# FEASIBILITY ANALYSIS AND DESIGN OF WATER DISTRIBUTION SYSTEM FOR TIRUNELVELI CORPORATION USING LOOP AND WATER GEMS SOFTWARE

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## Abstract

Water supply in Tirunelveli Corporation is not evenly distributed due to undulating terrain and increase in population density. A study was undertaken to suggest measures for improvement to the distribution system. The paper presents results of analysis carried out using computer package LOOP developed by World Bank and Bentley Systems, 2008, Water Gems for optimal design of distribution system including cost analysis and reorganization measures needed for the design year 2044. The analysis of zone-III of the distribution network indicates that existing pipes need to be rehabilitated to cater to the demand for the year 2044 and CI/AC/PVC pipes needs replacement for the year 2044. New pipelines are to be proposed to ensure the service standards of 135l pcd with minimum residual head of 7 m. The network analysis with rate analysis with aid of software LOOP developed by World Bank and Bentley Water Gem has been made and Bentley Water Gems is found to be extremely user friendly for addressing such systems with varying demand pattern, peak factors, pipe condition, water supply modes and design horizons. In additions it has graphical interface which facilitate analyses more effective and lesser time requires to reanalyse the network.

## I. INTRODUCTION

Tirunelveli City is district head quarters of Tirunelveli District situated at a distance of about 600 Km south of Chennai City. Tirunelveli City Corporation has 55 wards. The distribution network system is serving for a longer period and due to aging, network components like CI pipes are corroded and AC mains are incursion condition and thus leaking. Furthermore there is no further extension of network on newly expanded area. Hence considering the need of the town "Remodeling distribution System" and construction of Over Head Tanks in Tirunelveli Town is required Tamil Nadu Government accorded approved for Water Supply Improvement system.

This project is being implemented to improve the water supply system, to minimize the leakage, and to optimise the water availability to the consumers. It was also intended to check the capability of existing water supply system components for 24 $\times$ 7 water supply and thus optimizing the cost of a project (Chuenchom, et al., 2009)

Remodeling plan of water distribution system (24 $\times$ 7) has considering every factor such as geographical conditions, demand assessment for entire town, future growth considering population density of each subzone, pressure, frictional losses, pipe size, losses etc. using pipe network analysis Moody and sophisticated software 'Water GEMS' from Bently /Loop of World Bank systems.

## II. STUDY AREA DESCRIPTION

Tirunelveli Municipal Corporation (TMC) commands a pivotal position in the southern region of Tamilnadu. The city is a popular pilgrimage and educational centre. It was known as the 'Oxford of Tamilnadu' in the sixties of the last century, because of the establishment of several colleges and other educational centers in the city. It is also known as one of the twin towns – Tirunelveli and Palayamkottai. The river Thamaraiparani flows bifurcates town. The city's growth has been stifled due to the lack of proper planning efforts and untapped revenue generation potential across sectors. The city has taken up measures to improve the existing situation, but it has met with limited success, as it lacks an integrated approach to town development. Over the last decade, the population of the town has increased from 321,445 in 1991 to 411,257 in 2001 with a decadal growth of 27.94%, which is higher than the state average of 14.94%. The annual growth during the same period was 2.51% p.a. The town is spread over an area of

108.65 sq. km covering 55 wards. The gross population density has increased to 3781 persons per sq. kilometer in 2001 from 2218 persons per sq. km in 1971 Detailed Project Report of Tirunelveli Corporation – Volume-I (STC PVT LTD)

For the design and analysis purpose consider the Zone-III in Tirunelveli administrative zone and covers ward No. 40, 41, 42 and 43. The ultimate population for the year 2044 of Zone-III was predicted to be of 27,740. Per Captia Water Supply was considered as 135 lpcd. Total service reservoir peak demand was 33.45 LL. Total length of the road was 11144 m.

Considering the population Peak factor 3 was adopted as per CPHEEO, 1991 norms. The existing Vaiapuri Nagar OHT capacity was 11.2 LL and staging height was 10 m. By using mass diagram capacity of OHT was estimated as 1/3$^{rd}$ capacity of ultimate demand ie 1/3$^{rd}$ of 33.45 LL was 11.04 LL. Hence existing OHT capacity was adequate.

*A. Water Distribution System*

In the design of water supply distribution system, it is being recognized that consumption varies with the season, month, day and hour. As far as the design of distribution system is concerned, it is the hourly variation in consumption that matters. The fluctuation in consumption is accounted for, by considering the peak rate of consumption (which is equal to average rate multiplied by a peak factor) as rate of flow in the design of distribution system.

The variation in the demand will be more pronounced in the case of smaller population and will gradually even out with the increase in population. This is so because in a large population different habits and customs of several groups tend to minimize the variation in the demand pattern.

