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COMPARATIVE STUDY OF LINING WATERCOURSES TECHNIQUES IN BAHAWALNAGAR DISTRICT IN PAKISTAN

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Abstract - Dissemination of water in irrigated areas of the Indus Basin did not bring about crop water demand that system felled out in widespread groundwater suction. In Pakistan groundwater was depleting swiftly which was alarming for a country. It was considered PCPL and rectangular lining watercourses have different losses on being subjected to same hydro geological uniqueness of soil. It was observed that for the PCPL watercourses, the irrigation water losses ranged from 35 to 52 percent and for the rectangular lining these were from 64 to 68 percent. Therefore, it was the need of hour to line the watercourses to minimize the conveyance losses. A comparison study is conducted between watercourses in different shapes by using the brick masonry in rectangular shape and pre cast parabolic segments in circular design. By using these techniques, it is predictable that which watercourse is hydraulically more efficient, minimum cost of structure, more durable, less conveyance losses and most suitable for farmer community. It is examined that the impact of different techniques on cropping intensity, crop yield and cropping pattern is diverse. It is surely said that there is a huge difference between brick masonry and PCP linings as per the crop yield, cropping intensity and cost. In this study, it is determined that the design structure of different techniques is diverse. The study is based on the comparisons of techniques that which is the best by all perspectives.

Keywords- PCPL, watercourses

I. INTRODUCTION

Agriculture is the greatest sector of Pakistan. Although the share of agriculture in financial system of Pakistan has slowly decreased from 28% of Gross Domestic Product (GDP) in 1985 to 21.8% in 2010 (ES, 2010), yet the farming is still the single largest sector of the economy, contributing 21.8% to GDP and employing 44.7 percent of the work power. More than two-third of Pakistan's inhabitants belongs to natural areas and their occupation continues to revolve agriculture and allied activities (ESP, 2010). More than 90% of agricultural production is totally reliant on irrigation and irrigated land supplies. The increased scarcity of water sets the future stage for severe competition over water resources between the agricultural sector and non-agricultural users. The emergent demand for food and fiber of Pakistan's increasing population limits the per capita availability of water. Due to limited prediction for enhancing irrigation facilities, the estimated increase in irrigated agriculture would have to come from considerable improvements in the performance of existing systems.

Water is falling resource now, and increased in agriculture production is only achievable through intensive and extensive irrigation and better administration both on the canal and farm. A significant amount of water is lost through conveyance system (canals, distributaries, minors

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and watercourses allowing only 52 BCM at field inlet and 38 BCM for crop use in the field). Because of not enough technical skills and lack of inspiration of farmers, the watercourses have deteriorated, resulting in excessive conveyance losses. Despite this extensive system, agricultural efficiency in Pakistan was only 35.5%. It was estimated that about 40% of water was lost due to leakage, seepage, spillage and percolation in the century old rectangular lining watercourses (Adil, 2007).

The prim, and second, canal, of the irrigation system of the Indus Basin arc looked after by the Provincial Irrigation Department; whereas, the construction of tertiary canals (watercourses) and their operation and maintenance is the liability of the farmers. Lining of irrigation channels help to conserve water and move water more efficiently. It reduces seepage, which prevents the loss of water from the system. The loss of water is not only economically undesirable, but it would .cp on to adjacent land adding detrimental effect. Lining is a long term effective technique for reducing seeping losses from the watercourses. But on account of being costly; it was somehow provided only on 15-30% length from head of watercourse, (NPIW, 2009). Although, there is great pressure from the farming community for its intensive increase in lining length because:

- It helps in efficient and convenient water conveyance
- It helps in eliminating disputes related to water theft, illegal water diversion
- It provides a smooth surface
- It saves cultivable area from wider section of watercourse
- It prevent water logging by reducing seepage to the adjacent land
- It prevents or reduces weed growth in watercourse
- It reduces maintenance costs

In order to reclaim this loss of scarce irrigation resource, the Government of Pakistan took a bold and approximate initiative of rehabilitating archaic watercourse system. Under the guidance of The President of Pakistan, the Government of Pakistan has begin a national program to improve on-farm irrigation base to conserve water that would lead to more water availability, effective and efficient use of water. A colossal sum of Rs. 66 billion was fixed to be expended through National Program for Improvement of Watercourses (NPIW). This program was under execution in the Punjab since 2004. The Punjab component of this program started rehabilitation of 28000 watercourses and 2000 irrigation projects concerning a total outlay of 28 billion rupees.

