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Comparison of Seepage and Evaporation Losses of Field Data Analysis with Analytical Approach Analysis- A Study of Narwana Branch Canal, Kurukshetra

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Abstract: The loss of water from canal networks for irrigation and drinking water supply is a major cause of concern as considerable amount of useful water is lost from the source to the final destination. This water loss can be attributed mainly to seepage loss from the wet channel geometry of the canal system and evaporation loss from the surface area of the canal. The seepage loss can be reduced to great extent by lining of the canal but cannot be stopped completely. Similarly evaporation loss can be controlled by mechanical or chemical covering of the canal water surface. However, these means are cost prohibitive. Thus, there is a need of assessing the likely amount of water loss in the canal system so that appropriate preventive action could be taken. The present study analytically estimates seepage and evaporationlosses from the irrigation canal system of Narwana Branch, Kurukshetra, Haryana from Reduced Distance (R.D.) 1, 60,000ft to 3,20,398ft and compares the sum of these two with the total water loss in the canal reach from field studies. The canal is completely brick lined between these two points and its cross section is trapezoidal. The records of discharge measurements at these RDs and all intermediate withdrawals have been collected from Haryana Irrigation Department. These data are useful in estimating total loss of water in this reach. For estimation of evaporation loss data of mean air temperature, relative humidity andwind velocity of the area were collected from neighboring meteorological station. The seepage loss in the canal has been worked out by mass balance method applied in the catchment area of the canal reach including contribution of surface runoff from the rainfall. The study helps to identify contribution of seepage loss and evaporation loss in total loss of water, which will be useful to water resource planners and engineers.

Keywords: Reduced Distance, Seepage loss, Evaporation loss, Inflow- Outflow, Canal.

1. Introduction:

The loss of water due to seepage and evaporation from irrigation canals constitutes a substantial part of the usable water. By the time the water reaches the field, more than half of the water supplied at the head of the canal is lost in seepage and evaporation [6]. Seepage loss is the major and the most important part of the total water loss [8]. The other part i.e. evaporation loss is important particularly in water scarce areas. Considerable part of flow may be lost from a network of canals by the way of evaporation in high evaporating conditions. This needs special consideration for a long channel carrying small discharge in arid regions. Thus, care must be taken in the design of such canals to account for evaporative losses along with seepage loss. Considerable works has been done on the estimation of seepage and evaporation losses in a canal networks,later section deals with the review ofthese. In the present study the total water loss have been obtained by analytical methodsusing explicit equations for seepage loss [4] and evaporation loss for flowing channel [3], and have been compared with estimation from field studies to quantify each loss for use in planning and operation of canals.

2. Study Area:

The Narwana Branch Canal, Kurukshetra (Haryana) is the main line canal of the Bhakra Main Canal. It was constructed in 1954-55 to augment supplies of the Western Yamuna Canal. It off takes from Bhakra Main Line and supplies water to Sirsa Branch and main branch of Western Yamuna Canal. A few distributaries like Malaur, Jansui, Thanesar, Pabnawa, Head Saraswati Feader, Thaska distributaries take off from Narwana Branch and provide irrigation in the intervening area.

The layout plan of the area taken into consideration for estimating seepage and evaporation losses is given in Fig.1:

