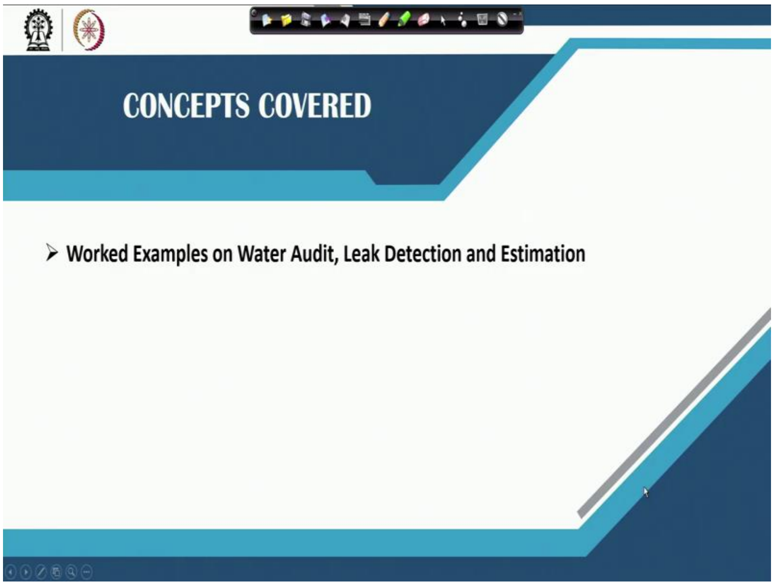
Water Supply Engineering
Prof. Manoj Kumar Tiwari
School of Water Resources
Indian Institute of Technology, Kharagpur

Lecture-49
Practice Problems on Water Audit and Water Loss Estimation

Hi friends and welcome back, so we have the last we are in the last lecture of week 9 this week we have talked about the water losses and control. Primarily we did talk about the what are the different type of water losses the real losses and the apparent losses. And how they are estimated using the concept of water audits. So, we did discuss about the IWA and AWA Performa for water audit which helps in estimating certain performance indicators as well.

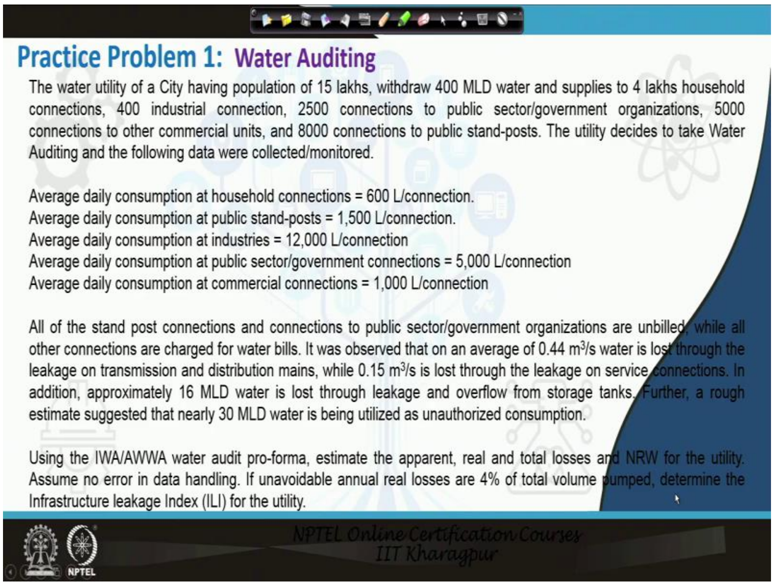
Like the unaccounted for water or the NRW. Then we also discussed about the measurement or the quantification of losses what are the various techniques for doing that. We did talk about the leak detection, how do we detect leak? So, and lastly we did talk about some of the leak control measures or water loss control measures as well.

(Refer Slide Time: 01:22)



So, now in this class we are going to take some worked example on water audit leak detection and estimation.

