ROLE OF HYDRAULIC MODELING IN DEVELOPMENT OF ROAD MAP FOR ACHIEVING 24 x 7 CONTINUOUS WATER SUPPLY

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ABSTRACT

Most of the water supply schemes (WSS) in India operate intermittently and provide sub-optimal service to end-consumers. Efforts being made at all levels to convert intermittently operating WSS to 24 X 7 continuous water supply schemes. In this study role of hydraulic modeling has been explained in achieveing 24 x 7 water WSS. A clear road map for achieving 24 X 7 water supply has also been devised for old WSS operating intermittently. The study reveals that there is critical role of hydraulic modeling in the development of road map for achieving 24 x 7 water supply.

1. INTRODUCTION

The increase in population and improvements in quality of life have led to a high demand for municipal and domestic needs. Demand for municipal drinking water needs will be driven by the rapid pace of urbanization and the high rate of per capita requirements for the urban population. India's urban population as presently defined will be close to 600 million by 2031, more than double that in 2001. Already number of metropolitan cities with population of 1 million and above has increased from 35 in 2001 to 50 in 2011 and is expected to increase further to 87 by 2031 (HPEC,2011). The focus of government departments has been to satisfy the present water demands of the city without giving full considerations to future demand. Such kind of approach also lacks in intergrated approach which shall include financial plan to sustain water supply scheme, improvement in operation of the project and other issues related to water quality and sanitation.

In most of the cities in India, water supply is limited to 4-6 hours. In the State of Maharashtra, the water supply schemes (WSS) have been designed and commissioned 25-30 years ago, at a norm of 70 Litre Per Capita per Day (LPCD) of water supply for cities having no underground sewerage scheme and 135 LPCD for cities having underground sewerage scheme, either existing or under process of sanction (CPHEEO, 1999). For bigger townships, norm adopted may be even 150 LPCD. Over a period, the negligence in operation and maintenance (O&M) of the water supply schemes has resultaed in sub-optimal service of water supply in terms of both water quantity and quality.

PRESENT STATUS OF WATER DISTRIBUTION SYSTEMS IN INDIAN TOWNS :

1. Water supply in most of the Indian towns, at present , is operated on intermittent basis, normally 2-3 hours in morning and 1-2 hours in evening. As water is supplied for limited hours, peak factor sometimes rises to 10-12 or even more as most of the pipelines are empty and lot of water is consumed in filling empty pipelines and reservoirs get emptied within a short time before water reaches the end consumers (Sashikumar et al., 2003),. Due to empty reservoirs, end consumers do not get desired pressure and hence, the do not get desired pressure and hence, there is inequitable distribution of water.
2. There are no district metering areas (DMs) formed and water distribution systems emerging from all reservoirs are interconnected and hence, coverage zone of each reservoir is not clearly defined.
3. Most of the systems are not metered and hence, there is no control over consumers for optimum usage of water. Hence, consumers residing near reservoirs or in low-level zones, get more water with excessive pressure, consumers residing at tail end pockets or in high-level zones do not get water as per minimum needs. Thus, supply is most inequitable.
4. To overcome this problem to some extent and to reduce peaking in distribution system operation, it is practiced to divide city distribution in different zones by providing control valves and bifurcating supply timings to control flow outgoing from reservoirs and control possibility of emptting of reservoirs. However, such attempt has no scientific standing and is based on experience of field staff. This also involves lot of valve operation twice a day. Moreover, control of such a system goes in hand of field staff not trained properly. In addition, public & political interference while operating such system may lead to more inequitable distribution of water.

To overcome these problems, computerized analysis and scientific hydraulic modeling is necessary. This study reports a general methodology followed for modeling WSSs. Based on these modeling experiences a road map has been developed for achieving 24 x 7 water supply in old water supply shchemes.

