UNIT 16 STORAGE AND DISTRIBUTION RESERVOIRS

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16.1 INTRODUCTION

A water supply project consists of taking of raw water from source (river, stream or reservoir) conveying it to purification units, and finally distribution to the consumers. Thus, a water supply project consists of

(i) works for collection of water,

(ii) works for conveyance of water,

(iii) works for purification and treatment, and

(iv) works for distribution of water to the consumers.

The proper planning consists of an economical efficiently functioning units with minimum recurring and operational expenditure and trouble. It has been discussed in earlier units that water demand is not constant. There are several factors, which cause fluctuations in demand and well planned water supply scheme has to supply water as and when required depending upon the demand. Earlier it has been discussed that maximum daily demand goes as high as 1.8 times the average daily demand, of course only at peak hours, i.e., for certain hours in the day. We cannot expect purification units to be made to purify water at double of the average demand at peak periods. Hence, in the system one or more reservoirs are inserted to furnish elasticity to the distribution system so that different units to work at a constant average rate.

Distribution reservoirs also called service reservoirs are the storage reservoirs, which store treated water for supplying water during peak hours and emergencies such as during fire, breakdowns, repairs etc. Thus, helping in absorbing hourly fluctuations in the normal water demand.

Objectives

The unit will deal with distribution or service reservoirs. After going through this unit, you will know about

- purpose and use of distribution reservoirs,
- its suitable position in the system,
- different kinds of service or distribution reservoirs,
- procedure and guidelines for design, and
- estimation of designed capacity of a distribution reservoir.

16.2 DISTRIBUTION RESERVOIRS

In a water supply scheme, an independence of action is desirable from the standpoint of economy and safety and in many cases is of importance with respect to the quality of the water. For example where water is brought from the source through a long conduit, a distributing or equalising reservoir enables the conduit to be operated at a comparatively uniform rate and hence, can be made of minimum size. Similarly, such a reservoir makes it possible to reduce the capacity of pumps, filters or other similar units and to operate them more uniformly and economically. In a small works, the pumps will operate at full capacity for a portion for the day only, reducing the running cost of the pumps, to get relief from power failures or load shedding, which has become common in our country. In case of a ground water supply, a small reservoir increases the capacity of the source by making the demand more uniform. In a large distributing system, several reservoirs placed at different points or locations may effect considerable economy in the size of the pipe system and other units including the pumping plant. As a measure of safety against the interruption of the supply from accidents to conduit or machinery, distributing reservoirs are of great value. It gives cheaply additional safety against interruption when units may require duplication. With respect to quality also these reservoirs are of great advantage as they provide an additional opportunity for sedimentation and making it possible to avoid taking water from streams during period of great turbidity.

Small reservoirs may also be provided for convenience in operation. A receiving reservoir at the terminals of conduits, small reservoirs for regulating pressure at intermediate points and similar reservoirs on air chambers at pumping stations, may be provided for

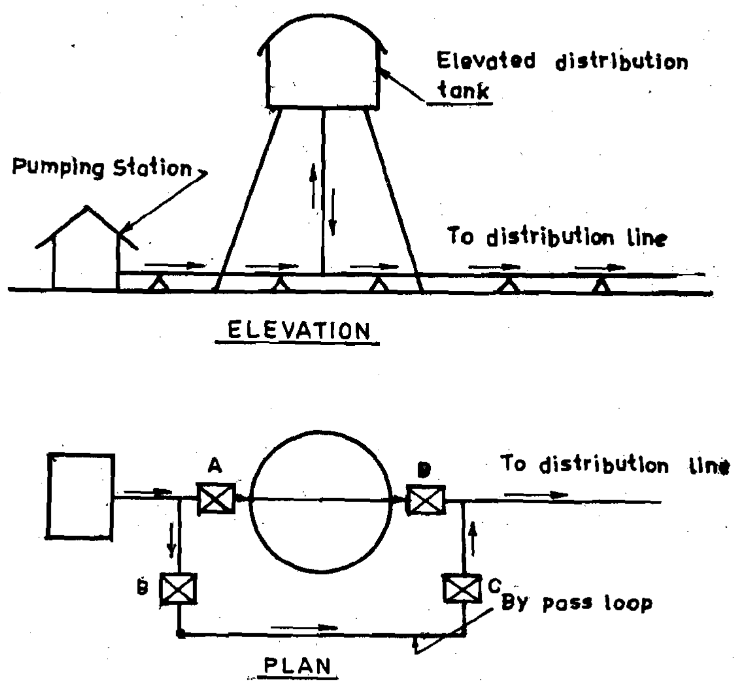

Figure 16.1 : Working of a Distribution Tank

equalising the action of pumps. The function of a balancing or distribution reservoir is explained in Figure 16.1. When the demand for water exceeds the rate of supply, the water flows into the distribution system both from the elevated distribution reservoir as well as water through direct pumping by means of a bypass loop (as shown in Figure 16.1) by closing valve at A but keeping valves B, C and D open.

When demand for water is less than the rate of supply, then the required demand is met by water pumped through the bypass loop, while the balance pumped water fills up the balancing reservoir by closing the valve D but keeping valves A, B and C open to regulate the flow.

The main functions served by the distribution reservoirs are summarised below :

(i) They absorb the hourly variations in demand and allow the water treatment units and pumps to operate at a constant rate. This reduces the running, maintenance and operational (RMO) costs and improves efficiency.

(ii) They help in maintaining constant pressure in the distribution mains. In their absence, the pressure falls down as the demand of water increases.

(iii) The pumping of water in shifts is made possible by them without affecting the supply. Thus, 8 to 12 hours of pumping can be carried out so as to supply the whole day demand.

(iv) The water stored in these reservoirs can be supplied during emergencies such as breakdown of pumps, heavy fire demand etc.

(v) They provide an overall economy by reducing the sizes of pumps, pipe lines and treatment unit and this is the most important aspect of service or distribution reservoirs.

16.3 TYPES OF DISTRIBUTION RESERVOIRS

Depending upon their elevation with respect to the ground, reservoirs may be classified as

(a) Surface reservoirs, and

(b) elevated reservoirs.

16.3.1 Surface Reservoirs

A surface reservoir may be constructed at ground level or below the ground level. Hence, they are also known as ground reservoirs. They are generally constructed at higher points of the area to be served. If the area to be served is undulating having more than one high points, more than one distribution reservoir may be provided. In that case the area is divided into several zones and a separate reservoir is provided in each zone for proper distribution of water.

In a gravitation type of distribution system, water is stored in the ground distribution reservoir and then directly sent from there to distribution mains, which are situated at lower elevations. In a combined gravity and pumping system, the treated water is first stored in a ground reservoir and then pumped to an elevated service reservoir from which water is supplied into the distribution mains.

16.3.2 Elevated Reservoirs

Elevated reservoirs are mostly rectangular or circular overhead tanks erected at a suitable elevation above the ground level and supported on towers. They are constructed where the pressure requirements require considerable elevation above the ground surface to serve multi-storyed buildings. They are provided in the area where the combined gravity and pumping system for water distribution is adopted. Water is pumped into these elevated tanks from filter units and then supplied to the consumers.

Stand Pipes

Stand pipes are a kind of elevated tanks without any supporting towers for resting the tank body. They are tall cylindrical shell resting directly on ground. Stand pipes are generally 15 to 20 m high and 10 to 15 m in diameter. Figure 16.8 shows typical cross-section of a stand pipe.

