Availability and Management of Groundwater Resources
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Lecture - 18
Confined and Unconfined Aquifer and their Parameters (Continued)

Welcome you all in the part 4 of the model 4 confined and unconfined aquifers and their parameters. So, now we have well understood the different formations are remaining inside the earth surface and which are storing the water. So, in this lecture we will try to know about the different important parameters, however we will discuss the important parameters in greater details in the coming lectures.

But here at least the important parameters which are very well related with the aquifers both in the case of confined aquifers and unconfined aquifers will be discussed in a brief way.

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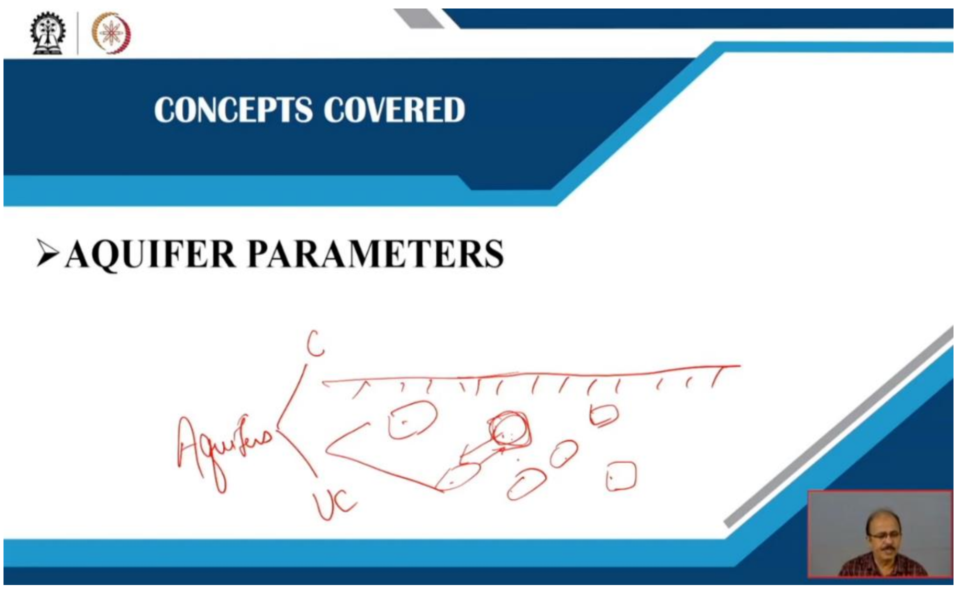

Now we have understood that in the, we have just understood that the inside the earth surface just inside the earth surface what is happening. The different formations remain one remains at shallower depth and other remains are greater depth. So, this type of formations we may get several inside the earth surface at different depths, we may get several type of this type of formations. The formations are of rock formations.

So, these rock formations are generally called as our aquifers, these are called as our aquifers. These aquifers are lying inside the earth surface or and these aquifers may be your confined aquifers or unconfined aquifers. Both the type of a aquifers can remain inside the earth surface at different, different depths. Some aquifers we are getting at the shallower depth and some aquifers we are getting at a greater depth.

So, we are also knowing that any aquifers should have some important properties only then it can store the water. The important properties we have come across that porosity, specially permeability. These are some of the important parameters which is very well related with the aquifers. So, that these aquifers can retain groundwater within itself and it is being used by withdrawing. So, in the present lecture the discussion will be based on what are the parameters?

What are the important parameters? Which are very well related with these unconfined and confined aquifers? Inside the earth surface because the two types of aquifers are there and the different the two different types of an aquifers should have certain properties then only the groundwater can store within these formations. These on second thing then only this aquifer may take ground water from this aquifer or it may send groundwater to this aquifer.

So, until unless this property will not remain groundwater will remain stored in any aquifer but it will be an enabled to send and receive ground water from our other aquifers. So, just one by one we will discuss the different properties.

