GROUNDWATER

1

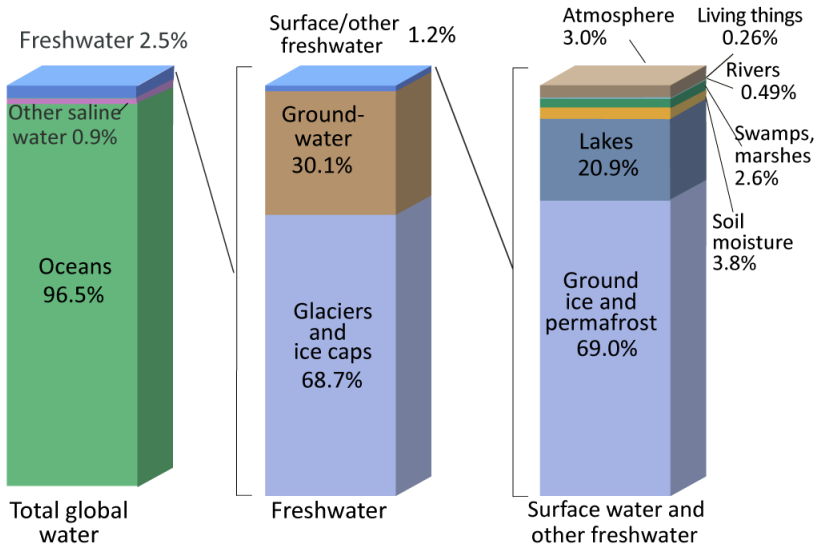
Basics of Groundwater

- Groundwater is one of the most widely available natural resources.
- Groundwater also represents the largest reservoir of freshwater readily available to man.
- The value of ground water, in terms of both economics and human welfare, is incalculable.
- Consequently, its sound development, diligent conservation, and consistent protection from pollution are important concerns of everyone.

2

2

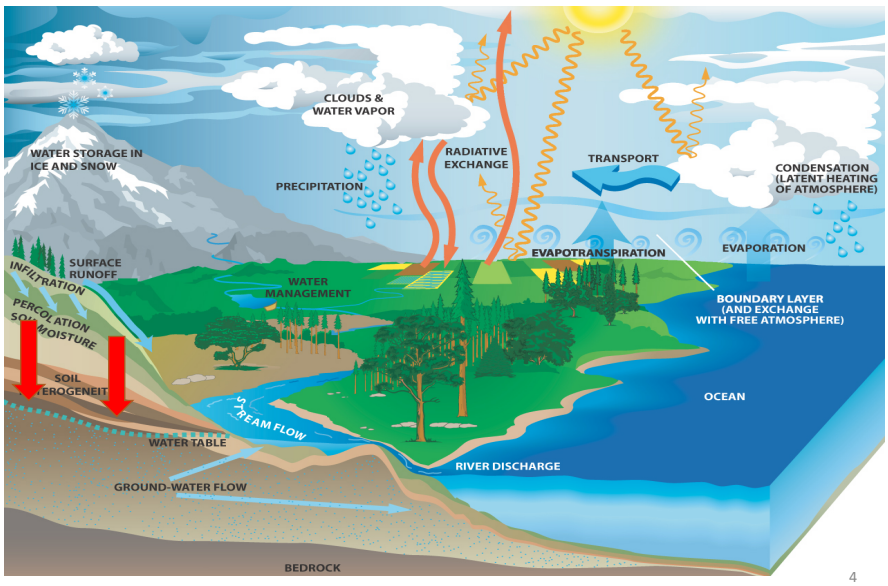
Distribution of Earth's water



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources. (Numbers are rounded).

3

Origin of Groundwater: Hydrologic Cycle



4

4

Hydrologic Cycle

- Essentially composed of natural storages and fluxes (e.g. ocean (storage) & precipitation (flux))
- A dynamic system constantly powered by the solar radiation and embraced by constant flow.
- A recycling system which enables water to remain clean.
- Almost all groundwater can be thought as a part of the hydrologic cycle including surface and atmospheric water.

