Dr. Md. Sabbir Mostafa Khan
mostafakhan@wre.buet.ac.bd

Lecture Note – 1

Hydrology

Hydrology deals with the waters of the earth, their distribution and circulation, their physical and chemical properties, and their interaction with the environment, including interaction with living things and, in particular, human beings.

Engineering Hydrology

Engineering hydrology includes those segments of the field pertinent to design and operation of engineering projects for the control and use of water.

Practical Applications of Hydrology

- Design and operation of hydraulic structures
- Water supply
- Wastewater treatment and disposal
- Irrigation and drainage
- Hydropower generation
- Flood control
- Navigation
- Erosion and sediment control
- Salinity control
- Recreational use of water
- Fish and wildlife protection

Dr. Md. Sabbir Mostafa Khan
mostafakhan@wre.buet.ac.bd

Geologic Cycle

Throughout the nearly 4.6 billion years of earth's history, chemical compounds that make up the surface and bedrock near the surface have been continuously created from the chemical elements, maintained, and changed by physical, chemical, and biological processes. Collectively, the processes responsible for formation and change of earth materials are referred to as the geologic cycle, which is actually a group of subcycles: tectonic, hydrologic, rock, and biogeochemical.

Hydrologic cycle (Water cycle)

The hydrologic cycle is a continuous process by which water is transported from the oceans to the atmosphere to the land and back to the sea. Water on earth exists in a space called the hydrosphere which extends about 15 km up into the atmosphere and about 1 km down into the lithosphere, the crust of the earth. Water circulates in the hydrosphere through the maze of paths constituting the hydrologic cycle.

