Implementation of District Metering Area (DMA) in Zone 11 of Water Distribution Network of Ambikapur Town for Effective Water Management

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ABSTRACT - Water being the basic requirement to fulfil the needs of the growing population of developing cities, needs to use effectively, which leads to the need to upgrade the WDN (Water Distribution Network). Conventional WDN has some flaws due to which there is problem of NRW (Non-revenue water) which lost in various form such as due to thefts, leakages, unauthorized use of water, etc. which needs to be rectified.

To repair this, regular monitoring is required. But the complexity of the WDN due to many factors such as large size, hydraulic functioning and growing urban areas make the planning, analysis and management difficult. So, the solution to this problem is the segmentation of the network i.e., Divides the network into different parts, which will ultimately reduce the size of the network and will be easy to monitor the flow in WDN.

DMA (District Metering Areas) is the best method to cluster the network into different parts. Formation of DMA includes locating isolation valves, flow meters etc., due to which the network gets divided into different districts. This makes it easy to assess whether the water is supplied with adequate quality, quantity, sufficient pressure and it also helps to improve the quality of network and reduces the breakdowns in the network.

***Key Words*: District Metered Areas, Non-Revenue Water, WaterGems, Pressure Management**.

1. INTRODUCTION

In the past few decades increased population and urbanization have led to exponential growth in the water demand. Catering to this increased demand requires the water distribution network to be hydraulically efficient as wells as micro manageable.

Every municipal corporation is on a verge of converting its water distribution into a smart water distribution network while achieving the status of a smart city. Further 24X7 water supply schemes have also been initiated and even completed in most of the areas. However, the losses and theft contribute to the major hurdle in the generation of revenue which results in less maintenance of the network. Due to mismanagement of water, there are still around 40% of losses which results in water scarcity problems.

As a result, the reduction of Non-Revenue Water (NRW) is a major concern and its reduction will improve water management and result in increased revenue prospects. District Metered Areas (DMAs) is one of the most promising methods of improving the water supply efficiency. Implementation of same to zone 11 of Ambikapur city has shown promising results specially in case of pressure management in individual DMAs.

1.1 METHODOLOGY

For the case study Zone 11 of Ambikapur town is selected. The data required was population of selected area and topographic data. The next step was to forecast the water demand based on the forecasted population for the Design Period. The population was forecasted for a period of next 30 years and based on that population, demand is calculated. The population forecasting is done by five methods. Water demand was calculated separately for domestic and commercial usage.

After demand calculation the DMAs is demarcated in the network based on the population distribution and elevations. After DMA demarcation modifications are to done to the existing network i.e., pipe diameter, material and location of water meters and cut off valves will be decided. Further in critical segments in the modified network will be analyzed. Hydraulic simulations will be performed on the network with the help of WaterGEMS software and the network giving optimum results will be proposed for the selected area.

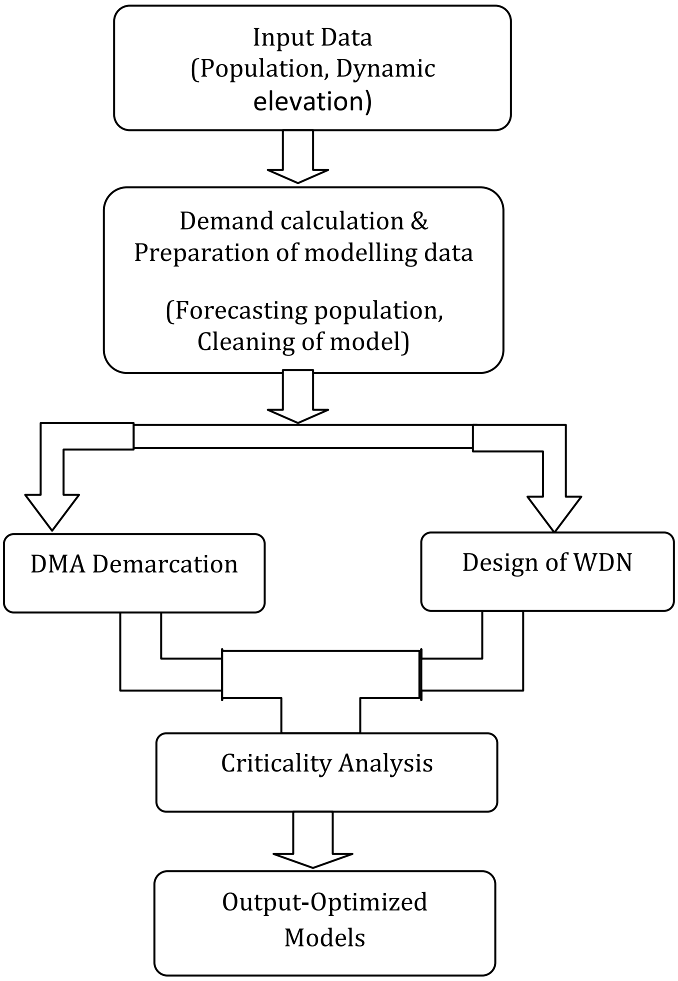


Fig -1: Methodology of Research work

2. CASE STUDY

Ambikapur is located at 338 KM from Raipur, 177 KM from Korba and 224 KM from Bilaspur. Ambikapur located at 23°12′N 83°2′E. has an average elevation of 623 meters. It is spread over area of 40.17 Km^2. Ambikapur is divided under 16 zones out of which zone 11 is considered as the case study. Majority of the terrain is forested and hilly.

