

POSTAL Book Package

2023

CIVIL ENGINEERING

Irrigation Engineering

Conventional Practice Sets

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Irrigation Principles, Practice and Project

Q1 What is the classification of irrigation water having the following characteristics: Concentration of Na, Ca and Mg are 22, 3 and 1.5 milli-equivalents per litre respectively, and the electrical conductivity is 200 micro mhos per cm at 25°C ?

Solution:

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} = \frac{22}{\sqrt{\frac{3 + 1.5}{2}}} = \frac{22}{\sqrt{2.25}} = \frac{22}{1.5} = 14.67$$

Which lies between 10 and 18 (S_2). Also conductivity of water is 200 μ .mho/cm < 250 μ .mho/cm which is low conductivity (C_1).

\therefore Given water is $C_1 - S_2$.

Q2 What problems may arise in using the water of $C_1 - S_2$ above and what are the possible remedies of the same if the soil is fine textured?

Solution:

In fine-textured soils, the medium sodium (S_2) water may create the following problems:

- (i) Soil becomes less permeable.
- (ii) It starts crusting when dry.
- (iii) It becomes plastic and sticky when wet.
- (iv) Its pH increases i.e., towards that of alkaline soil.

Gypsum ($CaSO_4$) addition, either to soil or to water is suggested to overcome sodium hazards posed by the given water.

Q3 Determine

- (i) The time required to irrigate an area of 0.05 hectare and
- (ii) The maximum area that can be irrigated from a tubewell with a discharge of 0.025 cumec. The infiltration capacity of soil is given as 5 cm/hour and average depth of flow of water may be taken as 10 cm.

Solution:

Given data: Area, $A = 0.05$ ha = 500 m^2 , Discharge, $Q = 0.025$ m^3/s , Infiltration rate, $I = 5$ cm/hour, Depth of flow, $y = 10$ cm

- (i) Time required to irrigate the area,

$$t = \frac{2.303y}{I} \log_{10} \left(\frac{Q}{Q - IA} \right) = \frac{2.303 \times 10}{5} \log_{10} \left(\frac{0.025}{0.025 - \frac{5 \times 10^{-2}}{3600} \times 500} \right)$$

$$= 0.652 \text{ hrs} = 39 \text{ minutes}$$

- (ii) Maximum area that can be irrigated,

$$A_{\max} = \frac{Q}{I} = \frac{0.025 \times 3600}{5 \times 10^{-2}} = 1800 \text{ m}^2 = 0.18 \text{ ha}$$

Soil Water Plant Relationship

Q1 Explain the term Base period and Crop period. After how many days will you order irrigation in order to ensure healthy growth of crops if:

- (i) Field capacity of soil = 29%
- (ii) Permanent wilting point = 11%
- (iii) Density of soil = 1300 kg/m^3
- (iv) Effective depth of root zone = 700 mm
- (v) Daily consumptive use of water of the given crop = 12 mm

Consider moisture content must not be less than 25% of the water holding capacity between the field capacity and permanent wilting point.

Solution:

Base period: It is the time between first watering of the crop after sowing to the last watering before harvesting.

Crop period: It is the time between sowing and harvesting of the crop. Thus crop period is marginally larger than base period.

In usual usage, both crop period and base period imply the same connotation.

Numerical: Available moisture = Field capacity – Permanent wilting point
 $= 29 - 11 = 18\%$

Given moisture content must not be less than 25% of water holding capacity of soil between the field capacity and permanent wilting point.

\therefore Readily available moisture = 75% of available moisture
 $= 0.75 \times 18 = 13.5\%$

Thus irrigation will be required to raise the soil moisture content from 13.5% to 29%.

\therefore **Depth of water stored is root zone** between these two limits of 13.5% and 29%

$$= \frac{\gamma_d \cdot d}{\gamma_w} [\text{F.C.} - \text{Optimum moisture content}]$$

$$= \frac{1300}{1000} \times 700 (0.29 - 0.135)$$

$$= 0.14105 \text{ m} \simeq 0.141 \text{ m} = 141 \text{ mm}$$

Thus 141 mm of water is available for consumptive use. But daily consumptive use of water by crop = 12 mm/day

\therefore 141 mm of water will be utilised in $\frac{141}{12} = 11.75 \text{ days} \approx 11 \text{ days}$

\therefore After 11 days, irrigation will be required.