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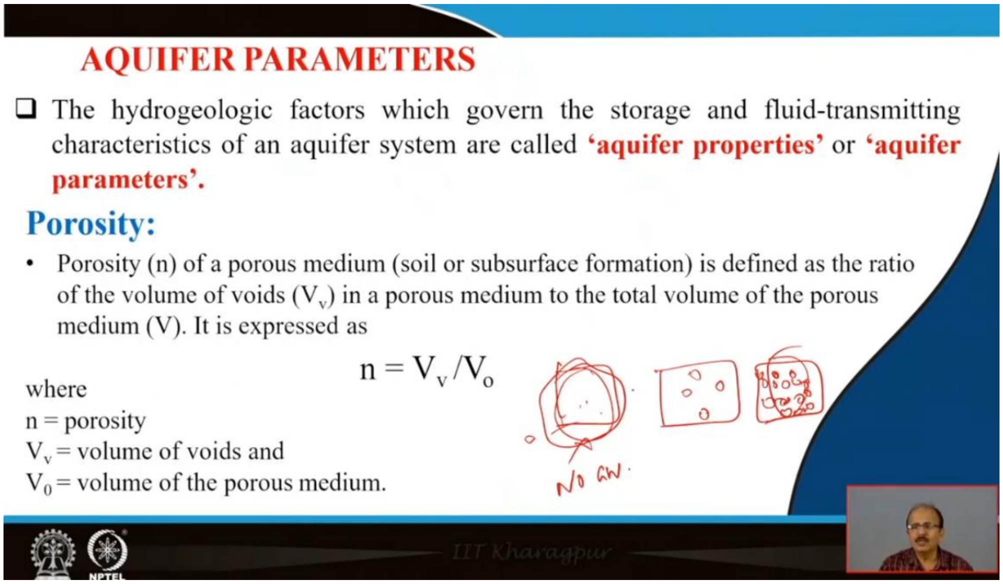

First property is the porosity from the very beginning of the classes we have seen porosity is the thing it is just telling about the criteria of the media to which the water remains. So, it is a porosity generally have the formations in which the ratio of number of voids is being counted with respect to the total volume of the porous media.

So, this

$$\text{Porosity (Sr)} = \frac{\text{volume of voids (Vr)}}{\text{total volume of the voids in the media(V)}}$$

Generally, the porous media in which we are finding the porosity. So, this is very important because if the rocks will have space see the three different types of rocks are there in one rock, we are having no porous spaces in it, so here we are having no porous space. In this rock, we are having the porous space but very lesser amount but, in this rock, we are having porous spaces in a number of porous spaces we are getting in this rock.

So, in this rock we are getting number porous spaces. So, whatever we have acquired the knowledge in this rock may be your igneous or metamorphic rock very compact rock it is not having any space if the space will not remain definitely no groundwater will be there where the groundwater will remain, no space is there nothing nor it is weathered or eroded. So, there are no chances of having the groundwater in to this type of rock, rock means formation.

We are knowing aquifers nothing but it is a rocky formation holding the groundwater. Now, this is an aquifer in which the porous spaces are there but these porous spaces are in a very lesser amount, so very less amount. So, here what will happen the groundwater will remain but in a very little volume. So, this is a case of some of the formations some of the aquifer which may remain porous.

But in a very little amount we are getting groundwater in it because we have read in the earlier lecture also that three different conditions may exist porous and not porous, second is the porous but the porous are not connected. So, it is impermeable and third is the porous, the pore are connected means it is permeable. So, here also in three different aquifers what is happening? The ground in this decision aquifer in which there is no porous spaces no groundwater will remain here.

But in this case where it few porous spaces are there, so anyway few very few amount of groundwater we may get in such type of conditions. But in the case of the some rocks in which number of pores are more, so there are more chances of having the volume of groundwater within such type of formations. Why? Because more number of porous spaces are there. Porosity is greater here than compared to here.

So, in this way porosity plays very important role for any media for knowing about the quantity of groundwater inside it.