(Refer Slide Time: 01:26)



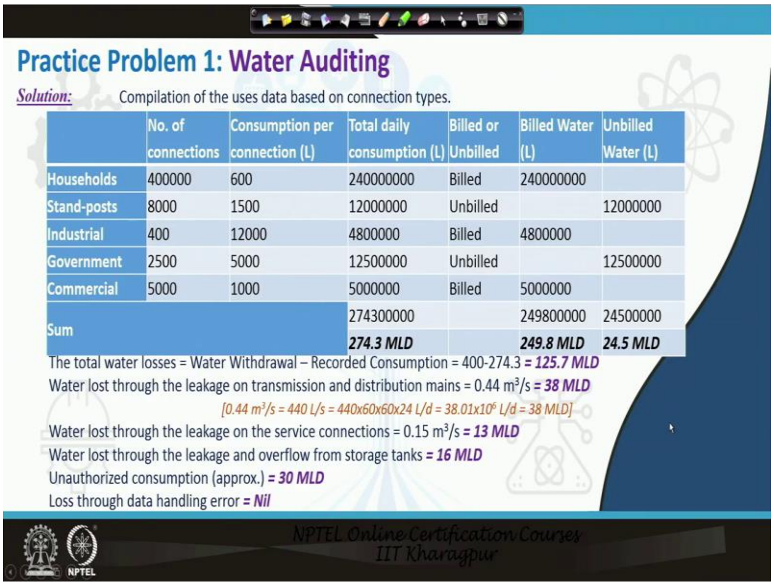
So, the first problem that we are going to discuss is on the water auditing so it is a bit like lengthy problem statement but the water utility of a city is having 15 lakh population and 4000 mld water is supplied to 4 lakh households, 4000 industrial connections, 2,500 connections to public sector and government organizations, 5,000 connections to other commercial unit and 8,000 connections to public stand post.

The utility decides to take water auditing and the following data are collected or monitored. The average daily consumptions for each type of consumption is monitored like for household connections it is 600 liters for connection, for public stand post 1500 liters per connection, industries 12000 liters per connection, public sector government connections 5000 liters per connection and commercial connections 1000 liters per connection.

Now it says that all these 10 post connections and connections to the public sector or government organizations are unbilled. So, utility is not charging any money from these stand post connections. So, these are unbilled and public sector and government connections these are unbilled while all other connections are charged for water bills. It was observed that an average of 0.44 meter cube per second water is lost through the leakage on transmission and distribution means while 0.15 meter cube per second is lost through the leakage in the service connections.

In addition approximately 16 million liters per day water is lost through the leakage and overflow from the storage tanks and a rough estimate suggested that nearly 30 mld water is being utilized as unauthorized consumption. Now we need to use IWA and AWA water audit pro-forma estimate the apparent real and total losses and NRW for the utility. We can assume no error in the data handling and if unavoidable annual real losses which is UARL. So, UARL are 4% of the total volumes pumped determine the infrastructure leakage index of the utility. So, this is the problem statement.

(Refer Slide Time: 03:49)



	No. of connections	Consumption per connection (L)	Total daily consumption (L)	Billed or Unbilled	Billed Water (L)	Unbilled Water (L)
Households	400000	600	240000000	Billed	240000000	
Stand-posts	8000	1500	12000000	Unbilled		12000000
Industrial	400	12000	4800000	Billed	4800000	
Government	2500	5000	12500000	Unbilled		12500000
Commercial	5000	1000	5000000	Billed	5000000	
Sum			274300000		249800000	24500000
			274.3 MLD		*249.8 MLD*	*24.5 MLD*

Now let us see the first thing we will do the computation of the uses by each type of connections. So, we have 5 type of connections households, stand post, industrial, government and commercial connections number of connections are given 4 lakhs household connections, 8000 stand post, 400 industrial connections, 2500 government connections and 5000 commercial connections.

And we have been given connections consumptions per connection. So, we can compute the daily consumption this is actually per day. So, we can consume here daily consumption in the liters, so if we multiply these two we get the daily consumption from household, daily consumption from stand post, daily consumption from industries, daily consumption from government and daily consumption for commercial connections.

So this is the daily consumption from these different type of connections. Now as we were told in the problem statement that two types of connections like the stand post and the connection the one supplied to the government officials are unbilled. So, that would go to the unbilled connections which is this and this number. So, we have got this many liters and this many liters as unbilled water which is coming as 24.5 into 10 to the power 6 liters per day or 24.5 million liters per day.

