Report No. R-24

MANAGING IRRIGATION FOR ENVIRONMENTALLY SUSTAINABLE AGRICULTURE IN PAKISTAN

SURFACE IRRIGATION METHODS AND PRACTICES

Field Evaluation of the Irrigation Processes for Selected Basin Irrigation Systems During Rabi 1995 - 96 Season, Punjab, Pakistan

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Foreword

This report entails the synthesizing and evaluation of the field data on irrigation practices for small bunded fields (basin irrigation systems), collected from sample fields in three command areas of Fordwah and Azim distributaries, which encompass the tail reach of the Fordwah Eastern Sadiqia Irrigation System. The data were collected during the wheat season Rabi '95 - '96. The data collection activities are part of IIMI's research on Surface Irrigation Methods and Practices.

I would like to express my gratitude to Dr. M.S. Shafique for his continuous feedback during the analysis of the field data and sharing his long time field experience with me. I would like to thank Prof. G.V. Skogerboe for editing the report in so much detail and providing me new suggestions. Last, I would like to express my appreciation to the field team working with me, stationed at IIMI's field station in Hasilpur -- Hafiz Nafees, Hamid Mehmood and Nadeem Sarwar -- for all their time and effort in collecting the field data with so much care and dedication.

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Introduction

This field report entails the outcome of the field research activities on ***Surface Irrigation Methods and Practices***, based on the data collected during the Rabi 1995-1996 irrigation season. The research forms part of IIMI's program on Irrigation Methods and Practices which forms part of the Watercourse Management Sub-component under the Netherlands Govt. Grant Project ***Managing Irrigation for Environmentally Sustainable Agriculture in Pakistan***. The main focus, as elaborated in its short and long term objectives is: (i) ***the application of surface irrigation simulation technology to small bunded fields;*** (ii) ***the assessment of irrigation performance at the field (and farm) level***; and (iii) ***the development of improved surface irrigation methods and practices for water and salinity management, which are applicable to irrigated agriculture in Pakistan***.

Under the research on Irrigation Methods and Practices, other research activities are undertaken: (i) Testing of Low-Cost Pressurized Irrigation Systems at Malik Ghulam Hussain Farm near Hasilpur in collaboration with the Water Resources Research Institute (WRRI) in Islamabad; (ii) Surface Irrigation Scheduling at the Ali Tareen Farm, located near Lodhran, where field activities are undertaken by a national student of the Center of Excellence in Water Resources Engineering, University of Engineering and Technology, Lahore; (iii) simple flow measuring techniques, such as measurement of tubewell discharges by Pitot tube, determination of discharges in rectangular channels, and the calibration of a Vane Flow Meter to measure discharges; and (iv) socio-economic research on the adaptability of improved irrigation methods and practices, undertaken by one international student (Wageningen Agricultural University) and two national students (University of Agriculture, Faisalabad).

At present, the research on Surface Irrigation Methods and Practices has a focus on: (i) the surface and subsurface irrigation processes during the different irrigation events (i.e. the advance and infiltration and the factors which influence these processes under the traditionally used irrigation systems); (ii) the soil moisture behavior; and (iii) the simulation of these processes through an irrigation simulation software program (SIRMOD), developed by the Department of Biological and Irrigation Engineering, Utah State University (USA) in order to evaluate the field irrigation performance in terms of application efficiency, storage efficiency and distribution uniformity. The software provides three options, based on the assumptions used for solving the Saint-Venant Equations: (i) hydrodynamic model; (ii) zero-inertia model; and (iii) kinematic wave model. Although preliminary analyses have been conducted, the model verification awaits a more comprehensive set of field data and a more in-depth study on calibrating the empirical parameters[1]. For the traditional irrigation systems, Ph.D. research will be carried out by a Pakistani student on the "Application of Zero-Inertia Technique for the Design and Management of Existing Small Basin Irrigation Systems in Pakistan".

In the near future (Kharif '97), there will be in-depth focus on the bed & furrow irrigation system, which is considered as a less commonly used irrigation method in Pakistan. The focus will be on the possibilities of adapting this method by the farmers on a larger scale, where improved operation and management strategies will be proposed in order to achieve: (i) a more efficient use of canal water (i.e. to reduce the use of -often of poor quality- tubewell water); and (ii) an increase of crop productivity through improved irrigation operation and management at the farm. During Kharif '96, some existing bed & furrow irrigation systems have already been monitored; the results will be synthesized in a later report.

In this report, all of the field data being synthesized and analyzed are of fundamental importance for the model simulation and can provide insights for further improving the data collection activities.

The following sections discuss: (i) research specifications; (ii) cultural and irrigation practices; (iii) discharge data; (iv) advance behavior; (v) infiltration behavior; and (vi) soil moisture behavior.

[1] The empirical parameters to be calibrated are the Manning's Roughness Coefficient 'n', and the parameters 'k', 'a' and 'f_o' of the Modified Kostiakov Infiltration Equation.

Research Specifications

Research locale

This research program has been undertaken in one of IIMI's* research sites in Pakistan. It concerns the Fordwah-Eastern Sadiqia Irrigation System, which has two main canals (Fordwah and Eastern Sadiqia) taking off from the left bank of the Suleimanki Headworks, located on the Sutlej river. Fordwah canal bifurcates into Fordwah Branch Canal and MacLeod Ganj Branch Canal (IIMI, 1996). Each branch has many distributaries allocating the water between the *moghas* (outlets) to the watercourse channels. IIMI's research site with respect to Watercourse Management is confined to the command areas of Fordwah, Azim and Mehmood distributaries which are at the tail of the Fordwah Branch Canal. From an administrative point of view, the area encompassed by these distributaries forms part of the Chistian Sub-division. For the research on Surface Irrigation Methods and Practices, three watercourse command areas (W/C) of the Fordwah and Azim distributaries have been selected: W/C Fordwah 14-R; W/C Fordwah 62-R; and W/C Azim 111-L, respectively.

Methodology

The field research activities form a main core of the research. During the Rabi '95-'96 irrigation season, sample fields were selected for collecting the irrigation related data for each irrigation event. The irrigation data collection activities are elaborated in Table 1.

Table 1: Surface irrigation field data collection.

Irrigation Data	(i) Irrigation duration for one field; (ii) Advance trajectory; (iii) End of advance time; (iv) Time of recession; (v) Water level at cutoff time (t_{co}) and (vi) the ponding water level afterwards at the head and tail of the sample fields.
Soil Moisture Data	Sampling of the soil at four different depths (6",12",24" and 36") at the head and tail of the sample field; before and after an irrigation event.
Discharge data	A current meter is placed at three fixed locations in a rigid rectangular channel. The number of revolutions per 50 seconds of the current meter are noted.

Sample farms and fields

For this research, three sample farmers were selected. The basic selection criteria was to obtain a diversity in soil characteristics. From a practical point of view it was convenient that there was no overlap in the warabandi timings. Additionally, farmer's approval was required for performing the monitoring of the irrigation practices. Some of the farm characteristics are presented in Table 2.

Table 2: Characteristics of selected farms for monitoring surface irrigation practices.

Location	Farmer	Tenure type	Area (kila)	Warabandi
W/C Fordwah 14-R	M. Yasin	tenant	12.5	Thu. 12.46-16.53
W/C Fordwah 62-R	A. Majeed	owner	10	Tue. 12.00-14.30
W/C Azim 111-L	M. Nawaz	lessee	6	-none-

Note: 1 kila ± 1 acre.

The tail-end area of Azim Distributary does not generally receive any water. For this reason, the sample farmer in W/C Azim 111-L entirely relies on tubewell water, which he rents from the actual owner of the landholding.

For the research, two sample fields were selected at each farm. Table 3 presents the sample fields.

Table 3: Sample fields for monitoring surface irrigation practices.

Location	Field	Number (block/square/kila)	Field length (m) x width (m)	Crop
W/C Fordwah 14-R	3	550/01/14	58.40 x 17.50	wheat
W/C Fordwah 14-R	33	550/01/21	60.25 x 14.30	wheat
W/C Fordwah 62-R	8	352/9/4	57.10 x 17.30	wheat
W/C Fordwah 62-R	17	352/9/7	59.80 x 16.05	wheat
W/C Azim 111-L	4	173/15/18	71.35 x 62.05	wheat
W/C Azim 111-L	6	173/15/22	66.65 x 37.90	wheat

Note: Field 17 will not be used for further analysis.

Soil characteristics

The soil characteristics determine to a large extent the infiltration behavior in the sub-surface and, consequently, the advance and recession behavior. Additionally, certain soil characteristics determine the water holding capacity of a soil and are needed for the determination of the soil moisture deficit (SMD). Figures on specific weight of the soil particles and volumetric moisture content at field capacity for each soil type are required for calculating the SMD. In July 1996, a team of the Soil Survey of Pakistan (SSP) took undisturbed soil samples from these sample fields. The results are presented in Annexure 1. The data will be discussed later in this report.

Additionally, SSP undertook in collaboration with IIMI-Pakistan a detailed soil survey of eight watercourse command areas in the Chistian and Hasilpur Tehsils. The soil characteristics for the sample fields, listed in Table 3 are described in Table 4, which are mostly based on the findings of this survey (SSP, IIMI, 1996).

Table 4: Soil classification of the sample fields.

Location	Field	Soil name	Surface soil texture	Subsoil texture
W/C Fordwah 14-R	3	Haroonabad fine sandy loam	Fine sandy loam	Loams
W/C Fordwah 14-R	33	Bagh loam	Loam	Silt loams/ very fine sandy loam
W/C Fordwah 62-R	8	Rasulpur loam *'disturbed soil'*	Loam	Sandy loams/ fine sandy loams
W/C Fordwah 62-R	17	Rasulpur loam *'disturbed soil'*	Loam	Sandy loams/ fine sandy loams
W/C Azim 111-L	4	Nabipur loam with alkali crust	Loam	Loams
W/C Azim 111-L	6	Nabipur loam with alkali crust	Loam	Loams

Initially, Fields 8 and 17 were selected as lighter soils; however, the infiltration characteristics were more similar to a heavier soil. Being in the field with SSP, this phenomenon was checked; SSP concluded that both fields were 'disturbed soils', which are quite common in this area. According to the farmer, their grandparents used to tell the story that:

"In the past, the water used to come straight from the river (before the English made this irrigation system). An old river channel used to pass these fields. Whenever the water level was high in the channel, the area around the channel was inundated. After building the irrigation system, this channel was leveled and filled with sand, which caused this mixture of soil types. There may be more remainders of the old times" (field note July '96).

According to the SSP field team, this type of old channel contours have been identified on aerial photographs (in 1951). The profile of the disturbed soil is presented in Table 5 (the pit was excavated and interpreted by the SSP team).

Table 5: Soil types of a disturbed soil (Field 8).

Horizon	Depth (cm)	Soil Type
AP	0-18	Loamy
BW1	18-35	Very fine sandy loam
BW2	35-45	Silty loam
2BW3	45-95	Sandy loam
BW4K	95-120	Very fine sandy loam
BC	120-150	Sandy loam
C	150-	Loamy-sand

Some direct observations during the sampling: (i) dark layer at about 50 cm implied an Ap layer, which once was at the surface; (ii) it is a moisturized soil; and (iii) no water saturation, the profile is dry.

The pit at Field 3 showed a loamy profile up till 47 cm. The BC layer (47-80 cm) is of very fine sandy loam, and the C layer (80-113) of mainly loamy-sand. Over the depth, the measured pH is 8.2. The profile is moisturized throughout the depth of the pit. A low water table was identified (at 100 cm).

The pit at Field 6 showed a loamy profile up till 71 cm, followed by a very fine sandy loam (C1 layer; 71-111). The C2 layer (111-150 cm) is mainly sand. The measured pH was 8.4 for the first 30 cm; 8.3 at 30-71 cm and 8.2 for 71-150 cm. This soil has an alkali crust with a pH of 8.6-8.8.

Salinity problems do not seriously occur at our sample fields; however overall high pH values indicate that the soil quality is not very good. The frequent use of tubewell water might be a cause of this phenomenon. As additional information, Annexure 2 shows data on pH, ECe, soluble ions, SAR and ESP for the sample fields.

Meteorological data

The climate in the south of Punjab is arid to semi-arid. During Rabi '95-'96, three rains did occur in the research area, elaborated in Table 6.

Table 6: Rainfall data (p) in the research area during Rabi '95-'96.

Date	W/C Fordwah 62-R p (mm)	W/C Azim 111-L p (mm)
25-02 '96	8.2	8.1
18-03 '96	16.9	14.7
22-03 '96	3.4	3.9

Source: Cylinder data (IIMI).

Temperature data are obtained from Bahawanagar and Bahawalpur Meteorological Stations for the period November '95 - April '96 (Rabi '95-'96), which are presented in Table 7.

Table 7: Minimum and maximum temperatures at Bahawanagar and Bahawalpur.

Month	Bahawalnagar	Bahawalnagar	Bahawalpur	Bahawalpur
	Max. temp. °C	Min. temp. °C	Max. temp. °C	Min. temp. °C
November '95	29.2	13.1	29.6	11
December '95	22.2	8.9	23.0	7.3
January '96	20.2	6.5	21.5	5.7
February '96	23.3	10.1	24.2	8.5
March '96	28.3	16.7	29.2	14.8
April '96	36.7	19.2	36.2	18.4

Source: Regional meteorological center, Lahore.

Cultural and Irrigation Practices

During the entire season, farmers are occupied with on-farm activities in order to maintain the land, apply the irrigations and to apply the necessary fertilizers and chemicals in order to achieve the best possible yield. Some observation were made about the activities of the sample farmers during the Rabi '95-'96 irrigation season.

The farmer has divided the landholding into small bunded units or basins. The number of bunded units per acre (or *kila*) varies. Farmer Nawaz, who has his landholding in W/C Azim 111-L, has divided his six acres into eleven bunded units. For the wheat crop, the farmer made large bunded units of almost one acre. Also some smaller bunded units (less than half an acre) were made for cultivating wheat. One small bunded unit was made for the cultivation of onion and melon on beds, in which the water was applied through furrows (bed & furrow irrigation system). Two small bunded units were made for the cultivation of fodder crop. Farmer Majeed, who has his landholding in W/C Fordwah 62-R, has divided his landholding into twenty-four bunded units. Basically, he divided each acre into about four bunded units of about the same size. He mainly cultivated wheat during the Rabi '95-'96 season. Some fields were left fallow and on some fields fodder and grams were cultivated. Yasin, who has his landholding in W/C Fordwah 14-R, has divided his land into fifty-nine bunded units, with a number of bunded units ranging between three to five per acre. On almost all of the land, wheat was cultivated. A few bunded units were used for fodder crop, vegetables and sugarcane.

The bunds surrounding the fields are shaped after the first irrigation by means of a plow, which creates a small furrow near the bund. The height of the bunds are about one foot and often are made stronger; otherwise, the bunds are washed away by the irrigation water. However, leakage through the bunds have been observed during the season.

Each bunded unit has one or sometimes two field inlets, called *nakka*, made of soil "*kachcha nakka*" or concrete "*pacca nakka*". The *nakka* is opened when the farmer wants to irrigate the field. The general practice is that before closing the *nakka* of the field being irrigated, the farmer opens first the *nakka* of the following field to be irrigated, before closing the *nakka* of the irrigated field.

Box 1, 2 and 3 summarizes the irrigation applications and crop development for the sample fields during the season. The date of sowing, harvesting, the irrigation interval and occurred rainfalls are included.

The wheat season starts around November with applying a soaking irrigation (rouni irrigation), mostly when the cotton is still on the field, and ends towards late April when the harvest of the wheat takes place. Another rouni irrigation is sometimes applied before the seeds are sown. Before the sowing of the wheat starts, some cultural practices do occur on the field. With a rutavator the remaining roots from the crop of the previous season are removed from the soil. Next, several ploughings (mostly two times) and plankings (one or two times) are done in order to make the soil homogeneous and loose and to level the field. These activities are done by animal traction and/or by a tractor which has been temporarily hired by the farmer. Some of these cultural practices are repeated during the season. In the stage when the crop is not high, a plowing is done in order to remove the weeds and the soil becomes loose again. Because of these activities, small corrugations are created due to the shape of the plow. The first fertilizers are applied along with the first irrigation. Both the application of fertilizers and chemicals are repeated during the season.

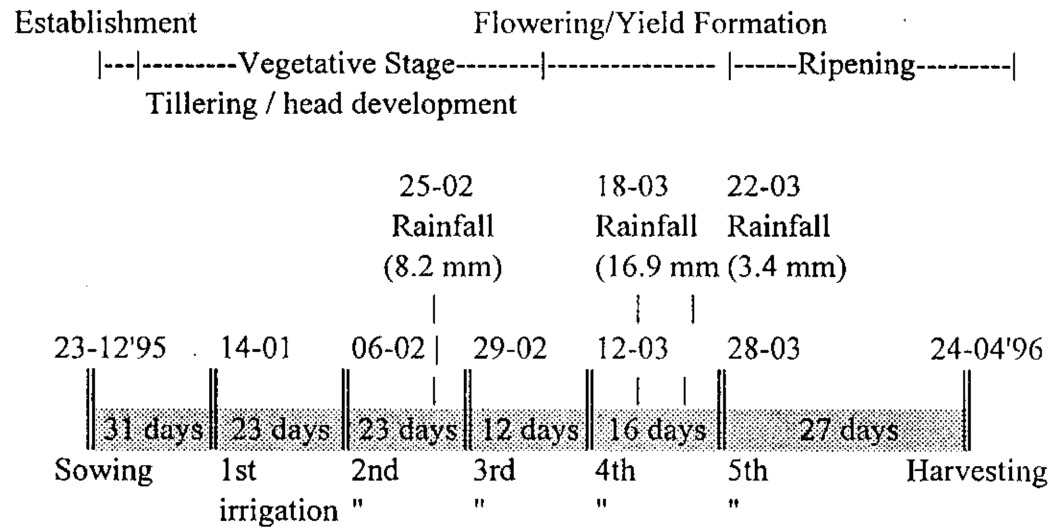
The first irrigation is applied between two weeks and one month after the day of sowing (sample farmers). The number of irrigation events is around 5 to 6 per wheat season. It can be observed from the presented boxes that two irrigations are applied during the vegetative stage, which often covers the third irrigation as well; one during the flowering stage; one during the yield formation stage; and one or two during the ripening stage. Concerning Field 3 and 8, it has not been clear whether a sixth irrigation was applied or not.

Table 8 presents some yield data of the sample fields. These data were additionally collected. Three samples were taken at the head, middle and tail of each sample field. One sample covers one square meter. The samples were weighed and the results were extrapolated for the whole field into maunds per acre (1 maund equals 40 kg).

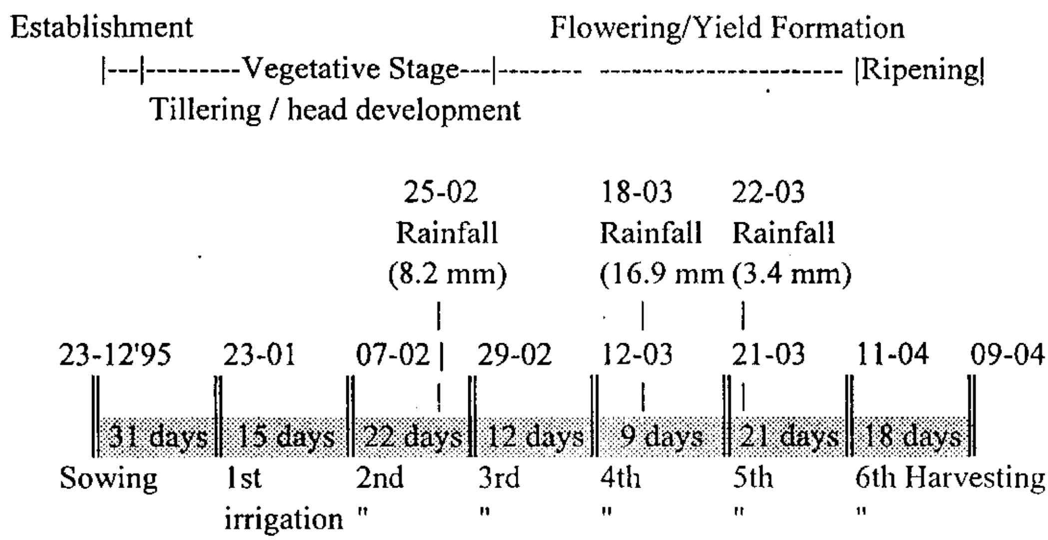
From the results, the wheat yields for Fields 3 and 8 are above average, while Field 33 is more close to an average yield. The average yield is considered to be around 20-25 maunds per acre. Fields 4 and 6 show very low yields. From field observations, towards the end of the season, the crop at this farm was affected by a virus which damaged the crop tremendously.

Box 1: Irrigation applications and crop development for Fields 3 and 33.

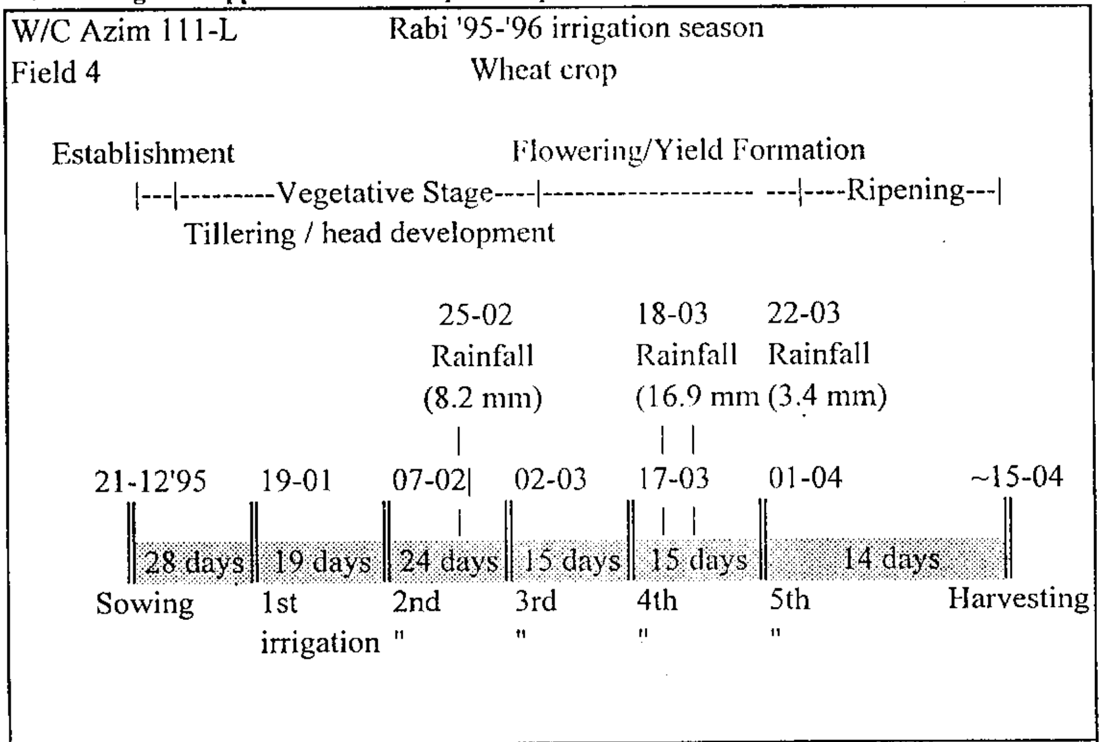
W/C Fordwah 14-R — Rabi '95-'96 irrigation season
Field 3 — Wheat crop

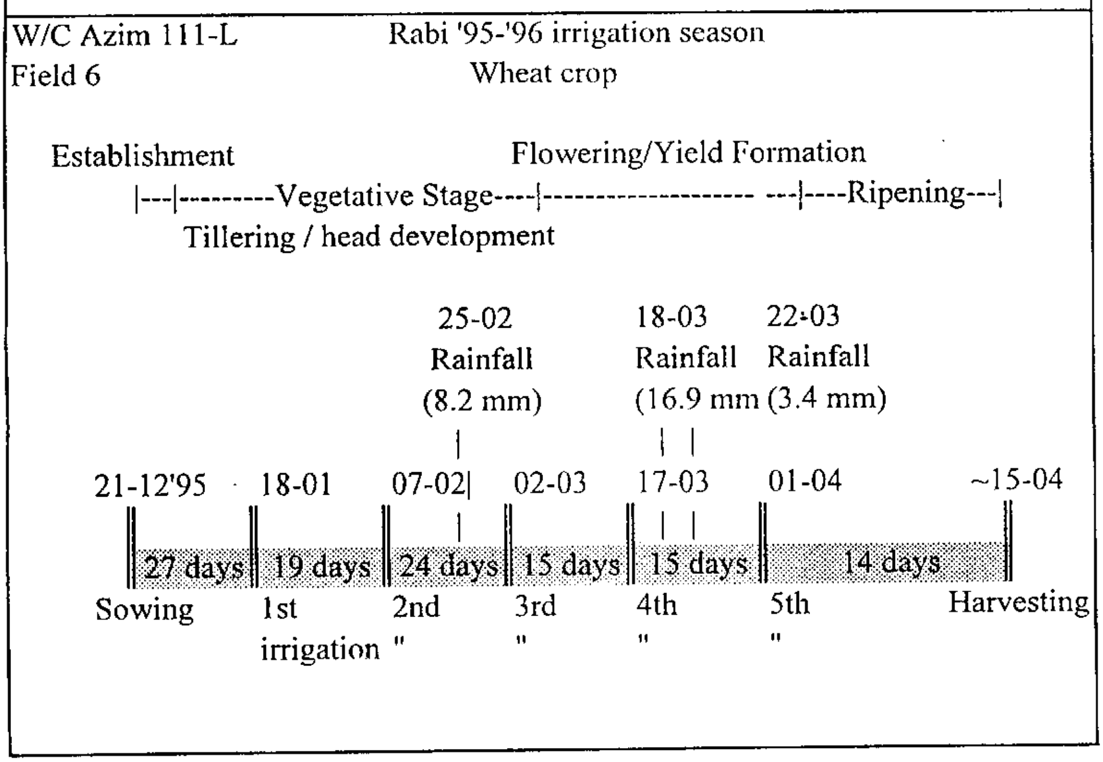


W/C Fordwah 14-R — Rabi '95-'96 irrigation season
Field 33 — Wheat crop



Box 2: Irrigation applications and crop development for Fields 4 and 6.





Box 3: Irrigation applications and crop development for Field 8.

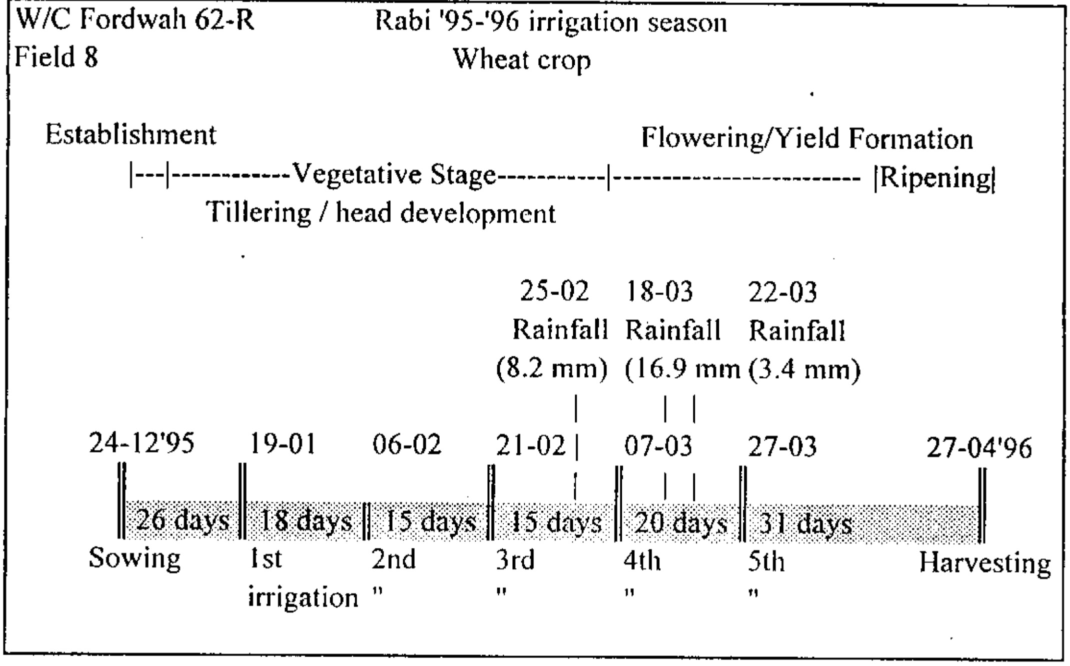


Table 8: Rabi '95-'96 wheat yields for the sample fields.

	Location	Weight (g/m2)	Avg. yld. (g/m2)	Area (m2)	Tot. yld. (kg)	Tot. yld. (maund	Tot. yld (maund/acre)
Field 3	Head	277.26	358.71	1,022	366.61	9.17	36.29
"	Middle	340.72					
"	Tail	458.16					
Field 33	Head	242.13	269.86	661.58	178.53	4.46	27.30
"	Middle	263.41					
"	Tail	304.04					
Field 8	Head	480.09	472.91	987.83	467.15	11.68	47.85
"	Middle	495.96					
"	Tail	442.68					
Field 4	Head	212.01	188.19	4,427.27	833.17	20.83	19.04
"	Middle	175.9					
"	Tail	176.66					
Field 6	Head	244.41	207.73	2,526.04	524.74	13.12	21.02
"	Middle	231.25					
"	Tail	147.54					

Discharge Data

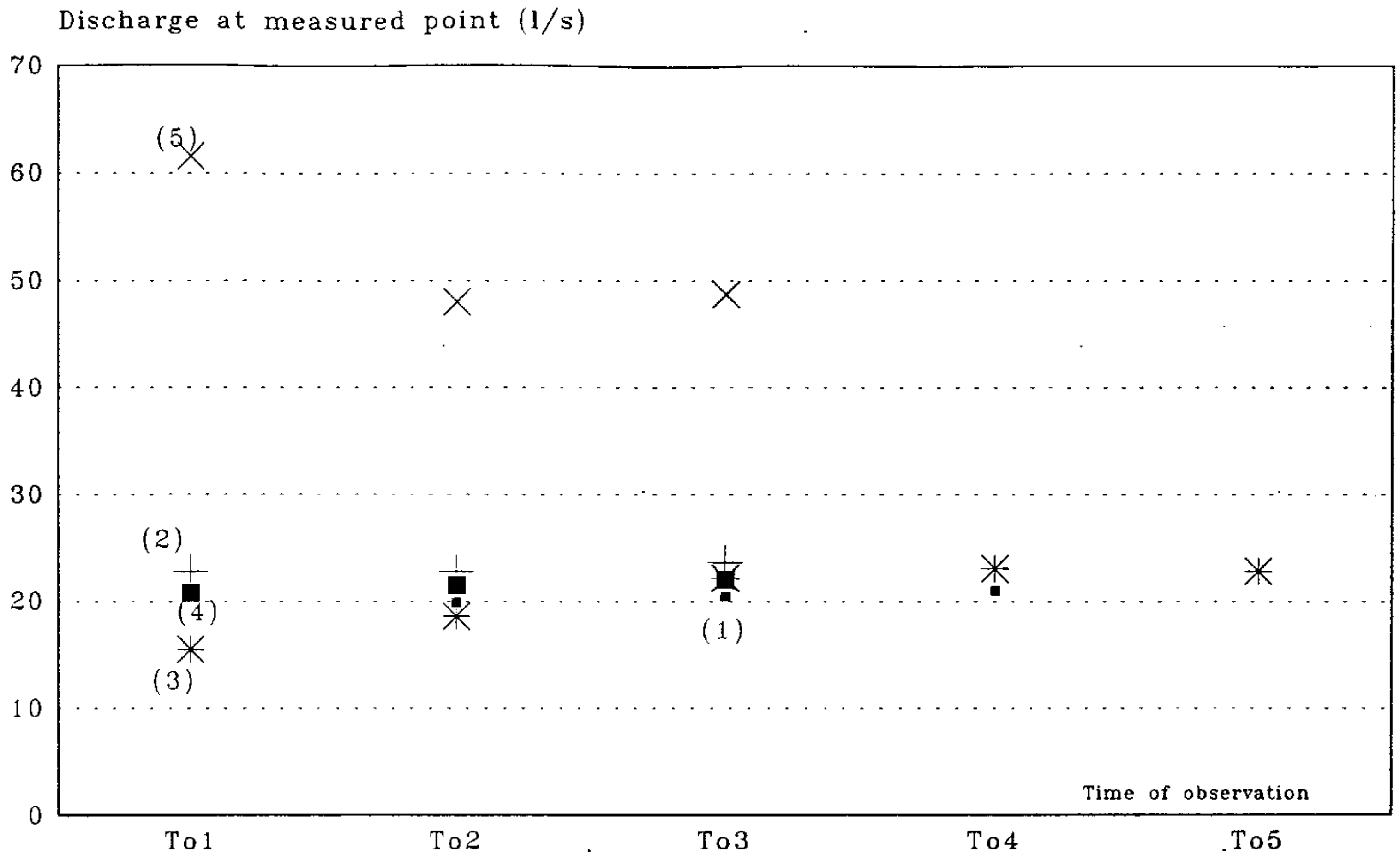
Discharge calculations

In the farm or watercourse channel, the revolutions per 50 seconds of a current meter placed at three fixed locations in a rigid rectangular channel were noted during the time that the sample field was irrigated. Basically, observations took place whenever the water level changed. At that time new measurements were taken. Sometimes, an interval was kept as an indication for measurement. The measurements were taken at 0.4 of the observed water depth at three locations along the width of the channel (i.e. right, center and left side, respectively). A calibrated rating table for the current meter was used for converting the number of revolutions into velocity. The discharge is obtained by multiplying the velocity with the cross sectional area (width of rectangular flume multiplied by the water depth). These calculations have been completed for the sample fields and are graphically presented in Figures 1 - 5.

From the graphs it can be observed that variations in the discharge do occur during the irrigation event; however, in most of the cases, the variation is not significant. On some occasions, only one measurement was obtained, related to practical reasons. Table 9 presents the average discharge (Q) and the standard deviation (Std) for each monitored irrigation event.

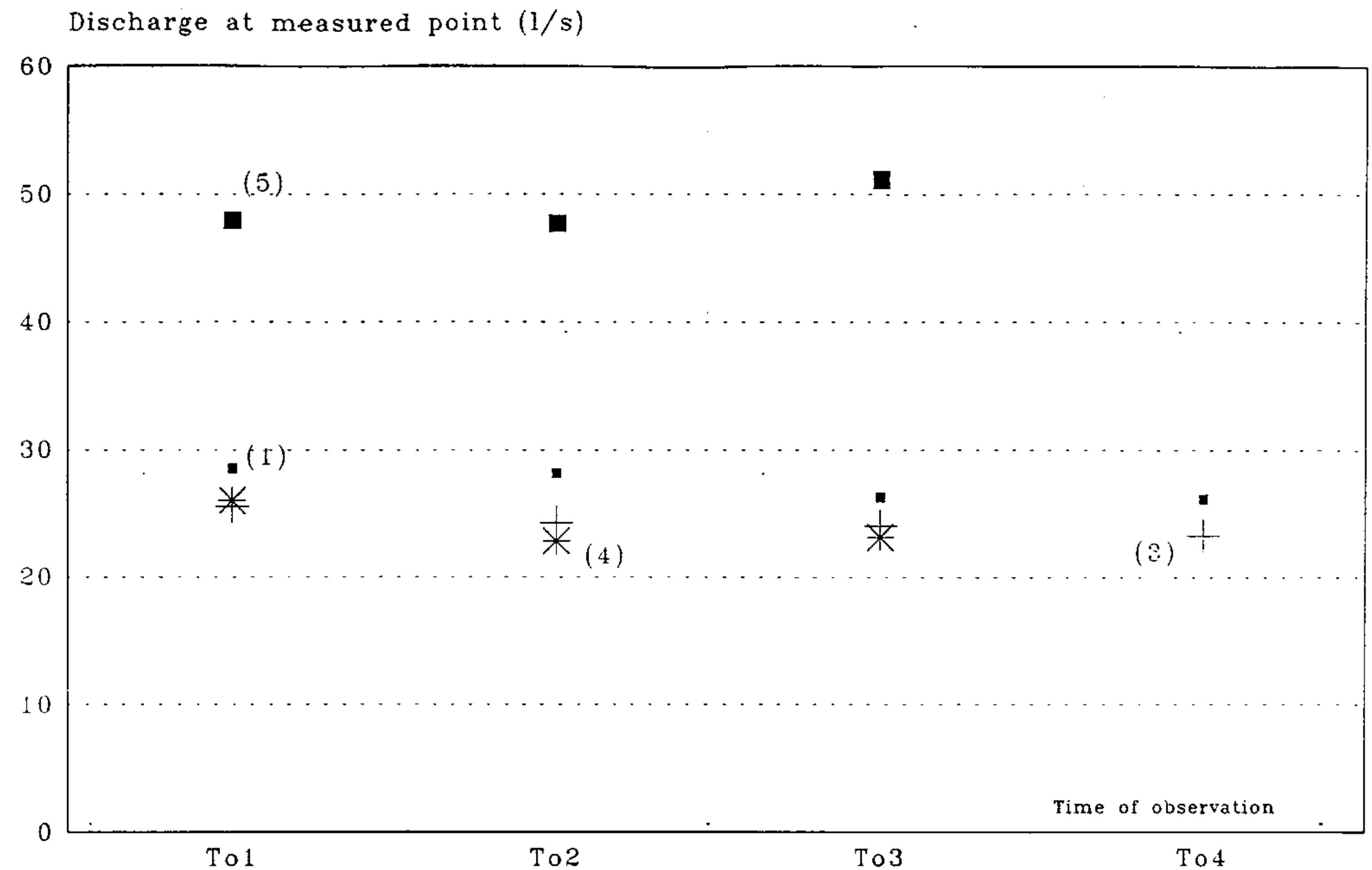
Adjustment in the discharge

In the previous calculations, water losses in the farm or watercourse channel have not been included, which concerns those water losses or seepage losses which occur in the channel between the location of the discharge measurement device and the field inlet. In order to quantify the actual amount of water applied to the field in a more accurate manner, corrections have to be made. Proper guidelines were not really available on this matter. For this reason, the approximation of the seepage losses in the channel are based on the report written by Barral (1994). Basically, he provided figures on seepage losses for different discharge rates for the main watercourse channel of Fordwah 62-R and 14-R. Through extrapolation, a quite satisfactory result has been obtained. The calculated losses for the sample fields in W/C Azim 111-L are



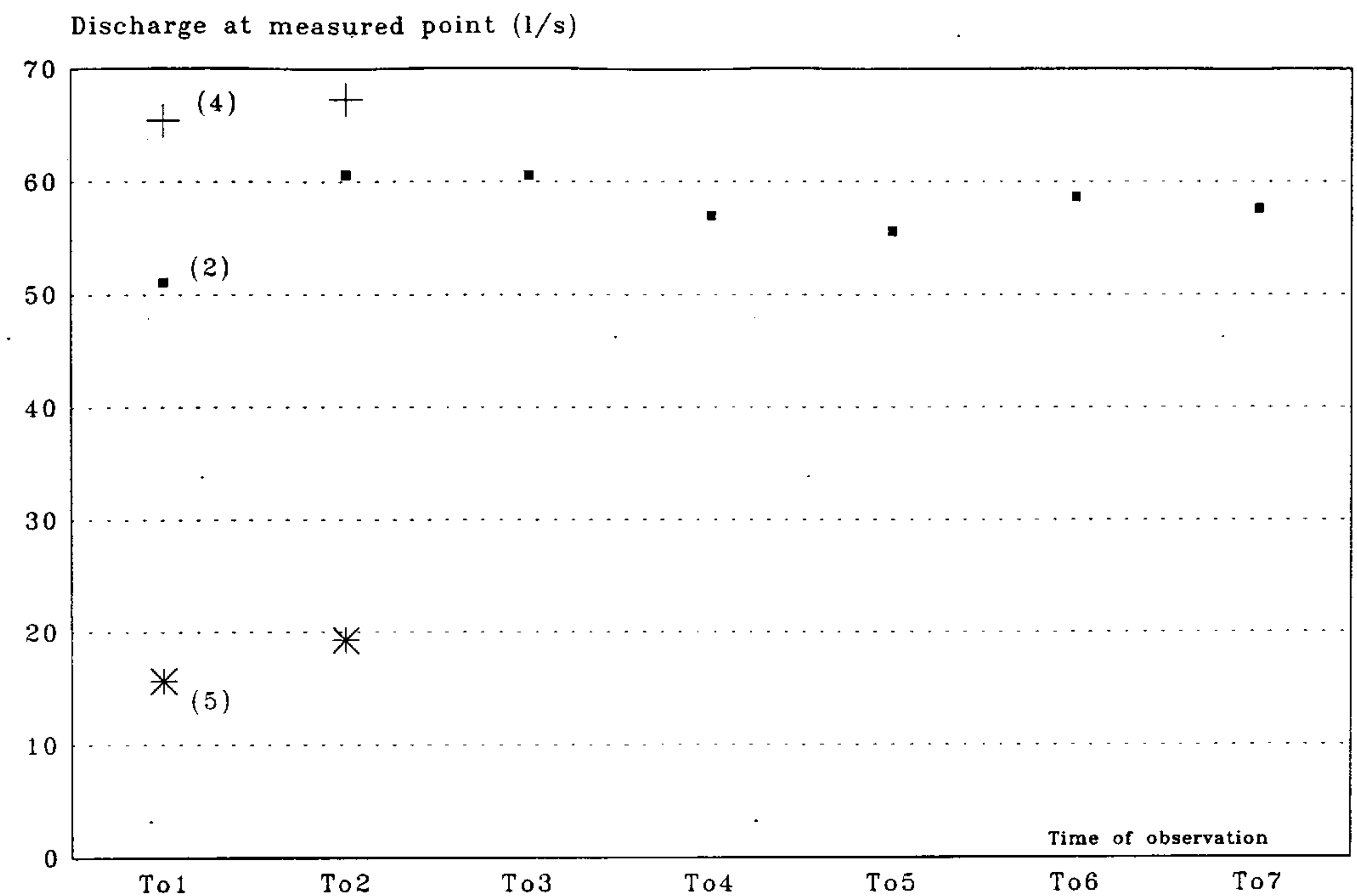
Event 1 ▪	20.42	19.89	20.44	20.98	
Event 2 +	22.79	22.8	23.66		
Event 3 ✳	15.48	18.61	22.18	23.05	22.8
Event 4 ■	20.78	21.5	22.03		
Event 5 ×	61.59	48.02	48.7		

Figure 1. Discharge variation for each irrigation event on Field 3.



