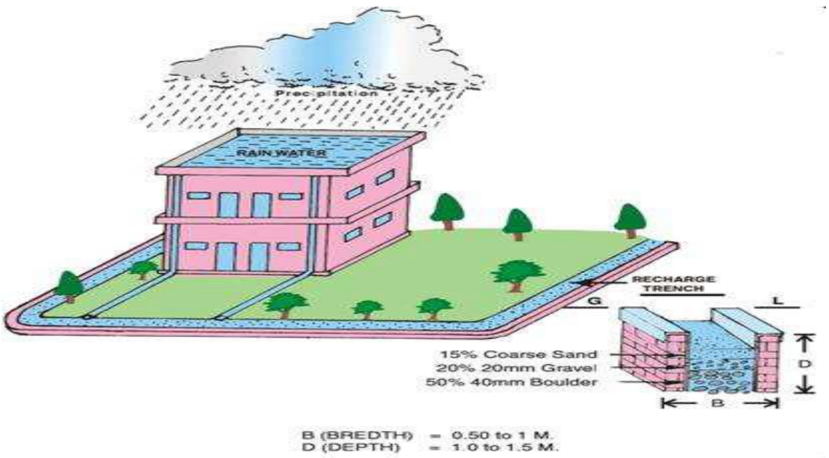
Paved and unpaved areas need to be harvested.

- The quantum of water is comparatively small.
- To recharge shallow aquifers.

- In alluvial areas, where permeable rocks are at shallow depth, this technique is used.
- Recharge pits generally, 1-2m wide and 2-3m deep.
- Filled with boulders at the bottom, gravel in between and course sand at the top.
- Suitable for buildings having a roof area of 100s square meters.
- A mesh is provided at the roof to avoid leaves/debris etc.



2. Recharge Trench



Suitable for buildings having roof area of 200- 300 square meters

- Suitable for permeable strata having shallow depths.
- 0.5-1.0m wide, 1.0-1.5m deep and 10.0-15.0m long trenches to be backfilled with boulders at bottom , gravel in between and graded course sand at top
- Bypass arrangement to be provided before collection chamber to reject water of first shower.
- Top sand layer to be periodically cleaned

3. Tube Wells

- Suitable for areas where shallow aquifers have dried up and existing tube-wells are tapping deeper aquifers.
- PVC pipes are connected to roof drains to collect rainwater
- After rejecting rain water of first shower, subsequent rain showers are taken through a T to an online PVC filter.
- Filter is 1-1.2m in length and its diameter depends on roof area
- Filter is divided into 3 chambers by PVC screens
- Chamber 1 filled with gravels(6-10mm), middle one with pebbles(12-20mm) and last one with stones 20- 40mm size.

Recharge technique for defunct bore-well:

- Recharging is feasible if bore-well accepts water poured in it at a constant rate from tanker of 5000- 6000 litre capacity.
- If bore-well overflows, it's not suitable for research.
- Around bore-well, pit of size 10.0ft*10.0ft*10.0ft to be excavated.
- PVC casing pipe with vertical slits of 50mm*2mm is provided up to 6 feet height from the bottom of the pipe.
- Cement concrete bed is put at pipe bottom for fixity.(Clamp can also be provided)