Interlinking of Rivers

Introduction

- River Linking is a project of linking two or more rivers by creating a network of manually created canals, and providing water to the land areas that does not have river water access and reducing the flow of water to sea using this means.

- It is based on the assumptions that surplus water in some rivers can be diverted to deficit rivers by creating a network of canals to interconnect the rivers.


Reasons & Motivation
Of
Inter Linking

Regional Rainfall Variation

- The rainfall over the country is primarily orographic, associated with tropical depressions originating in the Arabian Sea and the Bay of Bengal. The summer monsoon accounts for more than 85 % of the precipitation.
- Large parts of Haryana, Maharashtra, Andhra Pradesh, Rajasthan, Gujarat, Madhya Pradesh, Karnataka and Tamil Nadu are not only in deficit in rainfall but also subject to large variations, resulting in frequent droughts and causing immense hardship to the population and enormous loss to the nation.

Regional Rainfall Variation

- The water availability even for drinking purposes becomes critical, particularly in the summer months as the rivers dry up and the ground water recedes.
- Regional variations in the rainfall lead to a situations when some parts of the country do not have enough water even for raising a single crop. On the other hand excess rainfall occurring in some parts of the country create havoc due to floods.

Futuristic Demand Of Irrigation

- Irrigation using river water and ground water has been the prime factor for raising the food grain production in our country from a mere 50 million tonnes in the 1950s to more than 200 million tonnes at present, leading us to attain self-sufficiency in food.

- Irrigated area has increased from 22 million hectares to 95 million hectares during this period.

- At present estimate the "ultimate" irrigation potential of the country being stated as 113 million Ha.

Increasing Population and Food Demand

- The population of India, which is around 1000 million at present, is expected to increase to 1500 to 1800 million in the year 2050 and that would require about 450 million tonnes of food grains.

- For meeting this requirement, it would be necessary to increase irrigation potential to 160 million hectares for all crops by 2050.

To Control Floods & Droughts

- Floods are a recurring feature, particularly in Brahmaputra and Ganga rivers, in which almost 60 % of the river flows of our country occur.
- Flood damages, which were Rs. 52 crores in 1953, have gone up to Rs. 5,846 crores in 1998 with annual average being Rs. 1,343 crores affecting the States of Assam, Bihar, West Bengal and Uttar Pradesh along with untold human sufferings.
- On the other hand large areas in the States of Rajasthan, Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu face recurring droughts. As much as 85 % of drought prone area falls in these States.


Probable Benefits
Of
Inter Linking

I. **Irrigation** - By linking of rivers vast amount of land areas which does not have otherwise irrigated and unusable for agriculture become fertile.

II. **Flood prevention** – By creating network of rivers flood & drought problem can be greatly avoided by channeling excess water to areas that are not experiencing a flood or are dry. This works similar to ***canal system in Netherlands*** to channel excess water from sea.

III. **Generation of electricity** - With new canals built, feasibility of new DAMS to generate hydroelectric power becomes a possibility.

IV. **Navigation** - Newly created network of canals opens up new routes and ways and routes of water navigation, which is generally more efficient and cheaper compared to road transport.

V. **Higher GDP Growth** - By interlinking rivers, there will be a boost and increased employment in agricultural sector, power, transportation; construction etc. Interlinking can increase the GDP by 5to 6 %.

VI. **Business Opportunities** – It is expected to generate large-scale business opportunities in manufacture of mechanical equipments, earthmovers, stone crushers, power shovels, other transportation vehicles, etc. In addition, this project would also require large scale manufacturing of construction materials such as an estimated 56 million tones of cement and 2 million tonnes of steel etc.

VII. **Drinking Water** - Majority of our population will get drinking water; Special emphasis is that all the cities connected by Golden quadrilateral project will get drinking water.

VIII. **Revenue**- The government is expecting revenues from benefits of navigating through waters, increased tourism, joint ventures, private initiatives and cess on waters.

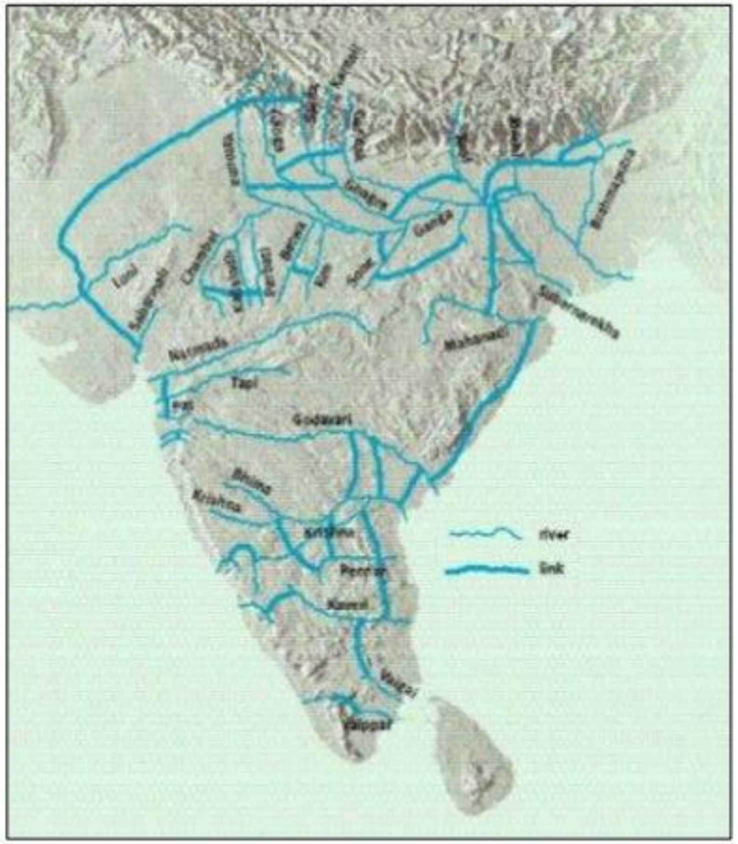

National River Linking Project
in
India

NRLP

- The **National River Linking Project (NRLP)** is designed to ease water shortages in western and southern India while mitigating the impacts of recurrent floods in the eastern parts of the Ganga basin.
- The **NRLP**, if and when implemented, will be one of the biggest inter basin water transfer projects in the world.

Contours of NRLP…

- Building 30 links, 3000 small and large reservoirs, 12500 km of canals to link 36 Himalayan and Peninsular rivers to effect 178 km^3 of inter-basin water transport.
- 35 million ha of new irrigated area; 35 GW of hydro-capacity; navigation and flood control benefits.
- Gestation Period: Proposed=2016; Most Likely=2050
- Cost = Rs 560,000 cr. at 2002 prices (US $ 120 Billion); 1 - 1.5% of India's GDP for the next 3 decades.



Goal	Purpose
• Support South Asia's quest for food livelihoods and water security • Capitalize on the uncommon opportunity created by the NRLP	•Promote a balanced, analytical and informed national discourse on India's Water Future 2050. •Approaches to shaping it, including through the River-Linking project.

PHASE	ACTIVITIES		OUTPUT	
Phase I 9 Months	11 Studies, Synthesis & National Workshop I		A Sharp, Well-Rounded Prognosis of India's Water Future - 2025/2050 & of the Water Challenge Facing the Nation	
Phase II 15 Months	Phase II A	Phase II B	Phase II A	Phase II B
	16 Studies, Synthesis & National Workshop II	7 Studies, Synthesis & National Workshop III	How adequate, complete and cost-effective a response is the River-Linking Project to India's Water Challenge 2050?	How to maximize net social benefit of the River-Link Project
Phase III 12 Months	Phase III A	Phase III B	Phase III A	Phase III A
	14 Studies, Synthesis & National Workshop IV	8 Studies, Synthesis & National Workshop V	If NRLP fails to take off, how else can India effectively meet its Water Challenge 2050?	How best to put into operation the National Perspective Plan

Concluding Workshop VI: Planning for a Food, Livelihoods and Water Secure India 2050

Present Status Of Interlinking Of Rivers Project

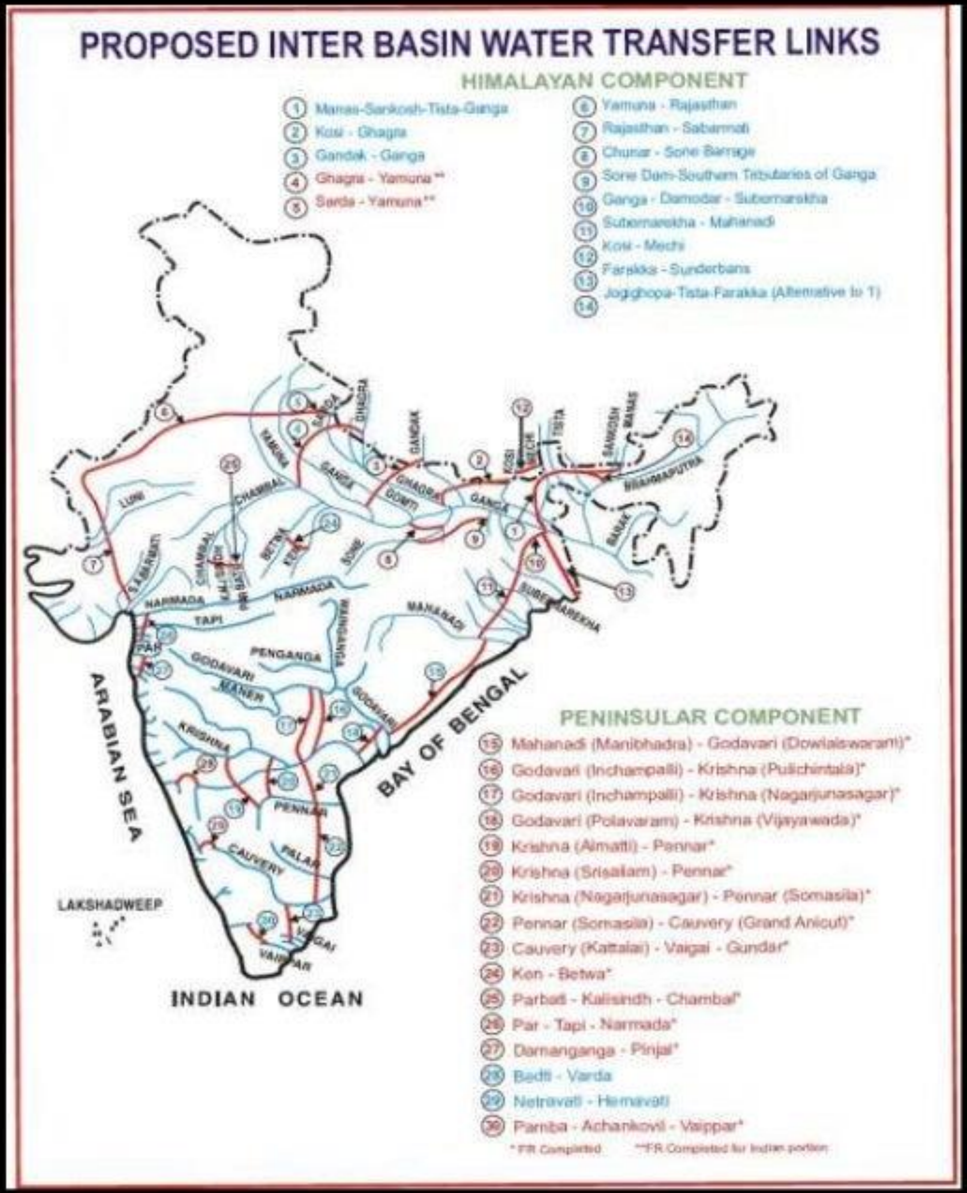
-Press Information Bureau release

- The Government has said that the National Water Development Agency (NWDA) under the Ministry of Water Resources (MoWR) has identified 30 inter-state River links (16 under Peninsular Component & 14 under Himalayan Component) for preparation of Feasibility Reports (FRs).

- Out of these, FRs of 14 links under Peninsular Component and 2 links (Indian Portion) under Himalayan Component have been completed.

पत्र सूचना कार्यालय, भारत सरकार

Press Information Bureau, Government of India



The Inter-link consist of two parts, a Northern Himalayan River Development Component and a Southern Peninsular River Development Component.

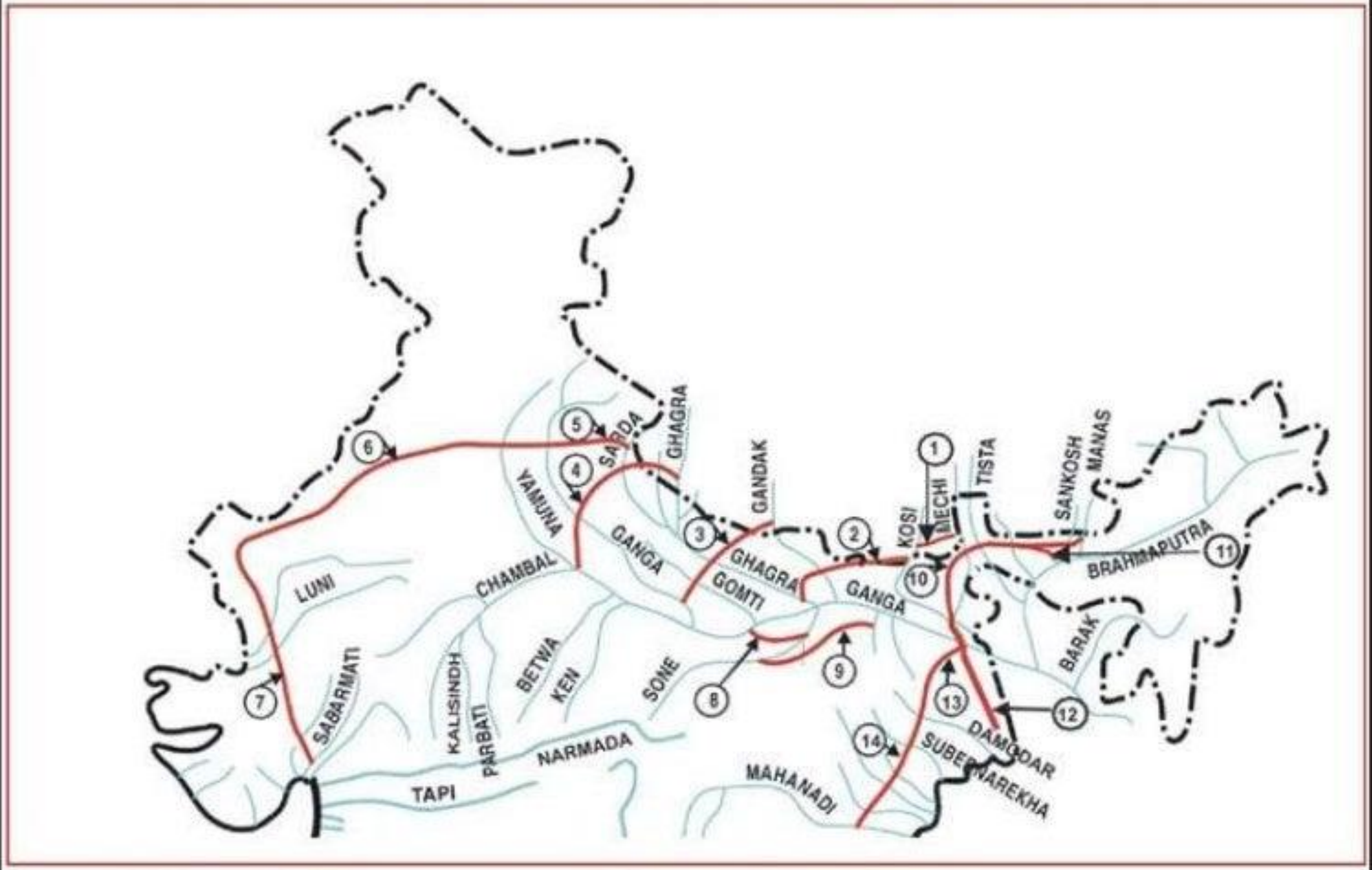
Himalayan Development

National Commission about ILR-1

- The northern component would consist of a series of dams built along the Ganga and Brahmaputra rivers in India, Nepal and Bhutan for the purposes of storage.
- Canals would be built to transfer surplus water from the eastern tributaries of the Ganga to the west.
- The Brahmaputra and its tributaries would be linked with the Ganga and the Ganga with the Mahanadi river.
- This part of the project would provide additional irrigation for about 220,000 square kilometers and generate about 30 gig watts of electricity.

PROPOSED INTER BASIN WATER TRANSFER LINKS

HIMALAYAN COMPONENT



1. Kosi – Mechi
2. Kosi – Ghagra
3. Gandak – Ganga
4. Ghagra – Yamuna *
5. Sarda – Yamuna *
6. Yamuna – Rajasthan
7. Rajasthan – Sabarmati
8. Chunar- Sone Barrage
9. Sone Dam – Southern Tributaries of Ganga
10. Manas –Sankosh - Tista - Ganga
11. Jogighopa – Tista – Farakka (Alternate)
12. Farakka – Sunderbans
13. Ganga (Farakka) – Damodar – Subernarekha
14. Subernarekha – Mahanadi

* FR Completed

Peninsular Development

National Commission about ILR-2

- **First**, the Mahanadi, Godavari. Krishna and Kaveri rivers would all be linked by canals. Extra water storage dams would be built along the course of these rivers. The purpose of this would be to transfer surplus water from the Mahanadi and Godavari rivers to the south of India.

- **Second**, those rivers that flow west to the north of Mumbai and the south of Tapi would be linked. The water would be used by the urban areas of Bombay and also to provide irrigation in the coastal areas of Maharashtra.

