Water Supply Engineering
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Lecture - 10
Demand Forecasting and Design Capacities

Welcome back friends. So we are in the last lecture for this week and this particular lecture, we will see how the overall net demand is forecasted or estimated. We have seen so far the different components wise. So like how we kind of select a per capita demand based on the certain recommendations or the suggested number in the various manuals and reports.

We did see how we consider the fluctuations in the demand. So for seasonal variations or daily variations and hourly variations. We also see how we estimate the population for which we need to determine demand because generally demand is estimated by multiplying the per capita demand to the population. So how the population is estimated for a future period as the water supply schemes are designed for a future period.

So what so ever is the design period, so based on the design period, we can estimate the population what we just discussed in the previous class. So for the forecasted population and assuming a per capita demand, how we can actually consider the demand from a town or community or a city. So that is what we will be discussing. We will see how the design capacities for the infrastructure is selected at some part of infrastructure is selected and we will see worked example of these calculations.

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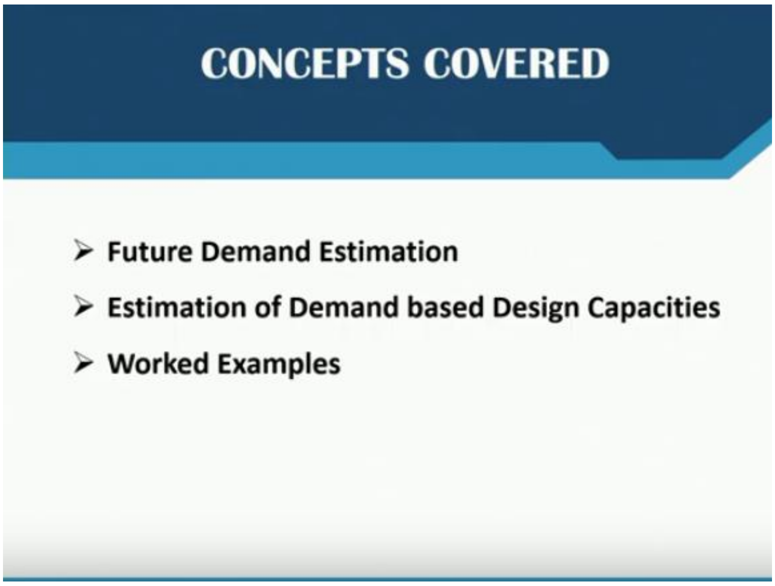

So practically we will see the future demand estimation and estimation of demand based on the kind of design capacities.

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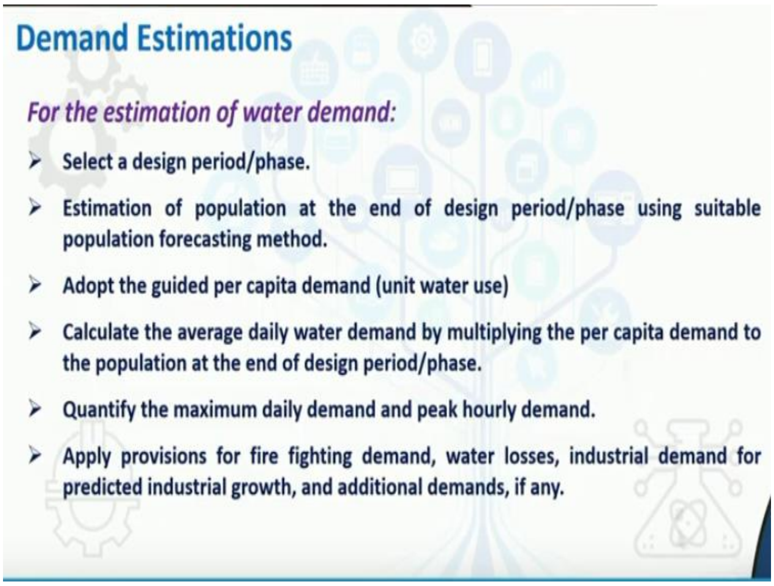

And we will see a worked example or practice problem on that. So for estimating demand we have to follow several steps okay. This we have in fact discussed this week over the various lectures concluded earlier. So first we need to select a design period or phase okay, if it is a phase wise design. So let us say we want to set up a system for 30 years period.