Q2 Determine the field capacity of a soil for the following data:

- (i) Depth of root zone = 1.8 m
- (ii) Existing moisture = 8%
- (iii) Dry density of soil = 1450 kg/m^3

- (iv) Quantity of water applied to soil = 650 m^3
 (v) Water lost due to deep percolation and evaporation = 10%
 (vi) Area to be irrigated = 1000 m^2

Solution:

Total volume of water applied = 650 m^3

Water wasted = 10% of $650 \text{ m}^3 = 65 \text{ m}^3$

Water used in raising the moisture content of soil up to field capacity

$$= 650 - 65 = 585 \text{ m}^3$$

Depth of water used in raising moisture content of soil up to field capacity from the existing 8%

$$= \frac{585 \text{ m}^3}{\text{Area}} = \frac{585}{100} = 0.585 \text{ m}$$

But water depth required in the root zone of depth 'd' to increase moisture content, is given by

$$\Rightarrow 0.585 = \frac{\gamma_d}{\gamma_w} [\text{Upper limit moisture content} - \text{Lower limit moisture content, as fractions}]$$

$$\Rightarrow 0.585 = \frac{1.45 \text{ t/m}^3}{1 \text{ t/m}^3} \times 1.8 \text{ m} [\text{F.C.} - 0.08]$$

$$\Rightarrow (\text{F.C.} - 0.08) = 0.224$$

$$\Rightarrow \text{F.C.} = 0.224 + 0.08 = 0.304$$

Hence, Field capacity = 30.4%

Q3 Estimate the depth and frequency of irrigation required for a certain crop for the following data:

Root zone depth = 90 cm

Field capacity = 22%

Wilting point = 12%

Apparent specific gravity of soil = 1.5

Consumptive use = 22 mm/day

Efficiency of irrigation = 60%

Assume 50% depletion of available moisture as the indicator to begin application of irrigation water.

Solution:

Available moisture = $\text{FC} - \text{WP} = 22 - 12 = 10\%$

Readily available moisture = 50% of available moisture = 5%

Irrigation will be done as soon as moisture content falls from 22% to 17%

Depth of irrigation water required to raise moisture content from 17% to 22%

$$= \frac{\gamma_d d}{\gamma_w} [\text{F.C.} - \text{Optimum moisture content}]$$

$$= 1.5 \times 90 (22\% - 17\%) = 6.75 \text{ cm}$$

$$\therefore \text{Water depth required in the field} = \frac{6.75}{0.6} = 11.25 \text{ cm}$$

Depth of water available to plants for evapotranspiration = 6.75 cm

Consumptive use = 22 mm = 2.2 cm/day

\therefore 2.2 cm depth of water gets used up in one day

\therefore Number of days required for 6.75 cm of water depth to be used up

$$= \frac{1}{2.2} \times 6.75 = 3.07 \text{ days}$$

Hence, 11.25 cm water depth will be supplies to fields at every 3 days.

Q4 A certain crop is grown in an area of 3000 hectares which is fed by a canal system. The data pertaining to irrigation are as follows:

- Field capacity of soil = 26%
- Optimum moisture = 12%
- Permanent wilting point = 10%
- Effective depth of root zone = 80 cm
- Relative density of soil = 1.4

If the frequency of irrigation is 10 days and the overall irrigation efficiency is 22%. Find (i) the daily consumptive use (ii) the water discharge (in m³/sec) required in the canal feeding the area.

Solution:

Field capacity (F.C.) = 26%

Optimum moisture capacity (O.M.C.) = 12%

Permanent wetting point (P.W.P.) = 10%

Depth of water stored in root zone between F.C. and O.M.C.

$$= \frac{\gamma_d}{\gamma_w} [F.C. - O.M.C.]$$

$$= \frac{1.40 \times 80}{1.0} [0.26 - 0.12] = 15.68 \text{ cm}$$

Frequency of irrigation = 10 days

$$(i) \text{ Daily consumptive use of water} = \frac{15.68}{10} = 1.568 \text{ cm}$$

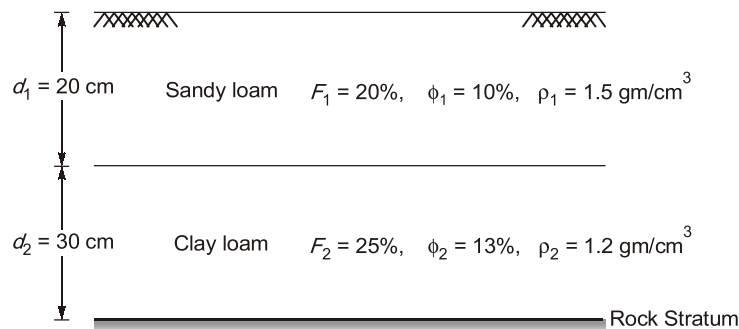
$$(ii) \text{ Total water required in 10 days} = \frac{3000 \times 10^4 \times 15.68}{100} = 4704000 \text{ m}^3$$

$$\text{Discharge required in canal} = \frac{4704000}{10 \times 24 \times 60 \times 60} = 5.44 \text{ cumec}$$