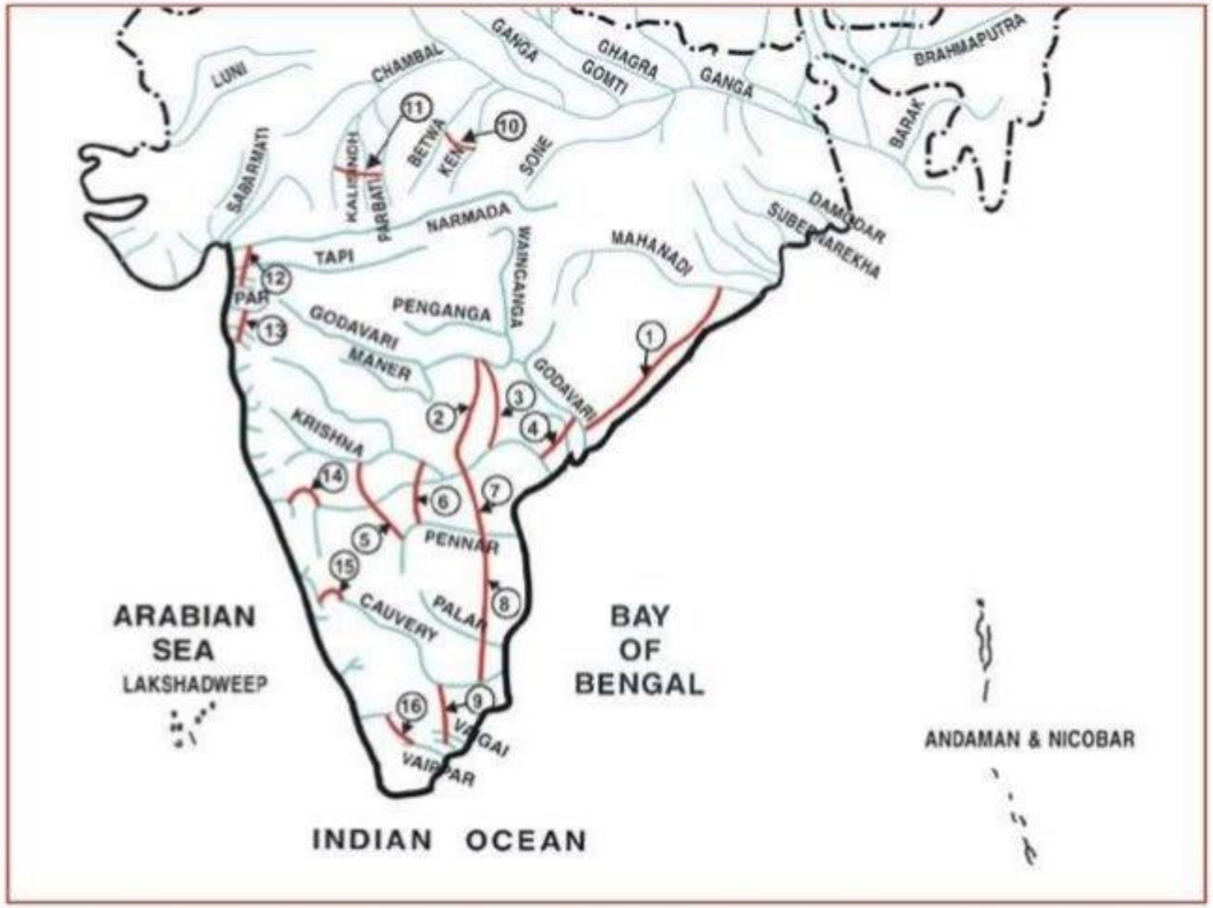
Peninsular Development

National Commission about ILR-2

- **Third** the Ken and Chambal rivers would be linked in order to provide better water facilities for Madhya Pradesh and Uttar Pradesh.
- **Finally** a number of west-flowing rivers along the Western Ghats simply discharge into the Arabian Sea.
- The Peninsular part of the project would provide additional irrigation to 130,000 square kilometers and generation an additional 4 gig watts of power.

PROPOSED INTER BASIN WATER TRANSFER LINKS

PENINSULAR COMPONENT



1. Mahanadi (Manibhadra) – Godavari (Dowlaiswaram) *
2. Godavari (Inchampalli) – Krishna (Nagarjunasagar) *
3. Godavari (Inchampalli) – Krishna (Pulichintala) *
4. Godavari (Polavaram) – Krishna (Vijayawada) *
5. Krishna (Almatti) – Pennar *
6. Krishna (Srisailam) – Pennar *
7. Krishna (Nagarjunasagar) – Pennar (Somasila) *
8. Pennar (Somasila)–Palar- Cauvery (Grand Anicut) *
9. Cauvery (Kattalai) – Vaigai – Gundar *
10. Ken – Betwa *
11. Parbati – Kalisindh – Chambal *
12. Par – Tapi – Narmada *
13. Damanganga – Pinjal *
14. Bedti – Varda
15. Netravati – Hemavati
16. Pamba – Achankovil – Vaippar *

* FR Completed

HISTORY OF INTERLINKING

- **1972-** Ganga cauvery link proposed by Dr. K.L.Rao .
- **1974-** "Garland canal" proposal by captain Dastur .
- **1980-** Ministry of water resources frames the National Perspective Plan(NPP) .
- **1982-** The National Water Development Agency (NWDA) set up to carry out pre – feasibility studies .
- **1999-** A National Commission for Integrated Water Resources Development plan (NCIWRDP) set up to review NWDA

HISTORY OF INTERLINKING

- **Aug 15, 2002-** President Abdul Kalam mentions the need for river linking in his independence day speech .
- **Oct 2002-** Supreme court recommends that the government formulate a plan to link the major Indian rivers by the year 2012.
- **Dec 2002-** Govt. appointed a task force on interlinking of 37 rivers led by Mr. Suresh Prabhu. The deadline was revised to 2016.


Issues caused
by
inter linking
and
it’s Concerns

1. **Ecological issues –** Major concern being the argument that rivers change their course in 70–100 years and once they are linked, future change of course can create huge practical problems for the project.

2. **Aqua life –** A number of leading environmentalists are of the opinion that the project could be an ecological disaster. There would be a decrease in downstream flows resulting in reduction of fresh water inflows into the seas seriously jeopardizing aquatic life.

3. **Deforestation –**Creation of canals would need large areas of land resulting large scale deforestation in certain area.

4. **Areas getting submerged -** Possibility of new dams comes with the threat that habitable or reserved land getting submerged under water.

5. **Displacement of people –**As large strips of land might have to be converted to canals, a considerable population living in this areas must need to be rehabilitated to new areas.


Alternatives
to
Indian River Linking

1. **Rainwater harvesting and conservation of water resources :** Changes in topography, soil system and runoff flow pattern in a changing climatic environment is considered. Not only stored rain water but soil erosion is also prevented.

2. **Recharging ground water reservoir :** Skills have to be developed for arresting rain water where it falls and allowing it to recharge these ground water reservoirs.

3. **Large scale utilization of ground water in deltas :** practically feasible and initiatives for bore well development and irrigation needed with responsibility lying .

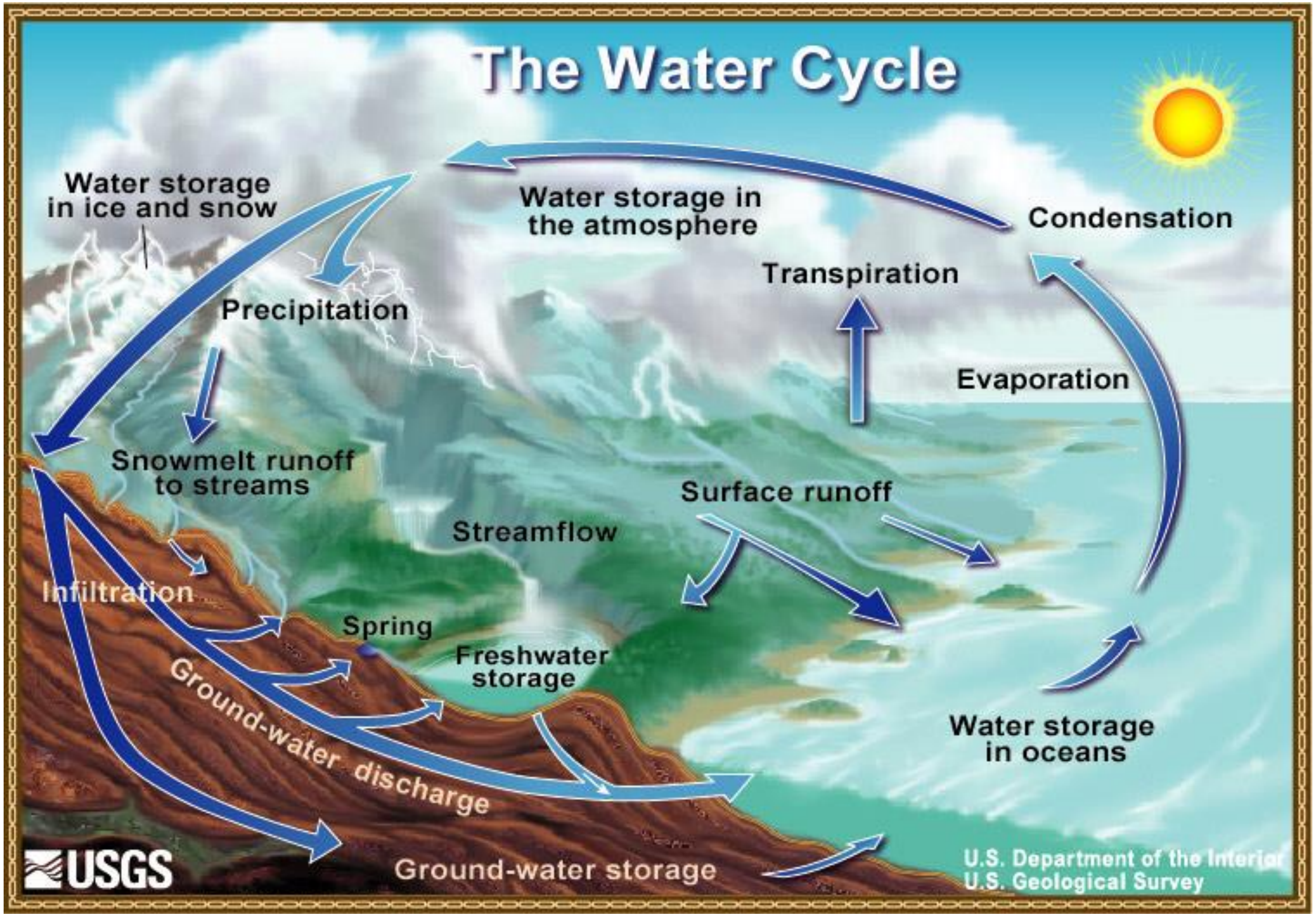
4. **Community participation:** Approaches of reducing water consumption by the affluent in the cities and reducing the wastage of water by the farmers in their field can be attempted.

CONCLUSION

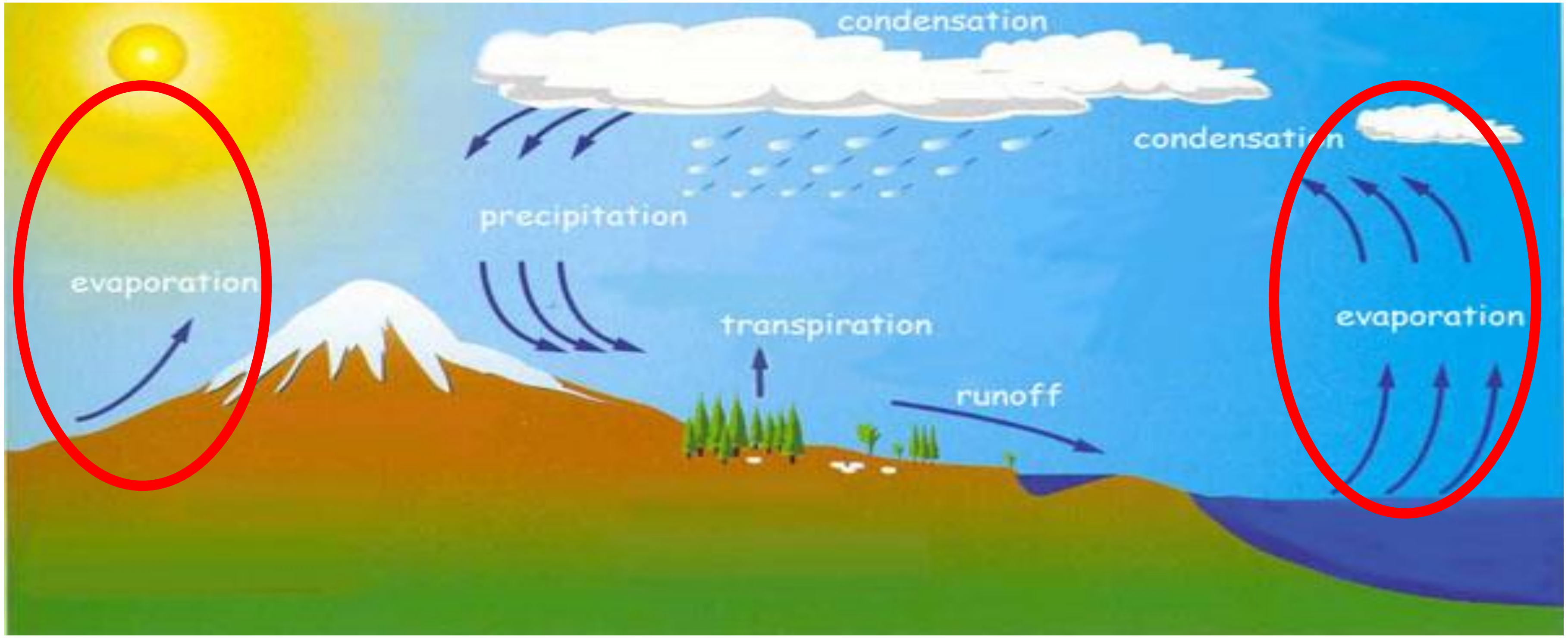
- Considering the pragmatic view of all the issues raised it can be concluded that implementation of this ambitious scheme is not possible in foreseeable future.
- Hence it can be a better option to concentrate on the local resources and think upon the alternatives available.

The Water Cycle

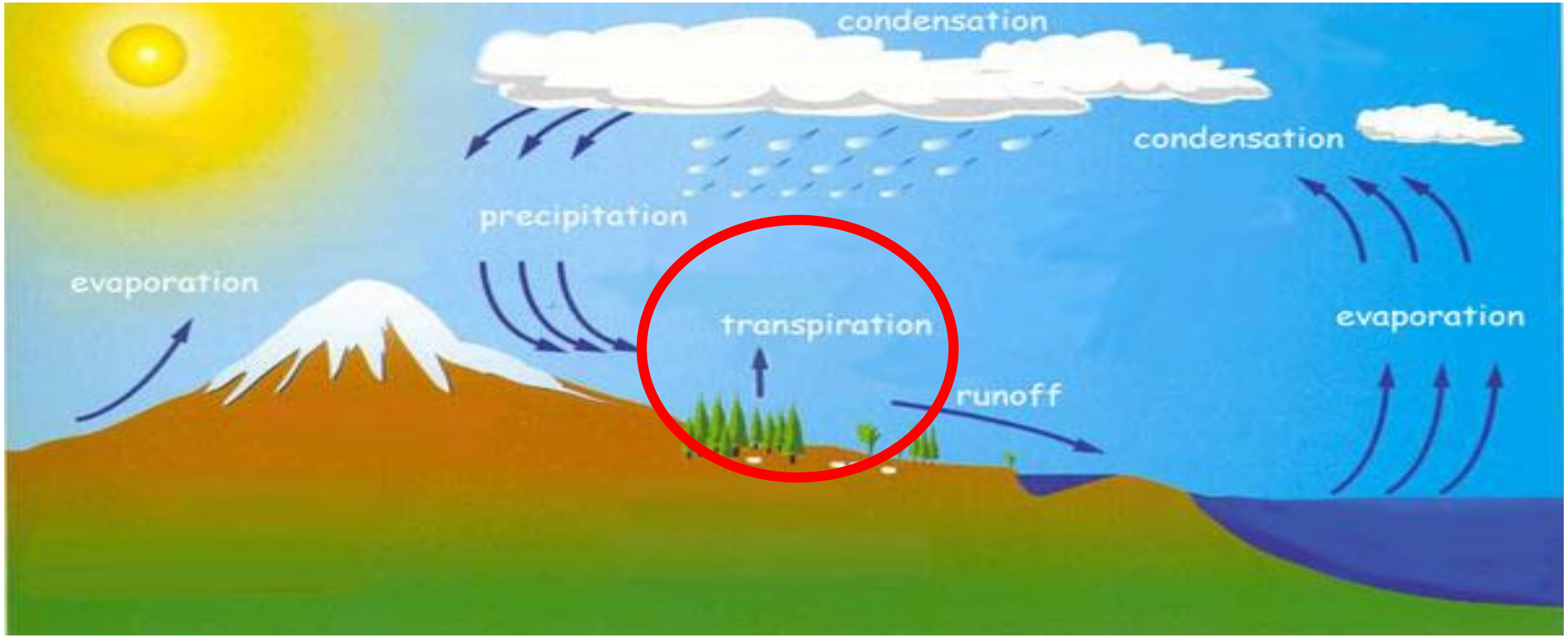
Water never leaves the Earth. It is constantly being cycled through the atmosphere, ocean, and land. This process, known as the **water cycle**, is driven by energy from the sun. The water cycle is crucial to the existence of life on our planet.