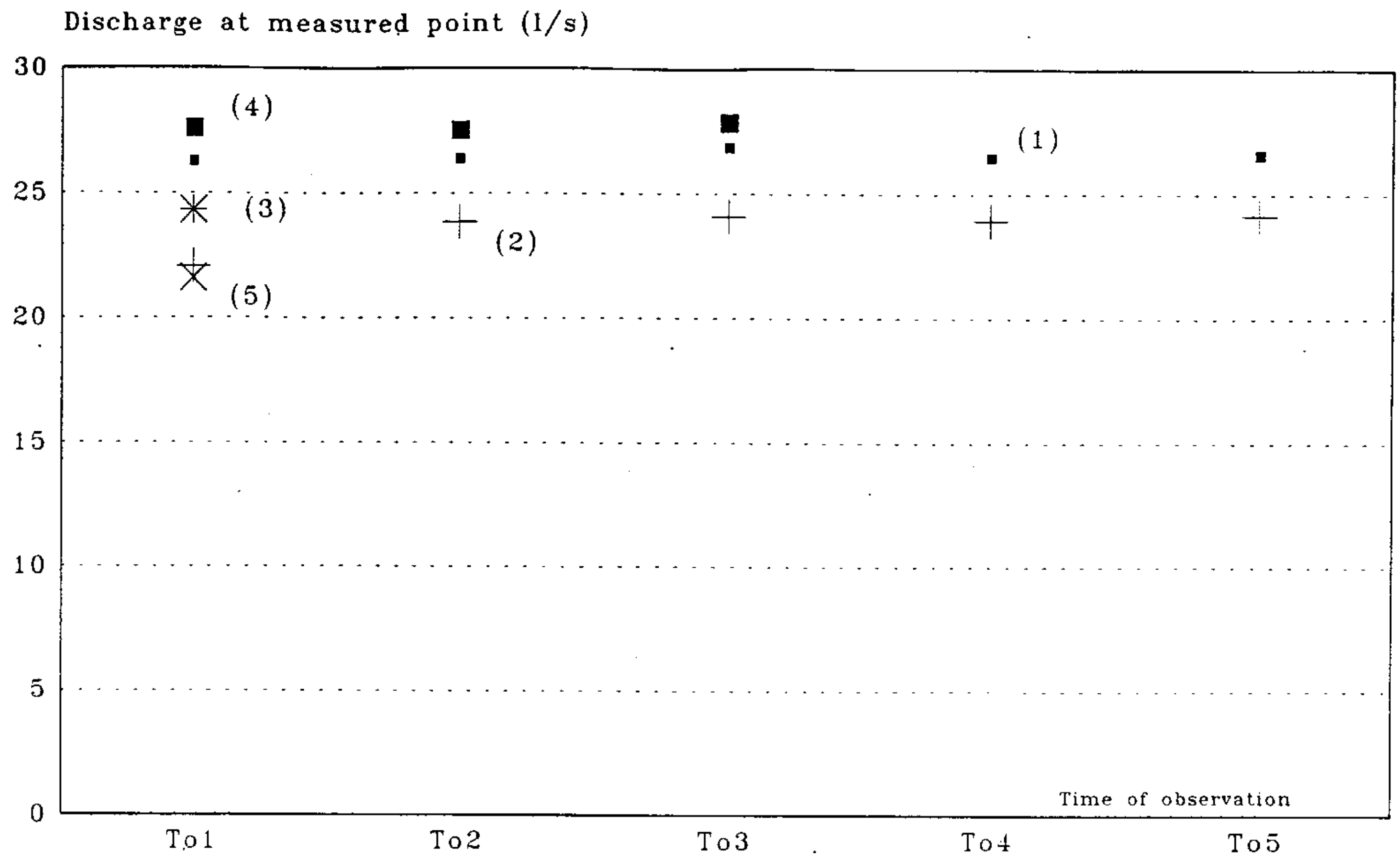
Event 1 ▪	28.52	28.14	26.29	26.13
Event 3 +	25.55	24.26	24.01	23.26
Event 4 ✳	25.99	22.84	23.12	
Event 5 ■	47.96	47.7	51.16	

Figure 2. Discharge variation for some irrigation events on Field 33.



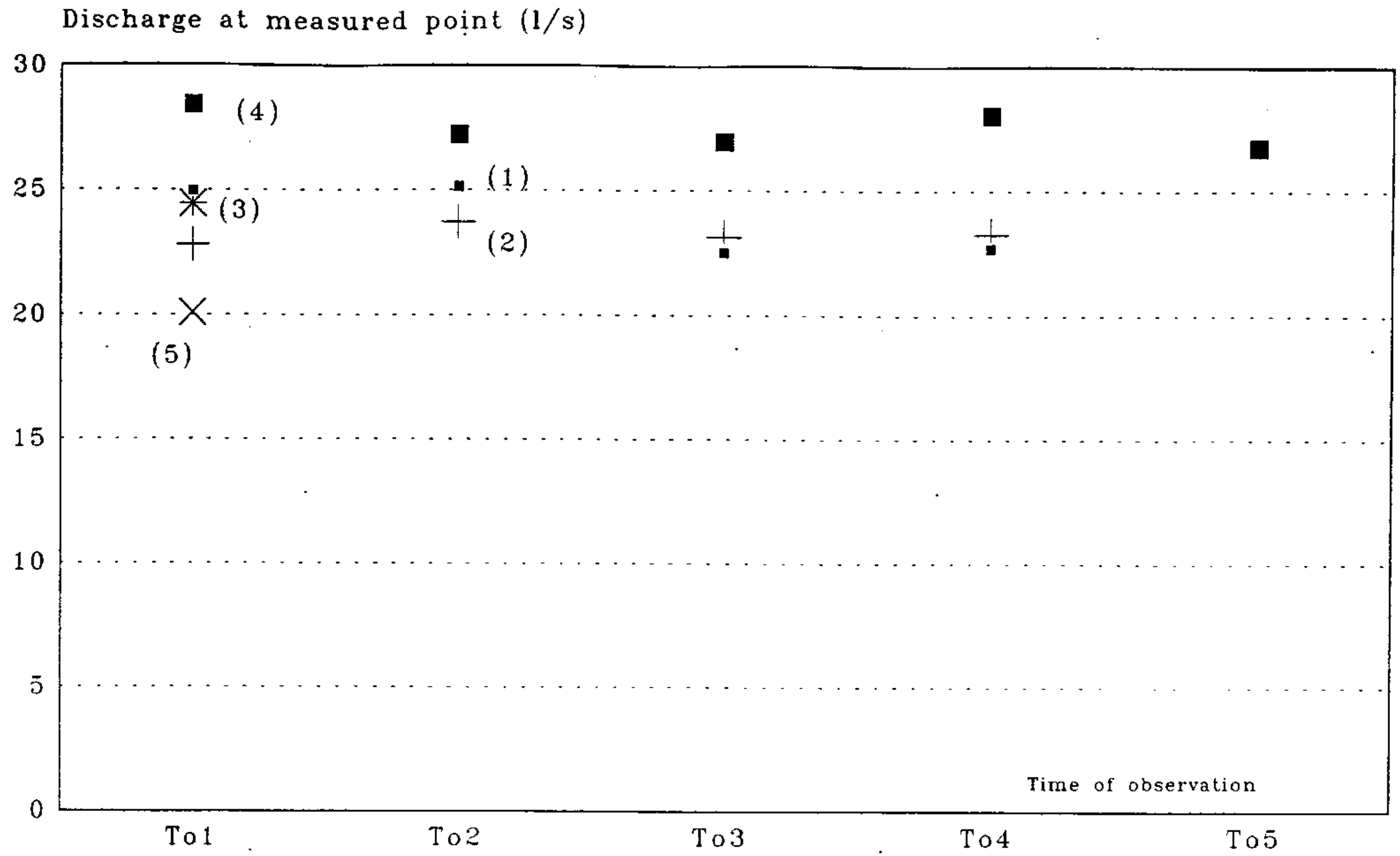
	To1	To2	To3	To4	To5	To6	To7
Event 2 ■	51.1	60.65	60.57	56.99	55.62	58.63	57.63
Event 4 +	65.41	67.29					
Event 5 ✳	15.69	19.27					

Figure 3. Discharge variation for some irrigation events on Field 8.



	To1	To2	To3	To4	To5
Event 1 ▪	26.29	26.4	26.86	26.47	26.59
Event 2 +	22.07	23.86	24.09	23.95	24.15
Event 3 ✳	24.34				
Event 4 ■	27.6	27.53	27.84		
Event 5 ✕	21.6				

Figure 4. Discharge variation for each irrigation event on Field 4.



Event 1 ▪	24.96	25.16	22.52	22.69	
Event 2 +	22.81	23.73	23.13	23.26	
Event 3 ✳	24.47				
Event 4 ■	28.42	27.24	26.96	28.04	26.76
Event 5 ╳	20.08				

Figure 5. Discharge variation for each irrigation event on Field 6.

based on the seepage loss data of watercourse channel Fordwah 14-R, since it was assumed that the soils in the W/C. Azim 111-L show more or less the same characteristics as the soils in W/C Fordwah 14-R.

Table 9: Average discharge and standard deviation for each monitored irrigation event on the sample fields.

Event	Date		Average discharge Q (l/s)	Standard deviation Std
W/C Fordwah 14-R; Field 3				
Event 1	(14-01)		20.43	0.385
Event 2	(06-02)		23.08	0.408
Event 3	(29-02)		20.42	2.945
Event 4	(12-03)		21.44	0.512
Event 5	(28-03)		52.77	6.243
W/C Fordwah 14-R; Field 33				
Event 1	(23-01)		27.27	1.070
Event 3	(29-02)		24.27	0.826
Event 4	(12-03)		23.98	1.424
Event 5	(21-03)		48.94	1.573
W/C Fordwah 62-R; Field 8				
Event 2	(06-02)		57.31	3.051
Event 4	(07-03)		66.35	0.940
Event 5	(27-03)		17.48	1.790
W/C Azim 111-L; Field 4				
Event 1	(19-01)		26.52	0.195
Event 2	(07-02)		23.62	0.784
Event 3	(02-03)		24.34	0.000
Event 4	(17-03)		27.66	0.133
Event 5	(01-04)		21.60	0.000
W/C Azim 111-L; Field 6				
Event 1	(18-01)		23.83	1.231
Event 2	(07-02)		23.23	0.331
Event 3	(02-03)		24.47	0.000
Event 4	(17-03)		27.48	0.639
Event 5	(01-04)		20.08	0.000

The seepage losses and adjusted discharges are presented in Table 10.

The adjusted discharge for each monitored irrigation event are now assumed to be the real discharge applied to the field, which will be used for the further calculations.

Table 10: Calculation of the seepage losses for the sample fields.

Event		Flume discharge Q (l/s)	Length watercourse (w.c.), (m)	Seepage losses w.c. (l/s/100m)	Length field channel (f.c.), (m)	Seepage losses f.c. (l/s/100m)	Adjusted discharge (l/s)
W/C Fordwah 14-R; Field 3							
Event 1		20.43	-	0.5	104.75	0.65	19.75
Event 2		23.08	-	0.5	104.75	0.65	22.40
Event 3		20.42	-	0.5	104.75	0.65	19.74
Event 4		21.44	-	0.5	104.75	0.65	20.76
Event 5		52.77	-	1	104.75	1.3	51.41
W/C Fordwah 14-R; Field 33							
Event 1		27.27	-	0.5	228.55	0.65	25.78
Event 3		24.27	-	0.5	228.55	0.65	22.98
Event 4		23.98	-	0.5	228.55	0.65	22.49
Event 5		48.94	-	1	228.55	1.3	45.97
W/C Fordwah 62-R; Field 8							
Event 2		57.31	50	7	50.6	9.1	49.21
Event 4		66.35	50	9.75	50.6	12.68	55.06
Event 5		17.48	50	3	50.6	3.9	14.01
W/C Azim 111-L; Field 4							
Event 1		26.52	-	0.5	130.78	0.65	25.67
Event 2		23.62	-	0.5	130.78	0.65	22.77
Event 3		24.34	-	0.5	130.78	0.65	23.49
Event 4		27.66	-	0.5	130.78	0.65	26.81
Event 5		21.60	-	0.5	130.78	0.65	20.75
W/C Azim 111-L; Field 6							
Event 1		23.83	-	0.5	257.41	0.65	22.16
Event 2		23.23	-	0.5	257.41	0.65	21.56
Event 3		24.47	-	0.5	257.41	0.65	22.8
Event 4		27.48	-	0.5	257.41	0.65	25.81
Event 5		20.08	-	0.5	257.41	0.65	18.41

Water source

As described in the second section, the farmers receive water from the watercourse through a warabandi schedule. However, the sample farmer of W/C Azim 111-L relied entirely on tubewell water, since the canal water does not come in this reach of the distributary at the timings when the water is needed. Additionally Azim distributary is a non-perennial canal and does not officially get water during the Rabi season. Also the other sample farmers are using tubewell water very frequently, especially for the first irrigation events. Due to canal closure, water was not available till mid-February. Additionally, in many instances, water was not available in Fordwah distributary even after the end of the canal closure.

Both the farmers of W/C Azim-111L and W/C Fordwah 14-R do not have constraints in terms of access to tubewell water, since both can use the tubewell of the actual owner of the farm. The sample farmer of W/C Azim 111-L has a fifty-fifty agreement with the owner which has his landholding adjacent to his landholding. The sample farmer of W/C Fordwah 14-R is a tenant but the tubewell water is available directly on the farm. The farmer of W/C Fordwah 62-R relies on the tubewell near the outlet and uses the water during his water turn or during the night, related to the availability of the tubewell for his purpose. Table 11 presents the frequency of canal and tubewell water use during the Rabi '95-'96 season.

Table 11: Water source used for each irrigation event on the sample fields.

	W/C Azim 111-L		W/C Fordwah 14-R		W/C Fordwah 62-R	
	Field 4	**Field 6**	**Field 3**	**Field 33**	**Field 8**	
Event 1	tubewell	tubewell	tubewell	tubewell	- no data -	
Event 2	tubewell	tubewell	tubewell	tubewell	tubewell	
Event 3	tubewell	tubewell	tubewell	tubewell	- no data -	
Event 4	tubewell	tubewell	tubewell	tubewell	canal	
Event 5	tubewell	tubewell	canal	canal	canal	
Event 6	tubewell	tubewell	-	canal	-	

Figures 6, 7 and 8 present the bar diagrams representing the actual discharge applied to the field during each irrigation event and the water source used.

Table 12 presents the total amount of water applied to each sample field during each monitored irrigation event, based on the data on the adjusted discharges and the irrigation duration (t_{co}).

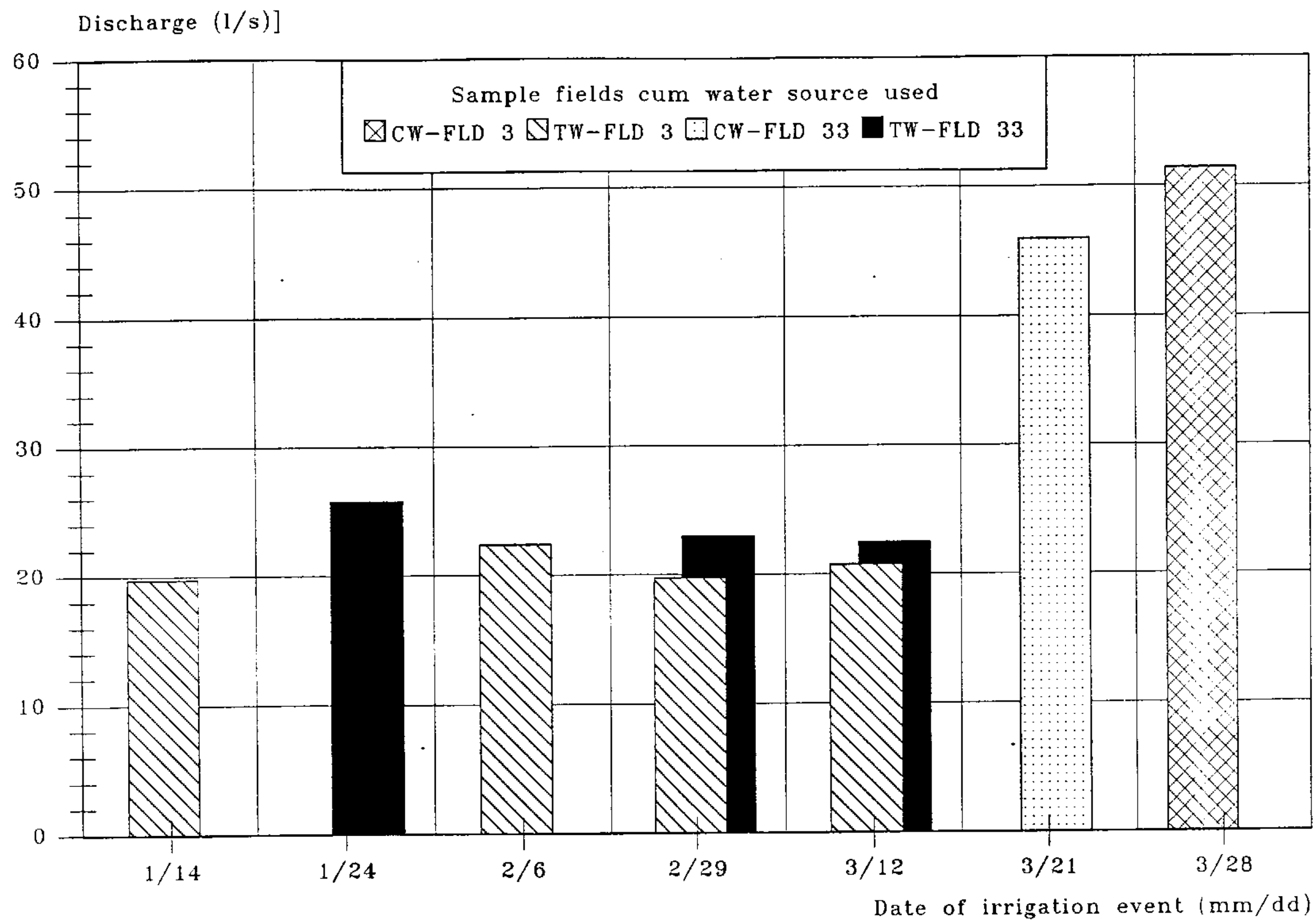


Figure 6. Discharge rate at the field inlet of Fields 3 and 33, W/C Fordwah 14-R.

CW = Canal water; TW = Tubewell water

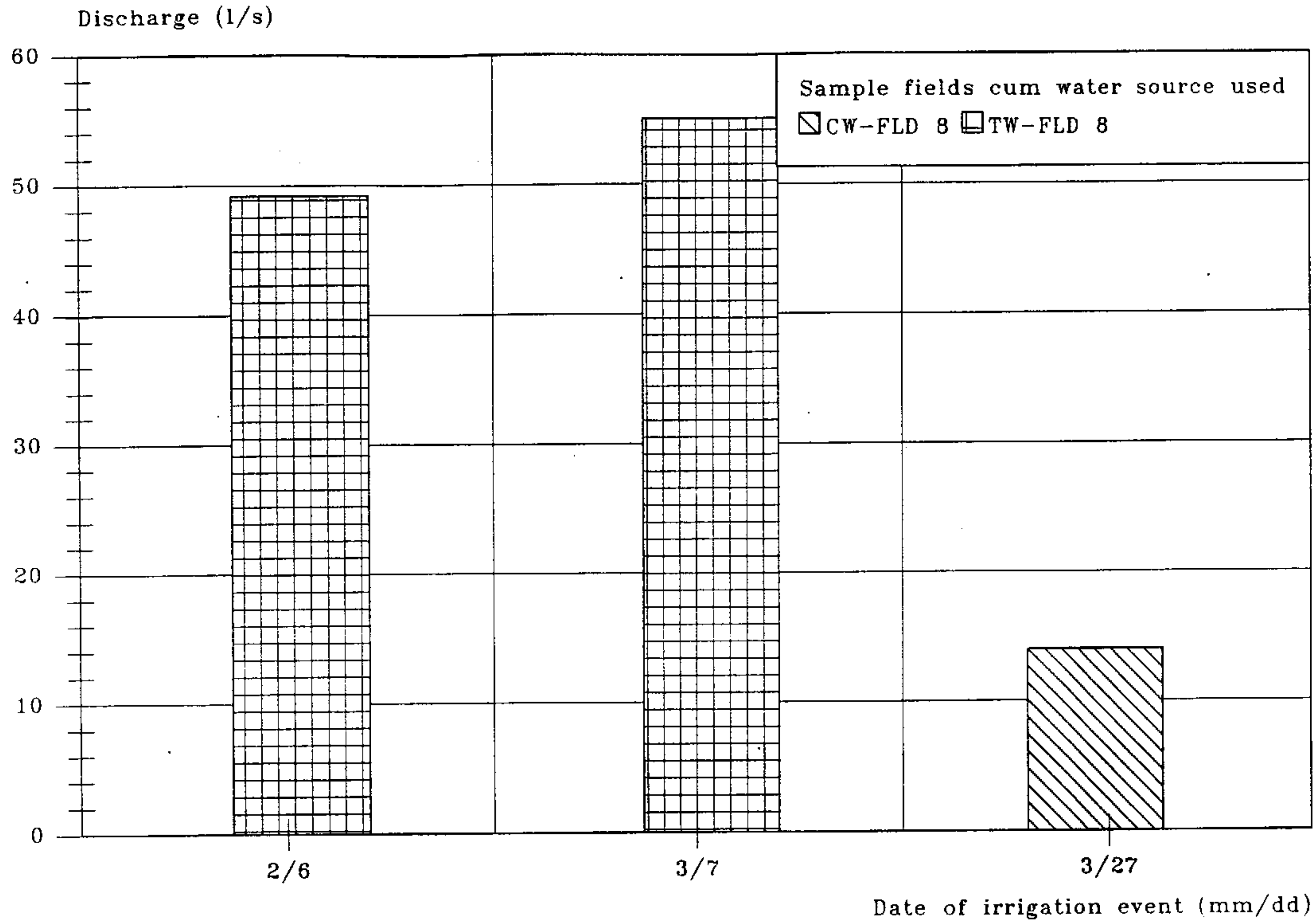


Figure 7. Discharge rate at the field inlet of Field 8, W/C Fordwah 62-R.

CW = Canal water; TW = Tubewell water

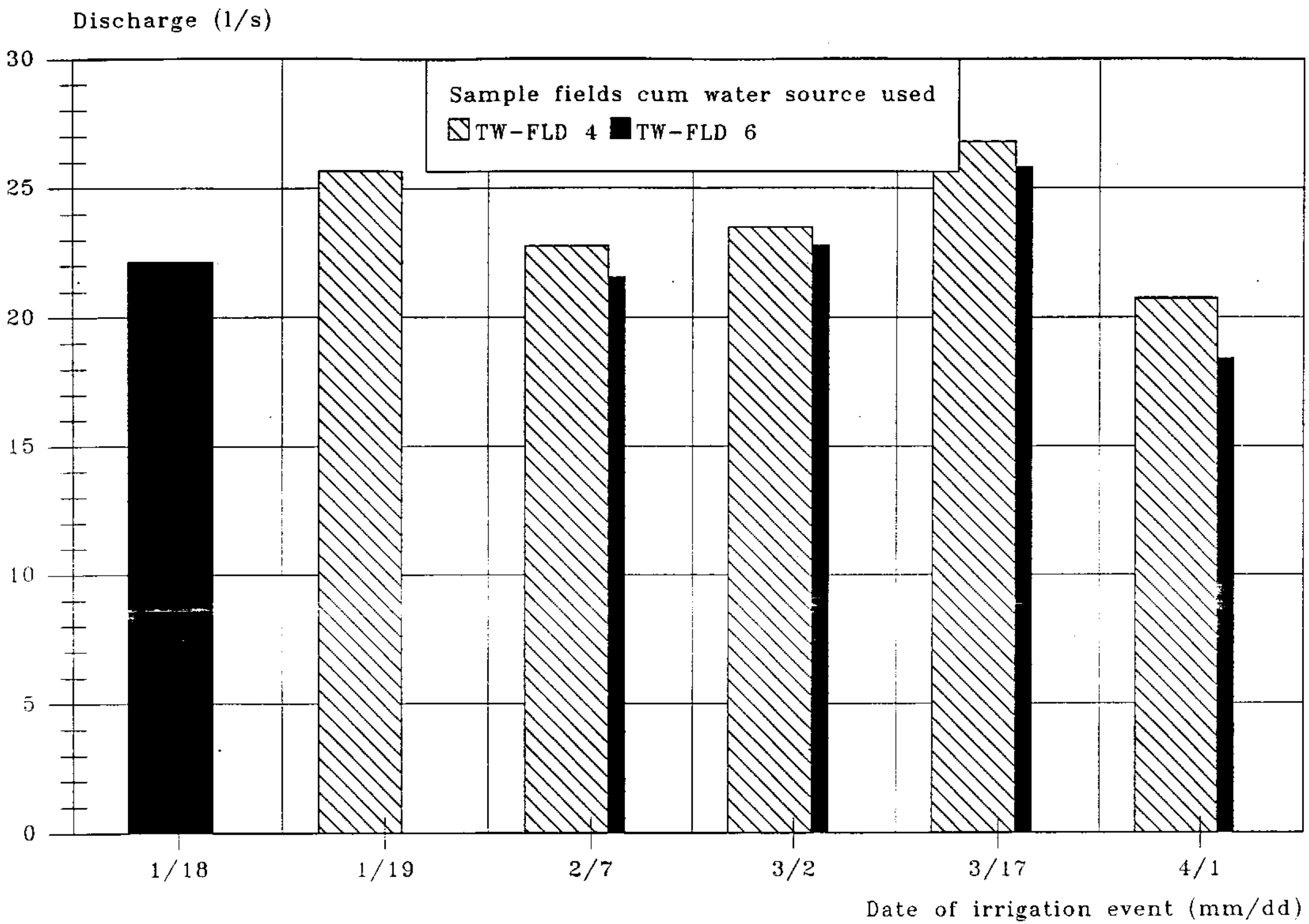


Figure 8. Discharge rate at the field inlet of Fields 4 and 6, W/C Azim 111-L.

TW = Tubewell water

Table 12: Total volume of water applied per irrigation event for the sample fields.

Event	Date		Adjusted discharge	Cutoff time t_{co}	Applied volume
			(l/s)	(min)	(m^3)
W/C Fordwah 14-R; Field 3					
Event 1	(14-01)		19.75	90	106.7
Event 2	(06-02)		22.40	44	59.1
Event 3	(29-02)		19.74	61	72.2
Event 4	(12-03)		20.76	46	57.3
Event 5	(28-03)		51.41	25	77.1
W/C Fordwah 14-R; Field 33					
Event 1	(23-01)		25.78	78	120.7
Event 3	(29-02)		22.98	55	75.8
Event 4	(12-03)		22.49	54	72.9
Event 5	(21-03)		45.97	29	80.0
W/C Fordwah 62-R; Field 8					
Event 2	(06-02)		49.21	27	79.7
Event 4	(07-03)		55.06	22	72.7
Event 5	(27-03)		14.01	26	21.9
W/C Azim 111-L; Field 4					
Event 1	(19-01)		25.67	303	466.7
Event 2	(07-02)		22.77	164	224.1
Event 3	(02-03)		23.49	155	218.5
Event 4	(17-03)		26.81	147	236.5
Event 5	(01-04)		20.75	182	226.6
W/C Azim 111-L; Field 6					
Event 1	(18-01)		22.16	223	296.5
Event 2	(07-02)		21.56	150	194.0
Event 3	(02-03)		22.8	147	201.1
Event 4	(17-03)		25.81	142	219.9
Event 5	(01-04)		18.41	180	198.8

Advance Behavior

Introduction

When the field inlet is opened, the water takes off from the (farm) channel and flows into the basin in an advance pattern which generally is subjected to different (physical) factors, such as (i) applied discharge; (ii) discharge fluctuation; (iii) position of the field inlet; (iv) crop type and density; (v) cultural practices; (vi) weed growth; (vii) topography; (viii) soil type; (ix) infiltration rate; and (x) basin geometry. In other words, the advance behavior is not an isolated process, but is a process exposed to its (physical) environment. This phenomenon makes the advancement of the irrigation water a complex process to interpret and foremost very difficult to simulate in an exact manner.

During the Rabi '95-'96 irrigation season, the advance front has been monitored for the sample fields during the different irrigation events. The comprehensiveness of the collected advance data has been the criteria for selecting some fields and corresponding events for this analysis, wherein the focus is on (i) the advancing front; (ii) advance velocity; (iii) derivation of the advance function by two different methods (i.e. two-point methods and a least square regression analysis).

Advance front

The advance front has been monitored by noting the time when each "visibly assumed" grid[2] is for the largest part covered with water. Later, during the analysis, the data has been converted to a time - wetted area relationship for the whole field. Monitoring the advance front is a quite precise job, and unfortunately, due to the increasing crop and weed growth over time during the season, it becomes difficult to monitor the center part of the field. In order to determine the advance front, extrapolation was required for some of the events. It may not be the exact water front profile; however, it will represent the general tendency of the advancing water front and the change in the advancing front for the subsequent irrigation events. The results of the monitoring and extrapolation are presented in Annexure 3. The criteria used for interpreting the advance front are: (i) consistency of the front during an irrigation event; (ii) tendency of the advance

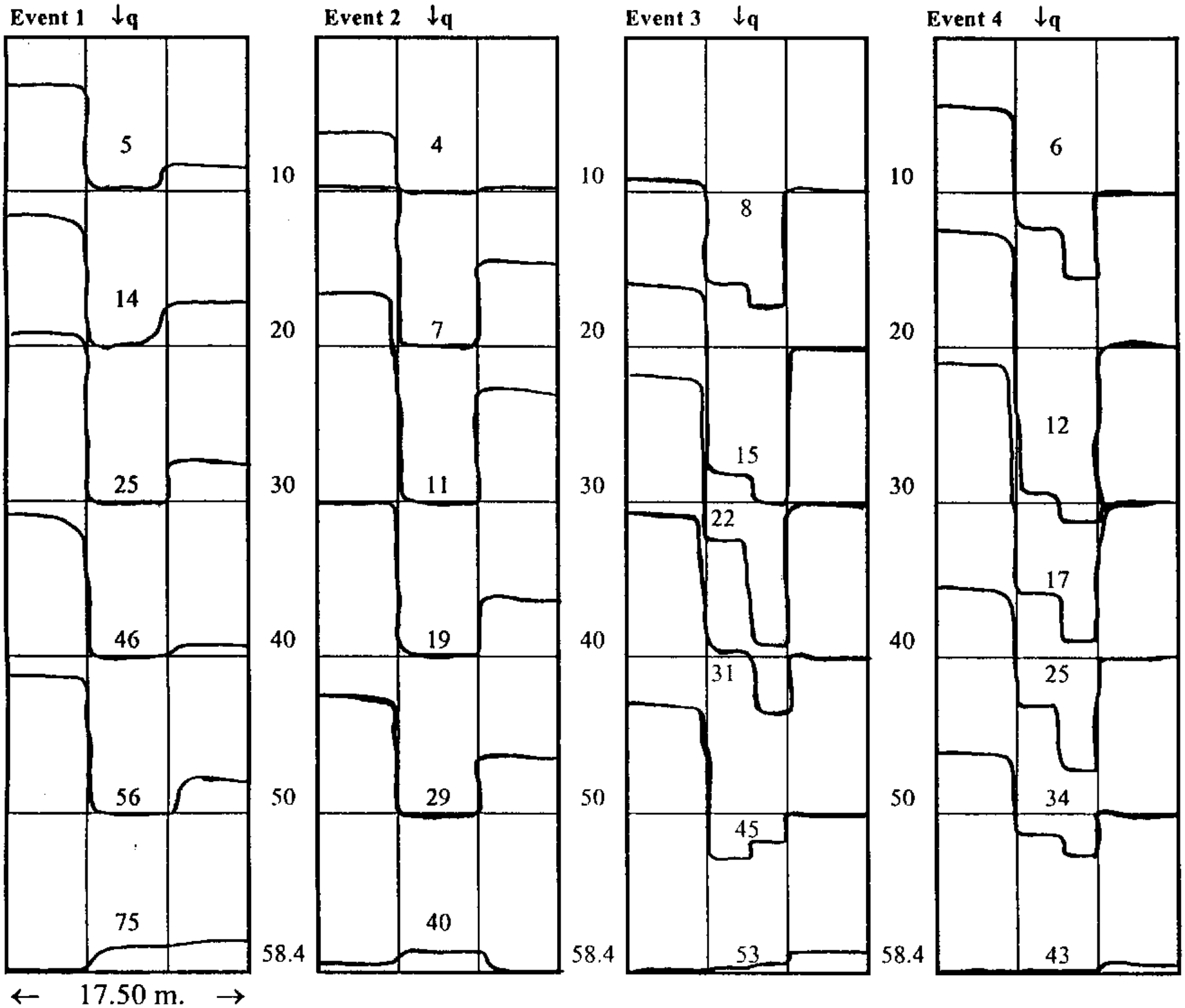
[2] For monitoring purposes, a field is divided into three or four rows, called left side, center or right side. The length of the field is marked after every ten meters till the end of the field is reached.

front between irrigation events; (iii) velocity distribution within a field; and (iv) discharge fluctuation during an irrigation event of the field and/or between the irrigation events. Fields 3 and 33 of W/C Fordwah 14-R are considered for demonstrating this purpose.

Field 3, W/C Fordwah 14-R

This field, classified as a *fine sandy loam soil*, has a rectangular shape of 58.40 m. by 17.50 m.

Figure 9: Advance contour lines for selected irrigation events on field 3, W/C Fordwah 14-R, Rabi '95-'96 season.



With a ratio (length : width) of 3.34, the field is quite long as compared to its width. The advance front follows a quite consistent pattern, with the advance front in the center moving ahead faster than on the left and right sides of the basin (Figure 9). This pattern remains consistent between the subsequent events, though with a decreasing tendency of the advance time for the subsequent irrigation events (Table 13). This decreasing tendency for any noted time can directly be observed from the advance contour lines as presented in Figure 9.

Table 13: Advance time (t_a) for each irrigation event on Field 3, W/C Fordwah 14-R, Rabi '95-'96 season.

Event	Event 1	Event 2	Event 3	Event 4	Event 5
Date	14-01	06-02	29-02	12-03	28-03
ta (min)	80	43	57	45	33

The shape of the advance front can be interpreted through the water flow velocity profile in the basin. In Figures 10 and 11, the velocity profiles in the basin are drawn (x-t relation) for events 1 and 2, respectively. Although the graphs show an overall decreasing tendency towards the lower end of the basin, high velocity fluctuations do occur across the basin width, as well as with distance along the length of the basin. Initial high velocity rates may be as a consequence of opening the field inlet and next, the water takes off into the field with a significant force. Basically, the irregularities and undulations in the basin topography were observed to significantly hamper the advance front and cause the extreme differences in velocity.

There is not much discharge variation for Field 3 during the first, second and fourth irrigation events (Figure 1). Events 3 and 5 show notable discharge variation (Std 2.945 and 6.243, respectively) which may have affected the tendency of the advance front during these events. With respect to Event 5, the average high discharge due to canal water use did have an impact on the total advance time.

Field 33, W/C Fordwah 14-R

In Figure 14, the contour lines are presented for the first and third irrigation events on this field, which is classified as a *silty-loam* soil. It has a stretched rectangular shape, with dimensions of 14.30 x 60.25 (1 : 4.2). The first event shows a reciprocal result of Field 3; the center of the basin shows considerable lag. One reason can be ascribed to the position of the field inlet, which is at the side of the upper boundary of the field, whereas for Field 3, the field inlet is located in the center of the upper boundary. Also, the right side of the field was observed to be lower than the left side. Along the left side, at a distance of between 30 and 40 meters, a depression occurs,

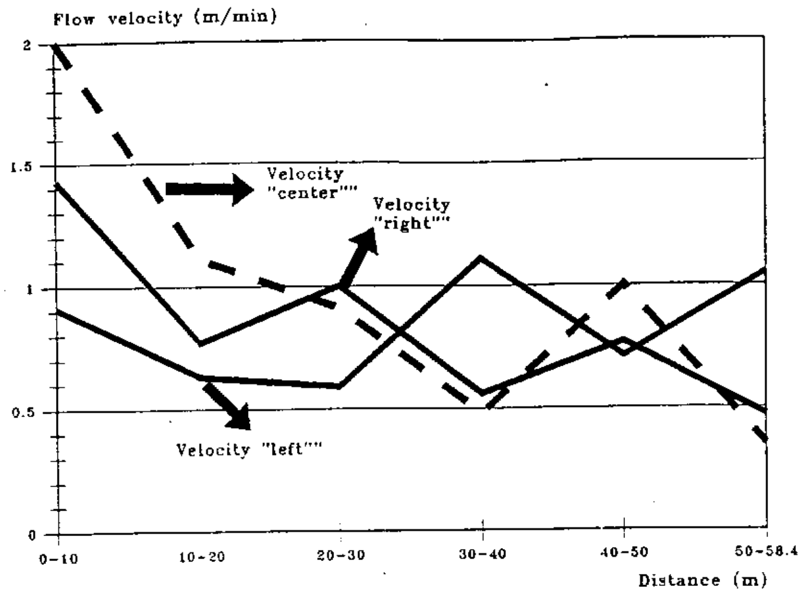


Figure 10. Velocity profile of advance front, Field 3, Event 1.

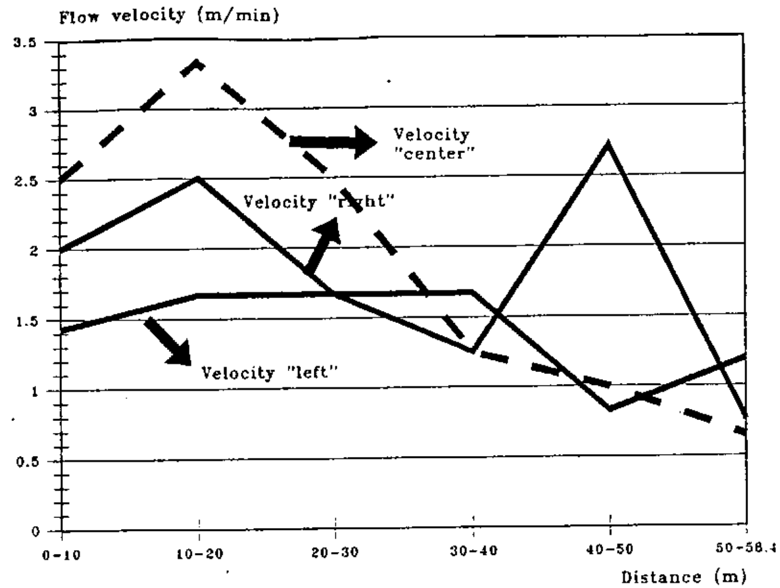


Figure 11. Velocity profile of advance front, Field 3, Event 2.

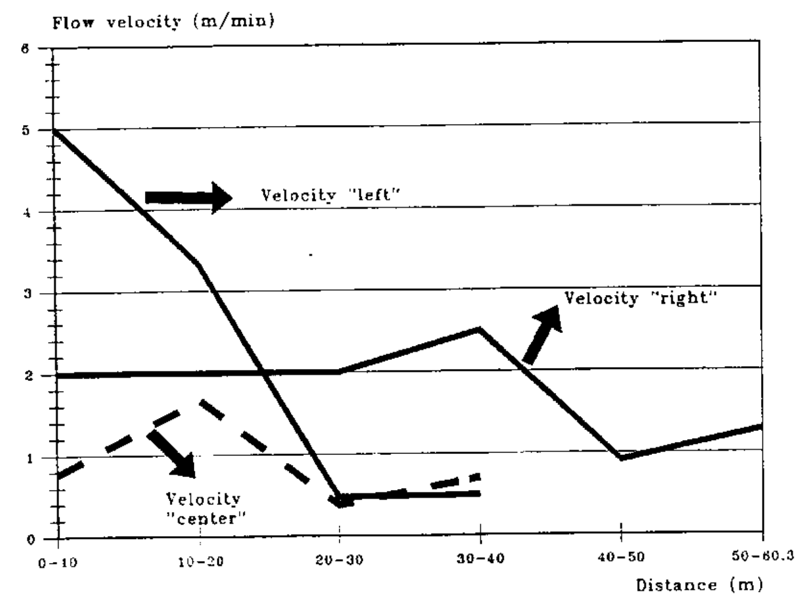


Figure 12. Velocity profile of advnace front, Field 33, Event 1.

