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## Influence of Discharge and Channel Geometry on Seepage Losses from Secondary Canal

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**Abstract**

Seepage is the most serious forms of water loss in an irrigation canal network. Seepage loss mostly depend on the channel geometry. Excessive seepage losses can cause water logging and soil salinity due to which the cultivable are reduced, and results in a loss of potential crop production. In this paper, seepage loss from a (Sarki Minor) that off takes from Shahu branch of Jamarao canal was determined. Relevant hydraulic data was recorded at strategic locations and seepage losses were measured by inflow- outflow method respectively. Linear regression was employed to develop empirical relations for computing seepage losses with respect to channel geometry. AA-Type and pygmy current meters was used to measure the discharge at the different section. The recorded data of hydraulic characteristics was correlated using linear regression analysis to develop an empirical equation for seepage losses with channel geometry parameters. The results revealed that the maximum seepage losses were at 0-5RD (4%) followed by 5-10RD (3.4%), 10-15RD (3.4%) 15-20RD (3.5%), and then 20-25RD (2.9%) and over all seepage losses was 17% in the minor. Statistical analysis (LRA) shows significantly positive relationship at (P<0.05) for seepage losses and discharge ( $r^2=0.962$ ), wetted perimeters ( $r^2=0.943$ ), flow area ( $r^2=0.914$ ) and top width ( $r^2=0.967$ ). These equations could be used to estimate canal seepage losses without going through the conventional method.

**Keywords:** Channel Geometry, Seepage Losses, Sarki Minor, Discharge, Inflow-Outflow Method, Sindh, Pakistan.

## INTRODUCTION

Seepage from irrigation canals has a major impact on surface and groundwater resources management (Yussuff *et al.*, 2018). Seepage from earthen channels arises due to a mutual effect of gravitational force and water tension gradients (Hansen *et al.*, 2008). The depth of water in the earthen channel is the most important factor affecting seepage. As the groundwater level is more than the design water surface of the earthen channel, water seeps into the channel accordingly. Likewise, as the groundwater level is lower than the water surface of the earthen channel, the water in the channel will continue to seep out of the channel until the groundwater level reaches equilibrium with the channel. It has been observed that 0.33% to 0.5% of all water diverted into the canals for irrigation is lost due to seepage which directly causes the water table to rise (Napan *et al.*, 2009). Continuous increase in water table elevation usually increases water evaporation from the ground surface which tends to bring saline or alkali salts to the ground surface which may then damage crops and soils.

Nowadays, different methods are used to compute the seepage flow through an earthen channel i.e. experimental

formula's, explanatory or simple studies, finite element method, finite difference method, and the immediate seepage estimation method etc (Carabineanu, 2011). Earthen channels are lined for reducing the seepage loss problems as lining may avoid all the seepage loss. However, canal lining may weaken after some time of its construction due to cracks development mainly occurs due to the construction defects and use of low quality lining materials, weathering, etc. Therefore, continuous renovation is required in this regard. In this study, the influence of flow and channel geometry on water losses from an earthen channel was computed and an empirical relationship was developed for different scenarios.

## MATERIALS AND METHODS

### Location

The present research work was conducted during 2015 at Sarki minor (Shahu branch of Jamrao canal) at RD 40+000 L/S located in Jhol sub division of Nara Canal Area Water Board. The minor is 7.62 km long with flow rate of 20.50 CUSEC (Figure 1).



Fig. 1. Site Map of Sarki Minor.

### Field Experiment

In order to compute the seepage loss for the Sarki minor, initially the starting and end point was selected at the head and tail of the minor respectively. The computation of seepage loss was estimated through a standard inflow-outflow method by using current meter at various sectors. This method is being widely adopted by the researchers for the seepage estimation in Pakistan for various research works. Discharge of the minor and off-taking was measured by using AA –type current meter and pygmy-

type current meter respectively. The measurement of (velocity and mean velocity) for each vertical cross-section was obtained at two different points i.e (0.2d and 0.8d) respectively. The discharge at the outlets was also measured respectively. At the starting and ending point the (Inflow) and (Outflow) discharge was measured. Inflow is the discharge at starting point of selected section of distributary and outflow is the sum of discharges at end point of reach on distributary and discharges of outlets off taking from the selected reach. Computation of different channel geometry parameters i.e. (Bed Width, Area of