The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Transpiration
Precipitation
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
USGS
Ground-water storage
U.S. Department of the Interior
U.S. Geological Survey

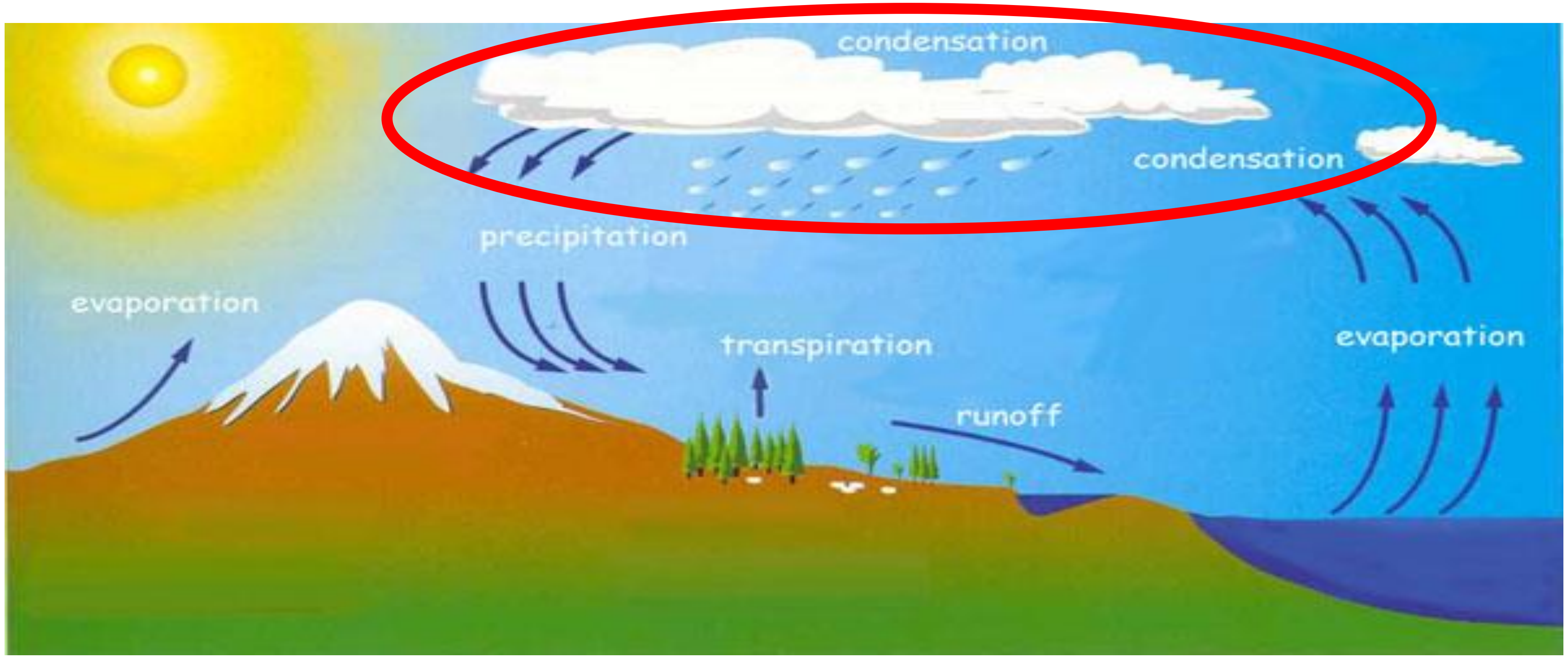
The Water Cycle



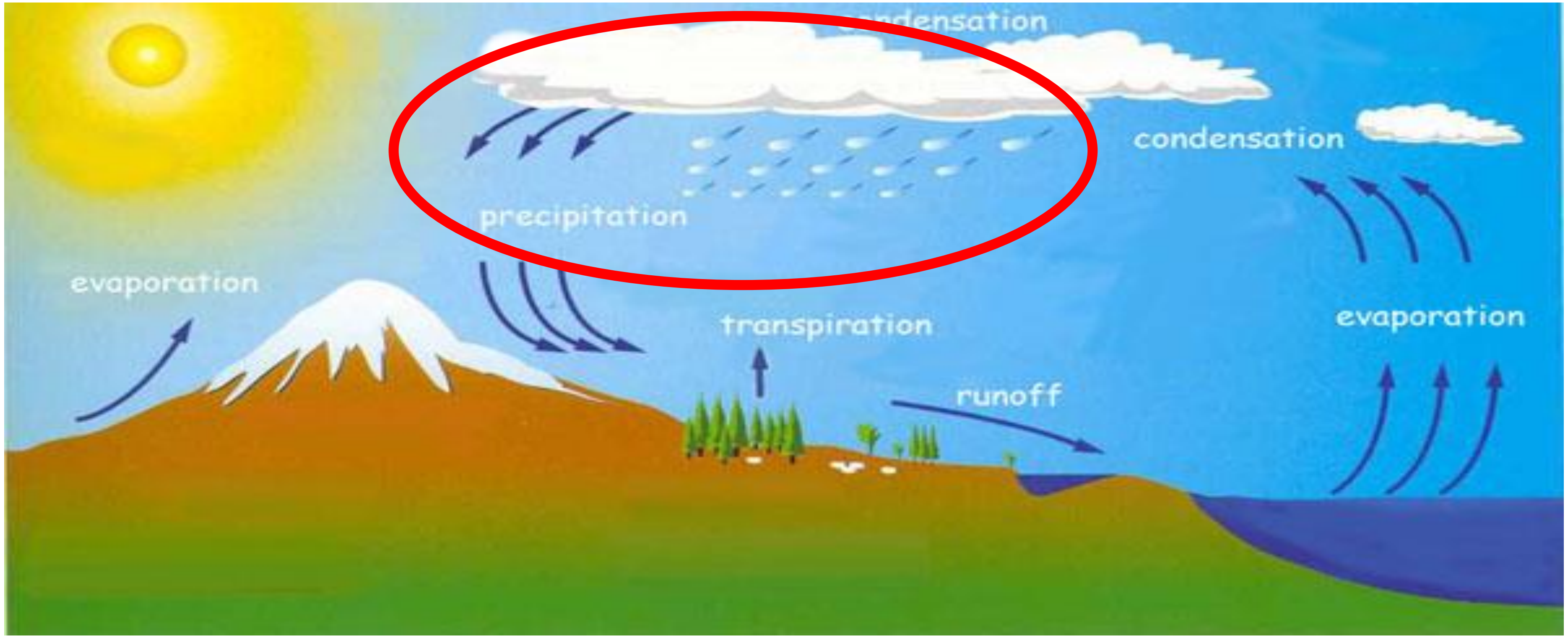
During part of the water cycle, the sun heats up liquid water and changes it to a gas by the process of evaporation. Water that evaporates from Earth's oceans, lakes, rivers, and moist soil rises up into the atmosphere.


condensation
condensation
precipitation
evaporation
transpiration
runoff
evaporation

The process of evaporation from plants is called transpiration. (In other words, it’s like plants sweating.)

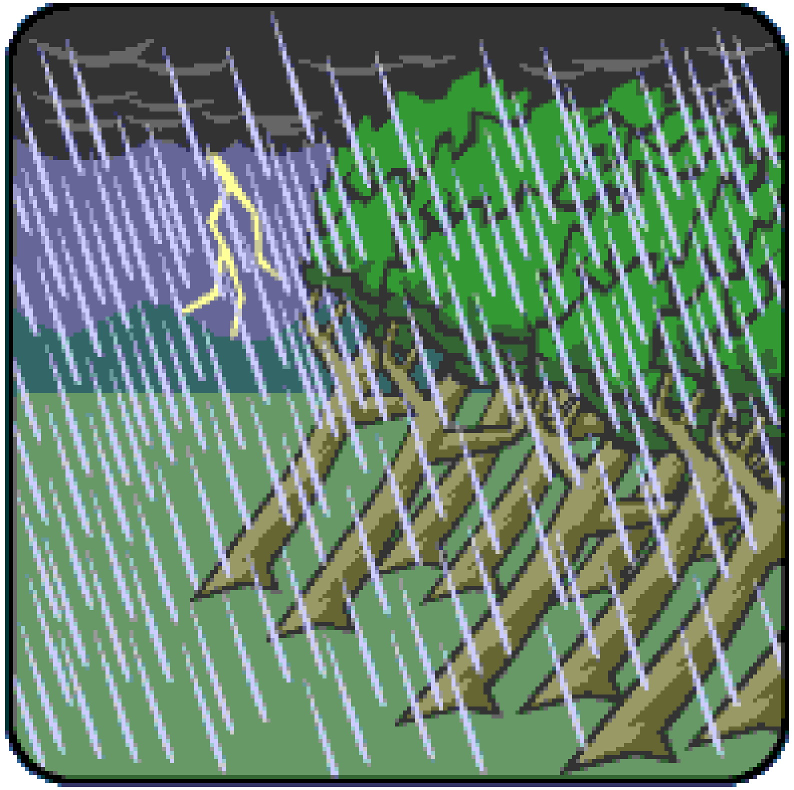

condensation
condensation
precipitation
evaporation
transpiration
runoff
evaporation

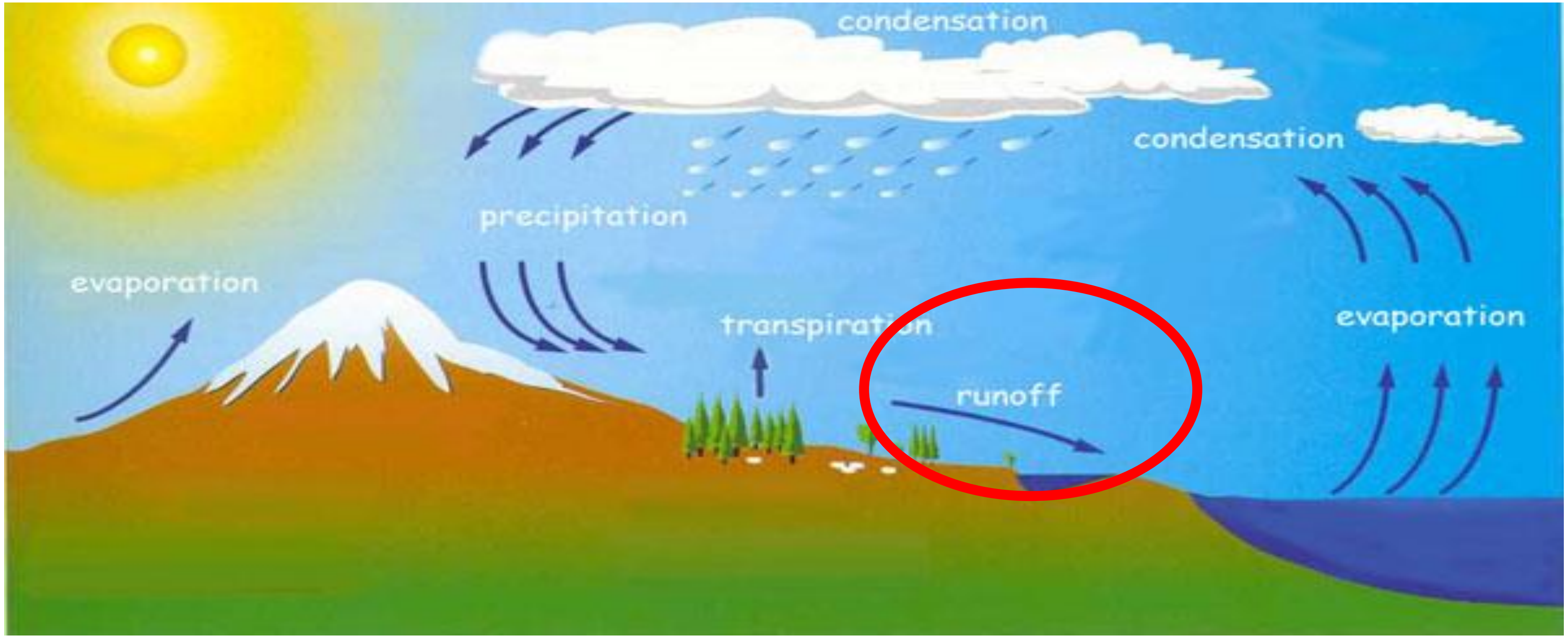
As water (in the form of gas) rises higher in the atmosphere, it starts to cool and become a liquid again. This process is called condensation. When a large amount of water vapor condenses, it results in the formation of clouds.



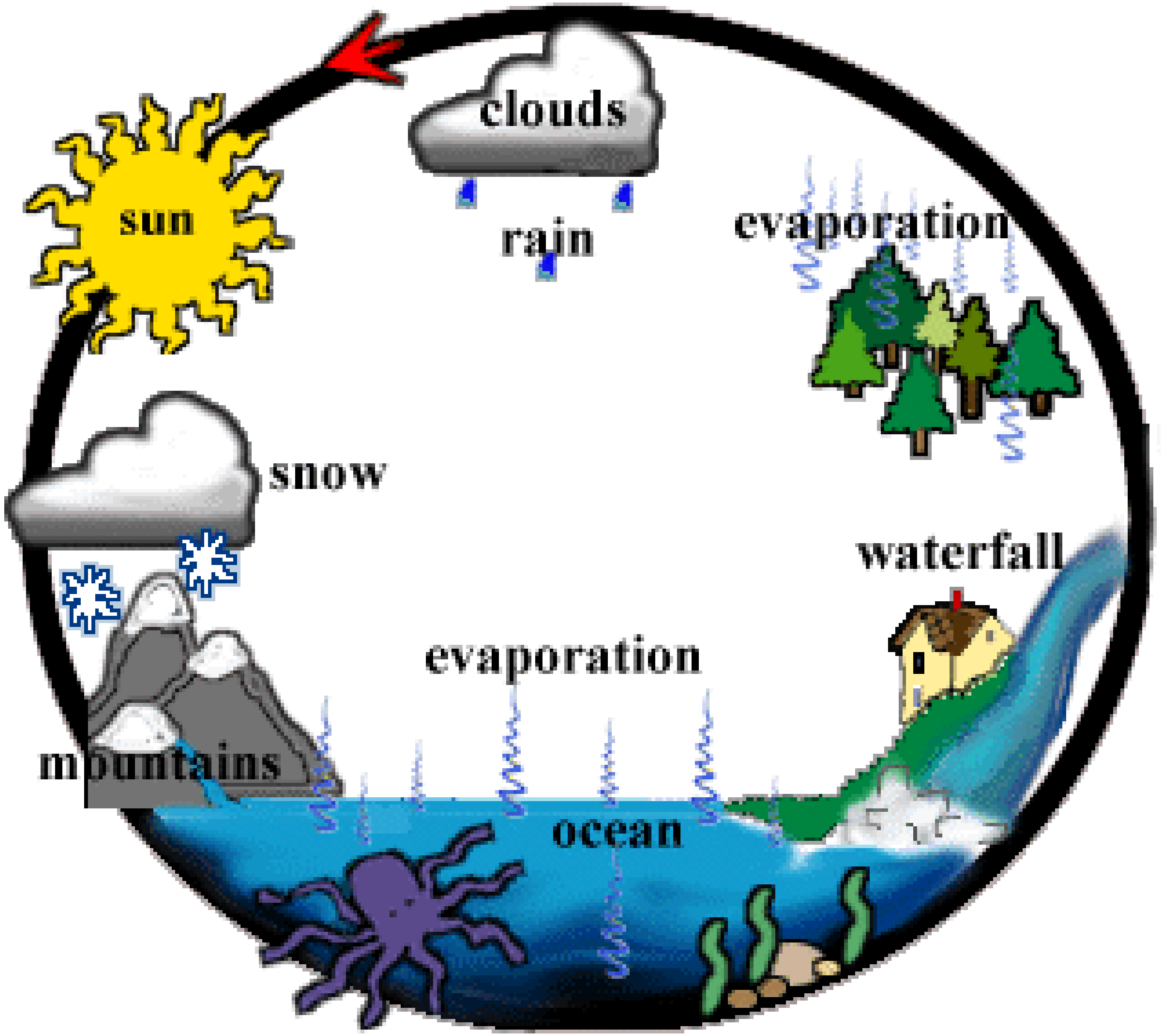
condensation
precipitation
evaporation
transpiration
runoff
evaporation

When the water in the clouds gets too heavy, the water falls back to the earth. This is called precipitation.