Water supply distribution system should adopt network design and operating strategies that prioritize issues closely linked to water supply hygiene. The following factors should be considered in the design:

- Identify and prevent low pressures, especially negative pressures, in the system;
- Prevent pressure surges in the network;
- Design the network to minimize the risks of contamination during operational activities and to avoid water stagnation;
- Design and operate service reservoirs to avoid contamination by ingress and to avoid stagnation;
- Control disinfectant residuals in distribution systems;
- Assess the effect of different supplies entering the network;
- Determine the benefits and problems of zoning the network;
- Select construction materials that do not promote microbial growth;
- Prevent cross-connections and backflow.

The distribution layout should be such as to facilitate hydraulic isolation of sections, metering for assessment and control of leakage and wastage.

*B. Hydraulics Consideration*

The purpose of a system of pipes is to supply water at adequate pressure and flow. However, pressure is lost by the action of friction at the pipe wall. The pressure loss is also dependent on the water demand, pipe length, gradient and diameter. Several established empirical equations Hazen's Williams and these have been incorporated into network (Hwang & Houghtalen, 1996).

Modelling software packages to facilitate their solution and use. When designing a piped system, the aim is to ensure that there is sufficient pressure at the point of supply to provide an adequate flow to the consumer. This minimum pressure increases as the number of properties supplied through a single service pipe increases (Colebrook, 1939). For the purposes of maintaining microbial quality it is important to minimize transit times and avoid low flows and pressures. These requirements have to be balanced against the practicalities of supplying water according to the location of consumers and where pipes can be laid. The system should not have excessive capacity (which will result in long transit times) unless this excess capacity is required to meet a known increase in future demand.

Ideally, low-flow dead-ends and loops should be avoided, but in practice this is not always possible. Low-flow sections of dead-ends should be as short as possible. Both dead-ends and loops in the system may cause problems by creating long residence times and sections where sediments can collect. Changes in flow direction ("tidal flows") in loops may disturb any deposits in the pipes.

*C. Present Water Supply Scenario*

Constituent Local Bodies got its own protected water supply scheme before formation of Municipal Corporation in 1994. The water supply schemes were implemented with Source as Tamaraiparani River, Pumping system, Service Reservoirs and Distribution systems. The present service level of the Town is reported as 84 Lpcd was lesser than the standards fixed for urban city as 135 lpcd. There was big gap between supply and demand due deficiency of existing water supply systems. The existing network components water distribution was not cover the entire town and the existing mains was dilapidated in condition due to aging distribution varying from 251 lpcd to 130 lpcd in equal distribution system. Due to above said reasons Improvement scheme for water supply component to be replaced and renewed. Furthermore the network to be extended to uncovered Areas.

## III. SOFTWARE TOOLS

*A. About Loop & Water Gems Software*

The analysis of zone-III of the distribution network indicates that existing pipes need to be rehabilitated to cater to the demand for the year 2044 and CI/AC/PVC pipes needs replacement for the year 2044. New pipelines are to be proposed to ensure the service standards of 135 lpcd with minimum residual head of 7 m. The network analysis with rate analysis with aid of software LOOP developed by World Bank and Bentley Water Gems Software

*B. About Loop Software Short Description of Program*

LOOP is an entirely new version developed and distributed under the joint efforts of UNDP/World Bank. LOOP could be used for the design and simulation of new partially or fully existing gravity as well as pumped water distribution systems. It allows for reservoirs (fixed head and variable head), valves (pressure reducing and check valves) and on line booster pumps. LOOP has been programmed on MicroSoft Quick BASIC. The Language used in this software is Quick basic 4.5 and the code is Structured Optimized and the memory handling is dynamic.

$$\Delta Q = \frac{\sum \text{head loss}_c - \sum \text{head loss}_{cc}}{n \cdot \left( \sum \frac{\text{head loss}_c}{Q_c} + \sum \frac{\text{head loss}_{cc}}{Q_{cc}} \right)}$$

Diameter in mm

It designs for the parallel pipes and different pipe materials and classes. It used different units and menu driven system and hierarchical structured and DOS based and electronic manual.

*C. Water Gems Software*

Water GEMS is a **comprehensive and easy to use** water distribution modeling application. Water GEMS can run from within **ArcGIS, AutoCAD, and Micro Station,** or as a **standalone application**. From fire flow and water quality simulations, to criticality and energy cost analysis, to advanced genetic algorithm optimization, Water GEMS comes equipped with everything you need in a flexible multi-platform environment.

## IV. RESULTS AND DISCUSSION

*A. Water Gems Software*

Analysis of water distribution system aims at demarcating the project boundary based on the contour levels. Such levels were derived the existing toposheets of Tirunelveli corporation. Levels of contour will be the criteria for water distribution system. Zoning of the distribution system is given in Fig. 1.

