Geomorphic Processes: Landforms and Landscapes
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Lecture - 8
Surface and Ground Water System and Management
(Part – II)

So, welcome back. So in last lecture, we were talking about the surface water and then basically the surface water when we say it, then immediately things comes in our mind is runoff. So, runoff will be affected by many factors, mainly the subsurface lithology, slope and of course, it will also affect the sediment yield, and then at last we discussed about that the 2 basins, basin A and basin B which shows the higher drainage density in the upper portion, whereas the lower density in the lower portion.

That was basically because the upper portion is occupied by or underlain by shale, whereas the lower portion is underlain by sandstone. The sandstone is more porous and permeable, whereas the shale which is mostly composed of very fine clay particles is mostly we see that it is less permeable and more porous.

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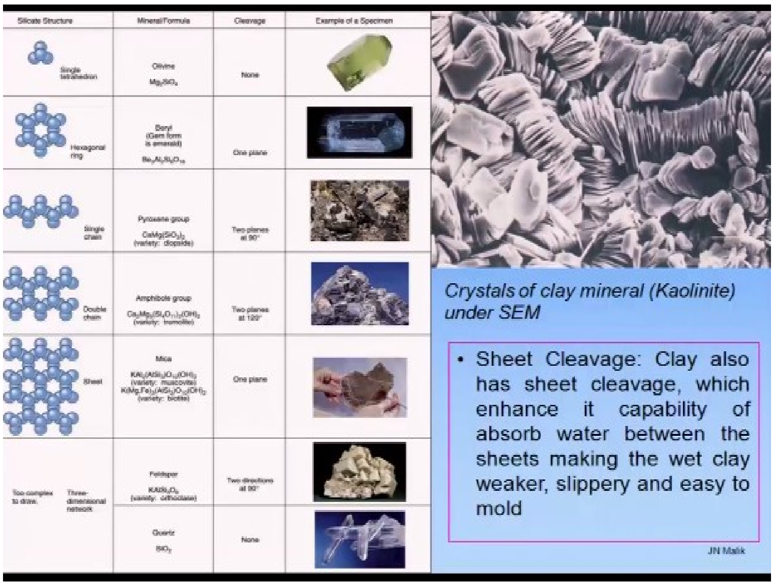

So, the clay has the capability of holding water, but it would not allow the water to flow through and that is one of the reason why we see a higher drainage density in the upper portion of two drainage basins A and B which we were showing in the previous slide.

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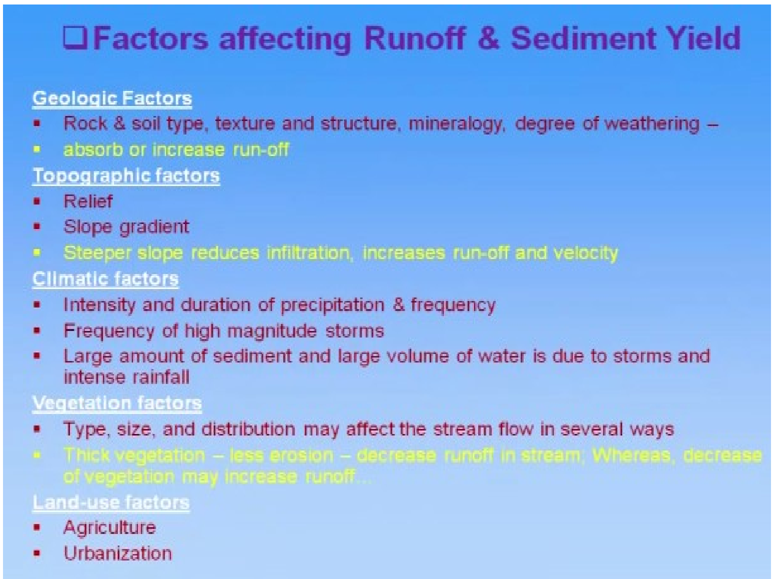

Moving further factors affecting runoff and sediment yield. So, most important is the geologic factors rock and soil type, texture and structure, mineralogy, and degree of weathering. Absorb or increase runoff. So, this will affect of course whether the water which is falling on the surface through precipitation will be absorbed or there will be increase in runoff. So, rocks or soil type and texture and structure, mineralogy, degree of weathering in the area will affect the runoff.

Then comes the topography that is relief, slope gradient, steeper slope reduce infiltration, will increase runoff and velocity. Now, these are couple of points which are very much important when we talk about the flood hazard, just keep in mind that these are the important points, these are important points which we will be talking when we talk about the floods hazard. Then climatic factors, intensity and duration of precipitation and frequency of precipitation, that is the frequency of rain that will also affect the runoff and sediment yield.

