ENVIRONMENTAL GEOSCIENCES

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Lecture-32

Hydrological Cycle

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. We are discussing the module 6. In the module 6, we have already discussed about the distribution of water on earth in the lecture one and groundwater provinces of India in lecture 2. Today, we will discuss the lecture three, that is the hydrological cycle. In this lecture, the important concepts will be covered like introduction to hydrological cycle, importance of hydrological cycle, main components of hydrological cycle, transportation components of hydrological cycle, basic components of hydrological cycle and water balance equation.

In the figure, we are seeing that the few terms are here. If you will see, the evaporation is at the top, then Condensation is there, then precipitation is there, infiltration is there, then, then transpiration is there. So these are the terms which are very well related in the hydrological cycle. Now we will discuss the introduction to hydrological cycle. Hydrology is the branch of geology in which generally is the scientific study of the distribution, movement and properties of water above and beneath the earth's surface.

It encompasses the full spectrum of water on earth including its history, occurrence and quantitative utilization. The hydrologic cycle describes the continuous movement of water within the earth atmosphere system and it consists of two main phases. The first phase is the atmospheric phase and second phase is the terrestrial phase. Now let us understand the first phase. Atmospheric phase involves the movement of water in its gaseous that is in water vapor form and liquid solid that is rain and snow form within the atmosphere.

Terrestrial phase is the second phase. This phase focuses on the movement of water on and within the earth's surface. So two different phases are in the earth atmospheric system. Atmospheric phase and Terrestrial phase. Now this terrestrial phase is further divided

into surface water phase which includes processes like runoff and stream flow where water flows across the land.

Now groundwater phase is the second type. It involves processes such as infiltration, water entering the soil, percolation, movement of water through soil layers, and aquifer recharge that is refilling underground water reservoirs. If you will recall the previous lecture's notes, we have seen that the earth's interior is made up of three important types of layers. The bottom most was the core, then the mantle, and then the crust. Crust.

So we have, we have seen already through the previous lecture notes that the crust is composed of heterogeneous type of rocks means all the different type of rocks we are getting in the crust. So here what happens? This is the earth's surface, this is the earth's surface and in the first slide i have already shown you the figure in which few components name were there, so on the earth's surface we are having only recharge source of water that is the precipitation, precipitation. So precipitation or rainfall is the only recharge source which is sending water to the earth's surface. Now what is happening. On the Earth's surface, this is the Earth's surface, and beneath it remains the soil. So what is happening?

When the raindrops just enter into the first layer of the soil, then this process is called as infiltration. Infiltration. And when the first layer of the drop will again move down towards the gravity, towards the gravity means it will come to the bottom layer of the soil and then these are the rocks which will hold the water termed as aquifers. So this movement of water from the top of the earth's surface to just the first layer of the soil is termed as infiltration. But movement of water which is just taking place, which is just taking place downward towards the gravity, this is known as percolation. This is known as percolation.

So, so what we have understood that The movement of rainwater through the first layer of the soil beneath the earth surface is termed as infiltration whereas those stop raindrops when it will further move down towards the gravity, towards the aquifer. towards the rock which will hold the water, then such type of movement in the soil is termed as your percolation. So here we have written also that water entering into the soil is termed as infiltration. Rainwater entering into the soil is termed as infiltration whereas movement of the rainwater through soil layers, different soil layers beneath is known as percolation. And lastly, this infiltrated water and percolated water will ultimately store in the aquifer.

These are the rocks which are just holding the water. These are the rocks which are just holding the water. So this is the aquifer recharge. So, what we have understood that teresterial phase has two components that is surface water phase which includes the runoff and stream flow and second is the ground water phase which involves the process of infiltration, percolation and aquifer recharge. Yes, one thing we should make it clear also. We have already known about the terms about the precipitation, then infiltration, then percolation, aquifer recharge.

