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RESEARCH PAPER

Evaluating the performances of surface drainage efficiency in left bank outfall drain (LBOD) at Sanghar component, Sindh

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Key Message: This study evaluates the delivery performance ratio of drainage tubewells. Drains didn't dispose of a considerable amount of water, while vegetation in the drains proved to be a strong factor to retard velocity by decreasing discharge and increasing flow depth.

Abstract: This study was conducted at Sanghar component of left bank outfall drain (LBOD) project for evaluating the efficiency of drainage system in terms of operation and maintenance. Makhi Branch Drain and Sanghar-1R drain were selected and their allied tubewells along with disposal channels for the system evaluation. The results showed that the operational efficiency of drainage tubewells was found very poor. The average operational efficiency was calculated as 24%, whereas the value of coefficient of variation of tubewell operational efficiency is greater than 0.30 and leads up to 0.90, which shows high variability in operation. The disposal channels are 88% efficient in terms of carrying the tubewell discharge into the main drain. This percentage is considered high in relation to the shorter length. Therefore, the losses from these channels under study were estimated as 2.5 million m^3 of drainage effluent which directly diverts to the adjacent land and builds up upper surface salinity. The drainage efficiency of surface drains was observed to be very poor. Despite of being drained out from the study area, the drains were contributing a considerable amount of drainage effluent to the groundwater. However, thick vegetation in main and branch drains has proved the strong factor to retard the velocity of flow in the drain. Due to high vegetation the main and branch drains have been inefficient. The operational efficiency of tubewells should be increased by operating them at the design hours in order to drain out the recommended magnitude of water to lower down the water table. There is a severe need to maintain disposal channels by providing design slope and cross-section to prevent drainage water from overtopping into the agricultural lands. This channel is the first that directly harms the adjacent land. Moreover the longitudinal slope may be checked to maintain the regime of flow.

Keywords: Wheat productivity, Weeds, Weed dynamics, Yield

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Introduction

Waterlogging is concentrated mainly in long canals. Not only because of seepage from irrigation canal, however over irrigation water application to crop in these areas raises the water table (Ali, 2011; Tagar et al., 2017). Due to the rising water table and the associated salinization of the non-cropped areas, fallow land is decreasing and abandoned land increasing (Chandio et al., 2013; Yu et al., 2018). To rise above the issue and problem of around 1.27 million acres land, the Water and Power Development Authority (WAPDA) started new surface drainage project in three districts of Sindh province i.e. Nawabshah, Sanghar and Mirpurkhas, in mid 1980s (Al-Agha et al., 2011). The rising water table resulted in water logging of agricultural lands and environmental problems (Bowonder et al., 1986). High evaporation rates with low annual rainfall flushed the salts from the soil profile, causing widespread salinization. As a result, agricultural production declined in large areas of Sindh and land became abandoned in most of the areas (Saeed et al., 2001; Chandio et al., 2013; Mahessar et al., 2019).

The rate of deterioration of agricultural productive land has been alarming and needed full attention (Soothar et al., 2019a; Soothar et al., 2019b). Looking at the severity of the problem the Government of Pakistan has launched a comprehensive drainage program in Sindh LBOD. The monitoring of physical effects is an essential component of LBOD projects. It greatly helps in assessing the impact of a project from socio-economic and engineering perspective. A complementary activity of LBOD is the provision of additional irrigation water to serve land and reclaimed the waterlogged and salt affected area by drainage. This is being addressed through the remodeling of

Nara canal and enlargement of Chotiari reservoir. Saline effluent from the LBOD Stage-1 Project area and from the Kotri command area is transported through the LBOD spinal drain and the Kadhan Pateji Outfall Drain (KPOD) to the Arabian Sea via the Tidal Link (Hasnain et al., 1997; Al-Agha, 2004; Reham & Battarai, 2005; Mahessar et al., 2019). The processes of checking the performance as well as it require some indicators that help in assessing its proper working. From time to time certain indicators are required to be developed for the drainage system depending upon the level of drainage efficiency. If surface drains are designed to carry out the required discharge to convey the drainage effluent from the target area to the disposal point but physically due to certain reasons or problems they are unable to carry the required effluent to the destination, it shows the inefficiency of the drainage system (Gilliam & Skaggs, 1986).

