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Feasibility of Pipe Distribution Network (PDN) over Canal Distribution Network (CDN) For Irrigation

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Abstract: ***Water, which is a valuable, finite, renewable and shared resource required by various sectors, must be managed optimally. Stress due to scarcity of water is growing at an alarming rate. To reduce this stresses and to meet water demand of all the sectors, construction of new water projects is essential, but it involves huge investment and social problems like land acquisition, rehabilitation etc. Therefore, it is essential to search innovative alternative for modernization of existing water distribution system. The Pipe Distribution Network (PDN) system is one of the best possible alternatives to overcome the limitations of conventional gravity flow Canal Distribution Network (CDN) system. The present paper is based on the experience of the Nagthana-2 Minor Irrigation (MI) project, Amravati district and the irrigation project of Dongarwadi Lift Irrigation (LI) scheme, Sangli district, Maharashtra state. Nagthana-2 MI project, which was initially designed as a CDN for Culturable Command Area (CCA) of 643 Ha and now implemented for gravity PDN and result implies that the same volume of water could irrigate CCA of 1207 Ha. This paper also covers a case study of Dongarwadi LI scheme, where PDN system comes out to be feasible alternative over other.***

Keywords: Canal Distribution Network (CDN), Pipe Distribution Network (PDN), Overall Project Efficiency(OPE).

I. INTRODUCTION

Irrigation sector is the largest consumer of water as more than 80 percent of available water resources in India are being presently utilized for irrigation purpose. The main sources of irrigation in the country are canals, tanks and wells including tube wells. Analyzing the data relating to net area irrigated by source from the year 2000-01 to 2011-12, it is observed that the major source of irrigation is ground water. It was found that wells (considering all types of wells viz. dug well, shallow tube-well, deep tube-well) contributed about 61 percent irrigation followed by canals with 24 percent at all- India level during 2000-01 to 2011-12, which shows that on increasing the efficiency of existing canals the problems like ground water depletion and pumping cost can be tackled.

A. Efficiency of Project

Conventional irrigation methods are surface gravity open channel systems such as furrows, basin, border etc. with field application efficiencies of 60 to 70 percent. The Overall Project Efficiency (OPE) of such irrigatrion project, at the design stage itself turns out in the range of 40 to 50 percent. But, in fact, due to various constraints the OPE during opreation is only 20 to 35 percent. The Overall Project Efficiency (OPE) can be expressed by the following formula.

$$\eta_o = \eta_m \times \eta_{br} \times \eta_{dy} \times \eta_{mi} \times \eta_{fc} \times \eta_{fa}$$

Where,
η_o = Overall Project Efficiency,
η_m = Efficiency of Main Canals,
η_{br} = Efficiency of Branch Canals,
η_{dy} = Efficiency of Distributaries,
η_{mi} = Efficiency of Minors,
η_{fc} = Efficiency of Field Channel,
η_{fa} = Field Application Efficiency.
(Note- All values are in percentage expressed in decimals)

From above formula, it is clear that efficiency of each and every component is necessary to improve to achieve better OPE. This objective can be achieved with the help Pipe Distribution Network (PDN) System.

II. EXPERIENCE AND CASE STUDY IN PDN

A. *Nagthana-2 Minor Irrigation (MI) project*

Command area of this project is hilly terrain with steep and undulating topography, and land slope varies from 1 to 5 percent. This type of topography is considered more suitable for PDN. Initially the project was designed as a CDN but in the view of all aspects such as topography of the area, request of farmers to recommend PDN and limitations of CDN etc. the project finally implemented as a gravity flow PDN for irrigation. Some of the important design aspects of Nagthana-2 project are compared in Table I.

Table I Comparison of design aspects of Nagthana-2 MI project

Sr. no.	Description	Conventional CDN System	PDN system	Percentage Increase	Percentage Decrease
1	Discharge at head regulator	1040 LPS	1040 LPS	-	-
2	OPE	41%	77%	36%	-
3	Land acquisition	31.58 Ha	7.00 Ha	-	77 %
4	Culturable command area (CCA)	643 Ha	1207 Ha	88%	-
5	Discharge at chak head	30 LPS	82 LPS	173%	-

LPS - Litre per second, Ha – Hector, OPE – Overall Project Efficiency.

It is seen that with the implementation of PDN water application efficiency on farm is 85 percent, efficiency of lateral is 95 percent, efficiency of sub- main is 98 percent and efficiency of main is 98 percent, which shows that there is remarkable increase in efficiency of overall system. Likewise CCA is almost doubled with the same volume of water.

Table II Cost comparison between conventional CDN and PDN system for Nagthana-2 MI project

Sr. No.	Description	Conventional CDN system	PDN system	Percentage decrease
1	Land acquisition cost	109.73 lakh	24.50 lakh	77%
2	Construction cost	422.18 lakh	404.34 lakh	4%
3	Total cost	532.01 lakh	428.84 lakh	19%

The construction cost of PDN system includes cost of P.V.C pipes, excavation and refilling, laying and jointing, accessories, and cost of distribution chamber etc. From Table II, it is clear that the land acquisition cost by implementing PDN instead of CDN has reduced to great extent.

