COMPARISON OF WATER LOSSES BETWEEN UNLINED AND LINED WATERCOURSES IN INDUS BASIN OF PAKISTAN

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The issue of water losses through irrigation systems has a major impact on surface water supplies and management. Although a number of national and international organizations have attempted to assess the degree of losses from the watercourses, the impact of lining on the same command on the water losses had not been addressed. A study was carried out to assess the differences in water losses through the lined and unlined watercourses in the particular area of Indus Basin of Pakistan. The selected watercourses were located on the same distributary; therefore, it was considered that all of these watercourses would be subjected to same hydro-geologic characteristics of soil. It was observed that for the lined watercourses, the irrigation water losses ranged from 35 to 52 percent and for the unlined these were from 64 to 68 percent. Comparing the average water loss of 43.5 % from lined to the average water loss of 66 % from unlined watercourses, it was concluded that the lining reduced water loss by 22.5 %. It is emphasized that the studied watercourses were quite old with poor maintenance conditions. Lining was deteriorated badly with frequent cracks in the walls. The excess leakage of water through these watercourses was probably due to cracks, eroded mortar and structural failure of the lined walls. Moreover, the lined watercourses were raised, which accelerated the leakage phenomena. In addition, the capacity of watercourse was reduced due to silting, resulting in overtopping of flows at many locations. Consequently, the lined watercourse could not effectively save the water losses and resulted in higher water loss than the normal.

Keywords: Groundwater, watercourse, irrigated fields, recharge, watertable

INTRODUCTION

The canal irrigation system in the Indus Basin of Pakistan is facing a number of operational problems resulting in high degree of losses of water during conveyance of irrigation water to agricultural lands. These water losses result in constrained water supplies of canal water in the Indus Basin. Water losses from these canals have major impacts on surface water supplies and needs management, and must be minimized, if not altogether eliminated. This is perhaps the most cost-effective method of augmenting water supplies (IDWR, 2005).

The main causes responsible for water losses in watercourses are leakages from turnouts, curves in the watercourse, high density of vegetation in the unlined canals, problem of siltation, deposition of sediments, weak and un-compacted banks, lack of maintenance and holes made by rodents (Zeb *et al.*, 2000). According to a survey, measured water losses in the watercourse conveyance system in Bhakkar, Bahawalpur (Punjab) and Moro (Sindh) were up to 40-51% (WAPDA and CSU, 1978). Thomas (1980) adopted inflow-outflow method to estimate the water losses and data were used to determine total

operational conveyance losses by calculating the volume of water entering the irrigation fields during a complete rotation. It was reported that total operational losses were 45 % of the inflow. WAPDA (1984) carried out a study on pre-improvement evaluation of 45 watercourses located at different locations of NWFP (North-Western Frontier Province), Sindh and Punjab provinces. The procedure adopted was, inflow-outflow method with the use of cutthroat flumes, which resulted 45% watercourse delivery losses. In another study, the delivery losses ranged from 38 to 62 % in the watercourses of Khushab district (Copland, 1987).

In order to overcome water losses occurring in conveyance of irrigation system, a series of On Farm Water Management (OFWM) projects including the Command Water Management Project (CWMP) were launched in the country, in addition to on going research projects. The watercourse improvement/ lining activities of these projects attempted to save irrigation water losses thereby increasing the supply of good quality water for irrigation crops. The research on mechanized construction, lining and maintenance of the earthen watercourses was started at Mona Reclamation Project to review and evaluate its feasibility under current condition of Pakistan. The

farmer's response was also studied and the conventional mechanized ditching equipment and procedures were adopted (Mohy-ud-Din and Mohammad, 1993).

Irrigation Research Institute (1992) tested various lining materials to reduce seepage losses from the watercourses. The study was conducted on 16 watercourses, which revealed that water seepage losses from lined watercourses ranged from 8 to 19.8% of inflow. PERI (1993) estimated that conveyance losses rates on per thousand meters on the improved (earthen) and unimproved watercourse were 32% and 39%, respectively, which showed a significant difference. Lining of irrigation channels is widely practiced in the world for controlling seepage losses and enhancing delivery efficiency. Lining is an ongoing activity in many irrigated areas that is driven by a range of factors including: contingent liability for flooding or waterlogging of land adjacent to channels, accessions to shallow watertables and salt mobilization, and water savings (Marsden Jacob Associates, 2003). IWASRI (2004) reported the studies carried out by Watercourse Monitoring and Evaluation Directorate of WAPDA. According to that water losses measurements were made on 26 watercourses of which 10 were lined (brick lining) and 16 were unlined. On the lined watercourses a net increase of 12-14% in the conveyance efficiency was found from head to tail reach. Lining of water canals is also expected to increase productivity by efficient utilization of resources, improved irrigation facilities, strengthened farmer's participation in the management of water, and generally promoted condition for progress of the rural areas (Zafar, 2004).

