28

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GROUND WATER RESOURCES

Ground water resources as the name suggests is the water found underneath the soil. This water falls as the rain fall or snow melt either lost as surface runoff. Some amount also percolates through soil under the influence of gravity and get collects in the soil pore spaces due to the presence of underlying above the impervious layer. In this lesson, you shall learn about the ground water resources which are vitally important for agriculture, industries and day to day living.

OBJECTIVES

After completing this lesson, you will be able to:

- *recall the difference between surface water and groundwater;*
- *list various ways in which groundwater can be obtained;*
- *suggest methods of economical use of water in our homes;*
- *describe how the groundwater is re-charged naturally and through human agencies;*
- *highlight the risk of depletion of groundwater if not properly managed.*

28.1 SURFACE WATER AND GROUNDWATER

Water and water vapour are in constant circulation, powered by the energy from sunlight and gravity as a natural process called hydrologic cycle about which you have learnt in the previous lesson. Water evaporates from the ocean and land surfaces, is held temporarily as water vapour in the atmosphere, and falls back to the earth's surface as precipitation. Source of all freshwater on earth is rainfall. When rainfall occurs, part of it flows on the surface of the land as run-off. The run-off water ultimately gets into a water body like stream, river, pond or lake. This water is called **surface water**.

Part of the precipitation infiltrates below the ground surface into the soil zone. When the soil zone becomes saturated, water percolates downward. A zone of saturation occurs where all the soil pores are filled with water. Part of the rain water slowly infiltrates into the soil under the pull of gravity. Thus, an underground water body is created called **aquifer** and the accumulated water is called **groundwater**. Under the pull of gravity, groundwater flows slowly and steadily through the soil. In low areas it emerges in springs and streams (Fig. 28.1).

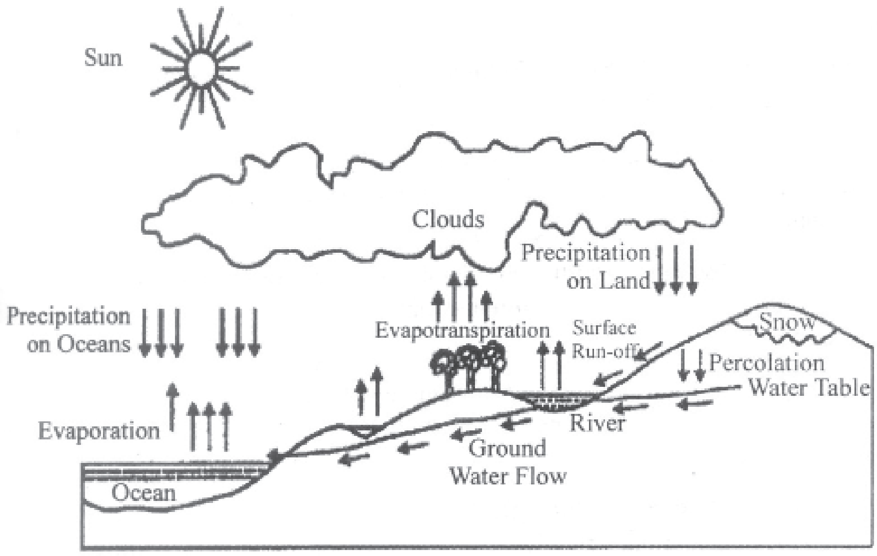

***Fig. 28.1:** Hydrological cycle depicting surface water, groundwater and water table*

Both surface water and groundwater eventually return to the ocean, where evaporation replenishes the supply of atmospheric water vapour. Winds carry the moist air over land, precipitation occurs, and the hydrologic cycle continues. The process of precipitation replenishing the groundwater supply is known as **recharge**. In general, recharge occurs only during the rainy season in tropical climates or during spring in temperate climates. Typically, 10 to 20% percent of the precipitation that falls to the earth percolates through soil and contributes to the water-bearing strata, i.e. aquifer.

Groundwater is constantly in motion. Compared to surface water, it moves very slowly, the actual rate depends on the transmissibility and storage capacity of the aquifer. Sometimes outflows of groundwater take place through springs and riverbeds. The renewal time of groundwater near the water table may be a year or less, while in deep aquifers it may be as long as thousands of years.

