Question Bank regarding the Reservoir Planning, Design, and Operations' Class

1. What are the various purposes served by a multipurpose reservoir?
    a. *Answer:*

    (1) Storage and control of water for irrigation.

    (2) diversion of water domestic use.

    (3) Water supply for industrial uses.

    (4) Development of hydroelectric power.

    (5) Increasing water depth for navigation.

    (6) Storage space for flood control.

    (7) Debris control.

    (8) Preservation and enhancement of aquatic life.

    (9) Recreation.

    (10) soil conservation.

    (11) Protection downstream from floods.

    (12) pollution control

2. What are the stages of planning and design of dams?
    a. *Answer:*

    Stages: Any dam project is carried out at following stages:

    I. Initial screening based on river profile and topographic maps.

    II. Reconnaissance plan-uses only any available data

    III. Pre-feasibility plan exploration and additional field data

    IV. Feasibility Plan-Extensive exploration and additional field data

    V. Design stage: – point tests/surveys to finalize design

3. What are the geological investigations of reservoirs? Describe each investigation briefly.
    a. *Answer:*

    1. Suitability of foundation for the dam

    The type and height of the dam mainly depend upon the type of foundation. Subsurface explorations are carried out to determine the depth of overburden to be removed for laying *the foundation of the dam, the type of rock, the nature and extent of the fault zones, if any, present in the rock.*

2. Water tightness of the reservoir basin

The reservoir basin should be watertight so that the stored water is not wasted due to the seepage through the bed and banks, otherwise the very purpose of constructing the reservoir would be defeated. Geological investigations are conducted to detect the presence of cavernous rock formations which have cavities and are porous. The stored water may escape through such cavities into adjacent valleys. If such formations exist in a small area, they may be treated and made watertight. However, if they are widespread, the site may have to be abandoned.

3. Location of the quarry sites for the construction materials.

Location of quarry sites large quantities of construction material such as stones, aggregates, sand, soil, rockfill, etc. are required for the construction of a dam. Geological investigations are conducted for location of suitable quarries for stones and borrow areas for soils. The quality and the quantity of the available construction materials are also ascertained.

4. What are the criteria of the selecting dam site?

a. Answer:

1. Small river channel width with steep side gorge: short dam crest length, leads to large storage for small dam length

2. A wide and gently sloping valley upstream of the dam site (for storage dams) and narrow and steeply sloping valley for hydropower dams.

3. River channel and valley has very flat slopes u/s of dam site (leads to large storage for small dam heights).

4. Deep reservoir possible – require less area and lesser land costs, less surface evaporation

5. Enough water flow/yield available to meet requirements/demand

6. High sediment load tributaries are excluded

7. Geology favorable for foundation (foundation can be designed at any site, but it increases costs), competent hard rock is most suitable.

8. Abutments are water tight, and reservoir rim allow minimum percolation and seepage losses.

9. Small river sediment rate (longer dam life) Depend on river morphology and catchment characteristics.

10. Land use of reservoir area is minimal – lower economic values means lower compensations.

11. Reservoir area not very sensitive to environment (wild life parks, endangered species, historical places, monuments etc).