Flow, Wetted Parameter, and Hydraulic Radius) was calculated with the help of different empirical formulas respectively. Seepage loss was calculated by using following relation;

- Water losses in 1<sup>st</sup> portion was =  $Q_1 - Q_2$
- Water losses in 2<sup>nd</sup> portion was =  $Q_2 - Q_3$
- Water losses in 3<sup>rd</sup> portion was =  $Q_3 - Q_4$
- Water losses in 4<sup>th</sup> portion was =  $Q_4 - Q_5$
- Water losses in 5<sup>th</sup> portion was =  $Q_5 - Q_6$

$Q_1$  = Discharge measured at section 1 (cusec)

- $Q_2$  = Discharge measured at section 2 (cusec)
- $Q_3$  = Discharge measured at section 3(cusec)
- $Q_4$  = Discharge measured at section 4(cusec)
- $Q_5$  = Discharge measured at section 5 (cusec)
- $Q_6$  = Discharge measured at section 5 out flow (cusec)

**RESULTS AND DISCUSSION**

The observations recorded for the pertinent hydraulic data linear regression were used to developed relation as a function of discharge, wetted perimeters, flow area and top width. The results are presented in Table 1.

**Table 1. Seepage losses and Hydraulic parameters**

RD	Inflow flow	Out flow	Outlet flow	Total out flow	Seepage	Selected reach Length	Avg: wetted perimeter	Avg: flow area	Avg: depth	Avg: top width	Seepage
	ft <sup>3</sup> /sec	ft <sup>3</sup> /sec	ft <sup>3</sup> /sec	ft <sup>3</sup> /sec	ft <sup>3</sup> /sec	ft	ft	ft <sup>2</sup>	ft	ft	%
0-5	25.6	23.2	1.8	24.6	1	5000	18	36	3	12	3.9
5-10	23.2	20.5	2.2	22.4	0.8	5000	16.74	31.57	2.87	11	3.4
10-15	20.5	18.65	1.4	19.8	0.7	5000	15.56	27.8	2.78	10	3.4
15-20	18.65	17	1.32	18	0.65	5000	15	26.125	2.75	9.5	3.5
20-25	17	15.5	1.25	16.5	0.5	5000	12.46	15.57	1.73	9	2.9
Cumulative Seepage Loss											17 %

**Empirical Relationship for Seepage Loss with Discharge**

To develop relationship between seepage losses and discharge, the data was plotted on a graph paper. The values of fitted parameters namely intercept (a) and slop (b) were obtained as (-0.376) and (0.052) respectively, to determine fitted parameter of linear model as shown in figure 2. Thus, the developed relationship is expressed.

$$S = 0.0527Q - 0.3768 \quad \text{----- (1)}$$

The value of coefficient of determination is (0.962) which indicate strong association between the variables. The developed equation is varied for measuring losses of secondary channels having flow rate ranging between 17 and 25 cusec. These results are according to the findings of (Chahar, 2006) who observed a linear combination of channel geometry and seepage function in contrast with silt and cross-section.

- Where
- S = seepage Loss (ft<sup>3</sup>/sec)
- Q= Discharge (Cusec)

**Empirical Relationship for Seepage Loss with Wetted Perimeters**

To develop relationship between seepage losses and wetted perimeters, the data was plotted on a graph paper. To determine fitted parameter of linear model as shown in figure 3, the values of fitted parameters namely intercept (a) and slop (b) wereobtained as (-0.620) and (0.086) respectively. Thus, the developed relationship is expressed.

$$S = 0.0868p - 0.6201 \quad \text{----- (2)}$$

The value of coefficient of determination is (0.943) which indicate strong relation between the variables. The developed equation is varied for measuring losses of secondary channels having wetted perimeters ranging between 12 and 18 ft. Similar results was observed by (Akbar, 2005) who developed ananalytical canal seepage equations with coefficients of determination ranging between (0.40 and 0.93) for wetted perimeter to the seepage loss along irrigation canals respectively.

