Evaluation of Water Losses in Unlined Canal: A Case Study of Malik Branch Canal, Bahawalnager, Pakistan

Adnan Ahmad Khan[1], Ishtiaq Hassan[1,] Muhammad Muneer[2]

[1]*Department of Civil Engineering, Capital University of Science & Technology, Islamabad, Pakistan,*
[2]*Department of Engineering Management, RIPHA International University, Rawalpindi, Pakistan*

Abstract: **Water is an essential component of nature for the survival of life on planet earth. It is the most valued reserve of nature. The two main sources of water are surface water and ground water. Surface water has its uses as domestic and for irrigation supply. Now-a-days, with an increase in demand of water, due to the gradual increase in population, it is becoming a scared source from an abundant resource. This study undergoes to estimates the water losses in unlined canal with a purpose of providing an estimation of water losses. Seepage losses & evaporation losses are determined also investigated the rate of water losses. There is a dire need to identify and prioritize the cause of losses in unlined canals so that rehabilitation and maintenance can be done accordingly. The Inflow and Outflow method was adopted to estimate the water losses on four sections of the selected canal. Average total water loss rate is calculated for four sections which is 1.74 x 10^3 cusecs/ft, whereas contribution of evaporation losses (during September to December) in total water losses is 1.22%. The amount of evaporation increases with the increase in temperature. It is observed from this research that there is 13.29% difference in water discharge between upstream and downstream of canal which badly affects the proper availability of water to irrigation lands at the tail, hence causes water scarcity**.

Keywords: **Unlined Canal, Water losses, Seepage losses, Evaporation Losses, Inflow outflow method,**

I. INTRODUCTION

Water is the most important resource of the world, necessarily utilized by living things for survival and also has a lot of uses in different industrial processes. The existence of life on planet earth is directly relying on the availability of this natural resource. Proper provision of water to field may cause a successful cropping while its deficiency may result a failure in crop production. According to Food & Agriculture Organization of United State (FAO, 2011) the number of crops grown in one year is increased from one to two hence increased water demands. The vast amount water which covers 71% of the blue planet out of which 2.5% is fresh water and only one third of this fresh water can be economically available for human use. The competing demand of this infinite resource is gradually increasing for drinking, hygiene, agriculture and industry in a world of 9 billion people. It quickly becomes clear that without proper water management now a days, the world is headed a crises of water scarcity that will affect every aspect of life. In regards of the above discussion it is realized that water saving has become the need of time. In Pakistan, about 70% of total water (125/175 Bm^3) consumed for irrigation, and rest of water around 35 Bm^3 is wasted in to Arabian Sea. In Indus Basin Irrigation system about 74 percent of mean annual river flow (140 MAF) is taken into canal networks and 19% flows to Arabian Sea and remaining 7% is water losses. Productivity of canal networks is tremendously low, as 53% of water (55 MAF) is disappeared during conveyance through canals, and water courses. So there is only 47% of conveyance efficiency in canal irrigation system. This disappearance in discharge having a volume of 55 MAF is estimated as a financial loss Rs.55 billion per year. The conveyance losses in channels are due to seepage, evaporation, spillage, vegetation, rodent holes and operational inefficiencies. These water losses must be minimized so that the efficiency of the system may increase and also to meet the future demands of irrigation water. A brief study has been carried out to provide an appropriate estimation of water losses in earthen canal which will be beneficial to take precautionary measures to minimize these water losses.

II. METHODOLOGY

Inflow outflow method is adapted to and the amount of water losses in total discharge from inlet to outlet and the factors responsible these water losses are considered as seepage losses, evaporation losses, leakage losses, over topping and canal erosion. Current meter is used for the determination of water losses in discharge. The inflow outflow technique offers direct measurement of water losses with disturbing the operation functions of the canal. This technique is based on determining the proportions of water owing in and out from a nominated section of canal. The alteration in discharge between inflow-outflow is recognized as water losses. The inflow outflow technique is a useful approach and it performs well under undulating situations of flow. Further, nonstop measurements can be executed without any inter looping in the system process. Correctness in the results depends on accurateness of inflow and outflow measurements. Inflow outflow technique gives the loss occurring throughout water passage in the open canals without hindering the regular irrigation process of the certain canal; at the similar time allow precise calculations. Table 1 describes different parameters of the canal involving it length, sloe and maximum design discharge.