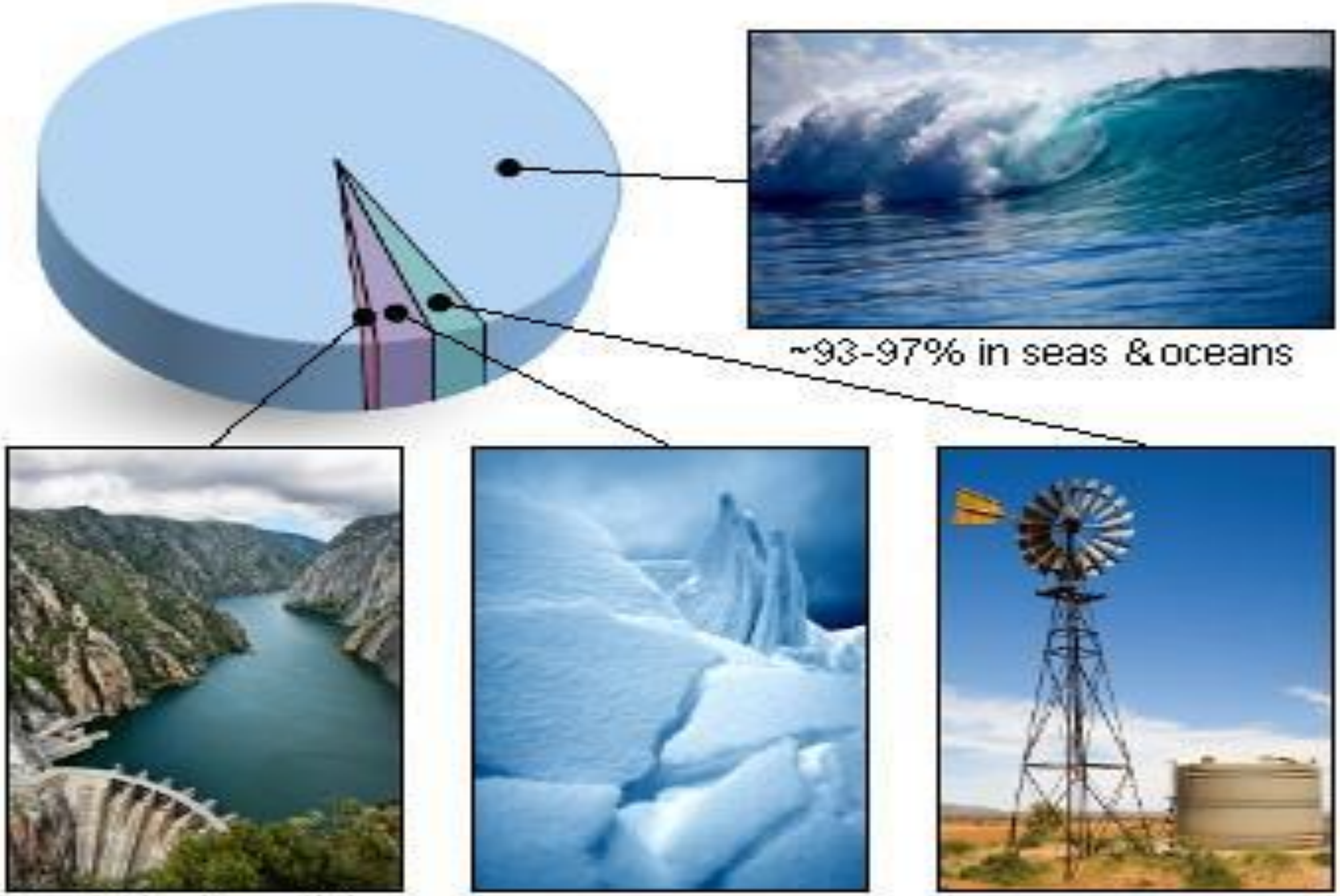


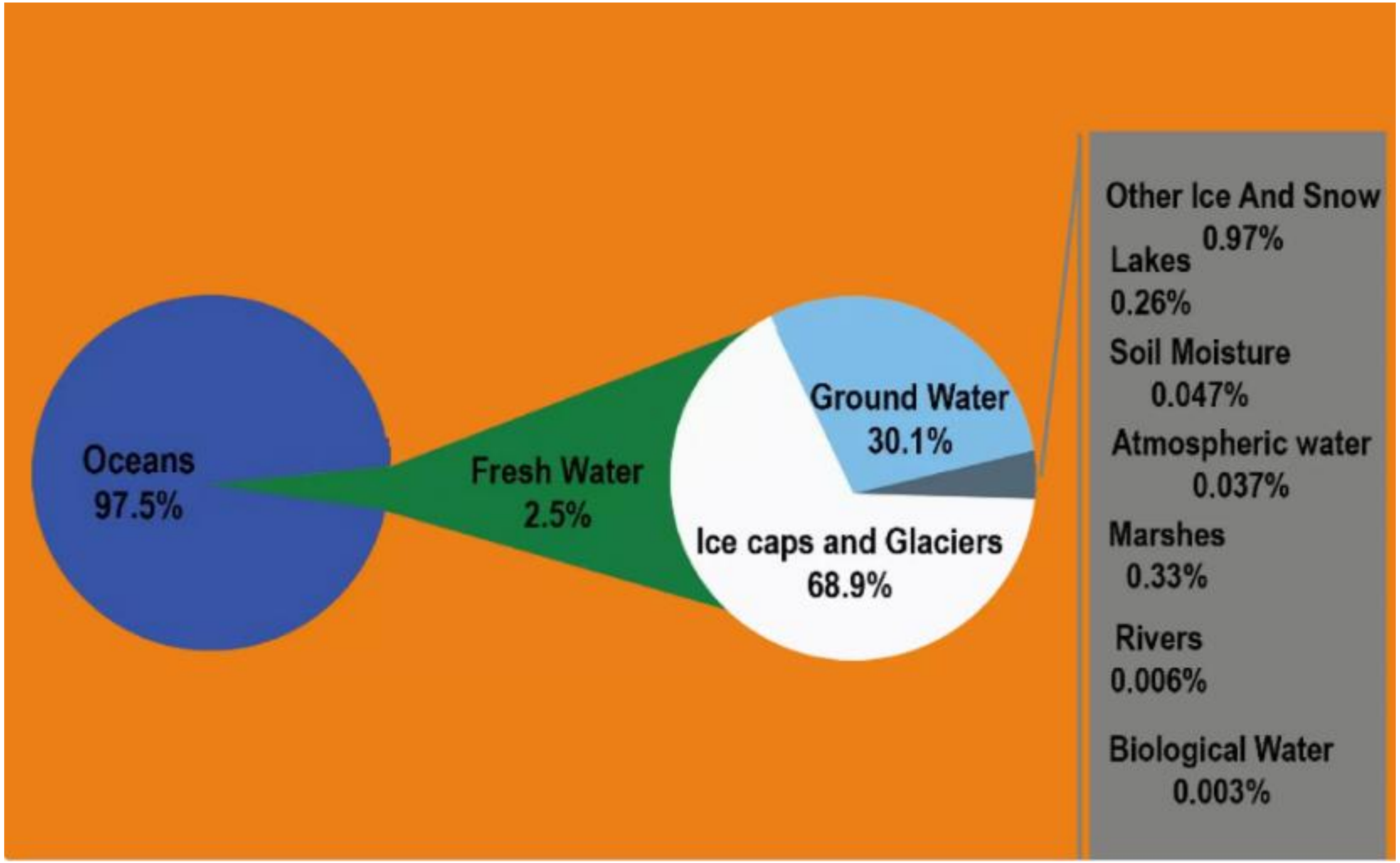

condensation
condensation
precipitation
evaporation
transpiration
runoff
evaporation

When rain falls on the land, some of the water is absorbed into the ground forming pockets of water called groundwater. Most groundwater eventually returns to the ocean. Other precipitation runs directly into streams or rivers. Water that collects in rivers, streams, and oceans is called runoff.


clouds
sun
rain
evaporation
snow
waterfall
evaporation
mountains
ocean

Global water resources



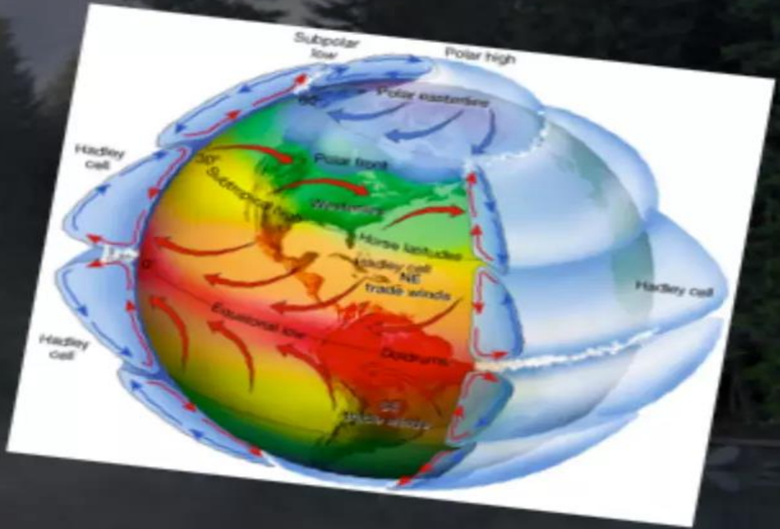

Oceans
97.5%
Fresh Water
2.5%
Ground Water
30.1%
Ice caps and Glaciers
68.9%
Other Ice And Snow
0.97%
Lakes
0.26%
Soil Moisture
0.047%
Atmospheric water
0.037%
Marshes
0.33%
Rivers
0.006%
Biological Water
0.003%

- According to most estimates, about 94-97% of all water on earth is seawater held in the oceans.
- All freshwater resources occur in the remaining 3-6%.
- Around half of this is frozen in snow, glaciers and icecaps, about half is found underground as groundwater and a fraction of a percent (less than 0.1%) is surface water found in rivers, lakes, reservoirs, the atmosphere and all living things.
- Water is constantly circulating between the oceans, continents and atmosphere in a system called the *hydrologic cycle*.
- This circulation is driven by a combination of the energy from sun, geological processes and gravity.
- Water from the oceans and land is transported into the atmosphere by evaporation.
- Water is also transferred to the atmosphere from vegetation by evapotranspiration.

- Water returns to the earth's surface by precipitation.
- On land, some of this water flows over the surface in streams and rivers into lakes, reservoirs and the oceans.
- The remainder infiltrates the land surface and percolates into aquifers.
- Some water can enter aquifers directly from the oceans.
- The energy of the earth's interior drives the geological processes that influence formation, influx, storage, movement and exsurgence of groundwater.
- Groundwater can be a source of surface water on land and can flow into the oceans.
- Understanding how water on land, in the oceans and in the atmosphere is connected in the hydrologic cycle is essential for the successful management of our water resources.
- Through these connections, factors affecting one part the cycle can influence the entire system.

Evaporation

Evaporation occurs faster when weather is hot and evaporation changes with seasons.



Water vapor distributes solar energy through atmospheric circulation. Water absorbs a lot of energy when it evaporates.

Fresh Water and Ground Water

Fresh water exists because precipitation is greater than evaporation on land.

Precipitation not used by plants or evaporated turns into ground water. Ground water feeds into rivers and the water table.

Material Cycle

The Hydraulic Cycle partners with the Material Cycle because rainfall erodes and weathers rock. This process releases key nutrients like Calcium and Sulfur.

Water Table and Zones

- Water Table

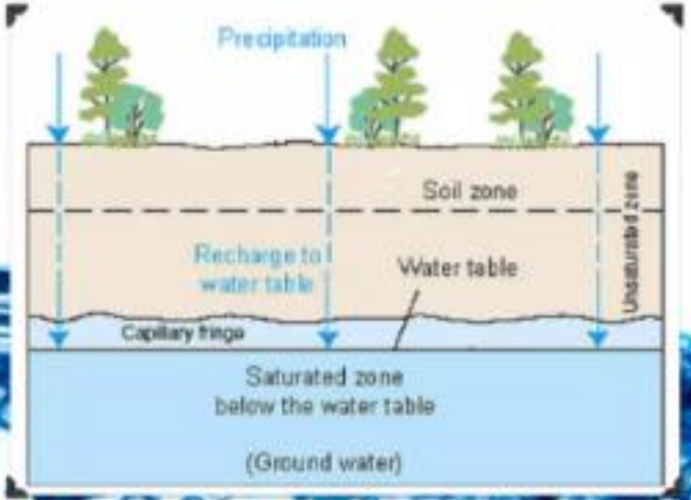
  -Where the water pressure head is equal to the atmospheric pressure.

- Vadose zone

  -AKA "The unsaturated zone" The area between the surface and the water table.

- Saturated

  -AKA "The phreatic zone" This area is an aquifer



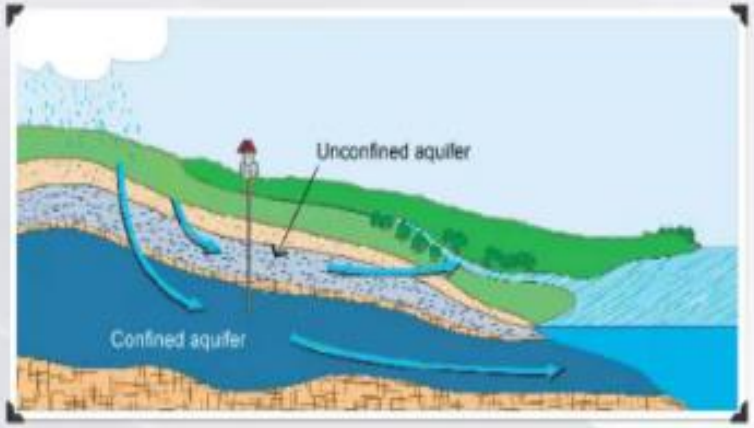
Aquifers

- Permeable geologic formations through which water flows easily.
- Confined

  -Under ground and Isolated
- Unconfined

  -Connected to other body water.

  (More likely to be contaminated)



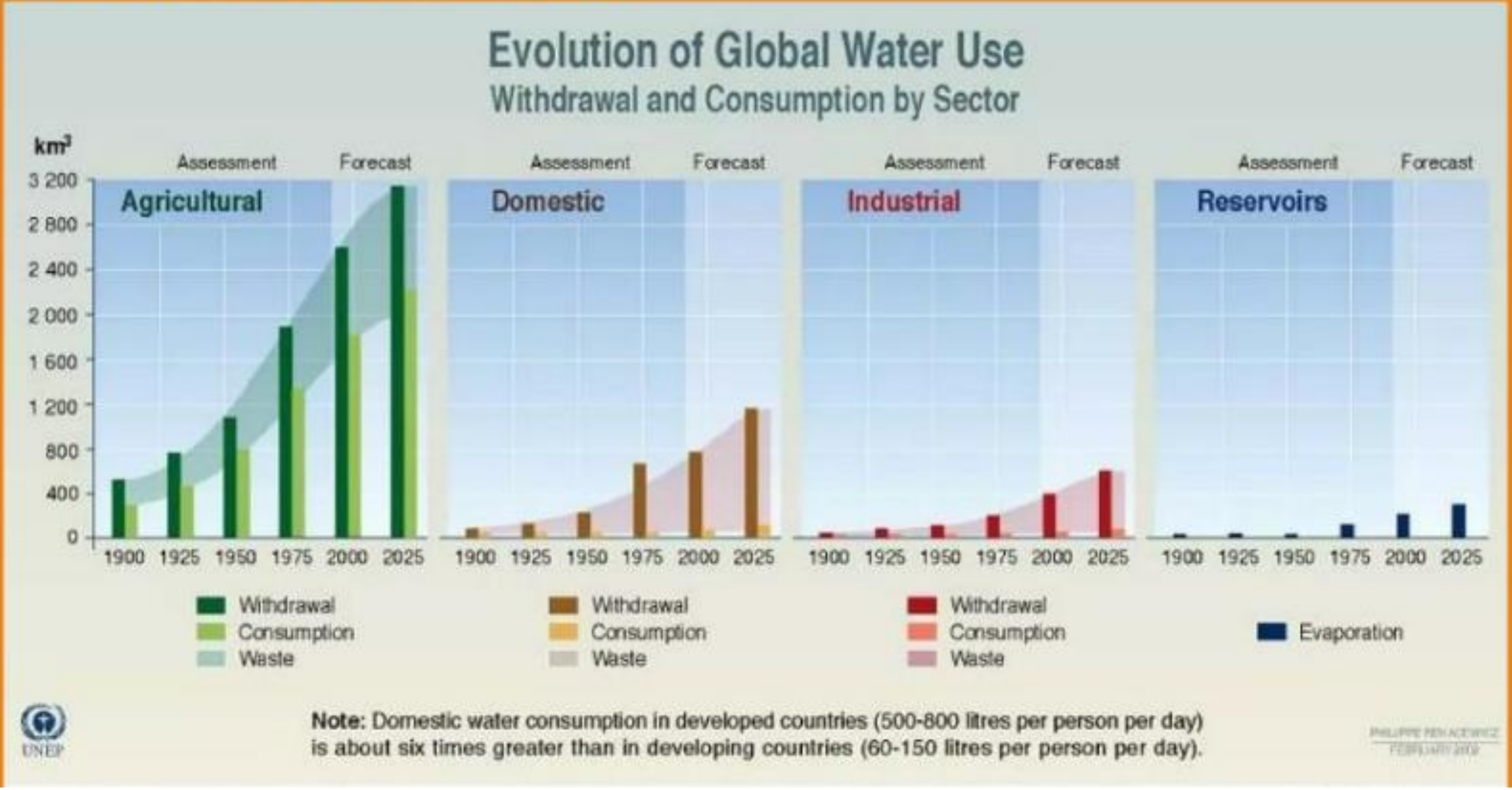
Ice Sheets

- Nearly 90 percent of the water in icecaps and glaciers is in Antarctica, with another 10 percent in the Greenland ice sheet
- Hold 68% of earths fresh water.

Rivers and Lakes

- Amazon carries 15 percent of total river flow on Earth, the Congo carries 3.5 percent, and rivers that flow into the Arctic Ocean carry 8 percent.
- The average residence time of water in rivers is less than a year.
- Account for 0.3% of all Fresh water

Evolution Of Global Water Use



INDIAN WATER RESOURCES

INTRODUCTION

- Water is a cyclic resource with abundant supplies on the globe.
- Approximately, 71 per cent of the earth's surface is covered with it but fresh water constitutes only about 3 per cent of the total water.
- The availability of fresh water varies over space and time.
- India accounts for about 2.45 per cent of world's surface area, 4 per cent of the world's water, resources and about 16 per cent of world's population.

WATER RESOURCES OF INDIA

- The source of water is precipitation.
- India receives annual precipitation of about 4000 km^3 (400 M ha m, 4000 billion cubic meters- BCM) including snowfall.
- Out of this, monsoon rainfall is of the order of 3000 km^3.
- Rainfall in the country is highly variable and irregular.
- Its special distribution varies from less than 100 mm per annum in Rajasthan to about 11000 mm per annum in Cherrapunji of Meghalaya.
- The total utilizable water resources of the country are assessed as 1086 km^3.

Cont…

- Rainfall is the only natural source of water.
- All the natural resources like stream, river, and underground water are the manifestations of rainfall.
- Although water is a renewable resource and reused only when resources are charged with water from natural rainfall.
- Water resources can be classified into:

  a) Surface water resources

  b) Underground resources

SURFACE WATER RESOURCES

- There are four major sources of surface water.
- These are rivers, lakes, ponds, and tanks.
- India has a large and intricate network of river systems.
- In the country, there are about 10,360 rivers.
- For the purpose of efficient water management, the Central Water Commission has divided India into 20 river basins, comprising 12 major basins, each with a catchment area exceeding 20000 km^2 and 8 composite river basins combining all other medium and small river systems.

Cont…

- Annual precipitation including snowfall is estimated as 4,000 km^3.
- Average annual potential flow in the rivers is about 1869 BCM.
- Due to various constrains of topography, uneven distribution of resource over space and time, it has been estimated that only about 1112 BCM of total potential of 1869 BCM can be put to beneficial use, 690 BCM being due to surface water resources and 432 BCM due to ground water.
- Water flow in a river depends on size of its catchment area or river basin and rainfall within its catchment area.

