Availability and Management of Groundwater Resources
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Lecture - 34
Estimation of Subsurface Runoff, Types of Wells, Well Hydraulics (Continued)

Welcome you all in the part 5 of the module 7 estimation of subsurface runoff, types of well and well hydraulics. So, in the last four parts we have discussed about the runoff; the runoff types that is subsurface runoff, the different types of wells. And now in this part 5, I will discuss the well hydraulics because in the last part we have seen the different types of wells exist in the nature; some are the shallow wells, some are the deep wells both remain in the form of open wells.

So, these two different types of wells are just providing water to the earth's surface for different purposes. So, here in this part five we will discuss about the well hydraulics already we have discussed about the wells now we will discuss about the well hydraulics.

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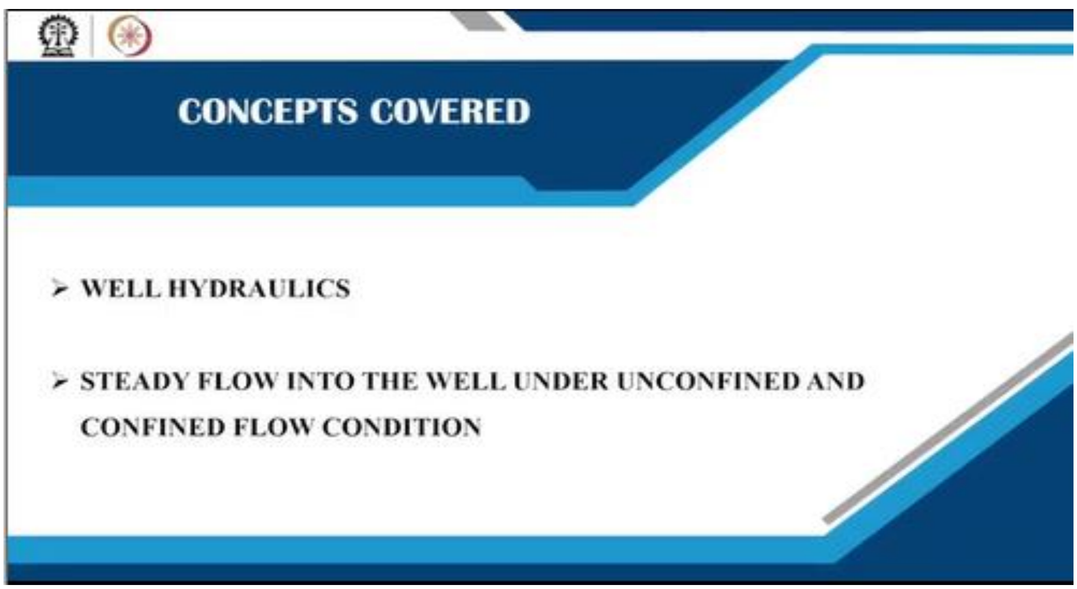

So, in this concept we will discuss well hydraulics in the form of steady flow in the well under both the conditions; unconfined and confined flow condition. We know that different types of aquifer exists in the nature, one is unconfined other is confined depending upon the ability of the impervious stratum and the two different types of the aquifer have also been classified. Now the wells; what we have discussed they also remain in certain type of water bearing formation that is an aquifer.

So, this aquifer just are having water and this water are being stored in the well. From this type of group of formations generally the water comes in the hollow structure that is in the well and from the well the water are being tapped out for different purposes. So, specifically we will discuss well hydraulics in greater detail in this part of lecture.

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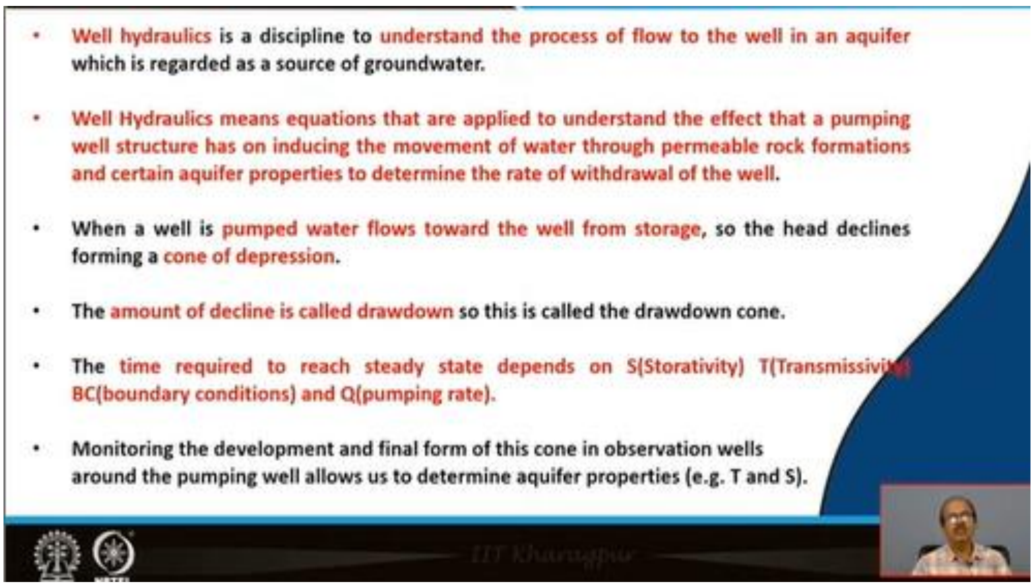

Now the question comes; what is well hydraulics, well hydraulics is a discipline just to understand the process of flow to the well in an aquifer. As I have told you; well remains in certain formations which is holding the water that is aquifer. So, it the well hydraulics is a discipline to understand the process of flow to the well in an aquifer which is regarded as a source of groundwater. So, well hydraulic means equations some of the equations.

That are applied to understand the effect that a pumping well structure has on inducing the movement of water through permeable rock formations and certain aquifer property is also very important and certain aquifer property to determine the rate of withdrawal of the well. So, this generally is being discussed in the well hydraulics. So, this is a very important part of the groundwater also, very important hydrological part.

When the well is pumped what where we have seen? Suppose this is a well and in this world when it is water remains this is the water table so this lies on the surface. So, maybe shallow; might be deep water wells but generally this hollow structure called as well having the water. So, when a valley pumped water flows towards what is happening? When a well is pumped; suppose through the pump the water is taking it out.

So, when it well is pumped to water flows towards the well from storage. So, what is happening? Water is just flowing from the well and it is just going this level earlier the level will remain at this place so level will go down. So, this usually happens when the pumping starts. So, what is happening? The head declines and then it forms the cone of depression. So, this we will see just we will see a cone of depression in just forms here.

