UNIT 1 WATER SOURCES AND REQUIREMENTS

Structure

1.1 INTRODUCTION

Water is a chemical compound of hydrogen and oxygen and can exist in solid, liquid and gaseous form. It is essential for life existence, next only to oxygen in order of importance. One can live without food for a couple of months but cannot survive even for a few days without water. Astronomers and scientists, in their quest for extra terrestrial life, search for traces of water on any planet for the possibility of organic life to exist there.

For normal human requirement, water is used for a variety of purposes, e.g. drinking, washing, and other domestic uses, agriculture, community and industrial uses. For meeting these requirements, a well planned and executed water supply scheme is needed to be designed concentrating on sources of supply, estimation of requirement, testing and maintaining the quality and storage capacity and the distribution network.

In this unit, the basic concepts of water supply scheme planning, sources of supply and requirement estimation are described.

Objectives

After studying this unit, you should be able to

- understand basic concepts of water supply scheme,
- assess and estimate the quantity of water needed for different types of uses,
- study and list various available sources of water,

- know factors which can affect the demand for water, and
- decide the selection criteria of water source selection for different uses, e.g. domestic, commercial or industrial.

1.2 PLANNING FOR WATER SUPPLY SCHEMES

The basic requirement of good planning of a water supply scheme is to ensure adequate amount of quality water supply to community as per their requirements at all the times of need. The essential components of the scheme are collection, storage, treatment, transportation and distribution.

Searching and selection of a perennial source of water is the first step of the collection process. The source should be as near as practicable to the town or area where water is planned to be supplied. More often than not, only one source of supply will not be adequate to meet the quantity requirement and hence more than one source need to be identified, e.g. augmentation of surface water source by exploiting the ground water. The designed water quality and quantity will depend on the requirement needs, which may be different for different user groups. For example, the quality and quantity of water requirement for drinking and domestic uses will be very much different for industrial use. Since natural water, as available from identified sources may not meet the quality standards prescribed for intended uses, some treatment of raw water is essentially required. The treatment process will also be different for different uses and for water from different sources. The water supply scheme including all its aspects of collection, storage, treatment and distribution is required to be so designed that it remains effective for a long life and be flexible enough to meet the changing requirements and increase in demand due to future development. The entire scheme should be easy to construct, economical to maintain and repair and constructed at minimum initial investment.

1.2.1 Financing the Water Supply Schemes

Water supply is an essential community welfare scheme hence its financing has also to be done by community or its agency like municipality, corporation or government. The government either meets this funding need from budgetary grants or by raising bank loans. The burden of capital repayment, in any case, is borne by customers, e.g. public. It is customary that loan is repaid in annual installments over a certain specified period by either capital plus interest method or by the annuity mode. As an alternative a sinking fund may also be created constituting of annual savings invested on a regular basis so that by the end of a certain fixed period sufficient fund is generated to redeem the loan in one single go. The revenue generated from the scheme should be sufficient to meet these repayment schedules along with maintaining the system operational during the whole designed life span. In general enough funding is not generated in a new project after deducting the operational expenses from revenue, hence some form of government grant or subsidy is essential. The requirement of initial investment also needs to be minimised and optimised by adopting appropriate technology and value engineering.

As discussed earlier, supplying adequate quantity of quality water even to the weakest section of the society is the duty and social obligation of the government. This is achieved by a system of water boards, municipalities and corporations. In some states the responsibility lies with Public Health Engineering Departments. The funding requirement is met by outright budgetary allocations, soft loans, and long term loans from national and international agencies, e.g. UNESCO, World Bank, WHO, etc. The loan repayment schedule is sought to be achieved by leving water tax or consumer charges. The demand of water can be controlled under some conditions by pricing policy. It is observed that following relationship may be valid in general conditions :

$$Q_P = k\,P^e \quad \text{or} \quad Q_P \propto P^e \qquad \ldots (1.1)$$

where Q_P is consumption at price P percent of consumption and e represents the measure of elasticity of demand. k is constant of proportionality.

Any increase in price P will thus tend to reduce the consumption, hence the demand. If $e = 0$ or $P^e = 1$, the demand is constant, whatever may be the price. This situation indicates that elasticity of demand is zero. Either the price of water is so low that it has no effect on consumption or the demand is so high that water must be had at whatever cost (in draught conditions). When e is – ve $\left(Q = \frac{1}{P^{(e)}}\right)$ the demand reduces with increase in cost.

1.2.2 Appropriate Technology

Water supply schemes are considered community welfare schemes, more or less a government responsibility throughout the world. In the context of increasing financial constraints and fund crunching, governments or municipal corporations are finding it more and more difficult to wholly sponsor or heavily subsidise such schemes. In addition they are bound to supply the water to economical and weaker sections of the society with little or no revenue return. It is imperative that new and innovative funding schemes are developed. It is also essential at the same time to minimise the cost of scheme by using appropriate technology while planning and designing such schemes.

While, not compromising the quality, the appropriate technology tries cost optimisation by using the simple plants, locally available technology and labour, with minimum energy requirement. Such plants can be easily constructed and maintained by local human resources. By avoiding too much automation, such technologies reduce complexity of operation. Any fault or damage, if occurs during operation, can be repaired locally.

1.2.3 Design Period of Water Supply Scheme

Water supply projects are designed to serve over a specified period of time. This useful life time after completion of the project is called “design period”. It is expressed in years. During design period, the structures, equipment and components of the water supply scheme are supposed to be adequate to serve the requirements. Generally, the water works are designed for a period of 30 years. Following factors are considered while taking a decision on design period of water supply schemes :

(a) Useful life of pipes, equipment and structures.

(b) The anticipated rate of growth. (If rate is more, design period would be less.)

(c) The rate of inflation during the period of repayment of loans. (When inflation rate is high, a longer design period is adopted.)

(d) Efficiency of component units. (The more the efficiency, the longer will be design period.)