For the design of network, the population is forecasted for next 30 years and it can be seen that the population is increasing gradually over a span of 15 years each. So, the forecasted population is used for the water demand calculation.

Table -1: Summary of Population forecast

Description	Project Horizon	Projected Population	Floating Population	Total Population
Base Year	2020	140419	14,042	1,54,461
Intermediate Year	2035	165463	16,546	1,82,010
Ultimate Year	2050	190508	19,051	2,09,559

In table 1 shows population obtained from Arithmetic Method and the same is taken in to consideration keeping in mind the previous constant growth of the city. Table 2 shows the demand calculations.

Table -2: Water Demand for Design year

Description	Water Demand (MLD)		
	2020	2035	2050
Residential Demand @135 lpcd	19.58	25.33	32.72
Hotels @ 180 lit/bed/day	0.11	0.16	0.19
Institutional @45 lpcd	0.17	0.23	0.28
Hospitals @340 lit/bed/day	0.28	0.39	0.47
Fire Fighting Demand	1.20	1.37	1.56
Add for UFW @15%	3.20	4.12	5.28
Total Demand	24.55	31.60	40.50

The following pipe diameters are mostly used in practice. Along with that several other diameters are also available in the market. From different pipe materials HDPE and Ductile Iron are selected as it possesses good life span and also HDPE has outstanding fatigue resistance.

Table -3: Various pipe diameters and their material used in Modelling

Internal Diameter (mm)	Material	Hazen William C
76	HDPE	145
93		

118		
169		
203		
250	Ductile Iron (K7)	140
300		
350		
400		
500		
700		
800		

3. VALVES USED IN WDN

- Isolation Valve: Isolation valves are the valves in the network which are used to stop the flow of media at a given location. These valves can be operated in fully closed or fully opened condition. Generally, these valves are used for conducting the repairing work in the network.
- Pressure Reducing Valve: These types of valves are used to maintain the desired pressure in the network. These valves are located at points of variable pressure. Once the required pressure value is set in the valve, that pressure will be maintained on the downstream side of the valves regardless of the variation in the supply pressure and network load variations.

3.1 DMA DEMARCATION AND HYDRAULIC MODELING

These two steps should be done simultaneously. The general procedure of hydraulic modeling includes following.

3.1.1 Data Acquisition: It is very important to carry out any operation. The following data is required –

- Geographic and terrain data (DTM, TIN, road networks)
- Population data and population forecast data
- Demand forecast data (as per city development plan)
- Material availability data
- Existing network (if any)

3.1.2 Data Processing: Once the data is acquired, it is analyzed and made ready for modeling process. This process includes-

- Setting the Units
- Importing the Contour shape file and setting it as background
- Creating the Model using 'Model Builder'
- Cleaning the Network using 'Network Navigator'
- Laying the Tank as per the Existing Position
- Assigning the Demand to junctions using 'Load builder'
- Assigning elevations to the Junctions using the 'TRex' Tool
- Assigning the operational levels to the respective tanks
- Validating the Network

3.2 HYDRAULIC MODELING

Hydraulic modelling is done using the WaterGEMS. For networks spanning hundreds of kilometre it is better to go for part-to-whole designing. For this, the total network is divided into sub-parts.

Total 3 models were prepared for the WDN of zone 11.

Model 1- In the first model the basic objective was to satisfy the hydraulic requirements i.e minimum residual pressure and head loss gradient kept within limits.

Model 2- The second model which was prepared was an improvement over the first in sense of pipe diameter optimization, where goal was to reduce the length of various diameters of pipes used.

Model 3- In the third model the entry of DMA 2 was altered and the whole model was redesigned to facilitate uniform branching of pipes in DMA 2 which resulted in better distribution of water.

Fig-2: Model 1 (a) Pipe layout (b) Pressure heads and Head loss gradient

Fig. (a)

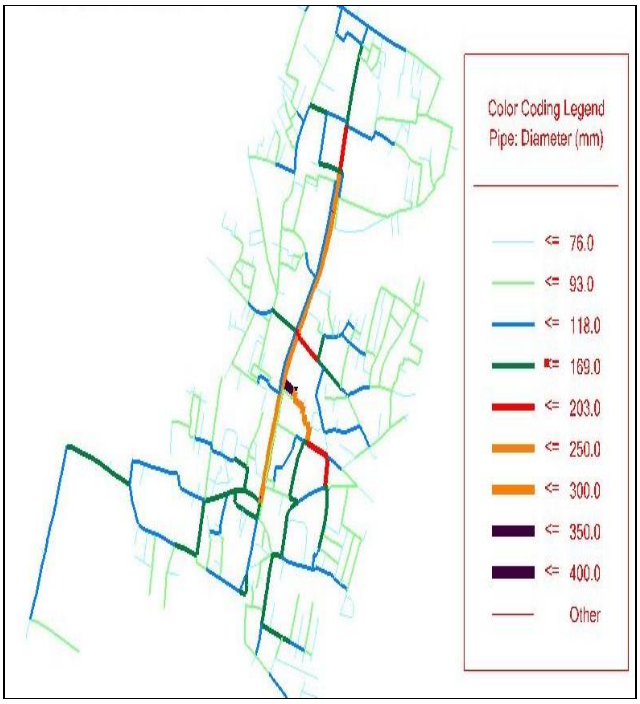


Fig. (b)