Water table also called **groundwater table**, is the upper level of an underground surface in which the soil or rocks are permanently saturated with water (Fig. 28.2). The depth at which the pore space in the soil is completely filled with water and the level at which this occurs is called the water table (Fig. 28.1). The water table separates the groundwater zone that lies below it from the capillary fringe, or zone of aeration, that lies above it. The water table fluctuates both with the seasons and from year to year because it is affected by rainfall and climatic variation. It is also affected by the quantum withdrawal from wells or by artificial recharging.

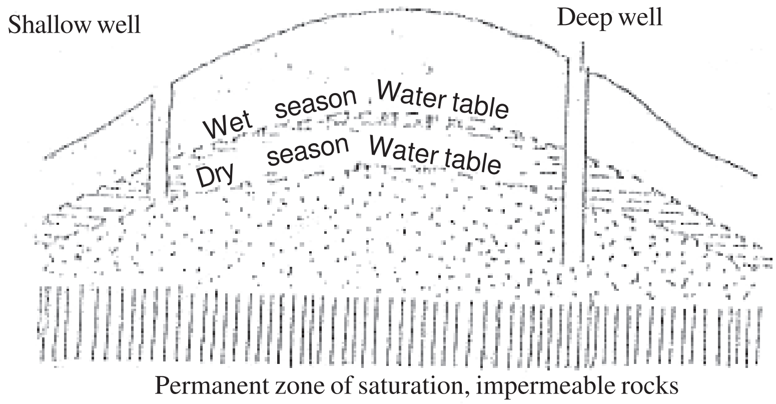

Fig. 28.2: Water Table

Ground water is exploited for domestic use, livestock and irrigation since time immemorial. In India a very large percentage of population depends on groundwater for domestic needs.

The major difference between surface water and groundwater are as follows:

Surface water	Ground water
Surface water is the water which remains on the surface of land in form of streams, rivers, ponds or lakes.	Groundwater is the water which is normally found underground and is obtained by digging wells, tube wells and hand pumps.
Surface water is exposed and can be easily contaminated.	Groundwater is underground (hidden) and thus can not be easily contaminated.
Surface water often needs to be transported to the place of use and is thus expensive.	Groundwater is often available at the place of their use and need not be transported. It is thus cheaper.
Surface water can not be directly consumed as it is contaminated.	Groundwater is mostly un-contaminated and can be directly consumed.
Surface water is exposed and subject to evaporation losses and thus less dependable in times of drought.	Groundwater is underground and does not get lost due to evaporation. It is thus more dependable in times of drought.

INTEXT QUESTIONS 28.1

1. What is groundwater?

____

2. Where does it come from?

____

3. What is an aquifer?

4. What do you mean by water table?

28.2 GROUNDWATER SOURCES

The value of an aquifer as a source of groundwater depends on the porosity of the geologic layer, of which it is formed. Water is withdrawn from an aquifer by pumping it out of a **well** or **infiltration gallery**. An infiltration gallery typically includes several horizontal perforated pipes radiating outward from the bottom of a large-diameter vertical shaft. Wells are constructed in several ways, depending on the depth and nature of the aquifer. Wells used for public water supplies, usually more than 100 feet (30 metres) deep and from 4 to 12 inches (10 to 30 cm) in diameter, must penetrate large aquifers that can provide dependable yields of good-quality water. A submersible pump driven by an electric motor can be used to raise the water to the surface.

28.2.1 Methods of groundwater abstraction

There are large number of methods to obtain groundwater. The most common methods are as follows:

1. **Springs:** The water table generally follows the topography of the ground surface. The slope in the water table profile results in sub-soil flow. Groundwater movement is comparatively very slow as compared to surface water. The flow depends on slope and permeability. When the water table is above the surface water level in some hilly areas, groundwater flows out as a spring. This spring water can be easily used as source of drinking. The oldest water supplies to towns as in Rome, Lyon were from such sources. A majority of our hilly population depends on such sources in Himalayan regions.
2. **Dug-well:** It covers ordinary open wells of varying dimension dug or sunk from the ground surface into water bearing stratum to extract water for irrigation purposes. These are broadly masonary wells, kuchcha wells and dug-cum-bore wells. All such schemes are of private nature belonging to individual cultivator.
3. **Shallow tube-well:** It consists of a bore hole built into ground with the purpose of tapping ground water from porous zones. The depth of a shallow tube well does not exceed 60-70 m. The tube wells are generally operated for 6 to 8 hours during irrigation season and give yield of 100-300 m/day, which is roughly 2 to 3 times that of a dug well.
4. **Deep tube well:** It usually extends to the depth of 100 m and more and is designed to give a discharge of 100 to 200 cubic m/h. These tube wells operate round the clock