Q5 A soil 50 cm deep over rock has two horizons, the first being a fine sandy loam 20 cm thick and the second clay loam 30 cm thick. The field capacity, wilting point and volume weight for the first horizon are 20%, 10% and 1.5 gm/cm³ respectively. The corresponding values for the second horizon are 25%, 13% and 1.2 gm/cm³. Determine the available moisture storage capacity of the soil profile. If consumptive use requirements of a crop in a particular season is 0.5 mm/day and the soil is initially at field capacity, how long will the crop survive without irrigation?

Solution:

The soil profile can be shown as in the figure:



Let F be the field capacity, ϕ be the wilting point, d be the depth of soil, ρ be the density of soil and γ be the unit weight of soil.

Moisture storing capacity of sandy loam is given by

$$\begin{aligned}
 d_s &= \frac{\gamma_1 d_1}{\gamma_w} [F_1 - \phi_1] \\
 &= \frac{\rho_1 d_1}{\rho_w} [F_1 - \phi_1] = \frac{1.5 \times 20}{1} \left[\frac{20}{100} - \frac{10}{100} \right] \\
 &= 3 \text{ cm}
 \end{aligned}$$

Moisture storing capacity of clay loam is given by

$$\begin{aligned}
 d_c &= \frac{\rho_2 d_2}{\rho_w} [F_2 - \phi_2] \\
 &= \frac{1.2 \times 30}{1} \left[\frac{25}{100} - \frac{13}{100} \right] = 4.32 \text{ cm}
 \end{aligned}$$

∴ Total moisture storing capacity of the soil = $d_s + d_c = 3 + 4.32 = 7.32 \text{ cm}$

It is given that consumptive use requirement of crop = 0.5 mm per day

∴ Maximum number of days in which the entire moisture storing capacity will be utilized

$$\begin{aligned}
 &= \frac{\text{Moisture storing capacity of soil in cm}}{\text{Consumptive use requirement of crop in cm per day}} \\
 &= \frac{7.32}{0.05} = 146.4 \text{ days}
 \end{aligned}$$

Thus, the crop can survive for a maximum of 146.4 days without irrigation.

Q6 A loam soil has a field capacity of 25% and wilting coefficient of 10%. The dry unit weight of soil is 1.5 gm/cc. If the root zone depth is 60 cm, determine the storage capacity of the soil. Irrigation water is applied when moisture content falls to 15%. If the water application efficiency is 75%, determine the water depth required to be applied in the field.

Solution:

Given Data:

Field capacity, $F = 25\%$
 Wilting coefficient, $\phi = 10\%$
 Dry unit weight of soil, $\rho_s = 1.5 \text{ gm/cc}$
 Root zone depth, $\gamma_d = 60 \text{ cm}$

Moisture storage capacity of the soil in the root zone depth, d is given by

$$\begin{aligned}
 &= \frac{\gamma_d}{\gamma_w} \times d [F - \phi] = \frac{\rho_d}{\rho_w} \times d [F - \phi] \\
 &= \frac{1.5}{1} \times 60 \times \left[\frac{25}{100} - \frac{10}{100} \right] = 13.5 \text{ cm}
 \end{aligned}$$

Now, when the moisture content falls to 15%, the deficiency of water depth created will be given by

$$\begin{aligned}
 &= \frac{\rho_d}{\rho_w} \times d \times [F - \text{fall in moisture content}] \\
 &= \frac{1.5}{1} \times 60 \times \left[\frac{25}{100} - \frac{15}{100} \right] = 9 \text{ cm}
 \end{aligned}$$

Hence, 9 cm depth of water is the net irrigation requirement.

$$\therefore \text{Water application frequency} = \frac{\text{Net irrigation requirement}}{\text{Water depth required in the field}}$$

$$\Rightarrow \frac{75}{100} = \frac{9}{\text{Water depth required in the field}}$$

$$\Rightarrow \text{Water depth required in the field} = \frac{9 \times 100}{75} = 12 \text{ cm}$$

Q7 The depth of moisture in root zone at field capacity and permanent wilting point per m depth of soil are 0.5 m/m and 0.2 m/m respectively. Compute the field capacity and permanent wilting point. Take dry weight of soil as 13.73 kN/m³.