Or we want to set up a system for 30 years period, but we want to set up it in three phases. So first phase ends say at 10 years. Then once we figure out the design period, we try to estimate the population at the end of the design period or phase. So if let us say our design period is 25 years, so we should estimate what is going to be the population at the after the 25 years.

Because our system has to serve that much of population, okay during the last phase of its service life. So during 24, 25th year it has to serve that many people. Or if it is a phased wise construction, so what is going to be the population at the end of the phase, okay. So if first phase is say for 10 years, is going to work for 10 years, so what is the population at the end of the 10 year.

Then we adopt the guided per capita demand, which is unit water use and calculate the average water demand by multiplying the per capita demand to the population at the end of the design period. So for say I am trying to set up a system for a city or town where the existing population is one lakh. I am planning it for 25 years.

Now through the historical data I forecasted a population that it is by the end of say 25 years the population is say going to go to around 3 lakhs. So my population is three lakhs for which my utility has to serve. So for 3 lakhs population now as based on the guidelines I can select a per capita use. Say I select a per capita use of 150 litres per capita per day. So I multiply this because per person demand is 150 litres per day.

And the total number of people the utility needs to serve is 3 lakhs towards the end of the design period. So this 3 lakhs has to multiply it with the 150. So this gives 45 into 10 to the power 6 litres per day requirement or we can say 45 million litres per day is going to be the requirement. And this will be the average daily water demand that will be coming from the city.

Now we quantify the maximum daily demand and peak hourly demand based on this. So like if we can take a certain peak factor, 1.8 is generally used in India, but at many places it is 2 or even higher peak factor is used. So let us say if we use 2 as a peak factor, so instead of 45 million litre the peak demand, peak daily demand becomes 90 million litres per day and then we can actually similarly using the appropriate peak factor, we can estimate the peak hourly demand as well.

And then we apply the provisions for firefighting demand, water losses, industrial demand for predicted industrial growth and additional demands, if any. So all those additional demands may further be implied if we are actually planning to.

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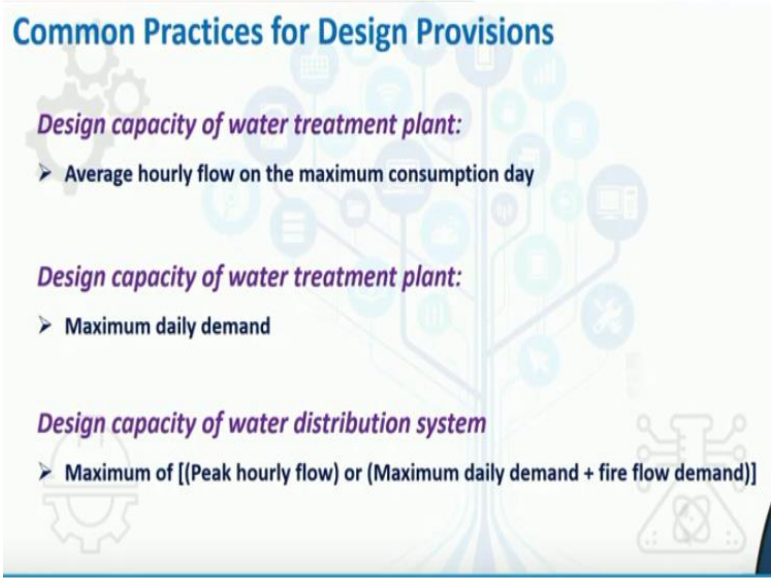

So common practices which are typically used for designing, so if you see the design provision, for water treatment plant the maximum daily demand is considered for designing water treatment plant, okay. So as just we were just discussing that if it is say around 70, if it is 45 litres 45 million litres per day demand, average demand, so the peak demand is going to be 90.