So this is going to be the water which is authorized but unbilled this is the water which utility knows where it is going but it is not billing for it. So, this is authorized unbilled consumption. Now we have the billed water the water which is being built so the other 3 type of connection household is being built total consumption from household is this much which is actually 240 million liters per day. Then these industries are also getting built and commercial connections are also billed.

So we get this build water as 249.8 million liters per day. So, we have to 249.8 million liters per day billed water and 24.5 million liters per day water which is authorized but unbilled. So, total amount total consumption if you add these two or we add all these we are getting to 274.3 million liters per day water for which utility is able to account where it is going. So, utility is pumping 400 you know that 400mld is being pumped and of that 400 ml lead to 274.3 mld is recorded of which 249.8 ml is being billed and 24.5 mld is not being billed.

So total water losses is the total water which is withdrawal at the one which is basically going to the consumer so recorded consumption, 400 is being withdrawn and 274.3 is the recorded consumption. So, 125.7, million litre water is actually not accounted for. So, this is your unaccounted for water UFW or you can say this is actually your total water loss. So, this is your total water loss 125.7 million liters per day is your water loss.

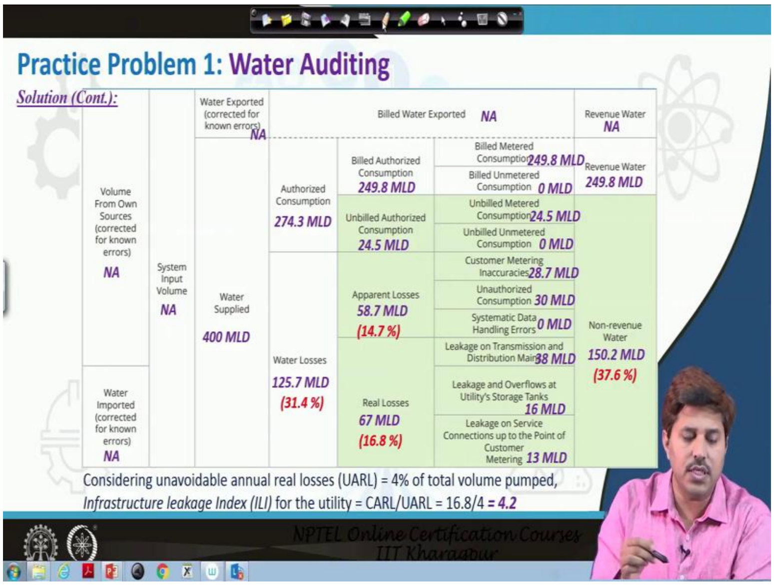
Now water loss through the leakage on transmission and distribution means the information is given that 0.44 meter cube per second water is getting lost through the transmission and distribution means so in one second 0.44 meter cube or 440 liter per second and then we multiply 440 liter with 3600 and 24 in order to get this is coming as 38.01 into 10 to the power 6 liters per day or approximately 38 million liters per day.

So that means water loss through leakage on the transmission and distribution mains is estimated as 38 million liters per day. So, this is the water lost through transmission and distribution means this is one of the component of the real losses because real losses has 3 components the water which is being lost through the transmission and distribution means the water which is lost through the service connections and water which is lost through the storage reservoirs.

So, through the transmission and distribution means it is 38 mld loss through the leakage on service connection is also estimated as 0.15 meter cube per second which again in a similar way will turn out to be 13 mld and water loss through the leakage and overflow from a storage tank is basically 16 mld. So, we have been given the 3 different components of the real losses as were estimated during the auditing purpose.

So, that means 38 + 16 + 13 is the net amount of water which is being lost from the network the real losses or physical losses. The unauthorized consumption is 30 million liters per day that is also given in the problem and says that loss through data handling error can be neglected or can be assumed as nil. So, we have estimated this different component of the various types of losses.

(Refer Slide Time: 09:38)



Now if we use the standard pro-forma of American Water Works Association or IWA then this is the pro-forma we will try to fill the different numbers in here based on whatever we have estimated so far. So, what we know is that water which is being supplied is 400 million liters per day what is the system input volume we don't know or not applicable in our case the volume from own sources or imported is not applicable or not kind of given.

