Water Supply Engineering
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Lecture-47
Water Balance for Water Loss Assessment and Performance Indicators

Welcome back friends, so we will continue our discussion on the water losses in just last class we have started talking about the water losses we did in had an introduction of the water loss and what are the reasons and sources of the water loss. And then we did talk about the two categories of water loss two major categories which are the real losses and apparent losses. So, now we move forward towards the estimation of water loss. So, we will talk about how we do water loss assessment through water auditing and water balance.

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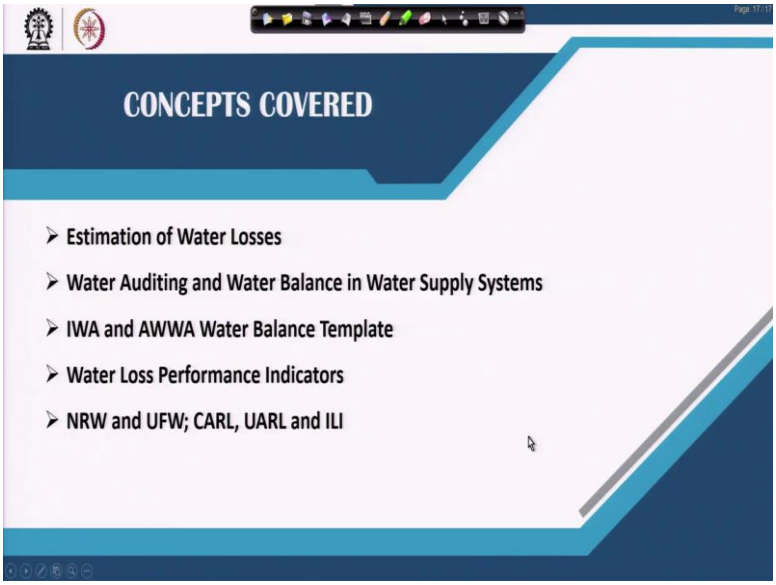

And what are the various performance indicators which gives in as an idea about the water loss occurring in a water distribution system. So, will be talking about the estimation of water losses we will be talking about the water auditing in water balance in the water supply system. We will discuss the International Water Association and American Water Works Association water balance template. We will talk about the water loss performance indicators specifically NRW and UFW which is non-revenue water and unaccounted for water.

We will talk about the current annual real losses unavoidable annual real losses and infrastructure leakage index as well.

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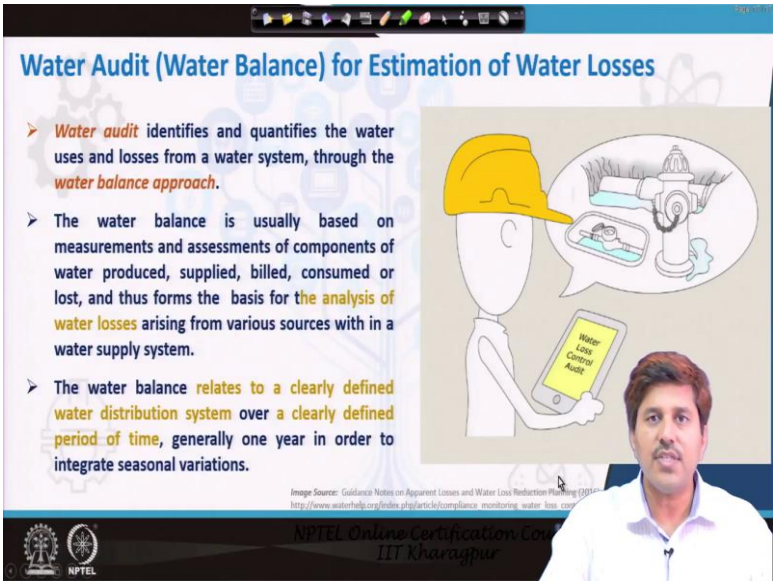

So, for the purpose of estimation of the water losses generally the water balance approach is adopted for numerical estimation. So, which is a kind of auditing the water distribution system so water audit typically identifies and quantifies the water use and losses from a water system and it is usually done through water balance approach now water audit in itself is a very broad term water audit is not only for the water distribution systems or water supply systems.

Water audit can be used for any company, for any factory, for any household for any product. So, for say like in a lifecycle period say how much water is consumed on how much water used in what different purposes can be a part of water audit for a product. Mostly like various industries are going for water audit these days. So, let us say a production unit so how much water intake how much water is consumed in the different process how much processed water come in the different forms what happens to that.

So, if we do accounting of all the inflows and all the outflows of water for a unit we call that as a water audit it is like similar to the financial audit when we like in a bank or in any organization you see how much funds has come and how much funds have gone and where it has gone, how much funds are accumulated or like whether it is running in a profit or loss that that kind of information comes from a financial audit.

So similarly instead of that like instead of those monetary units if we keep our unit as a water so physical water and do the similar exercise we call that as a water audit. So, what our audit that way is kind of like balancing inflow and outflow of the water. So, in water utilities or

water distribution system water audit essentially means how much water is being say abstracted from the source. How much water is processed then the treatment plant inflow treatment plant outflow distribution system inflow distribution system outflow through basically the consumer demands and in between if there are losses happening.

