Closed Conduit Irrigation Water Distribution System For Improving Water Use Efficiency To Mitigate Water Scarcity Crisis In 2050

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ABSTRACT:
It is needless to explain the importance of water, which is lifeblood for the existence of life on this earth. Water ensures food security, feed livestock, maintain organic life and fulfil domestic and industrial needs. Besides engineering and scientific angle, the present water situation has political, legal, environmental, social, economical and even religious connotations. The increasing gap between demand and availability of water is becoming crucial issue which divides people in to 'haves' and 'have not' in every nation. Further, to add pressure, apart from geographical demarcations, water divided people from urban and rural, rich and poor. Without efficient water management and optimum utilisation of this essential, scarce and valuable commodity, ecosystem will experience water crisis in future due to increasing water demand verses decreasing per capital water availability. The Climate Change is expected to worsen the situation. India is second largest populated country consists of more than a sixth of the world population with just 2.4% of world's total area and 4% water resources. The national per capita annual availability of water decreased to 1588 m^3 in 2010 from 5177 m^3 in 1951. It is estimated that in 2050, it will drop down to 1140 m^3 as a result of increase in population, which is expected to stabilize around 1640 million. From international perspective, country with per capita availability of water less than 1700 m^3 is tagged as water stressed and less than 1000 m^3 is water scarce. Thus India is water stressed today and it is likely to be water scarce by 2050. NCIWRD assessed water demand in 2050, for Irrigation, Domestic and Industrial use as 807, 111 and 262 km^3 respectively and equals to 1180 km^3. The available quantity of water in India will be 829 km^3 including 396 km^3 from surface water and 433 km^3 from ground water. The imbalance between demand and supply can be managed by enhancing supply (supply-side solution) or by curtailing demand (demand-side solution). Nearly 70 to 80% of water is used in irrigation sector, which is currently serving at just 25 to 50% efficiency. The focus of this paper is on curtailing demand for irrigation sector, without compromising with Net Irrigation Requirement (NIR), but by improving water use efficiency. A case study has been chosen to explain the Closed Conduit Irrigation Water Distribution System that was designed for Nagthana-II MI Project, Tal-Warud, Dist-Amravati, Maharashtra. The conventional Canal Distribution Network (CDN) could irrigate Culturable Command Area of 600 Ha with 41% efficiency converted to Closed Conduit Distribution Network (CCDN) to irrigate about 1200 Ha area at 80% efficiency. Implementing gravity based CCDN improves overall water use efficiency to 70 to 80 % as against conventional CDN having water use efficiency as 25 to 40 %. The other benefits of the CCDN are explained in the paper. In a nutshell, in order to mitigate water crisis in 2050, it is recommended that CCDN must be implemented so that water is utilized optimally and more crop per drop of water can be achieved.

1. INTRODUCTION

Sustainable development and efficient management of water is complex challenge all over the world. Water is lifeblood for the existence of life on this earth. Water ensures food security, feed livestock, maintain organic life and fulfil domestic and industrial needs. Besides engineering and scientific angle, the present water situation has political, legal, environmental, social, economical and even religious connotations. The increasing gap between demand and availability of water is becoming crucial issue which divides people in to 'haves' and 'have not' in every nation. Further, to add pressure, apart from geographical demarcations, water divided people from urban and rural, rich and poor. Without efficient water management and optimum utilisation of this essential, scarce and valuable commodity, ecosystem will experience water crisis in future due to increasing water demand verses decreasing per capital water availability. The Climate Change is expected to worsen the situation. As per Intergovernmental panel on Climate Change, by 2050, more than one billion people in the Asia alone are projected to experience the negative impact as a result of Climate Change. The United Nations projects that by 2050; as many as three out of four people around the globe could be affected by water scarcity.

2. GLOBAL WATER SCENARIO

According to United Nations Environment Programme (UNEP), it was estimated that the total volume of water on Earth is about 1400 million km^3, which is enough to cover the earth with a layer of 3 km depth of water. Freshwater resources are estimated around 35 million km^3, or in other words, it is about 2.5 percent of the total volume. Of these freshwater resources, about 24 million km^3 or 67 percent is in the form of ice and permanent snow cover in mountainous regions, the Antarctic and Arctic regions. Further, around 10.5 million km^3 or 30 percent of the world's freshwater is stored underground in the form of groundwater (shallow and deep groundwater basins up to 2000 metres, soil moisture, swamp water and permafrost). This constitutes about 97 percent of all the freshwater that is potentially available for human use. Freshwater lakes and rivers contain an estimated 0.105 million km^3 or around 0.3 percent of the world's freshwater.

