COMPARISON OF DIFFERENT METHODS FOR COMPUTING SEEPAGE LOSSES IN AN EARTHEN WATERCOURSE

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Abstract

Study was conducted on an earthen water course 1R Qaiser minor near Tando Jam. Aim of study was to compare two different methods of estimation seepage one was inflow–outflow and second was ponding method. Before study soil texture of bed of watercourse was analyzed which was varying from sandy soil to sandy loam, and bed slope was calculated with Autolevel which was 0.0002. Experiment was conducted on a straight reach of water course of 600 m length. This reach was divided into five sections of 120 m each. For inflow-out flow test reach inflow and reach outflow was measured by cut-throat flume. Ponding test was conducted over short sections of 30 m each in inflow-outflow sections of 120 m. Seepage loss was calculated 0.0016 m^3 per sec (LPS)/100 m by inflow-outflow test and 0.00123 m^3/100 m by ponding test. Ponding test measured water losses 23% less than inflow-outflow test. Reason of this difference may be over estimation of discharge through cut throat flume and under estimation of seepage loss through ponding test due to silt deposition in the water course, and actual seepage loss could be expected some where between these two.

Key words: seepage, inflow–outflow, cut-throat flume, Ponding

INTRODUCTION

Water is the basic input for crop production of the developing world. Seepage is defined as "the process of movement of water from the bed and sides of the canal into the soil".

Various methods are in use for the estimation of seepage from the proposed canals as well as it's measurement in the existing once. For proposed canals, seepage is usually estimated by empirical formulae or by graphical solution. Seepage from existing canals is usually evaluated by direct measurements various methods are used as inflow-outflow method, ponding method, seepage meter method are important.

In Pakistan seepage losses are usually high and are about 8 to 10 cusec per million square foot of the wetted area of the cross section and amounts to 35 to 40% of diversion into the canal. Studies carried out by the WAPDA indicate a total annual loss of 18.3 MAF (Iqbal, 2003) of valuable irrigation water to the ground from unlined canals and watercourses in Pakistan through seepage alone. This huge loss of supplies if prevented can irrigate approximately an additional 3.0 million acres annually.

The Indus river system is prime source of irrigation water in Pakistan. If we reduce the losses from canals and water courses more area can be cultivated.

It is estimated that about 25% water (26 MAF) is lost through canals, distributaries and minors. And about (45 MAF) water is lost from water courses through seepage, evaporation, transpiration and overtopping etc.

In Pakistan including Sindh province water management program is started from 1976–1977, which is known as "On Farm Water Management" main object of this program is to control the water losses, which are 40–50% in water courses, which is the cause of water logging and salinity. According to the announcement of Government of Pakistan 4000 watercourses will be lined in the 4th phase in four years. The remaining 29000 watercourses will be lined in crush program within next 4 years.

OBJECTIVES OF STUDY

To determine the rate of conveyance losses at a limited section of earthen water course.

The comparison of measurement of water losses with inflow-outflow and ponding method.

To check out the conveyance efficiency of earthen watercourse.

To determine the total quantity of water lost from earthen water course with seepage alone.

CALCULATION OF CONVEYANCE LOSSES

Ponding loss measurement method

The most dependable and reliable method for measuring the quantity of water loss through seepage from the existing canals in a particular reach is by the ponding method. It consists of constructions of a temporary water tight dyke of bulk head across the canal. The canal above the dyke is filled with water to a certain measured level. After allowing the water to stand for some time, the level of water in the canal is recorded. Any drop in the level is obviously due to seepage through the section of canal. The canal is then added sufficient quantity of water to maintain its original level.

This volume of water, which is measured accurately, is equal to the total seepage loss during the particular time interval. The volume of water divided by the time determines the rate of seepage loss through the canal.

Inflow–out flow loss measurement

We have used this method for measuring the conveyance losses. This method involves measuring the amount of water flows into a channel at inlet of the section and amount which flows out at the tail of the section when no water is being usefully directed between the two measuring points. The loss is the difference between these two measured points. The measurement can be either of total volumes of water or if the channel is flowing steadily with its little change in the measured flow rate at either end directly of flow rates.