So where that water is going what are the various routes through which losses are occurring. So, all this can be estimated using a typical water balance approach under the regime of water audit. So, this water balance is usually based on the measurements and assessment of the components like what how much water is produced, how much water is supplied, how much water is billed, how much water is consumed or lost and their way like it does the comprehensive analysis of all this system arising for water arising from a different sources in the water distribution system.

So, this water balance relates to basically a clearly defined water distribution system over a clearly defined period of time. Generally period of time is taken as one year so for let us say if you have a water distribution system for a city over a period of year how much water is coming into the system and how much water it is able to distribute. And then what are the different components through which water is getting lost within the system over a period of one year time.

So we need to have a defined time frame which is usually in here but it can be shorter time frame also we can audit for say monthly basis or any other time unit basis that way. And it audit is also done usually for a clearly defined distribution system. So, our domain of the audit has to be fixed or domain of the balance has to be fixed. If we are say doing audit of an industry or if you are to go for a water balance of industrial unit so then our domain become industry here our domain is the distribution system.

If you want to see the losses in the distribution system so we need to see how much water is being pumped into the distribution system, how much water is going out of the distribution system to the end consumers or various like consuming units and what is happening to the rest of water in that distribution network framework. So, that is that becomes basically our defined boundary. So, it has to be that like audit process or the balance process has to be done over a defined boundary and a defined time period.

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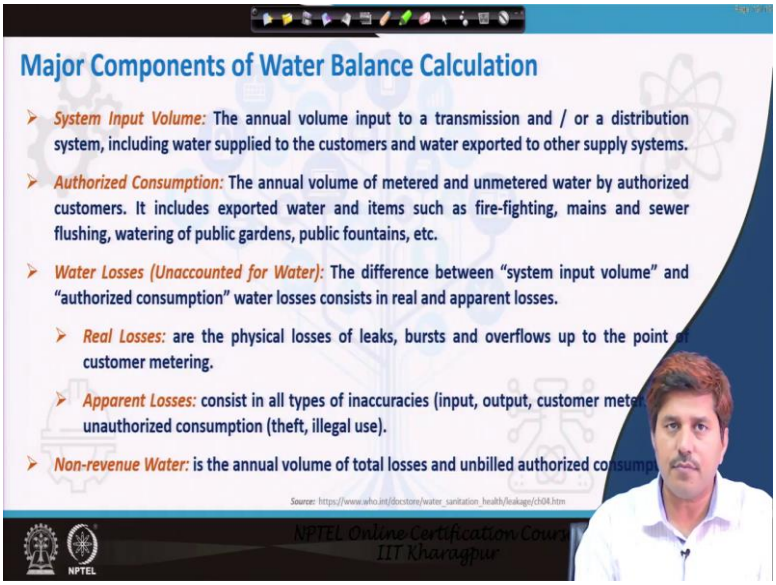

Now the major components of this water balance calculation is system input volume. So, how much water is being fed into the system. So, this is the annual volume input to a basically transmission or a distribution system it includes water supplies to the consumers and what are exported to the other supply system as well. So, if it is basically having some sort of import-export water that also needs to be included.

Then the authorized consumption authorize consumption is the annual volume of metered or unmetered authorized not necessarily has to be be metered actually authorized consumption can be unmetered also like in many places many cities we do not have meter but we pay bill. So, that is basically though it is not that we are stealing water if we are paying believe in without meter say with flat tariffs and all that so utility knows that they are supplying some amount of water to our households for which we are paying to them.

So it is it is a fully authorized consumption it maybe unmetered but it is authorized consumption. In other case there are many households which are say having meters so if my household is metered of course I am utility knows how much water I am consuming so that also is in completely authorized consumption. So, either metered or unmetered water by authorized customers. Now this includes exported water items such as exported water and other items such as like the water can be used for firefighting purpose for mains for sea were flushing for watering of public garden public fountains.

So this is basically all other uses and of course the major uses is the target and consumers so the domestic or industrial demand that also comes under the authorized consumption for the

legal customers. So, if the for legal customers the domestic demand for legal customers the industrial demand or institutional demand or commercial demand all comes under the authorized consumption. Then there are water losses which is basically also known as unaccounted for water so this is the difference between system input volume and authorized consumption.

Now water loss is practically if say we are producing a amount of water and we are having B amount of water as authorized consumption so that means the A - B amount of water is lost because we do not have any record it is not authorized. So, we do not have any record for this and that is why it is also known as unaccounted because we do not have any accounting for this much amount of what are A - B amount of water.

So that is basically known as the water loss or unaccounted for water and this water loss consists of both real and apparent losses and as just we discussed in the previous lecture as well. So, near losses are the physical losses due to leaks burst overflows and apparent losses basically consist all type of inaccuracies in input output or customer meters and unauthorized consumption which is like theft or illegal uses.

Another term which is used in these kind of calculation is non-revenue water NRW and it is actually the volume of the total loss and unbilled authorized consumption. So, of the authorized consumption also let us say like bees authorized consumption but we may not be actually billing the entire water in be we might be Billings only C part and maybe some part we are not billing. So, the amount that we are actually billing if we subtract that from the total system input volume.