Table. 1: Basic Parameters of Malik branch canal

` Number	Parameters	Description
1	Type	Unlined
2	Length	116900ft
3	Canal Bed Width	100ft
4	Full Supply Depth	6.80 ft
5	Slope	0.11%
6	Design Discharge (cusecs)	1866 Cusecs
7	Maximum Observed Discharge	1729 Cusecs
8	No of No Distributaries	5
9	No of Outlets	45

The canal selected for study is an unlined canal having no provisions (bricks, concrete work etc.) on it cross section. The Inflow-Out flow method overcome a widespread variety of losses and is assumed to be the most superior method for determining the losses in the Canals. Table 2 predicts the assessment of diverse factors disturbing losses in several approaches. It reveals that inflow-outflow technique is the solitary method that computes for all the factors involved in water losses. Others methods mainly discourse just seepage, excluding ponding method which also considers evaporation losses.

Table. 2: Comparison of Losses in various methods

Factor Affecting Losses	Tracer Method	Ponding Method	Inflow- Out Flow Method	Empirical Method
Seepage	Yes	Yes	Yes	Yes
Evaporation		Yes	Yes	
Spillage			Yes	
Rodent Holes			Yes	
Breaches/Cuts			Yes	
Dead storage			Yes	
Infiltration			Yes	
Operational			Yes	

Discharges at the start and end of section of the canal were determined agreeing to the velocity-area flow measurement method. The cross-section of the canal at the data collecting points was first distributed into sub-sections, and velocities were checked for both sub-sections according to the two-point method. Discharge velocity at the data collecting points was measured in relative to the revolutions of an Ott-type current meter completing duration of 60 seconds. Discharge velocity was measured by using the succeeding equation:

$$V = 0.2451\ n + 0.014 \qquad (3.1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (1)}$$

Where:

0.2541= the coefficient of the propeller type
0.014 = the coefficient of the friction of the propeller, found by calibration n = is the number of revolutions per second of the propeller
V = the flow velocity of the water (m/s)

While following the two-point method, the discharge velocity was calculated at two upright points, 0.2 (20%) and 0.8 (80%) depths, correspondingly, from the topmost of the water superficial. The discharges at these two heights were then averaged to obtain a single value. Velocity should usually be higher at the 0.2 depth, but should not be greater than double of the velocity of the 0.8 depths. In case the velocity at the 0.2 depths was not greater than the 0.8 depths or if it was two times as higher as at 0.8 depths, then a supplementary reading was engaged at the 0.6 depths. This 0.6 depth was average of the 0.8 and 0.2 means. Evaporation loss (E) was measured through evaporation pan. Moreover, the precipitation was not consider due to limitations that no flow was considered into the segment from outside (I), or distracted from the segment (D), both values were assumed zero. Evaporation pans are installed, a cylinder with a diameter of 47.5 in (120.7 cm) that has a depth of 10 in (25 cm). Following mathematical relations are used to measure total water losses, evaporation losses, seepage losses, water losses rate respectively. Determination of total water losses

$$\textit{Total water losses} = Qt - Qo - D + I \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. \quad (2)$$

Where:
Qt = Total discharge of water at inlet of section
Qo = Discharge at outlet of section
D = Flow diverted along the reach
I = Inflow along the reach

$$\text{Evaporation losses (in cusecs)} = \frac{\text{Drop in evaporation pan in inches} \times \text{surface area in ft}}{\text{Average day light hours} \times 12 \times 3600}$$

$$\text{Seepage losses(in cusecs)} = \text{Total water losses} - \text{Evaporation losses} \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq. (4)}$$

$$\text{Water losses rate losses in cusecs/ ft}^3 = \frac{\text{Total Water losses} \times 1000}{\text{Total Length of the canal section}} \quad \ldots \text{Eq. (3)}$$

Evaporation is measured on daily basis as the depth of water (in inches) evaporates from the pan at the site to measure the evaporation losses and also rainwater and precipitation are not considered during the data collection. The time duration for determination of evaporation is only considered average day light hours. In selecting the canal to be examined and the engaging of the segments, the sub- sequent conditions were taken into account, the discharge should be the normal working situation of the canal, there should be no fluctuation in water height during measurement, there should be no disturbance of the cross-sectional geometry of the segment where the measurement was taken and there should be nothing to avoid the flows. … Eq. (5)

III. RESULTS

The loss rate was measured through inflow outflow method for canal and given in the table 3. Average Evaporations losses are given table in the table 4 and the Water losses in Cusecs / ft × 10^3 are given in table 5. The losses are determined in cusecs & percentage losses with respect to total discharge are determined. The readings of discharge between 22-Oct-2018 to 02-Nov-2018 were not measured due short closure period of canal. Thirty nine readings for discharge are taken at each section with one day interval. Table gives the total average water losses in canal at four sections and also percentage losses with respect to head discharge of the canal. It shows the average water Losses 193.11 cusecs from head to tail of the channel. Also average water Losses percentage with respect to Head Discharge is 13.29%.

