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Performance Assessment of Bhimsagar Irrigation Project using Technical and Maintenance Performance Indicators

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Abstract **– Bhimsagar project is an important irrigation project for the Jhalawar district of Rajasthan state. Its location coordinates are 24^0 33' N and 76^0 21'E at mean elevation of 312 meters. Gross command area, Culturable command area and Irrigated command area of Bhimsagar irrigation project area as 10512, 9986 and 8903 ha respectively. The climate of the study area falls under sub-humid condition with average annual evapotranspiration is exceeding the average annual rainfall, which necessitates the application of artificial irrigation for crop production. Technical performance indicators were evaluated include Conveyance efficiency, Storage efficiency, on Farm Application efficiency; Distribution efficiency and Area Uniformity. Performance was evaluated using Maintenance indicators include duration of water delivery, relative change of water level and effectiveness of infrastructure.**

Conveyance losses were found from canals resulting in losses of water. On farm application efficiency was found whereas storage efficiency was found excellent. Distribution efficiency was found to be good whereas Area uniformity has shown fluctuations from minor to minor and outlets. Garlic has shown good crop water and field water use efficiency. Change of water level was observed at selected minors. Poor infrastructure ratio and non-dependability was observed for current year.

Keywords **– Conveyance Losses, Infrastructure Ratio, Comparative Performance Indicators, Storage Efficiency, Area Uniformity.**

I. INTRODUCTION

The outlook for the food security of many developing nations is a cause for serious concern. The problem of food security is exacerbated by the rapid growth of population and hence of the demand for food. In fact, the prices of foodstuffs in the world market have recently begun to rise.

In India, total irrigated area is only one-third of total cropping area but produce about two-third of total agricultural production. So, to fulfill the future demand, it is necessary to increase the total irrigated area and increase the efficiency of irrigation systems.

Efficient operation and management of an irrigation system plays an important role in the sustainability of irrigated agriculture. For this reason, irrigation project performance studies are being used with increasing frequency to promote this objective. Performance evaluations are being carried out for different purposes- to improve system operation, to assess the general health of the system, to assess impacts of intervention, to diagnose constraints, to better understand determinants of performance and to compare the performance of a system with other systems or with the same system over time. Water-delivery-system design has traditionally focused on specifying the carrying and regulating capacity of delivery structures and on increasing water conveyance efficiency. Yet, in many irrigation systems throughout the world inequitable and undependable distribution are also major water-management problems. There is a design need for performance measures that relate design and management decisions for achievement of measurable objectives. In monitoring water-delivery systems, it is necessary to know how well a system performs in its present state relative to system objectives. Furthermore, to assess need of improvement in the structural and management component of the system, it is necessary to evaluate the separate contributions of these components to the overall performance of the system.

II. DATA AND METHODOLOGY

2.1. Location of Study Area

The dam is located at, Mau-Borda, Tal. – Asnawar, about 2 Km in South, Jhalawar district, Rajasthan. Its location coordinates are 24^0 33' N and 76^0 21'E at mean elevation of 312 meters. The dam is 9.66 Km in North of Asnawar and 22.54 Km on East side of Jhalawar district place. The water distributing system consists of two main canals (RMC and LMC) and 19 minors. The live storage capacity of the dam is 72.53 Mcum and dead storage capacity of 4.07 Mcum. The area under irrigation of both the canals is 9986 hectare in Rabi season (7278 ha from LMC and 2708 ha from RMC). Three minors viz, Ratanpura, Chaplada and Marayata II were selected on Right Main Canal whereas Kherli, Bagher and Badankhedi from Left Main Canal at head, middle and tail reach respectively.

2.2. Technical Performance Evaluation

Technical performance indicators monitored in this study included the measurement of conveyance efficiency of the main canals and minors, storage efficiency, area uniformity, distribution efficiency and on farm application efficiency.

