AUDIT GUIDELINES

Non-Revenue
WATER

NATIONAL AUDIT DEPARTMENT
MALAYSIA

AUDIT GUIDELINES

NATIONAL AUDIT DEPARTMENT, MALAYSIA

NON-REVENUE WATER (NRW)

First Issue 2011

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Note:
These guidelines do not cover aspects of financial management and procurement. Please refer to the specific audit guidelines if necessary.

PREFACE BY
THE AUDITOR GENERAL OF MALAYSIA

The issue of non-revenue water (NRW) losses has often drawn the attention of Members of Parliament and State Legislative Assembly as well as the mass media. The losses incurred through NRW is detrimental to both the government and the people and can have a negative impact on the economy. The roles and responsibilities of auditors in the management and control of NRW losses are crucial in ensuring accountability of the responsible parties.

The publication of these guidelines is therefore timely as it will assist auditors in carrying out quality audit on NRW in an efficient and effective manner. With these guidelines, performance audit on key activities to control and reduce NRW throughout the country can therefore be standardised. I believe that these guidelines will become an important source of reference for auditors as well as the water supply entities.

I would like to take this opportunity to congratulate the Water Audit Division and Research Division, Special Audit and Research Sector as well as the State Audit Sector of the National Audit Department for preparing the NRW Audit Guidelines. These guidelines are one of five available guideline modules. The other four modules are:

- Production of Drinking Water
- Water Supply Distribution
- Water Supply Customer Service
- Water Supply Project Management

I hope that continuous efforts will be taken to update these guidelines consistent with current developments and changes.

(TAN SRI DATO' SETIA HAJI AMBRIN BIN BUANG)
AUDITOR GENERAL OF MALAYSIA

22 June 2011

ACRONYMS AND ABBREVIATIONS

Water Supply Entities

AKSB	Air Kelantan Sdn Bhd
SSWD	Sabah State Water Department
WSD	Water Supply Department (Kedah, Pahang, Labuan)
PWD (Water)	Public Works Department, Water Division (Perlis, Sarawak)
KWB	Kuching Water Board
LAKU	LAKU Management Sdn Bhd
PWB	Perak Water Board
PBAPP	PBA Pulau Pinang Sdn Bhd
SAJH	SAJ Holdings Sdn Bhd
SAINS	Syarikat Air Negeri Sembilan Sdn Bhd
SAMB	Syarikat Air Melaka Berhad
SATU	Syarikat Air Terengganu Sdn Bhd
SWB	Sibu Water Board
SYABAS	Syarikat Bekalan Air Selangor Sdn Bhd

Government Agencies and Independent Organisations

IKRAM	IKRAM QA Services Sdn Bhd
MEWC	Ministry of Energy, Water and Communications (2004–2009)
MEGTW	Ministry of Energy, Green Technology and Water (2009) / KeTTHA
MWA	Malaysian Water Association
IWA	International Water Association
SIRIM	Standards and Industrial Research Institute of Malaysia
NWSC	National Water Services Commission / SPAN

Designations

CEO	Chief Executive Officer
COO	Chief Operation Officer
GM	General Manager
MD	Managing Director

Parameters and Unit Measurements

mld	million litres per day
km	kilometre
m/s	metre per second
m^3	cubic metre
m^3/s	cubic metre per second
RM	Malaysian Ringgit

Others

ABS	Acrylonitrile Butadiene Styrene
AC	Asbestos Cement
CI	Cast Iron
DI	Ductile Iron
DMA	District Metering Area
DMZ	District Metering Zone
etc	*et cetera*
GI	Galvanised Iron
GIS	Geographic Information System
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HDPE	High Density Polyethylene
ICT	Information and Communication Technology
ILI	Infrastructure Leakage Index
WSI	Water Services Industry
LNF	Legitimate Night Flow
WTP	Water Treatment Plant
MNF	Minimum Night Flow
MS	Mild Steel
MWIG	Malaysian Water Industry Guide
NNF	Net Night Flow
NRW	Non-Revenue Water
PE	Polyethylene
PRV	Pressure Reducing Valve
SCADA	Supervisory Control and Data Acquisition
SMS	Short Message Service
SOP	Standard Operating Procedure
UFW	Unaccounted-for Water
uPVC	unPlasticised Polyvinyl Chloride
FT	Federal Territory
WSIA	Water Services Industry Act
ZPT	Zero Pressure Test

REFERENCES

1. Water Services Industry Act 2006 (Act 655, Laws of Malaysia)

2. Malaysian Water Industry Guide 2006 (MWIG 2006) (The Malaysian Water Association in collaboration with the Ministry of Energy, Water and Communications)

3. Malaysian Water Industry Guide 2007 (MWIG 2007), October 2008 (The Malaysian Water Association in collaboration with the Ministry of Energy, Water and Communications)

4. 2004 Performance Audit Guidelines (National Audit Department)

5. The Manager's Non-Revenue Water Handbook – Ranhill

6. Hot Tapping – Lestari Nilam Sdn Bhd

7. Water Loss Control Manual – Julian Thornton

8. Holistic NRW – A Guide for Water District Engineers – MEWC

9. Water Supply Leakage and Wastage Control – PWD

10. Workshop on NRW Management and Practice – MEWC

11. 2008 Water Loss Asia Conference and Exhibition – MWA

12. Karyanet *http://www.karyanet.com.my/* (Dewan Bahasa dan Pustaka)

CHAPTER A: PREAMBLE

CHAPTER A: PREAMBLE

A1 PURPOSE OF GUIDELINES

The purpose of these guidelines is to assist auditors to conduct the non-revenue water (NRW) audit in a complete, effective and prudence manner. The guidelines focus primarily on what needs to be done during audits.

These guidelines also describe briefly activities pertaining to control and monitoring of NRW. The auditor's understanding on matters to audit will help to produce a quality audit.

A2 BACKGROUND

According to the 1987 PWD issue of Water Supply Leakage and Wastage Control Report prepared by the World Health Organisation's consultants, the statistics in 1978 indicated that the overall percentage of Unaccounted-For Water (UFW) in Peninsular Malaysia was 26.5%. Analysis of data collected from 118 water supply districts showed that the UFW range was from 13.2% to 57.6%.

The term 'UFW', which has been used in the past, is now known as 'Non-Revenue Water (NRW)'. In determining the rate of water loss, UFW refers to the quantity of water that cannot be verified, whereas NRW takes into account all quantities of water that do not yield revenue.

Water loss in the distribution system is becoming more serious. In 2008, an average of 36.6% of total water supplied was lost during the distribution process. Sabah, Negeri Sembilan, Pahang, Kedah and Kelantan had recorded NRW rates exceeding 40%.

The overall value of NRW in 2008 at 36.6% rate with a projected average production of 13,860 million litres per day (mld) and at an operating cost of RM0.40/m3 was RM2 billion. This rate could have been realistically reduced to 15%, which would mean potential savings of 21% or RM1.1 billion for the year alone. This figure could increase should there arise a potential need at a higher selling price, which would raise the revenue of water supply entities.

The challenges faced by water supply entities to reduce NRW include age of pipe networks, financial constraints, design and poor project management.

Methods of implementation, equipment use and NRW calculations that were used in the past are also significantly different from current ones. Some of these differences include:

- A new and more accurate method of determining physical and commercial losses.

- Use of hardware and software technology to manage water leakage control and a more efficient pressure reduction system.

