Engineering Hydrology

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Module 1

Lecture 7: Numerical Examples

Hello all, welcome back. In the previous two lectures we were talking about Reynolds Transport theorem and deriving the conservation equations, that is mass, momentum and energy equations using Reynolds Transport theorem. So, today we will do some of the numerical examples for understanding the mass balance concept.

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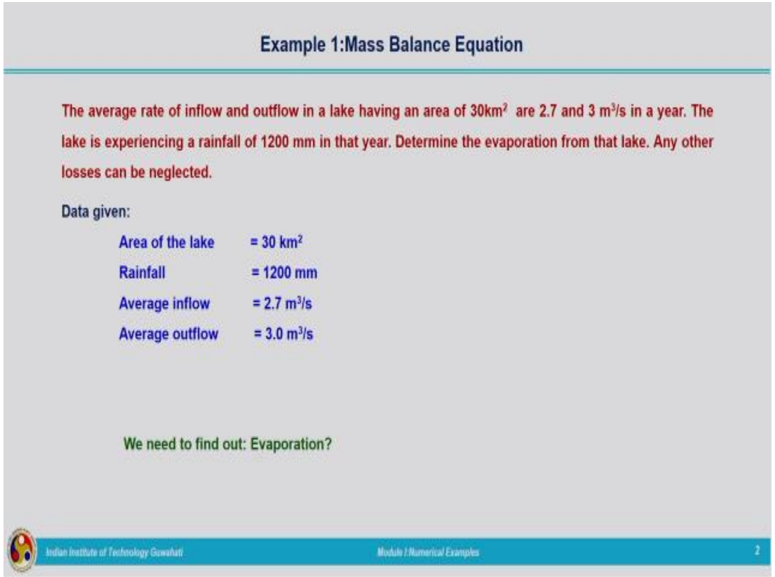

So we will start with one example. The question is, the average rate of inflow and outflow in a lake having an area of $30 km^2$ are 2.7 and $3 m^3/s$ in a year. The lake is experiencing a rainfall of 1200 mm in that year. Determine the evaporation from that lake. Any other losses can be neglected.

The question is that we are having a lake, the area of the lake is given, some inflow is coming to the lake and some outflow is going out of the lake and some rainfall of certain intensity is occurring in that particular area, we need to calculate the evaporation and it is also given that any other losses such as infiltration and other losses we have seen, those losses can be neglected.

Now let us start with doing this numerical example. So what are the data given,

Area of the lake = 30km^2,

Rainfall = 1200 mm,

Average inflow = 2.7m^3/s,

Average outflow = 3m^3/s.

So we need to find out the evaporation.

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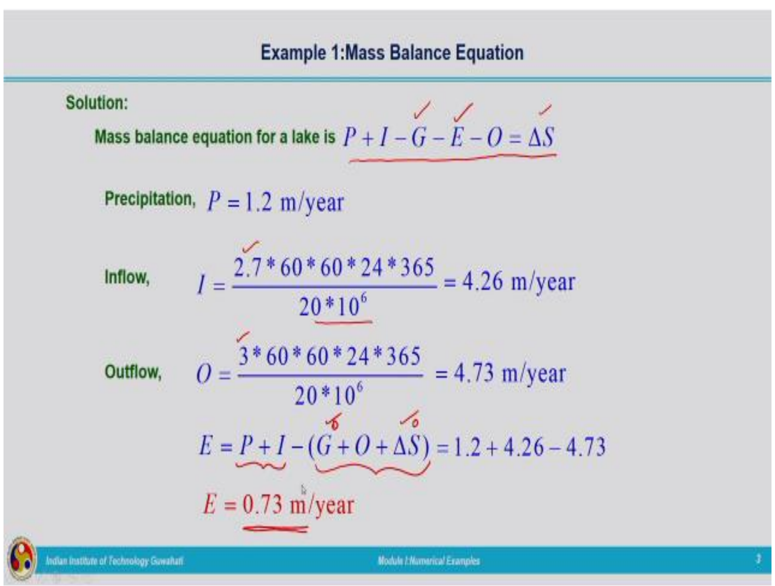

So imagine the case of a lake, the mass balance equation for a lake can be written as

$$P + I - G - E - O = \Delta S$$

In this we need to calculate the value corresponding to E. Groundwater seepage is not given and storage also not given, so G and ΔS can be neglected. We have been given the value, precipitation

$$P = 1.2 \text{ m/year.}$$

So we need to be consistent with the units, so other quantities which are given also should be converted to m/year. The value corresponding to inflow is given as 2.7m^3/s, so that need to be converted to meter per year. So, m^3/s can be converted to m/year by dividing it by the area of the lake.

$$I = \frac{2.7\times 60\times 60\times 24\times 365}{20\times 10^6} = 4.26 \text{ m/year}$$

In the similar way we need to calculate outflow in the unit of m/year. Outflow is given as 3m^3/s. When we convert it into meter per year, that is by dividing with area and multiplying with the conversion factor, we can calculate outflow as

$$O = \frac{3\times 60\times 60\times 24\times 365}{20\times 10^6} = 4.73 \text{ m/year}$$

$$E = P + I - \left(G + O + \Delta S\right) = 1.2 + 4.26 - 4.73 = 0.73 \text{ m/year}$$

So this is very simple example. Similar way by making use of the mass balance equation we can calculate any of these values corresponding to infiltration, evaporation, groundwater seepage, depending on the values given we can calculate those values.