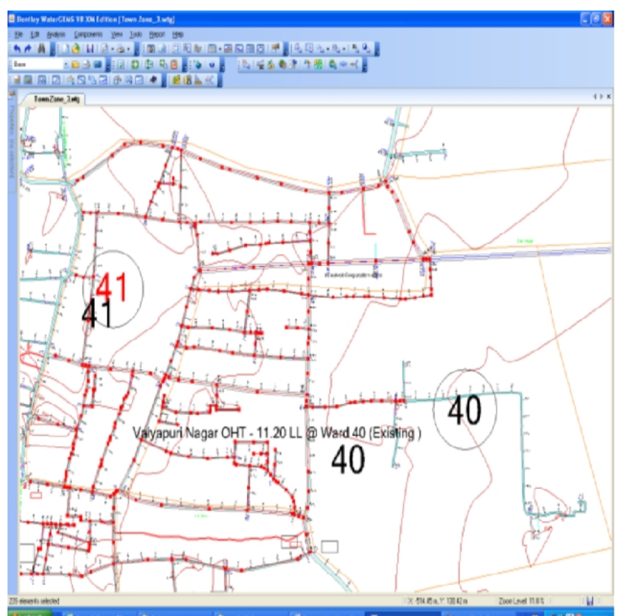


Fig. 1. Zoning of the distribution system

Primarily, reservoir was a focal point from where the pipes and nodes will be drawn through water gems software. Elevation and flow direction were automatically taken from the input parameters by the software. While digitizing the pipe line and the nodes care were taken elevation was considered from the previous level was considered.

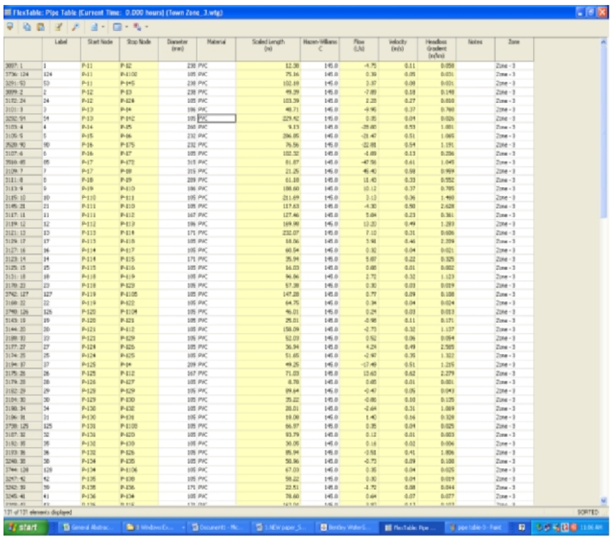

Fig. 2. Output of flow of distribution system

After finalizing, all the pipes and the nodes, inputs such as demand and the pipe materials will be provided to the software. Software takes into consideration of the elevation, contour, demand, pipe material and other parameters. A simulation was carried out by the software, were it decides the diameter of the pipe and flow direction and flow quantity along with the drawing profile as given in figures 2-6.

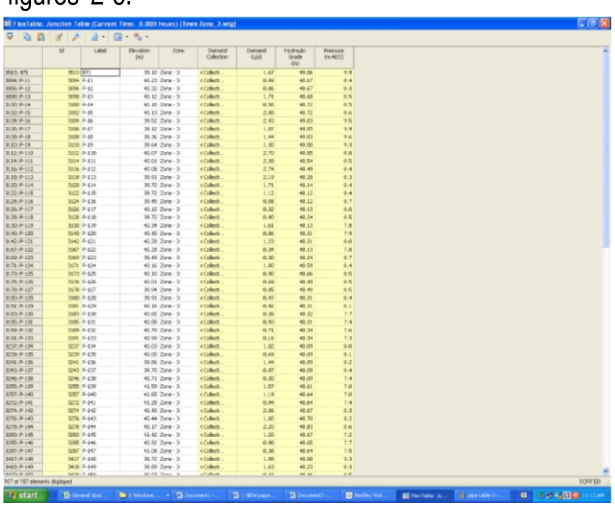

Fig. 3. Output of hydraulic grade of Zone-3 distribution system

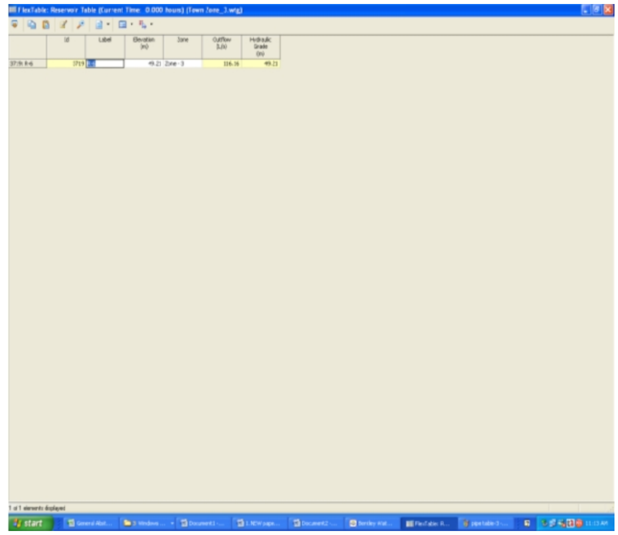

Fig. 4. Output of Reservoir data for Zone-3 distribution system

Such simulation study by water gems softwares for Tirunelveli corporation seems to be promising in deciding the pipe material taking into consideration of the feasibility of the cost of the material and also the shortest path through which water distribution system was drawn for the benefit of the society.