So, amount of decline how much amount is declined because earlier the water table was this one, this was the water table. When this from the well the water is being pumped out what will happen? The water table will come down. So, what will happen? It will just make a cone of depression here so this depth is known as the drawdown so this is called draw down cone. So, this is very important, the time required to reach again because you have pumped out the water.

So, this will try to just bring its back level this water table level will come to its original position. So, the time required to reach the steady state depends on certain aquifer properties and those aquifer properties are what? Storativity, transmissibility then boundary conditions what are the boundary condition and the pumping rate. All the four different parameters are having very important role for bringing the level of the water table to its previous position.

So, for this generally what is happening generally we are just taking the help of the aquifer parameters. Depending upon the types of the parameters the amount of the or the time required for bringing the water back to its original position, it depends solely on the aquifer properties of the area. So, monitoring the development and final form of this cone in observation wells around the pumping will allow us to determine the aquifer parameters, especially aquifer parameters that is T and S.

So, this usually happens means what? Means a well will definitely have water, water is coming from the since it is in porous formation definitely it is having water or in some hard rock formation through fissures or cracks the water is coming inside so it is having the water. This water is being pumped out. So, earlier when it is having the water the level of the water will be something so this say that by depth wise say it is at 10 meter.

As soon as you will start the pump for taking out the water out from different purposes, definitely the depth will earlier it was 10 meter so now the depth has become 10.5 meter. Because 0.5 meter, it has gone down so what happens? So, cone of depression just forms there and those the distance from the previous to the existing is generally called as drawdown. So, this we will discuss in coming lecture the coming slides.

But the point is that again the level of the water in the formation that is the formation in which the well exists will try to come to its original position. So, how much time it is taking? The time required to reach the steady state depends on some aquifer parameters and the aquifer parameters specially are storativity, transmissivity, boundary conditions and the pumping rate. So, on these generally the time required to reach the steady state is based on. Now we will discuss in a greater detail now.

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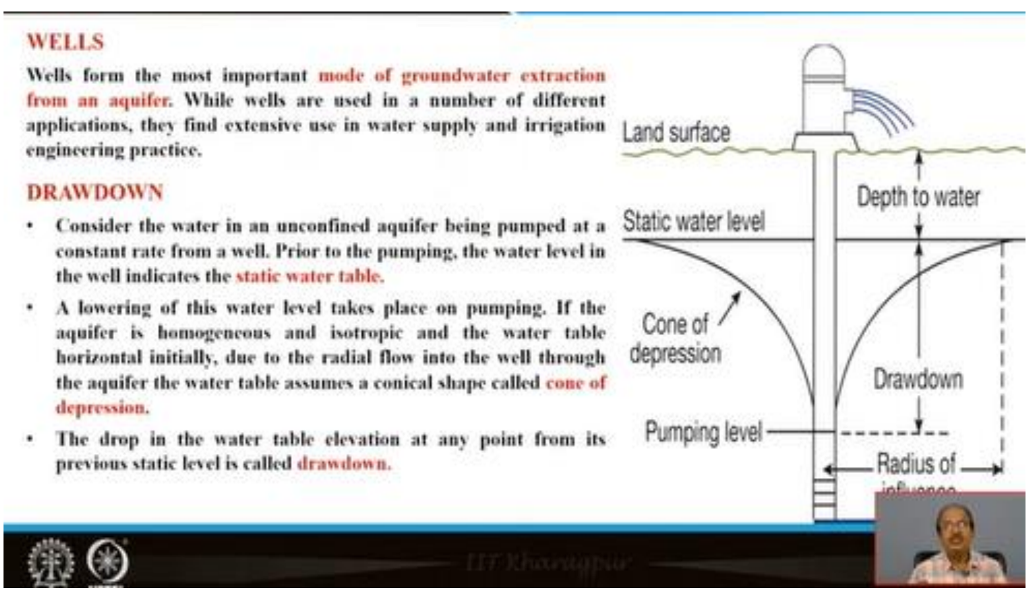

See this is well we have discussed, already drawdown. Consider the water in an unconfined aquifer so first we are just considering the unconfined aquifer. The water is being pumped at a constant rate from a well prior to pumping the water level in the well indicates the static water level. So, before pumping this is the depth of water so water table this one and this whole structure is in the unconfined aquifer. So, prior to pumping just the level is this one.

Now the lowering of this water level takes place then now the pumping starts and by pumping a lowering of water levels take place. Now you can see the water level is just lowering because through pumping what we are taking water from out. So, what is happening? This water static water level is just coming down, if you can see just coming down. So, what is happening if the aquifer is homogeneous and isotropic and the water table is horizontal initially.

Then what is happening? Due to radial flow into the well through the aquifer the water table assumes a conical shape and this conical shape is called as the cone of depression so this is called as cone of depression. So, I hope you have understood the point of depression a lowering of this water level because this is the static water level before pumping what is the prevailing water level in the formation.

So, now the pumping has started now whatever is start the loading of water levels starts we can see here and this forms a cone like a structure which is called as the cone of depression. And this drop in the water level or the drop in the water table elevation, drop means if water earlier the water level was here during pumping the water table has ultimately come reached here. So, this depth prevailing to the existing previous to the present and you can see this depth is known as your drawdown.

So, the drop in the water table elevation at any point from its previous static level; this one is generally known as drawdown so this is known as drawdown. And the area of influence how much area the from here to here the level has changed and the water level has changed during the pumping so this area is generally known as the radius of influence. This is very important; this point is very important for industrial point of view also.

When you are withdrawing water for your industrial uses generally you have to furnish the details about your radius of influence of your while withdrawing the water from your area because that is very important. Say just near to suppose this is the industry and see you are willing to just take the water for the different industrial uses. So, what is happening? Just you have to mention what is the radius of influence while you will start pumping for taking out huge amount of water for industrial uses.

Suppose if radius of influence is coming the within the area of the industrial area within the industry in the sense within the you know your the part of the core zone area, work zone area then it is all right no problem but if it is just exceeding. If the radius is exceeding too much too much then what will happen? Several villages residential premises will come in the buffer zone. So, what will happen?

The buffer zone people when they will just have the well open well only, open well or sell open they will not get the water. Why? Because while we are drawing your level is going coming down. So, this is the importance of the drawdown, cone of depression and the radius of influence which is very important and this usually happens when we start pumping for taking out water for different uses. So, this can be explained by this diagram also.

