Surface Water Hydrology
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Lecture 61
Hydrologic Design of Reservoirs - Introduction, and Determination of Storage Capacity

In this specific lecture, we will discuss the hydrologic design of reservoirs, and we will give some introduction and determination of the storage capacity, there are various factors are needed to be considered, so far as the hydrologic design is concerned and that will be the focus of this lecture.

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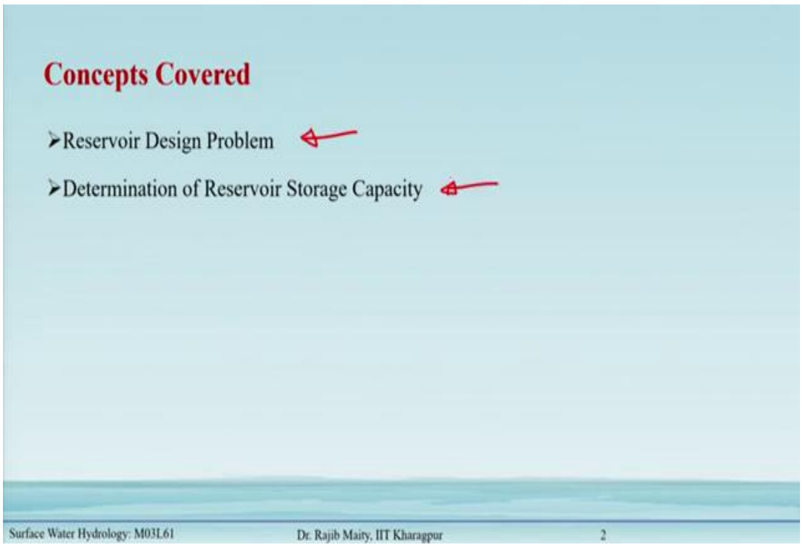

Under this concept covered, the reservoir design problem, particularly from the hydrologic design perspective and determination of reservoir storage capacity is the focus of this lecture.

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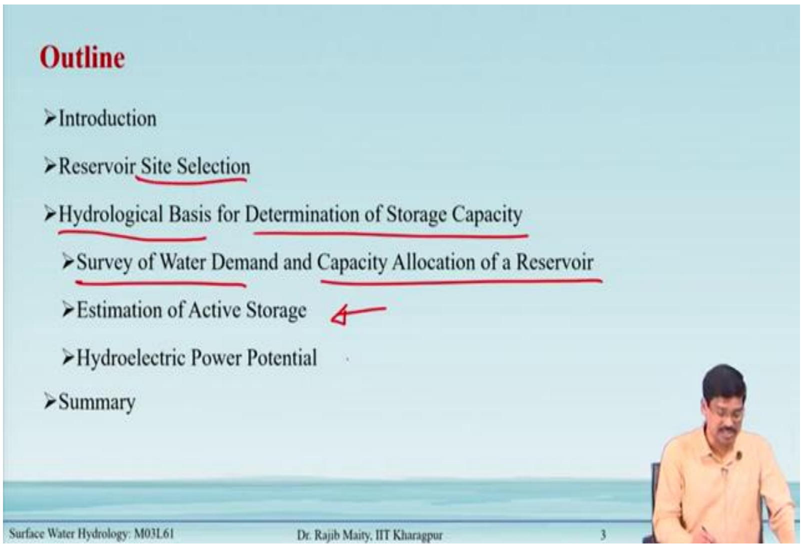

The outline of this lecture goes like this. First of all, will give some introduction, then there are two important considerations that come one another. First one is the site selection for the reservoir and then the determination of the storage capacity. We are discussing some of the hydrological basis.

So, you remember that there are some of the mathematical aspects that we have already discussed in during this hydrologic analysis. Now, some of these concepts will be utilized here also. We will give that overall outline and then we will refer to those methods that we have discussed earlier. Before that there are several considerations including the survey of water demand and the capacity allocation for the reservoir particularly for the multi-purpose reservoir system. Then comes estimation of the active storage, which is the main part of any storage reservoir. Hydroelectric power potential is also considered, so far as the multipurpose reservoirs are concerned. Then we will give a summary of this lecture.

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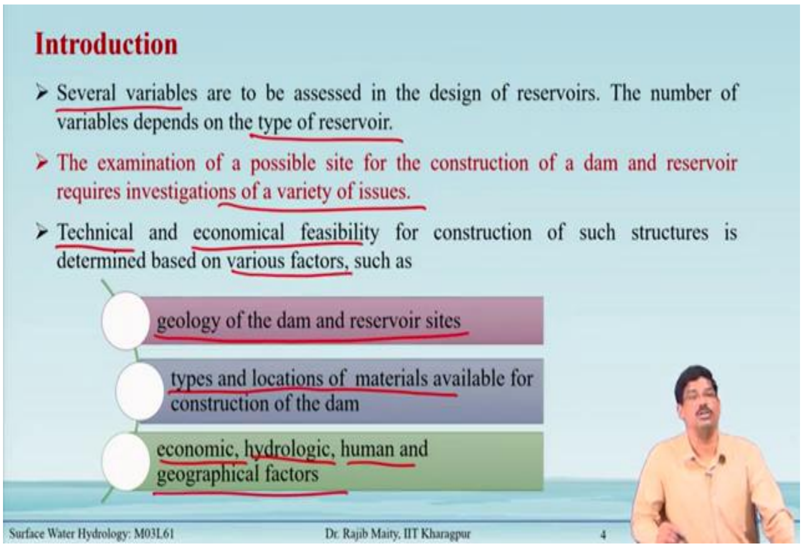

Introduction

There are several variables to be assessed in the design of a reservoir and these several variables depend on the type of reservoir that we are talking about, there is sometimes a single reservoir for a single purpose or it may be a single reservoir for multiple purposes or there may be a system of multiple reservoirs for multiple purposes. So, as the complexity goes up, the number of variables to be considered increases.