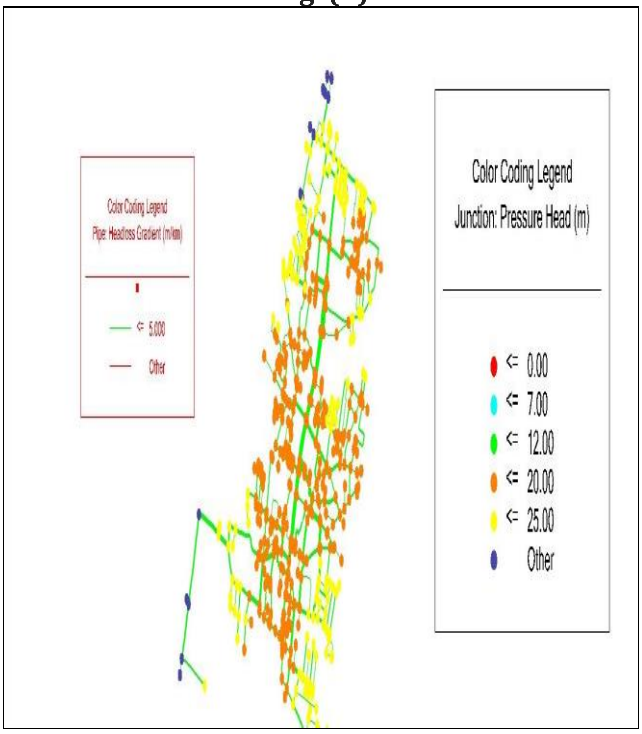


Table -4: Hydraulic parameters in model 1

Results	Model 1			
	Maximum	Mean	Minimum	Std Deviation
Pressure (Kpa)	307	185	132	31
Pressure Head (m)	31.37	18.9	13.53	3.15
Head Loss (m)	0.74	0.04	0	0.08
Head Loss Gradient (m/km)	4.61	0.585	0	0.78
Velocity (m/s)	1.22	0.19	0.2	0.2

Fig-3: Model 2 (a) Pipe layout (b) Pressure heads and Head loss gradient

Fig. (a)

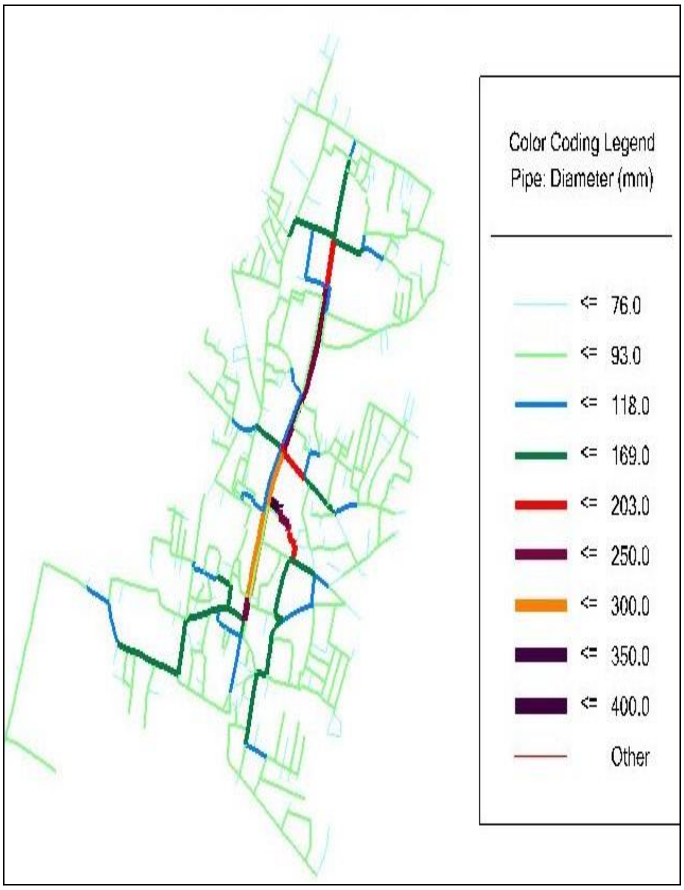


Fig. (b)