B. Dongarwadi Lift Irrigation (LI) Scheme

Dongarwadi LI scheme falls under Mhisal division of Krishna Koyana lift irrigation project of Sangli district in Maharashtra state.

1) *Status of the Project:* The construction of Dongarwadi gravity flow open canal from 0 to 10.87 km is already finished and the remaining work (from 10.87 km to 13.310 km) is taken into account. However it is observed that the reach of the channel from 10.87 km to 13.310 km passes through deep cut of black cotton soil. In order to construct the canal from this soil, the following alternatives were considered.

a) Construction of canal by provision of Cohesive Non Swelling (CNS) layer along with Cement Concrete (CC) lining.

b) Construction of canal by Reinforced Cement Concrete (R.C.C.) box conduit.

c) Construction of canal by use of PDN.

2) Evaluation of Alternatives:

a) Alternative 1: Construction of Canal by Provision of Cohesive Non Swelling (CNS) Layer along with Cement Concrete (CC) Lining: To construct the gravity flow open channel from the ground of black cotton soil, the CNS layer together with CC lining should be necessary. But the implementation of the open channel irrigation system is not feasible within this range due to the following reasons;

Frequently maintenance and repairs of canal is required due to swelling nature of black cotton soil.

Substantial amount of land acquisition is necessary as construction of open canal is from deep cut black cotton soil.

As the land in this reach is black cotton soil which is fertile and effective for production, the farmers in this area of canal are unwilling to hand over their land.

Number of farmers may become farm-less as they are holding small piece of land.

b) Alternative 2: Construction of Canal Through R.C.C. Box Conduit: Good foundation to support the R.C.C. box conduit is not available in this reach. So strengthening of foundation is necessary by providing deep layer of boulder filling along with good compaction and thick bed of concrete below the box. The thickness of R.C.C. box will be more due to excess overburden and it will affect the total project cost. Provision of inspection chambers at regular intervals are also required for maintenance of canal during operation, which is practically not feasible for canal passing through deep cut. So technically this option is not feasible in this reach.

c) Alternative 3: Construction of Canal by PDN System.: Taking into account, all difficulties in the construction and maintenance of the channel using the CNS layer or R.C.C. Box, PDN system adoption is only solution because the PDN system will reduce percolation losses, total channel cross-sectional area, and increase overall project efficiency. Farmer's opposition will also be removed in case of a PDN system, as the replenished soil can be used for fertilization. Therefore, the PDN system is proposed for the channel from 10.87 km to 13.31km

Table III Cost comparison between conventional CDN with provision of CNS layer and PDN system for Dongarwadi LI Project.

Sr.No.	Description	Conventional CDN System	PDN system	Percentage increase	Percentage decrease
1	Land acquisition cost	441.72 lakh	90.23 lakh	-	79 %
2	Construction cost	679.35 lakh	778.03 lakh	14 %	-
3	Total cost	1121.07 lakh	868.26 lakh	-	22 %

III. FUTURE SCOPE FOR PDN SYSTEM

PDN can be used for major, medium, minor and lift irrigation scheme. It is possible to implement this system as a new scheme or in an existing scheme. If PDN is implemented as a new project, it would be, easier to give justice to the principles of PDN. While implementing PDN system on existing scheme there could be following alternatives as given in Table IV

Table IV Alternatives while implementing PDN on existing CDN system

Alternative	CDN	PDN
1	Main canal, Distributary, Minor	Only FC
2	Main canal and Distributary	Minor and FC
3	Main Canal	Distributary, Minor and FC

From the case of Dongarwadi LI project, an another alternative came into focus that part of open canal can be converted into PDN system.

IV. ADVANTAGES OF PDN SYSTEM OVER CDN SYSTEM

A. As almost entire system is buried, there is considerable saving in land acquisition cost.
B. The losses due to seepage, evaporation, thefts can be avoided by implementation of PDN.
C. PDN is suitable in any type of strata like hard rock, black-cotton soil, saline land etc.
D. By use of PDN, Part of un-command area can be brought under irrigation.
E. Low maintenance cost- in PDN continuous maintenance is not required as in case of earthen channel. PDN system requires a minimal maintenance during first seven years.
F. Advanced technologies such as drip, sprinklers, sub-surface irrigation system of irrigation can be implemented.
G. Water logging can be reduced with the help of this system.
H. Irrigation principle may be achieved by equitable water supply from tail to head.
I. Minimum manual control is required in operation network.
J. Amount of revenues generated will be more as water can be supplied on volumetric basis.