Now, examination of a possible site for the construction of a dam and the reservoir requires the investigation of the variety of the issues that comes into play. Technical feasibility and economic feasibility are the two most important considerations for the construction of such structures, and it again, in turn, depends on the other different factors are there:

- Geology of the dam and reservoir sites
- Types and locations of materials available for construction of the dam
- Economic, hydrologic, human, and geographical factors

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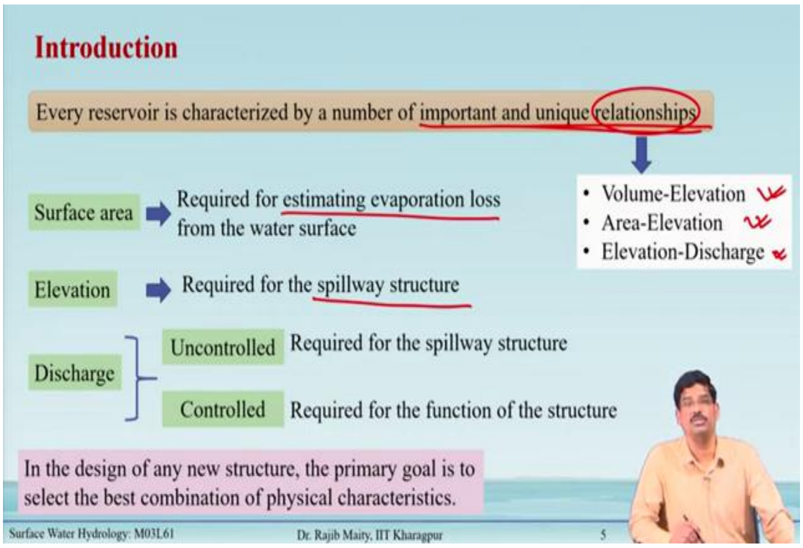

Every reservoir is characterized by several important and unique relationships between a couples of variables, these are pairwise say the volume-elevation, area-elevation, and elevation-discharge. So, when we talk about the surface area, it is a factor that is required for estimating the evaporation loss that directly depends on how much area is exposed to this. So, that evaporation loss becomes an important factor to be considered in this design.

Second one is the elevation. The elevation is required for the spillway structure which is one of the most important components of any such reservoir design. Next comes the discharge; again the discharge can be categorized into two categories, one is uncontrolled and the other one is controlled. So, in the design of this any new structure the primary goal is to select the best combination of all these physical characteristics before we select that ok, this is the location for the reservoir.

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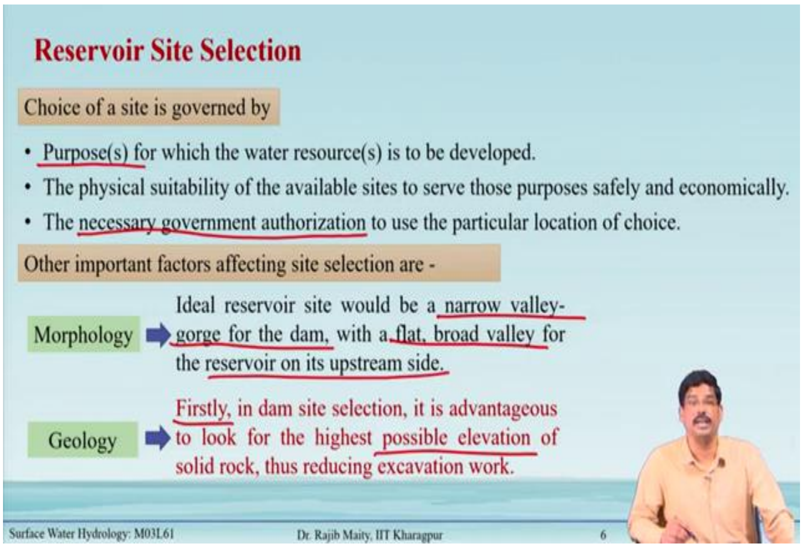

Reservoir Site Selection

Choice of a site is governed by

- Purpose(s) for which the water resource(s) is to be developed.
- The physical suitability of the available sites to serve those purposes safely and economically.
- The necessary government authorization to use the particular location of choice.

Other important factors affecting site selection are –

- *Morphology*: Ideal reservoir site would be a narrow valley-gorge for the dam, with a flat, broad valley for the reservoir on its upstream side.
- *Geology:* Firstly, in dam site selection, it is advantageous to look for the highest possible elevation of solid rock, thus reducing excavation work.