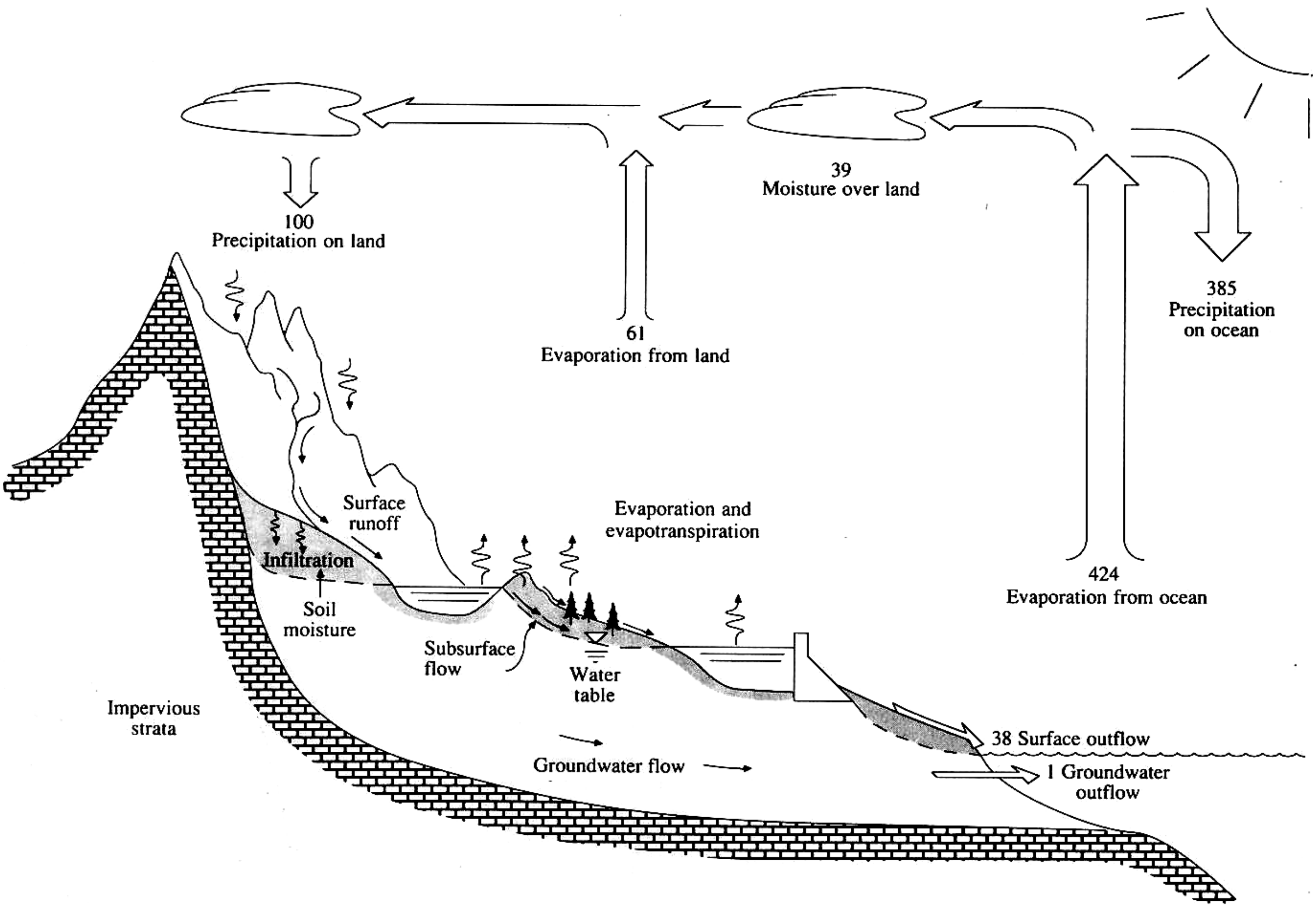

Fig. 1.1: Hydrologic Cycle

Dr. Md. Sabbir Mostafa Khan
mostafakhan@wre.buet.ac.bd

Processes in hydrologic cycle

Evaporation

Water evaporates from the oceans and the land surface due to the heat energy provided by the solar radiation to become part of the atmosphere.

Evapotranspiration

Evaporation from the land surface is accompanied by transpiration by plants. Transpiration is the evaporation of water from aerial parts and of plants, especially leaves but also stems, flowers and fruits. Transpiration is a side effect of the plant needing to open its stomata in order to obtain carbon dioxide gas from the air for photosynthesis.

Precipitation

Water vapor is transported and lifted in the atmosphere until it condenses and precipitates on the land or the oceans as rain, snow, hail, sleet etc. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years.

Interception by vegetation and depression storage

A part of the precipitated water may be intercepted by vegetation or temporarily retained in the soil in surface depressions (depression storage) near where it falls and is ultimately returned to the atmosphere by evaporation and transpiration by plants.

Infiltration and percolation

A portion of the water that reaches the ground enters the earth's surface through infiltration. Some part of it then penetrates further into the ground to reach the ground water table (percolation).

Subsurface flow and base flow

A part of the infiltrated water flows laterally through the unsaturated soil (subsurface flow). Lateral movement of groundwater in the saturated zone is known as base flow. Some groundwater stays close to the land surface and can seep back into surface-water bodies (e.g. lakes, rivers etc.) and the ocean. Some ground water finds openings in the land surface and emerges as freshwater springs.

Surface runoff

A portion of the precipitated water flows over the soil surface (surface runoff). Initially it is a thin layer of sheet flow known as overland flow. Ultimately it reaches minor channels (gullies, rivulets etc.), flows to major streams and rivers, and finally reaches an ocean. Sometimes, surface runoff flows into closed water bodies (i.e. lakes).

Snowmelt

Snow packs in warmer climates often melt when spring arrives, and the melted water flows overland as snowmelt.

