DAMS

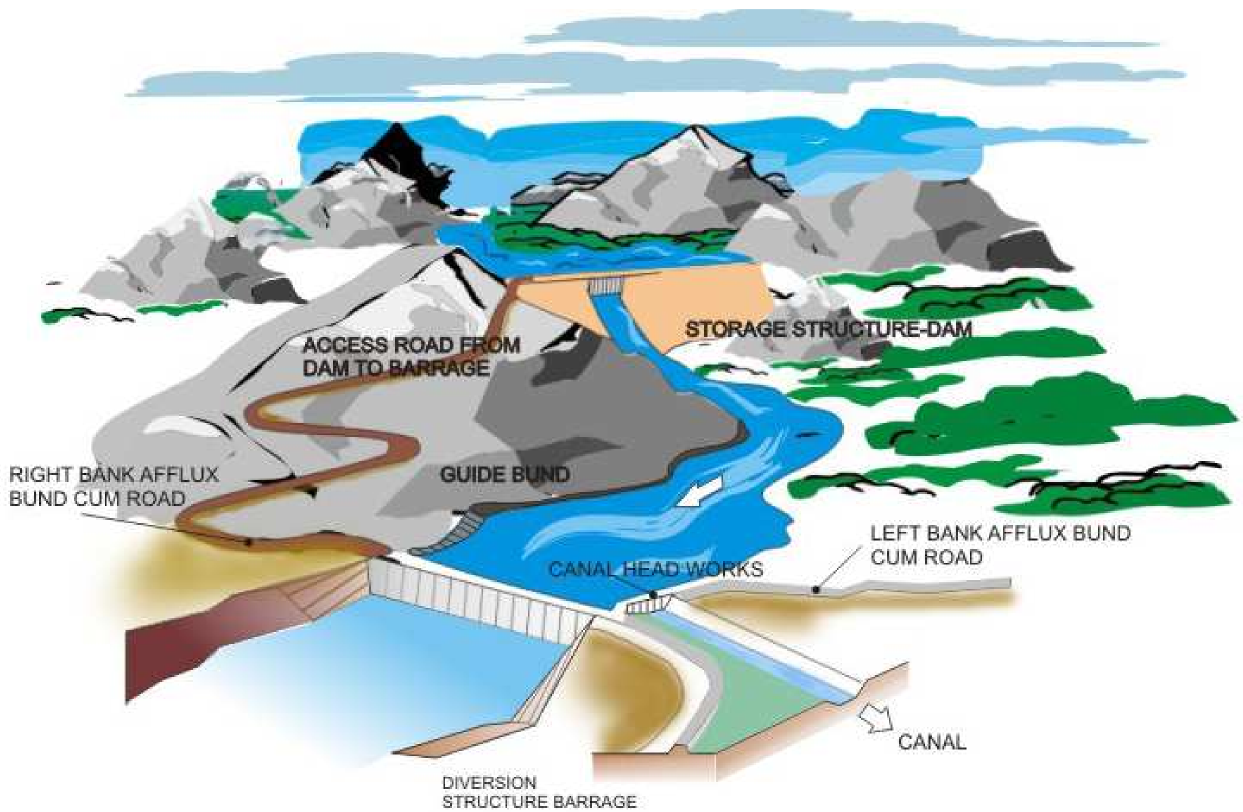


FIGURE 1. Structures for harnessing water resources potential of a river

Introduction:

A dam is a Hydraulic Structure constructed across a river to store water on its upstream side. It is an impervious or semi impervious barrier put across a natural stream so that a reservoir is formed. This water is ten utilized as and when it is needed.

Classification of Dams:

a) Classification according to use:

1. Storage dam Ex: Gravity dam, Earth dam, Rock fill dam, arch dam.
2. Diversion dam: Ex: Weir, barrage
3. Detention dam: Ex: Dike, Water spreading dam, Debris dam.

b) Classification by Hydraulic design:

1. over flow dam Ex: Spillways
2. Non over flow dams Ex: Earth dam, Rock fill dam

c) Classification by materials:

1. Rigid dams Ex: Gravity dam, Arch dam, Buttress dam, Steel dam, Timber dam.
2. Non rigid dams Ex: Earth dam, Rock fill dam.

Classification according to use:

Based on use dams are classified as follows:

1. Storage dam
2. Diversion dam
3. Detention dam

1. Storage dam: This is the most common type of dam normally constructed. Storage dam's constructed to impound water to its upstream side during the periods of excess supply in the river and is used in periods of deficient supply. The storage dams may be constructed for various purposes such as irrigation, water supply, power generation. A storage dam may be constructed of wide variety of materials such as stone, concrete, earth, rock fill etc.

2. Diversion dam: The purpose of a diversion dam is essentially different. While a storage dam stores water of its upstream for future use, a diversion dam simply raises water level slightly in the river and thus provides head for carrying or diverting water into ditches, canals. Common examples of diversion dams are weirs and barrages. During the floods, water pass over or through these diversion dams while during periods of normal flow, the river water, partly or wholly, is diverted to irrigation channel.

3. Detention dam: A detention dam is constructed to store water during floods and release it gradually at a safe rate, when the flood recedes. By the provision of artificial storage during the floods, flood damage downstream is reduced. There are usually two types of detention dams. In the first type, water is temporarily stored and released through a suitable outlet structure. In the other type of detention dam, water is not released and no outlet structure is provided. Instead, water is held in the reservoir as long as possible. This held water seeps into previous banks and foundation strata. Due to this seepage water, water level in wells in the adjoining area is increased and lift irrigation may be possible. A detention dam is sometimes called *water -spreading dam* or *dike*. Sometimes detention dams are constructed across tributaries carrying large silt and sediment. In such case, it is known as a '*debris dam*' used to trap the sediment to flow into the main reservoir.

Classification according to Hydraulic Design:

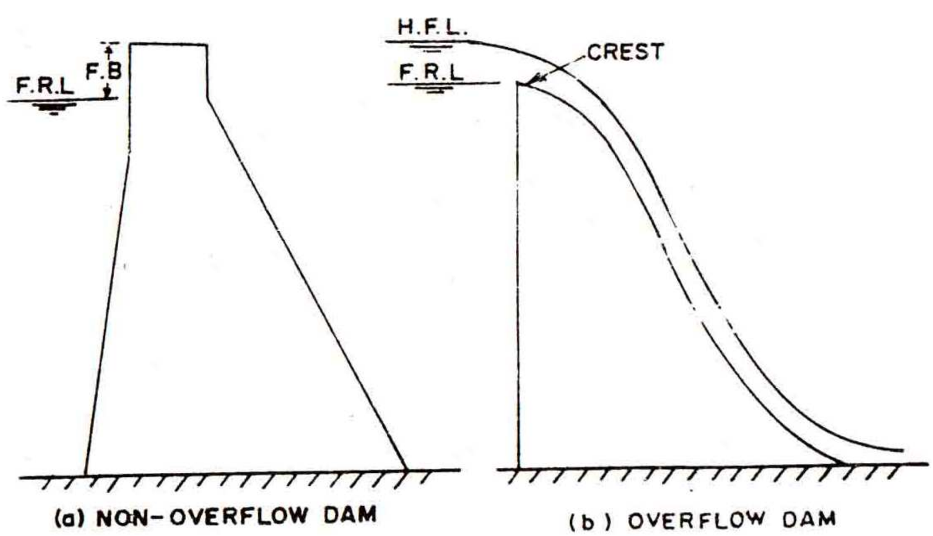
According to Hydraulic design, dams may be classified as follows:

1. Non – over flow dam
2. Over flow dam.

1. Non - over flow dam: A non - over flow dam is the one in which the top of the dam is kept at a higher elevation than the maximum expected flood level. Water is not permitted to over top the dam. Hence a non – over flow dam may be constructed of wide variety of materials such as earth, rock fill, masonry, concrete etc.

2. Over flow dams: An over flow dam is the one which is designed to carry surplus discharge (including floods) over its crest. Its crest level is kept lower than the top of the other portion of the dam. Such dams are generally made of concrete or masonry. An over flow dam's commonly known as '*spillway*'.

Very often in a river valley project, the two types of dams are combined. The main dam is kept as a non-over flow dam made of either rigid materials such as masonry or concrete or non rigid material such as earth and rock fill and some portion of dam is kept as over flow dam (spillway) at suitable location along the main dam.



Classification according to material:

According to this most common classification the dams may classified as follows.

1. Rigid dams
2. Non- rigid dams

1. Rigid dams: Rigid dams are those which are constructed of rigid materials such as masonry, concrete, steel or timber. Rigid dams may be further classified as follows:

a) Solid masonry or concrete gravity dam.

b) Arched masonry or concrete dam.

c) Concrete butters dam.

d) Steel dam.

e) Timber dam.

2. Non- rigid dams: Non-rigid dams are those which are constructed of non rigid materials such as earth and / or rockfill.The most common types of non-rigid dams are:

a) Earth dam

b) Rockfill dam

c) Combined earth and rockfill dam.