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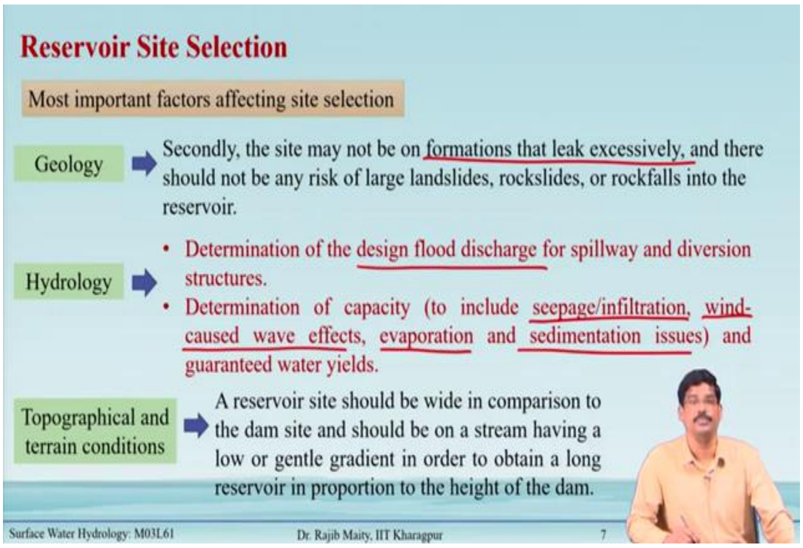

- *Geology*: Secondly, the site may not be on formations that leak excessively, and there should not be any risk of large landslides, rockslides, or rock falls into the reservoir.

- *Hydrology*: Determination of the design of flood discharge for spillway and diversion structures.

  Determination of capacity (to include seepage/infiltration, wind-caused wave effects, evaporation, and sedimentation issues) and guaranteed water yields.

- *Topographical and terrain conditions:* A reservoir site should be wide in comparison to the dam site and should be on a stream having a low or gentle gradient in order to obtain a long reservoir in proportion to the height of the dam.

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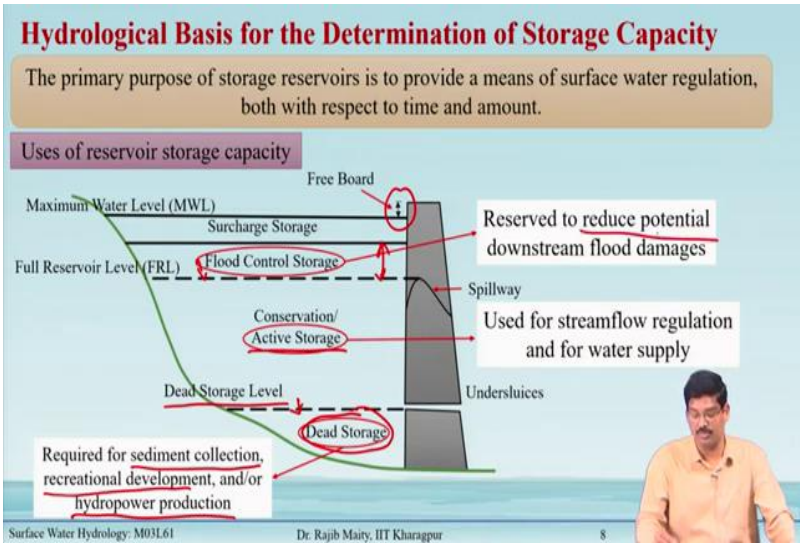

Hydrological Basis for the Determination of Storage Capacity

The primary purpose of storage reservoirs is to provide a means of surface water regulation, both with respect to time and amount. The use of this reservoir storage capacity can be grouped into different schematics, as shown in figure 1.