during the irrigation season, depending upon the availability of power. Their annual output is roughly 15 times that of an average shallow tube well.

5. **Handpump:** Handpumps are commonly used to draw groundwater in villages and slum areas in urban centres. These are manually operated. Thus no electricity or other power is required to operate them.

28.3 ECONOMIC USE OF WATER

a. At home

Economic water use can have major environmental, public health, and economic benefits by helping to improve water quality, maintain aquatic ecosystems, and protect drinking water resources. By using water more efficiently and by purchasing more water efficient products, we can also help mitigate the effects of drought. Efficiency measures can also save money on water and energy bills.

Bathroom	Kitchen and Laundry	Garden and landscaping	Equipment
• Do not let the water run while shaving or brushing teeth use mug while shaving or brushing teeth. • Take short showers instead of tub baths. Turn off the water while soaping or shampooing. • If you must use a tub, close the drain before turning on the water and fill the tub only half full. Bathe small children together. • Never use your toilet as a waste basket.	• Simple practices save a lot of water. • Store drinking water in the refrigerator. • Wash fruits and vegetables in a basin. Use a vegetable brush. • Do not use water to defrost frozen foods; then ahead of use. • Scrape, rather than rinse, dishes before loading into the dishwasher. • Add food wastes to your compost pile instead of using the garbage disposal. • Wash only full loads of laundry or use the appropriate water level or load size selection on the washing machine. **Note:** Homes with high-efficiency plumbing fixtures and appliances save about 30% of indoor water use and yield substantial savings on water, sewer, and energy bills.	• Depending on climate, up to 75% of a home's total water use during the growing season is for outdoor purposes. • Detect and repair all leaks in irrigation system. • Use properly treated wastewater for irrigation wherever available. • Water the lawn or garden during the coolest part of the day (early morning is best). Do not water on windy days. • Water trees and shrubs, which have deep root systems, for a longer time and less frequently than shallow-rooted plants that frequently require smaller amounts of water. Check with the local extension service for advice on watering needs in your area. • Set sprinklers to water the lawn or garden only – not the street or sidewalk. • Use soaker hoses or trickle irrigation systems for trees and shrubs. • Install moisture sensors on sprinkler systems. • Use mulch around shrubs and garden plants to reduce evaporation from the soil surface and to cut down on weed growth. • Minimize or eliminate fertilizing, which promotes new growth needing additional watering. • Do not use water that contains bleach, automatic-dishwashing detergent or fabric softener for irrigation.	• Install low-flow faucet aerators and showerheads. • Consider purchasing a high efficiency washing machine which can save over 50% in laundry water and energy use. • Repair all leaks. A leaky toilet can waste about 1000 litres per day. To detect leaks in the toilet, add food coloring to the tank water. If the colored water appears in the bowl, the toilet is leaking.

b. Outdoor uses

- Sweep driveways, sidewalks and steps rather than using hose pipes to wash them.
- Wash the car with water from a bucket, or consider using a commercial car wash that recycles water.
- When using a hose, control the flow with an automatic shut-off nozzle.
- Avoid purchasing recreational water toys which require a constant stream of water.
- Consider purchasing a new water-saving swimming pool filter.
- Use a pool cover to reduce evaporation when pool is not being used.
- Do not install or use ornamental water features unless they recycle the water. Use signs to show the public that water is recycled. Do not operate during a drought.

INTEXT QUESTIONS 28.3

1. State two ways each for saving water.

   (a) in bathrooms

   (b) at kitchen

2. Suggest two ways of judicious uses water while gardening and landscaping.

3. Give any two other judicious uses of water.

28.4 ARTIFICIAL RECHARGE

The increasing demand for water has increased awareness towards the use of artificial recharge to augment ground water supplies. Stated simply, **artificial recharge** is a process by which excess surface water is directed into the ground – either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration. In other words, to replenish an aquifer. Recharge refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet the demand in times of shortage.