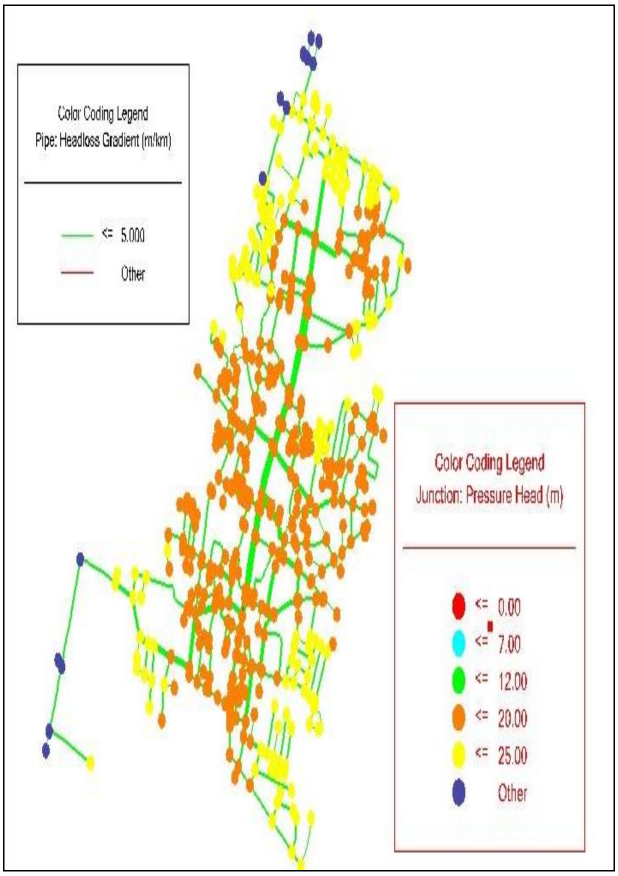


Table -5: Hydraulic parameters in model 2

Results	Model 2			
	Maximum	Mean	Minimum	Std Deviation
Pressure (Kpa)	287	183	133	30
Pressure Head (m)	29.28	8.65	13.54	3
Head Loss (m)	1.07	0.006	0	0.11
Head Loss Gradient (m/km)	4.84	0.735	0	1
Velocity (m/s)	1.22	0.21	0.1	0.22

Fig-4: Model 3 (a) Pipe layout (b) Pressure heads and Head loss gradient

Fig. (a)

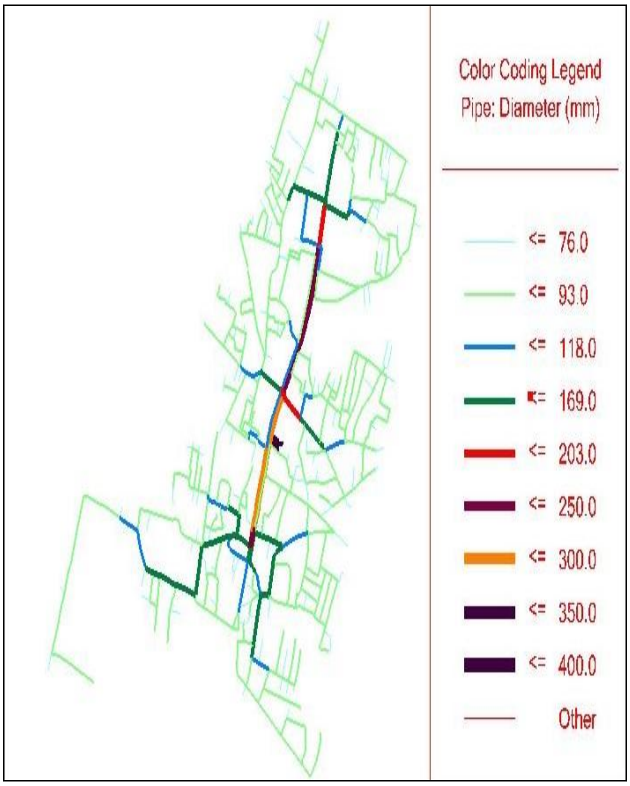


Fig. (b)

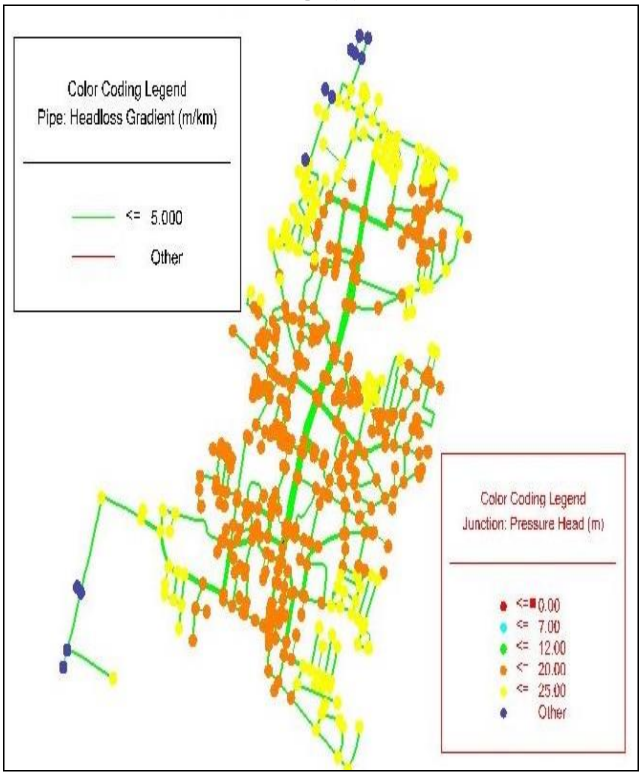


Table -6: Hydraulic parameters in model 3

Results	Model 1			
	Maximum	Mean	Minimum	Std Deviation
Pressure (Kpa)	280	181	133	30
Pressure Head (m)	28.65	18.5	13.58	3.05
Head Loss (m)	1.07	0.05	0	0.1
Head Loss Gradient (m/km)	4.845	0.717	0	0.98
Velocity (m/s)	1.22	0.2	0.1	0.22