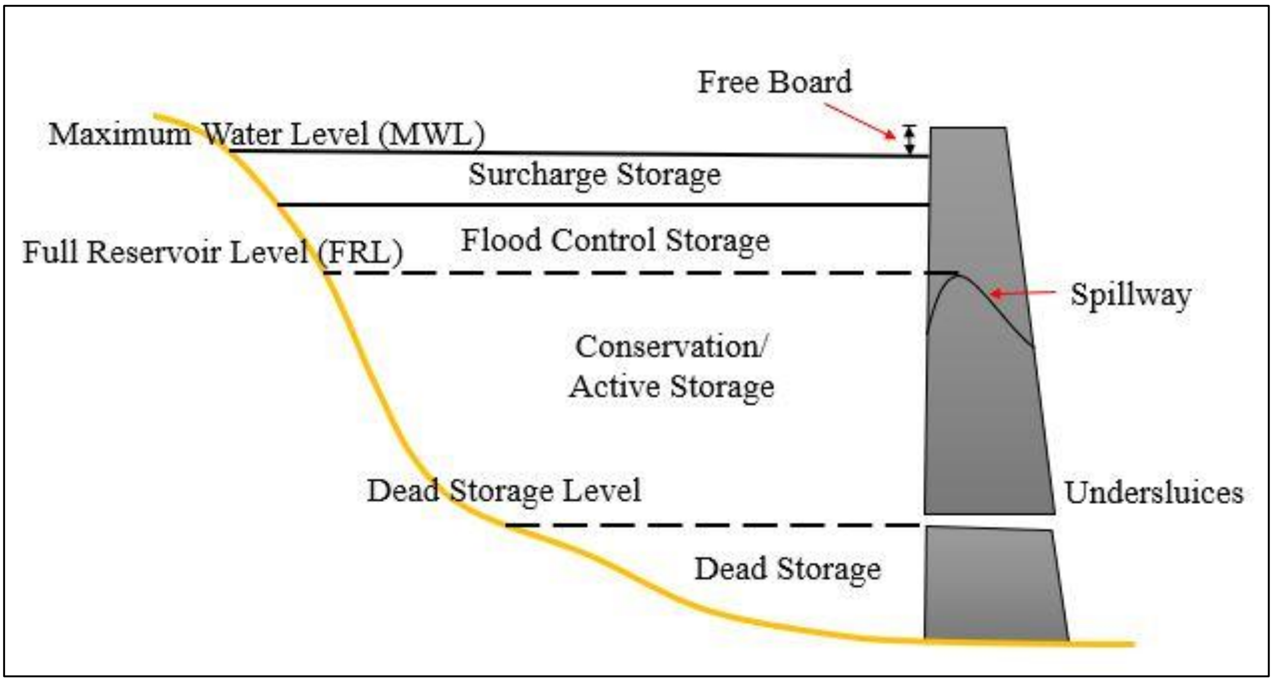

Figure 1: A typical cross-section of a reservoir storage

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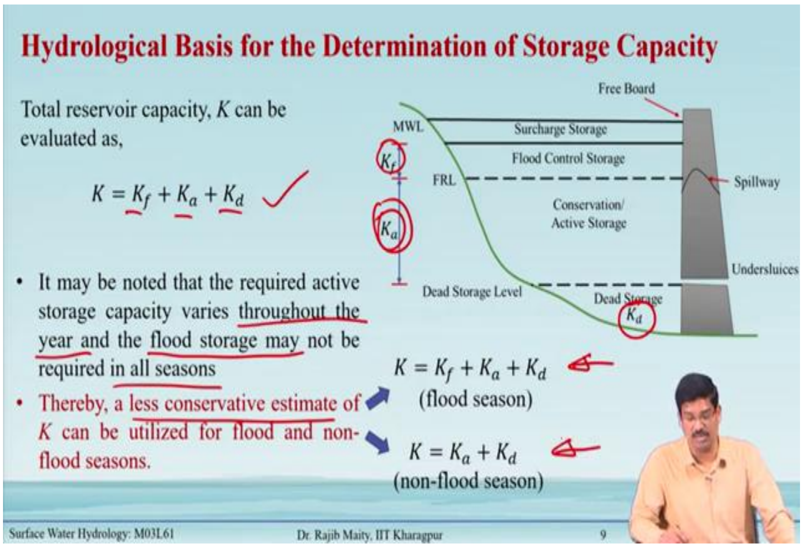

Total reservoir capacity, K can be evaluated as,

$$K = K_f + K_a + K_d$$

Where the dead storage is k_d and the active storage k_a and the flood control storage is k_f.

It may be noted that the required active storage capacity varies throughout the year and the flood storage may not be required in all the seasons, which is quite obvious, during the high monsoon time that particular component may be needed.

So, sometimes when you are talking about this less conservative estimate of this total storage, that where can be utilized for the flood and the non-flood season separately. Thereby, a less conservative estimate of K can be utilized for flood and non-flood seasons.

For the flood season $K = K_f + K_a + K_d$

For the non-flood season, $K = K_a + K_d$

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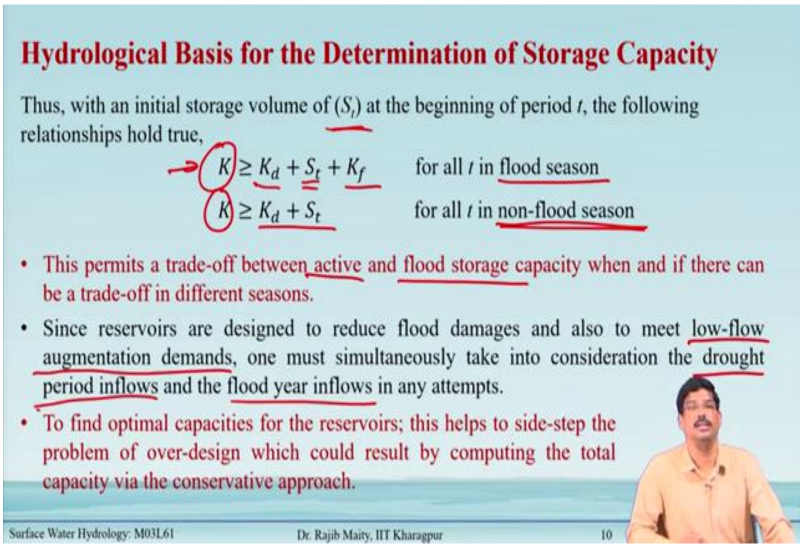

Thus, with an initial storage volume of (S_t) at the beginning of period t, the following relationships hold,

$$K \geq K_d + S_t + K_f \qquad \text{for all } t \text{ in flood season}$$

$$K \geq K_d + S_t \qquad \text{for all } t \text{ in the non-flood season}$$

This permits a trade-off between active and flood storage capacity when and if there can be a trade-off in different seasons.

Since reservoirs are designed to reduce flood damages and also to meet low-flow augmentation demands, one must simultaneously take into consideration the drought period inflows and the flood year inflows in any attempt.

To find optimal capacities for the reservoirs; this helps to side-step the problem of over-design which could result from computing the total capacity via the conservative approach.

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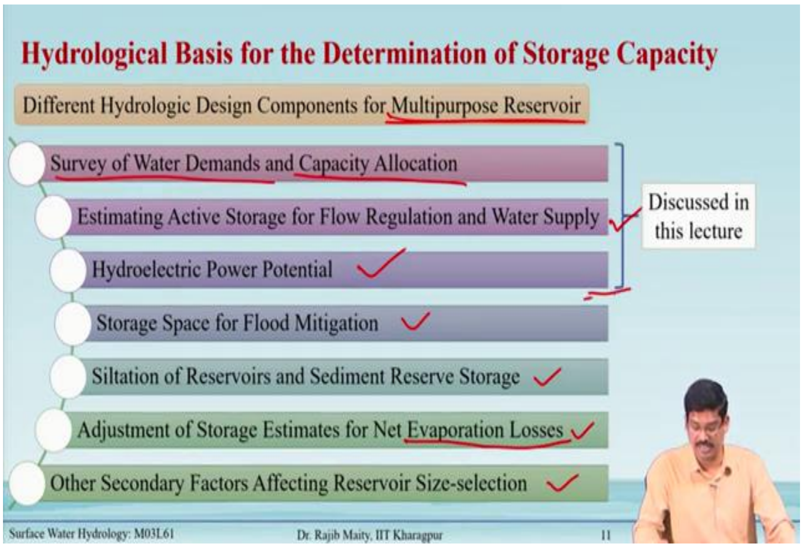

