Surface Water Hydrology
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Lecture – 57
Hydro-economic Analysis to Determine Return Period

In this particular lecture, we will learn about one analysis which is known as the hydro-economic analysis, which is very useful to determine the optimum return period with which a structure, particularly should be designed considering the hydrological as well as economical aspects of it.

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The hydro-economic analysis is under this concept cover.

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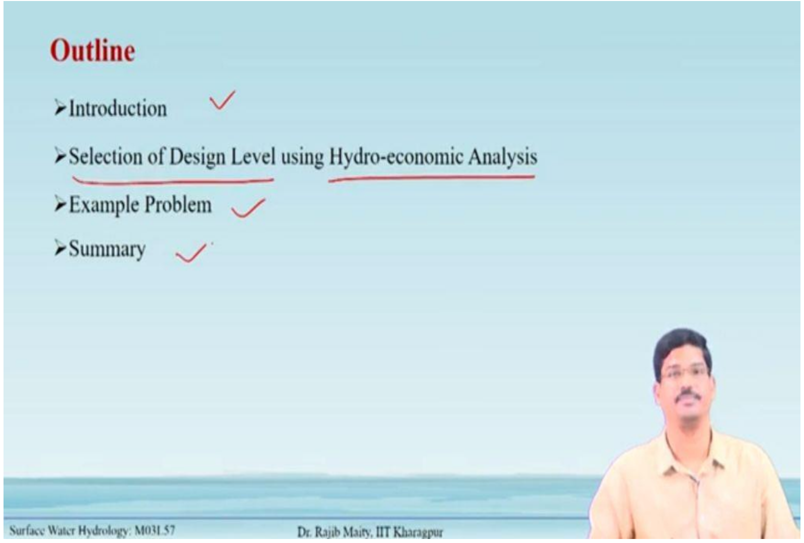

The outline for this talk will go like this. The first one is will give some introduction to what it is all about, why both the things have to be considered like hydrological aspect as well as the economical aspect. Next, the procedure for the selection of this design level or in terms of the return period, how to decide one that we will discuss. We will also take up one example problem, how to solve this kind of problem before we go to the summary.

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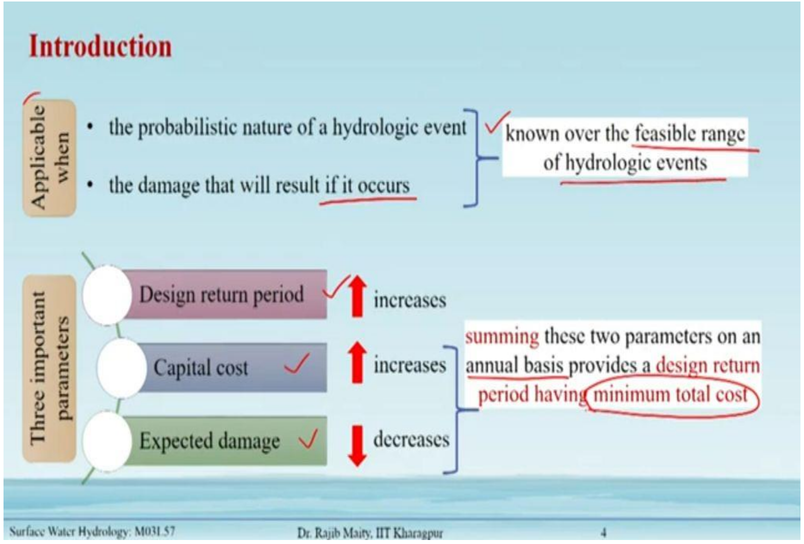

Introduction

In hydro-economic analysis, two things have to be there. The first one is the probabilistic nature of a hydrologic event should be known and the damage that will result if it occurs. So, both this information that is probabilistic nature of this hydrologic event and if it occurs. These two pieces of information should be known over the feasible range of these hydrologic events that it is minimum and maximum possible values.

Now, there are three important parameters are there that have to be considered. The first one is the design return period, capital cost, and expected damage. Their interrelationship between these two, these three things is that if the design return period increases. If increase the design return period, the capital cost will increase. To design for a higher design value, of course, the capital cost will increase.

