CHAPTER 1

INTRODUCTION

1.1 GENERAL IMPORTANCE

Of the many essential elements for the existence of human beings and animals and universally known as air, water, food, shelter etc., water's importance is rated as the highest. Water is considered absolutely essential to sustain life since the protoplasm of many living cells contains about 80 per cent water and any substantial reduction in this level is disastrous. Most of the biochemical reactions which occur in metabolism and growth of living cells involve the medium of water. As such, water is referred as the universal solvent.

It is estimated that two-thirds of the human body is constituted of water. Water is required for the satisfactory performance of physiological organisms, as a circulatory fluid, as a carrier of nourishing food and for the removal of products of wastes.

Man uses water for a variety of purposes. These include drinking, bathing, washing laundering, culinary, heating and air conditioning, irrigation, gardening, industrial processing, power generation, fire fighting, waste disposal, fishing, swimming, boating and other recreational purposes, navigation, fish and wild life propagation. In fact, every activity of man involves some use of water. Further, as water is often drawn from springs, rivers which give rise to site for human habitation and settlement, water has a political significance also.

1.2 DEVELOPMENT OF PUBLIC WATER SUPPLY

The earliest methods of obtaining water supply were (*a*) *natural* (*b*) *artificial*. Natural methods lay in tapping rivers, lakes and natural springs. Many towns and cities are known to have sprung up along such sources of water supply. Artificial methods lay in tapping underground wells. Considering the scanty requirements of the ancients which were mainly for domestic purposes, these sources, natural or artificial, were generally deemed as ample.

As, however, population grew and there was influx of people in urban areas, water had to be made available in adequate quantity near towns and cities. This led to the construction of *underground conduits* and *aqueducts* for the conveyance of water from a distance and subsequent storage to be ultimately distributed to the inhabitants through a pipe-system.

Where the source of water supply happened to be situated lower than the areas to be served, it became necessary to lift water by the installation of pumping machinery, which was, therefore, the next step in the development of public water-supply.

As civilization advanced further, there were rapid expansions in the fields of industry and commerce, the demands on the water supply systems correspondingly increased with higher consumption requiring larger quantities of water and greater and more dependable pressure of supply. This led to the construction of not only underground storage tanks but also of elevated or overhead reservoirs, known as *Service reservoirs*, located in hearts of towns and cities. These amply served to balance the variations in the public demand apart from regulating supplies at adequate pressures.

1.3 HISTORICAL REVIEW

Historically, digging of wells is considered as the most ancient method of obtaining water supply other than from springs and rivers. Mention of wells has been made in Rig Veda dating 4000 B.C. Besides India, wells were also constructed in ancient Greece and Persia. Along with digging of wells, other amenities like rain water storage and water distribution were also installed. Improvements on these water supply installations were made by the construction of infiltration galleries in Athens some 2000 years ago. Later on because of quantitative inadequacy of supplies available through these sources, water was tapped from springs by the Greeks and Romans and conveyed over far off distances through aqueducts. Simultaneously, underground reservoirs were constructed in Egypt and India to serve irrigation purposes.

It was during the Middle Ages that with the destruction of the Roman Empire and the aqueducts built by Romans, the water supply development received a big jolt. The supply of wholesome water became scanty and restricted to big and important cities. The majority of populace took to intake of grossly polluted waters and scourges of water-borne diseases swept the continents of Europe and America. It was only during eightteenth century that further appreciable progress in public water supply was witnessed. Power-operated pumps were introduced. These gave considerable impetus to the construction of modern water works developed in the following century. Besides the installation of a slow sand filter in England in the early eighteen hundred marked the starting point of the rapid development of water treatment in Europe and America. In India, Calcutta was the first city to have a modern water supply system constructed in the year 1870.

1.4 NEED FOR PROTECTED WATER SUPPLIES

From the public health point of view, it is necessary that all water supplies must be invariably free from all types of impurities whether suspended or dissolved in water and no untoward risk should occur to the health of the public as a result of any water contamination. In this respect, it shall be of interest to trace out the various methods for purification of water brought into use since the ancient times.