12. No seismic and tectonic activities or active faults in and near the site.

13. Socio-political stability (no unstable gestures)

14. Reservoir and dam area less populated

15. Site have adequate stream flow record

16. Site is easily accessible; approach road is present or can be developed easily.

17. Construction material available nearby easily

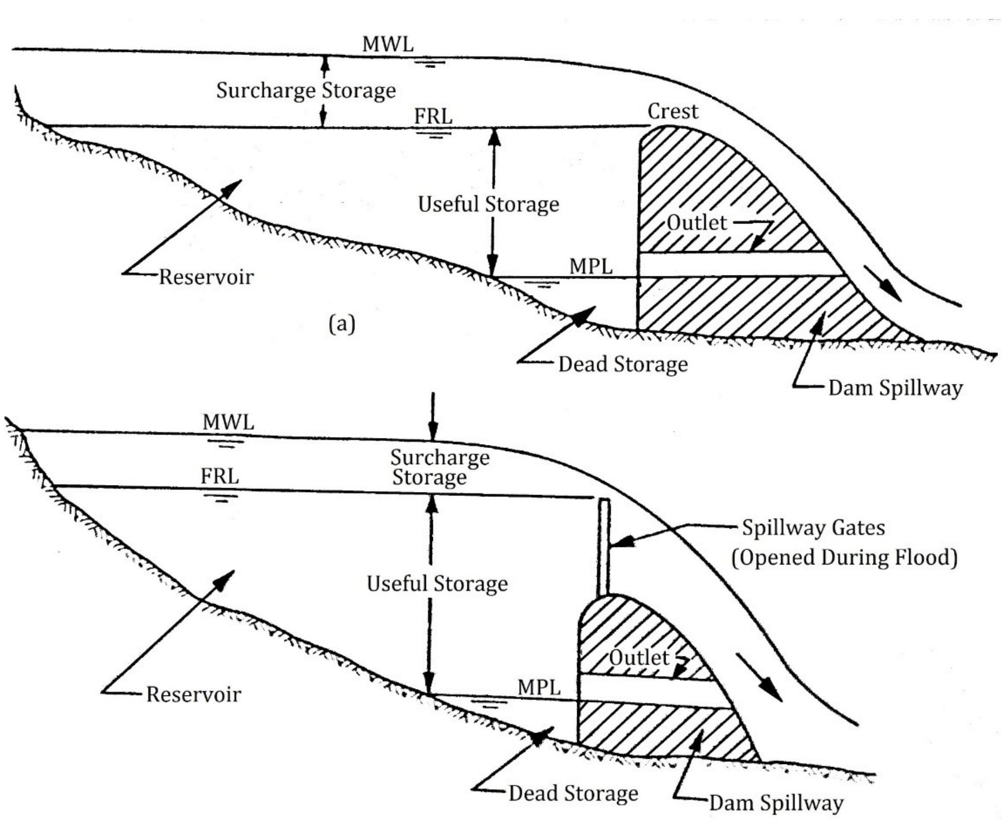
18. Site near load center (demand area) for water+ power

19. No mineral resources in reservoir area (present or future)

20. Site allows a deep reservoir & small surface area (less land costs and small evaporation losses).

21. Existing infrastructure, e.g. highway, least affected.

5. Graphical representation of reservoir storage levels with description of each level.
   a. Answer:



1. Full Reservoir Level (FRL):

The full reservoir level (FRL) is the highest water level to which the water surface will rise during normal operating conditions. The effective storage of the reservoir is computed up to the full reservoir level. The FRL is the highest level at which water is intended to be held for various uses without any passage of water through the spillway. In case of dams without spillway gates, the FRL is equal to the crest level of the spillway. However, if the spillway is gated, the FRL is equal to the level of the top of the gates.

2. Normal Conservation Level (NCL)

It is the highest level of the reservoir at which water is intended to be stored for various uses other than flood. The normal conservation level is different from the FRL as the latter may include a part of the flood. However, if there is no storage for flood up to FRL, the normal conservation level and the FRL become identical.

3. Maximum Water Level (MWL):

The maximum water level is the maximum level to which the water surface will rise when the design flood passes over the spillway. The maximum water level is higher than the full reservoir level so that some surcharge storage is available between the two levels to absorb flood.

4. Minimum pool level (MPL):

The minimum pool level is the lowest level up to which the water is withdrawn from the reservoir under ordinary conditions. The minimum pool level generally corresponds to the elevation of the lowest outlet (or sluiceway) of the dam.

However, in the case of a reservoir for hydroelectric power, the minimum pool level is fixed after considering the minimum working head required for the efficient working of turbines. The storage below the minimum pool level is not useful and is called the dead storage.

5. Useful storage:

The volume of water stored between the full reservoir level (FRL) and the minimum pool level is called the useful storage. The useful storage is subdivided into:

(a) the conservation storage for other purposes and

(b) the flood control storage for the flood control, in accordance with the adopted plan of operation of the reservoir. The useful storage is also known as the live storage.

6. Surcharge storage:

The surcharge storage is the volume of water stored above the full reservoir level up to the maximum water level. The surcharge storage is an uncontrolled storage which exists only when the river is in flood and the flood water is passing over the spillway. This storage is available only for the absorption of flood and it cannot be used for other purposes

7. Dead storage:

The volume of water held below the minimum pool level is called the dead storage. The dead storage is not useful, as it cannot be used for any purpose under ordinary operating conditions.