Water exported again nil there is no information of any water exports. So, these will basically be remain like not applicable now 400 million liters per day water is being supplied and 274.3 million liter is authorized consumption as we estimated so that means if we subtract this authorized consumption for 400 million liters we are going to get the water losses. So, the total water losses is going to be 400 – 274.3 which is coming out to be 125.7 mld and if we divide this by 400 and multiplied with the 100 will get in terms of percentage which is 31.4% water is actually getting lost all right.

Now we see that we have estimated the different components of the losses. So, leakage on transmission and distribution means we fill here 38 mld what we estimated leakage and overflow at these two utilities storage tank that is 16 mld that was given and leakage on service connection and the point of consumer metering is 13 mld. So, we have these three components of the real losses.

Now we add these 3 so this becomes 67 mld and if we divide again 67 by 400 and multiply with a 100 we get 16.8% as our real losses. Now as we have got like as we have got the total water losses as 125.7 and 67 as our real losses so we can subtract real losses from the total losses and we will get the apparent losses we see 58.7 mld that is 14.7% in terms of percentage again if we divide it with the system input volume.

So we got the apparent losses in real losses in the apparent losses it says that system handling data errors is zero and unauthorized consumption is 30mld so that means the consumer metering inaccuracies which is not estimated will be 28.7 mld because in this proforma this plus this plus this has to be equal to 58.7. So this is zero so an unauthorized consumption is 30, so we take 30 out of 58.7 that become 28.7.

And then 28.7 is going to be like as the losses due to the consumer metering and inaccuracy which is the third component of the apparent losses as per this Performa alright. So, we now have got the apparent losses we now have got the real losses we now have got the authorized consumption and water losses and all these components. Now for the authorized water the billed water is 249.8 mld and unbilled is 24.5 mld there is no info that water is unmetered part of this water is unmetered.

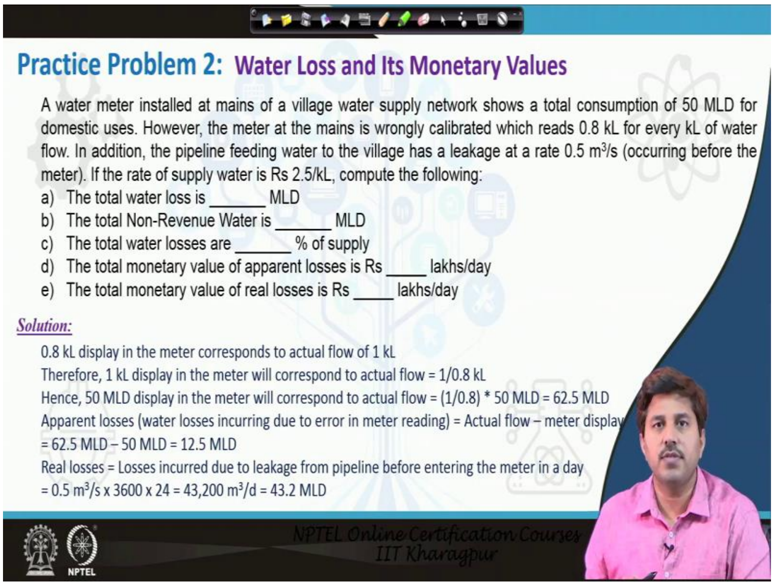
So that can be assumed as 0, 0 and metered 1 and all say is the metered connection, so, we got 249.8 and 25.4 again you add this will get the authorized consumption and as we said that like the billed authorized consumption is 248.9 and unbilled authorized consumption 24.5 which in combination gives us this authorized consumption and which gives us this losses real loss estimate is there and then from real losses we got the estimate of apparent losses and from apparent losses we got these.

So we have basically filled in all this now revenue water due to export is not applicable here revenue water on which we are able to collect revenue is the billed authorised consumption which is 249.8 and rest all is the non-revenue water. So, we subtract the 249.8 we substrate 249.8 from 400ml d we get 150.2 or we sum of these anyway we will get 150.2 mld which is 37.6% in terms of percentage of the total water.

So that way we are able to estimate the non-revenue water so what we were asked to estimate the real losses which is 67 mld 16.8% apparent losses 58.7 mld or 14.7% non-revenue water 150.2 mld or 37.6% now it also says that we if we assume unavoidable annual real losses as 4% then ILI infrastructure leakage index is as the current and real losses divided by unavoidable annual real losses.