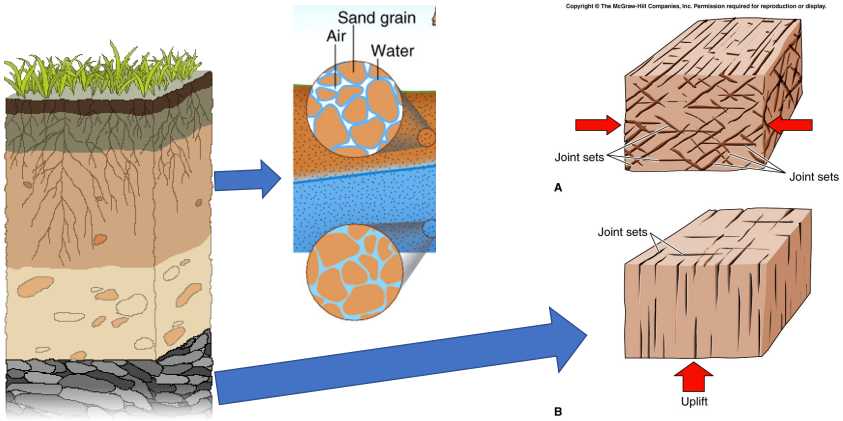
Thus, practically all groundwater originates as surface water

5

5

Where does water occur underneath the ground?

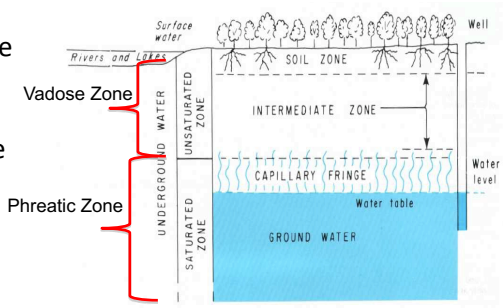
- Water fills up the spaces between soil particles and within the cracks and fractures in rocks.



6

Are all type of subsurface water termed as groundwater ?

- Water present in the sub surface openings that are completely saturated: **Groundwater**
- Water existing in the subsurface openings that comprise of both water and air: **Soil Moisture**
- **Groundwater** occurs in the Phreatic Zone while **Soil Moisture** occurs in the Vadose Zone



7

Occurrence of groundwater

- **Subsurface water** occurs in the void spaces of earth materials that range from consolidated rocks (Igneous, Metamorphic and Sedimentary rocks) to unconsolidated materials (ranging in size from fractions of a millimeter (clay size) to several meters (boulders)).
- **Groundwater** is that part of subsurface water in which the interstices are completely saturated with water
- Groundwater can be found in all three classes of rocks, but in general, the sedimentary rocks contain by far the greatest amounts of water due to their greater *porosity.*

Surface Reservoirs	Subsurface Reservoirs
Disadvantages	Advantages
High evaporative loss, even where humid climate prevails	Practically no evaporative loss
Need large areas of land	Need very small areas of land
May fail catastrophically	Practically no danger of failure
Varying water temperature	Water temperature uniform
Easily polluted	Usually high biological purity, although pollution can occur
Easily contaminated by radioactive fallout	Not rapidly contaminated by radioactive fallout
Water must be conveyed	Act as conveyance systems, thus obviating the need for pipes or canals

