

Evaluation of Border Irrigation System through Simulation

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Abstract – The term 'surface irrigation' refers to a broad class of irrigation methods in which water is distributed over the field by overland flow. A flow is introduced at one edge of the field and covers the field gradually. In this study, ability of zero inertia and kinematic wave models has been investigated in surface irrigation simulation. In this study WinSRFR (Surface Irrigation Analysis, Design, and Simulation Software) has been used for Simulation Modelling of Border Irrigation System (close-ended). For border irrigation system considered under study, the best possible inflow rate (Q) may be 25.5 l/s, compared to existing 31.3 l/s and cutoff Times (T_{co}) may be 25 minute, compared to existing 30 minute; wherein the application efficiency (AE) may be increased from the existing 58% to 85%, low-quarter adequacy (AD_{lq}) may be decreased from the existing 1.56 to 1.01 and deep percolation (DP) may be decreased from the existing 42% to 15%.

Keywords – Simulation Modelling, Border Irrigation System, Application Efficiency, Low-Quarter Adequacy, Deep Percolation.

I. INTRODUCTION

Surface irrigation system refers to application systems in which water is applied and conveyed over the field surface by gravitational force. Border, Basin and Furrow systems are the most common types of surface irrigation. Surface systems are the most widely used for the irrigation of crops and pasture. Simulation in surface systems is the process of mathematically describing the hydraulic characteristics of water as it flows from one end of the field to the other. The surface irrigation systems present the potential of applying water to crops with efficiency of 70 % to 80 %; actually, some automated systems have favored efficiency about 90 %; but most irrigation projects of the world have worked with application efficiency about 40 % to 50% or with values even lower. In simulation modelling, some parameters are measured which are Application efficiency (AE), Distribution Uniformity (DU), Adequacy (AD), and Deep percolation (DP). If the average low-quarter depth (D_{lq}) is used as the scheduling criteria, then a "proper" irrigation duration will result when $AD_{lq}=1.0$, with about 1/8 of the field under irrigated. With this definition, $AD_{lq}<1.0$ implies under irrigation, whereas $AD_{lq}>1.0$ implies over irrigation.

There are some methods used for simulation modelling such as SIRMOD, Hydrus, WinSRFR, SWDC etc. For this study WinSRFR software has been used. Bautista et al., (2009) have been involved in the development of hydraulic simulation models and related software tools for

analyzing surface irrigation systems. If slope (S_o) is less than 0.004 (m/m) then zero-inertia model has been created, otherwise kinematic wave model has been created. Walker and Raine (1997) reported on the use of SIRMOD to demonstrate the principles of surface irrigation performance and provide quantitative data on the performance of alternative irrigation design and management practices to irrigators. Koeh et al., (2010) stated that SIRMOD and WinSRFR appear to be the most widely used simulation tools in Australia and the US respectively.

II. STUDY AREA AND DATA COLLECTION

For this study, study area is selected near Water Resources Engineering and Management Institute in Samiala in Vadodara district in Gujarat, India. Fig.1 shows the study area of border irrigation system for simulation modelling. For infiltration rate, infiltrometer test is performed on field and for type of soil, sedimentation analysis is performed.

For the area considered under study, soil is Sandy loam (by sedimentation analysis) and infiltration rate is 2 mm/hr (by infiltrometer test). Here, type of crop is Maize. For simulation of border irrigation system, following data were collected (on field data): Slope (S_o) of the field in m/m, Length (L) of the field in m, Width (W) of the field in m, Depth (Y) in mm,



Fig.1. Study area at Samiala site (Source: Google maps)
Infiltration rate (K) in mm/hr, Co-efficient (a), Required depth (D_{req}) in mm, Inflow rate (Q) in l/s, Cutoff time (T_{co}) in minute and Manning N which depends on type of soil.

III. METHODOLOGY

For simulation, above data are collected from the field where, border irrigation system is adopted. Application efficiency, Low-quarter adequacy and Deep percolation

are found in the prevailing irrigation system on field. Then three alternatives have been used, i.e.: change in inflow rate (Q), change in cutoff time (T_{co}) and change in both inflow rate (Q) and cutoff time (T_{co}).

