Hydrological Cycle

Hydro Informatics – Spring 2024

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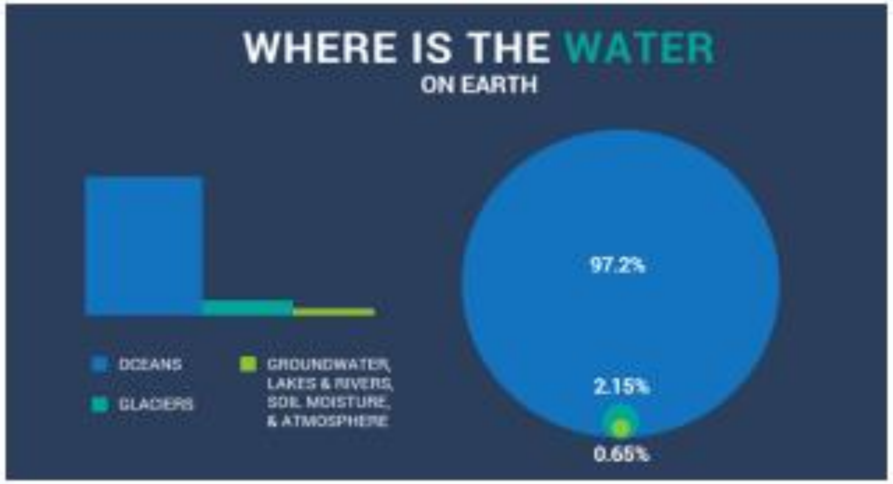
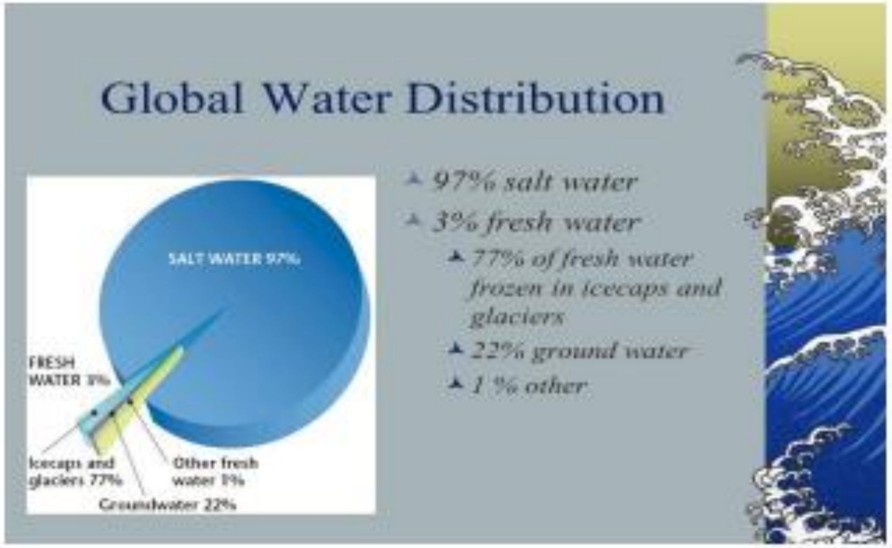
Hydroinformatics

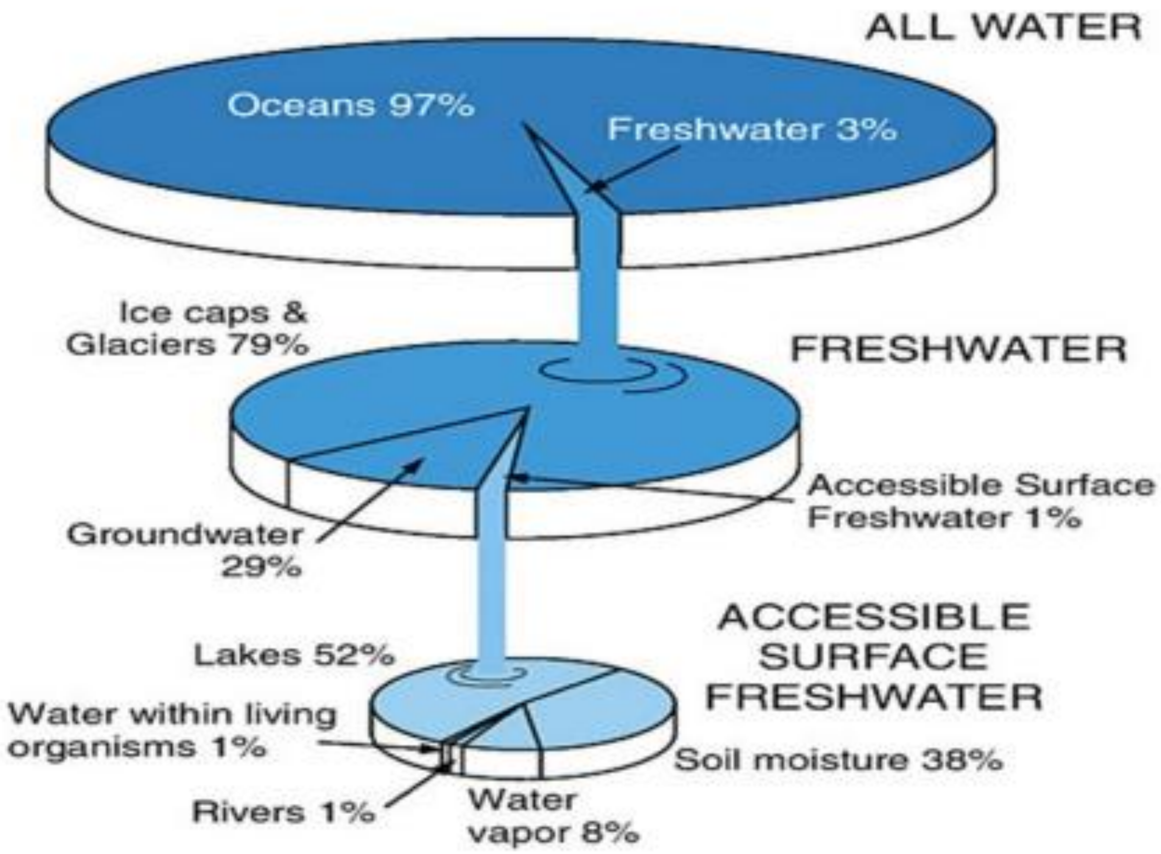
Hydroinformatics is a branch of informatics which concentrates on the application of information and communications technologies in addressing serious problems of the equitable and efficient use of water for many different purposes.