If the next world war happens; it may well be triggered by water scarcity across the continents. It has been already found that the one third of the world is suffering from water shortages. Increasing demand for water with rapidly growing rate of population, industrial growth, inadequate rainfall, uncontrolled use of water and climate change are some of the reasons behind it. As per the United Nation's estimate, water scarcity already affects every continent. Around 1.2 billion people, or almost one-fifth of the world's population, live in areas of physical scarcity, and 500 million people are approaching this situation. Another 1.6 billion people, or almost one quarter of the world's population, face economic water shortage.

3. INDIAN WATER SCENARIO

India is second largest populated country consists of more than a sixth of the world population with just 2.4% of world's total area. India constitutes around 16.5% of the world population, whereas the share of water resources is just 4%. The main source of water is annual precipitation including snowfall and it was estimated to be of the order of 4000 km^3. More than half of that returns to atmosphere by evaporation, and seepage in to ground. The balance water resource which occurs as natural run off in the rivers is estimated at 1869 km^3 considering both surface and groundwater into account. There are various constraints, such as topography, uneven distribution of resource over space and time, therefore, it has been estimated that only about 1123 km^3 can be put to beneficial use, out of which only 690 km^3 is surface water and rest 433 km^3 is ground water. A total storage capacity of about 225 km^3 has been created in the country as a result of construction of major & medium projects. The Projects under construction will contribute to additional 64 km^3 while the contribution expected from projects under consideration is 107 km^3. Thus likely storage available will be 396 km^3 once the projects under construction or consideration are completed against the total water availability of 1869 km^3 in the river basins of the country. (CWC, 2010)

4. WATER CRISIS IN INDIA

The national per capita annual availability of water decreased to 1588 m^3 in 2010 from 5177 m^3 in 1951. It is estimated that in 2050, it will drop down to 1140 m^3 as a result of increase in population, which is expected to stabilise around 1640 million. From international perspective, country with per capita availability of water less than 1700 m^3 is tagged as water stressed and less than 1000 m^3 is water scarce. Thus India is water stressed today and it is likely to be water scarce by 2050. Even after constructing 4525 large and small dams, the per capital storage of the country is 213 m^3 as against 6103 M^3 in Russia, 4733 m^3 in Australia, 1964 m^3 in USA and 1111 m^3 in China. It may touch to 400 m^3 in India only after the completion of all the ongoing and proposed dams.

The spatial and temporal variation in distribution of available water resource is great concern for management of water resources. About 64% of the geographical area of the country accounts for less than 29% of its total water resources. Over 80% of the country's annual rainfall is recorded in the summer mansoon, which last for 100 to 120 days in a year. According to National Commission on Integrated Water Resources Development (NCIWRD), 50% of the annual precipitation taking place in a short period of about 15 days and less than 100 hours all together.

5. WATER DEMAND IN 2050

The requirement of fresh water both for irrigation and other uses is growing continuously. The requirement of water for various sectors has been assessed by the NCIWRD in the year 2000. The water requirement in 2010 for Irrigation, Domestic and Industrial use were 557, 43, and 110 km^3, thus totalling to 710 km^3. About 80% of water was utilised for irrigation sector, at 35 to 40% water use efficiency. In 2050, water demand for Irrigation, Domestic and Industrial use will be 807, 111 and 262 km^3 respectively. Thus, total water demand for all the uses is likely to be 1180 km^3. (GoI, 1999) The quantum of available water will be 829 km^3 including 396 km^3 from surface water and 433 km^3 from ground water. The imbalance between demand (1180 $km^{3)}$ and supply (829 km^3) can be managed by enhancing supply (supply-side solution) or by curtailing demand (demand-side solution). Till now, the focus of initiatives for reducing of demand and supply gap has been in seeking supply side solutions. The option of demand side solution has been neglected due to its complexity. But with the constraints and limitations in supply side solutions, there is urgent need to look at demand side solutions as well.