As per Indian Standard, average design period of different components are given in Table 1.1

Table 1.1 : Design Period of Different Components of a Water Supply Scheme

Sl. No.	Components	Design Period (Years)
1.	Storage Dams	50
2.	Infiltration Work	30
3.	Pumping	
	i) Prime House (civil works)	30
	ii) Electric Motors and Pumps	15
4.	Water Treatment Units	15
5.	Pipe Connections to several treatment units and other small appurtenances	30
6.	Raw water and clear water conveying mains	30
7.	Clear water reservoirs at head works, balancing tanks and service reservoirs	15
8.	Distribution system	30

Source : *Manual on Water Supply and Treatment : III Edition* (1999).

SAQ 1

(a) Write a short note on planning of water supply schemes.

(b) List the factors which are considered before taking a decision on design period of water supply schemes.

1.3 WATER REQUIREMENT

Water requirement may be divided into following categories :

(a) Domestic.

(b) Institutional.

(c) Industrial.

(d) Public.

(e) Agricultural.

(f) Compensation of losses.

1.3.1 Domestic

Domestic water requirement may be divided as :

- in-house requirement, and
- sprinkling requirement.

In-house requirement includes drinking, cooking, sanitation, house cleaning, bathing, clothes washing etc.

Sprinkling requirement includes water requirement for garden watering, lawn sprinkling, car washing etc.

Domestic consumption under normal condition in an Indian city as per National Building Code, has been taken as 135 litres per head per day (in short designated as l/h/d) or litres per capita per day (lpcd).

Amount of domestic requirement may vary depending on size and location of a city or town. Depending upon location of a place, living habits and conditions, the demand varies. In a more civilized country, per capita requirement of water is more. Similarly, for a big city, per capita water requirement will be more than a small town. Per capita demand for a place may be as low as 75 lpcd to as high as 500 to 600 lcpd. Factors, which affect per capita requirement, are summarized below :

Climatic Condition

In warmer regions, more water is required than colder places because of frequent bathing, more cleaning and more requirement of water for gardening etc. In hot and dry climate, consumption of drinking water is also more.

Status and Habits of Residents

For affluent class of people, more water is required because of their habits and more sophisticated living style. For example, a house of rich people may have bathing tubs where excessive amounts of water may be required per capita. In some of the Asian countries, toilets are cleaned after using it by pouring buckets of water. In addition, for their personal cleaning, people use water. They do not use toilet papers, and in such practice more water is consumed. In some religion, people wash themselves before every prayer and due to such habits also consumption of water varies.

Size and Type of the City

For large city, per capita water requirement is more than that of a small town. For bigger city, where population density is high, special arrangement has to be made for fire fighting also. Although this type of demand may be taken up separately, it enhances per capita water demand. Large cities have sewer system for waste water disposal and for this water requirement may be as high as three times than that of open drain system. A town may be a smaller one but if it is an industrial town then per capita demand may be higher as compared to a big city because of indirect use of water. Although an average value of 135 lcpd is taken for an Indian town but the total demand may go as high as 240 to 260 lcpd for a big or an industrial city. The values varies from 75 lcpd to 260 lcpd depending upon size and location of a town or city.

Availability of Sewer

If sewage system has been provided in the locality, consumption of water will be more and per capita demand may go high, because for flow of sewage in closed conduits sufficient water should be available. Table 1.2 suggests tentative water supply levels for various schemes.

Table 1.2 : Recommended Per Capita Water Supply Levels for Designing Schemes

Sl. No.	Classification of Towns/Cities	Recommended Maximum Water Supply Levels (lpcd)
1.	Town provided with piped water supply but without sewerage system	70
2.	Cities provided with piped water supply where sewerage system is existing/ contemplated	135
3.	Metropolitan and mega cities provided with piped water supply where sewerage system is existing/contemplated	150

Source : *Manual on Water Supply and Treatment : III Edition* (1999).

Mode of Water Supply

Mode of water supply may be continuous or intermittent. In continuous system, water is supplied continuously for 24 hours, whereas in intermittent system, water is supplied at peak demand hours, in morning and evening. Sometimes when sufficient storage of water is available at the source, water is also supplied around noon hours. In both the systems, some advantages and disadvantages are there. In continuous supply, wastage of water may take place through open and cracked joints, whereas in intermittent supply, people leave taps open and when water supply is continued, water is wasted through these open taps. Generally, out of fear, people store more amount of water than required in intermittent supply, and when water supply is started, these collected water in pots and small tanks are thrown and again refilling is done. However, after getting confidence in the water supply system, this practice of temporary storage of water may be discontinued.

Policy for Water Tax Collection

Water tax may be collected by knowing amount of water consumed. This information is obtained by providing water meters at the entrance of premises of the consumers. In that case, controlled water is consumed by consumers. But provision of water meters causes head loss and pump capacity has to be enhanced which may cause additional expenditure. Water meters may go defective and hence do not ensure accurate measurement of consumption. Frequent replacement of meters, may be required which may cause inconvenience to consumers. To overcome this difficulty, water tax is levied on consumers as per assessment. Municipal or water supply agency assesses the size and quality of house and based on some basic consumption principle water tax is assessed. In some cases, water tax is levied on flat rate, which may result in more consumption and wastage of water.

1.3.2 Institutional and Commercial

In addition to domestic demand, water requirement for different institutions is also assessed for a town or city. A well developed city or town has hospitals, schools, restaurants, hotels, railway stations, bus terminus, offices, schools and colleges. To cater to the need for water of these establishments, water requirements of these units needs to be considered while planning for water supply system of a town or city. Bigger the town or city larger will be these requirements. On an average, additional per capita demand for these units may be taken as 25 litres/head/day to 60 litres/head/day depending on the town or city. Approximate water requirements for these units may be taken as given in Table 1.3.

Table 1.3 : Recommended Water Requirement for Various Institutions

Sl. No.	Institutions	Litres per Head per Day
1.	Hospital (including laundry)	
	(a) No. of beds exceeding 100	450 (per bed)
	(b) No. of beds not exceeding 100	340 (per bed)
2.	Hotels	180 (per bed)
3.	Hostels	135
4.	Nurses homes and medical quarters	135
5.	Boarding schools/colleges	135
6.	Restaurants	70 (per seat)
7.	Airports and sea ports	70
8.	Junction stations and intermediate stations where mail or express stoppage (both railways and bus stations) is provided	70
9.	Terminal station	45
10.	Intermediate stations (excluding mail and express stops)	45 (could be reduced to 25 where bathing facilities are not provided)
11.	Day schools/colleges	45
12.	Offices	45
13.	Factories	45 (could be reduced to 25 where bathing facilities are not provided)
14.	Cinema, concert halls and theatres	15

Source : *Manual on Water Supply and Treatment : III Edition* (1999).

