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COMPARISON OF AGRICULTURAL YIELD WITH AND WITHOUT A CANAL HEAD REGULATOR

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ABSTRACT

Canal discharge control systems can be very useful in reducing the surplus discharges of water over and above the required discharge for irrigation, thereby increasing the irrigation efficiency. Head regulators are most widely used discharge regulating devices. In this project work head regulators are designed for an existing irrigation canal system, which do not have any flow control devices. The regulators are designed for both main canal and branch canals. The advantages (in terms of reduction in surplus discharge to the canals) of using the discharge control device like head regulators was quite obvious when compared to the scenario in which there are no flow regulating devices. Other inherent advantages of head regulators would be the silt control into the channels and better control over water distribution among the farmers.

Keywords: Water Resources Engineering, Canal Control System, Canal Head Regulator.

I. INTRODUCTION

As we approach a new millennium, there are growing concerns and periodic warnings that we are moving into an era of water scarcity. With increasing demand for food and competing use within the water sector, the pressure is on irrigation professionals to manage water efficiently. The rallying cry is "more crop per drop". In response to this, strategic decisions and interventions need to be made on a continuous basis. These decisions should cover the full spectrum of the irrigation water supply system, from diversion and distribution to on-farm application down to the crop root zone. The management of irrigation in India differs conceptually from that practised in those developed countries where limited water is not a constraint. Good management, efficient operation and well-executed maintenance of irrigation systems are essential to the success and sustainability of irrigated agriculture. They result in better performance, better crop yields and sustained production. One of the key objectives in the management of an irrigation system is to provide levels of service as agreed with the relevant government authorities and the consumers at the minimum achievable cost.

The canal system transfers water from its source(s) to one or more points of diversion downstream. Operation deals with the movement and behaviour of water in a canal system, and relies on the principle of open channel hydraulics. The primary function of operation is to manage the changes in flow and depth throughout the canal system. The term `operation' refers to the hydraulic reaction in the canal pools which results from control actions. Several methods are available which can be used to convey water downstream through a series of canal pools. The method of operation determines how the water level varies in canal pools to satisfy the operational concept. A canal's recovery characteristics - the speed and manner in which the canal recovers to a steady state flow after a flow change - depend on the method of pool operation. The majority of canal systems in India are operated in a manner which is referred to as conventional operation. A conventional operation consists of a scheduled delivery, an upstream operational concept and a constant downstream depth operational method. Conventional operation evolved as a practical method of satisfying irrigation needs within traditional canal system limitations. By using delivery schedules, it essentially combines demand-based needs with supply-based operation. The purpose of conventionally operated canals is demand-oriented, since the primary goal is to satisfy the needs of the water users.By keeping in mind the importance of a flow regulating structure for smooth and efficient transfer of water from the main canal to sub-canals, the objectives of the project were identified as follows:To design canal automation system head regulator for a typical canal system in India, to study its effectiveness with respect to manually operated canal regulation system in Indi and to examine cost estimation and compare it with respect to manually operated canal regulation system in India.

II. PROJECT DESCRIPTION AND GOALS

The goal of any canal head regulation structure is to transfer the water from river or main canal to canals or sub-canals in an efficient way. Other auxiliary goal of a canal head regulator can be control the entry of silt from the river to the canal. Once a head regulator is installed over a canal, water can be diverted to sub canals in desired quantities and at required time. For the project, Perungal channel was selected for canal head regulator design. The canal takes off from Kannadian weir. The water from the canal is used for irrigating three irrigation fields; of the three fields, in two fields paddy is grown and in the other field vegetables are grown. The details of the project study are shown in Fig. 1. In order to simplify the design procedure, the entire project is divided into three phases:

Phase 1: Determination of the irrigation water requirement for different irrigation fields based on their crop type. From the irrigation water requirement, the discharge through the canals is determined.

Phase 2: In Phase 2, distributary canal head regulator and head canal regulators are designed for the discharges obtained in Phase 1.