Table 3: Average losses in the canal

Sr. No.	Month	Avg. Head Discharge	Avg. Water losses in each section				Avg. Water Losses	Avg. Tail Discharge	Avg. Percentage (%) Water Loses
			RD 0+000 to 23+400	RD 23+400 to 38+900	RD 38+900 To 95+900	RD 95+900 to 116+900			
1	September	1552.625	44.000	33.000	96.375	35.875	209.250	1343.375	13.48%
2	October	1490.714	40.286	31.429	91.000	34.571	197.286	1293.429	13.23%
3	November	1573.000	43.286	37.857	77.214	36.000	194.357	1378.643	12.36%
4	December	1218.429	34.000	32.429	72.143	33.000	171.571	1046.857	14.08%
Average Result		1458.692	40.393	33.679	84.183	34.862	193.116	1265.576	13.29%

Graphs describes the average discharges at head and tail

Table. 4: Evaporation Losses in cusecs

	Evaporation Losses (Inch/ Hour)	Evaporation Losses in Cusecs				Total Evaporation losses	Evaporation Losses % w.r.t Total Losses
		RD 0+000 To 23+400	RD 23+400 to 38+900	RD 38+900 To 95+900	RD 95+900 to 116+900		
Minimum	0.0060	0.305	0.196	0.622	0.222	1.344	0.69
Maximum	0.0169	0.917	0.589	1.870	0.667	4.044	1.88
Average	0.0102	0.55	0.35	1.12	0.40	2.43	1.22

Fig. 1

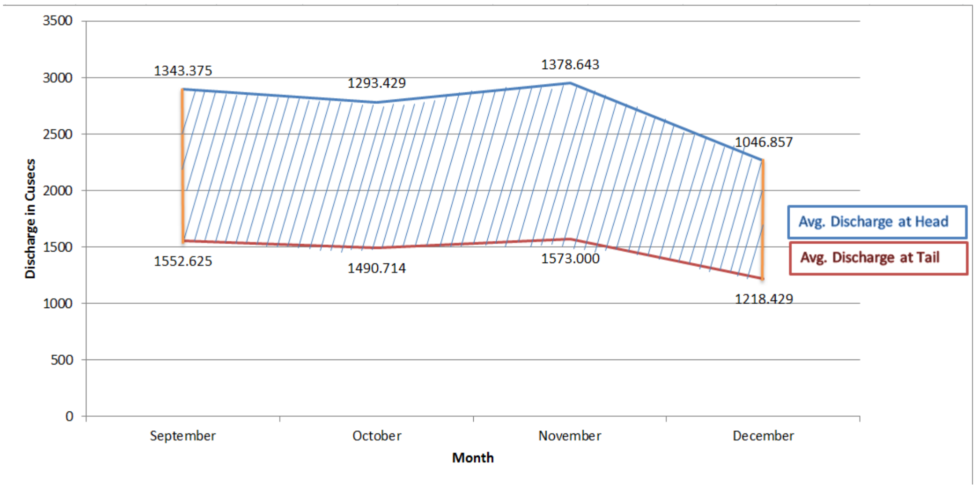

Table 5: Water losses in Cusecs / ft × 10^3

	Water losses rate in cusecs/ft x103 (% Difference According to Average losses)				Total losses from head to tail	Average
	RD 0+000 to 23+400	RD 23+400 to 38+900	RD 38+900 to 95+900	RD 95+900 to 116+900		
Minimum	1.28 (-13.5)	1.48 (1.5)	1.16 (-35.3)	1.29 (-25.1)	1.42 (-5.4)	1.46
Maximum	2.01 (12.8)	2.45 (29.5)	1.96 (7.2)	2.00 (13.1)	1.90 (-3.1)	1.99
Average	1.74 (-0.4)	2.07 (18.9)	1.57 (-9.6)	1.58 (-8.9)	1.67 (-3.9)	1.74

IV. CONCLUSSIONS

The case study, conducted for an earthen canal in district Bahawalnager aims at finding the water losses in unlined canal. Inflow outflow method is applied to determine water losses by splitting the canal in four sections. The difference in inflow and outflow discharge gives the amount of water lost during conveyance process and also indicates the efficiency of the channel. The results of the study highlight the need of safety precautions to avoid water losses and to meet water needs in irrigation sector.