Solution:

Depth of water stored in the root zone in filling the soil upto field capacity is given as

$$h = \frac{\gamma_d dF}{\gamma_w}$$

$$\Rightarrow 0.5 = \frac{13.73 \times 1 \times F}{9.81}$$

$$\Rightarrow F = \frac{0.5 \times 9.81}{13.73}$$

$$\Rightarrow F = 0.3572$$

$$\Rightarrow F = 35.72\%$$

Thus, field capacity is 35.72%.

Depth of water stored in the root zone in filling the soil upto permanent wilting point is given as

$$h_1 = \frac{\gamma_d dP}{\gamma_w}$$

$$\Rightarrow 0.2 = \frac{13.73 \times 1 \times P}{9.81}$$

$$\Rightarrow P = \frac{0.2 \times 9.81}{13.73}$$

$$\Rightarrow P = 0.1429$$

$$\Rightarrow P = 14.29\%$$

Thus, the permanent wilting point is 14.29%.

Q8 The moisture content of soil in the root zone of an agricultural crop at certain stage is found to be 0.05. The field capacity of the soil is 0.15. The root zone depth is 1.1 m. The consumptive use of crop at this stage is 2.5 mm/day and there is no precipitation during this period. Irrigation efficiency is 65%. It is intended to raise the moisture content to the field capacity in 8 days through irrigation. Determine the necessary depth of irrigation. (Assume $\gamma_d = 1.5 \text{ gm/cc}$)

Solution:

Depth of water required to raise the moisture content to the field capacity (without considering loss due to evaporation).

$$d_w = \frac{\gamma_d}{\gamma_w} \times d \times (\text{FC} - \text{Existing moisture content})$$

$$= 1.5 \times 1.1 \times (0.15 - 0.05)$$

$$= 0.165 \text{ m}$$

Adding, consumptive use @ 2.5 mm/day for 8 days.

$$\text{Water required} = 0.165 + \frac{8 \times 2.5}{1000} = 0.185 \text{ m}$$

$$\text{Irrigation efficiency} = 65\%$$

$$\therefore \text{The necessary depth of irrigation} = \frac{185}{0.65} \text{ mm} = 284.62 \text{ mm}$$

Note: This question is different from others as it is mentioned in the question itself that irrigation is done in a period of 8 days. So, to account for consumptive use in the period of 8 days, a depth of $2.5 \times 8 \text{ mm}$ is to be added to raise it to field capacity as otherwise, if not added, moisture content won't be raised to field capacity by the end of 8 days.

Q.9 Estimate the depth and frequency of irrigation required for a certain crop, given

Root zone depth : 90 cm

Field capacity : 22%

Wilting Point : 12%

Apparent Sp. gr. of soil : 1.5

Consumptive use : 22 mm/day

Efficiency of irrigation : 60%

Assume 50% of depletion of available moisture as indicator to begin application of irrigation water.

Solution:

$$\text{Available moisture in root zone} = (F.C - W.P) \frac{\gamma_d}{\gamma_w} \times d$$

$$= (0.22 - 0.12) \times 1.5 \times 900 = 135 \text{ mm}$$

$$\text{Now, 50\% of available moisture} = 135 \times 0.5$$

$$d = 67.5 \text{ mm}$$

$$C_u = 22 \text{ mm/day}$$

$$\Delta t = \frac{(50\% \text{ of available moisture depth})}{C_u} = \frac{67.5}{22} = 3.068$$

Being on safe side, frequency of irrigation = **3 days**

$$\text{Depth of irrigation} = \frac{d}{\eta_{\text{irrigation}}} = \frac{3 \times 22}{0.6} = 110 \text{ mm}$$

Q.10 A sandy loam soil holds water at 140 mm/m depth between field capacity and permanent wilting point. The root depth of the crop is 30 cm and the allowable depletion of water is 35%. The daily water use by the crop is 5 mm/day. The area to be irrigated is 60 ha and water can be delivered at 28 lps. The surface irrigation application efficiency is 40%. There are no rainfall and ground water contribution. Determine:

- allowable depletion depth between irrigations.
- frequency of irrigation
- net application depth of water
- volume of water required
- time to irrigate 4 ha plot

Solution:

Moisture holding capacity of soil = 140 mm/m depth of root zone of crop.

Depth of root zone = 30 cm = 0.3 m