8

8

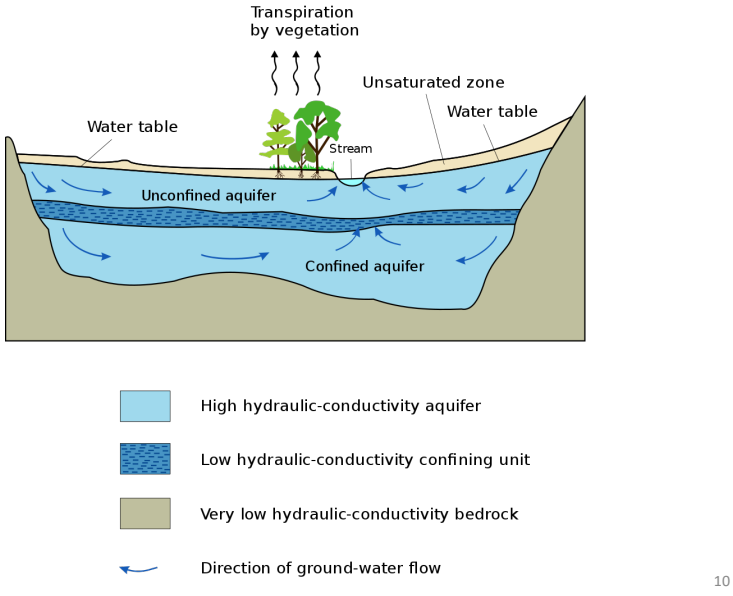
Types of natural storage

- An **aquifer** is a geologic unit that can store and transmit water at sufficient rates to supply wells.
- A **confining layer** is a geologic unit that has low to no intrinsic permeability (which is a measure of the how water flows through the rock layer).
- An aquifer is always underlain by a confining layer.
- Confining layers are subdivided into **aquifuges** (absolutely impermeable) and **aquitards** (impermeable relative to the adjacent units)
- Water table aquifers, those with no confining layer above, are called **unconfined aquifers**.
- Aquifers overlain by a confining layer are called **confined aquifers**

9

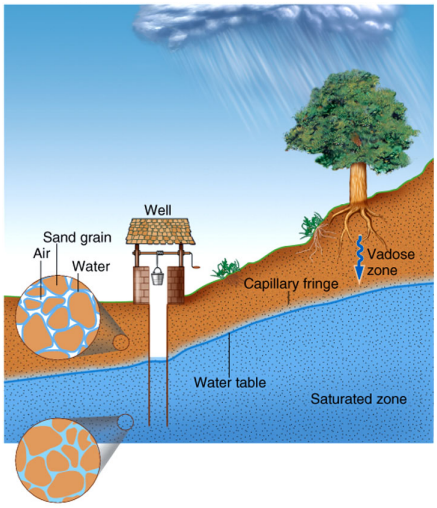
9

Types of natural storage

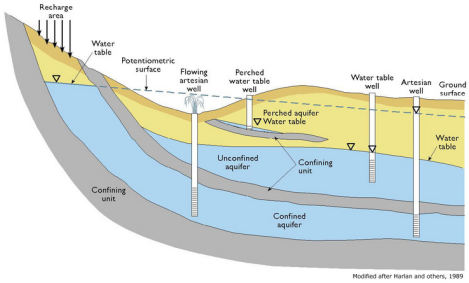


10

10



- **Water table** is the surface separating the vadose zone from the saturated zone.
- The water table is the level at which water in a well will stand.
- **Recharge** is termed as the process by which groundwater storage is replenished.



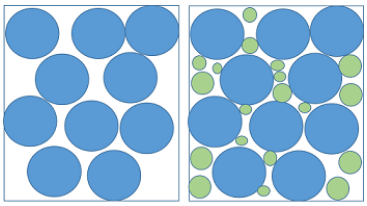
11

Important Hydraulic Properties of Earth Materials and Groundwater

- **Porosity** (n) determines how much water a rock or soil can hold and is defined as the volume of the pores of a rock or soil sample (V_v) divided by the total volume (V_T) of both pores and solid material, that is