V. LIMITATIONS OF PDN SYSTEM

A. Great care in design and construction of PDN is necessary.
B. Silt must be removed from water before supplying it to PDN.
C. High initial investment in pipeline- but in the long run pipelines are economical, because of saving in water, labour, maintenance, land & permanence of installation.
D. This is modern system, more study and experience is required in this field.

VI. CONCLUSION

The PDN system is one of the best solutions to improve the OPE of an irrigation project. Results of Nagthana MI project shows that, with the implementation of PDN as a new scheme, there is remarkable increase in efficiency of overall system and it is possible to double CCA with the same volume of water. Also from the case study of Dongarwadi LI project, it is seen that despite the high investment required in the construction of the PDN system, this system will be economical as compared to CDN when the land acquisition cost for the project is taken into account and PDN will be feasible over CDN particularly when the reach of the channel passes through the deep cut of black cotton soil. Thus depending on needs and techno-economic feasibility, PDN could be planned as a new scheme or in an existing scheme. Therefore, to overcome the limitations of CDN, the modernization of the irrigation distribution system may be possible and feasible with the help of the PDN system.

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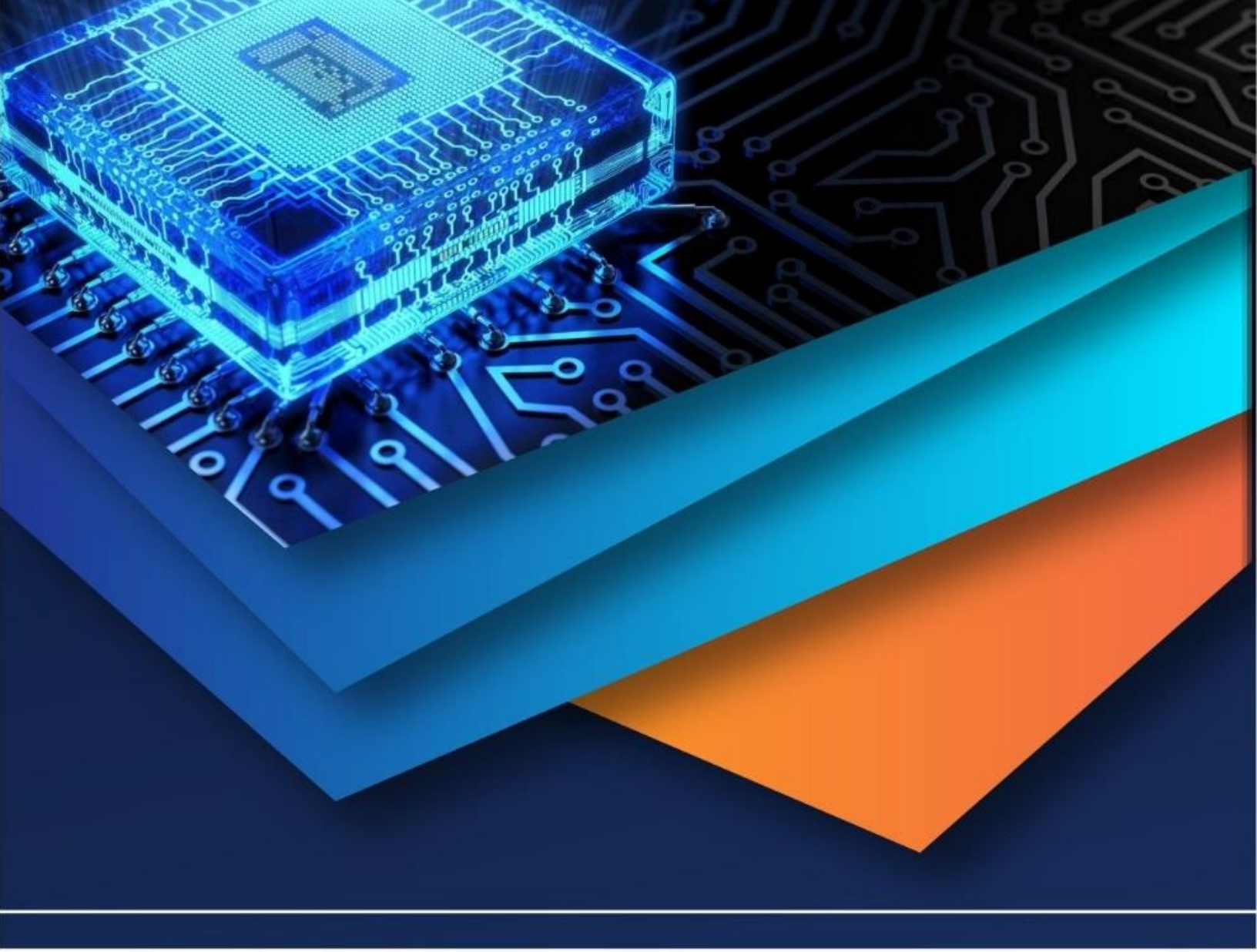

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