Current annual real losses are at 16.8% and unavoidable is at 4% so we divide that and we get 4.2 as the infrastructure leakage index or ILI. So, this way we can estimate these performance indicators we can estimate the non-revenue water we can estimate the ILI we can estimate the total water losses which is actually UFW, this is your NRW this is your ILI so these are all performance indicator these are your apparent and real losses estimates as was asked. So, this is how we can basically do water auditing with the given set of data.

(Refer Slide Time: 16:02)



Now let us move to the next problem which is estimation of water loss and it is monetary values so the question statement or the problem statement is a water meter installed at mains of a village water supply networks was a total consumption of 50 mld. So, we have say meter installed here which shows a consumption of 50 million liter per day. In one day it is showing consumption of 50 million liter per day. And then basically from here it is going to the village area some for distribution network all.

However the meter at the mains is wrongly calibrated which reads 0.8 kilo litre for every kilo liter of water flow. So, this meter is having some problem it is like if one kilo liter water is flowing through the meter it is just displaying as 0.8 kilo liter, so that there is a calibration error here in addition the pipe line feeding the water to the village has a leakage at a rate of 0.5 meter cube per second. So, somewhere in this pipeline you can assume that there is a leakage and this leakage is 0.5 meter cube per second.

And this is occurring before the meter so this leakage is before the meter somewhere in the pipeline. If the rate of supply water is rupees 2.5 per kilo liter we need to compute these following the total water loss the non-revenue water the water loss as a percentage of supply and the monetary value of apparent and real losses all right. So, first thing 0.8 kilo liter is being displayed for every 1 liter 1 kilo liter water actual flow so when meter is displaying 50 mld that means the actual flow will be 1 divided by 0.8 into 50 and that is going to be 62.5 mld.

So that means when meter is displaying 50 mld actually 60 2.5 ml d water has passed through. So, 62.5 million liters per day water has passed through this and it is being recorded just as 50. So, that means because of this error in the meter reading because of this error in the meter reading we there will be basically loss of 12.5 million liters per day water because if meter is accurate it will so the 62.5 million liters water flowing through that but it is just showing 50.

So, where that twelve point five is going 12.5 has not lost really it has gone to the network but meter has inaccurately read it as 50 mld. So, that means in the utility book records there is a gap utility has actually pumped 62.5 but they have a reading of 50 mld that means 12.5 has will be considered at a losses and this will be apparent type of loss because it is due to the inaccuracy of the meter.

So that way like it is 62.5 mld so that means the apparent loss is 60 like will be 62.5 - 50 that means 12.5 mld is going to be their apparent losses. Now what will be the real loss rear loss is the one which is happening because of the leakage in the pipeline and this is happening before the meter alright. So, the rate of loss is 0.5 meter cube per second so 0.5 meter cube per second into 3600 into 24 that means that is 43200 meter cube per day or 43.2 ml all right.

So we lost 24.5 mld due to meter reading which is an apparent loss and we lost here 43.2 mld which is apparently the real loss. So, we have got real loss we have got the e apparent loss. So, the total water loss will be basically adding these two so we have 43.2 + 12.5 in million liters per day and if we add this so basically 55.7 is going to be our real loss or the total water loss. So, that way like if you can see the total water loss which is unaccounted for water is going to be the real losses plus apparent loss.

43.2+12.5 which is 55.7 mld that becomes your first part here. The second part is the total non-revenue water. Now in this case there is no error or no information is given after meter so if utility is feeding 50mld water it is actually collecting revenue for 50 mld water only. However the total amount of water which is lost 55.7 it is not collecting any revenue on that there is no unbilled connection.

There is no information that part of that 50 mld is unbilled so if we assume all the 50 mld is generating revenue that means the water which is not generating revenue is the one which is not accounted for. And what is not accounted for is the summation of real losses plus apparent losses. So, that 55.7 mld is the one which is not generating any revenue also. So, in this case you will have UFW and NRW same so NRW is going to be 55.7 mld so that becomes your second part here.