1.3.3 Industrial

Industrial water requirement depends on several factors, such as, type of industry, size of industry and number of industries for a particular water supply scheme. A water supply scheme may be planned for a residential town and amount of water requirement may be enhanced to take care for existing or expected industry. Sometimes, a water supply scheme is planned for an industrial area where different types of industry of different sizes are located or likely to come. For very large industry water supply scheme has to be planned for that particular industry in addition to housing and other amenities associated with it. Water requirement for industries located in a town may be taken around 60 litres/head/day but the demand may go as high as 500 litres/head/day depending on type of industry. Table 1.4 gives an idea of water consumption for different kinds of manufacturing industrial units.

Table 1.4 : Industrial Needs of Water

Industry	Unit of Production	Water Requirement in Kilolitres per Unit
Automobile	Vehicle	40
Distillery	(Kilolitre Alcohol)	122-170
Fertilizer	Tonne	80-200
Leather	100 kg (tanned)	4
Paper	Tonne	200-400
Special quality Paper	Tonne	400-1000
Straw Board	Tonne	75-100
Petroleum Refinery	Tonne (crude)	1-2
Steel	Tonne	200-500
Sugar	Tonne (Cane crushed)	1-2
Textile	100 kg (goods)	8-14

Source : *Manual on Water Supply and Treatment : III Edition* (1999).

1.3.4 Public Use

This includes requirement for traffic terminals, fire, public gardens etc.

Requirement for Traffic Terminals and Stations

The water requirements for traffic terminals, such as railway stations, bus stations, harbours, airport etc. include provisions for waiting rooms and waiting halls. For retiring rooms, additional provisions are to be done. As per National Building Code, requirement for water supply for traffic terminals and stations may be taken as given in Table 1.5

Table 1.5 : Water Supply Requirements for Traffic Terminal and Stations

Nature of Station/Terminal	With Bathing Facilities	Without Bathing Facilities
	Litres/Head/Day	
Intermediate Stations (excluding mail and express stops)	45	23
Junction Stations and intermediate Stations where mail or express stoppage is provided	70	45
Terminal stations	45	45
International and Domestic airports	70	70

Estimation of number of persons are done by the average number of passengers handled by the station daily. Consideration should also be given for staff and vendors likely to use these facilities.

Requirement for Fire Fighting

With increase in density of population or at a place, where hazardous activities occur, chances of fire are more. For hazardous industries, such as explosive factories etc., special arrangements are made for fire fighting. For towns and cities, in general, arrangement of additional water supply is made for fire fighting for an accidental fire break out in the locality. Municipalities and corporations make provisions for fire hydrants and for multistorey private buildings in a thickly populated city, some mandatory provisions are enforced for fire fighting. Fire hydrants are generally provided with the water mains at a distance of around 150 meter apart. Fire fighting pumps are connected into them as soon as fire breaks out in the locality. Since pumps throw water on the fire at a very high pressure, the minimum water pressure available at fire hydrants should be around 1.5 kg/sq.cm. and this pressure should be available for around 4 to 5 hours of constant use of the fire hydrant.

As per the existing provisions one third of the fire fighting water requirement should be from storage reservoirs. The balance may be distributed in several static tanks at strategic point, which may be filled by nearest source of water such as streams, ponds or water tankers, etc.

For cities, having population more than 50,000, water required can be estimated as per the equation :

$$Q = 100\sqrt{P}$$

where Q is water required in m^3 and P is population in thousands.

Rate of fire demands can be calculated by Kuichling's formula which gives amount of water required in litres/minute

$$Q' = 3182\ \sqrt{P}$$

where, Q' = Amount of water requirement in litres/min, and

P = Population in thousands.

General Usage of Water

General usage of water for public is not measured separately from trade and industrial consumption in some countries. General or public use may comprise water for fountains, parks, governmental buildings and their grounds etc., which is to be supplied free of charge.

This may vary from nil to around 100 litres/head/day depending upon class and climate of the city. But the public demand for fire fighting, routine fire hydrant testing, temporary building supplies and sewer flushing is normally so small when expressed as an average daily per capita during the year that it seldom needs to be separately estimated.

1.3.5 Agricultural

Public water supply is not used in our country for agricultural purpose. Only in some farm houses, water may be used for kitchen gardens or minor agricultural purpose. In some foreign countries, private water resources are frequently used for farming, especially for irrigation of crops. Public supply is commonly used for dairies, cattle troughs, farm house purposes, horticulture and green house cultivation. An average consumption of these purposes are given in Table 1.6.

Table 1.6 : Agricultural Requirement

Usage	Estimated Consumption
Intensive dairy farming	80 litres/day per hectare of grazing fully utilized or 1350 litre/day per cow
Average agricultural demand for mixed farming	57 litre/day per hectare of farm land
Glass houses	12400 litre/day per hectare in winter and three times of this value in summer.

1.3.6 Per Capita Water Demand

It is defined as the annual average daily requirement of water of one person. It includes domestic requirement, institutional needs, water meant for public use (such as street washing, flushing of sewers etc.), industrial and commercial use and fire fighting, etc.

The average daily per capita demand (lpcd) can be written as

$$\frac{\text{Quantity required in 12 months (in litres)}}{365 \times \text{Population}}$$

Factors Affecting Per Capita Demand

Factors affecting per capita demand may be summarized as listed below.

(a) Habit of inhabitants

(b) Public services

(c) Climate

(d) System of supply

(e) Metering of water supply

(f) System of drainage

(g) Availability of alternative sources

(h) Distribution pressure

(i) Industrialization

(j) Cost of water

Wet processing industries require more quantity of water for cooling operations. However, requirement varies on type and size of the industries.