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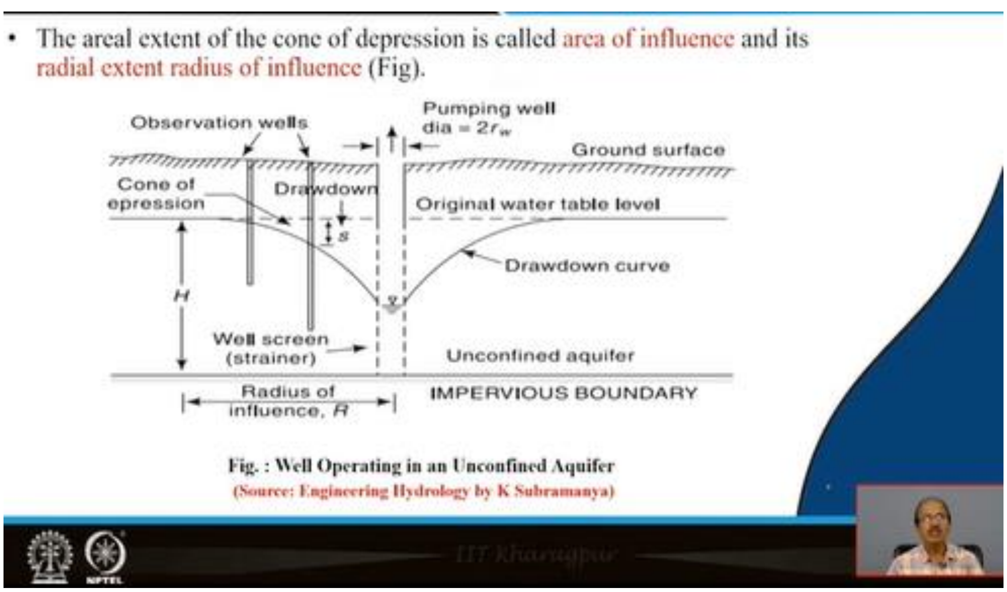

The same thing here we have seen. This is the one pumping well is there, this is the pumping well and these two are the observation valves. So, we can see the your radius of influence is also here, this is unconfined aquifer and original water level was this much. But when we start pumping through this well this is the pumping well what happens the drawdown curve we have seen and this is the drawdown curve. So, in this way and this is the cone of depression.

So, generally such type of aerial extent up to which there; we are having the cone of depression is known as the radius of influence. So, this is up to here; this is the radius of influence.

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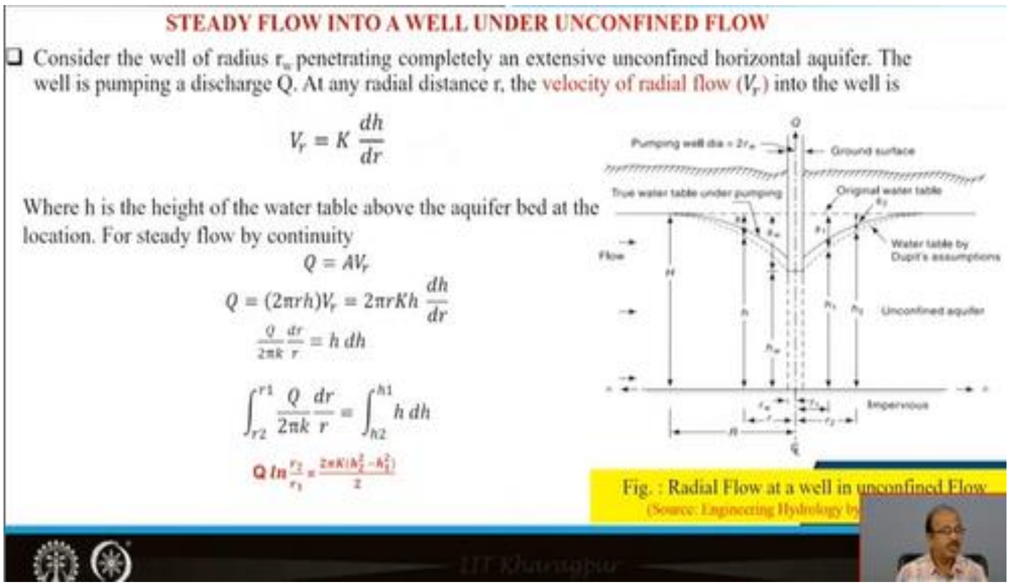

In some another diagram also, we can see anyway. So, now what is happening now we will see the steady flow into a well under unconfined flow condition. So, we have just assumed unconfined aquifer. What will happen in case of unconfined aquifer when well is having the pumping what will happen. So, here we can see the original water table is here and when the pumping starts the true water table under pumping is going down and this is the cone of depression.

So, here consider the well of radius r w this value having the radius of r w and which is penetrating completely in an extensive unconfined horizontal aquifer and the well is pumping a discharge Q and so then at any radial distance r the velocity of radial flow into the well will be

$$V_r = K\,\frac{dh}{dr}$$

This we have seen during the discussion of the Darcy law. Where h is the height of the water table above the aquifer bed at the location. For steady flow by continuity

$$Q = AV_r$$

$$Q = (2\pi r h)V_r$$

$$Q = 2\pi r K h \frac{dh}{dr}$$

$$\frac{Q}{2\pi k}\frac{dr}{r} = h\,dh$$

Integrating between limits r_1 and r_2 where the water-table depths are h_1 and h_2 respectively and on rearranging.

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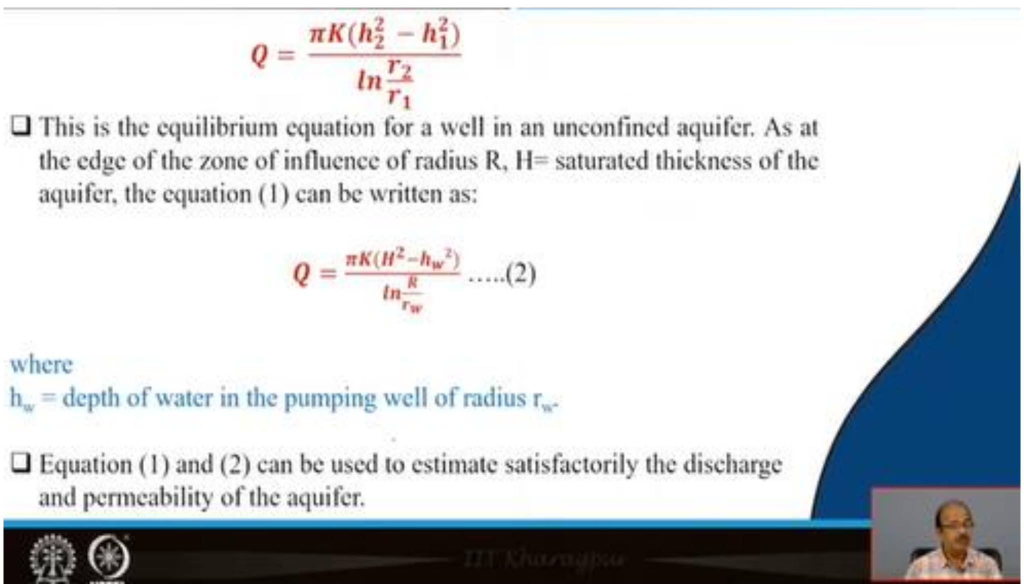