- Where
- S = is seepage Loss (ft<sup>3</sup>/sec)
- P= is wetted perimeter (ft)

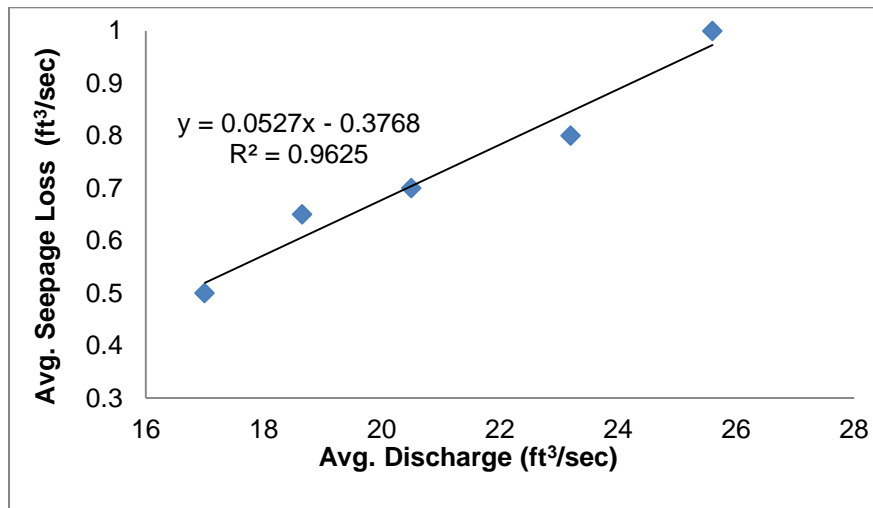


Fig. 2. Linear Regression Analysis of Seepage Loss with Discharge

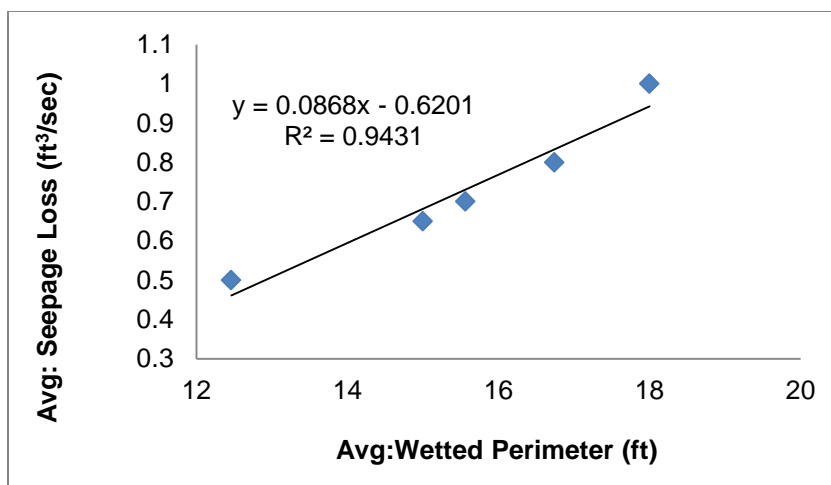


Fig. 3. Linear Regression Analysis of Seepage Loss with Wetted Perimeters

**Empirical Relationship for Seepage Loss with flow area**

In order to develop relationship between seepage losses & flow area, the data was plotted on a graph paper. To determine fitted parameter of linear model as shown in figure 4, the values of fitted parameters namely intercept (a) and slop (b) wereobtained as (+0.092) and (0.023) respectively. Thus, the developed relationship is expressed.

$$S = 0.0233A + 0.092 \quad \text{----- (3)}$$

The value of coefficient of determination is (0.914) which indicate strong relation between the variables. The developed equation is varied for measuring losses of secondary channels having wetted perimeters ranging between 15.57 and 36 ft<sup>2</sup>.

Where  
 S= is seepage Loss (ft<sup>3</sup>/sec)  
 A= is flow area (ft<sup>2</sup>)

