Conservation of Natural Resources

Module – 2: Water

Global Water Resources

Use of water and for its proper control it is essential to have an idea of availability of water resources of the world. World's oceans cover about ¾ of the earth's surface. The world's total water resources are estimated to be 1.36 x 10^8-million-hectare meters, which is enough to cover the earth with a layer of 3000 meters depth. Out these global water resources about 97.3% is in oceans as saline water only 2.7% is available as fresh water at any time on the earth. 77.2% of fresh water lies as frozen in Polar Regions and another 22.4% as groundwater and soil moisture. The rest is available in lakes, rivers, atmosphere and vegetation.

Distribution of water on the earth

- Saline water (oceans and seas) – 97.3%
- Fresh water - 2.7%

Fresh Water Resources

- Polar ice caps – 77.2%
- Groundwater and soil moisture – 22.4%
- Lakes, Reservoirs and Swamps – 0.35%
- Moisture in the Atmosphere – 0.04%
- Rivers and Streams – 0.01%

Water Resources of India

India has a geographical area of 329 million hectares is blessed with large river basins, which have been divided into 12 major and 48 medium river basins comprising of 252,8 Million hectares and 24.9 million hectares of catchment area respectively. India possesses about 4% of the total average annual runoff of the rivers of the world.

- Annual precipitation in our country includes snow = 4000 km^3
- Average annual runoff of various river basins = 2333 km^3
- Total average annual potential of water available in India = 1869 km^3
- Out of which only 1123 km^3 of water can be put to beneficial use
- Per capita availability of natural runoff = 2200 m^3/year, which is about 1/3rd of per capita availability in USA and Japan. This will further decrease with increase in population.

Availability of Water per capita/per annum in India

Sl No	Years	Per annum/per capita availability of water (m^3)
1	1951	6602
2	1971	4349
3	1981	2829
4	2000	2384
5	2050	1589

The reduction of forests due various man-made activity, has influenced the average rainfall resulting less and less annual rainfall and average water capita has reduced considerably.

Surface Water Potential in India

Sl No.	**River basins**	**Water Available in Million M^3**
1	West flowing rivers (Rivers in Kerala, Karnataka, Goa and also Tapti and Narmada basins)	305471.3
2	East flowing rivers (Kaveri, Godavari, Krishna, Pennar Mahanadi etc)	355599.9
3	Indus basin	79473.1
4	Ganga Basin	550082.7
5	Bramhaputra and Barak basins	590713.6

<u>Water Use Sectors</u>

Agriculture sector withdraws about 80% of all withdrawal. India has low water use efficiency compared to the developed countries. The overall irrigation project efficiency in developed countries is 50 – 60% as compared to only 38% in India. The industrial plants in our countries consume about 2 to 3.5 times more water per unit of production compared to similar plants operating in other countries. In the domestic water sector, the loss of water on account of leakages in mains, communication and service pipes and valves is approximately 30 to 40% of the total flow in the distribution system. The present utilization of water can be estimated as about 750 BCM whereas for the year 2050 it is estimated to be 1180 BCM

Water as a resource, is critical to sustainable development. Besides meeting basic human needs, it is a major source of energy in some parts of the world, while in others its potential as an energy source remains largely untapped. Water is also necessary for agriculture and for many industrial processes. And in more than a few countries, it makes up an integral part of transport systems. With improved scientific understanding, the international community has also come to appreciate more fully the valuable services provided by water-related ecosystems, from flood control to storm protection and water purification. Fresh water is a renewable resource, yet the world's supply of clean, fresh water is steadily decreasing. Water demand already exceeds supply in many parts of the world and as the world population continues to rise, so too does the water demand.

India is rich in surface water resources. Average annual precipitation is nearly 4000 billion cubic meter and the average flow in the river system is estimated to be 1869 cubic km. Because of concentration of rains in the three monsoon months, the utilizable quantum of surface water is about 690 BCM. However, conditions vary widely from region to region. Whereas, some regions are drought affected, others are frequently flooded. In India also, with the rapid increase in the population, the demand for irrigation, human and industrial consumption of water has increased considerably, thereby causing depletion of water resources.