Now we will just put the value then that will become the

$$Q = \frac{\pi K(h_2^2 - h_1^2)}{\ln\frac{r_2}{r_1}}$$

This is the equilibrium equation for a well in an unconfined aquifer. As at the edge of the zone of influence of radius R, H= saturated thickness of the aquifer, the equation (1) can be written as:

$$Q = \frac{\pi K(H^2 - h_w 2)}{\ln\frac{R}{r_w}}$$

So, where

h_w = depth of water in the pumping well of radius r_w.

You can see here also hw just there. So, this one is the hw this one, so depth of water in the pumping well of radius r^2. By equation 1 and 2 it can be used to estimate, satisfactorily, the discharge and permeability of any aquifer. Now on this formula we can solve a small numerical also.

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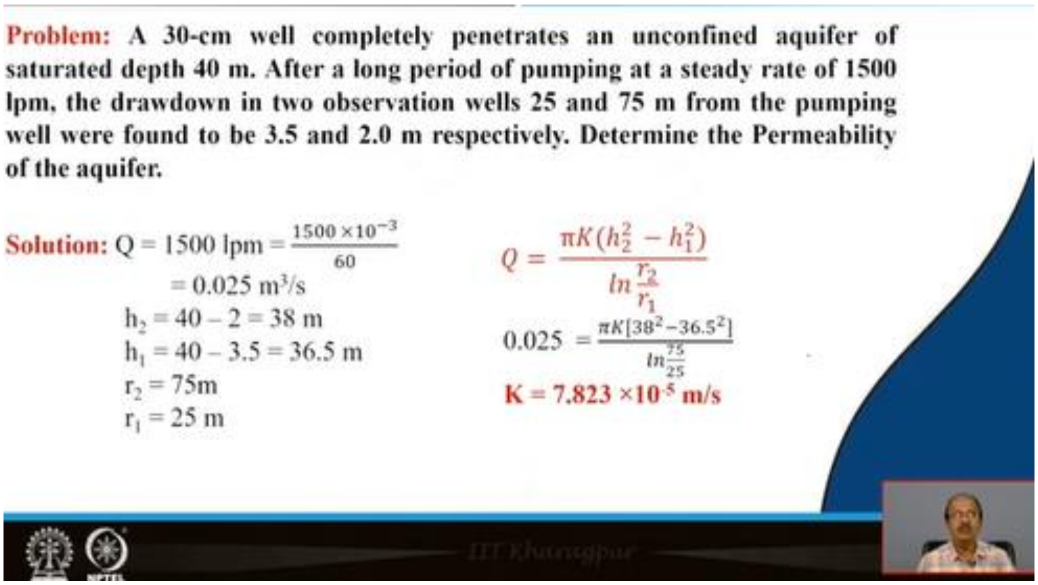

A numerical is a problem is A 30-cm well completely penetrates an unconfined aquifer of saturated depth 40 m. After a long period of pumping at a steady rate of 1500 lpm, the drawdown in two observation wells 25 and 75 m from the pumping well were found to be 3.5 and 2.0 m respectively. Determine the Permeability of the aquifer.

Solution:

Q = 1500 lpm = $\frac{1500 \times 10^{-3}}{60}$

= 0.025 m^3/s

h_2 = 40 – 2 = 38 m

h_1 = 40 – 3.5 = 36.5 m

r_2 = 75m

r_1 = 25 m

$$Q = \frac{\pi K(h_2^2 - h_1^2)}{ln\frac{r_2}{r_1}}$$

$$0.025 = \frac{\pi K[38^2 - 36.5^2]}{ln\frac{75}{25}}$$

$$K = 7.823 \times 10^{-5} \text{ m/s}$$

So, in this way we can find out the permeability also if we are having the data of the different depths of the your pumping well as well as the depth of the your aquifer.

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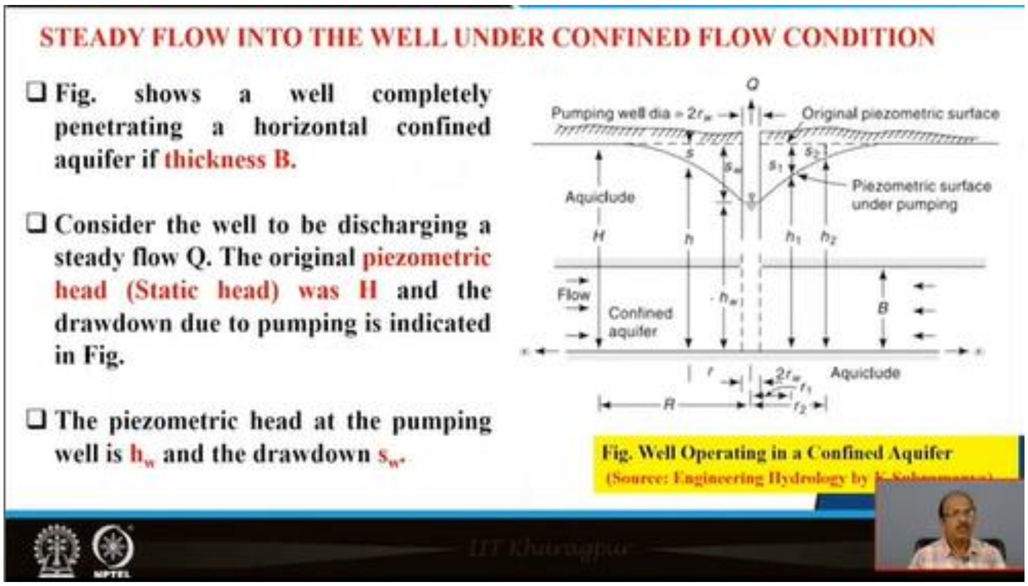

Now earlier one was the case of the unconfined aquifer. So, there the two variables were there one is the h height and other is the radius. But here in this case confined aquifer perhaps we are you are also knowing in detail also that when the upper and lower when any formations whose upper and lower layer is just bounded by some impervious stratum then it is called as confined aquifer.