If we take a factor if we take a peaking factor or maximum daily peak factor of 2, if we take 1.8 so it is going to be less than 90. So that would be the flow for which we should plan a treatment facility. The idea behind this is that we should be able to produce water in a day which can serve the demand, which can serve the demand on a day when the water, consumption of water demand is maximum, okay.

So we should not design it for a average period because my average demand is 45. That means, maybe during winter time the city will demand just 30, 35 million litres per day water. During the summer season the demand is going to be say 16 million litres per day. During on some say festive days or Holi or other like such period, it could actually rose by around 80, 85 million litres per day water.

So my utility should be able to meet all these demands in a day. And that is why the treatment plant which is considered because it works generally round the clock, so over a period of day it should be able to produce that much of water, okay. Same way the design capacity for the raw water mains from where we pump water and bring it to the treatment plant that also is designed for like hourly flow on a maximum consumption day.

And design capacity of water distribution system means treated water distribution system is to be designed for peak flow. Peak flow in a sense like so as we say that on a particular day say the demand is 80 million litres per day okay. Now that is also a demand over 24 hours, but it does not mean that all 24 hours will require the same flow of the water, okay. As we have seen earlier that there is hourly variation.

So during morning hours during evening hours there might be more requirement of water. So when the water requirement is highest so that flow must be met. And that is why it is typically designed on a peak hourly flow basis. Or alternatively, we take the maximum daily demand plus fire flow demand. So that is another like conventional practices mostly adopted in the US.

That you compute the hourly demand on a maximum daily maximum demand day. So let us say when my demand is 90 million litres per day, what is going to be the average hourly demand on that particular day, okay. So you take that average hourly demand on that particular day plus add fire flow demand to that. So these two, the summation of these two should be served.

Because what if a fire breaks down on a day when you are having the highest demand? So your system has to be kind of fulfill the demand of because fire can break anytime, okay. However, we do not add fire flow with the peak hourly flow because that is going to be a very rare like condition that whenever the water required at a peak flow during the year the fire breaks right at that time.

So that is a unlikely situation and even if that situation occurs utility can decide to cut down the flow in the normal service connections and meet the line where the fire flow demand is being supplied at that hours and that is why it is considered like the average flow on a maximum daily demand plus fire flow demand can be clubbed together. And the rate coming out of this might be compared with the peak hourly flow.

Whichever is the highest of these two can be considered as the design capacity of the distribution system.

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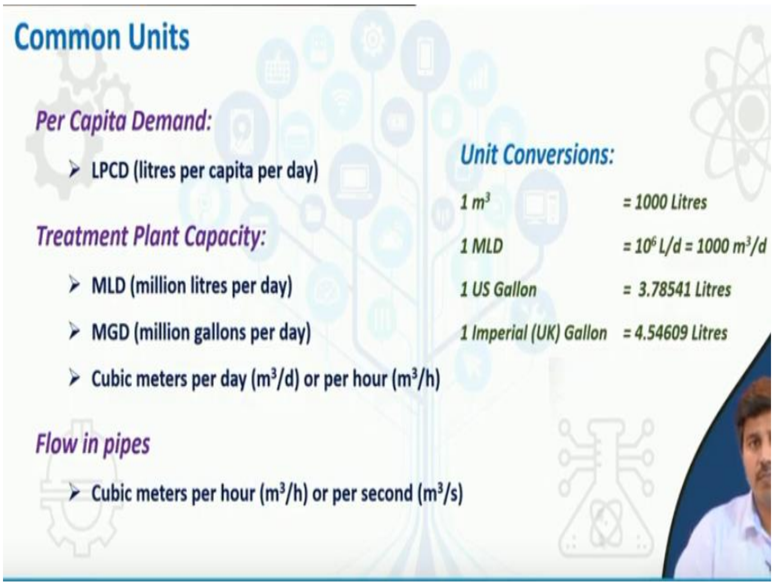

So we will see this through an example also in this very class. Some of the common units which are used for demand estimation or demand reporting. So per capita demand is typically reported in LPCD, which is litres per capita per day. The treatment plant capacity is maybe reported in MLD which is million litres per day or MGD million gallons per day which is more used in the US.

