Module 3: Abstractions from Precipitation

Abstractions represent the portion of precipitation that does not contribute to surface runoff due to processes such as evaporation, infiltration, and interception. These components are critical in hydrologic analysis, water budgeting, irrigation planning, and watershed modeling.

1. Evaporation Process

Evaporation is the phase change of water from liquid to vapor, primarily from open water surfaces, soil surfaces, and vegetation.

Factors Affecting Evaporation

- Temperature
- Wind speed
- Humidity
- Solar radiation
- Surface area and nature of water body

2. Evaporimeters

Used to measure evaporation from open water surfaces.

Common Types:

- **Class A Pan Evaporimeter:** Standard 120.7 cm diameter, 25 cm deep circular pan used globally; IS:5973 gives Indian standards.
- **Sunken Pan/Elevated Pan:** Modifications to account for varying field conditions.
- **Floating Pan:** Used to simulate open water bodies with surrounding water.

Correction factors are used to convert pan readings to actual reservoir evaporation, typically around **0.7–0.8** based on local calibration.

3. Analytical Methods for Estimating Evaporation

Common empirical and theoretical methods include:

Method	Description
Energy Budget	Based on energy balance on water surface
Water Budget	Based on inflow-outflow-storage changes
Penman's Equation	Combines aerodynamic and energy balance methods

Method	Description
Thornthwaite Method	Uses temperature data for potential evapotranspiration

4. Reservoir Evaporation and Its Reduction

Techniques to Reduce Reservoir Evaporation:

- **Surface Cover Methods:**
  - **Monomolecular films** (e.g., hexadecanol) form thin layers to reduce evaporation.
  - **Floating covers or balls**
- **Wind Breaks:** Reducing the wind speed across surface reduces evaporation losses.
- **Water Storage in Underground Tanks / Small Reservoirs:** Minimizes surface area and exposure.

5. Evapotranspiration

Combination of:

- **Evaporation** from soil and water surfaces
- **Transpiration** from plant surfaces

Types:

- **Potential Evapotranspiration (PET):** Maximum loss under ideal moisture conditions.
- **Actual Evapotranspiration (AET):** Real evapotranspiration under existing conditions.

6. Measurement of Evapotranspiration

Direct Methods:

- **Lysimeters:** Enclosed soil-vegetation units to measure actual evapotranspiration.
- **Field Water Balance:** Computation from irrigation, drainage, and changes in soil moisture.

Indirect/Analytical Methods:

- **Penman-Monteith Equation:** Standard method used by FAO.
- **Blaney-Criddle Method:** Requires temperature and crop coefficients.
- **Hargreaves Method:** Based on temperature and radiation data.

7. Evapotranspiration Equations

FAO Penman-Monteith Equation:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

Where:

- ET_0: Reference evapotranspiration (mm/day)
- R_n: Net radiation
- G: Soil heat flux
- $T, u_2, e_s - e_a$: Temperature, wind speed, vapor pressure deficit
- Δ, γ: Slopes of saturation vapor pressure curve, psychrometric constant

8. Potential and Actual Evapotranspiration in India

- **PET:** ~1400–1800 mm/year in arid regions (Rajasthan), ~900–1200 mm/year in humid East.
- **AET:** Typically lower than PET; determined by soil moisture and vegetation cover.
- Varies seasonally and spatially; higher in summer months.

9. Interception

- **Definition:** Rainfall stored on vegetative surfaces (leaves, branches) and evaporated back.
- Does not contribute to streamflow or infiltration.
- Depends on canopy density, rainfall intensity and duration, and leaf surface characteristics.

Typical interception losses:

- Forests: 10–30% of rainfall
- Crops: 5–15%

10. Depression Storage

- Water retained in small surface depressions that do not contribute to immediate runoff.
- Influenced by land surface roughness and micro-topography.

11. Infiltration

Infiltration is the process of water entering the soil surface.

Factors Affecting Infiltration:

- Soil texture and structure
- Vegetative cover
- Antecedent moisture
- Land use and compaction
- Rainfall intensity

12. Infiltration Capacity

- Maximum rate at which soil can absorb water under given conditions.
- Decreases over time as soil becomes saturated.

Measured Using:

- **Infiltrometers** (double-ring type)
- **Field ponding method**
- **Rainfall simulators**

13. Modeling Infiltration Capacity

Common empirical models:

Model	Expression	Notes
Horton's Model	$f(t) = f_c + (f_0 - f_c) e^{-kt}$	f_0: initial rate; f_c: final capacity
Philip's Model	$f(t) = \frac{A}{\sqrt{t}} + B$	A: sorptivity, B: conductivity
Green-Ampt Model	Uses soil properties, hydraulics	Physically based

14. Classification of Infiltration Capacities

Infiltration capacities are classified as:

- **High:** Sandy soils (>15 mm/hr)
- **Medium:** Loam soils (5–15 mm/hr)
- **Low:** Clayey soils (<5 mm/hr)

These values guide runoff estimation and irrigation scheduling.

15. Infiltration Indices

Used in runoff estimation to represent average losses due to infiltration:

Index	Description
Φ-index	Constant rate loss such that runoff volume = rainfall – loss

Index	Description
W-index	Like Φ-index but accounts only for infiltration (excludes initial loss)
W'-index	Modified to reflect changing infiltration with time

Summary

This module explains key abstraction processes in the hydrologic cycle—evaporation, interception, and infiltration—along with their quantification methods and implications for hydrological modeling, irrigation planning, and watershed analysis. Understanding these losses is essential for accurate estimation of available runoff and water resource potential.