So, here we can see the height is h the original piezometric head is was h and the drawdown due to pumping is indicated in this figure. We can see the thickness is the B and the well is discharging a steady flow Q, original piezometric head was H capital H and the drawdown due to pumping is indicated in figure you can see drawdown level. Now the piezometric head at the pumping well is h w and the drawdown is s w. So, for h_w it is s_w.

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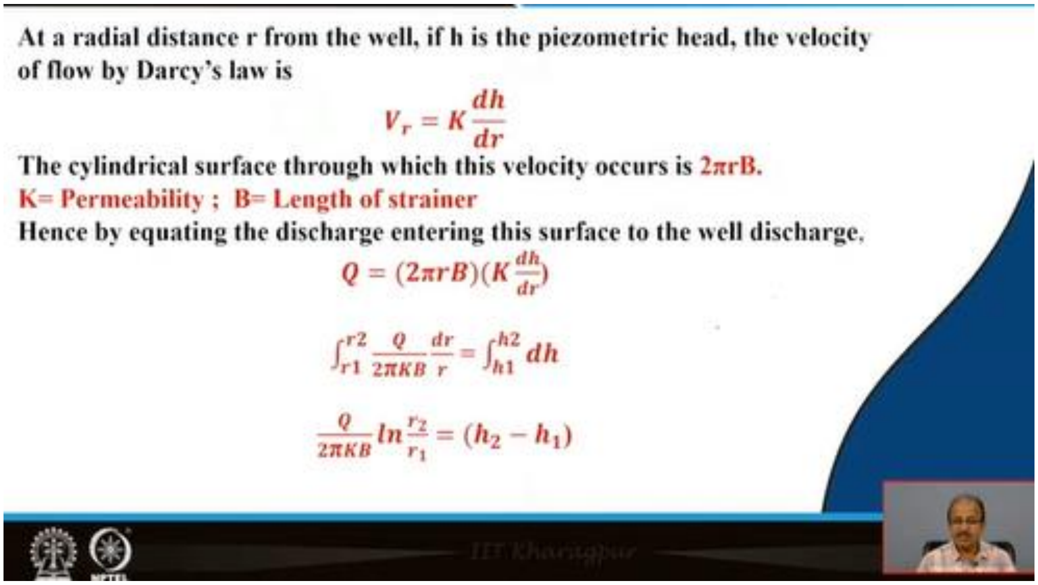

So, in this case at a radial distance r from the well if H is the piezometric head, the velocity of flow by the Darcy law is At a radial distance r from the well, if h is the piezometric head, the velocity of flow by Darcy's law is

$$V_r = K\frac{dh}{dr}$$

The cylindrical surface through which this velocity occurs is 2πrB.

Hence by equating the discharge entering this surface to the well discharge,

$$Q = (2\pi rB)(K\frac{dh}{dr})$$

$$\frac{Q}{2\pi KB}\frac{dr}{r} = dh$$

Integrating between limits r_1 and r_2 with the corresponding piezometric heads being h_1 and h_2 respectively.

$$\frac{Q}{2\pi KB} ln\frac{r_2}{r_1} = (h_2 - h_1).$$

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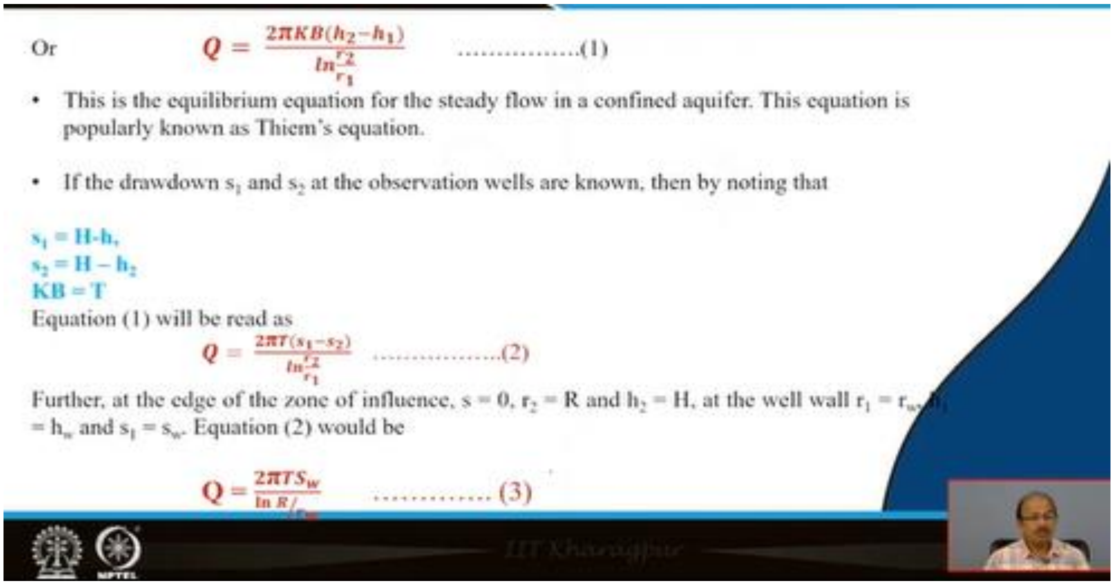

Now again further solving we are getting the

$$Q = \frac{2\pi KB(h_2-h_1)}{ln\frac{r_2}{r_1}} \;.....1$$

- This is the equilibrium equation for the steady flow in a confined aquifer. This equation is popularly known as Thiem's equation.
- If the drawdown s_1 and s_2 at the observation wells are known, then by noting that

s_1 = H-h,

s_2 = H – h_2

KB = T

Equation (1) will be read as

$$Q = \frac{2\pi T(s_1-s_2)}{ln\frac{r_2}{r_1}} \;........2$$

Further, at the edge of the zone of influence, s = 0, r_2 = R and h_2 = H, at the well wall r_1 = r_w, h_1 = h_w and s_1 = s_w. Equation (2) would be

$$Q = \frac{2\pi T S_w}{ln\, R/r_w}$$

So, this way just on the basis of this also we can have some problem we can solve and we can see that the 30 centimeter 30 meter diameter well completely penetrates a confined aquifer.