A3 AUDIT OBJECTIVES

The objectives of undertaking an NRW audit are to assess the:

1. Appropriateness of the implementation of NRW programmes according to financial provisions and scope of work.

2. Optimal NRW percentage target.

3. Sustainable reduction of NRW percentage levels in line with targets.

4. Actual effectiveness in terms of savings, such as reduced operating costs.

5. Continued effectiveness and sustainability.

A4 AUDIT SCOPE AND METHODOLOGY

The adopted approach is comprehensive and includes planning, implementation, control and monitoring. The audit will be conducted on the following components:

- Organisation of NRW Division
- NRW Programme Management
- Mapping using the Geographic Information System (GIS)
- Water balance
  - (i) System input volume
  - (ii) Billed consumption
  - (iii) Unbilled consumption
  - (iv) Physical losses
  - (v) Commercial losses
- Control of NRW
- Leak detection and repair
- Control of material and work quality

- NRW economic level
- NRW overall performance and achievement levels

The methodologies used in the audit are as follows:

1. Reviewing documents and analysing information in the organisation

2. Conducting physical inspections or site visits

3. Conducting tests and in-situ observations

4. Briefings, discussions and interviews with officers in the organisation

5. Obtaining professional viewpoints, advice and technical assistance from consultants.

A5 ORGANISATION OF WATER SUPPLY ENTITIES AND NRW DIVISION

The NRW Division lies under the purview of the water supply entity. In 2009, the water supply entities comprised the following:

- **Government departments/agencies** comprising Kedah, Pahang and Labuan Water Supply Departments, Sabah State Water Department (SSWD), Perlis and Sarawak State Public Works (Water) Departments, Perak Water Board (PWB), Kuching Water Board (KWB) and Sibu Water Board (SWB)

- **Statutory bodies/government-owned companies** comprising Syarikat Air Negeri Sembilan Sdn Bhd (SAINS), Syarikat Air Melaka Berhad (SAMB), Air Kelantan Sdn Bhd (AKSB), Syarikat Air Terengganu Sdn Bhd (SATU) and LAKU Management Sdn Bhd (LAKU)

- **Private agencies** comprising state water concessionaires:

    - PBA Pulau Pinang Sdn Bhd (PBAPP)

    - Syarikat Bekalan Air Selangor Sdn Bhd (SYABAS) in Selangor, Federal Territory of Kuala Lumpur and Federal Territory of Putrajaya

    - SAJ Holdings Sdn Bhd (SAJH) in Johor.

    Note: The audit of private companies is subject to the concern of His Majesty the King in accordance with Section 6.1 (d) of the Audit Act and gazettes from time to time.

FIGURE 1: ORGANISATIONAL STRUCTURE OF THE STATE WATER SUPPLY ENTITY

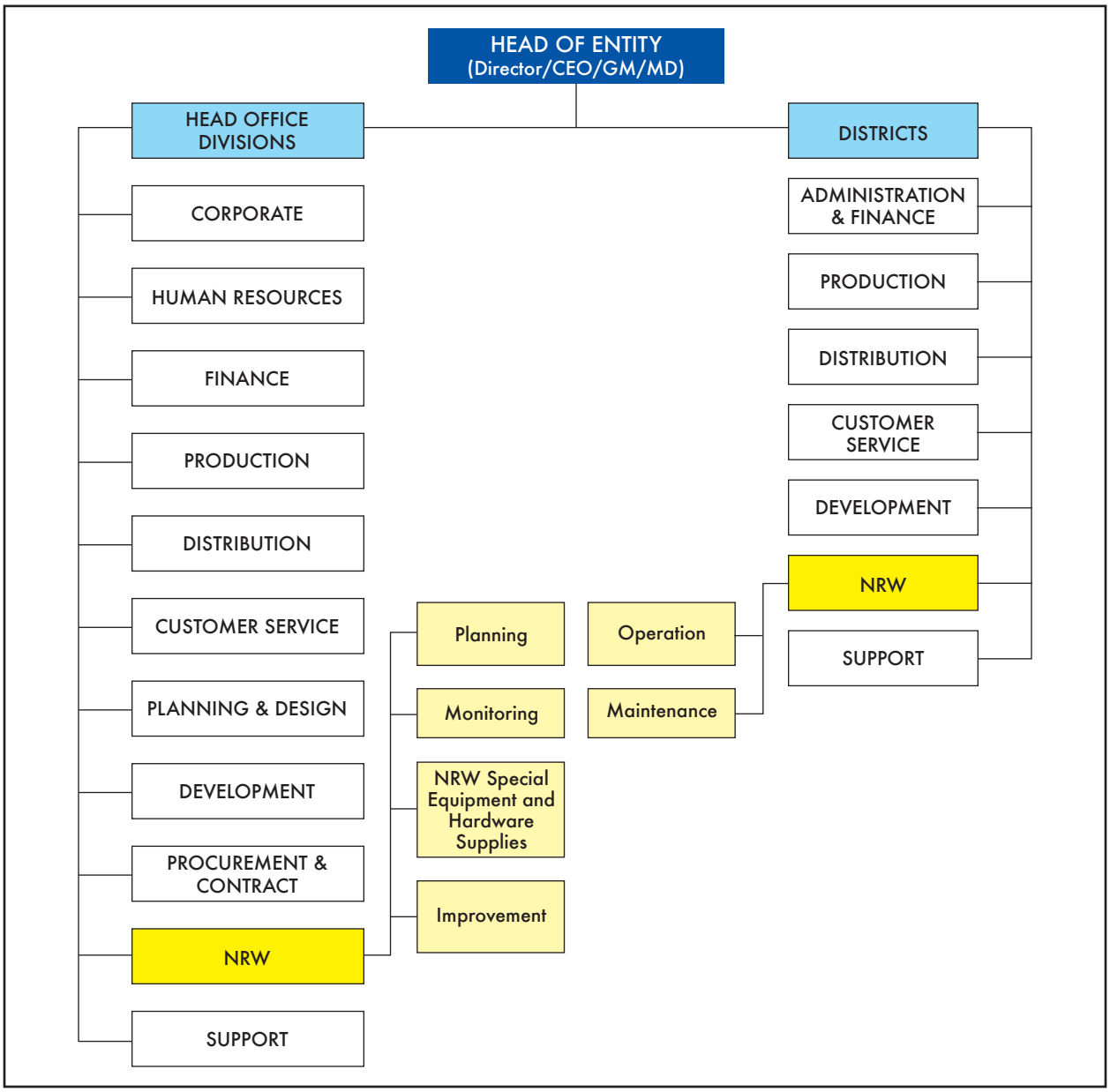

Figure 1 is a typical organisational structure of state water supply entities with differences only in the arrangement of the related fields. The main role of the **head office** is to determine **policies**, while the role at **district** level is to **implement** these policies.

At the management level, each entity is headed by a chief executive bearing such titles such as Director for government departments and Chief Executive Officer (CEO), Managing Director (MD) or General Manager (GM) for statutory bodies and companies.

Generally, the **head offices** of state water supply entities are responsible for:

- Preparing business plans, standard operating procedures (SOP) and centralised Information and Communication Technology (ICT) system

- Monitoring, coordinating, providing advisory services, improving and controlling key activities that are conducted at district level, including production, distribution system and customer service

- Handling corporate affairs, human resources, finance, planning and project management, procurement and centralised ICT systems.

The state water supply district office is headed by the District Water Engineer for government departments or Regional Manager or Senior Regional Manager or District General Manager for statutory bodies and companies. District level offices are responsible for:

- Implementing programmes developed by the head office

- Reporting on the progress of operations and maintenance of key areas

- Providing feedback for improvement

- Using and giving input to the centralised ICT system.

