International Journal of
Civil Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 4, Issue 2, Mar 2015, 57-64
© IASET

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

APPLICATION OF ZERO ONE MODEL FOR WATER DISTRIBUTION SCHEDULE IN AN IRRIGATION PROJECT

S. B. AJMERA[1] & ANAND KISHORE SINGH[2]

[1]Associate Professor, Department of Civil Engineering & Applied Mechanics,
Shri G. S. Institute of Technology & Science, Park Road, Indore, Madhya Pradesh, India

[2]Assistant Professor, Department of Civil Engineering, Indore Institute of Science & Technology,
Opposite Indian Institute of Management, Pithampur Road, Indore, Madhya Pradesh, India

ABSTRACT

This paper gives the application of Zero One Programming Model suggested by Ramesh et al. (2009) for the efficient use of irrigation water taking into the consideration of water management in terms of timely delivery of irrigation water into the fields with minimization of irrigation water looses. Scheduling of canals is an important activity whose outcome comes into the form of increase in crop production and effective and efficient utilization of water. Irrigation scheduling comprises in fulfilling the need of irrigation water in a systematic way as per the demand of the user. The present study is based on Mixed Integer Linear Programming technique for doing day wise scheduling of irrigation water. The distributaries of the Left Bank Main Canal Network of Man Irrigation Project are used to run at constant supply as per the irrigation water demand at each rotation for the entire base period of each crops.

KEYWORDS: Canals Irrigation Optimization Scheduling, Water

I. INTRODUCTION

Mass population of India depends on the agriculture sector for performing their livelihood activities. In spite of that most of the population related to agriculture sector still performing their farming activities with old farming methods and are also dependent on rainfall. The result comes in the form of decrease in crop production, increase in soil salinity and water logging problems. Increasing population and rapid urbanization will create the havoc in meeting the demand of the population in terms of food and water. The guidelines for computing crop water requirement should be adopted (Allen et al. 1998) and utilized for increase in crop production. For increase in crop production and decrease in the wastage of irrigation water it has become necessary task for the irrigation planners to develop the planning models for efficient use of water as well as the farmers to adopt new technology and models. For the past many years many mathematical models related to scheduling of irrigation water such as mixed integer linear programming technique (Anwar et al. 2001), linear programming technique (Azamathulla et al. 2009), irrigation planning models giving prioritization to each distributary canal on the basis of weights and obtaining the objective function by multiplying all the weights (Santhi and Pundarikanthan 2000), improved planning models giving prioritization to each distributary canal on the basis of weights in terms of equity, adequacy, timeliness and location criterion and obtaining the objective function by taking the average all the weights and then giving priority to each distributary canal (Sanimer et al. 2013) and other techniques had been developed.

The present study is based on Mixed Integer Linear Programming technique which has been suggested by Ramesh et al. (2009) and applied on the distributaries of Left Bank Main Canal (LBMC) of Man Irrigation Project for performing proper allocation and distribution schedule of irrigation water.

II. BRIEF REVIEW OF ZERO ONE MODEL

Zero One (Mixed Integer Linear Programming) Model as suggested by Ramesh et al. (2009) considers being a simple and effective model for doing the day wise scheduling of canals. As the name suggests the condition of the gate should be either in Open or Closed condition. This model is not only focused in fulfilling the demand of the branch canal and distributaries but also the operation of the canals are kept simple. The time period of 15 days (fortnight) are considered for fulfilling the demand of each distributary canals for each rotation. The distributary canals are closed on the eighth day in each rotation. The distributaries are to be operated to fulfil this demand with the constraints (i) The sum of supplies to distributaries on any day should be less than or equal to net daily supply in the canal (ii) The sum of daily supply of the distributaries for the complete rotation should be less than or equal to demand (iii) Other system constraints. In the present stated operation scenario described above of the system, on any day during the rotation, all the distributaries will be running in constant supply or closed condition as per the requirement of that rotation. Zero-One programming model is developed for this operation policy in fulfilling the demand of the crops sowed under the command area of each distributary. This modification does not vary more or less from their original demand in terms of irrigation water requirement.