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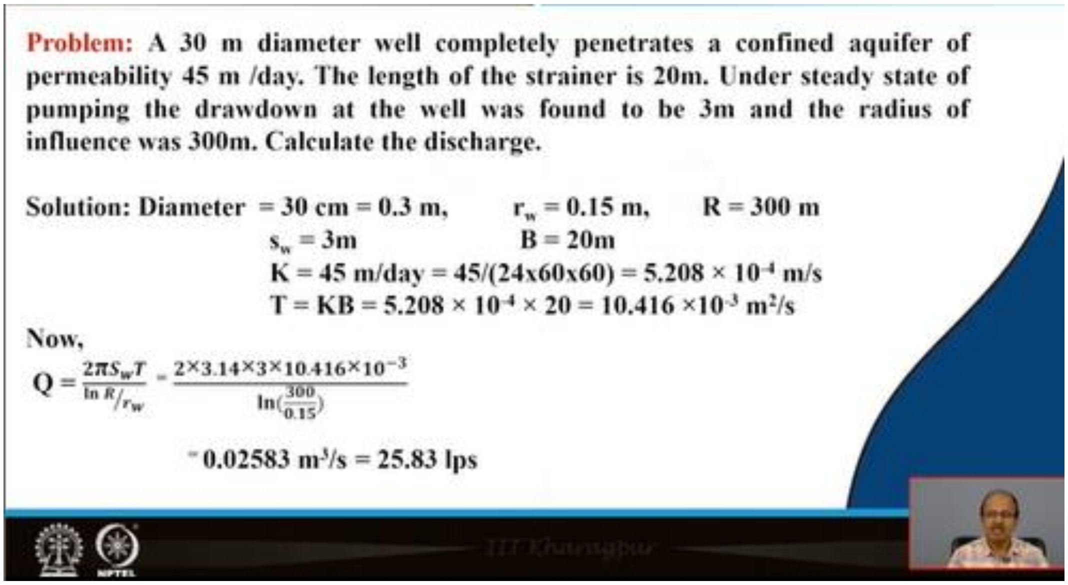

So, here it is penetrating confined aquifer in that problem it was in unconfined aquifer. So, permeability is given here in that question it was asked here permeability given. A 30 m diameter well completely penetrates a confined aquifer of permeability 45 m /day. The length of the strainer is 20m. Under steady state of pumping the drawdown at the well was found to be 3m and the radius of influence was 300m. Calculate the discharge.

Solution

Diameter = 30 cm = 0.3 m,

r_w = 0.15 m,

R = 300 m

s_w = 3m

B = 20m

K = 45 m/day = 45/(24x60x60) = 5.208 × 10^{-4} m/s

T = KB = 5.208 × 10^{-4} × 20 = 10.416 ×10^{-3} m^2/s

$$Q = \frac{2\pi S_W T}{\ln R/r_w}$$

$$Q = \frac{2\times3.14\times3\times10.416\times10^{-3}}{\ln(\frac{300}{0.15})}$$

$$Q = 0.02583\ m^3/s$$

$$Q = 25.83\ lps$$

So, this is generally coming this type of your Q discharge value in the confined aquifer.

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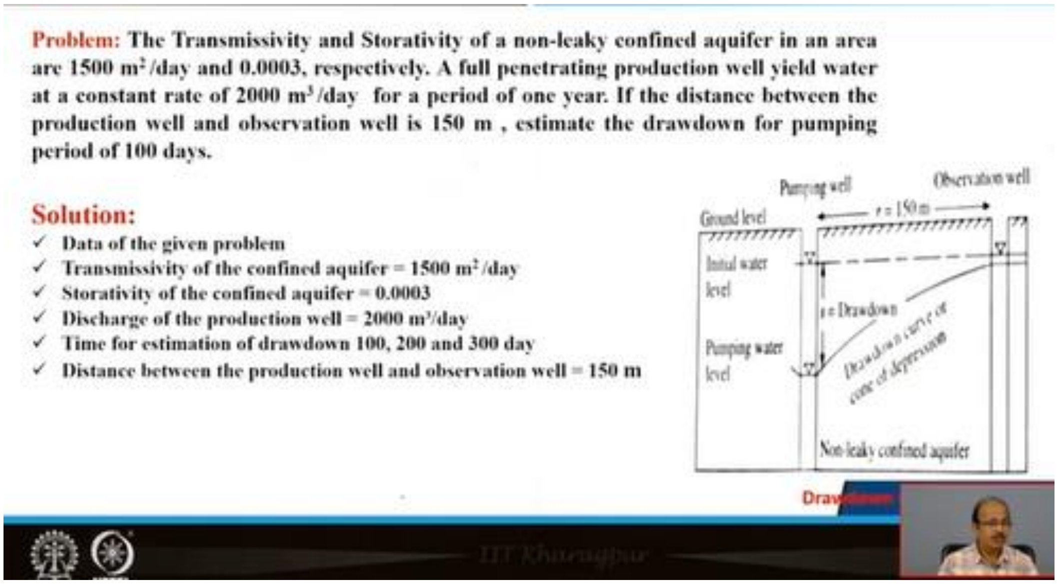

Now this is another problem our detailed problem and the transmissivity and storativity. As we have discussed that the water parameters depend in any sort of formation because of the boundary conditions then the transmissivity in the area and storativity in the area etcetera. So, the transmissivity and storativity of a non-leaky confined aquifer in an area are 1500 meter square per day and 0.0003 respectively. A full penetrating production well yield water at a constant rate of 2000 meter cube per day for a period of one year. If the distance between the production well and observation well is 150 meter the drawdown from pumping period of 100 days.

So, this has been given this is just the some of the pictorial diagram of this one drawdown curve. Now data given transmissivity of confined for 1500 m^2 /day, storativity 0.0003 it is a ratio. Discharge of the production well 2000 m^3/day, time for estimation around 100, 200, 300. Now you know distance between the production well and those are 150 meter. So, this is generally we have just extracted it out from the question.