The NRW Division at the head office and district levels is usually headed by an engineer/technical assistant for government departments and manager for statutory bodies and companies.

NRW activities at the head office include NRW planning and monitoring, NRW special equipment and hardware supplies, and improvement studies on controlling NRW.

The NRW unit at the district level is responsible for implementation, control and monitoring of NRW.

A6 LAWS AND REGULATIONS

The management of NRW is generally carried out in accordance with NRW-related provisions of the Water Services Industry Act 2006. Section 180(a)(iv) states that the National Water Services Commission (NWSC) may develop technical and performance standards and adopt key performance indicators for water supply systems. Additionally, water supply entities can refer to international institutions such as the International Water Association (IWA) for the adoption of their best practices.

The responsibilities pertaining to management of NRW are subject to the following laws and regulations:

1. Suruhanjaya Perkhidmatan Air Negara Act 2006 [Act 654]

2. Water Services Industry Act 2006 [Act 655] – WSIA

3. Occupational Safety and Health Act 1994 [Act 514]

4. Street, Drainage and Building Act 1974 (Act 133), Ministry of Housing and Local Government, Malaysia.

5. State Water Supply Enactments

    i) Selangor State Water Supply Order, Revised 1997
    ii) Kedah Darul Aman State Water Supply Enactment (First Revision)
    iii) Perak Water Board Enactment No 12 of 1988
    iv) Selangor State Water Supply Order, Revised 1997
    v) Negeri Sembilan State Water Supply Enactment (NBB Chapter 203), Negeri Sembilan Water Supply Rules 1981
    vi) Melaka State Water Supply Enactment 2002
    vii) Johor State Water Supply Enactment 1993
    viii) Pahang Water Resources Enactment 2007
    ix) Terengganu State Water Supply Enactment 1998
    x) Sabah Water Supply Enactment 2003
    xi) Sarawak Water Ordinance 1994
    xii) Sarawak Water Supply Regulations 1995
    xiii) Kelantan Water Supply Enactment1995, Kelantan Water Supply Rules

6. Technical Guidelines and Instructions (Road) 2002, Public Works Department

The Water Services Industry Act 2006 (WSIA) is applicable only in the states of Peninsular Malaysia and Federal Territory of Labuan, while Sabah and Sarawak fall under the water legislation and their respective state regulatory bodies.

CHAPTER B: NON-REVENUE WATER (NRW)

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B1 DEFINITION OF NRW

Water is a basic necessity of life and must be managed well to ensure adequate supply at all times. The loss of water in the water supply system is a problem that must be addressed in an efficient and effective manner. Water loss is not only a waste of natural resources but also an economic loss to the country.

NRW is defined as the quantity of water that is channelled into the water supply system but does not yield returns. Technically, NRW is the total production of fresh water (treated) minus the total billed metered consumption and billed unmetered consumption (reference: Water Loss Control Manual).

$$\text{NRW \%} = \frac{P - (M + N)}{P} \times 100\%$$

where;
P = Production of treated water
M = Billed metered consumption
N = Billed unmetered consumption

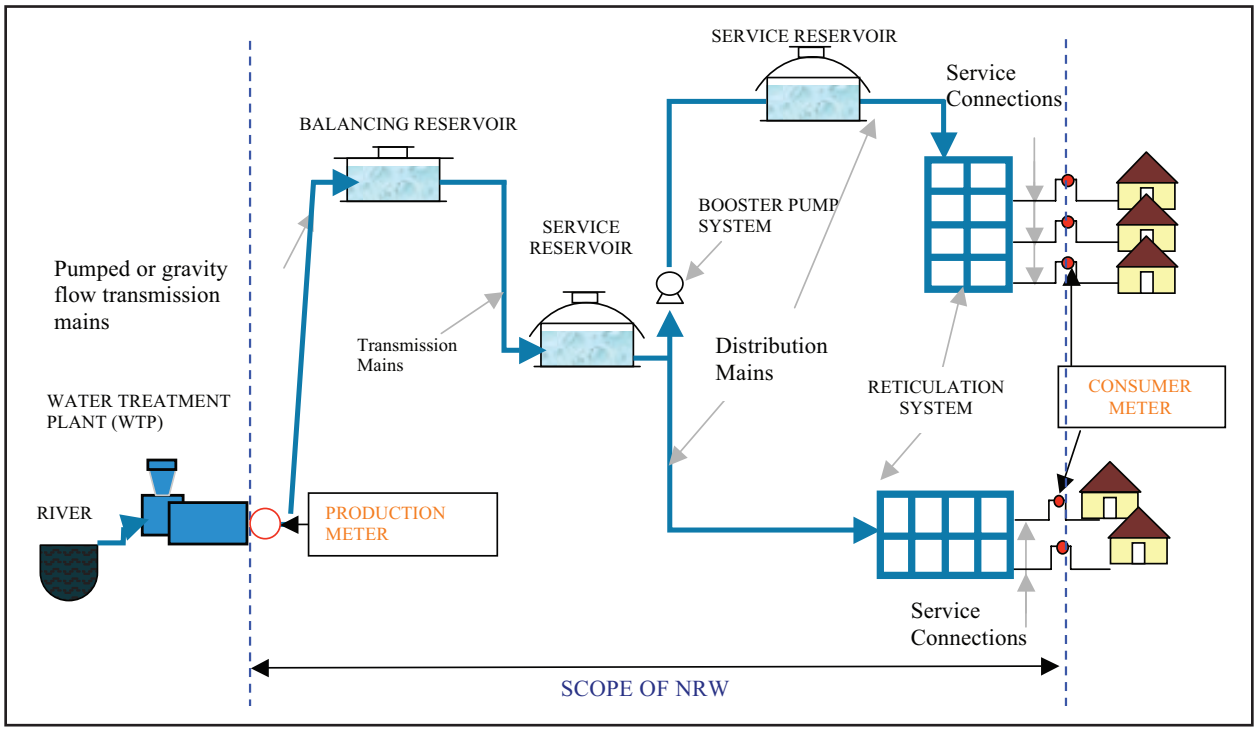
The unit used is in percentage (%).

Apart from percentage (%), other units that are used include cubic metre (m^3/time interval), litre/connection/day, litre/km/day and Infrastructure Leakage Index (ILI).

B1.1 Introduction to Water Supply System

Figure 2 shows a schematic drawing of the water supply system from a water treatment plant (WTP) to the end-user. The quantity of water supplied by the WTP is measured by a production meter before being distributed through the mains by gravity or pumped into an balancing reservoir.

FIGURE 2: WATER SUPPLY SYSTEM



From the balancing reservoir, water flows through the mains to the service reservoir and is then distributed to the end-users through connecting pipelines, either pumped by booster pumps to an elevated service reservoir or via gravity flow to the reticulation system. The quantity of water supplied to the end-users is measured by the consumer meter.

B1.2 NRW Performance Status

Every year, the Ministry of Energy, Green Technology and Communications (MEGTC), formerly MEWC, collects NRW performance reports from all states (Table 1) for publication in the Malaysian Water Industry Guidelines as a source of reference:

TABLE 1: NRW PERCENTAGE LEVELS (2005 – 2007)

NO	STATE	% NRW 2005	% NRW 2006	% NRW 2007
1	P. PINANG	19.40	18.60	16.9
2	MELAKA	28.80	27.00	28.6
3	PERAK	30.60	30.70	30.0
4	JOHOR	35.50	32.46	31.1
5	SARAWAK	24.70	32.00	31.5
6	TERENGGANU	34.70	31.50	31.6
7	PERLIS	36.30	35.54	34.2
8	W. P LABUAN	24.00	36.00	34.7
9	SELANGOR	38.40	36.60	34.8
10	KEDAH	43.80	45.00	45.2
11	PAHANG	49.70	46.40	45.2
12	KELANTAN	40.00	44.40	48.5
13	NEGERI SEMBILAN	53.00	60.10	53.2
14	SABAH	57.20	57.00	55.0
	NATIONAL AVERAGE	**36.30**	**38.00**	**37.7**

Source: Malaysian Water Industry Guidelines

Table 1 indicates that the average NRW level of the country in 2007 was high at 37.70%.