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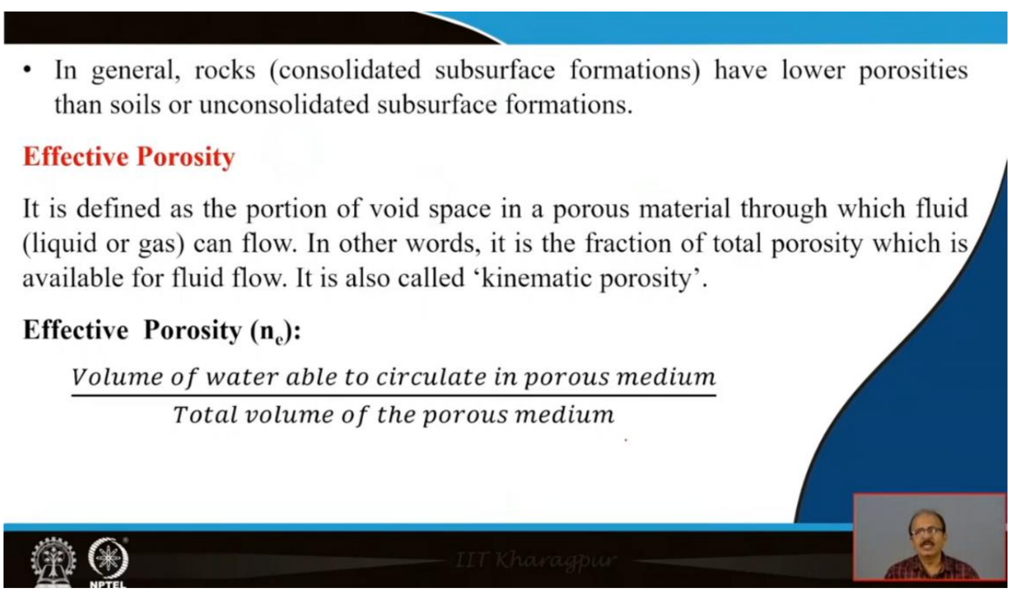

Now second is the in general the rocks have lower porosity than soils or unconsolidated, we I have already discussed also the hard rocks the consolidated rocks, the subsurface rocks, subsurface rocks are rocks which are inside deep into the earth's surface are having lower porosities compared to the soils which is just underneath the earth surface and the unconsolidated surface subsurface formation.

And so, at shallower depth we are generally getting unconsolidated formations in which we are having the some of the chances of we are getting the good amount of groundwater in this area. So, in general rocks have lower porosity than soils. Now second is the effective porosity it is defined as the just the definition if you will wish to know it is defined at the portion of wider space in a porous material through which fluid in the earlier case, we were discussing about the water only here the fluid which comprises of liquid as well as gas can flow. So, in some of the rock spaces the wide spaces are remaining present there but through this wide space generally the fluid is passing fluid is flowing. So, in other way we can say that it is the fraction of total porosity which is available for fluid flow it is nothing but it is the fraction of the total porosity for passing the fluid within the formations.

It is also sometimes called as kinematic porosity and you can see the formula,

$$\text{Effective porosity } (n_e) = \frac{\text{volume of water able to circulate in porous medium}}{\text{total volume of the porous medium}}.$$

So, effective porosity is also very important consideration in the case while we are discussing about the confined and unconfined aquifers. So, this is also one of the important parameters.

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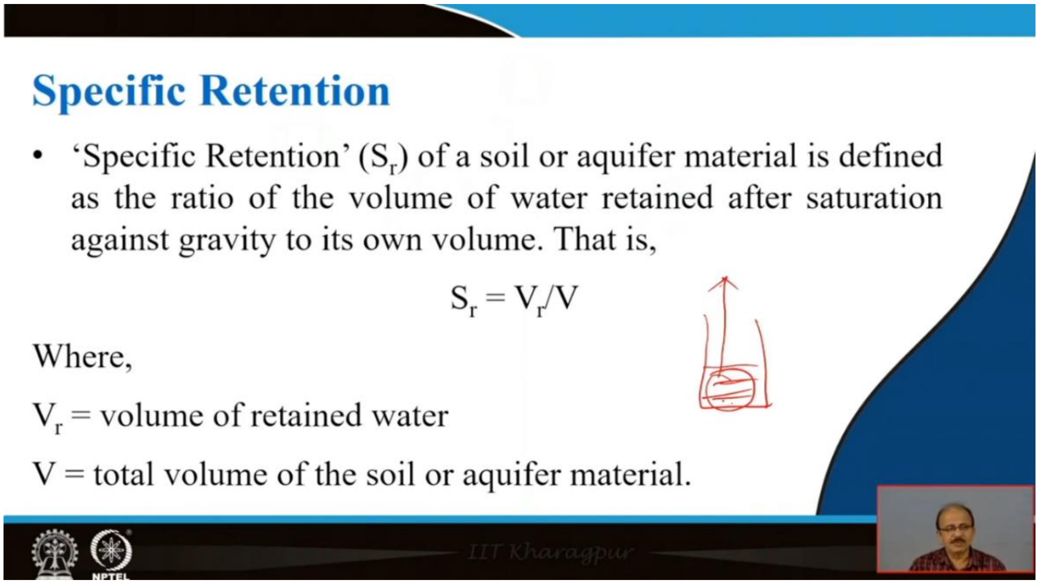