2. METHODOLOGY

Water Distribution System (WDS) modeling is becoming more and more challenging owing to increase in population, demand patterns and various types of end-users. Computer models are effective to handle the challenges of modeling and analyzing WDSs for different scenarios representing various demands, pipe materials, pipe sizes, etc. In the computer models pressure and flow distribution is determind using laws of conservation of mass (implyign that for each node the algebraic sum of flows must equal zero) and conservation of energy (implying that along each closed loop. the accumulated energy loss must be zero). These laws of conservation either are expressed as nonlinear algebraic equations in terms of pressures (node formulation) or volumetric flow rates (loop and pipe formulation) which reflect the relationship between pipe flow rate and the pressures drop across its length. The nonlinearity reflects the relationship between pipe flow rate and the pressure drop across its length. This nonlinearity in these equations leads to iterative numerical solutions for these equations. The iteration process starts with assumptions of appropriate flow difference between two successive, iterates is within an acceptable tolerance (Mays, 1999).

The hydraulic modeling procedure for WDS adopted in this study in depicted in Figure 1 and stepwise described is given in next section. In this study Bentley's Water GEMS V8i (SELECT series-2) version software has been used for hydraulic analysis and ESRT's Arc-GIS software has been used for handling Geographical Information System (GIS) data.

2.1 GENERAL METHODOLOGY OF HYDRAULIC MODELING

1. Information of existing distribution system such as capacity, locations and levels of reservoirs, layout of existing feeder mains and dsitribution system with diameters, type of pipes and lengths is collected from available maps and also verified using Global Positioning System (GPS). These maps are updated with information from distribution system operating staff and existing as well as recently laid pipelines are marked.
2. These maps and water networks are now imported Arc-GIS on satellite image of the town which is obtained from National Remote Sensing Agency (NRSA), Hyderabad.
3. Information available from GIS and consumer survey activities such as present and projected population and water demand load on each junction is added to the shape file as attribute data.
4. Once the analysis in Are-GIS is completed them the shape files (vector data) is imported in Water -GEMS.
5. Imported Network is validated and cross-checked for the accuracy. New pipelines are proposed for areas not covered with existing network.
6. Water demand for the base year is allocated to all the junctions in the network.
7. Now new hydrauliclly isolated zones (DMAs) are formaulated considering future water demand for 15 and 30 years based on population projections.
8. Considering base year water network as base scenario, new scenarios for future years and peak flows are created.
9. Based on the analysis in Water-GEMS zone wise demand as per existing network is estimated.
10. Capacities of reservoirs are checked for future demand for immediate stage of 15 years and ultimate stage of 30 years of each DMS and if capacity is found to be inadequate to meet immediate demand, additional reservoirs are proposed.
11. Now water network is analyzed for steady state to check the pressure at the junctions for ultimate stage peak flow conditions. Areas of negatives / lower diameter pipelines or parallel pipelines and valve controls are proposed in such zones and network is again analyzed to get satisfactory output with adequate pressure (say 7 m

or 12 m of water head as per CPHEEO norms) in all zones to achieve equitable distribution. If pressure is not sufficient, pipe diameters will be revised and again network wil be analyzed to check junction pressures.

12. Finally water network is also simulated for extended period (EPS) of 24 hrs where impact of water level change in tank and reservoir is observed. Also, EPS helps in understanding the effects of changing water usage over time or the response and valves to system changes.
13. A water supply pattern (for 24 hrs.) based on, water habits or urban population in Indian cities is considered for analysis.
14. Based on the analysis recommendations are drafted suggesting physical and operational changes in the water network.

2.2 MODELING EXISTING SCENARIOS

The existing scenario is created and analyzed for present actual consumption. In this study the water network is modeled up to consumer end connections (refer to **Figure 2)** to simulate exact field conditions. the actual demand exerted in each connection has been estimated using water audit study. The result of steady state simulation is shown in **Figure 3.**

2.3 MODELING PROPOSED SCENARIOS

The proposed scenarios are modeled to check the suitability of existing network to cater to required demand and pressure for future years. Two stages (intermediate and ultimate) with 15 years of differecne have been modeled. A demand for these stages has been estimated from population projection data. The adequacy of existing reservoirs is checked with respect to estimated projected demand for intermediate and ultimate stages.