Table 2 shows the NRW levels for 2007 as well as target levels for 2008, 2009 and 2010 for all states in Malaysia.

TABLE 2: NRW PERFORMANCE AND TARGETS

NO	STATE	PERFORMANCE IN 2007 (%)	TARGET (%)		
			2008	2009	2010
1	P. PINANG	*16.9	18.4	18.2	18
2	MELAKA	28.6	26.5	26	25
3	PERAK	30.0	29.5	29	29
4	JOHOR	*31.1	31.5	31.3	31
5	SARAWAK	31.5	31	31	31
6	TERENGGANU	31.6	31	30	29
7	PERLIS	34.2	35	34	33
8	LABUAN	*34.7	35	33	30
9	SELANGOR	34.8	32	29	22
10	KEDAH	45.2	44	43	42
11	PAHANG	45.2	44	43	42
12	KELANTAN	48.5	45	44	42
13	NEGERI SEMBILAN	53.2	53	50	45
14	SABAH	55.0	53	52	50
	NATIONAL AVERAGE	**37.7**	**35.2**	**33.8**	**31**

Source: Malaysian Water Industry Guidelines
* Note: Performance exceeds target

From the above data, it can be seen that the performance of three (3) states, namely Penang, Johor and Federal Territory of Labuan, exceeded their targets in 2007. Sabah, on the other hand, recorded the highest level of NRW at 55% in 2007. The average national target for 2010 is 31%.

The NRW yearly reduction target is important as a performance comparison for water supply entities. For this purpose, continuous efforts must be taken to promote positive perception of good water management.

B1.3 Allocation for Controlling NRW

Water supply entities must have specific allocations for the control and monitoring of NRW from approved sources. For example, an entity's own internal resource and that from a state government, Ministry of Energy, Green Technology and Water (MEGTW) and Pengurusan Aset Air Berhad (PAAB).

Allocations to reduce water loss as provided for under the 9th Malaysia Plan are shown in Table 3. A total of 46 projects amounting to RM1.004 billion has been allocated by the MEGTW.

TABLE 3: NRW PROGRAMME ALLOCATIONS UNDER 9MP (2006 – 2010)

NO	STATE	NUMBER OF PROJECTS	ALLOCATION CEILING (RM MILLION)
1	PERLIS	1	20.0
2	KEDAH	1	51.6
3	PERAK	5	80.0
4	SELANGOR	1	100.0
5	NEGERI SEMBILAN	1	166.0
6	MELAKA	1	74.0
7	PAHANG	11	145.0
8	TERENGGANU	6	45.7
9	KELANTAN	10	130.0
10	P. PINANG	1	50.0
11	SABAH	4	90.8
12	SARAWAK	3	50.0
13	LABUAN	1	1.5
	TOTAL	**46**	**1,004.6**

Source: Ministry of Energy, Green Technology and Water

From Table 3 above, Negeri Sembilan received the highest allocation of RM166.0 million or 16.5%. The Federal Territory of Labuan, on the other hand, received the smallest allocation of RM1.5 million or 0.15% of the total allocation.

B1.4 Benefits of Controlling NRW

The NRW control programme is a complex activity as it is closely linked to the overall activities of water supply entities. Moreover, in realising the implementation of the programme, the entities also have to ensure that the programme achieves its objectives.

Among the benefits of NRW control programmes are:

1. Reducing operating losses and improving revenue collection

2. Minimising unscheduled water supply disruption through water pressure control measures and close supervision of quality of work and materials

3. Increasing the efficiency of water supply distribution system management

4. Improving asset management and water supply network systems and their components through the use of latest hardware and software technology

5. Performing water audit as a tool for checking the overall performance of water supply activities

6. Determining capital expenditures.

B1.5 Performance Indicators

The purpose of performance indicators is to allow water supply entities to analyse water loss or measure the performance of NRW reductions and to develop standards. Among the performance indicators used in the water supply services are:

- Percentage of water loss from the production (%)
- Physical loss per connection per day (litre/connection/day)
- Physical loss per kilometre of mains per day (litre/km/day)
- Infrastructure Leakage Index (ILI)

The International Water Association (IWA) recommends the **Infrastructure Leakage Index (ILI)** as the best performance indicator for determining physical losses.

The method of acquiring ILI value has been simplified through the use of a programme called "WB-EasyCalc", which is water balance software available in the public domain. All required information and data have to be entered in the spaces provided by the program. The physical loss assessment matrix is described in Table 4 below:

TABLE 4: PHYSICAL LOSS ASSESSMENT MATRIX

Technical Performance Category		ILI	Litres/connection/day (When system is pressurised) at an average pressure of:				
			10 m	20 m	30 m	40 m	50 m
Situation in Developed Countries	A	1-2		<50	<75	<100	<125
	B	2-4		50-100	75-150	100-200	125-250
	C	4-8		100-200	150-300	200-400	250-500
	D	>8		>200	>300	>400	>500
Situation in Developing Countries	A	1-4	<50	<100	<150	<200	<250
	B	4-8	50-100	100-200	150-300	200-400	250-500
	C	8-16	100-200	200-400	300-600	400-800	500-1000
	D	>16	>200	>400	>600	>800	>1000

Source: World Bank Institute

The description of technical performance categories based on **Table 4** is as follows:

Category A - Good. Further loss reduction may be uneconomical unless there is a shortage of water; requires careful analysis to identify cost effective improvements.

Category B - Potential for further improvements; needs to consider pressure management, active leakage control and maintenance of pipe networks.

Category C - Poor leakage records; appropriate only if water is plentiful and cheap; however, level of analysis and leakage and active effort to reduce leakage need to be continued.

Category D - Inefficient use of resources; leakage reduction programme is crucial and needs to be given priority.

B2 WATER BALANCE

Water loss level can be determined by conducting a water balance audit on the volume that is channelled to the distribution system. Water balance is a measure or an estimate of water that is produced, based on volume of input water, volume of water supplied outside the border, consumption volume and volume of water lost. Input volume is the quantity of water that flows into the distribution system. Although input volume and consumption volume may be easily determined, it is difficult for water supply entities to determine water losses through the various components.

Table 5 shows the water balance and its components in a water supply system. Data in a water balance schedule comprises basic components which are calculated based on best practices developed by the IWA. All pertinent data is shown in the unit volume over a time period, typically one year. The description of each component is as follows:

TABLE 5: INTERNATIONAL STANDARD WATER BALANCE

<table>
<tr><td rowspan="8">System Input Volume</td><td rowspan="3">Authorised Consumption</td><td rowspan="2">Billed Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="6">Non-Revenue Water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Loss</td><td rowspan="2">Commercial Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Physical Losses</td><td>Leakage on Transmission, Distribution and Reticulation Mains</td></tr>
<tr><td>Leakage and Overflows at Utility Storage Reservoir/Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Metering</td></tr>
</table>

Source: Water Loss Control Manual

Water balance can be used to make an assessment of a particular zone, water treatment plant (WTP), district or state and country.