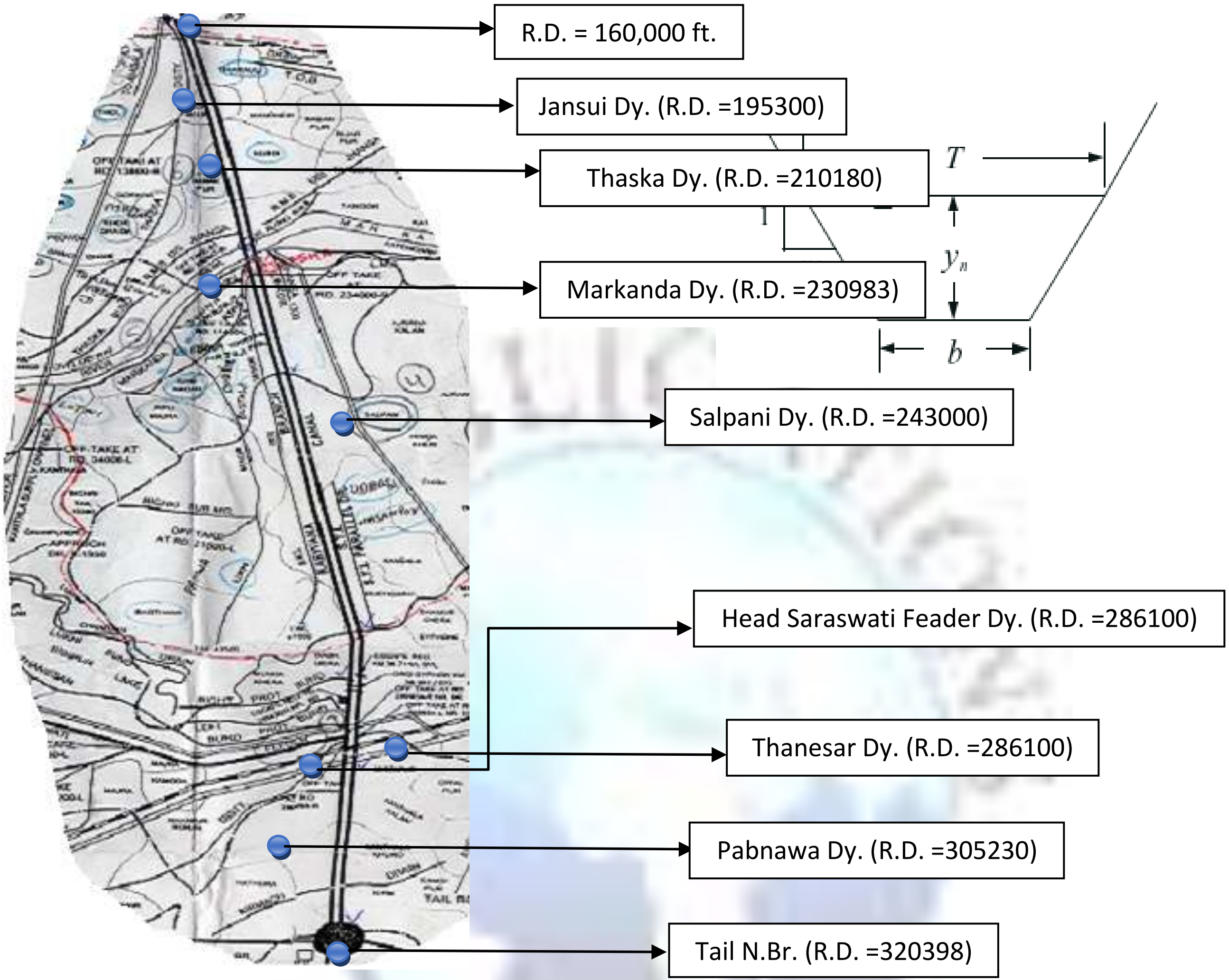

Fig. 1: Canal Section

Table - 1: Hydraulic particulars of Narwana Branch Canal

Description	Canal section from R.D. 160000 ft. to 320398ft
Bed width	34.20 ft.
Full supply level	843.05 ft.
Side slope	0.16/hundred
Discharge capacity	3914 cusecs
Free board	2.5 ft.
Bed level	826.05 ft.
Full supply depth	14.77 ft.

Various data for Narwana Branch canal are collected from Reduced Distance (R.D.) 1, 60,000 ft to 3, 20,398 ft and are given in Table -1[Data Source: Haryana Irrigation Department, Jyotiser, Kurukshetra (Haryana)] and cross-section is shown in Fig.2. The station located at R.D 1, 60,000 ft. is Malaur (Kurukshetra) and at R.D. 3, 20,398ft [11] is Budhera (Kurukshetra). There are many distributaries between these two R.D.'s.

3. Methodology:

This section discusses methods employed for estimation of total water losses on account of seepage and evaporation.

