

Planning and Design for Pipe Distribution Network for Distributory No. 4 on Talegaon Branch Canal of UPLBC

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Abstract: *Efficient water distribution is essential for improving irrigation performance and conserving water resources. This project focuses on the planning and design of a Pipe Distribution Network (PDN) for Distributory No. 4 on the Talegaon Branch Canal of UPLBC using WaterGEMS software. The study involves collection of survey data, contour mapping, plot verification through Bhunaksha, chak planning, and hydraulic analysis of the command area. The pipeline network was designed to ensure adequate pressure, acceptable flow velocity, and minimum head loss throughout the system. WaterGEMS was used to model and simulate the network, helping to optimize pipe sizes, alignment, and hydraulic components such as valves and delivery chambers. The proposed PDN system offers better water conveyance efficiency, reduces seepage and evaporation losses, and ensures equitable water distribution to farmers. The study demonstrates that a properly designed pipe distribution system can improve irrigation efficiency, support sustainable water management, and enhance agricultural productivity.*

Keywords: Pipe Distribution Network (PDN), WaterGEMS, Irrigation Engineering, Hydraulic Analysis, Bhunaksha, Chak Planning, Water Management, Head Loss, Hydraulic Grade Line (HGL), Irrigation Efficiency.

I. INTRODUCTION

Water is one of the most valuable natural resources and plays a vital role in agricultural production. In a country like India, where agriculture supports a large portion of the population, efficient utilization of available water resources is essential for sustainable development. Conventional irrigation systems based on open canals often experience significant water losses due to seepage, evaporation, weed growth, and unauthorized withdrawals, resulting in reduced irrigation efficiency and uneven water distribution [1].

To overcome these limitations, Pipe Distribution Networks (PDNs) have emerged as an effective alternative for irrigation water conveyance. A PDN transports water through closed pipelines under controlled hydraulic conditions, minimizing transmission losses and ensuring equitable distribution of water to agricultural fields [2]. Such systems improve water use efficiency, reduce maintenance requirements, and enhance the reliability of irrigation operations [3].

The planning and design of a Pipe Distribution Network require careful consideration of several factors, including command area characteristics, crop water requirements, topography, hydraulic conditions, and pipe material selection [4]. Accurate hydraulic analysis is necessary to determine suitable pipe diameters, flow velocities, pressure distribution, and head losses throughout the network [5]. Modern hydraulic modeling software has significantly improved the accuracy and efficiency of irrigation network design by enabling detailed simulation and optimization of complex pipeline systems [6].



WaterGEMS is a widely used hydraulic modeling software that provides advanced tools for designing, analyzing, and optimizing water distribution networks. The software helps engineers evaluate flow conditions, pressure variations, hydraulic grade lines, and system performance under different operating scenarios [7]. The use of WaterGEMS allows designers to identify critical sections of the network and develop economically feasible solutions while maintaining hydraulic stability [8].

In addition to hydraulic design, modern irrigation planning also utilizes geospatial and cadastral information for accurate command area assessment. The Maharashtra BhuNaksha portal provides plot-level land records and boundary information that assist in chak planning, outlet positioning, and pipeline alignment preparation [9]. Integration of such spatial data with hydraulic modeling improves the overall effectiveness of irrigation planning and management.

The present project focuses on the planning and design of a Pipe Distribution Network for Distributory No. 4 on the Talegaon Branch Canal of the Upper Pravara Left Bank Canal (UPLBC). The study involves data collection, contour analysis, chak planning, hydraulic design, pipe material selection, and network simulation using WaterGEMS software. The objective is to develop an efficient irrigation distribution system that minimizes water losses, ensures adequate pressure at outlets, and promotes effective water management for the command area [10].

