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IDENTIFYING THE LOCATION AND MAGNITUDE OF NON-REVENUE WATER: A CASE STUDY AT FELDA CHUPING, PERLIS

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Abstract-- Understanding and modelling of Non-Revenue Water components is crucial for the water authority and in Malaysia, NRW control has been given high priority by the Federal Government. NRW cannot be totally avoided and understanding its components is crucial before a reduction strategy can be developed and implemented. For that reason this study has taken the initiative to research the details of NRW management of Felda Chuping. The conceptual model for treated water distribution system that consists of the configuration for water source, water storage, water network, and the supply area has been identified. A framework for NRW classification has also been proposed. All the seven NRW components identified by International Water Association have been grouped/clustered into four different sections. The working procedure for the purpose of identifying the source and magnitude of NRW components has been formalized. The formulation of mathematical model has facilitated the estimation of the source and magnitude of NRW components.

Index Terms—Non Revenue Water, Water Loss, Modelling Water Management

I. Introduction

During the last decade, studies on the understanding and modeling of water loss components have been performed. Water lost from the many public water utilities due to poor water distribution network facilities and management, which resulted in a negative impact on the utilities is also known as non-revenue water (NRW). International Water Association (IWA) defined NRW as the difference between the System Input Volume and Billed Authorised Consumption [1]. System Input Volume is the annual volume input to that part of the water supply system to which the water balance calculation relates. Authorised Consumption is the annual volume of metered and/or non-metered water taken by registered customers, the water supplier and others who are implicitly or explicitly authorized to do so, for residential, commercial and industrial purposes. Figure 1 shows the IWA standard water balance and terminology. NRW consists of real losses, apparent losses and unbilled authorized consumption.

NRW control has been a high priority issue by the Malaysian Federal Government beginning from the Sixth Malaysian Plan. In the Seventh Malaysia Plan for example, the government spent more than RM500 million for rehabilitation of water supply system. In the Eighth Malaysia Plan a total of RM640 million was expended to reduce the NRW. The activities involve the replacement of old pipes and old water meters and reduction of water pilferages as well as the rehabilitation and upgrading of water distribution system. In the Ninth Malaysia Plan, the effort to reduce the NRW is to be continued in order to improve the efficiency of water supply. RM 1088.3 millions is budgeted to reduce the NRW from 38% (2007) to 30% (2011) [2].

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption (including water exported)	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	**Unbilled Metered Consumption**	**Non-Revenue Water (NRW)**
			Unbilled Unmetered Consumption	
	Water Losses	**Apparent Losses**	**Unauthorised Consumption**	
			Metering Inaccuracies	
		Real Losses	**Leakage on Transmission and/or Distribution Mains**	
			Leakage and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to point of Customer metering	

Fig. 1. IWA Standard International Water Balance and Terminology (NRW and its components shaded grey)

II. Felda Chuping Water Distribution System

Perlis, one of the smallest states in Malaysia, has also experienced high level of NRW that are 44% in 2000 and 37% in 2005. Perlis divide its water supply into four supply zone namely Wang Kelian, Timah Tasoh, Felda Chuping and Arau. Felda Chuping is one of the small consumer zones located in western Perlis. Previous research shows that Felda Chuping NRW is around 37.56% in January 2004 [3]. Currently, Felda Chuping treatment plant serves 662 consumers. Among these consumers, 650 are domestic consumers while others are commercial, institutional and industrial consumers

Felda Chuping obtains its raw water from three borewells [4]. Each borewells are equipped with a pump working at rate of 9.1 litre/second (l/s). The water runs through chlorination and chemical dosing house before it is delivered to Felda Chuping Elevated tank. This source is capable of supplying 0.84 Mld of water. Water transmission from the borewells to the storage tank is through HDPE Polypipe 8" (200mm). From the storage, water is distributed through HDPE Polypipe 10" (250mm) until it reach the consumers area. In consumer area the water supply through HDPE Polypipe 180mm.

Records from the Public Water Works indicate that, a total of 1156 consumer meters have been installed in Felda Chuping area since 1980s. These meters are classified into three statuses:active (0), inactive (1), and replaced (2). Active meters are those that are in use, while inactive meters are those that are not in use. Replaced meters are those that have been removed and no longer available. Table 1 shows the total of active an inactive meters and their age.

TABLE 1
METER STATUS AND AGE

Status	Total	Age	
		Range	Total
Active (0)	605	<=5	196
		>5 & <=10	170
		>10 & <=15	223
		>15 & <= 20	14
		> 20	2
Inactive (1)	56	<=5	5
		>5 & <=10	6
		>10 & <=15	21
		>15 & <= 20	19
		> 20	5

Figure 2 shows the consumer growth since 1975. The graph shows that number of consumer increases dramatically in 1975 until 1980. This scenario might probably be due to the increment of the Felda Chuping resident as these are the beginning years for Felda Chuping.