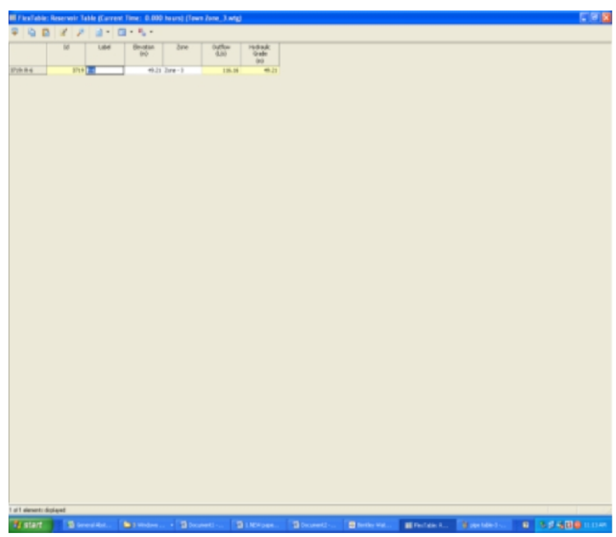

Fig. 5. Output of flushing report of Zone-3 distribution system

*B. Network of Zone-III Disribution System*

Fig. 6 shows the pipe number, node number , reservoir and alignment of zone-iii distribution system and the output data of water gem software are given in tables 1 and 2

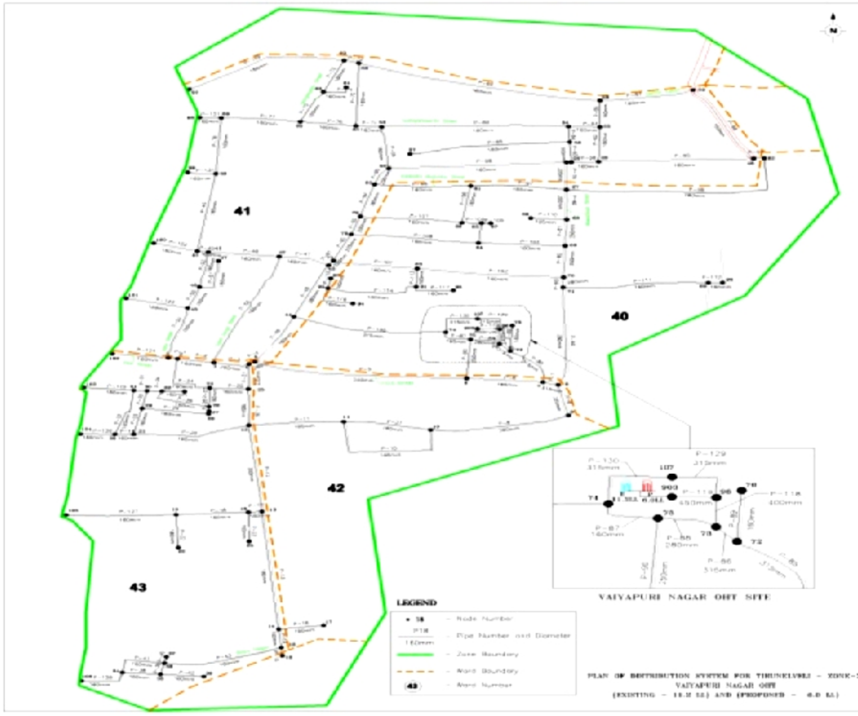


Fig. 6 Network of Zone-III distribution system

**Table 1. Output from Water Gems**

| Pipe No. | Start Node | Stop Node | Length (m) | Diameter (mm) | Material | Hazen-Williams C | Flow (L/s) | Velocity (m/s) | Headloss Gradient (m/km) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 11 | 12 | 12.38 | 238 | PVC | 145 | – 4.75 | 0.11 | 0.058 |
| 2 | 12 | 13 | 49.39 | 238 | PVC | 145 | – 7.89 | 0.18 | 0.148 |
| 3 | 13 | 14 | 48.71 | 186 | PVC | 145 | – 9.95 | 0.37 | 0.76 |
| 4 | 14 | 15 | 9.13 | 260 | PVC | 145 | – 28 | 0.53 | 1.001 |
| 5 | 15 | 16 | 286.85 | 232 | PVC | 145 | – 21.47 | 0.51 | 1.065 |
| 6 | 16 | 17 | 102.32 | 105 | PVC | 145 | – 1.09 | 0.13 | 0.206 |
| 7 | 17 | 18 | 21.25 | 315 | PVC | 145 | 45.4 | 0.58 | 0.959 |
| 8 | 18 | 19 | 61.18 | 209 | PVC | 145 | 11.43 | 0.33 | 0.552 |
| 9 | 19 | 110 | 188.6 | 186 | PVC | 145 | 10.12 | 0.37 | 0.785 |
| 10 | 110 | 111 | 211.69 | 105 | PVC | 145 | 3.13 | 0.36 | 1.46 |
| 11 | 111 | 112 | 127.46 | 167 | PVC | 145 | 5.04 | 0.23 | 0.361 |
| 12 | 112 | 113 | 169.98 | 186 | PVC | 145 | 13.2 | 0.49 | 1.283 |
| 13 | 113 | 114 | 232.07 | 171 | PVC | 145 | 7.1 | 0.31 | 0.606 |
| 14 | 114 | 115 | 35.94 | 171 | PVC | 145 | 5.07 | 0.22 | 0.325 |
| 15 | 115 | 116 | 16.03 | 105 | PVC | 145 | 0.08 | 0.01 | 0.002 |
| 16 | 114 | 117 | 60.54 | 105 | PVC | 145 | 0.32 | 0.04 | 0.021 |
| 17 | 113 | 118 | 18.06 | 105 | PVC | 145 | 3.91 | 0.46 | 2.209 |
| 18 | 118 | 119 | 96.86 | 105 | PVC | 145 | 2.72 | 0.32 | 1.123 |
| 19 | 120 | 121 | 25.01 | 105 | PVC | 145 | – 0.98 | 0.11 | 0.171 |
| 20 | 121 | 112 | 158.09 | 105 | PVC | 145 | – 2.73 | 0.32 | 1.137 |