In this 0-1 mixed integer linear programming model the decision variable will be either “ZERO” or “ONE”. The “ZERO” value of the decision variable may be represented as “OFF” condition of the distributary and value “ONE” as “ON” condition of the distributary.

Let i represents the distributary canal number, j the sub channel number, k the day number in the rotation. For formulation, each rotation is assumed of 15 days. Hence k will take value between 1 and 15. Let X_{ijk} represents the 0-1 decision variable for ith distributary, jth sub channel on kth day.

$$X_{ijk} = \begin{cases} 0 \text{ when the sub channel j of ith distributary is closed on kth day} \\ 1 \text{ when the sub channel j of ith distributary is open on kth day} \end{cases}$$

Following constraints are used for the canal system:

A. Main Canal Supply Constraint

The daily main canal supply at the head of the canal is constant for each rotation and only differs from the former one after each rotation. The important factor that should be considered is that the sum of the supplies to the distributary canals on any day should be less than or equal to net supply (Supply at the head of main canal minus losses in main canal) at the head of the main canal. Mathematical representation of this constraint is as under.

$$\sum_{i=1}^{n} \sum_{j=1}^{2} \frac{C_i}{2} X_{ijk} \leq q_k$$

for k = 1,2,…,14.

Where,

i = Canal Number = 1, 2…n

n = Number of canals in the system

C_i = Capacity of the canal (cumec)

$\frac{C_i}{2}X_{ijk}$ = Supply in the imagined j^{th} sub-channel of i^{th} distributary canal of k^{th} day in cumec-day.

B. Distributary Canal Demand Constraint

The irrigation water supply to the distributary canal during any rotation should not exceed its modified or final releases for that rotation. This constraint is represented by

$$\sum_{k=1}^{15}\sum_{j=1}^{2}\frac{C_i}{2}X_{ijk} \le D_i$$

for i= 1, 2…n

Where,

D_i= modified release of i^{th} distributary canal for the rotation (cumec-days)

C. Distributary Canal Capacity Constraint

On any day in the rotation, the irrigation water supplies to distributary canal should not exceed the capacity of the distributary canal. As the distributary canals are proposed to be operated at constant supply either equal to or less than their designed discharge condition the total supply to distributary canal for the rotation should not be greater than their capacity. Each distributary canal is imagined to consist of two sub channel of capacity equal to half the distributary canal capacity. The term $\frac{C_i}{2}X_{ijk}$ represents the supply in the j^{th} sub channel of i^{th} distributary canal on k^{th} day in cumecs. X_{ijk} is a discrete decision variable takes value 0-1 and C_i represents the capacity of distributary canal i. The sum of supplies of two sub channels (j=1 and 2) of ith distributary canal on k^{th} day gives the supply on k^{th} day of the rotation to i^{th} distributary canal. Hence declaring X_{ijk} as a 0-1 variable in the model can satisfy distributary canal capacity constraint.

$$\text{Supply to the Distributary Canal} \le \text{Capacity of the Distributary Canal}$$

D. Main Canal Sectional Capacity Constraint

The cross section of main canal of Left Bank Main Canal Network is not constant in complete reach of the canal. Hence the flow in the main canal at any section should not exceed the design discharge capacity of the main canal at that section. This constraint is formulated as follows.

The sum of the supplies to the distributaries downstream of the section‘s’ (assume) and the main canal conveyance loss below this section on any day in the period, should not exceed the main canal capacity at the section s.

If the section s is upstream of distributary v the constraint is written as

$$\sum_{i=m_s}^{n}\sum_{j=1}^{2}\frac{C_i}{2}X_{ijk} \le C_s - I_s$$

for all k= 1,2,…,14.