B2.1 System Input Volume

System input volume is the total production meter readings from the water treatment plant (WTP) or boundary water resource that flows into the distribution system. Every WTP has a production meter (photo 1) that measures the volume of potable water produced. The accuracy of production meter readings is essential in the calculation of NRW. Each meter must be able to measure accurately and continuously the amount of water flow. Errors in meter reading will have a significant impact on the calculation to obtain total input volume. Different types of production meters will give different accuracy readings as shown in Table 6. There are several types of production meters such as electromagnetic (emf), ultrasonic and mechanical. The commonly used type is the electromagnetic meter as it has a higher degree of accuracy as compared to the rest.

PHOTO 1: PRODUCTION METER READING DISPLAY

TABLE 6: RANGE OF METER ACCURACY

Type of Production Meter	Meter Accuracy Range
Electromagnetic flow meter	< 0.15% - 0.5%
Ultrasonic flow meter	0.5% - 1.0%
Insertion probe	< 2.0%
Mechanical meter	1.0% - 2.0%
Ventuary meter	0.5% - 3.0%
Volume calculated with pump curves	10.0% - 50.0%
Hydraulic structure	10.0% - 50.0%
Note: Meter accuracy is dependent on many factors (such as calibration, installation, maintenance) and has to be verified on a case-to-case basis.	

Source: World Bank Institute, 2007

All production meters must undergo maintenance on a regular basis to ensure their continued accuracy. Over time, meter reading may become inaccurate owing to factors such as water quality, dirt entering the meter and electronic malfunction. Therefore, calibration of meters must be carried out every six (6) months or as instructed in the manufacturer's manual.

In addition to these factors, meter inaccuracy can be due to incorrect meter size, fluctuating flow rate caused by changes in demand or flow direction, installation not in accordance with specifications and meter that has exceeded its shelf life.

System input volume comprises two (2) main components, namely authorised consumption (B2.2) and water losses (B2.3).

B2.2 Authorised Consumption

Authorised consumption is permitted usage of water, either billed or unbilled. It includes water exported across operational boundaries, use of fire hydrants for the purpose of training and fire-fighting, flushing of mains and reservoir/water tanks and community cooperation activities. These may be unmetered and unbilled.

Authorised consumption comprises two (2) types, namely:

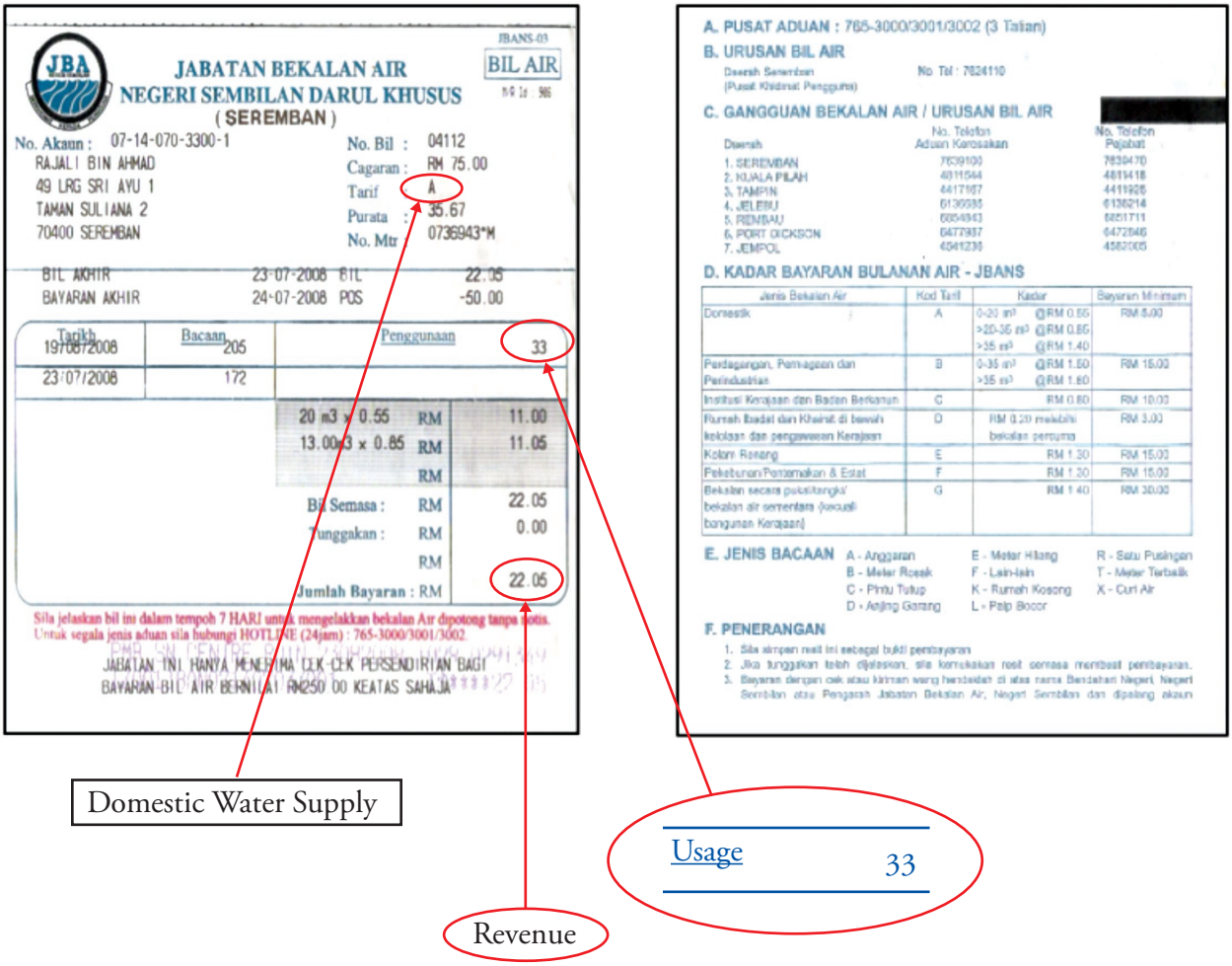
- Billed consumption
- Unbilled consumption

B2.2.1 Billed Consumption

The components of authorised consumption which are billed produce revenue to water supply entities (also known as revenue water). There are two (2) components of billed consumption:

- Billed metered consumption
- Billed unmetered consumption

DIAGRAM 2: SAMPLE OF WATER BILL



Source: Courtesy of SAINS

B2.2.1.1 Billed Metered Consumption

All customers having meters will be billed according to usage and water tariffs. Tariff-billed customers are categorised as domestic (photo 3), commercial and industrial (photo 4), government institutions and statutory bodies, shipping, bulk suppliers to esstate plantations.

PHOTO 3: DOMESTIC METER

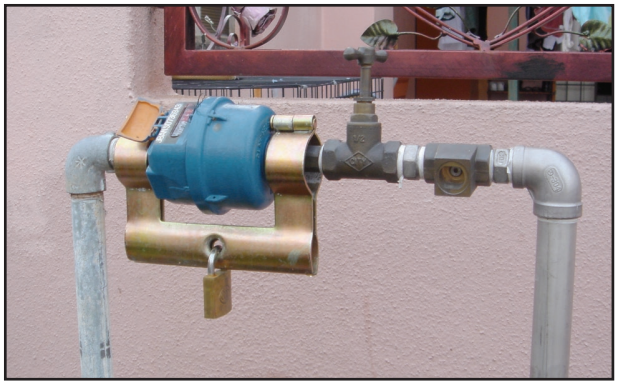


PHOTO 4: COMMERCIAL AND INDUSTRIAL METER

There are several types of bills issued to customers:

1. **Normal Bill**
   Periodic bills are issued based on actual reading of normal-functioning meters.