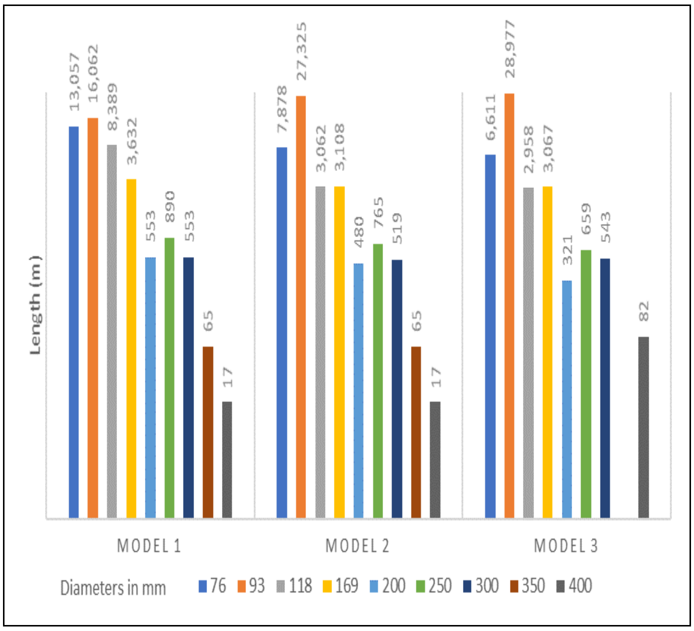
Table -7: Comparison of Hydraulic parameters of all 3 models

Results	Model 1	Model 2	Model 3
Pressure (Kpa)	185	183	181
Pressure Head (m)	18.9	8.65	18.5
Head Loss (m)	0.04	0.006	0.05
Head Loss Gradient (m/km)	0.585	0.735	0.717

Table -8: Length of pipes in all 3 models

Diameter (mm)	Total Pipe Length (m)		
	Model 1	Model 2	Model 3
76	13,057	7,878	6,611
93	16,062	27,325	28,977
118	8,389	3,062	2,958
169	3,632	3,108	3,067
203	553	480	321
250	890	765	659
300	553	519	543
350	65	65	0
400	17	17	82

Fig-5: comparison of length of pipes in models



It can be seen in fig 5 that the diameter has been optimized and it represents a hydraulically better option compared to the previous two due to the equitable distribution of water in model 3. Further for Pressure management model 3 was preferred for the same reason.

4. PRESSURE MANAGEMENT

Fig 6 shows that in top left-hand region of the DMA 1 there is formation of high-pressure head zone indicated by the Pink Junction color coding with pressure head ranging from 22 to 27m of water. The main reason for this to occur was the elevational difference between nodes near the entry and the nodes in the top left region. This resulted in greater flow to the highlighted junctions compared to the rest of the junctions within that DMA. This violates the objective of equitable flow and hence Pressure management within a DMA is done.

Fig-6: Residual pressures in DMA 1 before pressure management

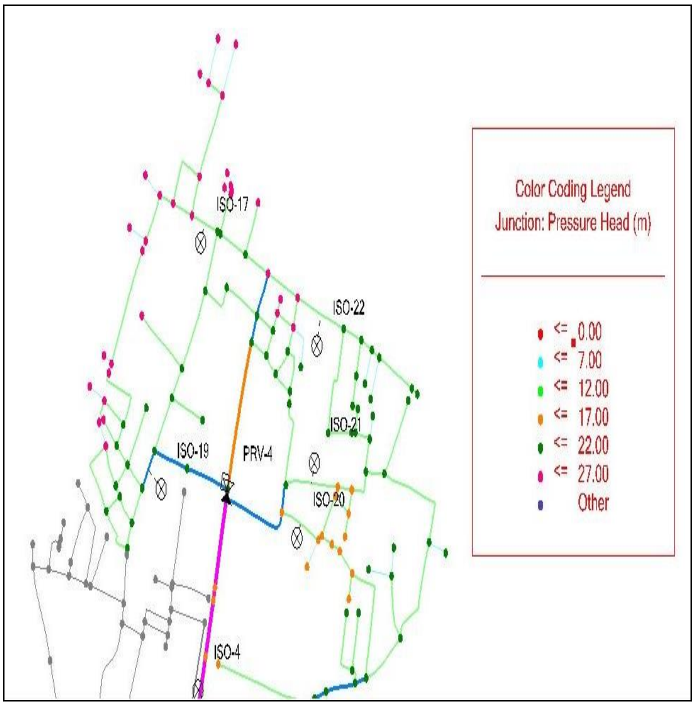
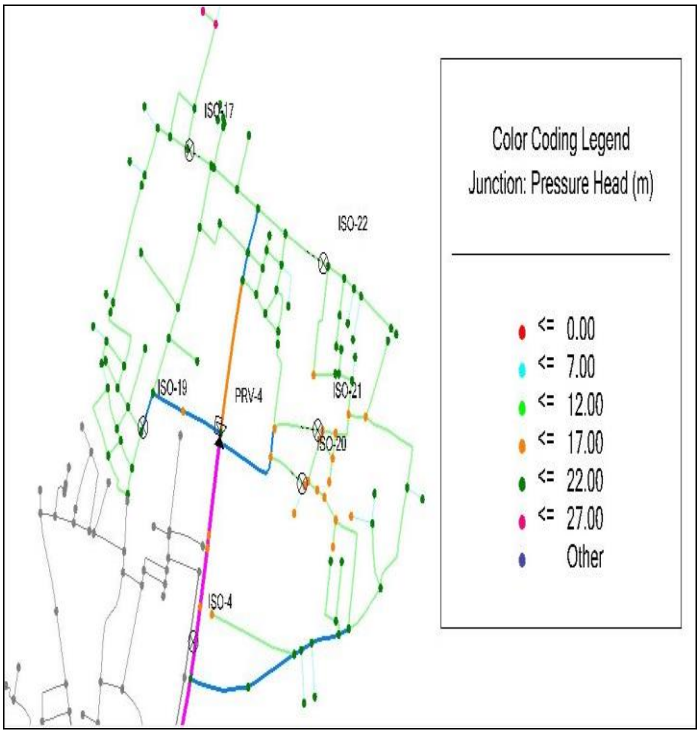
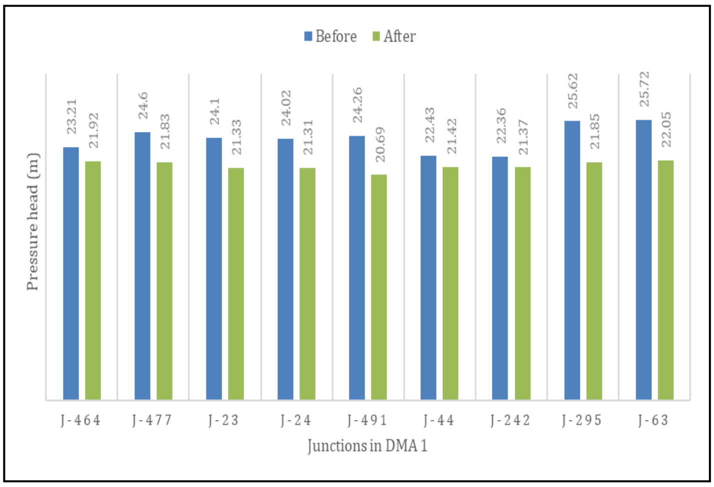