Now runoff is one of the terms coming here in the surface water phase. So runoff is those, suppose if the raindrop will just enter, these are the raindrops which will enter into the first layer of the soil. So this place will become saturated. Once the soil layer which is remaining just beneath the Earth's surface will become saturated, definitely it won't send the water downward. Rather, The surplus rainwater which will not enter into the earth layer is just flowing through the topography of the earth surface and ultimately it is meeting to some river body or stream channel.

So this surplus amount of rainwater which is not being allowed by the soil layer because it has already become saturated, this is termed as the runoff. This is termed as the runoff or surface runoff. Okay. Now moving ahead. In this diagram also you can see.

Here the same terms are coming once again. You can see the precipitation term is here. Then infiltration term is here. Then percolation term is here. Runoff or surface runoff term is here.

Besides these, we are also seeing some more terms here. Like first evaporation we are seeing. Then transpiration we are seeing. Okay. So now evaporation is the phenomenon when the water just move to the atmosphere by the temperature of the sunlight.

So these are the surface water sources. We have read in the previous lectures also that the surface water sources are running water that is river, then ponds, then lakes, then ditches, storage structure on the earth's surface etc. So when these water will evaporate and move to the atmosphere again, it won't goes down to the earth's surface, then such type of water is termed as evaporation. Okay. Secondly, plants uptake water from the soil layer beneath the earth's surface for the process of photosynthesis, that is food making process with the help of sunlight, etc. Now, the plants will uptake the water from the earth's surface that is within the soil layer and the surplus amount of water which will left behind after the process of photosynthesis that is again being sent to the atmosphere by the stomatal opening of the leaf.

Plant leaf have several openings. This is the plant leaves. It is having the opening which is called as stomatal opening, stomata. So, through the stomatal opening, generally the leaf surface just evaporates water to the atmosphere. But here, the term is called as transpiration.

The term is called as transpiration. So, what we are seeing, that the evaporation and transpiration, cumulatively called as evapotranspiration. Evapo-transpiration. Transpiration. So evapotranspiration is the process whereby the surplus amount of water from the earth's surface or from the leaf's surface are being sent back to the atmosphere again. So this is about the hydrogeological cycle or hydrological cycle.

Here we are seeing then after infiltration and percolation the water is just remaining in the rock in the rock, and then the groundwater, and we are just tapping the groundwater from the rock, which is termed as an aquifer. Okay, so these are some of the terminology which we have seen related with the hydrological cycle. That is, the first terminology is the precipitation. This is the first terminology, precipitation.

Second is the surface runoff. Third is the infiltration. Fourth is the percolation. Fifth is the evaporation. And sixth is the transpiration.

So these are the terminologies associated with the your hydrological cycle. Now we will discuss the importance of hydrological cycle. So we have understood the hydrological cycle already that the cycle consists of few important parameters what we have discussed. Now the hydrological cycle is of immense importance as it not only governs the movement and distribution of water on earth but also plays a vital role in regulating the planet's climate and sustaining life. One of Its key function is the exchange of energy which directly impacts on temperature and climate dynamics.

Now, we will see how the energy exchange is taking place in the hydrological cycle or water cycle. First, in the case of evaporation, we will look after when water from oceans lakes, rivers, soil evaporates, it absorbs heat energy from its surroundings. This process cools the immediate environment because the absorbed heat is used to convert the water into vapor. This phenomenon helps in keeping moderate temperatures particularly in coastal areas. Now second is the condensation.

When water vapor rises and cools, it condenses to form clouds from where we are getting the rain. During condensation, the energy absorbed during evaporation is released back into the atmosphere as latent heat. This release of energy warms the surrounding air,

influencing the weather patterns and contributing to phenomena like thunderstorms and cyclones. Now second is the impact on climate. The heat exchange during evaporation and condensation are fundamental to maintaining the earth's energy balance.