II. PROBLEM STATEMENT

Traditional open canal irrigation systems suffer from significant water losses due to seepage, evaporation, and inefficient water distribution, resulting in reduced irrigation efficiency and unequal water availability to farmers, especially in tail-end areas. In the command area of Distributory No. 4 on the Talegaon Branch Canal, there is a need for a reliable and efficient water conveyance system that can minimize losses, ensure adequate pressure and discharge at all outlets, and provide equitable distribution of irrigation water. Therefore, the planning and design of a Pipe Distribution Network (PDN) using WaterGEMS software is essential to optimize hydraulic performance, improve water management, and enhance agricultural productivity in the command area.

III. OBJECTIVES

- To collect and analyze command area, survey, and contour data for PDN planning.
- To develop an efficient chak layout and pipeline alignment for uniform water distribution.
- To design the Pipe Distribution Network by determining suitable hydraulic parameters.
- To perform hydraulic modeling and optimization using WaterGEMS software.
- To enhance irrigation efficiency by reducing water losses and improving water management.

IV. LITERATURE SURVEY

Government of Maharashtra (2017) presented comprehensive guidelines for the planning and design of Pipe Distribution Networks (PDN) in irrigation projects. The manual emphasized hydraulic design criteria, pipe material selection, valve placement, and Hydraulic Grade Line (HGL) analysis to improve irrigation efficiency and reduce water losses. The study highlighted the advantages of replacing conventional open canals with closed pipeline systems for equitable water distribution.

Ministry of Water Resources (2017) published guidelines for the planning and design of pipe irrigation systems focusing on water conservation and efficient conveyance. The document discussed discharge estimation, pressure management, head loss calculations, and network optimization techniques. The guidelines recommended the use of hydraulic modeling tools for developing reliable and economical irrigation networks.



Reddy and Rao (2020) carried out a hydraulic analysis of irrigation pipe networks using WaterGEMS software. Their study evaluated pressure distribution, flow velocity, and discharge behavior within the network. The results demonstrated that WaterGEMS provides accurate hydraulic simulation and helps optimize pipeline design while maintaining adequate pressure throughout the system.

Singh and Choudhary (2019) conducted a comparative study between conventional canal irrigation systems and Pipe Distribution Networks. The researchers observed that PDN systems significantly reduced seepage and evaporation losses while improving water delivery efficiency. The study concluded that pipeline-based irrigation systems offer better operational control and water management.

Joshi and Kulkarni (2018) investigated the importance of Hydraulic Grade Line (HGL) analysis in pressurized irrigation systems. Their research showed that proper HGL management is essential for maintaining sufficient pressure and preventing hydraulic failures. The study emphasized the role of profile analysis and hydraulic calculations in ensuring efficient pipeline performance.

Gupta and Meena (2019) studied head loss behavior in irrigation pipelines using the Modified Hazen-Williams equation. Their research highlighted the importance of accurate head loss estimation for selecting suitable pipe diameters and maintaining desired flow conditions. The study concluded that proper hydraulic design contributes to the overall efficiency and economic feasibility of irrigation distribution networks..

Comparison Table

Author & Year	Method Used	Advantages	Limitations
Government of Maharashtra (2017)	PDN planning guidelines, HGL analysis, pipe selection	Improves irrigation efficiency and reduces water losses	Limited focus on site-specific conditions
Ministry of Water Resources (2017)	Hydraulic design and network optimization guidelines	Provides standardized design procedures	Requires accurate field data for implementation
Reddy and Rao (2020)	Hydraulic modeling using WaterGEMS software	Accurate pressure and flow analysis	Dependent on software input accuracy
Singh and Choudhary (2019)	Comparison of canal and pipe irrigation systems	Reduces seepage losses and improves water distribution	Higher initial installation cost
Joshi and Kulkarni (2018)	Hydraulic Grade Line (HGL) analysis	Ensures adequate pressure throughout the network	Requires detailed topographical data
Gupta and Meena (2019)	Head loss analysis using Hazen-Williams equation	Helps in economical pipe sizing and design	Assumes steady flow conditions only

IV. WORKING OF SYSTEM

1. Data Collection Using BhuNaksha

The working process begins with the collection of survey maps, contour maps, command area details, crop patterns, and irrigation demand data.