Many of the drainage projects in Pakistan after some time have lost their efficiency due lack of proper maintenance and operation (Muhammad & Ali, 2008). Therefore, there is a need to assess some factors or to develop some indicators in the process of monitoring the project activities in order to chalk out the desirable variables which are the actual cause of their inefficient operation. Not only this but this inefficient operation is becoming harmful for the adjacent area by putting it into the saline conditions of soils. The quality groundwater which is being extracted through deep tubewells is much deteriorated and is very harmful if it is discharged into the adjacent lands. The excess water may occur either for a short time or for a prolonged time. The excess water on most lands does not cause any harm to the crops as long as the quantities are small, the occurrence is rare and of short durations, and that the excess occurs during non-critical season. Large quantities of excess water with prolonged durations and frequent occurrences at critical time periods are very harmful to the crops and lead to the drainage problems. The main goals of agricultural drainage from cultivated land are to ensure the harvest grain yield of agriculture products per unit area and therefore to enhance the profitability of farming the land. Solanki and Singh (2000) reported that the key issues facing during the crop irrigation and drainage sector are in every water management and drainage scheme. For this it is necessary to collect background descriptive data on each scheme, such as location, climate, water source, type of crops grown, area and drainage. Hammond et al. (2000) assessed that the main canal, secondary and tertiary channels in Pakistan has an already known flow rate and it is estimated that as far as possible the actual flow rate should equal the design flow rate.

The surface drainage development projects in the humid climate counties of South and south-east Asia, focusing predominantly on Malaysian experience and highlighting rainfall water induced surface drainage issues such as crop yield and water productivity affected by seasonal variations in the precipitations. Abdullah et al. (2000); Sohag and Laghari et al. (2004) reported the performance of spinal drain system during monsoon season, and discussed the actual tidal link canal design and described breaches cuts in different LBOD drains due to excess rainfall. Smedema et al. (2000); Bueno et al. (2020) suggested that in agricultural lands, the excess rain water may be available in the effective crop root zone or it spread over the ground surface around the crop leaves and stem. Manguerra and Garcia (1997) reported that the recent environmental constraints and further required irrigation and drainage strategies should satisfy the agricultural as well as environmental assurances goals. However, Abdul-Dayam (2000) stated that drainage is as necessary as irrigation for enhancing plant growth.

The installation of surface drainage systems is undertaken to lessen the impact of flooding of agricultural lands caused by excess irrigation or rain, or the combined effect of both (Oyarce et al., 2017). According to previous study the one of main causes of low productivity of the agriculture sector have been and to continue due to the poor drainage. In order to be self-sustained in the agriculture sector, around half of agricultural yields are too increased. Knowledge of the currently existing drain system will help by ensuring that corrective actions are taken in advance so that they manage flood and soil salinity issues (Ghorbani et al., 2017). The aim of this study was to assess the performances of surface drainage efficiency in the LBOD Sanghar component.

Table 1 Salient features of selected drains

Name of drain	Design Q (f^3 sec^{-1})	Total length (km)	Length under study (km)	Tubewells (no.)
MBD	96.6	20.73	9.75	5
S-1R	43.90	11.30	11.121	7

MBD = Makhi Branch Drain; S-1R = Sanghar-1R drain

Material and Methods

Experimental site

This study was conducted in the Sanghar component of LBOD area, in which the command area of one distributary was selected having a network of surface drains and tubewells. For this study two main drains were selected in the entire command of selected distributary. The salient features of the drainage network undertaken for the study are present in Table 1.

Discharge measurement of surface drains

To evaluate the drainage efficiency of surface drains, the discharge measurement at two points was necessary. The discharge measurement procedure was the same as in an unlined irrigation channel. Two points at each drain within the selected command area were selected at upstream called source and at downstream called disposal point. The data was conducted for three months (once in a month) preferably pre and post monsoon season of 2013.