Frequency of high magnitude storms in the region will also affect the runoff and sediment yield. A large amount of sediment and large volume of water is due to storms and intense runoff. Then comes the vegetation factor, type, size, and distribution may affect the stream flow in several ways. Thick vegetation will protect the erosion. So, less erosion will decrease runoff in streams, whereas decrease of vegetation may increase runoff. Land-use factors, agricultural, urbanization will definitely affect the runoff and sediment yield.

So, if you go for urbanization, you are going to remove lot of agricultural field or you are going to do deforestation and finally resulting into the erosion whenever there is a precipitation of the rain. So, these are few points, geological factors, topography, climate, vegetation, and land use factor which are affecting runoff and sediment yield.

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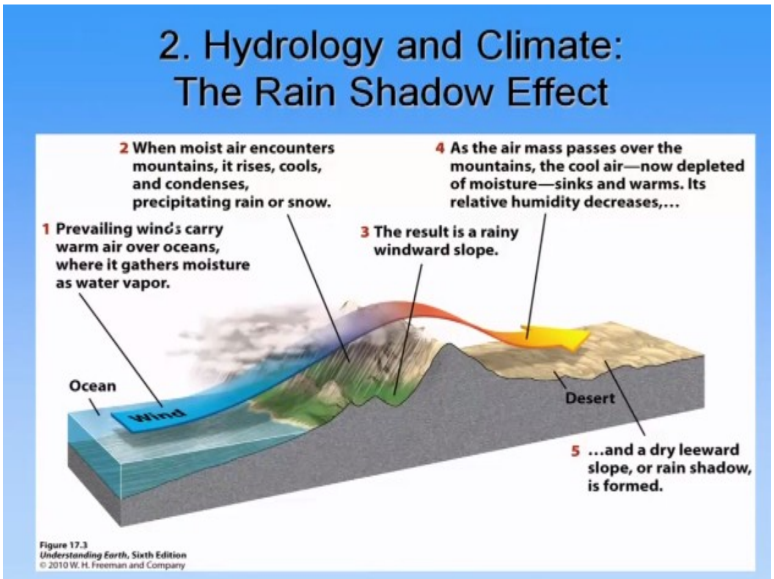

Hydrological or hydrology and climate. Again, this is what we see close to Himalayas. So we have the towering height of mountains and the wind which is flowing from ocean through or flow across the mountains. So, the prevailing winds carry warm air over oceans where it gathers moisture and water vapor. Further when it reaches close to the mountains, when the moist air encounters mountains, it rises, cools, and condense, precipitating rain and resulting into the rainfall or the snowfall, and third is that it is resulting or result into rainy windward slope, this is the windward slope.

As the air mass passes over the mountains, the cool air now depleted of moisture sinks and warms it, its relative humidity decreases. Hence, what we see in terms of the landform here is the desert. So, the fifth one is dry leeward slope or rain shadow region is formed. So, this is how the hydrological cycle is connected the landform formation. So, the desert what we see here in the leeward side is because of the air masses which passes over the mountains, its relative humidity decreases, and the best example is Himalaya and Tibet, on the other side of the Tibet where we have the desert.

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So, now we will talk about some important points, what we mean by aquifer, aquiclude, aquitard and what is the porosity and permeability of the material and how it varies from material to material, we will see in this part. So subsurface transfer, mainly the groundwater

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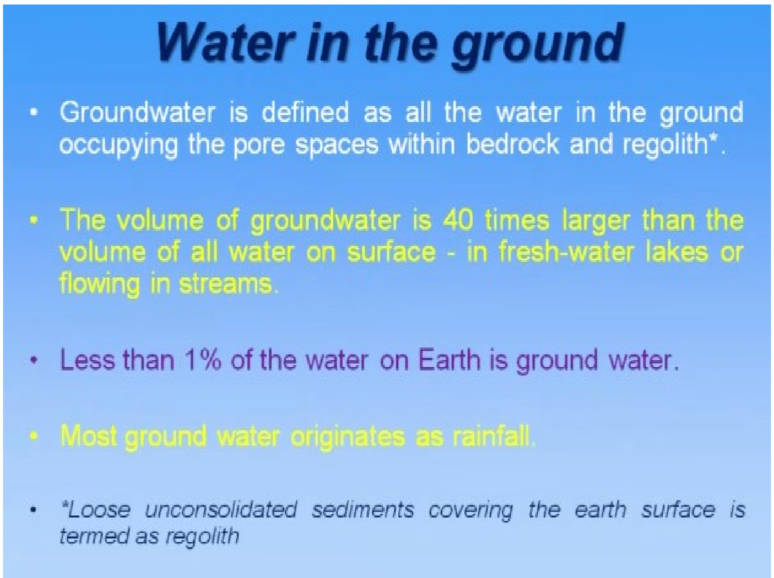

So, water in the ground, ground water is defined as all the water in the ground occupying the pore space within bedrock or soil. The volume of groundwater is 40% larger than the volume of all water on surface. So, this is another important point which you should keep in mind that the groundwater is 40 times larger than the volume of all water on surface, either it is in the form of fresh-water lake or flowing in the streams. Less than1% of water on earth is groundwater. Most groundwater originates as rainfall. Regolith is loose unconsolidated sediments covering the earth's surface.