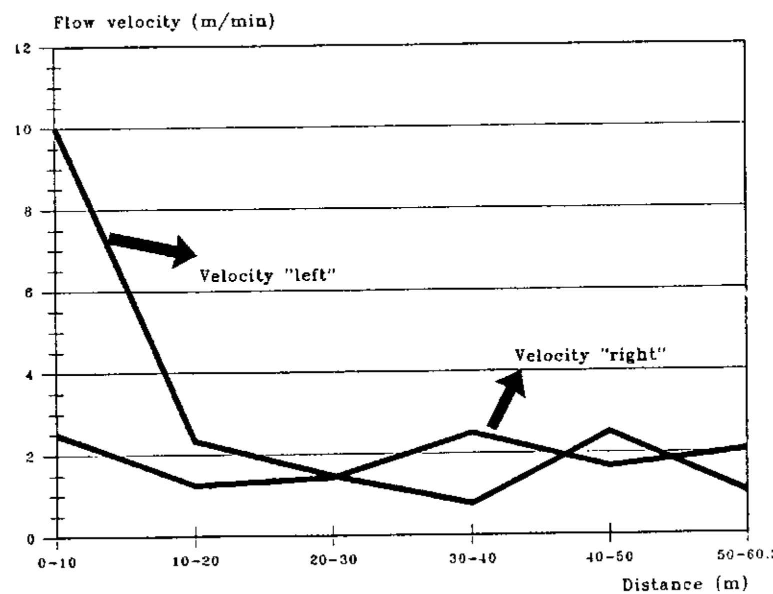


Figure 13. Velocity profile of advance front, Field 33, Event 3.

wherein the water front stagnates, as observed from the time pattern.

A decrease in advance time is observed for the subsequent irrigation events (Table 14), which can also be noted from the advance contour lines (Events 1 and 3).

Figure 14: Advance contour lines for Event 1 and 3 on Field 33, W/C Fordwah 14-R, Rabi '95-'96 season.

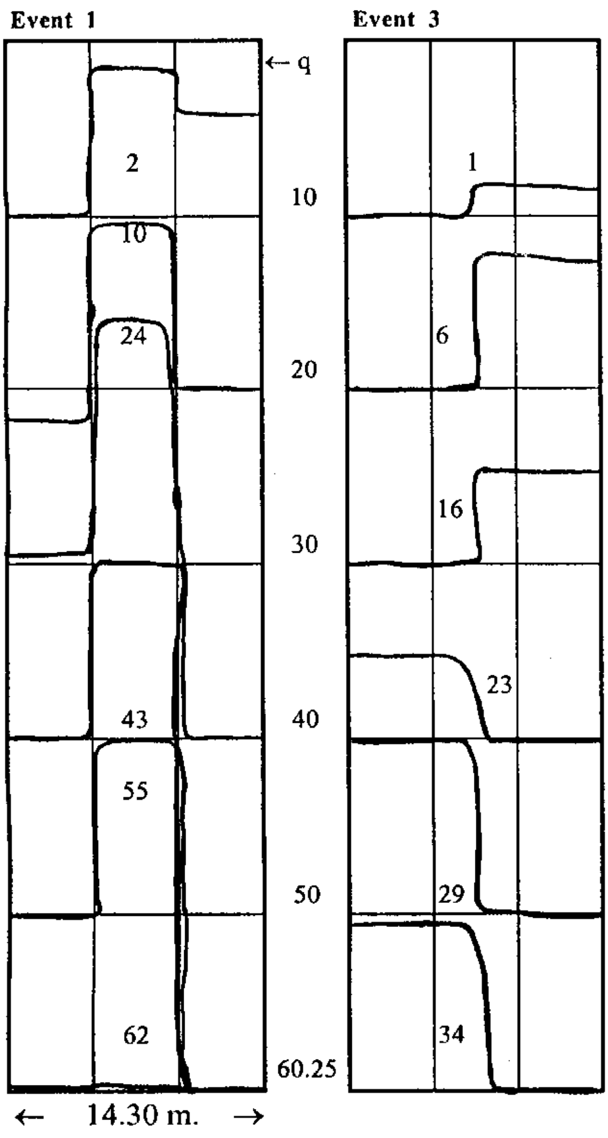


Table 14: Advance time (t_a) for selected irrigation events on Field 33, W/C Fordwah 14-R, Rabi '95-'96 season.

Event	Event 1	Event 3	Event 4	Event 5
Date	23-01	29-02	12-03	21-03
ta (min)	62	43	42	32

As observed for Field 3 and also for Field 33, a high velocity variation in the basin is derived for the different events. In Figures 12 and 13, the velocity profiles in the basin are drawn (x-t relation) for Events 1 and 3, respectively. These variations are ascribed to, as observed, the undulations and irregularities in the field. Additionally, later in the season the weeds hamper the water flow.

The modest discharge variability (Figure 2) may not affect the tendency of the advance front very much. However, for the last irrigation event, the average discharge rate was higher as compared to the previous monitored event. This may explain the relative short advance time for the fifth irrigation event.

Summarizing, different irrigation events have been monitored. Based on the time - wetted area relationship, the advance contour lines were drawn for Fields 3 and 33. A consistent, though irregular pattern, was observed for the sample fields, which, in fact, is characteristic for basin irrigation systems, since topographical irregularities and undulations occur and impact the development of the advance front. The provided details on the velocity of the advance front within the basin at different locations showed high variations with an inconsistent tendency. However, details on the discharge variations showed that during an event the variation is generally not high (with some exceptions) and is not really considered as being the cause of the irregular advance pattern. The predominant use of tubewell water would not be expected to result in much discharge variation, which proved to be the case for these field trials. With respect to the average discharge, it is noted that due to the use of canal water, the discharge is much higher and results in a more rapid advance time.

Based on direct observations in the field, the following factors are identified as causes of the high velocity variations and consequently the irregular advance pattern:

- Improper leveling of the field, which results in irregularities and undulations;
- Traces of the plow where water follows the traces (small corrugations) first and with a certain time lag, water exceeds the plow-trace and inundates the field;
- Fast corrugations near the left and right side boundary resulting from the method of creating the bunds;

- Water does not reach the lower boundary across the full width at the same time, which results in a "backwards advance" that covers part of the grid;
- Occasionally, leakage through the bunds appeared and the sample field was irrigated from an adjacent field or water leaked to the adjacent field; and.
- There is an increase of weeds during the season, which disturbs the water flow (advance front) across the field.

Advance functions

Theory

Mathematically, the advance of an irrigation stream (i.e. the time-distance or time-wetted area relationship) can be expressed as a power function, whereby the fitting parameters or constants have to be locally calibrated for each field and each irrigation event. As mentioned by Walker and Skogerboe (1987), Shafique and Skogerboe (1987), Clemmens and Dedrick (1981), the advance power function is expressed as:

$$(t_a)_x = px^r$$

where: x = advance distance (m); t_a = advance timing (min); and p and r are fitting parameters.

Primarily, this mathematical relationship is applied when it concerns the description of the advance trajectory for furrow and border irrigation. For basin irrigation, it is considered to be more appropriate to opt for the relationship between the time of advance and the cumulative ground surface coverage during the advance, because a basin, levelled or not has ground surface irregularities and undulations which have an impact on the movement of the proceeding advance front. A phenomenon that occured for the sample fields, is that they are not properly levelled and the remaining trace of the plow significantly affect the movement of the advance front. In Walker and Skogerboe (1987) the following mathematical relationship in the adjusted manner for basin irrigation systems is given:

$$A_x = p((t_a)_x)^r$$

where: A_x = wetted area (m^2) for a certain advance time. $(t_a)_x$; and p and r are fitting parameters.

In order to calibrate the fitting parameters r and p, two methods were applied in this regard, based on the different described advance derivation techniques in Shafique and Skogerboe (1987).

Two-point fitting method

Based on the conclusions of the study done by Elliot and Walker (1982), as mentioned in Shafique and Skogerboe (1987), the fitting parameters are derived by selecting two points in the field. The first set of data provides the time of advance (t_{a1}) and advance distance (x_{a1}) to the middle of the field. The second set of data provides the advance time (t_{a2}) for the entire length of the field (x_{a2}). The fitting parameters are solved by the following equations:

$$r = \frac{\ln(A_{a1} / A_{a2})}{\ln(t_{a1} / t_{a2})}$$

and

$$p = \frac{A_{a2}}{(t_{a2})^r}$$

where: r and p are the fitting parameters; t_{a1} and t_{a2} are the advance time (min) at respectively half length and the whole length of the field; A_{a1} and A_{a2} are the cumulative ground surface coverage (m^2) at respectively $t=t_{a1}$ (min) and $t=t_{a2}$ (min).

Least square regression technique

In this technique, the advance function is transformed into a linear "logarithmic" equation, $S = P' + rt'_i$, $\{\ln(x_i) = \ln(p) + r\ln(t_a)_{xi}\}$, where t' is the independent variable and equals "$\ln(t_a)_{xi}$"; S is the dependent variable and equals $\ln(x_i)$; and $P' = \ln(p)$ and r are constants.

A certain set of N values are taken into consideration.This set of N values consists of a number of t_i (i.e. advance time) and the corresponding S_i (i.e. wetted area) values.

In order to proceed with this regression analysis, the condition ***M is a minimum*** has to be met, with M equal to:

$$M = \sum (P' + r t_i - S_i)^2$$

More comprehensively:

$$r = \frac{N\sum t_i S_i - \sum t_i \sum S_i}{N\sum (t_i) - (\sum t_i)^2}$$

and

$$P' = (\sum S_i - r\sum t_i) / N$$

For Field 4 and Field 6 only, the two-point method has been applied, because for a recession analysis, insufficient data was available. Additionally, the first event on Field 3 concerns more of an estimation, since the water inflow to the field was disturbed by a electricity shut off after 5 minutes, which continued for more than an hour. Part of the field was irrigated by the remaining water during that period.

The results of the two-point method and the least square regression analysis are presented in Table 15; the calculations are elaborated in Annexure 3.

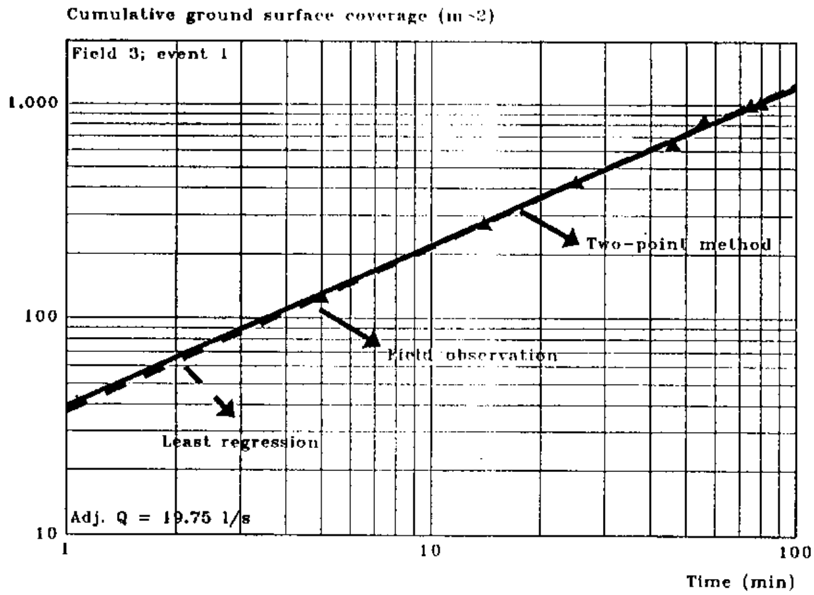
Comparison between the two approaches and the field observations

A comparison of the field data between the two methods was accomplished using a graphical analysis. In Figures 15, 16 and 17, selected advance graphs are presented for the sample fields, based on the analysis reported in Table 15 and Annexure 4. Basically, both of the approaches work satisfactorily and match the observed data to a large extent. However, it can be observed from the graphs that the advance rate is, in a number of instances, over estimated by the two-point fitting method, especially in the lower reach of the graphs. On the contrary, by applying the least square regression technique, even in the lower reach of the graph, the field observations do match quite well.

The difference in results for both the techniques can be derived from the fact that by selecting only two points, the remaining points are neglected and the advance trajectory is extrapolated whenever based on only two points, whereas with the least square regression analysis a considerable number of points are included and can be interpreted as being more representative for the actual observed field data and, therefore, for the advance rate as well. For this reason, the advance curves based on the least square regression technique are used for further interpretation (Fields 3, 33 and 8). However, for Fields 4 and 6, the advance graphs based on the two-point method are further used.

Table 15: Values of the calculated advance constants r and p, based on the least square regression technique and the two point fitting method.

Field 3	**Regression technique**	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Two point method**	**Event 1**	**Event 2**	**Event 3**	**Event 4**
	r	0.762	0.824	0.830	0.868	**r**	0.744	0.673	0.748	0.710
	p	36.98	50.52	37.10	40.28	**p**	39.24	81.30	49.66	68.99
Field 33	**Regression technique**	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Two point method**	**Event 1**	**Event 2**	**Event 3**	**Event 4**
	r	0.692	0.523	0.704	0.660	**r**	0.806	0.775	0.615	0.636
	p	46.90	109.42	63.86	87.98	**p**	31.01	46.62	86.49	95.04
Field 8	**Regression technique**	**Event 2**	**Event 4**			**Two point method**	**Event 2**	**Event 4**	**Event 5**	
	r	0.757	1.058			**r**	0.549	0.744	0.825	
	p	103.2	49.18			**p**	157.48	110.46	71.79	
Field 4	**Two point method**	**Event 1**	**Event 2**	**Event 3**	**Event 4**					
	r	0.747	0.477	0.496	0.530					
	p	71.88	393.70	382.46	442.81					
Field 6	**Two point method**	**Event 1**	**Event 2**	**Event 3**	**Event 4**					
	r	0.506	0.349	0.741	0.315					
	p	132.56	261.88	205.42	408.02					



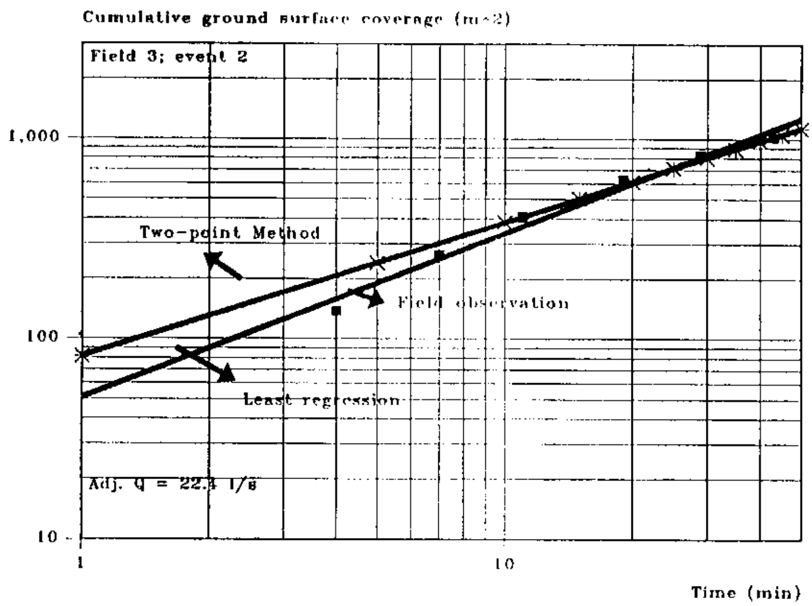
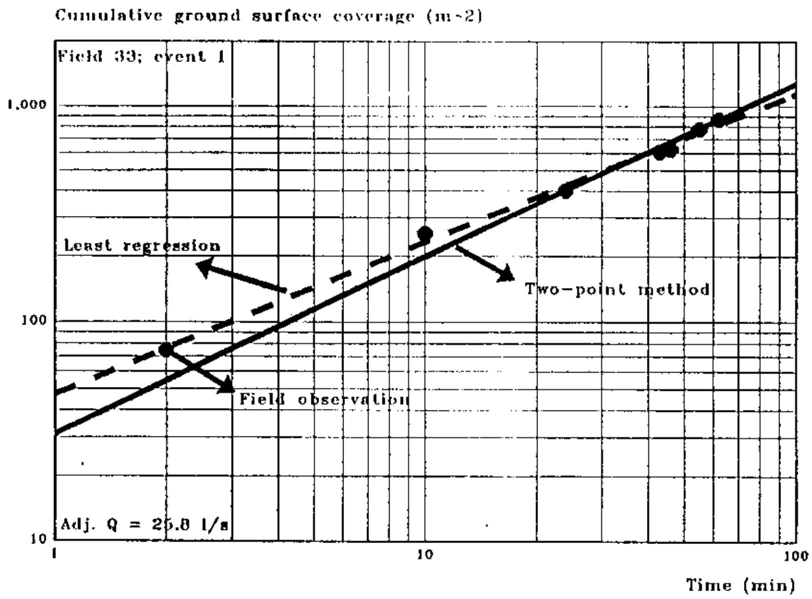


Figure 15. Advance curves and field data for Field 3, Events 1 and 2, W/C Fordwah 14-R.



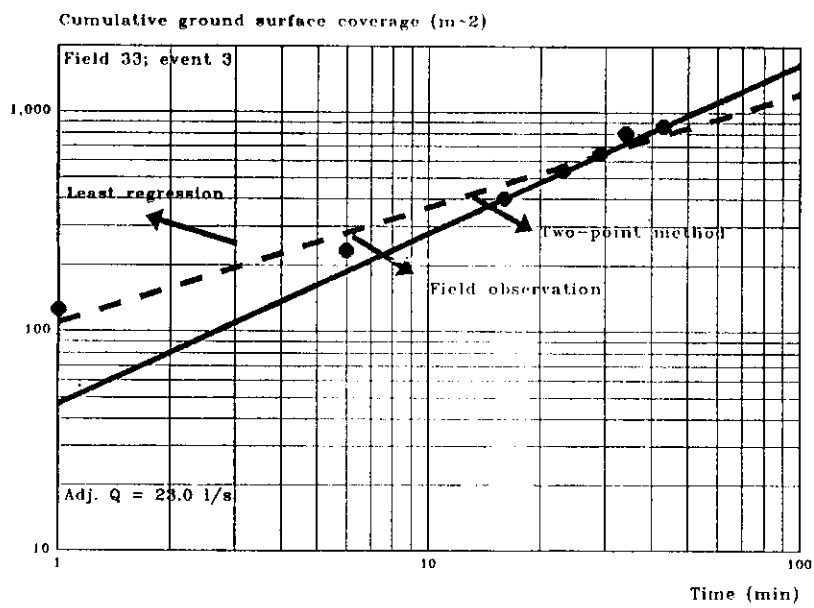
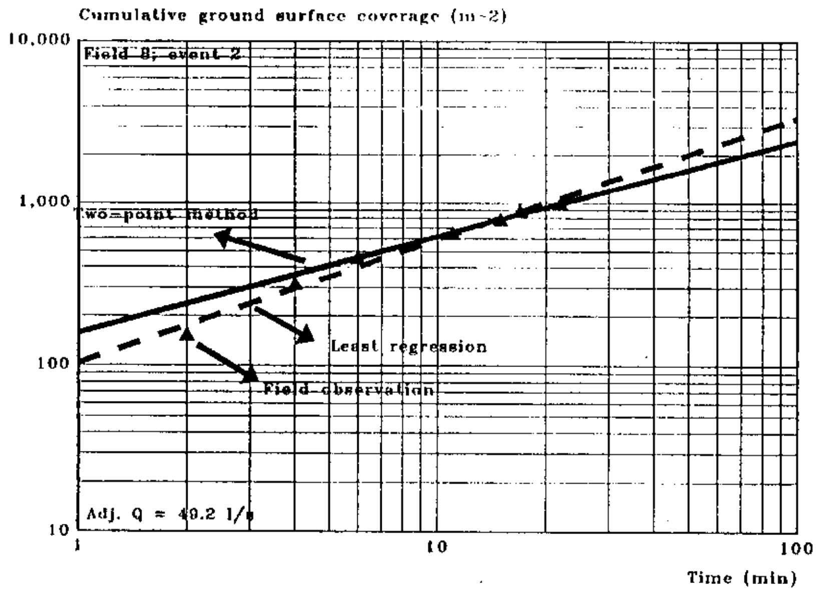


Figure 16. Advance curves and field data for Field 33, Events 1 and 3, W/C Fordwah 14-R.



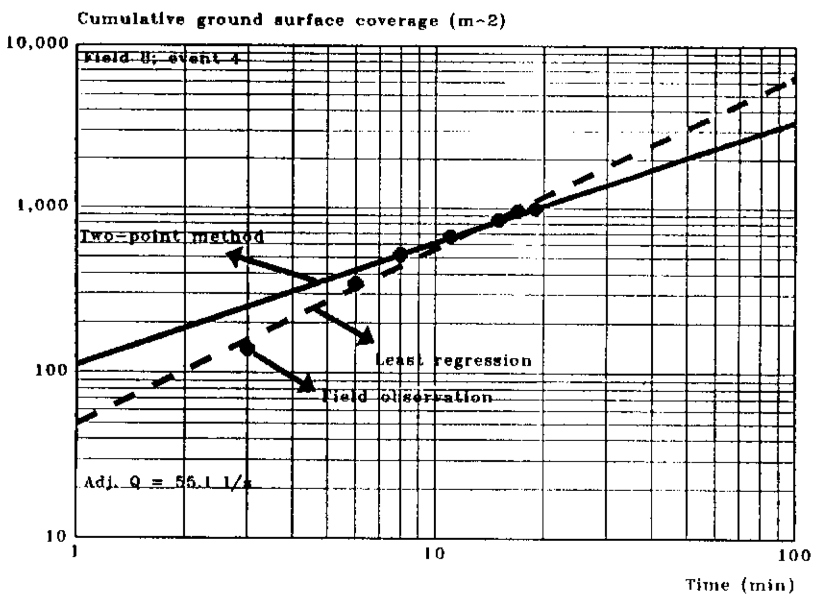


Figure 17. Advance curves and field data for Field 8, Events 2 and 4, W/C Fordwah 62-R.

Advance graphs

The advance graphs for Fields 3, 33, 8, 4 and 6 are presented in Figures 18 - 22 , respectively. From Figures 18, 19, 21 and 22 can be observed that the advance rate is the lowest for the first irrigation event, which can be ascribed to the rough surface in terms of soil particles due to the plowing, which indicates a high roughness. For the following event, the advance rate has increased, due to the first irrigation which made the soil surface more smooth, i.e. a decrease in the roughness. In some of the figures (18, 20, 22) it shows that after the second irrigation event the advance rate has increased again, followed by a decrease in the next event. From observations can be interpret that cultural practices may cause this second increase, since the soil roughness has increased due to the plowing,

Additionally, the advance behavior is related to the infiltration behavior, which is very high for the first irrigation event as compared to the next events. The infiltration rate generally shows a decreasing tendency. In the next section, it will be shown that the infiltration function is much higher for the first irrigation event as compared with later events, which results in a slower moving advance front during the first event because the surface water discharge rate is rapidly reducing as the front moves across the length of the basin. More comparison is done in the section on the infiltration behavior.

Relationship between discharge and r and p

When the advance function is calibrated, the discharge is not included in a direct manner; however, it is assumed that the amount of water applied to the field has an impact on the values of r and p, a tendency which has been observed, however not quantified. The velocity of the advancing front is related to the discharge (i.e. a higher discharge will automatically result in a higher initial velocity in the field. This is based on the relation Q = v*A, whereby A equals the cross-sectional area of the field inlet (m^2), v the velocity through the field inlet (m/s) and Q equals the discharge through the field inlet (m^3/s). However, to derive a proper relationship between the applied discharge and the advance front or advance rate, more insight should obtained in how the discharge affects the advance pattern throughout the field.

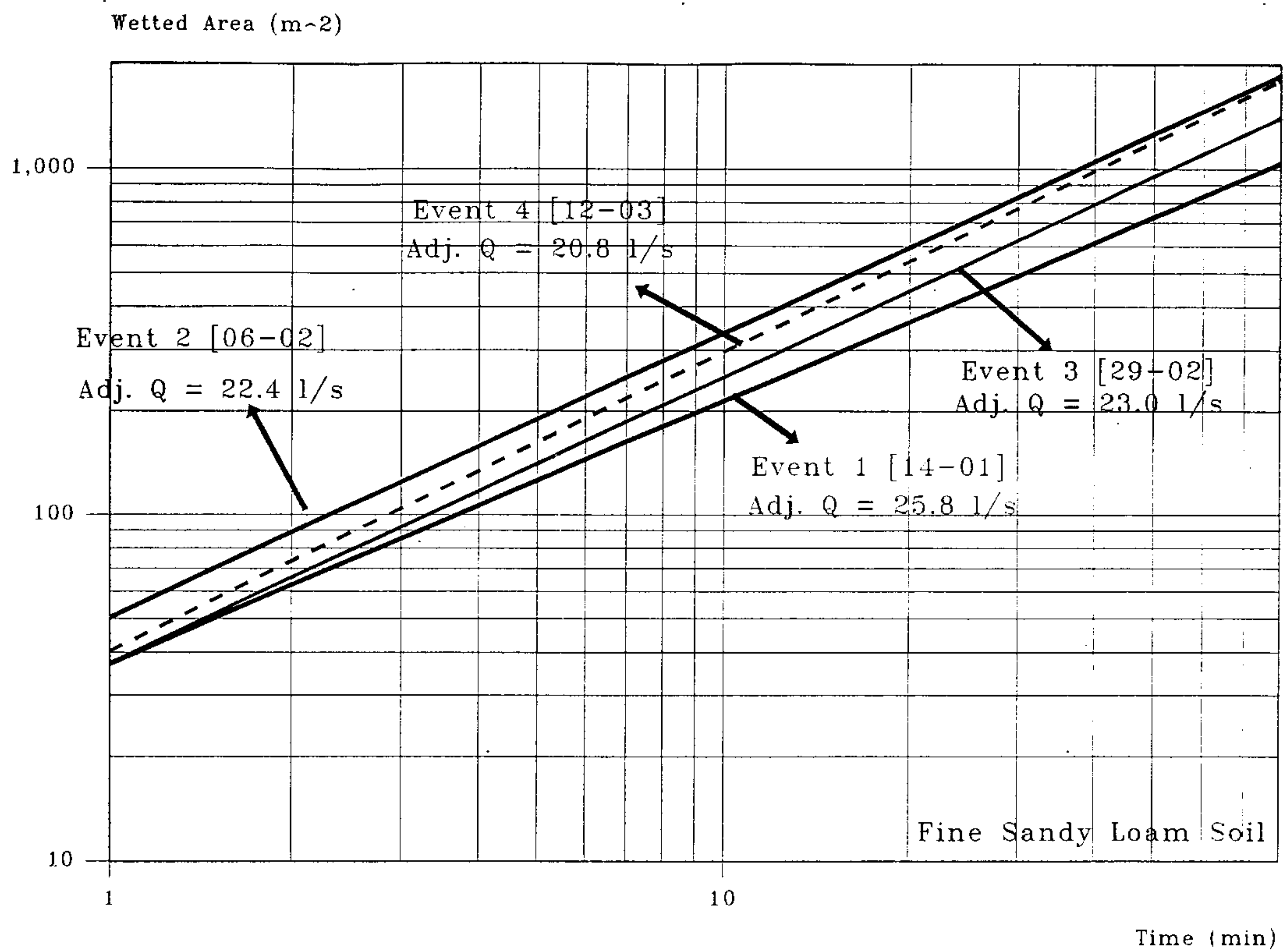


Figure 18. Advance graphs for Field 3, W/C Fordwah 14-R, Rabi '95-'96 season.

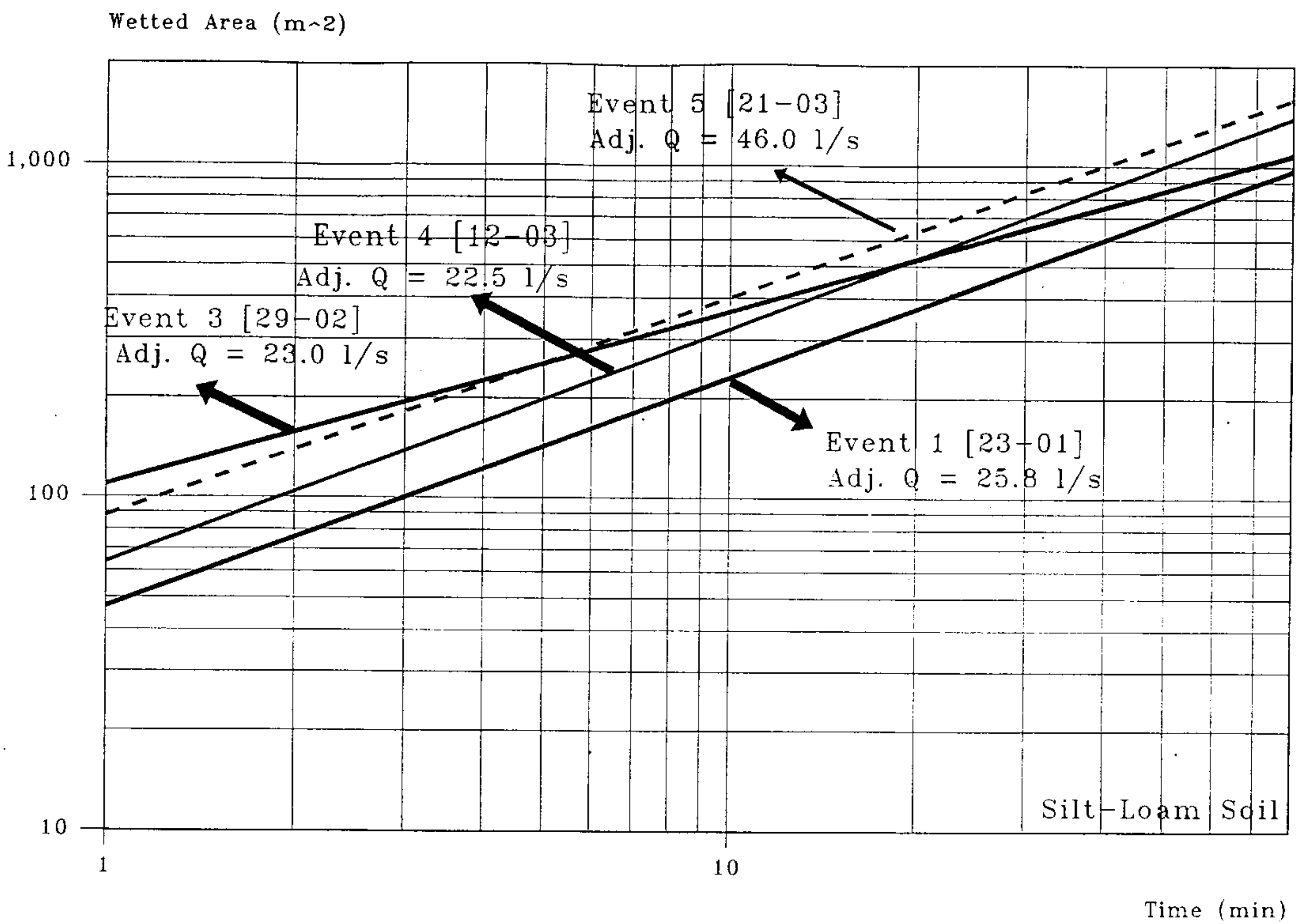


Figure 19. Advance graphs for Field 33, W/C Fordwah 14-R, Rabi '95-'96 season.

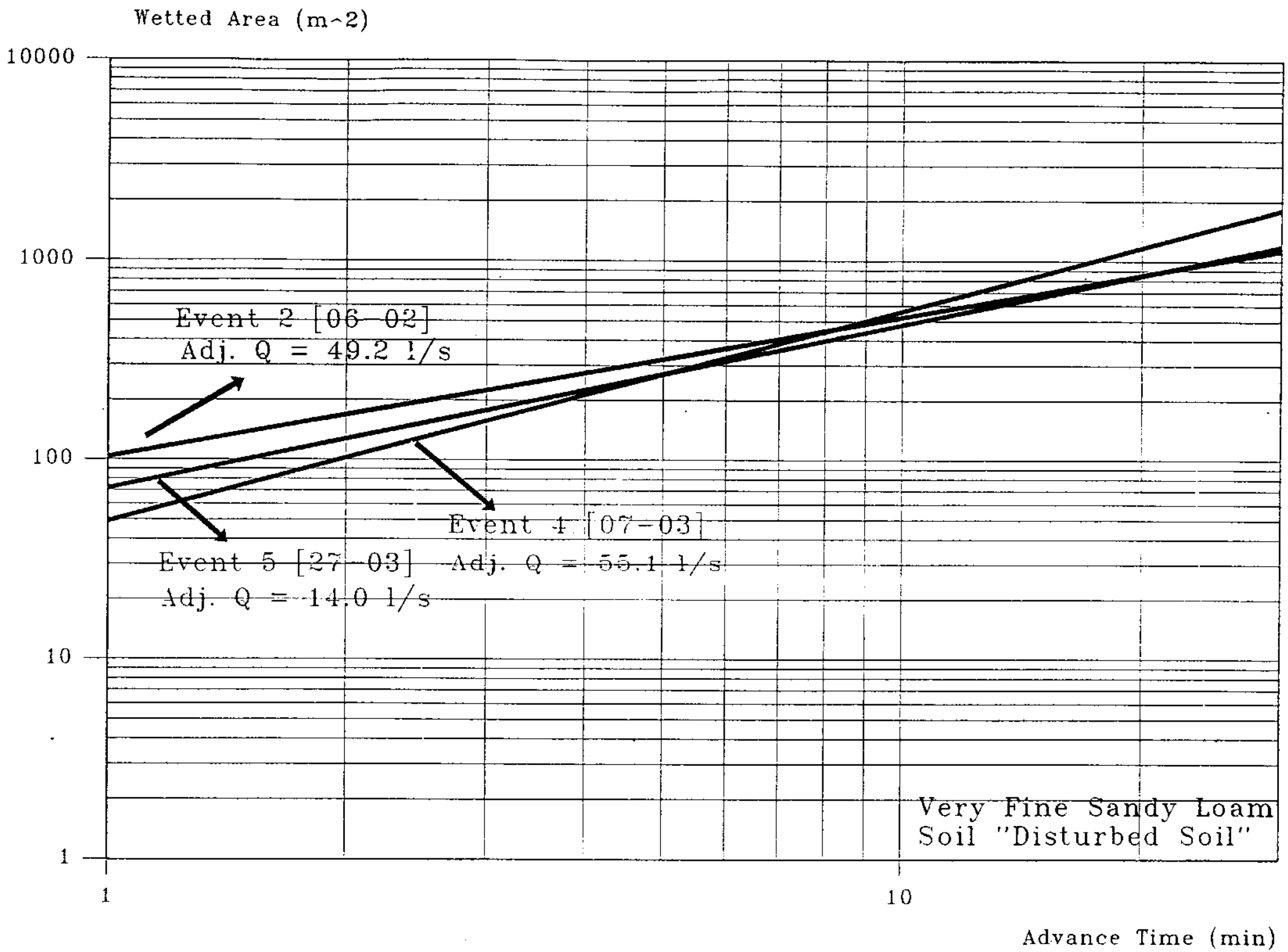


Figure 20. Advance graphs for Field 8, W/C Fordwah 62-R, Rabi '95-'96 season.

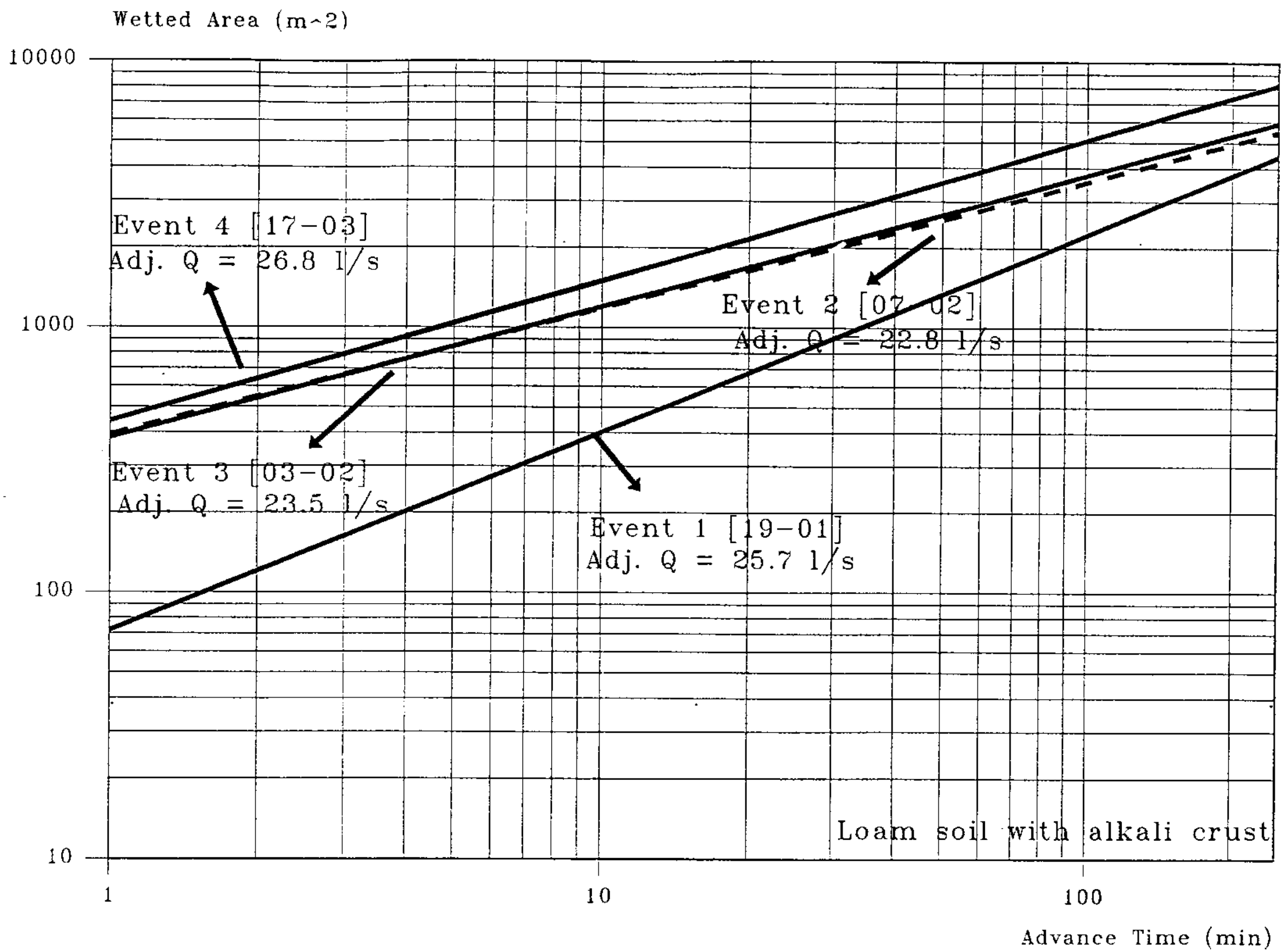


Figure 21. Advance graphs for Field 4, W/C Azim 111-L, Rabi '95-'96 season.