And it can also be reported in meter cube per day or meter cube per hour okay which is cubic meters. Flow in pipe is typically reported in meter cube per hour, meter cube per minute or meter cube per second and these units are all interchangeable. So one meter cube is equal to 1000 litres of water. 1 million litres per day as name itself is million means 10 to the power 6 litres per day or which is equal to 10,000 meter cubes per day.

One US gallon is as we discussed in one of the earlier classes as well. One US gallon is equal to 3.78541 litres whereas one Imperial gallon or which is UK or in fact used most of the places across the world apart from US is 4.546 litres, okay. So that is the units which are typically used for the demand purpose.

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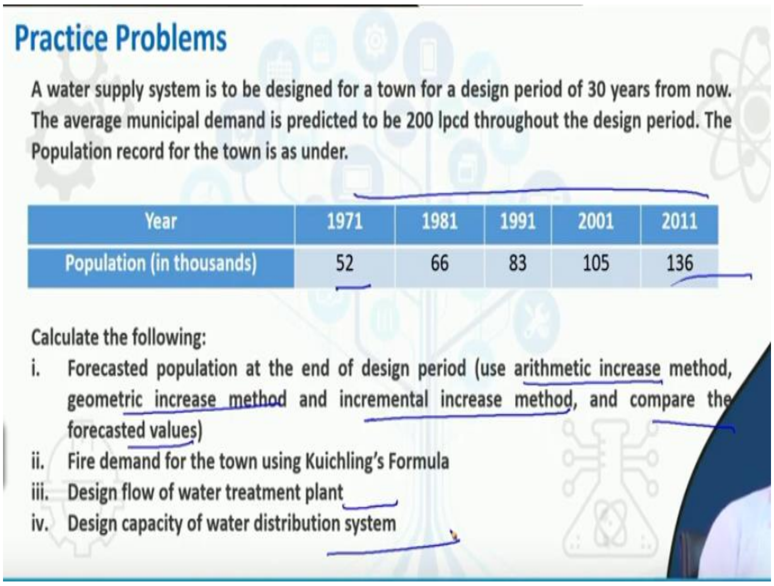

Now we will see a example, how the demand can be calculated and **what** how the design flows and design capacity of say treatment plant or distribution system can be estimated. So this is a problem say a water supply system is to be designed for a town with a design population of design period of 30 years from now. So the design period is 30 years from now, okay.

The average municipal demand is predicted to be 200 litres per capita per day throughout the design period. The Census population data is given to us. So in 1971 to say 2011 whenever is the population counting Census record is available so that gives the population which was actually in 1971 52000 and has increased to 136000 by 2011.

We need to forecast the population at the end of design period using arithmetic increase method, geometric increase method, and incremental increase method and compare the forecasted values, okay. Then we need to estimate the fire demand using say Kuichling's Formula. We need to get the design flow of the water treatment plant and design capacity of the water distribution system.

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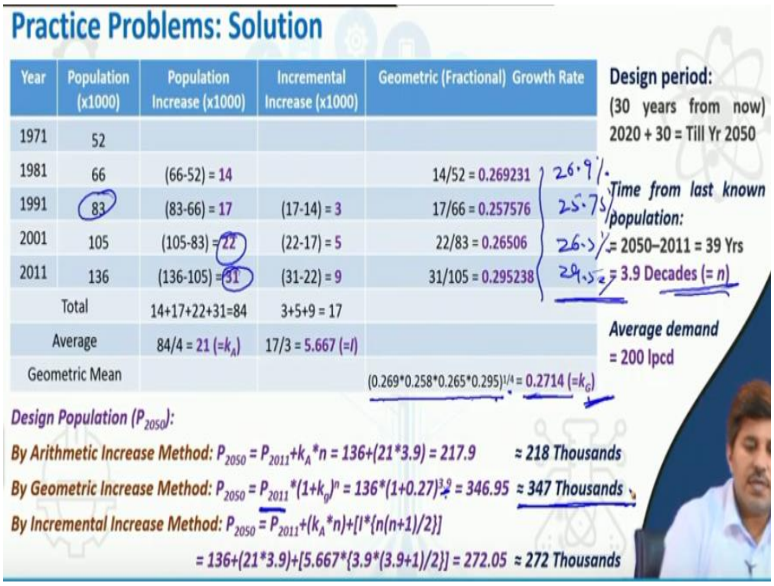

