Principles of Water Resources Engineering

Surface and Ground
Water Resources

1.1.0 Introduction
Water in our planet is available in the atmosphere, the oceans, on land and within the soil and fractured rock of the earth's crust Water molecules from one location to another are driven by the solar energy. Moisture circulates from the earth into the atmosphere through evaporation and then back into the earth as precipitation. In going through this process, called the Hydrologic Cycle (Figure 1), water is conserved – that is, it is neither created nor destroyed.

Figure 1. Hydrologic cycle

The earth's total water content in the hydrologic cycle is not equally distributed.
Fresh water 2.5%

Saline water in
Oceans 97.5%

Figure 2. Total global water content

The oceans are the largest reservoirs of water, but since it is saline it is not readily usable for requirements of human survival. The freshwater content is just a fraction of the total water available (Figure 3).

Lakes, Rivers, and Soil Moisture
0.4%

Ground Water
25.5 %

Ice caps and Glaciers
74%

Figure 3. Global fresh water distribution

Again, the fresh water distribution is highly uneven, with most of the water locked in frozen polar ice caps.

The hydrologic cycle consists of four key components
1 . Precipitation

2. Runoff

3. Storage

4. Evapotranspiration

These are described in the next sections.

1.1.1 Precipitation

Precipitation occurs when atmospheric moisture becomes too great to remain suspended in clouds. It denotes all forms of water that reach the earth from the atmosphere, the usual forms being rainfall, snowfall, hail, frost and dew. Once it reaches the earth's surface, precipitation can become surface water runoff, surface water storage, glacial ice, water for plants, groundwater, or may evaporate and return immediately to the atmosphere. Ocean evaporation is the greatest source (about 90%) of precipitation.

Rainfall is the predominant form of precipitation and its distribution over the world and within a country. The former is shown in Figure 4, which is taken from the

The distribution of precipitation for our country as recorded by the India Meteorological Department (IMD) is presented in the web–
(Courtsey: India Meteorological Department)

India has a typical monsoon climate. At this time, the surface winds undergo a complete reversal from January to July, and cause two types of monsoon. In winter dry and cold air from land in the northern latitudes flows southwest (northeast monsoon), while in summer warm and humid air originates over the ocean and flows in the opposite direction (southwest monsoon), accounting for some 70 to 95 percent of the annual rainfall. The average annual rainfall is estimated as 1170 mm over the country, but varies significantly from place to place. In the northwest desert of Rajasthan, the average annual rainfall is lower than 150 mm/year. In the broad belt extending from Madhya Pradesh up to Tamil Nadu, through Maharastra, parts of Andhra Pradesh and Karnataka, the average annual rainfall is generally lower than 500 mm/year. At the other extreme, more than 10000 mm of rainfall occurs in some portion of the Khasi Hills in the northeast of the country in a short period of four months. In other parts of the northeast (Assam, Arunachal Pradesh, Mizoram, etc.,) west coast

and in sub-Himalayan West Bengal the average annual rainfall is about 2500 mm.

Except in the northwest of India, inter annual variability of rainfall in relatively low. The main areas affected by severe droughts are Rajasthan, Gujarat (Kutch and Saurashtra).

The year can be divided into four seasons:

The winter or northeast monsoon season from January to February.
The hot season from March to May.

The summer or south west monsoon from June to September.

The post – monsoon season from October to December.

The monsoon winds advance over the country either from the Arabian Sea or from the Bay of Bengal. In India, the south-west monsoon is the principal rainy season, which contributes over 75% of the annual rainfall received over a major portion of the country. The normal dates of onset (Figure 6) and withdrawal (Figure 7) of monsoon rains provide a rough estimate of the duration of monsoon rains at any region.

(MARCH-MAY)

Runoff is the water that flows across the land surface after a storm event. As rain falls over land, part of that gets infiltrated the surface as overland flow. As the flow bears down, it notches out rills and gullies which combine to form channels. These combine further to form streams and rivers.

The geographical area which contributes to the flow of a river is called a river or a watershed. The following are the major river basins of our country, and the

Brahmaputra (Figure 10)
Krishna (Figure 11)
Godavari (Figure 12)
Mahanandi (Figure 13)
Sabarmati (Figure 14)
Tapi (Figure 15)

. Brahmani–Baitarani (Figure 16)
10.Narmada (Figure 17)
11.Pennar (Figure 18)
12.Mahi (Figure 19)

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FIGURE 8. INDUS BASIN (PORTION WITHIN INDIA)

Some statistical information about the surface water resources of India,

1.1.3 Storage

Portion of the precipitation falling on land surface which does not flow out as runoff gets stored as either as surface water bodies like Lakes, Reservoirs and Wetlands or as sub–surface water body, usually called Ground water.

