Comparison of Water Conveyance Losses in Unlined and Lined Watercourses in Developing Countries

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Abstract-Open conduits are the main systems for supplying irrigation water in developing countries. However, most of these schemes are frequently criticized for their low conveyance efficiencies. Under the water scarce situation, improving the conveyance efficiency offers an opportunity to realize basin level water savings. To define the significance of such opportunities, it is essential to identify the reason, location and conveyance losses in the tertiary canals that can be saved.The operationalcost of running canals have also been significantly reduced through savings in the conveyance infrastructures. The other benefits that may be attained are equitable water distribution and avoiding tail shortages.Lining of main watercourses attempts to save good quality canal water, which is used by all the share holders of the command.This paper mainly explains conveyance losses evaluation in the unlined and lined tertiary channels irrigation supply system situated in South Asia (Pakistan and India). The results indicate that in Pakistan almost 43.5% of the water losses occur in lined watercourses and 66% losses in unlined watercourses and in India 11% of water losses occur in lined watercourses and 20-25% in unlined watercourses. The conveyance losses in Turkey and Egypt have also been elaborated in the study for the purpose of comparison. The results indicate that the conveyance losses in tertiary irrigation system in Pakistan are high. Moreover, good quality lining and proper operation/maintenance are necessary for better effectiveness and sustainable water management.

Keywords-Cellular Manufacturing, Cross Over, Elitism, Genetic Algorithm, Mutation, Population, cell formation

I. INTRODUCTION

Open channels system is the main water supply intervention in the irrigation scheme in most regions around the world and it will remain as the central technique in the predictable future as well. However, a majority of these conveyance schemes are often criticized for their water conveyance losses. In irrigation network serviced by watercourses, conveyance losses are defined, the difference between water delivered to the irrigation system and water delivered to the nakkas. These conveyance losses fluctuate from year to year because of variations in operational methods, water accessibility, customer demands and climate.

Irrigation is one of the essential inputs required for sustainable irrigated agriculture in many countries. Watercourse distribution in developing countries is not equitable. Under the existing situation, the farmers of head reaches of irrigation channels (watercourses) receive more water than the tail reaches farmers. The conveyance losses had a remarkable effect on water distribution; as conveyance losses at the head sections were reduced, farmers were getting more discharge at their farm gates [1]. Thus there is a need to quantify this difference in terms of income to the farmers. Canal irrigation systems in numerous parts of the world are known to be performing well below their potential (ICID past president).

Major conveyance losses in watercourses are due to seepage. Efficient water saving can be achieved by keeping the conveyance losses to a minimum level. Large amount of water is lost during its route up to the farms level, especially the conveyance losses are pronounced at tertiary (watercourses) level of the irrigation system in Pakistan and India. The main reasons for conveyance losses in watercourses are leakages from turnouts, high density of vegetation in the unlined watercourses, turns in the watercourse, un-compacted and weak banks, deposition of sediments, siltation, holes made by rodents and lack of maintenance [2]. Reference [3] narrated that 40% of the total water supply is lost in the canals and watercourses before reaching the farm gate. Reference [4] reported that less irrigation supplies than its desired share is the main cause of the low productivity; out of

many reasons seepage and percolation from the canals and watercourses are the major one.

Lining of tertiary canals has been commonly practiced in the world for enhancing conveyance efficiency and saving water. Lining of tertiary canals is one of the main on-farm water management interventions. The lining results in curtailing the seepage from the tertiary canals. The seepage can be decreased to less than 25 percent of the total losses. Decreasing seepage losses results in saving of water and accordingly more water is available for irrigation at farm gate that can increase the cropped area and the crop yield. Lining is a long term effective technique for reducing seeping losses from the watercourse, but on account high cost; it is somehow provided only on 15-30% length at the head of several watercourses in Punjab province of Pakistan [5]. Lining has increased 25% conveyance efficiency and if we lined all other watercourses, it will not only enhance conveyance efficiency but will also help in equal water distribution among farmers and increase the command area of that watercourse [6]. Reference [7] compared the water conveyance losses between lined and unlined tertiary canals of Indus Basin of Pakistan. Four watercourses were selected for the study with two lined and two unlined watercourses. Conveyance losses were evaluated by inflow-outflow method using cut-throat flumes. The study concluded that lining decreases water conveyance losses by 22.5%. IWASRI [8] 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.

The another intervention of enhancing irrigation supplies through decreasing water “losses” from watercourses by choosing lining has been gradually adopted in India. Subsequently, tertiary canal conveyance losses in a complex distribution system in alluvial type soils are approximately one and a half times that of a main canal and three times that of a distributary canal. The lining of tertiary canals has been comprised by the engineering civic as a means of confirming water deliveries to the “unreached” in the tail end regions [9]. Methods have been developed for augmenting the length of a tertiary canal to be lined to curtail cost [10]. Channel lining is suggested in salty groundwater regions. Tertiary canal lining was known as an actual intervention to decrease seepage losses since more water losses occurred at this level of the water conveyance system [9]. Reference [11] stated that in the absence of proper lining, about 1035% of water is lost during conveyance from the source to the field due to seepage and evaporation losses.