To measure steady state (constant flow) conveyance losses in a channel section, the flow measurement devices should be installed at the beginning and end of the channel section. The same type and size of device should be used if possible, so that any biased errors in the devices are cancelled out. The flow should be monitored in both devices until the steady flow is obtained. The flow measurement device will generally change the depth of flow and channel storage upstream from the device, therefore five minutes to an hour may be required depending upon the slope of the channel / water course to reach constant measurements in a channel flow under steady state condition. If the flow in channel is fluctuating, It will effect the measurements at the head of the section earlier than the downstream measurement.

The loss can be represented either in the form as.

– A rate of decrease inflow rate per unit length of channel

$$Q_L = \frac{Q_1 - Q_2}{L} \quad (1)$$

Where:

Q_L = loss rate Lps/100 meter length

Q_1 = Flow rate in the upstream device (Lps)

Q_2 = Flow rate in the downstream device (Lps)

L = Length of the channel between the measurements 100 m

– In term of percent seepage loss.

$$\%\ \text{loss} = Q_L = \frac{(Q_1 - Q_2)}{(Q_1)} \times 100$$

– In terms of percent loss in flow per unit length of channel.

$$\frac{Q_{LP} - Q_2}{Q_1 \times L}$$

Where:

Q_{LP} = Loss rate (% per 100 feet)

– Conveyance efficiency = 100- water loss percentage.

INVESTIGATION OF SEEPAGE

The study on water losses by different methods has been carried out on an earthen water course (IR) of Qaiser minor near Tando Jam. Water course is located about 5 km in the east from Agriculture University. Before starting the measurement, the bed slope, operating surface water level, the conditions of water course and soil texture were determined. The measurement of seepage losses by inflow- outflow, and ponding methods were used. The reach of w/c was divided in to five test sections, and the length of each section was 120 m.

INFLOW-OUTFLOW METHOD

The two cut throat flumes having 8" × 1.5' sizes, one measuring tape, two sprit levels and two spades were used, while installing flumes it was necessary to reduce the discharge, in order to facilitate the easy fixation of flumes at sections the discharge measurements are given in Table 1. The bed slope of water course was measured with Autolevel the condition of water course section was recorded by visual observations. Soil type of water course sections was determined by collecting the soil samples from the bed of water course at 100 ft length, five samples were collected and soil texture was determine in the laboratory by sieve analysis.

FORMULAE USED FOR CALCULATING DISCHARGE BY CUT THROAT FLUME

$$Q_f = C_f \cdot hu^{nf} \quad (2)$$

f = Subscript denoting free flow

u = Subscript denoting upstream

Q_f = Free flow discharge rate

C_f = free flow coefficient L^{3-nf}/T; (from Table 4.1)

h_u = upstream flow depth L

n_f = free flow exponent, dimensionless (from Table 4.1)

$$Qs = \frac{Cs\,(hu - hd)^{nf}}{(-\log S)^{ns}} \quad (3)$$

Where

s = subscript denoting submerged flow

d = subscript denoting down stream

Q_s = submerged flow discharge rate L^{3-nf}/T

C_s = submerged flow coefficient L^{3-nf}/T

h_u = up stream head L

h_d = down stream flow depth L

n_s = submerged flow exponent, dimensionless (from Table 4.1)

S = submergence, dimensionless (S = hd/hu)

Tab. 1: Calculations of discharge through Cut throat flume

No	hu (Inch)	hd (Inch)	$S = \frac{hd}{hu}$	hu-hd (Ft)	Q (Cusec)	Q (Lps)	m^3/sec
Station A (Reach inflow)							
1	**6.3**	**5.5**	**0.87**	**0.066**	**1.07**	**29.96**	**0.02996**
2	**5.9**	**5.0**	**0.84**	**0.075**	**0.92**	**25.76**	**0.02576**
3	**5.4**	**4.4**	**0.81**	**0.083**	**0.811**	**22.71**	**0.02271**
4	**5.2**	**4.3**	**0.82**	**0.075**	**0.729**	**20.41**	**0.02041**
5	**6.0**	**5.8**	**0.96**	**0.016**	**0.6**	**16.8**	**0.0168**
Station B (Reach outflow)							
1	**6.2**	**5.5**	**0.88**	**0.058**	**0.96**	**27.0**	**0.027**
2	**5.9**	**5.4**	**0.91**	**0.041**	**0.845**	**23.66**	**0.02366**
3	**5.2**	**4.1**	**0.78**	**0.091**	**0.74**	**20.72**	**0.02072**
4	**4.9**	**4.2**	**0.85**	**0.058**	**0.673**	**18.79**	**0.01879**
5	**5.1**	**4.3**	**0.84**	**0.066**	**0.56**	**15.68**	**0.01568**