$$n = \frac{V_v}{V_T}$$

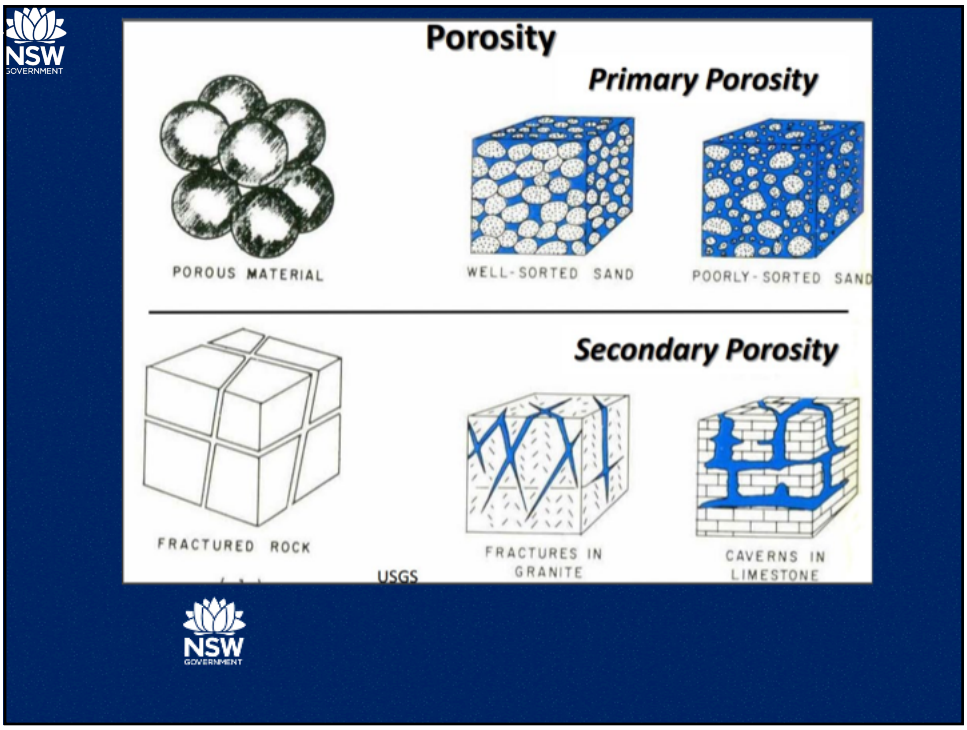
- Porosity has the units of $\frac{L^3_{voids}}{L^3_{R.E.V.}}$.
- It is a measure of the storage capacity



High porosity – large spaces Low porosity – small spaces

12

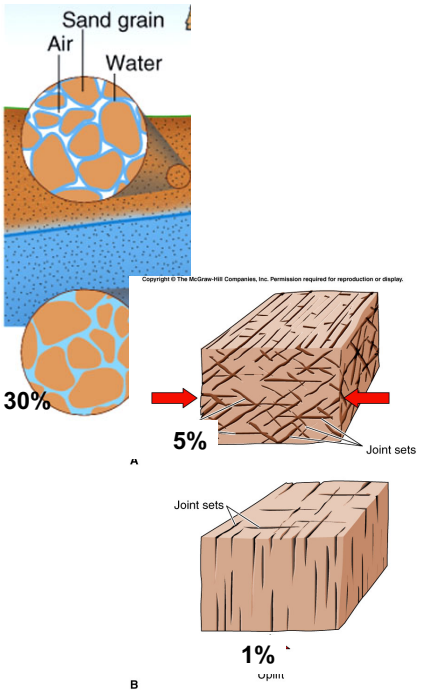
12



13

Porosity

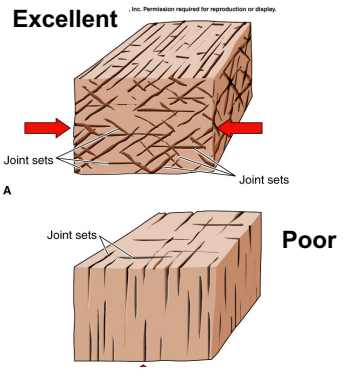
- **Unconsolidated sediments**: Determined by how tightly packed and how clean (silt and clay), (usually between 20 and 40%)
- **Rock**: Determined by size and number of fractures (most often very low, <5%)
- Extent of weathering



14

Permeability

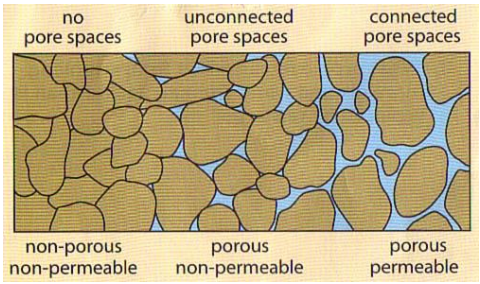
- Measure of the ease with which water will flow through a porous material
  - **Sediment**: Proportional to sediment size
    - Gravel→Excellent
    - Sand→Good
    - Silt→Moderate
    - Clay→Poor
  - **Rock**: Proportional to fracture size and number.
  - Continuity of the fractures
  - Can be good to excellent



15

Porosity and Permeability

- Permeability is **not proportional** to porosity.
- A rock may be extremely porous, but if the pores are not connected, it will have no permeability.
- Likewise, a rock may have a few continuous cracks which allow ease of fluid flow, but when porosity is calculated, the rock doesn't seem very porous.