Table 1. Origin, length and catchment areas of major river basins in India

Name of the river	Origin	Length of river (km)	Catchment area (M ha)
Indus	Mansarovar (Tibet)	1114 (2880)	32.12 (116.55)
Ganga	Gangotri(Uttar Kashi)	2525	86.15 (108.60)
Brahmaputra	Kailash Range (Tibet)	916 (2900)	19.44 (58.00)
Mahi	Dhar (M.P.)	583	3.48
Narmada	Amar Kantak (MP)	1312	9.88
Tapti	Betul (MP)	724	6.51
Brahmani	Ranchi (Bihar)	799	3.00
Mahanadi	Nazri (MP)	851	14.16
Godavari	Nasik (Maharastra)	1465	31.28
Krishna	Mahabaleswar (Maharastra)	1401	25.99
Pennar	Kolar (Karnataka)	597	5.52
Cauvery	Coorg (Karnataka)	800	8.12

GROUND WATER RESOURCES

- Groundwater is the water located beneath the earth’s surface in soil pore spaces and in the fractures of rock formations.
- India is blessed with a comparatively large resource of ground water.
- Groundwater is the most preferred source of water in various user sectors in India on account of its near universal availability, dependability and low capital cost.
- The annual potential natural groundwater recharge from rainfall in India is about 342.43 km^3, which is 8.56% of total annual rainfall of the country.
- The annual potential groundwater recharge augmentation from canal irrigation system is about 89.46 km^3.

Table 2. Groundwater resources of India (in km³/year)

S No	particulars	Quantity (km³ yr⁻¹)
1	Total replenishable groundwater resource	432
2	Provision for domestic, industrial and other uses	71
3	Available groundwater resource for irrigation	361
4	Utilizable groundwater resource for irrigation (90 % of S No 3)	325
5	Total utilizable groundwater resource (sum of S No 2 and 4)	396

Ground water regions of India

- The availability and development potential of groundwater in India on the basis of the geological consideration can be described under the following three broad categories:

  i. Unconsolidated rocks

  ii. Semi-consolidated rocks

  iii. Consolidated rocks

Rainfall contribution to Ground Water

* **Table 3. percentage of rainfall infiltration to ground water body in different rock types and formations**

S No	Rock type /formation	Percentage rainfall infiltrating to ground water body
1	Hard rock formations and Deccan traps	10
2	Consolidated rocks (sandstone)	5-10
3	River alluvia	15-20
4	Indo-Gangatic alluvium	20
5	Coastal alluvia	10-15
6	Western Rajsthan dune sand	2
7	Intermontane valleys	15-20
Raghava Rao, et al. (1969)		

UTILIZATION OF WATER

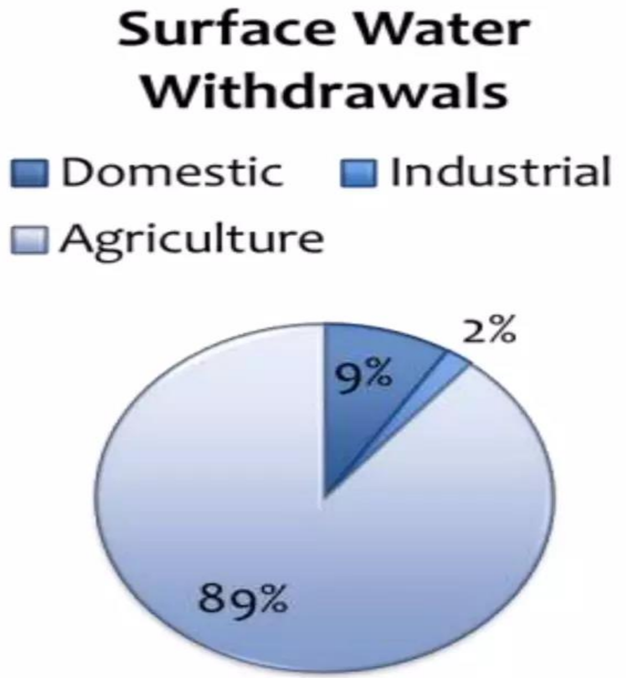


Fig 2. Sectoral Usage of Surface Water

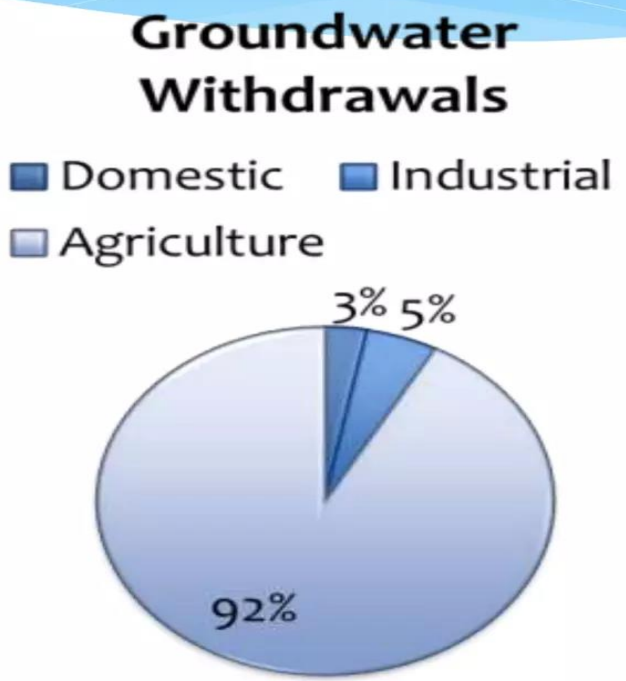


Fig 2. Sectoral Usage of Groundwater

PROBLEMS OF WATER RESOURCES IN INDIA

- Spatial and temporal distribution
- Conflicting objectives of Water Resources Development
- Increasing sectorial competition between sectors
- Pollution of Surface and Groundwater Resources
- Rising and falling water table

WATER RESOURCES TO MEET THE FUTURE NEEDS

- Irrigation Improvement
- Dew as water resource
- Reuse of drainage water
- Conjunctive use of Sodic and Canal waters
- Multi use of water
- Separation of Grey/ Black waters
- Technology upgradation in Agriculture

GROUND WATER AND ITS POTENTIAL

- Groundwater is water that exists in the pore spaces and fractures in rocks and sediments beneath the Earth’s surface.
- It originates as rainfall or snow and then moves through the soil and rock into the groundwater system, where it eventually makes its way back to the surface streams, lakes, or oceans.

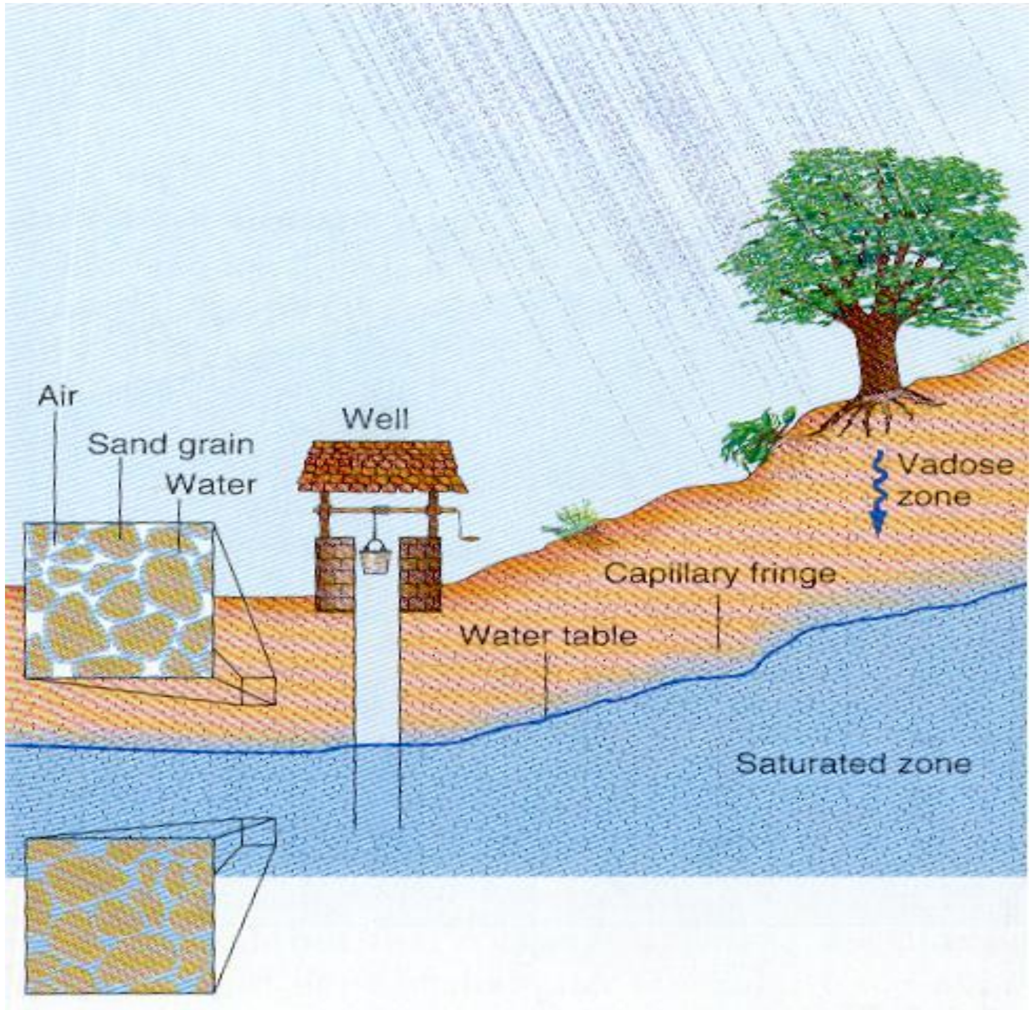
Porosity and Permeability

- porosity: the percentage of rock or sediment that consists of voids or openings
- permeability: the capacity of a rock to transmit a fluid such as water or petroleum through pores and fractures
- porous: a rock that holds much water
- permeable: a rock that allows water to flow easily through it
- impermeable: a rock that does not allow water to flow through it easily

The Water Table

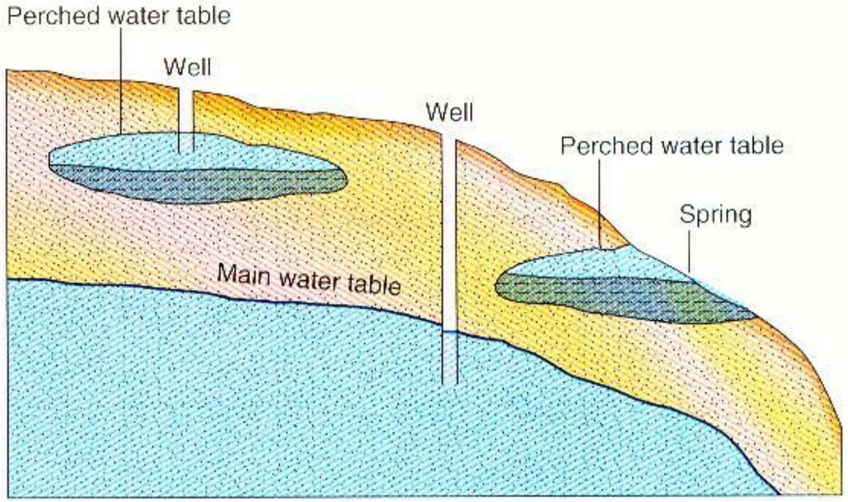
- saturated zone: the subsurface zone in which all rock openings are filled with water
- water table: the upper surface of the zone of saturation
- vadose zone: a subsurface zone in which rock openings are generally unsaturated and filled partly with air and partly with water; above the saturated zone
- capillary fringe: a transition zone with higher moisture content at the base of the vadose zone just above the water table

The Water Table (cont.)



The Water Table (cont.)

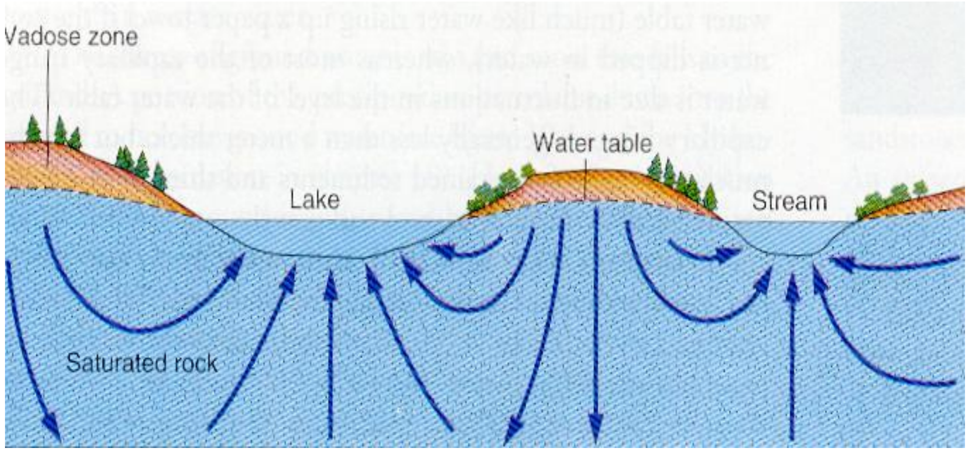
- perched water table: the top of a body of ground water separated from the main water table beneath it by a zone that is not saturated



The Movement of Ground Water

- Most ground water moves relatively slowly through rock underground

because it moves in response to differences in water pressure and elevation, water within the upper part of the saturated zone tends to move downward following the slope of the water table.



Movement of ground water beneath a sloping water table in uniformly permeable rock. Near the surface the ground water tends to flow parallel to the sloping water table

Movement of Ground Water (cont.)

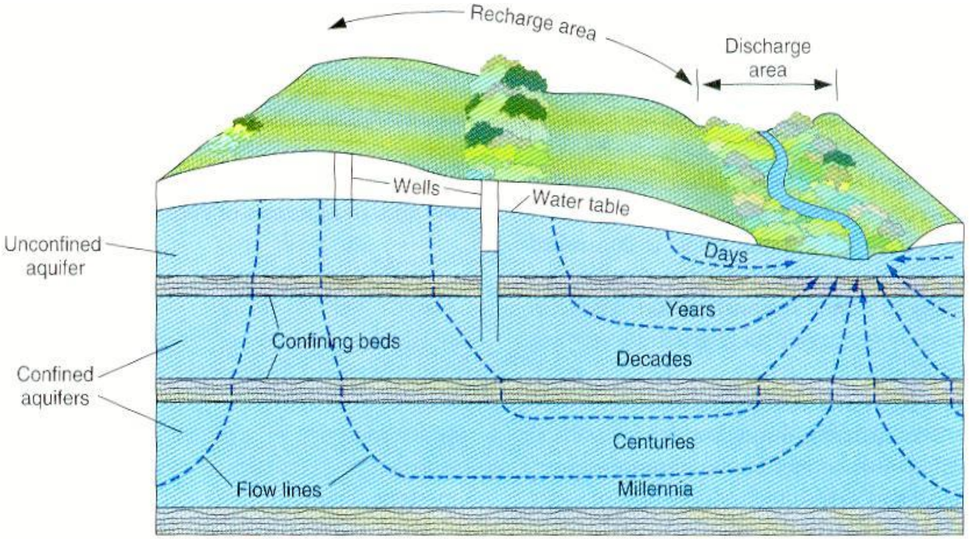
- **Factors affecting the flow of ground water:**
  - the slope of the water table - the steeper the water table, the faster ground water moves
  - permeability - if rock pores are small and poorly connected, water moves slowly; when openings are large and well connected, the flow of water is more rapid

Aquifers

- Aquifer: a body of saturated rock or sediment through which water can move easily
- Good aquifers include sandstone, conglomerate, well-joined limestone, bodies of sand and gravel, and some fragmental or fractured volcanic rocks such as columnar basalt
- Aquitards: when the porosity of a rock is 1% or less and therefore retards the flow of ground water

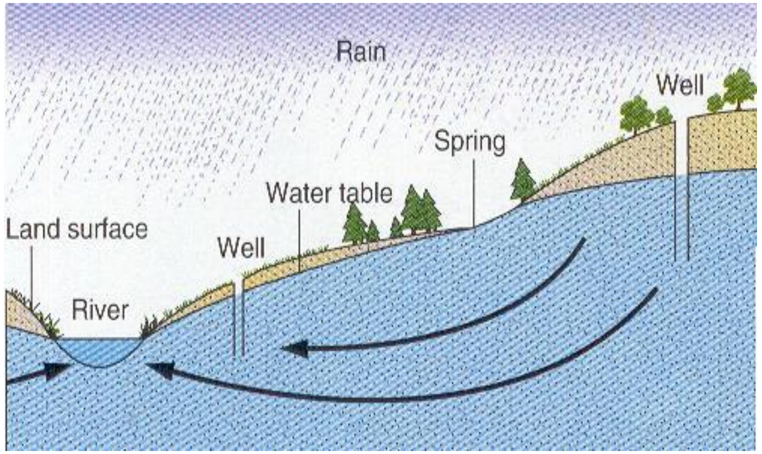
Aquifers (cont.)