So as we discuss the different aspects in this week okay, so let us see. First thing that is given to us is the design period which is 30 years from now, okay. Now, we are in 2020. So 30 years from now means basically we need to design the plant that should work till 2050 okay because from 2020 if we consider 30 years so it comes to 2050 okay.

So that is our design period is 30 year and we have to design a system which should work till 2050. So we have to kind of as a first step we discussed that we have to get the population in year 2050 because that is the maximum population that our system needs to serve, okay. So our first step is the population forecasting for the year 2050. Now we have the data, okay Census data for the population, okay.

And the last data available is 2011. So we have to use this last data 2011 to forecast a population in 2050 that is 39 years away from 2011 okay. So the for purpose of forecasting the population, the end value or the time value that we will get is 39 years or because the data, unit of the data is actually indicates from 71, 81, 91, 2001 and 2011. So since it is a span of 10 year, so in 10 year, it is basically 3.9 decades.

So this is a very useful number we have to use this number for forecasting the population. So we have to forecast population using the data available from 71 to 2011 for 2050, which is 3.9 decades away from 2011, okay. So how we do that for arithmetic increase method? First we see the population increase okay? As its population is in thousand, so it has increased, it has become 62 from 52, 66 from 52 so 14,000 increase.

Similarly in the next time step it is a 17,000 increase. In 2001 it become 105 as opposed to 83 of the 1991. So 22,000 increase and 31,000 increase in the next decade. So total increase becomes 84,000 and the average increase is 21,000. So for estimating population in 2050 we know that for arithmetic increase method, last known population is in 2011. So 2011 plus the average mean increase rate which is 21, okay.

So 2011 the population is 136,000 into 21,000 into the time period or decades after which we are estimating population. So from 2011 we are estimating for 2050. So that is 3.9 decades and this gives a total population of 217.9 or approximately 218,000. So that is the estimate using arithmetic increase method. Now if we see the geometric increase method okay, so the increase was 14 for a population of 52.

So what was the geometric growth rate or percentage growth rate or fractional growth rate, was 14 by 52 which is 0.269 or we can say this actually 26.9% also okay. Then again in next step population rose, population increase was 17 and it increased from a value of 66. So 17 by 66, which is actually 25.75% or the fractional growth rate is 0.257576 okay. For the next decade, the population increase was 22.

And this 22 increased from a base value of 83 so 22 by 83 again we get 26.5% increase and similarly in the last one population increased by 31,000 from a base value of 105,000. So total increase was 29.52% okay. So these are the fractional numbers okay or the kind of geometric growth rate and for using geometric increase method, we have to take the geometric mean of this.

So that means we have to multiply all the four, there are four data points so we multiply all the four data points and take fourth root of this number which gives us 0.2714 as the geometric mean okay. So this geometric mean is actually will be used and the formula for geometric increase is the P 0 which is population in 2011 into 1 plus this number if it is if you are taking in a percentage, so we have to divide by 100, which will eventually turn to same.

If we are taking the fractional number it is just the number. So 1 plus 0.2714 to the power the number of decades that we are considering and this gives us a estimated population as 347 thousands. So this is the population estimate by geometric increase method.