Different Hydrologic Design Components for Multipurpose Reservoir

- Survey of Water Demands and Capacity Allocation
- Estimating Active Storage for Flow Regulation and Water Supply
- Hydroelectric Power Potential
- Storage Space for Flood Mitigation
- Siltation of Reservoirs and Sediment Reserve Storage
- Adjustment of Storage Estimates for Net Evaporation Losses
- Other Secondary Factors Affecting Reservoir Size-selection

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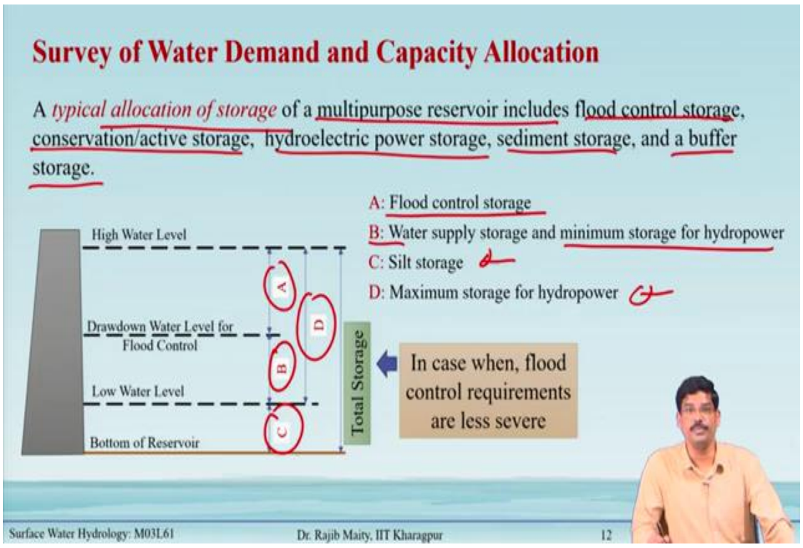

Survey of Water Demand and Capacity Allocation

A typical allocation of storage (in figure 2) of a multipurpose reservoir includes flood control storage, conservation/active storage, hydroelectric power storage, sediment storage, and buffer storage.

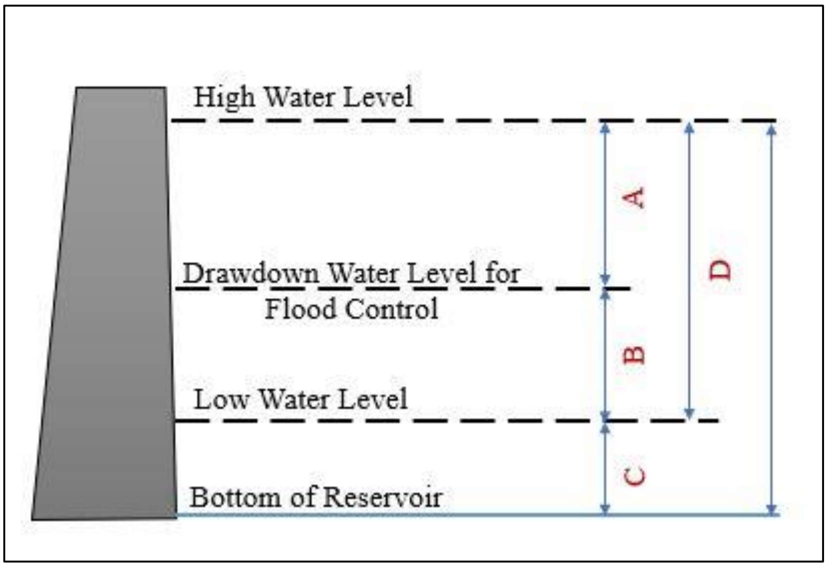

Figure 2: The different levels of water in a reservoir

Where, A: Flood control storage

B: Water supply storage and minimum storage for hydropower

C: Silt storage

D: Maximum storage for hydropower

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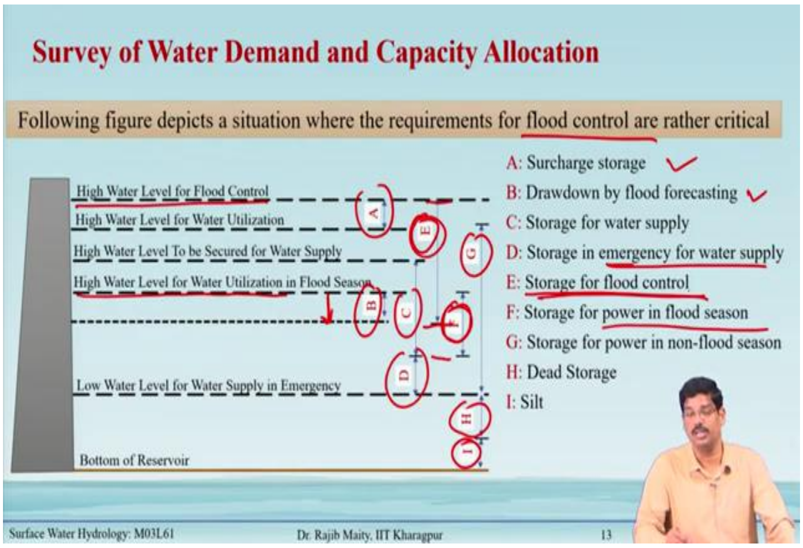