Classification based on Size:

The dams may be classified according to size by using the hydraulic head and gross storage behind the dam as given below.

Classification	Gross Storage	Hydraulic Head
Small	Between 0.5 to 10 million m^3	Between 7.5 m and 12 m
Intermediate	Between 10 to 60 million m^3	Between 12 m and 30 m
Large	Greater than 60 million m^3	Greater than 30 m

Gravity dams:

A gravity dam is the one in which the external forces (such water pressure, uplift pressure, silt pressure etc) are resisted by the weight of the dam itself. A gravity dam may be constructed by masonry or concrete. All major and important gravity dams are now constructed of concrete only. Masonry gravity dams are now-a-days constructed of only small heights.

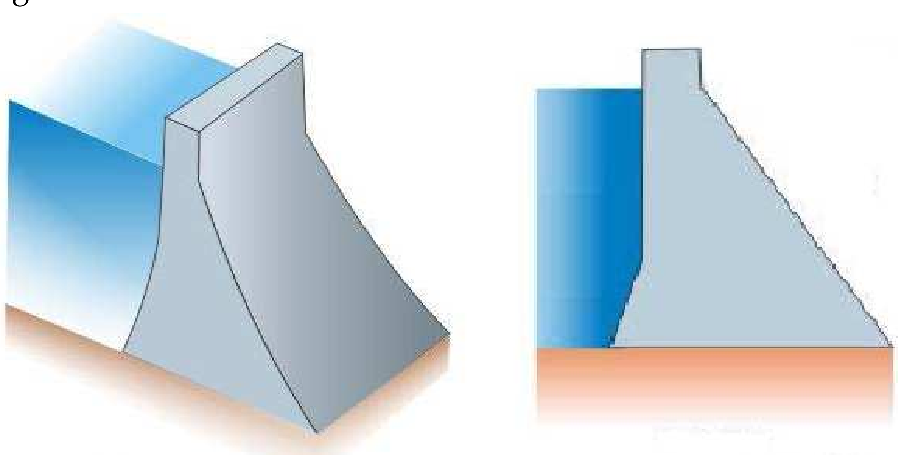


Fig.2: GRAVITY DAM

Advantages:

1. Gravity dams are relatively more strong and stable than earth dams. They are particularly suited across gorges having very steep side slopes where earth dam, if constructed may slip.
2. Gravity dams are well adapted for use as an over flow spillway crest. Earth dams cannot be used as over flow dams.
3. Gravity dams can be constructed of any height, provided suitable foundations are available to bear the stresses. Highest dams in the world are made of gravity dams only.
4. A gravity dam requires the least maintenance.
5. The failure of a gravity dam, if any, is not sudden. It gives enough warning time. An earth dam generally fails suddenly.
6. Deep–set sluices can be used in the gravity dams, to retard the sedimentation or silt deposit in the reservoir.
7. They are not affected by very heavy rain fall.

Disadvantages:

1. Gravity dams can be constructed only on sound rock foundations. They are unsuitable on weak foundations or permeable foundations.
2. The initial cost of a gravity dam is always higher than an earth dam.
3. Gravity dam take more time to construct.
4. Gravity dams require skilled labour or mechanized plants for its construction.
5. If height of the dam is to be raised, it cannot be done unless provision for it had been made in the construction of the lower part of the dam.

<u>Arch Dams:</u>

An arch dam is a dam curved in plan and carries a major part of its water load horizontally to the abutments by arch action. This part of water load depends primarily upon the amount of curvature. The balance of the water load is transferred to the foundation by cantilever action. The thrust developed by the water load carried by arch action essentially requires strong side walls of the canyon to resist the arch forces. The weight of arch dams is not counted on to assist materially in the resistance of external loads. For this reason, the uplift on the base is not an important design factor.

Advantages:

1. Arch dams are particularly adapted to the gorges where the length is small in proportion to height.
2. For a given height the section of an arch dam is much lesser than a corresponding gravity dam. Hence, an arch dam requires less material and is, therefore, cheaper.
3. Because of much less base width, the problems of uplift pressure are minor

4. Since only a small part of water load is transferred to the foundation by cantilever action, an arch dam can be constructed in moderate foundations where gravity dam requiring sound foundation.

Disadvantages:

1. If requires skilled labour and sophisticated from work. The design of an arch dam is also quite specialized.

2. The speed of construction is normally slow.

3. It requires very strong abutments of solid rock capable of resisting arch thrust. Hence it is not suitable in locations where strong abutments are not available.

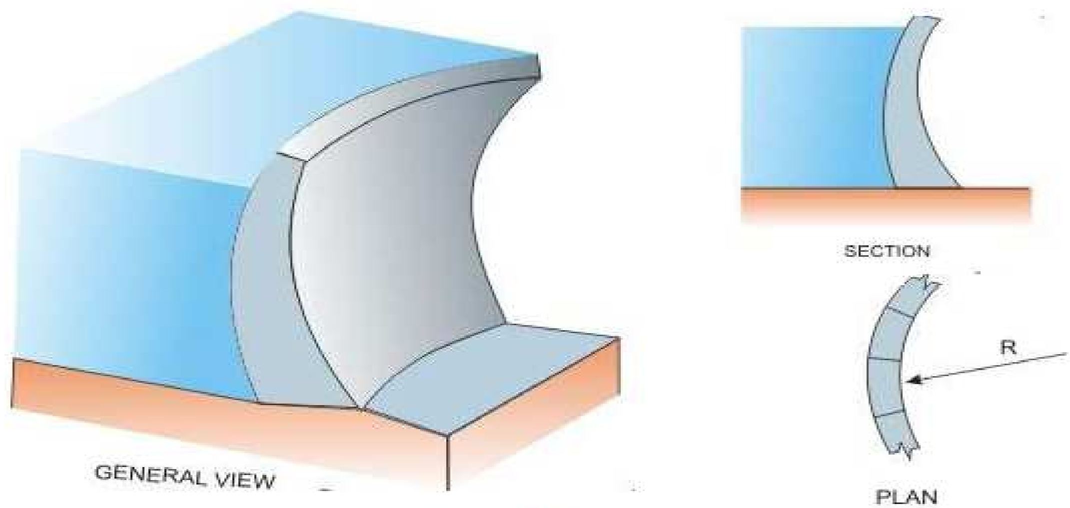


Fig.3: ARCH DAM

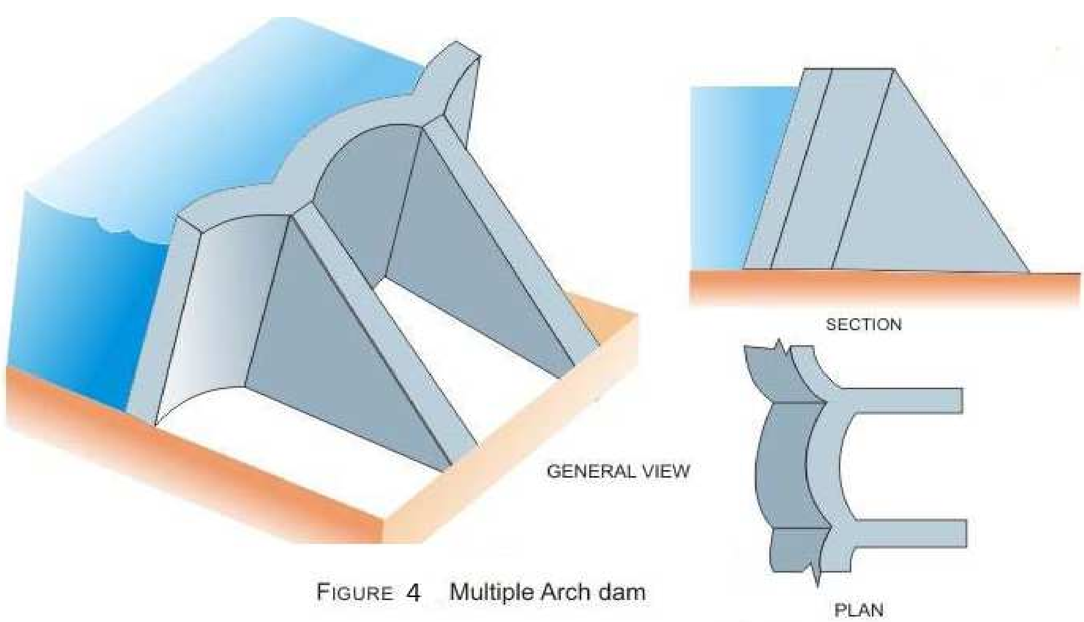


FIGURE 4 Multiple Arch dam

Buttress Dams:

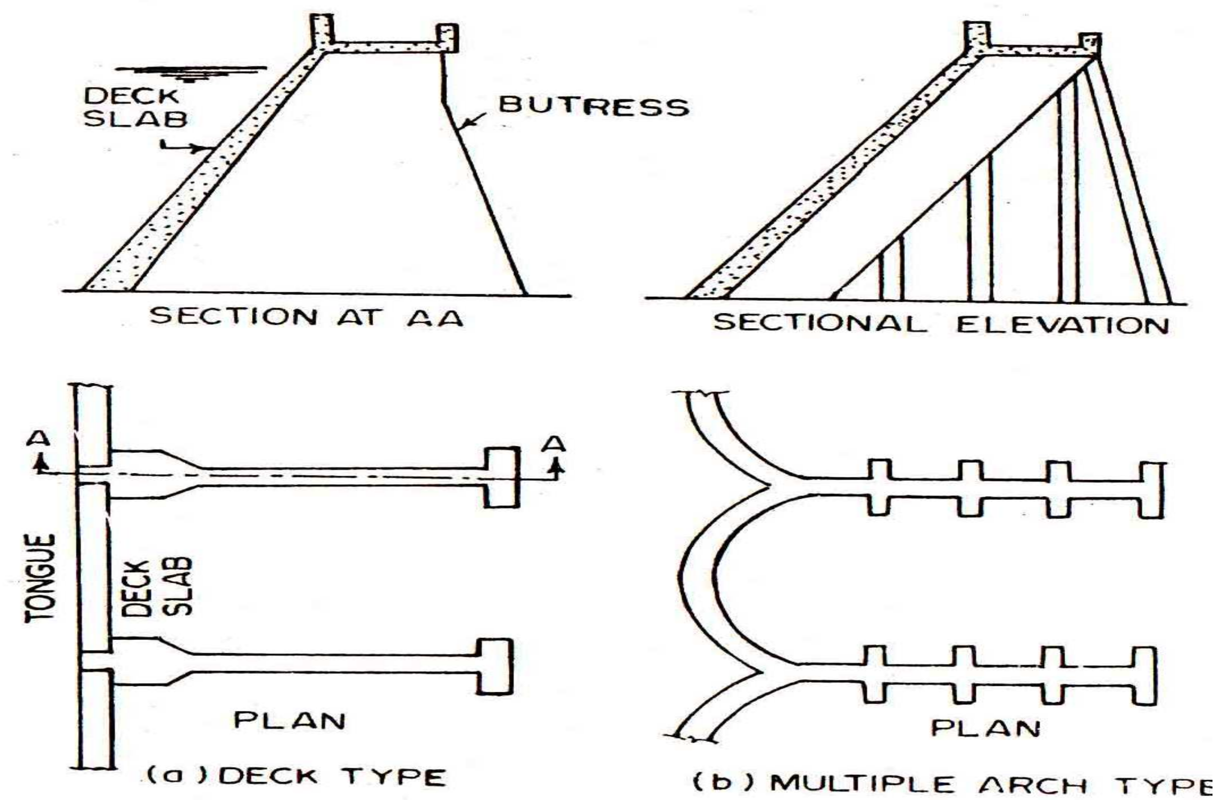
Buttress dam consists of a number of buttress or piers dividing the space to be dammed into a number of spans. To hold up water and retain the water between these buttresses, panels are constructed of horizontal arches or flat slabs. When the panels consist of arches it is known as multiple arches type buttress dam. If the panels consists of flat slab if is known as deck type buttress dam.

Advantages:

1. A buttress dam is less massive than a gravity dam; it can be constructed even on weak foundation on which gravity dam cannot be supported.
2. The water load acts normal to inclined deck. Hence the vertical component of the water load stabilizes the dam against both overturning and sliding.
3. The Ice Pressure is relative important since the ice tends to slide over the inclined U/S deck.
4. In the case of gravity dam, the height of the dam can be raised only by the provision of crest shutter at over flow section. However in the case of buttress dam, further rising of the height is possible and convenient by extending buttress and slab as shown in fig. consequently buttress dams are used where a future increase in reservoir capacity is contemplated.
5. Power houses and water treatment plants can be housed in between buttresses, thus saving some cost of construction.
6. The amount of concrete used in buttress dam is about $\frac{1}{2}$ *to* $\frac{1}{3}$ of the concrete used in gravity dam of same height.

Disadvantages:

1. Skilled labour requirements and shuttering concrete ratio are greater than for solid dams.
2. Deterioration of upstream concrete surfaces has serious effects on buttress dams with very thin concrete face.



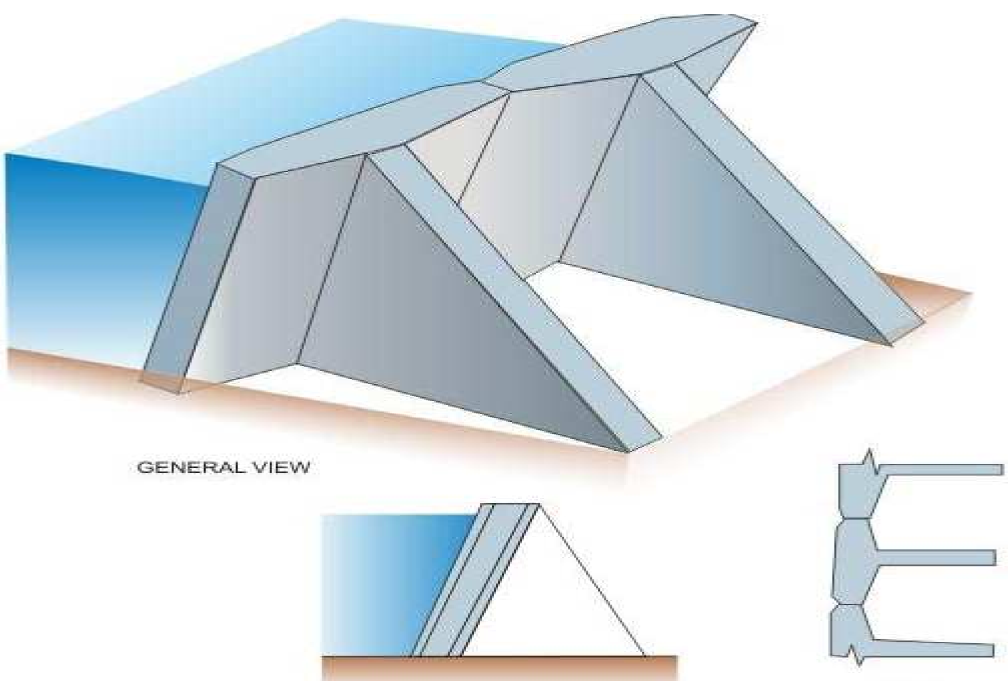


FIGURE 5 Buttress Dam

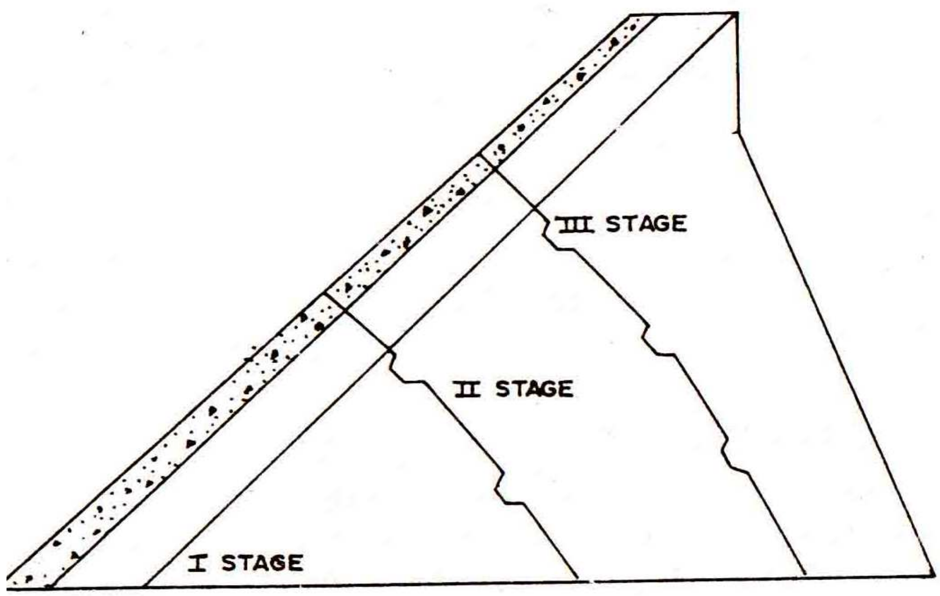


FIG. 6 RAISING HEIGHT OF BUTTRESS DAM.

Earth dams and rock fill dams:

Earth dams are made of locally available soils and gravels and therefore, are most common types of dams used up to moderate heights. Their construction involves utilization of materials in the natural state requiring a minimum processing. With the advancing knowledge of soil mechanics and with advent of more sophisticated earth moving equipment, earth dams are now becoming more common, even for higher heights. The foundation requirements of earth dams are less stringent than for other types. Fig.7 shows a typical section of composite earth dam.

A Rock fill dam is an embankment which uses variable sizes of rock to provide stability and on impervious membrane to provide water tightness. In modern practice, the rock fill dam has four fundamental parts:

1. Dumped rockfill at the downstream
2. Upstream rubble cushion of laid - up stone bonding in to the dumped rock
3. Upstream impervious facing resting on rubble cushion.
4. Upstream cutoff to check under seepage.