- **Unconfined aquifer**: a partially filed aquifer exposed to the land surface and marked by a rising and falling water table
- **Confined aquifer (artesian aquifer):** an aquifer completely filled with pressurized water and separated from the land surface by a relatively impermeable confining bed, such as shale

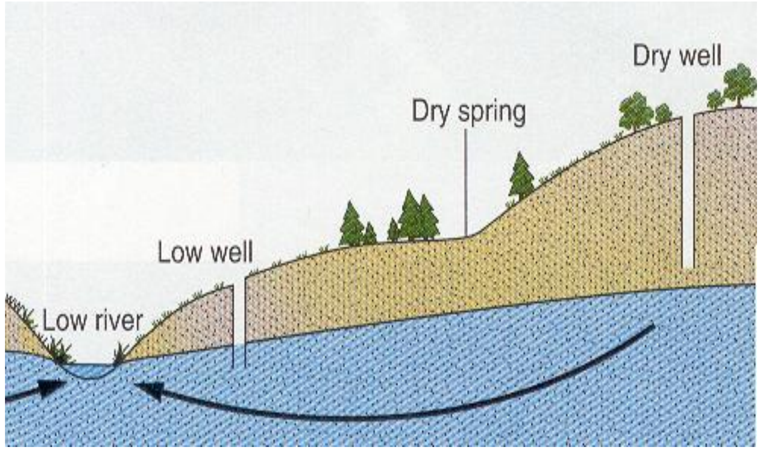


Wells

- Well: a deep hole, generally cylindrical, that is dug of drilled into the ground to penetrate an aquifer within the saturated zone
- Recharge: the addition of new water to the saturated zone
- The water table in an unconfined aquifer rises in wet seasons and falls in dry seasons as water drains out of the saturated zone into rivers



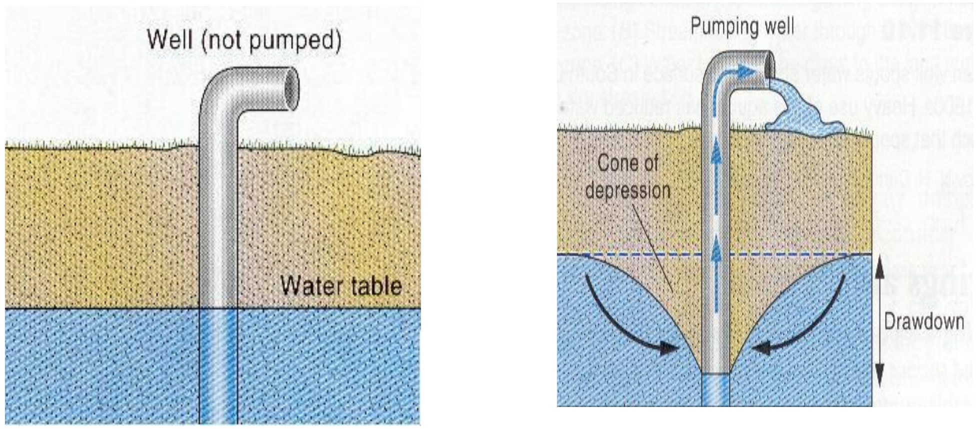
Wet season: water table and rivers are high; springs and wells flow readily



Dry season: water table and rivers are low; some springs and wells dry up

Wells (cont.)

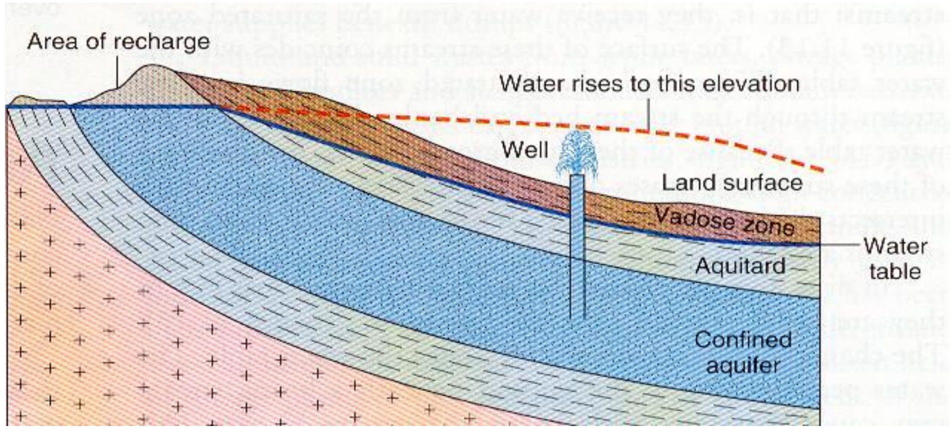
- **Cone of Depression:** a depression of the water table formed around a well when water is pumped out; it is shaped like an inverted cone
- **Drawdown**: the lowering of the water table near a pumped well

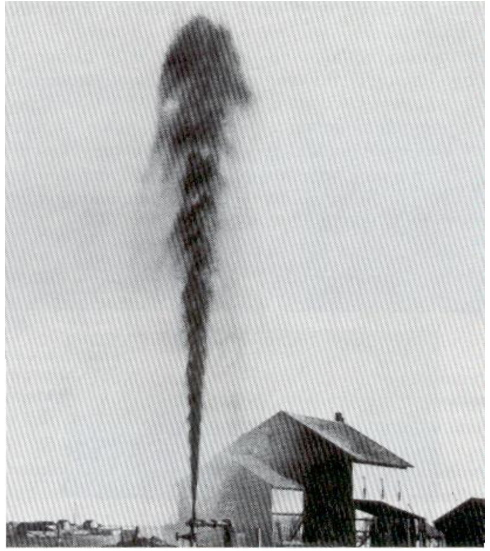


Pumping well lowers the water table into a cone of depression

Wells (cont.)

- artesian well: a well in which water rises above the aquifer

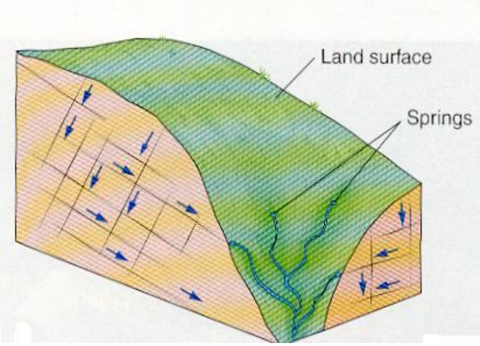




Artesian well spouts water above land surface in South Dakota, early 1900s. Heave use of this aquifer has reduced water pressure so much that spouts do not occur today

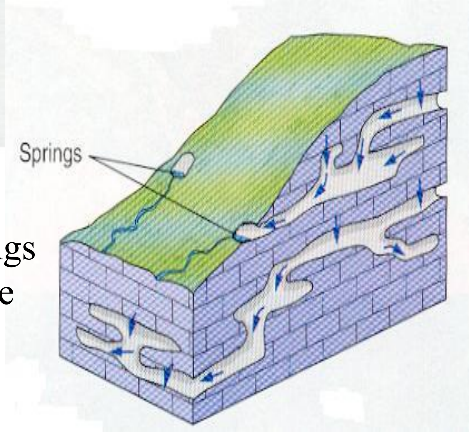
Springs and Streams

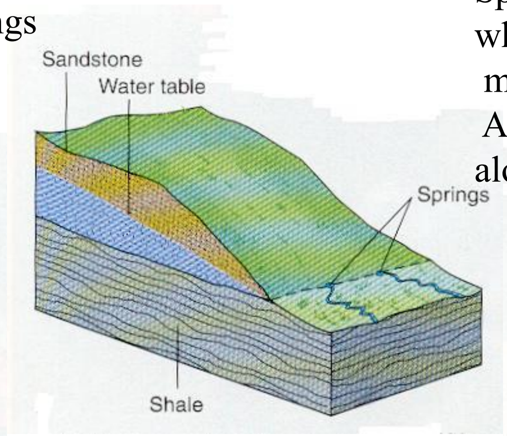
- Spring: a place where water flows naturally from rock onto the land surface
- Some springs discharge where the water table intersects the land surface, but they also occur where water flows out from caverns or along fractures, faults, or rock contacts that come to the surface



Water moves along fractures in crystalline rock and forms springs where the fractures intersect the land surface

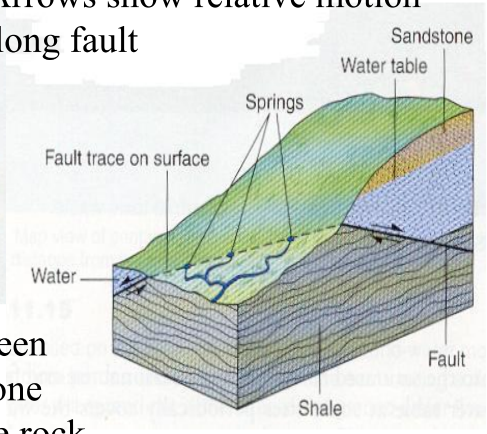
Water enters caves along joints in limestone and exits as springs at the mouths of caves





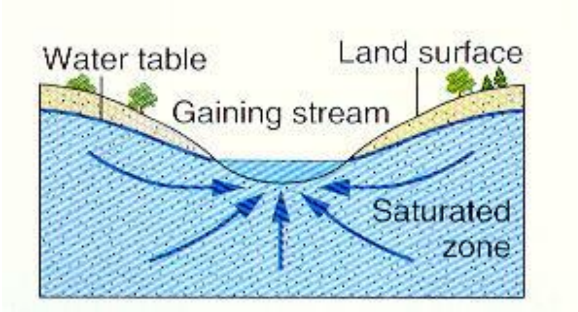
Springs form at the contact between a permeable rock such as sandstone and an underlying less permeable rock such as shale

Springs can form along faults when permeable rock has been moved against less permeable rock. Arrows show relative motion along fault

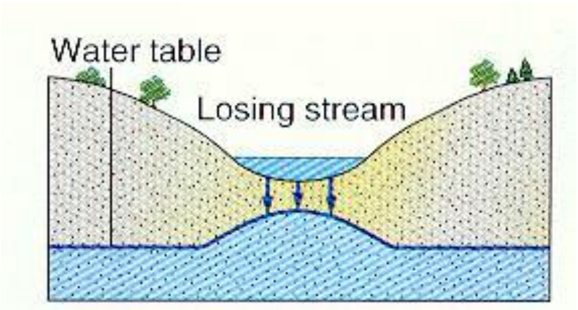


Springs and Streams (cont.)

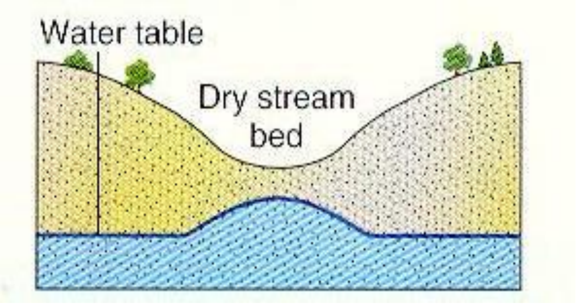
- Gaining stream: a stream that receives water from the zone of saturation
- Losing stream: a stream that looses water to the zone of saturation



Stream gaining water from saturated zone



Stream losing water through stream bed to saturated zone



Water table can be close to the land surface beneath a dry stream bed

Pollution of Ground Water

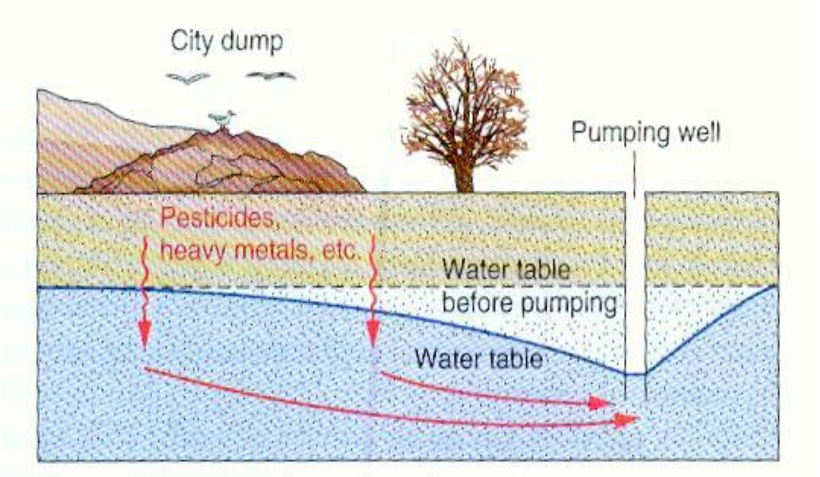
- Pesticides, herbicides, fertilizers: chemicals that are applied to agricultural crops that can find their way into ground water when rain or irrigation water leaches the poisons downward into the soil
- Rain can also leach pollutants from city dumps into ground-water supplies
- Heavy metals such as mercury, lead, chromium, copper, and cadmium, together with household chemicals and poisons, can all be concentrated in ground-water supplies beneath dumps

Pollution of Ground Water (cont.)

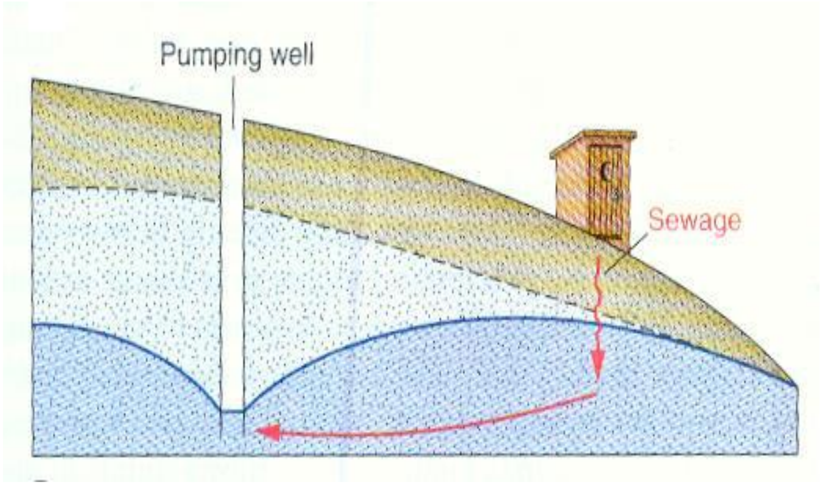
- Liquid and solid wastes from septic tanks, sewage plants, and animal feedlots and slaughterhouses may contain bacteria, viruses, and parasites that can contaminate ground water
- Acid mine drainage from coal and metal mines can contaminate both surface and ground water
- Radioactive waste can cause the pollution of ground water due to the shallow burial of low-level solid and liquid radioactive wastes from the nuclear power industry

Pollution of Ground Water (cont.)

- Pumping wells can cause or aggravate ground-water pollution



Water table steepens near a dump, increasing the velocity of ground-water flow and drawing pollutants into a well



Water-table slope is reversed by pumping, changing direction of the ground-water flow, and polluting the well

Balancing Withdrawal and Recharge

- a local supply of groundwater will last indefinitely if it is withdrawn for use at a rate equal to or less than the rate of recharge to the aquifer
- if ground water is withdrawn faster than it is being recharged, however, the supply is being reduced and will one day be gone

Balancing Withdrawal and Recharge

- Heavy use of ground water can result in:
  - a regional water table dropping
  - deepening of a well which means more electricity is needed to pump the water to the surface
  - the ground surface settling because the water no longer supports the rock and sediment

Subsidence of the land surface caused by the extraction of ground water, near Mendota, San Joaquin Valley, CA. Signs on the pole indicate the positions of the land surface in 1925, 1955, and 1977. The land sank 30 feet in 52 years.

Balancing Withdrawal and Recharge (cont.)

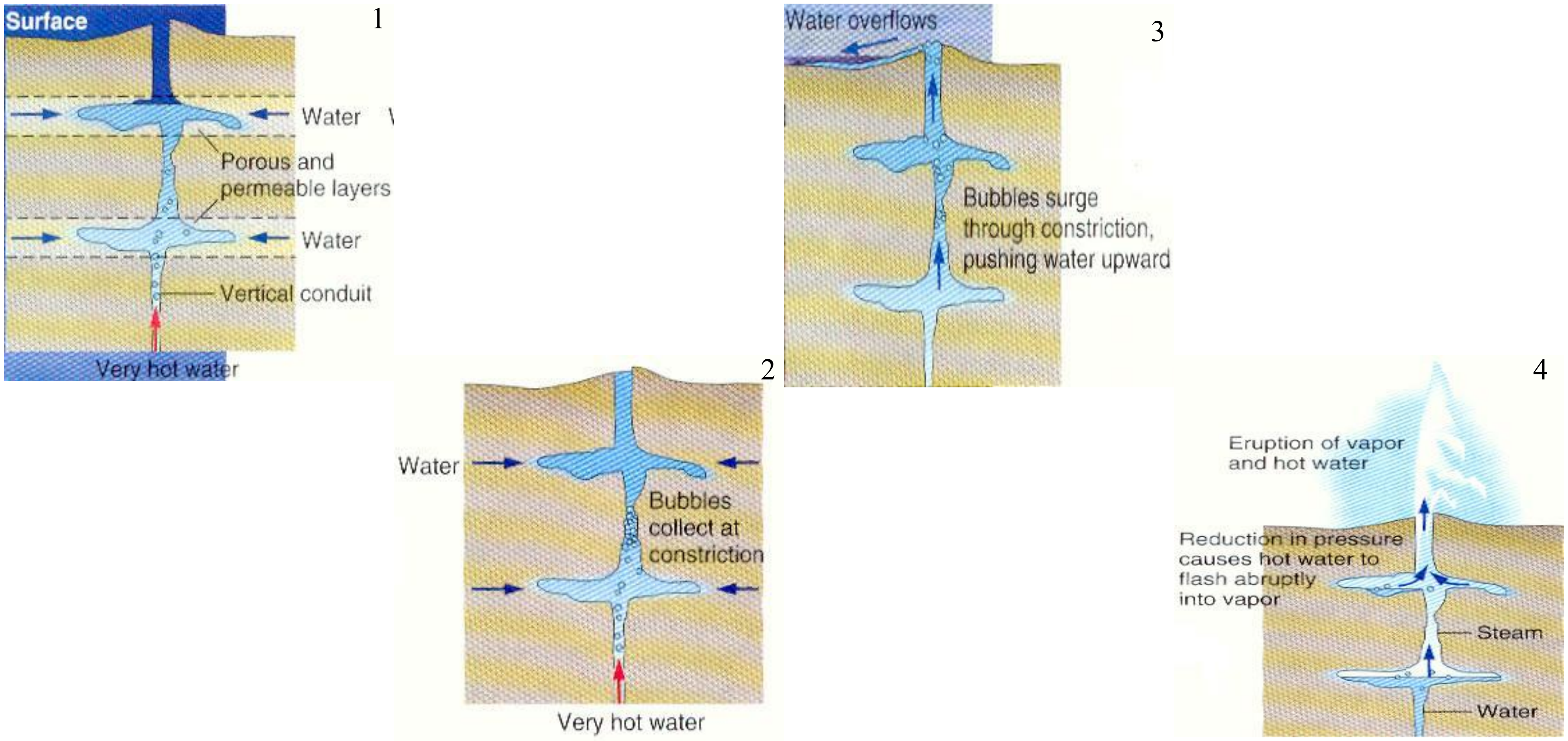
- To avoid the problems of falling water tables, subsidence, and compaction, many towns use artificial recharge to increase recharge; natural floodwaters or treated industrial or domestic wastewaters are stored in infiltration ponds in the surface to increase the rate of water percolation into the ground