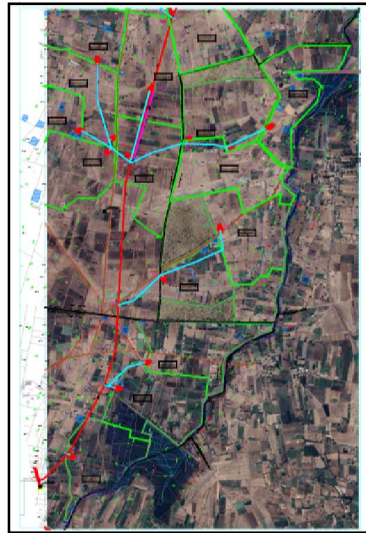


Fig: Integration

2. Plot Boundary Identification

BhuNaksha cadastral maps are used to identify survey numbers, plot boundaries, and land ownership details within the command area.

3. Chak Planning

The entire command area is divided into smaller irrigation units known as chak areas.

4. Pipeline Alignment Preparation

Based on topographical conditions and field survey data, the most suitable pipeline route is selected.

5. Water Requirement Calculation

The irrigation water demand is calculated using crop water requirements, command area size, irrigation efficiency, and operational considerations.

6. Hydraulic Design of Network

Hydraulic calculations are performed to determine pipe diameters, flow velocity, pressure, and head loss.

7. WaterGEMS Modeling

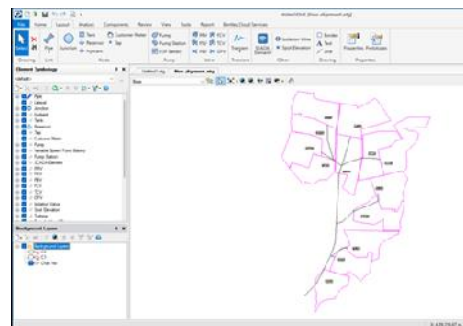


Fig.2 Preliminary PDN Alignment in WaterGEMS



The complete Pipe Distribution Network is developed in WaterGEMS software. Nodes, pipes, elevations, demands, and hydraulic parameters are entered to create a simulation model.

8. Hydraulic Analysis and Optimization

The software analyzes flow distribution, pressure conditions, velocity, and Hydraulic Grade Line (HGL). Necessary modifications are made to optimize the network and improve performance.

9. Design of Hydraulic Components

Essential components such as air valves, scour valves, sluice valves, delivery chambers, and flow meters are designed and positioned at appropriate locations for efficient operation.

10. Water Distribution and Monitoring

After finalization of the design, water is conveyed through the pipeline network and distributed to individual chak outlets. The system provides controlled, uniform, and efficient irrigation while minimizing water losses.

V. SYSTEM DESIGN

The proposed Pipe Distribution Network (PDN) is designed to provide an efficient, reliable, and controlled irrigation water distribution system for Distributory No. 4 of the Talegaon Branch Canal. The system utilizes a pressurized pipeline network instead of conventional open canals to reduce water losses and improve irrigation efficiency. The design integrates survey data, BhuNaksha plot information, hydraulic calculations, and WaterGEMS simulation to develop an optimized irrigation network capable of supplying water uniformly throughout the command area.

The network consists of a water source, main pipeline, branch pipelines, delivery outlets, control valves, and monitoring components. Water is conveyed through pipelines under pressure and distributed to individual chak areas according to their irrigation demand. The system is designed to maintain adequate pressure, acceptable flow velocity, and minimum head loss at all delivery points.

3.2 Components of the System

1. Water Source

The Talegaon Branch Canal serves as the source of water supply for the Pipe Distribution Network. Water enters the pipeline system through the offtake structure.

2. Main Pipeline Network

The main pipeline carries water from the source to different sections of the command area. It is designed to handle the maximum discharge requirement while minimizing hydraulic losses.

3. Branch and Distribution Pipelines

Branch pipelines distribute water from the mainline to individual chak areas. Their diameters are selected based on discharge requirements and pressure conditions.