16.3.3 Types with Respect to Construction Materials

With respect to form of construction i.e. construction materials, reservoirs may be classified as :

(i) Earthen,

(ii) Masonry,

(iii) Reinforced concrete, and

(iv) Steel.

When the reservoir is not required to be elevated above the natural ground level, the capacity is to be larger than the most economical form and the usual one is the open reservoirs with earthen embankments. The storage of surface water in such reservoirs does not usually affect their quality if they have previously been stored in large impounding reservoirs. But in the case of ground water or filtered surface water, it is desirable that they are stored in closed tanks or reservoirs. Covered reservoirs are mostly built with masonry walls and covers with RCC slabs. To economise the construction, it is better to put them partly in excavation and partly above the surface. Elevated reservoirs are provided when a reservoir requires to be considerably elevated.

16.4 POSITION AND ELEVATION OF RESERVOIRS

If the service storage is to be of maximum value as a safeguard to the undertaking against breakdown then it should be positioned as near as possible to the area of demand. From the service storage, the distribution system should spread directly with such a ramification of mains that no single breakage could cause a severe interruption to the continuity of the supply. There should be sufficient interconnection between the distribution mains so that if a breakdown of any one main occurs, the supply may be maintained by re-routing the water. It is not always possible to have a high point, which is in the centre of the distribution area and in such circumstances, the best possible should be done. If the high point is remote from the area of demand, the area is kept to feed the demand by two major mains from the service reservoir. If there is some high ground, which is not quite high enough then a water tower or several water towers may be provided to meet the requirement. It has to be seen that service reservoir is located at such an elevation that a steady pressure is available at all points of the distribution system, sufficient to reach the topmost storey of three or four storey buildings.

The elevation at which it is desirable to position a service or distribution reservoir depends upon the distance of the reservoir from the distribution area and the elevation of the highest buildings to be served. If the distribution area varies widely in elevation, it may be necessary to use two or more service reservoirs at different levels so that the lower areas do not receive an unduly high pressure. Generally 45 to 75 m static pressure is that which suits best to the domestic distribution system. It results in distribution pipes of moderate size and thickness and wastage from leaks is not excessive at this pressure. Pressure below 45 m may cause trouble in supplying extensive distribution areas and pressure above 120 m may be too high to result in excessive leakage losses.

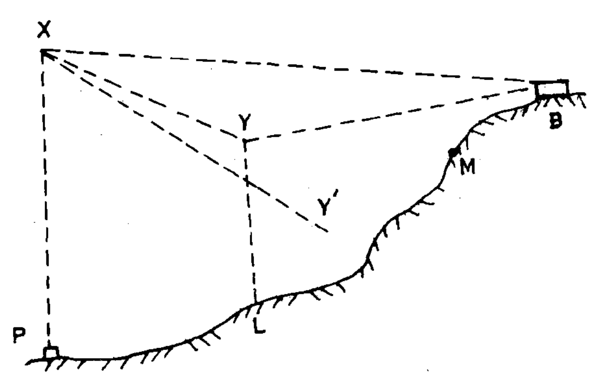

Figure 16.2 : Location of a Distribution Reservoir

In a pumping system, the pumps are usually located near one side of the city and for the best results, the reservoir should be located at some point on the opposite side of the distributing system. In this way, full benefit of the reservoir is secured in equalising pump action, providing reserve supply, reducing average head on the pumps and making the pressure more uniform in the system.

Figure 16.2 illustrates this condition : P is a pumping station, B is the reservoir and LM is the area to be served. PX is the pumping head. During night, water flows into the reservoir and the hydraulic gradient will be line XB. During day when consumption is more than the pumpage, the reservoir supplies the deficiency and water flows to the intermediate area from both directions giving pressure line XYB. With no reservoir or one located at L, the gradient would have been line XY', steeper than XY, if the size of pipes remain the same. A reservoir placed near the pumps at L will serve to equalise the pump load only and will provide reserve supply but it will not have effect on the distribution system. Hence, better location for the reservoir is at B.

If at all a service reservoir is placed at L, it will be a small stand pipe or a small elevated tank. The proper elevation of a reservoir depends on the required pressure in the mains. Where more than one zone of pressure is employed, a site is selected to serve all but the highest zone. The highest zone is then operated without a reservoir or with a tank or a stand pipe.

16.5 STORAGE CAPACITY OF DISTRIBUTION RESERVOIRS

It has been discussed that a distribution reservoir has mainly two functions :

(i) to balance the fluctuating demand from the distribution system against the output from the source.

(ii) to maintain continuous supply in case of any breakdown at the source or in the main trunk lines.

6.5.1 Balancing Storage

The first one is also commonly known as balancing storage or equalising or operating storage while the second one is popularly known as breakdown storage. In addition to these two types of storage, some storage of water has to be done for tackling the out-break of fire in the city or the distribution area and the storage for that is known as fire storage.

The source itself may give fluctuating output in step with the demand. But it is not economical to follow this policy. If the peak flow rate is twice the average flow then the source units are to be made of capacity to deliver twice the average demand and the delivery pipeline, coagulation units and filters should also be capable of delivering twice the average demand. Thus, the size of units has to be made double of the average demand, which will not be used continuously hence, there will be only 50% usage of the capital spent on these works. Therefore, it is to be seen that source and treatment works including the main trunk line to work as much as possible to their maximum capacity and the change in demand to be balanced by a service or distribution reservoir.

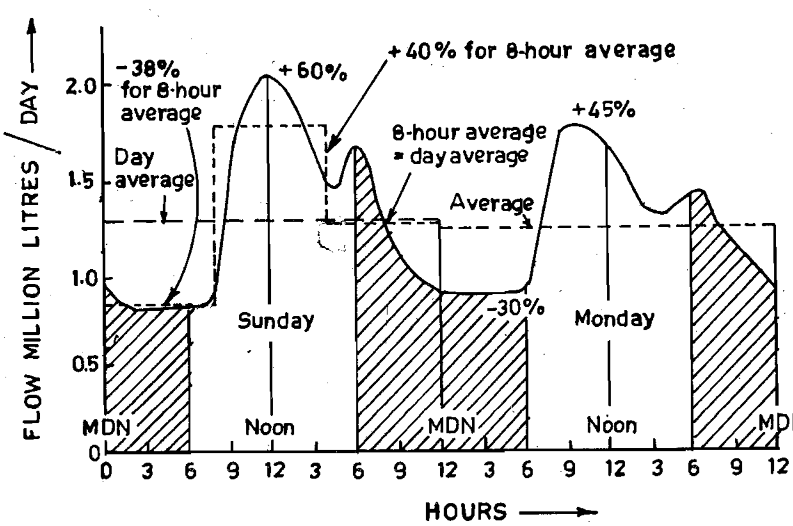

Figure 16.3 : Typical Variation in Consumption Rates for a Small Area

Figure 16.3 shows two consecutive days consumption into three 8-hour periods. Since Sunday is a holiday in most of the places, maximum day demand of a week has been taken into consideration.

From midnight until 8 a.m. flow is less than average (% loss in the figure shown), from 8 a.m. until 4 p.m. flow is greater than average (% greater in the figure shown) and from 4 p.m. until midnight, the flow is about the average. Now it can be deduced that during the period 8 a.m. to 4 p.m. excess flow will have to be from the storage (distribution reservoir). This amount of water will have to be put back into the reservoir during the following night in order to fill the reservoir ready for the next day. The maximum demand figure varies 15% to 40% in excess of the average for the whole day depending upon the size of the area considered. The lower percentage is applicable to large industrial area of a population one lac or more and the higher percentage applies to a smaller urban area of population under 20,000.