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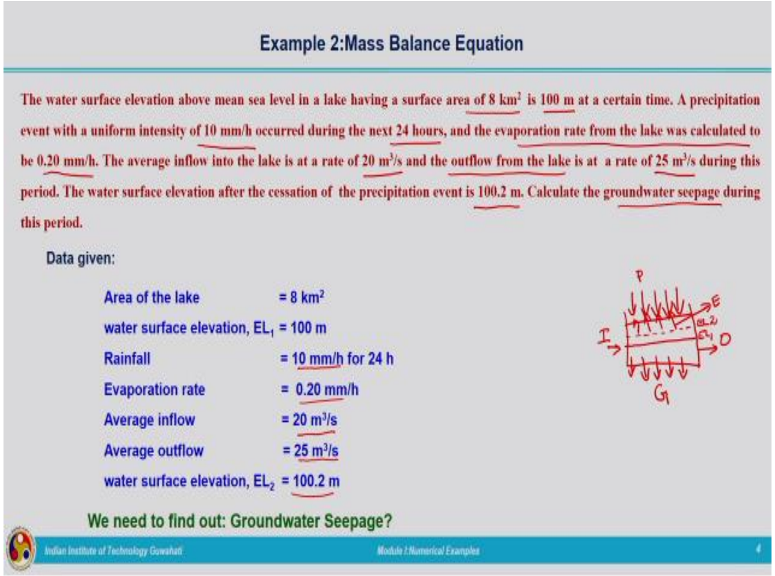

Second example is the water surface elevation above mean sea level in a lake having a surface area of 8 km^2 is 100 m at a certain time. A precipitation event with a uniform intensity of 10 mm/h occurred during the next 24 hours, and the evaporation rate from the lake was calculated to be 0.2 mm/hour. The average inflow into the lake is at a rate of 25 m^3/s and the outflow from the lake is at a rate of 28 m^3/s during this period. The water surface elevation after the cessation of the precipitation event is 100.2 m. Calculate the groundwater seepage during this period.

So this example is also similar to that of previous example but what we need to calculate here in this example, we need to calculate the groundwater seepage. So, we can see the data initially, data given are,

Area of the lake = 8km^2,

Water surface elevation, EL_1 = 100m

Rainfall = 10 mm/h lasting for 24 h,

Evaporation rate = 0.20 mm/h

Average inflow = 25 m^3/s,

Average outflow = 28 m^3/s.

Water surface elevation, EL_2 = 100.2 m

We need to calculate the ground water seepage.

We are having the inflow into the lake and outflow from the lake, we are having the rainfall which is falling over the lake. Rainfall is falling over the entire area, we are considering the lake separately. So we are having the precipitation *P* value. Then from the lake there is some evaporation taking place. So, evaporation from the lake is given to you that can be represented by *E* and water surface elevation at the beginning of the rainfall, just before the rainfall, EL_1 is given to you and just after the rainfall, once the rainfall is stopped what is the water surface elevation, EL_2 is also given to you.

What we need to calculate? During this event how much is the water which has gone as the groundwater seepage, this we need to calculate.

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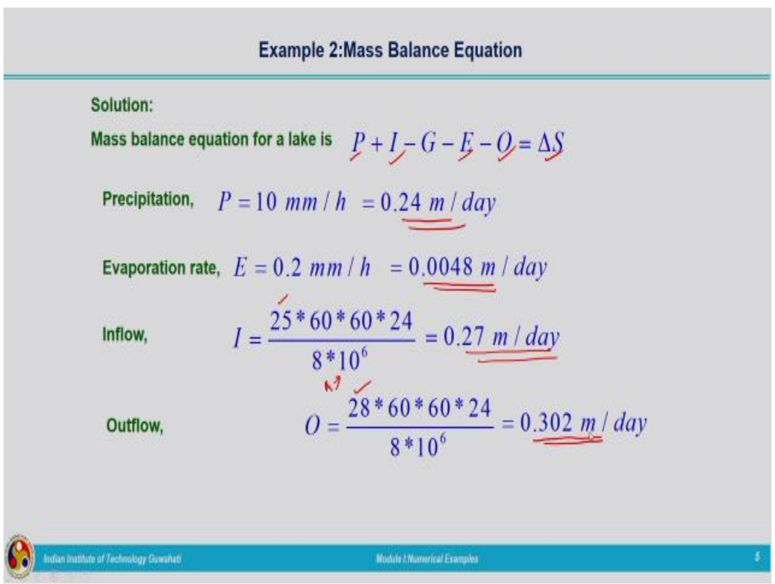

Let us start solving the problem. Same mass balance equation for the lake.

$$P + I - G - E - O = \Delta S$$

So here in this case the precipitation is given to you, inflow is given to you, evaporation from the lake is given to you, outflow from the lake is given to you and difference in water surface elevation is given to you. EL_1 and EL_2 is there, by taking the difference we can get how much water is stored in the lake, that can be taken as the storage ΔS.

