Analysis of Water Distribution Network by Forming District Metering Areas to achieve Continuous Water Supply with Minimizing Non-Revenue Water

A case study

Neeraj Sharma[1], Kafeel Ahmad[2], Syed Khursheed Ahmad[3]

[1]*M.Tech. Environmental Engineering, Al-Falah School Of Engineering AndTechnology Al-Falah University, Faridabad, Haryana, India.*

[2]*Professor, Civil Engineering Deptt, Jamia Milia Islamia, New Delhi*

[3]*Professor and HOD, Alfalah School Of Engineering And Technology Al-Falah University, Faridabad, Haryana, India.*

ABSTRACT

Non –revenue water may be defined as the water that has been produced at a water treatment plant but the one that doesn't reach the customer and thus remains unbilled and does not contribute to the revenues of the utility. The main components of non-revenue water may be enumerated as- Water lost during the transmission as leakages, the water used in an unauthorized manner or stolen during transmission or the water that is consumed by the customer, but not recorded due to non-metering or instances of faulty metering at the customer's premises. Apart from being a measure of poor infrastructure management, high NRW is also a direct loss to any utility. The objective of the present study was to estimate the NRW in three Group Housing Colonies (GH8, GH10 and GH12) in Paschim Vihar area in North West Delhi, by forming district metering areas (DMA). Water is supplied to these colonies from 40 MGD Nangloi Water Treatment Plant located in the same vicinity approximately 5 km from the study area. Data pertaining to supply, and consumption was collected over two distinct billing cycles i.e. Dec' 2017- Jan' 2018 and Feb' 2018- Mar' 2018. The consumption during both cycles was re-checked by verifying the consumer bills and meter readings of all 1032 consumers. The NRW for the two periods was then calculated as the difference between the total input volume and the corresponding billed volume and expressed as a percentage of the total input volume. It was observed that the NRW values for GH8, GH12 and GH10 for Dec'17- Jan'18 were 12.56, 23.66 and 29.82 %

respectively; for Feb'18-Mar'18 these were 20.86,24.87 and 25.56 % respectively. It was concluded that GH8 is a better managed DMA, the NRW for Feb- Mar'18 was higher due to major pipe burst in the area. Though NRW figures for GH 10 and GH12 are relatively higher yet they are much below the figures reported elsewhere in the country, however, there is a scope for improvement in GH12 and GH10.The observed NRW values are better than the figures reported elsewhere in Delhi (45%-50%) but considerably higher from 14% achieved in Jamshedpur or the targeted NRW values recommended by Asian Development Bank i.e. less than 20%.

Key Words: NRW, Losses, DMA, IWA, AWWA, ADB

I. INTRODUCTION

A huge gap was discovered when the volume of water supplied in its water distribution network was compared with the volume billed to various consumers. It made the government owned utilities to realize that financial losses due to huge gap between these two volumes. This difference between the volume of water that has been pumped is a water distribution network during a fixed period of time and the volume billed to the consumers in that time span is called Non- revenue water (NRW) as the water that remains unbilled, does not contribute to the revenues of the utility.

As per IWA Water Balance equation, the main components of non-revenue water are transmission leakages due to poor infrastructure, Leakages and overflows at the reservoirs, Leakages on Service Connection up to the metering point, Unauthorised consumption due to theft from the transmission or distribution mains, Customer meter inaccuracies resulting in faulty consumption data, Water used for social obligations such as fire-fighting, supplied to public hydrants in slum clusters etc., Unbilled metered Water consumption, Unbilled unmetered Water Consumption.

Reduction in the volumes of non-revenue water improves the billable component of water supplied to the consumers and thus ensures better revenue collections. Creation of district metering areas improves the knowledge about the distribution area which helps in reducing the time taken for repairs of the leakages thus reducing the water loss from the distribution network because of better knowledge of the network. Improved pressure in the pipelines due to reduction in losses also enhances the firefighting capabilities. Construction costs can be reduced as the necessity to create water storage facilities in individual houses becomes redundant due to improved and assured water supply at adequate pressure. The scenario gets much better under the 24 x 7 supply systems in which contamination risks are also reduced in the network as the pipelines are pressurized at all times. Creation of district metering area results in reduction in damage to the properties because of better efficiency in attending to leakage repairs as and when required and better utilization of pumping machinery and other appurtenant devices. Bogumil Ulanicki, Hossam Abdel Meguid, Peter Bounds and Ridwan Patel et al [1] (2008) conducted a study of pressure control in district metering areas with boundary and internal pressure reducing valves by implemented algorithm module in the FINESSE package and allows complete pressure control tasks to be solved. Daniele B. Laucelli, Antonietta Simone, Luigi Berardi and Orazio Giustolisi et al [2] (2016) also approaches a pressure driven hydraulic modelling to predict background leakage reduction and unsupplied customers demand based on multi-objective design strategy for optimal DMAs design which requires dynamic planning accounting availability of budget and network development. D.Savic and G. Ferrari [3] studied different DMAs as per their layout, number and size of the district by using automated method and an analysis of their performance which shows good results of DMAs improved water security, better control and management of the network and an additional benefit to meet fire flow and their performance in terms of reduction of leakage.

II. MATERIAL AND METHODS

In this section, formulation of methodology for the present study, detailed description of site, field data collection including network details, extent of water supply, verification of water distributes network, collection and verification of consumption data, collection and verification of supply data, data analysis including inferences are described in subsequent sections.