8. Bank storage:

If the banks of the reservoir are porous, some water is temporarily stored by them when the reservoir is full. The stored water in banks later drains into the reservoir when the water level in the reservoir falls. Thus the banks of the reservoir act like mini reservoirs

6. Depending upon the purpose served; classify reservoirs.
    a. *Answer:*
        A. *Storage (or conservation) reservoirs*
        B. *Flood control reservoirs*
        C. *Multipurpose reservoirs*
        D. *Distribution reservoirs*
        E. *Balancing reservoirs*
7. What are the multipurpose reservoirs?
    a. *Answer:*

    A multipurpose reservoir is designed and constructed to serve two or more purposes. Most of the reservoirs are designed as multipurpose reservoirs to store water for irrigation and hydropower, and also to effect flood control.

8. What are the Distribution Reservoirs?
    a. *Answer:*

    A distribution reservoir is a small storage reservoir to tide over the peak demand of water for municipal water supply or irrigation. The distribution reservoir is helpful in permitting the pumps to work at a uniform rate. It stores water during the period of lean demand and supplies the same during the period of high demand. Water is pumped from a water source at a uniform rate throughout the day for 24 hours but the demand varies from time to time.

i. During the period when the demand of water is less than the pumping rate, the water is stored in the distribution reservoir. On the other hand, when the demand of water is more than the pumping rate, the distribution reservoir is used for supplying water at rates greater than the pumping rate.

ii. *Distribution reservoirs are rarely used for the supply of water for irrigation. These are mainly used for municipal water supply.*

9. What are the Balancing Reservoirs?

   a. *Answer:*

   A balancing reservoir is a small reservoir constructed D/S of the main reservoir for holding water released from the main reservoir.

10. What are the formulas used for determination the capacity of reservoirs?

   a. *Answer:*

   Trapezoidal formula

   According to the trapezoidal formula, the storage volume between two successive contours of areas A1, and A2 is given by:

$$\Delta V1 = \frac{h}{2}(A1 + A2)$$

Where h is the contour interval.

Therefore, the total volume V of the storage is given by :

$$V = \Delta V1 + \Delta V2 + \Delta V3 + ..$$

$$V = \sum \Delta V$$

or

$$V = \frac{h}{2}[A1 + 2A2 + 2A3 + \cdots \ldots + 2An - 1 + An]$$

Cone formula

According to the cone formula, the storage volume between two successive contours of areas A1 and A2 is given by:

$$\Delta V1 = \frac{h}{3}\left(A1 + A2 + \sqrt{(A1A2)}\right)$$

The total volume V is given by:

$$V = \Delta V1 + \Delta V2 + \Delta V3 + \cdots \ldots \ldots \ldots . + \Delta Vn$$

$$V = \sum \Delta V$$

Prismoidal formula

According to the prismoidal formula, the storage volume between three successive contours is given by:

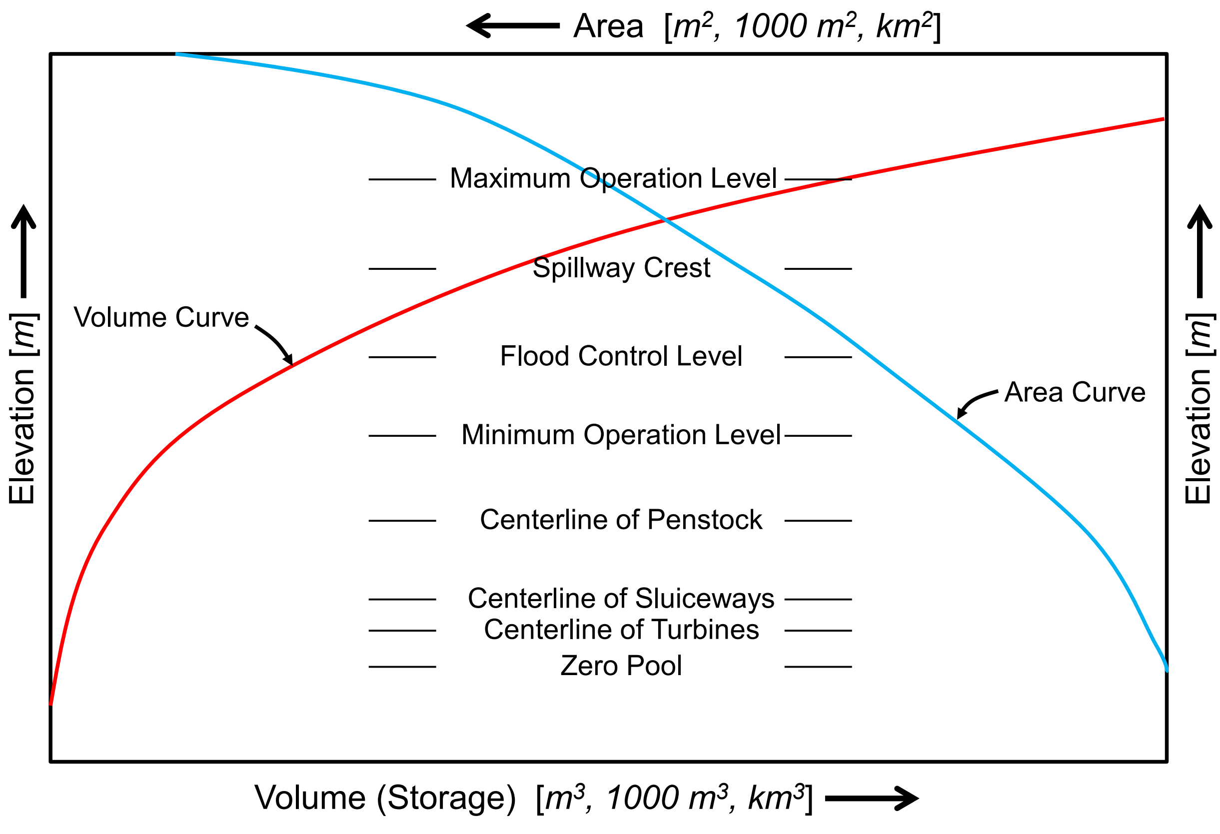
$$\Delta V = \frac{h}{3}(A1 \ + 4A2 \ + A3\ )$$

The total volume is given by:

$$V \ = \frac{h}{3}\ [(\ A1 \ + \ An) + 4(A2 \ + \ A4 \ + A6 \ + \cdots) \ + \ 2\ (A3 \ + \ A5 + \cdots)]$$

where A3, A5, etc. are the areas with odd numbers : A2, A4, A6, etc. are the areas with even numbers A1 and An are respectively, the first and the last area.

11. Plot typical combined area-elevation, capacity-elevation curve the indicate different elevation of a dam on the curves.
    a. Answer:



12. State the survey investigation in the planning of a Dam.
    a. Answer:

Surveying investigation usually done for two locations in the planning purpose:

I- Dam Site:

For the area in the vicinity of the dam site, a very accurate triangulation survey is conducted. A contour plan to a scale of 1/250 or 1/500 is usually prepared. The contour interval is usually 1 m or 2 m. The contour plan should cover an area at least up to 200 m upstream and 400m downstream and for adequate width beyond the two abutments.

II- Reservoir:

For the reservoir, the scale of the contour plan is usually 1/15,000 with a contour interval of 2 m to 3 m, depending upon the size of the reservoir. The area-elevation and storage-elevation curves are prepared for different elevations up to an elevation 3 to 5m higher than the anticipated maximum water level (M.W.L).

13. Why Hydrological investigation must be conducted in design and planning of a dam?
    a. *Answer:*

I. To study the runoff pattern and to estimate yield.

The most important aspect of the reservoir planning is to estimate the quantity of water likely to be available in the river from year to year and seasons to season. For the determination of the required storage capacity of a reservoir, the runoff pattern of the river at the dam site is required. If the stream gauging has been done for a number of years before the construction of the dam, the runoff pattern will be available from the record. It is generally assumed that the runoff pattern will be substantially the same in future also. The available record is used for estimating the storage capacity. The inflow hydrographs of two or three consecutive bad years when the discharge is low are frequently used for estimating the required capacity

II. To determine the maximum discharge at the site.

The spillway capacity of the dam is determined from the inflow hydrograph for the worst flood when the discharge in the river is the maximum. Flood routing is done to estimate the maximum outflow and the maximum water level reached during the worst flood.