The following table showing the water demand for different sectors in India (All the values are in Billion Cubic Meters)

Sector	**Year 2010**	**Year 2025**	**Year 2050**	**Year 2010**		**Year 2025**	
				Low	**High**	**Low**	**High**
Irrigation	688	910	1071	543	557	561	611
Drinking Water	56	73	102	42	43	55	62
Industry	12	23	62	37	37	67	67
Energy	5	15	130	18	19	31	33
Others	52	72	80	54	54	70	70
Total	**813**	**1093**	**1447**	**694**	**710**	**784**	**843**

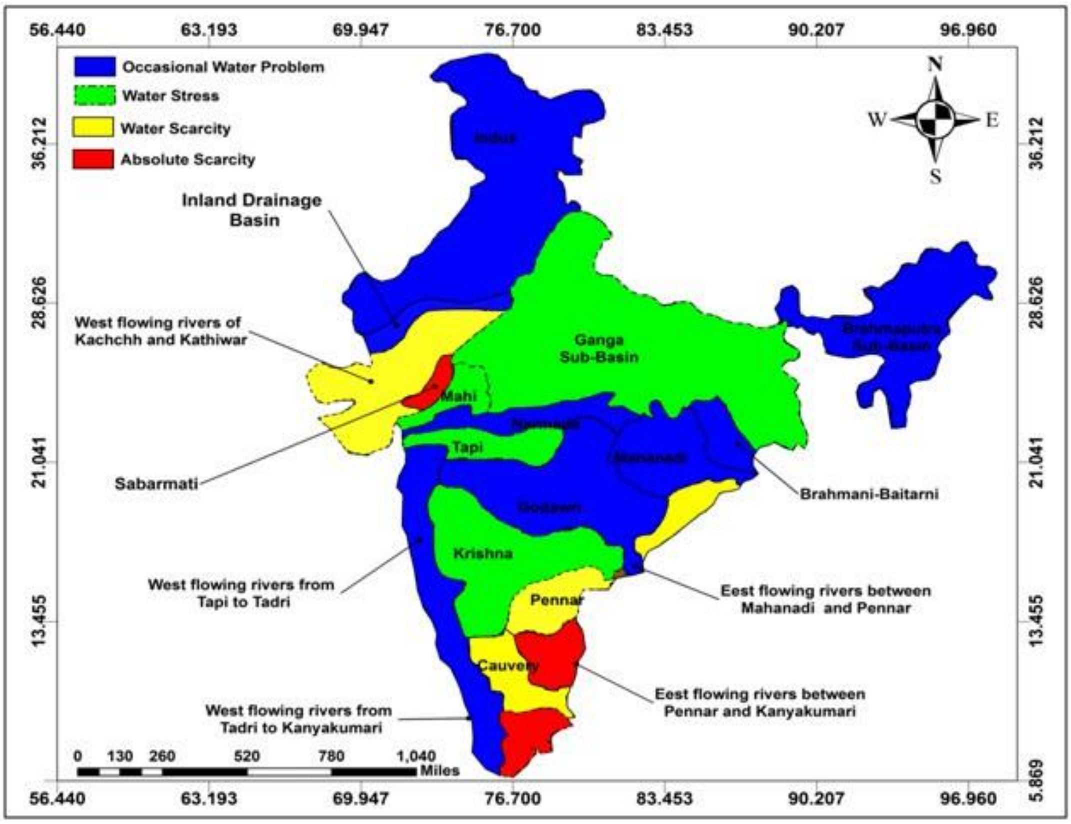
Water Deficit and Water Surplus Basins India

India is a large country with regional differences in per-capita water supply and demand. However, a comprehensive assessment of water accounting across river basins has not been available previously. Such an assessment is appropriate in the context of the increasing focus on integrated river basin management. Attempts to describe the water situation in India at a national level are often misleading because of tremendous diversity in the water situation across the country. To overcome this and obtain a better understanding of water use in India, this report uses data disaggregated at the river basin level, to assess the water supply and demand across the river basins of India, classify river basins according to water scarcities and crop production surpluses or deficits, and discuss issues that are important for future water supply and demand projections. India’s land area can be divided into 19 major river basins.