In the above calculation, minimum storage required to average out the flow of one particular day has been taken. In practice, storage more than this will be required due to following reasons :

(i) There will be variations from one day to the next day.

(ii) It may not be always possible to have the service reservoir full every morning at 8.00 a.m.

If double the theoretical requirement is provided then the contents of the service reservoir above or below the 50% full line can easily be fluctuated and this will give greater flexibility. Supposing that an 8 hour maximum flow rate is 30% in excess of the average flow for the day, then the amount of storage required for the distribution or service reservoir

$$= 2 \times 0.30 \times (1/3)\,(\text{day's total consumption}) \times 125\%$$

$$= 25\% \text{ of day's total consumption}$$

i.e., one quarter of the day's consumption. This storage will meet the hourly fluctuation of flow.

But this much amount of storage may not be sufficient to meet all contingencies.

16.5.2 Contingency Storage

Contingency storage is also known as breakdown storage. This storage is required to meet breakdowns at source, repair of pipe bursts on Mains. The storage depends upon the nature of the source, the layout of Mains and safety precautions to be taken.

Bore hole pumping stations or boosting stations can have four to five hours interruption of supply due to electricity supply failure at the same time such units should be designed for not more than 22 hours working out of 24 hours to take into account of routine maintenance. Water treatment plants also required to be shut down for four to five hours for necessary repairs. River intake sources sometimes present hazards due to sudden pollution, but this problem is tackled by providing raw water storage at the intake because polluted water is not allowed to pass to the treatment plants. For repair of major Mains, six to eight hours time for repair and two to four hours for refilling the system is allowed when the Main has been repaired. The loss of water from burst is also substantial. A breakdown may not conveniently occur just when the reservoir is full. It may occur during the maximum demand period when the overdraw may rise to 25% of the day's supply. In addition to these, some allowance is to be made for "bottom water". Bottom water has to be kept in the reservoir to prevent its complete emptying.

16.5.3 Fire Storage

This provision takes care of the requirement of water for extinguishing fires. Although this requirement seems to be high but when analysed, it comes to around 1 to 5 litres per day per person depending upon type of city. Hence, sometimes, storage for fire-fighting is clubbed with contingency storage.

Only for balancing flows to an average sized distribution system, about one quarter of day's supply is stored and thought to be sufficient. But this is not sufficient to run the supply against breakdown and fire-fighting. The minimum storage for safeguarding the continuance of a supply during breakdowns is one day's supply. But where daily and seasonal fluctuations are large (chances of more fire in summer) and trunk Mains are not duplicated, it is desirable to provide three days capacity to the distribution reservoirs.

16.6 DESIGN FOR STORAGE

The storage capacity of balancing or service reservoirs is worked out with the help of hydrographs of inflow and outflow by mass curve method or by analytical tabular solution.

16.6.1 Mass Curve Method

A mass diagram is the plot of accumulated supply or demand versus time. The supply is also known as inflow and demand as outflow. First mass curve of supply, known as supply line is drawn and over this demand curve is superimposed. The amount of balancing storage is determined by adding the maximum ordinates between the demand and supply lines. First hourly demand for all 24 hours from the day of maximum requirement is determined. Cumulative demand is plotted against time, which is known as mass curve of demand. Next cumulative supply against time is plotted, which is a straight line if the supply is constant. The storage required is calculated as the sum of the two maximum ordinates between demand and supply lines. (Reference to Example 16.3 and Figure 16.2 will make the procedure more clear.)

16.6.2 Analytical Method

In this method cumulative hourly demand and cumulative hourly supply are tabulated for all the 24 hours. The hourly excess demand and hourly excess supply are worked out. The summation of maximum of the excess of demand and the maximum of excess of supply gives the required storage capacity. The method will be more clear with the following example :

Example 16.1

A city has population of 1.5 lakhs and it has to be supplied water at the rate of 200 litres per person per day. The hourly variation in demand is given in the table.

Find out the capacity of the distribution reservoir to be provided for balancing the variable demand against a constant rate of pumping :

(i) when the pumping is done for all the 24 hours.

(ii) when pumping is done from 6 a.m. to 11 a.m. and then 2 p.m. to 9 p.m.

Period of days in hours	0 to 4	4 to 8	8 to 12	12 to 16	16 to 20	20 to 24
% of average hourly flow	16	70	190	88	166	70

Solution

Average daily supply = 200 × 15,000

= 30 × 106 litres = 30 million litres

Average hourly demand = 30/24 = 1.25 million litres.

Period in hrs	Demand in units of Avg. hrly. demand	Cum. demand in terms of Avg. hrly. demand	Cum. demand in million ltrs. (Col.3 × 1.25 ML)	Const. pumping rate in ML/hr	Cum. pumping in ML	Excess of demand 10 ML= Col.(4) – Col.(6) (+ ve values)	Excess of supply in ML= Col. 6 – Col.4 (+ ve values)
1	2	3	4	5	6	7	8
1	0.16	0.16	0.20	1.25	1.25	–	1.05
2	0.16	0.32	0.40	1.25	2.50	–	2.10
3	0.16	0.48	0.60	1.25	3.75	–	3.15
4	0.16	0.64	0.80	1.25	5.00	–	4.20
5	0.70	1.34	1.675	1.25	6.25	–	4.575

Period in hrs	Demand in units of Avg. hrly. demand	Cum. demand in terms of Avg. hrly. demand	Cum. demand in million ltrs. (Col.3 × 1.25 ML)	Const. pumping rate in ML/hr	Cum. pumping in ML	Excess of demand 10 ML= Col.(4) – Col.(6) (+ ve values)	Excess of supply in ML= Col. 6 – Col.4 (+ ve values)
1	2	3	4	5	6	7	8
6	0.70	2.04	2.55	1.25	7.50	–	4.95
7	0.70	2.74	3.425	1.25	8.75	–	5.325
8	0.70	3.44	4.30	1.25	10.00	–	5.70
9	1.90	5.34	6.675	1.25	11.25	–	4.575
10	1.90	7.24	9.05	1.25	12.50	–	3.45
11	1.90	9.14	11.425	1.25	13.75	–	2.325
12	1.90	11.04	13.80	1.25	15.00	–	1.20
13	0.88	11.92	14.90	1.25	16.25	–	1.35
14	0.88	12.80	16.00	1.25	17.50	–	1.50
15	0.88	13.68	17.10	1.25	18.75	–	1.65
16	0.88	14.56	18.20	1.25	20.00	–	1.80
17	1.66	16.22	20.275	1.25	21.25	–	0.975
18	1.66	17.88	22.35	1.25	22.50	–	0.150
19	1.66	19.54	24.425	1.25	23.75	0.675	–
20	1.66	21.20	26.50	1.25	25.00	1.500	–
21	0.70	21.90	27.375	1.25	26.25	1.125	–
22	0.70	22.60	28.25	1.25	27.50	0.75	–
23	0.70	23.30	29.125	1.25	28.75	0.375	–
24	0.70	24.00	30.00	1.25	30.00	–	–

From above table, it is observed that

(a) the maximum excess of demand = 1.5 million litres

(b) the maximum excess of supply = 5.70 million litres

Hence, total storage required = (a) + (b) = 1.5 + 5.7 = 7.2 million litres

Case (ii) when pumping is done for limited period.

When pumping is done from 6 a.m. to 11 p.m. and 2 p.m. to 9 p.m. i.e., 12 hrs. i.e., Rate of supply = 30/12 = 2.5 million litres/hr.