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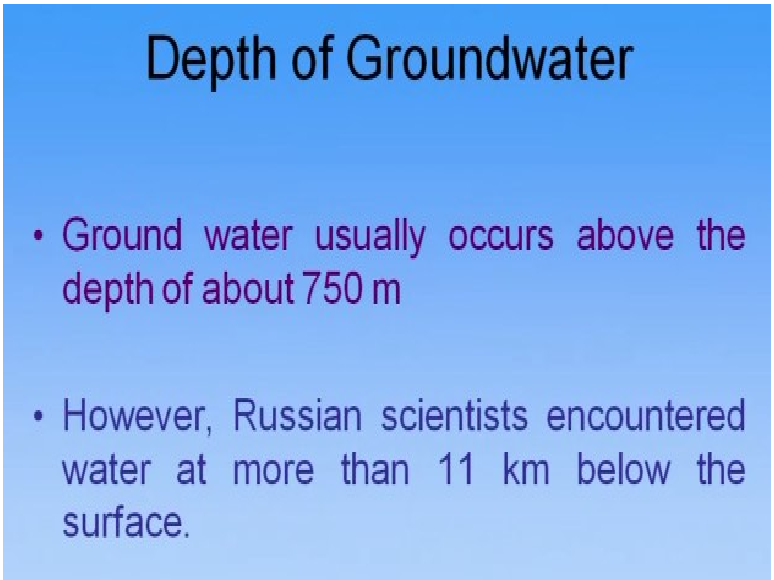

Depth of groundwater it varies from few meters or hundreds of meters to kilometers. So, the ground water usually occurs about the depth of 750 meters. However, Russian scientists encounter water at more than 11 kilometers below the surface.

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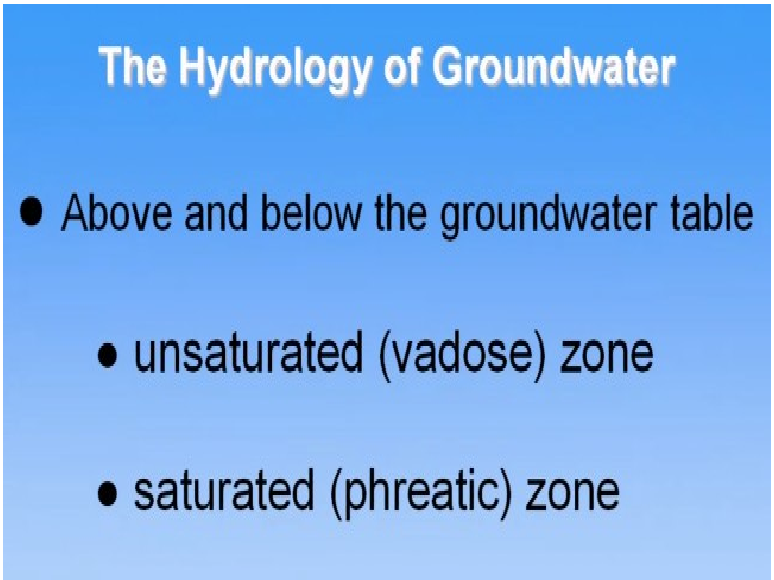

So, above and below the groundwater table, what we have is the unsaturated and saturated zone. So, unsaturated is also termed as vadose zone and the saturated zone is also termed as phreatic zone.

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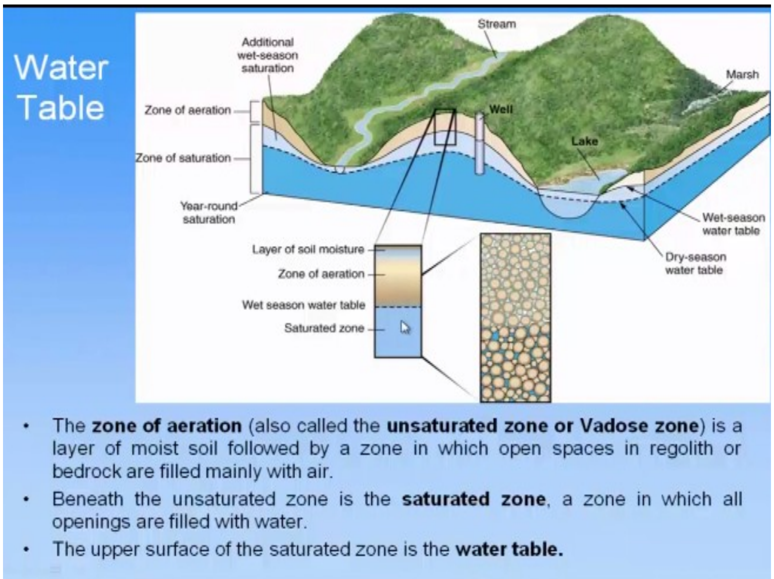