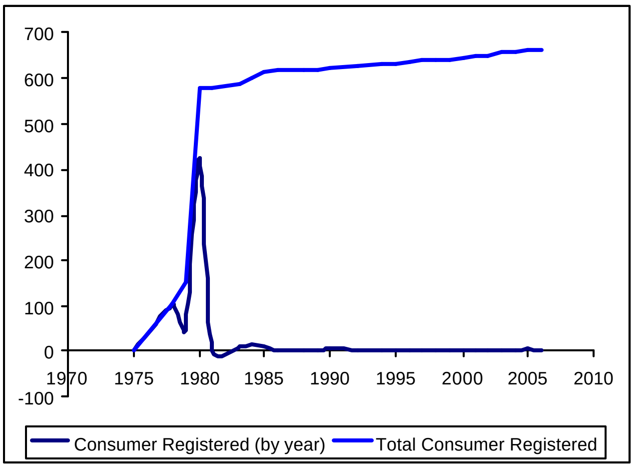

Fig. 2. Treated Water Consumer since 1975 (Source Perlis Water Works, 2006)

III. DATA COLLECTION

As suggested in the literature, data to be gathered should include water source, water use, water loss, and distribution facilities. In this study, data are gathered from three main sources: Perlis Water Department, Repoh Maintenance Unit and site operator. Data from the Perlis Water Department includes the following:

a) consumer – consumer reference number, name, address, type of tariff, and supply date.
b) meter - meter number, installation date, meter status, bill date, average bill amount, and arrears.
c) Consumer's water usage – arrears
d) water source - number of pumps, pumping rate, etc.
e) water transmission and distribution
f) service connection pipe
g) distribution components - sluice valve, scour valve, meter chamber, etc.
h) storage tank – capacity, level.

Data related to water production was obtained from site operator. The data include the total pumping hour per month, trip (pump interruption), production (m^3/month) and total production (m^3/month). Data related to the water losses at Felda Chuping area was collected from Repoh maintenance unit. Repoh maintenance unit performs site inspection at monthly interval and record the data on estimate loss due to leakages, frequencies of hydrant usage.

IV. CONCEPTUALIZE MODEL OF FELDA CHUPING TREATED WATER DISTRIBUTION SYSTEM

Felda Chuping treated water distribution system can be summarized as consists of water source, water treatment, storage, distribution pipes and service pipes, and consumers meter (consumer area). Based on the collected data and schematic diagram of Felda Chuping water production, a conceptualize model is formalized as shown in Figure 3. This model shows the main components of Felda Chuping water distribution system. As shown in Figure 3, water is pumped from borewells and treated at the pumping house before been stored in supply tank. The transmission is through the distribution mains. After the supply tank, the water is supplied to consumer through service connections.

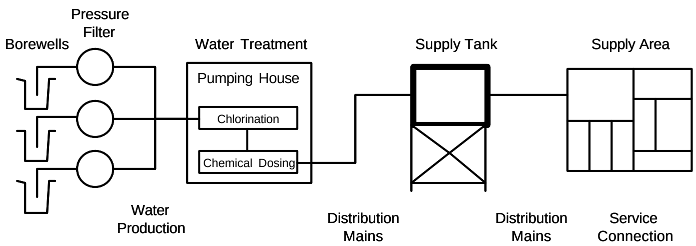

Fig. 3. Conceptualization of Felda Chuping treated water distribution system

V. FRAMEWORK OF NRW CLASSIFICATION

Based on the conceptualize model in Figure 3, further analysis have been made and four water loss areas have been identified. Details of the losses are described in Table 2. Figure 4 shows the framework of NRW classification, both by water loss area and type of NRW. The areas are at the water loss transmission pipe before tank (A1), the tank (A2), transmission pipe after tank (A3), and consumer area (A4). At each area, the possible type of NRW has been identified.

TABLE 2
NRW CODE DESCRIPTION

Code	Descriptions
NRW01	Unbilled Metered Consumption
NRW02	Unbilled Unmetered Consumption
NRW03	Unauthorized Consumption
NRW04	Meter Inaccuracies
NRW05	Leakage on Transmission and/or Distribution Mains
NRW06	Leakage and Overflow at Utility's Storage Tank
NRW07	Leakage on Service Connections up to point of Consumer metering

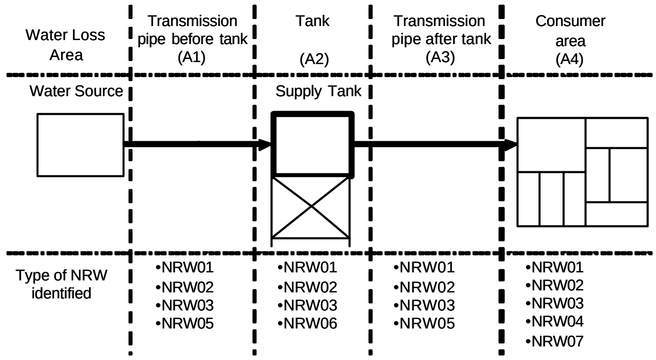

Fig. 4. Framework of NRW identification and classification

VI. NRW ANALYSIS FRAMEWORK

The total NRW can be determined by:

Total NRW = System Volume Input - Revenue Water

System volume input is the total water produced by the borewells. Revenue water is the total of billed authorized consumption made by the consumer in the supply area. Billed authorized consumption is calculated based on the consumer's meter reading and billed non-metered consumption. The total NRW is then used to estimate the other NRW components.