Period in hrs	Demand in units of Avg. hrly. demand	Cum. demand in terms of Avg. hrly. demand	Cum. demand in million ltrs. (Col.3 × 1.25 ML)	Const. pumping rate in ML/hr	Cum. pumping in ML	Excess of demand in ML= Col.(4) – Col.(6) (+ ve values)	Excess of supply in ML= Col. 6 – Col.4 (+ ve values)
1	2	3	4	5	6	7	8
1	0.16	0.16	0.20	–	–	0.20	–
2	0.16	0.32	0.40	–	–	0.40	–

Period in hrs	Demand in units of Avg. hrly. demand	Cum. demand in terms of Avg. hrly. demand	Cum. demand in million ltrs. (Col.3 × 1.25 ML)	Const. pumping rate in ML/hr	Cum. pumping in ML	Excess of demand 10 ML= Col.(4) – Col.(6) (+ ve values)	Excess of supply in ML= Col. 6 – Col.4 (+ ve values)
1	2	3	4	5	6	7	8
3	0.16	0.48	0.60	–	–	0.60	–
4	0.70	0.64	0.80	–	–	0.80	–
5	0.70	1.34	1.675	–	–	1.675	–
6	0.70	2.04	2.55	–	–	2.55	–
7	0.70	2.74	3.425	2.5	2.5	0.925	–
8	0.70	3.44	4.30	2.5	5.0	–	0.70
9	1.90	5.34	6.675	2.5	7.5	–	0.825
10	1.90	7.24	9.05	2.5	10.0	–	0.950
11	1.90	9.14	11.425	2.5	12.50	–	1.075
12	1.90	11.04	13.80	–	12.50	1.30	–
13	0.88	11.92	14.90	–	12.50	2.40	–
14	0.88	12.80	16.00	–	12.50	**3.50**	–
15	0.88	13.68	17.10	2.5	15.00	2.10	–
16	0.88	14.56	18.20	2.5	17.50	0.70	–
17	1.66	16.22	20.275	2.5	20.00	0.275	–
18	1.66	17.88	22.35	2.5	22.50	–	0.150
19	1.66	19.54	24.425	2.5	25.00	–	0.575
20	1.66	21.20	26.50	2.5	27.50	–	1.00
21	0.70	21.90	27.375	2.5	30.00	–	**2.625**
22	0.70	22.60	28.25	–	30.00	–	1.75
23	0.70	23.30	29.125	–	30.00	–	0.875
24	0.70	24.00	30.00	–	30.00	–	–

From the above table, the maximum excess of demand = 3.50 million litres

the maximum excess of supply = 2.625 million litres

∴ Total storage required = 3.5 + 2.625 = 6.125 million litres (Ans.)

Example 16.2

Calculate the storage required to supply the demand shown in the following table if the inflow of water to the reservoir is maintained at a uniform rate throughout 24 hours.

Time	00 - 04	04 - 08	08 - 12	12 - 16	16 - 20	20 - 24
Demand in million litres	0.48	0.87	1.33	1.00	0.82	0.54

Solution

Total demand during the day = 0.48 + 0.87 + 1.33 + 1.0 + 0.82 + 0.54
= 5.04 million litres

Total supply during the day = Total demand = 5.04 million litres

∴ Constant hourly supply = 5.04/24 = 0.21 Ml

∴ 4 hourly supply = 0.21 × 4 = 0.84 Ml

Time in hrs	Demand in million litres	Cum. Demand in Ml	Pumping In Ml	Cum. pumping in Ml	Excess of demand (Col.3 – Col.5) (+ ve values only)	Excess of supply (Col.5 – Col.3) (+ ve values only)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0 - 4	0.48	0.48	0.84	0.84	—	0.36
4 - 8	0.87	1.35	0.84	1.68	—	0.36
8 - 12	1.33	2.68	0.84	2.52	0.16	—
12 - 16	1.00	3.68	0.84	3.36	0.32	—
16 - 20	0.82	4.50	0.84	4.40	0.10	—
20 - 24	0.54	5.04	0.84	5.04	—	—

From above table, it is observed that the maximum of excess of demand = 0.32 Ml and the maximum of excess of supply = 0.36 Ml.

Therefore, total storage required = 0.32 + 0.36 = 0.69 Ml = 680,000 litres (Ans.)

Example 16.3

A town has population of one lakh. It is to be supplied with water at the rate of 200 litres per head per day. The variation in demand is as follows :

6 a.m. to 9 a.m.	:	40% of total
9 a.m. to 12 noon	:	10% of total
12 noon to 3 p.m.	:	10% of total
3 p.m. to 6 p.m.	:	15% of total
6 p.m. to 9 p.m.	:	25% of total

Determine the capacity of the service reservoir when the pumping is at a uniform rate from 6 a.m. to 6 p.m.

Solution

Total daily requirement = 1,00,000 × 200

$= 20 \times 10^6 = 20$ Ml

Calculation for cumulative demand

Period	No. of hours	Rate of Demand	Demand in Ml	Cumulative demand in Ml
6 a. m. - 9 a. m.	3	40% of 20 Ml	8	8
9 a. m. - 12 noon	3	10% of 20 Ml	2	10
12 noon - 3 p. m.	3	10% of 20 Ml	2	12
3 p. m. - 6 p. m.	3	15% of 20 Ml	3	15
6 p. m. - 9 p. m.	3	25% of 20 Ml	5	20

Demand and supply lines have been drawn in firm and dotted lines respectively in Figure 16.4. Two maximum ordinates enclosed between demand and supply lines have been red out as 5 million litres and 3 million litres respectively.

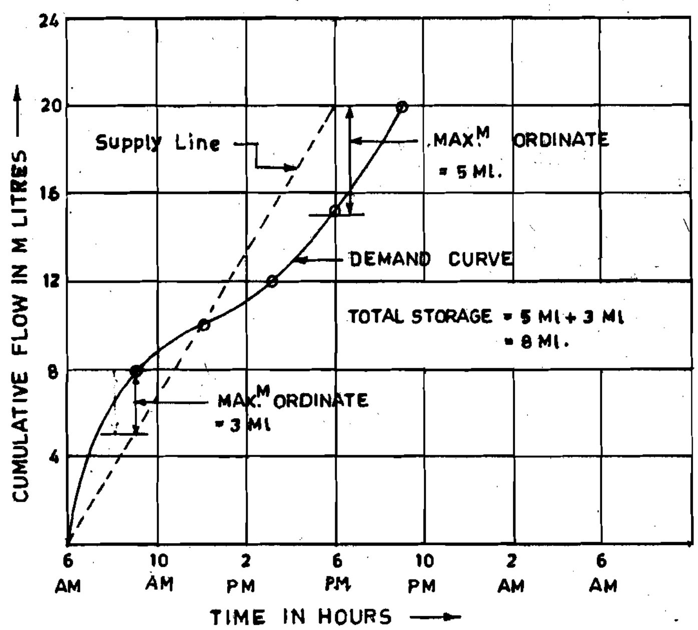

Figure 16.4

∴ Total Storage required = 5 + 3 = 8 million litres (Ans.)

16.7 GUIDELINES FOR DESIGN

For economical design of service or distribution reservoirs, site condition is very important. The reduced level of sites gives an idea whether the reservoir will be on ground or overhead tank supported on columns at higher elevation. The distribution reservoirs may be made of RCC or masonry. Depending upon their elevation with respect to the ground, they are classified as :

(a) surface reservoirs, and

(b) elevated reservoirs.