Hot Water Underground

- hot springs: springs in which the water is warmer than human body temperature
- water can gain heat in two ways while underground:
  - ground water may circulate near a magma chamber or a body of cooling igneous rock
  - ground water may circulate unusually deep in the earth

Hot Water Underground

- geyser: a type of hot spring that periodically erupts hot water and stream; the water is generally near boiling ($100^{o}C$)



Geothermal Energy

- Electricity can be generated by harnessing naturally occurring stream and hot water in areas that are exceptionally hot underground (geothermal areas);
- nonelectric uses of geothermal energy include space heating, as well as paper manufacturing, ore processing, and food preparation

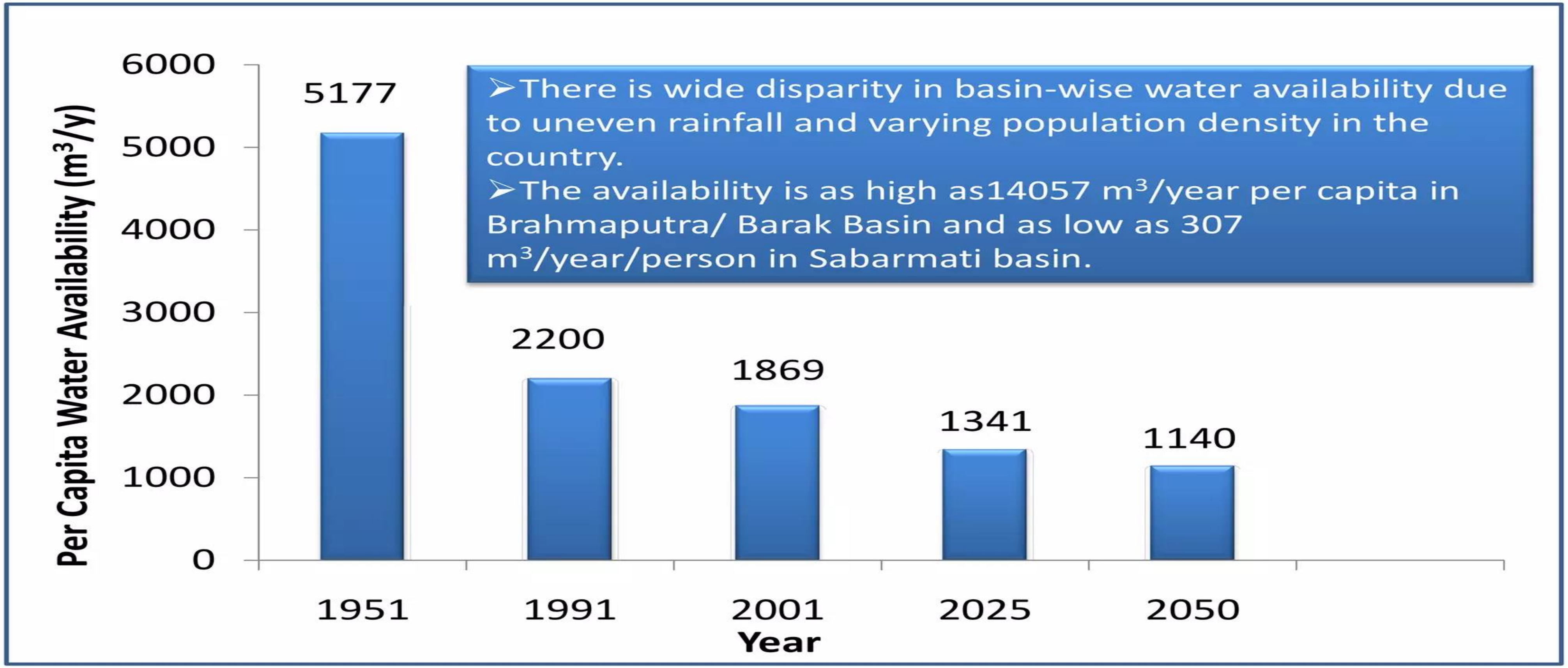
Water and Contamination Status

- 54% of Indian’s GW wells are declining
- 21 major city expected run out of groundwater (GW) by 2020
- 600 million people face high to extreme water stress
- Approximately two lakh people die every year due to inadequate access to safe water
- Approximately 3/4 of the households in the country do not have drinking water at their premise.
- With nearly 70% of water being contaminated.
- Water quality index: 120^{th} amongst 122 countries

cont.,

- Total population: 121 crore (2011 census)
- Distribution: rural 69% and urban 31%
- No of districts: 712 (as of 2018)
- 29 State and 7 Union territories
- 85 % of rural population of the country uses ground water for drinking and domestic purposes.
- Fluoride (>1.5 mg/l): 276 districts in 20 states or UT
- Nitrate (>45 mg/l): 387 districts in 21 states or UT
- Arsenic (>0.05 mg/l): 86 districts in 10 states or UT
- Iron (>1.0 mg/l): 297 districts in 24 states or UT
- Heavy metal [Lead (>0.01 mg/l), Cadmium (>0.003 mg/l), Chromium (>0.05 mg/l)]: 113 districts in 15 states or UT

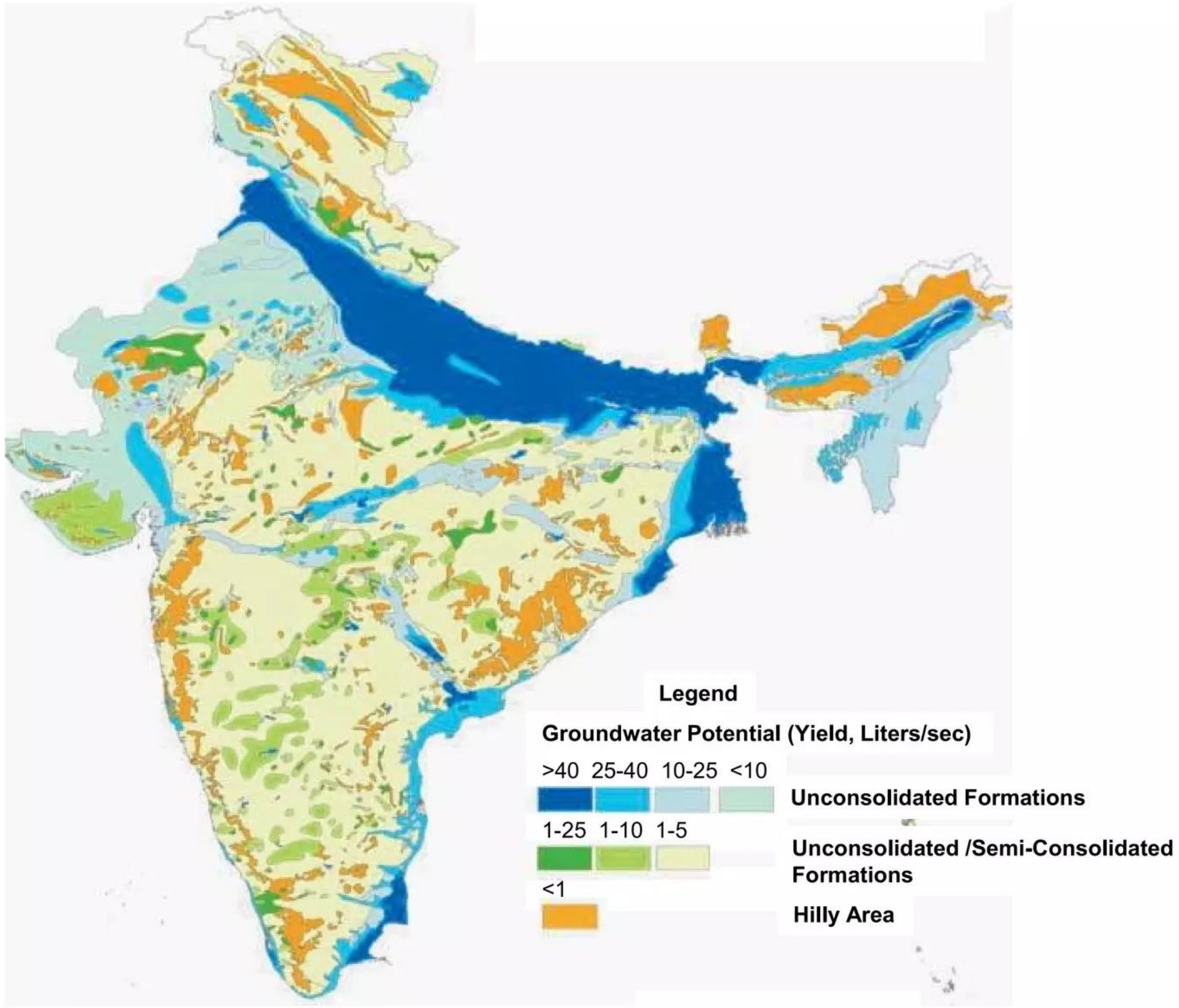
Per Capita Water Availability



Factors that Improve Water Availability

- Source augmentation and restoration of water bodies
- Source augmentation (Groundwater)
- Major and medium irrigation—Supply side management
- Watershed development—Supply side management
- Participatory irrigation practices—Demand side management
- Sustainable on-farm water use practices—Demand side management
- Rural drinking water
- Urban water supply and sanitation
- Policy and governance

Hydrogeology of India



Artificial Recharge

- Natural replenishment of ground water reservoir is slow.
- Artificial recharge to ground water has become an important and frontal management strategy .
- Generally, natural recharge is restricted to monsoon period.
- Need to prepare a systematic implementation plan for augmenting ground water resources under various hydrogeological situations.

Basic Requirement of Artificial Recharge

- Availability of non-committed water
  - Surplus monsoon run off.
  - Treated municipal and industrial wastewaters.

- Identification of suitable hydrogeological environment.
  - The aquifers best suited for artificial recharge are those aquifers which absorb large quantities of water and do not release them too quickly (vertical hydraulic conductivity- high, while the horizontal hydraulic conductivity -moderate).
  - The upper 3 m of the unsaturated zone is not considered for recharging, since it may cause adverse environmental impact e.g. water logging, soil salinity, etc.

- Cost effective artificial recharge techniques.

Criteria and Inputs for Planning

- Identification of Area
- Hydro-meterological Studies
- Hydrological Studies
- Hydrogeological Studies
- Soil Infiltration Studies
- Aquifer Geometry
- Chemical Quality of Source Water

ARTIFICIAL RECHARGE TECHNIQUES

Direct Surface Techniques

- Flooding
- Basins or percolation tanks
- Stream augmentation
- Ditch and furrow system
- Over irrigation

Direct Sub-surface Techniques

- Injection wells or recharge wells
- Recharge pits and shafts
- Dug well recharge
- Natural openings, cavity fillings.

Combination Surface – sub-surface Techniques

- Basin or percolation tanks with pit shaft or wells.

Indirect Techniques

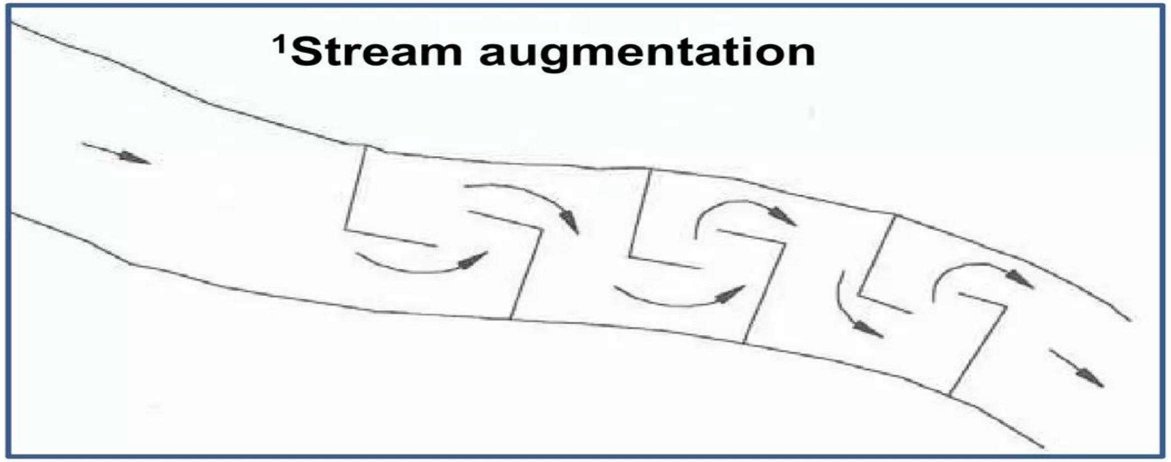
- Induced recharge from surface water source.
- Aquifer modification.

Artificial Recharge Structures

Basins or percolation tanks

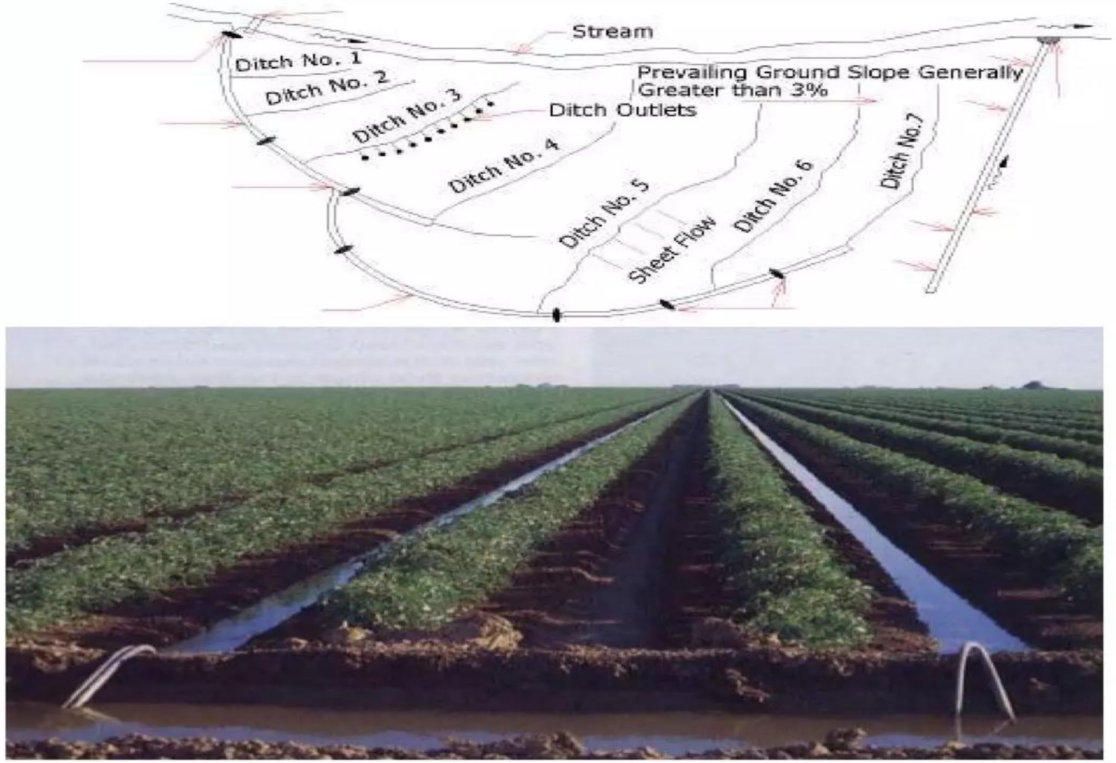
[1]Satpura Mountain front area in Maharashtra

[1]Stream augmentation

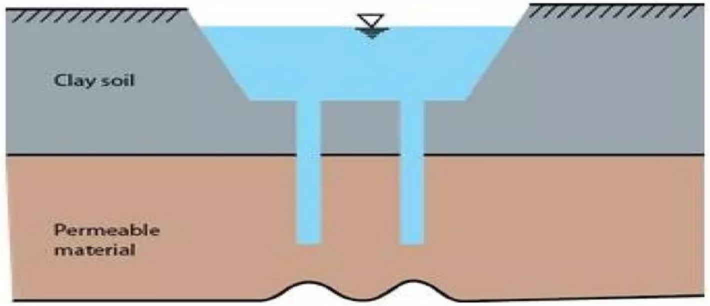


Source: [1]Google Images

Ditch and Furrow System[1]