So, if you are say getting a amount of water and we are billing just C amount of water of that so A - C is the water which is not built and that does not generate any revenue so this is known as NRW or non-revenue water. So, we will talk about this again.

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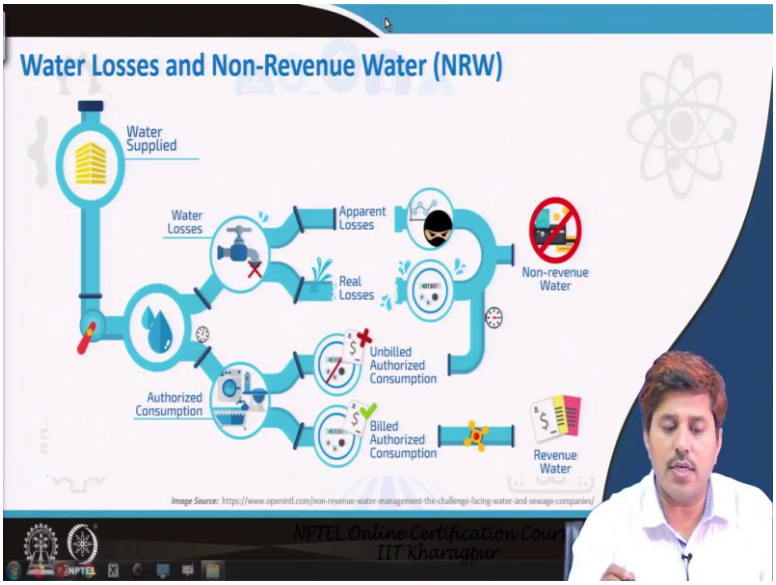

Now you know water distribution system if you see like we are actually supplying water. Now the water that are being supplied can actually be going to authorized channel or can be actually lost. So, as just we are discussing the water which is not authorized is considered as water losses. Now water losses can be apparent losses and can be real losses an authorized consumption can be built authorized consumption or unbilled authorized consumption.

So a few customers who get authorized consumption maybe meter or meter but are not billed so for them it is unbilled authorized consumption, so although it is authorized consumption it is not loss but it is not generating any revenue. So, for revenue purpose these all the losses apparent losses real losses and this unbilled authorized consumption in totality gives us the non-revenue water the water at which no revenue is being generated.

Whereas this build authorized consumption gives us the revenue water means the water at which we are able to generate revenue. So, these are the terminologies over here the way we are getting water which is either getting lost or getting through authorized consumption channel. Now in the authorized consumption channel if the water is generating returned or revenue or billing is done on that so that is known as revenue water if not it is known as the unauthorized means unbilled authorized consumption.

And this unbilled authorized consumption in addition to the water losses are basically component of the non-revenue water.

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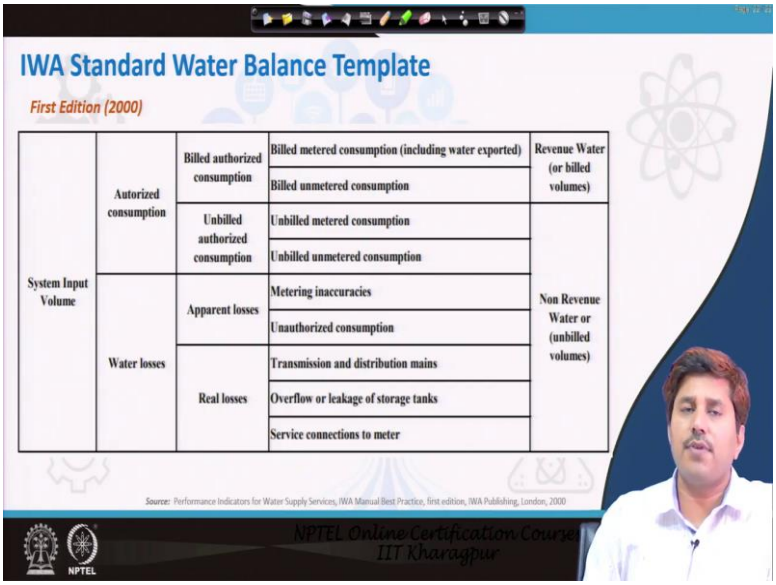

So, the if you see based on these kind of philosophy water balance template has been suggested. Now it was suggested as early as in 2000 by the IWA International Water Association. So, in the in its first edition of the best practice manuals the IWA suggested this water balance template or water audit template you can say so it suggested that whatever volume of water is coming into the system.

So this is our say system input volume the system input volume is basically can be you can be actually used through authorized consumption or can go to the water losses. So, there will be two parts of system input volume it can go to the authorized consumption channel or it can actually go to the water losses which are basically URW or unaccounted for water. Now in this authorised consumption we have build authorized consumption which could be like build meter consumption or build unmetered consumption.

Now since it is built so it is generating revenue so we will get basically this as a revenue water and then we have unbilled authorized consumption which could be unbilled metered consumption or unbilled unmetered consumption. And then water losses we have apparent losses in real losses apparent losses due to meter inaccuracies apparent losses due to unauthorized consumption.