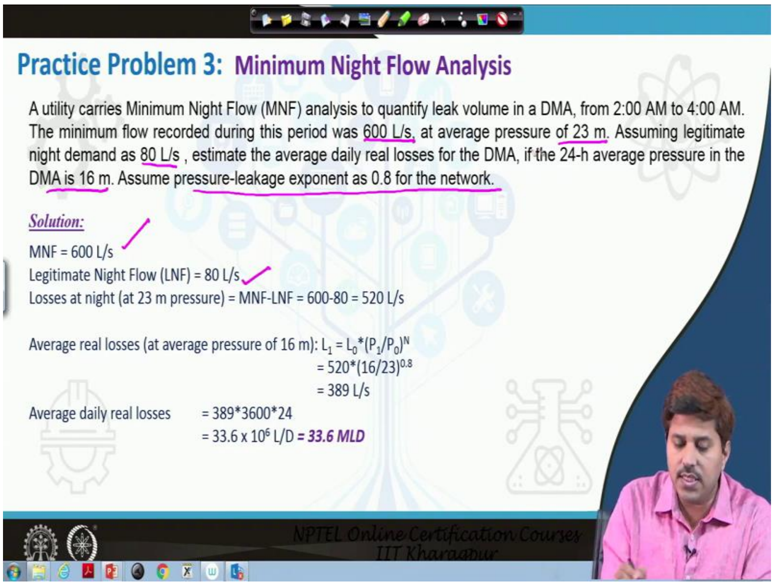
Then this as a percentage of supply so total water supply how much water is being supplied so 50 ml d is being recorded that is there so 50 mld is being recorded and 55.7 ml D is actually lost it is not recorded so total supply must be actually 50 plus fifty five point seven mld so we get the total metered supply plus water losses that is 50 + 55.7 that means 107.7 mld is the total water which is being supplied.

And if you want to like report the losses as a percentage of the supply, so losses are 55.7 you multiply that by 100 and divided by the total supply which is 105.7 this gives us 55.7% as the losses so total losses are 52.7% in this system. So, we can fill in 52.7 here. Now the next part is the total monetary value of the apparent losses in rupees lakhs per day and monetary value of the real losses.

So, apparent losses we know that it is actually 12.5 mld. 12.5 mld are our apparent losses that means 12500 kilo liter per day we can multiply with the 1000 in order to get in the kilo liter. So, 12500 kilo liter per day and rate is 2.5 rupees per kilo liter so we multiply this with 2.5, we get total rupees 0.31 lakhs per day. So, this becomes the value of apparent losses and similarly the monetary value of real losses.

Real losses are 43.2 mld so we again that means 43200 kilo liters per day and we multiply it 2.5 which is the value of per kilo liter of water so we get 1.08 lakhs per day. So, 1.08 lakhs per day is the value of the monetary value of the real losses so this is how basically we can estimate the financial losses happening in the system.

(Refer Slide Time: 24:06)



Now let us move to the third problem which is on the minimum night flow analysis, so as we discussed a utility carries a minimum night flow analysis to quantify the leak volume in a DMA from 2 to 4 a.m. The minimum flow recorded during this period was 600 liter per second at an average pressure of 23 meter assuming legitimate night demand as 80 liters per day we need to estimate the average daily real losses for the DMA.

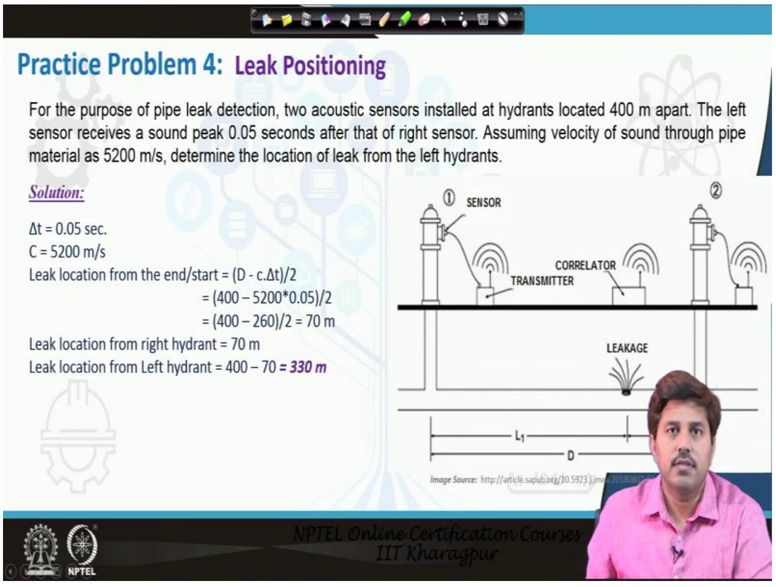
If 24-hour average pressure in the DMA is 16 meter and we need to assume the pressure leakage exponent as 0.8 for the network. so, minimum night flow recorded is 600 liters per second legitimate night flow is given 80 liters per second so that means losses at night when the pressure is 23 meter is minimum night flow minus legitimate night flow. So, 600 liters per second is the flow recorded 80 liters per second is the legitimate flow that means 520 liters per second are actually the losses.