Surface Reservoirs

They are circular, square or rectangular tanks constructed at ground level or below the ground level. Therefore, they are also sometimes known as ground reservoirs. They are mostly constructed at highest point in the city.

A circular tank is geometrically the most economic in shape giving the least amount of walling for a given capacity. But for circular tank, flat ground should be available which may not be always feasible. To make best use of available land, rectangular tanks are more economical. In fact, shape of the land available is often determining factor in built up areas. A rectangular tank or reservoir with ratio of sides 1.2 : 1.5 shows a benefit over a square tank when an internal well is provided to divide the reservoir into two compartments.

When size of the reservoir is very big earthen reservoirs are constructed. But distribution or service reservoirs should not be provided without cover because they contain treated water, which is directly supplied to the consumers. Hence, it is always preferable to make a masonry or concrete tank with cover.

When not limited by other considerations, the locations and elevation of the bottom are so chosen as to secure the most economical relation between excavation and filling. Where a town or locality is served by a single service reservoir, it is desirable to divide the reservoir into two or more basins for convenience of cleaning and repair.

16.7.1 Economical Depth

The most economical depth can be determined by trial. However, considering various elements, most economical depth may be determined approximately by analysis.

Let us assume the reservoir to be a square one having side length as x and depth = h, Q = given capacity and C = cost per unit area of all portion whose cost is proportional to the area such as land, reservoir lining, cover etc. The cost of exterior wall per metre may be assumed to vary approximately as 1/3.3 $h^{1.5}$ or will be equal to $C'h^{1.5}$ where C' is a constant. The cost of excavation, embankments for a given capacity vary slightly with the depth and will be nearly constant and let us take this as K.

$$\therefore \text{ Total cost } C = 4C'h^{1.5}x + Cx^2 + K \qquad \ldots(16.1)$$

But $\quad Q = hx^2$ or $x = \sqrt{Q/h}$

$\therefore$ Substituting in Eq. (16.1) we have

$$C = 4C'h\sqrt{Q} + C \cdot Q/h + K \qquad \ldots(16.2)$$

Differentiating with respect to h and equating to zero, we get that for a minimum cost C,

$$h = \tfrac{1}{2}\sqrt{C/C'}\, 4\sqrt{Q} \qquad \ldots(16.3)$$

The economical depth is, therefore, proportional to the fourth root of Q and hence, it should vary but little for considerable variations in capacity.

Since $\quad Q = hx^2$, we have from Eq. (16.3)

$$h = (C/4C')^{2/3} \cdot x^{2/3} \qquad \ldots(16.4)$$

which gives that h is proportional to $x^{2/3}$

From Eq. (16.3), we see that as the cost per unit area increases (because of any reason), h should also increase, but only in the proportion of $\sqrt{C}$. If the cost of wall varies as h^2, then Eq. (16.3) becomes as

$$h = (C/6C')^{2/3}\, Q^{1/3} \qquad \ldots(16.5)$$

Eq. (16.5) indicates that here h varies at a lesser rate with Q than in Eq. (16.3).

The value of h will then vary with $\sqrt{x}$. With a fixed bottom elevation, it is to be noted that the lift of the pump increases with increase in depth thus increasing the operation cost.

Most usual depths for different capacities are as follows :

Capacity (m^3)	**Depth of Water (m)**
Upto 3500	2.5 - 3.5
3500 - 15000	3.5 - 5.0
Over 15000	5.0 - 7.0

But these figures do not apply to water towers or pre-stressed reinforced concrete tanks. Factors influencing depth for a given storage are :

(i) depth at which suitable foundation conditions are encountered.

(ii) depth at which outlet main has to be laid.

(iii) slope of ground, nature and type of backfill soil.

(iv) the need to make the quantity of excavated material approximately equal to the amount required for banking or filling so as to reduce carting of surplus materials.

(v) the shape and size of land available.

16.7.2 Roofing

Water in a distribution or service reservoir is treated water ready for consumption. Hence, it should not be stored in open space which may cause pollution from the atmosphere.

Concrete roofs are designed as flat slabs on columns. Construction with cast in-situ-slabs resting on beams or as a series of precast and pre-stressed beams laid side by side and grouted together are also common. For ordinary reinforced construction span of 3.5 to 4.5 m, give a thickness in the range of 150 to 200 mm and are more common in use. Use of precast pre-stressed beams, however, permits the use of spans upto 7.5 m thus reducing number of columns. Due to temperature changes, the roof may have expansion. Hence, they are not fixed with the walls but should be free to slide over them. For heat insulation concrete roof slab is covered with gravel and finally a layer of earth. But if temperature does not go too high, the earth layer may be spared because it increases dead load on the slab making it more thick and thus, increasing the cost of construction. The gravel layer helps in drainage of water falling over the roof cover of the tank. Sometimes for larger spans arched or domed roofs are also made. Roofs are always provided with ventilators to allow free circulation of air.

16.7.3 Walls of Concrete Reservoirs

Walls of reservoirs may be classified in three categories. Mass concrete gravity walls, reinforced concrete walls and pre-stressed walls. For normal sizes of tank with good ground conditions, the mass concrete or reinforced concrete walls are more common, of course, R.C.C. walls being more preferable. To give the stability to the wall, the water face is made sloping. The wall is designed as a retaining wall, the worst condition of loading being, when the tank is empty.

Pre-stressed concrete tanks are usually circular with pre-stressing being applied only in the horizontal place by winding the pre-stressing wires around the outside of the tank wall. When the wires are placed and tensioned, a 50 to 100 mm thick pneumatic mortar is gunited on to the outside of the tank. Pre-stressed tanks can be made deep because the extra tension induced in the walls by greater water depth can be met by adding more strands of pre-stressing wires and, thus, thickness of walls not being greatly increased. Pre-stressed tanks can have domed roof because the thrust from the dome being taken by a thrust ring provided at the top of the tank. Due to unequal settlement in the ground, cracks develop in the walls. But cracking may be reduced by adopting following measures :

(i) Using a concrete grade not very rich in cement even though some greater thickness of sections are required.

(ii) Size of aggregate should be coarser.

(iii) Keeping water content of the mix as low as possible and adding an air-entraining agent to assist in producing adequate workability.

(iv) Using steel shutters (not wooden or plywood shutters) so that the maximum temperature gained during concrete setting is reduced quickly.

16.7.4 Floors of Reservoirs

Excepting a small size of tank the floor is cast as a separate structure from walls. Underdrains are provided to prevent uplift and these underdrains have a free fall to an open outlet. Sometimes, floors are laid in two layers. The joints in the upper layer are staggered in relation to the joints in the lower one.

16.7.5 Pipings

The inlet to a service reservoir may be kept at any elevation. If provided at the bottom, a non-return valve on the inlet pipe work should be provided so that in case of pipe burst, the water from tank should not flow back through the inlet main. The outlet pipe should be taken out at low level and can be arranged with its invert at floor level provided a sump is constructed just in front of the outlet into which debris (if at all present) will be trapped instead of being swept into the main. The overflow out of service reservoir is an important safety feature. Diameter or number of outlets should be such that maximum inflow to the tank under any circumstances should not rise so high to cause uplift pressure on the roof.

Stop valves must be put on both inlet and outlet mains. These may be made smaller in diameter than the pipeline by some 25% for lesser loss of head. Precautions are to be taken to lay all pipes beneath the surrounding embankment on solid ground so that differential settlement is minimised. When a pipe passes under the embankment and then through the wall of the reservoir, there should be at least two flexible joints incorporated in the line at the back of the wall to permit settlement of the wall without fracture of the pipeline.