Ground water storage is the water infiltrating through the soil cover of a land surface and traveling further to reach the huge body of water underground. As

mentioned earlier, the amount of ground water storage is much greater than that of lakes and rivers. However, it is not possible to extract the entire groundwater by practicable means. It is interesting to note that the groundwater also is in a state of continuous movement – flowing from regions of higher potential to lower. The rate of movement, however, is exceptionally small compared to the surface water movement.

The following definitions may be useful:

Lakes: Large, naturally occurring inland body of water

Reservoirs: Artificial or natural inland body of water used to store water to meet various demands.

Wet Lands: Natural or artificial areas of shallow water or saturated soils that contain or could support water–loving plants.

1.1.4 Evapotranspiration

Evapotranspiration is actually the combination of two terms – evaporation and transpiration. The first of these, that is, evaporation is the process of liquid converting into vapour, through wind action and solar radiation and returning to the atmosphere. Evaporation is the cause of loss of water from open bodies of water, such as lakes, rivers, the oceans and the land surface. It is interesting to note that ocean evaporation provides approximately 90 percent of the earth's precipitation.

Transpiration is the process by which water molecules leaves the body of a living plant and escapes to the atmosphere. The water is drawn up by the plant root system and part of that is lost through the tissues of plant leaf (through the stomata). In areas of abundant rainfall, transpiration is fairly constant with variations occurring primarily in the length of each plants growing season. However, transpiration in dry areas varies greatly with the root depth.

Evapotranspiration, therefore, includes all evaporation from water and land surfaces, as well as transpiration from plants.

1.1.5 Water resources potential

1.1.5.1 Surface water potential:

The average annual surface water flows in India has been estimated as 1869 cubic km. This is the utilizable surface water potential in India. But the amount of water that can be actually put to beneficial use is much less due to severe limitations posed by Physiography, topography, inter–state issues and the present state of technology to harness water resources economically. The recent estimates made by the Central Water Commission, indicate that the water resources is utilizable through construction of structures is about 690 cubic km (about 36% of the total). One reason for this vast difference is that not only does the whole rainfall occur in about four months a year but the spatial and temporal distribution of rainfall is too uneven due to which the annual average has very little significance for all practical purposes.

Monsoon rain is the main source of fresh water with 76% of the rainfall

occurring
between June and September under the influence of the southwest monsoon. The average annual precipitation in volumetric terms is 4000 cubic km. The average annual surface flow out of this is 1869 cubic km, the rest being lost in infiltration and evaporation.

1.1.5.2 Ground water potential:

The potential of dynamic or rechargeable ground water resources of our country has been estimated by the Central Ground Water Board to be about 432 cubic km.

Ground water recharge is principally governed by the intensity of rainfall as also
the soil and aquifer conditions. This is a dynamic resource and is replenished every year from natural precipitation, seepage from surface water bodies and conveyance systems return flow from irrigation water, etc.

The highlighted terms are defined or explained as under:

Utilizable surface water potential: This is the amount of water that can be purpose fully used, without any wastage to the sea, if water storage and conveyance structures like dams, barrages, canals, etc. are suitably built at requisite sites.

Central Water Commission: Central Water Commission is an attached office of

Ministry of Water Resources with Head Quarters at New Delhi. It is a premier technical organization in the country in the field of water resources since 1945.

The commission is charged with the general responsibility of initiating, coordinating and furthering, in consultation with the State Governments concerned, schemes for control, conservation and utilization of water resources throughout the country, for purpose of flood control, irrigation, navigation, drinking water supply and water power development.

Central Ground Water Board: It is responsible for carrying out nation-wide surveys and assessment of groundwater resources and guiding the states appropriately in scientific and technical matters relating to groundwater. The Central Ground Water Board has generated valuable scientific and technical data through regional hydro geological surveys, groundwater exploration, resource and water quality monitoring and research and development. It assists the States in developing broad policy guidelines for development and management of groundwater resources including their conservation, augmentation and protection from pollution, regulation of extraction and conjunctive use of surface water and
ground water resources. The Central Ground Water Board organizes Mass Awareness Programmes to create awareness on various aspects of groundwater investigation, exploration, development and management.

Ground water recharge: Some of the water that precipitates, flows on ground surface or seeps through soil first, then flows laterally and some continues to percolate deeper into the soil. This body of water will eventually reach a saturated zone and replenish or recharge groundwater supply. In other words, the recuperation of groundwater is called the groundwater recharge which is done to increase the groundwater table elevation. This can be done by many artificial techniques, say, by constructing a detention dam called a water spreading dam or a dike, to store the flood waters and allow for subsequent seepage of water into the soil, so as to increase the groundwater table. It can also be done by the method of rainwater harvesting in small scale, even at individual houses. The all India figure for groundwater recharge volume is 418.5 cubic km and the per capita annual volume of groundwater recharge is 412.9 cubic m per person.