Discharge measurement of disposal channels

In order to determine the efficiency of the disposal channel, the discharge at two points was measured. For this activity, the discharge at source (at weir of tubewell) were measured by broad crest weir formula developed by WAPDA through calibration and at the end of the section of disposal channel the discharge was measured through cut throat flume as in unlined watercourse. This data provided the seepage losses in disposal channels to estimate the drainage efficiency.

Discharge measurement of tubewells

The discharge of Tubewell was measured through a calibrated weir equipped at the pump house. The discharge was calculated by using the following formula:

$$Q = 0.001128 \quad x \ h^{1.5}$$

Where
Q = Discharge [f^3 sec^{-1}]
H = Head of water over the crest of weir [mm]

Discharge measurement at the disposal point of disposal channel

The discharge measurement at the end section of the disposal channel was measured through a cut throat flume of size (8" X 3') having the capacity of 2.86 f^3 sec^{-1}. This flume can operate under free flow and submerged flow conditions. The following relations were used to calculate the discharge.

a. Free flow condition

$$Q_f = 2.858(h_u)^{1.826}$$

Where
Q_f = Free flow discharge [f^3 sec^{-1}]
h_u = Upstream flow depth [ft]

b. Sub-merged flow condition

$$Q_s = \frac{1.6(h_u - h_d)^{1.826}}{(-\log S)^{1.489}}$$

Where
Q_s = Submerged flow discharge [f^3 sec^{-1}]
h_u = Upstream flow depth [ft]
h_d = Downstream flow depth [ft]
S = h_d/h_u

Development of drainage efficiency factor for disposal channels

There are 12 disposal channels to carry the drainage effluent of 12 tubewells in both drains. It was not possible to measure the discharge at the end section of all disposal channels. The discharge through CTF was measured at three disposal channels varying in length i.e. large, medium and small. The seepage losses from these three channels were reflected in the seepage losses in the disposal channels under study. For example if there will be 10% seepage losses in channels, these are 90% efficient to convey the discharge. The drainage efficiency factor of 0.9 was used to calculate the drainage efficiency of remaining channels.

Delivery performance of drainage tubewells

The delivery performance of tubewells in the selected drains command was checked with its design discharge to visualize the discharge performance. It was calculated as follow:
The delivery discharge performance of tube wells may be checked by operating hours per day simultaneously with the working or not functioning of the tube wells of the study component.

Seepage losses from disposal channels and drains

Seepage losses from disposal channels and drains were calculated by inflow-outflow method. Inflow (discharge at source) and outflow (discharge at disposal point). For calculating the seepage losses at the disposal channel, the inflow was the discharge at tubewell and outflow at its disposal point were measured by using cut throat flume. For drains the discharge at source and disposal point was measured by using current meter. Seepage losses were calculated by using following formula:

$$S_R = \frac{(Q_s - Q_d)}{L}$$

Where
S_R =Seepage rate
Q_S = Discharge at source [f^3 sec^{-1}]
Q_d = Discharge at disposal point [f^3 sec^{-1}]
L = Length of drain in ft

Diagnostic walk through survey of surface drains

To evaluate the maintenance level of any channel (drainage or irrigation) is to conduct a walk through survey along its length. This activity was conducted along both main surface drains and their allied disposal channels to check the maintenance level of channels. The survey chalked out the factors that are responsible for their less drainage efficiency and enable to develop some indicators that may help in future to check the level of maintenance. Under this activity photographs of channel sections were taken and measurement of vegetation length and intensity and noting the conditions of inlet points and structures within the drains that may be affecting its hydraulic and drainage efficiency.

