MANAGING WATER LOSS FOR SUSTAINABILITY OF RURAL WATER SUPPLY

Ku Ruhana Ku-Mahamud, Wan Hussain Wan Ishak, Muhamad Shahbani Abu Bakar
Faculty of Information Technology
Universiti Utara Malaysia, 06010 Sintok, Kedah, Malaysia
Tel. +604-9283118
ruhana@uum.edu.my, hussain@uum.edu.my , shahbani@uum.edu.my

ABSTRACT
Water supply for rural areas flows through pipelines from many sources such as underground water and reservoirs. Due to factors such as human activities, geographic changes and natural hazards, pipelines are exposed to the ground, crack, leak and burst. Water flows out from the pipelines before reaching to the consumers is considered as water loss and this is a major component in non-revenue water. This paper highlights a framework and a work procedure for non-revenue water analysis. Based on this analysis, a comprehensive and flexible web based prototype has been developed to manage the water loss. Functions that have been developed are data recording, non-revenue water estimation and report generation. This prototype can be used by the water authority for assisting decision making and planning.

Keyword: water loss, non revenue water, water management

1.0 INTRODUCTION

In rural areas, water encourages activities such as agricultural, small industrial activities, homes and outdoors. To serve this purpose, water is supplied from production facilities such as dams, reservoirs, and tanks. Supplying water is a crucial task since any fault occurred in the water distribution system might affect the users. In many countries, the water distribution system is organize in a network of pipes made of asbestos, cement, PVC, mild steel and others. Pipes are buried underground and lined along the road and highways. These pipelines are exposed to nature activities and will deteriorate and loose their initial water tightness [1]. Deteriorations were caused by corrosive environments, soil movement, poor construction standards, fluctuation of water pressure, and excessive traffic loads and vibration. Due to these causes, water loss could occur at different components such as transmission pipes, distribution pipes, service connection pipes, joints, valves, fire hydrants, and storage tanks and reservoirs.

Water loss 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). NRW is categorised as the amount of water put into the supply systems that brings no revenue to the supply authority and sometimes defined as the difference between water produced and water sold. International Water Authority (IWA) defined NRW as the difference between the volume produced and billed authorised consumption [2]. The source and magnitude of NRW will have to be identified for any NRW reduction program. Fig. 1 shows detail components of NRW as defined by IWA.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

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

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This study aims to formulate a NRW model that can be used to facilitate and assist the management of the water departments in their water reduction program and plan for future development.

2.0 CASE STUDY

Felda Chuping, the focus zone for this study is one of the small rural consumer zones located in western Perlis. Felda Chuping obtains its raw water from three borewells. Each borewell is 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 water source is capable of supplying 0.84 Mld of water. The water is conveyed to a supply tank before it reaches the consumer area. Currently, Felda Chuping serves 662 consumers. Among these consumers, 650 are domestic consumers while others are commercial, institutional and industrial consumers. Previous research shows that Felda Chuping NRW figure is around 37.56% in January 2004 [3].

In this rural area, the treated water distribution system consists of water sources, treatments and storages, distribution pipes and service pipes, and consumer meters. Fig. 2 depicts a conceptual model which highlights the main components of the water distribution system that is based on collected data and schematic diagram of Felda Chuping water production. Water is pumped from borewells and treated at the pumping house before it is stored in supply tanks. The water transmission is through the distribution mains. After the supply tanks, the water is supplied to consumers through service connections.