1. Conveyance Efficiency –

This was estimated by measuring inflowing and out flowing water along the selected canal lengths (Boss, 1997)

$$\text{Conveyance efficiency} = \frac{\text{Water flowing in the canal}}{\text{Water flowing out of the canal}} \quad \ldots(2.1)$$

2. Storage Efficiency:

The water storage efficiency refers how completely the water needed prior to irrigation has been stored in the root zone during irrigation. Storage efficiency was measured by selecting two farmers field that were growing Wheat.

$$\text{Er} = \frac{\text{Potential soil moisture storage volume}}{\text{Volume of water added to the root zone storage}} \quad \ldots(2.2)$$

3. Area Uniformity (AU):

It is defined as the ratio of water depth (Dw) (volume/irrigated area) for the worst supplied area in the system to the average water depth (DAVE) supplied to the whole system during the same time period was calculated for all six minors selected at hed, middle and tail section of Left and Right Main Canal. It is expressed by the following expression given below:

$$AU = Dw/DAVE \quad \ldots.(2.3)$$

4. Distribution Efficiency:

Distribution efficiency was calculated by conducting infiltration experiment. Distribution efficiency was calculated by using following equation given below:

The most common yardstick for uniformity evaluation is the coefficient proposed by Christiansen in 1942, defined as:

$$Cu=100(1-\Sigma |D|/nM);\ D= Xi - M \quad \ldots(2.4)$$

Where:

Cu = Christiansen's Coefficient of Uniformity (%);
D = Deviation of observation from the mean;
n = Number of observations;
M = Average depth infiltrated;
Xi = Depth infiltrated at observation point i;

5. On farm Application Efficiency:

The ratio of the depth of water added to the root zone to the depth of water applied to the field was measured from two farmer fields that were growing Wheat crop.

$$\textbf{On farm application efficiency (Ea} = \frac{\text{Depth of water applied to the field}}{\text{Depth of water added to the root zone}} \quad \ldots(2.5)$$

2.3. Maintenance Indicators

Proper maintenance enables the keeping of water control infrastructure in good working condition so that the design water level is maintained. The change in head (level) over structures in irrigation canals is the single most important factor disrupting the intended delivery of irrigation water. The maintenance indicators are evaluated by the following hydraulic performance indicators (Boss, 1997).

a. The Relative Change of Water Level (Rcwl)

Relative Change of Water Level was computed by taking the actual water level depth from the canal and comparing it with design value at the same position in the minors which were selected at hed, middle and tail reach of Left and Right Main Canal, i.e. changes of level to the intended level.

$$\text{Relative Change of Water Level} = \frac{\text{Change of depth}}{\text{Intended depth}} \quad \ldots(2.6)$$

b. Effectiveness of Infrastructure:

It measures the ratio of the number of functioning structures to the total number of structures initially installed. Data of total number of structures installed initially were taken from Detailed Project Report (DPR) of Bhimsagar Irrigation Project whereas information regarding number of functioning structures was collected through field survey.

c. Dependability of Duration:

It was estimated as the ratio of the actual duration of water delivery compared to the intended duration of water delivery. Intended and actual water delivery duration data were taken from Bhimsagar Irrigation Department. It is computed by:

$$\text{Dependability of duration} = \frac{\text{Actual duration of water delivery}}{\text{Intended duration of water delivery}} \quad \ldots(2.7)$$

III. Results and Discussions

3.1. Technical Performance Evaluation

1. Conveyance Efficiency:

Conveyance efficiency was obtained at head section of Left main canal as 86.94 percent with 13.06 losses/Km whereas at mid and tail reach, it was observed as 70.03 percent and 67.75 percent with 21.42 and 32.52 losses/Km, respectively. Average value of 74.90 percent conveyance efficiency was found for Left Main Canal, which is within all acceptable range for distribution system. Conveyance efficiency was obtained as 83.57 percent with 16.43 losses/Km at head reach whereas at mid and tail reach, it was observed as 78.42 and 64.90 percent with 23.80 and 35.10 losses/Km. Average conveyance efficiency for Right Main Canal was found as 75.63 percent. Table 1 shows water conveyance efficiency of Left and Right Main Canal. Figure 1 and Figure 2 shows conveyance efficiency of Left and Right Main Canal. Conveyance efficiency was also measured for selected minors located in head, middle and tail reach of Left and Right Main Canal. Average conveyance efficiency at head section of LMC minors were obtained as 76.92, at middle 70.05 and 66.92 percent at tail section whereas average values of conveyance efficiency of Right Main Canal minors located at head, middle and tail section were obtained as 74.80, 72.33 and 71.23 percent, respectively. Figure 3 shows conveyance efficiency of selected minors on Left and Right Main Canal.