Planned cities and towns require considerable amount of water for parks, gardens, hospitals and other government institutions.

Although continuous supply is seldom used, in continuous supply more water is wasted. However, in intermittent supply taps may be left open. The best way to solve this problem is to have overhead tanks for buildings through which water may be used by inhabitants wherever required. If water pressure is more, amount of wastage through leakage and joints will be more.

When water charge is taken based on consumed quantity, the consumption comes under control and people try to minimize wastage.

Fluctuations in Demand

Although this average daily demand is supplied at uniform rate throughout day and night. It will not be sufficient because the demand or requirement varies hourly, daily, weekly and monthly. The variations are known as fluctuations in demand.

Monthly Variations

The rate of consumption reaches a maximum in the summer. This high rate usually extends over two to four months depending upon location of the place. In cold countries, a secondary maximum often occurs in the winter owing to the wastage of water to prevent freezing.

Daily Variations

The maximum daily rate may be estimated at about 150% of the average. For the larger cities, the ratio of 150% is seldom exceeded but for the smaller cities the ratio is frequently above 200%. The larger the average consumption, the greater the variation. The maximum daily rate usually occurs in the month of maximum consumption. Thus, where the maximum daily consumption is 150% of the average, the maximum weekly consumption is likely to be about 130% of the average but for longer period of time, the rate will approach the monthly maximum.

Hourly Variations

Hourly variations are very important as they have a very wide range. During active household working hours in the morning around 6 a.m. to 10 a.m., and 4 p.m. to 8 p.m. in the evening, the bulk of water is consumed, especially, in the morning hours. During late hours in night demand is almost negligible. If a fire brakes out, a huge quantity of water is required to be delivered during a short duration and this may necessitate maximum rate of hourly supply. To accommodate all these fluctuation, the supply pipes, service reservoirs and distributing pipes must be properly sized.

Assessment of Variations

After assessing the total water requirement for different uses of a water supply scheme, peak discharge has to be assessed so that the components of the scheme such as source of supply, pipe mains, pumps, filters and allied units, service reservoirs and distribution system may be of sufficient capacity to meet the requirements. The smaller the town, the more variable will be the demand. The maximum monthly, daily or hourly demands are expressed as ratio of their means. For an average Indian town, the maximum daily consumption is taken as 180% of the average. Hence, maximum daily demand = 1.8 × Annual average daily demand.

The maximum hourly consumption is taken as 150% of the average hourly consumption of the day correspondingly to maximum consumption :

∴ Max. hourly consumption or peak demand

= 1.5 × 1.8 × Annual average hourly demand

= 2.7 × Annual average hourly demand

However, Peak factor is normally taken on the basis of size of population of any town or city. Table 1.7 gives the recommended Peak Factors.

Table 1.7 : Peak Factors for Cities and Towns

Sl. No.	Population	Peak Factor
1.	Up to 50,000	3.0
2.	50,001 to 2,00,000	2.5
3.	Above 2 lakh	2.0
4.	For Rural water supply schemes where supply is effected through stand post for around 6 hours	3.0

Source : *Manual on Sewerage and Sewage Treatment : II Edition* (1993).

SAQ 2

(a) List the various categories of water requirement for which provisions are made in water supply schemes. Please give the approximate break-up of each of these provisions if average daily demand of water is 270 lpcd.

(b) What is the importance of Fire Fighting water demand and how is it measured?

(c) Define average daily per capita demand and list the factors affecting it.

(d) Establish following relationship :
Hourly peak factor demand = 2.7 × Annual average hourly demand

1.4 SOURCES OF WATER

The sources of water supply may be divided into following classes according to the general source and the method of collection:

Surface Water

(a) Natural quiescent water in lakes and ponds

(b) Flowing water as in rivers and streams etc.

(c) Artificial quiescent water as in impounding reservoirs

(d) Sea Water

Ground Water

(a) Water from springs

(b) Water from shallow wells

(c) Water from deep and artesian wells

(d) Water from horizontal galleries

1.4.1 Surface Water Sources

Natural Quiescent Water as in Lakes and Ponds

The quality of water of natural ponds and lakes are more uniform in quality than any other flowing sources of water and does not need much purification. If the catchments of the lakes/ponds are protected and non-erodible, it normally does not get in touch with surface contamination and thus its water may be safely supplied just after disinfection. Larger and older lakes permit self purification of water due to sedimentation of suspended matter and removal of bacteria to a greater extent as compared to smaller and newer lakes. However, in still water of lakes and ponds the algae, weed and other vegetation grow freely, causing bad smell, taste and colour etc. Due to low catchment area of the lake basin, quantity of available water is normally less, hence these are not considered as principal source of water supply except in hilly and small towns, where there is no other source of water.

Flowing Water as in Rivers and Streams etc.

The water from rivers and streams etc., contains silt, sand and suspended impurities, beside containing treated or untreated sewage from upstream end. Therefore, water from these sources is considered as less satisfactory in quality than that from lakes or impounding reservoirs. The quality of water is also subject to the widest variation depending on the factors such as property of the catchment area, its climate, geological and topographical features, the extent to which it is subject to contamination from surrounding population, the seasonal variations and weather conditions. Substantial variation in the quality of the water may also occur from point to point along the course of same river. Normally the quality of water deteriorates as stream/river proceeds along its course. The water quality may also vary with maximum and minimum flow conditions.

The perennial and large rivers and streams constitute the main source of water supply scheme. However, the quantity of water available from non-perennial rivers and streams may vary throughout the year depending on weather conditions. It normally falls down during summers when water demand is maximum. Therefore, these are generally not considered as good sources of water supply schemes but may be adopted by providing storage reservoirs and barrages etc. They augment it with other sources of water supply.

The question of the flow through streams may be divided into three parts:

(a) The minimum flow through the stream

(b) The maximum or flood flow

(c) Variation in the flow through successive months and year.

The first information is necessary in case a stream is under consideration from which little storage is obtainable or in answer to the question whether it is practicable to draw water directly from the stream without storage. It is also important in problems of water power where power is to be furnished continuously throughout the year.

The second point is of importance in the design and execution of all river work especially in determining size of waste weirs.