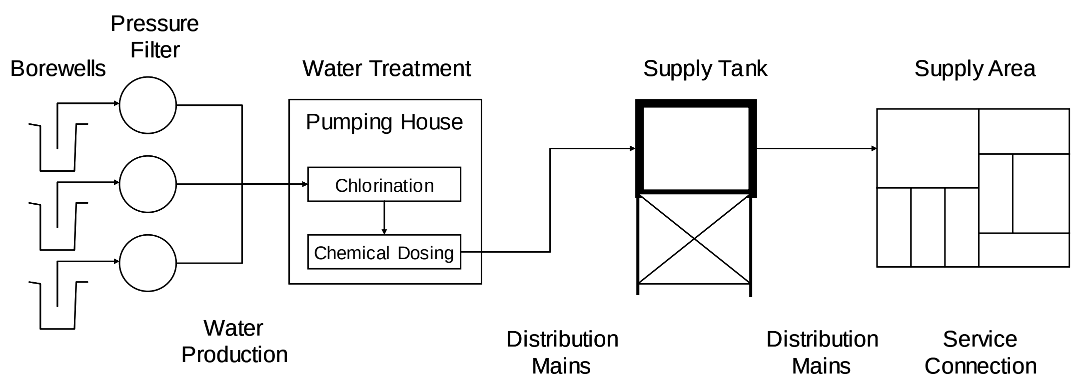

Fig. 2: Conceptual model of treated water distribution system

Based on the conceptual model, further analysis has been made and four water loss areas have been identified. Fig. 3 depicts the NRW classifications both by water loss areas and types of NRW (refer Table 1).

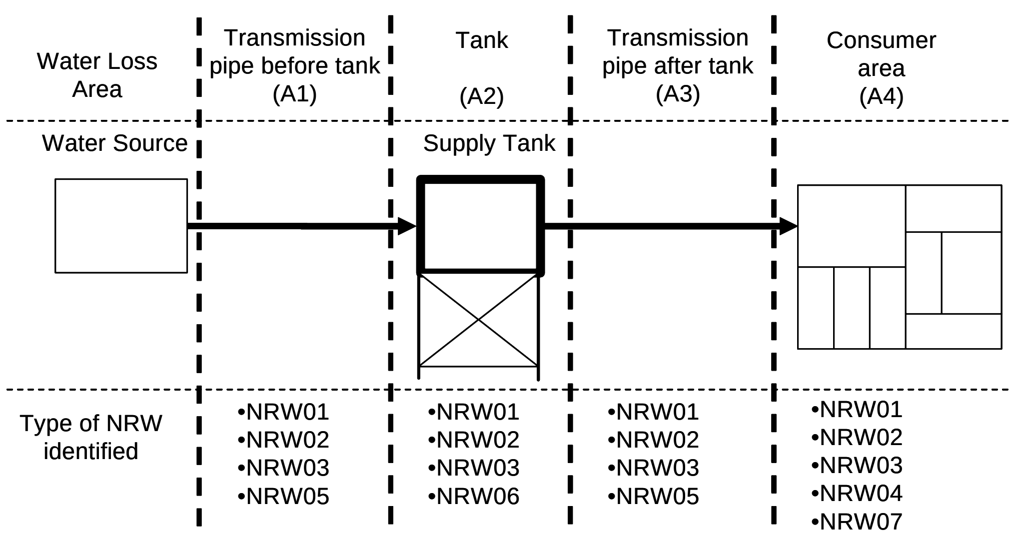

Fig. 3: NRW identification and classification

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Table 1: NRW Code Descriptions

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

However, before the NRW components can be estimated, the existing NRW estimation needs to be assessed. The assessment performed by the maintenance unit includes monitoring of all connections, valves, hydrants, and supply tanks. The proposed framework to estimate NRW components consists of seven steps as shown in Fig. 4. The steps are determining system volume input, determining revenue water, determining NRW components, data consolidation, computerize model and determining constant value.