This process influences first the temperature regulation. We will understand this. The transfer of heat during evaporation and condensation helps in distributing the thermal energy across the planet. Mitigating extreme temperature variations between day and night or different regions. So what we have seen that the evaporation and condensation helps in distributing the thermal energy across the planet.

Now second is the weather patterns. The release of latent heat during condensation drives atmospheric circulation shaping the weather systems like rainfall, snow and storms. Third is the climate feedback loops. Changes in the water cycle or hydrological cycle such as increased evaporation due to warming oceans can amplify global temperature shifts and affecting the long term climate trends. Third point is supporting ecosystems and life.

The hydrological cycle ensures the continuous replenishment of freshwater resources, supporting the ecosystems, agriculture activity and human life. The energy exchanges within the cycle also contribute to the stability of the ecosystems by maintaining favorable environmental conditions. In essence, the Hydrological Cycle is a critical natural processes that not only sustains life but also acts as a dynamic regulator of Earth's climate highlighting its significance in both environmental and human context. Now we will discuss the basic components of Hydrological Cycle. The basic components of Hydrological Cycle generally constitute two components the first component is the flow component that is transportation components and second component is the storage components

Here we will see, the, what are the different components coming under the transportation components. The first components which are coming in the transportation component flow component is precipitation that is rainfall. Second component is the runoff or surface runoff. Then the evaporation, fourth is the condensation, fifth is the transpiration, sixth is the sublimation and seventh is the infiltration and percolation. So these are all coming under the transportation flow components. Schematically, if you will see in the diagram, the interdependency of the transportation components in the figure, here we can see the quantities of water going through the various individual paths of the hydrological cycle in a given system can be described by the continuity principle and the principle is known as water budget equation or hydrologic equation. so here you can see that in all

the cases the flows are here because it is a transportation component see precipitation the water from the atmosphere coming to the earth surface then infiltration the water is entering into the surface that is in the soil layer then the runoff surplus amount of water is just meeting to the streams.

Then, the, here you can see evapotranspiration means I have told you in the previous slide that when we are just joining both evaporation and transpiration, then it is cumulatively termed as evapotranspiration. So, these all are the flow component that is the transportation components. They are all depending on each other and that's why there is a principle and the principle is the water budget equation. Now, We will discuss the component transportation components one by one. First is the precipitation.

Precipitation means transfers of water from the atmosphere to the earth's surface is known as precipitation. it initiates surface water flow through runoff if the surplus amount of water will remain on the earth surface it won't move towards the gravity towards the soil layer then those surplus amount of water will be termed as runoff. So these runoff flow to the rivers and streams ultimately. Surface flow facilitates groundwater recharge via infiltration and percolation also. It balances the global water cycle by redistributing water through precipitation. It links the atmospheric phase to the terrestrial phase of the hydrological cycle, sustains the continuity of the water cycle by replenishing wastewater reservoirs. It triggers processes like stream flow and aquifer recharge because these water, precipitated water is only going to the aquifer.

So it is recharging the aquifer also and the surplus amount of water which won't go to the aquifer, that those water will flow as a surface runoff or runoff and ultimately it will become a component of the river or stream flow. It drives evaporation by replenishing surface water bodies. So, what we have seen that its precipitation supports vegetation, which influences transpiration in the hydrological cycle. It helps in the regulating the earth's water distribution between land, oceans and the atmosphere. So, here also we can see the diagram in which we are seeing the precipitation is taking place, surface runoff component is there, percolation is going on, and the stream flow, surplus amount of water is just meeting.

And this is the rock in which the water remains. So, inside also we are seeing the groundwater flow. And the top layer of the water of the aquifer is generally termed as the water table, what we have noticed here. But it will remain confined to the unconfined

aquifer only. So these are the some of the concepts related to the precipitation. Now second is the runoff.