16.7.6 Testing for Watertightness

When a concrete reservoir is first filled, it should be left to stand for at least three days to allow the concrete to absorb water. Testing procedure states that total drop in water level over the next seven days should not exceed one thousandth of the average water depth of the full tank for a satisfactory test. In order to save water, it is best to put 0.6 to 0.9 m of water in the tank first so that the floor can be tested. If the floor appears to be watertight, the reservoir should be filled to half depth and then to full depth allowing the tank to stand to permit absorption at each level before taking final accepting test.

If leakage is observed then to detect the leakage path, about 0.6 m of water is put into the tank and be left to stand until water is quite still. Then crystals of potassium permanganate may be dropped into the tank, widely spaced and left for a considerable time. Then descending into the tank with a good and strong light source and walking over a pre-arranged walkway (which is provided in tanks for inspection) so as not to disturb the water, streaks of colour may be noticed from the permanent crystals showing some definite flow towards a point or points of leakage. Figure 16.5 shows typical cross-section of a service reservoir having slopped as well as flat base and Figure 16.6 shows a typical cross-section of a service reservoir having flat base.

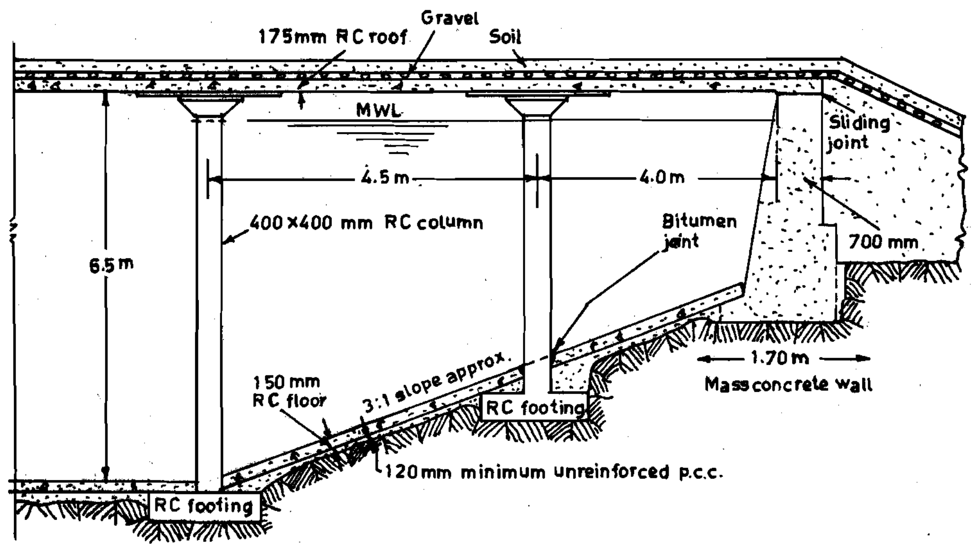

Figure 16.5 : Cross-section of a Distribution Reservoir with Sloping and Flat Floors

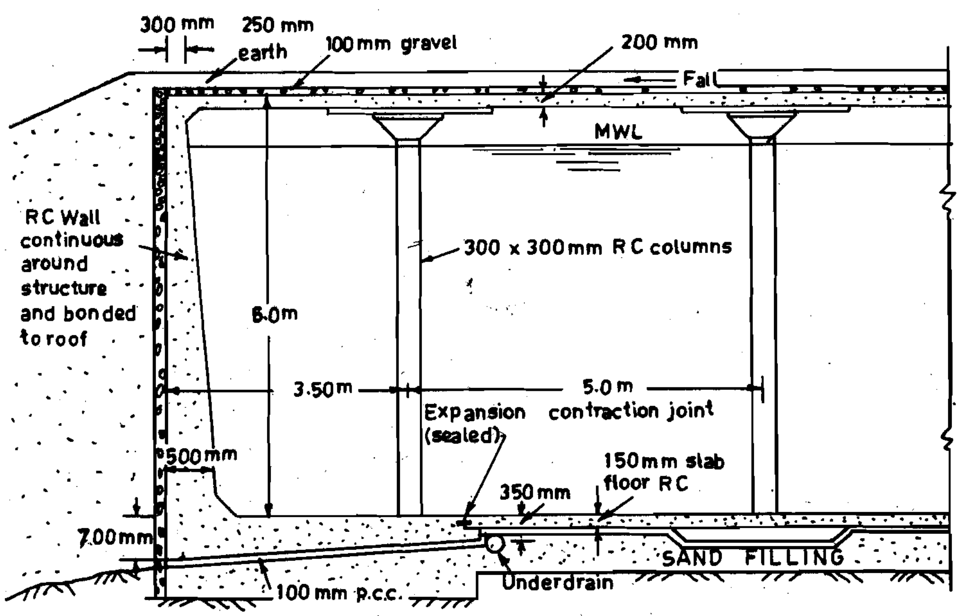

Figure 16.6 : Cross-section of a Small R.C.C. Distribution Reservoir with Flat Roof and Floor

16.8 ELEVATED RESERVOIRS

As discussed earlier, elevated reservoirs are overhead tanks supported on pillars and they may be circular, elliptical or other shapes also to suit the architectural requirement. For details of design, a book of R.C.C. design may be referred where design of components are discussed in detail.

16.8.1 Intz Tanks

An R.C.C. overhead tank of Intz type is most popular now-a-days whenever an overhead tank is to be provided as service or distribution reservoir. A typical cross-section has been shown in Figure 16.7. Intz tanks are structurally sound and economical as well. They are provided for higher capacities. Various accessories for such a reservoir are as follows :

(i) inlet pipe for the entry of water.

(ii) outlet pipe connected to the distribution mains for the delivery of water.

(iii) overflow pipe discharging into drain gutters and maintaining level in the tank.

(iv) an indicator for indicating depth of water, which can be read from outside.

(v) a drain pipe for removing water after cleaning of the tank.

(vi) an automatic device to stop plumping when the tank is full.

(vii) ladder to reach the top of the reservoir and then to the bottom of the reservoir or tank for inspection.

(viii) manholes in the roof for providing entrance into the tank for inspection and minor repairs, if any.

(ix) ventilators for fresh air circulation.