IV. RESULTS AND ANALYSIS

Here, slope is 0.0025 m/m, so zero-inertia model is created for border irrigation system. After simulation of border irrigation system, Application efficiency (AE) = 58 %, Low-quarter Distribution Uniformity (AD_{lq}) = 91 %, Low-quarter Adequacy (AD_{lq}) = 1.56 and Deep percolation (DP) = 42 %. Here, AD_{lq} is greater than 1. So field considered under study is over irrigated. For good quality and quantity of crop production, these results are not sufficient. For better crop production, there have been three alternatives used. They are given as below:

Alternative-1: Change in inflow rate (Q)

Alternative-2: Change in cutoff time (T_{co})

Alternative-3: Change in both inflow rate (Q) and cutoff time (T_{co})

Alternative-1:

Table 1: AE, AD_{lq} and DP for Various Changes in Inflow Rate at 30 minutes cutoff time

Q (l/s)	AE (%)	AD_{lq}	DP (%)
33	55	1.66	45
31.3	58	1.56	42
28	65	1.38	35
25	73	1.22	28
23	79	1.11	21
21	86	0.99	14
20	90	0.94	11

As shown in Table-1, when inflow rate (Q) increases from 31.3 l/s to 33 l/s, application efficiency (AE) decreases from 58% to 55%; low-quarter adequacy (AD_{lq}) increases from 1.56 to 1.66 and deep percolation increases from 42% to 45%. When, inflow rate (Q) decreases from 31.3 l/s to 21 l/s, application efficiency (AE) increases from 58% to 86%; low-quarter adequacy (AD_{lq}) decreases from 1.56 to 0.99 and deep percolation decreases from 42% to 14%.

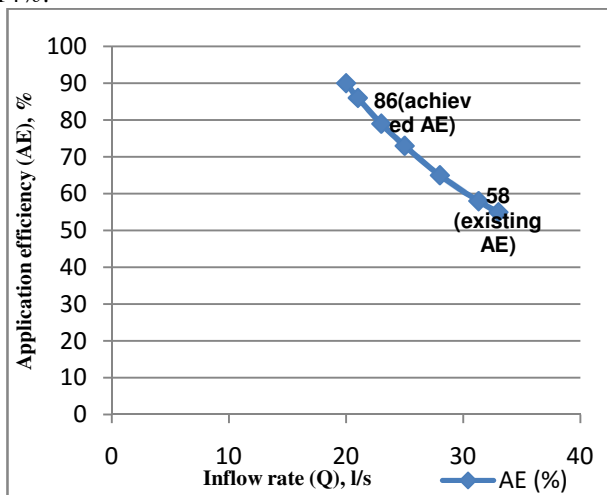


Fig.2. Application Efficiency at Various Inflow rate

This alternative saves inflow rate or water. Inflow rate is 21 l/s to field; low-quarter adequacy is 0.99≈1. So it can be said that field is completely irrigated. Fig.2 shows the application efficiency at various inflow rates. Fig.3 shows the deep percolation at various inflow rates. Fig.4 shows the low-quarter adequacy at various inflow rates.