The earliest method which the ancient people knew for securing potable supplies was by the use of water from wells or springs *i.e.*, ground water. It was believed that such water in the course of its movement through the porous sub-strata was completely relieved of all of its suspended load of impurities.

When the surface waters as from rivers or lakes were used, the method employed was to let such waters remain undisturbed or quiescent for some time till all the turbid suspended particles settled down and clear potable water drawn off from upper layers. This led to the construction of impounding reservoirs.

The next development in the purification methods was through the process of Filtration, allowing water to pass through beds of sand and gravel whereby minute suspended and dissolved particles which could not be removed earlier were caused to be removed. It was found that the process of filtration was greatly accelerated if waters were pretreated with certain substances which when added formed large masses of precipitates or flocs out of the impurities present and which in the process settled down and were ultimately removed. The water pre-treatment process is now called Coagulation, but this process was equally known to the ancients who used solutions of certain vegetables called *nirmali*. Nowadays, alum is chiefly used for this purpose.

The water having undergone through filtration was still found to contain minutely-sized living

1.7 ROLE OF AGENCIES

The agencies involved in making a water supply and sanitation programme really effective are the Government, the community and the sanitary or public health engineers. The Government through its Central and State Administration is admittedly the most logical agency to take the lead in promoting such a programme. It must initiate and promote all such programmes which aim at providing means to the basic necessity *i.e.*, health of its people. Realizing this objective, the Government of India evolved in 1954, the National Water Supply and Sanitation Programme with the primary object of providing throughout the country urban and rural schemes of water supply and sanitation.

Since it is the State Governments which are the implementing agencies for water supply and sanitation programmes, it is important that they should gear up their organisational and administrative machinery in order to utilize the plan funds most efficiently and productively. The organisational pattern for the execution of water supply and sanitation schemes varies in different states. But most of the states have already set up Water Supply and Sewerage Boards while in some states, other different agencies like Public Health Engineering Department, Panchayati Raj, Community Development, Rural Engineering Department and PWD are responsible for the execution of water supply and sanitation schemes. It is necessary that such agencies should be adequately equipped for the design, execution and maintenance of these schemes.

Poor maintenance of existing water supply schemes in rural areas, lack of involvement of the local community in maintenance arrangement, shortage of staff and inadequate funds for maintenance are some of the reasons why the existing water supply schemes have failed to produce the expected results. It is clear that the operation of small rural water supply schemes can only be ensured with the participation of village conmmunity and institution. In case of many of the villages which are generally of small size, it is possible for the block and village level functionaries to take care of relatively simple operation and maintenance requirements of rural water supply schemes.

For water supply schemes, community participation implies the drawing in of such agencies as the local body administration, prominent citizens and individuals. The part played by the community is an important one. It is through the local administration that the projects have to be financially borne and technically supervised on completion. Leading citizens though not sometimes members of the local administration can bring to bear considerable influence and support on the success of the project-programme. The individuals or the people of the community must have the necessary health education and awareness to make them realize the need for safe and wholesome water and the part played by the water supply system in fulfilling that need. Only then, it would be possible to marshal public support and make community active participant in the programme.

Since most of the diseases like cholera, hepatitis, typhoid, fluorosis etc; are caused by polluted water and insanitary conditions, water quality surveillance has to be given due importance. Realizing this, major programmes of water quality testing were undertaken by the Central and State Governments during the eighth plan under which water quality testing laboratories were established in all major districts of the country. Besides, problems were identified and public awareness programmes

QUANTITY OF WATER

2.1 ESTIMATING REQUIREMENTS

Of prime importance in the design of the water supply system, is the framing of an estimate giving the total quantity of water that will be required by the community after the completion of the works. The estimate enables the determination of sizes and capacities of all the constituents of the water supply system. This is arrived at with the help of two factors :

1. The probable population estimated at the end of the design period.
2. Rate of water supply per capita per day.

2.2 DESIGN PERIOD

This is the period into the future for which the estimate is to be made. The period should neither be too long so that full financial burden is not thrown on the present generation, nor should it be too short so as to avoid the design becomimg uneconomical. In practice, a period varying from 20 to 30 years is considered sufficient for design purposes.