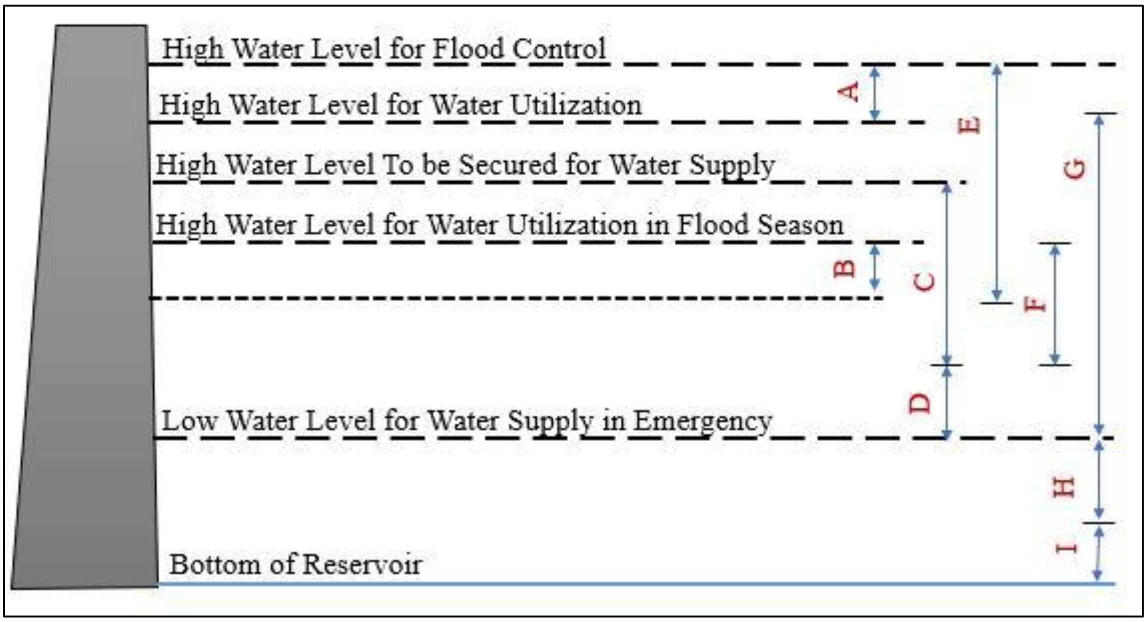

Figure 3: The depicts a situation where the requirements for flood control are rather critical

Where,

A: Surcharge storage

B: Drawdown by flood forecasting

C: Storage for water supply

D: Storage in emergency for water supply

E: Storage for flood control

F: Storage for power in flood season

G: Storage for power in non-flood season

H: Dead Storage

I: Silt

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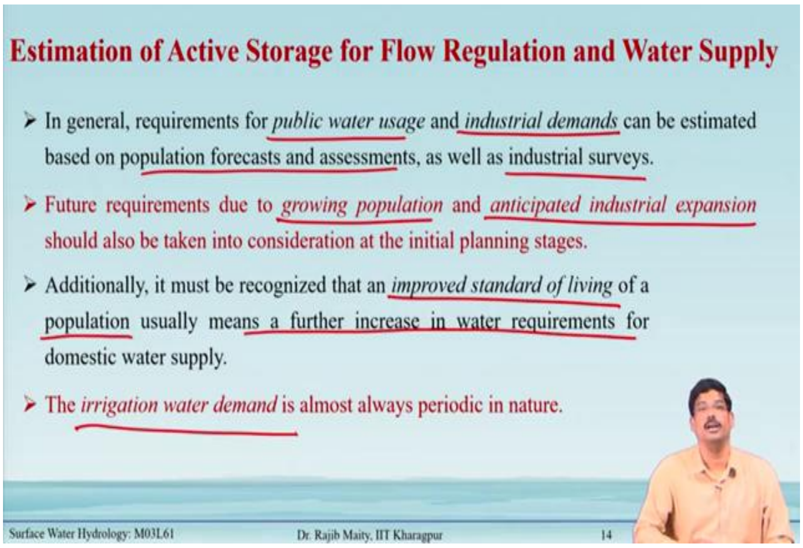

Estimation of Active Storage for Flow Regulation and Water Supply

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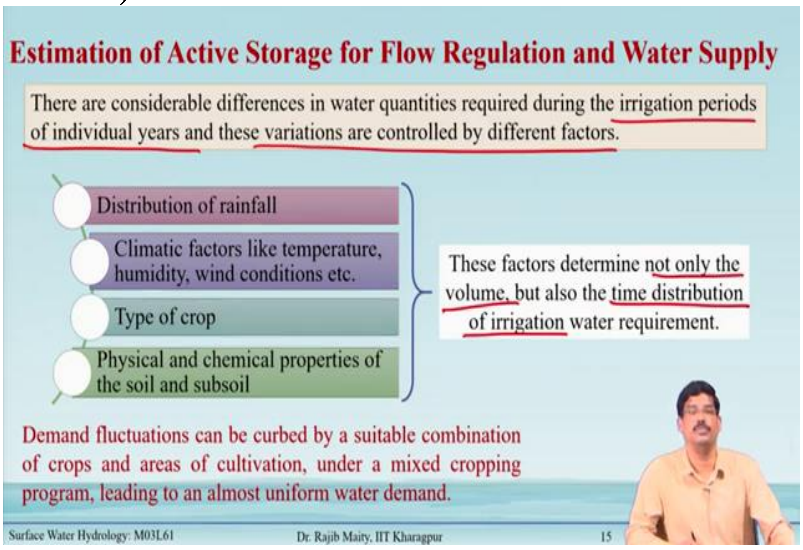

There are considerable differences in water quantities required during the irrigation periods of individual years and these variations are controlled by different factors.