4. Junction Nodes

Junctions are provided at pipeline intersections and branching points. These nodes help in controlling flow distribution within the network.

5. Air Valves

Air valves are installed at ridge points to release trapped air and prevent air-locking conditions within the pipeline.



6. Scour Valves

Scour valves are provided at low points of the network to remove sediment deposits and facilitate pipeline flushing operations.

7. Sluice Valves

Sluice valves are used for flow regulation, isolation of pipeline sections, and maintenance activities.

8. Delivery Chambers and Outlets

Delivery chambers are constructed at chak locations to provide controlled water supply to agricultural fields.

9. WaterGEMS Hydraulic Model

The complete network is modeled in WaterGEMS software for hydraulic simulation, pressure analysis, velocity verification, and network optimization.

10. Monitoring and Control System

Flow meters and hydraulic monitoring points are incorporated into the network to measure discharge and evaluate system performance during operation.

3.3 Design Features

- Closed pipeline system for reduced seepage and evaporation losses.
- Uniform water distribution to all chak areas.
- Optimized pipe diameters based on hydraulic analysis.
- Adequate pressure maintained throughout the network.
- Provision of control valves for safe and efficient operation.
- WaterGEMS-based hydraulic modeling for accurate design verification.
- Improved irrigation efficiency and water conservation.

The hydraulic calculations for all pipe reaches were carried out using Excel and WaterGEMS software.

Hydraulic Calculation Table

Pipe	Length (m)	Flow (LPS)	Diameter (mm)	Head Loss (m)	Velocity (m/s)
P-1	160	1860.24	1400	0.108	1.27
P-2	915	1850.31	1400	0.611	1.27
P-3	910	1833.06	1300	0.853	1.46
P-4	205	1825.06	1300	0.191	1.45
P-5	220	1815.63	1300	0.203	1.44
P-6	135	1045.76	1000	0.162	1.40



P-7	900	976.74	1000	0.954	1.31
P-8	320	955.54	1000	0.332	1.30
P-9	325	944.09	1000	0.324	1.27
P-10	2220	819.04	900	2.840	1.36
P-11	1560	693.40	800	2.601	1.45
P-12	1995	577.32	800	2.388	1.21
P-13	1225	444.41	710	2.229	1.35
P-14	1425	324.74	560	4.599	1.59
P-15	1515	195.42	500	3.364	1.20
P-16	1360	94.94	355	4.251	1.15
P-17	645	76.67	315	2.436	1.18
P-18	300	43.47	250	1.233	1.07
P-19	760	31.42	200	5.079	1.20
P-20	145	18.72	160	1.113	1.12
P-21	215	9.39	110	2.877	1.19

Result: Hydraulic Gradient = **0.675 m/km.**

VI. MATHEMATICAL EQUATIONS

4.1 Head Loss Calculation

Head loss is the reduction in hydraulic energy that occurs when water flows through a pipeline due to friction between the water and the inner surface of the pipe. In a Pipe Distribution Network, excessive head loss can reduce the available pressure at delivery points and affect irrigation performance. Therefore, head loss must be calculated to ensure efficient water conveyance and proper selection of pipe diameter.

Formula

$$H_f = \frac{10.67 \times L \times Q^{1.852}}{C^{1.852} \times D^{4.87}}$$

4.2 Velocity Calculation

Velocity represents the speed at which water travels through the pipeline. Maintaining an appropriate velocity is important for efficient operation of the irrigation system.

Formula

$$V = \frac{Q}{A}$$

4.3 Hydraulic Gradient Calculation

Hydraulic gradient is calculated as:

Formula

$$S = \frac{H_f}{L}$$

VI. RESULTS

The planning and design of the Pipe Distribution Network (PDN) for Distributory No. 4 on the Talegaon Branch Canal were successfully completed using hydraulic calculations and WaterGEMS software. The performance of the proposed network was evaluated in terms of water requirement, hydraulic efficiency, pressure distribution, head loss, velocity, pipe material selection, and overall operational feasibility. The obtained results indicate that the proposed PDN system provides reliable water conveyance with minimum losses and improved irrigation performance throughout the command area.