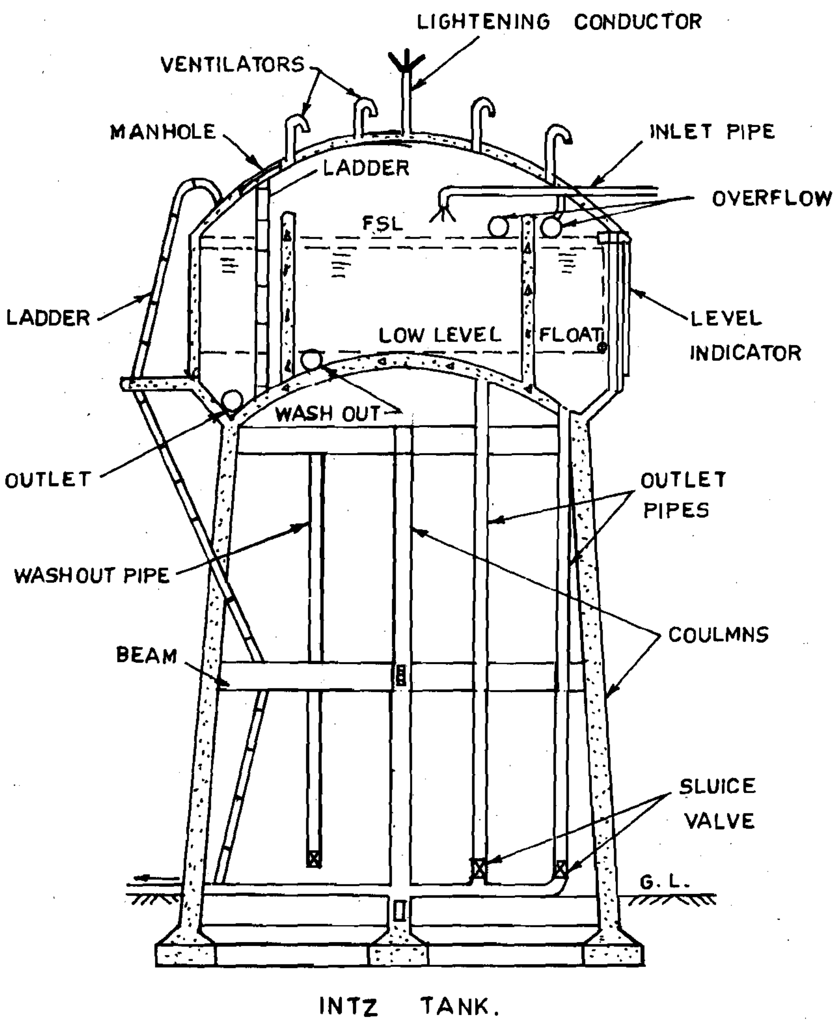

Figure 16.7 : Cross-section of an Intz Tank

16.8.2 Stand-pipes

It has been discussed earlier that stand-pipes are small tanks of diameter 10 to 15 metres. The useful storage of a stand-pipe is the volume above the elevation required to give the required pressure in the distribution system. The water stored below this level is utilised in emergency e.g., fire-fighting with the help of booster pumps. Figure 16.8 shows a typical cross-section of a stand-pipe with connections.

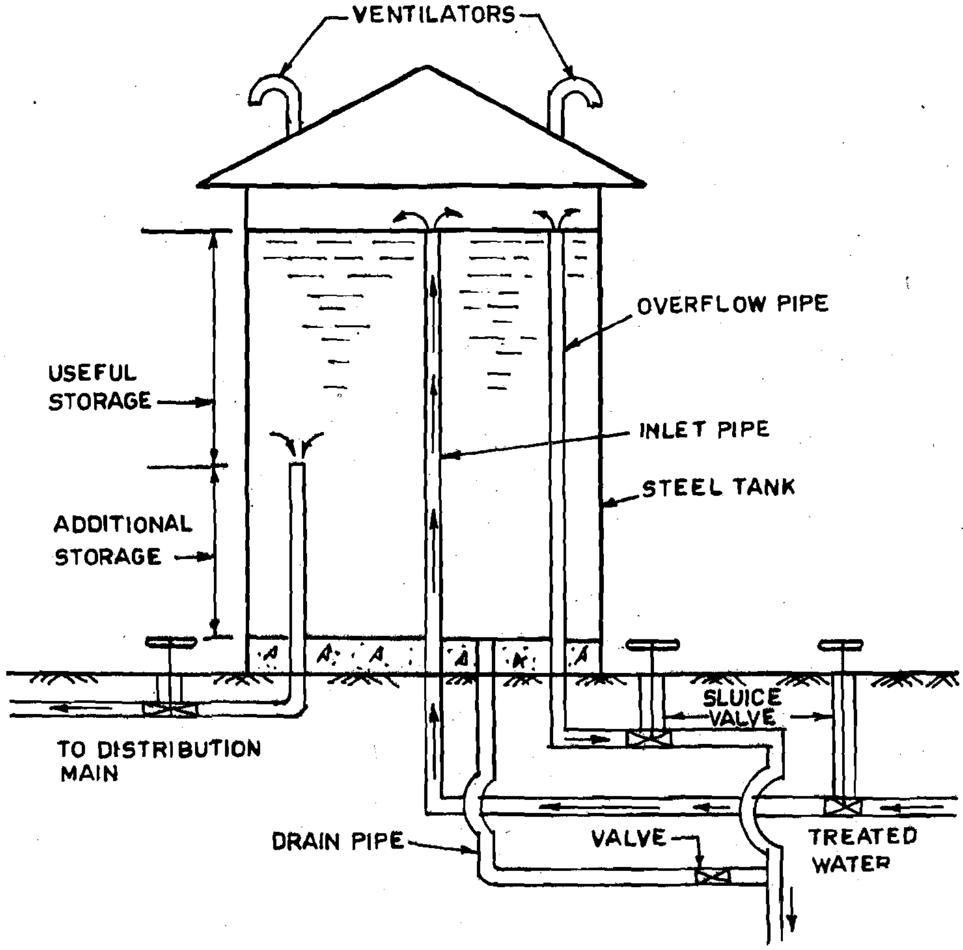

Figure 16.8 : Cross-section of Stand-pipe

SAQ 1

Discuss the graphical procedure for estimating capacity of a distribution reservoir.

(i) when pumping is done continuously for 24 hours.

(ii) when pumping is done for a limited period.

SAQ 2

An overhead tank is to be provided for a town water supply. Given the following data, calculate the minimum capacity of the tank without any fire demand. Tank is empty between 12 to 15 hours.

(i) Average water supply = 16,666 litres / hr

(ii) Rate of Pumping = 25,000 litres / hr

(iii) Hours of pumping = 4 to 12 and 15 to 23 hrs.

No.	Time (hr)	Hours	Draw off factor	Water pumped	Water consumed
1	0 - 4	4	0.2	0	13,333
2	4 - 6	2	1.2	50,000	40,000
3	6 - 10	4	1.8	100,000	120,000
4	10 - 12	2	1.0	50,000	33,333
5	12 - 15	3	0.5	0	35,000
6	15 - 16	1	0.5	25,000	8,333
7	16 - 20	4	1.6	100,000	106,666
8	20 - 23	3	1.0	75,000	50,000
9	23 - 24	1	0.2	0	3,333

SAQ 3

A service water tank is receiving water from the treatment plant at a rate of 200 m^3/hr for 24 hours. The high lift pumps are lifting water from the same tank at following rates: 4-14 hrs @ 120 m^3/hr and 15-24 hrs @ 400 m^3/hr. Determine the capacity for the service water tank.

SAQ 4

Discuss the location and height of distribution reservoirs.

SAQ 5

For a town daily requirement of water for supply to the population is 2 lakhs litres. The pattern of draw off is as follows :

6 a.m. to 9 a.m.	-	30% of day's supply
9 a.m. to 4 p.m.	-	35% of day's supply
4 p.m. to 7 p.m.	-	25% of day's supply
7 p.m. to 6 a.m.	-	10% of day's supply

The pumping is done for 10 hours a day from 8 a.m. to 6 p.m. Find out the storage capacity of the distribution reservoir for the water supply scheme.

16.9 SUMMARY

This unit deals with distribution reservoirs. When they are comparatively smaller in size they are called service or distribution tanks. Service reservoirs are put on surface of the ground or to provide additional head they are put at higher elevation supported on pillars. Smaller elevated service reservoirs are known as stand-pipes. This unit deals with procedure to evaluate or estimate capacity of distribution reservoirs with reference to demand and supply. Details of different components and types with respect to construction have also been discussed.

16.10 KEY WORDS

Booster Pump : A pump installed on a pipe line to raise the pressure of water on the discharge side of the pump.