3.1 Analytical Method

3.1.1 Seepage Loss

Providing perfect lining can prevent seepage loss from canals but cracks in lining develop due to several reasons and performance of canal lining deteriorates with time. An examination of canals by Wachyan and Rushton [10] indicated that even with the greatest care the lining does not remain perfect. A well maintained canal with99%perfect lining reduces seepage about 30-40% only [10]. Thus, significant seepage losses occur from a canal even if it is lined. The seepage loss from canals is governed by hydraulic conductivity of the subsoil, canal geometry, and potential difference between the canal and the aquifer underneath which in turn depends on the initial and boundary conditions. Seepage losses are also influenced by clogging of the canal surfaces depending on the suspended sediment content of the water and on the grain size distribution of the suspended sediment particles. The clogging process can decrease the seepage discharge both through bottom and slopes. Thus the seepage loss can change within time and under certain conditions it can diminish. Therefore, the seepage loss can be higher at the beginning of the canal operation and can be lower after a few years of operation. The seepage loss from a canal in an unconfined flow condition is finite and maximum when the potential difference is very large e.g. when the water table lies at very large depth. The steady seepage loss from an unlined or a cracked lined canal in a homogeneous and isotropic porous media, when water table is at very large depth, can be expressed as:

$$Q_s = K\, Y_n\, F_s \qquad (1)$$

Where Q_s = seepage discharge per unit length of canal (m^2/s); K= coefficient of permeability (m/s); Y_n= normal depth of flow in the canal (m); and Fs= seepage function (dimensionless), which is a function of channel geometry. The seepage function can be estimated from the wet channel geometry of the canal system.

3.1.2 Evaporation Loss:

Evaporation loss depends on (i) the supply of energy to provide the latent heat of vaporization and (ii) the ability to transport the vapor away from the evaporating surface, which in turn depends on the wind velocity over the surface and the specific humidity gradient in the air above the water surface. A large number of equations for estimating evaporative rate are available in the literature. A review indicated that these equations fall into the following categories; (a) energy balance equations; (b) mass transfer equations; and (c) combinations of the two. Warnaka and Pochop [9] and Ikebuchi et al. [8] then compared the merits of various equations. The energy balance equations require a variety of climatological data. The need of sophisticated equipment for direct measurement of radiation, frequent temperature surveys for heat storage etc. make the method unattractive. On the other hand, the mass transfer equations are most convenient and useful for determining evaporation from flowing canals [7]. The mass transport type equations are expressed as:

$$E = (e_s - e_d)\, f_w \qquad (2)$$

WhereE= evaporation discharge per unit free surface area (m/s); e_s= saturation vapor pressure of the air at the temperature of the water surface (Pa); e_d= saturation vapor pressure of the air at the dew point (Pa); and f_w= wind function (m/s/Pa).

The difference between the saturation vapor pressure of the air at the temperature of water surface and at the dew point (e_s-e_d) in Pa was given by [2]:

$$e_s - e_d = 610.78\left[\exp\left(\frac{17.27 Q_w}{237.3 + Q_w}\right) - R_h \exp\left(\frac{17.27 Q_a}{237.3 + Q_a}\right)\right] \qquad (3)$$

Where Q_w= water surface temperature in °C; Q_a= mean air temperature in °C; and R_h= relative humidity expressed as fraction. The wind function for a flowing channel in m/s per Pa was given by Fulford and Sturm [3]:

$$f_w = 3.704 * 10^{-11}(1 + 0.25u_2) \qquad (4)$$

whereu_2= wind velocity in m/s at 2 m above the free surface. Combining (3-4), E (in m/s) is obtained as:

$$E_e = 2.262 * 10^{-8}(1 + 0.25u_2)\left[\exp\left(\frac{17.27 Q_w}{237.3 + Q_w}\right) - R_h \exp\left(\frac{17.27 Q_a}{237.3 + Q_a}\right)\right] \qquad (5)$$

3.1.3 Total Water Loss

The total water loss has been calculated by adding seepage and evaporation loss for experimental data.

$$Q_T = K\, Y_n\, F_s + E_e\, T \qquad (6)$$

Where F_s is the seepage function, which depends on the function of channel geometry. T= b+2my$_n$, b= bed width of free surface (m), m is side slope, y_n = normal depth (m).