28.4.1 Direct artificial recharge

a. Spreading basins

This method involves surface spreading of water in basins which are excavated in the existing terrain. For effective artificial recharge highly permeable soils are suitable and maintenance of a layer of water over the highly permeable soils is necessary.

b. Recharge pits and shafts

Conditions that permit surface spreading methods for artificial recharge are relatively rare. Often areas of low permeability lie between the land surface and water table. In such situations artificial recharge systems such as pits and shafts could be effective.

Unfiltered runoff waters leave a thin film of sediment on the sides and bottom of the pits which require maintenance in order to sustain the high recharge rates. Shafts may be circular, rectangular, or of square cross-section and may be backfilled with porous material. Excavation for making pits and shafts may terminate above the water table level or may by hydraulic connectors extend below the water table. Recharge rates in both shafts and pits may decrease with time due to accumulation of fine grained materials and the plugging effect brought about by microbial activity.

c. Ditches

A ditch could be described as a long narrow trench, with its bottom width less than its depth. A ditch system can be designed to suit the topographic and geologic conditions that exist at a given site. A layout for a ditch and a flooding recharge project could include a series of ditches trending down the topographic slope. The ditches could terminate in a collection ditch designed to carry away the water that does not infiltrate. This would reduce the accumulation of fine material.

d. Recharge wells

Recharge or injection wells are used to directly recharge water into deep water-bearing zones. Recharge wells are suitable only in areas where a thick impervious layer exists between the surface of the soil and the aquifer to be replenished. They are also advantageous where land is scarce. A relatively high rate of recharge can be attained by this method.

28.4.2 Indirect methods of recharging

a. Enhanced streambed infiltration (induced infiltration)

This method of induced recharge consists of setting a gallery or a line of wells parallel to the bank of a river and at a short distance from it. Without the wells there would be unimpeded outflow of groundwater to the river. When small amounts of groundwater are withdrawn from the gallery parallel to the river, the amount of groundwater discharged into the river decreases. The water recovered by the gallery consists wholly of natural groundwater. Each groundwater withdrawal is accompanied by a drawdown in the water table. For high recovery rates this drawdown tends to lower the groundwater table at the shoreline below that at the river. Thus, surface water from the river will be induced to enter the aquifer and to flow into the gallery. In areas where the stream is separated from the aquifer by materials of low permeability, leakage from the stream may be so small that the system is not feasible .

b. Conjunctive wells

A conjunctive well is one that is screened in both a shallow confined aquifer and a deeper artesian aquifer. Water is pumped from the deeper aquifer and when its surface is lowered below the shallow water table, water from the shallow aquifer drains directly into the deeper aquifer. Water augmentation by conjunctive wells has the advantage of utilizing sediment-free groundwater which greatly reduces the damage of clogging well screens.

28.4.3 Advantages of artificial recharge

- While recharging, rain and surface water infiltrate the soil and percolate down through the various geological formations and get naturally cleansed.
- Very few special tools are needed to dig drainage wells.
- In rock formations with high, structural integrity few additional materials may be required (concrete, softstone or coral rock blocks, metal rods) to construct the wells.
- Groundwater recharge stores water during the wet season for use in the dry season, when demand is highest.
- Aquifer water can be improved by recharging with high quality injected water.
- Recharge can significantly increase the sustainable yield of an aquifer.
- Recharge methods are attractive, particularly in arid regions.
- Most aquifer recharge systems are easy to operate.
- In many river basins, control of surface water runoff to provide aquifer recharge reduces sedimentation problems.
- Recharge with less-saline surface waters or treated effluents improves the quality of saline aquifers, facilitating the use of the water for agriculture and livestock.

28.4.4 Disadvantages of artificial recharge

Artificial recharge has some disadvantages too:

- In the absence of financial incentives, laws, or other regulations to encourage land owners to maintain drainage wells adequately, the wells may fall into disrepair and ultimately become sources of groundwater contamination.