On-Farm Water Management has different features such as redesigning of fields with straight borders, shorter water movement, laser leveling, cleaning, strengthening and brick lining of earthen watercourses. The last two improvements alone could result in up to 40% savings in water that coming from the canals. NPIW has four mechanisms, one interrelated to each province. NPIW was currently being implemented with a priority and on war footing. It consists of construction and rearrangement of the watercourses and the fitting of concrete outlets (pakka nakkas) at all divaricator for efficient water diversion. This type of improvement has been found to minimize the conveyance losses by about 50% (OFWM, 2005). In spite of awfully high investment being made in lining watercourses, definitive studies on evaluating efficiency of PCPL watercourses in maintaining flow and impartiality in water distribution are very limited. The evaluation studies done so for have depended on farmer surveys, assessment of selected watercourses, and flow depth in few watercourses as well as on limited collection of data on output of water consumed. While these evaluations have indicated varying degree of reducing seepage through watercourse improvement, careful information and data on g effect of extent of lining and its age on performance have been-relatively poor and strewn. The sustainability gains by lining have also not been adequately evaluated. Although one study in Pakistan indicated that benefits have been persistent for ten years and could be expected to continue for some more years (World Bank, 1995).

Objectives of Study
The objectives of this study were:

- To explore Extensive durability and flexible design with low cost.
- To determine the reduction in conveyance losses of selected watercourses.
- To examine the impact on cropping intensity, crop yield and cropping pattern due to watercourses improvements.

II. MATERIALS AND METHODS

Description of the Study Area
The study area lied in Bahawalnagar district which stands in the rolling flat plains of northeast Punjab, between longitudes 73° " East, latitude 29° " North as shown in Fig 3.1.It covered an approximately 8878 Square KM of area and had

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a population of 191,313. It also contaied the administrative headquarters of the tehsil. The Sutlej River flows about 30 km to the north-west while the river Ravi meanders about 40 km south-east of the city. The Lower Sutlej canal is the main source of irrigation water, which meets the requirements of 80% of cultivated land. The district on the whole is flat alluvial plains formed by Sutlej. The land close to the river is relatively lower than that away from the river towards the west. The general elevation of the land is about 150 m above the sea level. Average altitude the area above mean sea level is about 214 m.