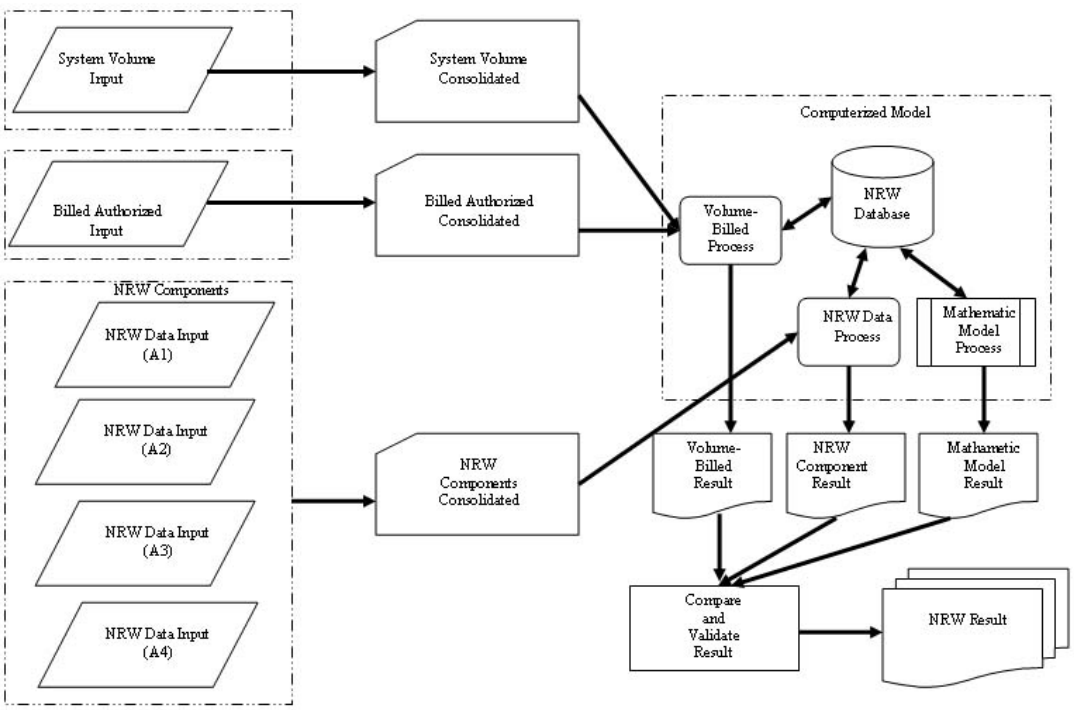

Fig. 4: Framework for NRW analysis

A mathematical model has also being produced for re-estimation of the source and magnitude of NRW components. NRW calculation can be formulated as follows:

$$NRW = a\text{NRW01} + b\text{NRW02} + c\text{NRW03} + d\text{NRW04} + e\text{NRW05} + f\text{NRW06} + g\text{NRW07}$$

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. This model can be modified according to various situations such as dry or raining sessions.

3.0 THE NRW MANAGEMENT SYSTEM

In this study, Visual Basic.NET and ASP.NET technology are used to develop the prototype. This technology centers on an integrated development environment that allows programmers to create standalone applications, web sites, web applications, and web services that run on any platform supported by Microsoft's .NET Framework. This solution can give rapid development and easy updating of the requirements. In addition, Microsoft SQL Enterprise Manager is used to store and manipulate data.

Fig. 5 shows the entities involved in this prototype development. The entities are consumer, meter and billing histories, source input, constant parameter and NRW consumption.