So, now some terminologies related to the water table. So, the zone of aeration is basically the unsaturated zone. So the zone of aeration also called the unsaturated zone or vadose ozone is a layer of moist soil followed by zone in which open spaces in regolith or the bedrock are filled mainly with air. So, this is unsaturated, of course, it is for us, but the voids are occupied by air and not water, whereas in terms of the saturated zone beneath the unsaturated one, a zone in which all openings are filled with water.

So, this is this portion where all voids or the space between the grains is occupied by water and that is termed as saturated zone. So, the line between the zone of aeration, unsaturated and saturated, is the water table and this keeps on fluctuating during different seasons. So, the upper surface of saturated zone is termed as water table, it is contact between the saturated and unsaturated zone.

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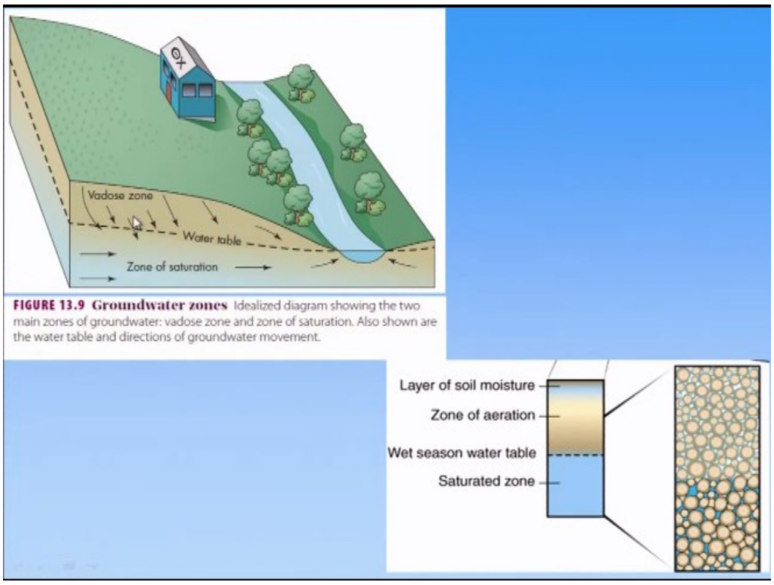

This is just the enlarged picture of the previous slide, saturated and unsaturated zone and this is the water table. So, in case of a sloping surface and nearby river, what you will be able to see the water level of the river will mark the water table in the nearby area.

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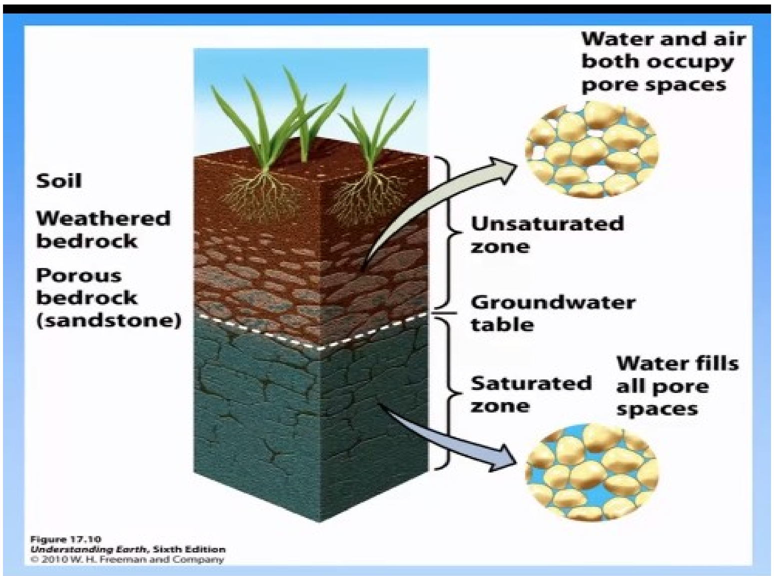

So, here it has been shown in more detail. So, what we have is in the profile soil with a rock, porous bedrock, mainly the sandstone. So, the porous bedrock is having the voids and what we see here is the upper portion is unsaturated zone which includes soil and weathered rock and then we have the groundwater table that is contact between the saturated and unsaturated zone and in saturated zone the pores are filled with water, whereas in unsaturated zone, the pores are filled partially by water, but mostly air occupies the pores in the unsaturated, that is the weathered bedrock ozone or the zone of aeration.