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Table 1. Calculation of Conveyance Efficiency of LMC and RMC

Canal	Length of Reach (m)	Inflow, cumec	Outflow, cumec	Conveyance losses/ km (%)	Conveyance Efficiency (%)
LMC					
Head	200	5.471	5.328	13.06	86.94
Middle	200	3.426	3.248	21.42	70.03
Tail	200	1.530	1.431	32.52	67.75
Average					**74.90**
RMC					
Head	200	3.956	3.826	16.43	83.57
Middle	200	2.386	2.283	23.80	78.42
Tail	200	1.168	1.086	35.10	64.90
Average					**75.63**

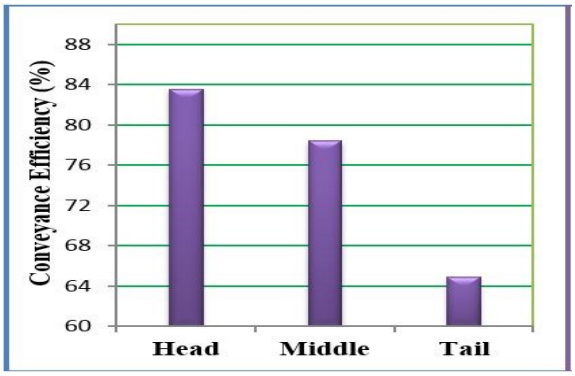

Fig. 1. Conveyance Efficiency of LMC

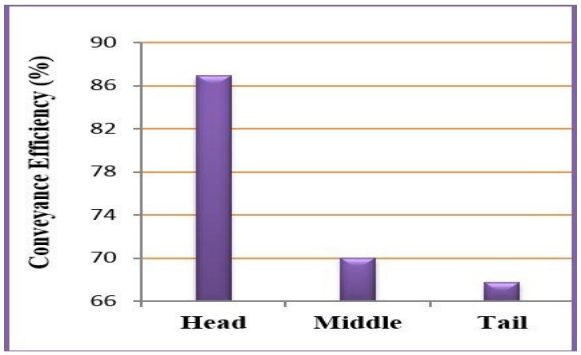

Fig. 2. Conveyance Efficiency of RMC

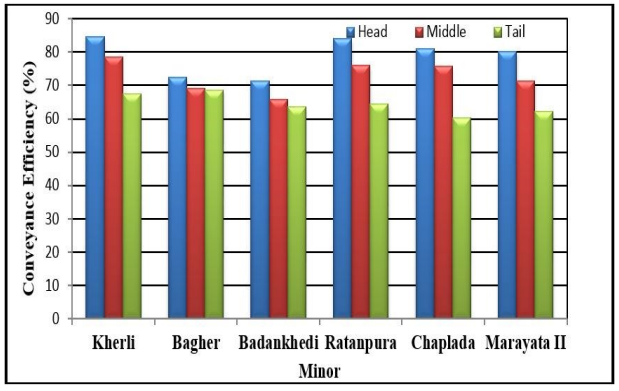

Fig. 3. Conveyance Efficiency of Minor's

2. Storage Efficiency

Storage efficiency was calculated at farmer's field. Two fields of known area were selected to find out storage efficiency. Volume of water added to the root zone was calculated by determining depth of water added to the root zone and then it was multiplied by area of the field. Potential soil moisture storage volume was determined by considering water holding capacity of the soil then moisture required in the root zone was calculated by assuming that irrigation is applied when soil moisture is depleted 50 % in the root zone. Storage efficiency was found to be 93.75 percent at field I and 99.76 percent at field II. Average storage efficiency was found to be 96.76 percent indicating excellent storage capacity of the soils in the command area. Figure 4 shows storage efficiency in percent at field I and field II.