14. What are the stages in the design of dam projects?
    a. *Answer:*
        A. *Initial screening based on river profile and topographic maps.*
        B. *Reconnaissance plan-uses only any available data*
        C. *Pre-feasibility plan exploration and additional field data*
        D. *Feasibility plan-Extensive exploration and additional field data*
        E. *Design stage: – point tests/surveys to finalize design.*

    At each succeeding stage, the plan is firmed up with more precise details, dimensions and analysis; More data collected at each successive stage. The design stage ends up with drawings appropriate for construction activities.

15. What are the data required for design of a dam?
    a. *Answer:*
        I. *Location & surrounding map*
        II. *Topographic maps/aerial photographs of dam site*
        III. *Elevation surveys/triangulation + bench mark*

IV. Transportation map (road, rail, air)
V. Geological / rock formations data of dam site
VI. Seismic/tectonic activity map
VII. Climatic data (P, T, ET, wind, sunshine)
VIII. Stream flow data (daily average flows)
IX. Sediment data
X. Demographic/land ownership/housing data for the reservoir area
XI. River environment/ecology (u/s, at site, d/s) (fish, w/life, birds, flora, fauna, vegetation)
XII. Project water requirement
XIII. Power requirements & national grid / transmission lines
XIV. Flood data (instantaneous peak flow rates, time to peak, base time, flood duration, flood volumes, flow hydrograph, etc) of all or major floods
XV. Water rights
XVI. River hydrographic data (bed levels, flood levels, cross section, bank/valley levels)
XVII. Groundwater table data in the vicinity, u/s and d/s area
XVIII. Public recreation need
XIX. Land evaluation
XX. Public/Private buildings
XXI. Availability of construction materials
XXII. River stage-discharge data (u/s, tail water)
XXIII. Geo-political economic data

16. State planning and design team for dam project.

a. Answer:

i. Site selection,
ii. topographic surveys,
iii. water availability assessment,
iv. sizing and layout,
v. geologic surveys and construction materials investigations,
vi. geologic evaluation of foundation, rim, abutment and pond area,
vii. dam section design,
viii. dam seepage and stability analysis,
ix. Diversion arrangements details (diversion tunnel, coffer dam),
x. floods and spillways,
xi. hydropower works,
xii. irrigation outlets and irrigation system design,
xiii. Reservoir sedimentation,
xiv. Reservoir operation studies,
xv. Material quantities and costing,
xvi. Environmental studies,
xvii. Land acquisition and replacement, etc.

17. What are the tasks that must take in consideration in dam planning?

   a. *Answer:*

      i. *Site selection,*
      ii. *topographic surveys,*
      iii. *water availability assessment,*
      iv. *sizing and layout,*
      v. *geologic surveys and construction materials investigations,*
      vi. *geologic evaluation of foundation, rim, abutment and pond area,*
      vii. *dam section design,*
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      xii. *irrigation outlets and irrigation system design,*
      xiii. *Reservoir sedimentation,*
      xiv. *Reservoir operation studies,*
      xv. *Material quantities and costing,*
      xvi. *Environmental studies,*
      xvii. *Land acquisition and replacement, etc.*

18. What are the criteria of selection of dam site?

   a. *Answer:*

      i. *Small river channel width with steep side gorge: short dam crest length, leads to large storage for small dam length*
      ii. *A wide and gently sloping valley upstream of the dam site (for storage dams) and narrow and steeply sloping valley for hydropower dams.*
      iii. *River channel and valley has very flat slopes u/s of dam site (leads to large storage for small dam heights).*
      iv. *Deep reservoir possible – require less area and lesser land costs, less surface evaporation*
      v. *Enough water flow/yield available to meet requirements/demand*
      vi. *High sediment load tributaries are excluded*
      vii. *Geology favorable for foundation (foundation can be designed at any site, but it increases costs), competent hard rock is most suitable.*
      viii. *Abutments are water tight, and reservoir rim allow minimum percolation and seepage losses.*
      ix. *Small river sediment rate (longer dam life) Depend on river morphology and catchment characteristics.*
      x. *Land use of reservoir area is minimal – lower economic values means lower compensations.*
      xi. *Reservoir area not very sensitive to environment (wild life parks, endangered species, historical places, monuments etc).*
      xii. *No seismic and tectonic activities or active faults in and near the site.*

xiii. *Socio-political stability (no unstable gestures)*
xiv. *Reservoir and dam area less populated*
xv. *Site have adequate stream flow record*
xvi. *Site is easily accessible; approach road is present or can be developed easily.*
xvii. *Construction material available nearby easily*
xviii. *Site near load center (demand area) for water+ power*
xix. *No mineral resources in reservoir area (present or future)*
xx. *Site allows a deep reservoir & small surface area (less land costs and small evaporation losses).*
xxi. *Existing infrastructure, e.g. highway, least affected.*