Now the second important parameter is the specific retention. Specific retention of a soil or any aquifer material is generally defined as the ratio of the volume of water retained after saturation against gravity to its own volume. So, we have discussed that any formations any saturated formations if you will pump the water from this saturated function out, then it will send the water no doubt but it is having a good yield.

So, it is just while we travel it is just sending the water out but still some amount of volume of water will retain their within the formations. Because of the some of the force's molecular attraction etcetera, it will retain and this volume it will retain with the soil or the rock formations. So, this retaining amount while pumping is generally termed as the specific retention and this is just the volume of water which retained after saturation.

In the case you can see that the

$$\text{specific retention } (S_r) = \frac{\text{volume of retained water (Vr)}}{\text{total volume of the soil or any aquifer material (V)}}$$

So, soil in any volume of retained water divided by total volume of the soil or aquifer material is generally termed as specific retention of the soil or the aquifer formations. So, this is about the specific retention.

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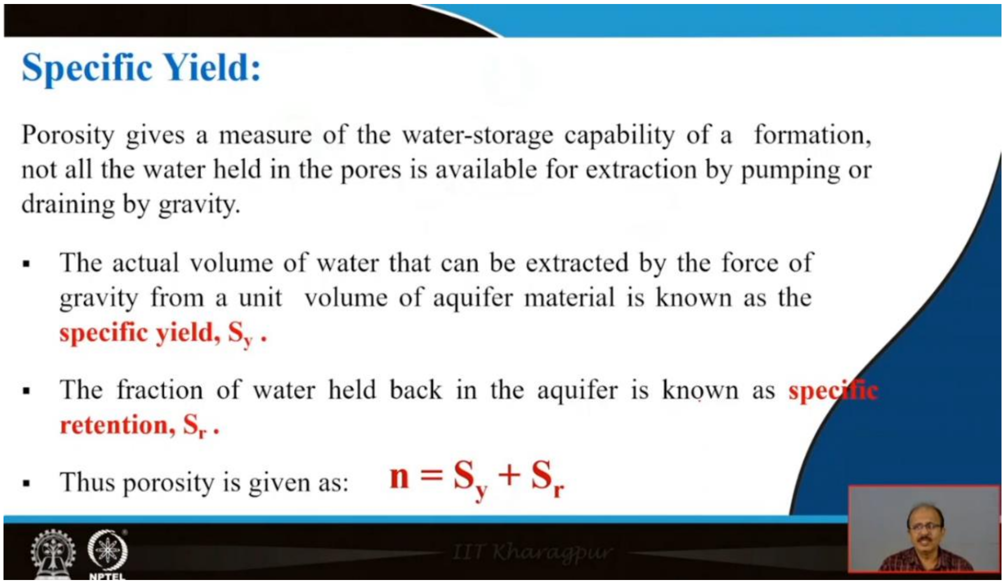

Now specific yield, specific yield is a very important because porosity gives a measure of the water storage capability of a formation. The porosity when we are discussing about the porosity, so it just giving a measurement of the water storage ability of any formation. Here not all the water held in the pores is available for extraction by pumping or draining by activity. So, what is happening the actual volume of water that can be extracted by force of gravity from a unit volume of aquifer material is known as the specific yield. This is known as the specific yield when you are just withdrawing the water from unit volume of any aquifer material, the volume of water which will be a extracted is known as the specific yield of that very formation that very your soil layers the fraction. This is called as specific yield and just now I have discussed the fraction of water held back.