2.3 PER CAPITA CONSUMPTION

For the purpose of estimating total requirement of water of a community, it is usual to calculate the consumption on an average basis and express it in litres per capita per day.

If Q is the total quantity of water in litres required by a community per year having P as its population, then the per capita consumption or demand in litres per capita per day (*lpcd*) is given as :

$$= \frac{Q}{P \times 365} \qquad ...(2.1)$$

2.4 FACTORS AFFECTING PER CAPITA CONSUMPTION

The various factors and the way they affect the per capita consumption are started as follows.

(*i*) *Climate*. Hotter places require higher consumption; in domestic use there is more of bathing, in public use more of lawn and street sprinkling. Hotter temperatures also lead to greater use of air conditioning.

(*ii*) *Class of Consumer*. For people having higher economic status and better standard of living, requirements of water supply would be greater.

(*iii*) *Industries and Commerce*. Consumption is usually higher when water supply has to cater for large industrial and commercial uses.

(*iv*) *Quality of Water*. A water works system having a safe and wholesome water supply would always be more popular with consumers who would, consequently, depend less for their requirements upon such sources of water supply as private wells.

...ities having a number of two or three-storeyed buildings. Adequate pressure would mean an uninterrupted and constant supply of water. ...Distribution System. These would be of great importance in the case of

(*vi*) *Extent of Metering System*. Good quality and higher pressure of water supply encourage a more liberal use of water resulting in large wastefulness. The latter is also as a result of charging consumers at flat rates. A metered supply ensures minimum of waste as the consumer then knows that he has to pay for the water used by him and consequently is more careful in use. Meters also help in cutting down waste or loss of water through leaks or breakages in pipes.

(*vii*) *Sewage Facilities*. Where ample facilities of a water-borne sewerage system exist, residences and buildings require more water for flushing of sanitary appliances *viz*., water closets, urinals etc., and for efficient drainage through pipes, drains and sewers.

(*viii*) *System of Supply*. An intermittent system *i.e.*, when water is supplied for certain fixed hours of the day only, results in some reduction of the consumption. This may be due to decrease in losses and other wasteful use.

(*ix*) *Number of Inhabitants*. This would affect the extent to which use is made of private water supply. Thus in large cities, the public water supply is almost a necessity while in small towns and villages, the private supplies may remain in use even long after the introduction of public water supply. Generally, the per capita consumption is found to increase with increase of population. The standards generally recommended for adoption in this country for water supply schemes may be taken as given in Table 2.1 on the next page. These standards are based on the recommendations of Environmental Hygiene Committee of India.

Table 2.1. Effect of Population on Rate of Consumption

Population	*Per Capita consumption in lpcd*[a]	
	Community without sewerage	*Community with sewerage*
1,000–5,000	60	80
5,000–20,000	80	100
20,000–50,000	100	120
50,000–200,000	160	160
Over 200,000	*b*	*b*

'*a*' with maximum permissible variation of 20%.

'*b*' industrial plus commercial uses including air conditioning or 180 lpcd. whichever is greater.

2.5 CONSUMPTION FOR VARIOUS USES

(*a*) *Domestic Use*. This includes water furnished to houses or private buildings for purposes of drinking, washing, bathing, cooking, sanitary and other purposes. This varies according to living conditions of consumers. The standard recommended for use in this country is a minimum of 135 litres per capita per day. This amounts to about 50 per cent of the total consumption.

The consumption standard of 135 litres per capita per day may be estimated as follows :

Drinking and cooking	4.5 lits
Washing clothes, utensils and houses, ablution and bathing	49.5 lits
Water closets	22.5 lits
Trade and industry	22.5 lits

Municipal street watering, public baths, flushing sewers, and extinguishing fires	22.5 lits
Animal drinking and cleansing of stables	13.5 lits
Total	135.0 lits

(*b*) *Industrial and Commercial Use*. This includes water required to be supplied to offices, stores, hotels, factories, breweries, sugar refineries etc. The consumption will vary greatly with the character of the city. An average of about 20 to 25 per cent may be allowed in the design.