Where,

m = Distributary canal number just downstream of the section s

C_s = Capacity just below the section s in the branch canal (cumec)

I_s = Seepage below the section

s = Section in branch canal

Objective Function

The main objective of this mixed integer linear programming modelling is daily allocation of the net available irrigation water at the head of the main canal to the distributaries of the system in accordance with the modified releases for the rotation of the distributary canal, operation criteria of the distributary canal and the constraints mentioned earlier. Therefore, the objective function is defined as maximization of the total supply to the distributaries for the overall rotation. If the constraints are all satisfied for the period the MILP objective function results will be equal to net supply at the head of the branch canal for the period. The mathematical representation of the objective function is

$$\text{Maximise } \sum_{k=1}^{15} \sum_{i=1}^{n} \sum_{j=1}^{2} \frac{C_i}{2} X_{ijk}$$

Where,

X_{ijk} = Discrete variable for j^{th} sub-channel of i^{th} distributary on k^{th} day

C_i = Capacity of the distributary canal

III. APPLICATION AND RESULT

In the present study left bank main canal network of Man Irrigation Project in the state of Madhya Pradesh, India has been considered as a case study for doing day wise irrigation water scheduling. The left bank main canal comprises of 24 distributaries. The details of the distributaries those related to their length from the left bank main canal, crop sown under each distributary for rabi season, designed discharge capacity are given Table 1. The crop water requirement of each distributary after prioritization is found for each rotation. There are 10 rotations. Each rotation comprises of 15 days of time interval. Gram and fodder is sown in the first rotation later in the second and third rotation vegetable, potato and wheat are sown. Since, the crop water requirement of each crop varies in the 15 days of time interval thus rotation of each canal is considered on the same. The model of daily scheduling of distributaries canal is illustrated for the fifth rotation. In the fifth rotation all the distributary canals are running at their designed discharge capacity. Table 2 indicates the allocation procedure for distibutaries. The distributaries in the table are indicated as canals for the ease of the work. The allocation of irrigation water is done in such a way that the demand of each distributary is fulfilled with that rotation. The total supply for the rotation at the head of the Left Bank Main Canal on different days of the rotation is indicated in column 2. The crop water requirement for crops for different distributaries for the rotation and capacity of each distributary is computed and is given in column 8 and 6. After prioritization demand of the distributary for the rotation is shown in column 9. Modified demand of distributaries after rounding off to nearest supply capacity is given in column 10. Hence the demands in the tenth column of different distributaries are taken in the Mixed Integer Programming model. Column 11 shows the condition of the distributaries for the rotation. The zero one programming model is used for the computation of day wise scheduling of irrigation water of all the rotations and for illustration purpose day wise scheduling of irrigation water for the fifth rotation is shown in Table 3. The model shows how the distributaries are to be operated during the rotation to surpass the demand. Figure 1 is shown in the form of bar graph for the fifth rotation which shows the running condition of the distributary canals on any day of the fifth rotation. Hence, this methodology is quite simple and efficient operation schedule which can be adapted to any canal system.

Table 1: Details of Left Bank Main Canal (LBMC) Network of Man Irrigation Project

Serial No.	Name of the Canal	Length of the Canal (km)	Design Discharge Capacity of Canal (cumec)	Culturable Command Area under Canal (Ha)	Crop Name
1	LBD2R	0.51	0.0500	62	Vegetable
2	LBLM-11	4.9	0.4720	433	Vegetable
3	LBD4R	1.07	0.1100	167	Wheat
4	LBD5R	1.38	0.0700	81	Wheat
5	LBD6R1	8.2	0.4200	499	Wheat
6	LBD6R2	5.82	0.2000	388	Potato
7	LBD7R	1.7	0.0500	79	Vegetable
8	LBD8R	13.38	3.0500	3090	Gram
9	LBD3R	0.51	0.0249	68	Wheat
10	LBLM-12	3.33	0.2370	117	Fodder
11	LBLM-2	1.08	0.0660	73	Wheat
12	LBRM-1	1.2	0.0920	126	Wheat
13	LBRM-2	1.2	0.0840	115	Wheat
14	LBLM-3	3.2	0.2770	454	Fodder
15	LBRM-3	3	0.4360	329	Wheat
16	LBLM-4	1	0.1030	129	Wheat
17	LBRM-4	0.7	0.0760	78	Wheat
18	LBRM-5	0.48	0.0700	87	Wheat
19	LBRM-6	3.9	0.2410	324	Wheat
20	LBLM-5	1	0.0730	91	Wheat
21	LBRM-7	1.4	0.1720	215	Wheat
22	LBRM-8	0.15	0.0370	50	Vegetable
23	LBRM-9	1.04	0.0880	117	Wheat
24	LBRM-10	1.83	0.1670	362	Wheat