2.1 Formulation of Methodology based upon literature review

The methodology was formulated after referring to the literature available on the matter including that published by ADB [1], IWA, AWWA and other authors such as, Alegre et al 2006 [2] Performance Indicators for water supply services, 2nd Ed, IWA Publications, AWWA., [3] 2003 Development of a Strategic Planning Process, AWWA research foundation, Denver. Baietti A., Kingdom W. and Ginneken M. [3], 2006, Brocklehurst C., Janssens J. [4], 2004, [5] Water Sector Reform in Senegal", Water Supply and Sanitation Sector Board Discussion Paper 1, January 2004, World Bank, Washington DC.

Charalambous, B [6] ,2008, Use of district metered areas coupled with pressure optimisation to reduce leakage, Water Science and Technology: Water Supply, vol. 8, no. 1, pp 57-62. Dyson et al. [7], 2003, United Nations World Water Development Report Water a Shared Responsibility. Fanner, P., Sturm, R., Thornton, J., and Liemberger, R. [8] (2007), Leakage Management Technologies, Awwa Research Foundation, AWWA, Denver, USA; IWA, London. Farley, M. and Trow, S., [9] 2003, Losses in Water Distribution Networks: A practionner's Guide to Assessment, Monitoring and Control. IWA Publishing, London. Farley, M., and Liemberger, R., [10] 2005, “Developing a non-revenue water reduction strategy: planning and implementing the strategy”, Water Science and Technology: Water Supply, Vol. 5 No.1, pp 41-50, IWA publishing, Jeffcoate, P., and Saravanapavan, A., [11] 1987, “The Reduction and Control of Unaccounted-for Water”. World Bank Technical Paper, No. 72, Water Supply Operations Management Series, The World Bank, Washington, D.C. Khin Myat Nwe, [12] 2008 - “Non-revenue water and water sustainability: A case of Yangon city urban water supply system “thesis presented to the higher Degree Committee of Ritsumeikan Asia Pacific University, Kingdom, B., Uemberger, R. and Marin, P. [13], 2006, The challenge of reducing Non- Revenue Water in developing countries. How private sector can help: a look at performance-based service contracting, The World Bank, Water Supply & Sanitation Sector Board, PPIAF, Washington. Lambert, A. O. [14] ,2002, "International report: Water losses management and techniques", Water Science and Technology: Water Supply, vol. 2, no. 4, pp. 1-20, Lambert, A.[15], 2003, "Assessing non-revenue water and its components: A practical approach", Water21, vol. (Aug.), pp. p.51-52. Langa, J. V. Q. and Quessouji, J. [16], 2007, "Water Losses in Maputo Suplly System: an overview of the strategic plan for leakage reduction.", IWA, in: Water Loss 2007, 23-26 sept 2007, Bucharest. Mahmoudi, S. [17], 2007, "Managing UFW in Iran", IWA, in: Water Loss 2007, 23-26 sept.2007, Bucharest. McKenzie, R. and Lambert, A. [18] 2004, Best Practice Performance Indicators for Non-Revenue Water and Water Loss Components: A Practical Approach", Water21, no. 8, Mclntosh, C. Arthur,[19] 2003 Asian Water Supplies: Reaching the Urban Poor, Asian Development Bank (ADB), Noor F.M.,[20] 2005 Non-Revenue Water Reduction Control: District Meter Area Method, Water, Queensland Environmental Protection Agency and Wide Bay Water, [21] 2002, “Managing and Reducing Losses from Water Distribution Systems”, Manual 7: Managing Apparent Loss, ISBN 0 7242 9499 6,Queensland Environmental

Protection Agency and Wide Bay Water, [22] 2002, "Managing and Reducing Losses from Water Distribution Systems", Manual 6: Real Loss Management, ISBN 07242 9494 5, Ringskog K., Hammond E. Mary, and Locussol A.[23], 2006a, "Using Management and Lease-affermage Contracts for Water Supply", Grid line, Note No. 12-Sept. 2006, PPIAF and the World Bank. (http://www.ppiaf.org/Gridlines/12Leaseaffermage.pdf), Science and Technology: Water Supply,[24] vol. 1, no. 6, pp. 11-20 Rizzo, A., [25] 2007, Apparent Water Loss Control, Theory and Application, in: Water Loss 2007, 2326 September 2007, Bucharest. Tabesh, M., and Asadiani H. Y,[26] 2005, "A Software Tool for Non-Revenue Water Calculations in Urban Water System in Conjunction with Hydraulic and GIS Models", Leakage 2005- Conference Proceedings.

2.2 Site Description

The area selected for this study are different Group Housing Pockets of Paschim Vihar (28.6687° N, 77.1019° E) which falls in the North West part of National Capital Delhi. It is serviced by the 40 MGD Nangloi Water Treatment Plant. The topography is plain. The roads and streets are either Bituminous or Concrete. The Network is a mix of Cast Iron, Ductile Iron, UPVC, with few lengths of Asbestos Cement pipes as well. The pipeline sizes vary from 300 mm diameter to 100 mm diameter. The study was conducted over two distinct cycles i.e. December 2017 to January 2018 and February 2018 to March 2018. The study area lies in the North Western part of the National Capital Delhi.

Figure 1 Study Area Description Delhi

The main study zone i.e. Paschim Vihar (28.6687° N, 77.1019° E) lies in North West Delhi, it is bounded by the Rohtak Road, Outer Ring Road, Najafgarh drain and Raghubirpuri Road.