(*c*) *Public Use*. This includes water used for public buildings such as schools, hospitals, city halls, jails etc. The water consumption is for sprinkling, flushing streets and fire protection. This may amount to about 10 per cent of the total consumption.

(*d*) *Loss and Waste*. This is the water "unaccounted for" and may be due to bad plumbing, worn or damaged meters, leaky mains, unauthorized water connections and other wastes. This can be minimized by careful maintenance and universal metering. With a fully metered system, it may be considered to be about 15 per cent of the total consumption.

The water supply requirements in case of public buildings of various types are given in Table 2.2 below.

Table 2.2. Water Supply Requirements for Public Buildings other than Residences*

S. No.	*Type of Building*	*Consumption per day (litres)*
1.	(*a*) Factories where bath-rooms are required to be provided	45 per head
	(*b*) Factories where no bath-rooms are required to be provided	30 per head
2.	Hospitals (including laundry) per bed	
	(*a*) No. of beds not exceeding 100	340 per bed
	(*b*) No. of beds exceeding 100	455 per bed
3.	Nurses homes and medical quarters	135 per head
4.	Hostels	135 per head
5.	Offices	45 per head
6.	Restaurants	70 per seat
7.	Hotels	180 per bed
8.	Cinemas, concert halls and theatres	15 per seat
9.	Schools	
	(*a*) Day schools	45 per head
	(*b*) Boarding schools	135 per head
10.	Railway and bus stations	
	(*a*) Intermediate stations (excluding express and mail stops)	
	(*i*) where bathing facilities are provided	45 per head
	(*ii*) where no bathing facilities are provided	23 per head

* IS: 1172–1983 *Indian Standard Code of Basic Requirements for Water Supply, Drainage and Sanitation.* (*Third Revision*)

11.	Junction stations and intermediate stations where mail or express stoppage is provided	
	(a) where bathing facilities are provided	70 per head
	(b) where no bathing facilities are provided	45 per head
12.	Terminal railway and bus stations	45 per head
13.	International and domestic airports	70 per head

Note. For items 10 to 13, the number of persons shall be determined by the average number of passengers handled by the stations daily ; due considerations may be given to the staff and vendors likely to use the facilities.

2.6 FIRE DEMAND

It is the quantity of water required for fire-fighting purposes. As compared to the total consumption, it is meagre seldom more than 5–10 per cent. Heavy demands for brief periods are usually the deciding factors in fixing capacities for pumps, reservoirs and service-pipes of distribution system.

Fire demand is a function of population but with a minimum limit, because greater the population, greater the number of buildings and greater the risk of fire. By the minimum limit of fire demand is meant the amount and rate of water supply required to extinguish the largest possible fire that could be started in the community.

The estimate of fire demand can be made with the help of the following empirical formulae :

National Board of Fire Underwriters Formula : ...(2.2)

$$Q = 4{,}637\sqrt{P}\left(1 - 0.01\sqrt{P}\right)$$

Freeman Formula : ...(2.3)

$$Q = 1{,}136.5\left(\frac{P}{5} + 10\right)$$

Q = Fire Demand in lits. per mt. (lpm)

P = Population in thousands.

The above formula usually gives quite high results. The following empirical formula due to Kuichling has been found to give satisfactory results : ...(2.4)

$$Q = 3{,}182\sqrt{P}$$

At a demand rate to be maintained at a minimum pressure at the hydrant of 1–1.5 kg./sq. cm. lasting for at least four hours and with automobile pumper in service.

Thus, for a population of 100,000, values of fire demand based on the above formulae are :

National Board of Fire underwriters $4{,}637\sqrt{100}\left(1 - 0.01\sqrt{100}\right) = 41{,}733$ *lpm*

Freeman $1{,}136.5\left(\frac{100}{5} + 10\right) = 34{,}095$ *lpm*

Kuichling $3182\sqrt{100} = 31{,}820$ *lpm*

The above formulae suffer from the drawback that these are not related with the type of distric
rved. Thus, although the probability of occurrence of fire with a given duration may be great

for the industrial area than the residential area, the formulae will give same values of the fire demand.