And a real loss due to the transmission and distribution means real losses due to overflow or leakage of the storage tank and real losses due to the service connection to the meters. So, these were the components of the real losses these were the components of the apparent

losses as was obtained and then this in totality gives the non-revenue water or unbilled volumes the water at which no billing is done.

So this template was given and like if a utility want to do its water balance or water like want to see the accounting of water so it has to basically filled all this. So, let us say if you are getting 100 unit system input volume so you will be say 40 say 50 is authorized and 50 is unauthorized out of here say 20 is apparent losses 30 is real losses and then out of this 50 say the forties build authorized consumption 10 is unbilled of 10 say this is all like all then is a unmetered zero is metered.

Here in the build if you say that built and metered consumption is say you can take any number say 5 was built on metered consumption so then that that means 35 was this way. So, we can fill in after of this 20 say there are metering and accuracies leading to 15 unauthorized consumption leading to 5 in the real law says say transmission in the distribution main leading to 25 overflow from a storage tank leading to say 2 this is leading to 3 so then you can see 35 + 5, 40 here and then remaining means 50 + 10, 60 becomes non-revenue water.

So this kind of information has to be filled in this template this is just in kind of example. So, this kind of information is to be filled in this particular template in order to get the water losses in terms of the total water losses the apparent losses real losses and NRW.

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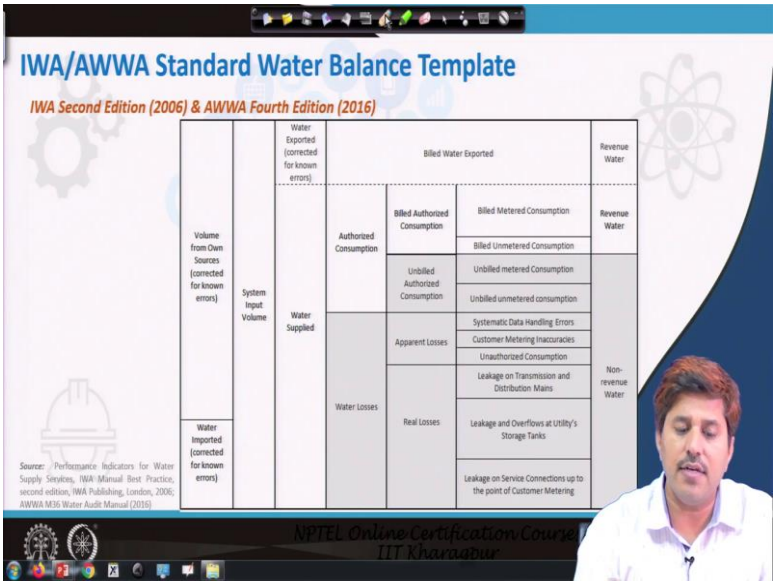

Now this was the template suggested in 2000 by IWA but later on it was amended and in the basically it is the second edition of the best practice manual in 2006 IWA again International

Water Association. And American Water Works Association in its fourth edition to 2016 proposed this kind of water balance template. So, it is essentially more or less similar if you see this part essentially is totally same they had this part was there in the original one only thing is instead of like having just earlier there was just two sources of apparent losses consumer metering inaccuracies an unauthorized consumption.

They added one more that systematic data handling errors. And then leakage of transmission and distribution main leakage of overflow utility storage tank and this these were already there and these parts were already there. So, this is still the same what they have added is that what if a utility imports and exports water so they have added for provision for water import and export. So, if let us say utility is importing some water so you can have the total system volume coming from volume from its own sources and coming from water imported from other sources.

Like for say Singapore so it imports part of its water from Malaysia. So, if Singapore want to do this kind of exercise so the system volume they are feeding, so how much they are getting from their own sources and how much they are importing say from Malaysia right. So, that way if you do not have any water import if all the water is being is being basically sourced from the local sources then this turn out to be zero.

So we have two components for system input volume and two components for system like this total system input volume we have got again it could be like water supplied which was in earlier part so this was our system input volume earlier the water which is being feed into the system. So, that is still there the water which is being fed into the system or what are being supplied.

But what if some utility is exporting some water it is producing water and then exporting water so it can export water and export water will obviously be billed because generally no one will export water for free. So, that is going to be another component of a revenue water but this export water is not going into the distribution system. So, this export water will not be kind of accounted or will not be considered for loss estimation.

So loss system mission purpose our original template still remains the same but like the other few other things for imported and expression for import and export were also added in this

standard water balance template. So, like in case of Singapore export would be 0 import will be from Malaysia in case of if you see the Malaysian utility which is exporting water to Singapore so for them this is going to be the significant and this will be 0.

So that way like we can have the import-export part as well otherwise rest of the template remains the same for the purpose of analysis. So, of this template as like if you see this template so we have authorized consumption and water law says water losses is apparent losses and real losses so real losses we discussed that it is practically from the leakage from the different sources. Apparent losses also we talked about that it is due to these kind of errors. The build authorized consumption is basically the build meter consumption.

So usually when someone is getting authorized water connection so he will pace like certain driven he will pay certain water fee for that where it is not free in case of light let us say some places it is free. Some utilities supply water for free for example say Delhi is giving a certain amount of water for free so that is another model altogether another model so it is a metered consumption but for free it is not generating any revenue. And so that that practically will come here that unbilled meter consumption.