Figure 2 Study Area Description Paschim Vihar, New Delhi

The three selected areas for creating District Metering Areas are GH8 block in the Paschim Vihar Area, shown in Fig 3.3, GH 10 block, shown in Fig 3.4 and the GH 12 block shown in Fig 3.5. All these areas were selected due to well defined geographic boundaries and also since creating a discrete hydraulic zone was possible. Another influencing factor was the presence of consumer meters installed at all the consumer premises, familiarity and availability of verifiable distribution network maps.

The three colonies though situated in the same vicinity were selected for the study fall in a plain area. Only a few localized low areas exist but the difference in elevation is not appreciable precluding the chances of localized pressure drops. All these colonies identified for have distinct boundaries that are well defined by presence of isolation valves that contributed in sectorization of the study area in to three District Metering Areas (DMAs)

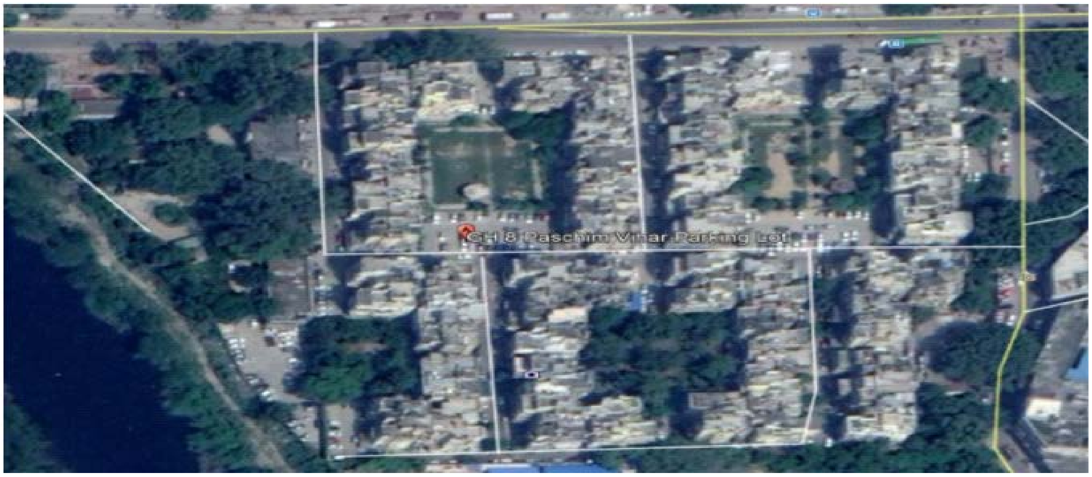

Figure 3 Study Area - GH 8 Block, Paschim Vihar

Figure 4 Study Area - GH 10 Block, Paschim Vihar

Figure 5 Study Area - GH 12 Block, Paschim Vihar

2.3 Data Collection

Various data that were required for analysing the water supply and the extent of NRW were acquired, these include Network details, topography of the area, extent of water supply, details of the water distribution network, metering, water supply bills, consumption patterns etc., were collected. The applicable and significant data required for analysis was collected and is represented in Chapter IV Worksheets and annexed at the end of this report as Observations.

2.3.1 Network Details

The details of the distribution network such as the material of construction of the pipeline, size, location and sizes of different valves and other appurtenances, size of the water meters installed at every customer location, locations of bulk flow meters, Supply hours, number and location of consumer households, their layout details, connection details such as Connection Number, consumer address etc. were acquired from the authorities. These were then superimposed on the Autocad drawing of the area to develop the representative distribution network.