6. SUPPLY AND DEMAND SIDE SOLUTIONS

The supply side solutions have three components, namely (1) creating new potential for enhancing supply, (2) achieving equitable distribution, and (3) meeting the needs of sustainable development. Where as, demand side solutions includes (1) creating new technologies for reducing water demand, (2)bringing about changes in the societal mindset about water usage, and (3) initiating and enforcing water related structural reforms. (Maheshwari, G.C)

7. DEMAND SIDE SOULTION FOR IRRIGATIN SECTOR

A well planned, well designed and well constructed distribution network for irrigation purposes should deliver water in the right quantities, at right rate, with the right pressure and at the right time without causing management and operational problems to the water authority or to the consumers. To this end, the distribution system has to incorporate all necessary structural and operational aspects such that the above requirements and any constraints imposed at the source or in other parts of the system are satisfied. Distribution systems vary greatly in size and complexity, from spreading of flood water over adjacent areas to the conveyance and distribution of surface water or groundwater to areas of intensive agricultural development. (FAO, 2000) Nearly 70 to 80% of water is used in irrigation sector. This demand can be cut down by more than one-third by developing higher yielding crop varieties that requires lower frequencies and quantum of water so that more crop per drop can be achieved.

According to Eleventh Five Year Plan, for a gross irrigated area of about 87MHa, the reported water use was 541 billion m^3, which gives a delta of 0.68m per Ha of gross irrigated area. Taking 70% of the average annual rainfall which is 1.17m as effective for crop consumptive use, the gross water use is about 1.45m per ha of gross irrigated area. This is very high as compared to water use in countries like US, where water allocation is less than 1m, per Ha of gross irrigated area. (Planning Commission, 2008) This indicates that our irrigation system is not efficient and there is urgent need to go for innovative solutions in order to improve the water use efficiency.

The irrigation water application methodology is also one of the great concern for reducing water demand. According to NCIWRD, 1999 the national weighted average value of Net Irrigation Requirement (NIR) is estimated as 0.36m depth of water application, against which the Gross Irrigation Requirement (GIR) is estimated at 0.9m for surface water usage and 0.65m for ground water usage. The surplus water requirement of about 80% (for groundwater usage) to 150% (for surface water usage) is mainly on account of conveyance and application inefficiencies.

8. IRRIGATION EFFICIENCY

The Irrigation projects are normally designed on values of efficiencies of various components of Irrigation Projects given in technical publication of Ministry of Water Resources, Government of India with the title, 'Guidelines for Estimating Water Resources Requirement'. (CWC Guidelines) The efficiency of project can be estimated by multiplying the efficiencies of individual components of the irrigation project, such as main canal, branch canal, distributaries, minors, field channels, and field application efficiency etc. The field irrigation methods are the traditional surface gravity - furrow, basin, border etc., with field application efficiencies of 60–70 percent, i.e. additional water losses of about 30–40 percent of the total. Studies from many countries show an average of 33 percent water losses during conveyance through a 100 m conventional channel. It has been observed that the overall project efficiency of the project, at the stage of design itself turns out in the range of 40 to 50 percent. But, in fact, due to various constraints, such as seepage, evaporation, leakage, evapo-transpiration (through weeds), pilferage etc it was assessed that the overall project efficiency during operation is only 20 to 35 percent. This implies that over 65 to 80% of the water used for irrigation is wasted. Furthermore, as the water supplied is not measured, farmers have a tendency to flood the field with excessive water without any additional cost. Such a practice has been creating a negative impact by way of increased cost of leached nutrients, pollution of ground water, increase in soil salinity and increase of pests and diseases.

9. CLOSED CONDUIT DISTRIBUTION NETWOK (CCDN)

A Closed Conduit Distribution Network is a network consisting of pipes, fittings and other devices properly designed and installed to supply water under pressure from the source of the water to the irrigable area. The basic differences between Canal Distribution Network (CDN) & Closed Conduit Distribution Network are (FAO, 2000):

1) The water flow regime:- In CDN, the size of the stream should be large, while in CCDN very small flows, even 1 m^3/ha, can be utilized.
2) The route direction of the flow:- In CDN, the irrigation water is conveyed from the source and distributed to the field through open canals and ditches by gravity following the field contours, whereas, in CCDN, irrigation water is conveyed and distributed in closed pipes by pressure following the most convenient (shortest) route, regardless of the slope and topography of the area.
3) The area irrigated simultaneously:- With CDN, the water is applied in large volumes per unit of area, while CCDN systems distribute the water at small rates over a very large area.
4) The external energy (pressure) required: Traditional surface gravity methods do not need external energy for operation, while piped irrigation systems require a certain pressure, 2-3 bars, which is provided from a pumping unit or from a supply tank situated at a high point.