3. ROAD MAP FOR TRANSITIONING TO 24x7 WATER SUPPLY

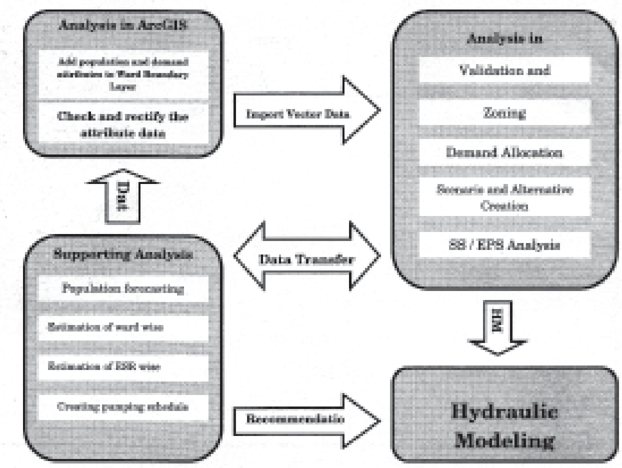

Figure 1: Flow chart showing methodology of Hydraulic Modeling

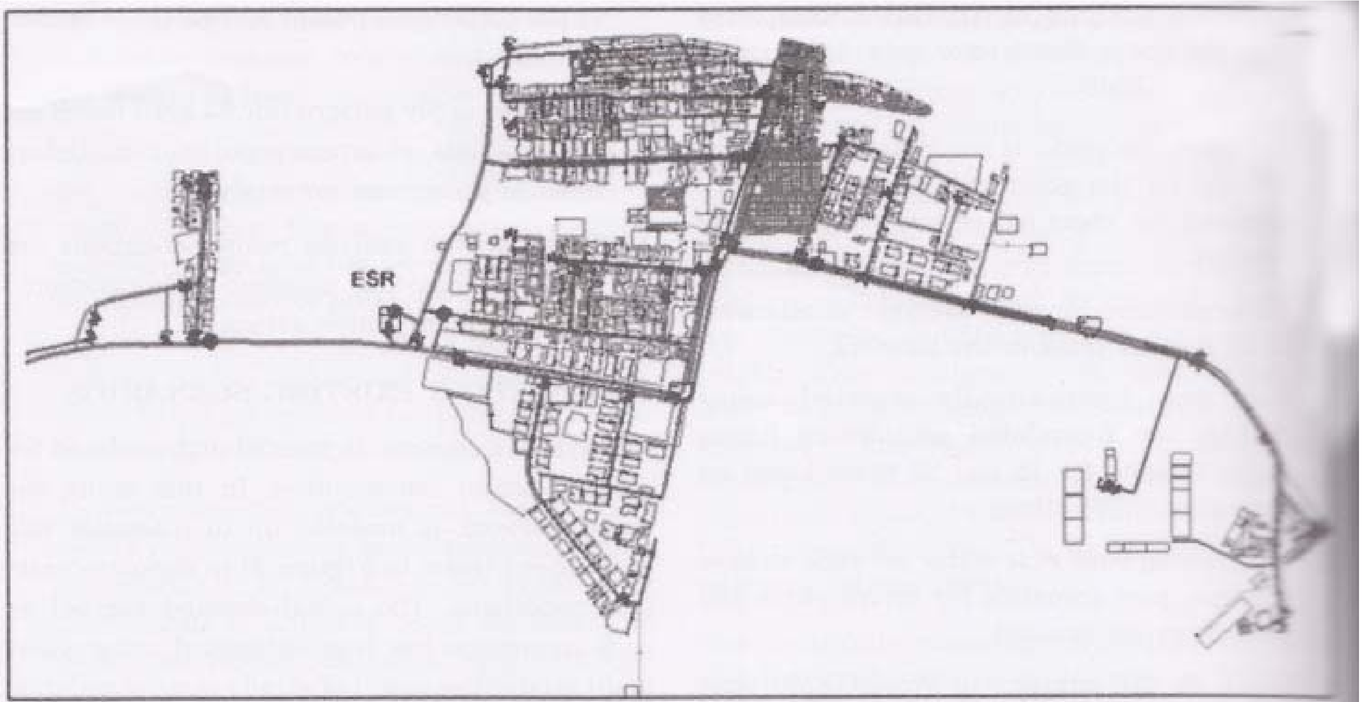

Figure 2: *Water Distribution Network along with building polygons*

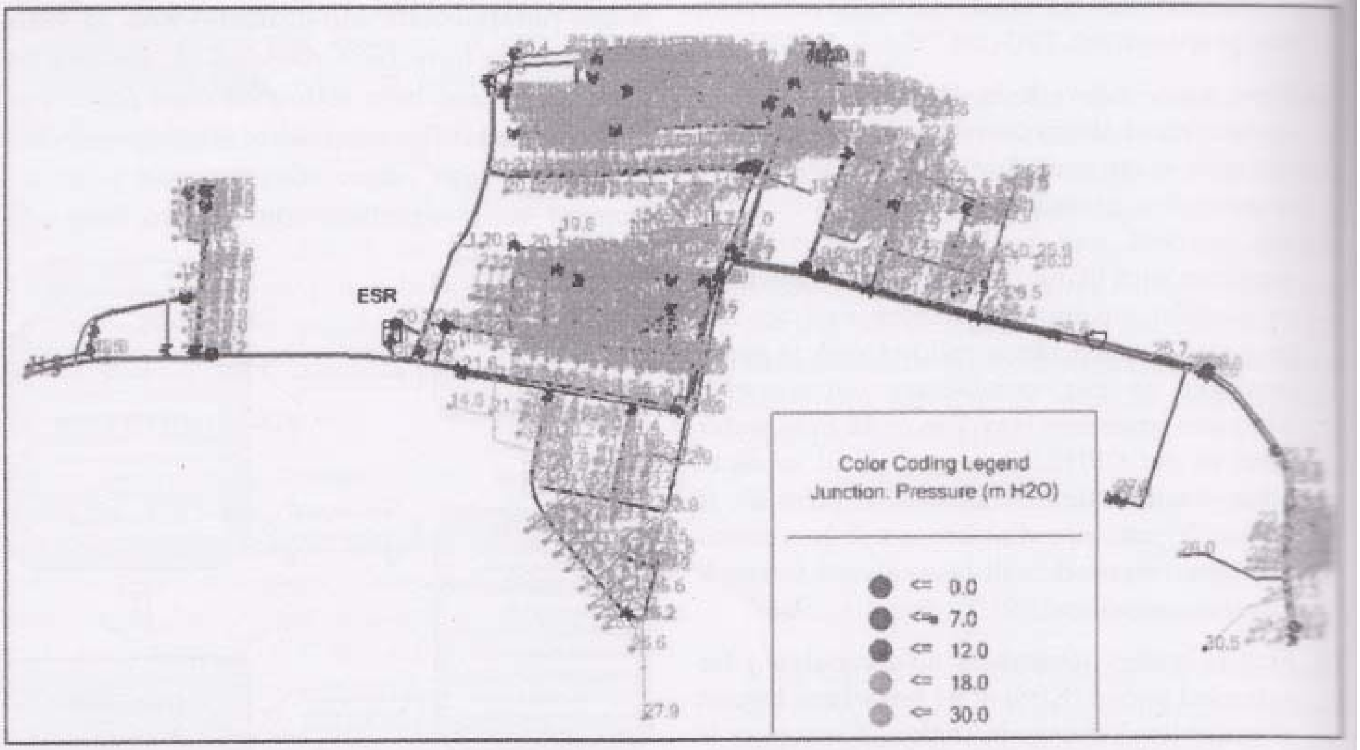

Figure 3: *Water Distribution Network showing positive pressure (>12 m)*

Based on the experience of analysis and modeling several WSSs a road map has been developed for transitioning to 24 X 7 water supply for old water supply schemes. The road map has been segregated into various components such as pre-requisite for 24 X 7 water supply, stepwise approach for transitioning to 24 X 7 water supply and expected time frame for implementation.

3.1 PRE-REQUISITE FOR 24 X 7 WATER SUPPLY

There is an urgent need to convert the present intermittent water supply systems to 24 x 7 continuous water supply systems. Before underking transition to 24 x 7 it is essential to conduct comprehensive study of the existing water supply infrastructure. The studies shall include consumer survey, GIS mapping, Computerized billing, hydraulic modeling, water audit and energy audit. These Studies will identify the present lacunae in the existing water supply system.