- Distribution of rainfall

- Climatic factors like temperature, humidity, wind conditions, etc.
- Type of crop
- Physical and chemical properties of the soil and subsoil

These factors determine not only the volume but also the time distribution of irrigation water requirements.

In general, the requirement for the public water uses and the industrial demand can be estimated based on the population forecast as well as industrial survey. These factors are going to grow during the lifetime of a reservoir.

Then future requirements of the anticipated growing population and anticipated industrial expansion should also be taken into consideration at the initial planning stage. Additionally, it must be recognized that the improved standard of living of a population usually leads to an increase in the water requirement. The irrigation water demand is almost always periodic throughout the year that also we have to consider. Demand fluctuations can be curbed by a suitable combination of crops and areas of cultivation, under a mixed cropping program, leading to almost uniform water demand.

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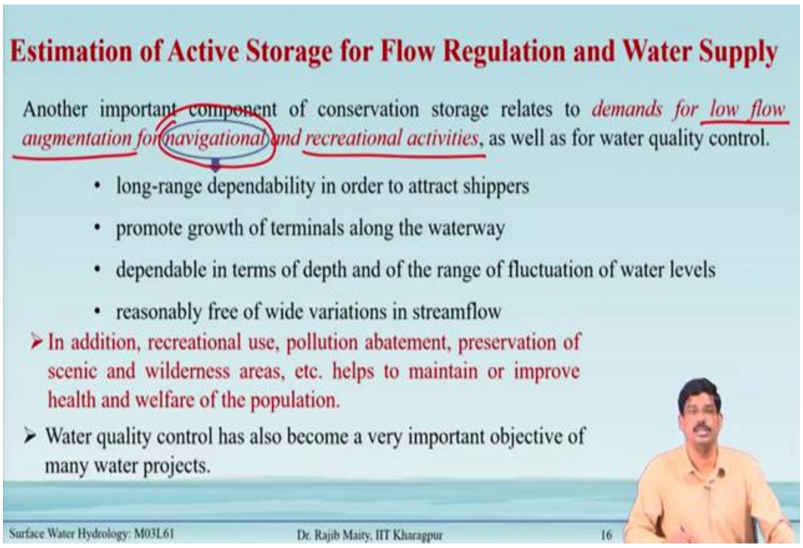

Another important component of conservation storage relates to demands for low flow augmentation for navigational and recreational activities, as well as for water quality control.

- long-range dependability to attract shippers

- promote the growth of terminals along the waterway
- dependable in terms of depth and the range of fluctuation of water levels
- reasonably free of wide variations in streamflow

In addition, recreational use, pollution abatement, preservation of scenic and wilderness areas, etc. helps to maintain or improve the health and welfare of the population. Water quality control has also become a very important objective of many water projects.

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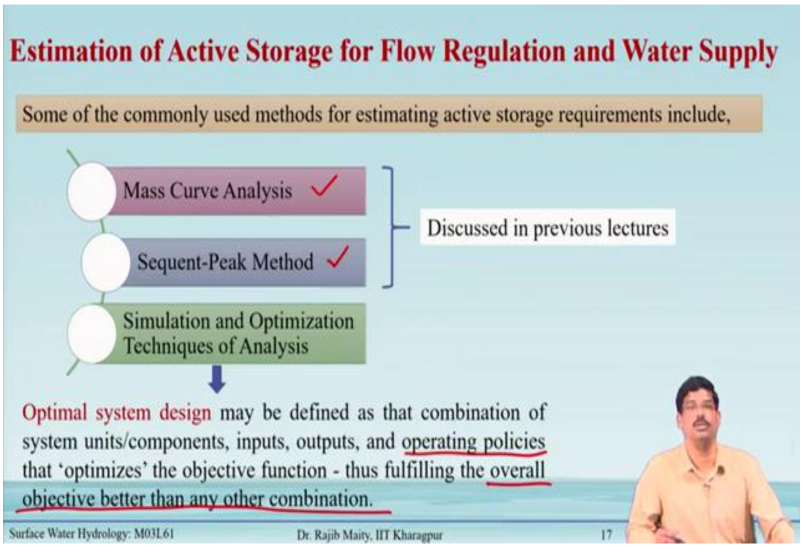

Some of the commonly used methods for estimating active storage requirements include,

- Mass Curve Analysis
- Sequent-Peak Method
- Simulation and Optimization Techniques of Analysis

Optimal system design may be defined as that combination of system units/components, inputs, outputs, and operating policies that 'optimizes' the objective function - thus fulfilling the overall objective better than any other combination.