Fig.8 shows a typical section. Fig.9 shows a combined earth and rockfill dam.

Advantages:

1. Earth dams can be constructed almost on any type of available foundations. However, Rock fill dams impose some restriction on the quality of foundation but they are much less rigid than those required for any other type.

2. They can be constructed rapidly with relatively unskilled labour and with materials available on the spot.
3. There are generally cheaper than other types.
4. They can be subsequently raised in height without much difficulty if such a need arises in future.

Disadvantages:
1. Fails suddenly without sufficient warning.
2. They cannot be used as over flow dams
3. They are not suitable at locations where heavy down pour is more common
4. They require heavy maintenance cost and constant supervision

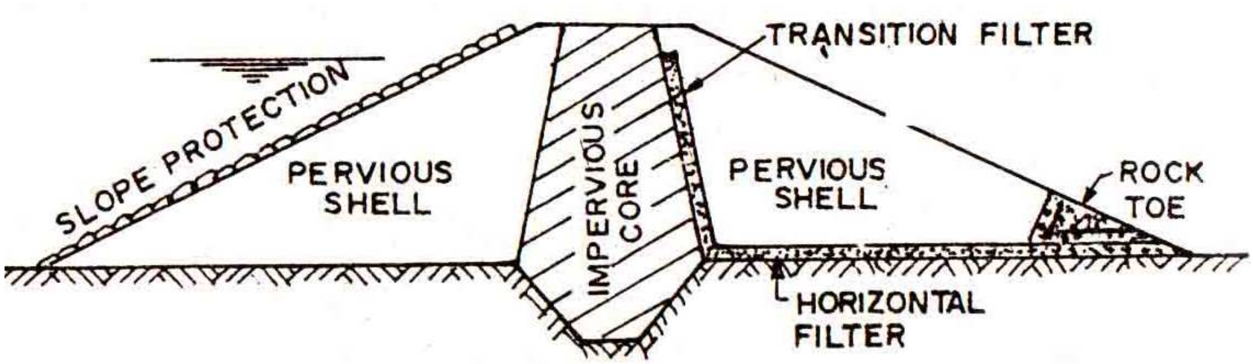


Fig.7 EARTH DAM

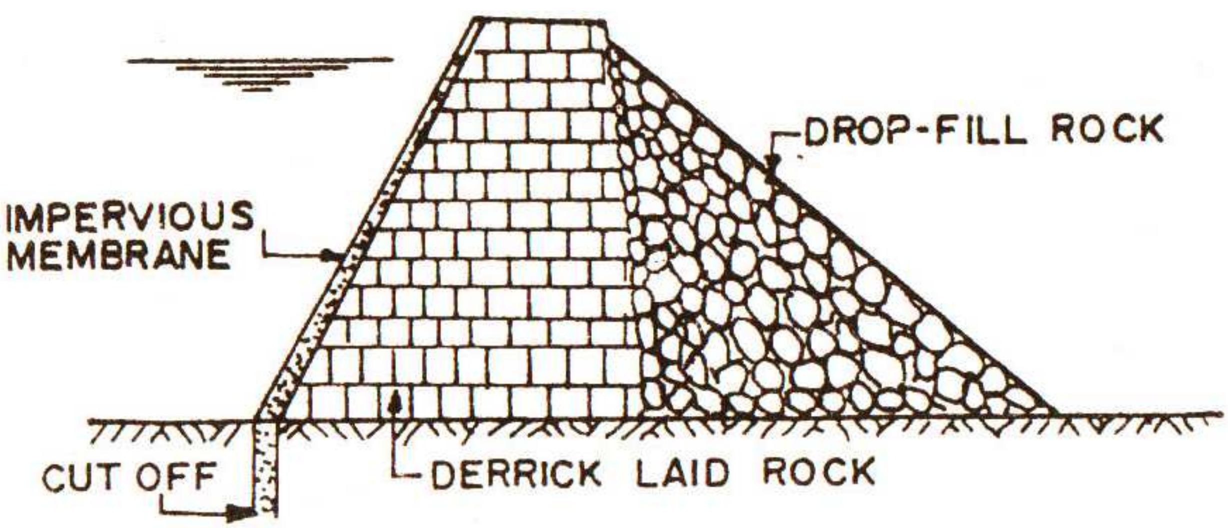


Fig.8 ROCKFILL DAM

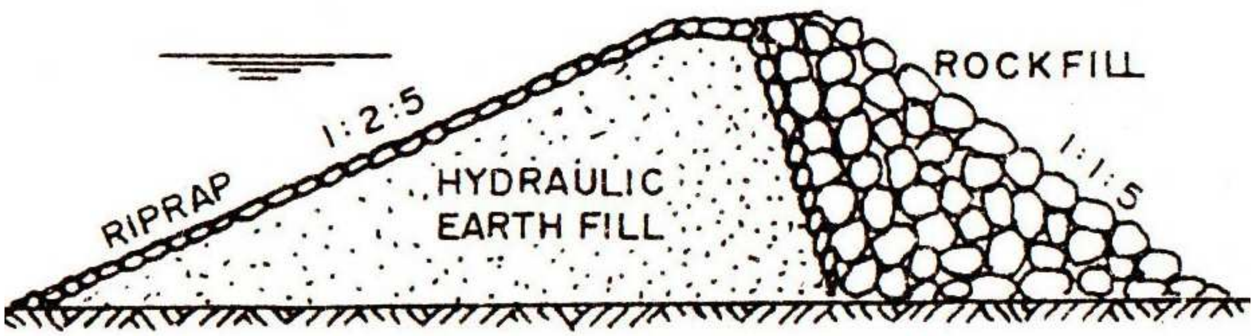


Fig.9 COMBINED EARTH AND ROCKFILL DAM

Factors governing selecting site for dam:

Following are the requisites of good sites for various types of dams:

1. Foundations:

Suitable foundations should be available at the site selected for a particular type of dam. For gravity dams, sound rock is essential. For earth dams, any type of foundations is suitable with proper treatment. In general, however the foundations should be free from seams, open pockets as fault planes. Formation in which hard and soft layers alternate are not generally good, because the penetration of water may weaken the soft layers and lead to movement along them. Alternations of sand, stones and shale's may also lead to slipping during the excavation of trench. The best conditions are when a dam can be built on one uniform formation; if more than one kind of rock is present in the foundation, different bearing strengths may lead to differential settlement of structure.

2. Topography:

(a).The river cross section at the dam site should preferably have a narrow gorge to reduce the length of the dam. However, the gorge should open out upstream to provide large basin for a reservoir.

(b). A major position of the dam should preferably be located on high ground as compared to river basin, as this would reduce the cost and facilitate drainage of the dam section.

3. Site for spillway:

A suitable site for the spillway should be available in the vicinity of the dam if the spillway is to be located separately from the dam, especially in the case of earth or rick fill dam. However, in the spillway is to be an integral part of the dam then there is no special site requirement for the spillway.

4. Materials:

Materials required for a particular type of dam should be available nearby, without requiring much of transportation. This would very much reduce the cost of construction.

5. Reservoir and Catchment Area:

1. The site should ensure adequate storage capacity of reservoir basin at a minimum cost.
2. The cost of land and property submerged in the water spread area should be minimum.
3. The reservoir site should be such that quantity of leakage through its side and bed is minimum.
4. The geological conditions of the catchment area should be such that percolation losses are minimum and maximum run off is obtained.
5. The site should be such that deep reservoir is formed. A deep reservoir is preferable to shallow one because of a) lower cost of land submerged per unit of capacity b)) less evaporation losses because of reduction in water spread area and c) less likelihood of weed growth.

6. Communication:

It would be preferable to select a site which is connected by a road or rail link or can be convenient by connected to the site for transportation of cement, labour, machinery, food and other equipment.

7. Locality:

The surrounding near the site should preferably be healthy and free of mosquito etc, as labour and staff colonies have to be constructed near the site.

Factors governing selection of type of dam:

The selection of a type of a dam at a given site depends upon many physical factors such as topography, geological and foundation conditions, available materials, suitable site for spillway, data about earthquake etc.

Before selecting the best type of dam at a particular site, one must consider the characteristics of each type of dam, as related to the physical features of the site and adaption to the purposes the dam is supposed to serve, as well as economy, safety and other pertinent limitations.

The choice of a dam may also be guided by many local problems such as availability of labour and equipment, accessibility of site, limitations imposed by outlet works and cost of protection needed from spillway discharge as well as time required for its construction.

Some of the physical facts governing the selection of type of dam are discussed below.

1. Topography:

The first choice of dam is usually governed by the topography for the site. A low rolling plains country suggests an earth dam with a separate spillway. A low narrow V-shaped valley suggests an arch dam; provided the top width of valley is less than one fourth its height and separate site for spillway is available. A narrow stream following between high, rocky walls (giving rise to a U-shaped valley) would suggest a concrete over flow dam. In intermediate conditions, other factors such as foundation condition, location of suitable site for spillway and availability of materials of construction play an important role in the selection of the type.