The third determines the supplying capacity of the water shed and the size of the impounding reservoirs.

Artificial Quiescent Water as in Impounding Reservoirs

Impounding reservoirs are formed by the construction of hydraulic structures across the river/stream. In general, water of these reservoirs have less pollution as compared to flowing streams because of settling of solid matters (except colloidal clays) in its relatively quiescent water. The water stored in impounding reservoirs are normally designed for multipurpose schemes and operated so as to get optimum benefits.

The growth of vegetation normally occurs on the top layers of large impounding reservoirs. Vegetation undergoes decay and adds an extra load on natural purification processes. Colour may be added from leaching of vegetable tannins and the subsequent oxidation of these substances to compounds of dark brown colour. Removal of vegetation from time to time is, therefore, essential.

Sea Water

Extracting potable water from sea is a very costly affair. However, it is adopted in the situation where there is no alternative source of water (such as ships on the high sea etc.) is available.

1.4.2 Ground Water Sources

Water precipitated upon the surface of the earth is disposed off in three ways – by evaporation, by surface flow and by percolation.

Percolating water that passes beyond vegetation, passes on downward in obedience to the law of gravitation until it reaches an impervious layer of some kind. The accumulation of water which exists in the ground is called ground water and its top is known as ground water level or ground water table. The volume of water stored in any soil/rock strata depends mainly on porosity (i.e. maximum water storage capacity) and permeability (which determines the ability to transmit water through itself) of rock/soil strata.

To obtain large quantity of water economically, it is necessary that water bearing strata be of open and porous character. The sand and gravel deposits possess high porosity as well as permeability, hence they are considered as most favourable formations for furnishing large quantity of water for public water supply schemes. The clay is highly porous but more impervious (practically nil permeability), whereas lime stone and dolomite possess medium porosity but contain water only if fissured.

The rate of water movement in the strata depends upon two factors; i.e.
(i) permeability of the soil strata, and (ii) driving force for the hydraulic gradient, usually expressed as the ratio between the difference in elevation of the two points on the water table in the direction of flow, and the distance between them.

The quality of ground water mainly depends on the contact of meteoric water with geologic strata in their downward percolation. It provides opportunity for the top soil which is continuously undergoing oxidation with the corresponding production of carbon dioxide. It is natural that percolating water contains gas in solution. Contact of this carbonic acid ($H_2O + CO_2 \rightarrow H_2CO_3$) laden water with lime, magnesia and ferrous iron leads to the solution of these substances. Iron containing sand yields iron-bearing water. Water traversing limestone strata usually contains good concentration of these minerals. Water flowing over and through igneous formations frequently contains little mineral matter. The greater the distance through a given formations water has traveled, the greater will be its mineral content.

Following are the main ground water sources :

Springs

Springs are formed due to emergence of ground water on the earth surface owing to various reasons. Springs may be perennial or intermittent. Normally very small amount of water can be tapped through springs, therefore these are used for supplying water for very small town/localities especially in hilly terrain, that too if the water flow is consistent. The quality of spring water depends on geological and topographical conditions of the strata through which spring water emerges. It may be hard, soft or may contain sulphur or other impurities depending on the type of soil/rock strata through which it passes. The spring water through shallow strata are more prone to get affected by surface pollution as compared to deep water springs.

Normally there are three types of springs as given below :

(a) Surface spring

(b) Gravity spring

(c) Artesian spring

Surface Spring

In this class of spring, water in its lateral movement is brought to the ground surface by the obstruction of any impervious layers (Figure 1.1). Due to the obstruction, underground storage becomes inclined, causing water table to go up and get exposed to ground surface. The yield of water from such springs varies with the variation in the water table and mainly depends on the direction of the slope of ground water surface.

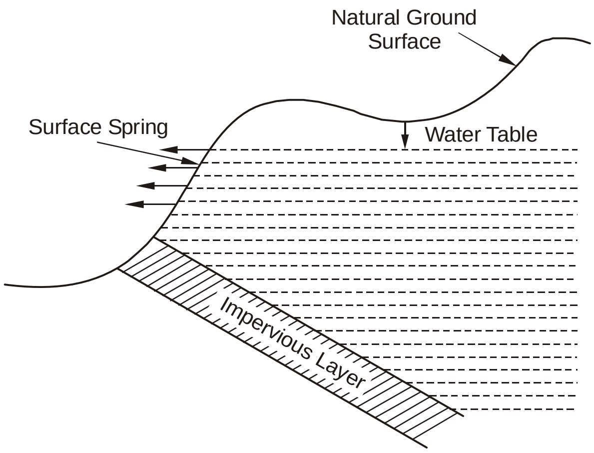


Figure 1.1 : Surface Spring

Gravity Spring

These are formed due to overflow of water to the ground surface through the sides of natural valley of depression, whenever water table becomes high. The yields from such springs have great fluctuations. The flow sometime ceases entirely. Normally a trench is constructed near the spring to meet such fluctuations and provide regular water supply.

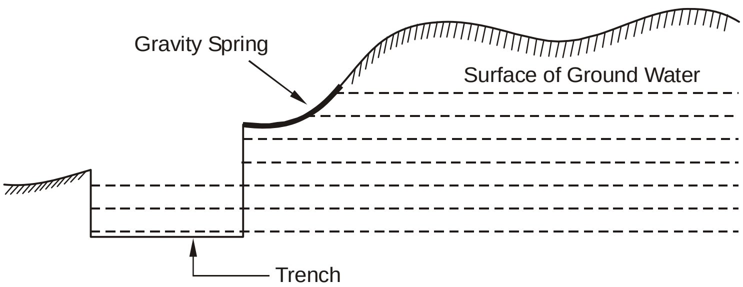


Figure 1.2 : Gravity Spring

Artesian Spring

The artesian springs are formed when water bearing strata is confined between two impervious layers and water comes to the surface under pressure. In this case, water finds its way to the surface where the overlying impervious material is absent or through a fault. It breaks through at places where it is not sufficiently strong or compact to resist the upward pressure.