MATERIALS AND METHODS

Experimental site

The experiment was conducted in the Rechna Doab ($71^o – 48^/$ to 75° -$20^/$ E and $30^o – 31^/$ to $32^o – 51^/$ N), the area between the River Ravi and River Chenab of the Indus Basin of Punjab, Pakistan. The climate has two distinct seasons; summers (Kharif)islong, hot and dry, lasting from April through September with average maximum daily temperatures up to $49^°C$ and winter (Rabi) extends from October through March. January and December are the coldest months with minimum temperatures frequently < 0^oC. Annual rainfall is approximately 490 mm with 70% of the rainfall occurring during monsoons between June and September. The area falls in the rice-wheat and sugarcane-wheat agro-ecological zones. Rice, sugarcane, and forage are dominant crops in the summer (Kharif) season and wheat, sugarcane and forage are the major crops in the winter (Rabi) season.

The experimental site is located in the command area of Ghourdour distributary of Upper Chenab canal irrigation system. The Ghoudour distributary takes its water from Upper Gogera branch canal approximately 31 km downstream of Sagar Head. The capacity of Ghoudour distributary is $1.36m^3 s^{-1}$. Its head regulator is controlled by stop logs and the canal is 20.7 km long serving 43 watercourses with a total command area of 8251 ha.

The four watercourses with the given design specifications located at Ghourdour distributary were selected for water loss measurement (Table 1).

Table 1. Design specifications of selected watercourses

Watercourse No.	Designed discharge ($L s^{-1}$)	Total length (m)	Average water depth (m)	Bottom width (m)
26680/R (unlined)	37	2439	0.305	0.406
28000/R (unlined)	17	1909	0.152	0.611
25373/R (lined)	41	5727	0.279	0.508
28915/L (lined)	7	1273	0.191	0.711

Although a number of national and international organizations have attempted to assess the degree of losses from the watercourses, the impact of lining on the same command on the water losses had not been addressed. Thus, there was a need to investigate the water losses through the unlined and lined watercourses at the same command under the given scenario of crop, land and water resources. This research paper presents the results of water losses through the unlined and lined watercourses in the same command area.

Measurement of water losses

The losses were calculated by taking the difference in the measured flow rates and corrected for any off takes or inflows (Planning and Development Department of Punjab, 1988). The inflow-outflow method was considered to be practical and reasonably accurate technique under dynamic flow conditions suited to actual field conditions of the reported study. Moreover, this method permitted continuous measurements and did not interfere with the regular operation of the system. Additionally, under operating conditions, there

may be other sources of loss such as over spilling, breaches, mole holes etc. from the watercourses due to the following factors:

- Irregular profile and zigzag alignment of banks, with many points of weakness
- Variable cross section of water channels
- Silt deposition, causing restriction in flows and overtopping
- Trees, shrubs and vegetation growing in the watercourses
- Damage caused by rodents and farm animals

Factors affecting the losses of water from the watercourses were numerous and had been thoroughly discussed by Thomas (1980). Thus, the water losses by any other methods do not represent the total losses occurring in the watercourse under flowing conditions.

The most common used device for flow measurement is cutthroat flume, since it can be easily installed in the watercourse and accurately calibrated under submerged conditions. The cutthroat flumes can be used to measure a fairly wide range of flows, and if calibrated for submerged flow, could accurately measure the discharge at low head loss. The flume is generally suited to flow measurement under free as well as submerged conditions (Skogerboe *et al.*, 1973). Losses of water in the field were measured by using 0.20 m X 0.91 m cutthroat flume. At each of the watercourses, a section of 244 m to 305 m length was chosen to measure the water losses. Three replications of water flow measurements through flumes at inflow and outflow sections were taken.

RESULTS AND DISCUSSIONS

The discharge measurements at the four watercourses were carried out in the field. These measurements include the inflow rate, outflow rate and the section length used in the experiment (Table 2).

The average water loss at unlined watercourse No. 26680/R was assessed as 1.39 L s^{-1} per 100 meter length of watercourse (4.37% of flow per 100 m length) or 10.95 m^3 s^{-1} per million.m^2 of wetted perimeter (Table 3). The total water losses for the total length of watercourse were found as 21.77 L s^{-1}, which were 68 % of the flow through the watercourse. The average loss of the water at the other unlined watercourse No. 28000/R was 0.93 Ls^{-1} per 100m length of watercourse (4.94% of flow per 100m length) or 8.93 m^3 s^{-1} per million.m^2 of wetted perimeter (Table 3). The total losses of water over the total length of the watercourse were 12.15 L s^{-1} (64% of the flow). It was found that the average water loss through lined watercourse No. 25373/R were assessed as 1.11 L s^{-1} per 100 meter length of watercourse (3.05% of flow per 100m length) or 10.41 m^3 s^{-1} per million.m^2 of wetted perimeter. Based on these results, the total water losses for the

total lined section of the watercourse were assessed as 18.42 Ls^{-1}, which was 52% of the flow of the watercourse. Similarly, the average loss of the water at lined watercourse No. 28915/L was 0.28 Ls^{-1} per 100 meter length of the watercourse (3.28% of flow per 100 m of watercourse length) or 2.56 m^3 s^{-1} per million.m^2 of wetted perimeter. Based on these measurements, the total water losses over the total length of the watercourse were estimated as 2.98 Ls^{-1}, which was 35% of the flow of watercourse (Table 3).