So these are the real losses which are happening in the night at 23 meter pressure. Now average real losses at basically at average pressure because if we take out throughout the day so throughout the day average pressure is 16 meter, so for the same rate what is going to be the losses, so as we discussed L 1 by L 0 is going to be equal to P 1 by P 0 to the power n where P is the pressure. So, here if we need to determine say this at 16 pressure 16 meter pressure so this is going to be L at 23 meter pressure into P at pressure when the pressure is 16 and pressure when this is actually 23 divided by n.

So this is 16 this number is 16 and this number is 23 and this we have estimated as 520 losses 23 pressure so this is 520 into 16 by 23 to the power 0.8 and this turns out to be 389 liters per second so average daily their losses is 389 like this is per second so we multiplied with 3,600 and 2400 to get per day so this becomes 33 point 6 into 10 to the power 6 liters per day or 33.6 million liters per day are going to be the real losses throughout the day.

So in a utility is expected to basically have real losses of thirty three point six million liters per day so that is how we estimate some real losses from the night flow analysis.

(Refer Slide Time: 26:57)



Now this is the last problem for this class which is on the leak positioning for the purpose of pipe leak detection the two acoustic sensors installed at a high drain located 400 meter apart the left center receives sound peak 0.05 seconds after that of right sensor. So, the right sensor receives a sound peak and after 0.05 seconds of that sensor the left sensor also receives a sound peak. Now assuming velocity of sound through the pipe material as 5200 meter per second we need to determine the location of the leak from the left hydrant.

So the time lag between the recording is 0.05 second and the velocity is 50 to 100 meter per second so leak location from the end is going to be D into D - C into delta T by 2 C is 5200 delta T is 0.05 so this becomes 260, 400 - 260 is 140 by 2 that is 70 meter. So, leak location from the right hydrant is going to be 70 meter and then that from left hydrant is going to be 330 meter because 70 meter will be here 70 meter like this you can see it this way also so this one is recording earlier and this one is recording after 0.05 seconds.

So this one is recording later that means leak is more closer to this hydrant because this is able to record it quicker as opposed to this hydrant so the 70 meter that you have got is actually this value and then from the other end because total distance between the two hydrants is 400. So, that means this value is going to be 330 meters. Or you can do it from very basic as well like if you try to see let us say the time recorded from say left minus time recorded in the right is 0.05 second.

Now time recorded in the left is basically L1 distance has to be covered and that is done with the C velocity minus time recorded in the right is the L2 distance has to be covered and recorded in the C time so that means L 1 - L 2 divided by C is 0.05 or L 1 - L 2 is C into delta T actually this is delta T right so from here we will get the L 2 can be written as 400 minus L 1 if this length is L 1.

So, L 1 - 400 - L 1 is equal to C into delta T is 260, 50, 200 into 0.06 so this is 260 and that means this will be 2 L 1 - 400 is equal to 260 or 2 L 1 is going to be equal to 260 + 400 that is equal to 660 and then L 1 will be equal to 660 divided by 2 that is going to be equal to 330 meters. So, from very basic concept also this can be solved. So, we will be basically getting 330 meter distance from the left one.

So that way like the leak positioning can be done using this type of study. So, with this we conclude the discussion for week 9 we have talked about the leakage is diminished leakage part here water loss estimation, assessment, auditing. Now we will meet again next week when we discuss about the advanced tools and technologies for water network designing. And we will talk about some of the popular software's like EPANET and water jams as well. So, see you next week thank you for joining.