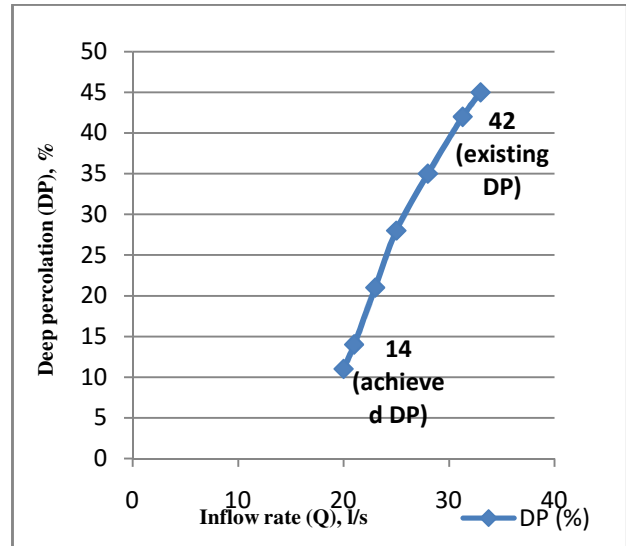


Fig.3. Deep Percolation at Various Inflow rate

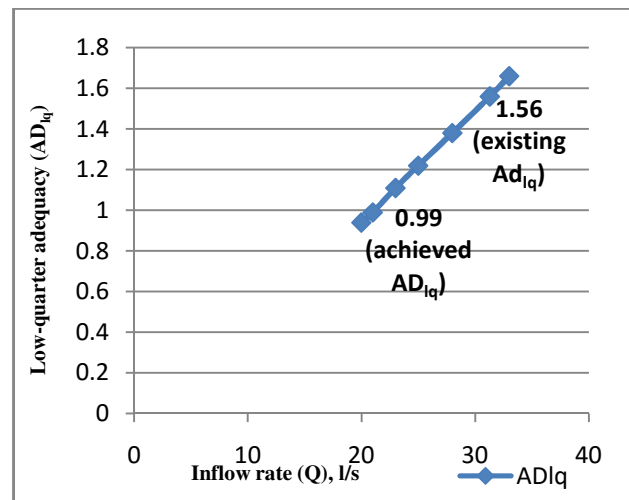


Fig.4. Low-quarter Adequacy at Various Inflow Rates

Alternative-2:

Table 2: AE, AD_{lq} and DP for Various Changes in Cutoff Time at 31.3 l/s inflow rate

T_{co} (min)	AE (%)	AD_{lq}	DP (%)
35	50	1.85	50
30	58	1.56	42
27	65	1.39	36
24	73	1.22	28
20	87	0.99	14
18	95	0.83	5

As shown in Table-2, when cutoff time (T_{co}) increases from 30 minutes to 35 minutes, application efficiency (AE) decreases from 58% to 50%; low-quarter adequacy (AD_{lq}) increases from 1.56 to 1.85 and deep percolation increases from 42% to 50%. When, cutoff time (T_{co}) decreases from 30 minutes to 20 minutes, application efficiency (AE) increases from 58% to 87%; low-quarter adequacy (AD_{lq}) decreases from 1.56 to 0.99 and deep percolation decreases from 42% to 14%. This alternative saves cutoff time. Cutoff time is 20 minutes to field; low-quarter adequacy is $0.99 \approx 1$. So it can be said that field is completely irrigated. Fig.5 shows the application efficiency at various cutoff times. Fig.6 shows the deep percolation at various cutoff times. Fig.7 shows the low-quarter adequacy at various cutoff times.