The label of pipe with length, diameter, minor loss, flow, velocity and head loss gradient was obtained from the pipe data

**Table 2. Junction Data from Water Gems**

| Label | Elevation (m) | Demand (L/s) | Hydraulic Grade (m) | Pressure (m $H_2O$) |
|---|---|---|---|---|
| 11 | 40.23 | 0.99 | 48.67 | 8.4 |
| 12 | 40.32 | 0.86 | 48.67 | 8.3 |
| 13 | 40.12 | 1.71 | 48.68 | 8.5 |
| 14 | 40.16 | 0.56 | 48.72 | 8.5 |
| 15 | 40.13 | 2.08 | 48.72 | 8.6 |
| 16 | 39.52 | 2.43 | 49.03 | 9.5 |
| 17 | 39.12 | 1.07 | 49.05 | 9.9 |
| 18 | 39.36 | 1.44 | 49.03 | 9.6 |
| 19 | 39.64 | 1.3 | 49 | 9.3 |
| 110 | 40.07 | 2.7 | 48.85 | 8.8 |
| 111 | 40.01 | 2.38 | 48.54 | 8.5 |
| 112 | 40.08 | 2.74 | 48.49 | 8.4 |
| 113 | 39.91 | 2.19 | 48.28 | 8.3 |
| 114 | 39.72 | 1.71 | 48.14 | 8.4 |
| 115 | 39.72 | 1.12 | 48.12 | 8.4 |
| 116 | 39.45 | 0.08 | 48.12 | 8.7 |
| 117 | 40.12 | 0.32 | 48.13 | 8 |
| 118 | 39.72 | 0.9 | 48.24 | 8.5 |
| 119 | 40.34 | 1.61 | 48.13 | 7.8 |

The pipes with elevation, demand, pressure and hydraulic grade obtained from the Junction data

## V. SUMMARY OF OUTPUT OF WATER GEMS SOFTWARE

The number of pipe and Junction involved in the design of Water Supply in the Zone III was 131 and node was 108. The pipe material used was PVC. The total length of distribution was 11144 m.The cost arrived by this Software was 51.583 lakhs. Water gems software considers all bends in the roads. Therefore the pressure in the nodes was reduced by 2 cm at the reference node.

## VI. LOOP SOFTWARE ANALYSIS OF WATER SUPPLY DISTRIBUTION BY LOOP SOFTWARE NETWORK ANALYSIS

*A. Output From Loop Software Design Parameters*

| | | |
|---|---|---|
| Title of the Project Tirunelveli Zone 3 | : | |
| Name of the User | : | Sumithra |
| Number of Pipes | : | 131 |
| Number of Nodes | : | 108 |
| Type of Pipe Materials Used | : | PV |
| Number of Commercial Dia per Material | : | 13 |
| Peak Design Factor | : | 3 |
| Newton-Raphson Stopping Criterion lps | : | .001 |
| Minimum Pressure m | : | 7 |
| Maximum Pressure m | : | 22 |
| Design Hydraulic Gradient m in km | : | 1 |
| Simulate or Design? (S/D) | : | D |
| No. of Res. Nodes with Fixed HGL | : | 1 |
| Type of Formula | : | Hazen's Willam's |

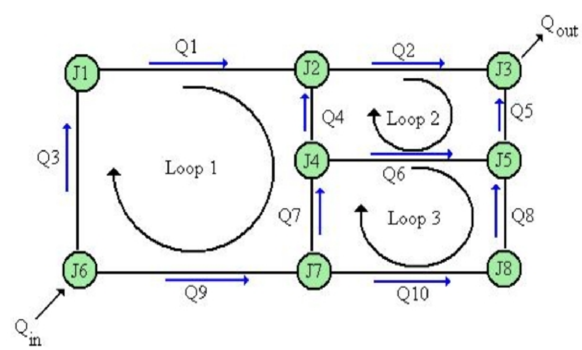


Fig. 7. Network analysis of Loop Software

Once the friction factors are solved for then we can start considering the network problem, the network has to satisfy two conditions.