Hydroinformatics includes the concepts of real-time monitoring, data analysis, artificial intelligence and Machine Learning and Internet of Things to monitor, manage and conserve water for the maximum benefit of mankind

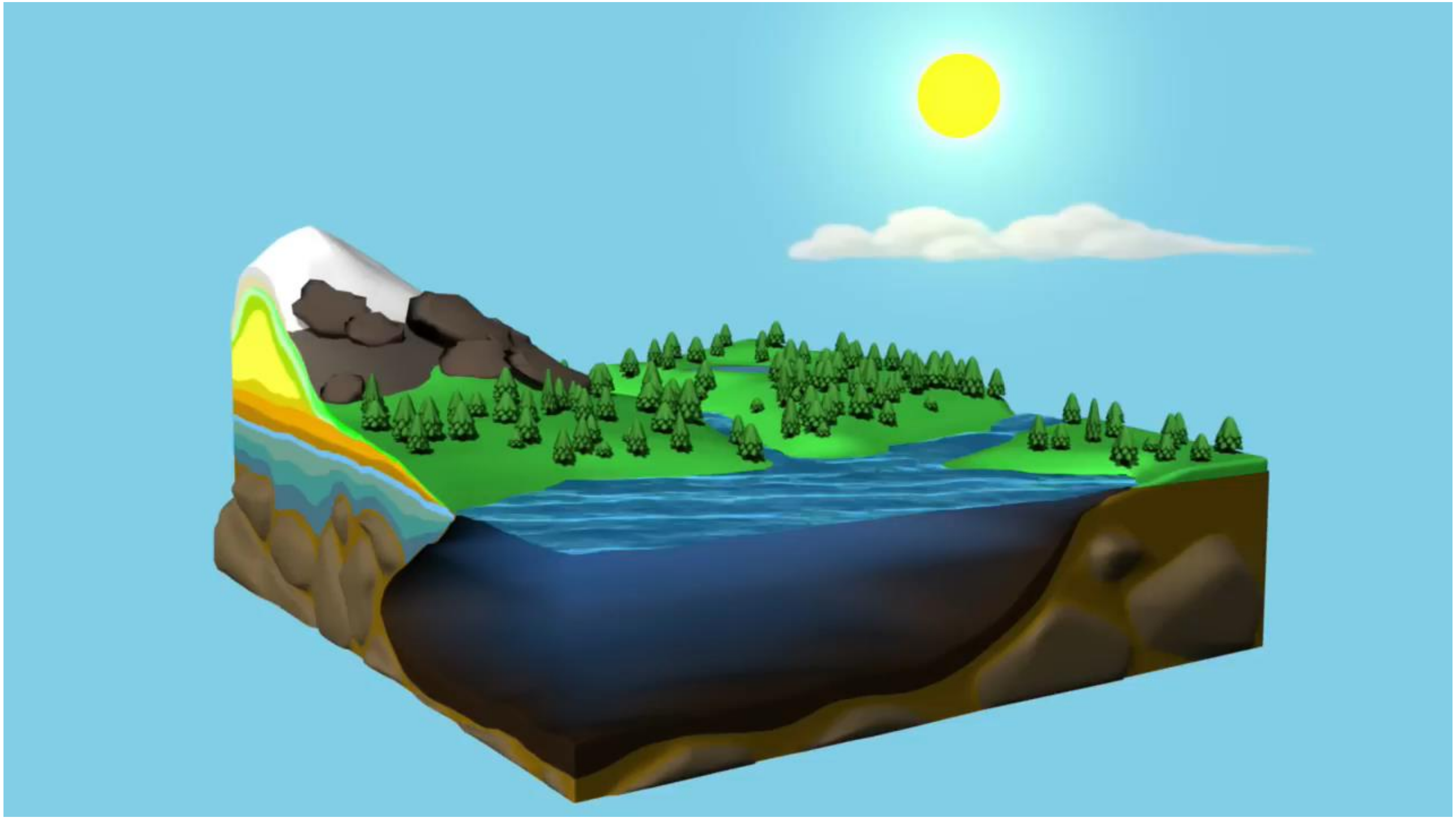