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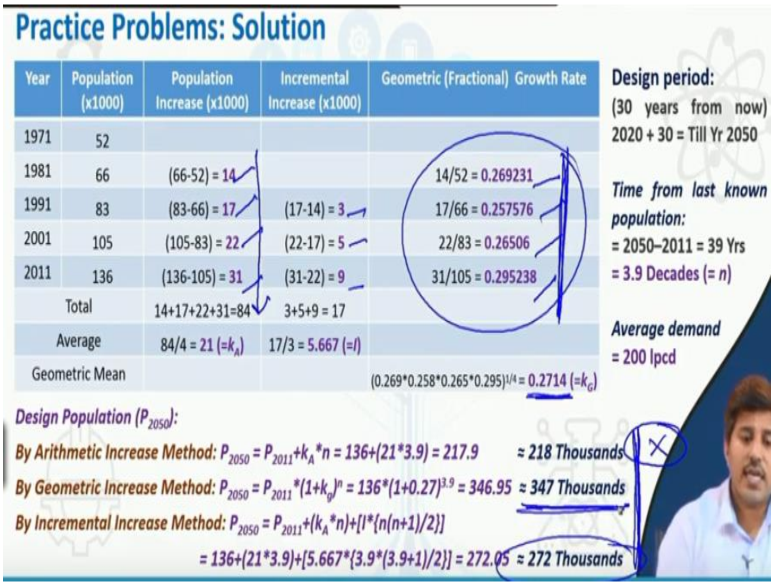

And by incremental increase method then, as we discussed earlier that incremental increase method we take another increment in the arithmetic increase.

So arithmetic increase things will be there plus there will be additional step when we will can compute the average increment and multiply that with n(n+1)/2 okay. So n we know, we have to calculate the average increment. So this we already have calculated. Now, we see the incremental increase. So after a first decade the population increased 14 whereas second population increased 17.

So it actually there was incremental increase of 3000. Similarly, in the next decade it increased by 22. So there was additional incremental increase of 5000 and then it increased by 31. So incremental increase of 9000. So these three values we get and the total 17 by 3 the average incremental increase comes out to be 5.667. So we use this incremental increase number to the arithmetic.

Rest remains the same, similar to arithmetic. So population in 2011 plus the component for arithmetic increase and this into n(n+1)/2. So this gives us the component for the geometric incremental increase method and this estimates a population of 272 thousand okay. So the point is now we have three different population estimate by three different methods okay.

And the original problem or question says that we need to compare these. So we have when we get into these kind of situation it becomes important to analyze which could be the more reasonable estimate, okay, which one we should adopt or which one we should discard. So like, you see that one is giving just 218, geometric is giving almost 1.5 times of this , which is not 1.5 times even higher in fact, okay.

And the incremental increase is giving around 272. So which one we should adopt? Now some of the trends that can be perceived from the data Census data can guide us on to selection of the better method, okay. As we discussed that there are other approaches like graphical approaches or ratio method or the master plan. Master plan is only applicable when the city is being developed following a standard master plan. If not, you cannot use that okay.

Then, graphical methods either simple or comparative graphical methods can be used if we have substantial data. Even this data also we can use the graphical increase method that will also kind of guide us some number, okay. But which is going to be more accurate? Anyway, so because the question suggested to estimate the population from these three methods, we have done that estimate.

And we have to make a call that which population estimate is more reasonable given the data set that we have at hand. Now it is interesting that you see, the arithmetic increase method has an assumption that the population increase is constant, okay. The rate at which population increases is constant, whereas we see that population increase in first decade was 14, 17, 22, 31.

So it is progressively increasing it has never actually become constant. And in that kind of cases, arithmetic increase method will always underestimate the population. So probably this is going to be a underestimate of the population and we should not use this population as a kind of for further analysis or demand estimation.

Incremental increase method suggest that the population increase is not same over the decades, but it is incremented by more or less average number. Now if we see the increments, it is 3, 5, 9 even the increments are not constant, okay. So population is getting incremented but it is getting incremented with more and more higher numbers. So first increment was 3 then second was 5, then it was 9.