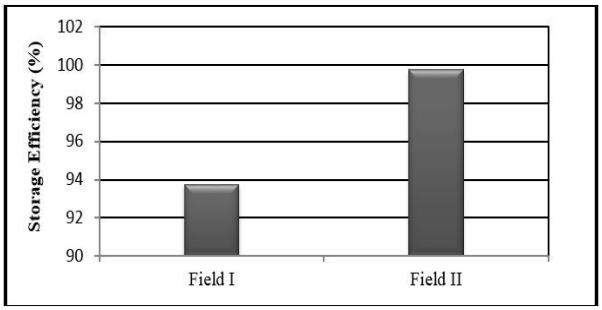

Fig. 4. Storage Efficiency

3. Area Uniformity (AU)

Area uniformity was calculated for selected minors located at Left and Right Main Canal in Rabi cop season for entire duration of canal run. Highest area uniformity was observed for Bagher minor had value of 0.89 indicates that the water had distributed well among the different outlets whereas lowest value of 0.11 was obtained for Badankhedi minor indicating that water had not well distributed. Ratanpura minor had area uniformity value of 0.43, Chaplada 0.64; Marayata II had are uniformity value of 0.44 indicating that water is not well distributed among the outlets. Chaplada minor obtained value of 0.64 indicates fair distribution of water among the outlets. Kherli minor had obtained area uniformity value of 0.60 indicating fair distribution of water. Bagher minor had Highest AU value of 0.89 indicating excellent distribution of water among the outlets whereas Badankhedi had obtained lowest value 0.11 indicating poor or unsatisfactorily distribution of water among the outlets. Table 2 shows area uniformity among selected minors located at Left and Right Main Canal. Figure 5 shows graphical presentation of area uniformity for selected minors.

Table 2. Area Uniformity (AU) of selected minors

Month / Minor	Area Uniformity					
	Nov	Dec	Jan	Feb	Mar	Average
Ratanpura	0.43	0.43	0.43	0.43	0.43	0.43
Chaplada	0.64	0.64	0.64	0.64	0.64	0.64
Marayata II	0.44	0.44	0.44	0.44	0.44	0.44
Kherli	0.60	0.60	0.60	0.60	0.60	0.60
Bagher	0.89	0.89	0.89	0.89	0.89	0.89
Badankhedi	0.11	0.11	0.11	0.11	0.11	0.11
Average						**0.52**

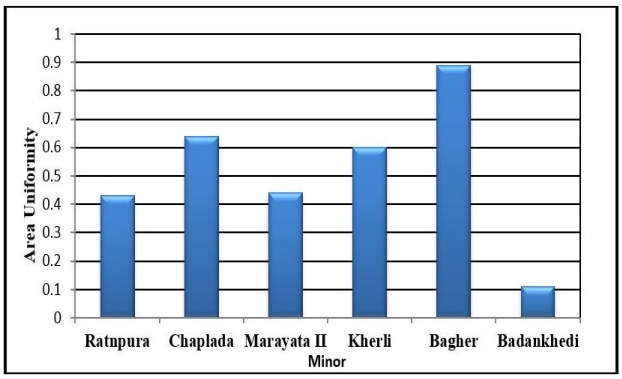

Fig. 5. Area Uniformity

4. Distribution Efficiency

Distribution efficiency was found to be 80.32 percent indicating well distribution of water in the soil. Distribution Uniformity was calculated by dividing the minimum infiltration depth with average infiltration depth. Distribution Uniformity was found as 63% which is insufficient according to FAO (1992). Average infiltration rate was found as 2.74 cm per hour.