Fig 3.1: Location of study area

III. RESEARCH METHODOLOGY

The research methodology in the form of flow chart is given in **Fig**

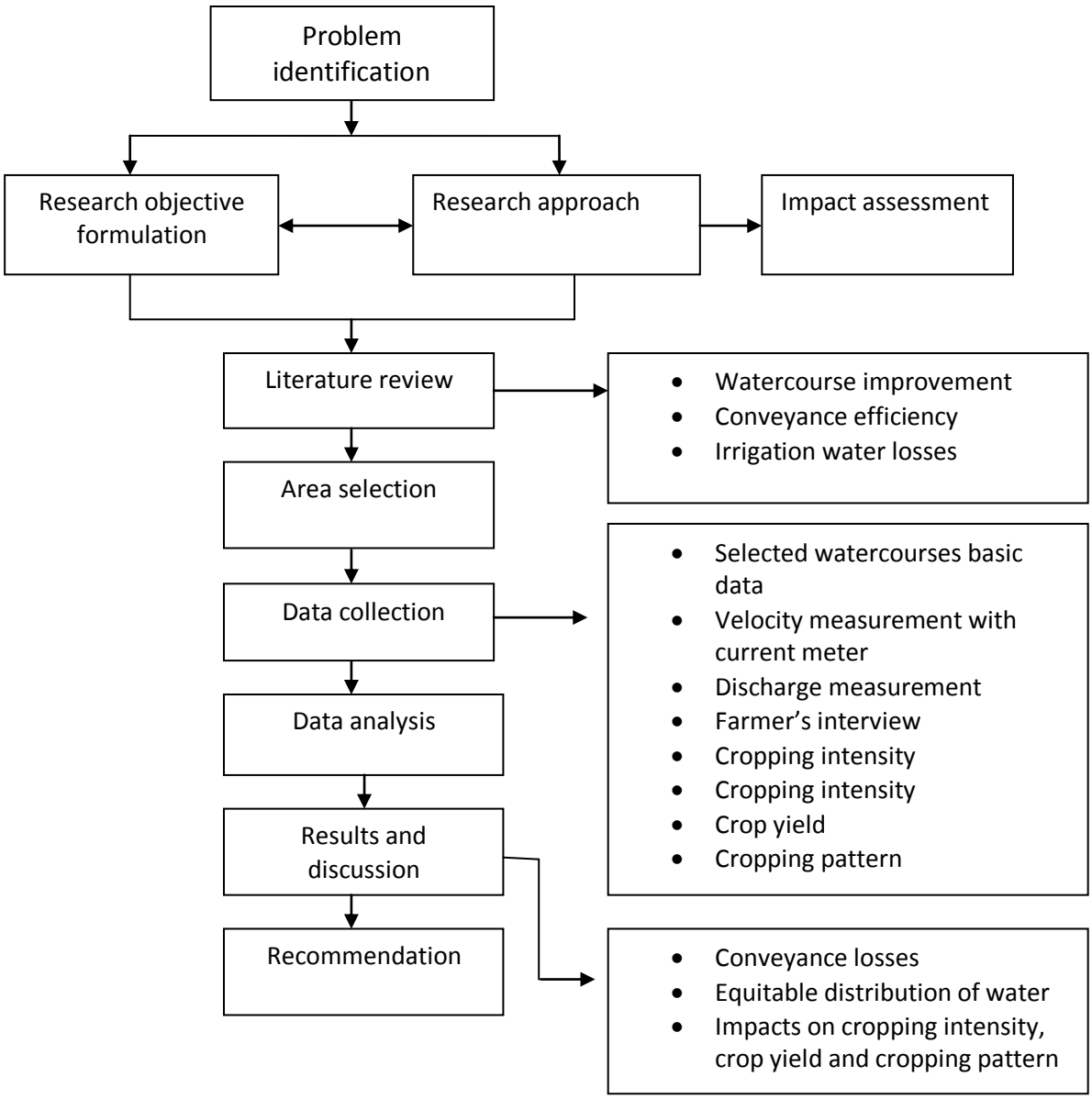

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Fig Research methodology flowchart

Velocity

Cropping intensity is of primary or secondary level. The source of data that is used is previous/interviews.

Crop Yield

Type of data that is selected is of primary/secondary level and the source is previous/Interviews.

Watercourse Improvement

Field Engineers have regularly inspected watercourses at the following four different stages as envisaged in quality assurance and quality control plan.

Survey and design

Field engineers visited the watercourses and physically checked their surveys in the field after receiving watercourse file for survey and design check (sample survey design sheet checked and signed by the PSC engineers is attached).

If surveys were found correct within permissible limits, design have been reviewed and approved as such are after incorporating necessary modifications. Material and their cost estimates have also been reviewed and approved. During the reporting period, a total number of 3913 surveys and designs have been approved; whereas, 73 surveys and designs were deferred due to technical deficiencies major shortfalls observed for different of survey and designs of watercourses included.

- Difference of elevation observed in the TBMs
- Incomplete bench mark survey
- Incomplete profile survey
- Incomplete TOPO survey
- Salinity features missing such as drains, road populated area and graveyard etc.

Watercourse improvements

Bricks:

All bricks used for construction of watercourses were insured to be good quality and confirming to following acceptable specifications

- 23cm x 11 cm x 7cm in size
- Fired without being vitrified
- Uniform color, regular in shape and size, with sharp square corners parallel faces
- Homogeneous in texture and emit a clear ringing sound when struck together
- Free from flaws and cracks
- Made of calcareous soil
- Not absorb more than 1/16 of their weight of water after being soaked for one hour, and no sign of efflorescence on drying
- The compressive strength of bricks not less than 105 kg/cm^2

Cement

Cement of ordinary Portland (type-1), stored in a dry well ventilated place and free of damp was ensured to be used for civil works activities.

Sand and Gravel

It was ensured that sand and gravel used for civil works must comply with the following acceptable specifications:

- Sand must be clean and free of clay, silt and organic matter
- Must be well graded. The whole of the sand must pass through a No. 4 sieve (4.75mm) and between 2 and 10 percent through a No.100 (sieve (0.15mm)
- Must be clean and free from lumps, soft and flaky particles, shale, alkali organic matter, loam, mica and other harmful substance
- Gravel must be hard, durable and reasonably well graded
- Minimum size of gravel must be 5mm and sieved through a 4.75mm sieve to exclude material below this size
- Maximum size must not exceed 1/3 the thickness of non-reinforced concrete

Water

Water used for making concrete and mortar for brick masonry and plaster was ensured to be clean and free from silt, oil, salt, alkali and acid.

Water-Cement Ratio

The water/cement ratio in a quality concrete varies from 0.45 to 0.50 and for 1:4 Cement/Sand mortar, was ensured to be 0.48 as per acceptable standards.

Precast Concrete Parabolic Segments (PCPS)

The quality of PCPS and aggregates used in manufacturing of these PCPS was ensured to be as per agreed following specifications:

- Ratio of concrete (cement-sand-gravel) must ne 1:1:2
- Compression strength must not be less than 4500 PSI after 28days curing and

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70% of specified strength after 7 days as well as 85% -90% after 14 days curing.
- Slump must not be more than 1 inch in any case.
- Casting of PCPS must be done in agreed condition i.e. approved moulds must be used as well as vibrating table should be used for proper compaction.
- Mortar of 1:3 ratios must be used for joining PCPS.