- There is a potential for contamination of the groundwater from injected surface water runoff, especially from agricultural fields and road surfaces unless the surface water runoff is not pre-treated before injection.
- Unless significant volumes are injected into an aquifer, groundwater recharge may not be economically feasible.
- The hydrogeology of an aquifer should be investigated and understood before any future full-scale recharge project is implemented.

INTEXT QUESTIONS 28.4

1. What is artificial recharge?

   ____

2. State two methods by which groundwater can be recharged artificially.

   ____

3. Give two advantages and disadvantages of artificial recharge?

   ____

28.5 GROUNDWATER QUALITY

Ground water plays an important role in India, particularly as a drinking water source. Groundwater has a number of unique features that render it particularly suitable as a water supply source. The unique features are:

1. Generally uncontaminated and thus can be consumed directly without any treatment;
2. It can be available in close proximity to place where it is required as it is widely distributed;
3. It is dependable and relatively less affected by drought;
4. Large storage, treatment and distribution can be avoided.
5. It is less expensive.

For the reasons mentioned above, nearly 85% of India's population today is dependent on groundwater for their domestic demands. Groundwater is particularly important as a source of drinking water in rural areas. Groundwater also plays an important role in agriculture, for both irrigation and bathing cattle.

Industrial demands for groundwater are also high, as many prefer to use groundwater for the unique features mentioned above.

Groundwater quality is being increasing threatened by agricultural, urban and industrial wastes, which leach or are injected into underlying aquifers. Once pollution has entered the sub-surface environment, it may remain concealed for many years and become dispersed over wide areas, rendering groundwater supplies unsuitable for human uses.

28.5.1 Reasons for declining ground water quality

A vast majority of groundwater quality problems are caused by contamination, over-exploitation, or combination of the two. Most groundwater quality problems are difficult to detect as they may be concealed below surface. They are also hard to resolve. The solutions are usually very expensive, time consuming and not always effective. Many times the contamination is not detected until noxious substances actually appear in water used, by which time the pollution has often dispersed over a large area.

All kinds of activities, urban, industrial or agricultural carried out on land have the potential to contaminate groundwater. Industrial discharges, landfills and subsurface injection of chemicals and hazardous wastes, are an obvious source of groundwater pollution. These concentrated sources can be easily detected and regulated but the more difficult problem is associated with diffuse sources of pollution like leaching of agrochemicals and animal wastes, subsurface discharges from latrines and septic tanks and infiltration of polluted urban run-off and sewage where sewerage does not exist or defunct. Diffuse sources can affect entire aquifers, which is difficult to control and treat. The only solution to diffuse sources of pollution is to integrate land use with water management. Table 28.1 presents land-use activities and their potential threat to groundwater quality.

Table 28.1: *Land-use activities and their potential threat to groundwater quality*

Land Use	Activities potential to groundwater pollution
Residential activities	• Unsewered sanitation. • Land and stream discharge of sewage. • Sewage oxidation ponds. • Sewer leakage, solid waste disposal, landfill. • Road and urban run-off, aerial fall out.
Industrial and Commercial activities	• Process water, effluent lagoon. • Land and stream discharge of effluent. • Tank and pipeline leakage and accidental spills. • Well disposal of effluent. • Aerial fall out. • Landfill disposal and solid wastes and hazardous wastes. • Poor housekeeping. • Spillage and leakages during handling of material.
Mining	• Mine drainage discharge. • Process water, sludge lagoons. • Solid mine tailings. • Oilfield spillage at group gathering stations.
In Rural areas	• Cultivation with agrochemicals. • Irrigation with wastewater. • Soil salinization. • Livestock rearing.
Coastal areas	• Salt water intrusion.

28.5.2 Common groundwater contaminants

1) **Nitrates:** Dissolved nitrates commonly contaminate groundwater. High level of nitrates can cause blue baby disease (Methaemoglobinaemia) in children, may form carcinogens and can accelerate eutrophication in surface waters. Sources of nitrates include sewage, fertilizers, air pollution, landfills and industries.