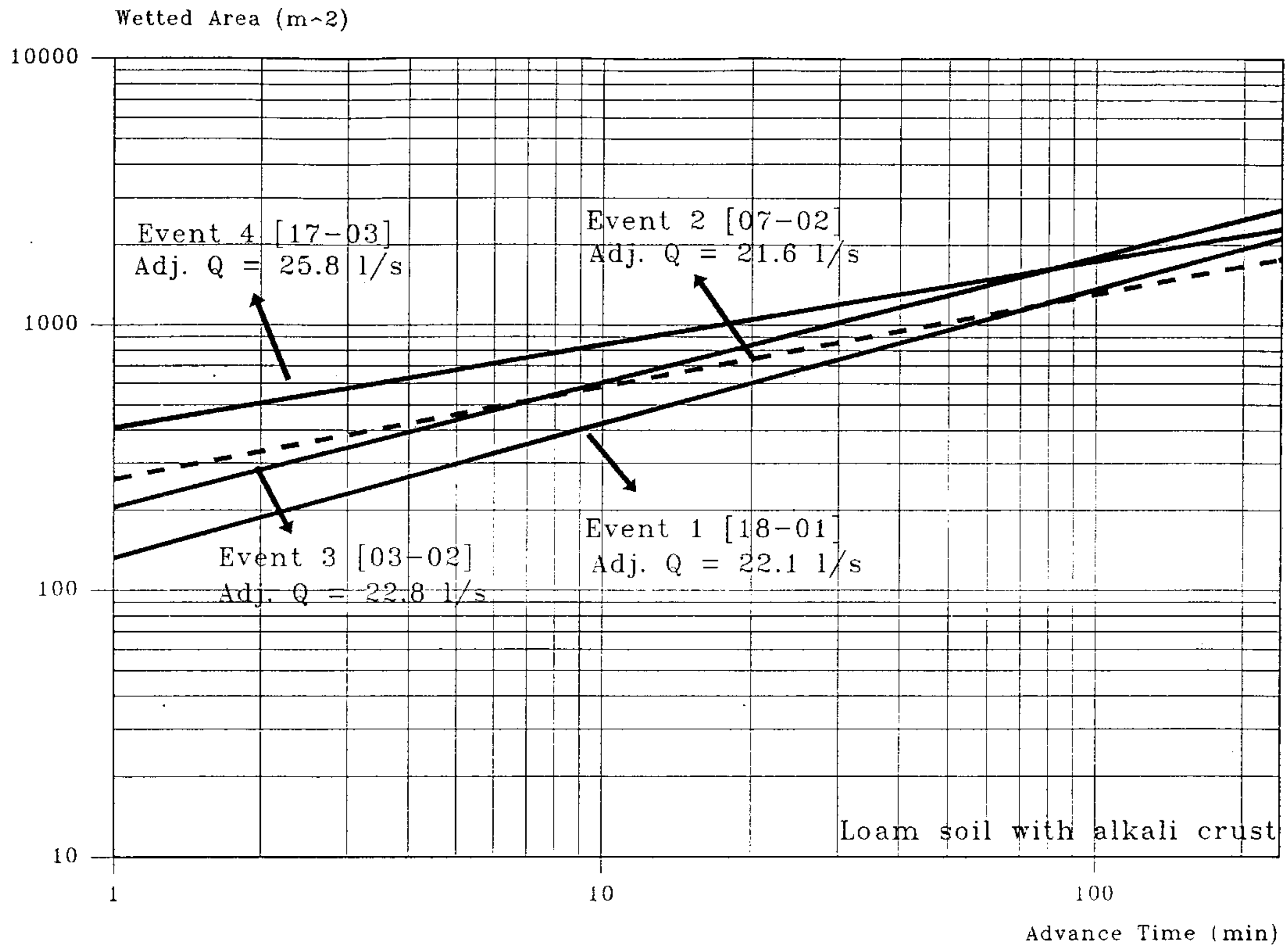


Figure 22. Advance graphs for Field 6, W/C Azim 111-L, Rabi '95-'96 season.

Infiltration Behavior

Introduction

Simultaneously with the advancing of the irrigation water after the opening of the field inlet, the infiltration process starts and will last, related to physical factors, till a considerable time after all the water has disappeared from the soil surface. The infiltration behavior in the sub-surface cannot be observed in a direct manner, and measurement techniques are necessary to obtain an indication of the infiltration behavior. Although infiltration functions are mostly graphically derived, based on data obtained through ring infiltrometer or ponding method tests, in this study a reciprocal approach, as suggested by Shafique and Skogerboe (1987), is used. This approach is used to make a *first estimation* of the cumulative infiltration function (Kostiakov-Lewis) based on advance, recession, irrigation duration and discharge data.

Basically, this section has a focus on: (i) behavior of the infiltration water after cutoff time (gauge readings) and the determination of the time when the infiltration rate becomes constant (basic intake rate) and the recession time; (ii) derivation of the infiltration function for the different irrigation events on each sample fields; and (iii) interpretation of the advance-infiltration relationships.

Gauge readings

During the irrigation monitoring, gauge readings were taken, respectively, at the head and tail reach of the field, right after the cutoff time. The drop in the water level was noted until the water level became zero. Although the infiltration cannot be quantified by interpreting the drop in the water level, these gauge readings are only used as an <u>indication</u> for the infiltration behavior for different soil types and for different irrigation events <u>after cutoff time</u>. This data has been used in order to facilitate the determination of the time when the infiltration rate becomes almost constant, which is called the basic intake rate and represents the nearly saturated infiltration rate (there is always some entrapped air in the soil profile). This data is needed for deriving the infiltration function. In Annexure 4, the results are graphically presented, along with the calculations.

The infiltration rate, I (mm/min) between two subsequent timings[3] after the cutoff time is equal to the difference between two gauge readings and the corresponding timings:

$$I = \frac{h_1 - h_2}{t_2 - t_1}$$

where: h_1 (mm) is the water level at time t_1 (min); h_2 (mm) is the water level at time t_2 (min); and I is the infiltration rate after the cutoff time (mm/min).

The calculation of the cumulative infiltration is based on the drop in the water level, which is assumed to be the infiltrated water depth for the corresponding time interval. For the cumulative values, the amount of decreased water level per time interval are accumulated.

Figure 23 gives an example of the behavior of the infiltration rate and the cumulative infiltration. The general tendency of the infiltration rate is an initially high rate, followed by a considerable "drop" and reaches a constant level after a certain time period. Similarly, the cumulative infiltration has initially a high value but reduces over time towards a constant level.

Table 16 shows the results of determining the time when the infiltration rate becomes almost constant. As shown in Table 16, extrapolation of the collected data has taken place in some of the cases; generally, the average has been taken between the head and tail. In other cases, only graphs were used for this determination. Sometimes, the gauge data were insufficient in order to make a proper graphical presentation.

Gauge readings were also used in order to determine the recession time. The assumption is taken that the time when the water level reaches zero near the head and tail gauge, represents the time of recession. Based on field observation, this approach turned out to be quite satisfactory. The monitoring of the recession data is quite impractical, since in many instances the time of recession took many days. In Table 17, data are presented on recession time (t_{rec}).

In most of the cases, the water level starts dropping after a certain period. This period between the end of advance and the time of cutoff, t_{co}, is the so called ponding phase. In some of the events, there was not a ponding phase. The ponding phase is followed by a depletion phase and lasts

[3] The tail reading turned out not to be adequate for this exercise, since the interval between the timing was too large.

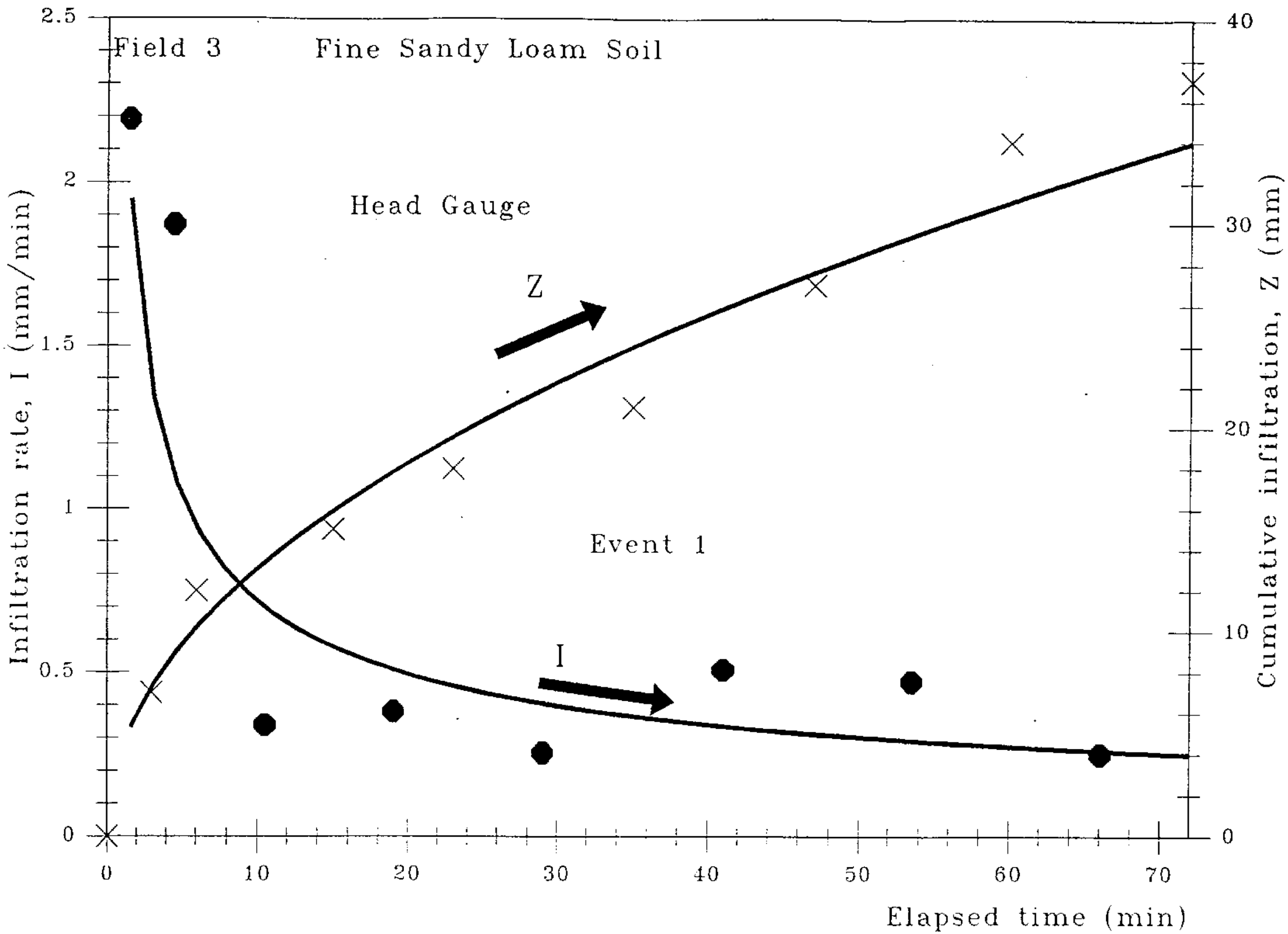


Figure 23. Infiltration rate and cumulative infiltration for Event 1, Field 3, W/C Fordwah 14-R.

Table 16: Determination of the time (t_{cir}) when the infiltration rate becomes almost constant.

Event	Date	Cutoff time t_{co}	$t_{cir'}$	t_{cir}	Applied method for determining t_{cir}
		(min)	(min)	(min)	
W/C Fordwah 14-R; Field 3					
Event 1	(14-01)	90	80	170	Extrapolation of the gauge readings
Event 2	(06-02)	44	199	243	-do-
Event 3	(29-02)	61	100	161	Graphically interpreted
Event 4	(12-03)	46	100	146	Based on Event 3
W/C Fordwah 14-R; Field 33					
Event 1	(23-01)	78	299	377	Extrapolation of the gauge readings
Event 3	(29-02)	55	600	655	Graphically interpreted
Event 4	(12-03)	54	805	859	Graphically interpreted
Event 5	(28-03)	29	805	834	Based on Event 4
W/C Fordwah 62-R; Field 8					
Event 2	(06-02)	27	1500	1527	Graphically interpreted
Event 4	(07-03)	22	843	865	Extrapolation of the gauge readings
Event 5	(27-03)	26	857	883	Extrapolation of the gauge readings
W/C Azim 111-L; Field 4					
Event 1	(19-01)	303	3000	3303	Based on results of Field 6
Event 2	(07-02)	164	2000	2164	-do-
Event 3	(02-03)	155	2500	2655	-do-
Event 4	(17-03)	147	2500	2647	-do-
W/C Azim 111-L; Field 6					
Event 1	(18-01)	223	3000	3223	Graphically interpreted
Event 2	(07-02)	150	2000	2150	Graphically interpreted
Event 3	(02-03)	147	2500	2647	Graphically interpreted
Event 4	(17-03)	142	2500	2642	Based on Event 3

Note: tcir = tco + tcir.

till the first dry spot occurs at the soil surface, which indicates the start of the recession phase, which on its turn lasts till the time when all of the water has infiltrated into the basin. Since the gauge readings were noted after the cutoff time, the irrigation duration has to be added to the duration of the recession phase in order to find the final recession time at the head and tail reach of the field, respectively. In this case, the depletion phase has not been monitored and is included in the recession phase.

Concerning the recession timings, there is a difference between the head and tail, as well as between the different irrigation events. Field 3 shows a lower recession time as compared to the more heavier soils. Although Field 8 was initially selected as a loamy-sand soil, the high recession time indicates more of a tendency towards a more heavier soil. The recession timings

Table 17: Ponding and recession data for the monitored events on the sample fields.

Field 3	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Event 5**
Advance time, ta (min)	80	43	57	45	33
Cutoff time, tco (min)	90	44	61	46	25
Ponding phase (min)	10	1	4	1	0
Recession time, trec					
- head gauge, trec (min)	166	170	204	179	225
- tail gauge, trec (min)	178	315	183	163	200
Average trec (min)	172	242.5	193.5	171	212.5
Field 33	**Event 1**	**Event 3**	**Event 4**	**Event 5**	
Advance time, ta (min)	62	43	42	32	
Cutoff time, tco (min)	78	55	54	29	
Ponding phase (min)	16	12	12	0	
Recession time, trec					
- head gauge, trec (min)	329	1365	1354	-	
- tail gauge, trec (min)	380	1375	1379	-	
Average trec (min)	354.5	1370	1366.5	-	
Field 8	**Event 2**	**Event 4**	**Event 5**		
Advance time, ta (min)	22	19	24		
Cutoff time, tco (min)	27	22	26		
Ponding phase (min)	5	3	2		
Recession time, trec					
- head gauge, trec (min)	2268	1385	365		
- tail gauge, trec (min)	3027	2740	1553		
Average trec (min)	2647.5	2062.5	959		
Field 4	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Event 5**
Advance time, ta (min)	249	160	140	77	67
Cutoff time, tco (min)	303	164	155	147	182
Ponding phase (min)	54	4	15	70	115
Recession time, trec					
- head gauge, trec (min)	2956	4360	4035	5797	4370
- tail gauge, trec (min)	4317	4430	6945	8727	5775
Average trec (min)	3636.5	4395	5490	7262	5072.5
Field 6	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Event 5**
Advance time, ta (min)	214	175	126	156	140
Cutoff time, tco (min)	223	150	147	142	180
Ponding phase (min)	9	0	21	0	40
Recession time, trec					
- head gauge, trec (min)	2855	4346	3451	5792	4297
- tail gauge, trec (min)	4205	2895	5487	6492	4312
Average trec (min)	3530	3620.5	4469	6142	4304.5

for Fields 4 and 6 (loamy soils) are high as compared with Field 33 which is considered to b more heavy soil (silty-loam). The alkali crust on the soil surface may be the cause of a long recession time. Other physical factors may have an impact on the recession time as well, such as the applied discharge and the field condition.After the cutoff time, there is a difference in water level between the head and tail reaches of the fields (Annexure 4). In other words, assuming that the different identified water levels as observed, infiltrate into the soil and no runoff occurs, since it is a bunded unit, there is a difference in infiltration after the cutoff time between the head and tail reach, which would be expected. For Field 3, the water level at the tail reach is lower as compared to the head reach. However, Field 8 shows a higher level at the tail reach, which sometimes also occurred in the case of Field 33 and Field 4. A much lower water level at the tail might be an indication of under irrigation at the tail reach. A much higher water level at the tail might be an indication of over irrigation at the tail reach.

Infiltration functions

In order to give a first estimation of the infiltration function, an alternative technique is used for determining the empirical constant of the Modified Kostiakov equation as proposed by Shafique and Skogerboe (1987). Basically, three approaches are distinguished in this technique to predict the infiltration characteristic:

(i) Simple calibration technique of the Modified Kostiakov Equation, whereby changes in the infiltration behavior from event to event are primarily reflected in the exponent "a" of the concerning equation.
(ii) Using an iterative scheme in order to further refine the calculated values in the first approach.

For both of the approaches, the assumptions are made that the subsurface water profile is linear and the average infiltrated depth for the set can be approximated as a function of opportunity time at the mid-point of the field (Shafique and Skogerboe, 1987). These assumptions do not count for the third approach:

(iii) By knowing the advance relationship and having recession data, the opportunity time is calculated in relation to the wetted area. Next, the average opportunity time is determined for an average infiltrated depth. The remaining calculations are the same as used in the second approach.

The first approach has been used in order to derive the infiltration function, i.e. the Modified Kostiakov Equation:

$$Z = A\tau^{B} + C\tau$$

where: Z = infiltrated water depth (mm); A= intake constant (mm/min^B); B = intake power (-); C = final intake rate (mm/min); τ = time (min).

In the first approach, the Philip's equation (B=0.5) is initially used in order to (i) determine the time required to infiltrate some initial depth, τ_1 (min); and (ii) to make a first calibration of the value of A. Next, a modification is made by determining C, the basic infiltration rate. Generally, the value of C is fixed by plugging in the recession time or a large enough time value in the differentiated cumulative infiltration equation ($I = AB\tau^{B-1}$, I = infiltration rate mm/min) as the time when the infiltration rate is assumed to be constant. However, this time can give an over estimated value for C whenever the soil is of a heavy type and shows a very slow recession procedure. In this analysis, the t_{cir}, as calculated in the previous paragraph, is used in order to determine C.

Next, the following relationships are used in order to modify the value of B and A according to the Modified Kostiakov Equation:

$$B = \frac{\ln[(Z_1 - C\tau_1)/(Z_2 - C\tau_2)]}{\ln(\tau_1/\tau_2)}$$

$$A = \frac{(Z_2 - C\tau_2)}{\tau_2^B}$$

where: Z_1 = initial infiltrated water depth (mm); Z_2 = average infiltrated water depth (mm); A = intake constant (mm/min^B); B = intake power (-); C = final intake rate (mm/min); τ_1 = corresponding time (min) to infiltrate Z_1; and τ_2 = intake opportunity time (min).

Table 18 presents the followed procedure for deriving the Modified Kostiakov Infiltration Equation. Some remarks will be made regarding the performed calculations. The basic data needed for proceeding with the calculations are: (i) discharge (Q, m^3/min); (ii) time of cutoff (t_{co}, min); (iii) field area (A, m^2); (iv) r and p values of the advance functions; (v) average recession time ($t_{rec\text{-}mid}$, min); and the time when the infiltration rate becomes almost constant, t_{cir}, min).

Table 18: Calculation of the infiltration function for selected irrigation events on the sample fields during Rabi '95-'96 season.

Event	Date	Applied volume	Z_t	Advance Function r	p	$(t_a)_{ave}$	$t_{rec\text{-}mid}$	τ_2	τ_1	B	A	t_{cir}	C	B	A
		m^3	mm	-	-	min	min	min	min	-	mm/min^B	min	mm/min	-	mm/min^B
W/C Fordwah 14-R; Field 3															
Event 1	(14-01)	106.7	104.35	0.762	36.98	31.38	172	140.62	0.0129	0.5	8.8001	170	0.3375	0.4352	6.6104
Event 2	(06-02)	59.1	57.86	0.824	50.42	16.62	242.5	225.88	0.0675	0.5	3.8500	243	0.1235	0.4200	3.0769
Event 3	(29-02)	72.2	70.69	0.830	37.10	23.57	193.5	169.93	0.0340	0.5	5.4230	161	0.2137	0.4162	4.0554
Event 4	(12-03)	57.3	56.06	0.868	40.28	18.67	171	152.33	0.0485	0.5	4.5425	146	0.1880	0.4124	3.4524
W/C Fordwah 14-R; Field 33															
Event 1	(23-01)	120.7	140.03	0.692	46.90	24.65	354.5	329.85	0.0168	0.5	7.7103	377	0.1986	0.4365	5.9298
Event 3	(29-02)	75.8	88.02	0.523	109.42	13.74	1370	1356.26	0.1751	0.5	2.3900	655	0.0467	0.3590	1.8540
Event 4	(12-03)	72.9	84.57	0.704	63.86	15.05	1366.5	1351.45	0.1889	0.5	2.3006	859	0.0392	0.3897	1.9001
Event 5	(28-03)	80.0	92.84	0.660	87.98	11.10	1344	1332.90	0.1546	0.5	2.5429	834	0.0440	0.3904	2.0583
W/C Fordwah 62-R; Field 8															
Event 2	(06-02)	79.7	80.70	0.705	103.20	9.22	2647.5	2638.28	0.4051	0.5	1.5712	1527	0.0201	0.3790	1.3970
Event 4	(07-03)	72.7	73.57	1.058	49.18	8.85	2062.5	2053.65	0.3794	0.5	1.6235	865	0.0276	0.3301	1.3626
Event 5	(27-03)	21.9	22.12	0.825	71.79	10.36	959	948.64	1.9379	0.5	0.7183	883	0.0121	0.3859	0.7565
W/C Azim 111-L; Field 4															
Event 1	(19-01)	466.7	105.34	0.747	71.88	98.41	3636.5	3538.09	0.3189	0.5	1.7709	3303	0.0154	0.4223	1.6124
Event 2	(07-02)	224.1	50.57	0.477	393.70	37.40	4395	4357.60	1.7038	0.5	0.7661	2000	0.0086	0.3312	0.8260
Event 3	(02-03)	218.5	49.31	0.496	382.46	34.51	5490	5455.49	2.2438	0.5	0.6676	2655	0.0065	0.3401	0.7486
Event 4	(17-03)	236.5	53.37	0.530	442.81	20.86	7262	7241.14	2.5419	0.5	0.6272	2647	0.0061	0.2814	0.7572
W/C Azim 111-L; Field 6															
Event 1	(18-01)	296.5	147.61	0.506	132.56	54.7127	3530	3475.29	0.1595	0.5	2.5039	3303	0.0218	0.4283	2.1877
Event 2	(07-02)	194.0	96.60	0.349	261.88	47.0685	3620.5	3573.43	0.3829	0.5	1.6160	2000	0.0181	0.3800	1.4302
Event 3	(02-03)	201.1	100.11	0.471	205.42	29.0643	4469	4439.94	0.4430	0.5	1.5024	2655	0.0146	0.3878	1.3624
Event 4	(17-03)	219.9	109.47	0.315	408.02	17.4549	6142	6124.55	0.5110	0.5	1.3989	2647	0.0136	0.3485	1.2548

The average depth of application, Z_2 (mm) is equal to:

$$Z_2 = \frac{Q t_{co}}{A}$$

where: Z_2 = average depth of application (mm); Q = applied discharge (m^3/min); tco = cutoff time (min); and A = area (m^2).

The assumption is taken that the amount of water applied to the field during an irrigation event entirely infiltrates into the soil. Losses are not considered in this regard. The initial infiltrated depth (Z_1) is assumed to be 1 mm.

The average advance time of a basin $(t_a)_{ave}$, is assumed to correspond to the time when 50 % of the field is covered with water:

$$(t_a)_{ave} = \left(\frac{(A/2)}{p}\right)^{1/r}$$

where: $(t_a)_{ave}$ = average advance time (min); A = area (m^2); and p and r = constants of the advance function.

The average opportunity time, τ_2 (min) is equal to the difference between the average recession time and the average advance time for that specific field.

Figures 24 - 28 show the graphical presentation of the developed infiltration functions for the respective fields. Some observations are provided below.

For Field 3 (Figure 24), a considerable decrease in infiltration over time occurred between Events 1 and 2, followed by an increase in the infiltration over time for Event 3. Next, the infiltration over time for Event 4 decreased and comes close to Event 2. For Field 33 (Figure 25), a considerable decrease in the infiltration over time is observed between Events 1 and 3. For Event 4 an increase in the infiltration over time is observed. Next, a decrease is observed in the infiltration over time for Event 5, which comes close to Event 3. For Field 8 (Figure 26), it is slightly difficult to make an interpretation, since the infiltration graphs for the important first event, as well as Event 3, are missing. Most logically, the infiltration graph for Event 1 should be far above Event 4 and Event 3, somewhere between Events 1 and 4. Although, Field 4 and 6 (Figures 27 and 28) are of the same soil type, Field 6 shows a higher infiltration over time for the first event, but less reduction in the infiltration over time for the second event as compared to the infiltration over time as presented for Field 4. For Field 4, the infiltration over time for Event 3 remained close to the one for Event 2. For Field 4, the infiltration over time decreased more for Event 4, whereas for Field 6, a increase in the infiltration over time is observed.

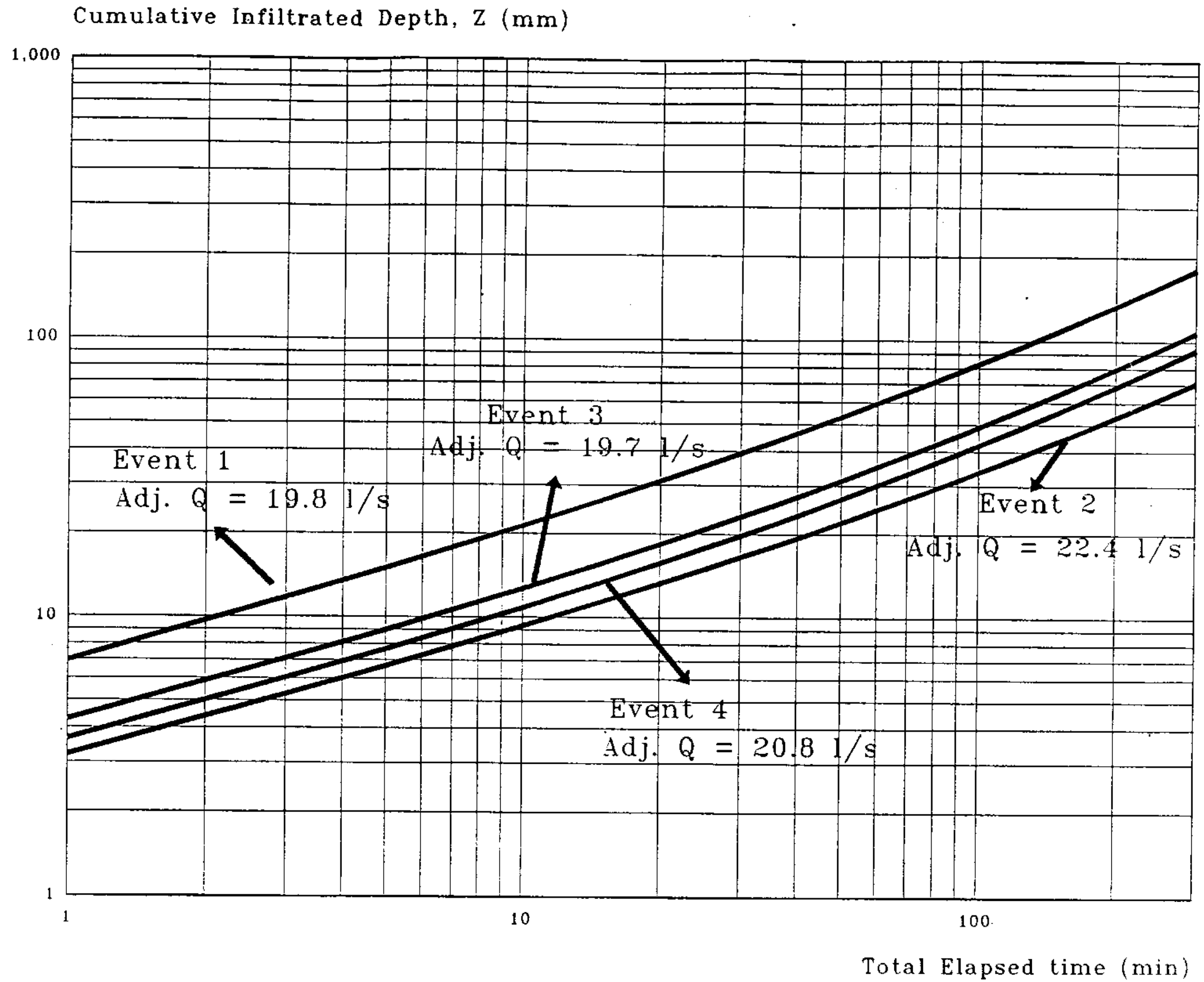


Figure 24. Infiltration graphs for selected irrigation events on Field 3, W/C Fordwah 14-R.

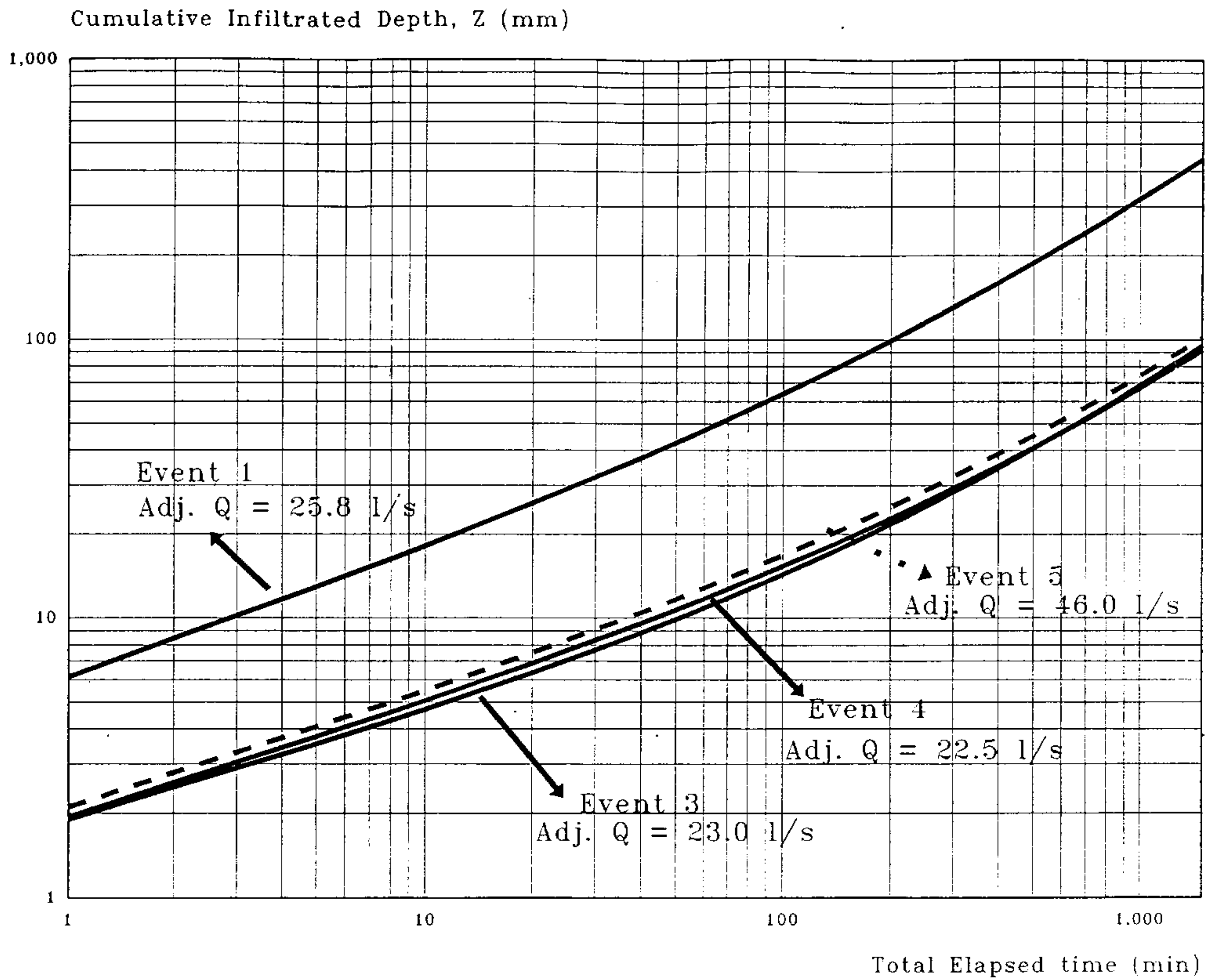


Figure 25. Infiltration graphs for selected irrigation events on Field 33, W/C Fordwah 14-R.

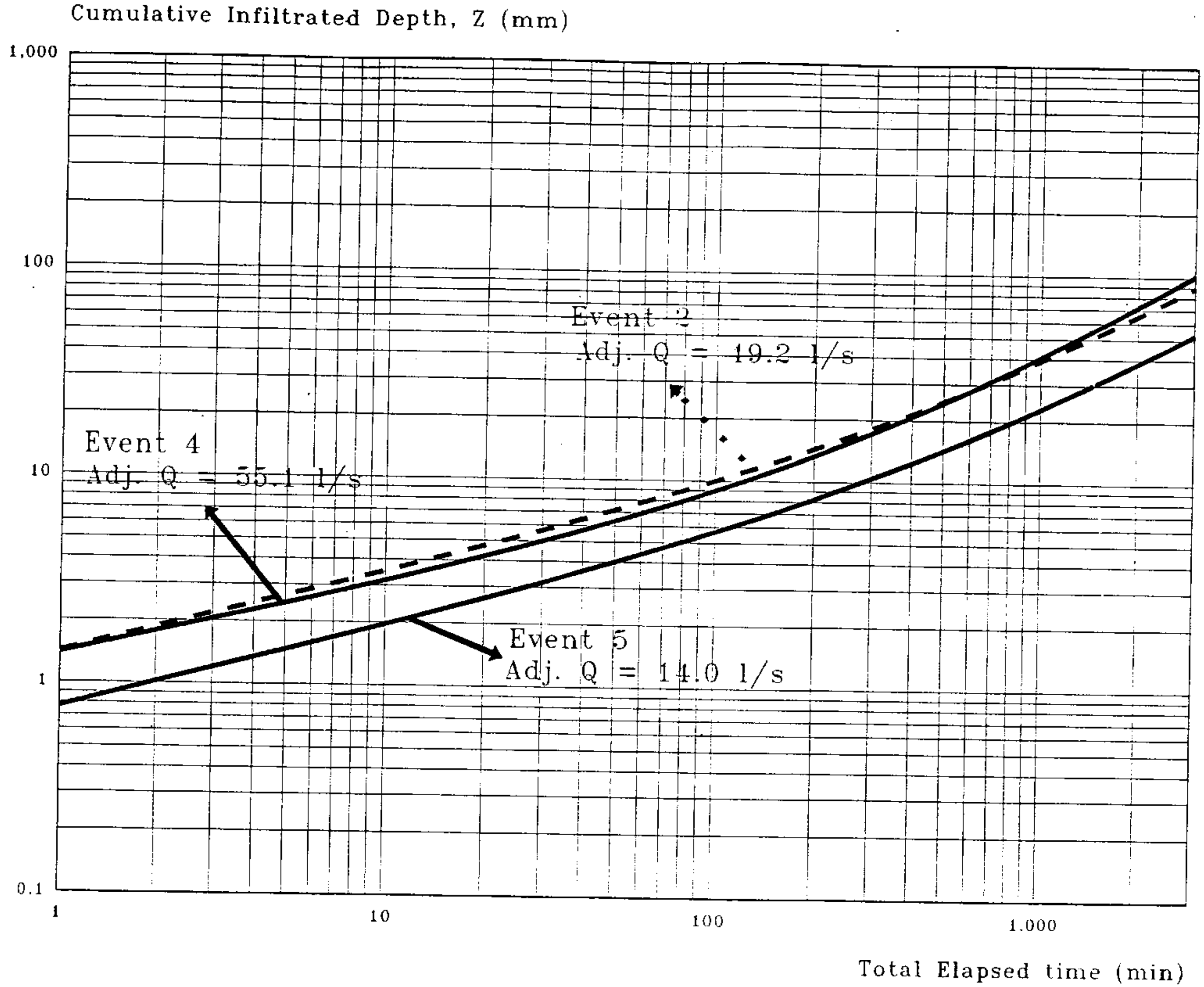


Figure 26. Infiltration graphs for selected irrigation events on Field 8, W/C Fordwah 62-R.

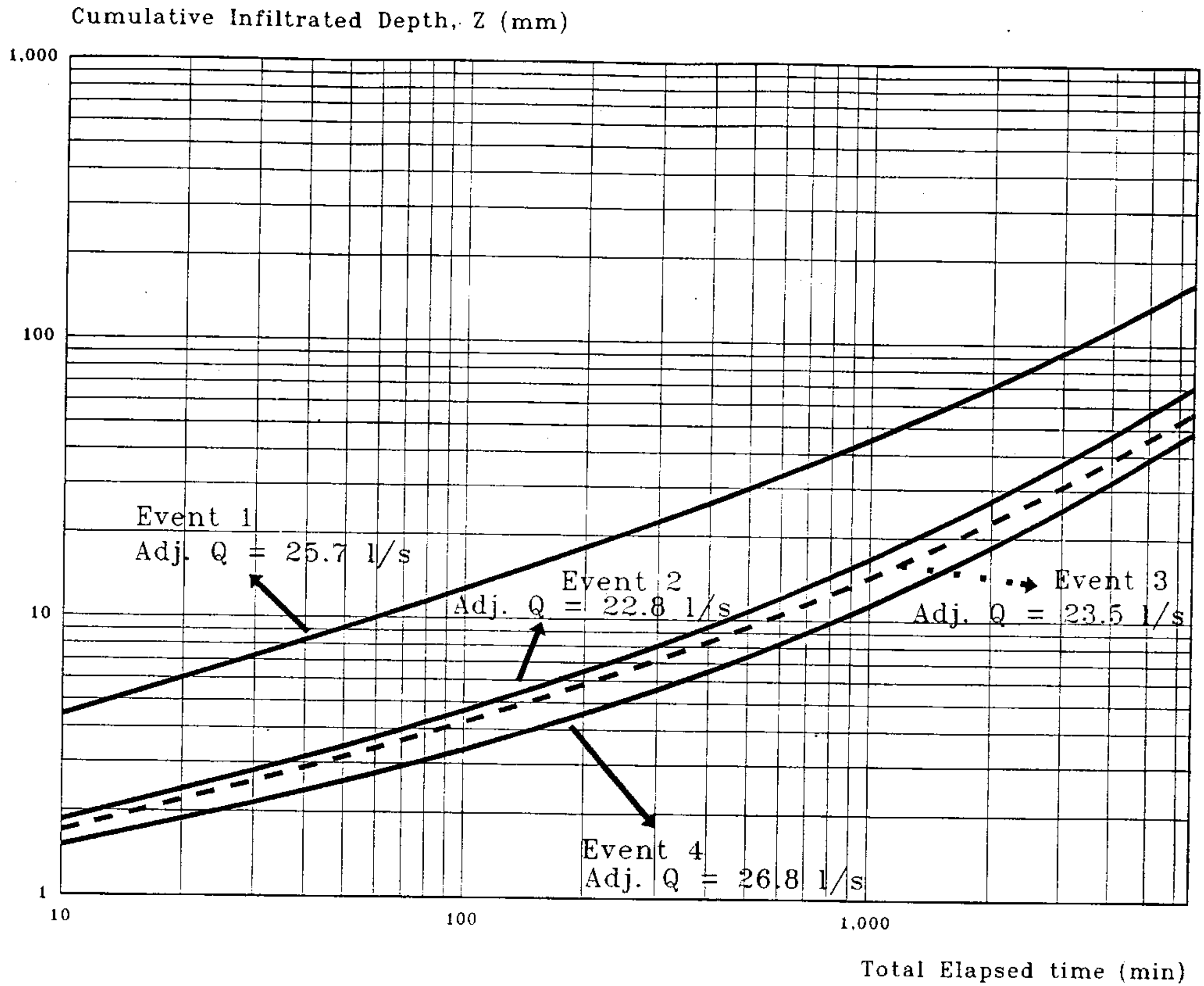


Figure 27. Infiltration graphs for selected irrigation events on Field 4, W/C Azim 111-L.

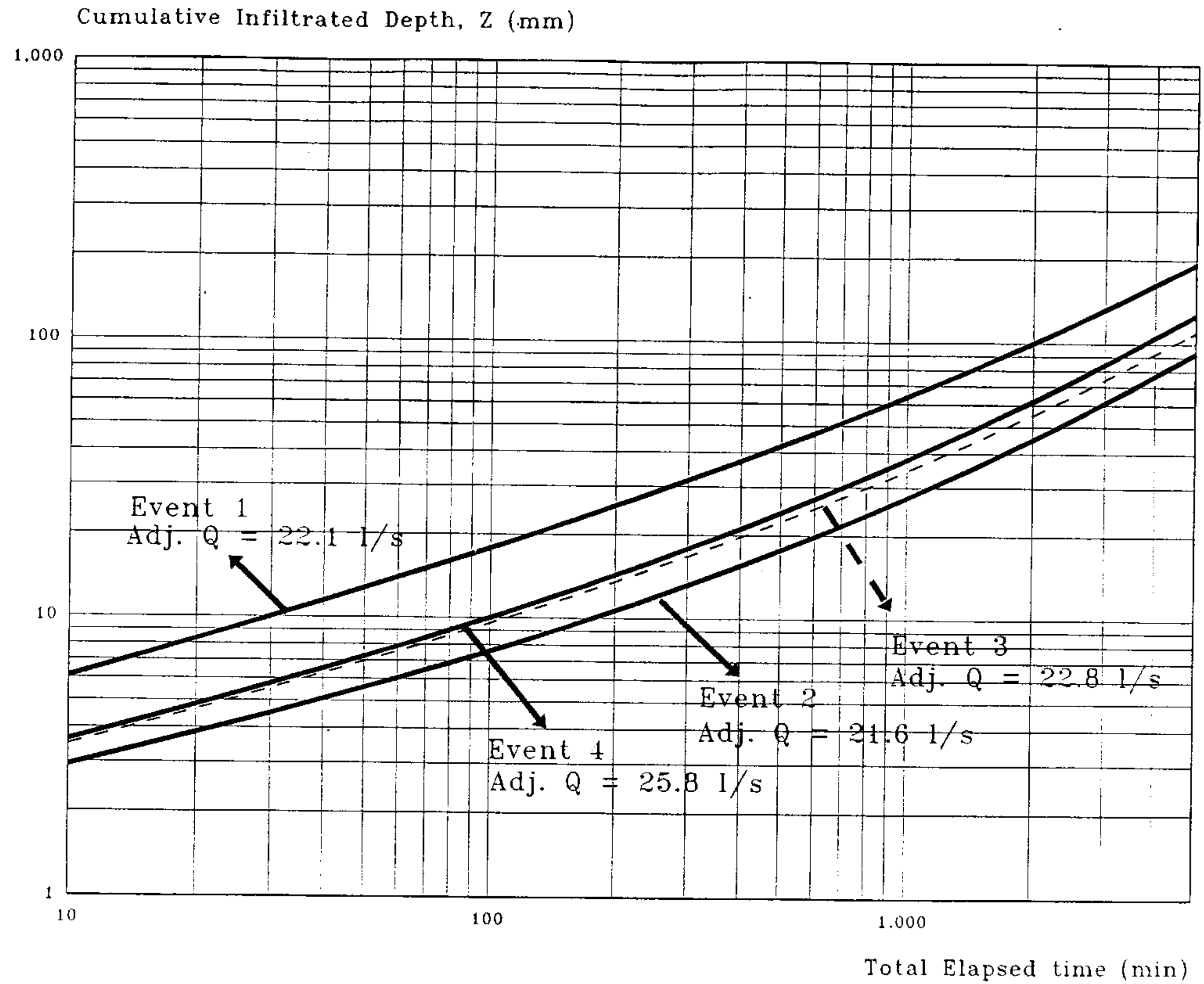


Figure 28. Infiltration graphs for selected irrigation events on Field 6, W/C Azim 111-L.