EXAMPLE FOR CALCULATIONS OF DISCHARGE

Station A

hu = 6.3 inch
hd = 5.5 inch
S = 0.87
hu-hd = 0.066 ft

$$\text{Formula} = Q = \frac{Cs(hu - hd)^{nf}}{(-\text{Log}\,S)^{ns}} \qquad (4)$$

nf

Where:
Cs = 1.606}
nf = 1.939} from Table 4.1
ns = 1.728}

$$Q = \frac{1.606(0.066)^{1.939}}{(-\text{Log})^{1.728}} = \frac{0.00282}{0.00784} = 1.07\text{ft}^3/\text{sec} = 29.96 \text{ lps}$$

Formula for seepage loss

$$Qs = \frac{Q_u - Q_d}{L/100} \qquad (5)$$

Where:
Qs = seepage rate (LPS/100m)
Q_d = reach outflow (LPS)
Q_u = reach inflow (LPS)
L = reach length (m)

PONDING METHOD

Measuring watercourse losses by the ponding method involves filling a section of channel at both ends and determining the decrease in the volume of water in the section over time. This volume decrease is determined by measuring the area of the surface of the ponded water (Top width times the section length) and the rate of recession of water surface. Table 3 the loss rate is taken per unit distance LPS/100 meters (CFS/1000 fit).

For conducting the ponding test, sections of 30 meters length was selected at every reach of 120 m, to check the variability in the result. No changes were made in the natural state of the watercourse such as sealing, leaking, insect holes or the disturbing the vegetation etc. Staff gauges were firmly inserted at the bottom of watercourse at a distance of 5 m in the section, for measuring the water depth changes. These gauges were inserted before the supply of water in the section.

While collecting the data other parameters which describes the conditions of test sections were measured. Width of each bank at osl was measured at six places with tape. Formula used for this method is as under:

$$Q\ (\text{lps}/100\text{m}) = \frac{dd}{dt} \times TW_A \times C \qquad (6)$$

Q = loss rate (lps/100m)
$\frac{dd}{dt}$ = rate of change of flow depth (cm/hr) obtained by graphical analysis
TW_A = average top width (cm)
C = conversion factor
= (1/3600) hr/sec × (1/1000) lit/cm^3 × (100) m × (100) cm/m = 0.0028

DISCUSSION

The data on water losses in an earthen watercourse 1R Qaiser minor was collected for soil type five soil samples were collected from the bed of water course at a depth of 20 cm each from a distance of 100 ft apart. The result is presented in Table 9, in which the bed of water course varies from sandy soil to sandy loam.

The bed slope of the watercourse was determined with Autolevel and it was 1:5 000, i.e. S = 0.0002.

The watercourse was not clean and fairly maintained there was some vegetation and grasses, there was no visible leakage. For conducting the inflow-outflow test a straight reach was selected at a distance of 60 m to 660 m from mogha (Table 2). This reach was divided into five sections of 120 m each.

Individual ponding measurements were made on the short sections of 30 m long within the inflow outflow sections of 120 m the data collected from these sections is presented in Table 3.

These tables show the loss of water within five selected sections. The loss of water varies in these sections as shown in Figure 1. The loss of water in five section measured with inflow outflow test was 2.40, 1.75, 1.65, 1.35 and 0.93 respectively. Figure 2 show the variation in loss of five sections by ponding test. Loss of water (LPS/100m) measured by ponding test for five sections were 1.47, 1.32, 1.23, 1.16 and 0.99.

One reason for the variability between ponding and inflow–outflow loss measurement may be that ponding test sections were of short lengths 30 m, these were 25% of the inflow-outflow test sections 120 m. If ponding test would be conducted on entire sections, the results may have been comparable.