The usual values of water conveyance loss in the study area canal were higher than the provision of extra discharge in design. The surplus in conveyance loss demonstrate that there is no proper restoration work, was accompanied on conveyance canal during land consolidation, maintenance and repair work done are not done by the Punjab Irrigation which is the major reason for this increased water loss situation. Furthermore this study may help the Punjab Irrigation Department to nominate the critical sections of the canal and to carry rehabilitation work on priority bases. Seepage and evaporation losses occurring in canal cause deficiency in water supply to fields especially at the tail of the canal and causes huge financial problems. In order to avoid such difficulties, certain actions should be taken. The results predict an overall 13.29% water losses with respect to the total discharge of the canal which has an average amount of 193.11 cusecs. Average evaporation Losses percentage with respect to total losses is 1.22%.

V. RECOMMENDATIONS

Losses can be mitigated by proper renovation work of the canal and there should be no obstruction in the canal or algae which may decrease the velocity of flow, so that seepage and water losses can be decreased at maximum possible level. The application of suitable technical measures is crucial to decrease water conveyance loss in the network. For this reason, the following actions may be recommended as a start:

- Install lining at sections where seepage losses are prominent.
- Grow proper plants on both sides of canal which may shelter the canal against evaporation losses as the temperature of the region is high for a long portion of year.
- Some more accurate future technique should be adopted to determine more appropriate results for water losses.

REFERENCES

[1] Qureshi, Asad Sarwar. (2011). Water Management in the Indus Basin in Pakistan: Challenges and Opportunities. Mountain Research and Development 31 (3), 25260.

[2] Sufi, A.B., Hussain, Z., Sultan, J.S., & Tariq, I. (2011). Integrated water resource development in Pakistan. WRM Publications, WAPDA, Lahore.

[3] DROUGHT ALERT, (2018) National Drought Monitoring Centre Pakistan Meteorological Department

[4] Roshni Patel & Sanhal Patel, (2016). Water Losses in Canal Networking (Nar- mada Canal Section Near Gandhinagar-Ahmedabad. International Journal of Sci- ence Technology & Engineering, 2349-784X.

[5] Ashfaque A. Memon et al. (2013). Design and Evaluation of Dadu Canal Lining for Sustainable Water Saving Journal of Water Resource and Protection, 5,689-698.

[6] Alam, M. M. and Bhutta, M. N. (2004). Comparative evaluation of canal seepage investigation techniques. Agricultural Water Management, 66(1), 65-76.

[7] Kahlown, M. A. & Kemper, W. D. (2004). Reducing water losses from channels using linings: Cost and benefits in Pakistan. Agricultural Water Management, 74, 57-76.

[8] Ahuchaogu, et al. (2015). Evaluation of Seepage Losses in Earthen Lined Canal. International Journal of Engineering Sciences & Management Research, ISSN: 2349-6193.

[9] Sayed A., and Hossain M. A. (2014). Impact of Lined Canal on Shallow Tube- well Irrigation and Their Acceptability by the Farmers. A Scientific Journal of Krishi Foundation. The Agriculturists 12(2): 116-125(2014)

[10] Saha, B. (2015). A critical study of water loss in canals and its reduction measure. International Journal of engineering research and application, 5(3), 53- 56.

[11] Jadhav P. B., et al. (2014). Conveyance Efficiency Improvement through Canal Lining and Yield Increment By Adopting Drip Irrigation in Command Area. International Journal of Innovative Research in Science, Engineering and Technology. 2319 8753.

[12] Irrigation Research Institute, (1992). Studies on water losses from water- courses and their lining measures. Lahore, Pakistan.

[13] Brockway and Worstell, (1968). Field Evaluation of Seepage Measurement Methods. In Proceedings of the Second Seepage Symposium 121-127. Phoenix, Arizona: USDA, Agricultural Research Services.

[14] Awan, M. et al. (1978). Watercourse cleaning and maintenance program Annual report, CSU, 394-426.

[15] Planning & Development, (1988). Report on water losses. Technical commit- tee, Lahore, Pakistan.

[16] Kraatz, D. B. (1977). Irrigation Canal Lining. Rome New York: Food and Agriculture Organization of the United Nations.

[17] Dhillon, G. S. (1967). Estimation of Seepage Losses from Lined Channels. Indian Journal of Power and River Valley Development, 17, 16-20.

[18] Akkuzu, E. (2012). Usefulness of Empirical Equations in Assessing Canal Losses through Seepage in Concrete-Lined Canal. Journal of Irrigation and Drainage, 138, 455-460.

[19] Arshad, et al. (2009). Comparison of Water Losses between Unlined and Lined Watercourses in Indus Basin of Pakistan. Pakistan Journal Agricultural Science, 46(2), 280-284.