Runoff is water from precipitation that flows over or through the soil into streams, rivers, lakes or ocean. So here the term is over and through the soil also. So let us understand first the rain water which will enter to the soil through the process of infiltration it will again further move towards the gravity that, that it will percolate down it will percolate down means percolation process will take place and ultimately it will reach to the aquifer the rock which is holding the ground water, but the surplus amount of water which will not go inside means it won't infiltrate or percolate, Those surplus amount of water will flow through the topography.

So that water will ultimately goes to the river channel or stream channel. So runoff is water from precipitation that flows over to the streams, rivers, lakes or oceans. Also a word is that through the soil layer. So when the percolated water or infiltrated water won't move down further this water is again moving to the bed of the aquifer. Horizontally it also follows the topography inside.

It also follows the slope inside and then ultimately it is just reaching to the bed of the river channel. So this runoff is called as subsurface runoff. So what we have understood that one term is runoff or surface runoff means the precipitated water if it is remaining in surplus amount it is not entering into the soil rather it is just following the topography of the earth surface and ultimately meeting to the streams, rivers, lakes or oceans then those amount of rainwater is called as surface runoff. And the inside water means infiltrated water, percolated water through the soil layer. If it is reaching to the stream, river, lakes or oceans, then it is called as subsurface runoff.

So these two terms we have understood here, runoff means surface runoff or subsurface runoff. Both the types of water, that is the surface runoff water and subsurface runoff water ultimately reaching to the nearby streams, river, lakes or oceans. Runoff occurs when the rate of precipitation exceeds the soil infiltration capacity, what I have discussed just now. If the saturation will be there, definitely it won't allow water inside, rather it will move towards the topography. It contributes to the recharge of water bodies supporting the aquatic systems.

It can cause soil erosion. Runoff can cause soil erosion and sediment transport, shaping the landscapes ultimately. Excessive runoff can lead to flooding also and water quality issues also generate here if there will be excessive runoff. Vegetation helps to reduce

runoff by promoting water infiltration and slowing surface flow. So runoff is influenced by factors like land use, rainfall, intensity and climate change.

Third component is the evaporation. Evaporation converts surface water, surface water into water vapor using solar energy. Oceans are the largest contributors supplying most atmospheric water vapor to the atmosphere. Evaporation begins the atmospheric phase of the hydrological cycle. Higher temperatures generally accelerate the evaporation process, especially in the tropical regions.

Because of the evaporation, it cools the earth's surface by absorbing heat during the processes. It combines with plant transpiration to form evapotranspiration, a key cycle component. It drives weather patterns by enabling cloud formation and precipitation. So this is all about the concepts of evaporation. The next transportation component is the condensation.

Condensation converts water vapor in the atmosphere into liquid water droplets. It occurs when rising water vapor cools to its dew point at higher altitudes. Dust particles also act as condensation nuclei for water vapor to form liquid droplets. It leads to the formation of clouds as droplets accumulate, it is just forming the clouds. During this process, there is a release in latent heat, thereby warming the surrounding atmosphere and influencing the weather pattern of the area.

So condensation plays a key role in the hydrological cycle by transitioning water back to the liquid form. It also facilitates precipitation when condensed droplets combine and grow larger. So this is the another term related to the hydrological cycle. Next transportation component is the transpiration. Transpiration process moves water from plant roots to the aerial parts.

Where it evaporates as water vapor. This aerial part is nothing but it is the leaf. It is the leaf. So it helps in transporting nutrients and minerals within the plant. Transpiration cools plants by releasing heat through evaporation.

It combines with soil evaporation to form evapotranspiration in the hydrological cycle. During this process, the water vapor is released into the atmosphere which contribute to humidity and cloud formation. It is influenced by factors like temperature, humidity, wind, sunlight and soil moisture. It links the terrestrial and atmospheric phases of the hydrological cycle. Next, transportation component is the sublimation.

Sublimation is direct transition of water from solid that is the ice-snow form to gaseous form that is the vapor state without becoming liquid. It is commonly occurs in snow fields, glaciers and ice caps. This process requires low atmospheric pressure, low humidity and solar radiation for energy. It is contributing to hydrological cycle by transfer of water directly from snow or ice to the atmosphere. It adds water vapor to the atmosphere affecting local humidity and weather pattern.