The per-capita water resource availability of these basins varies from a low of 240 m3 in the Sabarmati basin to a high of 17,000 m3 in the Brahmaputra basin, while water withdrawals vary from 243 m3 in the Meghna basin to 1,670 m3 in the Indus basin. Irrigation is by far the largest user of water in all the basins. The basins of the westerly flowing rivers of the Kutch and Saurashtra regions of Gujarat, and the Luni river—home to 6 percent of the Indian population—are classified as physically water-scarce and food-dependent. The second group of basins, the Indus and Pennar river basins—with 7 percent of India's population—are classified as physically water-scarce, but these basins have significant food surpluses. The grain surplus of the Indus basin alone is able to meet 85 percent of the grain demand from basins with grain production deficits. The water-scarcity problems of the third group of 11 river basins—home to 75 percent of the Indian population—are mixed, but almost all have significant deficits in crop production.

The fourth and fifth groups of river basins are classified as "non-water-scarce and food-sufficient" and "non-water-scarce and food-surplus," respectively. These last two groups of basins are home to 12 percent of India's population. Several factors influence India's future water supply and demand. These include spatial variation and future growth of the population, urbanization and income, and associated changes in dietary preferences, on the crop-consumption side; growth in crop yield, cropping intensity and groundwater use, and contribution to production from rain-fed agriculture, on the crop-production side; and future growth in other factors such as domestic, industrial and environmental water demand, and internal and international trade. These factors need to be carefully assessed in future water supply and demand projections.

The following Map showing the Water surplus and Water Deficit River Basins in India.



Groundwater Resources in India

The science deals with the occurrence distribution and movement of water below the surface of the earth. Groundwater referred to water occupying all the voids with in a geological stratum, the saturated zone, where voids are filled with water & air and distinguished from unsaturated zone. Unsaturated zones are usually found above saturated zones and extending upward to the ground surface. This water includes soil moisture within the root zone.

Geology governs the occurrence and distribution of ground water; hydrology determines the supply of water to ground and fluid mechanics explains its movement.

Groundwater is an important source of water supply. Its use in irrigation, industries, rural water supply has increased in recent times. Groundwater constitutes one portion of the hydrological cycle. Water bearing formations of the earth crust act as conduits for transmission and as reservoirs for storage of water. These aquifer parameters depend on porosity and permeability of the formation

Groundwater is that part of the surface water which occurs within the saturated zone of the earth's crust, where all pores are filled with water. Groundwater has also been referred to as that part of the subsurface water which can be lifted or which flows naturally to earth's surface.

The selection of groundwater as a source of water supply rather than surface water supply has following advantages:

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

Sources of Groundwater

Groundwater is derived from precipitation and recharge from surface water. It is that water that has infiltered into the earth directly from precipitation recharge from streams and other natural water bodies as well as artificial recharge. Infiltration and further sources like rain, melting of snow and ice, rivers and streams, lakes, reservoirs, canals and other water resources are the main sources that contribute to the groundwater of a region.

Conjunctive use of Water

Conjunctive use implies the planned and coordinated harnessing of ground and surface water resources so as to achieve optimal utilisation of total water resources. The ground water may be used to supplement surface-water supplies to reduce peak demands for irrigation and other uses, or to meet deficits in years of low rainfall. On the other hand, surplus surface water may be used in over-draft areas to increase the ground-water storage by artificial recharge. Surface water, ground water or both, depending on the surplus available, can be diverted from areas plentiful to water-deficit areas. In recent years, increasing canal and stream flows from augmentation wells is gaining currency. Better understanding of irrigation methods, irrigation intervals, crop requirements salinization, etc. is of much importance to successful implementation of conjunctive use project.

Groundwater Recharge

A region supplying water to a confined aquifer is known as recharge area. The area occupying higher elevation with deeper water table constitute recharge areas. Topographic lows with shallow water table comprise discharge areas.
Water that is in direct contact vertically with the atmosphere through open spaces in permeable materials is called unconfined water. Confined water is separated from the atmosphere by impermeable layer. The division between confined and unconfined water is entirely gradational the term semi confined water is used for the intermediate conditions. In many areas, the first unconfined water encountered is above the general zone of phreatic water and is a more or less isolated body of water which is controlled by structures and stratigraphy. This is called perched water table. Artesian systems are quite common in major sedimentary basin.