Results

Operational efficiency of saline tubewells

Drainage efficiency of tubewells is usually assessed by evaluating its delivery performance ratio (DPR) and its operational performance. Results of DPR are shown in Table 2 and monthly as well as average operational performance of drainage tubewells. From the result of DPR values it is clear that the delivery performance ratio of tubewell no. NS-63, NS-75 and NS-88 and NRS-46 are above 0.90, whereas the tubewells NS-64 and NS-74 have DPR value of 0.84 and two tubewells have very low DPR value i.e. below 0.60. This shows that all tubewells are discharging the drainage effluent at the rate less than the design discharge. The overall efficiency of tubewells is very low. The operational efficiency of tubewells as evaluated in four months is 24% which shows the inefficiency of tubewell operation. The operational efficiency of tubewells has increased to some extent and reached to 29%, but even it is very low as compared to its design value. In the month of April, it decreased to an average of 16%. Monthly operational efficiency of tubewells is shown in Table 3. The efficiency in terms of DPR and operational performance shows dual inefficiency in one parameter like defects on both sides of a coin.

Table 2 Delivery performance ratio of selected drainage tubewells

Tubewell No.	Measured discharge		Design Q	DPR
	h (mm)	Q (f^3 sec^{-1})	Q (f^3 sec^{-1})	
NS-63	138	1.83	2	0.91
NS-64	130	1.67	2	0.84
NS-74	130	1.67	2	0.84
NS-75	144	1.95	2	0.97
NS-88	140	1.87	2	0.93
NS-99	103	1.18	2	0.59
NS-109	95	1.04	2	0.52
NRS-46	142	1.91	2	0.95

h = flow depth; Q = discharge; DPR = Delivery performance ratio

Table 3 Average operational efficiency of drainage tubewells

Tubewell No.	Monthly operational efficiency [%]					
	January	February	March	April	Average	CV
NS-63	22	22	17	20	20	0.13
NS-64	5	6	16	11	10	0.50
NS-74	26	67	76	42	53	0.44
NS-75	5	10	5	7	7	0.36
NS-88	81	61	49	26	54	0.43
NS-99	9	6	2	2	5	0.76
NS-109	45	28	63	9	36	0.63
NRS-46	0	5	3	9	4	0.90
Average	24	26	29	16	24	0.90

CV = Co-efficient of variation

Variability of tubewell operation

The tubewell operation as observed in the four months resulted in very less operational hours as compared to the design operation of 16 hours in a day. Fig. 1 depicts the level of operated hours against the design line. It is clear that the operational target is very far from the designed target. The coefficient of variation values of operational efficiency of tubewells shows very poor performance as compared to mean CV values of operational performance which is much greater than 0.3. The CV values of individual performance are also weak. By this performance the efficiency of tubewells in terms to lower down the water table is very unsatisfactory.

Efficiency of disposal channels

To evaluate the efficiency of disposal channels the discharge measurement at source point i.e. at the weir of tubewell and at the disposal point i.e. at the inlet point where it discharges in the main drain. The seepage losses of selected disposal channels are shown in Table 4. The results show that the conveyance losses in the disposal channel vary depending on the physical condition of channel and level of maintenance. The channels in good condition have higher efficiency as compared to those which are less maintained. The responsibility of maintaining disposal channels in terms of vegetation clearance and shallow excavation falls on the farmer who is the beneficiary same as in case of irrigation water course.

The results in Table 4 clearly show that disposal channels are efficient in terms of carrying the tubewell discharge in to main drain. These are very shallow channels having very short length, therefore any losses from these channels directly affect the adjacent land through seepage of saline water and are responsible to build up upper surface salinity. The drainage water through the disposal channel also frequently overtops its banks and directly diverts into the land.