10. CASE STUDY OF CCDN

CCDN was designed for Nagthana-II MI Project, Tal-Warud, Dist-Amravati, Maharashtra. Originally it was proposed to have conventional CDN to irrigate Culturable Command Area of 600 Ha. The CCDN was designed for the same cropping pattern and it was observed that the same quantum of water could irrigate about 1200 Ha area. This is due to the improvement in the water use efficiencies as water loss in CCDN is about 100% less than that of CDN. In other words, there is 100% rise in the efficiency from 40% to 80%, as described in following paragraphs. Thus, CCDN carrying discharge under pressure would serve as a pilot scheme for switching over to this method for increasing efficiency of water conveyance. Water is planned to be supplied to farmers on volumetric basis by using closed conduit system. The farmers in command area have shown overwhelming response to the concept of volumetric basis, which would provide option of adopting cropping pattern to suit market demand.

11. EFFICIENCY OF CDN AND CCDN

Canal Distribution Network is extensively used to supply water from source to the individual farm plots by means of gravitational flow. During this, water is lost due to seepage, evaporation, leakages in the structures, gates, shutters etc and poor water management in the distribution network. While designing irrigation network, assessment of these losses is made and taken into account in total requirement of the irrigation water so that system meets the crop water requirements.

In case of CCDN, frictional loss is a major component of loss, and it has been estimated that a well planned, carefully designed, properly constructed, and systematically operated CCDN have the potential to operate at the efficiency of 70 to 80 percent. As operational efficiency of CDN is in the range of 20 to 35 percent, and about 80 percent water is utilised for the irrigation purpose, if this efficiency is increased to say 70 to 80 percent, it implies that there will be saving of more than 50 percent of water stored in the water resources project. Therefore, a greater area can be irrigated with a fixed quantity of water.

Further, CCDN overcome the topographic constraints and make it easier to establish water fees based on volume of water consumed because it is easy to measure the volume of water delivered. Consequently, a large quantity of water may be saved since farmers tend to maximize the net income by making an economical balance between costs and profits. Thus, because the volume of water represents an important cost, farmers tend to be efficient with their irrigation. Operation, maintenance and management activities are more technical but easier to control to maintain a good service. The huge gap between the water wasteful in CDN and the highly efficient improved irrigation techniques can be eliminated with the implementation of the CCDN.

12. DESIGN PHYLOSOPHY OF CCDN

In design of water distribution network, first step is the computation of the crop water requirements considering the type of soil, the climate, the water quality and the irrigation scheduling. The water supply conditions, the availability of electricity, field topography and economic considerations are also need to be considered, while designing CCDN. The irrigation system is selected after a thorough evaluation of the above data and the computation of the system’s flow, the irrigation dose, the duration of application and the irrigation interval.

The CCDN combines both the features of the open surface methods and the pressurized closed pipe techniques. The design criteria and the parameters are too many as compared to the simplicity of the installation. The topography of the area (shape, slope, etc.), the type of soil, the size of flow and the method of water delivery to the crop (furrow, basin, border or other) should be carefully examined. The take-off hydrants must be placed at the highest points of the field plots and at the right distances to enable efficient practices of the gravity irrigation techniques through the manifold ditches or by drip or sprinkler techniques, if enough head is available at the delivery point.

The most important criterion to be considered during the design is the possibility for future extension of the network for the adoption of any other low-medium improved irrigation system, such as sprinkling, drip, spitters, etc., with the minimum expenses. Then the careful design of a flexible skeleton-piping network, suitable to serve all methods of irrigation and water delivery techniques is of major importance.

