ESTIMATION OF EVAPOTRANSPIRATION BY CLIMATIC APPROACHES.

Some empirical and theoretical equations are derived on the basis of regional relationship between measured ET and climatic factors.

The following methods are the combinations of some empirical, analytical and theoretical approaches.

1. Blaney-Criddle Method
2. Penman Method
3. Christiansen Method
4. Thornthwaite Equation
5. Hargreaves Method
6. Lowry-Johnson Method
7. Jensen-Haise Method.

- The lack of reliable field data and the difficulties of obtaining reliable evapotranspiration data have given rise to a number of methods to predict PET (potential Evapotranspiration) by using climatological data.

1. BLANEY-CRIDDLE FORMULA.

It states that the monthly consumptive use is given by,

$$C_u = \frac{k \cdot p}{40}\left[1.8t + 32\right]$$

where, C_u = Monthly consumptive use (in cm)

k = Crop factor, determined by expts. for each crop, under the environmental conditions of the particular area.

t = Monthly mean temp. (in °C)

p = Monthly per cent of annual day light hrs that occur during the period.

If $\frac{p}{40}\left[1.8t + 32\right] = f$

then $C_u = k \cdot f$

- This formula has been extensively used throughout the world for estimating seasonal water requirements.
  However, it was found that the values of 'k' based on seasonal determinations were too low for the short periods b/w irrigations.
- This led to further development & finally the formula was expressed as,

$C_u = k \cdot \Sigma f$; where C_u = Seasonal consumptive use, i.e; consumptive use during the period of growth for a given crop in a given area.

- This formula doesnot take into consideration the factors such as humidity, wind velocity, elevation, etc. on which consumptive use depends.

Hargreaves class A pan evaporation method, is therefore, generally used in India.

Standard Class A Pan :— This pan is 1·2 m in dia., 25 cm deep & bottom is raised 15 cm above the ground surface. The depth of water is to be kept in a fixed range such that the water surface is atleast 5 cms & never more than 7·5 cm, below the top of the pan.

2. HARGREAVES CLASS A PAN EVAPORATION METHOD-

In this method, evapotranspiration (consumptive use) is related to pan evaporation by a constant K, called consumptive use coefficient.

$$K = \frac{\text{Evapotranspiration } (E_t \text{ or } C_u)}{\text{Pan Evaporation } (E_p)}$$

or $\boxed{E_t \text{ (or) } C_u = K \cdot E_p}$; E_p can be experimentally determined by directly measuring the quantity of water evaporated from the standard class A pan.

CONSUMPTIVE USE COEFFICIENT

- Consumptive use coefficient (K) is different for different crops & is different for same crops at different places.
- It also varies with crop growth, & is different at different crop stages for the same crop. Crop stages → Initial stage, Crop development stage, mid-season stage, last season stage (ripening).
- Where specific data are not available, avg. values can be used as recommended by Hargreaves [as given in Table 2.9, S.K. Garg]

In this method crops have been divided into 8 groups & the coefficients have been suggested for average conditions of soil, etc.

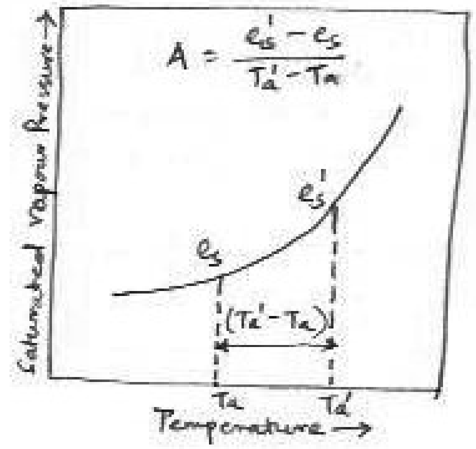
3. PENMAN'S EQUATION

Penman's equation for computation of PET or C_u for an area, has a sound theoretical reasoning, and it is not a simple empirical equation.

- This equation has been derived by intelligently combining the energy balance and mass transfer approaches of the computations of transpiration and evaporation, resp.
- Although slightly complicated mathematical conceptual work is involved here, yet its use is becoming more & more popular in today's modern computer age.

Penman's equation, incorporating some of the modifications suggested by other investigators, is given as

$$E_t = \frac{A \cdot H_n + E_a \cdot \gamma}{A + \gamma}$$; where



E_t = Daily potential evapo-transpiration.

A = Slope of the saturation vapour pressure Vs Temp. curve at the mean air temp.