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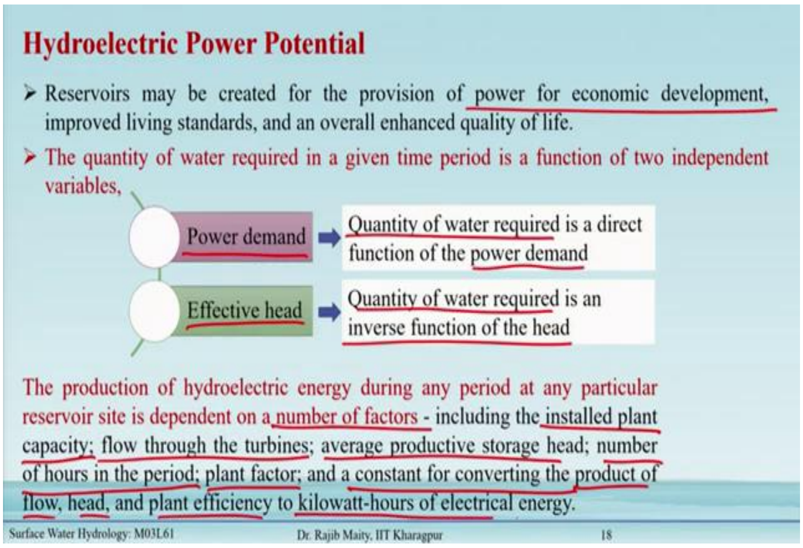

Hydroelectric Power Potential

Reservoirs may be created for the provision of power for economic development, improved living standards, and overall enhanced quality of life.

The quantity of water required in a given time period is a function of two independent variables,

I. *Power demand*: The quantity of water required is a direct function of the power demand.

II. *Effective head*: The quantity of water required is an inverse function of the head.

The production of hydroelectric energy during any period at any particular reservoir site is dependent on a number of factors - including the installed plant capacity; flow through the turbines; average productive storage head; the number of hours in the period; plant factor; and a constant for converting the product of flow, head, and plant efficiency to kilowatt-hours of electrical energy.

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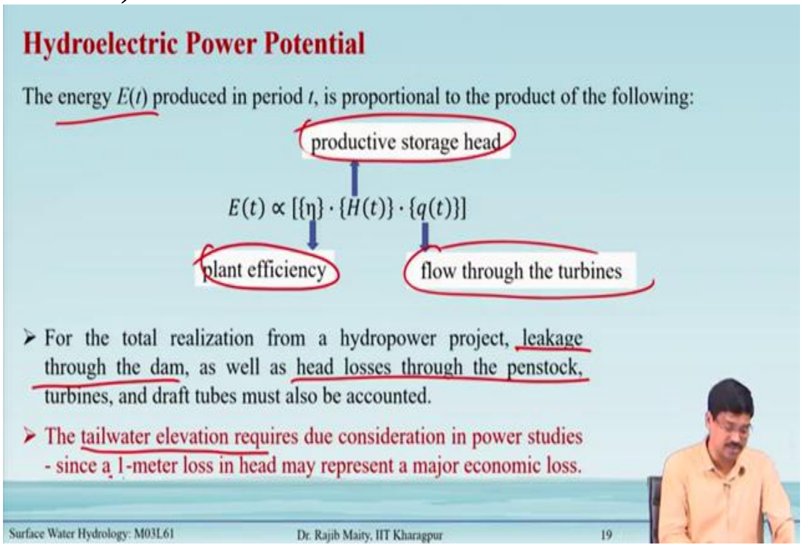

The energy E (t) produced in period t, is proportional to the product of the following:

$$E(t) \propto [\{\eta\} \cdot \{H(t)\} \cdot \{q(t)\}]$$

Where, η = plant efficiency

$H(t)$= productive storage head

$\{q(t)\}$= flow through the turbines

For the total realization of a hydropower project, leakage through the dam, as well as head losses through the penstock, turbines, and draft tubes must also be accounted.

The tail water elevation requires due consideration in power studies - since a 1-meter loss in the head may represent a major economic loss.

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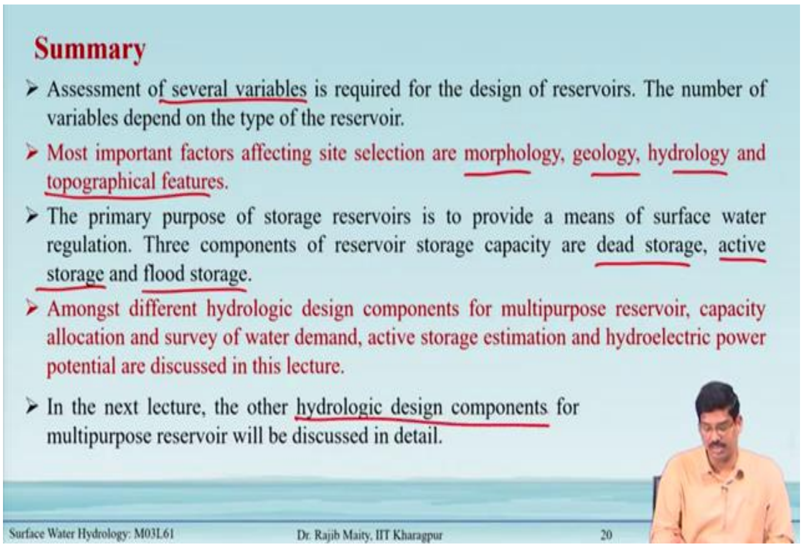

Summary

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

- Assessment of several variables is required for the design of reservoirs. The number of variables depends on the type of the reservoir.
- The most important factors affecting site selection are morphology, geology, hydrology, and topographical features.
- The primary purpose of storage reservoirs is to provide a means of surface water regulation. Three components of reservoir storage capacity are dead storage, active storage, and flood storage.
- Amongst different hydrologic design components for the multipurpose reservoir, capacity allocation and survey of water demand, active storage estimation, and hydroelectric power potential are discussed in this lecture.
- In the next lecture, the other hydrologic design components for multipurpose reservoirs will be discussed in detail.