Comparison of water losses between unlined and lined watercourses

The comparison of water losses between the unlined and lined watercourses indicates that for the tested unlined watercourses, water losses ranged from 64 to 68% (Table 4).

This is quite comparable to 61% loss as reported by PERI (1993). On the other hand, the lined watercourses showed water losses ranging from 35 to 52%. Comparing the average water loss of 66% from unlined to the average water loss of 43.5% from lined watercourses, it can be assessed that the lining reduced water loss by 22.5% (Table 4). However, it may be mentioned that studied watercourses were quite old with deteriorated condition resulting in water loss higher than the normal.

All the selected watercourses were located in the same type of soil. Therefore, it was considered that all of these watercourses would be subjected to same hydraulic characteristics of soil. Watercourse 25373/R was lined about 10 years before. The maintenance conditions during the flow measurement were found to be very poor. Lining was deteriorated badly with frequent cracks in walls. The excess leakage of water through this watercourse was probably due to cracks, eroded mortar and structural failure of the lined walls. Moreover, it was a raised watercourse, which accelerated the leakage phenomena. In addition, the capacity of watercourse was reduced due to silting, resulting in overtopping of flows at many locations. Consequently, this lined watercourse could not effectively save the water losses.

Goldsmith and Makin (1989) observed water losses from watercourses with lining older than four years were comparable to the water losses obtained from unlined watercourses. The best older watercourses were comparable to recently lined watercourses, but those in the poorest condition had loss rates higher than those measured in unlined watercourses. The second lined watercourse 28915/L was in good shape, although the lining was carried out about 25 years before. There were few cracks in the brick lining primarily caused by the roots of the trees. No specific breaches or overtopping was observed. The design depth was sufficient to carry the design discharge of 7.1 Ls^{-1}.

Table 2. Discharge measurements in the watercourses

Watercourse No.	Test	Inflow rate (L s^{-1})	Outflow rate (L s^{-1})	Section length (m)
26680/R	1	28.34	24.09	305
	2	34.01	29.76	305
	3	34.01	29.76	305
	Average	32.02	27.77	305
28000/R	1	17.00	14.17	244
	2	19.84	17.00	244
	3	19.84	17.00	244
	Average	18.99	16.15	244
25373/R	1	36.84	32.59	305
	2	34.01	31.17	305
	3	35.43	32.59	305
	Average	35.43	32.02	305
28915/L	1	8.50	7.65	274
	2	8.50	7.65	274
	3	8.50	7.65	274
	Average	8.50	7.65	274

Table 3. Water losses in the watercourses

Watercourse No.	Test	Loss (L s^{-1} Per 100m)	Percentage loss (flow per 100m length)	Loss (m^3 s^{-1} per million m^2)	Total loss (L s^{-1})
26680/R (unlined)	1	1.39	4.91	10.95	19.27
	2	1.39	4.10	10.95	23.13
	3	1.39	4.10	10.95	23.13
	Average	1.39	4.37	10.95	21.77
28000/R (unlined)	1	0.93	5.47	8.93	10.88
	2	0.93	4.69	8.93	12.70
	3	0.93	4.69	8.93	12.70
	Average	0.93	4.94	8.93	12.15
25373/R (lined)	1	1.39	3.78	13.04	19.16
	2	0.93	2.73	8.72	17.69
	3	0.93	2.62	8.72	18.42
	Average	1.11	3.05	10.41	18.42
28915/L (lined)	1	0.28	3.28	2.56	2.98
	2	0.28	3.28	2.56	2.98
	3	0.28	3.28	2.56	2.98
	Average	0.28	3.28	2.56	2.98

Table 4. Comparison of water losses between unlined and lined watercourses

Watercourse No.	Average loss (%)		Average loss difference (%)
	Unlined	Lined	
26680/R	68	-	
28000/R	64	-	
25373/R	-	52	
28915/L	-	35	
Average	66	43.5	22.5

In general these data show that rates of loss, while influenced by soil texture, are even more strongly influenced by the presence of leaky banks. Thomas (1980) identified high seepage losses due to rat and insect holes in the banks at around full supply level as the major cause. The watercourse 25373/R was located parallel to a road and water losses appear to be relatively higher for this watercourse. This was perhaps also due to elevated position of watercourse with respect to the road and poor maintenance along

the road. Moreover, the designed discharge for this watercourse was greater than its capacity. Therefore, the water losses were higher due to spilling as well.

CONCLUSION

Comparing the average water loss of 66% from unlined to the average water loss of 43.5% from lined watercourses, it was estimated that the lining reduced water loss by 22.5%. The excess leakage of water through the watercourses is probably due to cracks, eroded mortar and structural failure of the lined walls. In addition, the capacity of watercourse is also reduced due to silting, resulting in overtopping of flows at many locations. Consequently, it is concluded that the lining of watercourse can not effectively save the water losses and ultimately results in higher water loss than the normal unless properly maintained.

ACKNOWLEGEMENTS

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