However, at the same time, the expected damage will be reduced will decrease. Now, if we sum up these two that is a capital cost and expected damage, now summing up these two parameters on an annual basis annualized on an annual basis, will provide a design return period having minimum total cost. So, this is the overall target to minimize the total cost considering both this capital cost as well as the expected damage.

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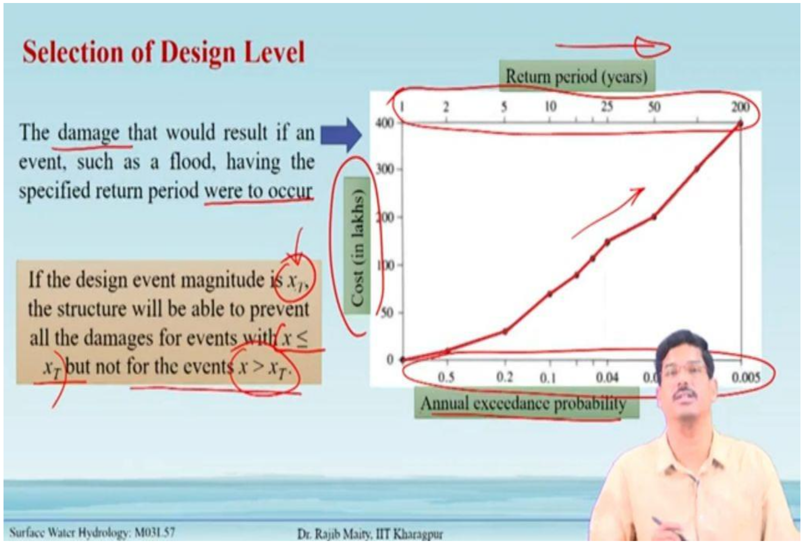

Selection of Design Level

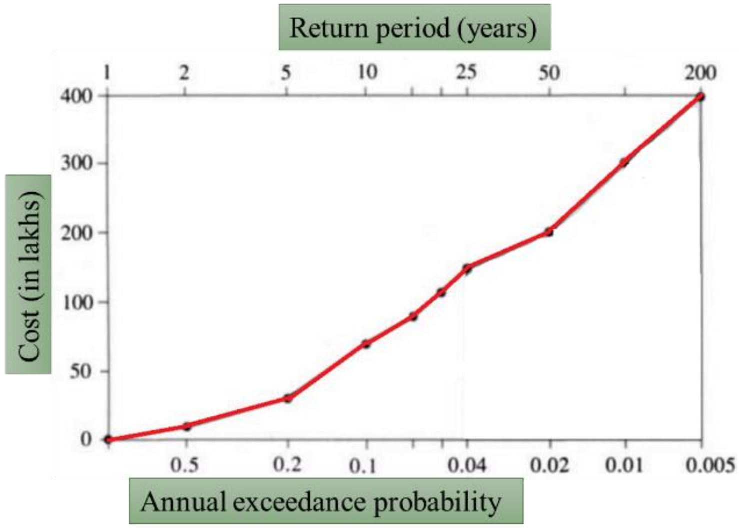

Figure 1shows the Damage cost for events under various return periods

Fig. 1 shows the damage that would result if an event, such as a flood having a specific return period was to occur. As it is understood here that it will increase, so higher and higher return period it will increase.

Now, to interpret this figure1, the top of this axis it is shown the return period 1 to 5, 10, 25, 50, up to 200 it is given here. On the lower side of this x-axis, it is shown that annual exceedance probability. Now, these two things are we already discussed many times, just inverse of this one, so one by return period equals to this annual exceedance probability.

The y-axis shows the cost in lakhs, that is the damage that would have been occurring, then for an as this return period increases, of course, this cost will gradually increase. Now, If the design event magnitude is x_T, the structure will be able to prevent all the damages for events with $x \leq x_T$ but not for the events $x > x_T$.