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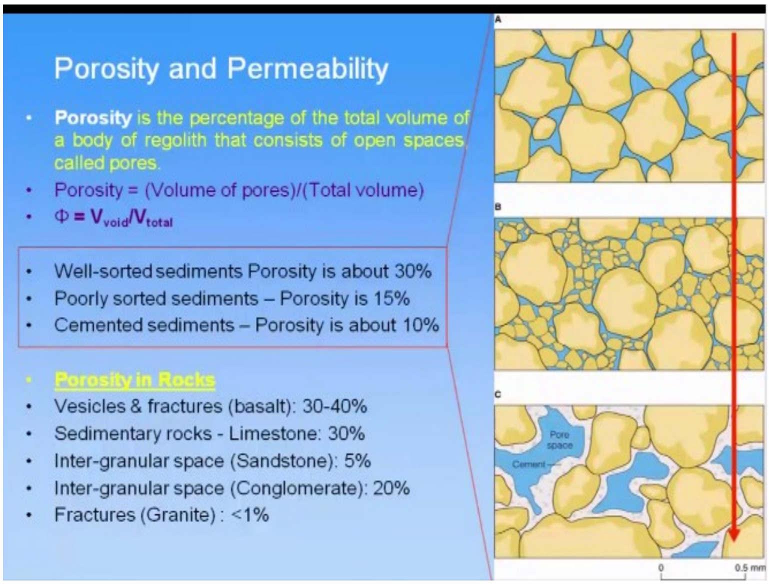

Porosity and permeability. Porosity is the percentage of the total volume of a body of regolith that consists of open space called pores. Porosity is measured as volume of pores by total volume of the zone, that is volume of voids or pores by total volume. Well-sorted sediments will have porosity about 30%, poorly sorted sediments porosity is 15%, cemented sediments porosity is hardly about 10%.

So this is what has been shown where you have A, B and C example where A is well sorted where the porosity is high because the space which is available between the well-sorted sediments or small fragments of rocks, they are more, hence the porosity is much higher as compared to the poorly sorted where we have different size of grains. Then if you are having cementation, then the porosity is hardly 10%. So, the porosity decreases from well sorted to cemented sediments. Porosity in rocks, vesicular and fractured basalt will have porosity up to 30 to 40%.

Similarly, if you are having fractured rocks in some regions, you will have more porosity, but in case of shale, porosity will be less sorry porosity of the shale, its permeability is less and the porosity is much higher. So, in terms of the sedimentary structures, limestone has a porosity of around 30%, an inter-granular space in the sandstone 5%, conglomerate 20%, and fracture granite is less than 1%. So this is in terms of the porosity. So, we are talking about here the open space or the pores which are available between the grains.

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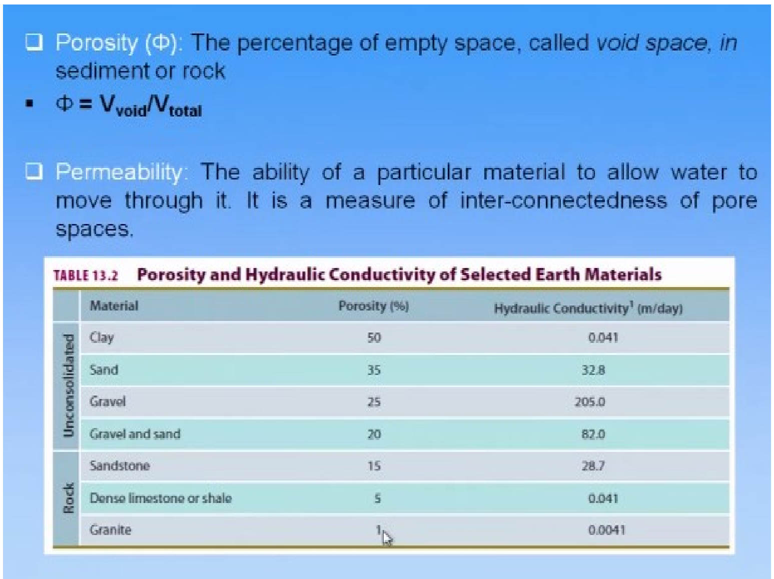

	Material	Porosity (%)	Hydraulic Conductivity[1] (m/day)
Unconsolidated	Clay	50	0.041
	Sand	35	32.8
	Gravel	25	205.0
	Gravel and sand	20	82.0
Rock	Sandstone	15	28.7
	Dense limestone or shale	5	0.041
	Granite	1	0.0041

Porosity, the percentage of empty space called voids, void space in the sediments or rocks and as we have already discussed this is measured at total number of voids by total volume and further another important parameter is permeability. Now, this has the ability of particular material to allow water to move through it. So, that means whether the layer allows the water to move through it.

