Chapter 43: Infiltration and Consumptive Use

Introduction

In hydrological studies, understanding how water moves into the soil and how it is used or lost from a hydrological system is crucial. Two fundamental concepts that aid in such analysis are **infiltration** and **consumptive use**. *Infiltration* is the process by which water on the ground surface enters the soil. It affects surface runoff, groundwater recharge, and the soil water balance. *Consumptive use*, on the other hand, refers to that portion of water withdrawn from available sources that is not returned to the original water source — typically due to evaporation or plant transpiration.

A deep understanding of these two aspects is essential for effective water resources planning, irrigation management, and design of drainage systems.

43.1 Infiltration

43.1.1 Definition of Infiltration

Infiltration is the **movement of water from the ground surface into the soil profile**. It is a critical component of the hydrologic cycle as it governs the division of rainfall into surface runoff and subsurface flow.

43.1.2 Factors Affecting Infiltration

Several factors influence infiltration rates, including:

- **Soil characteristics:** Texture (sand, silt, clay), structure, porosity, and organic content
- **Soil moisture content:** Saturated soils have lower infiltration capacity
- **Vegetation cover:** Roots create voids and organic matter that promote infiltration
- **Land use:** Urbanization and compaction reduce infiltration
- **Rainfall intensity and duration**
- **Temperature and seasonality**
- **Surface conditions:** Crusting, presence of mulch, slope of land

43.1.3 Infiltration Capacity

Infiltration capacity is the **maximum rate at which water can enter the soil under given conditions**. When rainfall intensity exceeds infiltration capacity, surface runoff begins.

- Initially high when soil is dry
- Decreases with time as soil becomes saturated
- Reaches a steady state (asymptotic value)

43.1.4 Infiltration Rate and Measurement

- **Infiltration Rate:** The actual rate at which water enters the soil, usually expressed in mm/hr.
- **Measurement Techniques:**
    - **Double Ring Infiltrometer**
    - **Tension Infiltrometer**
    - **Rainfall simulation method**
    - **Lysimeters**
    - **Empirical estimation from hydrographs**

43.1.5 Infiltration Indices

These are simplifications used in hydrological modeling and flood estimation:

1. **ϕ-index** – The constant rate of infiltration such that the volume of excess rainfall equals the volume of direct runoff.
2. **W-index** – Takes into account the infiltration before runoff begins.
3. **Horton's Equation (Empirical):**

$$f(t)=f_c+(f_0-f_c)e^{-kt}$$

Where:

- $f(t)$ = infiltration rate at time t
- f_0 = initial infiltration rate
- f_c = final (constant) infiltration rate
- k = decay constant

43.1.6 Applications of Infiltration

- Estimating groundwater recharge
- Surface runoff estimation
- Flood forecasting
- Designing infiltration trenches and basins
- Soil erosion control

43.2 Consumptive Use

43.2.1 Definition

Consumptive use refers to the **amount of water used by plants and evaporated from surrounding soil and water surfaces** in a given area and time. It is **not returned** to the immediate water source.

It includes:

- **Evapotranspiration (ET):** Total water lost by evaporation and transpiration
- **Interception losses:** Water retained on plant leaves that evaporates without reaching the ground
- **Water incorporated into plant tissues**

43.2.2 Components of Consumptive Use

- **Evaporation (E):** From soil and water surfaces
- **Transpiration (T):** Water absorbed and transpired by plants
- **Evapotranspiration (ET) = E + T**

43.2.3 Factors Affecting Consumptive Use

- **Type of crop**
- **Stage of crop growth**
- **Climatic conditions (temperature, humidity, wind, solar radiation)**
- **Soil characteristics and fertility**
- **Water availability**
- **Cultural practices and irrigation method**

43.2.4 Measurement and Estimation of Consumptive Use

a. Direct Methods

1. **Lysimeter Method:**

- Controlled environment
- Measures percolation and evapotranspiration precisely

2. **Soil Moisture Depletion Method:**
    - Change in soil moisture before and after crop cycle
    - Requires multiple soil samples

b. Indirect/Empirical Methods

1. **Blaney-Criddle Method:**

$$CU = K \cdot P \cdot (0.46T + 8)$$

Where:

- CU = Consumptive use (mm)
- K = Crop coefficient
- P = % of annual daytime hours for the period
- T = Mean monthly temperature (°C)

2. **Thornthwaite Method**
    - Uses air temperature and latitude
    - Good for preliminary planning
3. **Penman Method:**
    - Considers radiation, temperature, humidity, wind
    - One of the most accurate
4. **Modified Penman-Monteith Method**
    - Adopted as FAO standard for ET estimation

43.2.5 Consumptive Use vs Water Requirement

- **Consumptive Use** is the water actually consumed
- **Water Requirement** includes:
    - Consumptive use
    - Percolation losses
    - Leaching requirement
    - Other unavoidable losses

43.2.6 Effective Rainfall

The part of rainfall that is available to meet the consumptive use of the crop. It excludes:

- Deep percolation
- Surface runoff

43.2.7 Irrigation Requirement

$$IR = WR - ER$$

Where:

- IR = Irrigation Requirement
- WR = Water Requirement
- ER = Effective Rainfall

43.3 Integration of Infiltration and Consumptive Use in Hydrologic Planning

- Both infiltration and consumptive use are key for:
    - Designing **efficient irrigation systems**
    - **Managing drought** and **water scarcity**
    - Assessing **groundwater recharge**
    - Preventing **runoff-related erosion**
    - **Scheduling irrigation** based on crop water needs and soil moisture replenishment

Hydrologic models must simultaneously address infiltration losses and consumptive use to provide accurate water budgeting and resource planning.