Global Water Distribution on Earth



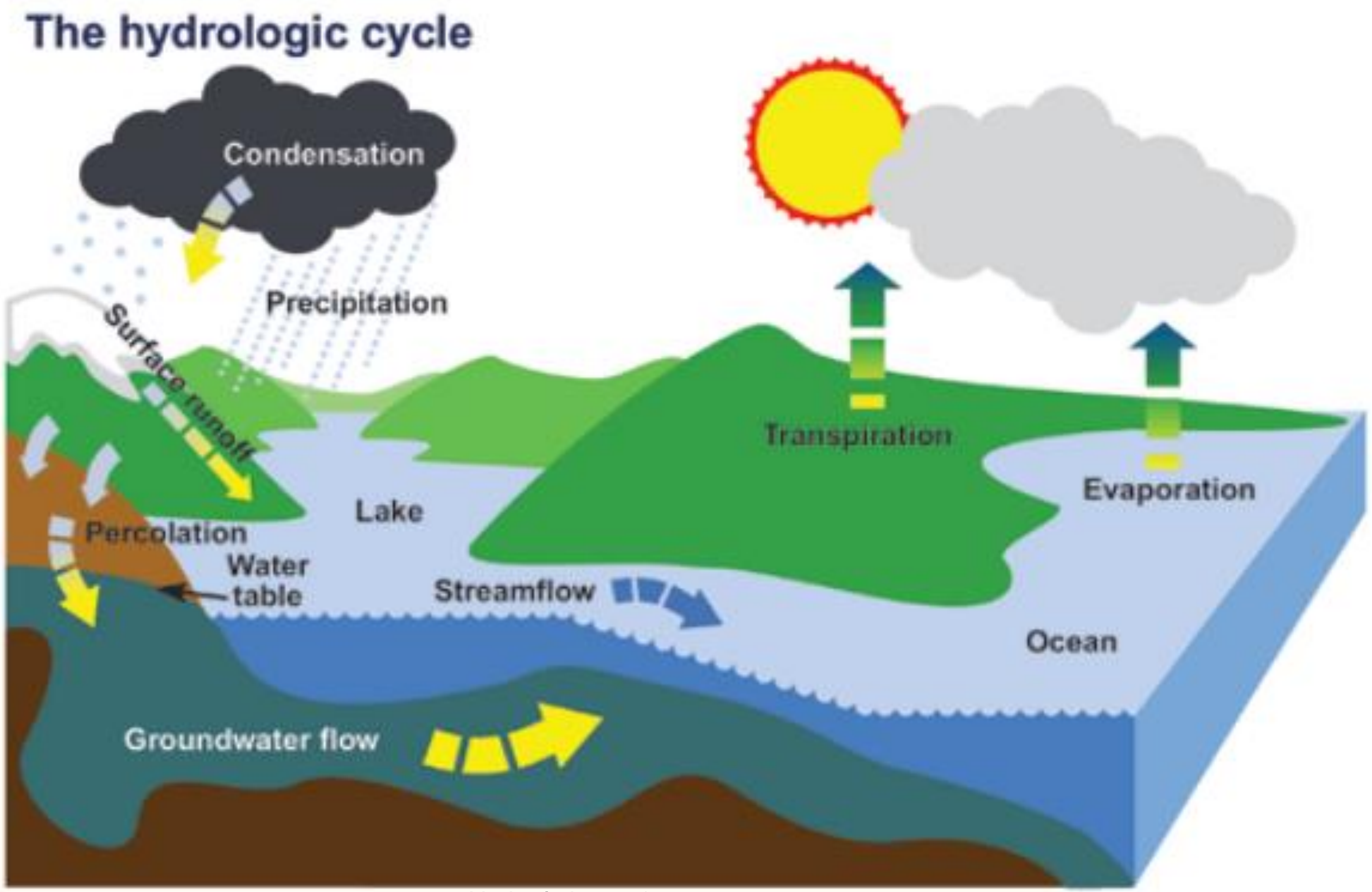




Hydrological Process



Water Resources System



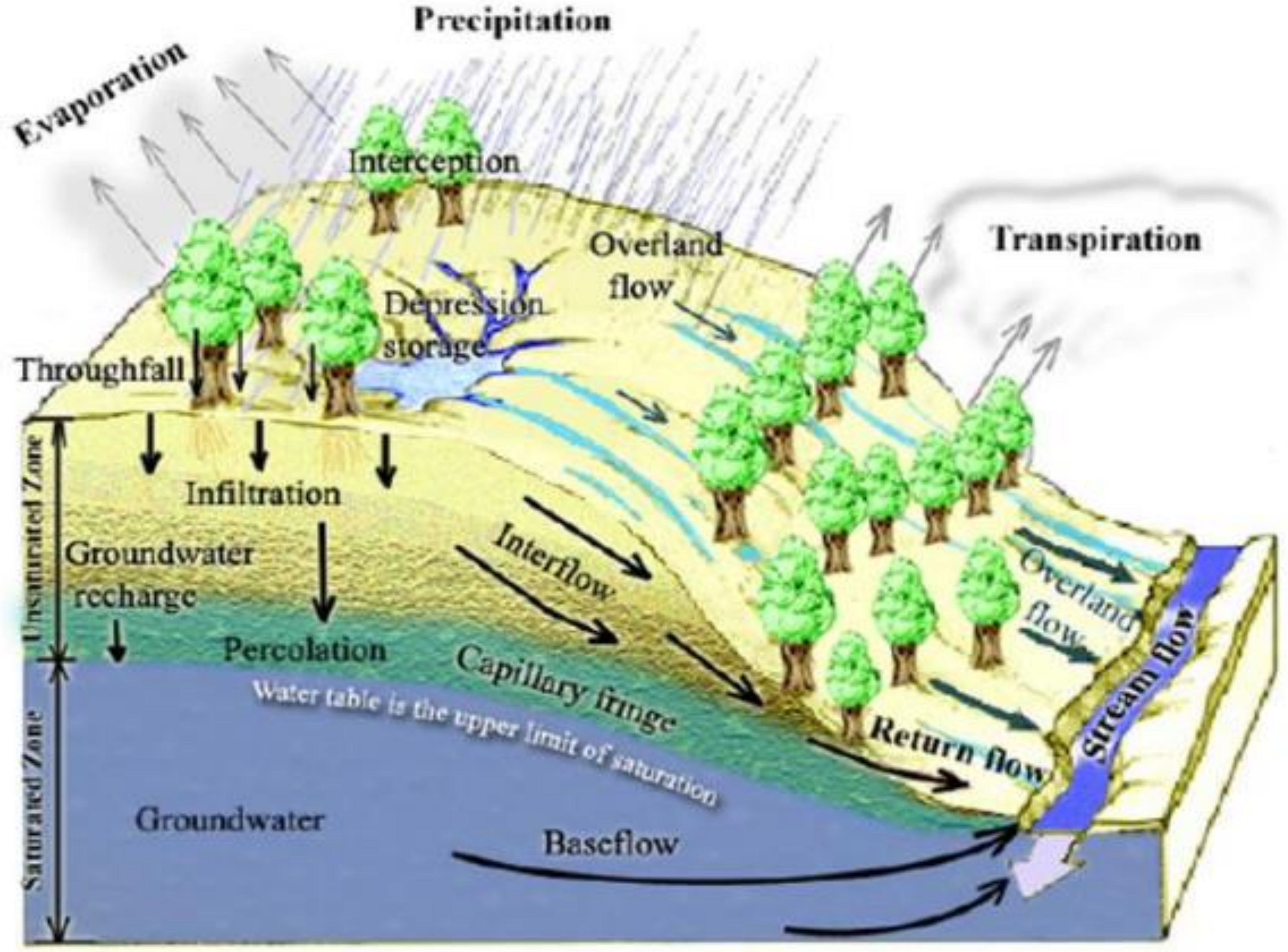


Figure 1. Physical Processes involved in Runoff Generation.