The measured discharge values from watercourses of distributaries in Sirsa district in India revealed a significant seepage loss of about 33% for lined and 48% for unlined watercourses [12]. Reference [13] reported that at tertiary level, seepage losses are evaluated 11% and 2025% in the lined and unlined watercourse, respectively.

The objective of the present paper is to study the conveyance losses in lined and unlined watercourses of Pakistan and India. This paper also explores conveyance losses and the saving of water by lining and thus, enhancing conveyance efficiency.

II. Areas of Study

The tertiary canal irrigation system in the world is facing a number of operational problems resulting in more losses of water during conveyance and of irrigation water to agricultural lands. These water losses result in constrained water deliveries of canal water. 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 problem of conveyance losses through irrigation systems has a major impact on on-farm water management and surface water supplies. While a number of international and national organizations have endeavored to evaluate the losses from the tertiary canals, the effect of lining on the water losses have not been addressed widely. The main areas focus in the study for estimating conveyance losses in lined and unlined watercourses are Pakistan and India.

Pakistan

In Pakistan, the water losses in unlined and lined tertiary canals of Indus Basin have been reviewed. Indus Basin Irrigation System (IBIS) of Pakistanis the strong heart of the country's economy. Pakistan is mostlysemi-arid and arid with less water resources. The agriculture zone in Pakistan is the major consumer of water. Approximately 97 percent of all river water is being used for farming. Several researchers concluded that reducing loss of water from watercourses carrying water from distributary/minor to farmers' fields is one of Pakistan's highest potentials for enhancing supplies delivered to those fields. The irrigation system comprises of a network of main canals, branch canals, distributaries and watercourses. Conveyance losses in the distributaries and watercourses are abouttwenty five and thirty percent respectively. Because of lack of adequate drainage infrastructure and constant percolation and seepage from distributaries and field channels, water-logging and soil salinity inflict severe threats to the irrigated regions.

Lining is a current activity in many irrigated regions of Pakistan that is focused by a number of factors including: contingent liability for water-logging of land adjacent to channels or flooding, accessions to salt mobilization and shallow water tables and water savings. Lining of watercourses 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.

The comparison of water losses between lined and unlined tertiary canals of Indus Basin in Pakistan indicates that for the tested unlined watercourses, water losses ranged from 64 to 68%.

India

Irrigation system has acquired augmenting significance in agriculture internationally. From impartial 8 million hectares (M Ha) in 1800, irrigated area across the world augmented fivefold to 40 Million Hectares (M Ha) (13.4 M Ha in India) in 1900, to 100 M Ha in 1950 and to just over 255 M Ha in 1995. With approximately one fifth of that area (50.1 M Ha net irrigated area), India has the highest irrigated land all over world nowadays (Postel, 1999).

In India the conveyance losses in lined and unlined tertiary canals of Haryana have been reviewed. Haryana is a frequently water-scarcity state in India. 80% of the farmingregion of the state (2.8 million hectares) is irrigated. The extent of area irrigated by canal water is approximately the same as that area irrigated by groundwater and in many instances, conjunctive intervention is adept.

The two main canal systems of the state are the Western Yamuna canal system, which is served from the Yamuna River and the Bhakra canal system, which takes its supply from the Indus basin.

Old earthen irrigation tertiary canals in permeable soils can lose a lot of water through seepage in India. Large losses through the bed and sides of canal lead to low conveyance efficiency; that is, (the ratio of water reaching farm turnouts to that released at the source of supply from a river or reservoir). Earthen canals also get clogged up with weeds which reduce the water-carrying capacity.

In unlined channels, only a portion of the water supplied at the canal head reaches the farmer's field. The main loss is through seepage. The commonly accepted figures for conveyance losses in alluvial plains of north India (Ganga basin) are 17% for main and branch canals, 8% for distributaries and 20% for water courses (Report of the Irrigation Commission, 1972).

In addition to Pakistan and India, the conveyance losses of lined and unlined channels in tertiary irrigation system of Egypt and Turkey have been reviewed. The conveyance losses in lined and unlined channels in tertiary irrigation system are 13 and 20 % in Egypt while 10 and 27 % in Turkey (Dennis Wichelns, 1999; Mohamed et al., 1995;ErhanAkkuzu et al., 2006).