Phase 3: In this phase, water releases and crop yields are compared under the scenarios of with and without a regulating structure. Also, a rough calculation will be made to determine the power required to operate a head regulator if they are automated.

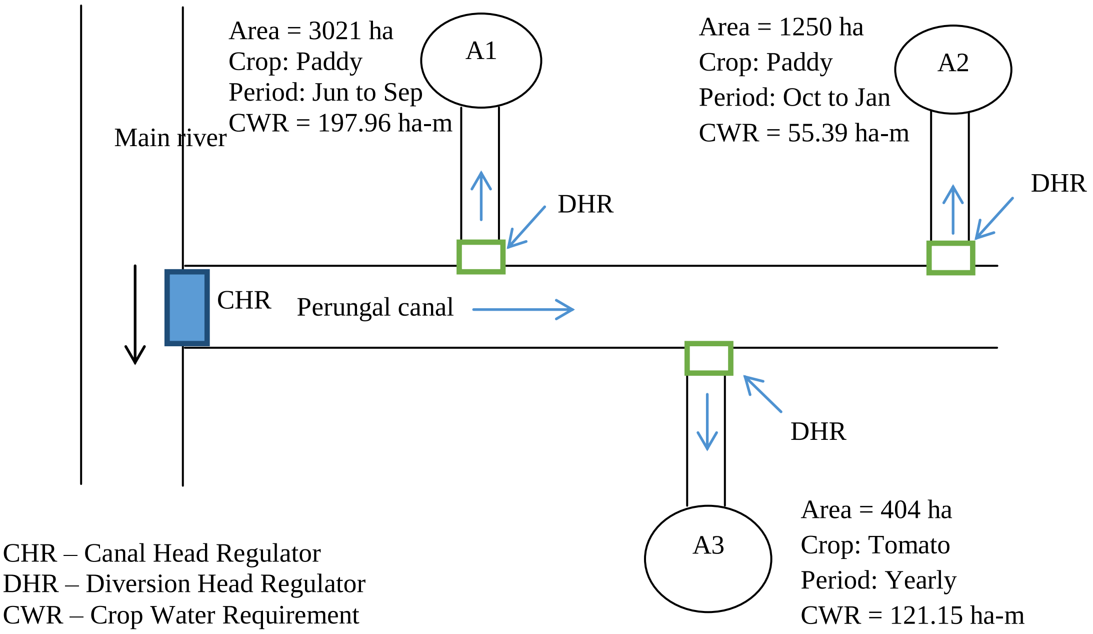

Figure 1 Schematic Representation of the Study Area Irrigation System

III. DESIGN APPROACH AND DETAILS

The steps for designing a head regulator were taken from Indian standard code of *IS – 6531*

The design steps for a head regulator as given in the code are explained here:

3.1 Hydraulic Design

The hydraulic design of canal head regulator consists of the following:

a) Fixation of pond level (including losses through structures)

b) Fixation of sill level, width of sill and shape of sill

c) Fixation of waterway, number and width of spans and height of gate openings, requirements of breast wall etc.

d) Shape of approaches and other component parts

e) Safety of structure from surface flow considerations

f) Safety of structure from sub-surface flow consideration and

g) Energy dissipation arrangements, terminal structures

3.1.1 Pond level

Pond level, in the under-sluice pocket, upstream of the canal head regulator should generally be obtained by adding the working head to the designed full supply level in the canal. The working head should include the head required for passing the designed discharge into the canal and the head losses in the regulator.

3.1.2 Sill level

Sill level should be fixed by subtracting from pond level the head over the sill required to pass the full supply discharge in the canal at a specified pond level. To obtain control on entry of silt into the canal it is desirable that the sill of head regulator should be kept as much higher than the sill of under sluices, as possible, commensurate with the economic waterway and the driving head available.

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3.1.3 Effective Waterway

The required head over the sill H, for passing a discharge Q, with the effective waterway Le, should be worked from the following formula:

$$Q = CL_eH_e^{3/2}$$

Where

Q = discharge in m^3/s

C = a coefficient (= 0.66)

Le = effective waterway in m and

He = required head over the crest for passing a discharge Q, in m.