1. At any junction, the flow into a junction equals the flow out of the junction.
2. Between any two junctions, the head loss is independent of the path taken.

The classical approach for solving these networks as in Fig. 7 is to use the Hardy Cross method. In this formulation, first you go through and create guess values for the flows in the network. That is, if Q7 enters a junction and Q6 and Q4 leave the same junction, then the initial guess must satisfy $Q7 = Q6 + Q4$. After the initial guess is made, then, a loop is considered so that we can evaluate our second condition. Given a starting node, we work our way around the loop in a clockwise fashion, as illustrated by Loop 1. We add up the head losses according to the Hazen's Willams equation for each pipe if Q is in the same direction as our loop like Q1, and subtract the head loss if the flow is in the reverse direction, like Q4. In order to satisfy the second condition, we should end up with 0 about the loop if the network is completely solved. If the actual sum of our head loss is not equal to 0, then we will adjust all the flows in the loop by an amount given by the following formula, where a positive adjustment is in the clockwise direction.

where

- N is 1.85 for Hazen-Williams and

The clockwise specified (c) means only the flows that are moving clockwise in our loop, while the counter-clockwise specified (cc) is only the flows that are moving counter-clockwise.

Our head loss is not equal to 0, then we will adjust all the flows in the loop by an amount given by the following formula, where a positive adjustment is in the clockwise direction.

This adjustment won't solve the problem, since with most networks we will have several loops. It is ok to do this adjustment, however, because our flow changes won't alter condition 1, and therefore, our other loops will still satisfy condition 1. However, we should use the results from the first loop if we progress to any other loops.

The more modern method is simply to create a set of conditions from your junctions and head-loss criteria. Then, use a Root-finding algorithm to find Q values that satisfy all the equations. The literal friction loss equations will use a term called Q2, but we want to preserve any changes in direction. Create a separate equation for each loop where the head losses are added up, but instead of squaring Q, use |Q|•Q instead (with |Q| the absolute value of Q) for the formulation so that any sign changes will reflect appropriately in the resulting head-loss calculation Moody, 1944.

**Table 3. Flow output from Loop Software**

| Pipe No. | From Node | To Node | Flow (lps) | Dia (mm) | HL/1000 m (m) | Length (m) | Velocity (m/s) |
|---|---|---|---|---|---|---|---|
| 1 | 11 | 12 | – 4.759 | 238.0 | – 0.06 | 12.38 | – 0.11 |
| 2 | 12 | 13 | – 7.897 | 238.0 | – 0.15 | 49.39 | – 0.18 |
| 3 | 13 | 14 | – 9.968 | 186.0 | – 0.75 | 48.71 | – 0.37 |
| 4 | 14 | 15 | – 27.965 | 260.0 | – 1.00 | 9.13 | – 0.53 |
| 5 | 15 | 16 | – 21.463 | 232.0 | – 1.06 | 286.85 | – 0.51 |
| 6 | 16 | 17 | – 1.091 | 105.0 | – 0.20 | 102.32 | – 0.13 |
| 7 | 17 | 18 | 45.419 | 315.0 | 0.96 | 21.25 | 0.58 |
| 8 | 18 | 19 | 11.469 | 209.0 | 0.55 | 61.18 | 0.33 |
| 9 | 19 | 110 | 10.170 | 186.0 | 0.78 | 188.60 | 0.37 |
| 10 | 110 | 111 | 3.147 | 105.0 | 1.44 | 211.69 | 0.36 |
| 11 | 111 | 112 | 5.091 | 167.0 | 0.37 | 127.46 | 0.23 |
| 12 | 112 | 113 | 13.197 | 186.0 | 1.27 | 169.98 | 0.49 |
| 13 | 113 | 114 | 7.092 | 171.0 | 0.60 | 232.07 | 0.31 |
| 14 | 114 | 115 | 5.064 | 171.0 | 0.32 | 35.94 | 0.22 |
| 15 | 115 | 116 | 0.078 | 105.0 | 0.00 | 16.03 | 0.01 |
| 16 | 114 | 117 | 0.318 | 105.0 | 0.02 | 60.54 | 0.04 |
| 17 | 113 | 118 | 3.915 | 105.0 | 2.16 | 18.06 | 0.45 |
| 18 | 118 | 119 | 2.715 | 105.0 | 1.10 | 96.86 | 0.31 |
| 19 | 120 | 121 | – 0.976 | 105.0 | – 0.17 | 25.01 | – 0.11 |
| 20 | 121 | 112 | – 2.725 | 105.0 | – 1.11 | 158.09 | – 0.31 |