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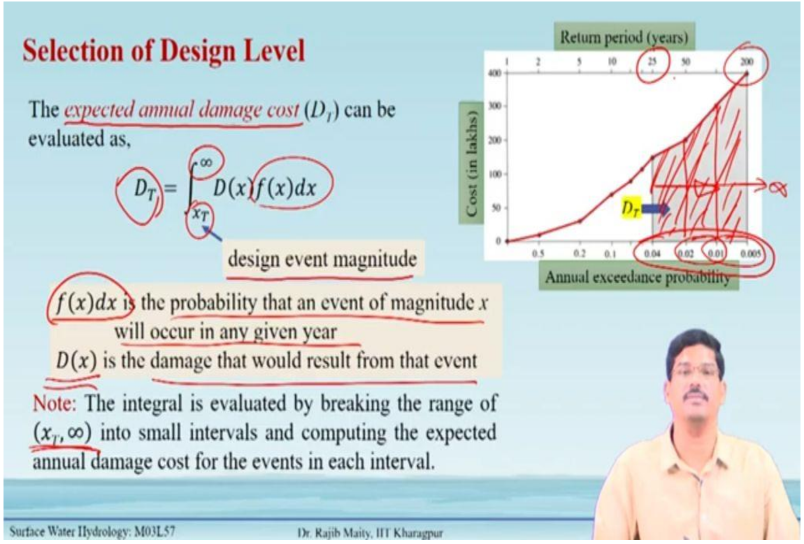

The *expected annual damage cost* (D_T) can be evaluated as,

$$D_T = \int_{x_T}^{\infty} D(x) f(x) dx$$

Where, $f(x)dx$ is the probability that an event of magnitude *x* will occur in any given year

$D(x)$ is the damage that would result from that event

It may be noted that the integral is evaluated by breaking the range of (xT, ∞) into small intervals and computing the expected annual damage cost for the events in each interval.

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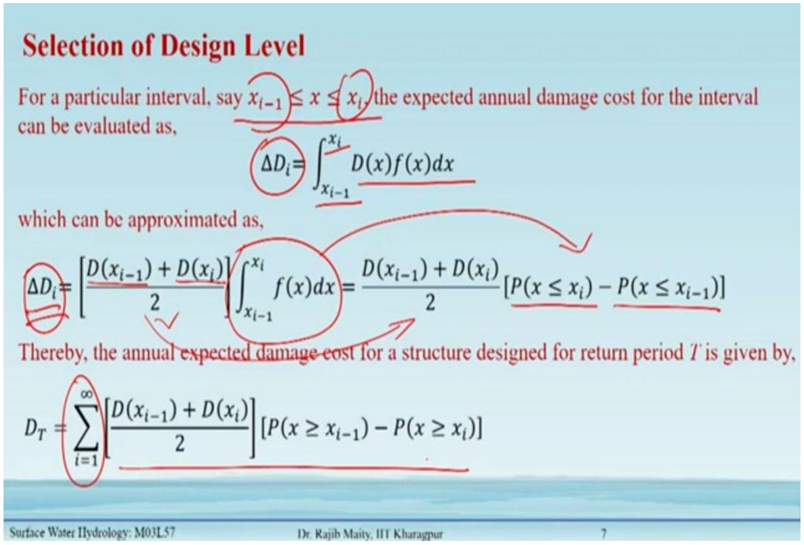

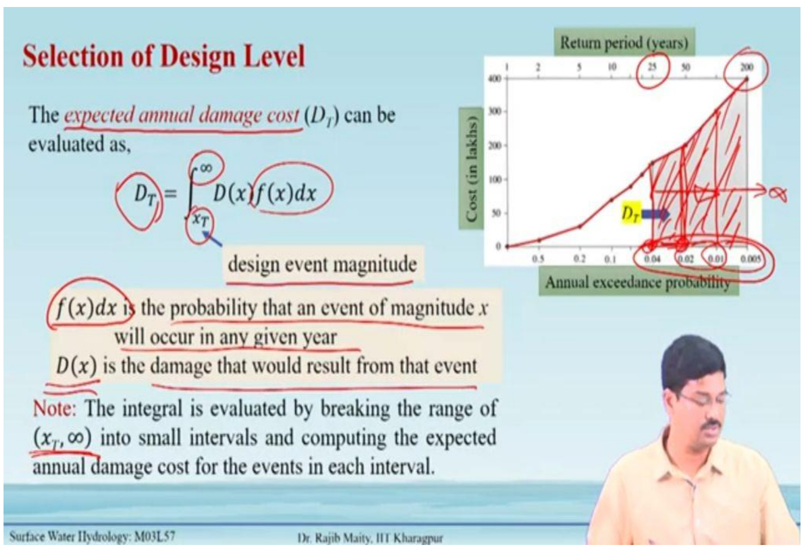

For a particular interval, say $x_{i-1} \leq x \leq x_i$, the expected annual damage cost for the interval can be evaluated as,