3.1.4 Width of the Sill

Width of sill should be kept according to the requirements of the gates, trash and stop logs subject to a minimum of 2/3 He.

3.1.5 Shape of the Sill

The edges of sill should be rounded off with a radius equal to He. The upstream face should generally be kept vertical and the downstream sloped at 2 : 1 or flatter.

3.1.6 Total Length of Waterway

Having decided upon the effective waterway, the total water way between the abutments including piers should be worked out from the following formula:

$$L_t = L_e + 2(NK_p + K_a)H_e + W$$

where

L_t = total waterways (in m)

L_e = effective waterways (in m)

N = number of piers

K_p = pier contraction coefficient (= 0.01 for round nosed piers)

K_a = abutment contraction coefficient (= 0.2 for square abutments)

H_e = head over crest (in m)

W = total width of all piers (in m)

3.2 Design Calculations

The first step in the design of a regulator is to determine the design discharge for the head regulator. The design discharge is calculated based on the type of crop grown and the crop area. Table 1, Table 2, and Table 3 show the calculations for the total crop water requirement for each of the crops.The formula used for the calculation of discharge into the different field is given by-:

$$V_{it} = D_{it} * A_I - P_t + E_{pt}$$

Where V_{it} is the volume of water required for irrigation field in m^3

D_{it} is the depth of the standing water required for the irrigation field in m

A_I is the area of the irrigation field in m^2

P_t is total volume of precipitation during time t in m^3

E_{pt} is the total evapo-transpiration in time t in m^3

The discharge required then can be determined as follows-:

$$Q_{it} = \frac{V_{it}}{f_i}$$

Where f_i is the irrigation frequency for irrigation field in days

The water requirements for the three irrigation fields is calculated and are given in Table 1,2, 3 and 4 respectively.

Table 1: Crop Water Requirement for Tomato

Crop	Growth phase	duration of phase(Days)	water requirement(mm)	NO. of irrigation
Tomato	establishment	25-35	69	12
	vegetative	20-25	123	7
	flowering	20-30	180	10
	yield formation	20-30	234	10
	ripening	15-20	180	6

Table 1: Contd.

Area(ha)	Phase W.R(m3/cycle)	Rainfall(mm)	Rainfall Volume(m3/cycle)	Evapotranspiration(mm)
424	243800	36.6	12932	220.5
424	745028.5714	26	15748.57143	26.33333333
424	763200	50.5	21412	52.33333333
424	992160	29.2	12380.8	51.66666667
424	1272000	27.2	19221.33333	26.5

Table 1: Contd.

Evapotranspiration losses (m3/cycle)	Total water requirement(m3/cycle)	Dischare(m3/s)
77910	308778	0.510545635
15950.47619	745230.4762	1.232193248
22189.33333	763977.3333	1.263190035
21906.66667	1001685.867	1.656226631
18726.66667	1271505.333	2.102356702

Table 2: Crop Water Requirement for Paddy

Crop	Growth phase	duration of phase(Days)	water requirement(mm)	NO. of irrigation
Paddy	Nursery	0-25	40	7
	Main field preparation	25-28	200	5
	Planting to panicle initiation	29-50	458	8
	Panicle initiation to flowering	51-70	417	10
	Flowering to maturity	71-120	125	8

Table 2 Contd

Area(ha)	Phase W.R(m3/cycle)	Rainfall(mm)	Rainfall Volume(m3/cycle)	Evapotranspiration(mm)
3021	172628.5714	15.3	66030.42857	147.5
3021	1208400	15.3	92442.6	18
3021	1729522.5	50.67	191342.5875	116.9
3021	1259757	41.1	124163.1	114
3021	472031.25	45.5	171819.375	294

Table 2 Contd

Evapotranspiration losses (m3/cycle)	Total water requirement(m3/cycle)	Dischare(m3/s)
636567.8571	743166	1.228779762
108756	1224713.4	2.024989087
441443.625	1979623.538	3.273187066
344394	1479987.9	2.44706994
1110217.5	1410429.375	2.332059152