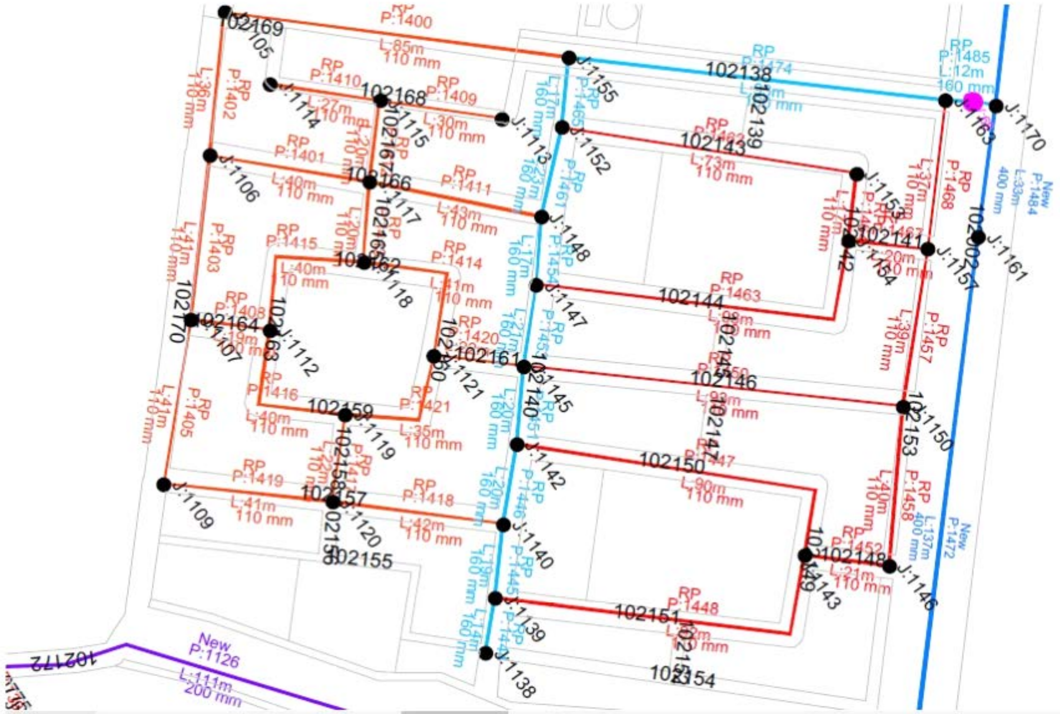

Figure 6 GH 8 Distribution Network

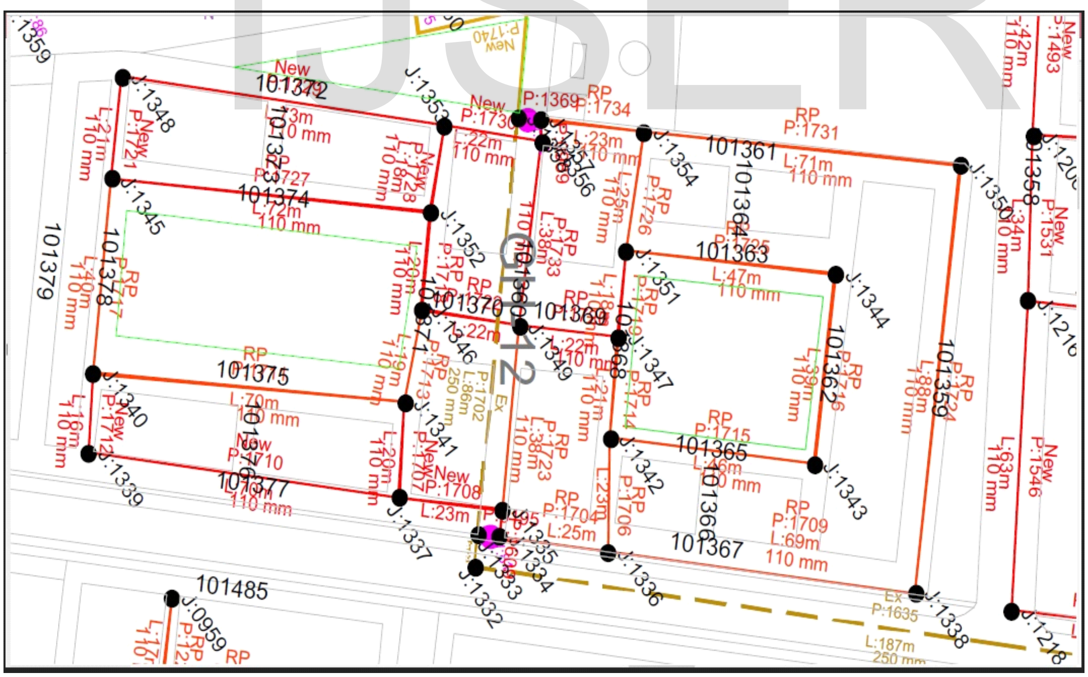

Figure 7 GH 12 Distribution Network

2.3.2 Extent of Water Supply

All the three DMAs have an intermittent water supply. The supply hours meet the peak demand hours i.e. Mornings between 5:30 AM to 8:00 AM and Evenings between 6:30 PM to 8:30 PM. The water demands are met through locally placed Under ground reservoirs that are filled over-night and between the non-supply hours. Water is supplied to the household through local pumping stations.

2.3.3 Verification of Water Distribution Network

The sizes of pipelines and other appurtenant devices were tallied with the details obtained (network drawings in Auto-CAD format) to ensure that the analysis is representative of the actual distribution network. Different valves were identified, locations of flow meters checked, condition of consumer water meters installed in each individual consumer premises, unique connection numbers and working status of the water meters were checked. Those meters that were faulty or where the premises were locked were recorded as not working. The network drawings are available in Annexure 1 for ready reference.

2.3.4 Collection and Verification of Consumption Data

The individual water consumption details such as the volume of water consumed between both the cycles over which the study was undertaken were obtained from the concerned meter reading department and verified with the billing department for accuracy. The daily consumption was arithmetically calculated as an average by dividing the total consumption by the number of days.

The total consumption during each study cycle for respective DMA was derived as the Arithmetic total of the consumption by each customer in that DMA over the study periods selected by adding the bills in the billing cycle.

2.3.5 Collection and Verification of Supply Data

The bulk flow meter reading at the start of each study cycle (initial reading) was obtained and recorded. The bulk flow meter reading at the end of the study cycle (final reading) was also recorded.

The total volume of total water supply to respective DMA was thus obtained as the difference between the final and initial readings from respective bulk flow meters for each DMA.

2.3.6 Data Analysis Including Inferences

The total consumption in each DMA for the study cycle was divided by the total number of consumers to arrive at the average per day consumption for that period.

The total volume of water supplied during the cycle similarly was divided by the number of consumers for arriving at the average quantity of water supplied during that period.

The difference between the actual volume supplied and the actual amount billed for each cycle gives us the NRW for that cycle, which is expressed as a percentage of the actual volume of water supplied daily to the respective DMA.

III. RESULTS & DISCUSSION

In this section results and discussion are made w.r.t. average daily consumption, Average daily supply, total number of consumers, total daily consumption and computation of non-revenue water. The details discussion has been given to subsequent sections.