2. **Special Bill**
   Similar to normal bill except that meter reading is taken upon the customer's request for purpose of closing an account.

3. **Average Bill**
   Bill that is issued based on average water consumption of three (3) normal bills due to faulty meter.

4. **Estimated Bill**
   Bill that is issued based on average water consumption of three (3) normal bills when meter reading is cannot be read (e.g. locked gate, fierce dog).

5. **Miscellaneous Bill**
   Bill that is issued based on the quantity of water used or supplied either for temporary work (e.g. testing/cleaning/sterilising/commissioning of new water tanks or pipelines) by the contractor or supply of water using tankers.

B2.2.1.2 Billed Unmetered Consumption

Any kind of consumption that is charged by estimates, such as water delivery by tankers, flushing of mains and new reservoirs/water tanks. This component is usually charged through the issue of miscellaneous bills.

B2.2.2 Unbilled Consumption

Unbilled consumption is authorised consumption but it is calculated as a component of NRW. There are two (2) components of unbilled consumption:

- Unbilled metered consumption
- Unbilled unmetered consumption

B2.2.2.1 Unbilled Metered Consumption

Sometimes the user is never billed due to weaknesses in the system leading to the user's data not being recorded or updated. Although meters have already been installed at the user's premises, no bill has ever been issued. Such cases usually occur after reconnection work of meters and the new meters were not updated in the billing system.

Some water supply entities do not charge certain premises, such as places of worship. Water consumption in such cases falls under the category of unbilled metered consumption.

B2.2.2.2 Unbilled Unmetered Consumption

This component usually includes fire hydrant use for fire fighting and training purposes and flushing of mains during scheduled cleaning and after-repair work of burst pipes (photo 5). The quantity of water consumption depends on the flow rate and duration of usage. The quantity of water used will not be charged, but its volume is measured using the following formula:

Quantity, Q = 250 gallons per minute

PHOTO 5: FLUSHING OF MAINS

B2.3 Water Loss

Water loss is the volume of water that does not yield revenue to the water supply entities. There are two (2) components of water loss:

- Commercial losses
- Physical losses

DIAGRAM 3: CLASSIFICATION OF WATER LOSS

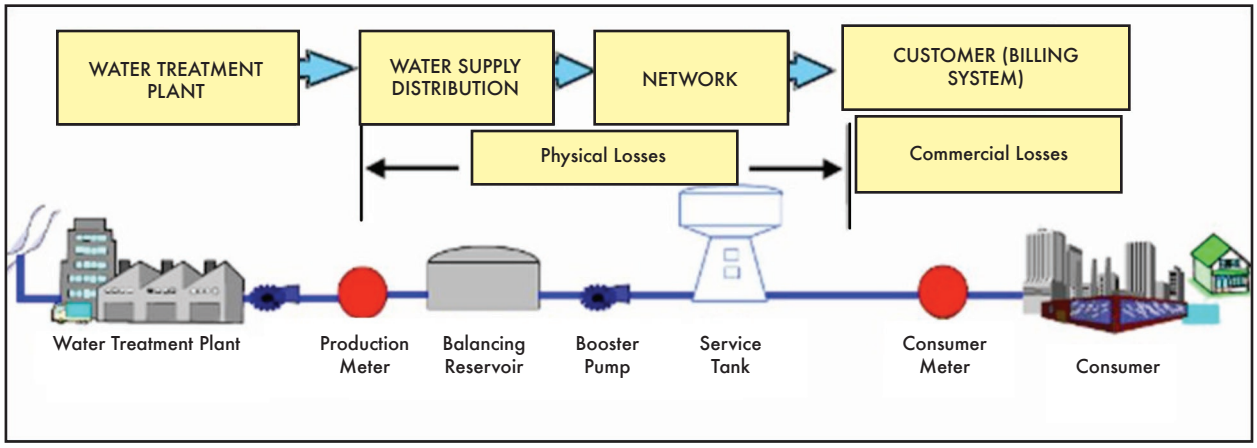


Diagram 3 shows the location at which physical and commercial losses occur in the water supply system. Physical losses usually occur in the distribution system, whereas commercial losses occur during meter reading and billing.

B2.3.1 Commercial Loss

Commercial loss is sometimes referred to as 'apprent losses'. There are two (2) components of commercial loss:

- Unauthorised consumption
- Customer metering inaccuracies and data handling errors

B2.3.1.1 Unauthorised Consumption

Unauthorised consumption includes illegal connections, meter by passing, illegal use of hydrants and poor billing collection systems. This is usually done through illegal connections from pipelines and illegal personal use of fire hydrants. Illegal connections involve the installation of short-piece connection (photo 6) to the meter, pipeline tapping and bypass connection. Bypass connections are installed for purpose of bypassing the meter and are often buried and difficult to detect. A small volume of water will pass through the meter and the rest through the bypass connection. This situation can be detected by using the step test method, which is the systematic closure of valves in a meter zone. Each time the valve is closed, the waterflow will change and the changes are recorded by a data logger. Typically, step testing is carried out at night when water consumption is low.

The use of fire hydrants other than for purposes of fire fighting and training is illegal. This situation often occurs at new construction sites and squatter areas.

PHOTO 6: UNMETERED WATER

To overcome the problem of unauthorised water consumption, public cooperation is needed/encouraged to report such illegal activities to the authorities so that appropriate action can be taken. The estimated volume of water loss is calculated based on the average consumption after meter installation.

B2.3.1.2 Inaccuracies of Customer Metering and Data Handling Errors

(i) Inaccuracies of Customer Metering

The main cause of inaccuracies of customer metering is meter under-registration reading. This occurs when the meter either has exceeded its economic lifespan, blocked or damaged. Damage to meters may be due to either water quality or vandalism.

The life expectancy of a meter will affect the efficiency of water reading (photo 7). A periodic meter replacement programme needs to be put in place to reduce inaccuracies in meter reading. The timeframe for a scheduled meter replacement (photo 8) will depend on the guidelines of each state.

Inaccuracies in meter reading can also be due to the use of low quality meters and meters of an unsuitable size.

The estimated volume of water loss is calculated based on the difference in average consumption for three (3) months before and after the meter has been replaced.

PHOTO 7: AGEING METERS

PHOTO 8: METER REPLACEMENT

(ii) Data Handling Errors

Data handling errors are usually due to staff negligence. These include:

(a) Meter reading errors
This may occur when the meter digits look similar, the counter screen is faded or the digital counter is not aligned.

(b) Data input errors
This error may occur during the key-in process of customer account data by the employee.

(c) Failure to update data or records

All customer account data must be recorded and updated regularly. This has to be monitored by the officer-in-charge.

Any delay or account not being updated caused by poor monitoring can also contribute to commercial losses.

(d) No billing

Sometimes customers are not billed due to poor management of the billing process or due to disconnection of water supply. Water supply may not have been actually disconnected but the account has been suspended, and no bill is issued.

PHOTO 9: SCHEDULED BILLING OF CUSTOMERS

Though in some cases, water supply connections are carried out accordingly but due to weaknesses in the billing system, billing is not made to the new account. These occurrences can be detected during the meter reading cycle by meter readers (photo 9). Water supply entities must conduct a customer survey to record all important information to help identify and correct all errors in the billing system. Frequent inspection of major customers (industrial/ commercial) is the best method to detect high commercial losses.