5. On Farm Application Efficiency

Application efficiency was calculated by measuring volume of water diverted to the field and estimating volume of water added to the root zone. Then, volume of water diverted and volume of water added to the root zone were converted into depth units by diving it with area. Volume of diverted water to the field was calculated by measuring discharge rate using Parshall flume and recording total time required to irrigate the field. Volume of water added to the root zone was determined by measuring soil moisture content at different depth of soil before and after irrigation. It was found as 71.26 percent at field I and 68.85 at field II with an average value of 70.05 percent. Results' indicating that on farm application efficiency found is poor. Figure 6 shows on farm application efficiency at farmer's field.

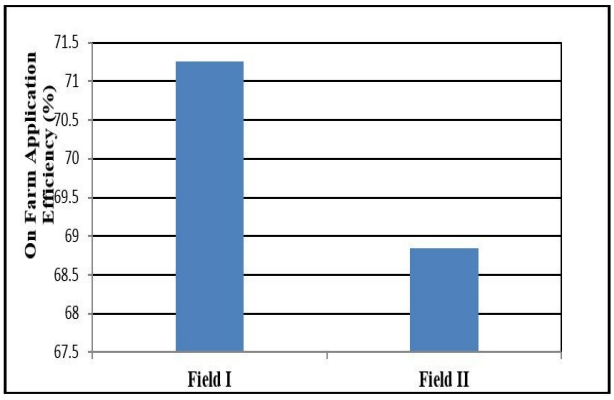

Fig. 6. On-Farm Application Efficiency

3.2. Maintenance Indicators

1. Relative Change of Water Level

Relative Change of Water Level (RCWL) is used to find deterioration in canal structure by weakening of walls, breaches, seepage, siltation etc. Actual depth of three minors located at head, mid and tail section of Left and Right Main Canal was considered for analysis. The water levels were measured regularly during entire irrigation cycle, which were then divided by the design values to estimate Relative Change in Water Level. Table 3 and 4 shows results of RCWL indicating a decrease in depth due to inefficient water supply and maintenance. Increase in value of RCWL was observed from head to tail minors of Left and Right Main Canal.

An average value of RCWL at three locations was measured to be 11 percent for LMC whereas 13 percent for RMC. Figure 7 and 8 shows pictorial presentation of RCWL for minors of Left and Right Main Canal.

Table 3. Calculation of Relative Change of Water Level for Left Main Canal

Location of Minor (CH)	Design Depth (m)	Measured Depth (m)	RCWL (%)
60	0.45	0.43	5
150	0.45	0.42	9
482	0.45	0.34	25
Average			**13**

Table 4. Calculation of Relative Change of Water Level for Left Main Canal

Location of Minor (CH)	Design Depth (m)	Measured Depth (m)	RCWL (%)
190	0.85	0.83	3
343	0.45	0.42	7
438	0.45	0.35	23
Average			**11**