The lower values of ponding measurements were due to deposition of silt in water course, resulting in low infiltration.

Ali et al. (1978) indicates that the flumes loss overestimates from 5 to 30% than the actual loss of the channel due to increase in depth of flow caused by head loss in the flume. This may be the reason of overestimation of discharge.

According to the result the quantity of water lost per km length of the watercourse with seepage only, was 2.255 LPS/100 m. This quantity of water lost per year will be 572 806 080 Lit/year or 579 282 m^3/year.

CONCLUSIONS

Results indicate that the average ponding loss measurement is 23% lower than the inflow-outflow loss measurement. This variability in ponding and inflow-outflow loss measurements ranged from 1.236 to 1.616 (LPS/100 m) respectively as represented in Figure 1.

Average water loss % age and conveyance efficiency of the watercourse calculated at a reach of 360 m is shown in Table 5. According to the result average water loss % age was 30.895, and conveyance efficiency was 69.105%.

Seepage loss rate was calculated in (ft^3/ft^2/day) by both methods – Table 6 show the Seepage loss rate (S.L.R) by inflow-outflow test according to the result average S.L.R was 2.665, in this way S.L.R was calculated by ponding test as shown in Table 7 and 8, result indicate that S.L.R by ponding test was 2.013, which is 24.5% less then measured with inflow-outflow test. Inflow-out flow test should be conducted at the time when flow is constant otherwise steady state condition would not be achieved and results would not be comparable to other method.

Vegetation, Trees and silt deposition should be removed for improving the conveyance efficiency of watercourse.

Rodent holes should be blocked for stopping water seeping through them.

Watercourse should be lined.

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Tab. 2: Inflow-outflow test on 1R w/c at Qaiser minor near Tando Jam

SR No:	Distance from mogha (m)	Section length L (m)	Flume size	Type of the flow	Q_u (LPS)	Type of the flow	Q_d (LPS)	$Qs = \frac{Q_u - Q_d}{L/100}$ (LPS/100m)	m^3/sec/100m
1	60–180	120	8"×1.5'	S.F	29.06	S.F	27.0	2.40	0.0024.
2	180–300	120	8"×1.5'	S.F	25.76	S.F	23.66	1.75	0.00175
3	300–420	120	8"×1.5'	S.F	22.71	S.F	20.72	1.65	0.00165
4	420–540	120	8"×1.5'	S.F	20.41	S.F	18.79	1.35	0.00135
5	540–660	120	8"×1.5'	S.F	16.80	S.F	15.68	0.93	0.00093

Tab. 3: Ponding test on 1R water course at Qaiser minor near Tando Jam

Sr No:	Section length (m)	Test section (m)	Loss rate $\frac{dd}{dt}$ (cm/hr)	Top width TW_A (cm)	Loss rate $\frac{dd}{dt} \times TW_A \times C$ (LPS/100m)	m^3/sec/100m
1	60–180	30	3.9	135.0	1.47	0.00147
2	180–300	30	3.6	132.0	1.33	0.00133
3	300–420	30	3.4	129.4	1.23	0.00123
4	420–540	30	3.2	130.2	1.16	0.00116
5	540–660	30	2.7	131.0	0.99	0.00099

Tab. 4: Percent water loss (Q) and loss/100m, length of water course IR-Qaiser minor

S. No.	Dist. From St. A–B (m)	Discharge in m^3/sec		Water loss (Q) m^3/sec	Water loss % age	Loss in cumec per 100 m	% loss per 100 m
		Q_u	Q_d				
1	360	0.02996	0.02072	0.00924	30.84	0.000256	8.56
2	360	0.02271	0.01568	0.00703	30.95	0.000195	8.59
Average				0.008135	30.895	0.0002255	8.575

Tab. 5: Conveyance Efficiency of Water Course. w/c 1R Qaiser minor

S. No.	Distance A–B (m)	Discharge in m^3/sec		Water loss (Q) m^3/sec	Water loss % age	Conveyance effiecency C.E (% age) C.E=100-W.L%AGE
		Q_u	Q_d			
1	360	0.02996	0.02072	0.00924	30.84	69.16
2	360	0.02271	0.01568	0.00703	30.95	69.05
Average				0.008135	30.895	69.105