Next thing we need to look into is the units. Units for all these processes should be same.

$$P = 10 \text{ mm/year} = 0.24 \text{ m/day}$$

Now coming to evaporation rate,

$$\text{E} = 0.2 \text{ mm/hour} = 0.0048 \text{ m/day}.$$

Now coming to inflow,

$$I = \frac{25 \times 60 \times 60 \times 24}{8 \times 10^6} = 0.27 \text{ m/day}$$

Now outflow value

$$O = \frac{28 \times 60 \times 60 \times 24}{8 \times 10^6} = 0.302 \text{ m/day}$$

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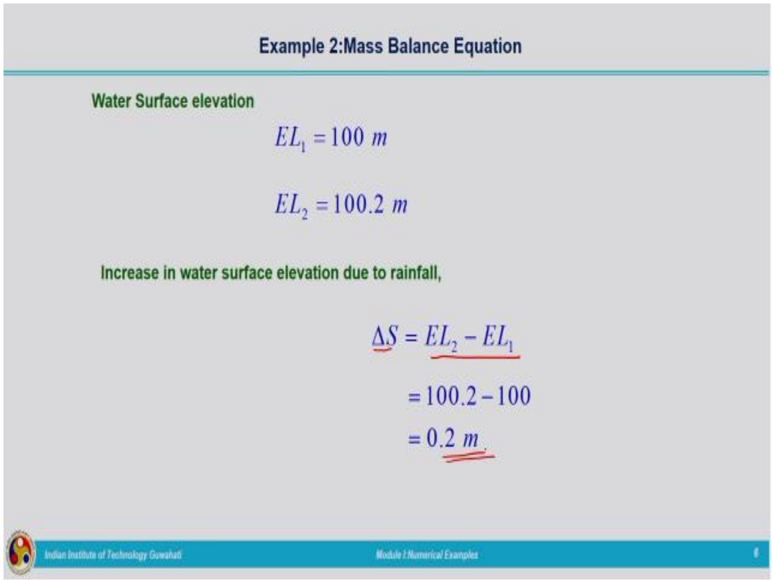

Now additional data which are given are water surface elevation before starting the rainfall and after stopping the rainfall.

So, $EL_1 = 100$ m

$EL_2 = 100.2$ m

So we can calculate the change in storage by subtracting these two water surface elevations. So the increase in water surface elevation due to rainfall can be taken as

$$\Delta S = EL_2 - EL_1 = 0.2 \text{ m}$$

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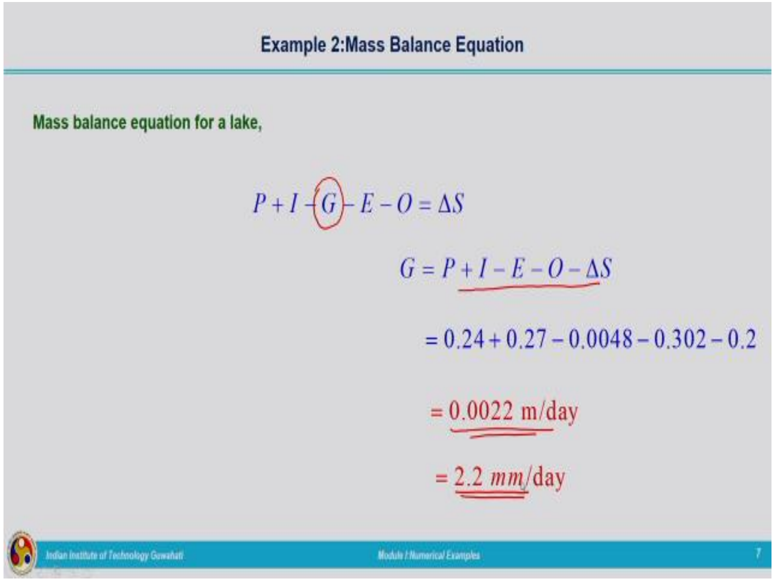

Now we are going to make use of our mass balance equation. We just have to calculate the value corresponding to groundwater seepage *G*.

$$\begin{aligned} G &= P + I - E - O - \Delta S \\ &= 0.24 + 0.27 - 0.0048 - 0.302 - 0.2 \\ &= 0.0022 \text{ m/day} \\ &= 2.2 \text{ mm/day} \end{aligned}$$

So when you look at this particular problem, you can see the final, after doing the mass balance, that is after making use of the mass balance equation, we got the groundwater seepage to be 2.2 mm/day. 24 hours we were having rainfall, before the rainfall and after the rainfall how much is the water levels are given to you, we have calculated the water level difference that is taken as the change in storage and we could calculate the seepage from the lake.

So in the similar way different, different types of problems can be there, that is sometimes we will be making use of some water from the lake for irrigation purposes or satisfying some demands, so that can be taken as the loss from the particular lake, that is we are withdrawing water from there, so this can be subtracted. Sometimes some extra inflow will be coming. So, that way some changes or modifications have to be done in the formula depending upon the data given to you. Here I am winding up this lecture, thank you.