Hydrologic Cycle

- The Global hydrologic cycle is one of the most important natural cycles that operates on Earth.
- It describes the circulation of water through the atmosphere, the land, and the oceans.
- This cycle consists of set of storages (snow, soil moisture, and groundwater) and fluxes (precipitation, evapotranspiration, and runoff) that link the storages together.
- Precipitation is the main driver of the water cycle and, on average, 70% of annual precipitation is lost due to evapotranspiration.

Precipitation may be in the form of rain or snow.

Vegetation may ***intercept*** some fraction of precipitation. A large fraction of intercepted water is commonly evaporated back to the atmosphere.

Precipitation that penetrates the vegetation is referred to as ***throughfall*** and may consist of both precipitation that does not contact the vegetation, or that drops or drains off the vegetation after being intercepted.

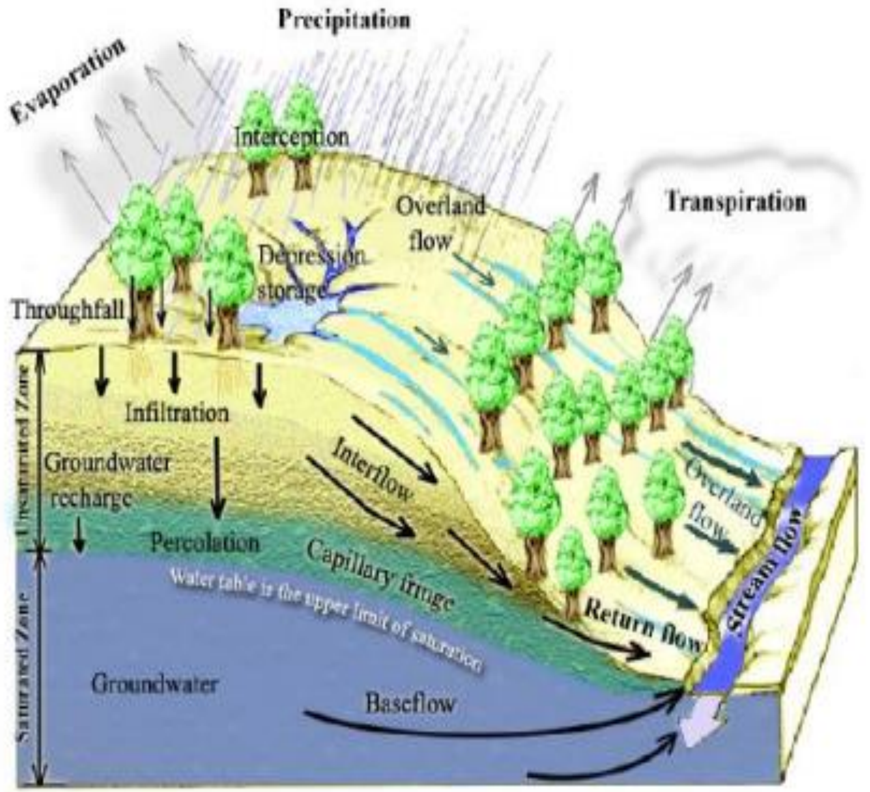


Figure 1. Physical Processes involved in Runoff Generation.

There is also flux of water to the atmosphere through transpiration of the vegetation and evaporation from soil and water bodies, ***Evapotranspiration***

The surface water input available for the generation of **runoff** consists of throughfall and snowmelt.

Surface water input may accumulate on the surface in ***depression storage***, or flow overland towards the streams as ***overland flow***, or ***infiltrate*** into the soil, where it may flow laterally towards the stream contributing to ***interflow***.

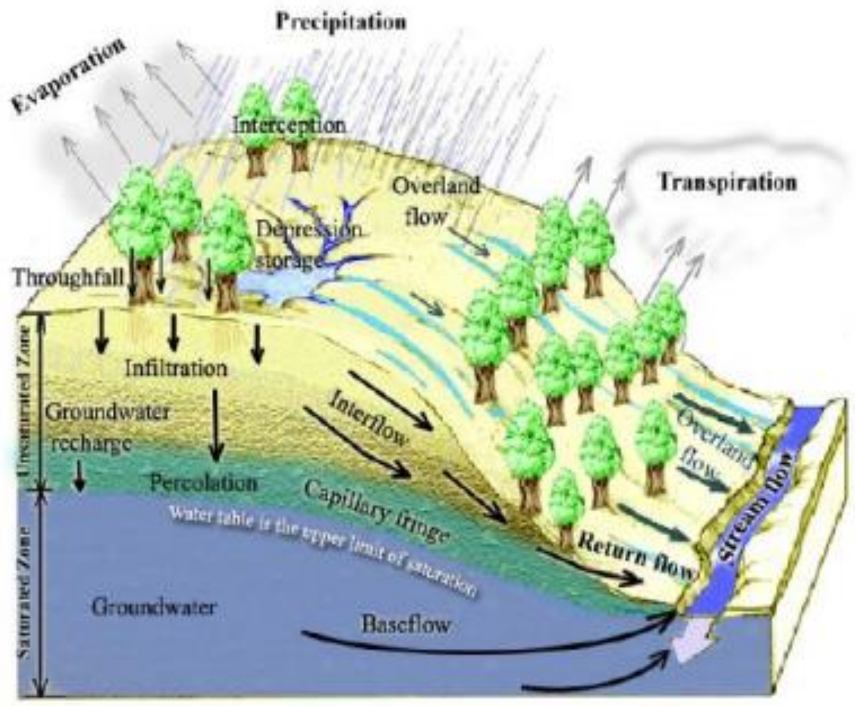


Figure 1. Physical Processes involved in Runoff Generation.

Infiltrated water may also ***percolate*** through deeper soil and rock layers into the ***groundwater***. The ***water table*** is the surface below which the soil and rock is saturated and at pressure greater than atmospheric.