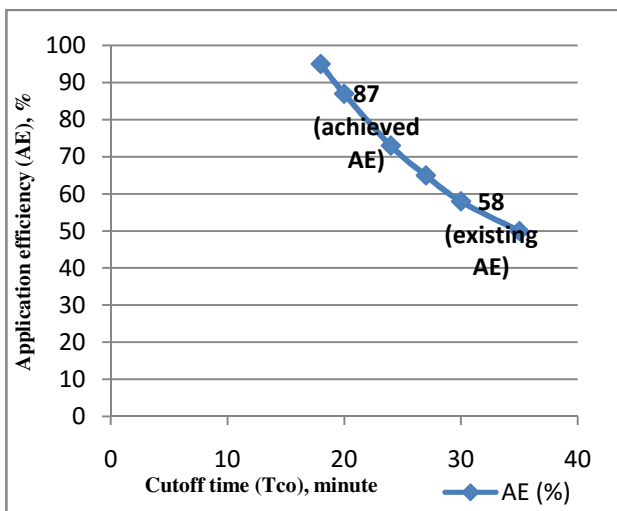


Fig.5. Application Efficiency at Various Cutoff Time

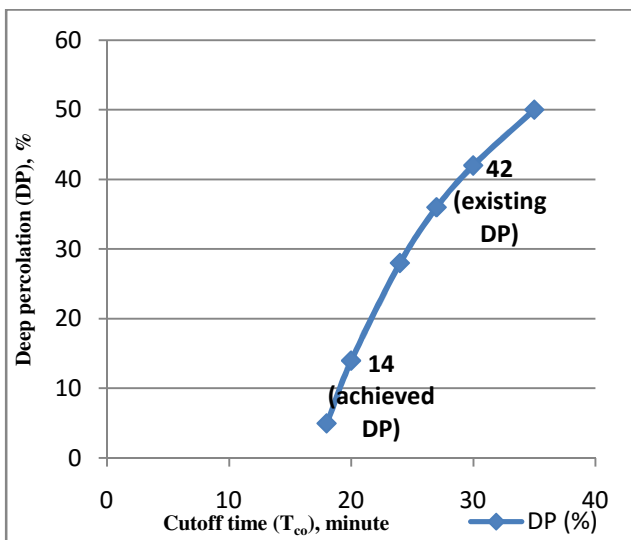


Fig.6. Deep Percolation at Various Cutoff Time

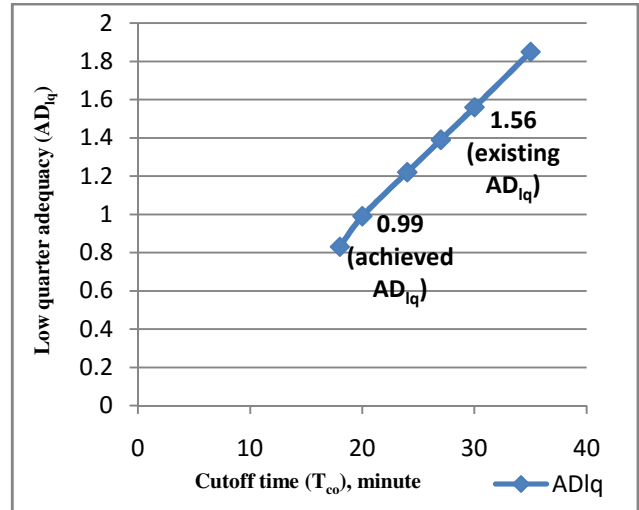


Fig.7. Low-quarter Adequacy at Various Cutoff Time

Alternative-3:

Table 3: AE, AD_{lq} and DP for Various Changes in Inflow Rate and Cutoff Time

Q (l/s)	T_{co} (min)	AE (%)	AD_{lq}	DP (%)
33	35	47	1.96	53
31.3	30	58	1.56	42
28	27	72	1.23	28
26	25	84	1.03	16
25	24	90	0.94	11
25.5	24	88	0.96	12
25.5	25	85	1.01	15
25.5	24.5	87	0.98	13

As shown in Table-3, when both inflow rate (Q) and cutoff time (T_{co}) increases from 31.3 l/s to 33 l/s and 30 minutes to 35 minutes respectively, application efficiency (AE) decreases from 58% to 47%; low-quarter adequacy (AD_{lq}) increases from 1.56 to 1.96 and deep percolation increases from 42% to 53%. When, inflow rate (Q) and cutoff time (T_{co}) decreases from 31.3 l/s to 25.5 l/s and 30 minutes to 25 minutes respectively, application efficiency (AE) increases from 58% to 85%; low-quarter adequacy (AD_{lq}) decreases from 1.56 to 1.01 and deep percolation decreases from 42% to 15%. This alternative saves both inflow rate or water and cutoff time. Inflow rate and cutoff time is 25.5 l/s and 20 minutes to field respectively; low-quarter adequacy is $1.01 \approx 1$. So it can be said that field is completely irrigated. Fig.8 shows the application efficiency at various inflow rate. Fig.9 shows the application efficiency at various cutoff times. Fig.10 shows the deep percolation at various inflow rate. Fig.11 shows the deep percolation at various cutoff time. Fig.12 shows the low-quarter adequacy at various cutoff time. Fig.13 shows the low-quarter adequacy at various inflow rate.