1.1.6 Land and water resources of India

The two main sources of water in India are rainfall and the snowmelt of glaciers in the Himalayas. Although reliable data on snow cover in India are not available, it is estimated that some 5000 glaciers cover about 43000 km2 in the Himalayas with a total volume of locked water estimated at 3870 km3. considering that about 10000 km2 of the Himalayan glacier is located within India, the total water yield from snowmelt contributing to the river runoff in India
may be of the order of 200 km3/year. Although snow and glaciers are poor producers of fresh water, they are good distributors as they yield at the time of
need, in the hot season.
ear to Bangladesh ("|rrigation in Aisa in Figures",
Food and Agricultural Organisation of the United Nations, Rome, 1999;
http://www.fao.org/ag/agL/public.stm). For further information, one may also check the web–site "Earth Trends" http://elearthtrends.wri.org.

The land and water resources of India may be summarized as follows.

Geographical area 329 million
hectare
Natural runoff (Surface water and ground water) 1869 cubic
km/year
Estimated utilizable surface water potential 690 cubic
km/year
Ground water resources 432 cubic
km/year
Available ground water resource for irrigation 361 cubic
km/year
Net utilizable ground water resource for irrigation 325 cubic
km/year

1.1.7 International indicators for comparing water resources
potential

Some of the definitions used to quantify and compare water resource potential internationally are as follows:

1. Internal Renewable Water Resources (IRWR): Internal Renewable
Water Resources are the surface water produced internally, i.e., within a country. It is that part of the water resources generated from endogenous precipitation. It is the sum of the surface runoff and groundwater recharge occurring inside the countries' borders. Care is taken strictly to avoid double counting of their common part. The IRWR figures are the only water resources figures that can be added up for regional assessment and they are being used for this purpose.

. Surface water produced internally: Total surface water produced

internally includes the average annual flow of rivers generated from endogenous precipitation (precipitation occurring within a country's borders). It is the amount of water produced within the boundary of a country, due to precipitation. Natural incoming flow originating from outside a country's borders is not included in the total.

. Groundwater recharge: The recuperation of groundwater is called the

groundwater recharge. This is requisite to increase the groundwater table elevation. This can be done by many artificial techniques, say, by constructing a detention dam called a water spreading dam or a dike, to store the flood waters and allow for subsequent seepage of water into the soil, so as to increase the groundwater table. It can also be done by the method of rainwater harvesting in small scale, even at individual houses. The groundwater recharge volume is 418.5 cubic km and the per capita annual volume of groundwater recharge is 412.9 cubic m per person.

. Overlap: It is the amount of water quantity, coinciding between the

surface water produced internally and the ground water produced internally within a country, in the calculation of the Total Internal Renewable Water Resources of the country. Hence, Overlap = Total |RWR– (Surface water produced internally + ground water produced internally). The overlap for Indian water resources is 380 cubic km.

. Total internal Renewable Water Resources: The Total Internal

Renewable Water Resources are the sum of IRWR and incoming flow originating outside the countries' borders. The total renewable water resources of India are 1260.5 cubic km.

. Per capita Internal Renewable Water Resources: The Per capita annual

average of Internal Renewable Water Resources is the amount of average IRWR, per capita, per annum. For India, the Per capita Internal Renewable Water Resources are 1243.6 cubic m.

. Net renewable water resources: The total natural renewable water

resources of India are estimated at 1907.8 cubic km per annum, whereas the total actual renewable water resources of India are 1896.7 cubic km.

. Per capita natural water resources: The present per capita availability of

natural water, per annum is 1820 cubic m, which is likely to fall to 1341 cubic m, by 2025.

. Annual water withdrawal: The total amount of water withdrawn from the

water resources of the country is termed the annual water withdrawal. In India, it amounts 500000 to million cubic m.

10. Per capita annual water withdrawal: It is the amount of water withdrawn from the water resources of the country, for various purposes. The per capita annual total water withdrawal in India is 592 cubic m per person.

The above definitions have been provided by courtesy of the following web–site: http://earthtrends.wri.org/text/theme2vars.htm.

1.1.8 Development of water resources

Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, water as a resource requires special attention. Requirement of technological/engineering intervention for development of water resources to meet the varied requirements of man or the human demand for water, which are also unevenly distributed, is hence essential.

The development of water resources, though a necessity, is now pertinent to be made sustainable. The concept of sustainable development implies that development meets the needs of the present life, without compromising on the ability of the future generation to meet their own needs. This is all the more important for a resource like water. Sustainable development would ensure minimum adverse impacts on the quality of air, water and terrestrial environment.
The long term impacts of global climatic change on various components of hydrologic cycle are also important.