However before the NRW components can be estimated, the existing NRW estimation needs to be assessed. The assessment performed by Repoh Maintenance Unit includes monitoring of all connections, valves, hydrants, and supply tank. The framework is formalized as depicted in Figure 5.

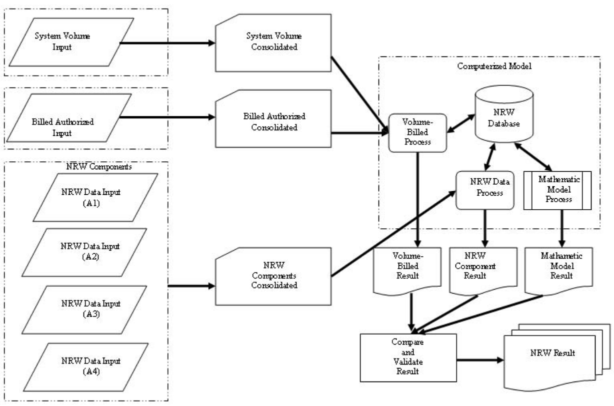

Fig. 5. Framework for NRW analysis

The framework consists of seven steps:

a) Step 1 – Determining System Volume Input
b) Step 2 – Determining Revenue Water
c) Step 3 – Determining NRW components
d) Step 4 – Data consolidation
e) Step 5 – Computerized Model
f) Step 6 – Compare and Validate the results to get the constant value
g) Step 7 – NRW result

VII. NRW ESTIMATION FORMULATION

Examples of data collected by Repoh Maintenance Unit are shown in Table 3. These data covers all NRW categories. The comparisons of all NRW components are shown in Figure 6. Based on this comparison, and estimation for the constant value can be determined.

TABLE 3
SAMPLE DATA OF NRW COMPONENTS

Month / Types of NRW	February	April	Jun
NRW01	0.00	0.00	0.00
NRW02	202.00	279.00	306.50
NRW03	1526.00	1808.00	1527.00
NRW04	992.00	770.00	687.00
NRW05	336.00	366.00	302.00
NRW06	28.00	30.00	30.00
NRW07	4700.00	4470.00	4550.00
TOTAL	7784.00	7723.00	7402.50

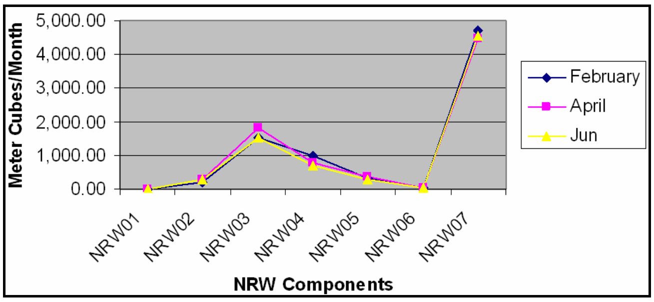

Fig. 6. Comparison of NRW components by month

Based on Table 3 and comparison of NRW components Figure 6, new NRW calculation can be formulate as follows:

NRW = aNRW01 + bNRW02 + cNRW03 + dNRW04 + eNRW05 + fNRW06 + gNRW07

where a, b, c, d, e, f and g are constants. The constant values are the ratios between the averages of NRW components and total NRW (i.e. for February and April 2006). Based on data in Table 3, the constant values obtained are as follows.

a = 0.00, b = 0.031, c = 0.215, d = 0.114, e = 0.045 f = 0.004, and g = 0.591.

This formula is viable when no modifications are made in the present distribution system (i.e pipe changes, treatment plant upgrade, drastic water demand, and etc.). Thus, if the changes occurred in network distribution system, new values for the constants need to be determined by performing steps 1-7 as given in Figure 5. The new constants values need to be input into the prototype. User may choose the applicable constant in estimating the NRW components based on current water distribution system.

VIII. DISCUSSION AND CONCLUSION

Analysis activity of the present Felda Chuping water distribution system has produced two models, a framework and work procedure related to NRW. The first contribution is the conceptual model for treated water distribution system which consists of the configuration the water source, water storage, water network, and the supply area. The second contribution is a framework for NRW classification, where all the seven NRW components identified by IWA have been grouped/clustered into four different sections. The sections are between water source and supply tank, at supply tank, after supply tank up to consumer area, and consumer area.

Third contribution is the working procedure for the purpose of identifying the source and magnitude of NRW components. It is a comprehensive procedure which includes determining actual system volume input, revenue water and NRW components, data consolidation as well as the source and magnitude of NRW. This procedure is also able to compare NRW obtained from two different approaches. The first approach is the NRW deduced from water production and revenue, while the second is the actual collected NRW data.

A mathematical model has also being produced for re-estimation of the source and magnitude of NRW components. This model can be modified according to various situations such as dry or raining sessions.

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