14. ADVANTAGES OF CCDN OVER CDN

Beside improved water use efficiency, other benefits of CCDN can be listed as below-

1) Saving in cost of land acquisition, which is very sensitive issue in the India, as per capital land holding is very less.
2) The use of thermoplastic pipes and fittings, made of unplasticized polyvinyl chloride (rigid PVC), low density polyethylene (LDPE), high density polyethylene (HDPE), and polypropylene (PP), which are manufactured in almost every country in many sizes and classes, has reduced the cost of CCDN installations to a relatively low level at a time when CDN are becoming increasingly expensive.
3) Saving in maintenance cost of canal structures and earthwork. In the CDN, expensive operations are carried out to prevent damage caused by roots; seepage through banks; the spread of weeds; siltation and sedimentation; clogging of outlets and gates; etc. Where as, in CCDN, no maintenance or continuous repair of constructions are required. The basic component parts of the CCDN require minimal maintenance during the first seven years. The complete CCDN system requires a yearly maintenance costing about 5 percent of the initial investment.
4) Part of un-command area under CDN can be brought under irrigation.
5) The losses due to, evaporation, seepage, phreatophytes, and leakage in gates, spillways,

etc. in the CDN can be avoided by CCDN, in which, no such losses occur.

6) Water logging can be minimized.
7) CCDN is feasible in any type of strata i.e. hard rock, BC soil, saline land etc.
8) Advanced technologies such as drip, sprinklers, sub-surface irrigation system of irrigation can be implemented.
9) May be operated 24x7x365 basis.
10) 'Equitable water supply' and 'from tail to head', irrigation principle may be achieved.
11) Accurate volumetric supply of water can be ensured. So that volumetric water pricing mechanism can be established. This results in more crop per drop of water.
12) Minimized manual control involved in operation of network.
13) The man-hours needed in the piped systems range from one-tenth to one-quarter of those required for open canals. Any person can easily operate the piped systems, while the open canals can require skilled labour.

15. LIMITATIONS OF PIPE NETWORK

1) Great care in design and construction of CCDN in required.
2) Silt must be extracted from water before feeding to CCDN.
3) Being recent topic in India, more study and experience in this field is required.

16. CONCLUSION

India is not a water deficit country, but due to severe neglect and lack of monitoring of water resources development projects, several regions in the country experience water stress from time to time. Further neglect in this sector will lead to water scarcity during the next 1-2 decades. It is therefore necessary to prevent this crisis by making best use of the available technologies and resources to conserve the existing water resources, convert them into utilisable form and make efficient use of them for agriculture, industrial production and human consumption. Imposing regulatory measures to prevent the misuse of water and introducing rewards and punishment to encourage judicious use of water, will be helpful to conserve water. Awareness and orientation of all the water users to change their lifestyle to conserve water, can help the country to tide over the water crisis in the future. The challenge is manageable provided we have favourable policies and mechanisms to persuade our people to change their lifestyle by efficient water use.

Irrigation is one of the major sector, using about 80% of water. The water is supplied to the individual farm of command area by means of open canal distribution system by means of gravitational force. The design efficiency of such canals due to various inherent losses is only 40%, whereas operational efficiency is about 25% to 40% depending upon terrain, soil characteristics, maintenance etc. In this paper, it has been explained that using gravity based CCDN improves overall water use efficiency to 70 to 80 % as only frictional loss is major component of loss, and other losses including seepage, evaporation, leakage can be substantially controlled. Therefore, it is recommended to implement CCDN over all ongoing Lift Irrigation Schemes (LIS) as pressure head is easily available and other ongoing irrigation projects as well in first phase. In second phase conversion of existing CDN in to CCDN in part or whole command area, depending on techno-economic feasibility may be exercised.

The irrigation water requirement of Indian Agricultural sector in 2050 can be curtailed from 807 km^3 to half of that by improving water use efficiency from 40% to 80%. Therefore, only 404 km^3 water will be sufficient for the irrigation sector to irrigate the same area. Thus the total need for water in 2050 becomes 777 km^3 which can be fulfilled by available water of 829 km^3. This allows policy maker to allot balanced water to another sector. Thus closed conduit irrigation water distribution system can mitigate the water crisis in 2050.

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DISCLAIMER

Views expressed in this paper are those of the authors and do not necessarily reflect those of the department or governments.

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