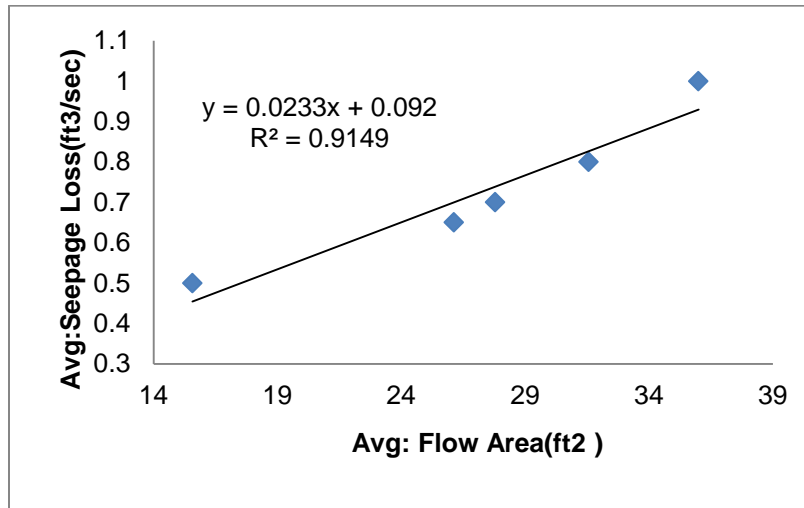


Fig. 4. Linear Regression Analysis of Seepage Loss with Flow Area

**Empirical Relationship for Seepage Loss with top width**

To develop relationship between seepage losses and top width, the data was plotted on a graph paper. To determine fitted parameter of linear model as shown in figure 5, the values of fitted parameters namely intercept (a) and slop (b) wereobtained as (-0.0832) and (0.15) respectively. Thus, the developed relationship is expressed.

$$S = 0.1517T - 0.8328 \quad \text{----- (4)}$$

The value of coefficient of determination is (0.967) which indicate strong relation between the variables. The developed equation is varied for measuring losses of secondary channels having wetted perimeters ranging between 12 and 6 ft. Approximately same results were obtained during a research study conducted in a Utah irrigation district having flux rate of 1.95% per kilometer (Akkuzu *et al.*, 2007).

Where  
 S= is seepage Loss (ft<sup>3</sup>/sec)  
 T= is top width (ft)

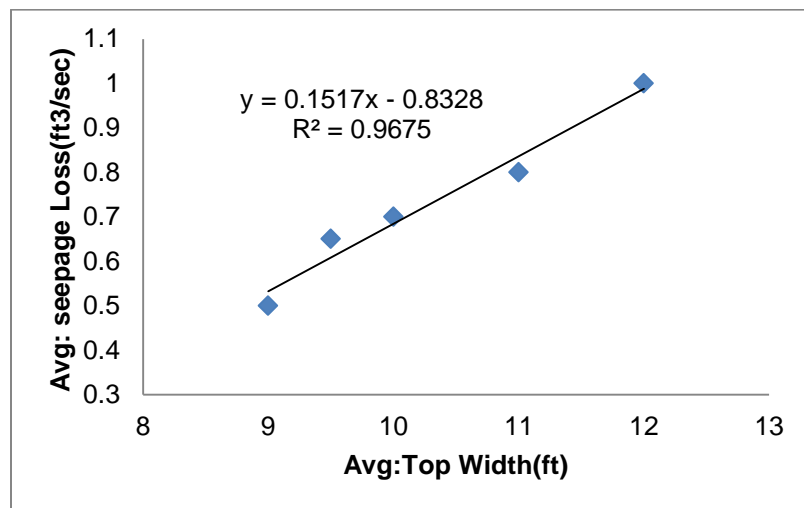


Fig. 5. Linear Regression Analysis of Seepage Loss with Top Width

## CONCLUSION

The Linear Regression for the selected secondary earthen canal have been developed viz. Seepage loss with discharge, seepage loss with wetted perimeter, seepage loss with flow area and seepage loss with top width and the results indicates that the maximum seepage losses were at 0-5 RD (4%) followed by 5-10RD (3.4%), 10-15RD (3.4%) 15-20RD (3.5%), and then 20-25RD (2.9%) and over all seepage losses was 17% in the minor. Further, statistical analysis indicates that there was significant positive relationship between seepage losses and discharge ( $r^2=0.962$ ), wetted perimeters ( $r^2=0.943$ ), flow area ( $r^2=0.914$ ) and top width ( $r^2=0.967$ ). These equations give a window of opportunity to the water resource engineers and hydrogeologists to predict seepage losses occurs in an earthen channel. Hence, it can be concluded that the lining and maintenance of earthen channels may overcome the seepage losses and may also control water-logging and salinization of the area up to some extent.

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## CONFLICT OF INTEREST

All the authors have declared that no conflict of interest exists.

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