Observation Data – Dec'17 to Jan'18

DATE	LOCATION	VOLUME	LOCATION	VOLUME	LOCATION	VOLUME
12/1/2017	GH-8	330.8	GH-10	424.1	GH-12	139.7
12/2/2017	GH-8	336	GH-10	416	GH-12	134.2
12/3/2017	GH-8	331.8	GH-10	412.9	GH-12	132.8
12/4/2017	GH-8	330.3	GH-10	418.7	GH-12	139.4
12/5/2017	GH-8	334.2	GH-10	414.6	GH-12	133.4
12/6/2017	GH-8	330.8	GH-10	417.9	GH-12	131.2
12/7/2017	GH-8	332	GH-10	424.9	GH-12	139.3
12/8/2017	GH-8	338.1	GH-10	420.4	GH-12	135.2
12/9/2017	GH-8	335.4	GH-10	425.9	GH-12	142.7
12/10/2017	GH-8	340.1	GH-10	421.8	GH-12	137.2
12/11/2017	GH-8	336.8	GH-10	426.7	GH-12	139.5
12/12/2017	GH-8	341.2	GH-10	429.8	GH-12	142.1

12/13/2017	GH-8	337.4	GH-10	479.8	GH-12	135.3
12/14/2017	GH-8	331.4	GH-10	475.5	GH-12	132.8
12/15/2017	GH-8	329.5	GH-10	470.5	GH-12	137.9
12/16/2017	GH-8	333.8	GH-10	485.2	GH-12	130.4
12/17/2017	GH-8	331.5	GH-10	474.8	GH-12	140.2
12/18/2017	GH-8	333.8	GH-10	480.9	GH-12	135.4
12/19/2017	GH-8	328.9	GH-10	475.9	GH-12	138
12/20/2017	GH-8	347.1	GH-10	470.2	GH-12	134.9
12/21/2017	GH-8	345.5	GH-10	485.3	GH-12	140.5
12/22/2017	GH-8	346.1	GH-10	480.2	GH-12	134.6
12/23/2017	GH-8	347.5	GH-10	479.3	GH-12	140.4
12/24/2017	GH-8	343.1	GH-10	460.5	GH-12	135.6
12/25/2017	GH-8	340.2	GH-10	490.2	GH-12	133.8
12/26/2017	GH-8	348.9	GH-10	482.5	GH-12	139.6
12/27/2017	GH-8	346.7	GH-10	479.5	GH-12	135.8
12/28/2017	GH-8	340.2	GH-10	490.4	GH-12	133.9
12/29/2017	GH-8	350.5	GH-10	478.6	GH-12	140.5
12/30/2017	GH-8	346.9	GH-10	497.8	GH-12	143.1
12/31/2017	GH-8	308.4	GH-10	380.7	GH-12	127.4
1/1/2018	GH-8	308.4	GH-10	380.7	GH-12	127.4
1/2/2018	GH-8	302.2	GH-10	377.9	GH-12	123.3
1/3/2018	GH-8	310.7	GH-10	382.6	GH-12	130.5
1/4/2018	GH-8	302.4	GH-10	379.2	GH-12	129.3
1/5/2018	GH-8	315.6	GH-10	384.1	GH-12	126.6
1/6/2018	GH-8	336.6	GH-10	377.6	GH-12	136.7
1/7/2018	GH-8	333.4	GH-10	375.9	GH-12	134.2
1/8/2018	GH-8	332.4	GH-10	385.3	GH-12	132.1
1/9/2018	GH-8	340.2	GH-10	383.7	GH-12	138.5
1/10/2018	GH-8	333.7	GH-10	385.6	GH-12	138.6
1/11/2018	GH-8	337.9	GH-10	380.6	GH-12	134.3
1/12/2018	GH-8	340.5	GH-10	379.8	GH-12	134.6
1/13/2018	GH-8	334.1	GH-10	387.3	GH-12	138.3
1/14/2018	GH-8	329.8	GH-10	377.8	GH-12	131.9
1/15/2018	GH-8	348.1	GH-10	402.9	GH-12	148
1/16/2018	GH-8	340	GH-10	386.5	GH-12	128.9
1/17/2018	GH-8	340	GH-10	386.5	GH-12	128.9
1/18/2018	GH-8	298.3	GH-10	354	GH-12	126.9
1/19/2018	GH-8	294.3	GH-10	349	GH-12	122.9
1/20/2018	GH-8	300.4	GH-10	354.6	GH-12	128.3
1/21/2018	GH-8	295.3	GH-10	350.6	GH-12	125.8
1/22/2018	GH-8	290.6	GH-10	360.4	GH-12	130.2
1/23/2018	GH-8	311.2	GH-10	354.6	GH-12	127.8

1/24/2018	GH-8	318.6	GH-10	372.5	GH-12	124.6
1/25/2018	GH-8	318.6	GH-10	370.5	GH-12	122.8
1/26/2018	GH-8	316.9	GH-10	375.2	GH-12	125.3
1/27/2018	GH-8	316.3	GH-10	368.7	GH-12	120.8
1/28/2018	GH-8	315.9	GH-10	380.1	GH-12	126.3
1/29/2018	GH-8	325.5	GH-10	368.4	GH-12	128.3
1/30/2018	GH-8	314	GH-10	370	GH-12	126.5
1/31/2018	GH-8	313.1	GH-10	375.6	GH-12	123.5

Computation:

Average daily consumption in GH-08		0.48274	
Average daily consumption in GH-10		0.586262	
Average daily consumption in GH-12		0.484222	
Volume supplied in GH-08 per day		329.0467	
Volume supplied in GH-10 per day		414.35	
Volume supplied in GH-12 per day		133.2081	
Total registered consumers in GH-08 as per active PP3 file			596
Total registered consumers in GH-10 as per active PP3 file			496
Total registered consumers in GH-12 as per active PP3 file			210
Total daily consumption in GH-08			287.7129
Total daily consumption in GH-10			290.7859
Total daily consumption in GH-12			101.6866
Non-revenue Water in GH-08			**12.56166**
Non-revenue Water in GH-10			**29.82119**

Non-revenue Water in GH-12		**23.66335**

Observation Data – Feb'18 to Mar'18

FLOW METER (VOLUME ANALYSIS) READING TIME 5 PM						
DATE	LOCATION	VOLUME	LOCATION	VOLUME	LOCATION	VOLUME
2/1/2018	GH-8	315.2	GH-10	372.8	GH-12	128.3
2/2/2018	GH-8	312.8	GH-10	375.3	GH-12	125.8
2/3/2018	GH-8	315	GH-10	356.4	GH-12	128.8
2/4/2018	GH-8	322.9	GH-10	377.9	GH-12	131.4
2/5/2018	GH-8	320.5	GH-10	375.6	GH-12	130.5
2/6/2018	GH-8	323.8	GH-10	376.5	GH-12	129.6
2/7/2018	GH-8	320.4	GH-10	377.9	GH-12	132.4
2/8/2018	GH-8	322.7	GH-10	375.4	GH-12	130.5
2/9/2018	GH-8	324.6	GH-10	379.9	GH-12	132.7
2/10/2018	GH-8	325.4	GH-10	382.2	GH-12	132.9
2/11/2018	GH-8	285.1	GH-10	368.4	GH-12	132.3
2/12/2018	GH-8	282.9	GH-10	365.8	GH-12	130.2
2/13/2018	GH-8	286.4	GH-10	370.8	GH-12	129.8
2/14/2018	GH-8	287.3	GH-10	365.4	GH-12	134.6
2/15/2018	GH-8	285.6	GH-10	370.8	GH-12	135.1
2/16/2018	GH-8	283.4	GH-10	369.4	GH-12	132
2/17/2018	GH-8	331.3	GH-10	371.1	GH-12	136.8
2/18/2018	GH-8	330.4	GH-10	370.4	GH-12	134.6
2/19/2018	GH-8	329.5	GH-10	373.8	GH-12	135.2
2/20/2018	GH-8	333.4	GH-10	375.1	GH-12	136.7
2/21/2018	GH-8	331.5	GH-10	369.8	GH-12	134.2
2/22/2018	GH-8	332.8	GH-10	370.5	GH-12	137.2
2/23/2018	GH-8	329.7	GH-10	373.1	GH-12	134.5
2/24/2018	GH-8	332.8	GH-10	375.9	GH-12	137.2
2/25/2018	GH-8	330.9	GH-10	372.8	GH-12	138.2
2/26/2018	GH-8	329.7	GH-10	371.2	GH-12	133.2
2/27/2018	GH-8	332.9	GH-10	358.8	GH-12	147.2
2/28/2018	GH-8	318.5	GH-10	375.6	GH-12	142.8
3/1/2018	GH-8	316.2	GH-10	372.5	GH-12	140.6
3/2/2018	GH-8	318.4	GH-10	376.3	GH-12	141.8
3/3/2018	GH-8	315.7	GH-10	377.4	GH-12	142.3
3/4/2018	GH-8	315.2	GH-10	375.6	GH-12	140.5
3/5/2018	GH-8	316.2	GH-10	374.9	GH-12	143.5
3/6/2018	GH-8	315.6	GH-10	372.1	GH-12	140.7

3/7/2018	GH-8	318.6	GH-10	377.3	GH-12	142.7
3/8/2018	GH-8	320.2	GH-10	375.3	GH-12	143.5
3/9/2018	GH-8	317.2	GH-10	372.3	GH-12	142.3
3/10/2018	GH-8	318.9	GH-10	376.3	GH-12	139.5
3/11/2018	GH-8	319.5	GH-10	379.3	GH-12	141.8
3/12/2018	GH-8	320.8	GH-10	377.4	GH-12	142.8
3/13/2018	GH-8	318.9	GH-10	375.6	GH-12	141.6
3/14/2018	GH-8	317.5	GH-10	376.4	GH-12	140.4
3/15/2018	GH-8	320.4	GH-10	374.1	GH-12	143.6
3/16/2018	GH-8	318.4	GH-10	377.2	GH-12	145.1
3/17/2018	GH-8	319.5	GH-10	375.4	GH-12	146.7
3/18/2018	GH-8	318.6	GH-10	370.1	GH-12	148.2
3/19/2018	GH-8	326.8	GH-10	380.9	GH-12	146.6
3/20/2018	GH-8	317	GH-10	381.1	GH-12	146.2
3/21/2018	GH-8	316.5	GH-10	378.5	GH-12	144.5
3/22/2018	GH-8	320.1	GH-10	377.6	GH-12	143.6
3/23/2018	GH-8	314.2	GH-10	380.6	GH-12	146.2
3/24/2018	GH-8	315.8	GH-10	382.6	GH-12	145.6
3/25/2018	GH-8	314.5	GH-10	379.4	GH-12	143.8
3/26/2018	GH-8	317.6	GH-10	378.6	GH-12	147.9
3/27/2018	GH-8	316.3	GH-10	383.6	GH-12	146.3
3/28/2018	GH-8	318.9	GH-10	383.5	GH-12	143.9
3/29/2018	GH-8	319.4	GH-10	385.6	GH-12	154.2
3/30/2018	GH-8	347.7	GH-10	407.5	GH-12	144.6
3/31/2018	GH-8	345.8	GH-10	410.2	GH-12	146.2