2. Geology and foundation conditions:

The next important fact is the geology and foundation conditions. If the foundation consists of sound rock, with no fault or fissures, any type of dam can be constructed on it. Rocks like granite, gniss and schist make very satisfactory foundation for gravity dam. However, these rocks may have sums or fractures. The removal of disintegrated rock together with the sealing of seams and fractures by grouting will frequently be necessary.

1. Poor rock or gravel foundations are suitable for earth dam, rock fill dam or low concrete gravity dam. Since there will be considerable under seepage in this case, effective water cutoffs or seals have to be provided.

2. Silt or fine sand foundations have the problems of settlement, seepage and toe-erosion. Hence such foundations are suitable only for either earth dam or low concrete gravity dam but not rock fill dams.

3. Clay foundations have often the problems of long range consolidation under the weight of the dam, resulting in cracks. Hence only earth dams are suitable with proper foundation treatment. Gravity dams or rock fill dams are not suitable on clay foundations.

3. Materials of Construction:

The next important fact is the availability of materials of construction for dam. The cost of construction of a particular type of dam will depend upon the availability of the materials in nearby area, so that transportation charges are reduced. If sand, gravel and crushed stone are available, a concrete gravity dam may be more suitable. If however, course and fine grained soils are available an earth dam may be suitable. The preliminary selection of a particular type, based on the first tow physical factors, must correspond with the easy availability of the materials required for its construction otherwise that type of dam should be dropped.

4. Spill way size and location:

The safe discharge of flood water through a dam is very essential, and for that suitable site for spillway should be available. The size and type of spillway are mainly decided by the magnitude of the flood to be bypassed and its location depends on the site conditions. The choice of the type of dam is also affected by size, type and location of spillway.

If a large spillway is required to be provided, and then spillway and dam are combined in to one structure, in which case concrete dam may be adopted.

If small spillway is required, then earth dam or rock fill dam may the choice.

The spillway may be located either away from the dam or within t he limits of the dam.

When spillway is located at a site away from the dam, then entire dam can be non-over flow type and the choice may include rigid as well as non-rigid dams.

In case the spillway to occupy only a portion of Main River the dam will include an overflow type of spillway and the reminder could be non-over flow dam of earth, rock or concrete.

5. Road way:

If road a way is to be passed over the top of the dam an earth dam or gravity dam could be preferred.

6. Length & Height of Dam:

If the length of dam is very long and its height is low, an earth dam could be better choice. If the length is small but height is more gravity dam is preferred.

7. Life of dam:

Concrete or Masonry gravity dams have very long life. Earth and Rock fill dams have intermediate life. However timber dams are adopted only for temporary storages.

QUESTIONS

1. Classify various types of dams.
2. Discuss in brief merits and demerits of various types of dams.
3. Discuss, with illustrations the selection of type of dam.
4. What are the factors on which selection of site for a dam depends?
5. What are the de merits of butters dam
6. What are the various types of dams?
7. Explain any four different types of dams along with merits and demerits.
8. Write any four advantages and four disadvantages of earthen dams.

RESERVOIRS

When a barrier is constructed across some river in the form of a dam, water gets stored on the upstream side of the barrier, forming a pool of water, generally called a *reservoir*, or an *impounding reservoir* or a *storage reservoir*.

Storage is done during the period when the flow is in excess of the demand for release during the lean supply period.

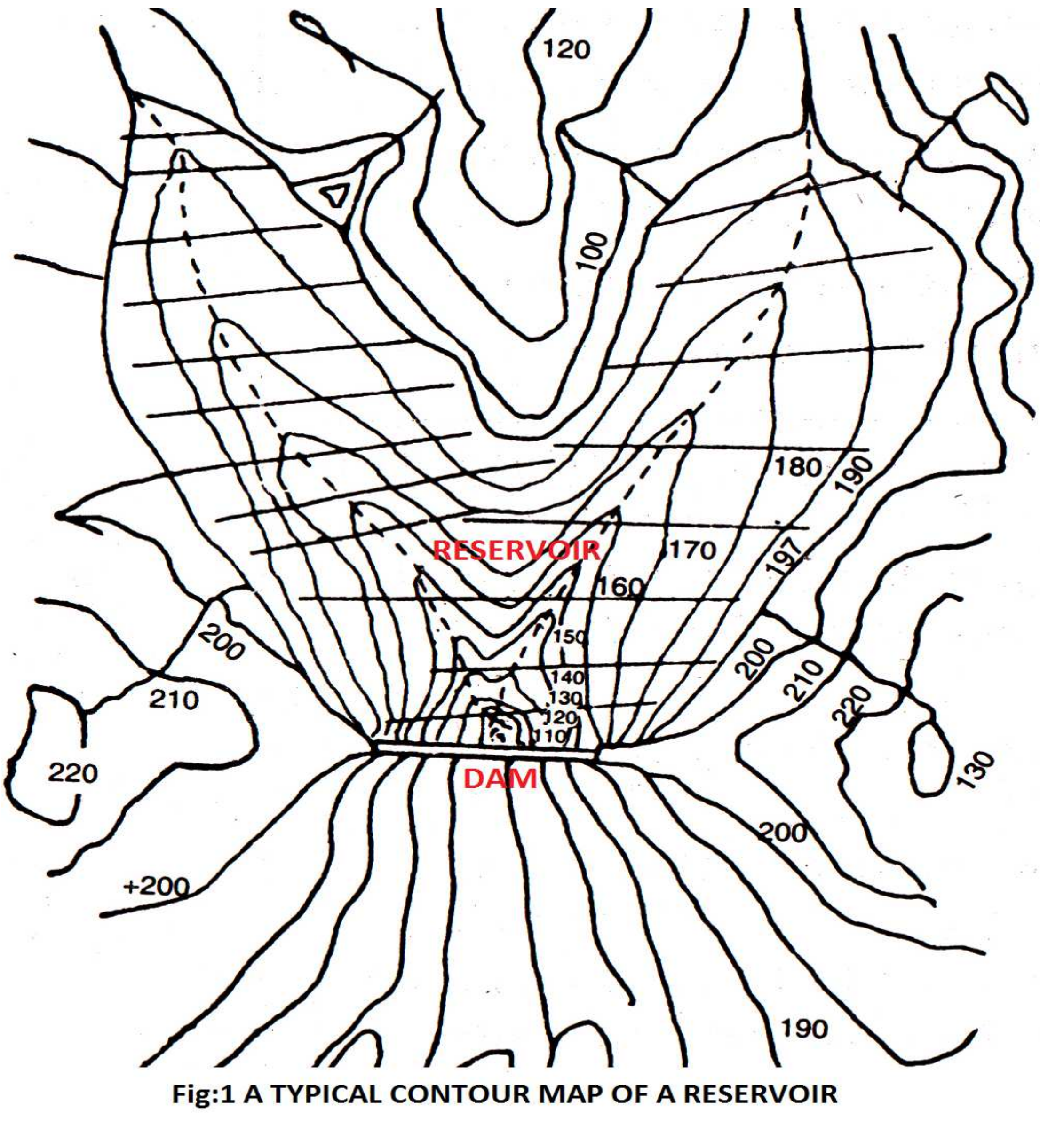


Fig:1 A TYPICAL CONTOUR MAP OF A RESERVOIR

Reservoirs are constructed to serve many purposes, which includes:

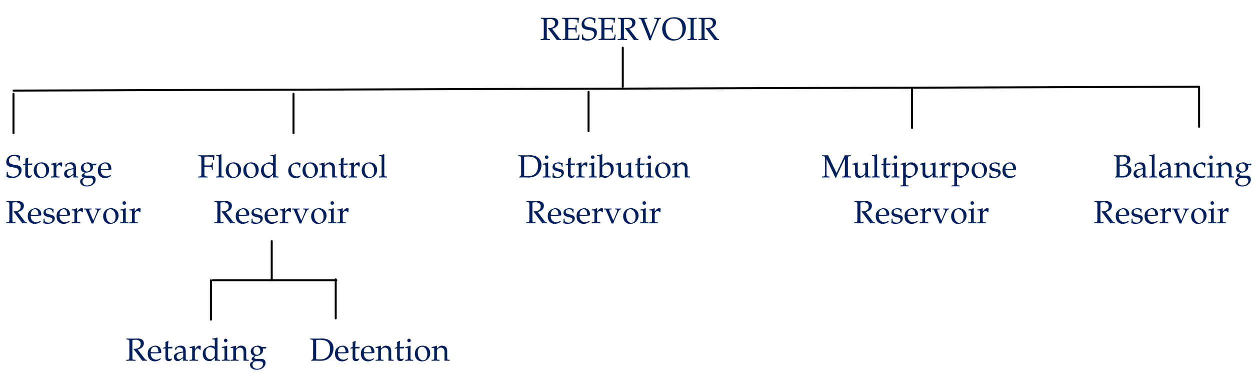
1. Storage and control of water for irrigation.
2. Storage and diversion of water for domestic uses.
3. Water supplies for industrial uses.
4. Development of Hydroelectric power.
5. Increasing water depths for navigation.
6. Storage space for flood control.
7. Reclamation of low-lying lands

The reservoirs on the other hand have certain disadvantages:

1. Submergence of fertile valley lands.
2. Displacement of large population from reservoir area and their resettlement cost at new area.
3. Adverse effects on the ecology of the present area.
4. Flooding the forest and displacement of wild life.