Using Swamee et al [8] equations for trapezoidal channel section was reduced to:

$$Q_T = ky_n \left\{\left[(4\pi - \pi^2)^{1.3} + (2m)^{1.3}\right]^{\frac{0.77+0.462m}{1.3+0.6m}} + \left(\frac{b}{y_n}\right)^{\frac{1+0.6m}{1.3+0.6m}}\right\}^{\frac{1.3+0.6m}{1+0.6m}} + (b+2my_n)\, E_e \qquad (7)$$

3.2 Field Study Method:

3.2.1Seepage loss

Methods for measuring the rate of seepage loss from field data, is adoptedas below:

Inflow – Outflow Method:

The inflow-outflow method consists of performing both upstream and downstream discharge measurements and compares the values obtained in those canal sections. The main advantage of this approach is represented by the fact that the losses are measured under the normal operating conditions of the canal. The major disadvantages of this method are the need for a large number of very accurate measurements over time and the impossibility to identify localized losses. The inflow-outflow method is a water balance approach that consists in the direct measurement of the flow rate flowing into and out of a reach of canal. Thus, from Eq. 3 it is possible to estimate the flow that goes into the soil through the wetted perimeter. Figure 2 shows the scheme of this method [12].

The layout structure of the inflow – outflow method of seepage loss in a canal network is as follow:-

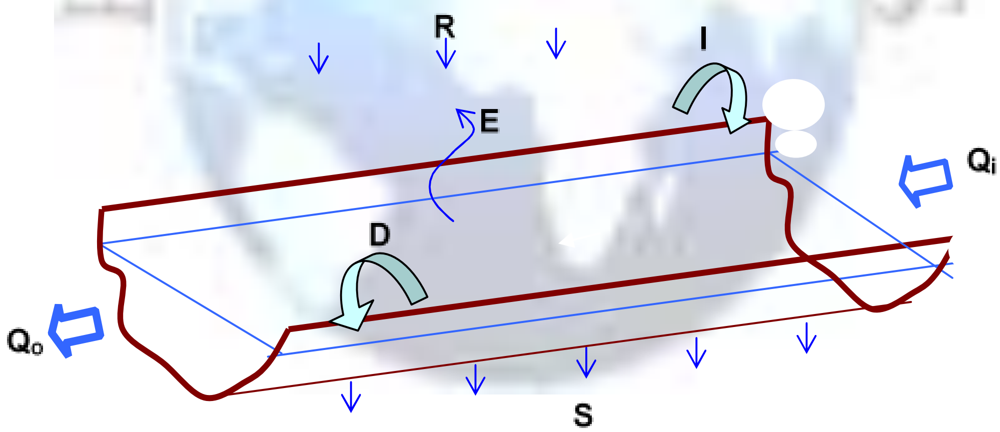

Fig. 2: Reach of the canal showing Inflows and Outflows

$$S = Qi + R - Q_O - D + I - E \qquad (8)$$

Where S= seepage loss; Q_i= upstream inflow; R= rainfall; Q_o= downstream out flow; D= flow diverted along the reach; I= inflow along the reach; and, E = evaporation. To use this method it is necessary to assume steady flow conditions and take long canal reaches to obtain a measurable loss [5].

3.1.2Evaporation Loss

Methods for measuring the rate of evaporation loss from field data[Data source: Central Soil Salinity Research Institute (CSSRI), Karnal (Haryana)]
, using evaporation equation:

$$E = \text{Depth of evaporation} * L*T \qquad (9)$$

Where, E = evaporation rate; L = length of the canal (m); T= top width of canal (m);

3.1.3 Total Water Loss:

$$Q_t = S + E$$

4. Results and Analysis

The amount of total water loss in canal section as given below:

	Field Studies Analysis				Analytical Approach Analysis			
Months	Seepage (cs.)	Evap. (cs.)	Total Loss(cs.)	% (Seepage)	Seepage (cs.)	Evap. (cs.)	Total Loss(cs.)	% (Seepage)
Aug-12	91.05	0.76	91.81	99.17	86.33	0.58	86.91	99.33
Sep-12	83.85	0.73	84.58	99.14	86.33	0.68	87.01	99.22
Oct-12	65.18	0.65	65.83	99.01	86.33	0.64	86.97	99.26
Nov-12	94.24	0.43	94.67	99.55	86.33	0.56	86.89	99.36
Dec-12	89.9	0.4	90.3	99.56	86.33	0.42	86.75	99.52
Jan-13	96.53	0.3	96.83	99.69	86.33	0.23	86.56	99.73
Feb-13	53.61	0.39	54	99.28	86.33	0.3	86.63	99.65
Mar-13	79.45	0.67	80.12	99.16	86.33	0.65	86.98	99.25
Apr-13	123.23	1.38	124.61	98.89	86.33	1.66	87.99	98.11
May-13	142.59	1.91	144.5	98.68	86.33	2.49	88.82	97.20
Jun-13	130.23	1.28	131.51	99.03	86.33	1.47	87.8	98.33
Jul-13	142.85	1.02	143.87	99.29	86.33	0.85	87.18	99.03