But otherwise generally if water is being supplied to a household some revenue is collected from the household. So, that is billed authorized consumption it may be metered or it may be unmetered like particularly in Indian cases if you see so majority of the household in most of the cities are still on metered but they end up paying certain amount of water fee so maybe just like 200 bucks 500 bucks or 150 bucks 100 bucks whatever it is.

But they pay some amount of fee for the water so that is authorized consumption and the places where there is a meter is installed again they pay based on the water consumption so on even if flat there but meter is installed so they also are paying so that is the build authorized consumption on which billing is done and it generates revenue. But the other term like the unbilled authorized consumption.

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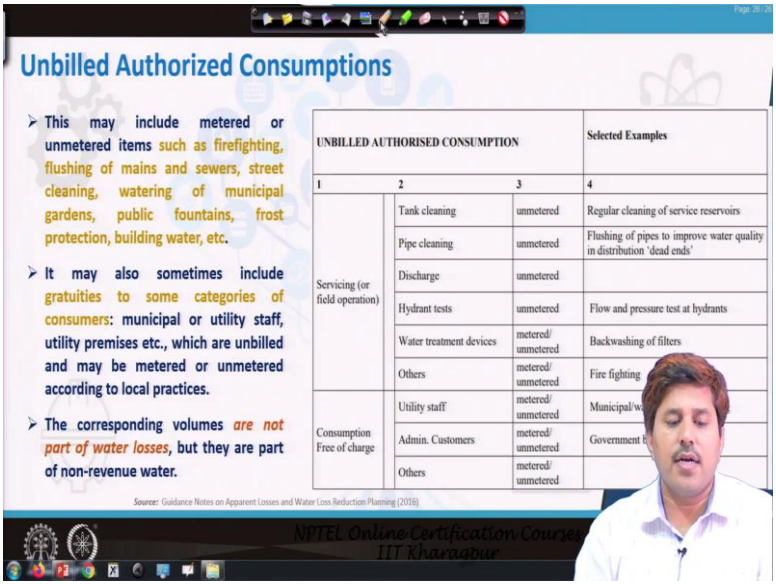

So just we were discussing that this unbilled authorized consumption may like there is there are provisions where basically we may include metered or unmetered items such as firefighting flushing of mains and sewers street cleaning watering or municipal gardens public fountains, frost protection then building water so these are or so various recreational uses various institutional uses are authorized consumption water is intentionally given to the let us say water is being given to the park.

But nobody pays for that usually water is put in the public fountains nobody pays for nobody is paying for that water is basically going to the purpose of street cleaning road washing nobody is paying for that because it is a municipality who is collect so they may not basically charge themselves for these kind of uses. So, these are authorized consumption it is not that these consumption or unauthorized these are authorized consumption but unbilled.

Similarly many times like there are due to gravities to some category consumers say the municipality or utility staff then people living in utility premises many time the like administrative officers they get water for free. So, again that water may be billed or unbilled metered and sorry it is unbilled it may be metered or unmetered according to the local practices but it is usually unbilled so they are not paying anything for the water they are consuming and that way it is the authorized consumption.

Because the utility has given connection to its staff but it is not charging its own staff so that way like the municipal or utility staff might get water for free as an authorized consumption but since that water is not generating any revenue it is not being billed so it is come it comes

under the category of unbilled authorized consumption. So, unbilled authorized consumption can be because of servicing or field operation like tank cleaning, pipe cleaning discharge, hydrant testing water treatment devices others and majority of them are unmetered some might be metered or unmetered.

These are like some of the examples or it can be basically free of charge consumption by the utility staff administrative because customers and other customers again this could be metered or and metered depending on the local practices that it is being adopted. So, this volume is not a part of water loss because this is authorized consumption but it is part of NRW because it is not generating any revenue.

So, this is absolutely like not loss directly but it comes under NRW because it is not generating any revenue.

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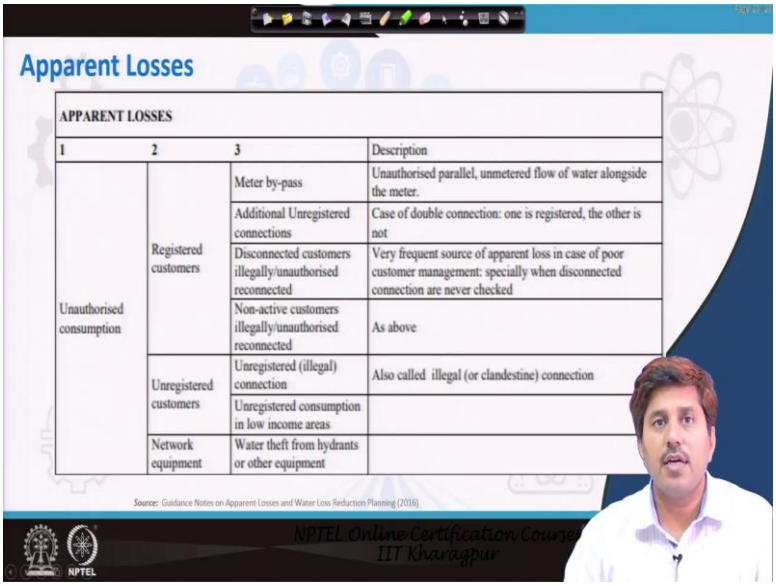

Now similarly the apparent losses so apparent losses also are off very categories, so apparent losses could be because of unauthorized consumption. Now unauthorized consumption can be from the registered customers can be from the unregistered customers and can be from the network equipment. Now registered customers might actually some might bypass meter so that is one route through which basically water can loss then there could be additional unregistered connections so we have one registered customers but it is basically withdrawing various like from one connection it is taking up several other connections.