So, in this case, the permeability of the sandstone will be higher as compared to the permeability of the shale and this will be reflected very much on the surface as we have seen in one of the example in the previous slide and that is the higher density and lower density. So, the porosity and the hydraulic conductivity of selected material if you look at unconsolidated rock, so unconsolidated clay for example, clay the porosity is porosity is quite high 50%. Then we have sand, gravel, gravel and sand is around 20 whereas is in terms of rocks, 15% is sandstone and one percent 1% is hardly porosity what it has for granite..

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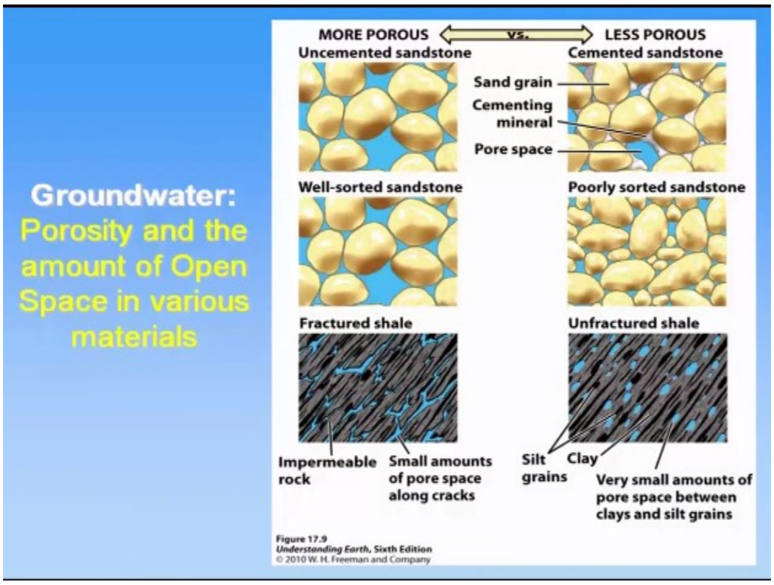

So, this is again another example which talks about the uncemented sandstone and the cemented sandstone. So, more porosity and less porosity in terms of the unconcentrated uncemented or cemented sandstone. Well-sorted sandstone, more porosity; poorly sorted sandstone, less porosity. Fractured shale will have more porosity, whereas unfractured shale can have less porosity. A very small amount of pore space between the clay and silt grains will be available whereas small amount of pore spaces available along the fractures, the fractured shale will have more porosity as compared to the unfractured shale.

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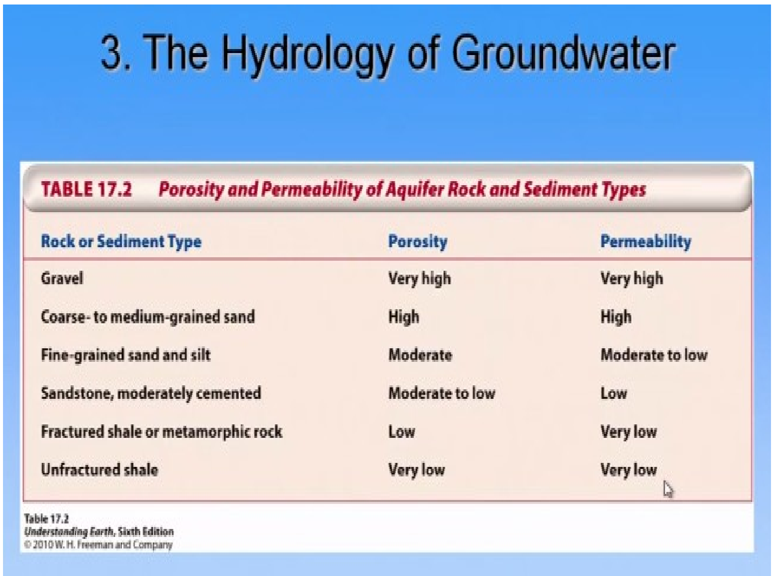

TABLE 17.2 Porosity and Permeability of Aquifer Rock and Sediment Types

Rock or Sediment Type	Porosity	Permeability
Gravel	Very high	Very high
Coarse- to medium-grained sand	High	High
Fine-grained sand and silt	Moderate	Moderate to low
Sandstone, moderately cemented	Moderate to low	Low
Fractured shale or metamorphic rock	Low	Very low
Unfractured shale	Very low	Very low

Table 17.2
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So again porosity and permeability of Aquifer of rocks and sediment types. So, the gravel, porosity is very high, permeability is very high. Coarse sand to medium-grained sand, again the porosity is high, permeability high. Fine-grained sand and silt, moderate porosity, moderate to low permeability. Sandstone, moderately cemented, moderate to low porosity and low permeability. Fractured shale and metamorphic rocks, low porosity, very low permeability. Unfractured shale, very low porosity, very low permeability also.