For Indian conditions, we have the following methods which give estimate of fire reserve.

(*i*) *Ministry of Urban Development Formula*

$$Q = 100\sqrt{P} \ lpm \qquad ...(2.5)$$

for communities larger than 50,000.

(*ii*) *Indian Standards** recommend that the fire reserve should be provided at the rate of 1800 lpm for every 50,000 population and an additional 1800 *lpm* for each 1 lakh population more than 3 lakhs. For towns of population 1 lakh and below, the total requirement should be doubled. The fire reserve should be maintained for at least 4 hours.

2.7 INDUSTRIAL DEMAND

For the growth and development of industry and commerce, it is necessary that sufficient quantities of water are made available. As water required would vary depending upon the types of industries, units of production and the different processes involved, a detailed study would have to be made to predict the industrial demand of water. In some cases however, the industries may choose to develop their own water supply arrangements or recycle the waste water for reuse after treatment. This could result in little or no demand on the municipal system. Since zoning the city affects the location of industries, zoning information would also be needed in estimating future industrial demands.

Table 2.3 gives the estimated requirement of water for use in different industries in the country. It would be seen that there is a large variation of water use by industries.

Table 2.3. Water Requirements of Industrial Products

Industry	*Unit of Production*	*Water Requirement (Kilolitres per unit)*
Fertilizer	Tonne	100–200
Distillery	Kilolitre	125–175
Leather	Tonne	45
Automobile	Vehicle	50
Paper	Tonne	300
Textile	Tonne	90–150
Petroleum (crude)	Tonne	1.5–3.0
Steel	Tonne	250
Sugar	Tonne	2

in predictions will be the study of population trends of similar cities and consultations with local officials.

The following methods are generally used for predicting population :

(1) Annual Rate of Increase Method

(2) Arithmetical Progression Method

(3) Geometrical Progression Method

(4) Incremental Increase Method

(5) Changing Rate of Increase Method

(6) Graphical Methods.

These are described as follows :

2.9.1. Annual Rate of Increase Method. In this method, the rate of increase per annum is first determined and the population predicted therefrom.

Thus,

$$P_n = P(1 + i)^n \quad ...(2.6)$$

P_n = Population at the end of n years

P = Population at any time

i = Annual rate of increase of population.

As the rate of increase of population is not a constant, the results obtained are approximate.

2.9.1.1. Example. The population of a certain town was 40,000 in the year 1950 and 50,000 in 1960. Determine its population in the year 1970.

Solution. The increase of population is obtained from

$$i = \sqrt[\frac{1}{n}]{\frac{P_n}{P}} - 1$$

$$= \sqrt[\frac{1}{10}]{\frac{50,000}{40,000}} - 1 = 0.0226$$

$\therefore$ Population in 1970 = $50,000\,(1 + 0.0226)^{10} = 62,500$ **Ans.**

2.9.2. Arithmetical Progression Method. In this method, a constant increase in the growth of population is added periodically. The population may be determined at the end of n years or n decades.

Thus,

$$P_n = P + n_i \quad ...(2.7)$$

P = Present population

i = Per year or per decade increase of population.

The method is good for old cities or small towns which have stabilized. Its use is limited as it gives rather low results.

2.9.3. Geometrical Progression Method. In this, a constant percent age growth is assumed for equal periods of time. Thus, the population at the end of n years or decades is given as :

$$P_n = P\left(1 + \frac{i}{100}\right)^n \quad ..(2.8)$$

where i = Per year or per decade percentage rate of increase.

This method should be used carefully as it may give erroneously high results when applied to young and rapidly advancing cities having expansion of short duration only.

2.9.4. Incremental Increase Method. In this, the average of increase in population is found out as per Arithmetical Progression method and to that is added the average of the net incremental increase once for every future decade. Evidently, this method embodies the advantages of both the preceding methods and the value of population obtained is therefore more correct.

2.9.5. Changing Rate of Increase Method. This is similar to the Geometrical Progression method except that a changing rather than a constant rate of increase is assumed. The changing rate for large and grown up cities is usually considered to be a decreasing rate. This method gives quite rational results.