Computation:

Average daily consumption in GH-08		0.4229413	
Average daily consumption in GH-10		0.5695141	
Average daily consumption in GH-12		0.4933539	
Volume supplied in GH-08 per day		318.53898	
Volume supplied in GH-10 per day		375.99661	
Volume supplied in GH-12 per day		139.18475	
Total registered consumers in GH-08 as per active PP3 file			596

Total registered consumers in GH-10 as per active PP3 file		496
Total registered consumers in GH-12 as per active PP3 file		210
Total daily consumption in GH-08		252.07303
Total daily consumption in GH-10		282.47901
Total daily consumption in GH-12		103.60433
Non-revenue Water in GH-08		**20.86588**
Non-revenue Water in GH-10		**24.87193**
Non-revenue Water in GH-12		**25.56345**

3.1 Average Daily Consumption

During the cycle from Dec'17 to Jan'18, the average daily consumption recorded in GH8, GH10 and GH 12 were 0.483, 0.586 and 0.484 KL respectively. These are graphically represented as under in figure 8.

Figure 8: Representation of Average Daily Consumption, KL from Dec 2017-Jan 2018

The average daily consumptions recorded during the Feb'18-Mar'18 cycle for GH 8, GH10and GH 12 were 0.423, 0.569 and 0.493 KL respectively. These are graphically represented in figure 9 below.

Figure 9: Representation of Average Daily Consumption, KL from Feb 2018-March 2018

From study of two graphs while GH 8 and GH 10 recorded a decline in average consumption, GH12 showed a rise in the average consumption. This could possibly be due to better meter reading during the 2nd cycle, i.e., Feb'18- Mar'18.

3.2 Average Daily Supply

During the corresponding cycles of time i.e. Dec'17 – Jan'18 and Feb'18-Mar'18, the average volume supplied per day to the three DMAs i.e. GH 8, GH 10 and GH12 were 329.05, 414.35 and 133.21 KL and 318.54, 376.00 and 139.18 KL respectively. These are graphically represented in fig 10 and fig 11.

The volume of water supplied in GH12 increased by 4.48%, while it dipped by 3.19% and 9.25% in GH8 and GH 10 respectively.

Figure 10: Representation of Volume Supplied Per Day, KL from Dec 2017-Jan 2018

Figure 11: Representation of Volume Supplied Per Day, KL from Feb 2018-March 2018

3.3 Total Number of Consumers

There was no change in number of registered customers during the two cycles. The number of consumers remained constant for GH8, GH10 and GH12 i.e. 596, 496 and 210 respectively. This is represented in figure 12 below.

Figure 12: Representation of Total Number of Registered Consumers from Dec 2017-Jan 2018 and Feb'18-Mar'18.

3.4 Total Daily Consumption

The total daily consumptions for the three DMAs over the two study cycles are represented in fig 13 and 14 below. While daily consumption in GH8 dropped from 287.72 to 252.07 KL, the corresponding decline in GH10 was from 290.79 to 282.48 KL, however GH12 reported a rise from 101.67 to 103.60 KL.

Figure 13: Representation of Total Daily Consumption, KL from Dec 2017-Jan 2018

Figure 14: Representation of Total Daily Consumption, KL from Feb 2018-March 2018

3.5 Computation of Non-Revenue Water

Figure 15: Representation of Non-Revenue Water, (%) from Dec 2017-Jan 2018

Figure 16: Representation of Non-Revenue Water, (%) from Feb 2018-March 2018

Non -Revenue Water (NRW) %

Using the above equation, the NRW values were computed for both study cycles and found to be 23.66, 29.82 and 12.56 in GH 12, GH10 and GH8 respectively for the first cycles as graphically represented in fig 15 above. For the second cycle, the corresponding values were 25.56, 24.87 and 20.87 for GH12, GH10 and GH8 respectively, as graphically represented in figure 16 above.

A graphical comparison between the NRW figures along with the Supply and Consumption data for all the three DMAs over both the cycles is represented in figure 17 and 18 given hereunder.

Figure 17: Representation of Comparison of NRW, (%) from Dec 2017-Jan 2018

Figure 18: Representation of Comparison of NRW, (%) from Feb 2018-March 2018

IV. CONCLUSIONS

It can be concluded from the results that by proper monitoring of the input volumes, active and accurate metering, effective leakage control and comprehensive design of the network the NRW can be reduced. Moreover, the pressure monitoring, and step testing were not conducted due to the limited scope of this study. Several permutations and combinations of still efficient DMA aimed at more efficient i.e. lowest NRW are possible however, that has several influencing factors such as the capital costs likely to be incurred for installation of new pipelines, valves, flow meters etc. During the evolution of the proposed 24X7 supply of water under the Nangloi Command area, with better and efficient leak management, real time pressure variation studies, installation of AMR meter, proposed SCADA controls and implementation of installation of proposed appurtenances, the study areas need to be assessed further to verify the extent of NRW reduction vis a vis the cost. It is quite possible that the NRW might be reduced to within 15% which is reported from some of the advanced countries of the first world.

V. ACKNOWELDEGEMENT

I wish to express my heartfelt thanks to the staff of Delhi Jal Board (India) and Nangloi Water Services, Delhi (India) for allowing me access to the area and sharing the revenue as well as the supply data during the studies.