H_n = Net incoming solar radiation or energy, expressed in mm of evaporable water per day.

E_a = A parameter including wind velocity & saturation deficit

γ = psychromatic constant = 0·49 mm of Hg/°C.

The net radiation (H_n) in the above eq^n is estimated by the equation

$$H_n = H_c(1-r)\left(a + b\cdot\frac{n}{N}\right) - \sigma\cdot T_a^4\,(0.56 - 0.092\sqrt{e_a}) \times \left(0.10 + 0.90\frac{n}{N}\right).$$

where H_c = mean incident solar radiation at the top of the atmosphere on a horizontal surface, expressed in mm of evaporable water per day. This value is a function of latitude (ϕ) of the place and the period of the year, as per the mean monthly values given in table 2.17.

r = reflection coefficient (albedo) of the given area. Usual values of this coefficient for different types of areas are given in Table 2.18.

a = a constant depending upon the latitude (ϕ) and is given as $a = 0.29\cos\phi$

b = a constant having avg. value = 0.52

n = actual duration of bright sunshine in hrs.

N = maximum possible hrs of bright sunshine (mean value).

σ = Stefan-Boltzman constant $= 2.01\times10^{-9}$ mm/day.

T_a = mean air temp. in °K = 273 + °C

e_a = actual mean vapour pressure in the air (in mm of Hg).

$$E_a = 0.35\left(1+\frac{V_2}{160}\right)(e_s - e_a)\ \text{mm/day}$$

where,

V_2 = mean wind speed at 2m above the ground (in km/d)

e_s = saturation vapour pressure at mean air temp. (in mm of Hg)

1. Wheat is to be grown at a certain place, the useful climatological conditions of which are tabulated below. Determine the evapotranspiration & consumptive irrigation requirement of wheat crop. Also determine the field irrigation requirement if the water application efficiency is 80%. Make use of Blaney-Criddle equation & a crop factor equal to 0.8.

Month	Monthly temp in °C, averaged over the last 5 years (t)	Monthly percent of day-time hrs of the yr. (p)	Useful rainfall in cm, averaged over the last 5 years, Re	$f = \frac{p}{40}(1.8t+32)$
November	18.0	7.20	1.70	11.6
December	15.0	7.15	1.42	10.5
January	13.5	7.30	3.01	10.3
February	14.5	7.10	2.25	10.3
			Σ = 8.38 cm	Σ = 42.7 cm

$C_u = k\Sigma f = 0.8\times42.7 = 34.16$ cm.

Consumptive irrigation requirement (C.I.R) $= C_u - R_e = 34.16 - 8.38 =$

Field Irrigation Requirement (F.I.R) $= \frac{C.I.R}{\eta_a}$

POTENTIAL EVAPOTRANSPIRATION (PET)

If sufficient moisture is always available to completely meet the needs of vegetation fully covering the area, thus resulting evapotranspiration is called PET.

PET no longer critically depends on soil & plant factors but depends essentially on the climatic factors.

REAL EVAPOTRANSPIRATION (OR) ACTUAL EVAPOTRANSPIRATION (AET)

The AET occurring in a specific situation is called actual evapotranspiration.

Chapter 3 ·

CANAL IRRIGATION SYSTEM (CIS) :

1. DIRECT IRRIGATION SCHEME :- Direct Irrigation Scheme make use of a weir or a barrage.

2. STORAGE IRRIGATION SCHEME :- Storage Irrigation Scheme make use of a storage dam or a storage reservoir.

The entire system of main canals, branch canals, distributaries and minors is to be designed for peak discharge.

→ Classification of canals :
The canals have to be aligned and excavated either in alluvial soils or non-alluvial soils; depending upon which they are called alluvial canals or non-alluvial canals.

(i) ALLUVIAL CANALS :—
(Indo-Gangetic plain)
Alluvial Soil :- The soil which is so formed by the continuous deposition of silt - from the water flowing through a given area, is called Alluvial soil.
The canals when excavated through such soils, are called Alluvial canals.

- The rivers flowing through such alluvial areas, have a tendency to shift their courses. Whenever, an irrigation structure is to be constructed on such a river, special precautions & design method are to be adopted.
- Direct irrigation using a weir / barrage is generally preferred in such areas.

(ii) NON-ALLUVIAL CANALS

Non-Alluvial Soil :- Mountaineous regions may go on disintegrating over a period of time, resulting in the formation of a rocky plain area : called non-alluvial soil.
It has an uneven topography, and hard foundations are generally available.
Canals passing through such areas are called non-alluvial canals.