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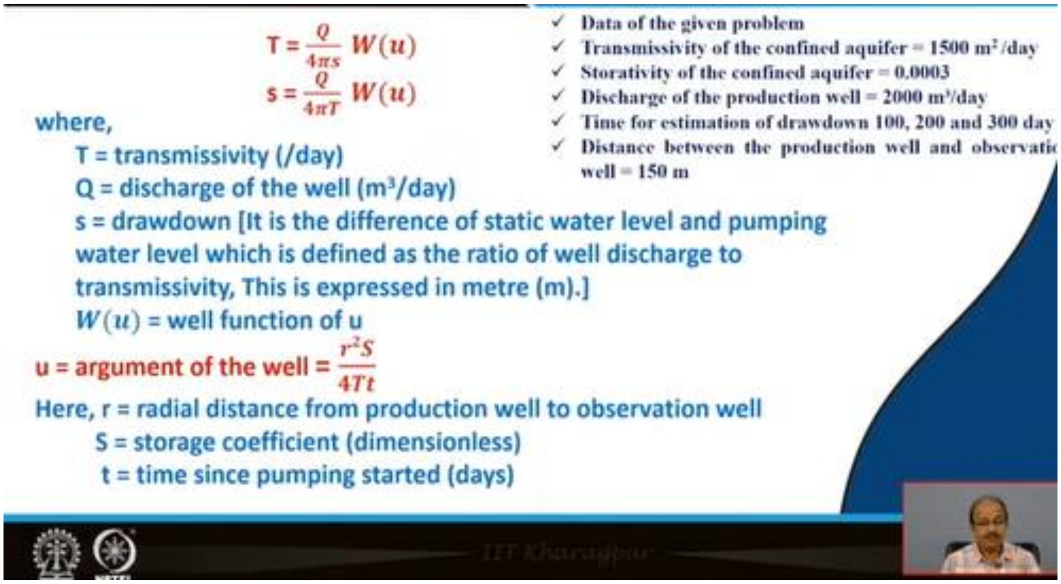

So, now T the formula of your transmissibility is

$$T = \frac{Q}{4\pi s}W(u)$$

$$S= \frac{Q}{4\pi T}W(u)$$

So, T is the transmissivity in per day discharge of the well Q is equal to the discharge of the well, s is the drawdown it is the difference of static water level and pumping water level which is defined as the ratio of well discharge to transmissivity.

So, this is expressed in meter and W u is equal to the well function of u. So, this is very important general these are being find out from certain graph or chart. So, u is the argument of the well and its value remains say

$$u= \frac{r^2}{4Ts}$$

So, r is the real distance from production well to observation wells, S is the storage coefficient that is storativity and t is the time since pumping started, capital T is the transmissivity. So, data given transmissivity is in this much 1500 cubic meter square per day.

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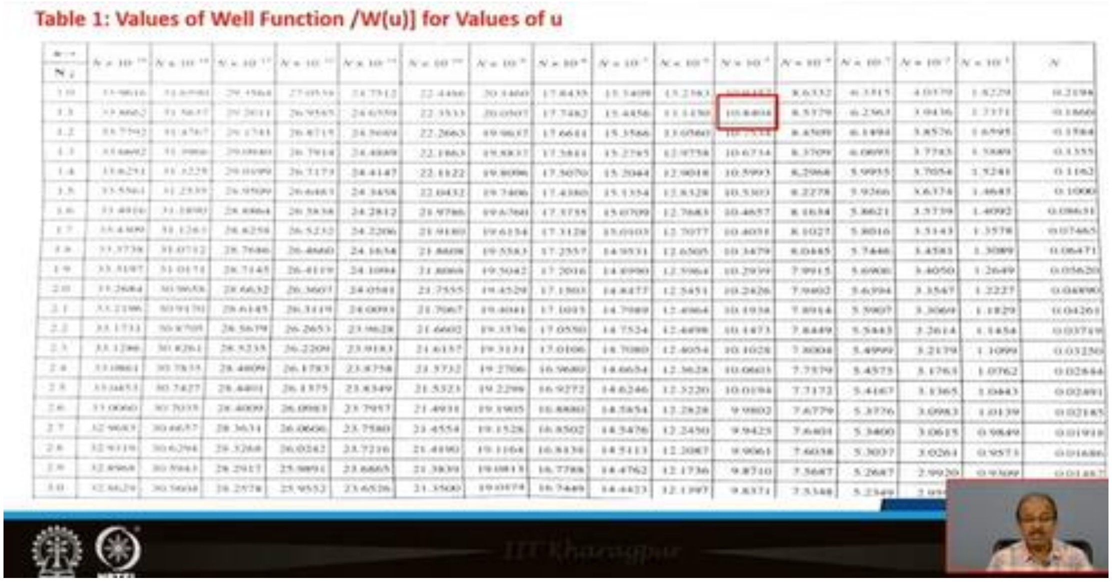

So, in this way we can just see this is the one of the table through which we can just see the value 10.804. So, this value will be required just in this problem.

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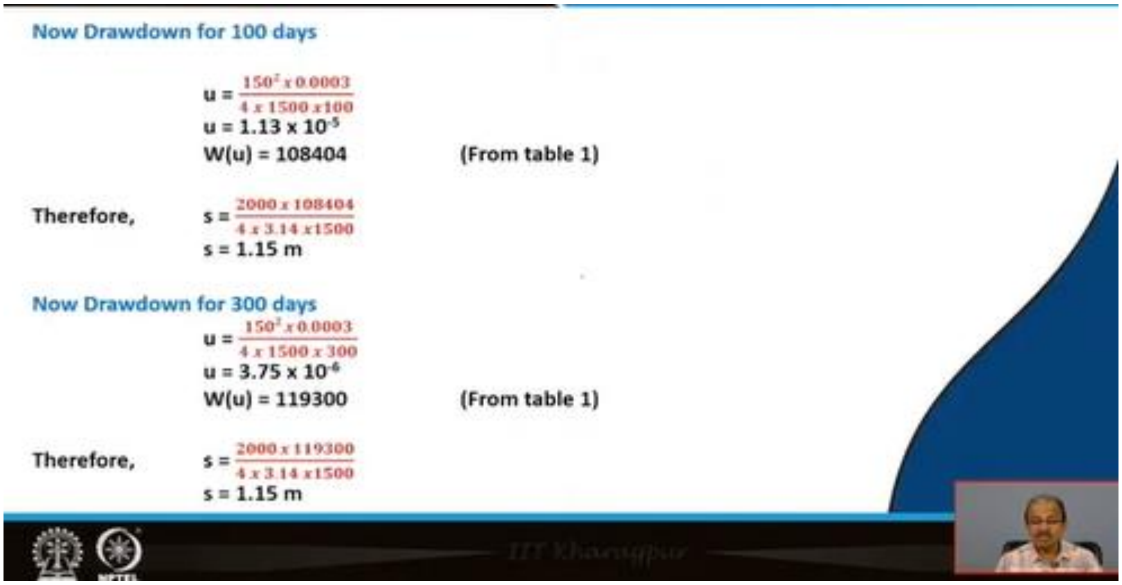

Now in this problem and drawdown for 100 days we have to find out. So, u value just if you will put the data in this u value is coming, just put this we have to solve. So, here

$$u = \frac{150^2 * 0.0003}{4 * 1500 * 100}.$$

$$u = 1.13*10^{-3}$$

$$W(u) = 108404$$

Therefore,

$$s = \frac{2000*108400}{4*3.14*1500}$$

$$s = 1.15 \text{ m}$$

Now Drawdown for 300 days

$$u = \frac{150^2*0.0003}{4*1500*300}$$

$$u = 3.75*10^{-6}$$

$$W(u)= 119300 \quad \text{(From Table 1)}$$

$$s = \frac{2000*108400}{4*3.14*1500}$$

$$s = 1.15 \text{ m}$$

s = 1.15 meter. So, this is for 100 days and for 300 days.