IV. RESULTS AND DISCUSSION

- **Assessment of Physical Conditions of Selected Watercourses**

The head to middle section of all selected watercourses were PCPL, whereas the tail sections of the sample watercourses were rectangular lining. The detailed specification of the selected watercourses is given below in Table

Table of Physical condition of selected watercourse observed in the field

Sr. No.	Name of distributor	W/C No.	CCA (ha)	Total length (m)	Length (m)	
					PCPLS length (m)	Rectangular length (m)
1	Dhaban	7/R	267	3420	751.36	5706
2	3/L	5	241	4200	842	3581
3	Darbari Wah/ Ford	61200/L	126	1776	530	3604
4	Harres Wah	6790/L	111	2088	626	8785
5	Murid Wah	46262/L	38	818	245	809

Conveyance Efficiency

The ratio of the water delivered into the field from outlet point of the channel (Nucca) to be pumped into the channel at the starting point or module (mogha) Using the flow rate of the PCPL and rectangular of the watercourses (at inlet and outlet), the conveyance efficiencies computed are shown in the Annexure A1, A2, A3, A4, and A5. The results in the Table 4.4 revealed that the average conveyance efficiency in the PCPL watercourse was 91:64, while the conveyance efficiency in the rectangular lining of the watercourses is 75.5%. The reason of the less conveyance efficiency in rectangular lining portion of the watercourses was absolutely due to lake of proper maintenance of the watercourses hence more seepage and leakage losses presence of Vegetation, improper alignment of the watercourses and rodent effect. The improved Conveyance efficiency to the turn of l6.l4 was attributed to the improvement / lining of the watercourses. **Average conveyance efficiency of sample watercourses in PCPL and rectangular**

Watercourse No.	Conveyance efficiency in PCPL section (%)	Conveyance efficiency in rectangular lining section (%)
7/R	93	75.75
5	93	69.75
61200/L	91	79.5
6790/L	90.75	78.75
46262/R	90.5	73.75

Effect of Improvement of Watercourse on Farmers Irrigation Practices

A total of 30 fanners were interview., at a times generally coinciding with their warabandi turns. The interview results are given below in which the effect of improvement of watercourse on their irrigation practices, crop yields, cropping intensities are discussed in detail.

Cropping intensities in the Research Area

The data regarding cropping intensity of five watercourses under study for both seasons are shown in Table 4.6 It was evident from Table 4.6 that the annual cropping intensity of watercourses located at the head of the 7/R and w/c 5 minor rectangular lining are 1.20 and 142 respectively and PCP lining were recorded as 140 and 167 respectively. Thus there was an increase of 20 and 25% in cropping intensities with the improvement of watercourses. Likewise annual cropping intensity of the watercourses located at the middle reach of the distributaries had perform 118% mid 101% (before 4Mg) to 137% and 119% (PCP lining) indicating an increase of 19 and 18% in cropping intensities respectively. Similarly, the annual cropping intensity for the watercourse located at the tail of the Murid Wah distributry can be seen as 92% and 81% before and PCP lining respectively showing an increase of 12%.

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It is further clear that cropping intensity has increased on overall basis as shown in Fig. 4.8. The annual cropping intensity in the reach rectangular lining was 2, 41% and 28, 50% more than that in middle and tail reaches respectively. Similarly, PCP lining the cropping intensity in head reaches was 3%. 48% and 36, 63% more than that in the middle and tail reaches respectively, which can be attributed water saving achieved due to lining.

4.4.2. Cropping Pattern

The cropping pattern of the watercourses under study for the Rabi and Kharif seasons for the cropping year 2008-2009 was assessed through designed questionnaire as shown in Annexure C. The data collected revealed no significant change in the cropping pattern. The farmers were invariably growing the same crops, which they did before the improvement of the watercourses, despite the fact; the improvement of each sample watercourse to save a considerably quantity of water per annum lack of marketing and storage facilities remained hurdle for farmers to grow other crops such as fruits and different vegetables.

4.5: Impact of Watercourse Improvement

Different impacts evaluation studies have been carried out by various agencies under previous OFWM projects. The findings of these assessments have indicated significant benefits accruing from watercourse improvement including average reduction of about 33 percent in water conveyance losses, improvement in delivery efficiency to tune of 38.5 percent, increase in cropping intensity by nearly 20 percent and overall increase in crop yields by around 24 percent.
In addition to water saving, inter alia, the followings.