Fig-7: Residual pressures in DMA 1 after pressure management



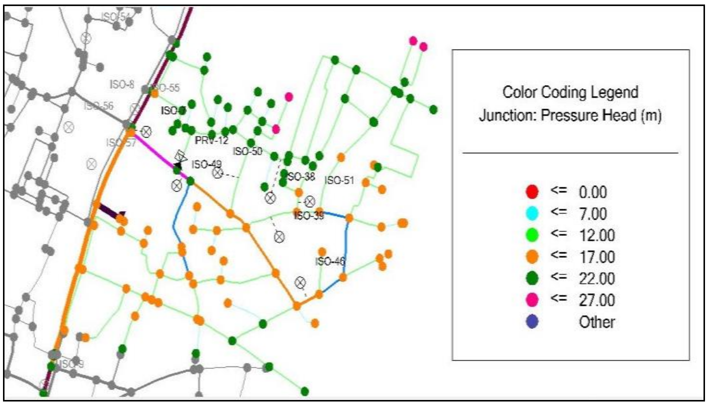
In pressure management optimum numbers of isolation valves are placed as shown in the fig no 6 and After the placement of Isolation valves it can be visually observed in fig 7 that the pressure head has been reduced. The values of some randomly selected junctions from DMA 1 before and after pressure management are as shown in the fig 8.

Fig-8: Comparison of pressure head before and after pressure management in DMA 1



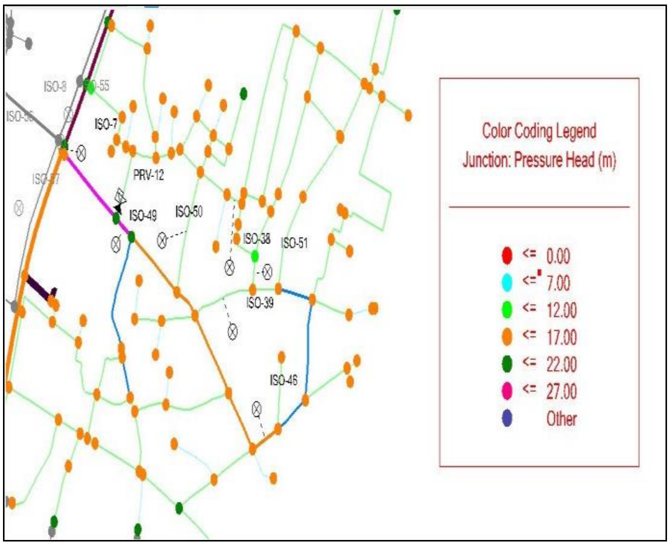
It can be seen in fig 8 that pressure heads have considerably reduced with the help of PRVs and isolation valves.