- The rivers, passing through such areas, have no tendency to shift their courses & they donot pose much problems for designing irrigation structures on them.
- Major portion of Maharastra state is non-alluvial.
- Storage irrigation is preferred to canal irrigation in this type of soil.

ALIGNMENT OF CANALS.

Irrigation canals can be aligned in any of the following 3 ways:

(i) As watershed or ridge canal

(ii) as contour canal; and

(iii) as side-slope canal. (Branch or Distributary channels are aligned as side slope canals)

(i) WATERSHED CANAL (OR) RIDGE CANAL

Ridge :- The dividing ridge line between the catchment areas of two streams (drains) is called water-shed or the ridge. Thus between two major streams, there is the main watershed (ridge line), which divides the drainage area of the two streams.

Subsidiary Watersheds :- Between a main stream & any of its tributary, there are subsidiary watersheds (ridge lines), dividing the drainage between the two streams on either side.

The canal which is aligned along any natural watershed (ridge line) is called "watershed or ridge canal".

- Aligning a canal (main canal or branch canal or distributary) on the ridge, ensures gravity irrigation on both sides of the canal.
- Moreover, since the drainage flows away from the ridge, no drainage can cross a canal aligned on the ridge. (Saves the cost of construction of C.D. works)

Figure shows main canal takes off from a river at point A, and mounts the watershed at point B.

Let the canal BL at A = 200m;

the elevation of the highest pt. Q along the section PQA = 210m;

Assuming, ground slope is 1m per Km;

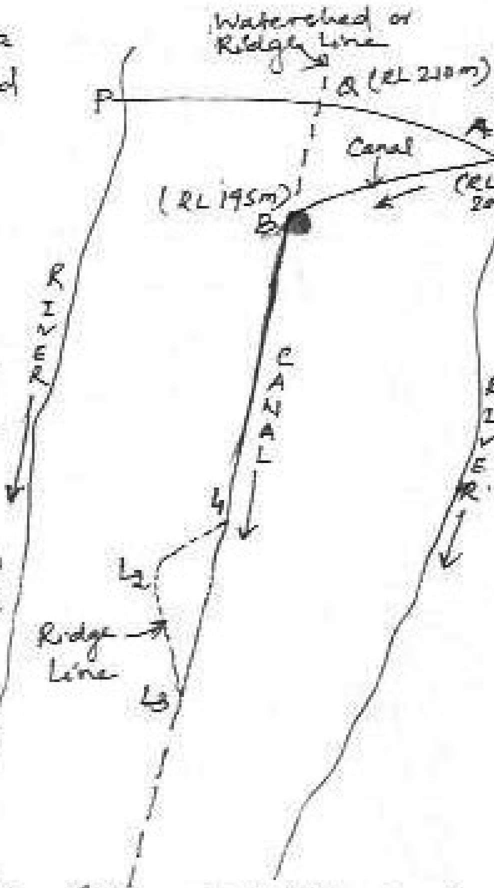
distance of pt. B (RL 195) from pt. Q (RL 210m) on the watershed would be 15 Km.

If the designed canal bed slope is 1 in 4000 (i.e; 0.25 m per Km), then the length AB of the canal would be 20 km. (1m in 4 km)

The exact location of B would be determined by trial, so that the alignment AB results in the economic as well as an efficient canal system.

On the watershed side of the canal AB, the ground (i.e; area AQB) is higher than the ground area on valley side (river side). Therefore, this canal portion AB can irrigate only on one side. (i.e; on left side) of the canal.

type
1m in 4km = 4000m
H = 4km, V = 1m
AB = 5km
$\frac{H}{V} = \frac{4}{1} = \frac{x}{5}$
$x = 20$ km