Recharge by Vertical Leakage: The major sources of recharge are direct precipitation on intake areas and/or downward percolation of stream runoff. Recharge from precipitation on intake areas is irregularly distributed in time and place. In humid areas, most recharge from precipitation commonly occurs during spring months when evapo-transpiration is small and soil moisture in maintained at or above the field capacity by frequent rain. During summer months evapo-transpiration and soil moisture requirements are so great that little precipitation percolates to the water table except during excessive rainfall.

The amount of precipitation that reaches the zone of saturation depends upon:

- The character and thickness of the soil and other deposits above and below the water table
- The topography, vegetal cover and land use
- Soil moisture content
- Depth of the water table
- Intensity, duration and seasonal distribution of rainfall
- Occurrence of precipitation
- Meteorological factors like temperature, humidity and wind speed

Recharge direct from precipitation and by infiltration of surface water involves the vertical downward movement of groundwater under the influence of vertical head difference. Recharge involves vertical leakage of water through deposition. The quantity of vertical leakage is varies from place to place and it controlled by:

- The permeability and thickness of the deposit through which leakage occurs/takes place.
- The head difference between the source of water and aquifer.
- The area through which leakage occurs.

Deeply buried aquifers are recharged in part by the vertical leakage of water through thick unconsolidated deposits including clayey material. The water travel in shallow dug or bore wells fluctuates through a wide range in response to periods of above or below normal precipitation. The rate of recharge by vertical leakage through the deposits under pumping conditions may be expressed mathematically;

The recharge rate:

- Varies with vertical head loss, associate with leakage of water
- Dependent on vertical head loss
- Greatest in the deepest part of the cone of depression and decreases with distance from the pumping centre.
- Increases as the piezometric surface declines and the vertical head loss increases.
- Maximum when the piezometric surface of the aquifer is at the base of the deposits through which leakage occurs.
- Valid for one and only one average vertical head loss.

The permeabilities of deposits through which leakage occurs are expressed as co-efficient of permeability (P) and can be computed by multiplying leakage co-efficient by the saturated thickness of the deposit.

Artificial Recharge

It means augmenting the natural infiltration of surface water into a groundwater reservoir at rate vastly exceeds that which would occur naturally. It includes variety of methods such as wells or other specialized construction, water spreading, changing the natural conditions. Other than induced infiltration two major techniques of artificial recharge are surface spreading and injection wells. In surface spreading method large areas of the land may be flooded, basins constructed, ditches or furrows are excavated or exiting stream channels may be modified. Water is diverted into these catchment structures and allowed to infiltrate. Recharge or injection wells might consist of shallow, relatively large pits or shafts or screened wells. Recharging wells or shafts permit direct access from the surface water source to the groundwater reservoir.

Artificial recharge techniques have been used throughout the world for:

- Groundwater management
- Reduction of land subsidence
- Renovation of waste water
- Improvement of groundwater quality
- Storage of stream water during excessive flow
- Reduction of flood flow
- Increase of well yield
- Control of sea water intrusion
- Increase stream flow
- Storage of fresh water etc.

Consideration for Artificial Recharge

The type of artificial recharge system that can be developed at any specific site is controlled by geological and hydrological conditions of that site. Site selection criteria includes:

- Source of recharge water
- Physical and chemical characteristics of water
- Availability of an aquifer
- Thickness and permeability of the material overlying the aquifer
- Thickness and permeability of the aquifer
- Water level difference
- Topography
- Availability of water

Rain Water Harvesting

It consists of two types of water harvesting systems and they are Roof top and In-situ water harvesting systems.

Roof Top Water Harvesting

Roof top rain water harvesting in the collection, filtration and storage of rain water falling on roof tops for domestic consumption both for potable and non-potable purpose. It is in rural context mainly for domestic consumption only. This system needs to be designed based on several factors.

- Roof size and quality of roofing material
- Rainfall quantity, pattern and distribution
- Water demand for household
- Storage space availability and costs
- Availability of alternate reliable source, their distance to the village
- To improve the vegetation
- To raise the water levels in wells, bore wells that are drying up
- To reduce the power consumption

It is defined as augmentation of recharge to the groundwater reservoir by different methods. It may also be practiced for conservation and disposal of run-off reducing the decline in groundwater table and salt water intrusion.