Data handling errors can also be reduced if debit and credit adjustments to water use are made against billing amounts in the consumption volume for a billing period. However, adjustments may be made after the billing period. It is necessary that adjustments should be made immeditely.

B2.3.2 Physical Loss

Physical loss is 'real losses' that can be physically detected. There are three (3) components of physical loss:

- Leakage from transmission, distribution and reticulation mains
- Leakage and overflows from the utility's reservoirs/storage tanks
- Leakage on service connections up to the customer's meter

B2.3.2.1 Leakage from Transmission, Distribution and Reticulation Mains

The pipe system which channels water from the balancing reservoir to the service reservoir is known as the transmission mains. The diameter of transmission mains is usually over 400 mm. There are also smaller-sized mains for small capacity plants or where the demand is low. The main causes of leakage of transmission mains include corrosion, soil movement in the surrounding area and traffic load (photo 10). Leakage of transmission mains usually occur at the valves, joints and specials that have not been maintained (photo 11). The non-compliance of specifications in terms of materials used and workmanship during the installation stage also contributes to the problem of burst pipes and leakages.

The distribution mains channel water from the service reservoir to the reticulation system. The size of distribution mains is usually between 300 and 600 mm in diameter but smaller or larger ones may also be used, subject to volume demand of the supply area. The function of the distribution mains is to distribute water to the customers. The main causes of pipe burst and leakage of distribution mains are similar to those of the transmission mains.

PHOTO 10: BURST MAINS

Source: MWA – Workshop on NRW Management

The reticulation mains are water mains that transport water to the residential areas through service connection pipes. Reticulation pipe are typically between 100 and 300 mm. Among the reticulation system designs are the branch system, grid system and ring system. Damage to components in the reticulation system, such as sluice valves, air valves, fire hydrants, saddles and ferrules, is the main cause of leakages in the reticulation system (photo 12). Besides leakages, water loss from the reticulation mains can also be caused by burst pipes and illegal connections.

Compared to the transmission and distribution mains, the volume of water loss from the reticulation system is the highest as statistics indicate that leakages often occur at the saddle and ferrule joints of service connection pipelines.

PHOTO 11: AIR VALVE LEAKAGE ON TRANSMISSION MAINS

PHOTO 12: PIPE LEAKAGE IS ONE OF THE MAIN CAUSES OF NRW

The high rate of leakage indicates inefficiency in the management of the water supply system.

Several factors influence the rate of leakage in water supply systems. Before any steps are taken to address the problem, the contributing factors of leakages must first be understood. These factors include:

(i) Type of Pipe

There are several types of pipe used for new installations (photo 13) in the Malaysian water supply system. The type of pipe to be used depends on its suitability. Each type of pipe has its advantages and disadvantages. Among the commonly used types are asbestos cement (AC), cast iron (CI), ductile iron (DI), unplasticised polyvinyl chloride (uPVC), high density polyethylene (HDPE), mild steel (MS) and acrylonitrile butadiene styrene (ABS) pipes.

PHOTO 13: TYPES OF PIPE COMMONLY USED IN NEW CONNECTIONS

TABLE 7: TOTAL LENGTHS AND TYPES OF PIPE USED IN 2005 AND 2006

Water Supply Entity	2005							
	Pipe Length	Type of Pipe						
	(km)	AC	MS	DI	CI	PE	uPVC	Others
Johor	11,125	4,832	1,928	764	156	435	2,673	337
Kedah	9,537	3,350	1,082	574	140	2,680	1,711	0
Kelantan	4,492	3,641	161	161	14	219	233	63
Kuching	1,956	501	150	857	254	190	0	4
Labuan	449	233	37	32	0	147	0	0
Laku	1,306	487	34	274	0.26	509	1	1
Melaka	2,979	2,540	197	67	30	85	60	0
Negeri Sembilan	6,408	4,276	1,359	70	41	530	132	0
P. Pinang	3,574	1,556	660	357	128	760	101	12
Pahang	12,394	7,316	2005	120	60	2,418	475	0
Perak	9,770	3,086	998	216	228	3,408	1,833	1
Perlis	1,755	991	176	4	4	577	3	0
Sabah	7,815	2,591	1,710	629	17	752	1,501	615
Sarawak [1]	4,420	1,286	80	631	0	2,422	0	1
Selangor [2]	13,341	3,771	7,309	477	21	462	1,217	84
Sibu	913	22	37	502	44	254	0	54
Terengganu	4,745	1,613	584	302	11	331	1,904	0
TOTAL	**96,976**	**42,091**	**18,507**	**6,037**	**1,149**	**16,179**	**11,844**	**1,172**

Water Supply Entity	2006							
	Pipe Length	Type of Pipe						
	(km)	AC	MS	DI	CI	PE	uPVC	Others
Johor	15,181	7,391	2,389	1,102	159	518	3,622	0
Kedah	9,631	3,254	1,126	585	140	2,815	1,711	0
Kelantan	4,621	3,641	193	161	14	309	240	63
Kuching	2,005	499	152	902	254	194	0	4
Labuan	4,61	233	37	32	0	159	0	0
Laku	1,379	485	38	275	0.26	581	0.50	0
Melaka	3,825	1,762	304	61	58	76	506	1058
Negeri Sembilan	6,408	4,276	1,359	70	41	530	132	0
P. Pinang	3,674	1,502	680	430	127	823	99	13
Pahang	8,395	3,618	1,086	173	4	2,026	621	867
Perak	9,941	2,874	1,031	221	253	4,132	1,329	1
Perlis	1,768	988	176	4	4	593	3	0
Sabah	8,020	2,534	2,163	660	17	809	1,576	261
Sarawak [1]	4554	1,187	81	729	0	2,556	0	1
Selangor [2]	19,938	6,304	10,605	391	32	655	1,950	1
Sibu	917	22	37	523	44	240	0	51
Terengganu	4,795	1,572	613	317	11	331	1,951	0
TOTAL	**105,513**	**42,242**	**22,070**	**6,636**	**1,158**	**17,347**	**13,741**	**2,320**

Note: PE pipe includes HDPE pipes
Also includes GI, ABS pipes, etc
[1] Excluding LAKU, Kuching & Sibu
[2] Including Federal Territories of Kuala Lumpur & Putrajaya
Source: 2007 Malaysian Water Industry Guide

Table 7 shows that AC pipes (photo 14) are most often used as compared to other types of pipe. However, their use is decreasing as there are no new installations. AC pipes have a short lifespan and are relatively more fragile than other types of pipe. As such, better quality pipes need to be identified to replace the AC pipes.

PHOTO 14: ASBESTOS CEMENT (AC) PIPE

(ii) Type of Joint

Several types of joints are used to connect pipes or specials. Each joint that is installed must be compatible with the pipeline and fittings (photo 15). Joint materials and workmanship that are not in accordance with specifications during the installation stage is a factor that contributes to leakages (Photo 16).