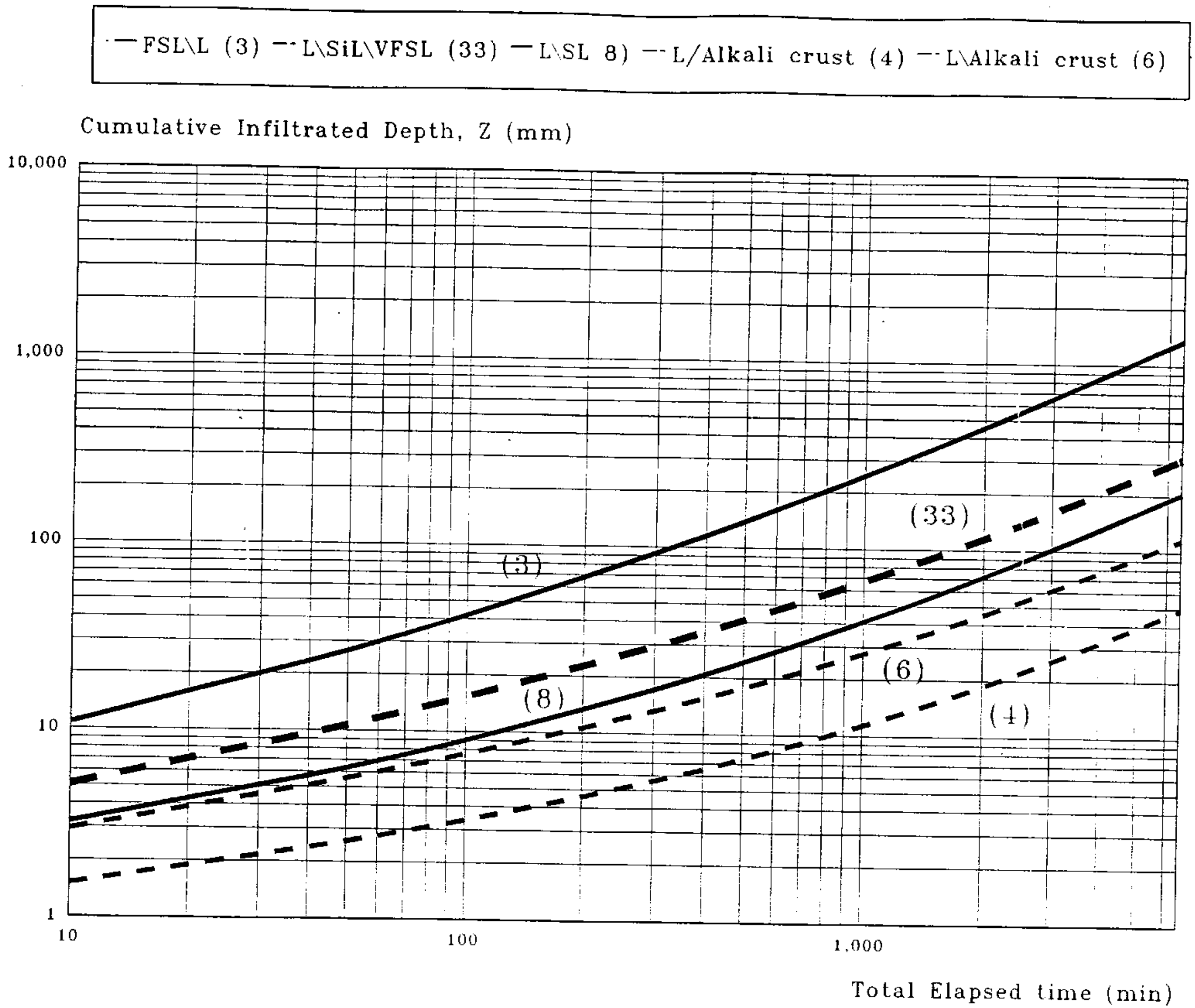


Figure 29. Infiltration graphs during Event 4 for different soils, Rabi '95-'96 season.

Generally, the infiltration over time shows a decreasing tendency, with the infiltration over time for the first event always exceptionally high. This can be ascribed to the soil condition. Due to the cultural practices, the soil has become loose and, thus, the infiltration rate of the soil is very high. Once the water has been applied to the field, the soil becomes more compact and results in a decrease in the infiltration rate. Similarly, the sudden increase of the infiltration over time for mostly the third irrigation event can be ascribed to the (inter) cultural practices, such as ploughing, done in order to remove the weeds. These practices make the soil loose again, but most probably due to surface soil sealing, the soil will not become that loose again as at the commencement of the irrigation season. Also, the plowing is done in a less intensive manner. Generally, over time, the infiltration rate will not change significantly, i.e. for the late irrigations the soil condition remains more or less the same and does not have much affect on the infiltration rate.

In Figure 29, the infiltration graphs for the different fields for the fourth irrigation event are presented. The fields are of different soil types, and it can be observed that the graph presents different results for the selected fields. Field 3 is a lighter soil (fine sandy loam \ loam) and shows a higher infiltration over time. Field 33 is a heavier soil (loam/silt loam/very fine sandy loam) and shows a lower infiltration over time. As indicated earlier, Field 8 turned out to be a disturbed soil (classified as loam/sandy loam), which showed an infiltration tendency more similar to a heavier soil. Fields 4 and 6 are loamy soils, but due to an alkali crust, the infiltration over time is very low; in this case, it was even observed that it took at least a day before a measurable drop in the water level was observed.

When the infiltration behavior is compared with the advance behavior, as elaborated in the previous section, it can be observed that the tendency is of a reciprocal character. This means that the behavior of the infiltration has an impact on the advance behavior. In other words, when more water infiltrates into the soil, it will take more time before the water reaches the end of the field. This is an important physical relation, which should be known when the irrigation scheduling takes place. Mostly, the farmers do not plan how long to irrigate. Mostly, this is a decision, based on his experience, the water availability, or on his decision as to how many fields have to be irrigated. The irrigation duration will be evaluated in the next section.

Sensitivity analysis of the basic intake rate, C

Based on the derived infiltration function, a sensitivity analysis was conducted for C (in relation to A and B). For this purpose, the first irrigation events on a lighter (Field 3) and heavier soil (Field 6) have been selected. The results are presented in Tables 19 and 20 for Field 3 and Field 6, respectively.

These tables demonstrate that an increase of C results in a decrease in B and A, and a decrease in C results in an increase of the parameters B and A, which represents the interdependent character of these three empirical parameters. However, the sensitivity in terms of percentage changes is much higher in the case of a 10% increase of C as compared to the 10% decrease of C. Furthermore, the greater C becomes, the higher the change of B and A in terms of percentage, whereas, the smaller C becomes resulting smaller changes of B and A in terms of percentage. Apparently, a lower value for C results in a more stable Modified Kostiakov Equation.

By comparing a lighter soil (Field 3) with a heavier soil (Field 6), it is noted that the same tendency occurs as mentioned for Field 3; however, the measure of changes in the parameters is relatively much less for Field 6 as compared to Field 3. Apparently, when the C value is relatively low (which is the case for heavier soils due to the long recession time), a fixed increase or decrease of C in terms of percentage has a smaller impact on C and, consequently, on A and B.

In order to see too what extent a change in the C value has an impact on the infiltration rate , I (mm/min), some of the calculated infiltration parameters as presented in Tables 19 and 20 are used for this demonstration. The infiltration functions used are marked (*) in the Tables 19 and 20, respectively. The purpose of this demonstration is to see to what extent a change in the C value has an impact on the basic intake rate in time. The results are presented in Figures 30 and 31 for Fields 3, Event 1 and Field 6, Event 1, respectively.

Figures 30 and 31 demonstrate that the main differences in infiltration rate occurs during the first time period of the infiltration process (i.e. the first 20 minutes for Field 3, Event 1; and the first 10 minutes for Field 6, Event 1), while on the longer term, little differences occur in the infiltration rate for the different infiltration functions. Furthermore, the differences in the beforementioned timings for Fields 3 and 6, respectively, indicate that for a lighter soil the C value is more sensitive as compared to a heavier soil.

The graphs also demonstrate that by increasing the value of C, the infiltration rate is under-estimated as compared to the original derived C value and visa versa. In other words, over-estimating C is a consequence of underestimating the intake opportunity time and visa versa.
It is essential to determine an accurate value of C in order to avoid over or under estimation of the infiltration rate and, consequently, the infiltration function.

Table 19: Sensitivity analysis of the basic intake rate for Event 1 on Field 3.

Field 3	Event 1				
	C (mm/min)	B (-)	A (mm/minB)	Decrease in B	Decrease in A
10% increase of C				%	%
*	0.3375	0.4353	6.6073		
*	0.3713	0.4260	6.3411	2.14	4.03
*	0.4084	0.4147	6.0331	2.64	4.86
*	0.4492	0.4008	5.6727	3.36	5.97
	0.4941	0.3830	5.2440	4.44	7.56
	0.5435	0.3593	4.7217	6.19	9.96
	0.5979	0.3252	4.0593	9.50	14.03
Field 3	Event 1				
	C (mm/min)	B (-)	A (mm/minB)	Increase in B	Increase in A
10% decrease of C				%	%
	0.3375	0.4353	6.6073		
*	0.3038	0.4438	6.8621	1.964	3.856
*	0.2734	0.4510	7.0827	1.611	3.215
*	0.2460	0.4570	7.2750	1.341	2.714
	0.2214	0.4622	7.4434	1.130	2.314
	0.1993	0.4666	7.5913	0.961	1.988
	0.1794	0.4705	7.7219	0.824	1.719
	0.1614	0.4738	7.8373	0.711	1.495
	0.1453	0.4767	7.9396	0.617	1.305
	0.1308	0.4793	8.0305	0.538	1.144
	0.1177	0.4816	8.1113	0.470	1.006
	0.1059	0.4835	8.1833	0.413	0.887
	0.0953	0.4853	8.2475	0.364	0.784
	0.0858	0.4869	8.3048	0.321	0.695
	0.0772	0.4882	8.3560	0.284	0.617
	0.0695	0.4895	8.4018	0.252	0.548
	0.0625	0.4906	8.4428	0.224	0.488
	0.0563	0.4915	8.4795	0.199	0.435
	0.0507	0.4924	8.5123	0.177	0.388
	0.0456	0.4932	8.5418	0.158	0.346
	0.0410	0.4939	8.5683	0.141	0.309
	0.0369	0.4945	8.5920	0.126	0.277
	0.0332	0.4951	8.6133	0.112	0.248
	0.0299	0.4956	8.6324	0.101	0.222
	0.0269	0.4960	8.6495	0.090	0.199
	0.0242	0.4964	8.6649	0.081	0.178
	0.0218	0.4968	8.6788	0.072	0.160
	0.0196	0.4971	8.6912	0.065	0.143
	0.0177	0.4974	8.7024	0.058	0.129

Table 20: Sensitivity analysis of the basic intake rate for Event 1 on Field 6.

Field 6	Event 1				
	C (mm/min)	B (-)	A (mm/minB)	Decrease in B	Decrease in A
10% increase of C				%	%
*	0.0218	0.4283	2.1874		
*	0.0240	0.4171	2.1424	2.60	2.05
*	0.0264	0.4033	2.0878	3.32	2.55
*	0.0290	0.3854	2.0195	4.43	3.27
	0.0319	0.3611	1.9307	6.30	4.40
	0.0351	0.3252	1.8063	9.97	6.44
	0.0386	0.2604	1.6029	19.92	11.26
Field 6	**Event 1**				
	C (mm/min)	**B (-)**	**A (mm/minB)**	**Increase in B**	**Increase in A**
10% decrease of C				%	%
	0.02180	0.4283	2.1874		
*	0.01962	0.4383	2.2287	2.335	1.888
*	0.01766	0.4465	2.2632	1.874	1.551
*	0.01589	0.4533	2.2925	1.535	1.295
	0.01430	0.4591	2.3176	1.277	1.094
	0.01287	0.4641	2.3392	1.075	0.933
	0.01159	0.4683	2.3580	0.914	0.802
	0.01043	0.4720	2.3744	0.783	0.694
	0.00938	0.4752	2.3887	0.676	0.604
	0.00845	0.4779	2.4013	0.586	0.528
	0.00760	0.4804	2.4124	0.511	0.463
	0.00684	0.4825	2.4222	0.447	0.407
	0.00616	0.4844	2.4309	0.392	0.359
	0.00554	0.4861	2.4386	0.345	0.317
	0.00499	0.4876	2.4455	0.305	0.281
	0.00449	0.4889	2.4516	0.270	0.250
	0.00404	0.4901	2.4571	0.239	0.222
	0.00364	0.4911	2.4619	0.212	0.198
	0.00327	0.4920	2.4662	0.189	0.176
	0.00294	0.4929	2.4701	0.168	0.157
	0.00265	0.4936	2.4736	0.150	0.140
	0.00239	0.4943	2.4767	0.134	0.125
	0.00215	0.4948	2.4795	0.119	0.112
	0.00193	0.4954	2.4820	0.107	0.100
	0.00174	0.4958	2.4842	0.095	0.090
	0.00157	0.4963	2.4862	0.085	0.081
	0.00141	0.4966	2.4880	0.077	0.072
	0.00127	0.4970	2.4896	0.069	0.065
	0.00114	0.4973	2.4910	0.061	0.058

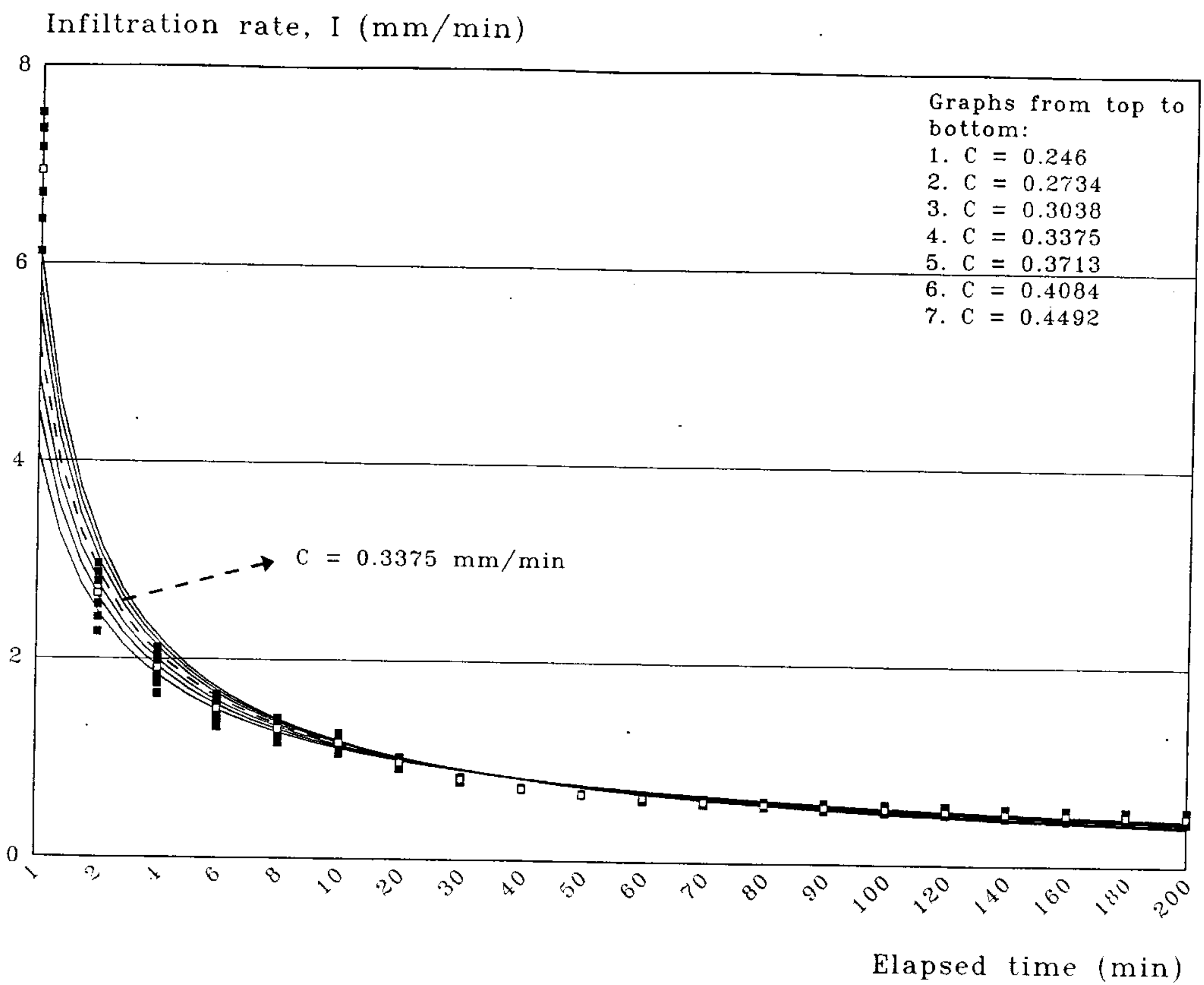


Figure 30. The infiltration rate for different values of C, A and B, for Event 1 on Field 3.

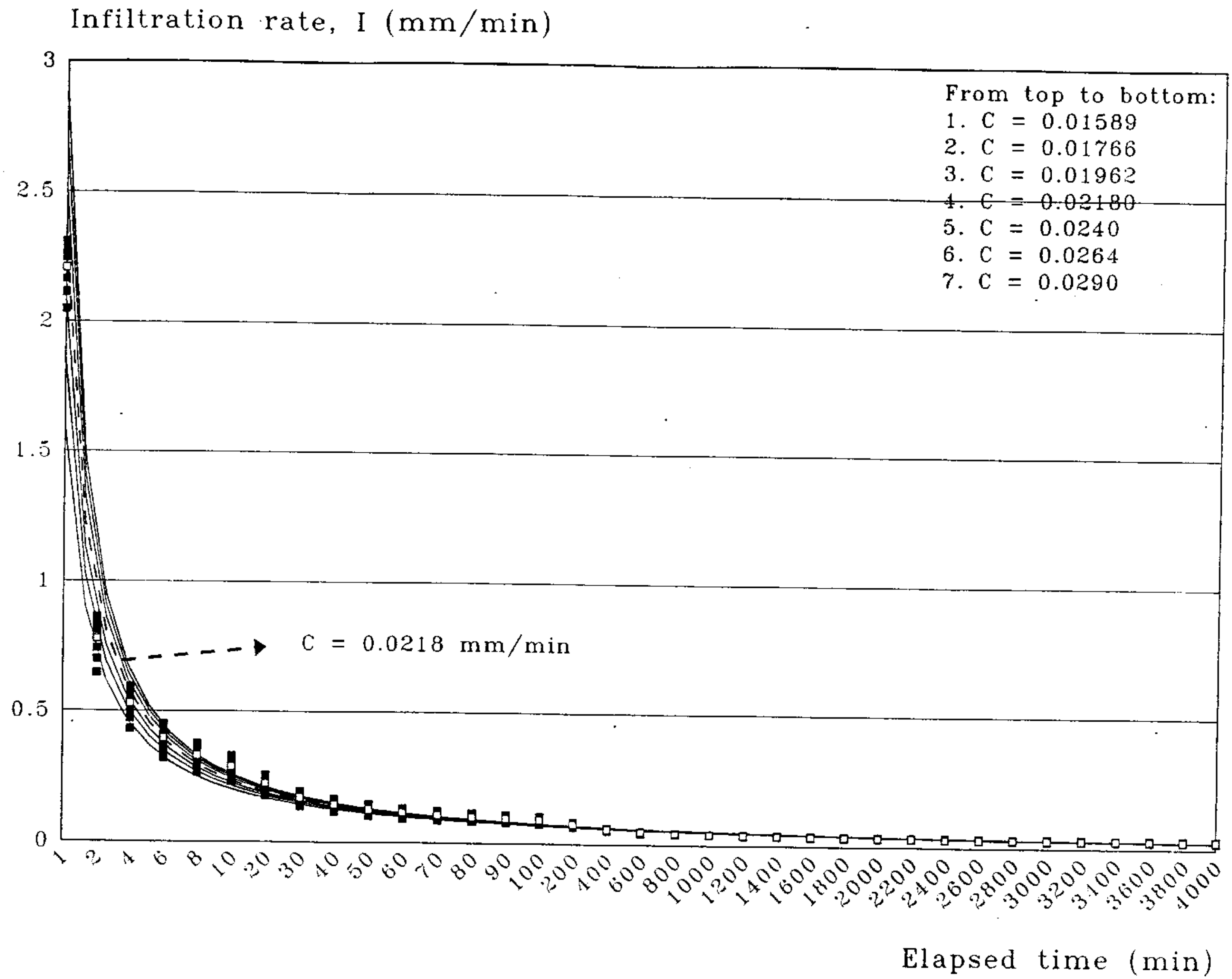


Figure 31. The infiltration rate for different values of C, A and B, for Event 1 on Field 6.

Soil Moisture Behavior

Introduction

In order to evaluate how much water is needed by the crop for a particular irrigation event, and how much water has actually been applied, the actual crop water requirement must be known. During the season, soil samples were taken before and after each irrigation event and a calculation procedure was followed in order to determine the Soil Moisture Deficit (SMD), which equals the crop water requirement, for each irrigation event. Next, a part of the irrigation scheduling is discussed and evaluated in this section, i.e. how long to irrigate in order to meet the crop water requirements. For this latter, an approach has been selected which is proposed in Shafique and Skogerboe (1987). Additionally, the irrigation performance is evaluated in terms of application and storage efficiencies and distribution uniformity.

Soil Moisture Deficit

By calculating the SMD, the entire sample depth has been taken into consideration, which concerns the first 36 inches of soil depth (91.44 cm). The assumption is taken that during the rouni irrigation the whole profile has been saturated with water; any change in the soil moisture content in this profile has to be addressed when calculating the SMD. Additionally, this assumption ignores the actual rooting depth at that specific irrigation event. With this approach, a degree of safety has been incorporated in the scheduling (evaluation) process.

Annexure 5 presents the calculations performed in order to determined the SMD. The calculations are done per field per irrigation (before and after) for four different depths (0 - 15.24 cm; 15.24 - 30.48 cm; 30.48 - 60.96 cm; and 60.96 - 91.44 cm) at the head and tail of the field. The soil samples were weighed before being dried in an oven (Wet wt, g) and after having been dried in the oven (Dry wt, g). The dry weight moisture fraction (W) has been calculated as:

$$W = \frac{Wet(wt) - Dry(wt)}{Dry(wt)}$$

wherein: W = dry weight fraction (-); Wet(wt) = wet weight of soil (g); Dry(wt) = dry weight of soil (g).

The calculation are done as suggested in FAO, 1989. Data on bulk density (g/cm^3) and the volumetric moisture content at Field Capacity (vmc FC) are derived from Annexure 1.

The volumetric moisture content (vmc; θ) is calculated as follows:

$$\theta = \frac{\gamma_b}{\gamma_w} W$$

wherein: θ = volumetric moisture content (-);γ_b = bulk density (g/cm^3); γ_w = specific weight of water (1.0 g/cm^3); and W = dry weight fraction.

The soil moisture deficit is defined as follows:

$$SMD = (\theta_{fc} - \theta)RD$$

wherein: SMD = Soil Moisture Deficit (cm); θfc = moisture content at FC (-); θ initial moisture content (-); RD = root depth or depth of the considered soil depth (cm).

Comparing the figures on SMD (Annexure 5) on differences between before and after an irrigation, it can be observed that most of the changes do occur in the first two sample layers (till 30.48 cm). Additionally, in most of the instances, the SMD is higher at the head of the field as compared to the tail. After the irrigation, often negative SMD values were derived. This indicates that apparently the field moisture condition was not yet at FC.

In order to find the overall SMD for a field per event, the average has been taken between the SMD at the head and tail of the field. Where the SMD showed negative values, the SMD was assumed to be equal to zero. Table 21 shows the results on the average SMD for each field and irrigation event (before and after). These data are used for further calculations.

Table 21: Soil moisture deficit for each irrigation event on the sample fields during the Rabi '95-'96 season.

Field 3	**Event 1**	**Event 2**	**Event 3**	**Event 4**	**Event 5**
	(14-01)	**(06-02)**	**(29-02)**	**(12-03)**	**(28-03)**
SMD (mm)		**Before irrigation**			
- at head	58.88	56.10	79.74	55.90	55.61
- at tail	44.90	55.30	40.24	41.35	65.50
Average:	**51.89**	**55.70**	**59.99**	**48.63**	**60.56**
SMD (mm)		**After irrigation**			
- at head	31.96	36.41	34.35	123.52	53.70
- at tail	29.39	15.97	36.28	29.47	60.62
Average:	**30.68**	**26.19**	**35.32**	**76.50**	**57.16**

.....continued

....continuation of Table 21

Field 33	Event 1	Event 3	Event 4	Event 5	Event 6
	(23-01)	(29-02)	(12-03)	(22-03)	(11-04)
SMD (mm)		Before irrigation			
- at head	56.58	66.68	72.16	57.23	141.35
- at tail	47.28	59.72	47.42	24.52	88.21
Average:	**51.93**	**63.20**	**59.79**	**40.88**	**114.78**
SMD (mm)		After irrigation			
- at head	43.49	34.59	126.83	125.11	26.09
- at tail	19.70	29.19	45.03	83.93	27.38
Average:	**31.60**	**31.89**	**85.93**	**104.52**	**26.74**

Field 8	Event 1	Event 2	Event 3	Event 4	Event 5
	(19-01)	(06-02)	(21-02)	(07-03)	(28-03)
SMD (mm)		Before irrigation			
- at head	89.80	54.41	-	55.99	71.42
- at tail	82.81	54.88	-	70.23	78.74
Average:	**86.31**	**54.65**	-	**63.11**	**75.08**
SMD (mm)		After irrigation			
- at head	-	67.76	-	56.83	37.32
- at tail	-	43.02	-	65.12	61.33
Average:	-	**55.39**	-	**60.98**	**49.33**

Field 4	Event 1	Event 2	Event 3	Event 4	Event 5
	(19-01)	(07-02)	(02-03)	(17-03)	(01-04)
SMD (mm)		Before irrigation			
- at head	91.56	79.21	67.39	60.77	76.78
- at tail	62.55	59.40	42.50	61.89	91.85
Average:	**77.06**	**69.31**	**54.95**	**61.33**	**84.32**
SMD (mm)		After irrigation			
- at head	38.24	47.37	61.39	63.02	98.81
- at tail	47.70	22.87	26.42	24.41	49.00
Average:	**42.97**	**35.12**	**43.91**	**43.72**	**73.91**

Field 6	Event 1	Event 2	Event 3	Event 4	Event 5
	(18-01)	(07-02)	(02-03)	(17-03)	(01-04)
SMD (mm)		Before irrigation			
- at head	64.11	61.67	57.91	50.89	134.31
- at tail	40.28	50.11	50.28	88.61	104.26
Average:	**52.20**	**55.89**	**54.10**	**69.75**	**119.29**
SMD (mm)		After irrigation			
- at head	27.24	33.75	45.02	80.80	84.52
- at tail	29.67	86.58	38.75	96.54	68.48
Average:	**28.46**	**60.17**	**41.89**	**88.67**	**76.50**

Evaluation of the irrigation duration

This evaluation is based on the first approach as described in Shafique and Skogerboe (1987). The approach is based on the volume balance principals, and takes into account that for basins, the water has to be cutoff before the right depth is infiltrated.

For calculating the desired cutoff time, basic information is needed on: (i) discharge (m^3/min); (ii) the advance function (r and p); (iii) the infiltration function (A, B, and C); and (iv) area, A (m^2).

The first step is to estimate the volume of water infiltrated at the time when the water has advanced to the end of the field ($(t_a)_L$):

$$(Vinf)_{(t_a)_L} = Z_0 \sigma_Z A$$

wherein: $(Vinf)_{(ta)L}$ = volume of water infiltrated at $(t_a)_L$ (m^3); Z_0 = the infiltrated depth at the inlet at $(t_a)_L$ (mm); shape factor = 0.65; A = area (m^2).

The second step is to calculate the volume of water delivered at $(t_a)_L$:

$$(Vin) = Q(t_a)_L$$

wherein: (Vin) = volume of water delivered at $(t_a)_L$; Q = discharge to the field (m^3/min); $(t_a)_L$= time when water has advanced to the end of the field (min).

The third step is to estimate the volume of surface water storage at $(t_a)_L$:

$$(Vsurf)_{(t_a)_L} = (Vin) - (Vinf)$$

wherein: $(Vsurf)_{(ta)L}$ = the volume of surface water storage at $(t_a)_L$,(m^3); (Vin) = the volume of water delivered at $(t_a)_L$,(m^3); and (Vinf) = the volume of water infiltrated at $(t_a)_L$,(m^3).

The fourth step is to determine the volume of water required to be applied:

$$V_{reqd} = \frac{(SMD)\ A}{1000 mm / m}$$

wherein: Vreqd = the volume of water required to be applied (m^3); SMD = Soil Moisture Deficit (mm); and A = area (m^2).

The fifth step is to determine the time difference in cutoff time as compared with the advance time:

$$t_{dif} = ((Vreq) - (Vsurf)) / Q$$

wherein: t_{dif} = difference in cutoff time compared to advance time; Vreqd = the volume of water required to be applied (m^3); $(Vsurf)_{(ta)L}$ = the volume of surface water storage at $(t_a)_L$,(m^3); and Q = discharge applied to the field (m^3/min).

Based on these findings, the cutoff time is calculated as follows:

$$t_{co} = (t_a)_{x=L} \pm t_{dif}$$

wherein: t_{co} = calculated cutoff time (min); $(t_a)_{x=L}$ = end of advance time (min); t_{dif} = difference in cutoff time as compared with the advance time (min).

Whenever the t_{dif} turned out to be negative; the cutoff time was assumed to be equal to the end of the advance time.

The calculations are presented in Annexure 6. In Table 2 the results are summarized:

For all of the fields, a difference in the calculated cutoff time and the actual cutoff time as practiced by the farmers is observed. However, in four instances (Field 33, Event 3, Field 8, Events 2 and 4), the difference is negligible (≤ 3 min.). For about 32 % of the events, the farmers irrigated a too long time period (presented as negative values). For about 47 % of the events, the farmers irrigated a too short time period (presented as positive values).

These statistics indicates that for most of the time the practiced irrigation duration does not correspond to the actual crop water requirements; consequently, the fields are irrigated for too long or too short of a time period, which may have over and under irrigation as a consequence, respectively. In the next paragraph, the measure of over and under irrigation is further specified.

Table 22: Calculated and practiced irrigation durations for selected irrigations events on the sample fields during the Rabi '95 - '96 irrigation season.

Field 3		**Calculated**	**Practiced**	
Event	**Date**	**tco**	**tco**	**Difference**
		(min)	**(min)**	**(min)**
Event 1	14-01	84	90	-6
Event 2	06-02	52	44	8
Event 3	29-02	70	61	9
Event 4	12-03	53	46	7
Field 33		**Calculated**	**Practiced**	
Event	**Date**	**tco**	**tco**	**Difference**
		(min)	**(min)**	**(min)**
Event 1	23-01	67	78	-11
Event 3	29-02	52	55	-3
Event 4	12-03	42	54	-12
Event 5	21-03	32	29	3
Field 8		**Calculated**	**Practiced**	
Event	**Date**	**tco**	**tco**	**Difference**
		(min)	**(min)**	**(min)**
Event 2	06-02	25	27	-2
Event 4	07-03	20	22	-2
Event 5	27-03	90	28	62
Field 4		**Calculated**	**Practiced**	
Event	**Date**	**tco**	**tco**	**Difference**
		(min)	**(min)**	**(min)**
Event 1	19-01	260	303	-43
Event 2	07-02	237	164	73
Event 3	02-03	183	155	28
Event 4	17-03	174	147	27
Field 6		**Calculated**	**Practiced**	
Event	**Date**	**tco**	**tco**	**Difference**
		(min)	**(min)**	**(min)**
Event 1	18-01	215	223	-8
Event 2	07-02	343	150	193
Event 3	02-03	127	147	-20
Event 4	17-03	158	142	16

Irrigation performance

For basin irrigation systems, three independent hydraulic performance indicators are needed in order to evaluate the field irrigation performance. These three indicators are: (i) application efficiency; (ii) storage efficiency; and (iii) distribution uniformity; whereby (i) and (iii) evaluate the adequacy of an applied irrigation, and (iii) evaluates the equity of an applied irrigation (soil moisture distribution).

As mentioned in Hart et. at. (1979), three assumptions are made while using these three parameters: (i) all the water delivered to the field edge but not absorbed through infiltration or collected as runoff for reuse is considered as loss, and the nature of this loss (i.e., evaporation, runoff, etc.) is not important; (ii) the requirement at the time of irrigation is the water required to fill the available rootzone water storage, and this requirement is equal throughout the field; and (iii) a single lumped parameter is adequate to characterize the distribution of water from an irrigation.

With respect to point (ii) above, for calculating the crop water requirement at the time of irrigation, the entire sample depth has been taken into consideration instead of the actual rooting depth at the time of irrigation.

The following definitions are ascribed to the indicators (Jensen, 1983):

- **Application Efficiency, E_a (%):**

The ratio of the average depth of the irrigation water infiltrated and stored in the rootzone to the average depth of irrigation water applied.

- **Storage Efficiency, E_s (%):**

The ratio of the average depths of water stored in the rootzone to the average depth storable

- **Distribution Uniformity, DU (%):**

The ratio of the average low-quarter depth of irrigation water infiltrated (or caught) to the average depth of irrigation water infiltrated (or caught).

The basic data needed for the calculations are (i) the applied water depth; (ii) the SMD; and (iii) the infiltration function. Table 23 presents the calculated values for the E_a, E_s and DU. It was assumed that the deep percolation ratio (DPR) equals the difference between the SMD and the applied water depth (Z_2). Annexure 7 presents the calculations of the DU for the selected irrigation events on the sample fields.

Table 23: Application and storage efficiencies and distribution uniformity for selected irrigation events on the sample fields.

Event	Date	Z_2 (mm)	SMD (mm)	DPR (mm)	Stored (mm)	E_a (%)	E_s (%)	DU (%)
W/C Fordwah 14-R; Field 3								
Event 1	(14-01)	104.35	51.89	-52.46	51.89	49.73	100	85.52
Event 2	(06-02)	57.86	55.70	-2.16	55.70	96.27	100	95.33
Event 3	(29-02)	70.69	59.99	-10.70	59.99	84.86	100	91.42
Event 4	(12-03)	56.06	48.63	-7.43	48.63	86.75	100	92.80
W/C Fordwah 14-R; Field 33								
Event 1	(23-01)	140.03	51.93	-88.10	51.93	37.08	100	95.46
Event 3	(29-02)	88.02	63.20	-24.82	63.20	71.80	100	98.96
Event 4	(12-03)	84.57	59.79	-24.78	59.79	70.70	100	99.16
Event 5	(28-03)	92.84	40.88	-51.96	40.88	44.03	100	99.32
W/C Fordwah 62-R; Field 8								
Event 2	(06-02)	80.70	54.65	-26.05	54.65	67.72	100	99.73
Event 4	(07-03)	73.57	63.11	-10.46	63.11	85.78	100	99.68
Event 5	(27-03)	22.12	75.08	52.96	22.12	100.00	29.46	99.40
W/C Azim 111-L; Field 4								
Event 1	(19-01)	105.34	77.06	-28.28	77.06	73.15	100	98.14
Event 2	(07-02)	50.57	69.31	18.74	50.57	100	72.96	99.14
Event 3	(02-03)	49.31	54.95	5.64	49.31	100	89.74	99.37
Event 4	(17-03)	53.37	61.33	7.96	53.37	100	87.02	99.67
W/C Azim 111-L; Field 6								
Event 1	(18-01)	147.61	52.20	-95.41	52.20	35.36	100	98.26
Event 2	(07-02)	96.60	55.89	-40.71	55.89	57.86	100	98.67
Event 3	(02-03)	100.11	54.10	-46.01	54.10	54.04	100	99.43
Event 4	(17-03)	109.47	69.75	-39.72	69.75	63.72	100	99.38

The results reveal that for 47% of the monitored irrigation events the irrigation turned out to be either insufficient or excessive (35 % $\leq E_a \leq$ 70 % and E_s = 100 % or E_a = 100 % and $E_s \leq$ 25 %). More specifically:

- *Balanced irrigation* (E_a = 96.27 % and E_s = 100 %):

Field 3, Event 2.

Towards a balanced irrigation ($E_a \approx$ 85 % and E_s = 100 % or Ea = 100 % and Es ≈ 88 %):
Field 3, Events 3 and 4; Field 4, Events 3 and 4.

- *Excessive irrigation or over-irrigation* (35 % $\leq E_a \leq$ 70 % and E_s = 100 %):

Field 3, Event 1; Field 33, Events 1 and 5; Field 8, Event 2; Field 6, Events 1 - 4.

- *Tendency towards over-irrigation* ($E_a \approx 70$ % and $E_s = 100$ %):
Field 33, Events 3 and 4; Field 4, Event 1.

- *Insufficient irrigation or under-irrigation* ($E_a = 100$ % and $E_s \leq 25$ %):
Field 8, Event 5.

- *Tendency towards under-irrigation* ($E_a = 100$ % and $E_s \approx 70$ %):
Field 4, Event 2.

In the case of the excessive irrigations, the crop water requirement was met, however, the DPR is excessive. In the case of insufficient irrigations, the crop water requirement has not be met (i.e. the deficit is excessive).

For all the irrigation events, the equity in water distribution across the field or the soil moisture distribution was good, which is reflected in a high percentage of DU (90 % ≤ DU ≤ 99.7 %). Only Event 1 on Field 3 shows a lower DU of 85.52 %, which is quite surprising, since Event 1 of Field 3 was pointed out as being excessively irrigated. Apparently, other factors than applied volume of water influence the performance indicators. These factors might be related to variation in soil characteristics or the variation in condition of the soil surface.

This statement may also hold good as explanation of some of the differences in results between what has been analyzed in Table 22 (i.e. the difference in calculated and practiced irrigation durations for the selected irrigations on the sample fields) and the results, obtained through the performance assessment (Table 23). When the two tables are compared with each other, it turns out that in some instances an over irrigation or tendency towards over irrigation was indicated (Table 23), while the practiced irrigation duration was either too long or too short (e.g. Field 3, Event 1; Field 33, Event 5; Field 8, Event 2; and Field 6, Events 1, 2 and 4). The extreme difference for Event 2 of Field 6 can be explained from the fact that the total irrigation duration has been estimated, and consequently, the total volume applied, since the tubewell was temporarily shut off during the time of irrigating this field. This also happened during the first irrigation event on Field 4. With respect to under-irrigation or the tendency towards under-irrigation, contradictions did not occur.

Overall, this performance can be considered quite critical when compared with the results for the crop stages (boxes 1, 2 and 3). The low performance of the first irrigation event can affect the seed germination and emergence during the establishment stage. Another critical stage during the flowering period (occurred closely after Irrigation Event 3). During that period, the irrigation performance was not satisfactory for Field 33, Field 4 and Field 6.

Conclusions

In this report, a maximum effort has been made on analyzing and synthesizing the irrigation field data collected during the Rabi '95-'96 season. The report has provided insights into the main surface and subsurface irrigation processes (i.e. advance, infiltration and soil moisture behavior).

Concerning the advance behavior, an irregular advance profile was observed, mainly due to the insufficient leveling of the fields, lack of weed control, and the corrugations which occurred due to the traces of the plow. This also made the advance behavior a difficult phenomenon to monitor. A suggestion which can be given is to monitor the advance distances versus time instead of the time versus the advance distance. The basins turn out to be not exactly basins; initially, the water follows the corrugations, but with a small time lag, the water overtops the corrugations and the field becomes a basin.