India has sizeable resources of water and a large cultivable land but also a large and growing population to feed. Erratic distribution of rainfall in time and space leads to conditions of floods and droughts which may sometimes occur in the same region in the same year. India has about 16% of the world population as compared to only 4% of the average annual runoff in the rivers.

With the present population of more than 1000 million, the per capita water availability comes to about 1170 m3 per person per year. Here, the average does not reflect the large disparities from region to region in different parts of the country. Against this background, the problems relating to water resources development and management have been receiving critical attention of the Government of India. The country has prepared and adopted a comprehensive National Water Policy in the year 1987, revised in 2002 with a view to have a systematic and scientific development of it water resources. This has been dealt with in Lesson 1.3, “Policies for water resources development”.

Some of the salient features of the National Water Policy (2002) are as follows:

0 Since the distribution of water is spatially uneven, for water scarce areas, local technologies like rain water harvesting in the domestic or community level has to be implemented.

o Technology for/Artificial recharge of water has also to be bettered.
o Desalination methods may be considered for water supply to coastal towns.

1.1.9 Present water utilization in India

Irrigation constitutes the main use of water and is thus focal issue in water resources development. As of now, irrigation use is 84 percent of total water use. This is much higher than the world’s average, which is about 65 percent. For advanced nations, the figure is much lower. For example, the irrigation use of water in USA is around 33 percent. In India, therefore, the remaining 16 percent of the total water use accounts for Rural domestic and livestock use, Municipal domestic and public use, Thermal-electric power plants and other industrial uses.
The term irrigation is defined as the artificial method of applying water to crops.

Irrigation increases crop yield and the amount of land that can be productively farmed, stabilizes productivity, facilitates a greater diversity of crops, increases farm income and employment, helps alleviate poverty and contributes to regional development.

1.1.10 Need for future development of water resources

The population of India has been estimated to stabilize by about 2050 A.D. By that time, the present population of about 1000 million has been projected to be about 1800 million (considering the low, medium and high estimates of 1349 million 1640 million and 1980 million respectively). The present food grain availability of around 525 grams per capita per day is also presumed to rise to about 650 grams, considering better socio–economic lifestyle (which is much less than the present figures of 980 grams and 2850 grams per capita per day for China and U.S.A., respectively). Thus, the annual food grain requirement for India is estimated to be about 430 MT. Since the present food grain production is just sufficient for the present population, it is imperative that additional area needs to be brought under cultivation. This has been estimated to be 130 Mha for food crop alone and 160 Mha for all crops to meet the demands of the country by 2050 A.D.

Along with the inevitable need to raise food production, substantial thrust should be directed towards water requirement for domestic use. The national agenda for governance aims to ensure provision of potable water supply to every individual in about five years time. The National Water Policy (2002) has accorded topmost water allocation priority to drinking water. Hence, a lot of technological intervention has to be made in order to implement the decision. But this does not

mean that unlimited funds would be allocated for the drinking water sector. Only 20% of urban demand is meant for consumptive use . A major concern will therefore be the treatment of urban domestic effluents.

Major industrial thrust to steer the economy is only a matter of time. By 2050, India expects to be a major industrial power in the world. Industry needs water fresh or recycled. Processing industries depend on abundance of water. It is estimated that 64 cubic km of water will be needed by 2050 A.D. to sustain the industries. Thermal power generation needs water including a small part that is consumptive. Taking into account the electric power scenario in 2050 A.D., energy related requirement (evaporation and consumptive use) is estimated at 150 cubic km.

Note:

Consumptive use: Consumptive use is the amount of water lost in evapo-transpiration from vegetation and its surrounding land to the atmosphere, inclusive of the water used by the plants for building their tissues and to carry on with their metabolic processes. Evapo-transpiration is the total water lost to the atmosphere from the vegetative cover on the land, along with the water lost from the surrounding water body or land mass.

1.1.11 Sustainable water utilisation

The quality of water is being increasingly threatened by pollutant load, which is on the rise as a consequence of rising population, urbanization, industrialization, increased use of agricultural chemicals, etc. Both the surface and ground water have gradually increased in contamination level. Technological intervention in the form of providing sewerage system for all urban conglomerates, low cost sanitation system for all rural households, water treatment plants for all industries emanating polluted water, etc. has to be made. Contamination of ground water due to over-exploitation has also emerged as a serious problem. It is difficult to restore ground water quality once the aquifer is contaminated. Ground water contamination occurs due to human interference and also natural factors . To promote human health, there is urgent need to prevent contamination of ground water and also promote and develop cost–effective techniques for purifying contaminated ground water for use in rural areas like solar stills.

In summary, the development of water resources potential should be such that in doing so there should not be any degradation in the quality or quantity of the resources available at present. Thus the development should be sustainable for future.