Dr. Md. Sabbir Mostafa Khan
mostafakhan@wre.buet.ac.bd

Estimated world water quantities

Table 1.1: Estimated world water quantities

Item	Area (10^6 km^2)	Volume (km^3)	Percent of total water	Percent of fresh water
Oceans	361.3	1,338,000,000	96.5	
Groundwater				
Fresh	134.8	10,530,000	0.76	30.1
Saline	134.8	12,870,000	0.93	
Soil Moisture	82.0	16,500	0.0012	0.05
Polar ice	16.0	24,023,500	1.7	68.6
Other ice and snow	0.3	340,600	0.025	1.0
Lakes				
Fresh	1.2	91,000	0.007	0.26
Saline	0.8	85,400	0.006	
Marshes	2.7	11,470	0.0008	0.03
Rivers	148.8	2,120	0.0002	0.006
Biological water	510.0	1,120	0.0001	0.003
Atmospheric water	510.0	12.900	0.001	0.04
Total water	510.0	1,385,984,610	100	
Fresh water	148.8	35,029,210	2.5	100

Table from World Water Balance and Water Resources of the Earth, Copyright, UNESCO, 1978.

The Table 1.1 lists estimated quantities of water in various forms on the earth. About 96.5% of all the earth's water is in the oceans. If the earth were a uniform sphere, this quantity would be sufficient to cover it to a depth of about 2.6 km. Of the remainder, 1.7% is in the polar ice, 1.7% in groundwater and only 0.1% in the surface and atmospheric water systems. The atmospheric water system, the driving force of surface water hydrology, contains only 12,900 km^3 of water, or less than one part in 100,000 of all the earth's water.

Of the earth's fresh water, about two-thirds is polar ice and most of the remainder is groundwater going down to a depth of 200 to 600 m. Most groundwater is saline below this depth. Only 0.006% of fresh water is contained in the rivers. Biological water, fixed in the tissues of plants and animals, make up about 0.003% of all fresh water, equivalent to half the volume contained in rivers.

Table 1.2: Global annual water balance

		Ocean	Land
Area (km^2)		361,300,000	148,800,000
Precipitation	(km^3/yr)	458,000	119,000
	(mm/yr)	1270	800
	(in/yr)	50	31
Evaporation	(km^3/yr)	505,000	72,000
	(mm/yr)	1400	484
	(in/yr)	55	19
Runoff to ocean			
Rivers	(km^3/yr)	–	44,700
Groundwater	(km^3/yr)	–	2200
Total runoff	(km^3/yr)	–	47,000
	(mm/yr)	–	316
	(in/yr)	–	12

Global annual water balance shown in the Table 1.2; Fig. 1.1 it shows the major components in units relative to an annual land precipitation volume of 100. It can be seen that evaporation from the land surface consumes 61% of this precipitation, the remaining 39% forming runoff to the oceans, mostly as surface water. Evaporation from the oceans contributes nearly 90% of atmospheric moisture.

Residence time

The residence time T_r is the average duration for a water molecule to pass through a subsystem of the hydrologic cycle. It is calculated by dividing the volume of water S in storage by the flow rate Q (i.e. $T_r = S/Q$).

The volume of atmospheric moisture (Table 1.1) is 12,900 km^3. The flow rate of moisture from the atmosphere as precipitation (Table 1.2) is 458,000 + 119,000 = 577,000 km^3/yr (or the flow rate of moisture to the atmosphere as evaporation is 505,000 + 72,000 = 577,000 km^3/yr), so the average residence time for moisture in the atmosphere is T_r = 12,900/577,000 = 0.022 yr = 8.2 days. The very short residence time for moisture in the atmosphere is one reason why weather cannot be forecast accurately more than a few days ahead.

Similarly, the volume of water in the rivers (Table 1.1) is 2,120 km^3. The average flow rate of water in global rivers (Table 1.2) is 44,700 km^3/yr, so the residence time for global rivers is T_r = 2,120/44,700 = 0.0474 yr = 17.3 days. The global residence time for groundwater is T_r = (10,530,000+12,870,000)/2,200 = 10,636.36 yrs. The very long residence time for groundwater is the reason why it takes long time to clean groundwater if it is contaminated.