1. Consumer survey and Geographic Information System (GIS) mapping will help in identifying all the legal and illegal connections and water demand in various zones / DMAs. The up to date consumer billing data can be fed to computer software specifically developed for billing and collection which will result in increase in revenue generation. Entire water distribution network including source, transmission lines and storage reservoirs are digitized in GIS.
2. Hydraulic modeling is essential for checking adequacy of service reservoirs and pipes for delivering 24 X 7 water supplies up to ultimate stage flow conditions. New operationg zones and DMSs will be formulated to deliver water at equitable pressure. Such kind of engineered approach will help in designing a robust system for water supply with optimum investment.
3. Water audit identifies DMA wise non-revenue water (NRW) in the system which enables development of priority wise action plan for addressing DMAs having high NRW.
4. Energy audit helps in identifying optimum investment in electrical equipments such that energy efficiency can be improved which will directly reduce the bill for the electricity. There can be many zero investment or low investment measures which will bring significant saving in the electricity bills of ULBs.
5. Ensure that all the ESR / GSRs have bulk flow meters at the inlet and outlet of the tank. Also, bulk flow meters shall be installed at the inlet of all the operating zones and DMAs.

3.2 STEPWISE APPROACH FOR TRANSITIONING TO 24 x 7 WATER SUPPLY

After completion of above mentioned reforms studies a detailed plan can be formulated for transitioning to 24 x 7 water supply. scheme can be converted to 24 X 7 water supply using following **stepwise approach :**

1. Select a pilot operating zone / DMA for undertaking transitioning to 20 X 7 water supply (a DMA for which adequate service reservoir is available shall be selected.)
2. Estimate the valve controls for each sub-DMA from lower level (tail end) to

higher level (towards reservoirs) Such that controlling a lower valve will increase pressure at higher side. It should be seen that quantum of supply does not get increased. Proceed upwards with this approach and control each valve at starting of each DMA and sub-DMA and sub-DMA. It is important to note that to do such type of valve operations a good communicaiton system along with good number of manpower is required during field phase. The adjustment of valves can be done in phase wise manner in day to day basis such that will be minimal disturbance to the end user.

3. As valve adjustment is started, the supply hours may be incereased step by step simultaneously. The increase in demand with increase in supply hours, if any shall be noted. In this process of control we need a back-up reserve to feed the aspiring areas instantly.

4. Simultaneously record the ESR / GSR level of the DMA so that the effect can be monitored on the level of ESR / GSR.

5. The trial and error adjustment in the valve control along with increase in supply hours shall be carried out until the ESR / GSR is not getting emptied / overflowing. This requires an exhaustive effort with a team work along with participation from the community. In the course of time the ultimate objective shall be to bring valve control adjustments to nil.

6. An awareness drive for the community shall accompany the transition period to avoid any panic due to change of service in the water supply.

7. After successful adjustment with regard to valve control and supply hours a continuous monitoring plan shall be devised and implemented. Parameters such as ESR / GSR level, inflow and outflow from the reservoirs, water pressure at the consumer end, etc. should be continuously monitored.

8. Once 24 x 7 water supply is achieved in one DMA, based in this experience and the approach, other DMAs can be undertaken for transitioning to continuous 24 x 7 Water supply.

3.3 EXPECTED TIME SPAN FOR THE CHANGE.

As emphasized above the efforts of converting intermittent water supply to 24 X 7 water supply are exhaustive and it takes considerable time along with team work. **Table 1** provides tentative timeframe for converitng intermittent water supply to 24 X 7 water supply.

During the transition process it wil be of help to keep a record of man power inputs and material inputs and get valued each day. AT each mile-stone the cumulative financial input can be noted . Final cost inputs will be available for getting required for the other areas to be covered. It is very likely that the process will be more streamlined in the areas to follow.