Classification of Reservoirs:

Reservoirs are classified as below, on the basis of the purpose served by them.



1. Storage Reservoir:

Also termed as *conservation reservoir*. They are primarily used for water supply for irrigation, hydro electric power development, domestic and industrial uses. Storage reservoir stores surplus water during the period of excess flow so as to maintain continuous supply during the period of lean supply in the river, but when demand is keen.

2. Flood Control Reservoir:

Flood protection reservoirs are those which store water during flood and release it gradually at a safe rate when the flood reduces. By the provision of artificial storage during the floods, flood damage downstream is reduced.

Fig.2 shows a typical inflow and out flow Hydrograph for a reservoir. ABC is the natural Hydrograph at the dam site having a maximum flood discharge Q_1. By the construction of the dam, the natural Hydrograph is moderated by the reservoir as shown by dotted lines AB'C. Thus the flood discharge is reduced from Q_1 to Q_2. The area shown as hatched represents the storage to be provided in the reservoir. The portion marked by dots represents the excess volume released latter. Construction of reservoir solely for flood control measures is not advisable except in very special cases due to high cost of construction.

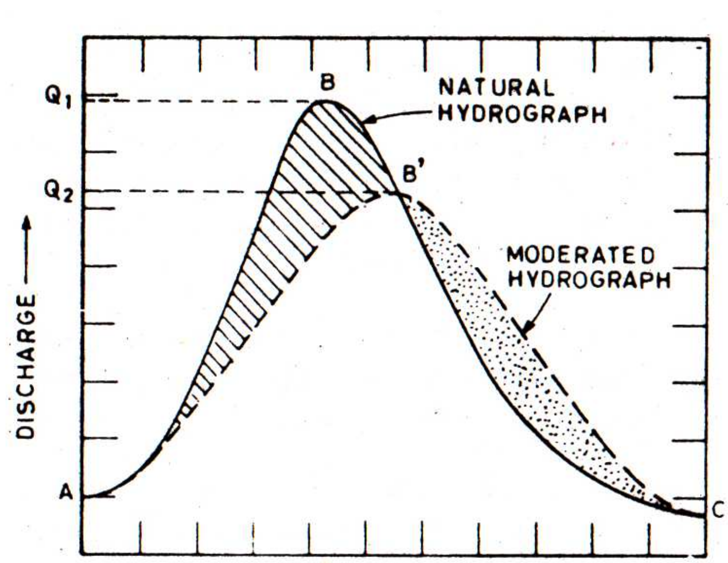


FIG:2, HYDROGRAPH MODERATED BY FLOOD CONTROL RESERVOIR

Flood control reservoirs may be either *retarding reservoirs* or *detention reservoirs*.

Retarding Reservoirs: A retarding reservoir is the one which is provided with outlets and spillway not controlled by gates or valves. The discharging capacity of the outlets and spillway is so fixed that it is not in excess of the flood carrying capacity of the reservoir channel downstream. With the rise in the reservoir level, the amount of water released is such as would not create flooding the areas downstream. They are preferred on small rivers.

Detention Reservoirs: Detention Reservoirs are those which have gated outlets so as to provide greater flexibility in the operation of reservoirs. They are especially suitable when the area under control increased in size and protected area is wide spread.

3. Distribution Reservoir:

A distribution reservoir is a small storage reservoir constructed within a city water supply system. Such a reservoir is required to fulfill the varying demands of the consumers at different periods of the day. The water is stored during the period of no demand or slack demand to meet the demand in excess of constant pumping rate form the storage during the period of maximum demand. The reservoir thus permits the pumping plants and water treatment plants to work at uniform rate.

4. Multipurpose Reservoir:

A Multipurpose reservoir is that which serves more than one purpose. For example a reservoir designed to protect the downstream area from floods, and to store water for irrigation and Hydroelectric purposes is a multipurpose reservoir.

5. Balancing Reservoir:

It is a reservoir, usually of limited capacity located downstream of (or subsidiary to) a main reservoir, to store the water let down from the reservoir in excess of that reservoir for irrigation or additional power generation.

Selection of site for a Reservoir:

The selection of site for reservoir depends on the following factors:

1. Suitable dam site must be available where the reservoir is proposed to be constructed.
2. The river valley at the site should be narrow so that the length of the dam to be constructed is less, but it should be open out on upstream side to provide a large basin for the reservoir.
3. The surrounding hills which constitute the rim of the reservoir should be water tight, so that there is no leakage of water through any part of the rim.
4. The site should be such that as far as possible minimum land and property is submerged in the reservoir.
5. The site should be such that it avoids water from those tributaries which carry unusually high content of sediment.
6. The site must be such that adequate reservoir capacity is made available.
7. As far as possible a deep reservoir must be formed so that the land costs per unit capacity is low, evaporation loss is less and there is less likelihood of weed growth.
8. Soil in the catchment area does not contain harmful soluble salts and minerals
9. Good run off from the catchment area with minimum percolation losses.
10. The site should be such that the costs of associated works such as roads, rails housing colonies for workers and other staff etc are not excessive.

Storage zones of a Reservoir:

The entire storage capacity of a reservoir may be divided into a number of zones by certain water surfaces or pool levels in the reservoir as indicated below:

Normal pool level (N.P.L):

It is the maximum elevation to which the water surface will rise in the reservoir during ordinary operating conditions. In case of an ungated spillway the normal pool level is determined by the elevation of the spillway crest. However, if the spillway is gated then the normal pool level is determined by the top of the spillway gates. The normal pool level is also known as *Full Reservoir Level (FRL) or Full Tank Level (FTL).*

Minimum Pool Level:

It is the lowest elevation to which the water is drawn from the reservoir under normal conditions. This level may be fixed by the elevation of the lowest outlet in the dam, or in case of hydroelectric reservoir, by the minimum head required for efficient functioning of turbines.

Maximum Pool Level:

During high floods water is discharged over the spillway, but will cause the water level to rise in the reservoir above the normal pool level. It is the max elevation to which the water surface will rise in the reservoir during the design flood (or worst flood). It is also known as *Maximum Water Level (MWL)* or *Full Reservoir Level (FRL)* or *Maximum Pool Level*.

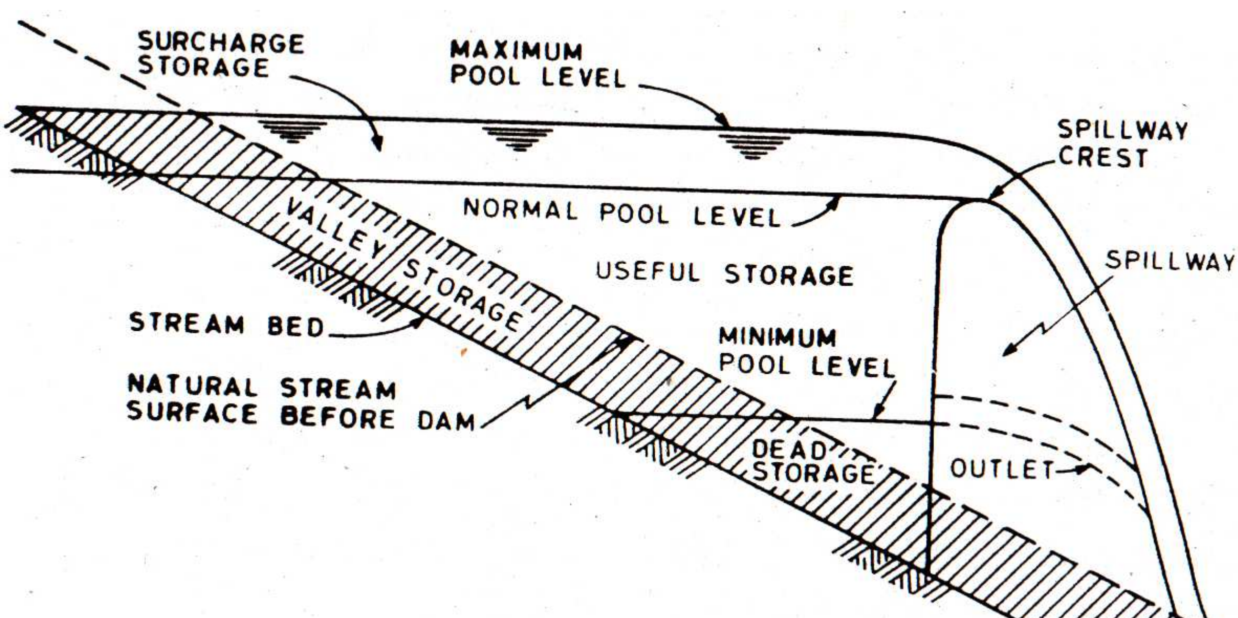


Fig. .3. Zones of storage in a reservoir.