Fig-9: Residual pressures in DMA 5 before pressure management



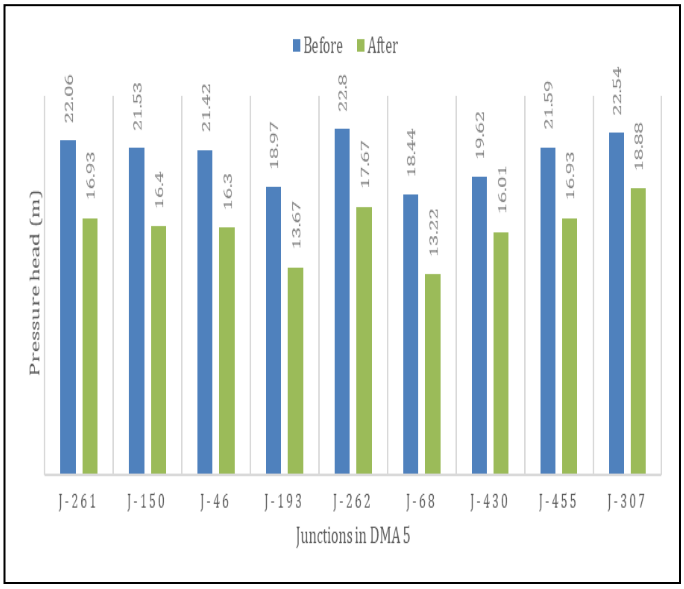
Similarly, it was observed that in the upper right reaches of the DMA 5 as indicated by green and pink color coding the pressure difference within that DMA exceeded, hence by appropriate placement of required PRVs and isolation values it was brought within range.

Fig-10: Residual pressures in DMA 5 after pressure management



The placement of isolation valves can be observed in fig 10, also it can be seen that the pressures are considerably reduced. The actual values of some randomly selected junctions within DMA 5 before and after the pressure management is shown in the fig 11.

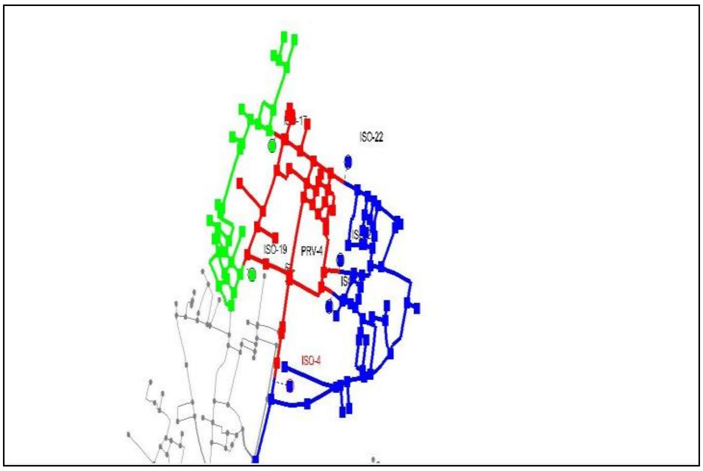
Fig-11: Comparison of pressure head before and after pressure management in DMA 5



5. CRITICALITY ANALYSIS

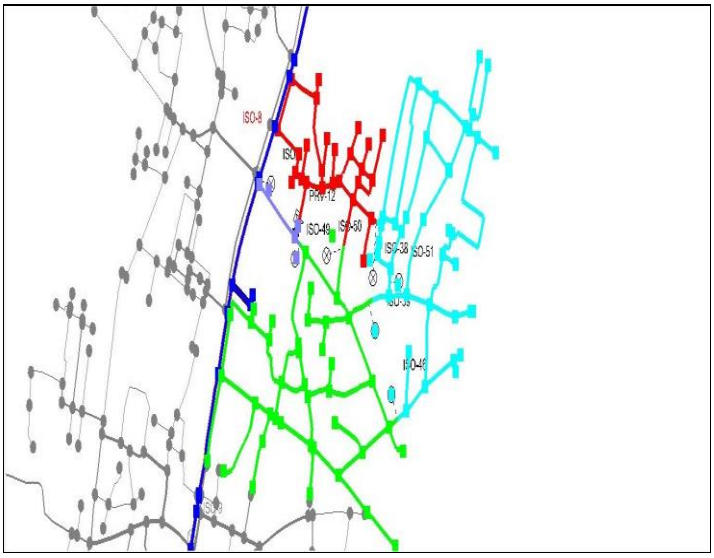
Criticality analysis involved identifying the critical segments within the DMAs. The Isolation valves placed at the appropriate positions helps in further macro management in case of breakdowns or repair works. It helped to identify the area affected by the operation of a particular isolation valve.

Fig-12: Critical segments within DMA 1



The Fig. 12 shows that in green color-coded area of the network gets affected by isolation valves no 19 and 17. The physical significance of this is that in order to isolate green colour coded area that valves are turned to inactive or closed state

Fig-13: Critical segments within DMA 5



The fig 13 shows critical segments within DMA 5. The study of critical segments helps in identifying segments of pipe that affect the network in case of a breakdowns.

6. RESULTS & CONCLUSIONS

In first glance it seems that the third hydraulic model has more capital cost than other two models but in the long run it will result in less operation and maintenance cost as it gives better hydraulic results in terms of head loss and residual pressure head within individual DMAs to counteract the continuous water supply, rapid leakage detection and will help to reduce the Non-Revenue Water.

Pressure Management results implied that after the proper placement of isolation valve and pressure reducing valve the network resulted in significantly reduced pressure head differences within junctions of a particular DMA. The placement of pressure reducing valve helps in equitable supply of water to every consumer by ensuring approximately equal flow to each junction in a DMA. The criticality analysis facilitates the further macro management of the network in case of breakdown or maintenance work and helps in better management of WDN network which results in better revenue generation.

DMA demarcation and hydraulic modelling are two simultaneous operations requiring probable modifications in every successive steps of planning WDN and hence the finalized DMA demarcation suggested for zone 11 of Ambikapur is as shown in Fig 14.