It is basically disconnected customers illegally non active customers illegally can be basically withdrawing water and then unregistered customers again so they might go for unregistered or illegal connections they might basically do unregistered consumption in low-income areas directly like in the say big pipeline is going and then for from fire hydrants or those places people take unregistered connections.

Then the network equipment; so, water theft from hydrants and other equipments can also be there as a part of the unregistered consumption.

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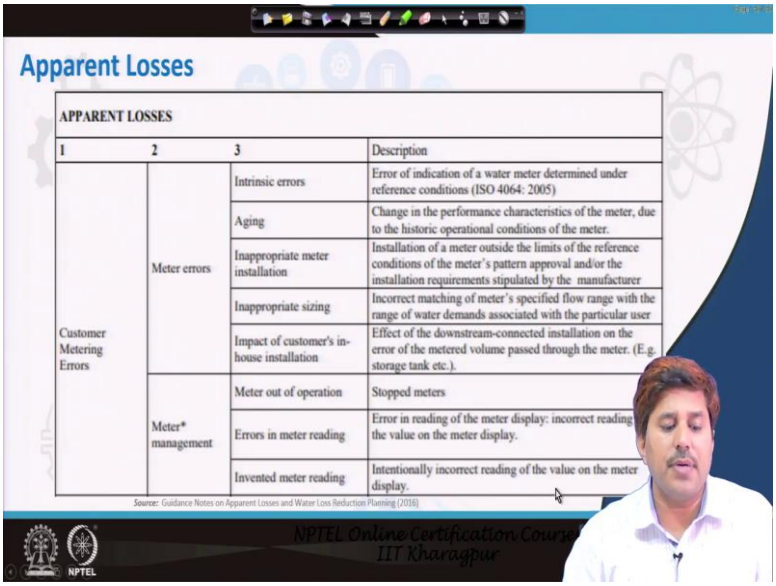

The other constituent of apparent losses is the customer metering errors, so that could be because of the meter errors. So, basically intrinsic error in the meter, meter has aged the calibration error has come in appropriate meter is installation meter has not been installed appropriately or size of meter or the capacity of meter is not appropriate. Impact of customer in house installation can be there.

And then the meter management means it could be say out of operation or the error in the meter reading or invented meter leading because of the poor calibration. So, these could be another source of the apparent losses which is related to the metering errors.

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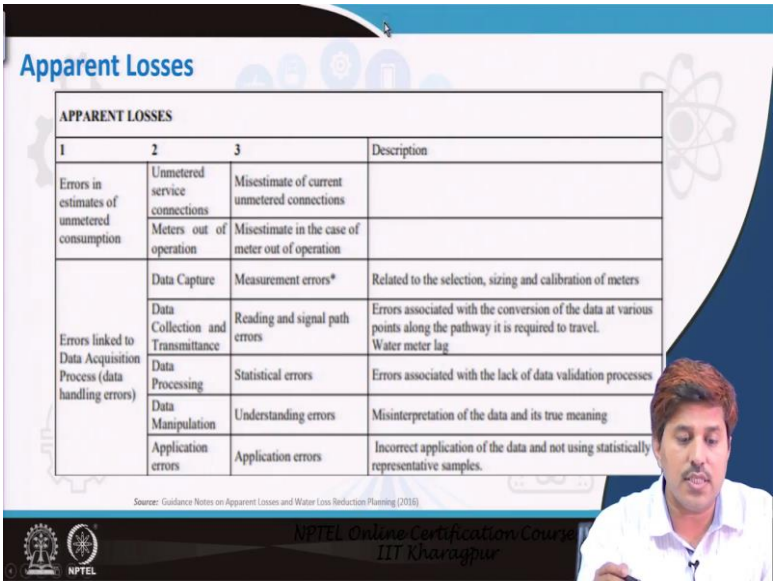

The couple of other sources for the apparent losses can be errors in the estimation of the unmetered consumption. So, for unmetered consumptions it is basically unmetered service connections or meter out of operation and there could be error like data acquisition processing, data handling errors means the data recording how much like how the data is being recorded how the data is being entered how the data is being processed how the data is being manipulated entered and how it is being applied for estimation of bills.

So if there is any error or inaccuracy occurring over there so that also might lead to the apparent losses.