19. What are yield and types of yield in a reservoir?

   a. *Answer:*

Yield from a Reservoir*: Yield is the volume of water which can be withdrawn from a reservoir in a specified period of time. The time period for the estimation of yield is selected according to the size of the reservoir. It may be a day for a small reservoir and a month or a year for a large reservoir. The yield is usually expressed as Mha-m/year or Mm3/year for large reservoirs.*

1- ***Safe yield (Firm yield)****: Safe yield is the maximum quantity of water which can be supplied from a reservoir in a specified period of time during a critical dry year. Generally, the lowest recorded natural flow of the river for a number of years is taken as the critical dry period for determining the safe yield. There is generally a firm commitment by the organization to the consumers that the safe yield will be available to them. It is therefore also called the firm yield or the guaranteed yield.*
2- ***Secondary yield****: Secondary yield is the quantity of water which is available during the period of high flow in the rivers when the yield is more than the safe yield.*
3- ***Average yield****: The average yield is the arithmetic average of the firm yield and the secondary yield over a long period of time.*
4- ***Design yield****: The design yield is the yield adopted in the design of a reservoir. The design yield is usually fixed after considering the urgency of the water needs and the amount of risk involved. The design yield should be such that the demands of the consumers are reasonably met with, and at the same time, the storage required is not unduly large. Generally, a reservoir for the domestic water supply is planned on the basis of firm yield. On the other hand, a reservoir for irrigation may be planned with a value of design yield equal to 1.2 times the firm yield because more risk can be taken for the irrigation water supply than for domestic water supply.*

20. Distinguish between Mass inflow curve and Mass Demand curve.

   a. *Answer:*

1- ***Mass inflow curve****: A mass inflow curve, also called a mass curve, is a plot between accumulated inflow volume as ordinate and time as abscissa. A mass inflow curve is* *prepared from the inflow hydrograph of a river for a large number of consecutive years. When we have hydrograph of a river at a particular site from a number of years. The discharge ordinates represent the annual average discharge [i.e. average discharge of the full year, obtained from the total, annual volume of stream flow by dividing it by (365 x 24 x 3600). The area under the hydrograph from the starting year 1960 to 1961 (shown hatched) represents the volume of water in cumec-year that has flowed through the river (1 cumec-year =1*24*60*60*365=31.536 Mm3). The Inflow Mass Curve, shows the mass inflow curve. The ordinate of the curve at the year 1960 is zero and at the year 1961 is equal to the volume of water flowed from the year 1960 to 1961. The ordinate at the year 1962 represents the total volume of water from the year 1960 to 1962. It may be noted that the mass curve is a continuously rising curve as it shows the accumulated volume upto that time. If there is no flow during a certain period, the mass curve can be horizontal but it can never fall. On the other hand, the mass curve will rise steeply when there is large inflow. Thus the slope of the curve at any point indicates the rate of inflow at that time. Relatively dry periods are indicated as depressions with concavity upwards, whereas the periods of high discharge are indicated as crests with convexity upwards.*

2- ***Mass Demand Curve**: A demand curve is a plot between the demand rate as ordinate and the time as abscissa. The mass demand curve is a plot between the accumulated demand volume as ordinate and the time as abscissa. The mass demand curve is determined from the demand curve in the same manner as the mass inflow curve is obtained from the hydrograph. If the demand is uniform, the demand curve is a horizontal line, and the corresponding mass demand curve is a straight line, having a slope equal to the demand rate. On the other hand, if the demand is variable, the mass demand curve is a rising curve. The mass demand curve is obtained from the demand curve after finding out the area of the demand curve for consecutive years, as in the case of a mass inflow curve.*