The yield from artesian spring is often uniform throughout the year. Where a spring of this type exists, it has been found that the ground water stream from which it is fed is of considerable size and the water of the spring is from a small portion of entire flow. In such cases, the yield is increased by enlarging the opening or by sinking wells and pumping from them as in case of ordinary ground water supply.

Development of Ground Water

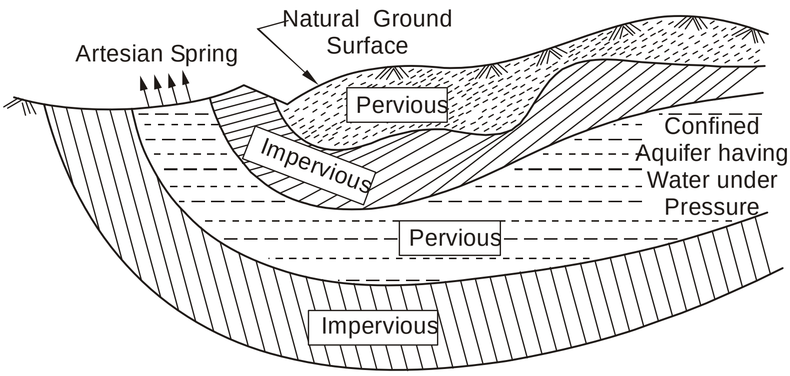


Figure 1.3 : Artesian Spring

Infiltration Galleries

The ground water travels towards lakes, rivers or streams. This traveling water can be intercepted by digging trench or by constructing a tunnel with holes on sides at right angles to the direction of flow of the ground water. These underground tunnels used for tapping underground water are called infiltration galleries. The yield from infiltration galleries varies with its length depending upon the ground condition. For maximum yield, galleries should be placed at the full depth of the aquifer. Infiltration galleries may be constructed with masonry or concrete with deep holes of 5 cm × 10 cm. Infiltration galleries are surrounded on the sides and top with gravel or pebbles to increase their intake capacity. Longitudinal slope is given to the galleries and at the end a sump-well is constructed from which water is pumped out. The rate of flow of ground water into infiltration gallery is given by :

$$Q = KL \frac{H^2 - h^2}{2R}$$

where, Q = Rate of flow in m^3/d,

K = Permeability constant in m/d,

L = Length of the gallery in meter,

H = Initial depth of water level in meter,

h = Final depth of water level in meter, and

R = Radius of influence in meter.

Figure 1.4 shows cross-section of an infiltration gallery.

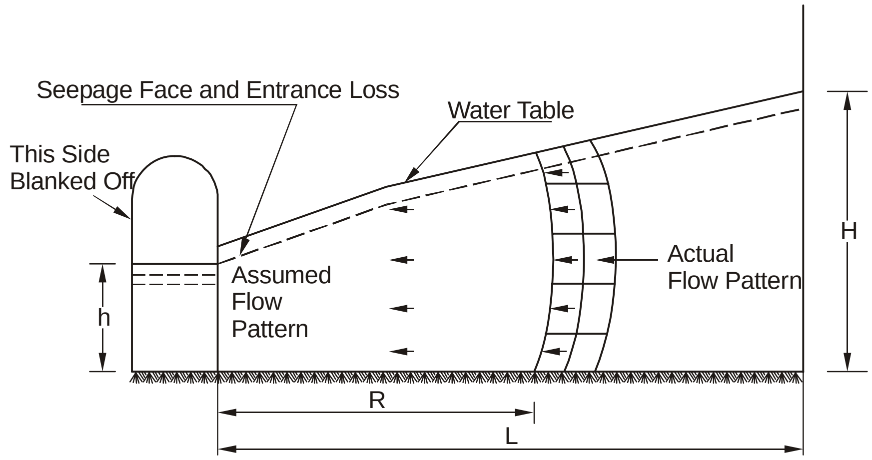
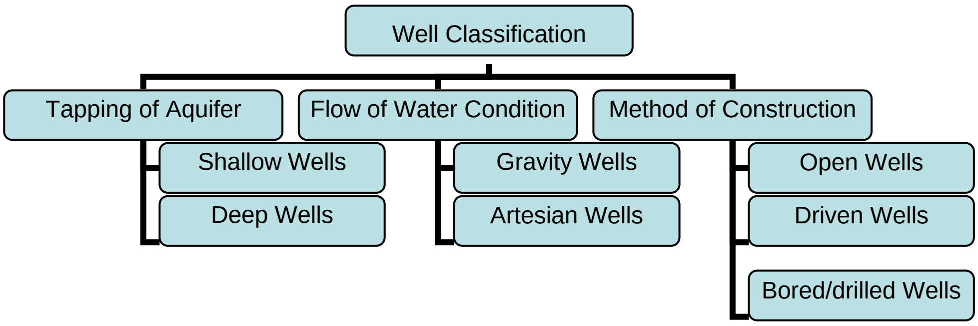


Figure 1.4 : Infiltration Gallery under Equilibrium Condition.

Wells

Wells are usually vertical holes constructed for bringing ground water to the surface. These may be classified on following criteria :



Classification Based on Tapping of Aquifer

Shallow Wells

These wells are in the upper layers of the earth's strata, usually less than 30 metres deep. The water which enters a shallow well is derived from shallow percolation and, therefore, not perfectly purified by natural process. The amount, distance and nature of immediate pollution and the character of underlying strata determine to a large extent, the purity of such water. Location of shallow wells with respect to known pollution source is one of the important criteria in the use of water, especially when large quantities are to be withdrawn.

Unsafe bacteriological condition results if there is carelessness in construction of shallow wells. Dug wells are to be covered with concrete water-tight wall a few meters below the vertical zone of pollution, which usually extends around four to five meters below normal surface level. The lining wall should extend about a metre above the surface grade and cover should be attached with a water tight joint and a man-hole. Driven well is the safest form of shallow wells. Still they should be driven ten metres and more to provide the required degree of protection.

Deep Wells

A deep well is the one which rests on an impervious layer and draws its supply from the pervious formation lying below through a bore hole made into the impervious layer. The impervious layer may be of clay, cemented sand, kankar or other hard materials which are often found lying a few metres below the water table in the sub-soil. The impervious layer gives structural support to the open well resting on its surface. This impervious layer may be continuous or sometimes localized and can be of varying thickness.