$$\Delta D_i = \int_{x_{i-1}}^{x_i} D(x)f(x)dx$$

which can be approximated as,

$$\Delta D_i = \left[\frac{D(x_{i-1}) + D(x_i)}{2}\right] \int_{x_{i-1}}^{x_i} f(x)dx = \frac{D(x_{i-1}) + D(x_i)}{2} [P(x \leq x_i) - P(x \leq x_{i-1})]$$

Thereby, the annual expected damage cost for a structure designed for return period T is given by,

$$D_T = \sum_{i=1}^{\infty} \left[\frac{D(x_{i-1}) + D(x_i)}{2}\right] [P(x \geq x_{i-1}) - P(x \geq x_i)]$$

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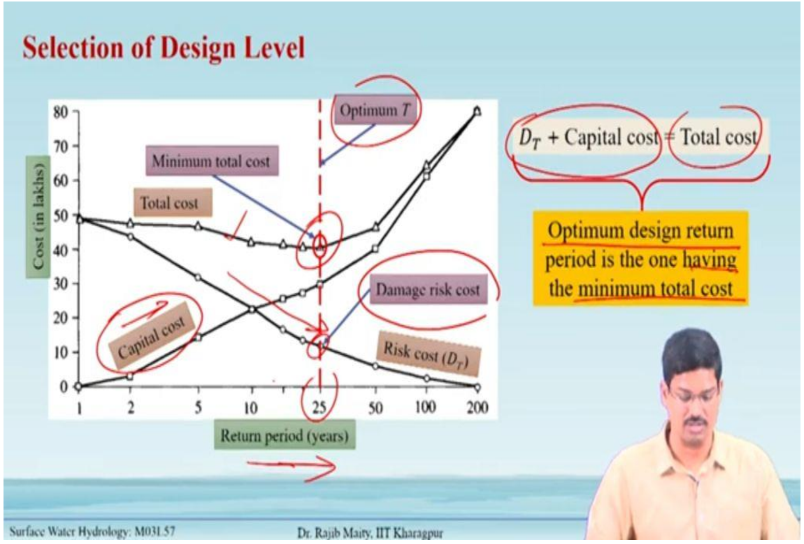

Selection of Design Level

If the return period increases, this capital cost will increase. Now, the risk cost per year if go for the higher and higher return period, the risk cost will gradually decrease. Now, if I just add these two that DT and the capital cost, I will get the total cost. So, this will gradually reduce and go, so the minimum optimum design return period is having the minimum total cost, this is how we have to decide. So, if this is the minimum one, then we can say that this is the optimum return period. As you can see here, this is the minimum total cost which is coming from the capital cost as well as from the risk cost. And this is a damage risk, this is, this value is the damage risk cost for these three things that we can get.

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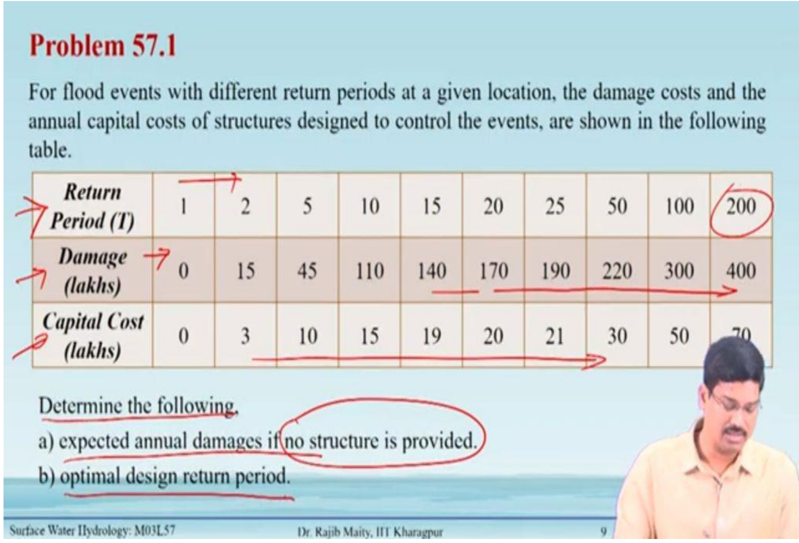

Problem 57.1

For flood events with different return periods at a given location, the damage costs and the annual capital costs of structures designed to control the events, are shown in the following table.