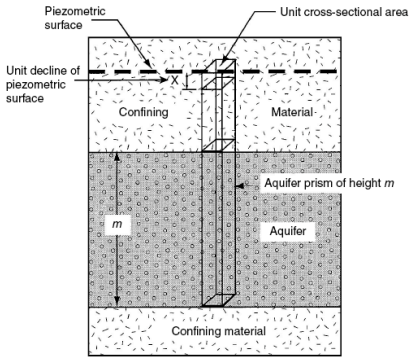


Sediment	Porosity (%)	Permeability
Gravel	25 to 40	excellent
Sand (clean)	30 to 50	good to excellent
Silt	35 to 50	moderate
Clay	35 to 80	poor
Glacial till	10 to 20	poor to moderate

16

Storage Coefficient (Storativity (S)/Specific Yield(S_y))

- Storativity/Specific Yield is defined as the volume of water per unit aquifer surface area taken into or released from storage per unit increase or decrease in head respectively.
- Hence Storativity (S) and Specific Yield (S_y)are both measures of water yield from aquifers. The difference is that S is specifically used for confined aquifers, whereas S_y is to unconfined aquifers only.
- It is a dimensionless quantity. In confined aquifers the value of storativity ranges from 0.005 to 0.00005.
- Typical range of S_y is 0.02 to 0.3



17

17

Groundwater Yield

- For an unconfined aquifer the value of S_y is typically several orders of magnitude greater than the value of S.
- The volume of water drained from an aquifer due to the drop in hydraulic head can be estimated from the formula

$$V_w = S.A.\Delta h$$

- where V_w is the volume of water released, S is the storativity (S_y incase of unconfined aquifers), A is the surface area of the drained aquifer, and Δh is the decline in hydraulic head/water table.

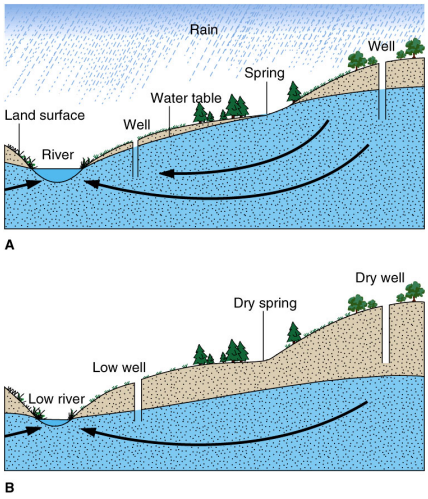
18

18

Darcy's Law

Answers the fundamental questions of hydrogeology.

- What controls:
  - How much groundwater flows?
  - How fast groundwater flows?
  - Where groundwater flows?

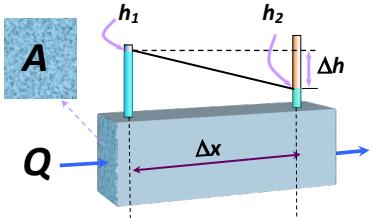


19

Darcy's Law

Henry Darcy's Experiment (Dijon, France 1856)

Darcy investigated ground water flow under controlled conditions



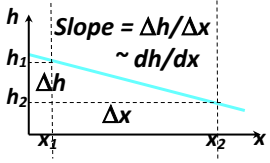
$$Q \propto \Delta h, \quad Q \propto 1/\Delta x, \quad Q \propto A$$

Q: Volumetric flow rate [L^3/T]

A: Cross Sectional Area

K: The proportionality constant is added to form the following equation:

$\nabla h \approx \frac{\Delta h}{\Delta x}$: Hydraulic Gradient



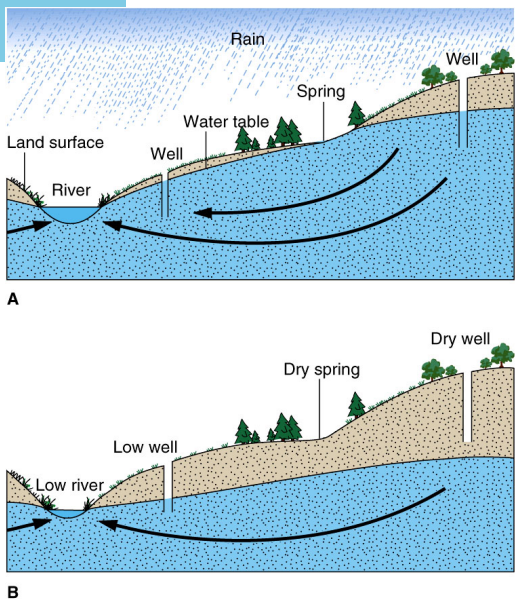
$$Q \propto A\frac{\Delta h}{\Delta x} \quad \Rightarrow \quad Q = -K A\frac{\Delta h}{\Delta x}$$

K units [L/T]

20

Natural Water Table Fluctuations

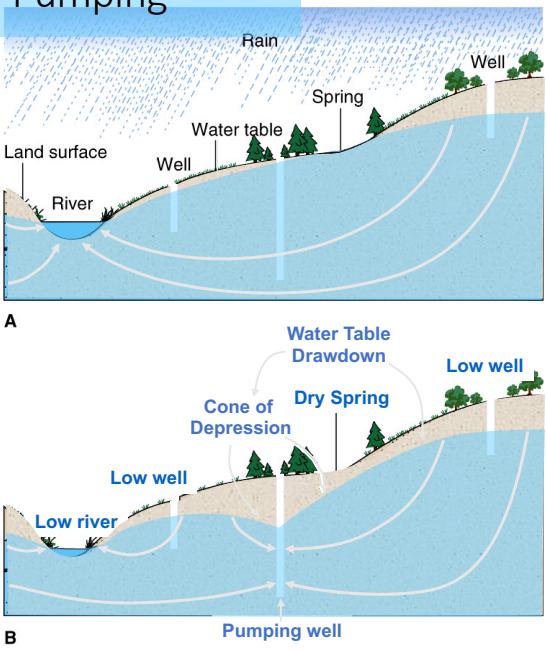
- Infiltration
  - Recharges ground water
  - Raises water table
  - Provides water to springs, streams and wells
- Reduction of infiltration causes water table to drop



21

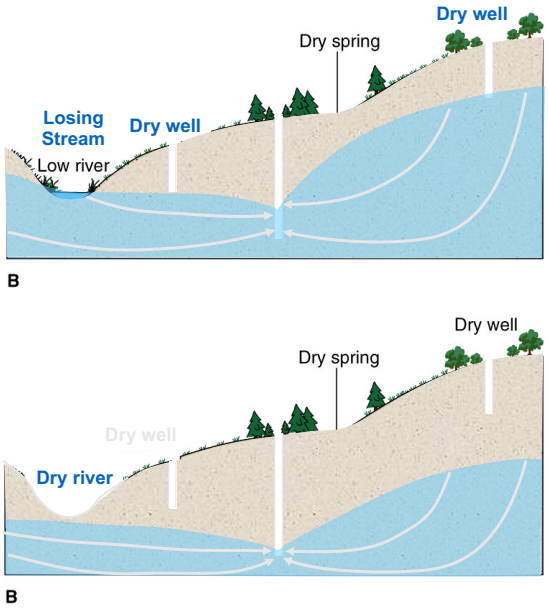
Effects of Short-term Pumping

- Change in flow regime
- Loss in hydraulic gradient
- Low flow in rivers/streams
- Temporary drying of springs and well