So increment is also higher. And that is why this could also possibly be an underestimate. Now if we see the trends from the geometric growth, so geometric growth we see that the percentage population growth, or the fractional population geometric population growth in the first decade was 0.27. Second decade was 0.26. Again 0.27, 0.29 or 0.3 you can say.

So this percentage increase rather is more or less consistent, it is not varying too much okay. As opposed to the problem we discussed in the earlier week, when the percentage increase was varying a lot, percentage increase varies from like, the fractional increase varies from 1.8 to came down to less than 0.4 or around 0.4. So they are it is inappropriate to use a geometric increase method, okay.

However, here it is quite apparent that the percentage increase is more or less consistent. The average value that you get 0.27 is very well reflective of the average of the kind of increase that is taking place over different decades. So presumably out of these three numbers, this one although the highest but looks more reasonable.

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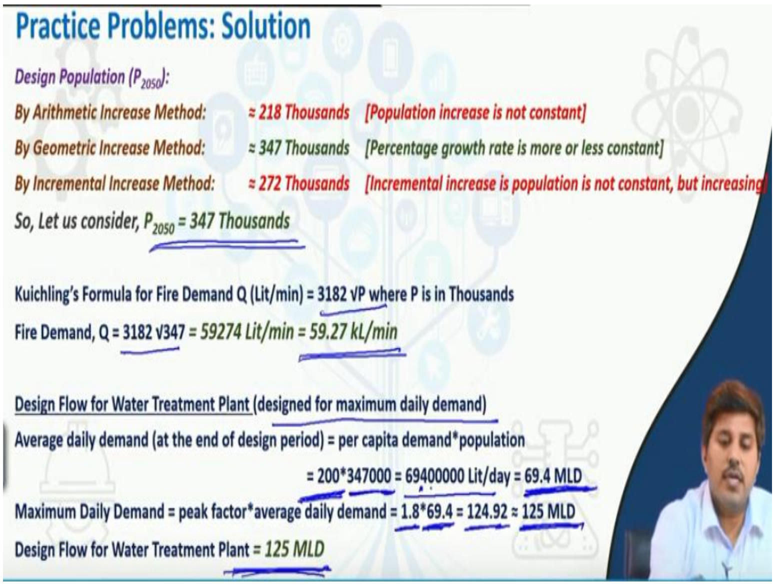

So that kind of like that kind of analysis one needs to make by seeing the trends from the data, okay. So the design population if you see your final answer by arithmetic increase we got 218 thousand and the population increase is not constant. So this is underestimate, we should not use this. By incremental increase method we got 272 thousand.

Incremental increase in the population is also not constant, but increasing. So that is another kind of setback for this method. Probably we should discard this number as well. Geometric increase looks more reasonable because the percentage growth rate is more or less constant. So we can use that and this gives us the 347 thousand as the population.

Now if we go for estimating the fire demand okay using Kuichling's formula, so Kuichling's formula is 3182 P where P is in thousand So we can place 347 here and this gives us a demand of 59.27 kilolitre per minute or 59,217 litres per minute or 59.27 kilolitres per minute. So this is going to be our firefighting demand okay.

Now we need to estimate the design flow for water treatment plant which is as we discussed earlier is designed for a maximum daily demand. So we have to estimate the maximum daily demand. Maximum daily demand is estimated by applying a daily peak factor over the average daily demand, okay. And average daily demand can be emitted by multiplying per capita demand with the population okay.

So per capita demand is 200 lpcd as given in the problem and the population that we have estimated is 347 thousand is 347000 population. So this gives us the 69400000 litres per day okay. Now this is actually if we take the 6 digit over here it becomes 69.4 into 10 to the power 6 litres per day or 10 to the power 6 litres we can write as million litres.

So this becomes 69.4 million litres per day and this is our average daily demand. So maximum daily demand we have to apply a peak factor and we can take 1.8 as a peak factor which is recommended in Indian conditions. So we take 1.8 and multiply it with 69.4 we get 124.9 or approximately 125 MLD. So the design flow for the treatment plant should be 125 million litres per day, which is the maximum daily demand that will be arised from this city, okay.