2) **Pathogens:** Poor hygiene of well and inadequate segregation of drainage charcoal from wells may cause pathogenic contamination of good water seepage from solid waste dumps and municipal drains may also cause pathogenic contamination. Bacteria and viruses cause water borne diseases such as typhoid, cholera, dysentery, polio, and hepatitis may pass into groundwater through discharges from sewage, landfills, septic tanks and livestock shelters.

3) **Trace metals:** Include lead, mercury, cadmium, copper, chromium and nickel. These metals can be toxic and carcinogenic. Seepage of industrial and mine discharges, fly ash ponds of thermal power plants can lead to metals in groundwater.

4) **Organic compounds:** Seepage of agricultural run off loaded with organic compounds like pesticides and may cause pesticide pollution of ground water.

INTEXT QUESTIONS 28.5

1. How do mining activities affect groundwater?

2. Name any two contaminants of groundwater.

3. State two reasons for the decline of quality of groundwater.

28.6 RISK OF DEPLETION OF GROUNDWATER

The demand for water has increased over the years and this has led to water scarcity in many parts of the world. About 2 billion people, approximately one-third of the world's population, depend on groundwater supplies, withdrawing about 20% of global water (600-700 km3) annually — much of it from shallow aquifers. The situation is aggravated by the problem of water pollution or contamination. Groundwater problems are becoming increasingly serious in many areas of the world. Rapid increase in the rates of pumping of groundwater in many aquifers has caused a steady lowering of water table levels where extraction of water has exceeded rates of recharge.

28.6.1 Causes of groundwater depletion

Groundwater crisis is not the result of natural factors:

1. It has been caused by human actions. During the past two decades, the water level in several parts of India has been falling rapidly due to an increase in extraction. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately increased. India's rapidly rising population and changing lifestyles has also increased the domestic need for water.
2. The water requirement for the industry also shows an overall increase. Intense competition among users as an agriculture, industry, and domestic sectors is steadily lowering the groundwater table. The quality of groundwater is getting severely affected because of the widespread pollution of surface water. Besides, discharge of untreated waste water through bores and leachate from unscientific disposal of solid wastes also contaminate groundwater, thereby reducing the quality of fresh water resources.
3. Unlike surface storage, the groundwater is slow in accumulation. Groundwater has two components. One, a static part, and the other is dynamic, which comprises annual additions due to recharge. The quantum of yearly use needs to be limited. During deficit years, however, a part of static componnent is drawn for use expecting recuperation during the next surplus year. Dependence on static storage for long amounts to mining of groundwater. Ideally, the age of groundwater used should be as young as possible. Greater the age means longer the period for which mining has been carried out.

28.6.2 Risks

Groundwater depletion is a pressing challenge for India. Groundwater played an important role in sustaining India's green revolution. The high-yielding varieties of crops which all increasing agricultural productivity, depended on the timely application of water. This led to a spurt in groundwater structures with enterprising farmers making technological and institutional innovations not only to extract groundwater, but also to transport it to the fields of other farmers – giving rise to flourishing groundwater markets.

1. Falling water tables in several states now threaten agricultural sustainability. This has been encouraged by policies for cheap electricity and the absence of a property rights structure for water withdrawals.
2. During rainy season, availability of water from precipitation is far in excess of natural and man-made holding capacity which results in floods. During the non-rainy period, high evaporation rates coupled with high water demands cause drought conditions requiring import of water. Flood and drought thus constitute the extreme manifestations of hydrologic cycle. The situation is exacerbated due to depleting forest cover in the country.

3. The supply of groundwater is not unlimited, nor it is always available in good quality. In many cases, the abstraction of excessive quantities of groundwater has resulted in the drying up of wells, salt-water intrusion and drying up of rivers that receive their flows in dry seasons from groundwater.

4. The water found in groundwater bodies is replenished by drainage through the soil, which is often a slow process. Rates of groundwater recharge are greatest when rainfall inputs to the soil exceed evapotranspiration losses. When the water table is deep underground, the water of the aquifer may be exceedingly old. The water is being used extensively for water supply and irrigation purposes, which might be thousands of years old. The use of such water, which is not being recharged under the current climatic regime, is termed groundwater mining.

5. In India and Bangladesh, millions of people are exposed to groundwater contaminated with high levels of arsenic, a highly toxic and dangerous pollutant. It has been estimated that close to 5 million people in West Bengal, India are affected. In next-door Bangladesh, half the entire population of 120 million are exposed to elevated levels of arsenic in their drinking water.