Return Period (T)	1	2	5	10	15	20	25	50	100	200
Damage (lakhs)	0	15	45	110	140	170	190	220	300	400
Capital Cost (lakhs)	0	3	10	15	19	20	21	30	50	70

Determine the following,

a) Expected annual damages if no structure is provided.

b) Optimal design return period.

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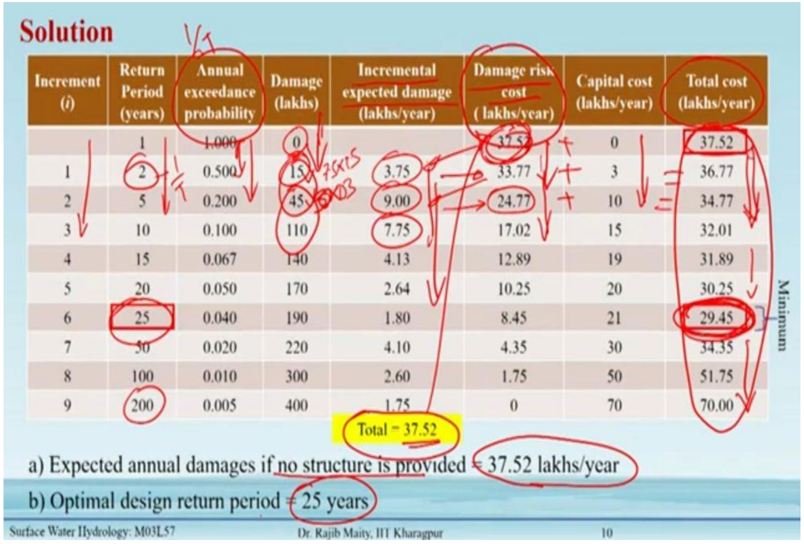

Solution

Increment (i)	Return Period (years)	Annual exceedance probability	Damage (lakhs)	Incremental expected damage (lakhs/year)	Damage risk cost (lakhs/year)	Capital cost (lakhs/year)	Total cost (lakhs/year)
	1	1.000	0		37.52	0	37.52
1	2	0.500	15	3.75	33.77	3	36.77
2	5	0.200	45	9.00	24.77	10	34.77
3	10	0.100	110	7.75	17.02	15	32.01
4	15	0.067	140	4.13	12.89	19	31.89
5	20	0.050	170	2.64	10.25	20	30.25
6	25	0.040	190	1.80	8.45	21	29.45
7	50	0.020	220	4.10	4.35	30	34.35
8	100	0.010	300	2.60	1.75	50	51.75
9	200	0.005	400	1.75	0	70	70.00

Total = 37.52

a) Expected annual damages if no structure is provided = 37.52 lakhs/year

b) Optimal design return period = 25 years

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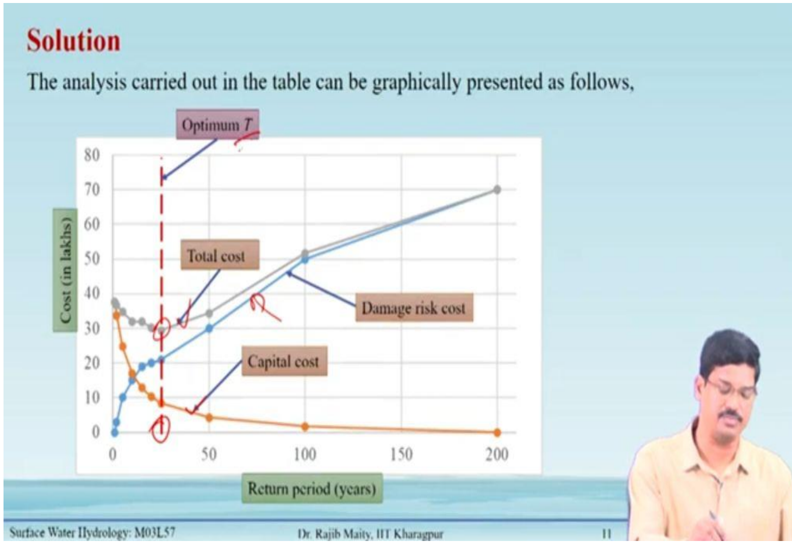