While pumping the few fractions of water will remain held back in the aquifer or the formation which is termed as specific retention. So,

$$\text{Porosity}(n) = \text{specific yield } (S_y) + \text{specific retention } (S_r)$$

and this plays very important. I have told you for the not consideration of best aquifer generally one two parameters are very important, the first parameter is the parameter is porosity. Second parameter is the specific yield and the next parameter, important parameter is your permeability ability to transmit water. So, these three parameters are very important because if the rocky porous permeable, so we have to find out whether how much is the yield quality of those very formations. So, yield should be more yield will be more only when it will have a very good saturation formations inside the earth surface.

Because few amounts will water will be pumped out and few more waters will retain inside the your formations. So, in this way we are just categorizing the specific yield and specific retention and when we are just summing these two specific yield or specific retention, we are getting the porosity of the those very formations. So, this is about the aquifer parameters important aquifer parameters of any formations.

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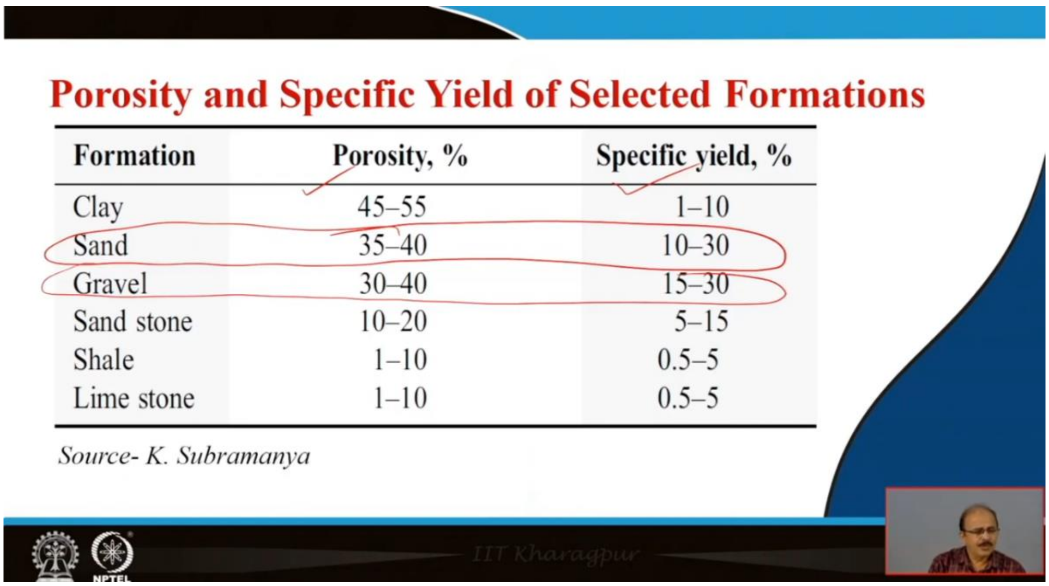

So, now next we can see here a tabular way we can see these are the formations clay, sand, gravel sandstone, shale, limestone. These are some of the formations inside the earth surface it remains inside just inside the earth surface and these are having porosity also we are seeing porosity is our is given in percentage, we can say clay is having 45 to 55% porosity, so 45 to 55%. So, clay is a very good repository of groundwater.

Why? Because it is having the ability to store more amount of groundwater but just see the yield only 1 to 10% yield is there. It is having only 1 to 10% yield so although it is having a very good storage behaviour of but it is not having a very good behaviour for during its extraction. Very fewer amount of water these coming out while extracting from the clay formations while stepping from a clay formation we are getting very lesser yield in the case of the clay formations.

Sand next year you see sand 35 to 40% is there but compared to clay the yield is 10 to 30% so good yield we are getting in the case of sand. It means that this sand this category sand category is the best aquifer condition inside the earth surface. When we are getting formations as an aquifer make made up of sand then it is having a very good porosity also 35 to 40% as well as it is also having a very good yield that is 10 to 30%.

Gravel also, gravel in second best aquifer formation in which we are getting 30 to 40% porosity and 15 to 30% specific yield. So, the consideration of these two factors porosity and specific yield very important for designation of at best good poor aquifer. So, this is very important because only then we can say that how much water we can get after some days months or year from this very formation.