REFERENCES

[1] ADB, 2006 Nonrevenue Water: A Governance Challenge," http://www.adb.org/water/topics/non- revenue/default.asp.

[2] Alegre et al., 2006, Performance Indicators for water supply services, 2nd Ed, IWA Publications

[3] AWWA., 2003 Development of a Strategic Planning Process, AWWA research foundation, Denver.

[3] Baietti A., Kingdom W. and Ginneken M., 2006, "Characteristics of Well-Performing Public Water Utilities", Water Supply and Sanitation Working Notes 9, February 2006, World Bank, Washington DC.

[4] Brocklehurst C., Janssens J., 2004, "Innovative Contracts, Sound Relationships: Urban

[5] Water Sector Reform in Senegal", Water Supply and Sanitation Sector Board Discussion Paper 1, January 2004, World Bank, Washington DC.

[6] Charalambous, B. ,2008, Use of district metered areas coupled with pressure optimisation to reduce leakage, Water Science and Technology: Water Supply, vol. 8, no. 1, pp 57-62.

[7] Dyson et al., 2003, United Nations World Water Development Report Water a Shared Responsibility.

[8] Fanner, P., Sturm, R., Thornton, J., and Liemberger, R. (2007), Leakage Management Technologies, Awwa Research Foundation, AWWA, Denver, USA; IWA, London.

[9] Farley, M. and Trow, S., 2003, Losses in Water Distribution Networks: A practionner's Guide to Assessment, Monitoring and Control. IWA Publishing, London.

[10] Farley, M., and Liemberger, R., 2005, “Developing a non-revenue water reduction strategy: planning and implementing the strategy”, Water Science and Technology: Water Supply, Vol. 5 No.1, pp 41-50, IWA publishing

[11] Jeffcoate, P., and Saravanapavan, A., 1987, “The Reduction and Control of Unaccounted-for Water”. World Bank Technical Paper, No. 72, Water Supply Operations Management Series, The World Bank, Washington, D.C.

[12] Khin Myat Nwe, 2008 “Non-revenue water and water sustainability: A case of Yangon city urban water supply system “thesis presented to the higher Degree Committee of Ritsumeikan Asia Pacific University

[13] Kingdom, B., Uemberger, R. and Marin, P., 2006, The challenge of reducing Non-Revenue Water in developing countries. How private sector can help: a look at performance-based service contracting, The World Bank, Water Supply & Sanitation Sector Board, PPIAF, Washington.

[14] Lambert, A. O. ,2002, "International report: Water losses management and techniques", Water Science and Technology: Water Supply, vol. 2, no. 4, pp. 1-20

[15] Lambert, A., 2003, "Assessing non-revenue water and its components: A practical approach", Water21, vol. (Aug.), pp. p.51-52.

[16] Langa, J. V. Q. and Quessouji, J., 2007, "Water Losses In Maputo Suplly System: an overview of the strategic plan for leakage reduction.", IWA, in: Water Loss 2007, 23-26 sept 2007, Bucharest.

[17] Mahmoudi, S., 2007, "Managing UFW in Iran", IWA, in: Water Loss 2007, 23-26 sept.2007, Bucharest.

[18] McKenzie, R. and Lambert, A., 2004, Best Practice Performance Indicators for Non-Revenue Water and Water Loss Components: A Practical Approach", Water21, no. 8

[19] Mclntosh, C. Arthur, 2003 Asian Water Supplies: Reaching the Urban Poor, Asian Development Bank (ADB)

[20] Ndokosho, J., Hoko, Z. and Makurira, H., 2007, "Assessment of management approaches in a public water utility: A case study of the Namibia water corporation (NAMWATER)", Physics and Chemistry of the Earth, Parts A/B/C, vol. 32, no. 15- 18, pp. 1300-1309.

[21] Noor F.M., 2005 Non-Revenue Water Reduction Control: District Meter Area Method, Water

[22] Queensland Environmental Protection Agency and Wide Bay Water, 2002, "Managing and Reducing Losses from Water Distribution Systems", Manual 7: Managing Apparent Loss, ISBN 0 7242 9499 6

[23] Queensland Environmental Protection Agency and Wide Bay Water, 2002, "Managing and Reducing Losses from Water Distribution Systems", Manual 6: Real Loss Management, ISBN 07242 9494 5

[24] Ringskog K., Hammond E. Mary, and Locussol A., 2006a, "Using Management and Lease-affermage Contracts for Water Supply", Grid line, Note No. 12-Sept.

2006, PPIAF and the World Bank.
http://www.ppiaf.org/Gridlines/12Leaseaffermage.pdf

[25] Science and Technology: Water Supply, vol. 1, no. 6, pp. 11-20 Rizzo, A., 2007, Apparent Water Loss Control, Theory and Application, in: Water Loss 2007, 2326 September 2007, Bucharest.

[26] Tabesh, M., and Asadiani H. Y, 2005, "A Software Tool for Non-Revenue Water Calculations in Urban Water System in Conjunction with Hydraulic and GIS Models", Leakage 2005- Conference Proceedings

[27] Vermersh, M. and Rizzo, A. ,2004, "An action planning model to control for Non-Revenue Water", Water 21, April 2004

[28] Pressure control in district metering areas with boundary and internal pressure reducing valves by Bogumil Ulanicki, Hossam Abdel Meguid, Peter Bounds and Ridwan Patel.