Table 3: Crop Water Requirement for Paddy

crop	Growth phase	duration of phase(Days)	water requirement(mm)	NO. of irrigation
Paddy	Nursery	0-25	40	7
	Main field preparation	25-28	200	5
	Planting to panicle initiation	29-50	458	8
	Panicle initiation to flowering	51-70	417	10
	Flowering to maturity	71-120	125	8

Area(ha)	Phase W.R(m3/cycle)	Rainfall(mm)	Rainfall Volume(m3/cycle)
1249.84	71419.42857	115	205330.8571
1249.84	499936	115	287463.2
1249.84	715533.4	253	395261.9
1249.84	521183.28	172.5	215597.4
1249.84	195287.5	35.9	56086.57

Table 3: Contd

Evapotranspiration(mm)	Evapotranspiration losses (m3/cycle)	Total water requirement(m3/cycle)	Dischare(m3/s)
136.6	243897.3486	109985.92	0.181855026
136.6	341456.288	553929.088	0.915888042
140	218722	538993.5	0.891192956
147.5	184351.4	489937.28	0.810081481
116.6666667	182268.3333	321469.2633	0.531529867

Table 4 Discharge Requirement for the Three Irrigation Field

Crop	Area (ha)	Crop period	Crop water requirement (ha-m)	Canal discharge requirement (m^3/sec)
Paddy	3021	Jun to Sep	197.96	3.27
Paddy	1250	Oct to Jan	54.32	0.92
Tomato	404	Yearly	127.15	2.10

IV. COMPARISON OF WATER EFFICIENCY BETWEEN LINED AND UNLINED CANAL

Scenario-1 (No regulating structure and no canal lining)

Crop: Paddy (jun-sept)

Table 5: Required, Actual and Deficit Discharge Values in m^3/sec for Paddy Crop (June to Sept)

Month	Required rate	Actual rate	Deficit rate
June	1.228779762	1.06	0.16
July	2.024989087	1.06	0.96
August	3.273187066	0.82	3.07
Sept	2.44706994	0.63	1.81

Table 6: Required, Actual and Deficit Discharge Values in m^3/sec for Paddy Crop (Oct to Jan)

Month	Required rate	Actual rate	Deficit rate
Oct	0.181855026	0.63	0.45
Nov	0.915888042	0.49	0.42
Dec	0.891192956	0.76	0.13
Jan	0.810081481	0.69	0.12

Table 6: Required, Actual and Deficit Discharge Values in m^3/sec for Tomato Crop (Feb to May)

Month	Required rate	Actual rate	Deficit rate
Feb	1.232193248	0.57	0.63
Mar	1.263190035	0.45	0.81
Apr	1.656226631	0.42	1.18
May	2.102356702	1.1	1

V. COST ANALYSIS FOR THE DESIGN SCENARIOS

The project considers two different scenarios, i.e. scenario one (S1) and scenario two (S2). Scenario one is irrigation system without any control structure or lined canal system, whereas scenario two is the irrigation system with head regulators and lined canal system. The benefits accrued from irrigation (in terms of total crop yield) are estimated in both scenarios, along with the cost of constructing and operating the canal head regulation. The scenario for which the net benefits are greater will be the obvious choice of irrigation system.

5.1 Cost Estimation for the Construction and Operation of Canal Head Regulating Structures

The cost estimation of head regulators includes different components that are to be considered during the design of typical canal head regulator such as concrete, steel, bricks, stone works etc. These head regulators are designed as per the discharge required by the main and minor head regulator for each particular crop. Given below are the cost estimation of different regulating structures-:

Table 7: Quantity Estimation for the Main and Minor Canal Head Regulators

Quantity	**Main Head Regulator**					
Sr. No.	Item	No's	L	B	H	Quantity
1	Stone Work					
I	Launching Apron	2	1.4	12	1	33.6
Ii	Block Protection	1	1	12	1	12
2	Concrete Work					
I	Floor Thickness	1	12	12	2	288
Ii	Block Protection Downstream	1	1	12	0.4	4.8
iii	Piers	3	2	12	1	72
3	Brick Work					
I	Brick Wall	1	0.8	12	1	9.6
4	Steel Works					
I	Gates	2	4.4	0.5	3.5	15.4
	Quantity	Rate	Cost			
Cost of Gravel =	45.6	4464	203558.4			
Cost of Cement =	52.11428571	25200	1313280			
Cost of Aggregates =	208.4571429	1600	333531.4			
Cost of Sand =	104.2285714	535.7143	55836.73			
Cost of Steel =	15.4	141300	2176020			
Cost of Bricks =	9.6	4460.432	42820.14			
		Cost	4125047			
Quantity	**Tomato**					
Sr. No.	Item	No's	L	B	H	Quantity
1	Stone Work					
I	Launching Apron	2	2.2	5.86	1	25.784
Ii	Block Protection	1	1	5.86	1	5.86
2	Concrete Work					
I	Floor Thickness	1	8	5.86	2	93.76
Ii	Block Protection Downstream	1	1	5.86	0.4	2.344
iii	Piers	3	0.6	5.86	1	10.548
3	Brick Work					
I	Brick Wall	1	0.2	5.86	1	1.172
4	Steel Works					

	Gates	2	2	0.5	2.5	5
	Quantity	Rate	Cost			
Cost of Gravel =	31.644	4464	141258.8			
Cost of Cement =	15.236	25200	383947.2			
Cost of Aggregates =	60.944	1600	97510.4			
Cost of Sand =	30.472	535.7143	16324.29			
Cost of Steel =	5	141300	706500			
Cost of Bricks =	1.172	4460.432	5227.626			
		Total cost	1350768			

Quantity	**Paddy (June to September)**					
Sr. No.	Item	No's	L	B	H	Quantity
1	Stone Work					
I	Launching Apron	2	2.2	7.45	1	32.78
Ii	Block Protection	1	1	7.45	1	7.45
2	Concrete Work					
I	Floor Thickness	1	9.5	7.45	2	141.55
Ii	Block Protection Downstream	1	1	7.45	0.4	2.98
Iii	Piers	3	1.2	7.45	2.5	67.05
3	Brick Work					
I	Brick Wall	1	0.2	7.45	1	1.49
4	Steel Works					
I	Gates	2	2	0.5	2.5	5
Cost Estimation						
	Quantity	Rate	Cost			
Cost of Gravel =	40.23	4464	179586.7			
Cost of Cement =	30.22571429	25200	761688			
Cost of Aggregates =	120.9028571	1600	193444.6			
Cost of Sand =	60.45142857	535.7143	32384.69			
Cost of Steel =	5	141300	706500			
Cost of Bricks =	1.49	4460.432	6646.043			
		Total cost	1880250			

Quantity	Paddy (September to January)					
Sr. No.	Item	No's	L	B	H	Quantity
1	Stone Work					
I	Launching Apron	2	1.4	3.6	1	10.08
Ii	Block Protection	1	1	3.6	1	3.6
2	Concrete Work					
I	Floor Thickness	1	6	3.6	2	43.2
Ii	Block Protection Downstream	1	1	3.6	0.4	1.44
Iii	Piers	3	0.5	3.6	2.5	13.5
3	Brick Work					
I	Brick Wall	1	0.2	3.6	1	0.72
4	Steel Works					
I	Gates	2	2	0.5	2.5	5
Cost Estimation						
	Quantity	Rate	Cost			
Cost of Gravel =	13.68	4464	61067.52			
Cost of Cement =	8.305714286	25200	209304			
Cost of Aggregates =	33.22285714	1600	53156.57			
Cost of Sand =	16.61142857	535.7143	8898.98			
Cost of Steel =	5	141300	706500			
Cost of Bricks =	0.72	4460.432	3211.511			
		Total cost	1042139			