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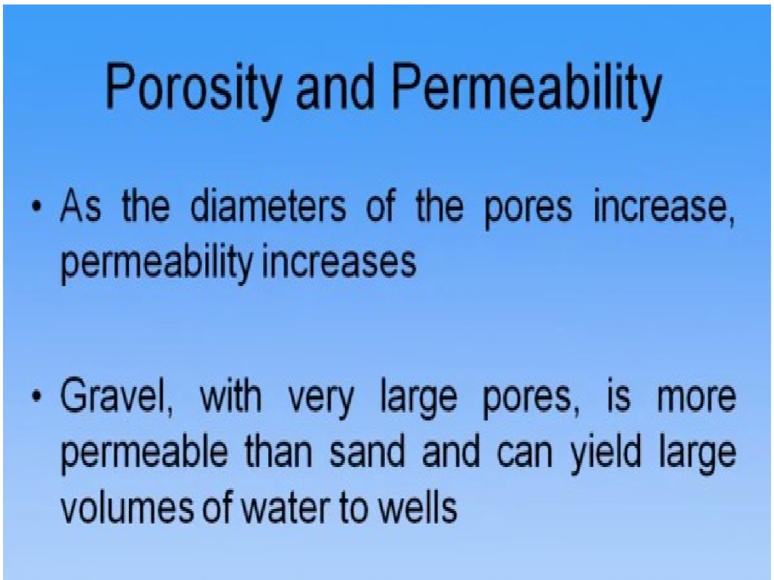

So, as the diameter of the pores increases, permeability increases. Gravel with very large pores is more permeable than sand and can yield large volume of water to wells.

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Now, the another important topic is groundwater movement and subsurface reservoirs.

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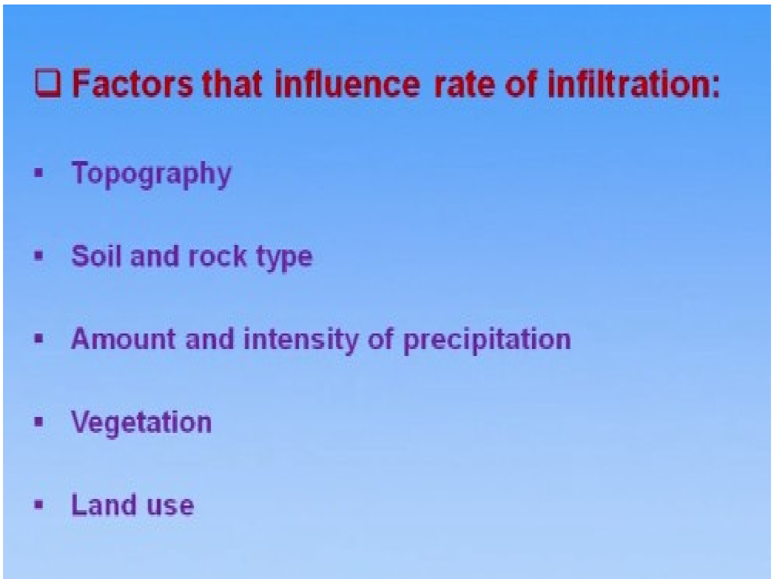

So, factor that influence rate of infiltration. So, rate of infiltration means rain falling on ground, that is the precipitation, and then runoff, all it is infiltered into the ground. So, filtration into the ground the rate will be influenced by topography, soil and rock type, amount and intensity of precipitation, vegetation, land use, this we have talked about. So, these are the few important points which one need to remember because the infiltration will also affect the recharge of the subsurface reservoir. So, if the runoff is more, the infiltration will be less and less recharge will be experienced in subsurface.

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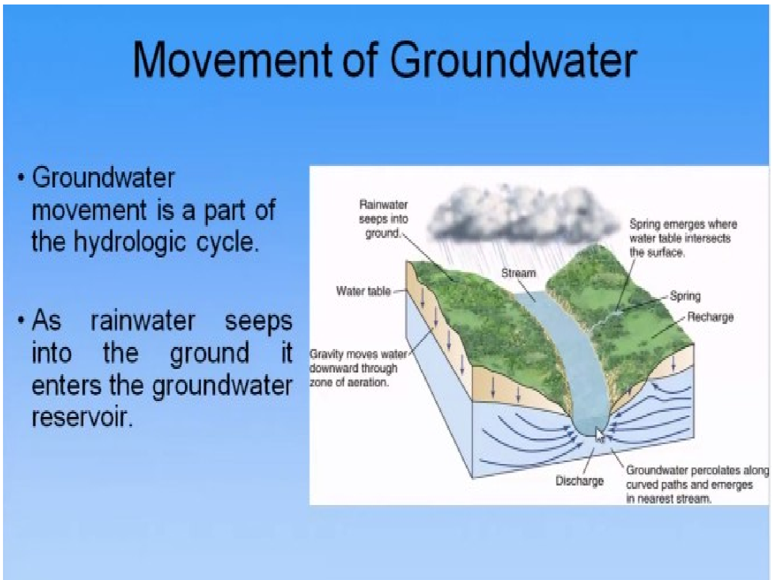