The various zones of storage in a reservoir are as follows:

a) Useful Storage
b) Dead Storage
c) Surcharge Storage
d) Bank Storage
e) Valley Storage

a) Useful Storage:

The volume of water stored between the Normal Pool Level and Minimum Pool Level of reservoir is called *Useful Storage.* In multipurpose reservoir the useful storage may be subdivided into *conservation storage* and *flood control storage* in accordance with the adopted plan of operation of the reservoir. The useful storage is also known as *'live storage'* as it can be used for various purposes required to be served by the reservoir.

b) Dead Storage:

The volume of water hold below the Minimum Pool Level of a reservoir is known as *dead storage*. It cannot be used for any purpose under ordinary operating conditions.

c) Surcharge Storage:

The volume of water stored between the Normal Pool Level and Maximum Pool Level of a reservoir is called *surcharge storage*. The surcharge storage is an uncontrolled storage as it exists only while a flood is occurring and cannot be retained for later use.

d) Bank Storage:

The *bank storage* is the volume of water that is temporarily stored in the permeable banks of a reservoir when the reservoir fills and drains out as the water level in the reservoir is lowered. The bank storage effectively increases the capacity of the reservoir above that indicated by elevation-capacity curve. The amount of bank storage depends on geologic conditions and may account to several percent of the reservoir volume.

e) Valley Storage:

The volume of water held by a natural stream channel is known as *Valley Storage*. Even before a reservoir is constructed certain amount of water is stored in the natural stream channel as a Valley Storage which may however vary.

Reservoir Yield:

The most important aspect of the design of storage reservoir is an analysis of the relation between yield and capacity.

Yield is the amount of water which can be supplied from the reservoir in a specified interval of time.

The time interval may vary from a day for small distribution reservoir to a year or more for a large storage reservoir. Yield is dependent upon inflow and will vary from year to year.

For most of the storage reservoir in addition to yield it is also necessary to know safe or firm yield and secondary yield.

Safe or firm yield is the maximum quantity of water which can be supplied during a critical (or worst) dry period. In practice the period of lowest natural flow on record for the stream is usually taken as the critical period.

Secondary yield is the quantity of water available in excess of safe yield during periods of high flows.

Average yield is the arithmetic average of firm or secondary yield over a long period of time.

The yield of a reservoir and its storage capacity are very much dependent on each other. Further the storage capacity of reservoir also depends on the inflow to a reservoir. The Inflow, yield and storage capacity of a reservoir are related by the following storage equation:

Inflow – Yield = change in storage

The reservoir capacity corresponding to a specific yield is determined with the help of a mass inflow curve or mass curve and the demand curve.

Mass Curve:

A *mass curve* or mass inflow curve is a plot between cumulative inflows in the reservoir with time. Or it is a plot between accumulated flows in a river against time.

A mass curve can be prepared from the flow hydrograph of a river for a large number of consecutive previous years.

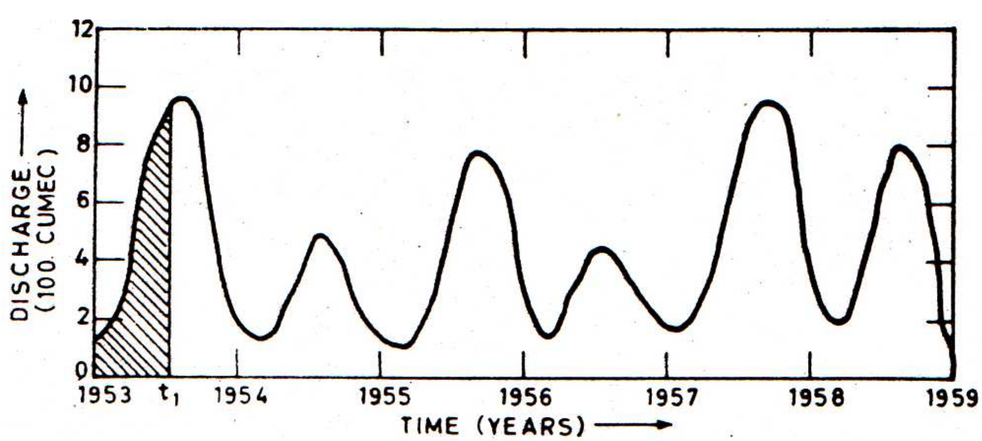


FIG:4, FLOOD HYDROGARPH

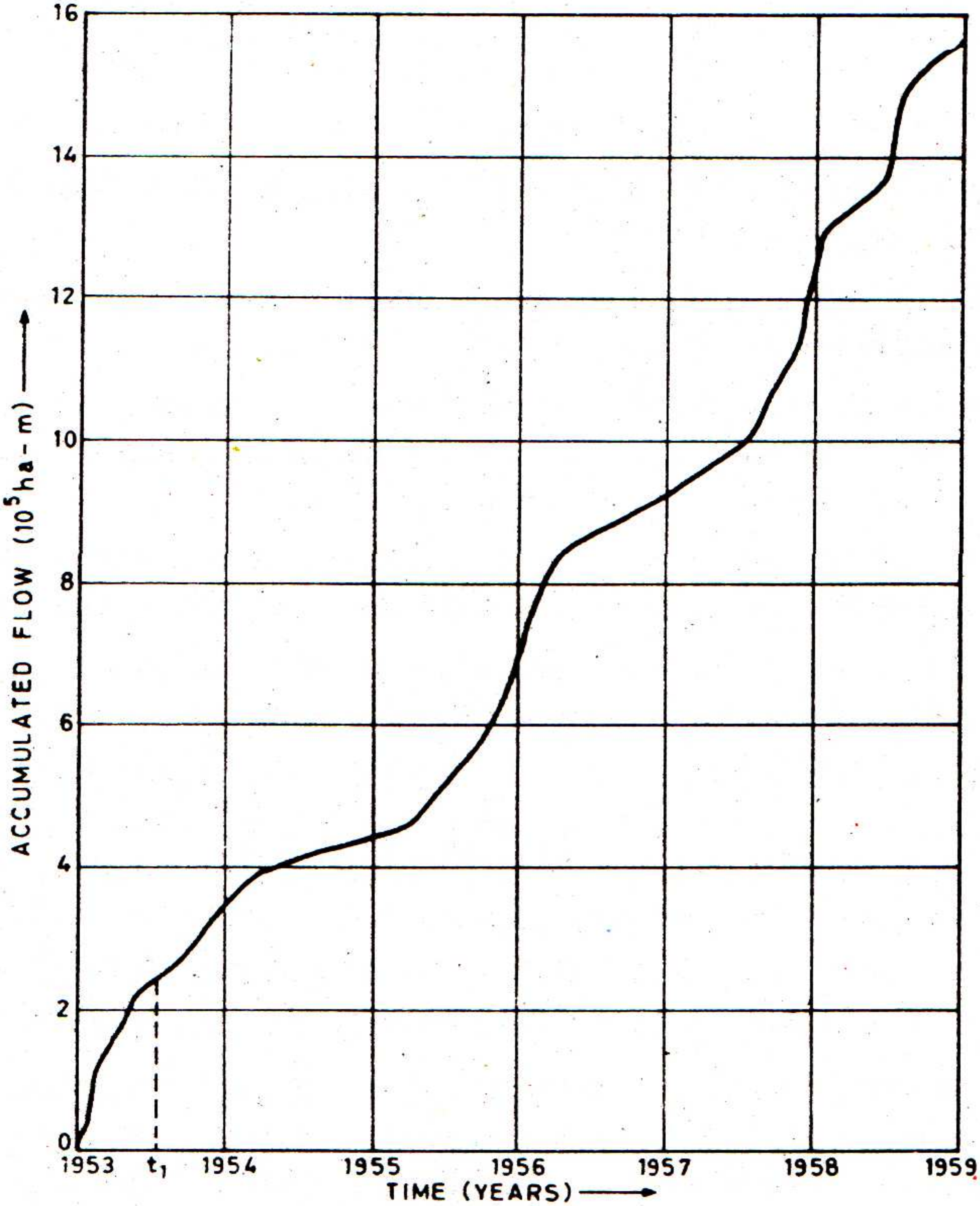


FIG:5. MASS CURVE

Fig.4 shows a flood hydrograph of inflow for several years. Fig.5 shows a mass curve prepared from the flood hydrograph of Fig 4.Taking the starting year (i.e. 1957) as the base, the total quantity of water from 1957 to time t_1 (say 1960) that has flown through the river is the volume represented by the hatched area. In the mass curve (Fig 5), the corresponding ordinate at time t1 (ordinate AB) will, therefore, be equal to the volume of water indicated by the hatched area of Fig 4. Similarly, the ordinates of the mass curve corresponding to other years can be computed from Fig 4 and plotted.