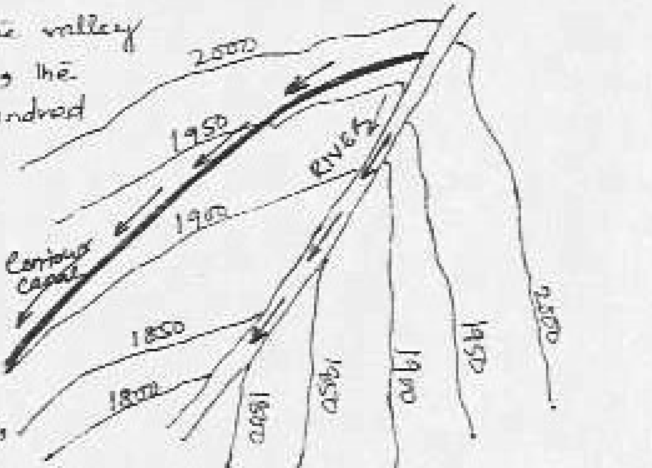


Alignment of Ridge Canal (Head reach of a main canal

- Since the available ground slope in the head reaches of a canal is usually much higher than the required canal bed slope, the canal generally needs only a short distance to reach the ridge line.
- For a canal system in plain areas, where land slopes are relatively flat and uniform, it is often necessary & advantageous to align canal on the watersheds.

(ii) CONTOUR CANALS

- In hills, the river flows in the valley well below the watershed. Infact, the ridge line (watershed) may be hundred of metres above the river. It therefore becomes impossible to take the canal top of such a higher ridge line. In such conditions, contour canals are usually constructed.
- Contour channels follow a contour, except for giving the required longitudinal slope to the channel.

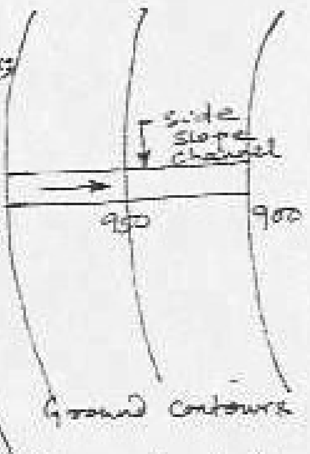


Alignment of contour canals (Head reach of main canal in hills)

- A contour canal irrigates only one side because the area on the other side is higher.
- As the drainage is always right angles to the ground contours, such a channel would definitely have to cross natural drains and streams, necessitating the construction of CD-works.

(iii) SIDE SLOPE CANALS

- It is aligned at right angles to the contours i.e, along the side slopes.
- Such a canal runs parallel to the natural drainage flow, it usually doesnot intercept drainage channels, thus avoiding the construction of cross-drainage structures.



Ground contours

Alignment of side slope canal

ALIGNMENT OF A CANAL IN PRACTICE

For finalizing canal networks for an irrigation project, trial alignment of canal are initially marked on the map prepared during detailed survey.
A large scale map is required to work out the details of individual canals. However a small scale map showing the entire command area of the irrigation project.
The alignment of canals on the map are transferred on the field, and adjustment & changes are made, wherever found necessary.
The adjustments are transferred on the map as well.

* Wrong alignment may lead to stagnation of water at some places or too fast moving water that may damage the canal itself.

→ Irrigation channels are generally aligned with reference to the contours of the country in one of the following different ways:

(i) as contour channels.
(ii) as Ridge channels
(iii) as side-slope channels

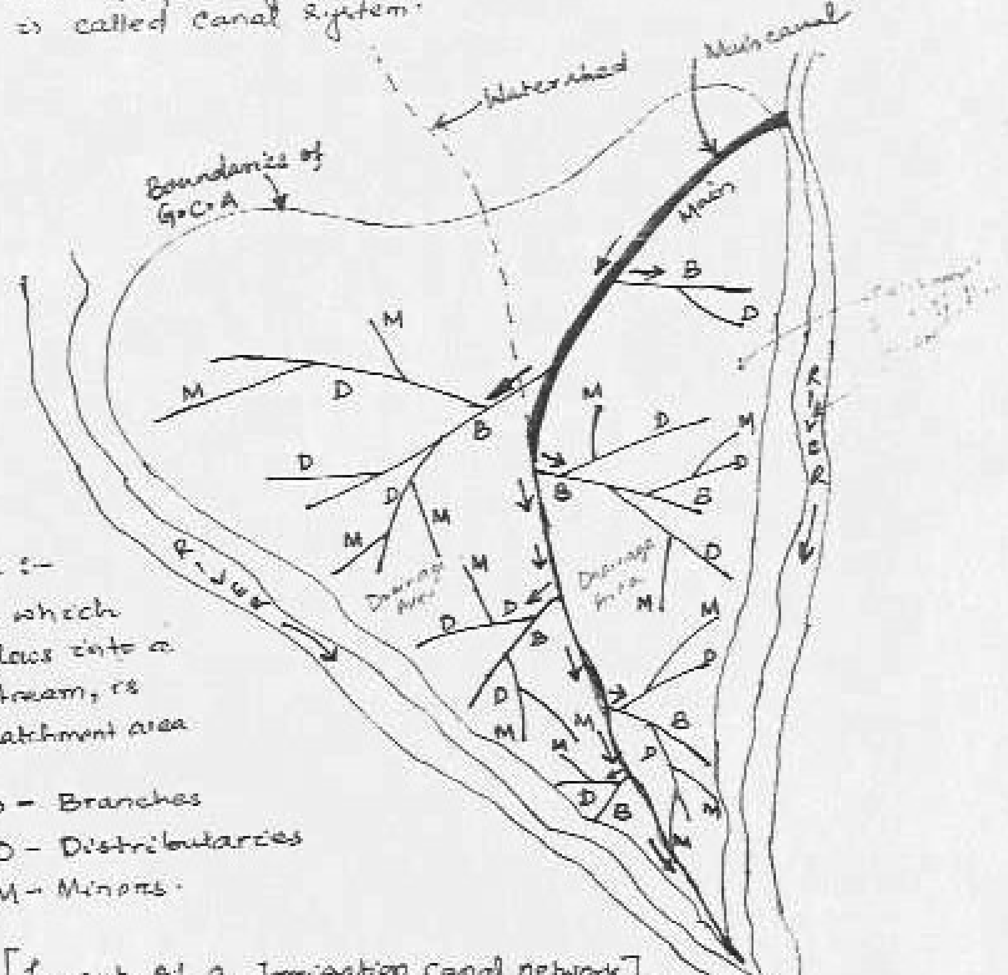
The main aim of these arrangements of layout of a distribution system is
- to secure the most economical way of effective water distribution
- adequate command of the area to be irrigated.
- little interference as possible with natural drainage.

The above statements aims to suggest an alignment along any watershed within the irrigable area as securing command of all ground upto the next valleys on either side of the alignment without any interference with drainage.

1. The root zone of an irrigation soil has dry weight of 15 kN/m³ & f.c of 30%. The root zone depth of a certain crop, having p.w.p of 8% is 0.8 m. Determine (a) depth of moisture in the root zone at f.c (459 mm/m) $\frac{\gamma_d}{\gamma_w} \times F_c$
   (b) " " " " " " " at PWP (122 mm/m) $\frac{\gamma_d}{\gamma_w}$ PWP
   (c) depth of water available in root zone (269 mm) $\frac{\gamma_d}{\gamma_w}[F_c - PWP]$

DISTRIBUTION SYSTEM FOR CANAL IRRIGATION.

The entire network of irrigation channels of different sizes and capacities is called canal system.



Catchment Area :-
The area from which rain water flows into a drain or a stream, is known as its catchment area

B - Branches
D - Distributaries
M - Minors.

[Layout of a Irrigation canal network].

Reservoir redistribute the water in time (storing water in raining season & releasing it in lean season); while the barrage & the canal system will redistribute it in space, taking it upto the fields.

(a) Main canal (Head reach) : canal headworks are generally situated on the river flowing in a valley, and the canal should reach the ridge line in the shortest possible distance. The canal, in this reach, must therefore, be aligned very carefully, and has to be generally excavated in deep cuttings below N.S.L (natural surface level).

(b) Main canal (portion b/l head reach) : Attempts are made to align the canal along the ridge & somewhat central to the command area. Main canal is not required to do any irrigation.

(c) Branch canal : Branch canals are taken off from the main canal on either side to take irrigation water to the whole tract required to be irrigated. Attempts are made to align them along subsidiary ridges. Discharge in a branch channel, is generally more than 30 cumecs.

(d) Distributaries : Smaller channels which take-off from the branch canals & distribute their supply through outlets into minors or water courses, are called distributaries. They are aligned either as ridge canals or as contour canals. Discharge is generally less than 30 cumecs.

(e) Minors : If the distance between the distributary outlet & the farmer's field is very long (say more than 3Km or so), small channels called minors are taken off from the distributaries so as to supply water to the cultivators at the point nearest to their fields.

(f) Water courses: These are not the government channels and belong to the cultivators. They are small channels, which are excavated & maintained by the cultivators at their own costs, to take water from the government-owned outlet points, provided in the distributary or the minor.

CERTAIN IMPORTANT TERMS OR DEFINITIONS

1. GROSS COMMAND AREA (G.C.A):

It is the total area, bounded within the irrigation boundary of a project, which can be economically irrigated without considering the limitation of the quantity of water.