**Table 4. Pipe Dimensions from Loop Software**

| Pipe No. | From Node | To Node | Length m | Diameter mm | Hazen's Const | Pipe Material |
|---|---|---|---|---|---|---|
| 1 | 11 | 12 | 12.38 | 238.0 | 145.000 00 | PV |
| 2 | 12 | 13 | 49.39 | 238.0 | 145.000 00 | PV |
| 3 | 13 | 14 | 48.71 | 186.0 | 145.000 00 | PV |
| 4 | 14 | 15 | 9.13 | 260.0 | 145.000 00 | PV |
| 5 | 15 | 16 | 286.85 | 232.0 | 145.000 00 | PV |
| 6 | 16 | 17 | 102.32 | 105.0 | 145.000 00 | PV |
| 7 | 17 | 18 | 21.25 | 315.0 | 145.000 00 | PV |
| 8 | 18 | 19 | 61.18 | 209.0 | 145.000 00 | PV |
| 9 | 19 | 110 | 188.60 | 186.0 | 145.000 00 | PV |
| 10 | 110 | 111 | 211.69 | 105.0. | 145.000 00 | PV |
| 11 | 111 | 112 | 127.46 | 167.0 | 145.000 00 | PV |
| 12 | 112 | 113 | 169.98 | 186.0 | 145.000 00 | PV |
| 13 | 113 | 114 | 232.07 | 171.0 | 145.000 00 | PV |
| 14 | 114 | 115 | 35.94 | 171.0 | 145.000 00 | PV |
| 15 | 115 | 116 | 16.03 | 105.0 | 145.000 00 | PV |
| 16 | 114 | 117 | 60.54 | 105.0 | 145.000 00 | PV |
| 17 | 113 | 118 | 18.06 | 105.0 | 145.000 00 | PV |
| 18 | 118 | 119 | 96.86 | 105.0 | 145.000 00 | PV |
| 19 | 120 | 121 | 25.01 | 105.0 | 145.000 00 | PV |

The Pipe data will give pipe number, from and to node, length, pipe material and pipe diameter of the distribution system as shown in Table 3 & 4.

*B. Node Data*

The Node data will give the node number with peak factor, flow, elevation, minimum and maximum pressures of the distribution system

## VII. SUMMARY OF OUTPUT FROM LOOP SOFTWARE

The number of pipes involved in the design of Water Supply in the Zone III was 131 and node was 307. Fixed head for the Reservoir was 49.20 m. Pipe material used is PVC and number of loops was 24 and Newton Raphson Iteration was 7. The total length of distribution was 11144 m. The cost arrived by this Software was 51.583 lakhs. Loop software will not consider the bends, it takes as a straight pipes. Therefore the pressure increased by 2 cm.

## VIII. CONCLUSION OF LOOP SOFTWARE

The Software does not consider fiction losses in bends for design calculation, it assumes road has a straight line. It will design for loop system only and requires branch software for branch design. It is limited to design only for 1000 pipes. It requires manual entry, where computation error is more freely But it is easily available. Manual entry was required to pipe and node, length of each node and nodal Elevation are to be manually ascertain from the survey map which requires much time and leads to erroneous entry in certain datas. On completion of the design process the entire data are to be incorporated into drawing which requires more attention.

## IX. COMPARISON OF OUTPUT FROM THE SOFTWARES

All bends in the road network was considered for design calculation. ie it will calculate minor losses. Water gems will perform both distribution and feeder main design. It will design both for the branch and loop system. It could be used for designing more than 1000 pipes. But it is expensive Commercial Software.

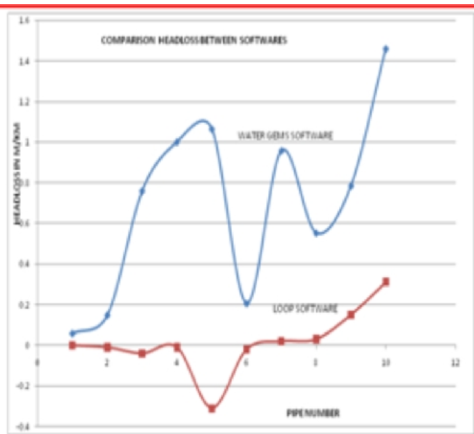


Fig. 8. Graph for Head Loss Between two Softwares

The Water gems Software calculates head loss including all bends in the roads it was more while the loop software does not include all bends in the head loss calculation.

## X. RESULTS

The software has Graphical interface. User friendly and modifications and further modification is easy. Therefore the System with WATER GEMS Software is more convenient and consumes lesser time computation. Treated water conveyed through a piped network is exposed to numerous surfaces. It is important that no materials placed in contact with the drinking water in the network promote microbial growth or leach any contaminants into the water that can support microbial growth (see the WHO companion text Managing the Safety of Materials and Chemicals Used in the Production and Distribution of Drinking-water, in preparation (Wu and Sage, 2007) .

A materials approval system, where materials are tested to see if they meet defined standards before they can be added to a list of approved materials, is a recommended approach. There is no universally accepted system for such approvals. Some countries have their own national approval scheme (NAS), others leave the selection of safe materials to the individual water supply organizations.