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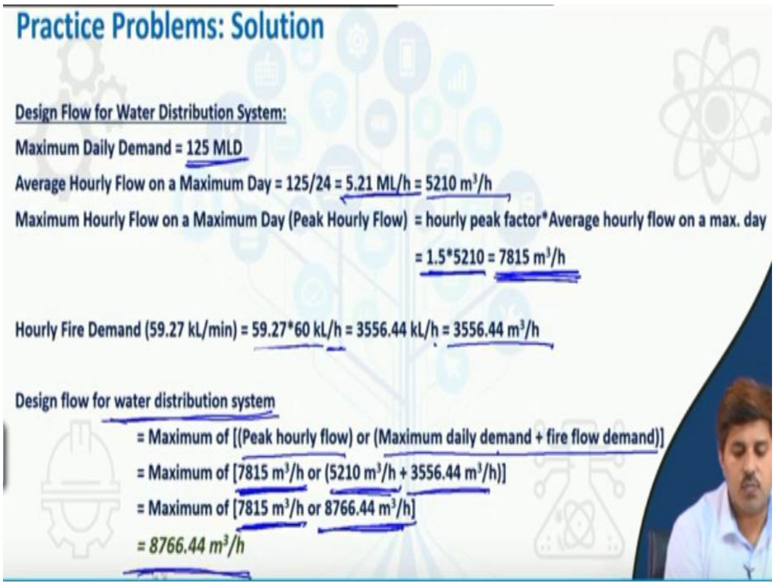

Now the last part which says that we need to calculate the design flow for water distribution system and for that purpose we need to calculate the peak hourly flow demand okay. Now the maximum daily demand we got is 125 million litres per day. The average hourly flow on a maximum day is going to be because this is 125 million litres in one day that means one day means 24 hours.

So in 24 hours the maximum flow needed is 125 millions. So per hour the flow needed is 125/4. So this becomes 5.21 million litres per hour or 5210 meter cube per hour flow is needed. This is an average flow on a maximum day okay because we take the demand on a maximum day and we divided it with 24 hours. So this what we got is an average flow on a maximum day.

Now the maximum flow on a maximum day which is known as peak hourly demand is to be again we have to apply hourly peaking factor which is 1.5. So we multiply this number with 1.5 and we get the peak hourly flow. So peak hourly flow becomes 7815 meter cube per hour. Now the hourly fire demand we estimated fire demand earlier as 59.27 kilo liter per minute, okay.

So we multiply that by 16 in order to get the flow in an hour which is 3556.4 kilolitre per hour okay or 3556 kilolitre we can convert to meter cube also, 1 kilolitre is equal to 1 meter cube okay. So this becomes 3556.44 meter cube per hour. So this is our hourly fire demand, okay. Now the design flow for water distribution system is taken as maximum of the peak hourly flow or maximum daily demand and fire flow demand.

Peak hourly flow we know that 7815 meter cube per hour. Maximum daily demand again because it is a hourly demand so we have to take that in hour and we know that average hourly flow on a maximum day is 5210 meter cube per hour. So 5210 meter cube per hour added with the fire flow demand 3556.44 meter cube per hour, okay.

So this summation comes 876644 meter cube per hour whereas, the peak hourly flow was 7815 meter cube per hour. So we have to design the water distribution system for the maximum of these two which is actually 8766.44 meter cube per hour, okay. So that way we can get the capacity or design flow for the water distribution system as well, okay. So this is how things are estimated.

With this we will conclude the discussion for this week okay when we discussed the different aspects of water demand, how the demand is conceptualized, how the average per capita demand is estimated. Then we also talked about how the population is forecasted and then how the demand can be estimated, how the design flows can be calculated for treatment plant for the distribution system.

So that was the discussion for this week. We will conclude this discussion here and in the next week then now we are going to start about the first step of setting up a water supply system, which is we have to identify a source and abstract water from there. So we will talk about the source selection and water abstraction or water intake what we typically refer in the next week. So thank you for joining and see you in the next class.