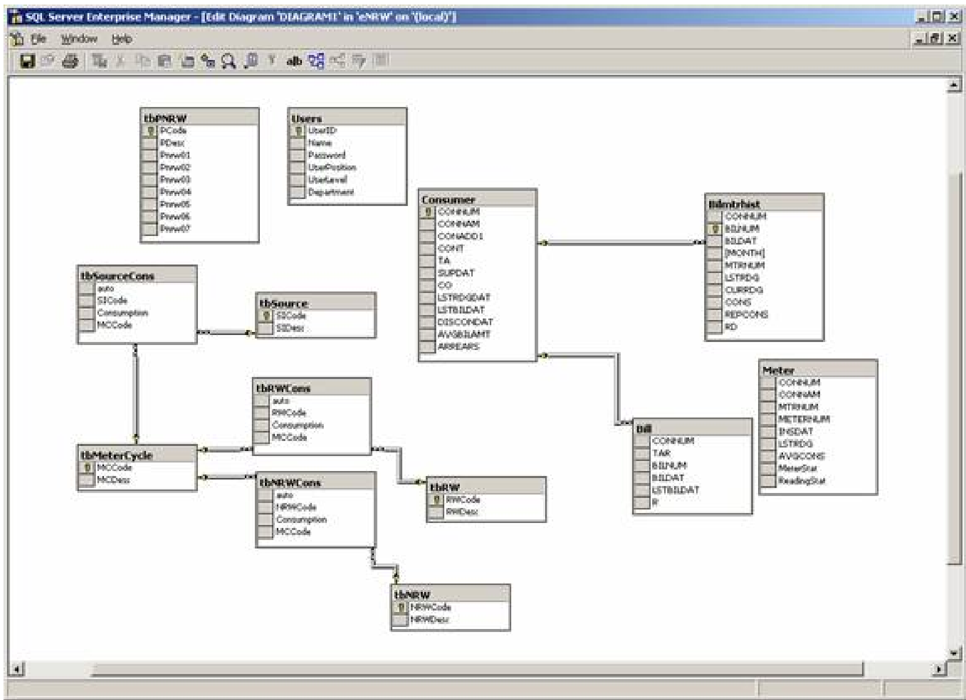

Fig. 5: Entity Class Diagram for NRW-Felda Chuping Prototype

The prototype is designed and developed based on Web-based application to ensure the accessibility of rural users. The prototype main components are client sites and server sites. The client sites are located at the Perlis Water Authority headquarters, Repoh Maintenance Unit, and Rumah Pam Felda Chuping. The computer server using Windows Server 2003 operating system, which supports ASP.net technology and VB.net scripts is located at the Perlis Water Authority headquarters in Utan Aji. Access to the prototype is through existing Perlis Water Authority network facility. This prototype employs Microsoft SQL Enterprise Manager database for storing and manipulating the NRW data. Fig. 6 shows the physical layout of the prototype.

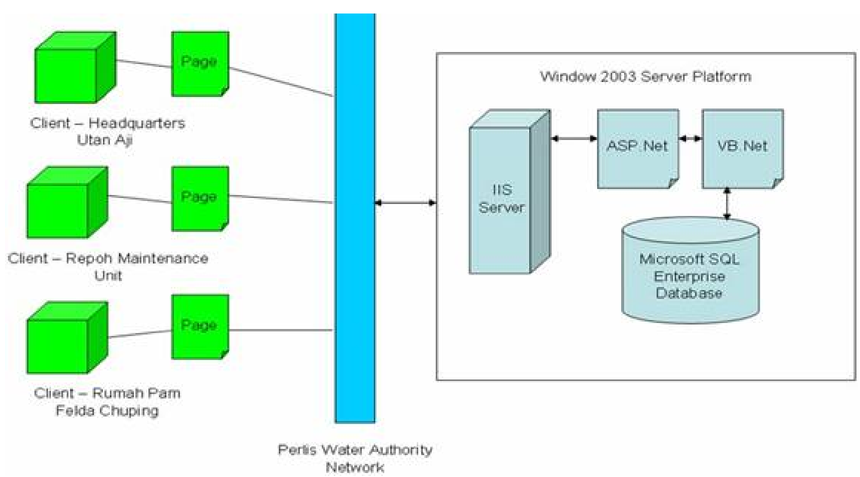

Fig. 6: Prototype Physical Layout

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The prototype menu consists of four main functions, which are system parameter set up, data entry, data manipulation, and report generation. The system parameter setup can be used to initialize the parameters of the water distribution system. There are six sub-menus available. The functionalities of these sub-menus are shown in Table 2.

Table 2: Functionalities of System Parameters

Sub-Menu	Description
Month Cycle Code	Define the month cycle code
System Input Code	Define the system input code
Revenue Water Code	Setup the revenue water code
NRW Code	Setup the NRW code
NRW Parameter	Define NRW constant value
System User	Manage system user account

Data entry sub-menu consists of source input consumption, revenue water consumption, and NRW consumption. The functions of the sub-menus are listed in Table 3.