Water table serves as the boundary between the saturated zone containing groundwater and unsaturated zone. Water added to the groundwater is referred to as ***ground water recharge.***

Immediately above the water table is a region of soil that is close to saturation, due to water being held by capillary forces. This is referred to as the ***capillary fringe.***

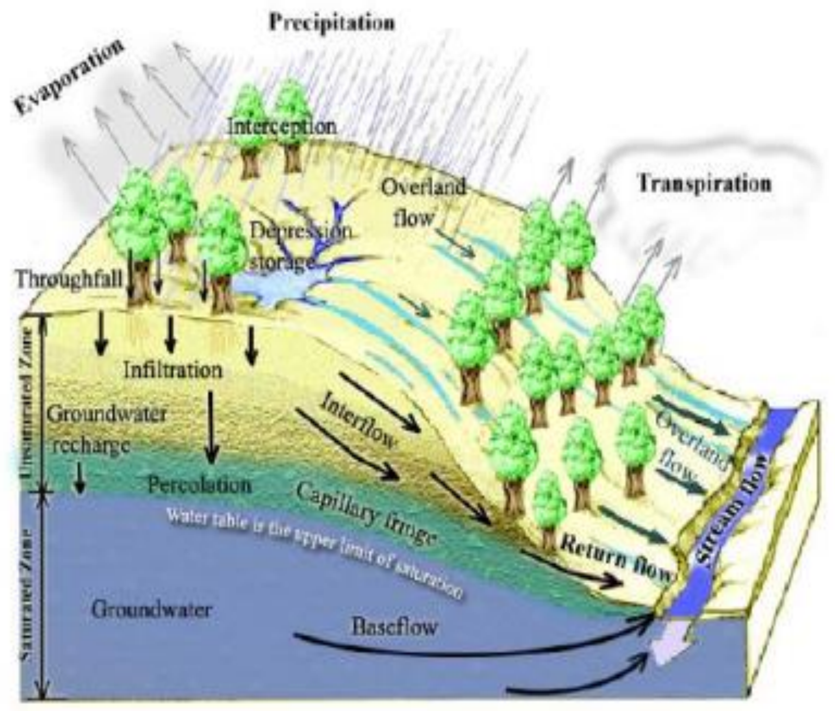
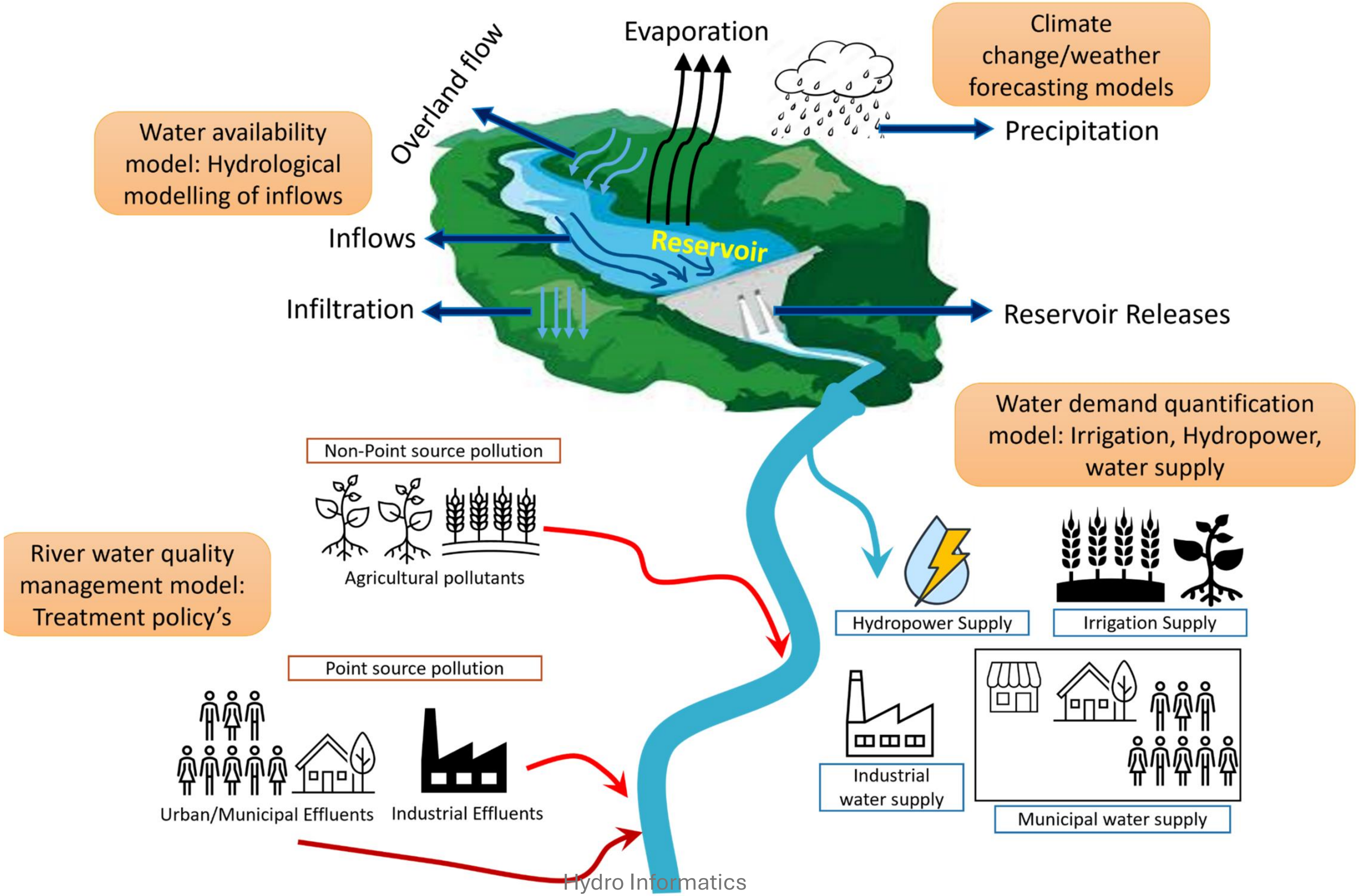


Figure 1. Physical Processes involved in Runoff Generation.