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So, now these are the references which I have taken help from the different textbooks for discussion of the well hydraulics chapters as well as the runoff and the different types of wells.

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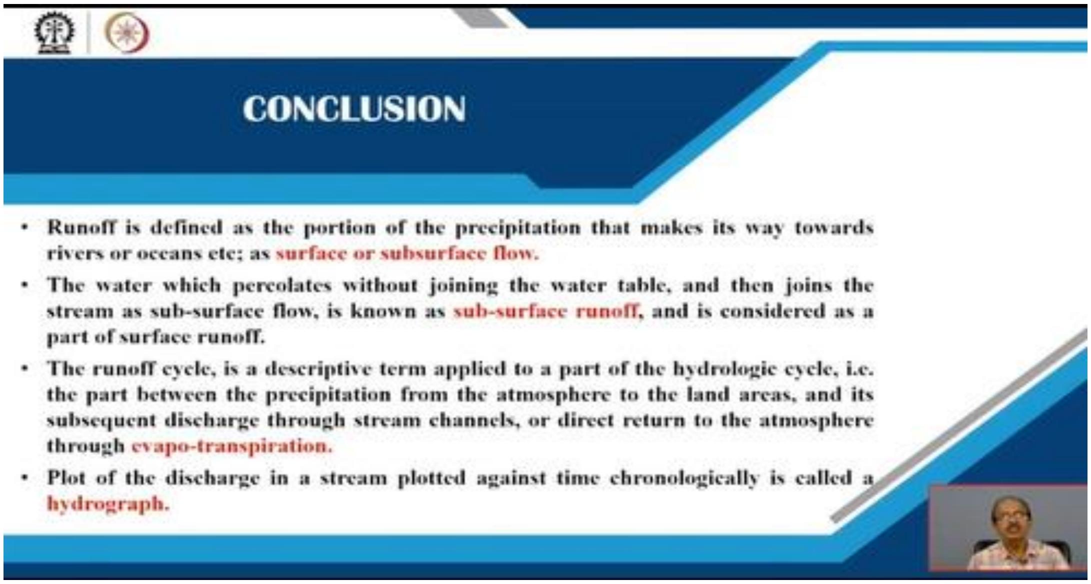

And now just to conclude, the conclusion of this very chapter is that runoff is defined as the portion of the precipitation that makes its way towards the river or stream as surface of subsurface flow. The water which percolates without joining the water table and then joins the steam or subsurface flow is known as the subsurface runoff and it is considered as a part of surface runoff. The runoff cycle is a descriptive term generally applied to a part of the hydrological cycle.

That is the part between the precipitation from the atmosphere to the land areas and its subsequent discharge through stream channels or direct return to the atmosphere through evapotranspiration. Now just the plot of the discharge in stream against time is called as hydrograph.

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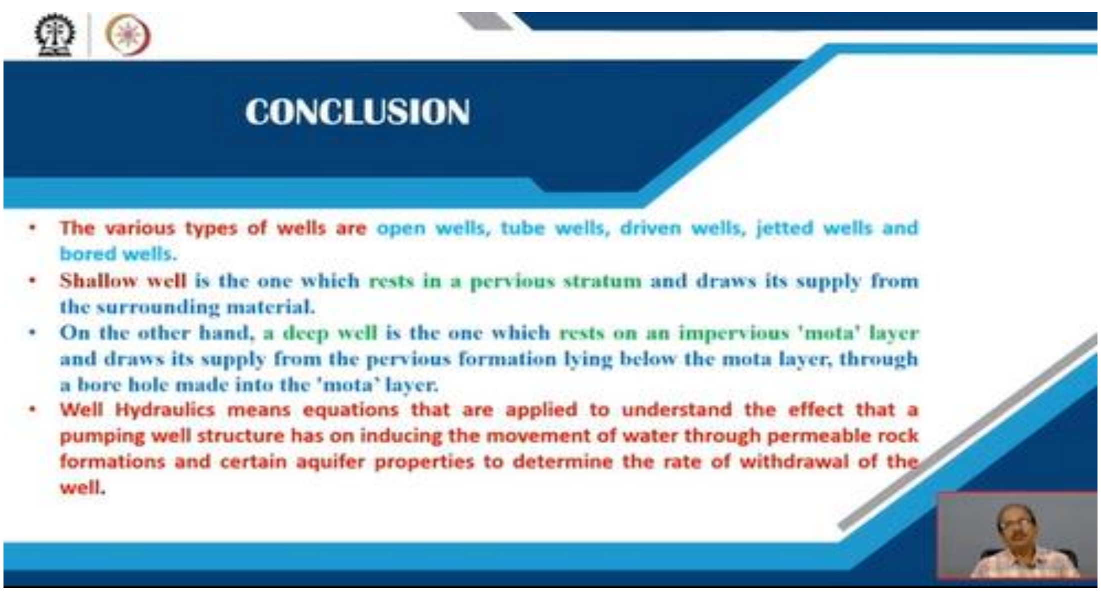

The various types of wells we have also discussed like open wells, tube wells, driven wells, jetted wells and bored wells and shallow wells is the one which rest in pervious stratum and draws a supply from the surrounding material. But the point is it is having very limited yield. Whereas the deep well is one which rest on an impervious mota layer first and then below it remains the pervious stratum.

And it draws supply from the pervious formation which is just lying below the mota layer and through a bore hole made into the mota layer it is giving better rain compared to the shallow open well. So, well hydraulics also we have discussed in greater detail which means equations that are applied to understand the effect that a pumping well structure has on inducing the movement of water through permeable rock formation.

And certain aquifer parameter properties to determine the rate of withdrawal of the well. So, these are the very important aquifer properties plays, very important role. So, this whole thing by this whole thing we have just came to the conclusion that the precipitation is responsible for just converting the sort of water and this water remains in your inside the aquifer also as well as in the streams also. So, the next component will be discussed in the next lecture. So, thank you very much to all.