Table 3: Data Entry Sub-menu Functionalities

Sub-Menu	Description
Source Input Volume	Input source water consumption
Revenue Water Consumption	Input revenue water consumption
NRW Water Consumption	Input NRW Water consumption

In this study, the source input considered are from the treatment plants and imported water. Water from treatment plants is the water produced from borewells and pumped to Felda Chuping area, while imported water is water obtained from treatment plants or transmission pipes in other NRW zones. This data is recorded monthly. Revenue water is water that is charged to the consumers in Felda Chuping area and this data is obtained from billed metered consumption and billed unmetered consumption on monthly basis in the present water billing system.

NRW water consumption data is obtained from reports produced by Repoh Maintenance Unit. This unit is responsible for site inspection, maintenance and repair. NRW data includes unbilled metered consumption, unbilled unmetered consumption, unauthorized consumption, metering inaccuracies, leakage on transmission pipe, leakage at utility's storage, and leakage on service connections up to consumers' meters. This data is recorded on monthly basis.

The data manipulation function involves estimating the NRW volume and percentage. Estimating NRW volume is based on defined constant values. The report function on the main menu consists of 19 type of reports available for the user to generate. The types are : system input, authorized consumption, water losses, billed authorized consumption, unbilled authorized consumption, apparent losses, real losses, billed metered consumption, billed unmetered consumption, unauthorized consumption, metering inaccuracies, leakage on transmission, leakage at utility's storage, leakage on service connections, revenue water, non-revenue water, and consumer information.

Testing of the prototype includes validations of the main modules of the prototype. The main modules are the source input data, revenue water consumption, calculating the NRW figure and recording monthly NRW data. The source input is validated using the following formula (as suggested by Distribution Engineer at Perlis Water Work);

$$\text{pumping rate} = \frac{\text{tank width x tank length x tank height x 6.25}}{\text{pumping hour}} \quad (1)$$

where 6.25 is a fixed parameter for an imperial tank that represents the water cubes. The new pumping rate for the imperial tank can be obtained for 16 pumping hours test is calculated as follows.

$$\text{pumping rate } = \frac{120{,}000\ \text{gallons}}{16\ \text{hours}}$$

$$= 7503\,\text{gallons/hours} \equiv 34.11\text{m}^3\,/\,\text{hour}$$

The difference between the adopted pumping rate and the new pumping rate is around 2.54%. This shows that the pumping rate adopted (i.e. 35 m^3/hours) is acceptable. The result also shows that accuracy of the source input volume is 97.46%.

The revenue water is validated based on the estimation of water used per day. As suggested by Bina Runding (1991), average water use per day is around 0.23m^3/day (equivalent to 50 gallons/day). Bina Runding also suggested that the average number of persons or consumers in Felda Chuping is 4 persons per active consumer. The formula to calculate the monthly revenue water is as follows:

Revenue Water = (per month)	No. of active consumer x Average usage per active consumer x Average water use x No. of days	(2)

Based on the formula and Felda Chuping consumers information, the monthly revenue water can be estimated as follows:

Revenue Water (for February) = 605 x 4 x 0.23 x 28
= 15585 m^3

The percentage of accuracy of the metered revenue water is about 97.88% when comparison is performed between the actual and the estimated data. The NRW volume estimated by the prototype is validated by comparing this volume with the actual data collected on the NRW. The result of this comparison shows that the accuracy of the result produced by the prototype is more than 85%.

4.0 CONCLUSION

A prototype for the Felda Chuping water loss management has been developed that could facilitate the water authority in their water loss reduction program especially in the rural area. The prototype has the capability of performing monthly NRW calculation where previously NRW can only be obtained on yearly basis. As the prototype covers all aspects of water management, the output produced from the prototype can be used by the rural water authority for decision making and planning. This study has also increased the researchers' knowledge on the distribution system and consumption patterns in the rural area.

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