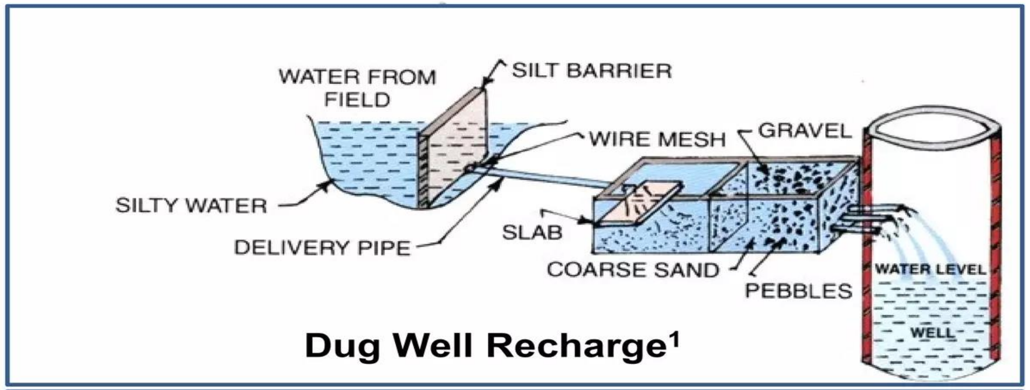


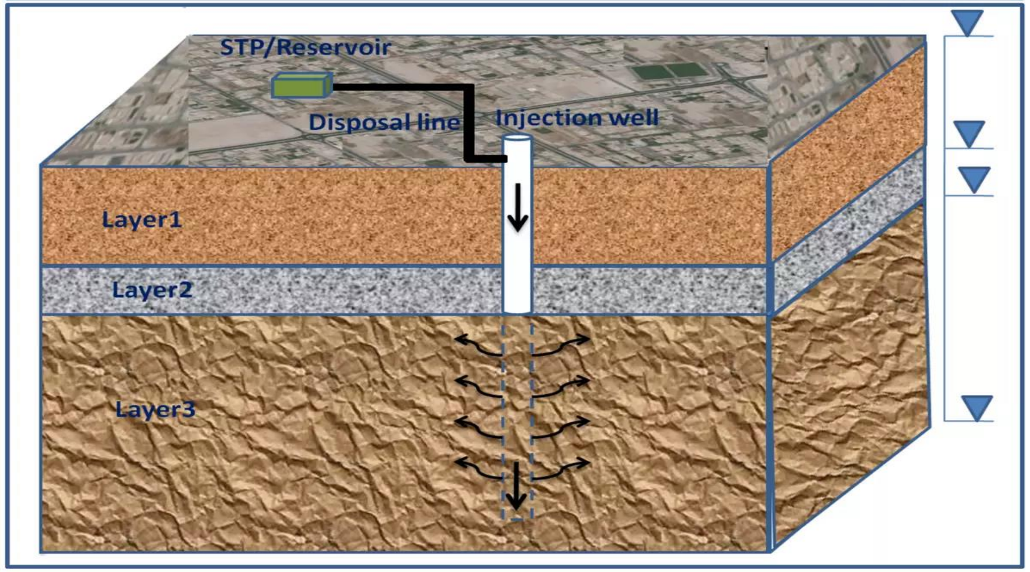
Research Pit and Shaft[2]



Check Dam[1]

Source: [2]http://nptel.ac.in/courses/105103026/module4/lec29/3.html, [1]Google Images





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Conclusion

- Do not have/do not want to adopt latest groundwater management technology (especially, for GW recharge)at local to national level.
- Most policies have not enforce properly at local and state level.
- Leak of coordination betweens state and central agencies.
- Illegal GW extraction at a single house through tube well/pumping well (even lots of real estate housing also).
- A small park at colony/mohal level have a GW extraction well (might be government registered but operated by colony person-**misuse**).
- Provide free/fix rate electricity for farmer-**misuse**

cont.,

- Each every policy evaluate by technical committee and also responsible for implementation with no/minimal interfere of politicians. May be introduce some reward schemes for engineer/professional and states.

- Groundwater-Surface interaction model for regional level and local model for Over-Exploited blocks should be used for strategic decision and planning.

- Should have better characterization of GW aquifer.

- Develop and implement real-time water quality alarms tools/ software at water supply units.

- Our focus should be GW qualitative and quantitative both.

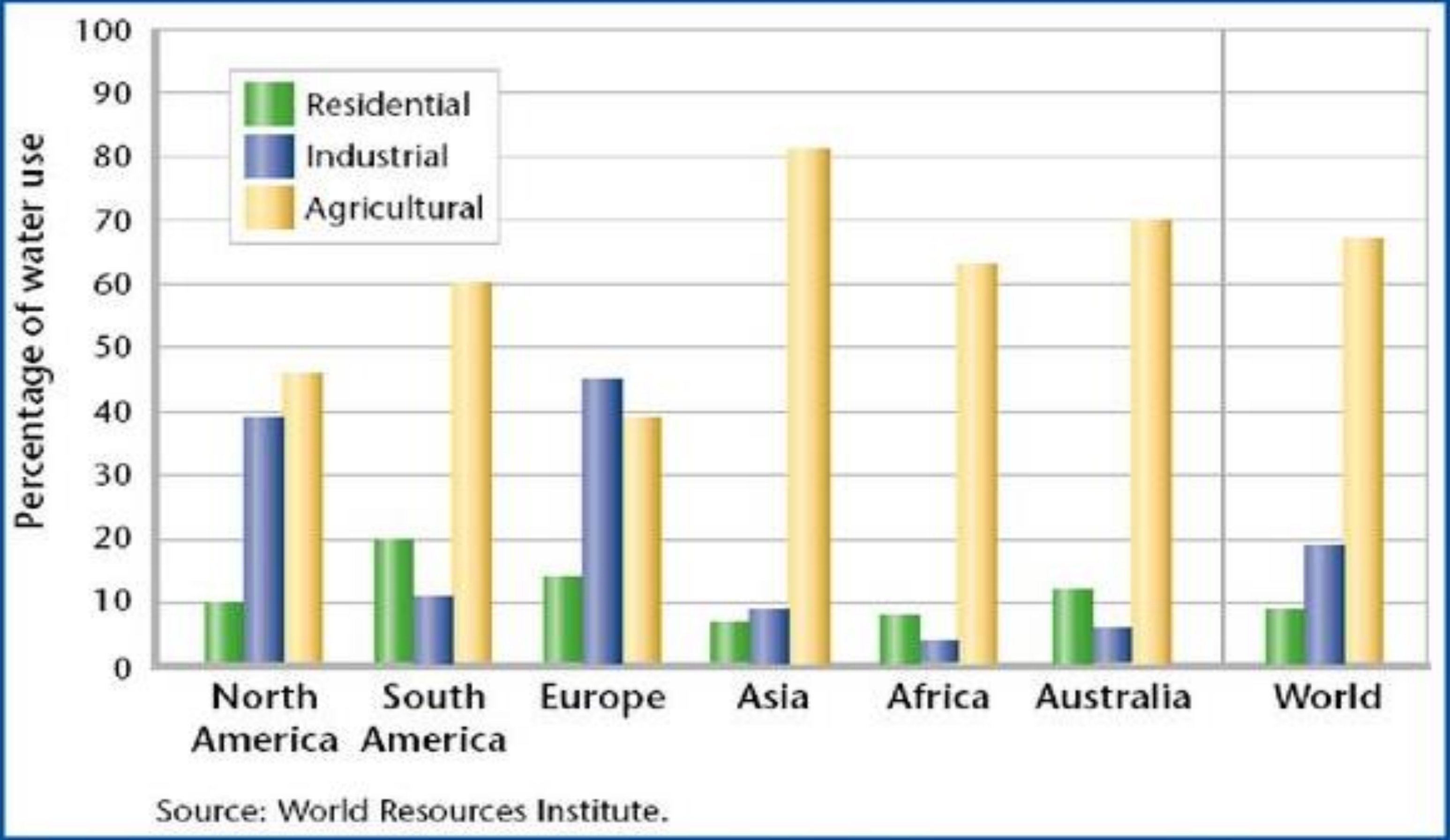
WATER USE SECTORS

Water Use and Management

- When a water supply is polluted or overused, everyone living downstream can be affected.
- A shortage of clean, fresh water is one of the world's **most pressing** environmental problems.
- According to the World Health Organization, more than **1 billion** people lack access to a clean, reliable source of fresh water.

Global Water Use

- There are three major uses for water: **residential use, agricultural use, and industrial use**.



Global Water Use

- Most of the fresh water used worldwide is used to **irrigate crops**.
- However, patterns of water use are not the same everywhere. The availability of fresh water, population sizes, and economic conditions affect how people use water.
- Industry accounts for about **19 percent** of the water used in the world, with the highest percent occurring in **North America and Europe**.
- About **8 percent** of water is used by households.

Residential Water Use

- There are striking differences in residential water use throughout the world.
  - For example, the average person in the United States uses about **300 L** of water a day.
  - But in India, the average person uses only **41 L** of water everyday.
- In the U.S., only about half of residential water use is for activities inside the home, such as drinking and cooking. The remainder of the water used residentially is used for activities outside the home such as watering lawns.

Residential Water Use

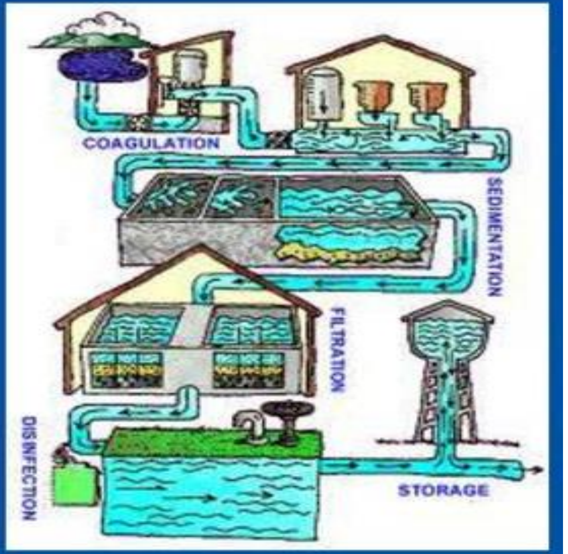
Daily Water Use in the United States (per Person)	
Use	Water (L)
Lawn watering and pools	95
Toilet flushing	90
Bathing	70
Brushing teeth*	10
Cleaning (inside and outside)	20
Cooking and drinking	10
Other	5

Water Treatment

- Most water must first be made potable.
  - **Potable** means suitable for drinking.
- Water treatment removes elements such as **mercury, arsenic, and lead**, which are poisonous to humans even in low concentrations.
- These elements are found in polluted water, but they can also occur naturally in groundwater.

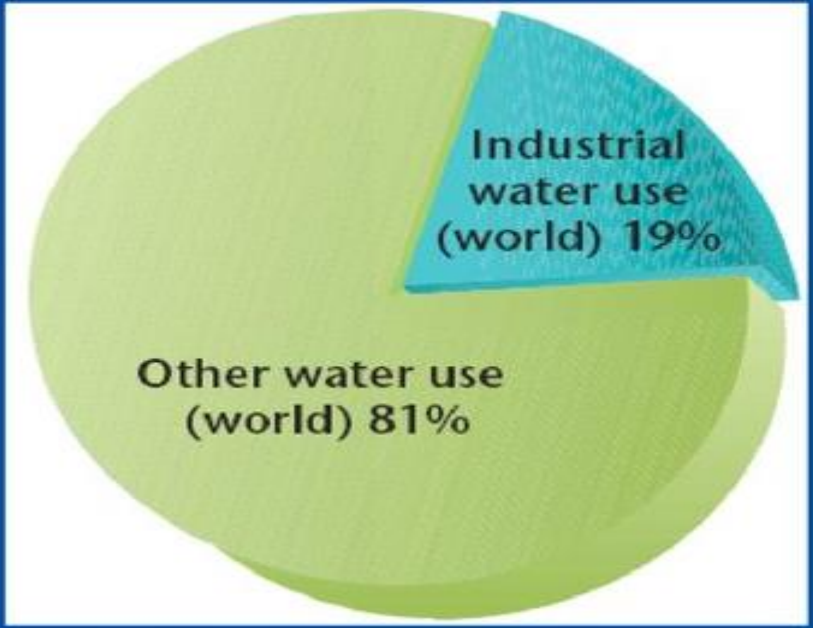
Water Treatment

- A **pathogen** is a virus, microorganism, or other substance that causes disease.
- Pathogens are found in water contaminated by **sewage or animal feces**, but can be removed with water treatment.
- There are several methods of treating water to make it potable. A common method includes both **physical and chemical treatment**.



Industrial Water Use

- Industry accounts for **19 percent** of water used in the world. Water is used to manufacture goods, to dispose of wastes, and to generate power.

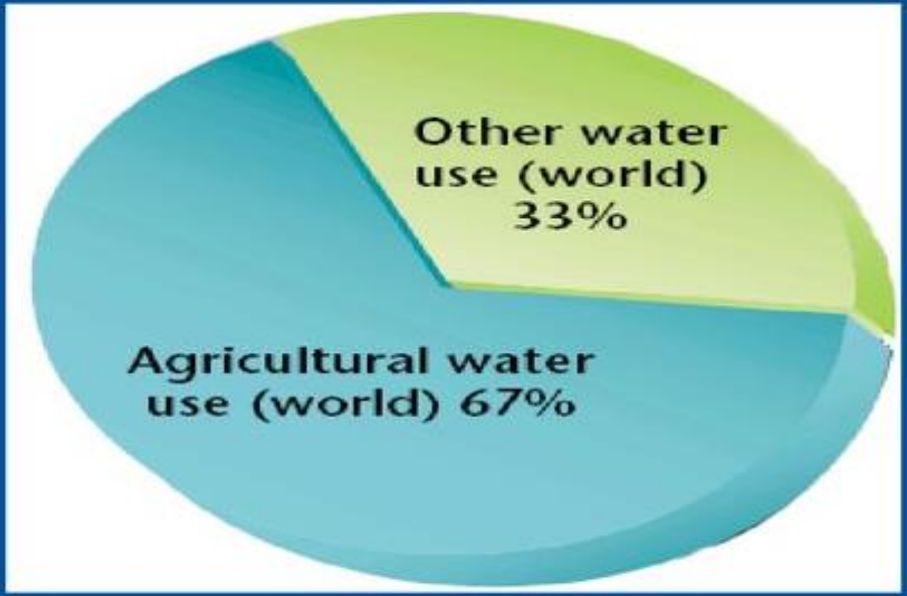


Industrial Water Use

- Most of the water that is used in industry is used to **cool** power plants.
- Power-plant cooling systems usually **pump water** from a surface water source such as a river or a lake, carry the water through pipes in a **cooling tower**, and then **pump** the water back into the source.
- The water that is returned is usually warmer than the source, but is generally clean and can be used again.

Agricultural Water Use

- Agriculture accounts for **67 percent** of the water used in the world. Plants require a lot of water to grow, and as much as 80 percent of the water used in agriculture evaporates.



Irrigation

- **Irrigation** is a method of providing plants with water from sources other than direct precipitation.
- Many different irrigation techniques are used today. For example, some crops are irrigated by shallow, water filled ditches.
- In the U.S., **high-pressured overhead** sprinklers are the most common form of irrigation.
- However, this method is **inefficient** because nearly half the water evaporates and never reaches the plant roots.

Water Management Projects

- People often prefer to live in areas where the natural distribution of surface water is inadequate.
- Water management projects, such as **dams**, are designed to meet these needs.
- Water management projects can have various goals, such as
  - bringing in water to make a dry area **habitable**
  - creating a **reservoir** for drinking water,
  - **generating electric power**, which then allows people to live and grow crops in desert areas.

Water Diversion Projects

- To supply dry regions with water, all or part of a river can be diverted into canals that carry water across great distances.
- The Colorado River begins as a glacial stream in the Rocky Mountains and quickly grows larger as other streams feed into it.
- As the river flows south, it is divided to meet the needs of 7 states.
- So much of the river's water is diverted for irrigation and drinking water that the river runs dry before it reaches the Gulf of California.

Water Conservation

- As water sources become depleted, water becomes more expensive.
- This is because wells must be dug deeper, water must be piped greater distances, and polluted water must be cleaned up before it can be used.
- **Water conservation** is one way that we can help ensure that everyone will have enough water at a reasonable price.

Water Conservation in Agriculture

- Most of the water loss in agriculture comes from **evaporation, seepage, and runoff**, so technologies that reduce these problems go a long way toward conserving water.
- **Drip irrigation systems** offer a promising step toward conservation.
  - They deliver small amounts of water directly to plant roots by using **perforated tubing**.
  - Water is released to plants as needed and at a controlled rate.

Water Conservation in Industry

- In industry today, the most widely used water conservation practices involve the **recycling of cooling water and wastewater**.
- Instead of discharging used water into a nearby river, businesses often recycle water and use it again.
- In an innovative program, Denver, Colorado pays small businesses to introduce water conservation measures.
- This not only saves money for the city and the business but also makes more water available for agricultural and residential use.

Water Conservation at Home

- People can conserve water by changing a few everyday habits and by using only the water that they need.
- Water-saving technology, such as **low-flow toilets**, can also help reduce household water use.
- To conserve water, many people water their lawns at night to reduce the amount of evaporation.
- Another way some people conserve water outside the home is by **xeriscaping**, or designing a landscape that requires minimal water use.

Water Conservation at Home

What You Can Do to Conserve Water

- Take shorter showers, and avoid taking baths unless you keep the water level low.
- Install a low-flow shower head in your shower.
- Install inexpensive, low-flow aerators in your water faucets at home.
- Purchase a modern, low-flow toilet, install a water-saving device in your toilet, or simply place a water-filled bottle inside your toilet tank to reduce the water used for each flush.
- Do not let the water run while you are brushing your teeth.
- Fill up the sink basin rather than letting the water run when you are shaving, washing your hands or face, or washing dishes.
- Wash only full loads in your dishwasher and washing machine.
- Water your lawn sparingly.

Solutions for the Future

- In some places, conservation alone is not enough to prevent water shortages, and as populations grow, other sources of fresh water need to be developed.
- Two possible solutions are:
  - **Desalination**
  - **Transporting Fresh Water**

Desalination

- **Desalination** is the process of removing salt from ocean water.
- Some countries in drier parts of the world, such as the Middle East, have built desalination plants to provide fresh water.
- Most desalination plants heat salt water and collect the fresh water that evaporates.
- Because desalination consumes a lot of energy, the process is too expensive for many nations to consider.

Transporting Water

- In some areas of the world where freshwater resources are not adequate, water can be transported from other regions.
- For example, ships regularly travel from the mainland to the Greek islands towing enormous plastic bags full of fresh water.
- The ships anchor in port, and fresh water is then pumped onto the islands.

Transporting Water

- This bag solution is also being considered in the United States, where almost half of the available fresh water is in Alaska.
- Because **76 percent** of the Earth's fresh water is frozen in icecaps, icebergs are another potential freshwater source.
- For years, people have considered towing icebergs to communities that lack fresh water. But an efficient way to tow icebergs is yet to be discovered.

THANK YOU