So, first of all we should know what is the condition of its porosity and what is the condition of its specific yield. On this basis only we may decide the consideration of any bore well in the area where we may get good amount of water throughout the year. It is also important, see while taking out the water from the clay formation we may get very good amount of water from those very formation for a shorter duration.

Because in the clay, clay is impervious so it will never accept water from other aquifer nor it will send its own water to some distance or nearby aquifer. So, it may have a very great amount because porosity is more in the clay compared to sand and gravel but point is it may store good amount of water but it may not transmit good amount of water to another aquifer or it may not receive good amount of water from another aquifer inside the earth surface.

That is why clay is not a good aquifer inside the earth surface. Now come down sandstone here, sandstone it is sedimentary rocks shale it is a sedimentary rocks limestone it is sedimentary rock. So, all the three are sedimentary rocks and these rocks are having the porosity also but see in the case of sandstone the porosity is 10 to 20% and yield is 5 to 15%. Sedimentary rock sandstone is a bit lesser compact than the shale and limestone.

So, what is happening in the case of sale and line stone what is happening porosity has drastically reduced to 1 to 10% and see specific yield also going down that is 0.5 to 5. So, this tabular information tells us that the sand and gravel as are the best aquifer formation inside the earth surface, why these are best because these are having good porosity as well as good specific yield.

So, if the porosity will be good what will happen too much amount of water will remain stored there and whenever we wish to withdraw the water from the formation, we may get a very good amount why because specific yield of those very formations are also a bit better than your clay and shale and limestone. So, this is the important parameters aquifer parameters which are deciding your characteristics of the different underneath aquifer formations inside the earth surface.

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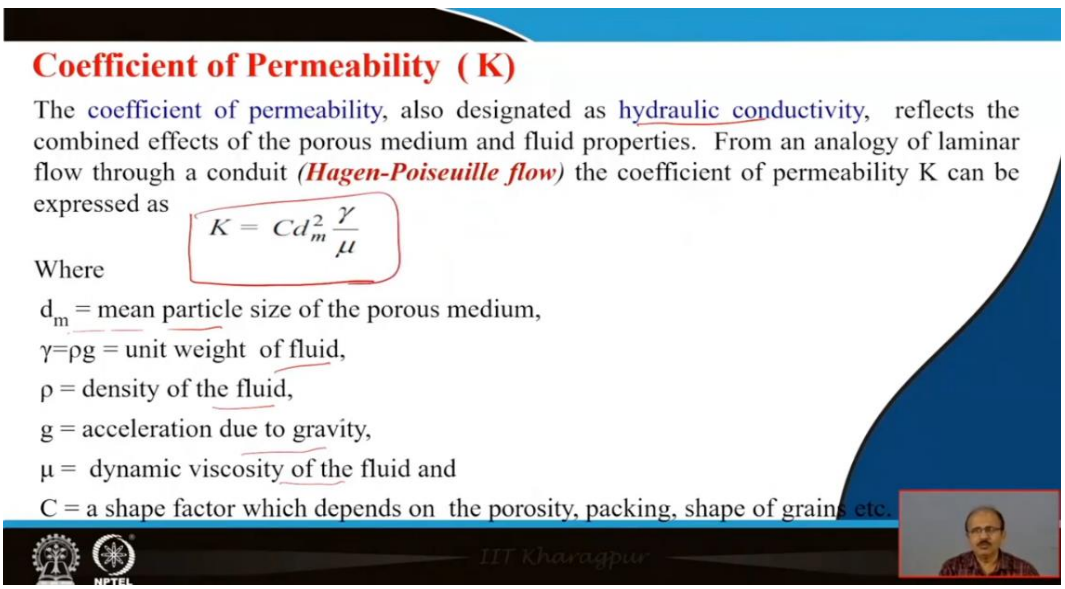

So, now next is the important to is the coefficient of permeability which is called as capital K. Permeability, we are knowing ability to transmit and receive water. So, what is coefficient of permeability? Generally, is termed as hydraulic conductivity, this hydraulic conductivity depicts or reflects the combined effects of porous medium and fluid properties. You can see Hagen-Poiseuille-flow.