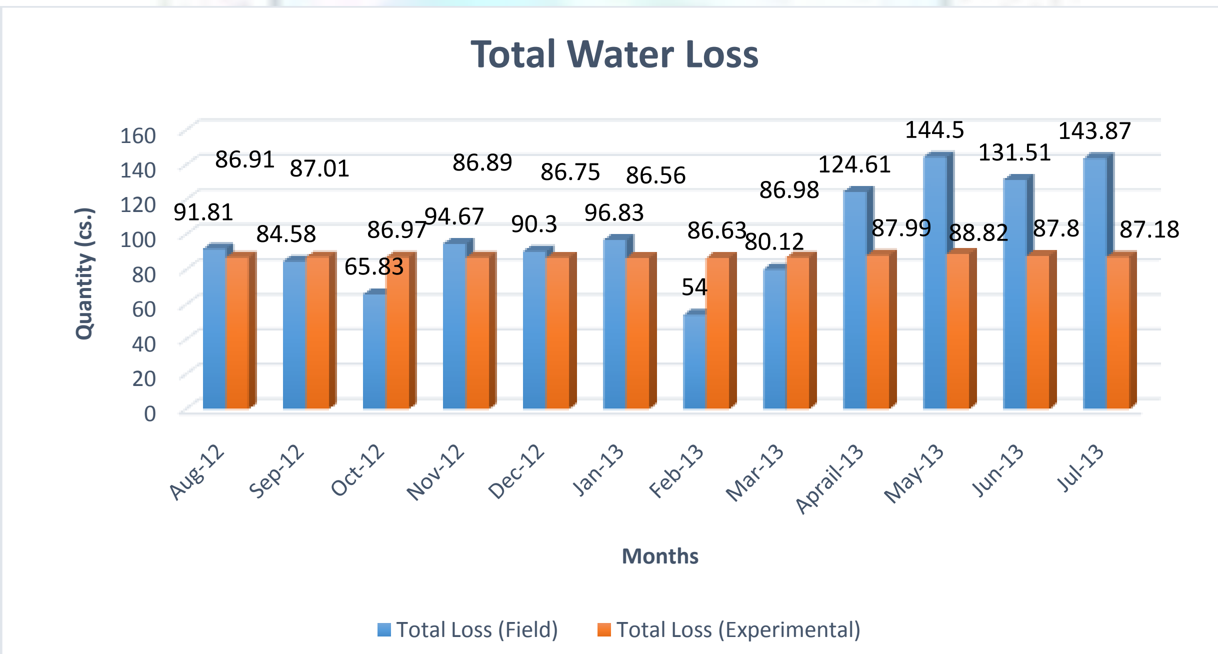

Fig. 4: Comparison of Total Water Loss using and Field Studies and Analytical approach

The results for seepage loss, evaporation loss and total loss obtained for the two methods are given in Table-2. Comparison of total water losses using analytical and field study approaches from August 2012 to July 2013 is shown in Fig.4. The average of total water loss of field studies and analytical approaches are 100.21 cusecs/day and 87.20 cusecs/day, respectively from August, 2012 to July, 2013. These results indicate that the average of total water loss from analytical approach is 13% lower than the field studies. It may be seen from Fig.4 that average of Seepage and Evaporation using field studies from R.D. - 1, 60,000 ft. to R.D. – 3, 20,398are 99.39 cusecs/day and 0.82 cusecs/day, respectively. And also from Fig.4, that the average of Seepage and Evaporation using analytical approach are 86.33 cusecs/day and 0.87 cusecs/day, respectively. It is seen that in spite of lining of the canal section, the seepage loss is ranging from 98.6 to 99.69 % of total water loss.

5. Conclusion:

Thus the study helps to quantify contribution of seepage loss and evaporation loss in total loss of water.Thus, indicating that contribution of evaporation loss in total loss is insignificant and hence there is need of managing seepage loss. This knowledge will be useful to engineers for water resource planning and operation of canals.

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