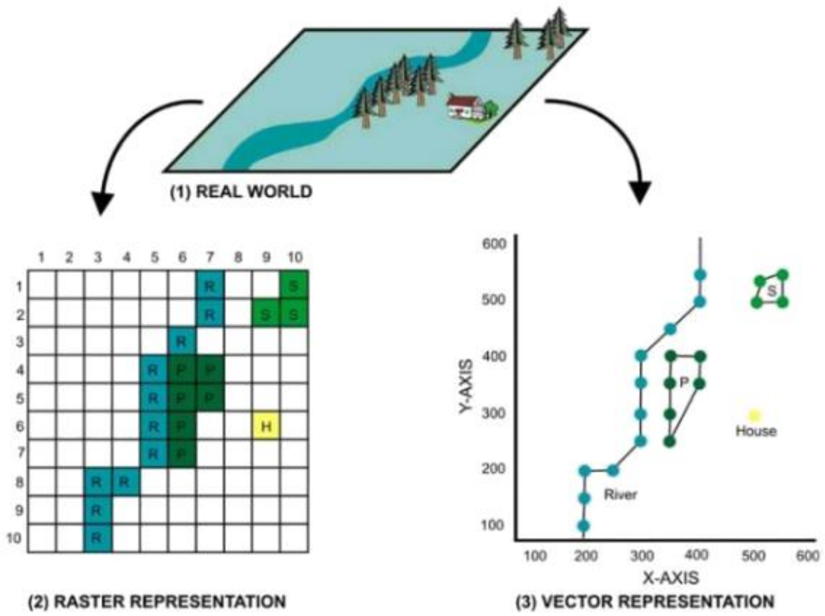
Lateral drainage of the groundwater into streams is referred to as ***baseflow***, because it sustains streamflow during rainless periods.

Regional Water resource system

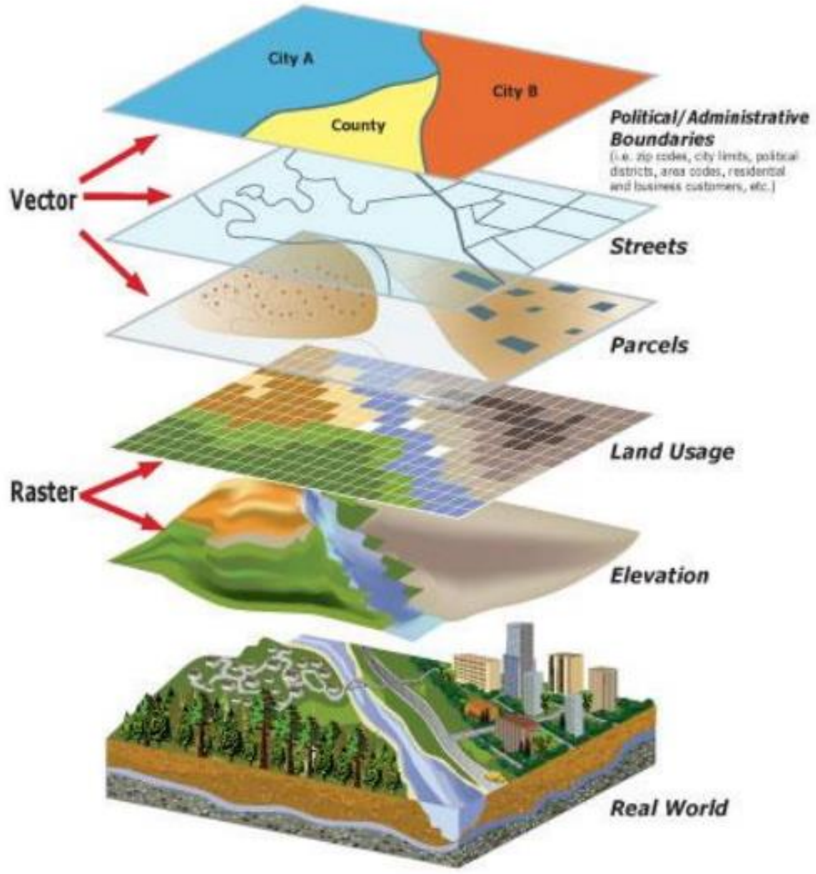
Components involved in water resources system



Scaling of a Water Resources System



- The real world can only be depicted in a GIS through the use of models that define phenomena in a manner that computer systems can interpret, as well perform meaningful analysis.
- There are two fundamental approaches to the representation of the spatial component of geographic information:
- **Vector Model** (Points, Lines, Polygons)
- **Raster Model** (Surfaces)