These wells are frequently polluted through the surface openings. A newly constructed well, sometimes, shows pollution from the drilling operations, which carry surface matter into the well with tools.

Entrance of surface water should be entirely prevented by every known means. Well pits in which the pipe system is located should be so drained that neither storm nor sanitary water may back-up through the drains into the pits and enter the well. The well casing should extend around one meter above the floor. Because of the longer travel of ground water to reach pervious layer below the top impervious layer, deep well yields safer water than shallow wells.

Classification Based on Water Flow Condition

Gravity Wells

In gravity well, the surface of the water outside and surrounding the well is at atmospheric condition. The flow of ground water in such a well under equilibrium condition is given by :

$$Q = \frac{1.36\ K\ (H^2 - h^2)}{\text{Log}\ \dfrac{(R)}{(r)}}$$

where, Q = Rate of flow into well in m^3/d,

K = Permeability constant in m/d,

H = Depth of water in the well before pumping in meter,

h = Depth of water in the well after pumping = (H – drawdown) in meter,

R = Radius of influence in meter, and

r = Radius of well in meter.

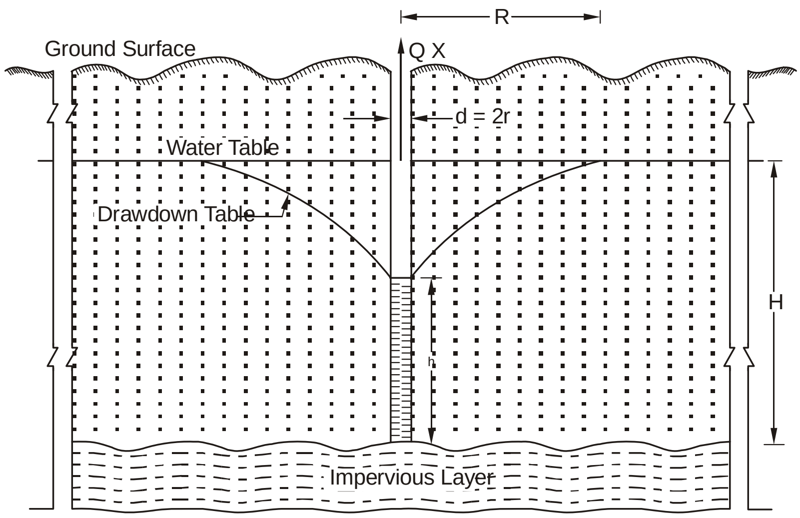


Figure 1.5 : Gravity Well under Equilibrium Condition

Artesian Well

In artesian well, water is drawn from a porous stratum underlying a relatively impervious one and so located that the contained water drawn from a distant elevated outcrop exerts more pressure upon the overlying cover. Due to this property, these are also known as pressure wells.

Whenever a water-bearing stratum dips below a relatively impervious one, the former becomes a closed conduit and if the flow out of this conduit at the lower end is impeded by any cause, the water accumulates and exerts more pressure against the impervious cover. The amount of this pressure depends on the extent to which the flow is obstructed and on the elevation of the upper end of the conduit. If a well is sunk through this impervious stratum at any point, the water rises in it. If surface topography and pressure are favourable, the water may rise to the surface in which case the well becomes a true artesian or flowing well.

The flow of ground water under equilibrium condition in artesian well is confined and is given by :

$$Q = \frac{2.72 \text{ KZ } (H - h)}{\text{Log } \frac{(R)}{(r)}}$$

where, Q = Rate of flow in to well in m^3/d,

K = Permeability constant in m/d,

Z = Thickness of the confined aquifer in meter,

H = Depth of water in the well before pumping in meter,

h = Depth of water in the well after pumping in meter,

R = Radius of influence in meter, and

r = Radius of well in meter.

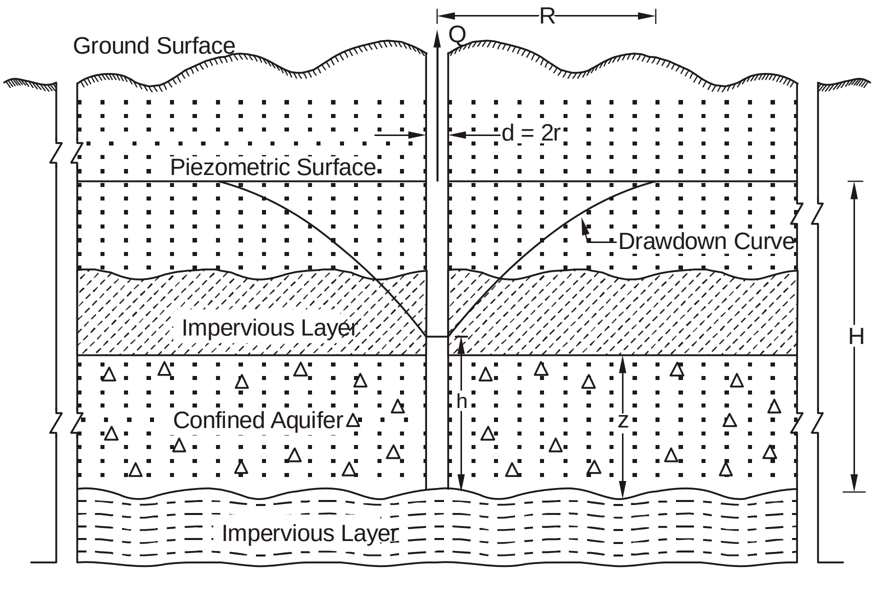


Figure 1.6 : Artesian Well under Equilibrium Condition

In general, the artesian wells have plentiful water and quality-wise it is relatively pure and normally does not need any treatment. However, it is very rare to get ideal artesian conditions.