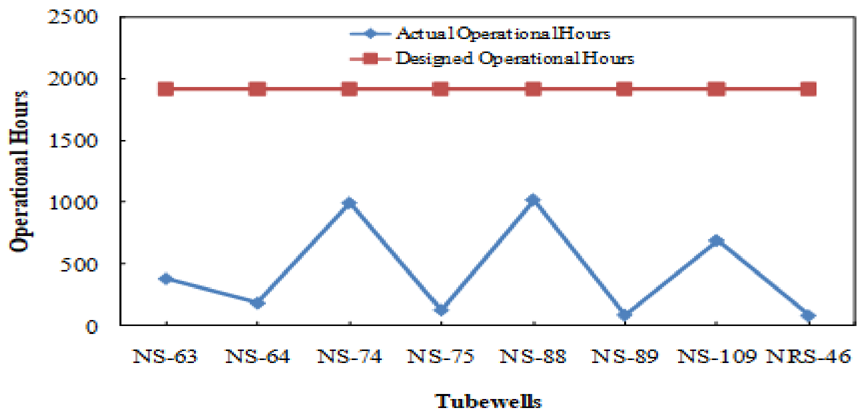

Fig. 1 Total operational hours of tubewells in the period of 4 months

Table 4 Seepage losses from disposal channels in LBOD command area

Channel	Discharge at tubewell weir	Discharge at disposal point	Difference	Losses	Length of disposal channel	Drainage efficiency factor
		[f^3 sec^{-1}]		[%]	[ft]	Fraction
DC NS-74	1.67	1.51	0.16	9.581	1.67	0.904
DC NS-88	1.87	1.60	0.27	14.439	1.87	0.856
Average				12.0		0.88

Table 5 Losses of drainage water from disposal channels

Disposal channel	Length of disposal channel [ft]	Wetted area of disposal channel [ft^2]	Drainage efficiency factor	Operational hours	Discharge of the pump [f^3 sec^{-1}]	Losses [10^6 ft^3/period]
DC NS-63	1476	8609.5	0.88	380	1.83	0.30
DC NS-64	2034	10509.6	0.88	183	1.67	0.13
DC NS-74	492	1940.44	0.88	993	1.67	0.72
DC NS-75	3608	19844	0.88	126	1.95	0.11
DC NS-88	1312	5904	0.88	1018	1.87	0.82
DC NS-99	4552	20675	0.88	87	1.18	0.04
DC NS-109	525	1954.05	0.88	689	1.04	0.31
DCNRS-46	7281	45812.05	0.88	82	1.91	0.07
Total	21280	115248.6	0.88	3558	13.12	2.50

Reflection of drainage efficiency factor for other disposal channels

As it is not possible to measure conveyance losses through inflow outflow test on all disposal channels in the selected area, therefore average value of drainage efficiency factor determined for selected disposal channels could be used for the remaining disposal channels of tubewells in order to calculate the effective volume of water that is being disposed in to the drain. Table 5 depicts that the volume of 2.5 million cubic feet water was being lost only from disposal channels. This quantity of water can quickly affect the neighboring land.

Volume of water drained by Makhi branch drain (main drain)

The discharge measurement of two surface drains (one main drain and other branch drain) for four months at source and at disposal point is shown in Table 6. The results for Makhi Branch Drain (Main Drain) revealed that volume that main drain receives at source and from drainage tubewells is not properly disposed off forward from the area. In the month of January the discharge difference is 0.33 with volume of 0.86 million cubic feet, but the effective volume of drainage tubewells is 1.57 million cubic feet drained, by this account the volume 0.71 million cubic feet disappears within the selected reach Fig. 2. This situation remained with the same trend throughout the observation period except in the month of April in which 0.31 million cubic feet of drainage effluent drained forward from the selected reach, this is also the minimum amount drained. The results are summarized in Table 6 and Fig. 2. The figures show that the surface drains are less efficient in terms of carrying design quantities of water. The water that disappears within the reach again contributes the groundwater remained retarded within the drain due to high vegetation in it. The level of maintenance was observed to be very poor in surface drains resulting in reduced velocity of flow.