It includes the cultivable as well as the un-cultivable area.
e.g: Ponds, residential areas, roads, reserved forest etc are the uncultivable areas of the gross command area.

- The boundaries of gross command of a canal system is fixed by the drainages on both sides of the main irrigation canal.

Culturable Command Area (CCA) → Culturable cultivated area; culturable uncultivated area.

2. CULTURABLE OR CULTIVABLE COMMAND AREA (C.C.A):

- Culturable area is the cultivable part of the gross command area, and includes all land of GCA on which cultivation is possible.
- It will include pastures (grazing land suitable for grazing cattle) & fallow (left unplanted to restore its fertility) lands which can be made cultivable.
- Obviously, it does not include uncultivable part of the gross command, like populated areas, ponds, roads, reserved forests, ushar land etc.

C.C.A → Cultivated portion of C.C.A; Cultivable but not cultivated portion of C.C.A.

★ In absence of detailed data, C.C.A = 80% of G.C.A.

Irrigation sectors: Major irrigation → C.C.A above 10,000 ha; Medium Irrigation → 2000 – 10000 ha; Minor irrigation → C.C.A < 2000 ha. (M.WR, M.RD & MoA)

3. INTENSITY OF IRRIGATION (Seasonal & Annual)

- The percentage of CCA proposed to be irrigated in a given season is called the intensity of irrigation of that season, or seasonal intensity of irrigation.

eg. Sanctioned intensity of irrigation under Bhakra (Sutlej) canal system is only 27.6% for Kharif season, and 34.4% for Rabi season.

→ Annual Irrigation Intensity / Annual Intensity of Irrigation (AII): is the percentage of CCA which may be irrigated annually.

$$AII = \frac{\text{Gross irrigated area (total area irrigated once in a yr + area irrigated more than once in that year)}}{\text{Culturable commanded Area}}$$

Annual Intensity of Irrigation = Sum total of intensities of irrigation of all seasons of the year.

AII = Intensity of irrigation for Kharif season + Intensity of irrigation for Rabi season.

= 27.6 + 34.4 = 62 %

The annual irrigation intensity is usually found to be in the range of 40 to 60 %, but needs to be raised to the range of 100 - 150% by cultivating larger parts of CCA with more than one crop in a year, and through improved management & economical utilisation of the available irrigation water.

4. Net and Gross Sown Areas

Gross cropped or Gross sown area (during a year)

= Net cropped area, i.e; area sown once in a year during the same year + Area shown more than once.

5. Net and Gross Irrigated Areas.

Area which is irrigated once during a year is called net irrigated area, and when to this is added the area irrigated more than once.

Gross irrigated area (in a given year)

= Net irrigated area (i.e; area irrigated once in a year)

+ Area irrigated more than once during the same year.

6. Area to be Irrigated.

Area to be irrigated = CCA * Seasonal / Annual Intensity of irrigation

* The areas to be irrigated are usually worked out separately for each crop seasons, because the water requirements of the crops of two seasons are quite different.

7. Time Factor.

[To check the dangers of over irrigation, leading to water-logging & salinity, no distributary is allowed to operate on all the days during any crop season]

$$\text{Time factor (of distributary)} = \frac{\text{Actual operating period of distributary}}{\text{Crop Period}}$$

Actual Discharge / Designed Discharge

e.g; for Bhakra canal system, the time factors for Kharif & Rabi seasons are fixed at 0.8 & 0.72 resp., which means that each distributary would receive its full supply for a period of 0.8 x 180 = 144 days, and 0.72 x 180 = 129 days, resp.

8. Capacity factor (to be discussed after design capacity of an irrigation channel)

Capacity factor for a canal is the ratio of the mean supply discharge in a canal during a period to its designed full capacity.

Kharif (Summer) season (C.F) = 0.9 to 0.95

Rabi (Winter) season (C.F) reduces to about 2/3rd times the full supply = 0.6 to 0.7.

$$\text{Capacity factor} = \frac{\text{Mean Supply Discharge}}{\text{Designed full capacity}}.$$

9. **Full Supply Coefficient** (or Design Duty)

Full supply coefficient is the design duty at the head of the canal. The no. of hectares irrigable per cumec of the canal capacity at its head, is known as full supply coefficient of the canal.

$$\text{Full Supply Coefficient} = \frac{\text{Area estimated to be irrigated during base period}}{\text{Design full supply discharge at the head of the canal}}$$

10. **Nominal Duty.**

It is the ratio of the area actually irrigated by the cultivators to the mean supply discharge let out from the outlet of the distributary over the crop period.

e.g.; Let x cumec of water is released daily from the outlet of a distributary for 100 days (say) in a total crop period of 125 days (say).