A mass curve continuously rises as it shows accumulated inflow. If there is no inflow during certain period, the mass curve will be horizontal during that period. The mass curve will rise very sharply during the period of high flood. Thus relatively dry periods are indicated as concave depressions on the mass curve. The mass curve may also be called RIPPLE DIAGRAM. The slope of the mass curve of any time is a measure of the inflow rate at that time.

Demand Curve:

A demand curve is a plot between accumulated demands with time. If the demand is at constant rate then the demand curve is a straight line having its slope equal to the demand rate (Fig 6a).If the demand is not constant then the demand curve will be curved indicating variable rate of demand (Fig 6b).

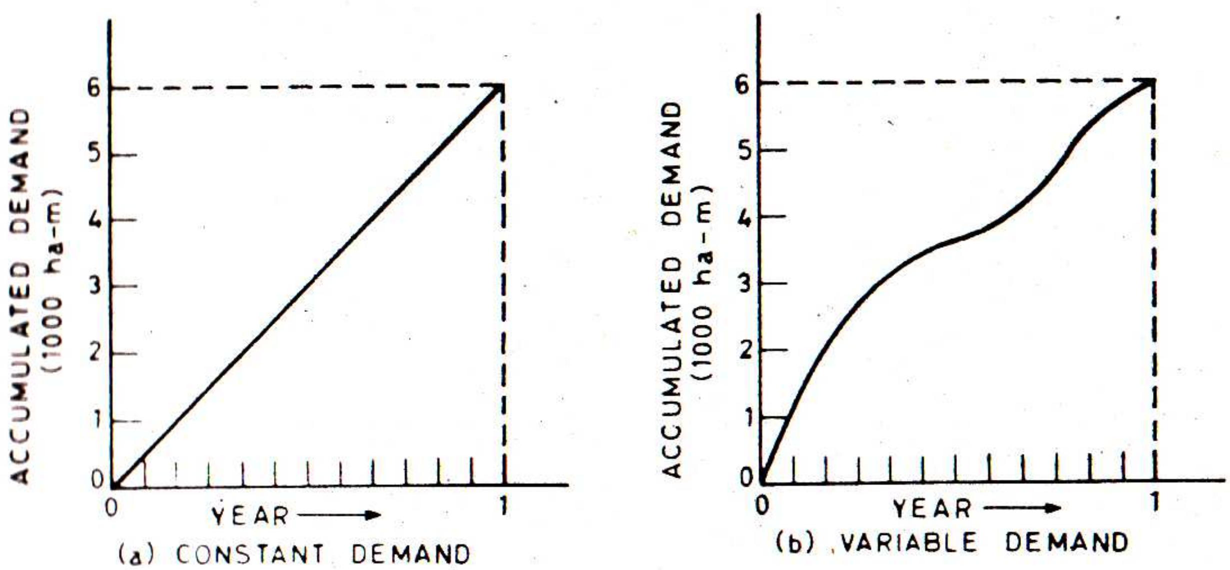


FIG:6, DEMAND CURVES

Estimation of capacity of reservoir using mass curve:

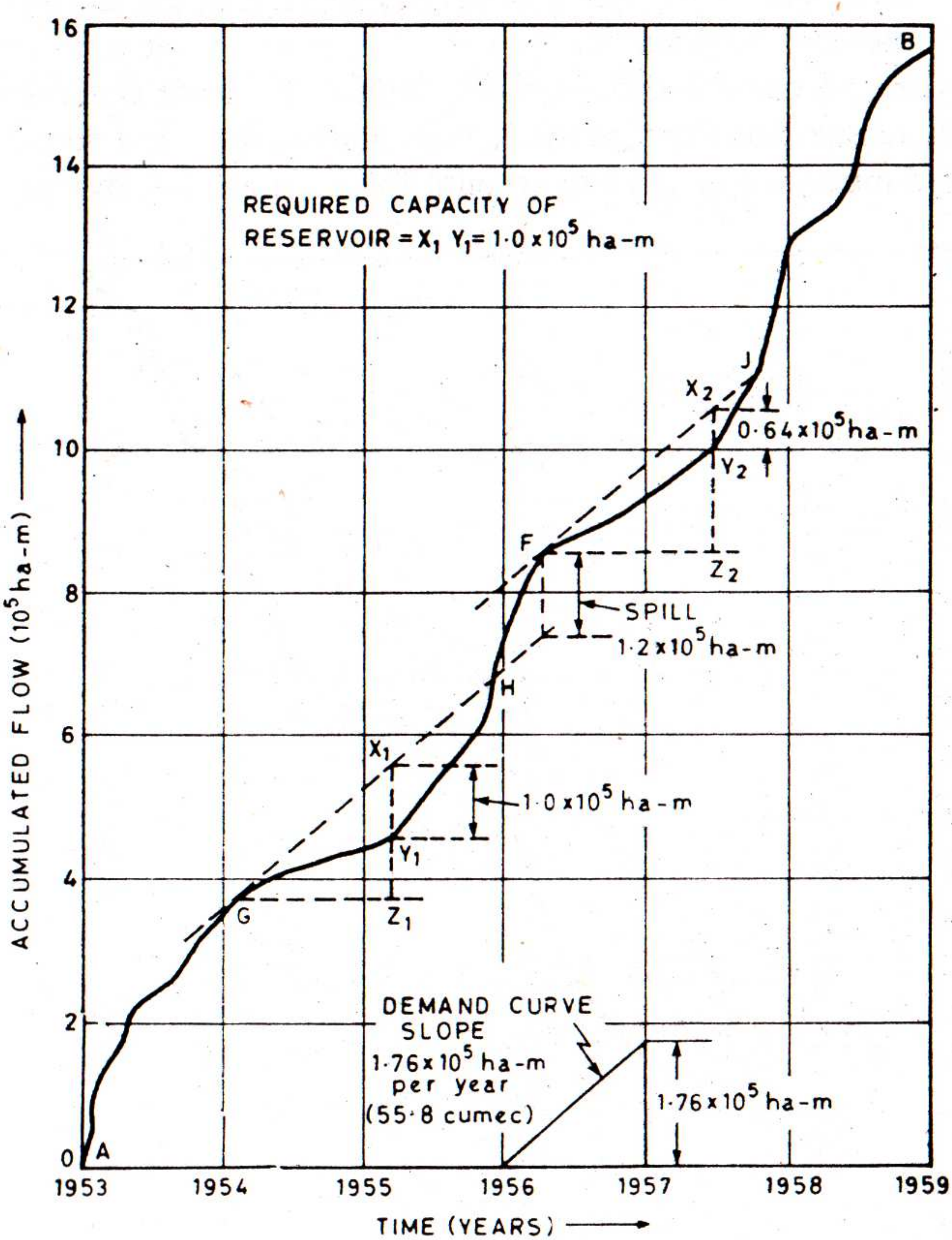


FIG:7, DETERMINATION OF RESERVOIR CAPACITY

1. A mass curve is prepared form the flow hydrograph for the number of consecutive years.
2. Corresponding to the given rate of demand, a demand occurs is prepared. If the rate of demand is constant, the corresponding demand curve is a straight line.
3. Lines such as **GH, FJ** etc are drawn parallel to the demand curve and tangential to the high points **G, F**, etc, of the mass curve (or the points at the beginning of dry periods)
4. The maximum vertical intercepts X_1Y_1; X_2Y_2 etc between tangential lines drawn in step (3) and the mass curve are measured. The vertical intercepts indicate the volume by which the total flow in the stream falls short of the demand and hence required to be provided from the reservoir storage. For example assuming the reservoir to be full at **G**, for periods corresponding to points **G** and Z_1, there is a total flow in the stream represented by $Y_1 Z_1$ land there is total demand represented by X_1Z_1,leaving a gap of volume represented by $X_1 Y_1$ which must be met with from the reservoir storage.
5. The largest of the max vertical intercepts X_1Y_1, X_2Y_2 etc., determined in step (4) represents the reservoir capacity to satisfy the given demand. However the requirement of storage so obtained would be the net storage which must be available for utilization and it must be increased by the amount of water lost by evaporation and seepage.
The vertical distance between the successive tangential lines such as **GH** and **FJ** represents the quantity of water which would spill over from the reservoir through the spillway and so as a waste to the downstream side. This is so because between **H** and **F** the reservoir would remain full and all inflow in excess of demand would flow through the spillway to the downstream side.
Further it may also be noted that tangential lines drawn parallel to the demand curve when extended forward must intersect the mass curve such as **H, J** etc so that the reservoir which was full at **G** and **F** will be filled again at **H** and **J**. However if the line does not intersect the mass curve, the reservoir will not be filled again. Moreover, if the reservoir is very large the time interval between the points **G** and **H, F** and **J** may be several years.

QUESTIONS:

1. What are different types of reservoirs? Explain the various purposes of different types of reservoirs.

2. Explain Flood control reservoir.

3. What considerations will you have while selecting the site of a reservoir?

4. Explain “zones of reservoir”

5. Explain the method for determination of the required storage capacity of a reservoir.