Table 1 : Tentative Timeframe for 24 x 7 water supply

Sr. No.	Activity	Time	Cumulative time
1	Collecting field information such as ESR operating levels, pumping hours, inlet / outlet flows, etc.	7days	7days
2	Locating / identifying salient valves and opening for operations	4 days	11 days
3	Valve control and observations for trials. Once the opening areas are fixed valves, they can be replaced by master pieces (pipe in pipe), in a phased manner	3 days each (total 12 days)	23 days
4	First change of supply from 5 hours to 8 hours, start meterization.	14 days	37 days
5	Second change from 8 hours to 12 hours, complete 70% meterization	30 days	67 days
6	24 hours supply in storage and 12 hours supply, complete 100% meterization	13 days	80 days
7	a. 24 hours of incoming and 24 hours of supply b. Checking the consumer wise LPCD and overall supply quantity to the DMAs.	60 days	140 days
8	Optimization of supply level and LPCD as a reaction to bills, indication their satisfaction level	60 days	200 days

3.4 PROPOSED AUTOMATION

Apart from above steps it is essential to install sophisticated instrumentation and control system for easy operation of the system. Some of the instrumetation systems are suggested below:

1. Leakege detection system : This is required when the network is vast especially for municipal corporations. The automation provides hooking up of the local leakage analyzer's interactive mode to SCADA and as the leakege in a section starts, provides on line information of the section of distribution to ease the immediate rectification.
2. Automatic ESR management system: The principle is based on the inlet and outlet valves installed for each ESR where the valves have remote connectivity with SCADA. It maintains the optimum level of the ESR with minimum offset which is decided for equitable pressure in distribution. These valves operate 10% to 90% controllable range for efficient automation to control the water level. These valves have additional feature of calculating the volumetric flow through time averaging on

basis of valve opening. Valves could be commanded through SCADA for timed opening and various logical combinations to ease the operation either in normal mode or in an emergency mode.

3. AMR consumer meters.
4. Portable Ultrasonic meters.

4 DISCUSSION

The above road map suggests that conversion form intermittent operation to 24 X 7 water continuous supply is a step-by-step process with a defined direction. It has a slow transition as it supports and identifies the resistance to change in the operational exercise and also in the consumer behavioral reactions. Slow process of pressure reduction mixed with increase in supply hours shall not have the reactions to resist for the change from the proactive residents in the area. Instead there shall be a constant interaction with the consumers in different areas where change is occurring.

24 x 7 supply is normally resisted for the fear for the increased billings. Meterization shall be associated with the transition. It will help and educate consumer to react positively to the increased billings. Being a slow process consumer need not feel change in the bills for at least three billing cycles. Initially daily AMR meters can be read to understand the change by the operational staff and the consumers and required information based change can be monitored by both.

Hence, putting efforts on the level of service improvement shall also address the level of satisfaction of the consumer and lead to the success of the transitional change. It is important to note that initially system will be tested for the capacity to run at higher level of service and from operational side there should no hiden or open resistance to the transition, till consumer reacts positively to the increased bill and controls the consumption to the norms. It will take at least two billing cycles more. Operational staff shall have to bear with the change.

Finally, following changes will be observed as indicators for successful implementation of 24 X 7 water uspply operation :

1. ESR will not become empty, and not overflow.
2. There are equitable pressures in the system actually observed. Valve operation will be minimized.
3. Consumers at any point will get practically equal water quantity in a day.
4. In-house water storage will be eliminated with the confidence building in the consumers.
5. Any shut downs can be, planned shut downs.
6. Billing efficiency will be improved.
7. When the staff is consistently on watch in the transition period, unauthorized connections are identified.
8. Working of meters will be improved.
9. Seasonal changes in supply can be easily worked out.
10. Cosumer behavior will be correlated with operational system.

5. CONCLUSIONS

The study shows that achieving 24 X 7 in old water supply schemes is a challenging task. In this study it has been emphasized that before undertaking transition of WSS to 24 X 7 water supply it is necessary to undertake reform works. Reform works gives an opportunity to ULBs to understand their WSSs better, both technically and financially. Without complete know-how of the present status of WSS it is difficult to developa a road map for conversion to 24 x 7 water supply.

It is found that hydraulic modeling plays a critical role in development of road map for converting WSS from intermittent operation to 24 X 7 continuous mode. Hydrulic modeling analysis help in developing rehabilitation plan for WSS with better utilization of existing water supply infrastructure. The optimal investment can be suggested with hydraulic modeling. Hydraulically isolated DMAs can be formulated for better service delivery and monitoring of WSS.

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