Mean Supply Discharge over the crop period will be $\frac{x \times 100}{125}$
$= 0.8x$ (cumec)

If the area of crop irrigated by this discharge is A hectares,

$$\text{Nominal Duty} = \frac{A\ (ha)}{0.8x\ (cumec)} = 1.25\,\frac{A}{x}\ ha/cumec.$$

Computing the Design capacity of an Irrigation Canal.

The sum of discharges (cumec) required by the

(i) Rabi + Sugarcane (including garden crops, if any)

(ii) Kharif + Sugarcane (including garden crops, if any)

The canal capacity may then be fixed for the maximum of the (i) & (ii).

- Channel capacity must be designed for keenest demand of the crop & not the average demand.

e.g.; let Rice require 120 cm of water during 120 days, then giving an average outlet factor of 864 hectares/cumec.

$$\left(\text{i.e; } D = \frac{864B}{\Delta} = \frac{864 \times 120}{120} = 864\right) \rightarrow \text{Average Demand}$$

But a canal designed on this average outlet factor will prove to be very inadequate, as it will fail to supply the required water to the crop at its peak demand, i.e; at the time of Kor-watering.

The Kor depth for Rice is about 19 cm and the Kor period is about 2 weeks (i.e; 14 days). Therefore the Outlet factor for this works out to be,

$$\left(D = \frac{864B}{\Delta} = \frac{864 \times 14}{19} = 637\right) \rightarrow \text{Duty for keenest Demand.}$$

$D = \frac{A}{Q}$

Now, discharge required to mature A hectares of land for an outlet factor of 864 is $\left(\frac{A}{864}\right)$ cumecs; while that for an outlet factor of 637 is $\left(\frac{A}{637}\right)$ cumecs.

Out of these two values, the second value $\left(\frac{A}{637}\right)$ is more, and hence, the discharge required for fulfilling the Kor demand of the crop is more than that of the average demand.

NOTE :-
The Peak demand (i.e, Kor-demand) of the crop should be taken into account while fixing the capacity of a canal. Moreover, the provision for canal losses should also be made, while deciding the final capacity of the channel.

Problems.

① The gross comanded area for a distributary is 6000 hectares, 80% of which is culturable irrigable. The intensity of irrigation for Rabi season is 50% and that for Kharif season is 25%. If the average duty at the head of the distributary is 2000 hectares/cumec for Rabi season & 900 hectares/cumec for Kharif season, find out the discharge required at the head of the distributary from average demand considerations.

$$Q = \frac{A}{D} = \frac{\text{hectares}}{\frac{\text{hectares}}{\text{cumec}}}$$
$$Q = \text{Cumecs}$$

Solution :-

G.C.A = 6000 hectares.

C.C.A = 0.8 × 6000 = 4800 hectares.

Area to be irrigated in Rabi season

$$= 4800 \times \frac{50}{100} = 2400 \text{ hectares}.$$

Area to be irrigated in Kharif season

$$= 4800 \times \frac{25}{100} = 1200 \text{ hectares}.$$

Water required (in cumecs) at the head of the distributary to irrigate Rabi area,

$$Q = \frac{A}{D} = \frac{2400}{2000} = 1.20 \text{ cumecs}.$$

Water required at the head of the distributary to irrigate Kharif area,

$$= \frac{1200}{900} = 1.33 \text{ cumecs}.$$

Thus, the requirement in Kharif season is 1.33 cumec & that in Rabi season is 1.20 cumecs. The required discharge is maximum of the two i.e. 1.33 cumecs. Ans.

Hence, the distributary should be designed for 1.33 cumecs ~~and that in Rabi season~~ discharge at its head, from average demand considerations. The head regulator should be sufficient to carry 1.33 cumec; and in Rabi season, only 1.2 cumec will be released.

NOTES :- Canal method of water conveyance and distribution is a dynamic system with variation in demand occurring according to the crops planted in the command area. Also, the source of water, usually a river, may not be able to supply sufficient amount of water all time. Nevertheless, the canal system has to be planned & designed for the maxm expected demand.