1) Reduction in time to fill reaches of a watercourse, leading to increased time for field application; This is often perceived as the greatest benefit by the farmers.
2) Control of tempering with watercourse turn-outs (nuccas), particularly in PCPL sections.
3) Saving in land taken for watercourse right of way due to narrower cross section of improved/PCPL reaches.
4) Decrease in water logging, particularly adjacent to watercourses.
5) Lessening the drudgery of irrigation operation to a great extent.

A recently completed "Project Impact Evaluation Study (PIES) for National Program for Improvement of watercourses in Pakistan (NPIW)" by the planning Commission of Pakistan reveals that the intervention is highly cost effective option for improving farm gate water availability. The salient impacts of watercourse improvement reported in the study are summarized hereunder.

- Annual saving of 123 acre feet (AF) of irrigation water per watercourse
- Increase of 21 percent in irrigated area
- Improvement of crop yields by 10.8 percent, 5.9 percent, 12.4 percent, and 15.4 percent for wheat, rice, cotton and maize respectively
- Enhancement of cropping intensity by 4.37 percent
- Reduction in soil salinity by about 87 percent
- Shift to high delta crops like vegetables

It is, accordingly, highly essential that improvement of remaining watercourses may be completed in the shortest time frame to mitigate farm gate water shortage.

V. CONCLUSIONS

The distribution within the sample watercourses was also inequitable. The head and middle portion of watercourse 7/R, 5, 61200/L, 6790/L, 46262/R receive fair share of water delivered in these watercourses because their head to middle sections were mostly PCPL. The lining was done 15% or 30% of the total length of watercourse which depend upon the quality of ground water, where ground water was saline or brackish lining up to 30% was done and where ground water was sweet here 15% of the total length of watercourse was improved. In study area mostly the ground water was saline so all sample watercourses were 30% PCPL. The tail reaches of the sample watercourses receive water ranging 50 to 83% of the water delivered at the head of the watercourse. The water distribution with the watercourses is affected by the watercourse elevation with respect to the fields watercourse maintenance and discharge availability in the watercourse.

1. The conveyance losses were lower in the head to middle sections, whereas there were higher conveyance losses in the middle to the tail sections. The middle to tail section was totally rectangular lining that is why there are higher conveyance losses in this portion of watercourse. Other factors like watercourse maintenance, length and amount of discharge available in the watercourse also affect the conveyance losses. The conveyance losses in the head to middle

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sections, mostly PCPL, of sample watercourse ranged from 2% to 14% where as conveyance losses in the middle to the tail sections, ranged from 15% to 46%.

2. The water distribution was inequitable along the distributaries. The Watercourse 6790/L receives 22.53% less discharge than. the design discharge, lowest among aft the sample watercourses. Watercourse 5 receives 77.59% more discharge than the design discharge, highest percentage among all the sample watercourses. The watercourse 7/R and 61200/L often receive more water than design discharge. The water distribution within the watercourse is highly affected by the outlet structure and the water level in the distributaries.
3. The cropping intensity at the command area of watercourses was increased by about 45% in Rabi and 49% in kharif seasons. The annual cropping intensity in the head reach rectangular lining was 2% and 28 more than that in middle and tail reaches respectively. Similarly, PCP lining the cropping intensity in head reach. is 3% and 36% more than that in the middle and tail reaches respectively, which can be attributed water saving achieved due to lining. The cropping pattern assessed in the command area of the watercourses before and PCP lining remained unchanged. Crop yield increased. an average of 534 kg/ha for wheat, 9682 kg/ha for sugarcane and 207 kg/ha cotton niter the lining of the watercourses.

VI. RECOMMENDATIONS

The following recommendations were suggested.

1. It is recommended that the additional lining of watercourse should be carried out for attaining maximum conveyance efficiency.
2. Motivation to the farmers that rectangular lining section of the watercourse should be maintained and cleaned properly for better conveyance of water.
3. Discharge in rectangular lining section of the watercourse should be measured with the help of cross-section instead of flume because it will give more accurate results as compared to the flume.
4. The results of this study show quantitative impact of watercourse lining on crop yield and cropping intensity at different locations. Serious efforts are needed to overcome dilemma addressed in this study. The issue of inequity distribution of water needs to be addressed specifically at tertiary level, only watercourse lining will not solve the problem as the country has witnessed the efforts of 3 decades yet the issue is almost unturned Combining the lining of watercourse and redefine the water allocation rules/ criteria solution may help to empowered the situation with involvement of the end users. Factors like water theft, outlet tempering etc. must be addressed seriously

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