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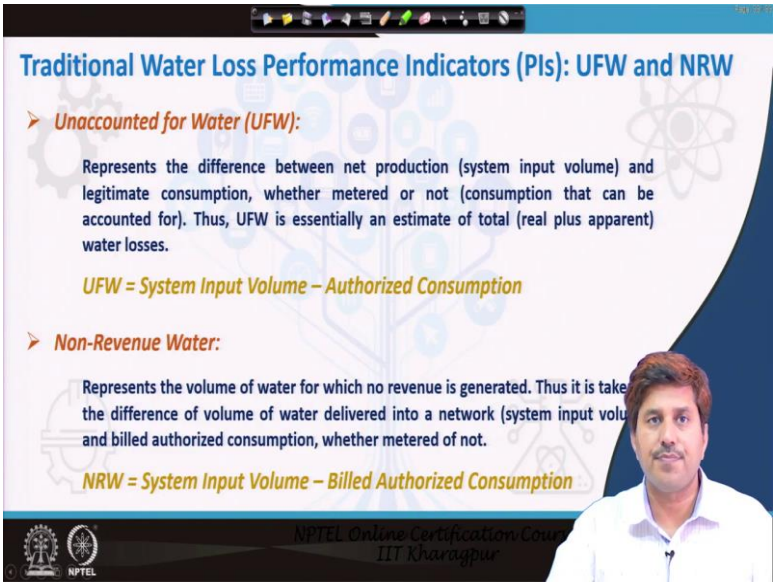

So, based on the kind of water balance analysis what we were discussing a few performance indicators can be estimated. The performance indicators are generally like the traditional

performance indicators are UFW and NRW. So, UFW is actually unaccounted for water it is a volumetric performance indicator, so, how much percentage of water or how much volume of water is getting lost in the utility. So, that is basically given in an unaccounted-for water again it is a practically a combination of the real losses and apparent losses.

So it represents the difference between the net production which is basically system input volume and legitimate consumption which is basically the; which is kind of authorized consumption. So, whether the connection is metered or not that secondary but it it is that way so the consumption that can be accounted for the authorized consumption is the consumption that can be accounted for. So, if you reduce the accountable consumption from the total consumption what you get is the unaccounted for consumption.

And that is why this has been named as unaccounted for water or UFW. So, UFW essentially system input volume minus authorized consumption. The other indicator which is more so actually the financial indicator is non-revenue water which is just we are discussing is the amount of water at which no revenue is generated. So, thus it is basically taken as the difference of the volume of water which is delivered to a network which is again a system input volume and billed authorized consumption.

Again the billed authorised consumption could be metered or not so this is NRW is equal to system input volume minus build authorized consumption. So, these are the values that way again if you want to represent them in terms of percentage we can divide them.

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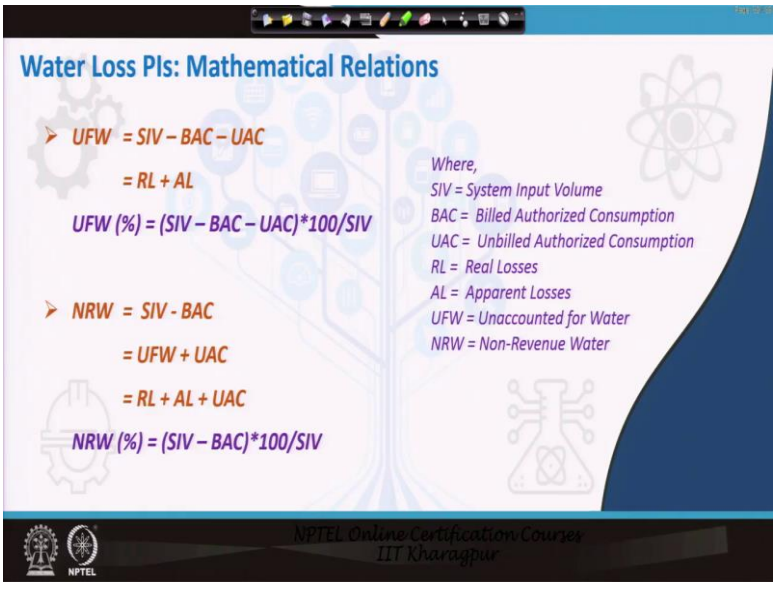

So, if you see the mathematical relations between these terms so UFW is basically the system input volume so minus the billed authorized consumption minus unbilled authorized consumption because this still are enough authorized consumption either billed or unbilled but with this is authorized consumption and this is equal to the real losses plus apparent losses. So, in terms of percentage again we can divide it with the system input volume to get the value.

Then NRW is system input volume minus billed authorized consumption. Now your system input volume is there and the billed authorized consumption from here you can see is actually the UFW minus unbilled authorized consumption so that can be basically given as the UFW minus plus unbilled authorized consumption that gives the NRW. So, UFW is the real losses plus apparent losses and if you add unbilled authorized consumption to that because that is also not generating any revenue so we get the NRW.

And again in terms of percentage we divide it with the system input volume and we will get the NRW in percentage.