Next is the next important aquifer parameter is the coefficient of permeability that is also termed as hydraulic conductivity. This is also one of the important parameters of aquifers it reflects the combined effects of porous medium and fluid properties where we can see it has been given by Hagen-Poiseuille-flow equations

i,e

$$K = C(d_m)^2 \frac{\gamma}{\mu}$$

In which we can see,

d_m = mean particle size of the porous medium,

$\gamma = \rho g$ = unit weight of fluid,

ρ = density of the fluid,

g = acceleration due to gravity,

μ = dynamic viscosity of the fluid and

C = a shape factor which depends on the porosity, packing, shape of grains etc.

So, these are very important parameter because hydraulic conductivity also important for any aquifer.

And its calculations generally it is calculated

$$K = C(d_m)^2 \frac{\gamma}{\mu}.$$

So, in this way we can find out the details about the aquifer formations coefficient of permeability.

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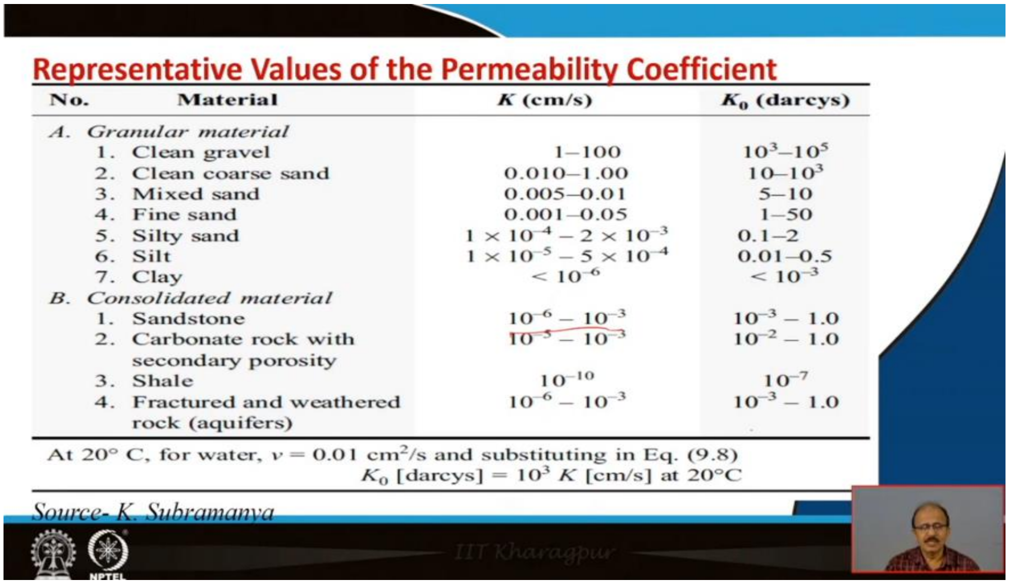

No.	Material	K (cm/s)	K_0 (darcys)
A.	*Granular material*		
1.	Clean gravel	1–100	10^3–10^5
2.	Clean coarse sand	0.010–1.00	10–10^3
3.	Mixed sand	0.005–0.01	5–10
4.	Fine sand	0.001–0.05	1–50
5.	Silty sand	$1 \times 10^{-4} - 2 \times 10^{-3}$	0.1–2
6.	Silt	$1 \times 10^{-5} - 5 \times 10^{-4}$	0.01–0.5
7.	Clay	$< 10^{-6}$	$< 10^{-3}$
B.	*Consolidated material*		
1.	Sandstone	$10^{-6} - 10^{-3}$	$10^{-3} - 1.0$
2.	Carbonate rock with secondary porosity	$10^{-5} - 10^{-3}$	$10^{-2} - 1.0$
3.	Shale	10^{-10}	10^{-7}
4.	Fractured and weathered rock (aquifers)	$10^{-6} - 10^{-3}$	$10^{-3} - 1.0$

At 20° C, for water, $\nu = 0.01$ cm²/s and substituting in Eq. (9.8)
K_0 [darcys] = 10^3 K [cm/s] at 20°C

Now next is the tabular information in which we can see representative values some of the formations of the representative value permeability is given here in which we can see in centimetre squares as well as in Darcy's. So, the point is that in general material in the case of granular material clean gravel then clean coarse sand, then mix and fine sand, silty sand, silt, clay this information are there and hydraulic conductivity in the just in the next column, you can see K is delivered per second for clean gravel it is 1 to 100.