A comparison between the two-point fitting method and least square regression technique was made in order to develop the best possible advance functions for the fields and their respective events. Results have shown that the least square regression technique is more accurate, since it includes more observation points. However, the two-point method is more practical and useful when less observation points are available. Inaccurate monitoring occurred when the crop becomes too dense; consequently, the advance function can then only be an approximation.

The advance graphs show a general tendency of increasing from event to event. However, at the third irrigation event, mostly a decrease was observed, followed by a decrease again for the following events.

The gauge readings provided insights into the infiltration rate, the time when the infiltration rate becomes almost constant, and the recession time, both difficult to observe; and for which the gauge readings were used as a guideline. However, the irregularities in the taken readings made it sometimes difficult to do a proper graphical analysis. It is suggested that the readings be taken more frequently; especially in the initial stage after cutoff time and later towards the end of the recession time. Similarly, the depletion phase should be indicated more clearly.

The infiltration functions were calculated and graphically presented. The general tendency which could be observed from the graphs is a high infiltration over time for the first irrigation, followed by a decrease for the following irrigations. Mostly, the third irrigation showed an increase in the infiltration rate, due to inter-culture practices by the farmer (such as plowing / weeding). Next, a decrease occurred again in the infiltration rate over time. The later irrigations generally showed a less significant change in the infiltration over time. A similar but reciprocal tendency was observed for the advance behavior. It became clear that their is a strong correlation between the advance and infiltration behavior; the higher the infiltration rate, the longer it takes for the water to advance to the end of the field. This physical phenomenon has to be taken into account when it comes to irrigation scheduling.

Irrigation scheduling is discussed in the last section of the report. The SMD data show that their is a considerable difference in SMD between the head and tail of the field. Next, when the SMD conditions before and after irrigation are compared with each other, it has been observed that the major changes do occur in the first 30 cm of the subsurface. In some of the instances, the SMD showed positive results. This indicates that the soil moisture condition was not yet at FC. This reflects the main constraint of the gravimetric soil sampling; it is difficult to judge when the field condition is at FC. Additionally, the collecting of the samples is quite disturbing for the farmers, since each time holes are made by using an Auger, and people have to go in the field. These holes, although they are filled with soil again, do disturb the original texture of the soil.

The evaluation on how long to irrigation revealed that for 79 % the irrigation duration has been either too long (32 %) or too short (47 %). Only in four instances was the irrigation duration well performed (i.e. minor differences in calculated and practiced irrigation duration occured).

The overall performance in terms of application and storage efficiencies and distribution uniformity reflects to a large extent the above mentioned results on irrigation duration, but presented in a more refined manner. However, some contradictions do occur. Apparently, the field irrigation performance is not only a result of the irrigation duration, but other practices or physical factors (e.g. variation in soil characteristics and particularly in the condition of the soil surface condition) do influence this performance.

The results on the performance assessment of the field irrigation revealed that for 47% of the monitored irrigation events the irrigation performance turned out to be low, indicating that the water was not applied in an adequate manner to the field. Especially, over-irrigation or a tendency towards over-irrigation turned out to occur quite frequently. Generally, the soil moisture distribution turned out to be well performed.

Farmers have developed their own measure for deciding when to irrigate. Basically, farmers rely on their experience by checking the top soil and the leaves or condition of the crop. Although they are quite familiar with the different crop stages and those stages which need water the most, they simply do not know how long to irrigate in order to meet the crop water requirement. Additionally, they face the problem of unreliable canal water supply and are most of the time inclined to use tubewell water, which gives less discharge and takes a longer time to irrigate one bunded unit. Too often he is in a fix, whether to irrigate everything a little bit or just some fields a lot. Thus, farmers could benefit from an irrigation scheduling program that would provide them more insights about how much water to apply.

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Annexure 1. Soil physical data.

Location	Sampling depth (cm)	Horizon	Bulk density (g/cm^3)	Total porosity (%)	Vol % of Moisture at 0.2 pF	2.0 pF	2.5 pF	4.2 pF	Wt. oven dry soil (g)	Wt. sat. soil (g)
FD 14R 550/01/44	5-9	Ap	1.39	47.0	37.20	24.59	20.58	6.51	137.72	173.86
	16-20	BAd	1.62	39.0	37.48	27.02	21.07	8.79	159.60	196.53
	29-33	BW1k	1.78	33.0	34.04	25.75	21.44	8.30	175.52	209.07
	43-47	BW2k	1.56	41.0	33.93	25.07	22.46	8.58	154.40	190.44
	76-80	BC	1.48	44.0	38.93	33.84	29.90	8.83	145.64	184.07
	109-113	C	1.63	39.0	35.54	25.46	16.84	3.68	160.16	195.19
FD 14R 12/550/07	0-12	Ap	1.29	51.0	39.16	26.83	21.58	7.04	127.12	165.65
	12-23	BA	1.51	43.0	39.10	26.53	19.26	9.03	148.77	188.36
	23-60	BW	1.56	41.0	36.34	28.64	21.42	9.37	153.61	189.42
	60-73	BC	1.48	44.0	39.81	30.62	26.40	7.61	145.75	184.96
	73-88	C1	1.51	43.0	39.25	26.65	14.93	2.85	148.58	187.26
FD 62R 352/09/07	3-7	Ap	1.49	44.0	40.25	33.07	27.66	8.51	146.23	185.86
	19-23	BA	1.50	43.0	45.63	37.94	27.32	2.64	148.07	193.12
	36-40	BW2	1.45	45.0	46.98	42.43	40.71	10.57	142.46	190.90
	70-74	BW3	1.62	39.0	34.77	21.88	13.68	4.73	159.75	194.04
A 111L 173/15/22	18-22	BA	1.77	33.0	33.38	29.07	26.64	13.71	174.30	207.20
	40-44	BW	1.70	36.0	36.44	30.71	28.24	11.11	167.66	203.79
	76-80	C1	1.36	49.0	46.51	33.51	22.46	5.49	134.24	187.74

Source: Soil Survey of Pakistan, Government of Pakistan; Samples are taken in July 1996.

Annexure 2. Soil texture and chemical data.

Location	Horizon	Depth cm.	% Sand U.S.	% Silt U.S.	% Clay U.S.	Texture Class	pH sat. paste	ECe x 10^3	Soluble ions meg/1 CO 3	HCO3	Cl	SO4	Ca+Ng	Na	SAR	ESP
A-111L	AP	0-16	32	47	21	L	8.32	3.02	A	2.6	6.9	20.7	11.6	18.6	7.75	9.0
173/15/25	BA	16-30	38	39	23	L	8.49	3.64	A	3.0	10.0	23.4	11.2	25.2	11.23	12.0
	BCO	30-71	28	43	29	CL	8.55	3.09	0.4	2.2	6.0	22.3	11.2	19.7	8.34	10.0
	C1	71-111	34	61	5	SIL	8.50	3.00	0.4	2.2	6.4	21.0	14.0	16.0	6.06	7.0
	C2	111-150	95	2	3	S	8.80	1.09	0.4	2.2	3.5	4.8	4.0	6.9	4.87	4.0
FD-62R	AP	0-18	46	45	14	L	8.25	1.92	A	3.0	4.1	12.1	8.8	10.4	4.97	6.0
352/09/07	BW1	18-35	28	63	9	SIL	8.43	2.16	A	2.8	5.9	12.9	8.8	12.8	6.12	7.0
	BW2	35-48	12	62	26	SIL	8.48	1.81	A	2.4	6.0	9.7	4.0	14.0	9.90	11.0
	BW4	48-150	48	39	13	L	8.60	1.73	A	2.6	5.4	8.9	4.4	12.9	8.71	10.1
FD-14R	AP	0-12	58	33	9	SL	8.15	7.96	A	2.8	21.8	55.0	57.0	22.6	4.24	4.8
550/01/44	BA	12-21	48	38	14	L	8.31	4.08	A	2.2	7.7	30.9	12.0	25.8	11.80	12.0
	BWK	21-41	54	34	12	SL	8.40	5.38	A	2.6	11.1	40.1	19.2	34.6	11.19	11.9
	BW2 K	41-66	44	37	19	L	8.56	6.26	0.4	2.6	10.9	48.7	17.2	45.4	15.48	18.0
	BC	66-90	34	44	12	L	8.68	8.35	0.4	2.0	17.8	63.3	26.0	57.5	16.00	18.1
	C	-	72	19	9	SL	8.44	3.20	A	2.4	8.9	20.7	14.0	18.0	6.81	7.8
FD-14R	AP	-	72	21	7	SL	-	-	-	-	-	-	-	-	-	-
550/12/07	BA	-	42	39	19	L	-	-	-	-	-	-	-	-	-	-
	BW	-	25	54	21	SIL	-	-	-	-	-	-	-	-	-	-
	BC	-	47	39	14	L	-	-	-	-	-	-	-	-	-	-
	C	-	69	24	7	SL	-	-	-	-	-	-	-	-	-	-

Source: Soil Survey of Pakistan; Government of Pakistan; Samples are taken in July 1996.

Annexure 3. Advance data and calculated advance functions.

Field 3 **Event 1** **14-01**

Advance data

Time (min)	Distance (m) Row 1	Row 2	Row 3	Area Wetted (m ^ 2)
5	4.5	10.0	7.1	126.5
14	11.8	20.0	15.4	275.3
25	18.8	30.0	25.0	430.2
46	32.2	40.0	38.9	648.1
56	42.2	56.0	46.2	842.0
75	58.4	56.7	56.5	1,000.8
80	58.4	58.4	58.4	1,022.0

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	0.91	2.00	1.43
10-20	0.63	1.11	0.77
20-30	0.59	0.91	1.00
30-40	1.11	0.48	0.56
40-50	0.71	1.00	0.77
50-58.4	1.05	0.35	0.47

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
126.5	5	4.84	1.6094	2.5903	7.7896
275.3	14	5.6178	2.6391	6.9646	14.8256
430.2	25	6.0643	3.2189	10.3612	19.5201
648.1	46	6.4741	3.8286	14.6585	24.7870
842.0	56	6.7358	4.0254	16.2035	27.1138
1,000.8	75	6.9086	4.3175	18.6407	29.8277
1,022.0	80	6.9295	4.382	19.2022	30.3653
Sum/N	Sum/N	Sum	Sum	Sum	Sum
620.6988	43	43.57	24.021	88.6209	154.2292

r 0.762

p 36.98

Two point method

A1	430.2
A2	1022
t1	25
t2	80
r	0.744
p	39.24

Field 3 **Event 2** **06-02**

Time (min)	Distance (m) Row 1	Row 2	Row 3	Area Wetted (m ^ 2)
4	5.7	10.0	8.0	138.3
7	10.0	20.0	15.0	262.4
11	16.7	30.0	23.3	408.3
19	30.0	40.0	36.7	622.2
29	44.0	50.0	46.7	820.6
40	57.6	57.1	58.4	1,010.0
43	58.4	58.4	58.4	1,022.0

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	1.43	2.50	2.00
10-20	1.67	3.33	2.50
20-30	1.67	2.50	1.67
30-40	1.25	1.25	1.67
40-50	2.00	1.00	0.83
50-58.4	0.76	0.65	1.20

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
138.3	4	4.9295	1.3863	1.9218	6.8337
262.4	7	5.5698	1.9459	3.7866	10.8383
408.3	11	6.012	2.3979	5.7499	14.4162
622.2	19	6.4332	2.9444	8.6697	18.9423
820.6	29	6.7101	3.3673	11.3387	22.5948
1,010.0	40	6.9177	3.6889	13.6078	25.5185
1,022.0	43	6.9295	3.7612	14.1466	26.0633
Sum/N	Sum/N	Sum	Sum	Sum	Sum
611.9702	21.86	43.502	19.492	59.2211	125.2071

r 0.824

p 50.42

Two point method

A1	408.3
A2	1022
t1	11
t2	43
r	0.673
p	81.30

Field 3 **Event 3** **29-02**

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m ^ 2)
8	8.0	16.1	17.7	10.0	199.0
15	15.6	27.2	30.9	20.0	366.2
22	22.7	33.2	39.5	30.0	501.4
31	30.9	39.1	44.6	40.0	641.7
45	44.5	55.9	52.9	50.0	877.1
53	58.4	58.4	57.9	56.1	1,008.7
57	58.4	58.4	58.4	58.4	1,022.0

Distance (m)	Velocity (m/min) Row 1	Row 2a	Row 2b	Row 3
0-10	1.00	[1.97]	[2.14]	1.25
10-20	1.11	[2.08]	[2.34]	1.43
20-30	0.91	[1.38]	[1.91]	1.43
30-40	0.91	[0.65]	[1.24]	1.11
40-50	1.11	[1.06]	[0.57]	0.71
50-58.4	2.80	[1.66]	[0.63]	0.76

[ ] = derived

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
199.0	8	5.2935	2.0794	4.3241	11.0075
366.2	15	5.9031	2.7081	7.3335	15.9858
501.4	22	6.2174	3.091	9.5545	19.2181
641.7	31	6.4641	3.434	11.7923	22.1975
877.1	45	6.7766	3.8067	14.4907	25.7963
1,008.7	53	6.9164	3.9703	15.7632	27.4602
1,022.0	57	6.9295	4.0431	16.3463	28.0164
Sum/N	Sum/N	Sum	Sum	Sum	Sum
659.4333	33	44.501	23.133	79.6046	149.6818

r 0.830

p 37.1

Two point method

A1	501.4
A2	1022
t1	22
t2	57
r	0.748
p	49.66

Field 3 **Event 4** **12-03**

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m ^ 2)
6	6.0	13.6	16.9	10.0	172.8
12	14.0	29.8	31.7	20.0	372.3
17	22.9	35.0	38.7	30.0	512.2
25	34.3	43.7	46.3	40.0	687.9
34	46.3	52.9	53.0	50.0	870.2
43	58.4	58.4	58.4	56.9	1,013.1
45	58.4	58.4	58.4	58.4	1,022.0

Distance (m)	Velocity (m/min) Row 1	Row 2a	Row 2b	Row 3
0-10	1.00	[1.97]	[2.14]	1.67
10-20	2.00	[3.76]	[2.73]	1.67
20-30	1.43	[2.17]	[2.67]	2.00
30-40	1.43	[1.02]	[1.34]	1.25
40-50	1.25	[1.19]	[0.89]	1.11
50-58.4	1.40	[1.83]	[0.63]	0.76

[ ] = derived

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
172.8	6	5.1524	1.7918	3.2104	9.2318
372.3	12	5.9198	2.4849	6.1748	14.7102
512.2	17	6.2387	2.8332	8.0271	17.6754
687.9	25	6.5337	3.2189	10.3612	21.0311
870.2	34	6.7687	3.5264	12.4352	23.8690
1,013.1	43	6.9208	3.7612	14.1466	26.0305
1,022.0	45	6.9295	3.8067	14.4907	26.3783
Sum/N	Sum/N	Sum	Sum	Sum	Sum
664.375	26	44.464	21.423	68.8459	138.9264

r 0.868

p 40.28

Two point method

A1	512.2
A2	1022
t1	17
t2	45
r	0.710
p	68.59

Field 33 Event 1 23-01

Time (min)	Distance (m) Row 1	Row 2	Row 3	Area Wetted (m ^ 2)
2	10.0	1.5	4.0	74.0
10	22.4	10.4	20.0	251.5
24	29.0	15.2	40.0	401.1
43	38.5	28.7	60.3	607.9
46	40.0	30.7	60.3	624.5
55	-	-	-	775.9
62	-	-	-	861.6

Field 33 Event 1

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	5.00	0.77	2.00
10-20	3.33	1.67	2.00
20-30	0.48	0.38	2.00
30-40	0.50	0.71	2.50
40-50	-	-	0.91
50-60.3	-	-	1.29

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
74.0	2	4.304	0.693	0.4805	2.9836
251.5	10	5.528	2.303	5.3019	12.7277
401.1	24	5.994	3.178	10.1000	19.0500
607.9	43	6.41	3.761	14.1466	24.1096
624.5	46	6.437	3.829	14.6585	24.6447
775.9	55	6.654	4.007	16.0587	26.6649
861.6	62	6.759	4.127	17.0332	27.8943
Sum/N	Sum/N	Sum	Sum	Sum	Sum
513.798	34.57	42.09	21.9	77.7795	138.075

r 0.692

p 46.9

Two point method

A1	401.1
A2	861.6
t1	24
t2	62

r 0.806

p 31.01

Field 33 Event 3 29-02

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m ^ 2)
1	10.0	10.0	7.5	7.5	125.1
6	20.0	20.0	12.5	12.5	232.4
16	30.0	30.0	26.0	26.0	400.3
23	35.4	35.4	40.0	40.0	539.0
29	40.0	40.0	50.0	50.0	643.5
34	51.0	51.0	60.3	60.3	796.0
43	60.3	60.3	60.3	60.3	861.6

Field 33 Event 3 29-02

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	10.00	-	2.50
10-20	2.00	-	1.25
20-30	1.00	-	1.43
30-40	0.77	-	2.50
40-50	2.50	-	1.67
50-60.3	1.03	-	2.06

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
125.1	1	4.829	0	0.0000	0.0000
232.4	6	5.448	1.792	3.2104	9.7621
400.3	16	5.992	2.773	7.6872	16.6136
539.0	23	6.29	3.135	9.8313	19.7212
643.5	29	6.467	3.367	11.3387	21.7760
796.0	34	6.68	3.526	12.4352	23.5547
861.6	43	6.759	3.761	14.1466	25.4211
Sum/N	Sum/N	Sum	Sum	Sum	Sum
513.973	21.71	42.46	18.35	58.6495	116.849

r 0.523

p 109.4

Two point method

A1	400.3
A2	861.6
t1	16
t2	43

r 0.775

p 46.62

Field 33 Event 4 12-03

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m ^ 2)
2	10.0	10.0	4.0	4.0	100.1
7	20.0	20.0	15.0	15.0	250.3
13	28.6	28.6	30.0	30.0	418.8
18	32.5	32.5	40.0	40.0	518.5
26	37.6	37.6	50.0	50.0	626.1
32	42.5	42.5	60.3	60.3	735.0
38	50.0	50.0	60.3	60.3	788.6
42	60.3	60.3	60.3	60.3	861.6

Least Regression Analysis

N = 8

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
100.1	2	4.6062	0.6931	0.4805	3.1928
250.3	7	5.5225	1.9459	3.7866	10.7462
418.8	13	6.0375	2.5649	6.5790	15.4859
518.5	18	6.251	2.8904	8.3542	18.0676
626.1	26	6.4394	3.2581	10.6152	20.9803
735.0	32	6.5999	3.4657	12.0113	22.8735
788.6	38	6.6703	3.6376	13.2320	24.2639
861.6	42	6.7588	3.7377	13.9702	25.2620
		Sum	Sum	Sum	Sum
537.3761	22.25	48.886	22.193	69.0290	140.8722

r 0.704

p 63.86

Field 33 Event 4 12-03

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	5.00	-	2.00
10-20	2.00	-	2.50
20-30	1.43	-	2.50
30-40	0.63	-	2.00
40-50	1.25	-	1.25
50-60.3	2.58	-	1.72

Two point method

A1	418.8
A2	861.6
t1	13
t2	42
r	0.615
p	86.49

Field 33 Event 5 21-03

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m ^ 2)
1	10.0	10.0	2.5	2.5	89.4
5	20.0	20.0	13.4	13.4	239.0
10	30.0	30.0	27.5	27.5	411.1
14	33.1	33.1	40.0	40.0	522.5
19	36.9	36.9	50.0	50.0	621.5
24	41.7	41.7	60.3	60.3	729.1
29	50.0	50.0	60.3	60.3	788.6
32	60.3	60.3	60.3	60.3	861.6

Least Regression Analysis

N = 8

Ai	ti	ln A	ln ti	(ln ti) ^ 2	ln ti x ln A
89.4	1	4.4928	0	0.0000	0.0000
239.0	5	5.4766	1.6094	2.5903	8.8142
411.1	10	6.0189	2.3026	5.3019	13.8590
522.5	14	6.2587	2.6391	6.9646	16.5170
621.5	19	6.4322	2.9444	8.6697	18.9393
729.1	24	6.5918	3.1781	10.1000	20.9491
788.6	29	6.6703	3.3673	11.3387	22.4609
861.6	32	6.7588	3.4657	12.0113	23.4241
		Sum	Sum	Sum	Sum
532.8627	16.75	48.7	19.507	56.9766	124.9635

r 0.660

p 87.98

Field 33 Event 5 21-03

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	10.00	-	2.50
10-20	2.50	-	3.33
20-30	2.00	-	2.50
30-40	0.77	-	3.33
40-50	1.67	-	2.00
50-60.3	3.43	-	2.06

Two point method

A1	411.1
A2	861.6
t1	10
t2	32
r	0.636
p	95.04

Field 8 Event 2 06-02

Time (min)	Distance (m) Row 1	Row 2	Row 3	Area Wetted (m^2)
2	10.0	6.7	10.0	153.8
4	20.0	15.0	20.0	317.2
6	30.0	22.5	26.7	456.5
11	40.0	34.0	38.0	645.9
15	50.0	38.0	47.5	781.4
17	57.1	45.0	51.8	887.4
22	57.1	57.1	57.1	987.8

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti)^2	ln ti x ln A
153.8	2	5.036	0.693	0.4805	3.4904
317.2	4	5.759	1.386	1.9218	7.9843
456.5	6	6.124	1.792	3.2104	10.9722
645.9	11	6.471	2.398	5.7499	15.5158
781.4	15	6.661	2.708	7.3335	18.0385
887.4	17	6.788	2.833	8.0271	19.2328
987.8	22	6.896	3.091	9.5545	21.3143
Sum/N	Sum/N	Sum	Sum	Sum	Sum
604.29	11	43.73	14.9	36.2777	96.5483

r 0.757

p 103.20

Field 8 Event 2 06-02

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	5.00	3.33	5.00
10-20	5.00	5.00	5.00
20-30	5.00	2.50	3.33
30-40	2.00	2.00	2.00
40-50	2.50	1.67	2.50
50-57.1	3.55	3.55	1.78

Two point method

A1	456.55
A2	987.83
t1	6
t2	22
r	0.594
p	157.48

Field 8 Event 4 07-03

Time (min)	Distance (m) Row 1	Row 2a	Row 2b	Row 3	Area Wetted (m^2)
3	10.0	10.0	6.0	6.0	136.4
6	20.0	20.0	20.0	20.0	346.0
8	30.0	30.0	30.0	30.0	519.0
11	40.0	40.0	37.5	37.5	670.4
15	50.0	50.0	47.5	47.5	843.4
17	57.1	57.1	53.5	53.5	957.0
19	57.1	57.1	57.1	57.1	987.8

Least Regression Analysis

N = 7

Ai	ti	ln A	ln ti	(ln ti)^2	ln ti x ln A
136.4	3	4.93	1.099	1.2069	5.4163
346.0	6	5.846	1.792	3.2104	10.4754
519.0	8	6.252	2.079	4.3241	13.0005
670.4	11	6.508	2.398	5.7499	15.6051
843.4	15	6.737	2.708	7.3335	18.2452
957.0	17	6.864	2.833	8.0271	19.4467
987.8	19	6.896	2.944	8.6697	20.3034
Sum/N	Sum/N	Sum	Sum	Sum	Sum
637.43	11.286	44.03	15.85	38.5217	102.493

r 1.0575

p 49.18

Field 8 Event 4 07-03

Distance (m)	Velocity (m/min) Row 1	Row 2	Row 3
0-10	3.33	-	2.00
10-20	3.33	-	10.00
20-30	2.50	-	3.33
30-40	2.50	-	3.33
40-50	2.50	-	2.50
50-60.3	7.10	-	1.78

Two point method

A1	519
A2	987.83
t1	8
t2	19
r	0.744
p	110.46

Field 8 Event 5 27-03

Two-point method estmiation

A1	519	r	0.825
A2	987.83	p	71.79
t1	11		
t2	24		

Field 4 Event 1 19-01 "adjusted"

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	-	-	14	19
20	-	29	53	26
30	-	78	85	35
40	-	120	124	46
50	-	155	161	61
60	-	249	232	99
71.4	-	49	84	135

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
-		0.714	0.526
-	0.690	0.256	1.429
-	0.204	0.313	1.111
-	0.238	0.256	0.909
-	0.286	0.270	0.667
-	0.106	0.141	0.263
-	-	-	0.278

Two-point method

t1	100
t2	249
WA1	2240.005
WA2	4427.267
r	0.747
p	71.88

t (min)	**distance (m)** row 2	row 3	row 4
80	30.48	28.44	55.00
100	35.24	33.84	99.28

Field 4 Event 2 07-02

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	5	4	16	-
20	10	15	26	-
30	14	24	-	-
40	19	74	67	-
50	28	90	84	-
60	39	154	146	-
71.4	61	145	-	-

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
2.000	2.500	0.625	-
2.000	0.909	1.000	-
2.500	1.111		-
2.000	0.200	0.488	-
1.111	0.625	0.588	-
0.909	0.156	0.161	-
0.518	-	-	-

Two-point method

t1	40
t2	160
WA1	2285.922
WA2	4427.267
r	0.477
p	393.70

t (min)	**distance (m)** row 1	row 2	row 3
60	70.88	37.20	36.58
55	68.29	36.20	34.14
50	65.70	35.20	31.70
45	63.11	34.20	29.26
40	60.52	33.20	26.82

Field 4 Event 3 02-03

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	7	-	-	8
20	15	-	-	17
30	29	-	-	23
40	43	-	-	39
50	55	-	-	64
60	90	-	-	83
71.4	120	-	-	128

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
1.429	-	-	1.250
1.250	-	-	1.111
0.714	-	-	1.667
0.714	-	-	0.625
0.833	-	-	0.400
0.286	-	-	0.526
0.380	-	-	0.253

Two-point method

t1	35
t2	140
WA1	2227.285
WA2	4427.267
r	0.496
p	382.46

t (min)	**distance (m)**	
	row 1	**row 4**
40	37.86	40.63
35	34.29	37.50

Field 4 Event 4 17-03

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	4	-	-	11
20	12	-	-	16
30	17	-	-	20
40	21	-	-	26
50	26	-	-	36
60	36	-	-	47
71.4	57	-	-	64

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
2.500	-	-	0.909
1.250	-	-	2.000
2.000	-	-	2.500
2.500	-	-	1.667
2.000	-	-	1.000
1.000	-	-	0.909
0.543	-	-	0.671

Two-point method

t1	21
t2	77
WA1	2223.562
WA2	4427.267
r	0.530
p	442.81

t (min)	**distance (m)**	
	row 1	**row 4**
20	37.50	30.00
25	48.00	38.33
22	42.00	33.33
21	40.00	31.67

Field 6 Event 1 18-01

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	-	-	6	31
20	1	27	54	43
30	2	-	-	-
40	4	47	87	59
50	11	65	101	61
60	18	156	149	74
66.65	27	192	214	136

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
-		1.667	0.323
20	0.741	0.208	0.833
5			
2.500	1.000	0.606	1.250
0.909	0.556	0.714	5.000
0.556	0.110	0.208	0.769
0.739	0.185	0.102	0.107

Two-point method

t1	50
t2	214
WA1	961.08
WA2	2006.9
r	0.506
p	132.56

t (min)	**distance (m) row 1**	**row 2**	**row 3**	**row 4**
45	66.65	23.50	3.61	8.00
47	66.65	25.50	4.03	10.50
48	66.65	26.06	4.24	11.75
50	66.65	27.17	4.65	14.25

Field 6 Event 2 07-02

Advance data

Distance (m)	**row 1**	**row 2**	**row 3**	**row 4**
10	-	-	4	20
20	-	10	28	27
30	-	14	-	35
40	4	19	36	42
50	7	31	46	47
60	22	90	79	-
66.65	43	135	122	-

Velocity (m/min)

row 1	**row 2**	**row 3**	**row 4**
-		2.500	0.500
-	2	0.417	1.429
-	2.5		1.250
-	2	2.500	1.429
3.333	0.833	1.000	2.000
0.667	0.169	0.303	-
0.317	0.148	0.155	-

Two-point method

t1	30
t2	175
WA1	1001.2
WA2	2006.9
r	0.394
p	261.88

t (min)	**distance (m) row 1**	**row 2**	**row 3**	**row 4**
30	62.536	34.67	10.50	9.25

Field 6 Event 3 02-03

Advance data

Distance (m)	row 1	row 2	row 3	row 4
10	1	-	-	11
20	2	-	-	15
30	6	-	-	33
40	14	-	-	50
50	21	-	-	66
60	52	-	-	89
66.65	91	-	-	109

Velocity (m/min)

row 1	row 2	row 3	row 4
10.000	-	-	0.909
10.000	-	-	2.500
2.500	-	-	0.556
1.250	-	-	0.588
1.429	-	-	0.625
0.323	-	-	0.435
0.171	-	-	0.333

Two-point method

t1	30
t2	126
WA1	1020.5
WA2	2006.9
r	0.471
p	205.42

t (min)	distance (m) row 1	row 2	row 3	row 4
25	51.292	36.792	11.06	11.06
27	51.938	37.438	12.17	12.17
30	52.907	38.407	13.84	13.84

Field 6 Event 4 17-03

Advance data

Distance (m)	row 1	row 2	row 3	row 4
10	-	-	-	8
20	1	-	-	14
30	3	-	-	22
40	7	-	-	30
50	11	-	-	41
60	28	-	-	56
66.65	46	-	-	84

Velocity (m/min)

row 1	row 2	row 3	row 4
-	-	-	1.250
20.000	-	-	1.667
5.000	-	-	1.250
2.500	-	-	1.250
2.500	-	-	0.909
0.588	-	-	0.667
0.369	-	-	0.238

Two-point method

t1	20
t2	156
WA1	1049.8
WA2	2006.9
r	0.315
p	408.02

t (min)	distance (m) row 1	row 2	row 3	row 4
40	64.428	49.928	36.17	36.17
30	60.738	46.238	25.50	25.50
28	60	45.5	23.00	23.00
20	55.292	40.792	13.00	13.00

Annexure 4. Monitored recession data and calculated infiltration rates and graphical presentation of the infiltration rates.

Field 3 — Event 1 — 14-01 — Head Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.037				
3	0.03	1.5	6.576	2.192	6.576
6	0.024	4.5	5.616	1.872	12.192
15	0.021	10.5	3.048	0.339	15.240
23	0.018	19	3.048	0.381	18.288
35	0.015	29	3.048	0.254	21.336
47	0.009	41	6.096	0.508	27.432
60	0.003	53.5	6.144	0.473	33.576
72	0.000	66	3	0.250	36.576

Field 3 — Event 1 — 14-01 — Tail Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.030				
4	0.027	2	3.00	0.750	3
14	0.024	9	3.00	0.300	6
34	0.018	24	6.00	0.300	12
46	0.015	40	3.00	0.250	15
64	0.012	55	3.00	0.167	18
75	0.006	69.5	6.00	0.545	24
88	0	81.5	6.00	0.462	30

Field 3 — Event 2 — 06-02 — Head Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.030				
2	0.024	1	6	3.000	6
4	0.018	3	6	3.000	12
7	0.015	5.5	3	1.000	15
16	0.012	11.5	3	0.333	18
58	0.009	37	3	0.071	21
81	0.006	69.5	3	0.130	24
111	0.003	96	3	0.100	27
126	0.000	118.5	3	0.200	30

Field 3 — Event 2 — 06-02 — Tail Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.024				
31	0.021	15.5	3	0.097	3
48	0.018	39.5	3	0.176	6
74	0.015	61	3	0.115	9
103	0.012	88.5	3	0.103	12
152	0.006	127.5	6	0.122	18
241	0.003	196.5	3	0.034	21
271	0	256	3	0.100	24

Field 3 — Event 3 — 29-02 — Head Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.037				
3	0.024	1.5	13	4.333	13
7	0.018	5	6	1.500	19
17	0.015	12	3	0.300	22
42	0.012	29.5	3	0.120	25
64	0.009	53	3	0.136	28
87	0.006	75.5	3	0.130	31
124	0	105.5	6	0.162	37

Field 3 — Event 3 — 29-02 — Tail Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.015				
30	0.012	15	3	0.100	3
54	0.009	42	3	0.125	6
75	0.006	64.5	3	0.143	9
100	0.003	87.5	3	0.120	12
122	0.000	111	3	0.136	15

Field 3 — Event 4 — 12-03 — Head Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.046				
2	0.027	1	19	9.500	19
4	0.021	3	6	3.000	25
7	0.018	5.5	3	1.000	28
12	0.015	9.5	3	0.600	31
23	0.012	17.5	3	0.273	34
48	0.009	35.5	3	0.120	37
65	0.006	56.5	3	0.176	40
90	0.003	77.5	3	0.120	43
125	0	107.5	3	0.086	46

Field 3 — Event 4 — 12-03 — Tail Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.015				
12	0.012	6	3	0.250	3
36	0.009	24	3	0.125	6
55	0.006	45.5	3	0.158	9
82	0.003	68.5	3	0.111	12
117	0.000	99.5	3	0.086	15

Field 3 Event 5 28-03
Head Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.046				
3	0.043	1.5	3	1.000	3
6	0.034	4.5	9	3.000	12
8	0.030	7	4	2.000	16
10	0.027	9	3	1.500	19
22	0.021	16	6	0.500	25
65	0.015	43.5	6	0.140	31
90	0.009	77.5	6	0.240	37
113	0.006	101.5	3	0.130	40
140	0.003	126.5	3	0.111	43
160	0	150	3	0.150	46

Field 3 Event 5 28-03
Tail Gauge Readings

Time (min)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	cumulative infiltration (mm)
0	0.030				
60	0.024	30	6	0.100	6
85	0.018	72.5	6	0.240	12
105	0.012	95	6	0.300	18
135	0.006	120	6	0.200	24
150	0.003	142.5	3	0.200	27
175	0	162.5	3	0.120	30

Field 33	Event 4	12-03				
	Head gauge readings		Average	Drop in	Infiltration	Cumulative
Time (min)	Water level (ft)	Water level (m)	Time (min)	water level (mm)	rate (mm/min)	Infiltration (mm)
0	0.14	0.043				
10	0.13	0.040	5	3.048	0.305	3.048
45	0.12	0.037	27.5	3.048	0.087	6.096
80	0.11	0.034	62.5	3.048	0.087	9.144
125	0.1	0.030	102.5	3.048	0.068	12.192
190	0.08	0.024	157.5	6.096	0.094	18.288
220	0.07	0.021	205	3.048	0.102	21.336
390	0.02	0.006	305	15.24	0.090	36.576
1300	0	0.000	845	6.096	0.007	42.672

Field 33	Event 4	12-03				
	Tail gauge readings		Average	Drop in	Infiltration	Cumulative
Time (min)	Water level (ft)	Water level (m)	Time (min)	water lev (mm)	rate (mm/min)	Infiltration (mm)
0	0.16	0.049				
10	0.17	0.052	5	-3.048	(0.305)	-
30	0.16	0.049	20	3.048	0.152	3.048
83	0.15	0.046	56.5	3.048	0.058	6.096
134	0.13	0.040	108.5	6.096	0.120	12.192
198	0.12	0.037	166	3.048	0.048	15.240
225	0.11	0.034	211.5	3.048	0.113	18.288
395	0.07	0.021	310	12.192	0.072	30.480
1325	0	0.000	860	21.336	0.023	51.816

Field 33	Event 5	21-03				
	Head gauge readings		Average	Drop in	Infiltration	Cumulative
Time (min)	Water level (ft)	Water level (m)	Time (min)	water level (mm)	rate (mm/min)	Infiltration (mm)
0	0.21	0.064				
1	0.20	0.061	0.5	3.048	3.048	3.048
2	0.19	0.058	1.5	3.048	3.048	6.096
3	0.18	0.055	2.5	3.048	3.048	9.144
4	0.17	0.052	3.5	3.048	3.048	12.192
6	0.16	0.049	5	3.048	1.524	15.240
39	0.15	0.046	22.5	3.048	0.092	18.288

Note 1: The gauge readings were not further continued.

Field 33	Event 5	21-03				
	Tail gauge readings		Average	Drop in	Infiltration	Cumulative
Time (min)	Water level (ft)	Water level (m)	Time (min)	water lev (mm)	rate (mm/min)	Infiltration (mm)
0	0.10	0.030				
3	0.12	0.037	1.5	-6.096	(2.032)	-
4	0.13	0.040	3.5	-3.048	(3.048)	-
5	0.14	0.043	4.5	-3.048	(3.048)	-
6	0.15	0.046	5.5	-3.048	(3.048)	-
39	0.14	0.043	22.5	3.048	0.092	3.048

Field 33 Event 1 24-01

Time (min)	Head gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.16	0.049				
5	0.155	0.047	2.5	1.524	0.305	1.524
10	0.15	0.046	7.5	1.524	0.305	3.048
17	0.14	0.043	13.5	3.048	0.435	6.096
22	0.13	0.040	19.5	3.048	0.610	9.144
35	0.12	0.037	28.5	3.048	0.234	12.192
57	0.11	0.034	46	3.048	0.139	15.240
62	0.10	0.030	59.5	3.048	0.610	18.288
82	0.09	0.027	72	3.048	0.152	21.336
92	0.08	0.024	87	3.048	0.305	24.384
122	0.06	0.018	107	6.096	0.203	30.480
157	0.04	0.012	139.5	6.096	0.174	36.576
177	0.02	0.006	167	6.096	0.305	42.672
222	0.01	0.003	199.5	3.048	0.068	45.720
251	0	0.000	236.5	3.048	0.105	48.768

Field 33 Event 1 24-01

Time (min)	Tail gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water lev (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.03	0.009				
5	0.025	0.008	2.5	1.524	0.305	1.524
10	0.02	0.006	7.5	1.524	0.305	3.048
62	0.03	0.009	36	-3.048	(0.059)	-
82	0.05	0.015	72	-6.096	(0.305)	-
177	0.04	0.012	129.5	3.048	0.032	6.096
207	0.03	0.009	192	3.048	0.102	9.144
302	0.02	0.006	254.5	3.048	0.032	12.192
332	0.01	0.003	317	3.048	0.102	15.24
347	0	0.000	339.5	3.048	0.203	18.288

Field 33 Event 3 29-02

Time (min)	Head gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.18	0.055				
3	0.17	0.052	1.5	3.048	1.016	3.048
7	0.16	0.049	5	3.048	0.762	6.096
22	0.15	0.046	14.5	3.048	0.203	9.144
95	0.12	0.037	58.5	9.144	0.125	18.288
185	0.10	0.030	140	6.096	0.068	24.384
215	0.09	0.027	200	3.048	0.102	27.432
235	0.08	0.024	225	3.048	0.152	30.480
1310	0	0.000	772.5	24.384	0.023	54.864

Field 33 Event 3 29-02

Time (min)	Tail gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water lev (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.20	0.061				
2	0.21	0.064	1	-3.048	(1.524)	-
9	0.21	0.064	5.5	0.508	0.073	0.508
24	0.20	0.061	16.5	2.54	0.169	3.048
97	0.17	0.052	60.5	9.144	0.125	12.192
153	0.16	0.049	125	3.048	0.054	15.240
190	0.14	0.043	171.5	6.096	0.165	21.336
220	0.13	0.040	205	3.048	0.102	24.384
242	0.12	0.037	231	3.048	0.139	27.432
1320	0	0.000	781	36.576	0.034	64.008

Field 8 Event 2 06-02

Head gauge readings

Time (min)	Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.15	0.046				
2	0.10	0.030	1	15.24	7.620	15.24
4	0.08	0.024	3	6.096	3.048	21.34
12	0.07	0.021	8	3.048	0.381	24.38
820	0.02	0.006	416	15.24	0.019	39.62
1151	0.01	0.003	985.5	3.048	0.009	42.67
2241	0	0	1696	3.048	0.003	45.72

Field 8 Event 2 06-02

Tail gauge readings

Time (min)	Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.14	0.043				
2	0.20	0.061	1	-18.288	(9.144)	-
4	0.22	0.067	3	-6.096	(3.048)	-
6	0.21	0.064	5	3.048	1.524	3.05
817	0.14	0.043	411.5	21.336	0.026	24.38
1148	0.10	0.030	982.5	12.192	0.037	36.58
2238	0.07	0.021	1693	9.144	0.008	45.72
3000	0	0	2769	12.192	0.026	67.06

Note: The last timing is estimated (extrapolation between t=2538 and t=5066).