It is significant in polar and high altitude mountain regions with consistently low temperatures. It absorbs large amount of latent heat causing localized cooling effects. So this is the Another component of the hydrological cycle. Next component is the infiltration. Infiltration is the process where the water from rainfall moves downward into the soil layer as I have discussed.

The rate of infiltration is influenced by soil porosity, pore size and texture. If the porosity will be good, definitely the infiltration rate will be more. So some of the factors are here, soil porosity, porous size and texture of the soil. Soil moisture, vegetation, land slope and rainfall intensity generally affects the infiltration processes. Infiltrated water replenishes underground aquifers contributing to groundwater discharge as we have discussed.

High infiltration rates reduce surface runoff, minimizing erosion and flooding. This concept we have understood in the previous slides. If the infiltration rate will be more, definitely the more water will enter into the soil. And if the more water will enter into the soil, less surface runoff will generate. If there will be less surface runoff, definitely there will be less erosion and flooding on the earth's surface.

So this infiltration plays very, very active role or important role in reducing the surface runoff also. If the rate is good, infiltration rate is good. Infiltration supports soil moisture benefiting the agriculture system and ecosystems. It connects to the surface water to groundwater, maintaining the hydrological cycle. Next component is the percolation.

Percolation is the downward movement of water through the soil and rock layer due to gravity and capillary forces inside the earth's surface. Gravity pulls water down while capillary forces help to move it through the soil pores. Water that percolates eventually becomes part of the groundwater system and ultimately replenishing the aquifers. Soil texture and permeability affect the speed of the percolation. Here the term permeability has come.

It is the ability of movement of water inside the earth's surface that is from one pore to another pore of the soil layer or from one rock to another rock within the earth's surface. So coarse soils generally allow faster movement. If the texture of the soil will be coarse, definitely the movement of the water will be more. Percolation maintains soil moisture which is vital for plant growth and ecosystem. So percolated water remains in the soil layers and the helps in keeping the soil moisture there.

This soil moisture is being absorbed by the plant. So this is very very important for the life of the plants on the earth system. Percolated water can filter out impurities, improving the water quality as it moves through the different soil layers. So filtration will be take place. Water will become more pure.

Water quality will improve. Percolation contributes to the hydrological cycle by transferring surface water into the groundwater storage system. So this is one of the important components within the earth system. Now, we will discuss the second component, the storage components. We have already discussed the different terms related to the transportation components.

Now we will discuss the storage components. Surface water storage includes depression storage, ponds, lakes and reservoirs which are holding water temporarily on the surface of the earth. Soil moisture storage refers to the water retained in the soil, essential for plant growth. We have discussed in the previous slide that soil moisture remains within the soil and it helps in the growth of the plant. Groundwater is stored in the cracks and pore spaces beneath the earth's surface in aquifers.

And these aquifers are nothing, these are the rocks. These are the rocks holding the water. Rocks with water is called as an aquifer. So in the rock, Generally, if the rock is of sedimentary origin, means the pore spaces are good in that, definitely it will store the water. And in some hard rock, say metamorphic rock, what we are having, we are getting the cracks, cracks or lineaments.

We are getting some fine cracks or lineaments in which the water stores here. So groundwater is generally stored in cracks in the hard rocks and pore spaces in the soft rock beneath the earth's surface in the form of an aquifer. Aquifer's permeability and porosity both affect the groundwater storage and movement. Both point is very very important. The rocks should have the ability to store the water first and then it should have the ability to move the water from one aquifer to another aquifer, from one soil layer to another soil layer.