Outlet discharge required for wheat (Kor demand)
or
Peak Demand Discharge $= \frac{(Area)_W}{(Duty)_W} = \frac{6000}{1792} = 3.35$ cumec.

Outlet discharge required for Rice (Kor demand)
$= \frac{(Area)_R}{(Duty)_R} = \frac{2250}{636} = 3.54$ cumecs.

The required design discharge at the outlet, from peak demand considerations, is maximum of these two values, i.e; = 3.54 cumecs.

(3) A main canal, which off takes from a storage reservoir, has to irrigate crops in a certain country having three (3) seasons in a year. Data for the irrigated crops given in the table below:

Sl. No.	Name of crop	Crop Period (in days)	Area to be irrigated (in ha)	Duty at the head of the main canal (in ha/cumec)
1. (a)	Sugarcane	280	315	630
(b)	Overlap for Sugarcane in hot weather	100	70	630
2.	Jowar (Rabi)	120	4900	1600
3.	Bajra (Monsoon)	120	5600	2800
4.	Vegetables (Hot season)	120	350	700

(a) Find the discharge required at the head of the main canal, taking time factor for the main canal as 0.7.
(b) What should be the gross storage capacity of the reservoir? Assume suitable factors, wherever needed.

Solution :-
(i) Water required for Sugarcane (whole year) $= \frac{315}{630} = 0.5$ cumec.
(ii) Water required for Overlap Sugarcane (Hot season) $= \frac{70}{630} = 0.11$ cumec.
(iii) Water required for Jowar (Rabi season) $= \frac{4900}{1600} = 3.0$ cumecs.
(iv) Water required for Bajra (Monsoon season) $= \frac{5600}{2800} = 2.0$ cumecs.
(v) Water required for vegetables (Hot season) $= \frac{350}{700} = 0.5$ cumec.

Total water required in each season is as follows:
(a) in hot season $= 0.5 + 0.11 + 0.5 = 1.11$ cumecs;
(b) in monsoon season $= 0.5 + 2.0 = 2.5$ cumecs;
(c) in Rabi season $= 0.5 + 3.0 = 3.5$ cumecs;

It is evident that the maximum water is required in Rabi season, i.e; equal to 3.5 cumecs.
↳ Nominal Discharge

(2) The culturable commanded area for a distributary is 15,000 hectares. The intensity of irrigation (I-I) for Rabi (wheat) is 40% and for Kharif (rice) is 15%. If the total water requirement of the two crops are 37.5 cm & 120 cm and their periods of growth are 160 days and 140 days resp.;

(a) Determine the outlet discharge from average demand considerations;

(b) Also determine the peak demand discharge, assuming that the Kor water depth for two crops are 13.5 cm & 19 cm and their Kor periods are 4 weeks and 2 weeks resp.

Solution :- (a) C.C.A = 15,000 hectares.

I-I for Wheat (Rabi) = 40%

I-I for Rice (Kharif) = 15%

Wheat (Rabi) area = 15,000 × 0.4 = 6000 ha.

Rice (Kharif) area = 15,000 × 0.15 = 2250 ha.

Δ for wheat = 37.5 cm ; B for wheat = 160 days.

Δ for Rice = 120 cm ; B for Rice = 140 days

$$D = \frac{864\,B}{\Delta}$$

Average duty (D) for wheat $= \frac{864 \times 160}{37.5} = 3686$ ha/cumec.

Average duty (D) for Rice $= \frac{864 \times 140}{120} = 1008$ ha/cumec.

Outlet discharge required for wheat $= \frac{(\text{Area})_w}{(\text{Duty})_w} = \frac{6000}{3686} = 1.63$ cumecs.

Outlet discharge required for rice $= \frac{(\text{Area})_R}{(\text{Duty})_R} = \frac{2250}{1008} = 2.23$ cumecs

The required design discharge at outlet (from average demand considerations) is maximum of the two values, i.e; 2.23 cumecs. Ans.

(b) Kor water depth for wheat = 13.5 cm.

Kor period for wheat = (4 × 7) days = 28 days.

Kor water depth for Rice = 19 cm

Kor period for Rice = (2 × 7) days = 14 days.

Duty for wheat (for kor demand) $= \frac{864\,B}{\Delta} = \frac{864 \times 28}{13.5} = 1792$ ha/cumec. (B ← Kor period)

Duty for rice (for kor demand) $= \frac{864\,B}{\Delta} = \frac{864 \times 14}{19} = 636$ ha/cumecs.