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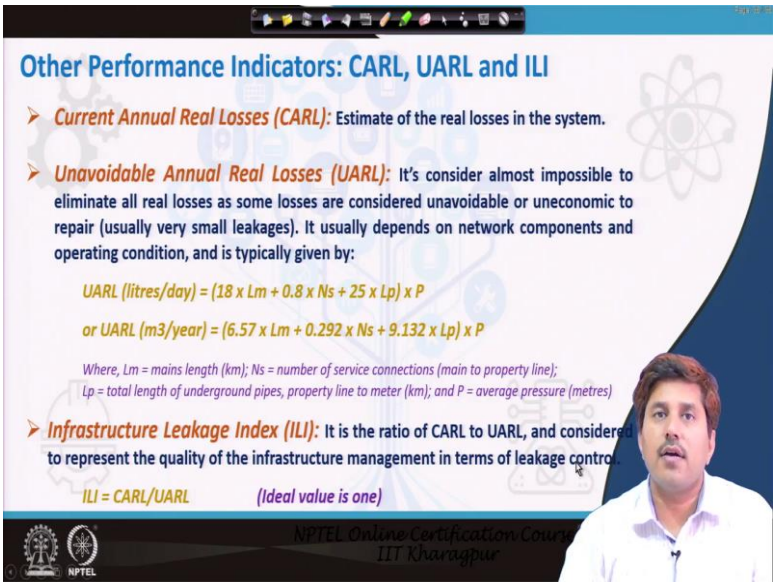

There are a couple of other performance indicators which are used which are in fact more recent. So, they are like unavoidable annual real losses and infrastructure leakage index primarily. The CRL which is current annual real losses is basically the estimate of real losses in the system. So, it is straightforward the real losses on an annual scale. Then there is an unavoidable annual real losses.

Now this is this is comes with the consideration that it is almost impossible to eliminate all the real losses in a water utility because some losses are considered unavoidable. So, how much percentage of losses or what fractions of losses are unavoidable in a utility. This unavoidable maybe in terms of like it is physically difficult to control if it is a very, very tiny fine sized leakage very tiny sized leakage.

So, it may be like physically difficult to repair trace those kind of losses or many a times even if you trace and repair that it is left because it turns out to be uneconomical to repair that. The amount of water lost through that is very, very little and the like input required to repair or the financial burden of repairing those kind of system is going to be huge and that is why it might be like not recommended to repair those kind of very, very small leakages.

So these are known as like so that kind of like if we consider this so the amount of loss in a utility which is unavoidable is basically given through the URL or unavoidable annual real losses. Now this depends on the network components and operating conditions and typically the unavoidable annual real losses are given as 18 into Lm which is Lm is the length of the mains length of the pipeline 0.8 Ns, Ns is the number of service connection plus 25 into Lp, Lp is the total length of the underground pipe into P, P is the average pressure in meters.

So this is this will give you RL in liters per day and we can convert it to meter cubed per year, so the numbers will change if we convert them to meter cubed per year. But this is what is this is how basically we give we get the URL. So, it is basically dependent on the network components what is the length of the pipeline, what is the number of service connection, what is the length of the underground pipes and what is the pressure at which the network is operating because the real losses depends on these factors as we discussed earlier.

So this will give us an idea of the unavoidable annual real losses now this could be very low and we do have current annual real losses in the system. So, if we take the ratio of the current annual real losses to unavoidable annual real losses then we the ratio is known as ILI or infrastructure leakage index. So, infrastructure leakage index is a ratio of CRL to URL and is basically considered that it represents the quality of the infrastructure managing mint in terms of leakage control.

Now you UARL is unavoidable and CARL is the current real losses or actual real losses so you usually these current losses will be much higher than the UARL or an avoidable losses. If say your unavoidable losses is 5 units and current losses what you are expressing is 40 units so that means your ILI is 8. In ideal case your current annual real losses should be minimum to the level of you UARL and for a best practice case if your current annual real losses is just equal to the unavoidable annual real losses then you are going to get ILI as the ratio of these two which are more or less similar and then ILI value will be 1.

So the kind of ideal value would be 1 of course it can get go to less than 1 also because unavoidable and well real losses is also a number estimated based on the network and for a very brilliantly managed water distribution network we may actually cut down losses to less than the unavoidable as well. Of course more financed and more stuff would be required more of hurts more technical skills inputs and financial resources might be needed but it is possible to cut it down to less than URL.

In that case ILI can be less than 1 but that is a very, very rare case. ILI is usually more than the like because it is unavoidable losses so generally it is believed that much losses is going to be there in that network. And the current losses will be much higher than that so the ratio of the two ILI which is in like usually greater than one in almost in all cases greater than one so you can assume that ILI will always be kind of greater than 1. One is the ideal value when it is minimized to the unavoidable level otherwise if it is higher.

So the more the ILI value the poorer the infrastructure, so il I value up to 2 to 4 is considered a good system but many places have ILI value in fact more than 10 so if ILI value is too high that means that system needs urgent attention and repairing and those things must be put in place. So, that the infrastructure could be improved and the current and real losses can be decreased. So, I will basically conclude this particular class here and then in next class we will be talking about the again detection of the water losses.

More so ever the real losses because the apparent losses are mostly because of the management practices so with the good degree of management these can be minimized these are not the physical losses anyway ok. So, that can be minimized but minimizing physical losses or real losses require a lot of effort from utility side so we will talk about the detection

of the losses and control of the losses in the next class. So, see you in the next class thank you for joining.