So porosity and permeability of any rock which is holding the water, that is aquifer, is affecting the groundwater storage of the area as well as the groundwater movement from one area to another area. Groundwater can be accessed through wells for irrigation, industrial use or drinking water. Groundwater discharge occurs when water exits from the underground storage, when we are just tapping the water for some different uses. From where? Through some springs, seepages or some wells.

Storage components play a key role in the hydrological cycle, maintaining water balance and supporting the ecosystem and human needs. Now, as we have discussed that the cycle gives us one of the important equation that is the water balance equation. So we will see how the water balance equation is coming. As per the water balance equation, the point is that the sum of inflow water on the earth's surface will remain equal to the sum of the outflow water. So we have already seen the different components of the hydrological cycles.

So out of the three processes that is precipitation, runoff and evaporation, inflow is precipitation. In this process if you will see the inflow is precipitation. Runoff and evaporation comes under the outflow because it is going to somewhere else. In runoff, we have seen that it is not remaining at the place where the rain is falling. Rather it is going to somewhere else through the topography of the earth surface.

And evaporation is the surplus amount of the rainwater which is going back to the atmosphere from the open surface water sources that is the stream, rivers, lakes, ponds, etc. So runoff and evaporation, both come under the outflow, whereas precipitation, runoff and evaporation, inflow is only the precipitation. So the precipitation minus runoff is equal to evaporation. That means precipitation is equal to evaporation plus runoff. Just we are summarizing this in the form of precipitation.

$$\text{Precipitation} - \text{Runoff} = \text{Evaporation}$$
$$\textbf{Precipitation (P)} = \textbf{Evaporation (E)} + \textbf{Runoff (R)}$$

If we will deduct the component, that is the surface runoff, that is the net groundwater flow, that is the evaporation, and that is the transpiration, we will ultimately get the storage, that is the change in storage. So water balance equation tell us that change of storage can be determined if we will just deduct the runoff amount the net groundwater amount the evaporation amount and transpiration amount from the precipitation amount then the we will get the net change in the groundwater storage.

- General water budget equation in hydrology for time internal Δt.

$$P - (R+G+E+T) = \Delta S$$

where,

P = Precipitation
R = Surface runoff
G = Net groundwater flows out of the catchment
E = Evaporation
T = Transpiration
ΔS = Change in storage

Now based on the above equation that is the water balance equation one problem is here just see the problem a river reach had a flood wave passing through it at a given instant the storage of water in the reach was estimated as fifteen point five hectare meter. Now question is what would be the storage in the reach after an interval of three hours if the average inflow and outflow during the time period are time period means three hours are fourteen point two meter cube per second and ten point six meter cube per second respectively. Now just we will put the data which are in the numerical.

First is the initial storage. It is mentioned here fifteen point five hectare meter. We will change in meter cube. Now inflow rate is also given in meter cube per second that is fourteen point two meter cube per second. Inflow volume in three hours we have to calculate because time is three hours interval.

Initial Storage = 15.5 ha-m = 15.5×10^4 m^3

Inflow rate = 14.2 m^3/s

Inflow volume in 3 hours = 14.2 x 3 x 60 x 60 = 153360 m^3

Outflow rate = 10.6 m^3/s

Outflow volume in 3 hours = 10.6 x 3 x 60 x 60 = 114480 m^3

Final Storage = ?

So just we have computed and it is coming to this value. now outflow rate also mentioned in the numerical so just it is ten point six meter cube per second for three hours we will calculate the outflow volumes it is coming to this much. Now we have to find out the storage of water how much storage of water is in the reach. So we will put the water balance equation which is also called as water budget equation we have seen the change in storage is nothing the amount of inflow minus amount of outflow so this inflow and outflow is the equal to we can write in this way final storage minus initial storage. Inflow volume we have already calculated outflow volume also we have calculated initial storage was given there and the final storage we have to find out Now final storage will be just if you will put the value and solve it you will get the final storage one nine three

eight eight zero cubic meter in the river reach. So this is about the numericals which is here.