Table 2: Allocation of Irrigation Water for the 5th Rotation

Day	Net Supply at the Head of the Canal	Name of the Canal	Canal Number (k)	Capacity of the Canal (cumec)	Capacity of the Canal for the Period (cumec)	Crop Name	Water Demand of Crops (cumec)	Water Demand of the Crops for the Period (cumec)	Net Release for the Period on Equitable Basis	Modified Allocations for the Period (Cumec- Days)	Condition of the Canal
1	4.69	LBD2R	1	0.05	0.7	Veg	0.0317	0.4443	0.44	0.44	Open
2	4.69	LBD3R	2	0.0249	0.3486	Veg	0.0154	0.2150	0.22	0.22	Open
3	4.69	LBD4R	3	0.11	1.54	Wheat	0.0731	1.0238	1.02	1.02	Open
4	4.69	LBD5R	4	0.07	0.98	Wheat	0.041	0.5733	0.57	0.57	Open
5	4.69	LBD6R2	5	0.2	2.8	Wheat	0.1336	1.8702	1.87	1.87	Open
6	4.69	LBD6R1	6	0.42	5.88	Potato	0.3259	4.5626	4.56	4.56	Open
7	4.69	LBD7R	7	0.05	0.7	Veg	0.0317	0.4443	0.44	0.44	Open
8	4.69	LBD8R	8	3.05	42.7	Gram	2.2622	31.671	31.67	31.67	Open
9	4.69	LBLM12	9	0.237	3.318	Wheat	0.1141	1.5972	1.60	1.60	Open
10	4.69	LBLM11	10	0.472	6.608	Fodder	0.3288	4.6039	4.60	4.60	Open
11	4.69	LBLM2	11	0.066	0.924	Wheat	0.0439	0.6143	0.61	0.61	Open
12	4.69	LBRM1	12	0.092	1.288	Wheat	0.0605	0.8464	0.85	0.85	Open
13	4.69	LBRM2	13	0.084	1.176	Wheat	0.0566	0.7918	0.79	0.79	Open
14	4.69	LBRM3	14	0.436	6.104	Fodder	0.3048	4.2667	4.27	4.27	Open
		LBLM3	15	0.277	3.878	Wheat	0.1853	2.5937	2.59	2.59	Open
		LBLM4	16	0.103	1.442	Wheat	0.0683	0.9556	0.96	0.96	Open
		LBRM4	17	0.076	1.064	Wheat	0.0507	0.7099	0.71	0.71	Open
		LBRM5	18	0.07	0.98	Wheat	0.0468	0.6553	0.66	0.66	Open
		LBRM6	19	0.241	3.374	Wheat	0.1609	2.2524	2.25	2.25	Open
		LBLM5	20	0.073	1.022	Wheat	0.0488	0.6826	0.68	0.68	Open
		LBRM7	21	0.172	2.408	Wheat	0.1151	1.6108	1.61	1.61	Open
		LBRM8	22	0.037	0.518	Veg	0.0235	0.3297	0.33	0.33	Open
		LBRM9	23	0.088	1.232	Wheat	0.0585	0.8191	0.82	0.82	Open
		LBRM10	24	0.167	2.338	Wheat	0.1121	1.5699	1.57	1.57	Open
	65.70			6.6659	93.3226			65.703	65.70	65.70	

Table 3: Day wise allocation of Irrigation Water for the 5th Rotation

Canal No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total Allocation (cumec)
Day Number	Capacity of Canal (cumec)																								
	0.05	0.0249	0.11	0.07	0.2	0.42	0.05	3.05	0.237	0.472	0.066	0.092	0.084	0.436	0.277	0.103	0.076	0.07	0.241	0.073	0.172	0.037	0.088	0.167	
1	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
2	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
3	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
4	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
5	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
6	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
7	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.000
9	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
10	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
11	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
12	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
13	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
14	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
15	0.032	0.02	0.07	0.04	0.13	0.33	0.03	2.26	0.114	0.33	0.04	0.06	0.057	0.305	0.19	0.07	0.05	0.05	0.16	0.05	0.12	0.02	0.06	0.11	4.693
Total Allocation (cumec-days)	0.444	0.22	1.02	0.57	1.87	4.56	0.44	31.67	1.597	4.604	0.61	0.85	0.792	4.267	2.59	0.96	0.71	0.66	2.25	0.68	1.61	0.33	0.82	1.57	**65.70**
Demand (cumec-days)	0.444	0.22	1.02	0.57	1.87	4.56	0.444	31.67	1.597	4.60	0.614	0.85	0.792	4.27	2.594	0.96	0.710	0.66	2.252	0.68	1.611	0.33	0.819	1.57	**65.70**