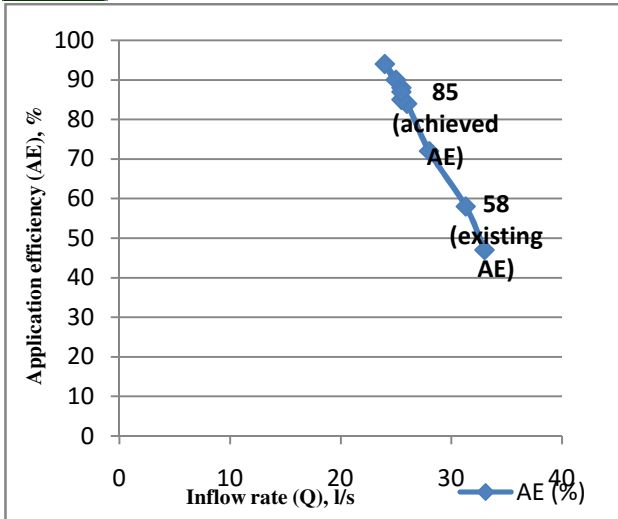


Fig.8. Application Efficiency at Various Inflow Rate

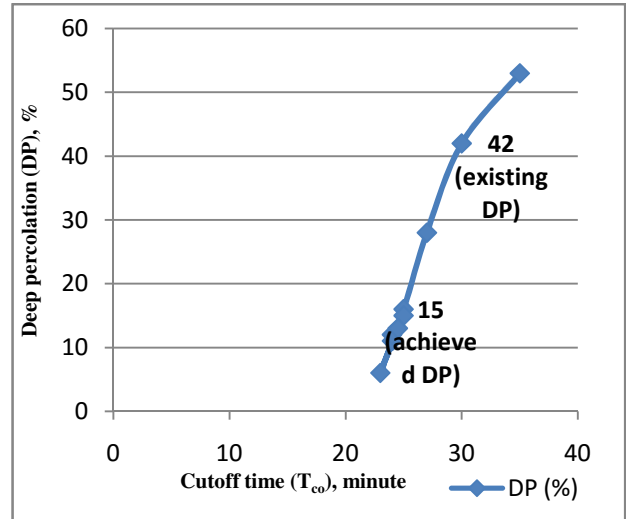


Fig.11. Deep Percolation at Various Cutoff time

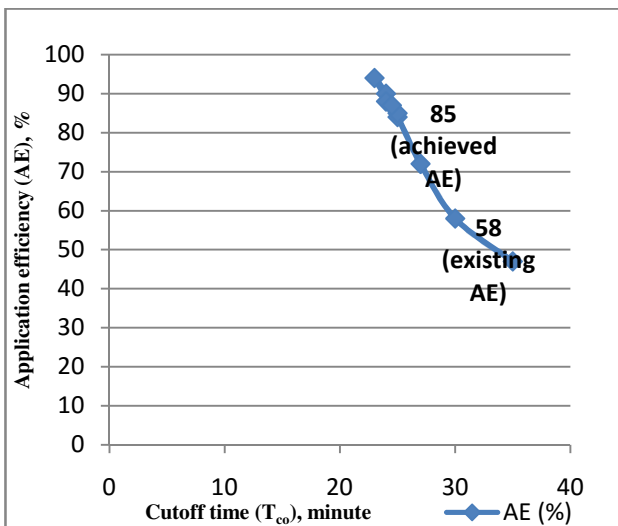


Fig.9. Application Efficiency at Various Cutoff Time

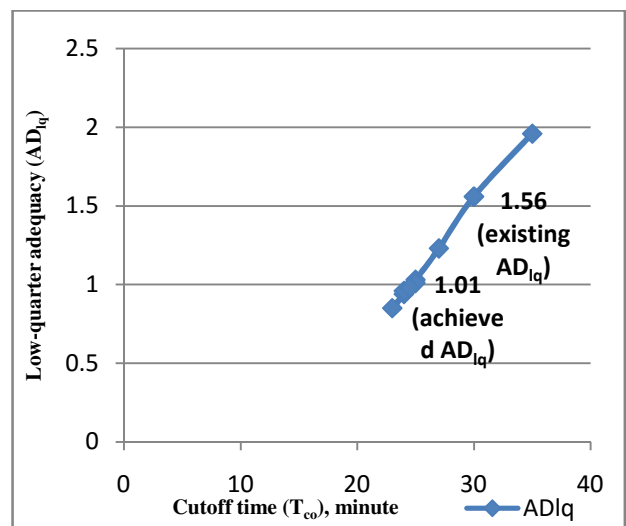


Fig.12. Low-quarter Adequacy at Various Cutoff Time

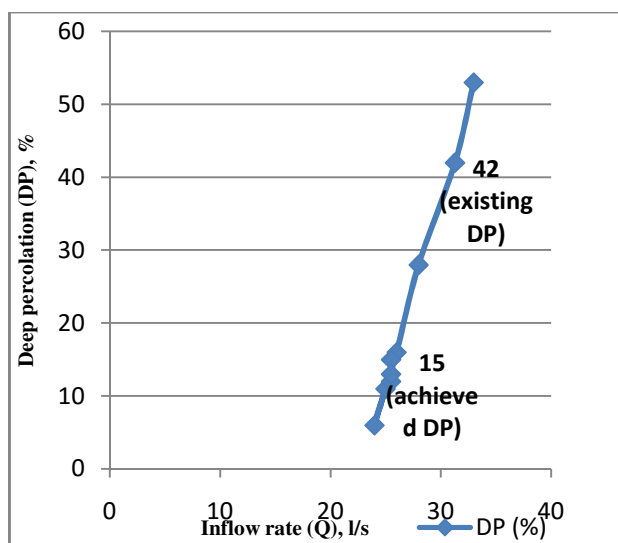


Fig.10. Deep Percolation at Various Inflow Rate

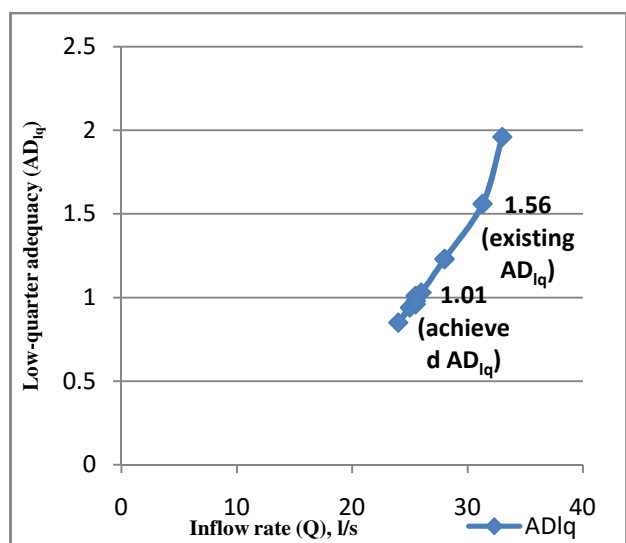


Fig.13. Low-quarter Adequacy at Various Inflow rate

V. CONCLUSION

Computer simulation modelling is used for prevailing for irrigation of water in surface irrigation system. Simulation models help irrigators make informed decisions concerning that irrigation practices. For the area considered under study, the best possible inflow rate (Q) may be 25.5 l/s, compared to existing 31.3 l/s and cutoff Times (T_{co}) may be 25 minute, compared to existing 30 minute; wherein the application efficiency (AE) may be increased from the existing 58% to 85%, low-quarter adequacy (AD_{lq}) may be decreased from the existing 1.56 to 1.01 and deep percolation (DP) may be decreased from the existing 42% to 15%.

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