5.1 Results and Discussion

Figure 5.1 presents the comparison between the irrigation efficiency of a conventional open canal system and the proposed Pipe Distribution Network system. The analysis shows that the irrigation efficiency of the open canal system is approximately 60%, whereas the efficiency of the Pipe Distribution Network reaches about 90%.

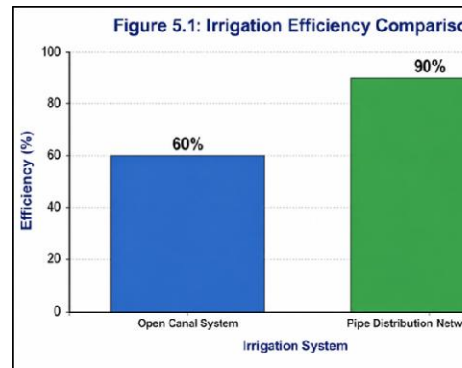


Fig.3. Irrigation Efficiency Comparison

The water requirement analysis confirmed that the calculated discharge was adequate to satisfy the irrigation demand of the entire command area. The adopted six-day ON and six-day OFF water distribution schedule was found suitable for maintaining a continuous and equitable water supply. Proper estimation of water demand also assisted in selecting appropriate pipe diameters and maintaining the required pressure conditions throughout the network.

The hydraulic analysis performed using WaterGEMS software demonstrated that adequate pressure was available at all outlets and no negative pressure conditions were observed. The Hydraulic Grade Line remained stable throughout the network, ensuring smooth and uninterrupted water flow. Flow velocities were maintained within the recommended range, preventing sediment deposition as well as excessive pressure surges.

Head loss calculations showed that friction losses remained within permissible limits for all pipeline sections. The selected pipe diameters effectively minimized energy losses and contributed to improved hydraulic performance. The use of PCCP pipes in larger diameter sections and HDPE pipes in smaller diameter sections provided an economical and durable solution for the irrigation network.

The finalized pipeline alignment minimized road crossings and excessive excavation while maintaining suitable hydraulic conditions. Proper placement of air valves, scour valves, and sluice valves enhanced operational safety, maintenance efficiency, and overall system reliability.

Overall, the results confirm that the proposed Pipe Distribution Network is hydraulically efficient, technically feasible, and economically beneficial. The considerable increase in irrigation efficiency from 60% to 90% demonstrates the effectiveness of the PDN system in improving water conservation, ensuring uniform water distribution, and enhancing agricultural productivity in the command area.

VII. CONCLUSION

The present study successfully developed a Pipe Distribution Network (PDN) for Distributory No. 4 on the Talegaon Branch Canal using hydraulic design principles and WaterGEMS software. The proposed system was found to provide efficient and reliable water distribution with adequate pressure, acceptable flow velocity, and minimum head loss throughout the command area. The use of a closed pipeline network significantly reduces seepage and evaporation losses compared to conventional canal irrigation systems, resulting in improved water use efficiency and better irrigation management. The integration of survey data, BhuNaksha-based plot information, chak planning, and hydraulic modeling contributed to an optimized and technically feasible design. Overall, the proposed PDN offers a



sustainable solution for water conservation, equitable distribution of irrigation water, and enhanced agricultural productivity.

VIII. FUTURE SCOPE

The designed Pipe Distribution Network can be improved in the future by adopting modern water management practices and automation techniques. Real-time monitoring of flow and pressure can be implemented to improve system operation and reduce water wastage. Further studies may focus on expanding the network to additional command areas, improving irrigation scheduling based on crop requirements, and evaluating the long-term performance of the system under varying field conditions. The use of advanced planning tools and digital technologies can also support better decision-making, enhance water conservation, and increase the overall effectiveness of irrigation management.

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