Draft : Withdrawal of water from a water storage or a reservoir.

Hydrant : A connection extending from a water main to or above the ground surface with valved connection to which a firehose is attached for discharging water at high rate.

Mass Curve or Mass Diagram : A graph of cumulative run-off versus time.

Sump : A depression that receives water or any liquid.

Stand-pipes : Small elevated service tanks of diameter around 10 to 15 metres.

16.11 ANSWERS TO SAQs

SAQ 1

Capacity of a distribution reservoir or balancing storage of a reservoir can be estimated with the help of hydrographs of inflow and outflow by mass curve method.

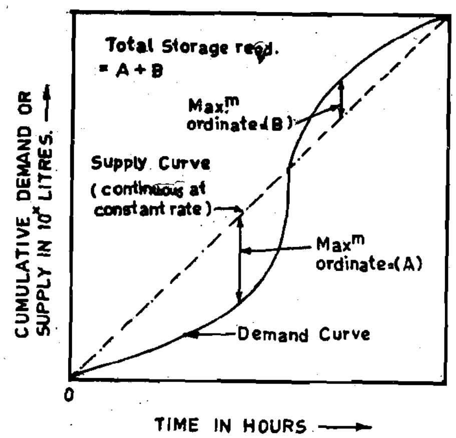

Figure 16.9

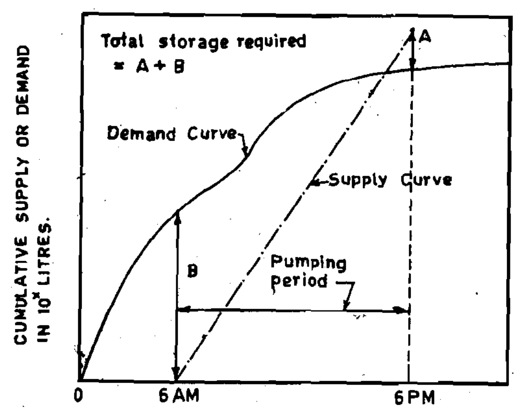

Figure 16.10

A mass curves is drawn for the accumulated supply versus time and over this, demand curve versus time is super-imposed. The amount of balancing storage is determined by adding maximum ordinates between the demand and the supply lines. Figure 16.9 explains the procedure when pumping is done continuously and Figure 16.10 explains the procedure when pumping is done for a limited period.

SAQ 2

Problem has been solved analytically in table given below.

As given in the question, the tank is empty between 12 and 15 hours. Hence, we shall start from Sl. No. 5. At Serial No. 6 storage is (+) 16,666 again at S. No. 7, it has reduced by 6666 litres. Hence, net storage is (16,666-6,666) = 10,000 and so on proceed Sl. No. 8, 9, 1, 2, 3 and finally at 4.

Sl. No.	Time	Hours	Water pumped (Litres)	Water consumed (Litres)	Accumulation (+), draw off Col. 4 - Col. 5	Water in service reservoir in litres
1	2	3	4	5	6	7
1	0 - 4	4	—	13,333	(–) 13,333	18,334
2	4 - 6	2	50,000	40,000	(+) 10,000	28,334
3	6 - 10	4	100,000	120,000	(–) 20,000	8,334
4	10 - 12	2	50,000	33,333	(+) 16,667	25,001
5	12 - 15	3	0	25,000	(–) 25,000	0
6	15 - 16	1	25,000	8,333	(+) 16,667	16,666
7	16 - 20	4	100,000	106,666	(–) 6,666	10,000
8	20 - 23	3	75,000	50,000	(+) 25,000	35,000
9	23 - 24	1	0	3,333	(–) 3,333	31,667

Now from Column No.7, it is clear that maximum balance storage is 35,000 litres. Hence, minimum capacity of the tank should be 35,000 litres (Ans.)

SAQ 3

The problem has been solved in the table given below.

The cumulative supply over demand i.e., excess supply to the tank is 1800 m^3. Hence, the capacity of the tank should be 1800 m^3.

Time in hour	Demand from clear water tank lifted by high lift pumps (m^3)	Cumulative demand from clear tank (m^3)	Supply in the clear water tank (m^3)	Cumulative supply (m^3)	Accumulation (+) Draw off (–) Col.5 – Col.3
1	2	3	4	5	6
0 - 4	Nil	Nil	$200 \times 4 = 800$	800	(+) 800
4 - 14	$120 \times 10 = 1200$	1200	$200 \times 10 = 2000$	2800	(+) 1600
14 - 15	Nil	1200	$200 \times 1 = 200$	3000	(+) 1800
15 - 24	$400 \times 9 = 3600$	4800	$200 \times 9 = 1800$	4800	0

SAQ 4

A distribution reservoir should be located in the centre of the distribution area so that maximum reach could be served. It should be nearer to the area of heaviest demand so that friction loss through pipes is minimum. It is preferable to locate them at the highest elevation available in the area so that sufficient head is available in distribution system. Next point to be considered keeping in view of above points is that they should be placed between pumping station and distribution area. For more detail, refer Section 16.4.

SAQ 5

Total daily requirement = 200,000 litres

Now the cumulative demand covered is tabulated in the table given below :

Period	Rate of Demand	Demand in Litres	Cumulative Demand
6 a.m. to 9 a.m.	30% of 2 lacs litres	60,000	60,000
9 a.m. to 4 p.m.	35% of 2 lacs litres	70,000	130,000
4 p.m. to 7 p.m.	25% of 2 lacs litres	50,000	180,000
7 p.m. to 6 a.m.	10% of 2 lacs litres	20,000	200,000

The mass curve of demand has been plotted in Figure 16.11.

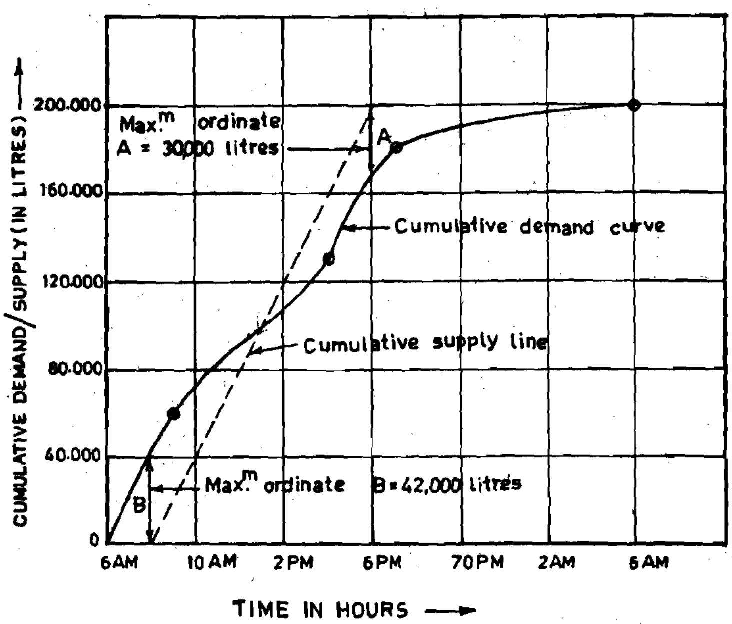

Figure 16.11

Total demand is met in 10 hours

∴ Rate of supply = 200,000/10 = 20,000 litres/hr.

Two maximum ordinates between supply and demand lines are

A = 30,000 litres

B = 42,000 litres

∴ Total storage capacity = A + B = 72,000 litres (Ans.)