Tab. 6: Cross section of water course and wetted area Water course 1R Qaiser minor

S. No.	Distance from the station L (m)	Bed width B (m)	Depth of flow in the cross section				Av: Depth of flow d (m)	Wetted Perimeter P = B + 2d (m)	Wetted area Pa Pa = P × L (m^2)
			d_1 (m)	d_2 (m)	d_3 (m)	d_4 (m)			
1	60–180	1.335	0.196	0.196	0.193	0.192	0.194	1.723	206.76
2	180–300	1.305	0.212	0.215	0.205	0.215	0.212	1.729	207.48
3	300–420	1.312	0.203	0.207	0.207	0.201	0.205	1.722	206.64
4	420–540	1.295	0.220	0.210	0.220	0.221	0.218	1.731	207.72
5	540–660	1.320	0.221	0.221	0.225	0.225	0.223	1.766	211.92

Tab. 7: Seepage loss rate by inflow-out flow method w/c 1R Qaiser minor

S. No.	Test section	Discharge channel m^3/sec		Water crosses (Q) CYMIC	Wetled area Pa m^2	S.L.R m^3/m^2/day
		Q4	Q1			
1	60–180	0.02996	0.0270	0.00296	206.76	1.230
2	180–300	0.02576	0.02366	0.00210	207.48	0.874
3	300–420	0.02271	0.02072	0.00199	206.64	0.832
4	420–540	0.02041	0.01879	0.00162	207.72	0.673
5	540–660	0.0168	0.01568	0.00112	211.92	0.456
Average						0.813

Tab. 8: Seepage loss rate by Ponding method water course 1R Qaiser minor

Sr. No .	Length of section L (m)	Average depth of water D (m)	Average width B (m)	Wetted perimeter P = B + 2d (m)	Wetted area Pa Pa = P × L (m^2)	Loss rate $\frac{dd}{dt}$ (m/hr)	Volume of water lost $hr = \frac{dd}{dt} \times B \times L$ (m^3/hr)	S.L.A.= $\frac{vol}{Pa}$ (m^3/m^2/day)
1	30	0.195	1.350	1.740	52.20	0.039	1.579	0.726
2	30	0.207	1.320	1.734	52.02	0.036	1.425	0.657
3	30	0.205	1.294	1.704	51.12	0.034	1.310	0.615
4	30	0.202	1.302	1.706	51.18	0.032	1.249	0.585
5	30	0.215	1.310	1.740	52.2	0.027	1.061	0.487
Average								0.614

Tab. 9: Soil texture analysis

Sections	Sand (%)	Silt (%)	Clay (%)	Texture class
1	88.0	8.0	4.0	Sandy
2	86.0	8.0	6.0	Sandy
3	58.0	27.4	14.6	Sandy loam
4	61.5	23.0	15.5	Sandy loam
5	60.0	20.5	19.5	Sandy loam

Tab. 10: Topographic survey of water course IR Qaiser Minor

Station	B.S	H.I	F.S	Elevation	Remarks
	1.24	11.24			TBM1.on Paka structure +l0 m assume
0+00			1.87	9.37	FSL of w/c
			2.30	8.94	Bed of w/c
0+50			1.88	9.36	FSL of w/c
			2.31	8.93	Bed of w/c
1+00			1.8875	9.3525	FSL of w/c
			2.325	8.915	Bed of w/c
1+50			1.895	9.3475	FSL of w/c
			2.33	8.91	Bed of w/c
			0.755	10.485	TBM:2 on trunk of tree
2+00			1.91	9.33	FSL
			2.39	8.85	Bed
2+50			1.925	9.315	FSL of w/c
			2.41	9.83	Bed of w/c
	1.55		1.4	9.84	Tp1. on a wooden Peg
		11.39			New H.I
3+00			2.08	9.31	FSL of w/c
			2.53	8.86	Bed of w/c
3+50			2.8875	9.3025	FSL of w/c
			2.54	8.85	Bed of w/c
4+00			2.1025	9.2875	FSL of w/c
			2.51	8.88	Bed of w/c
			1.65	9.74	TBM.3: on a brick
4+50			2.1175	9.2725	FSL of w/c
			2.53	8.86	Bed of w/c
5+00			2.13	9.26	FSL of w/c
			2.52	8.87	Bed of w/c
5+50			2.135	9.255	FSL of w/c
			2.55	8.84	Bed of w/c
6+00			2.14	9.25	FSL of w/c
			2.54	8.85	Bed of w/c

$$\text{Slope} = \frac{\text{Elevation at first station} - \text{Elevation at last station}}{\text{Total distance}} = \frac{9.37 - 9.25}{600} = \frac{0.12}{600} = 0.0002 \text{ m/m}$$