Fig-14: Finalized DMA demarcation consisting of five DMAs

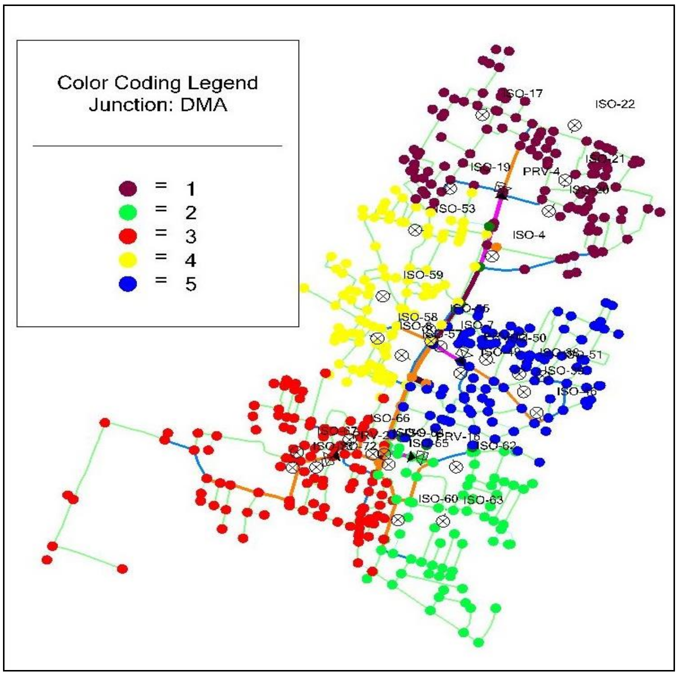
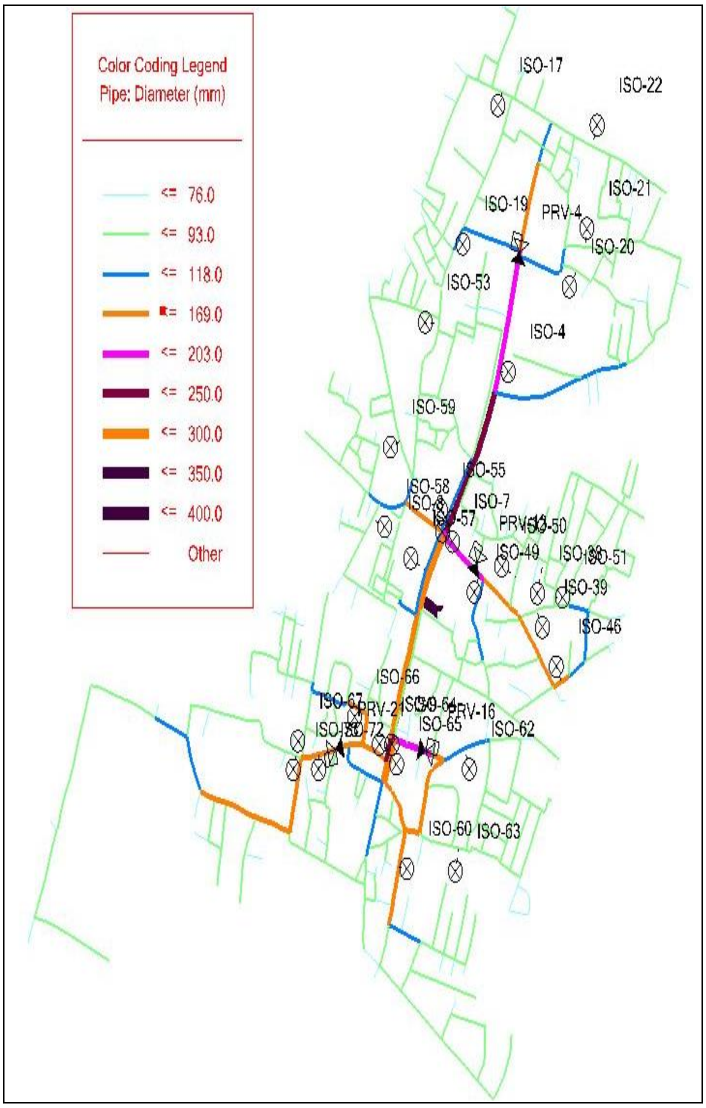


Fig. 15 shows the locations of Isolation valves and PRVs in the entire network for better pressure and WDN management. Greater pressure leads to more flow towards that node violating equitable supply for remaining nodes and hence location of Isolation and PRVs played critical role in present study.

Fig-15: Location of Isolation Valves and PRVs



So, the present study concludes that a small hydraulic network can be self-sufficient even without formation of DMAs. However, the scope and complexity of the network in Zone 11 causes the management of the network a tedious job. Provision of DMAs in Zone 11 helped in isolating the whole network into manageable scale. The single-entry concept of DMA helps in monitoring inflow into a DMA and facilitates better water auditing. The proper operation of different valves within a DMA can help in diverting the flow in a specific area of zone 11 as per the required scenario, also criticality analysis helps in identifying critical segments and their effects on the system. During Night hours when demand is low the PRVs are utilized to further reduce pressure which in turn helps in leakage deduction. Night Step test (Isolation Step Test) can be used to find out the leaking segment of network which helps to reduce the share of Non-Revenue water. Future scope of the work can be to achieve equitable pressures in clusters of DMAs collectively i.e., entire zone.

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