INTEXT QUESTIONS 28.6

1. State two reasons for reduction in water table.

____

2. Give two reasons for lowering of water table.

____

3. Mention two risks of reduced water table and contaminated groundwater.

____

WHAT YOU HAVE LEARNT

- Source of all freshwater on earth is rainfall.
- The rain water which gets accumulated in ponds, lakes or flows in the rivers is called surface water.
- Part of rain water that infiltrates the Earth's surface slowly seeps downward into extensive layers of porous soil and rock. This water is called **groundwater**.
- The process of precipitation replenishing the groundwater is known as **recharge**.

- The depth at which the pore space in the soil is completely filled with water and the level at which this occurs is called the **water table.**
- Water from underground has been exploited for domestic use for livestock and irrigation since time immemorial.
- Surface water is exposed to atmosphere and can be easily contaminated, whereas the groundwater does not as it is hidden underground.
- Groundwater can be abstracted through dug-wells, tube-wells, hand-pumps, or springs.
- Artificial recharge is a process by which excess surface water is directed into the ground – either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration – to replenish an aquifer.
- Artificial recharge can be achieved through recharge pits, shafts, wells, ditches or spreading basins. It can also be achieved through enhanced streambed infiltration or conjunctive wells.
- Recharge can significantly increase the sustainable yield of an aquifer.
- Artificial recharge may degrade the groundwater quality if the recharge water is contaminated.
- The demand for water has increased over the years and this has led to water scarcity in many parts of the world.
- Rapid increase in the rates of pumping of groundwater in many aquifers has caused a steady lowering of water table levels where extraction has exceeded rates of recharge.
- In India, the ground water levels are receding in some regions at an alarming rate.
- Depletion of groundwater increases pumping costs, causes wells and rivers to dry up, and in coastal regions seawater can intrude in groundwater

TERMINAL EXERCISE

1. State three important differences between groundwater and surface water.
2. What is water table?
3. How can you obtain groundwater?
4. Describe in brief how water can be saved at home.
5. What are the main groundwater quality problems in India?
6. Explain the natural and anthropogenic contaminants of groundwater.
7. Describe the methods of artificially recharging groundwater.

8. What are the main causes of groundwater depletion?
9. What are the main adverse effects of groundwater depletion?
10. How can quality of recharge water be maintained?

ANSWER TO INTEXT QUESTIONS

28.1

1. The water found on the surface of land and underneath.
2. Part of rain water that infiltrates the earth's surface slowly seeps downward into extensive layers of porous soil and rocks.
3. Under groundwater body is created called aquifer.
4. Water table is the upper level of an underground surface in which the soil or rocks are permanently saturated with water.

28.2

1. Because it comes through various levels of sub-soil and it is mostly uncontaminated and safer to consumer.
2. Refer to text.
3. Refer to text.

28.3

1. (a) i. Use mug while shaving or brushing teeth.

   ii. Take short showers

   iii. Turn off the water while soaping or shampooing.

   (b) i. Detect and repair all leaks in irrigation system.

   ii. Use properly treated water for irrigation (any other)
2. Refer to section 28.3.
3. • to designate a water efficiency coordination.
   • to Develop a water efficiency plan
   • to calculate and involved employees, residents & school children in water efficiency efforts. (Any two)

28.4

1. Artificial recharge is a process by which excess surface water is directed into the ground – either by spreading on the surface by using recharge wells, or by altering natural conditions to increase infiltration.
2. Through spreading basins, recharge pits and shafts, ditches and recharge wells.
3. Refer to text, section 28.4.3 and 28.4.4 respectively.

28.5

1. Mine drainage discharge, solid mine tailings, process water, sludge lagoons, oilfield spillage of group gathering stations.
2. Urban, industrial and agricultural activities (any two)
3. Unsewered sanitation, sewage leakage, solid waste disposal, aerial fall out, land fill waste, poor house keeping.

28.6

1. By human factor, overuse in industries, slow accumulation in surface (any other)
2. Rapid increase in the rates of pumping of ground water has caused a steady lowering of water table levels.
3. Refers to text section – 28.6