Most approval schemes are based on tests where the product is kept in contact with test water under specified test conditions. Various tests are undertaken to assess whether the material, or contaminants arising from the material, can:

- adversely affect general water quality;
- exceed permissible levels set in national standards and positive lists, etc;
- pose a health risk to consumers.

These schemes may or may not address the ability of the materials to support or promote microbial growth. Details are beyond the scope of this review but a summary of the European approval systems and the development of a harmonized European acceptance scheme is available (WRc-NSF, 2001). The USA approval systems are based on plumbing codes and standards set by the American National Standards Institution and NSF (www.nsf.org).

### *A. Calculation of Quantity of Distribution System*

Cost Comparison for various pipe materials viz PVC, AC, Ductile Iron, Cast Iron, Steel, HDPE, GRP and is represented in Table 5 and Fig. 9. The range of cost of material varies from L1-PVC, L2-AC, L3-GRP, L4 –HDPE, L5-DI,L6- Steel and L8 - CI. Economic design of distribution system by using L1-PVC in the range of 110 to 400 mm and the cost works out to 51.583 lakhs.

**Table 5. Cost Comparison of Various Pipe Materials**

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COST OF DISTRIBUTION SYSTEM (SUPPLY AND DELIVERY ALONE) FOR VARIOUS MATERIALS OF PIPES

| DIA | DESCRIPTION QUANTITY | PVC | | AC | | DI | | CI | | STEEL | | HDPE | | GRP | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) | RATE Rs | AMOUNT Rs(Lakhs) |
| 110 | 7680 | 325 | 24.996 | 565 | 43.437 | 1235 | 94.947 | 1697 | 130.465 | 1373 | 105.556 | 733 | 56.353 | 733 | 56.358 |
| 180 | 820 | 417 | 3.415 | 929 | 7.618 | 1727 | 14.161 | 2475 | 20.295 | 1715 | 14.063 | 1450 | 11.892 | 1308 | 10.726 |
| 200 | 542 | 520 | 2.818 | 929 | 5.035 | 1727 | 9.360 | 2475 | 13.415 | 1715 | 9.295 | 1450 | 7.858 | 1308 | 7.088 |
| 225 | 501 | 664 | 3.327 | 1185 | 5.937 | 2311 | 11.578 | 3337 | 16.718 | 2389 | 11.969 | 2237 | 11.207 | 1769 | 8.958 |
| 250 | 711 | 826 | 5.873 | 1185 | 8.425 | 2311 | 16.431 | 3337 | 23.726 | 2389 | 16.986 | 2237 | 13.905 | 1783 | 12.677 |
| 280 | 374 | 1038 | 3.882 | 1407 | 4.018 | 2931 | 10.962 | 4304 | 14.097 | 2937 | 10.984 | 2831 | 10.588 | 2109 | 7.865 |
| 315 | 450 | 1318 | 5.931 | 1607 | 7.232 | 2931 | 13.190 | 4304 | 19.368 | 2937 | 13.217 | 2831 | 12.740 | 2109 | 9.466 |
| 400 | 19 | 2290 | 1.351 | 2791 | 1.641 | 4342 | 2.562 | 6736 | 3.974 | 3630 | 2.142 | 4660 | 2.749 | 2839 | 1.675 |
| | TOTAL | | 51.583 | | 85.338 | | 173.196 | | 244.099 | | 194.212 | | 129.291 | | 114.792 |
| | | | L1 | | L2 | | L5 | | L7 | | L6 | | L4 | | L3 |

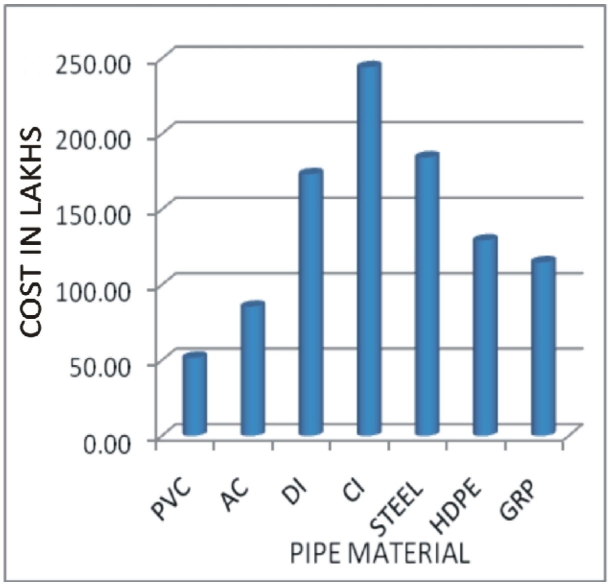


Fig. 9. Graph for Cost Comparison of Various Pipe Materials

## XI. CONCLUSION

LOOP SOFTWARE does not have Graphical interface and any changes or modification is cumbersome. WATER GEMS SOFTWARE have Graphical interface and more efficient and changes can be done very easily. The cost of various pipe materials is worked out and PVC cost is the loosest among the all materials and also have durability. Therefore PVC is suggested for adoption.

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