2.9.5.1. Example. The population figures of a town during the four decades *i.e.*, 1940, 1950, 1960 and 1970 are 20,000, 24,500, 29,500 and 35,200 respectively. Predict its population in the year 1980 and compare the results through the Arithmetical Progression, Geometrical Progression, Incremental Increase and the Changing Increase Rule methods.

Solution. The computation involved in these methods is illustrated through Table 2.3.

Table 2.3. Prediction of Population

Year	*Population*	*Increase per decade*	*Incremental Increase*	*Percentage Increase*	*Decrease in Percentage Increase*
1940	20,000	—	–	–	
1950	24,500	4,500	–	22.5	–
1960	29,500	5,000	500	20.4	2.1
1970	35,200	5,700	700	19.3	1.1
Total		15,200	1,200	62.2	3.2
Average		5,070	600	20.7	1.6

Population in 1980 :

(1) Arithmetical Progression Method

$$= 35{,}200 + 5{,}070 = 40{,}270$$

(2) Geometrical Progression Method

$$= 35{,}200 + \frac{20.7}{100} \times 35{,}200 = 42{,}486$$

(3) Incremental Increase Method

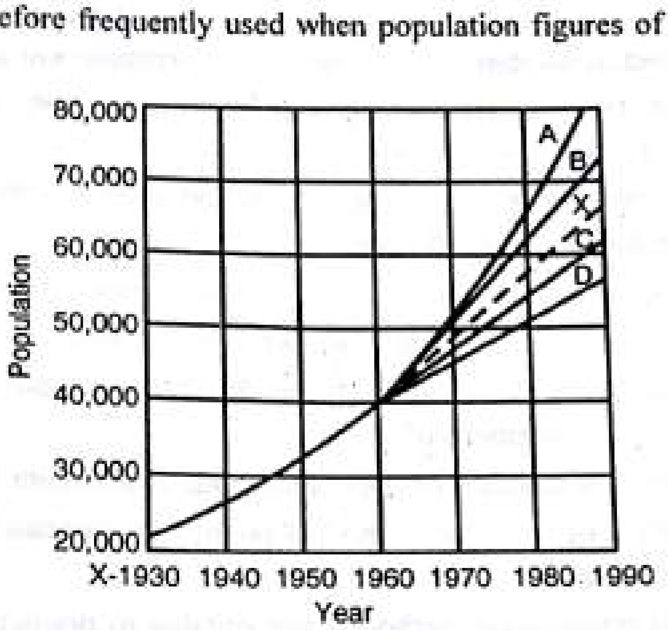
$$= 35{,}200 + 5{,}070 + 600 = 40{,}870$$

(4) Changing Increase Rate Method

$$= 35{,}200 + \frac{19.3 - 1.6}{100} \times 35{,}200 = 41{,}430.$$

The above shows that the predicted population figures of the A.P. and G.P. methods give too low and too high results. Though the figures obtained with the Incremental Increase method are better and lie in between those of the first two methods, the figures of the Changing Increase Rate Method are the most rational and accurate.

2.9.6. Graphical Methods. These mostly involve extension of the plotted data on a population-time curve. Considering towns which were in similar situations over 30 or 40 years ago and drawing graphs of their increase of population, the extension of plotted data for the city under consideration can then be reasonably assumed. This method being logically based gives quite accurate prediction of population and is therefore frequently used when population figures of other similar cities are known.



A	...	1930	1940	1950	1960
B	...	1935	1945	1955	
C	...	1933	1943	1953	
D	...	1934	1944	1954	

Fig. 2.2. Graphical Method of predicting Population.

In Fig. 2.2, the population time curve for the city *X* is plotted upto the year 1960 in which its population was 40,000. City A reached 40,000 in the year 1930, so its curve is plotted from the year 1930 onwards. Similarly curves are drawn for cities B, C and D from the year they reached *X*'s population of 1960 *i.e.*, 40,000. The curve of city *X* can now be continued allowing it to be influenced by the rates of growth of cities B, C and D.