Field 8 Event 4 07-03

Head gauge readings

Time (min)	Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.15	0.046				
2	0.14	0.043	1	3.048	1.524	3.05
3	0.13	0.040	2.5	3.048	3.048	6.10
4	0.12	0.037	3.5	3.048	3.048	9.14
13	0.11	0.034	8.5	3.048	0.339	12.19
38	0.10	0.030	25.5	3.048	0.122	15.24
103	0.09	0.027	70.5	3.048	0.047	18.29
123	0.08	0.024	113	3.048	0.152	21.34
313	0.05	0.015	218	9.144	0.048	30.48
1363	0	0.000	838	15.24	0.015	45.72

Field 8 Event 4 07-03

Tail gauge readings

Time (min)	Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.22	0.067				
2	0.24	0.073	1	-6.096	(3.048)	-
6	0.26	0.079	4	-6.096	(1.524)	-
13	0.25	0.076	9.5	3.048	0.435	3.048
32	0.24	0.073	22.5	3.048	0.160	6.096
58	0.23	0.070	45	3.048	0.117	9.144
78	0.22	0.067	68	3.048	0.152	12.192
107	0.21	0.064	92.5	3.048	0.105	15.240
318	0.18	0.055	212.5	9.144	0.043	24.384
1378	0.08	0.024	848	30.48	0.029	54.864

Field 8 Event 5 27-03

Time (min)	Head gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.14	0.043				
2	0.12	0.037	1	6.096	3.048	6.096
5	0.1	0.030	3.5	6.096	2.032	12.192
9	0.08	0.024	7	6.096	1.524	18.288
36	0.07	0.021	22.5	3.048	0.113	21.336
67	0.06	0.018	51.5	3.048	0.098	24.384
106	0.05	0.015	86.5	3.048	0.078	27.432
332	0	0.000	219	15.24	0.067	42.672

Note 1: Recession is approx. for 75% completed.

Field 8 Event 5 27-03

Time (min)	Tail gauge readings Water level (ft)	Water level (m)	Average Time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative Infiltration (mm)
0	0.16	0.049				
1	0.18	0.055	0.5	-6.096	(6.096)	-
3	0.22	0.067	2	-12.192	(6.096)	-
7	0.24	0.073	5	-6.096	(1.524)	-
38	0.22	0.067	22.5	6.096	0.197	6.096
70	0.21	0.064	54	3.048	0.095	9.144
108	0.19	0.058	89	6.096	0.160	15.240
342	0.15	0.046	225	12.192	0.052	27.432
1372	0.01	0.003	857	42.672	0.041	70.104
1527	0	0.000	1449.5	3.048	0.020	73.152

Field 6 Event 1 19-01

Head Gauge Readings

Time (min)	Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.14	0.043				
2	0.14	0.043	1	0	0	-
7	0.14	0.043	4.5	0	0	-
22	0.14	0.043	14.5	0	0	-
37	0.14	0.043	29.5	0	0	-
1237	0.07	0.021	637	21.336	0.018	21.34
1431	0.04	0.012	1334	9.144	0.047	30.48
2632	0	0.000	2031.5	12.192	0.010	42.67

Event 1 19-01

Tail Gauge Readings

Time (min)	Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.17	0.052				
2	0.18	0.055	1	(0.003)	(0.002)	-
7	0.19	0.058	4.5	(0.003)	(0.001)	-
1237	0.11	0.034	622	24.384	0.020	24.384
1431	0.07	0.021	1334	12.192	0.063	36.576
2632	0.03	0.009	2031.5	12.192	0.010	48.768
3982	0	0.000	3307	9.144	0.007	57.912

Field 6 Event 2 07-02

Head Gauge Readings

Time (min)	Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.08	0.024				
2	0.07	0.021	1	3.048	1.524	3.048
4	0.05	0.015	3	6.096	3.048	9.144
11	0.04	0.012	7.5	3.048	0.435	12.192
76	0.03	0.009	43.5	3.048	0.047	15.240
1294	0.02	0.006	685	3.048	0.003	18.288
4196	0	0.000	2745	6.096	0.002	24.384

Event 2 07-02

Tail Gauge Readings

Time (min)	Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.04	0.012				
2	0.05	0.015	1	(0.003)	(0.002)	-
4	0.06	0.018	3	(0.003)	(0.002)	-
6	0.07	0.021	5	(0.003)	(0.002)	-
76	0.06	0.018	41	3.048	0.044	3.048
201	0.05	0.015	138.5	3.048	0.024	6.096
1294	0.02	0.006	747.5	9.144	0.008	15.240
4196	0	0.000	2745	6.096	0.002	21.336

Field 6 Event 3 02-03

Time (min)	Head Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.14	0.043				
5	0.13	0.040	2.5	3.048	0.610	3.048
426	0.07	0.021	215.5	18.288	0.043	21.336
1894	0.02	0.006	1160	15.240	0.010	36.576
3304	0	0.000	2599	6.096	0.004	42.672

Event 3 02-03

Time (min)	Tail Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.32	0.098				
414	0.29	0.088	207	9.144	0.022	9.144
2505	0.24	0.073	1459.5	15.240	0.007	24.384
3870	0.2	0.061	3187.5	12.192	0.009	36.576
5340	0.17	0.052	4605	9.144	0.006	45.720

Field 6 Event 4 02-03

Time (min)	Head Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.14	0.043				
5	0.13	0.040	2.5	3.048	0.610	3.048
2690	0.06	0.018	1347.5	21.336	0.008	24.384
5650	0	0.000	4170	18.288	0.006	42.672

Event 4 02-03

Time (min)	Tail Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.25	0.076				
2700	0.18	0.055	1350	21.336	0.008	21.336
5660	0.1	0.030	4180	24.384	0.008	45.720
6350	0	0.000	6005	30.480	0.044	76.200

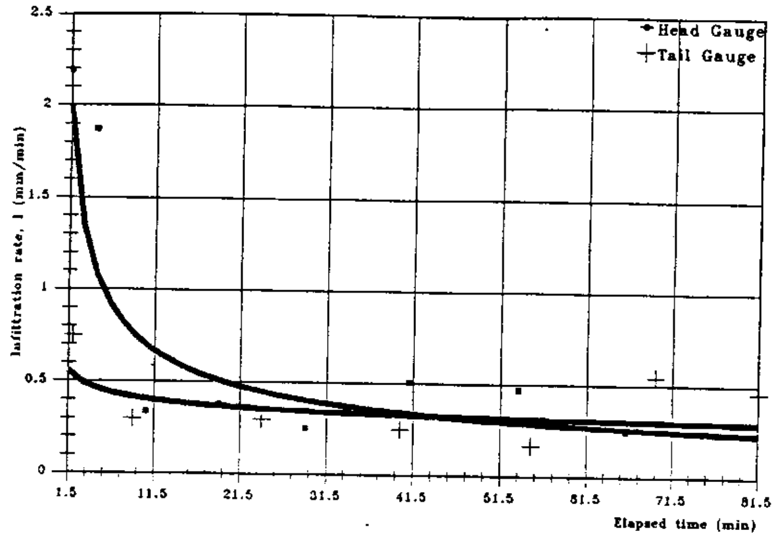
extrapolated last value

Field 6 Event 5 01-04

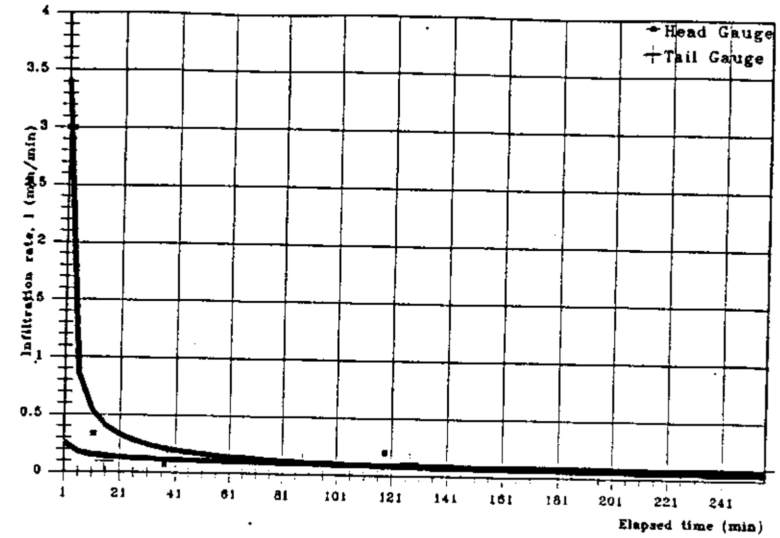
Time (min)	Head Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.14	0.043				
105	0.13	0.040	52.5	3.048	0.029	3.048
237	0.12	0.037	171	3.048	0.023	6.096
2675	0	0.000	1456	36.576	0.015	42.672

Field 6 Event 5 01-04

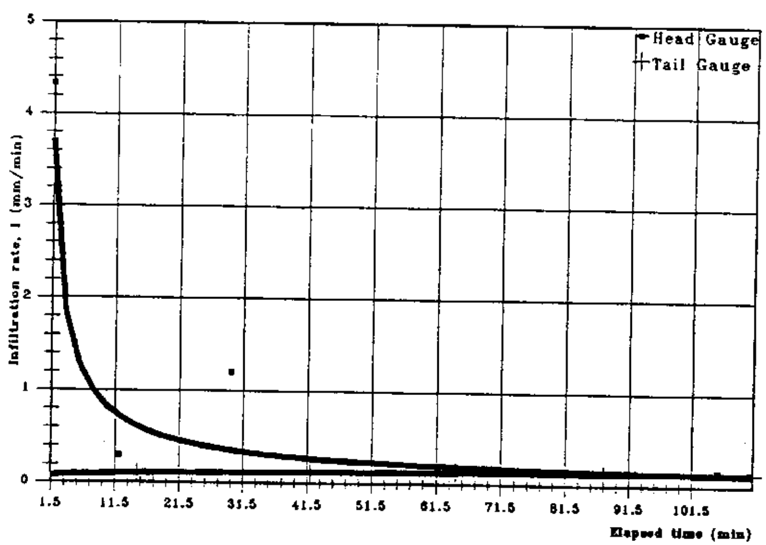
Time (min)	Tail Gauge Readings Water level (ft)	Water level (m)	Average time (min)	Drop in water level (mm)	Infiltration rate (mm/min)	Cumulative infiltration (mm)
0	0.08	0.024				
5	0.09	0.027	2.5	(3.048)	(0.610)	-
105	0.08	0.024	55	3.048	0.030	3.048
165	0.06	0.018	135	6.096	0.102	9.144
2690	0.02	0.006	1427.5.	12.192	0.005	21.336
3435	0	0.000	3062.5	6.096	0.008	27.432



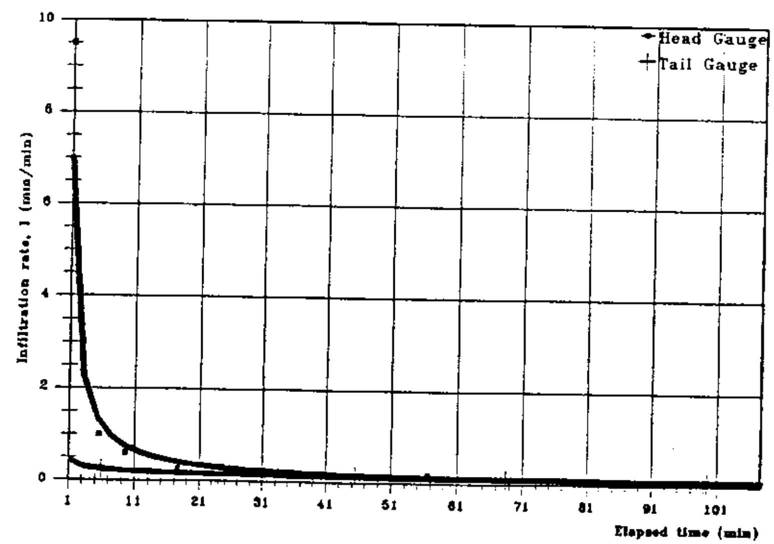
Infiltration rate, based on gauge readings
Field 3: Event 1 [14-01]; Rabi'95-'96



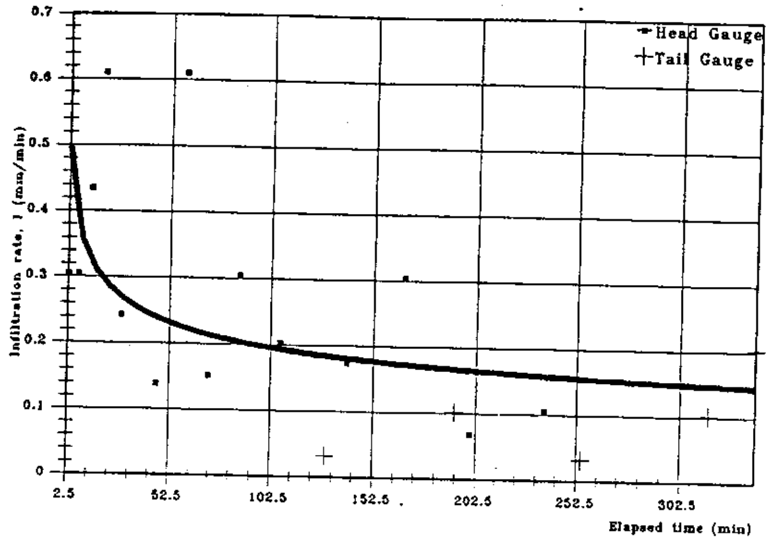
Infiltration rate, based on gauge readings
Field 3: Event 2 [06-02]; Rabi'95-'96



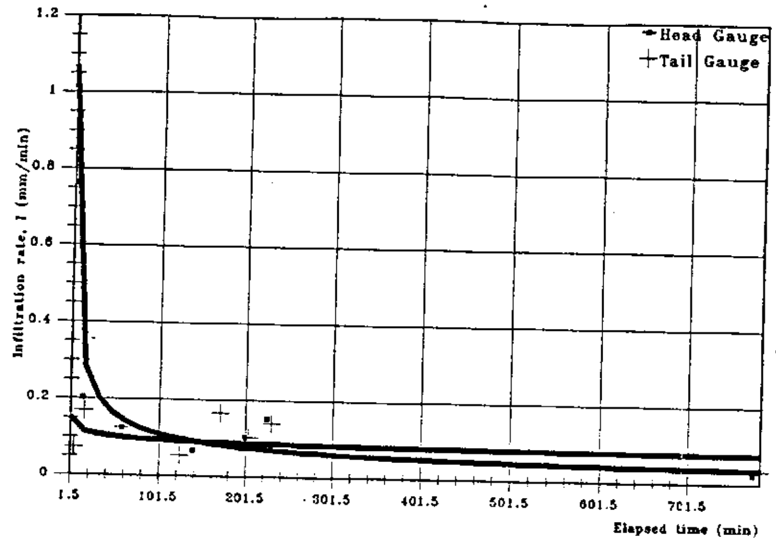
Infiltration rate, based on gauge readings
Field 3: Event 3 [29-02]; Rabi'95-'96



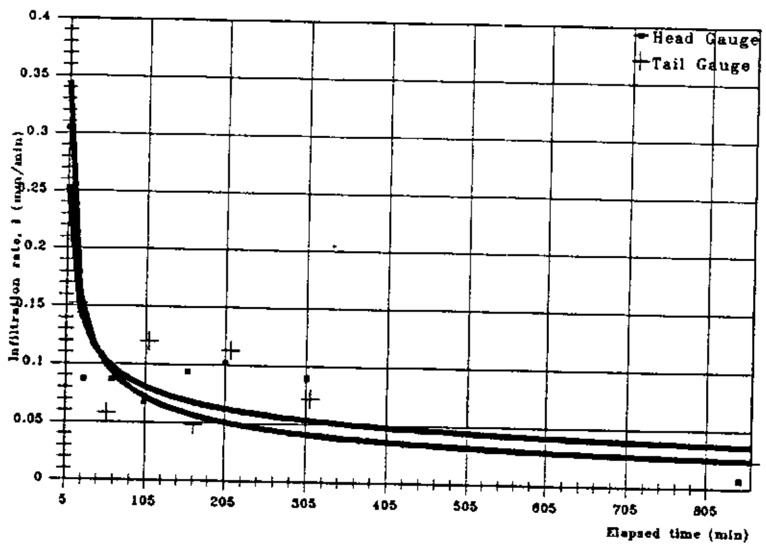
Infiltration rate, based on gauge readings
Field 3: Event 4 [12-03]; Rabi'95-'96



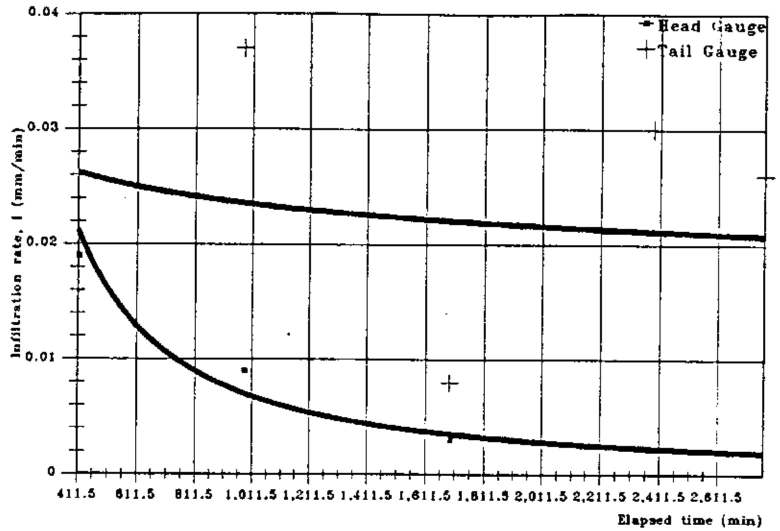
Infiltration rate, based on gauge readings
Field 33; Event 1 [24-01]; Rabi'95-'96



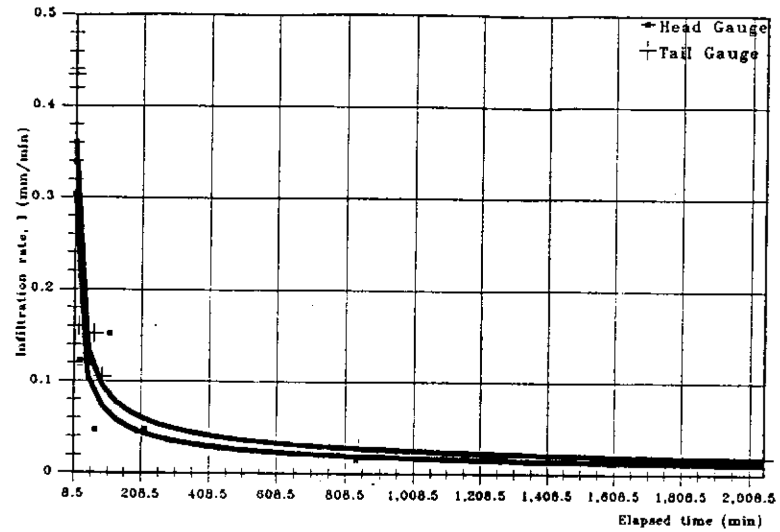
Infiltration rate, based on gauge readings
Field 33; Event 3 [29-02]; Rabi'95-'96



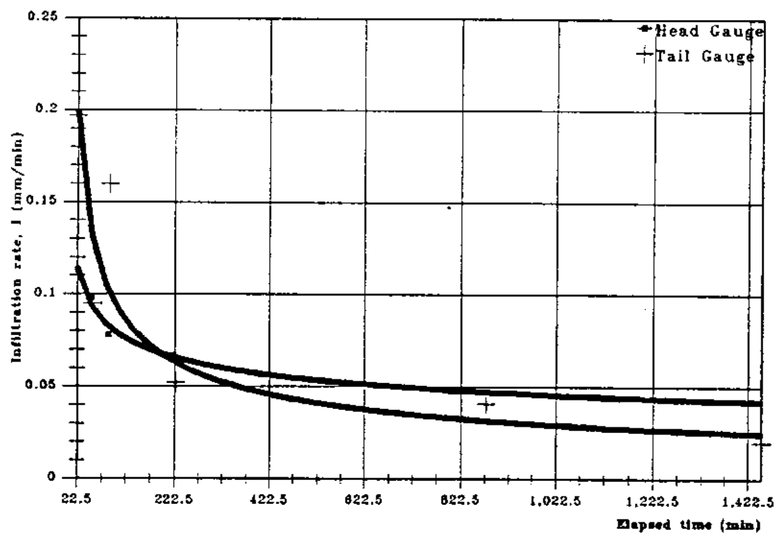
Infiltration rate, based on gauge readings
Field 33; Event 4 [12-03]; Rabi'95-'96



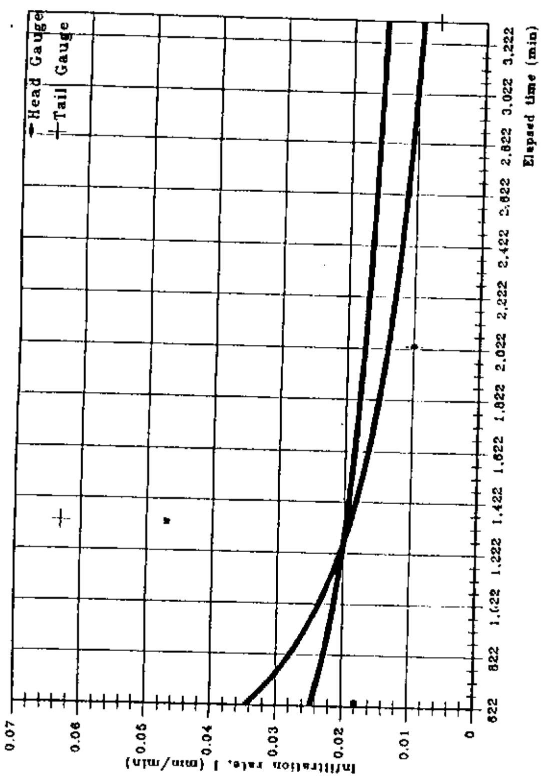
Infiltration rate, based on gauge readings
Field 8; Event 2 [06-02]; Rabi'95-'96



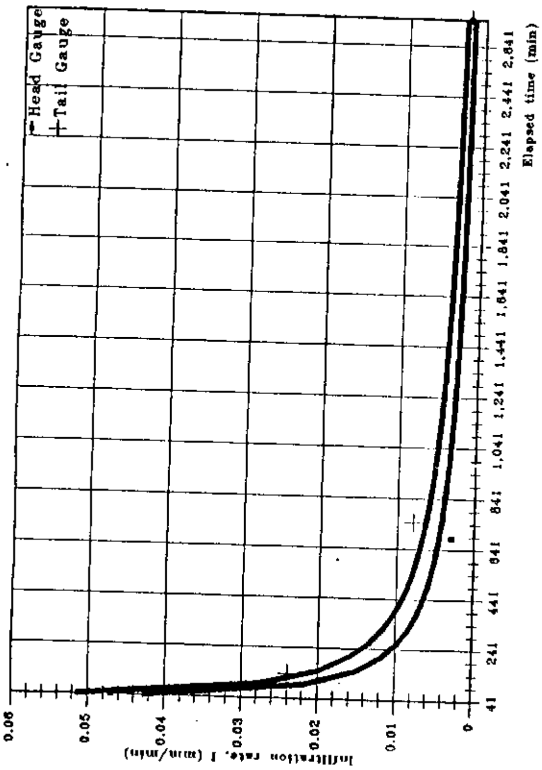
Infiltration rate, based on gauge readings
Field 8; Event 4 [07-03]; Rabi'95-'96



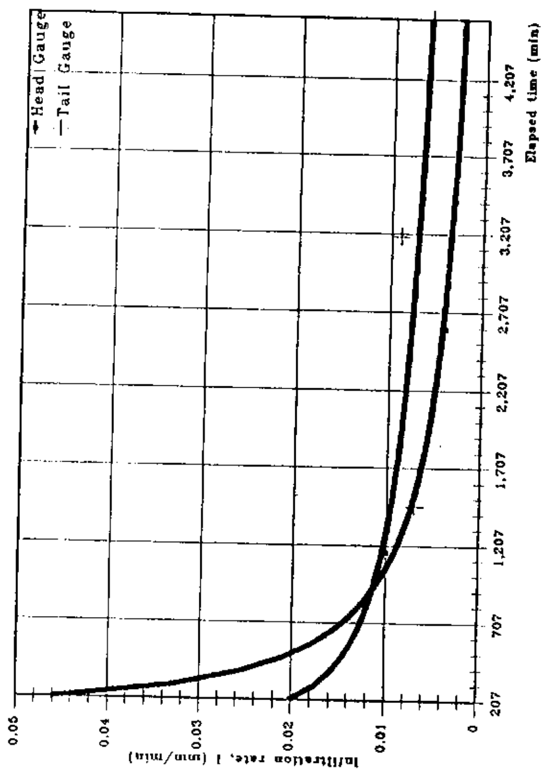
Infiltration rate, based on gauge readings
Field 8; Event 5 [27-03]; Rabi'95-'96



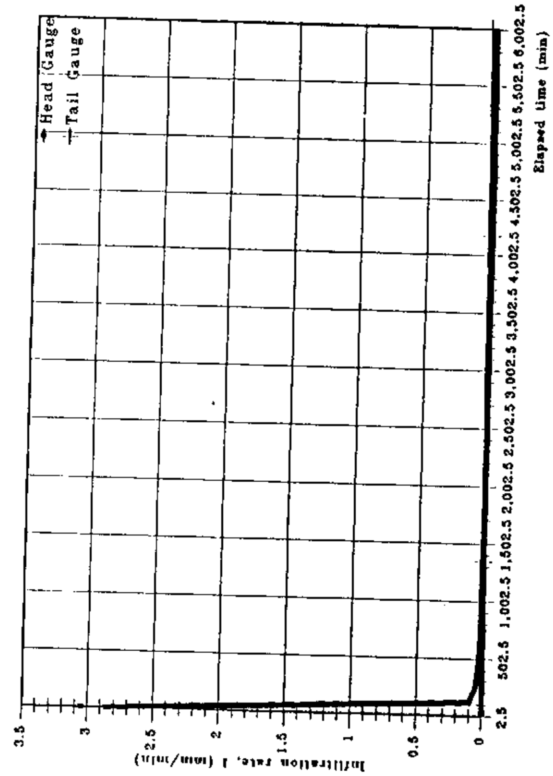
Infiltration rate, based on gauge readings
Field 6 : Event 1 [18-01]; Rabi'95-'96



Infiltration rate, based on gauge readings
Field 6 : Event 2 [07-02]; Rabi'95-'96



Infiltration rate, based on gauge readings
Field 6 : Event 3 [02-03]; Rabi'95-'96



Infiltration rate, based on gauge readings
Field 6 : Event 4 [17-03]; Rabi'95-'96

Annexure 5. Calculated soil moisture deficits.

Field 3 Event 1 14-01'96

Before Irrigation (14-01)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	293.48	270.54	0.085	1.620	0.137	0.270	15.24	2.024
2	"	30.48	310.51	280.36	0.108	1.780	0.191	0.270	15.24	1.201
3	"	60.96	344.61	304.14	0.133	1.480	0.197	0.251	30.48	1.639
4	"	91.44	388.67	327.44	0.187	1.630	0.305	0.338	30.48	1.024
9	Tail	15.24	349.02	314.39	0.110	1.620	0.178	0.270	15.24	1.398
10	"	30.48	330.61	295.96	0.117	1.780	0.208	0.258	15.24	0.748
11	"	60.96	344.17	303.01	0.136	1.560	0.212	0.251	30.48	1.182
12	"	91.44	394.93	328.31	0.203	1.480	0.300	0.338	30.48	1.161

After Irrigation (15-01)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	409.71	346.40	0.183	1.620	0.296	0.270	15.24	(0.394)
2	"	30.48	394.98	346.84	0.139	1.780	0.247	0.258	15.24	0.159
3	"	60.96	399.30	346.15	0.154	1.480	0.227	0.251	30.48	0.715
4	"	91.44	517.27	445.59	0.161	1.630	0.262	0.338	30.48	2.322
9	Tail	15.24	372.62	323.95	0.150	1.620	0.243	0.270	15.24	0.409
10	"	30.48	401.98	349.56	0.150	1.780	0.267	0.258	15.24	(0.144)
11	"	60.96	468.53	405.34	0.156	1.480	0.231	0.251	30.48	0.609
12	"	91.44	470.21	417.19	0.127	1.630	0.207	0.270	30.48	1.922

Field 3 Event 2 06-02'96

Before Irrigation (06-01)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	294.89	268.21	0.099	1.620	0.161	0.270	15.24	1.662
2	"	30.48	314.48	288.57	0.090	1.780	0.160	0.258	15.24	1.489
3	"	60.96	335.91	295.07	0.138	1.480	0.205	0.251	30.48	1.398
4	"	91.44	387.97	327.06	0.186	1.630	0.304	0.338	30.48	1.062
5	Tail	15.24	333.91	300.61	0.111	1.620	0.179	0.270	15.24	1.383
6	"	30.48	357.90	320.91	0.115	1.780	0.205	0.258	15.24	0.797
7	"	60.96	397.97	349.21	0.140	1.480	0.207	0.251	30.48	1.343
8	"	91.44	437.10	374.48	0.167	1.630	0.273	0.338	30.48	2.007

After Irrigation (12-02)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	354.57	308.72	0.149	1.620	0.241	0.270	15.24	0.451
2	"	30.48	337.31	300.67	0.122	1.780	0.217	0.258	15.24	0.619
3	"	60.96	340.93	301.89	0.129	1.480	0.191	0.251	30.48	1.808
4	"	91.44	412.93	346.35	0.192	1.630	0.313	0.338	30.48	0.764
5	Tail	15.24	380.60	326.91	0.164	1.620	0.266	0.270	15.24	0.063
6	"	30.48	316.27	280.03	0.129	1.780	0.230	0.258	15.24	0.414
7	"	60.96	391.13	341.73	0.145	1.480	0.214	0.251	30.48	1.120
8	"	91.44	395.93	338.67	0.169	1.630	0.276	0.270	30.48	(0.164)

Field 3 Event 3 29-02'96

Before Irrigation (28-02)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	346.13	321.09	0.078	1.620	0.126	0.270	15.24	2.193
2	"	30.48	353.17	320.60	0.102	1.780	0.181	0.258	15.24	1.168
3	"	60.96	382.59	338.47	0.130	1.480	0.193	0.251	30.48	1.761
4	"	91.44	395.67	344.00	0.150	1.630	0.245	0.338	30.48	2.852
5	Tail	15.24	314.03	287.37	0.093	1.620	0.150	0.270	15.24	1.827
6	"	30.48	383.83	345.86	0.110	1.780	0.195	0.258	15.24	0.946
7	"	60.96	431.70	378.13	0.142	1.480	0.210	0.251	30.48	1.251
8	"	91.44	442.42	365.77	0.210	1.630	0.342	0.338	30.48	(0.097)

After Irrigation (05-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	354.67	312.31	0.136	1.620	0.220	0.270	15.24	0.769
2	"	30.48	338.82	301.72	0.123	1.780	0.219	0.258	15.24	0.589
3	"	60.96	361.10	317.34	0.138	1.480	0.204	0.251	30.48	1.421
4	"	91.44	428.50	358.76	0.194	1.630	0.317	0.338	30.48	0.657
5	Tail	15.24	323.73	283.37	0.142	1.620	0.231	0.270	15.24	0.601
6	"	30.48	372.46	329.01	0.132	1.780	0.235	0.258	15.24	0.342
7	"	60.96	392.81	346.29	0.134	1.480	0.199	0.251	30.48	1.581
8	"	91.44	401.10	350.75	0.144	1.630	0.234	0.270	30.48	1.104

Field 3 Event 4 12-03'96

Before Irrigation (12-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	324.50	297.57	0.090	1.620	0.147	0.270	15.24	1.884
2	"	30.48	353.87	321.80	0.100	1.780	0.177	0.258	15.24	1.221
3	"	60.96	435.05	384.37	0.132	1.480	0.195	0.251	30.48	1.693
4	"	91.44	452.26	379.52	0.192	1.630	0.312	0.338	30.48	0.792
5	Tail	15.24	369.79	332.81	0.111	1.620	0.180	0.270	15.24	1.375
6	"	30.48	343.54	309.43	0.110	1.780	0.196	0.258	15.24	0.934
7	"	60.96	397.02	345.98	0.148	1.480	0.218	0.251	30.48	0.987
8	"	91.44	492.33	413.48	0.191	1.630	0.311	0.338	30.48	0.840

After Irrigation (14-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	334.28	305.01	0.096	1.620	0.155	0.270	15.24	1.749
2	"	30.48	316.66	286.95	0.104	1.780	0.184	0.258	15.24	1.116
3	"	60.96	400.86	372.24	0.077	1.480	0.114	0.251	30.48	4.173
4	"	91.44	411.42	373.80	0.101	1.630	0.164	0.338	30.48	5.314
5	Tail	15.24	406.81	351.78	0.156	1.620	0.253	0.270	15.24	0.256
6	"	30.48	372.95	330.93	0.127	1.780	0.226	0.258	15.24	0.480
7	"	60.96	441.37	379.77	0.162	1.480	0.240	0.251	30.48	0.324
8	"	91.44	459.65	407.57	0.128	1.630	0.208	0.270	30.48	1.887

Field 3 Event 5 28-03'96

Before Irrigation (28-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	326.22	299.04	0.091	1.620	0.147	0.270	15.24	1.874
2	"	30.48	369.18	338.51	0.091	1.780	0.161	0.258	15.24	1.466
3	"	60.96	394.22	344.67	0.144	1.480	0.213	0.251	30.48	1.156
4	"	91.44	438.22	369.44	0.186	1.630	0.303	0.338	30.48	1.065
5	Tail	15.24	338.04	305.26	0.107	1.620	0.174	0.270	15.24	1.467
6	"	30.48	347.78	312.53	0.113	1.780	0.201	0.258	15.24	0.865
7	"	60.96	369.75	326.20	0.134	1.480	0.198	0.251	30.48	1.619
8	"	91.44	438.29	379.38	0.155	1.630	0.253	0.338	30.48	2.600

After Irrigation (30-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	352.08	314.73	0.119	1.620	0.192	0.270	15.24	1.188
2	"	30.48	360.16	330.26	0.091	1.780	0.161	0.258	15.24	1.468
3	"	60.96	412.95	359.06	0.150	1.480	0.222	0.251	30.48	0.871
4	"	91.44	437.29	373.59	0.171	1.630	0.278	0.338	30.48	1.843
5	Tail	15.24	394.65	349.17	0.130	1.620	0.211	0.270	15.24	0.902
6	"	30.48	349.15	315.99	0.105	1.780	0.187	0.258	15.24	1.078
7	"	60.96	434.43	382.70	0.135	1.480	0.200	0.251	30.48	1.544
8	"	91.44	461.96	414.44	0.115	1.630	0.187	0.270	30.48	2.539

Field 33 Event 1 23-01'96

Before Irrigation (23-01)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	351.65	319.97	0.099	1.510	0.150	0.265	15.24	1.765
2	"	30.48	415.43	364.90	0.138	1.560	0.216	0.286	15.24	1.073
3	"	60.96	485.04	404.84	0.198	1.480	0.293	0.306	30.48	0.396
4	"	91.44	360.43	320.72	0.124	1.510	0.187	0.267	30.48	2.424
5	Tail	15.24	292.40	264.51	0.105	1.510	0.159	0.265	15.24	1.617
6	"	30.48	336.36	304.81	0.104	1.560	0.161	0.286	15.24	1.904
7	"	60.96	413.68	350.54	0.180	1.480	0.267	0.306	30.48	1.208
8	"	91.44	363.82	303.25	0.200	1.510	0.302	0.267	30.48	(1.070)

After Irrigation (24-01)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	357.14	314.50	0.136	1.510	0.205	0.265	15.24	0.923
2	"	30.48	430.08	372.55	0.154	1.560	0.241	0.286	15.24	0.693
3	"	60.96	398.00	338.67	0.175	1.480	0.259	0.306	30.48	1.430
4	"	91.44	358.17	311.94	0.148	1.510	0.224	0.267	30.48	1.302
5	Tail	15.24	406.17	349.65	0.162	1.510	0.244	0.265	15.24	0.323
6	"	30.48	338.95	301.36	0.125	1.560	0.195	0.286	15.24	1.399
7	"	60.96	416.62	346.78	0.201	1.480	0.298	0.306	30.48	0.248
8	"	91.44	325.10	271.98	0.195	1.510	0.295	0.267	30.48	(0.866)

Field 33 Event 3 29-02'96

Before Irrigation (28-02)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	360.46	325.76	0.107	1.510	0.161	0.265	15.24	1.592
2	"	30.48	371.36	328.49	0.131	1.560	0.204	0.286	15.24	1.262
3	"	60.96	461.79	395.36	0.168	1.480	0.249	0.306	30.48	1.753
4	"	91.44	408.28	360.76	0.132	1.510	0.199	0.267	30.48	2.060
5	Tail	15.24	336.38	305.13	0.102	1.510	0.155	0.265	15.24	1.686
6	"	30.48	397.33	350.05	0.135	1.560	0.211	0.286	15.24	1.154
7	"	60.96	335.70	295.13	0.137	1.480	0.203	0.306	30.48	3.132
8	"	91.44	344.54	287.40	0.199	1.510	0.300	0.267	30.48	(1.028)

After Irrigation (05-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	330.39	289.96	0.139	1.510	0.211	0.265	15.24	0.834
2	"	30.48	344.48	305.37	0.128	1.560	0.200	0.286	15.24	1.320
3	"	60.96	447.87	380.21	0.178	1.480	0.263	0.306	30.48	1.305
4	"	91.44	409.49	346.81	0.181	1.510	0.273	0.267	30.48	(0.195)
5	Tail	15.24	315.75	276.73	0.141	1.510	0.213	0.265	15.24	0.798
6	"	30.48	370.10	328.05	0.128	1.560	0.200	0.286	15.24	1.317
7	"	60.96	402.22	338.26	0.189	1.480	0.280	0.306	30.48	0.803
8	"	91.44	393.13	328.31	0.197	1.510	0.298	0.267	30.48	(0.964)

Field 33 Event 4 12-03'96

Before Irrigation (12-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	306.49	279.34	0.097	1.510	0.147	0.265	15.24	1.807
2	"	30.48	429.00	381.34	0.125	1.560	0.195	0.286	15.24	1.393
3	"	60.96	401.02	338.99	0.183	1.480	0.271	0.306	30.48	1.078
4	"	91.44	395.02	355.02	0.113	1.510	0.170	0.267	30.48	2.937
5	Tail	15.24	309.78	281.49	0.101	1.510	0.152	0.265	15.24	1.730
6	"	30.48	319.47	294.01	0.087	1.560	0.135	0.286	15.24	2.306
7	"	60.96	426.74	358.23	0.191	1.480	0.283	0.306	30.48	0.706
8	"	91.44	394.73	328.58	0.201	1.510	0.304	0.267	30.48	(1.143)

After Irrigation (14-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	393.58	366.59	0.074	1.510	0.111	0.265	15.24	2.349
2	"	30.48	399.55	351.15	0.138	1.560	0.215	0.286	15.24	1.088
3	"	60.96	460.88	426.29	0.081	1.480	0.120	0.306	30.48	5.673
4	"	91.44	321.63	292.70	0.099	1.510	0.149	0.267	30.48	3.574
5	Tail	15.24	343.30	310.04	0.107	1.510	0.162	0.265	15.24	1.574
6	"	30.48	382.83	337.67	0.134	1.560	0.209	0.286	15.24	1.185
7	"	60.96	408.41	349.59	0.168	1.480	0.249	0.306	30.48	1.743
8	"	91.44	400.50	331.46	0.208	1.510	0.315	0.267	30.48	(1.464)

Field 33 Event 5 22-03'96

Before Irrigation (21-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	356.59	324.86	0.098	1.510	0.147	0.265	15.24	1.795
2	"	30.48	381.82	329.96	0.157	1.560	0.245	0.286	15.24	0.628
3	"	60.96	439.36	366.03	0.200	1.480	0.297	0.306	30.48	0.296
4	"	91.44	335.87	302.25	0.111	1.510	0.168	0.267	30.48	3.003
5	Tail	15.24	306.62	277.84	0.104	1.510	0.156	0.265	15.24	1.659
6	"	30.48	323.98	279.65	0.159	1.560	0.247	0.286	15.24	0.596
7	"	60.96	451.90	375.79	0.203	1.480	0.300	0.306	30.48	0.197
8	"	91.44	372.36	308.72	0.206	1.510	0.311	0.267	30.48	(1.365)

After Irrigation (24-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	402.09	371.51	0.082	1.510	0.124	0.265	15.24	2.149
2	"	30.48	402.34	352.03	0.143	1.560	0.223	0.286	15.24	0.967
3	"	60.96	497.77	472.95	0.052	1.480	0.078	0.306	30.48	6.966
4	"	91.44	368.46	327.90	0.124	1.510	0.187	0.267	30.48	2.430
5	Tail	15.24	448.47	426.27	0.052	1.510	0.079	0.265	15.24	2.845
6	"	30.48	393.84	332.46	0.185	1.560	0.288	0.286	15.24	(0.025)
7	"	60.96	467.35	402.96	0.160	1.480	0.236	0.306	30.48	2.125
8	"	91.44	415.56	377.06	0.102	1.510	0.154	0.267	30.48	3.424

Field 8 Event 1 19-01'96

Before Irrigation (18-01'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	288.77	262.63	0.100	1.490	0.148	0.331	15.24	2.780
2	"	30.48	392.22	351.88	0.115	1.500	0.172	0.379	15.24	3.161
3	"	60.96	335.42	303.24	0.106	1.620	0.172	0.219	30.48	1.429
4	"	91.44	334.51	303.42	0.102	1.620	0.166	0.219	30.48	1.610
9	Tail	15.24	160.60	146.49	0.096	1.490	0.144	0.331	15.24	2.853
10	"	30.48	188.30	169.20	0.113	1.500	0.169	0.379	15.24	3.202
11	"	60.96	187.64	167.97	0.117	1.620	0.190	0.219	30.48	0.887
12	"	91.44	194.13	175.22	0.108	1.620	0.175	0.219	30.48	1.340