22

Effects of long-term Pumping



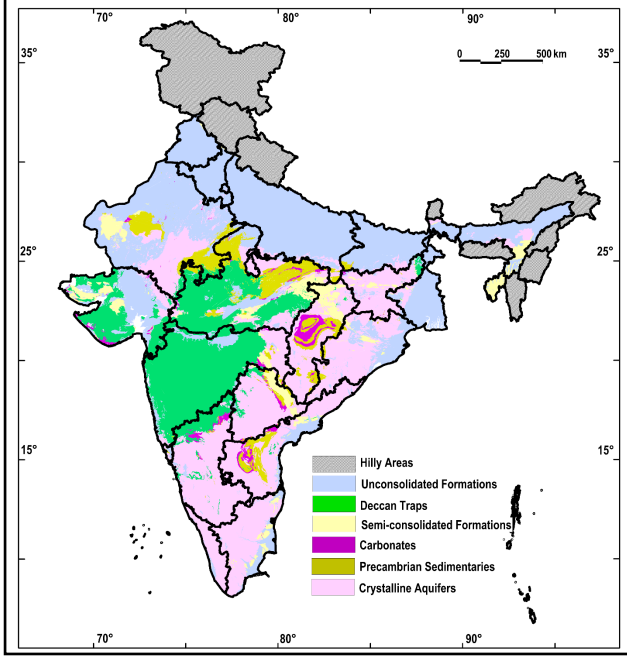
23

Ground Water - Indian Scenario

- India is the largest user of Ground Water in the world
  - ✓249 billion cubic meter (BCM) per year
  - ✓25% of global withdrawals
  - ✓More than the ground water extraction of USA & China combined.
- Nearly 60% of irrigation requirements met from from ground water
- Nearly 85% of rural and 50% of urban drinking water supply met from ground water
- Increasing dependence on ground water has resulted in over-exploitation- leading to dwindling well yield and declining water levels

24

Principal Aquifer Systems of India

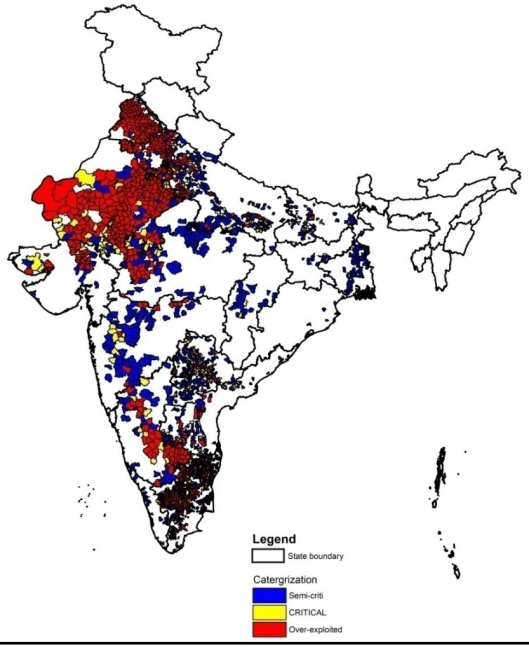


Alluvial aquifers along the Indo-Ganga-Bramhaputra plains are highly potential.

Hard rock aquifers occupying nearly 70% have low to moderate potential.

25

Categorization of Groundwater Assessment Units of India



More than 20% of the assessment units are categorized as either ***over-exploited*** or ***critical***

Nearly 90% of ground water withdrawal is for irrigation purposes.

Assessed units	6881	
Over-Exploited	1186	(17%)
Critical	313	(4.5%)
Semi-Critical	972	(14%)
Safe	4310	(63%)
Saline	100	(1.5%)

26

Groundwater Quality

- Ground water in major part of the country is potable.
- Major contaminations reported are Arsenic, Fluoride, Salinity, Iron and Nitrate
  - Arsenic contamination has been reported mostly from the Indo-Ganga-Bramhaputra Alluvial plains.
  - Fluoride contamination is most prevalent in north-western part and the southern peninsula.
  - Ground water salinity can be attributed mostly to the following two reasons: Inland salinity (north western India) and sea water ingress (Gujarat coast and the eastern coastal plains).
  - Nitrate is the most prevalent man-made ground water contamination reported from shallow aquifers in several parts of the country.

27

THANK YOU

28