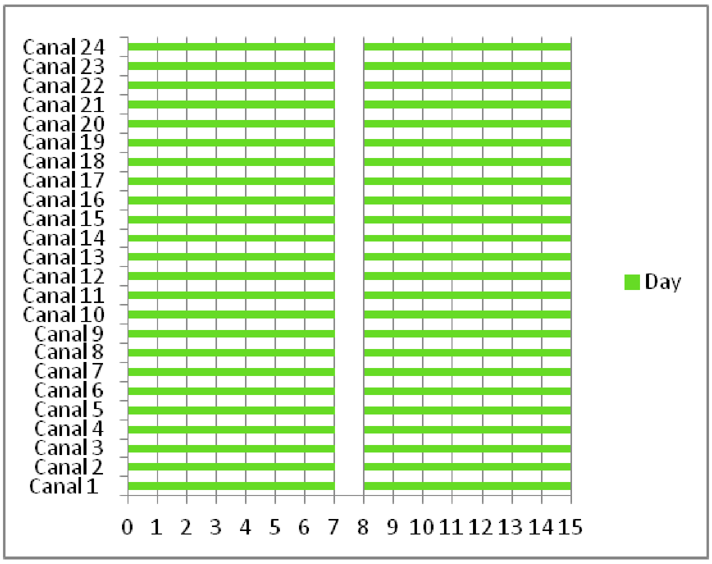

Figure 1: Days of Operation of Distributary Canals for the 5th Rotation

IV. CONCLUSIONS

Zero One (Mixed Integer Linear Programming) model illustrated the satisfactory outcome in terms of day wise scheduling of irrigation water. The irrigation water demand for each rotation is found out initially and then divided by the total number of days within each rotation which gives the result in terms of amount of irrigation water that should be supplied to the area under each distributary per day. This method makes work easy for the gate operator to fix the height of gates from the first day to the last day in each rotation respectively. However, the heights of the gates are changed according to the demand of irrigation water for each rotation. Thus, Zero One model proves to be an effective and efficient tool for catering the demand in terms of irrigation water through the distributaries to the fields.

V. REFERENCES

1. A. A. Anwar, and D. Clarke, “Irrigation Scheduling Using Mixed-Integer Linear Programming.” *Journal of Irrigation and Drainage Engineering,* 127(2), 2001.

2. B. R. Ramesh, K. Venugopal, and K. Karunakaran, “Zero One programming model for Daily Operation Scheduling of Irrigation Canal.” *Journal of Agricultural Science*, 1(1), 2009. C. Santhi and N.V. Pundarikanthan, “A New Planning Model for Canal Scheduling of Rotational Irrigation”. *ELSEVIER, AWM* (Agricultural Water Management) Vol. 43, pp. 327-343, 2000.

3. K. Sanimer, D.K. Shrivastava, and D.S. Arya, “Improved Planning Model for Canal Scheduling of Rotational Irrigation”. *Journal of Irrigation and Drainage Engineering*”. Vol. 139, pp. 560-570, 2013.

4. Md. H. Azamathulla, A.B. Ghani, Aminuddin., A. N. Zakaria, and C. C. Kiat, “Linear Programming Approach for Irrigation Scheduling”. Kuching, Sarawak, 2009.

5. R. G. Allen, L. S. Pereira, D. Raes, and M. Smith, “FAO Irrigation and Drainage Paper No. 56 Crop Evapotranspiration (guidelines for computing crop water requirements).” *Water Resources, Development and Management Service Rome, Italy,* 1998.