VI. COMPARISON BETWEEN THE SEEPAGE LOSSES FOR THE EARTHEN CANAL AND LINED CANAL SYSTEM

The Earthen canal system that is majorly being practiced in India results in seepage losses and moreover it is the major cause for poor crop yield as due to percolation losses the quantity of water available for the crop is insufficient which results in poor crop yield and it is more economical in terms of water use efficiency whereas in case of Lined canal system the seepage losses are very less when compared to Earthen canal system though the initial cost of lining is more but when we consider long term usage it has more advantage in terms of crop yield and water use efficiency. Following are the losses in Earthen and Lined canal system-:

The formula used for the calculation of seepage losses for are given as -:

For lined canal $S = 0.35(Q^{0.056})$

For Unlined canal $S = 1.90(Q^{0.0825})$

Where S = Seepage Loss in Mcm

Q = Discharge in m^3/s

Channel type	discharge(Q)(m3/s)	seepage loss(m3/s/million m2)	Chennel bed width(m)
Lined	8.12	0.39	22
Unlined	8.12	2.25	22
Lined	S=0.35(Q^0.056)		
Unlined	S=1.90(Q^0.0825)		

Depth(m)	wetted perimeter(m)	Length(m)	Area(million m2)	annual seepage losses(S)(mcm)
1.55	25.1	1000	0.0251	0.308705904
1.55	25.1	1000	0.0251	1.7809956

From the above table it is clear that the seepage losses in Lined canal are drastically small when compared to Earthen canal system used in India, therefore lining the canal system in terms of water use efficiency is Preferred over earthen canal system.

6.1 Yield Calculation for Different Crops and Cost Comparison as per Required Discharge and Actual Releases in Tambarparani River Basin

Crops	Area(Ha)	Yield(reference)(Kg/Ha)	Required Discharge(m3/s)	Net yield(million Kg)
paddy(jun-sep)	3021	3260	3.27	9.84846
paddy(oct-jan)	1250	3260	1.14	4.075
tomato	404	45000	2.4	18.18

Actual discharge(m3/s)	Net yield(million Kg)
1.14	4.521316402
1.14	0.652200739
1.14	6.125674877

Price(Rs./kg)	Price(Rs.) (actual discharge)	Price(Rs.) (calculated discharge)	yield profit(Rs.)
50	226.0658201	492.423	266.3571799
50	32.61003695	203.75	171.1399631
20	122.5134975	363.6	241.0865025

From the above calculation it is clear that the Actual releases results in poor yield due to insufficient water supply which further results in loss in terms of crop revenue.

VII. POWER CONSUMPTION REQUIRED BY HEAD REGULATOR

In the canal head regulator, the power is utilized for uplifting the head regulator gates in vertical direction. We have made the assumption that the gate will be uplifted till the height of 0.1m.The formula for calculating power consumption is given by:

$$P = WQH$$

Where P is power consumption in KWh, W is weight of gates in Kg, Q is discharge in m^3/s and H is the height of uplifting canal gates.

The calculation of power consumption for the canal was done to calculate total cost of canal head regulator system. This cost was added to cost of construction to find out total cost.

power consumption	**(Minor Regulators)**				
	Volume of steel reqd.(m3)	Mass Density of steel(kg/m3)	Mass of gates(kg)	weight(N)	Discharge(m3/s)
Paddy(june-sep)	2.5	7850	19625	192325	3.68
Paddy(oct-jan)	2.5	7850	19625	192325	1.14
Tomato(may-aug)	2.5	7850	19625	192325	2.4
Major Regulator	15.4	7850	120890	1184722	8.12

Height opening(m)	Power Required(KWh)	Per Unit cost(RS.)	No. of Gates	Total Cost(RS.)
0.1	70775.6	7	2	990858.4
0.1	21925.05	7	2	306950.7
0.1	46158	7	2	646212
0.1	961994.264	7	2	13467919.7

REFERENCES

[1] IS – 6531: Criteria for Design of Canal Head Regulators

[2] Irrigation Engineering and Hydraulic Structures, Santosh Kumar Garg, Khanna Publishers, 2006

[3] Irrigation and Water Power Engineering, Punmia, B. C., PandeBrijBasi Lal, Ashok, K. Jain, and Arun, K. Jain