So, groundwater movement is a part of the hydrological cycle, we have been talking for right from the beginning that surface, runoff, and underground movement of the groundwater is the part of the hydrological cycle. So, as rain water seeps into the ground, enters the groundwater reservoir. Now, this sketch which explains the overall that is precipitation, percolation, and the movement of groundwater and discharge subsurface. So, this is the water table it has been marked. So, this is the ground water movement and it goes into the river.

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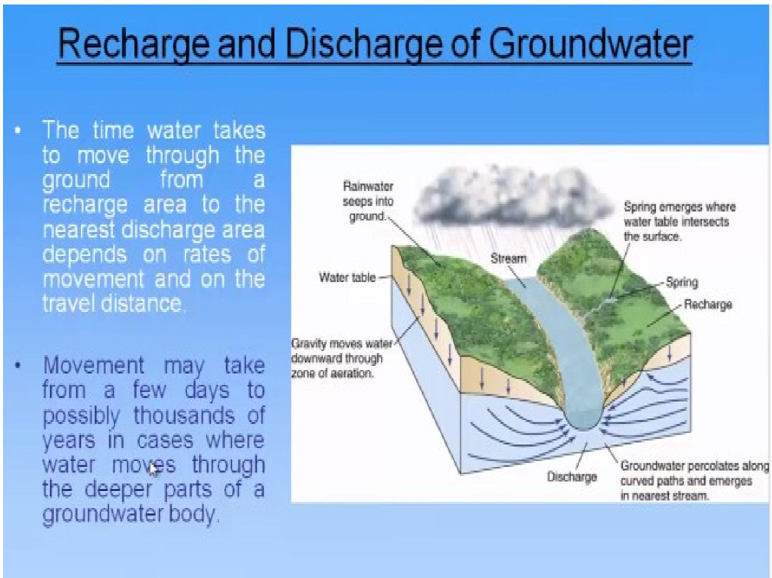

Recharge and discharge of groundwater. The time takes to move through the ground from a recharge area to the nearest discharge area depends on rate of movement and on the distance travel. So, what it says that the deeper part where the ground water moves will take longer time. So, the movement may take from a few days to possibly thousands of years in case of where the water moves through the deeper part of the groundwater. So, it may take a long time the deeper part of the groundwater to move into the surface, so it may take thousands of years.

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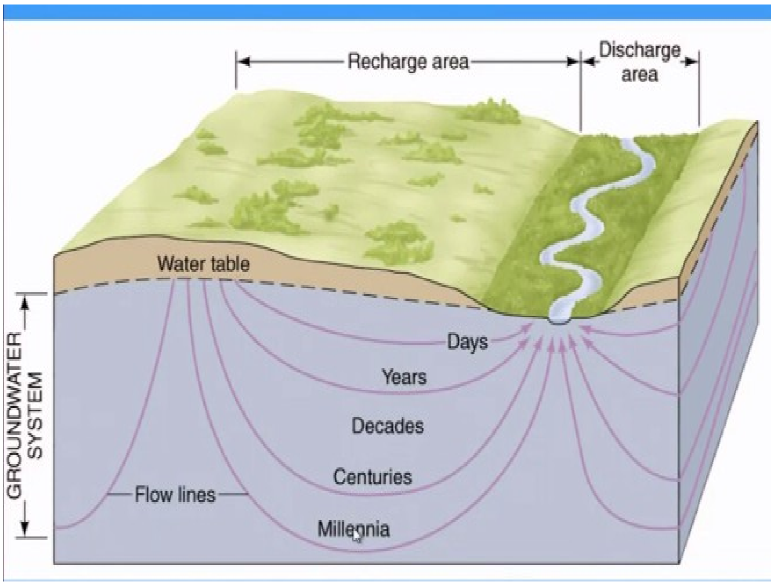

This is what has been shown here, that is the recharge area and the discharge area is basically in form of the river, the fluvial landscape and the water which is infiltrated will take days or years or millennia. So, I will stop here and we will continue in the next lecture. Thank you so much.