III. Results and Discussions

Results

Table 1. provides the comparison of conveyance losses in developing countries:

Discussions

Comparing the average water loss from lined and unlined tertiary canals, it can be assessed that the lining reduces water conveyance loss significantly in developing countries. In developing countries like Pakistan and India, lining of watercourses increases the conveyance efficiency by 22.5% and 12% respectively. Similarly in Turkey and Egypt, lining impact is that it reduces the conveyance losses by 17 and 7% respectively. It may be concluded from the Table 1 that only lining intervention of tertiary irrigation channels result in substantial reduction of conveyance losses and accordingly enhancing the conveyance efficiency. Also the improvement of conveyance efficiency of water courses significantly contributes in overall irrigation system upto farm level.

TABLE 1
Comparison of Conveyance Losses in Developing Countries

Country Name	Irrigated Land (km2)	Conveyance Losses (%)		Conveyance Efficiency (%)		%age enhance in conveyance Efficiency due to lining	Source
		Lined Water Courses	Unlined Water courses	Lined	Unlined		
Pakistan	198,700	43.5	66	56.5	34	22.5	Arshad et al.(2011)
India	622,860	11	23	89	77	12	Ambast et al. (1990)
Turkey	52,150	10	27	90	73	17	ErhanAkkuzu et al. (2006)
Egypt	35,300	13	20	87	80	7	Dennis Wichelns. (1999); Mohamed et al. (1995)

However, it can be improved by adopting lining option coupling with other interventions at farm level i.e. bed & furrows and zero tillage etc.Moreover, the lining of distributaries and minors (secondary irrigation system) must be evaluated and done to further enhance the conveyance efficiency of irrigation system. Recently, Provincial irrigation and Agriculture departments in Pakistan have recognized the fact of huge benefits of lining of irrigation system (secondary and tertiary) and initiated several projects for lining, improvement, rehabilitation and remodeling of secondary and tertiary irrigation system upto farm level i.e. Mega Irrigation Projects Punjab, Punjab Irrigation system Improvement Project, Irrigation Systems Rehabilitation Project, Rehabilitating Lower Chenab Canal System Project , Lining of Distributaries and Minors in Punjab, Lining of Distributaries and Minors in Sindh, Twenty Small Irrigation Schemes in Balochistan, Remaining Punjab Irrigated Agriculture Investment Programme and Water Conservation and Productivity Enhancement Through High Efficiency Irrigation Systems. The regular and proper operation and maintenance of irrigation system is necessary to achieve the desired objectives. Most of these projects were started after 2005 and now at different stages of execution, even some of the projects are near completion. These projects are scattered all over Pakistan in all the four provinces. After the successful completion of these projects, the conveyance efficiency of overall irrigation system will substantially enhanced. It will also improve the crop yield, crop intensity, water productivity, gross and net benefits.

The proper operation of irrigation system also involves running the channels at design discharge to maintain the desired full supply level, velocity and other hydraulic parameters. The proper hydraulic parameters tend to keep the channel in "neither silting nor scouring" state. It results in equitable water distribution and avoiding tail shortages. Improving conveyance efficiency also results in reducing water theft as the farmers of head, middle and tail reaches get their desired share of water.

The reasons identified for excess loss of water through the tertiary canalsare due to eroded mortar, cracks and structural failure of the lined banks. The capacity of tertiary canal also decreases due to silting, resulting in overtopping of flows at many sites.

V. Conclusions

The canal irrigation scheme, especially, the tertiary system is facing a number of operational problems resulting in high losses of water during its conveyance.

The extra leakage of water through the tertiary canals is probably due to eroded mortar, cracks and structural failure of the lined banks. In addition, the capacity of tertiary canal is also curtailed due to silting, resulting in overtopping of flows at many sites.

The reason of the less conveyance efficiency in unlined portion of the watercourses was absolutely due to lack of proper maintenance of the watercourses hence more seepage and leakage losses presence of vegetation, improper alignment of the watercourses and rodent effect.

In developing countries i.e. Pakistan and India, lining of watercourses increases the conveyance efficiency by 22.5% and 12% respectively. The lining of watercourse effectively save the water losses and ultimately needs proper maintenances and cleaning otherwise losses will be higher than the normal.

VI. Recommendations

As a result of this study and from the perusal of other pertinent literature review work, the following recommendations are suggested for minimizing the losses in conveyance system and for improvement of watercourses.

The liningof channelshouldbe decided on the extent of seepage losses.

Frequent maintenance and cleaning of earthen watercourses are necessary to maintain high conveyance efficiencies. Proper improvement with bricks, concrete lining, with naccas and check may be done so as to save high amount of water lost through seepage, rodent holes and other losses etc.

Selection of lining for tertiary channels may be based on factors in addition to cost/benefit ratios and delivery efficiencies, such as the ability of the lining to manage and observe water and soil.

Therefore, it is recommended that watercourses must be lined for better effectiveness and sustainable water management.

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