From the water budget equation,

Inflow - Outflow = Change in storage

Inflow - Outflow = Final storage - Initial Storage

$153360 - 114480 =$ Final storage $- 15.5 \times 10^4$

Final Storage $= 38880 + 15.5 \times 10^4 = 38880 + 155000$

Final Storage $= 193880 \ m^3$

Now second numerical we will see again. Here the estimate the constant rate of bed travel from one three seven five hectare reservoir. In a month of thirty days during which the reservoir level dropped by zero point seven five meter in spite of an average inflow into the reservoir of zero point five million cubic meter per day during the month. The average seepage loss from the reservoir was two point five centimeter. The total precipitation was eighteen point five centimeter.

And total evaporation was nine point five centimeter. So here some more components are mentioned. Its values are also given. Now just we will put those components value first. Reservoir area is given one three seven five hectare.

We will bring it into meter square. Inflow into the reservoir given zero point five into ten to the power six meter cube per day. Now inflow volume in month because thirty days time is there. So inflow volume in month we have to calculate value is coming to this much. Inflow in terms of depth is coming fifteen into ten to the power six divided by one three seven five into ten to the power four.

The value is coming one point zero nine one meter. Change in storage is zero point seven five meter. Now, seepage loss. Given two point five centimeter. Then precipitation eighteen point five centimeter.

It will be in this much in meter. Evaporation nine point five centimeter. It will be in zero point nine five meter. And withdrawal has been asked. This has been asked.

In the question. Now we will put the water balance equation. In this form. Change of storage. P plus I. Minus Q plus G plus C. So here.

Just we will put the data, the value of the different components. And then we can able to find out this Q. And Q is coming to zero point four zero six meter for a month. So the rate of withdrawal it will be zero point four zero six into one three seven five, which is the area of the reservoir. Then ten to the power four divided by thirty into twenty four into sixty into sixty. It is coming to 2.15 meter cube per second.

Seepage Loss (G) = 2.5cm = 0.025m

Precipitation (P) = 18.5 cm= 0.185m

Evaporation = 9.5 cm = 0.095 m

Withdrawal (Q) =?

Writing water balance equation

(P+I) - (Q + G + E) = Δs

(0.185 + 1.091) - (Q + 0.025 + 0.095) = 0.75

(1.27) – (Q + 0.12) = 0.75

Q = 0.406 m for a month

Rate of withdrawal = 0.406 x 1375 x 10⁴/(30 x 24 x 60 x 60) = **2.15 m³/s**

So, this is just based on the different values given for the different components of the hydrological cycle. So, with the help of the water balance equation, we can solve such type of numericals. Now, we will summarize the lecture. Introduction to hydrological cycles, firstly we have discussed. In it, we have seen that the hydrological cycle describes the continuous movement of water on and above and below the earth's surface through processes like evaporation, condensation, precipitation runoff.

It plays a vital role in sustaining life and maintaining ecological balance. Secondly, we have discussed the importance of hydrological cycle in which we have discussed that hydrological cycle is regulating the ability of fresh water, supporting agriculture, activity, ecosystems and human consumption and it is essential for climate control and weather

patterns. Thirdly, we have discussed the main components of hydrological cycle. Key components include the evaporation, transpiration, condensation, precipitation, infiltration, runoff, groundwater flow and all are interconnected to maintain the earth's water balance. Transportation components of hydrological cycle we have also discussed.

We have seen transportation processes such as evaporation, transpiration and atmospheric movement, transfer water in different phases across the earth's systems influencing the global weather pattern and the climate. Basic components of hydrological cycle we have discussed. The basic components which include the change of water among the atmosphere, surface water and subsurface water through processes like precipitation, evaporation and storage. And lastly, we have discussed the water balance equation in which we have seen that it expresses the relationship between the inputs that is precipitation and outputs that is the evaporation, transpiration, runoff to determine changes in the water storage in a system. Based on this, we have solved few numericals.

Thank you very much to all.