The analysis carried out in the table can be graphically presented as follows,

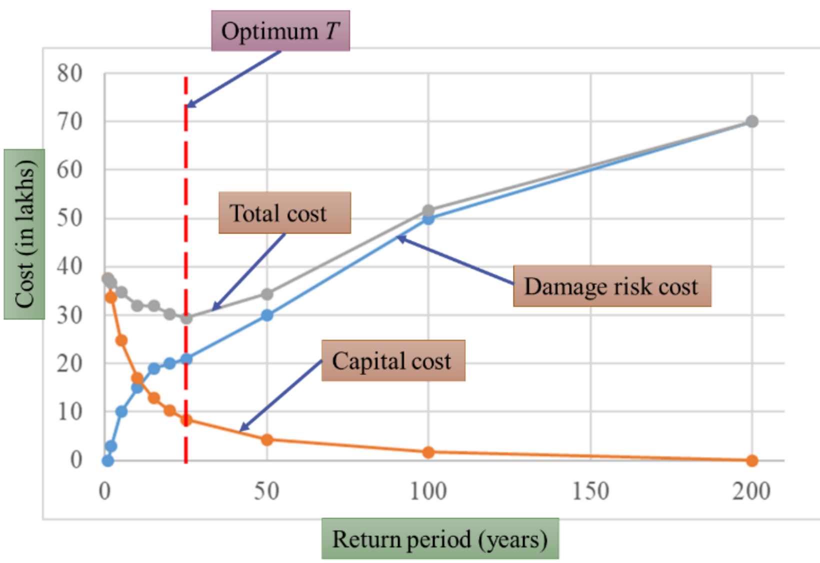

Figure 2 shows the determination of the optimum return period of the example 57.1

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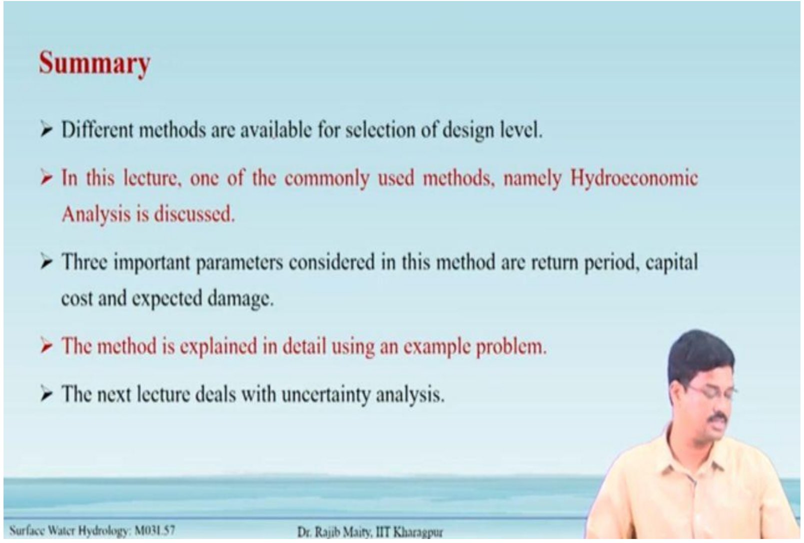

Summary

In summary, we learned the following points from this lecture:

- Different methods are available for a selection of design levels.
- In this lecture, one of the commonly used methods, namely Hydro economic Analysis is discussed.
- Three important parameters considered in this method are return period, capital cost, and expected damage.
- The method is explained in detail using an example problem.
- The next lecture deals with uncertainty analysis.