And for the just as we are moving down, we are seeing the clay it is tell you 10^{-6}. So, this is the hydraulic conductivity, permeability coefficient of the different formations of the granular material whereas in the concentrator formation you can see the sandstone which is having the value of this much of the K in centimetre per second. As we see these different rocks also carbonate rock with secondary porosity.

Then shale and fractured and weathered rock the amount in 10^{-6} to 10^{-3}. So, in the Darcy's also the same has been just changed and it is in the Darcy's also. So, the point is that your hydraulic conductivity also varies in the different your formations from clay sand and gravel in these formations the hydraulic conductivity is behaviours are something different then the hydraulic conductivity of the consolidated formations.

Example for sandstone, carbonate rock, shale, fracture and weathered rock the different hydraulic conductivity remains.

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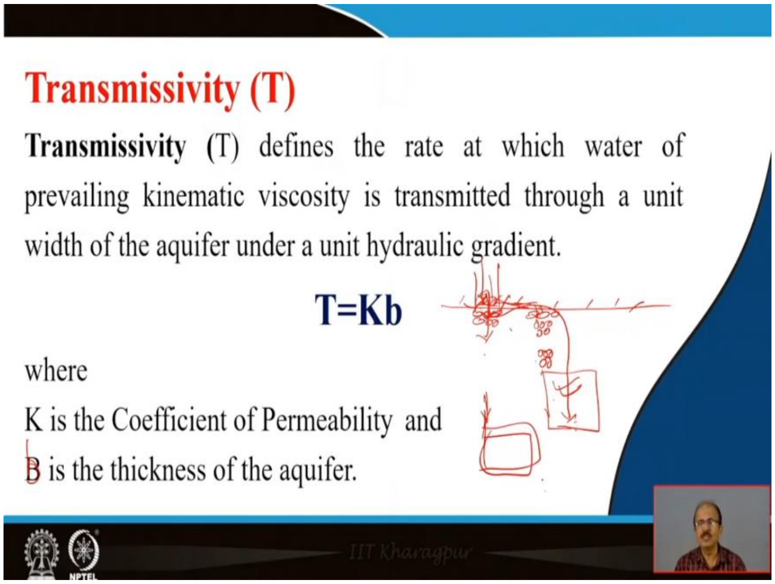

Now after the porosity and hydraulic conductivity the one of the important parameters is the transmissivity. This is important because the transmissivity defines the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient. So, this is important because

$$T = K*b,$$

Where,

K is nothing but it is the coefficient of permeability and,

b is the thickness of the aquifer. So, in this way we can just find out the transmissivity also of the area. Point is that in the area because whenever we are discussing about the groundwater, so I have told you that this groundwater is the groundwater what we are getting in that aquifer it suppose here the rain falls so it we are not sure that this rainfall drop will infiltrate and percolate and then it will recharge this aquifer only.

It may not be this condition may not get at several locations we may not get, yes at few locations we may get but generally it does not happen inside the earth surface also. So, what is happening? This infiltrated water I have discussed before also in the lectures that infiltrated water, we just saturate the underlying soil cover. Once it will become saturate then this water, they thus this soil layer will not accept further drop of water.

Then what will happen this water which will just pour here it will float from the earth surface. Then what will happen here this layers the soil layers are dry then this will enter into infiltration process take place here and then the through the infiltration process the percolation process will start and it will recharge the water of displace aquifer. See we got the drop of rain here but it is recharging to here.

So, this thing also we should understand that how much distance inside the earth surface generally the ability of movement of water remains in a certain formation. So, this we are also finding out with by one of the tests known as pumping test study through which we are also finding the transmissivity as well as to storavity in the area in the regional scale. Whenever we are discussing about the groundwater, I have told you the amount of water which you are just seeing it is going inside.

It may not recharge the layer of the formations just wherever it is entering. But definitely it will recharge to some distant places wherever it will move inside. So, this is the basic conditions of the your formations which generally holds remain there inside the earth surface and these are few parameters, we will discuss the different other parameters also related with the aquifer formations in the coming lectures. Thank you very much.

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