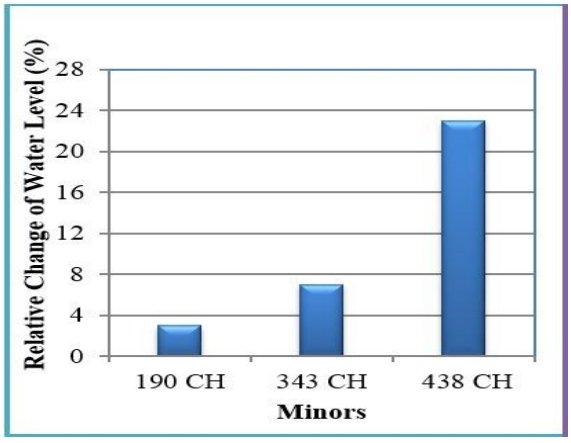

Fig. 7. RCWL for Left Main Canal

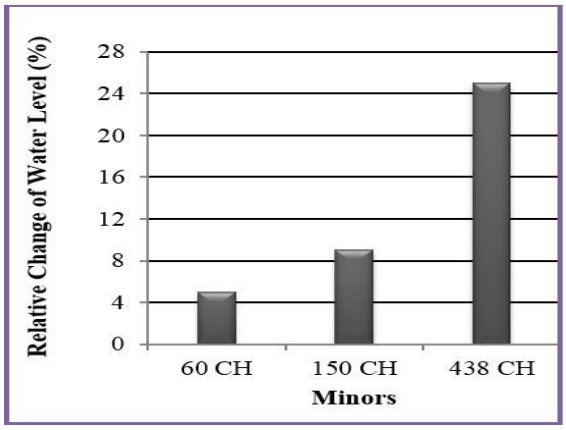

Fig. 8. RCWL for Right Main Canal

2. Effectiveness of Infrastructure

Effectiveness of Infrastructure (EOI) values helps in assessment of the performance of the canal operation. As per the design document, the total number of different structures constructed was 105, but only 86 of them were functioning at present. As a result, the value of Effectiveness of Infrastructure was obtained to be 82 percent for year 2013-14. Nearly 10 percent of the structures had been damaged. Severe disfigurement of water control structures were found as their iron bars not in proper shape reported. Results are shown in Table 5.

Table 5. Effectiveness of Infrastructure

Canal	Total no. of Structures	No. of Functioning Structures	Effectiveness of Structures
Left Main Canal	72	58	0.80
Right Main Canal	33	28	0.84
Average			**0.82**

3. Dependability of Duration

Dependability of duration was attained value 1 in Ist and IInd irrigation while 0.64 and 0.63 during IIIrd and IVth irrigation respectively. DOD value 1 indicates that water was supplied as per schedule while a value lower than 1 indicates that water was not supplied as per schedule. Table 6 shows calculation of dependability of duration. Figure 9 shows pictorial representation of dependability of duration.

Table 6. Calculation of Dependability of Duration

Canal	Duration	Ist Irrigation	IInd Irrigation	IIIrd Irrigation	IVth Irrigation
LMC and RMC	Actual Duration	23	31	20	23
	Intended Duration	23	31	31	36
DOD	Actual / Intended Duration	1.00	1.00	0.64	0.63

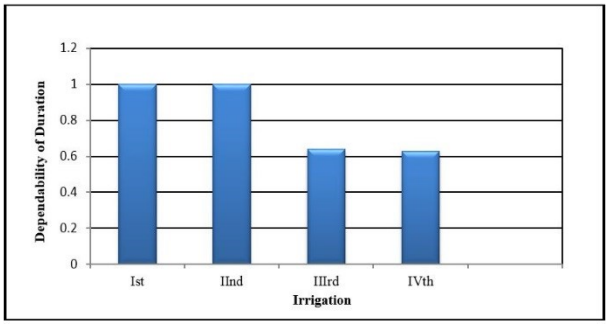

Fig. 9. Dependability of Duration of Bhimsagar Canal System

IV. CONCLUSIONS

The average value of conveyance efficiency at head, middle and tail sections of Main Canals were obtained as 75.26 percent indicating that approx 25 percent of water is lost during conveyance. Average storage efficiency was found to be 96.76 percent indicating that excellent storage capacity of the soils in the command area. Area uniformity was found poor indicating unequal distribution of water with respect to proposed area of each outlet/minor. Distribution efficiency was found to be 80.32 percent which indicated that good distribution of water in the soil. Application efficiency was found fair indicating water is not applied efficiently to the land. An overall average change in water level was found around 12 percent which has eventually affected discharge and velocity of water in minor to some extent. This small deficiency in system operation can be overcome by proper function and maintenance. Relatively less number of structures was present in matter-of-fact (86) than mentioned in design document (105). This indicates poor upkeep and maintenance of physical system Bhimsagar Canal network. Duration of water supply was not very much reliable with dependability value of 0.64 and 0.63 during third and fourth irrigation indicating poor vigilance of system managers regarding maintenance of canal. Therefore, there is urgent need to derive optimum operation policies.

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