Table 6 Inflow outflow discharge and volume drained by drain MBD

Month	Inflow volume	Volume from tubewells	Total inflow	Volume at disposal	Effective volume drained
			[10^6 ft^3]		
January	125.3	1.6	126.9	126.2	-0.7
February	123.1	2.6	125.7	125.5	-0.2
March	130.8	2.9	133.7	131.6	-2.1
April	125.0	2.1	127.1	127.4	0.3

Table 7 Inflow outflow discharge and volume drained by drain S-1R

Month	Inflow volume	Volume from tubewells	Total inflow	Volume at disposal	Effective volume drained
			[10^6 ft^3]		
January	52.7	3.17	55.9	55.9	-0.03
February	48.1	2.27	50.3	50.4	0.05
March	55.0	2.50	57.5	57.4	-0.09
April	46.7	1.17	47.8	47.8	-0.06

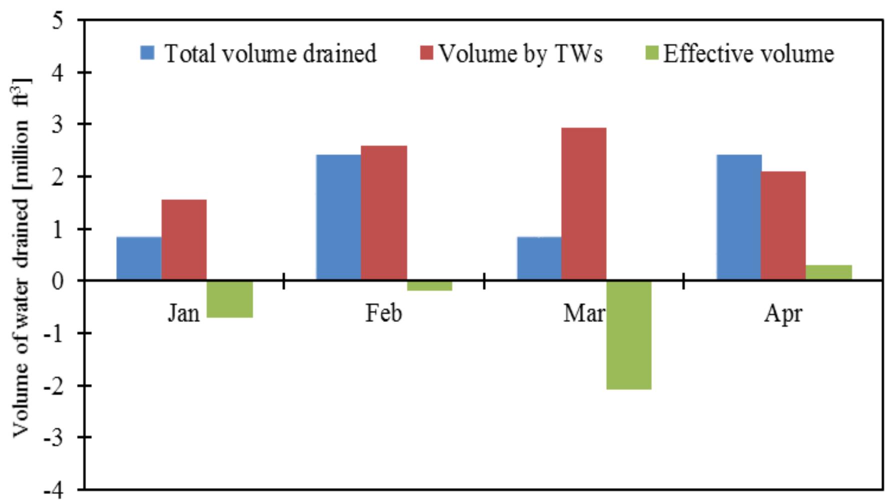

Fig. 2 Efficiency of Makhi Branch Drain (MBD) in terms of carrying drainage effluent

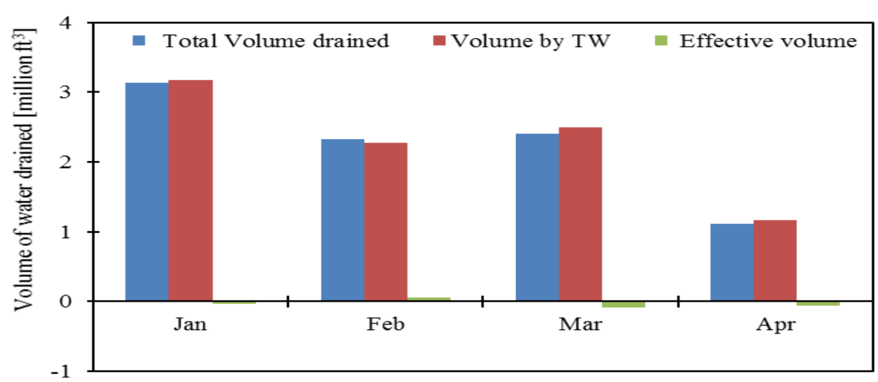

Fig. 3 Efficiency of Sanghar 1-R drain (S-1R) in terms of carrying drainage effluent

Volume of water drained by Sanghar-1R (S-1R) (branch drain)

The discharge measurement at source and disposal point within the selected reach of S-1R drain is shown in Table 7 for four months and summarized in Table 7. The results reveal that the volume that drain receives at source and from drainage tubewells is not properly dispose-off forward from the area. In the month of January the discharge difference is 1.21cfs with volume of 3.14 million cubic feet, but the effective volume of drainage tubewells is 3.17 million cubic feet drained, by this account the volume 0.03 million cubic feet disappears within the selected reach (Fig. 3). This situation showed similar trends throughout the observation period except in the month of February in which 0.22 million cubic feet of drainage effluent drained forward from the selected reach, this is also the minimum amount drained. Fig. 3 shows that the surface drains are less efficient in terms of carrying design quantity of water. The water that disappears within the reach again contributes the groundwater remained retarded within the drain due to high vegetation in it. The level of maintenance was observed to be very poor in surface drains resulting in reduced velocity of flow.