Significant data to be considered

Data to be considered

↓

Climate or weather data
Or Meteorological data

↓

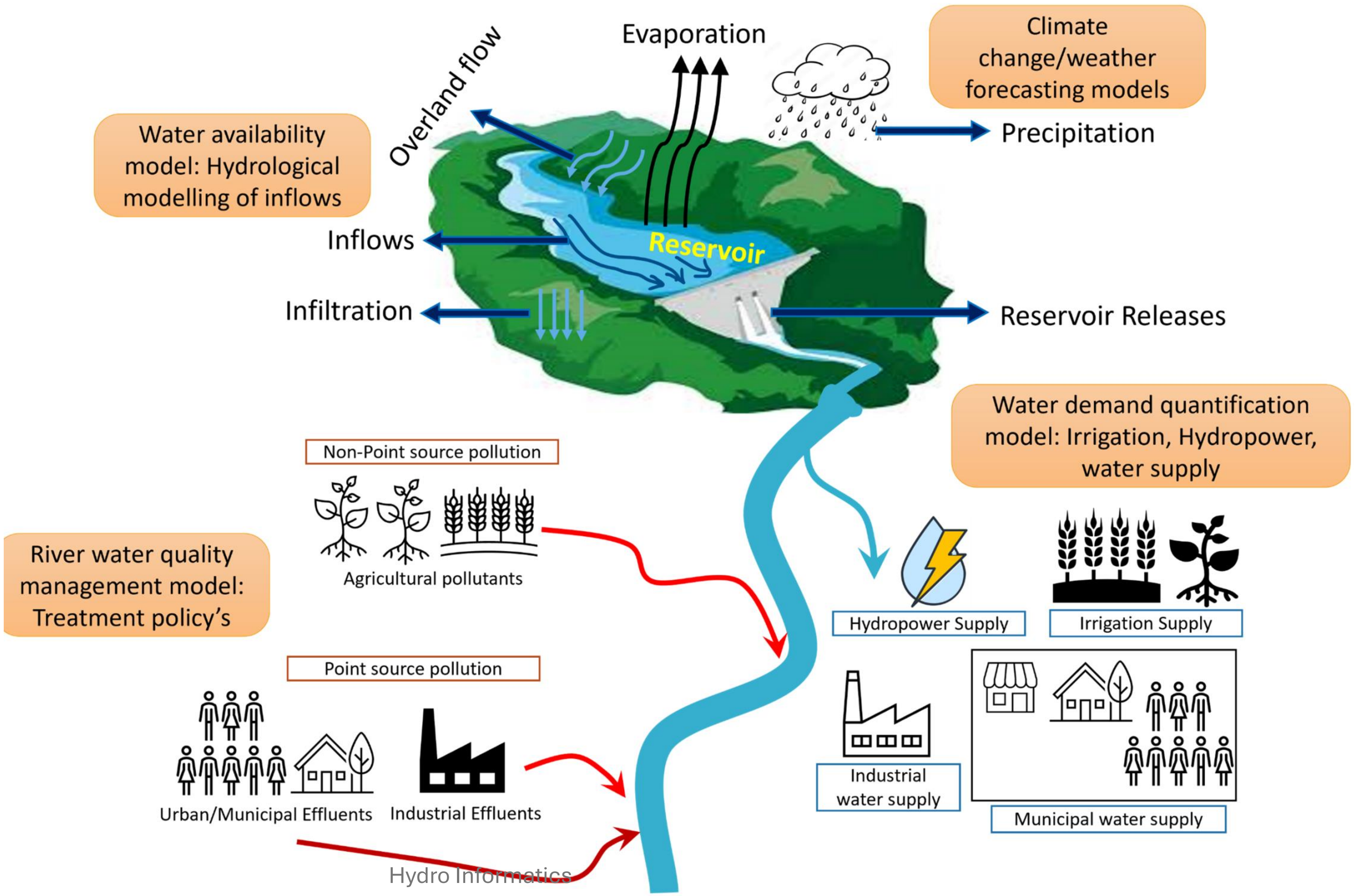
Hydrological data

↓

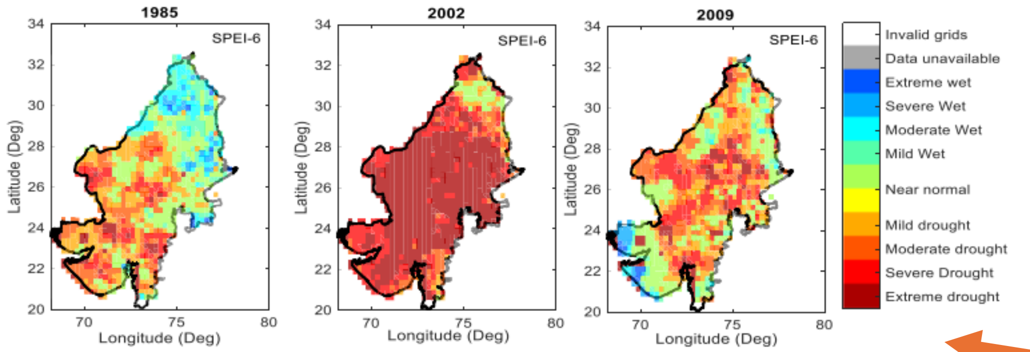
Water Quantity data

↓

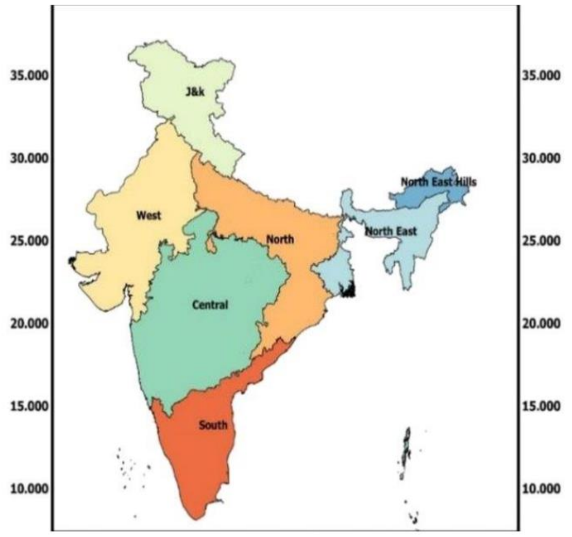
Water Quality data

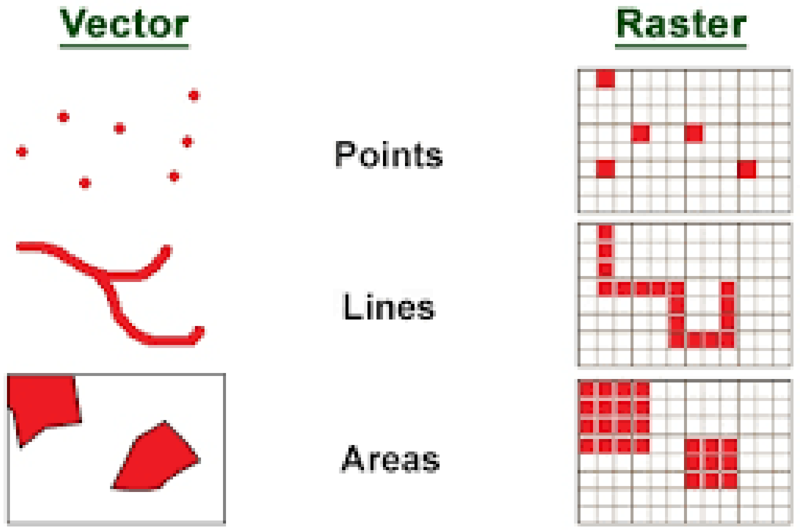


To Learn about Data



- Types of data
  - Spatial resolution
  - Temporal variability
- Dimension of data
  - 1D, 2D, 3D, 4D
- Point and gridded data
- Vector, Raster and Image data





More about DATA

1. **Weather and climate records** : temperature, humidity, radiation, wind.
2. **Precipitation data**: predicting runoff volume and peaks, water-budget-equation for basin.
3. **Stream flow data**: reservoirs planning, design of spillways, bridges, culverts, hydro power, used to determine peak flood, flood magnitude, flood frequency etc.
4. **Evaporation & transpiration data**: water budget of river basin, reservoir capacity.
5. **Infiltration characteristics**: rainfall excess and run off computation
6. **Ground water characteristics**: estimation & location of ground water reservoir, ground water development.
7. **Physical and Geological characteristics**: Runoff pattern and silt load movement.