Classification According to Method of Construction

Dug or Open Wells

In open or dug wells, a hole is made into ground till the flow of water is reached. The depth and the diameter of hole is decided on the basis of seepage area to be exposed for intercepting and the required yield from the sub-soil. Its diameter may vary from 2 meter to 9 meter and depth is normally less than 20 meter. To prevent entry of water directly from the surface, a watertight steining up to few meters below the vertical zone of pollution (normally 3 to 5 meter or more below natural ground surface) is provided. The walls of the steining is normally made of pre-cast concrete or brick/stone masonry and its thickness is kept between 0.50 to 0.75 meter depending on the depth of the well. This method is suitable for water discharge upto 10 m^3/hour.

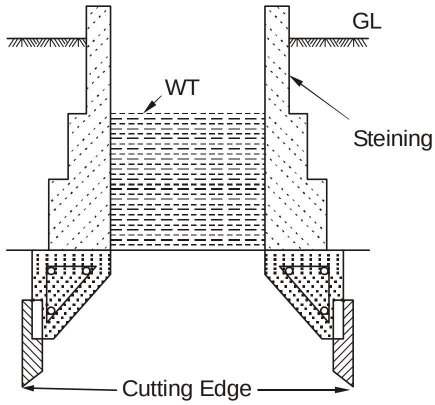


Figure 1.7 : Dug or Open Well

Driven Wells

The driven well mainly consists of tube of 40 meter to 100 meter in diameter. The one end of the tube is closed and pointed and perforated for some distance, while other end (upper) is connected to pump. The pointed end is driven into the ground with the help of heavy wooden blocks until it penetrates water bearing stratum. These types of wells are useful in tapping water from soft soil strata or sand upto the depth of approximately 25 meters or places where water is thinly distributed. Where the well is sunk in sand, the perforated portion of its tube is covered with wire gauge of suitable size depending on the fineness of the sand.

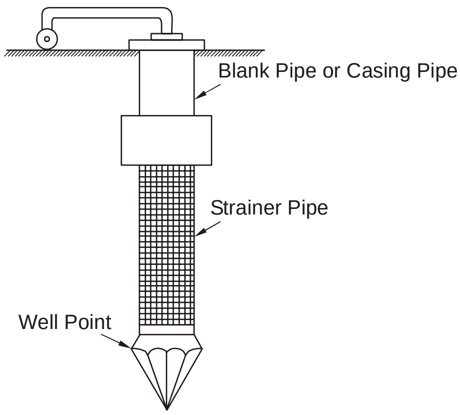


Figure 1.8 : Driven Well

Bored Wells

These are the tubular wells bored or drilled deep into the ground, intercepting one or more water bearing strata to abstract ground water from range(s) of water bearing strata. This method is adopted for the construction of tube-wells. With the help of bored wells ground water can be obtained from both shallow as well as deep aquifers. Discharge upto 40-50 litre per second can be obtained with the help of these wells. Therefore, in India bored/drilled wells are most commonly used for water supply scheme.

1.4.3 Selection of Source of Water

In selecting a particular source of water for a town or city following important points are generally considered:

The Quantity Available

The quantity of water available from the source must be sufficient to meet the various demands during the entire design period of the scheme.

Water Quality

The water available from the source must not be toxic, poisonous or in any other way injurious to health. The impurities present should be such so as to be removed easily and economically by normal and standard treatment methods.

Distance of the Source

The source of water should be situated as near the city or town as possible. When the distance between source and city is less, lesser length of pipe conduits are required which are quite costly.

General Topography of the Intervening Area

The area or land between the source and the city should not be quite uneven. It should not contain deep valleys and high mountains. In case of such uneven topography, the cost of trestles of carrying water pipes in valleys and that of constructing tunnels through mountains will be enormous.

Elevation of the Source of Supply

The source of water must be on a high contour, lying sufficiently higher than the city so as to make the gravity flow possible. When water is available at lower elevation than the average city level, pumping has to be resorted which involves huge installation and operational cost.

SAQ 3

(a) List commonly used surface and ground water sources.

(b) Write short notes on :

- (i) Artesian spring
- (ii) Surface water in river and stream
- (iii) Classification of well

(c) How will you select source of water for water supply schemes? Discuss.

1.5 SUMMARY

In this unit, we have discussed :

(a) Basic concepts in planning of water supply schemes.

(b) Various types of water requirement.

(c) Sources of water.

Whenever water supply scheme is planned, it is essential to ascertain the requirement of water and the probable sources from which the requirement could be met. In case sufficient amount of water as per requirement is not available then either we curtail the requirement if possible and use the source available, or if requirement cannot be curtailed then more than one source is to be searched to supplement total water requirement. In Indian conditions, total water requirement may vary from place to place and climatic conditions besides the status and habit of the residents.

There are mainly two sources of water in Indian conditions, i.e. surface water and underground water. The ground water are generally clearer and free from impurities, while surface water contains suspended impurities and are more polluted. Water sources are selected based on the quantity and quality available, distance of the source from the city, general topography of the intervening area, elevation of the source of supply and total finance available.

1.6 ANSWERS TO SAQs

SAQ 1

(a) Refer Section 1.2.

(b) Normally following factors are considered before taking a decision on design period of water supply schemes :

- Useful life of pipes, equipment and structures.
- The anticipated rate of growth. If rate is more, design period will be less.
- The rate of inflation during the period of repayment of loans. When inflation rate is high, a longer design period is adopted.
- Efficiency of component units. The more the efficiency, the longer will be design period.

SAQ 2

Refer Section 1.3. Breakup of 270 l/hd for a city is given below :

Sl. No.	Categories	Demand in l/h/d
1.	Domestic	135
2.	Industrial	50
3.	Commercial	20
4.	Public use	10
5.	Wastes and thefts	55
	Total	270 l/h/d

(b) Refer Section 1.3.4.

(c) Refer Section 1.3.6

(d) Maximum daily demand = 1.8 × Annual average daily demand.

The maximum hourly consumption is taken as 150% of the average hourly consumption of maximum day.

$\therefore$ Maximum hourly consumption or peak demand

= 1.5 × 1.8 × Annual average hourly demand

= 2.7 × Annual average hourly demand

SAQ 3

(a) Refer Section 1.4.

(b) Refer Section :

(i) 1.4.2

(ii) 1.4.1

(iii) 1.4.2

(c) Refer Section 1.4.3.