Table 8 Average watertable depth (ft) of selected drainage command area

Month/week	October	November	December	January	February	March
1st	4.1	3.9	4.1	3.5	4.6	5.2
2nd	3.9	3.8	4.9	4	3.9	3.7
3rd	3.8	3.8	3.8	3.1	3.6	4
4th	3.3	4	4.1	3.2	4.6	5.4
Mean	3.78	3.88	4.23	3.45	4.18	5.10
Overall average						4.10

Assessment of maintenance problems in drainage system

Diagnostic walk thru survey was conducted along disposal channels of tubewells and surface drains in order to assess existing condition of channels and the maintenance level. However, the average water table fluctuations in each month are shown in Table 8.

Disposal channels of tubewells

During a walk through survey it was observed that the level of maintenance of disposal channels in the LBOD area was very poor. This is the initial channel that carries water discharge from tubewell to the branch drain. It was observed that the channel had very shallow depth with increased wetted perimeter, usually overtopping in the adjacent land. This is the first channel that creates the problem. As the flowing water is sediment free, having more erosion ability in less stable and shallow soil disturbs the cross section of the disposal channel. There was no vegetation found in the bed and sides of the channel, but due to erosion its longitudinal slope was not as per design. Maintenance of these channels is the prime responsibility of farmers, but in practice this is not being done so as in the case of watercourse.

Makhi branch drain (MBD).

There was high vegetation intensity found in the bed in most of the portion. This height of vegetation ranged between 4 and 6 ft in most of the portions of bed width of surface drains. Due to the narrow drainage water way, the flow in terms of velocity is reduced creating stagnant positions raising water level in the drain. According to local farmers, the rehabilitation program was recently commissioned by Sindh Irrigation Drainage Authority (SIDA), the banks of drains were found clean.

Sanghar -1R (S-1R) drain

Walk thru survey along the S-1R drain was conducted to diagnose the maintenance level. The banks were in good condition with damaged berm. Very thick vegetation was found in the bed of the channel reducing the drainage effluent flow. This condition was continuously persisting at most of the portions of S-1R Drain. The maintenance of the berm and bank of the drainage channel was visible and they were found in good condition but thick vegetation which is the main reason that directly influences the carrying capacity of the channel was dominant.

Discussion

Study conducted along disposal channels of tubewells and surface drains to assess existing condition of channels and their maintenance level revealed that the maintenance of disposal channels in the LBOD area was very poor (Mangrio et al., 2015). It was observed that the channel was very shallow in depth with increased wetted perimeter (Soothar et al., 2015). This usually resulted in overtopping of water in the adjacent land that creates the problem (Chandio et al., 2013). As the flowing water is sediment free, it has more erosion ability when water passes through less stable and shallow soils which in turn some time erode the cross section of the disposal channel (Edwards & Glysson, 1999). There was no vegetation found in the bed and sides of the channel, but due to erosion its longitudinal slope was not as per design.

Maintaining these drain channels is the responsibility of farmers, but in practice this is not being done so as in the case of watercourse. The operation of tubewells varied during the period of study. The values of delivery performance ratio (DPR) suggested that six tubewells studied had higher ratios that ranged between 0.84 and 0.9, while two tubewells had very low DPR ratio. It was below 0.60 suggesting that they were discharging the drainage effluent at the rate less than the design discharge.

The overall efficiency of tubewells ranged between 16 and 29% which is very low, it reveals inefficiency of tubewell operation. The efficiency in terms of DPR and operational performance shows dual inefficiency in one parameter like defects on both sides of a coin. Tubewell operation as observed in the four months resulted in very less operational hours as compared to the design operation of 16 hours in a day.