FORMS OF PRECIPITATION:

Drizzle: Size of water droplet < 0.5 mm, its intensity < 1 mm/hour.
Rain : Size of drops > 0.5 mm. Maximum size of drop = 6.25mm.
Glaze: Drizzle or rain freezes as it comes In contact with cold objects.
Sleet: Frozen rain drops cooled to the ice stage while falling through air at sub-freezing temperature.
Snow: form of ice-crystals resulting from sublimations (vapour to ice).
Snowflakes: Number of ice crystals fused together form snow flakes.
Hail: Lumps or bulbs of ice over 5 mm dia formed by alternate freezing or melting as they are carried up and down in highly turbulent air currents.

Drizzle

Rain

Snow

Snowflakes

Sleet

Glaze

Rainfall Data

- Temporal - hourly, daily, monthly, annual
- Seasonal –
  - Winter Season - January – February
  - Pre Monsoon Season - March – May
  - Southwest Monsoon Season - June - September
  - Northeast Monsoon Season - October – December

MEASUREMENT OF RAIN FALL:

The amount of precipitation expressed as the depth in centimetres (or inches) which falls on a level surface, and is measured by *Rain-gauge.*
Mainly there are two types of rain-gauges, they are:

1. Non-automatic rain-gauge : also known as non-recording rain-gauge.

- ❑ Symons rain-gauge- used in all Govt rain-gauge stations in India

2. Automatic rain-gauge : integrating type recording rain-gauge.

- ❑ Weighing bucket rain-gauge
- ❑ Tipping bucket rain-gauge
- ❑ Float type rain-gauge

- What if rainfall not recorded for some time ?
- What if rain gauge under maintenance ?
- What if error in the recorded rainfall data ?

ESTIMATION OF MISSING RAINFALL DATA:

Missing data can be predicted with the help of following methods:

1) Arithmetic mean method

The missing rainfall Px at station X is computed by simple arithmetic average of the rainfall at the near by stations (known as index stations)

$$P_x = \sum_{i=1}^{n} P_i/n = \frac{1}{n}(P_1 + P_2 + \ldots\ldots P_n)$$

Where n = number of index stations

Above method is used only under following conditions:

- Normal annual rainfall of the missing station is within 10% of the normal annual rainfall of the index stations.
- Data of at least 3 index stations should available.
- Index stations should evenly spaced and as close as possible to missing station.

1) Rain gauge X was out of operation for a month during which there was a storm. The rainfall amounts at three adjacent stations A, B, and C were 37, 42 and 49 mm. The average annual precipitation amounts for the gauges are X = 694, A = 726, B = 752 and C = 760 mm. Using the Arithmetic method, estimate the amount of rainfall for gauge X.

Stations	Amounts of precipitation (mm)	Normal Annual Precipitation (mm)
A	37	726
B	42	752
C	49	760
D	?	694

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Solution

If

$N_x = 694$

Then 10% from 694 = $\frac{10}{100} \times 694 = 69.4\ mm$

Therefore, precipitation allowed $= (694 - 69.4) \sim (694 + 69.4)$ mm

$= 624.6$ mm ~ 763.4 mm

Since all annual precipitations (726, 752 and 760) mm are within the ranges, **Arithmetic Method** can be applied :

$$P_x = \frac{1}{3}\{37 + 42 + 49\} = 42.7mm$$

ESTIMATION OF MISSING RAINFALL DATA:

2) Normal ratio method:

$$P_x = \frac{1}{n}\left[P_1 \frac{N_x}{N_1} + P_2 \frac{N_x}{N_2} + \ldots\ldots P_n \frac{N_x}{N_n}\right] = \frac{N_x}{n}\left[\frac{P_1}{N_1} + \frac{P_2}{N_2} + \ldots\ldots \frac{P_n}{N_n}\right]$$

where $N_1, N_2 \ldots\ldots N_n$ = normal annual rainfall of index stations.

N_x = normal annual rainfall of missing station

n = number of index stations.

Above method is used only under following conditions:

- Normal annual precipitation of index stations differ more than 10% of missing station.
- Data of at least 3 index stations available and all index stations should be evenly spaced.

Class activity 1:

2) One of four monthly-read rain gauges on a catchment area develops a fault in a month when the other three gauges record 48, 58 and 69 mm respectively. If the average annual precipitation amounts of these three gauges are 741, 769 and 855 mm respectively and of the broken gauge 707 mm, estimate the missing monthly precipitation at the latter.

3) The records of precipitation of hydraulic monitoring stations (x) in a rainy day are missing. The data indicate that the estimates of rainfall at three stations (b), (c) and (d) adjacent to the station (x) are equal to: 80, 70 and 60 mm, respectively. If the average annual rainfall at stations (a) and (b) and (c) and (d) is: 650, 240, 320 and 140 mm, respectively, find the value of rainfall during the rain storm in station (x).

2) One of four monthly-read rain gauges on a catchment area develops a fault in a month when the other three gauges record 48, 58 and 69 mm respectively. If the average annual precipitation amounts of these three gauges are 741, 769 and 855 mm respectively and of the broken gauge 707 mm, estimate the missing monthly precipitation at the latter.

Solution

- Data: $P_a = 48$ mm, $P_b = 58$ mm, $P_c = 69$ mm, $N_a = 741$ mm, $N_b = 769$ mm, $N_c = 855$ mm, $N_x = 707$ mm.
- Find the value of rainfall during the storm at station (a) by using the following equation:

$$P_x = \frac{\frac{N_x P_a}{N_a} + \frac{N_x P_b}{N_b} + \frac{N_x P_c}{N_c}}{3} = \frac{\frac{707x48}{741} + \frac{707x58}{769} + \frac{707x69}{855}{}_{69}}{3} = 52 \quad mm$$