Figure 1: Comparison of water losses by inflow outflow and ponding methods

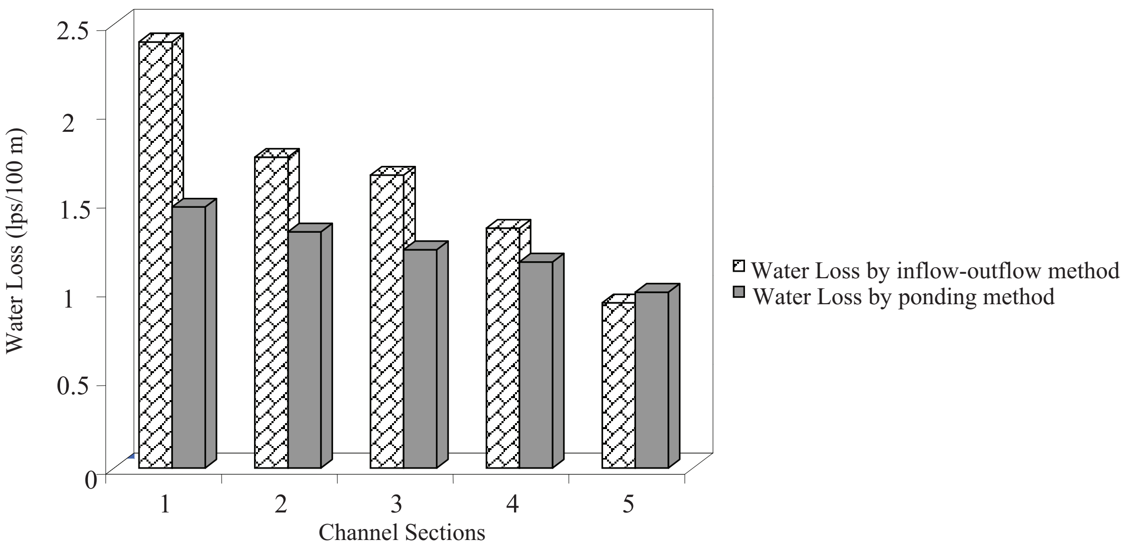


Figure 2: Comparison of seepage loss rate by inflow-outflow and ponding methods

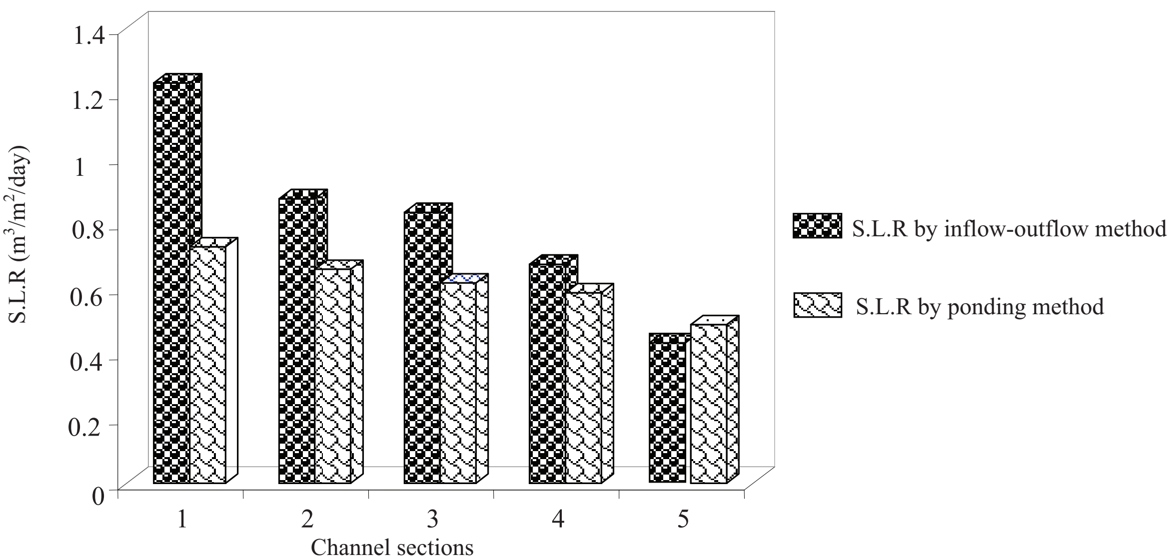