Field 8 Event 2 06-02'96

Before Irrigation (06-02'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	164.93	148.28	0.112	1.490	0.167	0.331	15.24	2.490
2	"	30.48	185.57	163.01	0.138	1.500	0.208	0.379	15.24	2.618
3	"	60.96	193.52	169.26	0.143	1.620	0.232	0.219	30.48	(0.408)
4	"	91.44	204.00	180.80	0.128	1.620	0.208	0.219	30.48	0.333
9	Tail	15.24	164.72	148.62	0.108	1.490	0.161	0.331	15.24	2.580
10	"	30.48	181.30	161.05	0.126	1.500	0.189	0.379	15.24	2.908
11	"	60.96	192.70	169.27	0.138	1.620	0.224	0.219	30.48	(0.166)
12	"	91.44	192.70	169.70	0.136	1.620	0.220	0.219	30.48	(0.023)

After Irrigation (14-02'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	368.86	324.40	0.137	1.490	0.204	0.331	15.24	1.928
2	"	30.48	336.85	304.47	0.106	1.500	0.160	0.379	15.24	3.351
3	"	60.96	337.26	304.09	0.109	1.620	0.177	0.219	30.48	1.283
4	"	91.44	416.26	368.14	0.131	1.620	0.212	0.219	30.48	0.215
9	Tail	15.24	364.61	320.05	0.139	1.490	0.207	0.331	15.24	1.878
10	"	30.48	362.24	314.69	0.151	1.500	0.227	0.379	15.24	2.328
11	"	60.96	374.79	330.76	0.133	1.620	0.216	0.219	30.48	0.096
12	"	91.44	389.52	342.27	0.138	1.620	0.224	0.219	30.48	(0.147)

Field 8 Event 4 07-03'96

Before Irrigation (07-03'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	346.01	311.15	0.112	1.490	0.167	0.331	15.24	2.496
2	"	30.48	349.55	308.98	0.131	1.500	0.197	0.379	15.24	2.780
3	"	60.96	397.01	338.44	0.173	1.620	0.280	0.219	30.48	(1.876)
4	"	91.44	411.03	364.22	0.129	1.620	0.208	0.219	30.48	0.323
9	Tail	15.24	323.65	291.82	0.109	1.490	0.163	0.331	15.24	2.563
10	"	30.48	353.13	319.00	0.107	1.500	0.160	0.379	15.24	3.336
11	"	60.96	400.08	357.82	0.118	1.620	0.191	0.219	30.48	0.837
12	"	91.44	379.05	335.66	0.129	1.620	0.209	0.219	30.48	0.286

After Irrigation (14-03'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	355.01	316.21	0.123	1.490	0.183	0.331	15.24	2.254
2	"	30.48	357.84	315.69	0.134	1.500	0.200	0.379	15.24	2.730
3	"	60.96	365.20	326.43	0.119	1.620	0.192	0.219	30.48	0.804
4	"	91.44	426.91	375.41	0.137	1.620	0.222	0.219	30.48	(0.105)
9	Tail	15.24	341.11	308.76	0.105	1.490	0.156	0.331	15.24	2.661
10	"	30.48	367.96	324.34	0.134	1.500	0.202	0.379	15.24	2.708
11	"	60.96	390.18	349.74	0.116	1.620	0.187	0.219	30.48	0.960
12	"	91.44	422.89	373.80	0.131	1.620	0.213	0.219	30.48	0.184

Field 8 Event 5 27-03'96

Before Irrigation (27-03'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	346.82	314.52	0.103	1.490	0.153	0.331	15.24	2.708
2	"	30.48	380.18	339.61	0.119	1.500	0.179	0.379	15.24	3.051
3	"	60.96	362.69	322.05	0.126	1.620	0.204	0.219	30.48	0.438
4	"	91.44	425.65	381.43	0.116	1.620	0.188	0.219	30.48	0.945
9	Tail	15.24	315.96	290.73	0.087	1.490	0.129	0.331	15.24	3.069
10	"	30.48	313.99	288.52	0.088	1.500	0.132	0.379	15.24	3.764
11	"	60.96	381.20	337.93	0.128	1.620	0.207	0.219	30.48	0.347
12	"	91.44	401.25	357.94	0.121	1.620	0.196	0.219	30.48	0.694

After Irrigation (30-03'96)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	431.27	369.17	0.168	1.490	0.251	0.331	15.24	1.220
2	"	30.48	414.78	362.87	0.143	1.500	0.215	0.379	15.24	2.512
3	"	60.96	445.91	386.00	0.155	1.620	0.251	0.219	30.48	(0.995)
4	"	91.44	489.73	429.73	0.140	1.620	0.226	0.219	30.48	(0.225)
9	Tail	15.24	395.48	348.64	0.134	1.490	0.200	0.331	15.24	1.989
10	"	30.48	352.10	311.39	0.131	1.500	0.196	0.379	15.24	2.793
11	"	60.96	400.85	358.97	0.117	1.620	0.189	0.219	30.48	0.908
12	"	91.44	399.97	355.18	0.126	1.620	0.204	0.219	30.48	0.442

Field 4 Event 3 02-03'96

Before Irrigation (02-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	362.76	327.97	0.106	1.770	0.188	0.291	15.24	1.569
2	"	30.48	377.78	339.12	0.114	1.700	0.194	0.307	15.24	1.727
3	"	60.96	372.35	322.13	0.156	1.700	0.265	0.307	30.48	1.282
4	"	91.44	350.20	293.18	0.194	1.360	0.265	0.335	30.48	2.161
5	Tail	15.24	399.91	357.83	0.118	1.770	0.208	0.291	15.24	1.258
6	"	30.48	374.46	330.51	0.133	1.700	0.226	0.307	15.24	1.235
7	"	60.96	361.30	308.22	0.172	1.700	0.293	0.307	30.48	0.437
8	"	91.44	355.82	292.91	0.215	1.360	0.292	0.335	30.48	1.320

After Irrigation (12-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	324.75	288.98	0.124	1.770	0.219	0.291	15.24	1.091
2	"	30.48	415.81	369.16	0.126	1.700	0.215	0.307	15.24	1.406
3	"	60.96	455.35	391.27	0.164	1.700	0.278	0.307	30.48	0.874
4	"	91.44	331.33	280.82	0.180	1.360	0.245	0.335	30.48	2.767
5	Tail	15.24	368.24	322.87	0.141	1.770	0.249	0.291	15.24	0.640
6	"	30.48	375.40	328.67	0.142	1.700	0.242	0.307	15.24	0.997
7	"	60.96	393.75	334.40	0.177	1.700	0.302	0.307	30.48	0.164
8	"	91.44	366.96	299.24	0.226	1.360	0.308	0.335	30.48	0.842

Field 4 Event 4 17-03'96

Before Irrigation (16-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	296.67	272.31	0.089	1.770	0.158	0.291	15.24	2.017
2	"	30.48	319.15	290.33	0.099	1.700	0.169	0.307	15.24	2.108
3	"	60.96	310.17	263.23	0.178	1.700	0.303	0.307	30.48	0.120
4	"	91.44	343.06	285.30	0.202	1.360	0.275	0.335	30.48	1.831
5	Tail	15.24	326.92	296.84	0.101	1.770	0.179	0.291	15.24	1.697
6	"	30.48	335.78	297.55	0.128	1.700	0.218	0.307	15.24	1.351
7	"	60.96	317.67	275.56	0.153	1.700	0.260	0.307	30.48	1.442
8	"	91.44	331.97	275.35	0.206	1.360	0.280	0.335	30.48	1.699

After Irrigation (24-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	375.25	327.37	0.146	1.770	0.259	0.291	15.24	0.485
2	"	30.48	252.36	224.89	0.122	1.700	0.208	0.307	15.24	1.516
3	"	60.96	396.77	341.25	0.163	1.700	0.277	0.307	30.48	0.930
4	"	91.44	324.64	278.59	0.165	1.360	0.225	0.335	30.48	3.371
5	Tail	15.24	373.69	323.26	0.156	1.770	0.276	0.291	15.24	0.222
6	"	30.48	425.04	369.20	0.151	1.700	0.257	0.307	15.24	0.762
7	"	60.96	362.77	304.68	0.191	1.700	0.324	0.307	30.48	(0.519)
8	"	91.44	364.42	300.81	0.211	1.360	0.288	0.335	30.48	1.457

Field 6 Event 3 02-03'96

Before Irrigation (02-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	338.12	303.77	0.113	1.770	0.200	0.291	15.24	1.380
2	"	30.48	384.14	344.89	0.114	1.700	0.193	0.307	15.24	1.732
3	"	60.96	353.76	301.23	0.174	1.700	0.296	0.307	30.48	0.324
4	"	91.44	405.89	341.14	0.190	1.360	0.258	0.335	30.48	2.355
5	Tail	15.24	329.14	297.08	0.108	1.770	0.191	0.291	15.24	1.519
6	"	30.48	336.61	302.99	0.111	1.700	0.189	0.307	15.24	1.805
7	"	60.96	362.99	308.75	0.176	1.700	0.299	0.307	30.48	0.258
8	"	91.44	372.77	306.41	0.217	1.360	0.295	0.335	30.48	1.245

After Irrigation (12-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	364.93	322.25	0.132	1.770	0.234	0.291	15.24	0.858
2	"	30.48	386.87	342.42	0.130	1.700	0.221	0.307	15.24	1.317
3	"	60.96	395.67	331.98	0.192	1.700	0.326	0.307	30.48	(0.580)
4	"	91.44	378.32	317.79	0.190	1.360	0.259	0.335	30.48	2.327
5	Tail	15.24	380.69	335.78	0.134	1.770	0.237	0.291	15.24	0.822
6	"	30.48	325.06	287.06	0.132	1.700	0.225	0.307	15.24	1.251
7	"	60.96	355.93	303.51	0.173	1.700	0.294	0.307	30.48	0.411
8	"	91.44	409.67	336.38	0.218	1.360	0.296	0.335	30.48	1.191

Field 6 Event 4 17-03'96

Before Irrigation (16-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	330.02	295.61	0.116	1.770	0.206	0.291	15.24	1.290
2	"	30.48	352.77	311.68	0.132	1.700	0.224	0.307	15.24	1.265
3	"	60.96	382.35	324.10	0.180	1.700	0.306	0.307	30.48	0.048
4	"	91.44	349.11	294.20	0.187	1.360	0.254	0.335	30.48	2.486
5	Tail	15.24	341.43	309.67	0.103	1.770	0.182	0.291	15.24	1.664
6	"	30.48	382.32	340.27	0.124	1.700	0.210	0.307	15.24	1.479
7	"	60.96	318.16	278.35	0.143	1.700	0.243	0.307	30.48	1.950
8	"	91.44	327.10	281.86	0.161	1.360	0.218	0.335	30.48	3.570

After Irrigation (24-03)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	367.38	328.86	0.117	1.770	0.207	0.291	15.24	1.271
2	"	30.48	433.49	386.88	0.120	1.700	0.205	0.307	15.24	1.559
3	"	60.96	421.82	365.76	0.153	1.700	0.261	0.307	30.48	1.419
4	"	91.44	326.10	282.54	0.154	1.360	0.210	0.335	30.48	3.832
5	Tail	15.24	392.97	367.53	0.069	1.770	0.123	0.291	15.24	2.563
6	"	30.48	353.32	318.76	0.108	1.700	0.184	0.307	15.24	1.871
7	"	60.96	386.56	335.01	0.154	1.700	0.262	0.307	30.48	1.387
8	"	91.44	376.36	324.73	0.159	1.360	0.216	0.335	30.48	3.632

Field 6 Event 5 01-04'96

Before Irrigation (01-04)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	294.88	272.81	0.081	1.770	0.143	0.291	15.24	2.248
2	"	30.48	344.18	311.94	0.103	1.700	0.176	0.307	15.24	2.003
3	"	60.96	368.56	324.34	0.136	1.700	0.232	0.307	30.48	2.296
4	"	91.44	315.30	291.80	0.081	1.360	0.110	0.335	30.48	6.885
5	Tail	15.24	318.24	294.43	0.081	1.770	0.143	0.291	15.24	2.249
6	"	30.48	324.72	292.08	0.112	1.700	0.190	0.307	15.24	1.785
7	"	60.96	365.62	318.66	0.147	1.700	0.251	0.307	30.48	1.724
8	"	91.44	321.64	282.43	0.139	1.360	0.189	0.335	30.48	4.468

After Irrigation (06-04)

Sr No.	Location	Depth (cm)	Wet wt (g)	Dry wt (g)	W (-)	Bulk den. (g/cm^3)	vmc (-)	vmc FC (-)	RD (cm)	SMD (cm)
1	Head	15.24	372.37	327.13	0.138	1.770	0.245	0.291	15.24	0.700
2	"	30.48	368.06	333.44	0.104	1.700	0.177	0.307	15.24	1.990
3	"	60.96	384.00	340.16	0.129	1.700	0.219	0.307	30.48	2.682
4	"	91.44	343.97	293.41	0.172	1.360	0.234	0.335	30.48	3.080
5	Tail	15.24	300.17	271.76	0.105	1.770	0.185	0.291	15.24	1.610
6	"	30.48	340.98	318.34	0.071	1.700	0.121	0.307	15.24	2.838
7	"	60.96	359.26	307.60	0.168	1.700	0.286	0.307	30.48	0.658
8	"	91.44	392.81	324.79	0.209	1.360	0.285	0.335	30.48	1.542

Annexure 6. Calculation of the irrigation time period, tco.

Field 3

Event	Date (dd/mm)	Area (m ^ 2)	Q (m ^ 3/min)	Advance function r (-)	p (-)	(ta)L (min)	Infiltration function C (mm/min)	B (-)	A (mm/min ^ B)
Event 1	14-01	1022	1.185	0.762	36.98	78	0.3375	0.4352	6.6104
Event 2	06-02	1022	1.344	0.824	50.42	39	0.1235	0.4200	3.0769
Event 3	29-02	1022	1.184	0.830	37.10	54	0.2137	0.4162	4.0554
Event 4	12-03	1022	1.246	0.868	40.28	41	0.1880	0.4124	3.4524

Event	Date (dd/mm)	Zo(ta)L (mm)	Vinf(ta)x=L (m ^ 3)	Vin(ta)x=L (m ^ 3)	Vsurf(ta)x=L (m ^ 3)	Deficit (mm)	Vreqd (m ^ 3)	tdif (min)	tco (min)
Event 1	14-01	70.31	46.70	92.35	45.64	51.89	53.03	6.23	84
Event 2	06-02	19.02	12.64	51.81	39.17	55.70	56.93	13.21	52
Event 3	29-02	33.00	21.92	64.33	42.41	59.99	61.31	15.97	70
Event 4	12-03	23.85	15.84	51.69	35.85	48.63	49.70	11.11	53

Field 33

		Area (m ^ 2)	Q (m ^ 3/min)	Advance function r (-)	p (-)	(ta)L (min)	Infiltration function C (mm/min)	B (-)	A (mm/min ^ B)
Event 1	23-01	861.58	1.547	0.692	46.90	67	0.1986	0.4365	5.9298
Event 3	29-02	861.58	1.379	0.523	109.42	52	0.0467	0.3590	1.8540
Event 4	12-03	861.58	1.949	0.704	63.86	40	0.0392	0.3897	1.9001
Event 5	22-03	861.58	2.758	0.660	87.98	32	0.0440	0.3904	2.0583

		Zo(ta)L (mm)	Vinf(ta)x=L (m ^ 3)	Vin(ta)x=L (m ^ 3)	Vsurf(ta)x=L (m ^ 3)	Deficit (mm)	Vreqd (m ^ 3)	tdif (min)	tco (min)
Event 1	23-01	50.52	28.29	103.81	75.52	51.93	44.74	(19.90)	67
Event 3	29-02	10.06	5.63	71.31	65.68	63.20	54.45	(8.14)	52
Event 4	12-03	9.60	5.38	54.35	48.98	59.79	51.51	1.30	42
Event 5	22-03	9.33	5.23	87.49	82.27	40.88	35.22	(17.06)	32

Field 8

Event	Date (dd/mm)	Area (m ^ 2)	Q (m ^ 3/min)	Advance function r (-)	p (-)	(ta)L (min)	Infiltration function C (mm/min)	B (-)	A (mm/min ^ B)
Event 2	06-02	987.83	2.953	0.705	103.20	25	0.0201	0.3790	1.3970
Event 4	12-03	987.83	3.304	1.058	49.18	17	0.0276	0.3301	1.3626
Event 5	28-03	987.83	0.841	0.825	71.79	24	0.0121	0.3859	0.7565

Event	Date (dd/mm)	Zo(ta)L (mm)	Vinf(ta)x=L (m ^ 3)	Vin(ta)x=L (m ^ 3)	Vsurf(ta)x=L (m ^ 3)	Deficit (mm)	Vreqd (m ^ 3)	tdif (min)	tco (min)
Event 2	06-02	5.20	3.34	72.74	69.40	54.65	53.98	(5.22)	25
Event 4	12-03	3.94	2.53	56.30	53.77	63.11	62.34	2.60	20
Event 5	28-03	2.87	1.84	20.18	18.34	75.08	74.17	66.38	90

Field 4				Advance function			Infiltration function		
Event	Date (dd/mm)	Area (m ^ 2)	Q (m ^ 3/min)	r (-)	p (-)	(ta)L (min)	C (mm/min)	B (-)	A (mm/min ^ B)
Event 1	19-01	4430.4	1.540	0.747	71.88	249	0.0154	0.4223	1.6124
Event 2	07-02	4430.4	1.366	0.477	393.70	160	0.0086	0.3312	0.8260
Event 3	02-03	4430.4	1.409	0.496	382.46	140	0.0065	0.3401	0.7486
Event 4	17-03	4430.4	1.609	0.530	442.81	77	0.0061	0.2814	0.7572

Event	Date (dd/mm)	Zo(ta)L (mm)	Vinf(ta)x=L (m ^ 3)	Vin(ta)x=L (m ^ 3)	Vsurf(ta)x=L (m ^ 3)	Deficit (mm)	Vreqd (m ^ 3)	tdif (min)	tco (min)
Event 1	19-01	20.40	58.75	383.31	324.55	77.06	341.40	10.94	260
Event 2	07-02	5.81	16.73	218.46	201.73	69.31	307.07	77.11	237
Event 3	02-03	4.92	14.18	196.69	182.51	54.95	243.45	43.25	183
Event 4	17-03	3.04	8.76	124.10	115.34	61.33	271.71	97.19	174

Field 6				Advance function			Infiltration function		
Event	Date (dd/mm)	Area (m ^ 2)	Q (m ^ 3/min)	r (-)	p (-)	(ta)L (min)	C (mm/min)	B (-)	A (mm/min ^ B)
Event 1	18-01	2008.7	1.348	0.506	132.56	215	0.0218	0.4283	2.1877
Event 2	07-02	2008.7	1.325	0.349	261.88	343	0.0181	0.3800	1.4302
Event 3	02-03	2008.7	1.364	0.471	205.42	127	0.0146	0.3878	1.3624
Event 4	17-03	2008.7	1.544	0.315	408.02	158	0.0136	0.3485	1.2548

Event	Date (dd/mm)	Zo(ta)L (mm)	Vinf(ta)x=L (m ^ 3)	Vin(ta)x=L (m ^ 3)	Vsurf(ta)x=L (m ^ 3)	Deficit (mm)	Vreqd (m ^ 3)	tdif (min)	tco (min)
Event 1	18-01	26.53	34.64	286.33	251.69	52.20	104.85	(108.93)	215
Event 2	07-02	19.35	25.27	443.83	418.56	55.89	112.27	(231.16)	343
Event 3	02-03	10.75	14.04	173.21	159.17	54.10	108.67	(37.02)	127
Event 4	17-03	9.46	12.35	244.13	231.77	69.75	140.11	(59.37)	158

Field 3 Event 3 29-02

ta(x=0.75L)= 38 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	193.5	193.5	0.2137	0.4162	4.0554	77.64
2	5	193.5	188.5	0.2137	0.4162	4.0554	76.18
3	10	193.5	183.5	0.2137	0.4162	4.0554	74.71
4	15	193.5	178.5	0.2137	0.4162	4.0554	73.23
5	20	193.5	173.5	0.2137	0.4162	4.0554	71.75
6	25	193.5	168.5	0.2137	0.4162	4.0554	70.27
7	30	193.5	163.5	0.2137	0.4162	4.0554	68.77
8	35	193.5	158.5	0.2137	0.4162	4.0554	67.27
9	40	193.5	153.5	0.2137	0.4162	4.0554	65.76
10	45	193.5	148.5	0.2137	0.4162	4.0554	64.24
11	50	193.5	143.5	0.2137	0.4162	4.0554	62.71
12	55	193.5	138.5	0.2137	0.4162	4.0554	61.17
13	57	193.5	136.5	0.2137	0.4162	4.0554	60.55
						Average Zinf (mm):	68.79
						Average Zinf-LQ (mm):	62.88
						DU (%):	91.42

Field 3 Event 4 12-03

ta(x=0.75L)= 30 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	171	171	0.1880	0.4124	3.4524	60.92
2	5	171	166	0.1880	0.4124	3.4524	59.63
3	10	171	161	0.1880	0.4124	3.4524	58.34
4	15	171	156	0.1880	0.4124	3.4524	57.03
5	20	171	151	0.1880	0.4124	3.4524	55.72
6	25	171	146	0.1880	0.4124	3.4524	54.41
7	30	171	141	0.1880	0.4124	3.4524	53.08
8	35	171	136	0.1880	0.4124	3.4524	51.75
9	40	171	131	0.1880	0.4124	3.4524	50.41
10	45	171	126	0.1880	0.4124	3.4524	49.06
						Average Zinf (mm):	55.04
						Average Zinf-LQ (mm):	51.07
						DU (%):	92.80

Field 33 Event 1 23-01

ta(x=0.75L)= 44 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	377	377	0.1921	0.4335	5.6914	146.91
2	5	377	372	0.1921	0.4335	5.6914	145.52
3	10	377	367	0.1921	0.4335	5.6914	144.12
4	15	377	362	0.1921	0.4335	5.6914	142.72
5	20	377	357	0.1921	0.4335	5.6914	141.32
6	25	377	352	0.1921	0.4335	5.6914	139.92
7	30	377	347	0.1921	0.4335	5.6914	138.51
8	35	377	342	0.1921	0.4335	5.6914	137.10
9	40	377	337	0.1921	0.4335	5.6914	135.69
10	45	377	332	0.1921	0.4335	5.6914	134.27
11	50	377	327	0.1921	0.4335	5.6914	132.85
12	55	377	322	0.1921	0.4335	5.6914	131.42
13	60	377	317	0.1921	0.4335	5.6914	129.99
14	62	377	315	0.1921	0.4335	5.6914	129.41
						Average Zinf (mm):	137.84
						Average Zinf-LQ (mm):	131.59
						DU (%):	95.46

Field 33 Event 3 29-02

ta(x=0.75L)= 30 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	1370	1370	0.0467	0.3590	1.8540	88.76
2	5	1370	1365	0.0467	0.3590	1.8540	88.50
3	10	1370	1360	0.0467	0.3590	1.8540	88.23
4	15	1370	1355	0.0467	0.3590	1.8540	87.97
5	20	1370	1350	0.0467	0.3590	1.8540	87.70
6	25	1370	1345	0.0467	0.3590	1.8540	87.43
7	30	1370	1340	0.0467	0.3590	1.8540	87.17
8	35	1370	1335	0.0467	0.3590	1.8540	86.90
9	40	1370	1330	0.0467	0.3590	1.8540	86.63
10	43	1370	1327	0.0467	0.3590	1.8540	86.47
						Average Zinf (mm):	87.58
						Average Zinf-LQ (mm):	86.67
						DU (%):	98.96

Field 33 Event 4 12-03

ta(x=0.75L)= 27 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	1366.5	1366.5	0.0567	0.3979	2.5873	123.24
2	5	1366.5	1361.5	0.0567	0.3979	2.5873	122.89
3	10	1366.5	1356.5	0.0567	0.3979	2.5873	122.54
4	15	1366.5	1351.5	0.0567	0.3979	2.5873	122.19
5	20	1366.5	1346.5	0.0567	0.3979	2.5873	121.84
6	25	1366.5	1341.5	0.0567	0.3979	2.5873	121.49
7	30	1366.5	1336.5	0.0567	0.3979	2.5873	121.14
8	35	1366.5	1331.5	0.0567	0.3979	2.5873	120.79
9	40	1366.5	1326.5	0.0567	0.3979	2.5873	120.44
10	42	1366.5	1324.5	0.0567	0.3979	2.5873	120.30
						Average Zinf (mm):	**121.69**
						Average Zinf-LQ (mm):	**120.67**
						DU (%):	**99.16**

Field 33 Event 5 21-03

ta(x=0.75L)= 21 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	1344	1344	0.0440	0.3904	2.0584	93.40
2	3	1344	1341	0.0440	0.3904	2.0584	93.24
3	6	1344	1338	0.0440	0.3904	2.0584	93.08
4	9	1344	1335	0.0440	0.3904	2.0584	92.92
5	12	1344	1332	0.0440	0.3904	2.0584	92.75
6	15	1344	1329	0.0440	0.3904	2.0584	92.59
7	18	1344	1326	0.0440	0.3904	2.0584	92.43
8	21	1344	1323	0.0440	0.3904	2.0584	92.27
9	24	1344	1320	0.0440	0.3904	2.0584	92.11
10	27	1344	1317	0.0440	0.3904	2.0584	91.94
11	29	1344	1315	0.0440	0.3904	2.0584	91.83
12	32	1344	1312	0.0440	0.3904	2.0584	91.67
						Average Zinf (mm):	**92.52**
						Average Zinf-LQ (mm):	**91.89**
						DU (%):	**99.32**

Field 8 Event 2 06-02

ta(x=0.75L)= 16 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	2647.5	2647.5	0.0201	0.3790	1.3970	80.91
2	2	2647.5	2645.5	0.0201	0.3790	1.3970	80.86
3	4	2647.5	2643.5	0.0201	0.3790	1.3970	80.82
4	6	2647.5	2641.5	0.0201	0.3790	1.3970	80.77
5	8	2647.5	2639.5	0.0201	0.3790	1.3970	80.72
6	10	2647.5	2637.5	0.0201	0.3790	1.3970	80.67
7	12	2647.5	2635.5	0.0201	0.3790	1.3970	80.62
8	14	2647.5	2633.5	0.0201	0.3790	1.3970	80.58
9	16	2647.5	2631.5	0.0201	0.3790	1.3970	80.53
10	18	2647.5	2629.5	0.0201	0.3790	1.3970	80.48
11	20	2647.5	2627.5	0.0201	0.3790	1.3970	80.43
12	22	2647.5	2625.5	0.0201	0.3790	1.3970	80.38
						Average Zinf (mm):	80.65
						Average Zinf-LQ (mm):	80.43
						DU (%):	99.73

Field 8 Event 4 07-03

ta(x=0.75L)= 13 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	1903.5	1903.5	0.0287	0.3445	1.4212	73.79
2	2	1903.5	1901.5	0.0287	0.3445	1.4212	73.73
3	4	1903.5	1899.5	0.0287	0.3445	1.4212	73.66
4	6	1903.5	1897.5	0.0287	0.3445	1.4212	73.60
5	8	1903.5	1895.5	0.0287	0.3445	1.4212	73.54
6	10	1903.5	1893.5	0.0287	0.3445	1.4212	73.47
7	12	1903.5	1891.5	0.0287	0.3445	1.4212	73.41
8	14	1903.5	1889.5	0.0287	0.3445	1.4212	73.34
9	16	1903.5	1887.5	0.0287	0.3445	1.4212	73.28
10	19	1903.5	1884.5	0.0287	0.3445	1.4212	73.18
						Average Zinf (mm):	73.50
						Average Zinf-LQ (mm):	73.27
						DU (%):	99.68

Field 8 Event 5 27-03

ta(x=0.75L)= 17 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	1089.5	1089.5	0.0113	0.3742	0.7254	22.24
2	2	1089.5	1087.5	0.0113	0.3742	0.7254	22.22
3	4	1089.5	1085.5	0.0113	0.3742	0.7254	22.19
4	6	1089.5	1083.5	0.0113	0.3742	0.7254	22.16
5	8	1089.5	1081.5	0.0113	0.3742	0.7254	22.13
6	10	1089.5	1079.5	0.0113	0.3742	0.7254	22.10
7	12	1089.5	1077.5	0.0113	0.3742	0.7254	22.07
8	14	1089.5	1075.5	0.0113	0.3742	0.7254	22.04
9	16	1089.5	1073.5	0.0113	0.3742	0.7254	22.01
10	18	1089.5	1071.5	0.0113	0.3742	0.7254	21.98
11	20	1089.5	1069.5	0.0113	0.3742	0.7254	21.95
12	22	1089.5	1067.5	0.0113	0.3742	0.7254	21.92
13	24	1089.5	1065.5	0.0113	0.3742	0.7254	21.89
						Average Zinf (mm):	22.07
						Average Zinf-LQ (mm):	21.94
						DU (%):	99.40

Field 4 Event 1 19-01

ta(x=0.75L)= 169 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	3369	3369	0.0160	0.4266	1.6760	107.50
2	10	3369	3359	0.0160	0.4266	1.6760	107.27
3	20	3369	3349	0.0160	0.4266	1.6760	107.04
4	30	3369	3339	0.0160	0.4266	1.6760	106.81
5	40	3369	3329	0.0160	0.4266	1.6760	106.58
6	50	3369	3319	0.0160	0.4266	1.6760	106.36
7	60	3369	3309	0.0160	0.4266	1.6760	106.13
8	70	3369	3299	0.0160	0.4266	1.6760	105.90
9	80	3369	3289	0.0160	0.4266	1.6760	105.67
10	90	3369	3279	0.0160	0.4266	1.6760	105.44
11	100	3369	3269	0.0160	0.4266	1.6760	105.21
12	110	3369	3259	0.0160	0.4266	1.6760	104.98
13	120	3369	3249	0.0160	0.4266	1.6760	104.75
14	130	3369	3239	0.0160	0.4266	1.6760	104.52
15	140	3369	3229	0.0160	0.4266	1.6760	104.30
16	150	3369	3219	0.0160	0.4266	1.6760	104.07
17	160	3369	3209	0.0160	0.4266	1.6760	103.84
18	170	3369	3199	0.0160	0.4266	1.6760	103.61
19	180	3369	3189	0.0160	0.4266	1.6760	103.38
20	190	3369	3179	0.0160	0.4266	1.6760	103.15
21	200	3369	3169	0.0160	0.4266	1.6760	102.92
22	210	3369	3159	0.0160	0.4266	1.6760	102.69
23	220	3369	3149	0.0160	0.4266	1.6760	102.45
24	230	3369	3139	0.0160	0.4266	1.6760	102.22
25	240	3369	3129	0.0160	0.4266	1.6760	101.99
26	249	3369	3120	0.0160	0.4266	1.6760	101.79
						Average Zinf (mm):	104.64
						Average Zinf-LQ (mm):	102.69
						DU (%):	98.14

Field 4 Event 2 07-02

ta(x=0.75L)= 87 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	4360	4360	0.0086	0.3326	0.8276	50.93
2	10	4360	4350	0.0086	0.3326	0.8276	50.84
3	20	4360	4340	0.0086	0.3326	0.8276	50.74
4	30	4360	4330	0.0086	0.3326	0.8276	50.64
5	40	4360	4320	0.0086	0.3326	0.8276	50.55
6	50	4360	4310	0.0086	0.3326	0.8276	50.45
7	60	4360	4300	0.0086	0.3326	0.8276	50.36
8	70	4360	4290	0.0086	0.3326	0.8276	50.26
9	80	4360	4280	0.0086	0.3326	0.8276	50.16
10	90	4360	4270	0.0086	0.3326	0.8276	50.07
11	100	4360	4260	0.0086	0.3326	0.8276	49.97
12	110	4360	4250	0.0086	0.3326	0.8276	49.87
13	120	4360	4240	0.0086	0.3326	0.8276	49.78
14	130	4360	4230	0.0086	0.3326	0.8276	49.68
15	140	4360	4220	0.0086	0.3326	0.8276	49.58
16	150	4360	4210	0.0086	0.3326	0.8276	49.49
17	160	4360	4200	0.0086	0.3326	0.8276	49.39
						Average Zinf (mm):	50.16
						Average Zinf-LQ (mm):	49.73
						DU (%):	99.14

Field 4 Event 3 02-03

ta(x=0.75L)= 78 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	5202	5202	0.0067	0.3484	0.7581	49.80
2	10	5202	5192	0.0067	0.3484	0.7581	49.72
3	20	5202	5182	0.0067	0.3484	0.7581	49.64
4	30	5202	5172	0.0067	0.3484	0.7581	49.57
5	40	5202	5162	0.0067	0.3484	0.7581	49.49
6	50	5202	5152	0.0067	0.3484	0.7581	49.41
7	60	5202	5142	0.0067	0.3484	0.7581	49.33
8	70	5202	5132	0.0067	0.3484	0.7581	49.26
9	80	5202	5122	0.0067	0.3484	0.7581	49.18
10	90	5202	5112	0.0067	0.3484	0.7581	49.10
11	100	5202	5102	0.0067	0.3484	0.7581	49.03
12	110	5202	5092	0.0067	0.3484	0.7581	48.95
13	120	5202	5082	0.0067	0.3484	0.7581	48.87
14	130	5202	5072	0.0067	0.3484	0.7581	48.79
15	140	5202	5062	0.0067	0.3484	0.7581	48.72
						Average Zinf (mm):	49.26
						Average Zinf-LQ (mm):	48.95
						DU (%):	99.37

Field 4 Event 4 17-03

ta(x=0.75L)= 45 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	6492	6492	0.0064	0.3105	0.7638	53.21
2	5	6492	6487	0.0064	0.3105	0.7638	53.17
3	10	6492	6482	0.0064	0.3105	0.7638	53.14
4	15	6492	6477	0.0064	0.3105	0.7638	53.11
5	20	6492	6472	0.0064	0.3105	0.7638	53.07
6	25	6492	6467	0.0064	0.3105	0.7638	53.04
7	30	6492	6462	0.0064	0.3105	0.7638	53.00
8	35	6492	6457	0.0064	0.3105	0.7638	52.97
9	40	6492	6452	0.0064	0.3105	0.7638	52.93
10	45	6492	6447	0.0064	0.3105	0.7638	52.90
11	50	6492	6442	0.0064	0.3105	0.7638	52.86
12	55	6492	6437	0.0064	0.3105	0.7638	52.83
13	60	6492	6432	0.0064	0.3105	0.7638	52.79
14	65	6492	6427	0.0064	0.3105	0.7638	52.76
15	70	6492	6422	0.0064	0.3105	0.7638	52.72
16	77	6492	6415	0.0064	0.3105	0.7638	52.67
						Average Zinf (mm):	52.95
						Average Zinf-LQ (mm):	52.77
						DU (%):	99.67

Field 6 Event 1 18-01

ta(x=0.75L)= 122 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	2711	2711	0.0256	0.4399	2.5471	151.87
2	10	2711	2701	0.0256	0.4399	2.5471	151.48
3	20	2711	2691	0.0256	0.4399	2.5471	151.09
4	30	2711	2681	0.0256	0.4399	2.5471	150.70
5	40	2711	2671	0.0256	0.4399	2.5471	150.31
6	50	2711	2661	0.0256	0.4399	2.5471	149.92
7	60	2711	2651	0.0256	0.4399	2.5471	149.52
8	70	2711	2641	0.0256	0.4399	2.5471	149.13
9	80	2711	2631	0.0256	0.4399	2.5471	148.74
10	90	2711	2621	0.0256	0.4399	2.5471	148.35
11	100	2711	2611	0.0256	0.4399	2.5471	147.96
12	110	2711	2601	0.0256	0.4399	2.5471	147.56
13	120	2711	2591	0.0256	0.4399	2.5471	147.17
14	130	2711	2581	0.0256	0.4399	2.5471	146.78
15	140	2711	2571	0.0256	0.4399	2.5471	146.38
16	150	2711	2561	0.0256	0.4399	2.5471	145.99
17	160	2711	2551	0.0256	0.4399	2.5471	145.59
18	170	2711	2541	0.0256	0.4399	2.5471	145.20
19	180	2711	2531	0.0256	0.4399	2.5471	144.81
20	190	2711	2521	0.0256	0.4399	2.5471	144.41
21	200	2711	2511	0.0256	0.4399	2.5471	144.01
22	214	2711	2497	0.0256	0.4399	2.5471	143.46
						Average Zinf (mm):	147.75
						Average Zinf-LQ (mm):	145.18
						DU (%):	98.26

Field 6 Event 2 07-02

ta(x=0.75L)= 150 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min ^ B)	Zinf. (mm)
1	0	4822.5	4822.5	0.0160	0.3397	1.2660	99.74
2	10	4822.5	4812.5	0.0160	0.3397	1.2660	99.56
3	20	4822.5	4802.5	0.0160	0.3397	1.2660	99.38
4	30	4822.5	4792.5	0.0160	0.3397	1.2660	99.21
5	40	4822.5	4782.5	0.0160	0.3397	1.2660	99.03
6	50	4822.5	4772.5	0.0160	0.3397	1.2660	98.86
7	60	4822.5	4762.5	0.0160	0.3397	1.2660	98.68
8	70	4822.5	4752.5	0.0160	0.3397	1.2660	98.50
9	80	4822.5	4742.5	0.0160	0.3397	1.2660	98.33
10	90	4822.5	4732.5	0.0160	0.3397	1.2660	98.15
11	100	4822.5	4722.5	0.0160	0.3397	1.2660	97.98
12	110	4822.5	4712.5	0.0160	0.3397	1.2660	97.80
13	120	4822.5	4702.5	0.0160	0.3397	1.2660	97.62
14	130	4822.5	4692.5	0.0160	0.3397	1.2660	97.45
15	140	4822.5	4682.5	0.0160	0.3397	1.2660	97.27
16	150	4822.5	4672.5	0.0160	0.3397	1.2660	97.09
17	160	4822.5	4662.5	0.0160	0.3397	1.2660	96.92
18	170	4822.5	4652.5	0.0160	0.3397	1.2660	96.74
19	175	4822.5	4647.5	0.0160	0.3397	1.2660	96.65
						Average Zinf (mm):	98.16
						Average Zinf-LQ (mm):	96.85
						DU (%):	98.67

Field 6 Event 3 02-03

ta(x=0.75L)= 69 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	4905	4905	0.0139	0.3774	1.3006	100.32
2	10	4905	4895	0.0139	0.3774	1.3006	100.15
3	20	4905	4885	0.0139	0.3774	1.3006	99.99
4	30	4905	4875	0.0139	0.3774	1.3006	99.82
5	40	4905	4865	0.0139	0.3774	1.3006	99.66
6	50	4905	4855	0.0139	0.3774	1.3006	99.50
7	60	4905	4845	0.0139	0.3774	1.3006	99.33
8	70	4905	4835	0.0139	0.3774	1.3006	99.17
9	80	4905	4825	0.0139	0.3774	1.3006	99.00
10	90	4905	4815	0.0139	0.3774	1.3006	98.84
11	100	4905	4805	0.0139	0.3774	1.3006	98.68
12	110	4905	4795	0.0139	0.3774	1.3006	98.51
13	120	4905	4785	0.0139	0.3774	1.3006	98.35
14	126	4905	4779	0.0139	0.3774	1.3006	98.25
						Average Zinf (mm):	**99.25**
						Average Zinf-LQ (mm):	**98.69**
						DU (%):	**99.43**

Field 6 Event 4 17-03

ta(x=0.75L)= 63 min.

	ta (min)	trec (min)	topp (min)	C (mm/min)	B (-)	A (mm/min^B)	Zinf. (mm)
1	0	4469	4469	0.0159	0.3891	1.4578	109.43
2	10	4469	4459	0.0159	0.3891	1.4578	109.23
3	20	4469	4449	0.0159	0.3891	1.4578	109.04
4	30	4469	4439	0.0159	0.3891	1.4578	108.85
5	40	4469	4429	0.0159	0.3891	1.4578	108.66
6	50	4469	4419	0.0159	0.3891	1.4578	108.46
7	60	4469	4409	0.0159	0.3891	1.4578	108.27
8	70	4469	4399	0.0159	0.3891	1.4578	108.08
9	80	4469	4389	0.0159	0.3891	1.4578	107.89
10	90	4469	4379	0.0159	0.3891	1.4578	107.69
11	100	4469	4369	0.0159	0.3891	1.4578	107.50
12	110	4469	4359	0.0159	0.3891	1.4578	107.31
13	120	4469	4349	0.0159	0.3891	1.4578	107.12
14	130	4469	4339	0.0159	0.3891	1.4578	106.92
15	140	4469	4329	0.0159	0.3891	1.4578	106.73
16	150	4469	4319	0.0159	0.3891	1.4578	106.54
17	156	4469	4313	0.0159	0.3891	1.4578	106.42
						Average Zinf (mm):	**107.89**
						Average Zinf-LQ (mm):	**107.22**
						DU (%):	**99.38**

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	Volume II: Research Approach and Interpretation	Carlos Garces-R Ms. Zaigham Habib Pierre Strosser Tissa Bandaragoda Rana M. Afaq Saeed ur Rehman Abdul Hakim Khan	June 1994
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