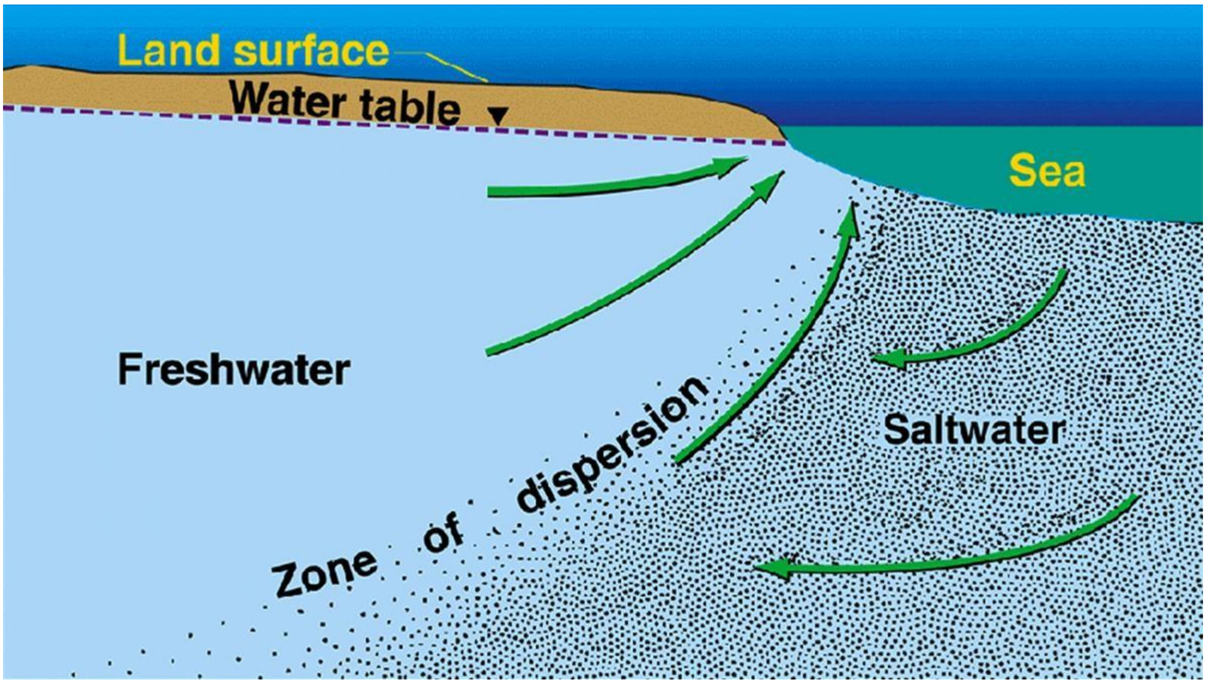
Benefits

- Relief of groundwater overdraft
- Use of groundwater basin as cyclic storage and distribution systems
- Reduction in pumping lift resulting in lower operational cost
- Eliminate capital expenditure for drilling bore wells
- Increased agricultural production
- Prevent salt water intrusion in coastal aquifers
- Present dewatering of all or part of groundwater reservoir
- Prevent land subsidence due to lowering in groundwater table
- Improvement in the quality of water

Sea Water Intrusion and Its Control

Seawater intrusion (SWI) is one of the most challenging and widespread environmental problems that threaten the quality and sustainability of fresh groundwater resources in coastal aquifers. The excessive pumping of groundwater, associated with the lack of natural recharge, has exacerbated the SWI problem in arid and semi-arid regions. Therefore, appropriate management strategies should be implemented in coastal aquifers to control the impacts of SWI problems, considering acceptable limits of economic and environmental costs. The management of coastal aquifers involves the identification of an acceptable ultimate landward extent of the saline water body and the calculation of the amount of seaward discharge of freshwater that is necessary to keep the saline–freshwater interface in a seacoast position.

In general, under natural conditions, the seaward movement of freshwater prevents seawater from encroaching coastal aquifers. An interface between freshwater and seawater is maintained with denser seawater underlying freshwater. When groundwater is pumped from a coastal aquifer, lowered water levels can cause seawater to be drawn toward the freshwater zones of the aquifer. The intruding seawater decreases the freshwater storage in the aquifers. Without treatment, this groundwater does not conform to drinking-water or agricultural water-quality standards.


Land surface
Water table
Sea
Freshwater
Saltwater
Zone of dispersion