The coefficient of variation values of operational efficiency of tubewells shows very poor performance as the value CV of mean values of operational performance is much greater than 0.3. The CV values of individual performance are also weak. By this performance the efficiency of tubewells in terms to lower down the water table is very unsatisfactory. The conveyance losses in disposal drain were dependent on the physical condition of channel and level of maintenance. The channels with good physical conditions have higher efficiency as compared to one with poorly maintained. It is worth mentioning here that the responsibility of maintaining disposal channels in terms of vegetation clearance and shallow excavation lies on the part of the farmer who in turn is the ultimate beneficiary same as in case of irrigation watercourse.

The study further revealed that disposal channels connecting tubewell and main drain had high efficiency that is attributed to very shallow channels having very short length, therefore any losses from these channels directly affect the adjacent land through seepage of saline water and are responsible to build up upper surface salinity. The drainage water through the disposal channel also frequently overtops its banks and directly diverts into the land. It is not possible to measure conveyance losses through the inflow outflow method on all disposal channels in the selected area; it is therefore advisable to use the average value of drainage efficiency factor for selected disposal channels in order to calculate the effective volume of water that is being disposed into the drain. It was observed that about 2.5 million cubic feet water was being lost through seepage from disposal channels; it reflects a huge quantity of water that can quickly affect the neighboring land. The discharge measurement at source and disposal point within the selected area reveal that volume that drain receives at source and from drainage tubewells, is not being properly disposed-off. The disposal rate varied with time during the study months.

In most cases quite significant volume seeped within the selected reach suggesting that the surface drains are less efficient in terms of carrying design quantities of water. The water that disappears within the reach again contributes the groundwater remained retarded within the drain due to high vegetation in it. The level of maintenance was observed to be very poor in surface drains resulting in reduced velocity of flow (Jasortia et al., 2009). The selected portions of two drains (Makhi Branch Drain and Sanghar-1R (S-1R) Drain) surveyed by walk-thru suggest high vegetation intensity ranging between 4-6 ft in height at the full bed width of surface drains in most of the portions. Due to the narrow path to drainage water, the flow velocity is reduced that creates a stagnant position raised water level in the drain. This requires attention by the government to take necessary measures. It was also witnessed that Sindh Irrigation and Drainage Authority (SIDA) has recently commissioned rehabilitation programs. The banks were in good condition with damaged berm at S-1R drain. Very thick vegetation was found in the bed of the channel reducing the drainage effluent flow. This condition was continuous at most of the portion of this drain. The maintenance of the berm and bank of the drainage channel was visible and they were found in good and factor conditions but thick vegetation which is the factor that directly influences the carrying capacity of the channel was dominant. The density of vegetation is clearly seen near culvert where all the channel geometry is full of vegetation.

Conclusions

The delivery performance ratio of drainage tubewells varies between 0.5 and 0.95. Thus the discharge of tubewells was not being delivered as per design. The average operational efficiency was calculated as 24%, whereas the value of coefficient of variation of tubewell operational efficiency is greater than 0.30 and leads up to 0.90, which shows high variability in operation. Groundwater was recharged in October, November and January and discharged in months of December, February and March of Rabi season. The disposal channels are 88% efficient in terms to carry the tubewell discharge into the main drain. This percentage is considered high in relation to the shorter length. These are very shallow channels having very short length. Therefore, the losses from these channels under study were estimated as 2.5 million cubic feet of drainage effluent which directly diverts to the adjacent land and builds up upper surface salinity. The drainage efficiency of surface drains was observed to be very poor. Drainage water losses were observed as 0.03, 0.09 and 0.06 million cubic feet of water from S-1R in the months of January, March and April, respectively. Similarly, in the month of February this drain drained out 0.05 million cubic feet of water from the study area, which is very less. The thick vegetation in main and branch drains has proved the strong factor to retard the velocity of flow by decreasing its discharge and increasing the depth of water in the drain.

Recommendations

There is a severe need to maintain disposal channels by providing design slope and cross-section to prevent drainage water from overtopping into the agricultural lands. This channel is the first that directly harms the adjacent land. Thick vegetation from main and branch drains should be removed regularly in order to provide a clear path to the drainage effluent to be passed on forward. Moreover, the longitudinal slope may be checked to maintain the regime of flow.

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