Figure 3: Loss rate as a function of discharge

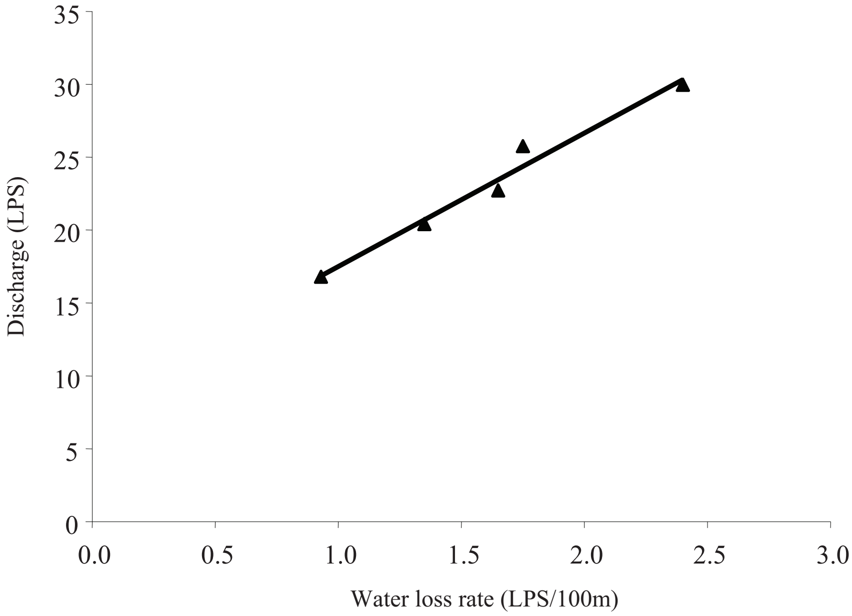
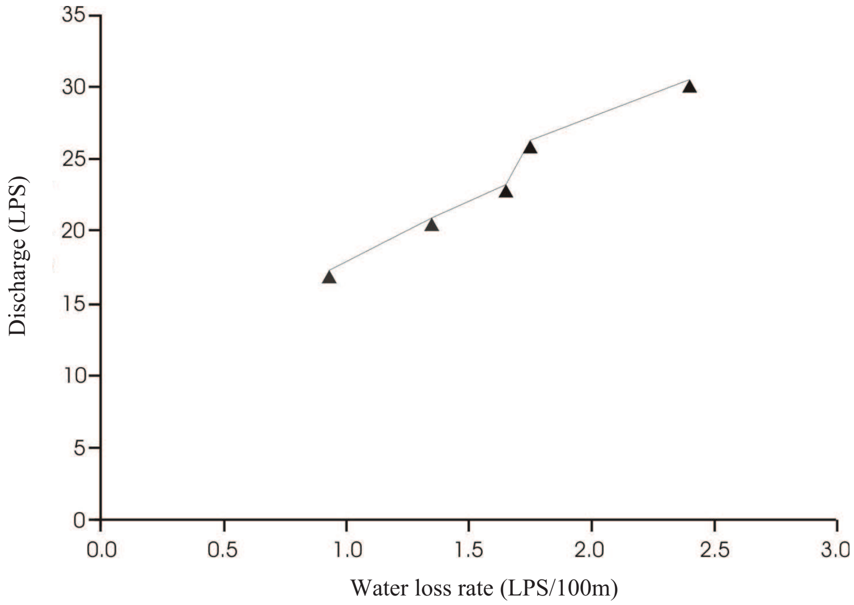


Figure 4: Loss rate as a function of discharge



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