PHOTO 15: TYPES OF JOINT

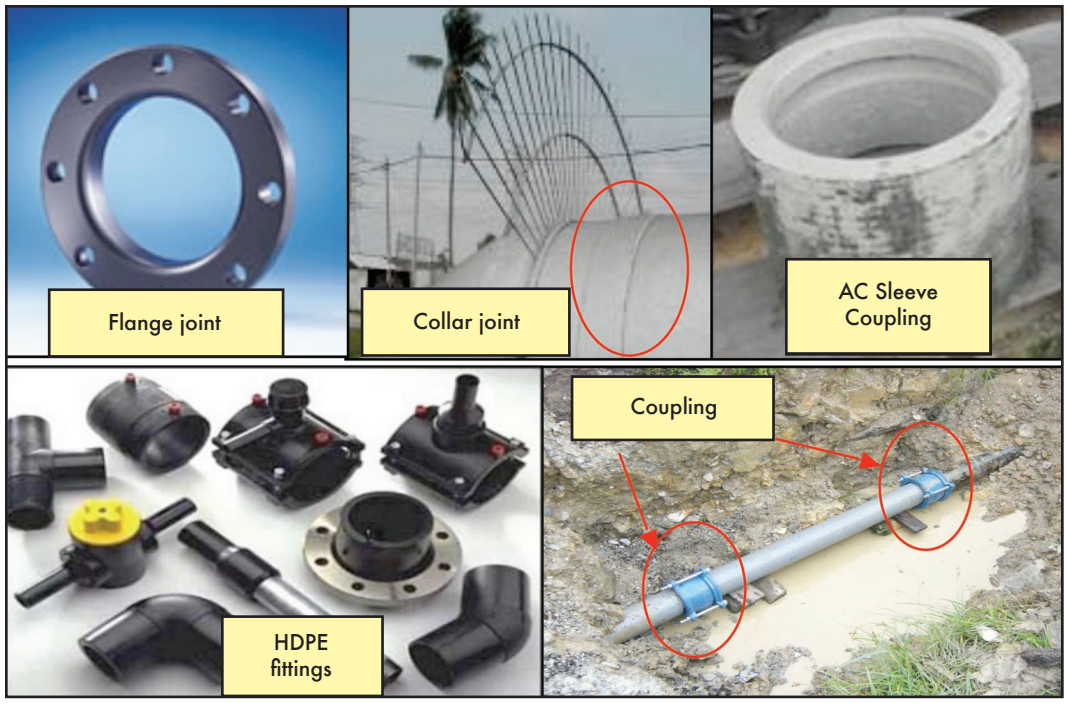


PHOTO 16: JOINT LEAKAGE

(iii) Pipe Lifespan

Pipes that are in use must have their economic lifespan reviewed. Inefficient pipes and those that have exceeded their lifespan need to be replaced so that they are more economical in the long run.

Generally, old pipes would have a high degree of surface cracks which can cause the pipes to fail at any time (photo 17). Furthermore, the selection of new pipes must be studied carefully to ensure maximum lifespan by taking into account conditions of the surrounding soil. For instance, in coastal and swampy areas, MS pipes are not suitable as corrosion of the pipes can occur.

PHOTO 17: OLD PIPE

(iv) Pipe Internal Pressure

Excessive water pressure in the pipe can lead to burst pipes and leakage (photo 18). High pressure in pipes will cause cracks to appear or enlarge existing cracks and subsequently increase the size of leakage. Pressure in the pipes needs to be controlled by installing pressure-reducing valves (PRV).

PHOTO 18: LEAKING PIPE

(v) Soil Characteristics

Soils have varying degrees of corrosivity. While some soil types may have negligible effect on pipes, others can adversely affect the pipe structure. For instance, clay, peat soil and coastal soil have aggressive properties that can cause corrosion to the structure of AC and MS pipes. It is therefore crucial that a soil study be conducted before determining the type of pipe to be used.

(vi) Degree of Leakage

The size of leakage also affects the volume of water loss. Logically, the bigger the size of leakage, the higher the quantity of water loss that occurs. Repairs should therefore be carried out immediately to avoid further enlargement of the orifice which will result in a higher volume of water being lost.

The formula below is used to calculate the volume of water loss during leakage.

Formula: $Q = C_d \times V \times A$

$= C_d \times (2gh)^{0.5} \times A$

where; Q = Flow rate (m^3/s)

Cd = Discharge coefficient

A = Cross-sectional area of leakage (m^2)

V = Flow velocity through leakage (m/s)

$g = 9.81\ m/s^2$

h = Head across the orifice (m)

(vii) Traffic Load

Traffic load can cause underground pipes to vibrate and thus, increase the risk of leakage. AC pipes tend to fail in such circumstances, particularly when road expansions are carried out on road shoulders where the underground pipelines are located.

(viii) Quality of Materials

All materials used such as pipes, valves, joints, fittings and specials must be approved by SPAN, SIRIM and IKRAM to ensure quality control. The water supply entities are required to monitor the quality of materials to ensure strict compliance with specifications.

(ix) Workmanship

The workmanship in the installation of pipes, valves, joints, fittings and specials has to be carefully controlled and monitored as this will directly affect the levels of leakage in the pipeline system. Therefore, specifications on installation methods must be established and adhered to. Emphasis on competence and skills of the worksforce must be given priority during installation work. The final test to determine the quality installation is the pressure and leakage test.

B2.3.2.2 Leakage and Overflows from the Reservoirs/Storage Tanks

(i) Leakage

Leakage in reservoirs or water tanks can occur when there are cracks or structural failure. This usually occurs in old reservoirs and water tanks. Leakage to these structures can be detected visually.

(ii) Overflow

Every reservoir or water tank has a maximum capacity according to its size. The uncontrolled inflow of water into the reservoir or water tank will lead to overflow.

There are two (2) methods of inflow water into the reservoir or water tank:

(a) Pump system

In this system, the water level of the reservoir/tank is controlled by electrodes or altitude valves. For pumps that use electrodes, automatic control of the water level is important. However, in the event of a system failure, the pump will be manually operated while repairs are carried out. The manual operation of the pumps must be carried out properly to avoid the occurrence of overflow.

Altitude valves control the water level of reservoirs using pressure sensors to stop the pump when the pressure exceeds the prescribed level. The pump will restart when the pressure falls to its predetermined level as the water level decreases.

If the flow control valve in the system malfunctions, overflow will occur, particularly in an automatic control system. Therefore, flow control valves require maintenance on a regular basis.

(b) Gravity flow system

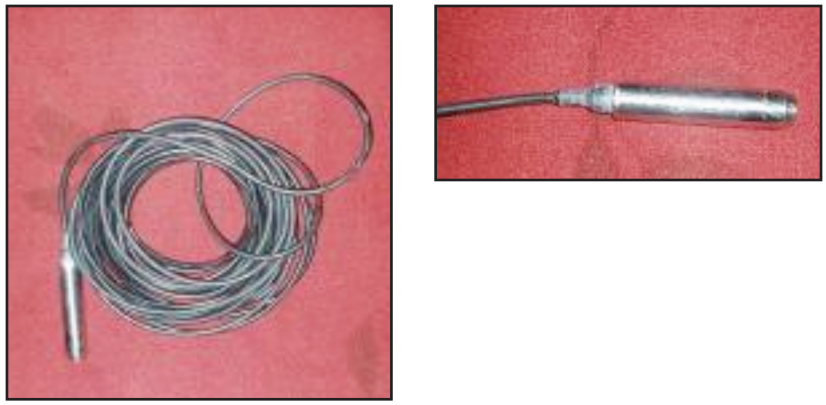
In this system, overflow is prevented by using float or altitude valves to control the water level of reservoirs/water tanks. As with altitude valves in the pump system, these flow control valves require maintenance on a regular basis.

One way of detecting reservoir/water tank overflow is by checking the overflow pipes for any water discharge (photo 19). Alternatively, a data logger equipped with a pressure transducer can be used to detect overflows (photo 20).

Telemetry is used to transfer water depth information from a remote reservoir or water tank. Telemetry communication can be transmitted via radio frequency, GSM and GPRS. SMS, web-based or similar facilities provide flexibility in terms of receiving information from anywhere and at any time.

PHOTO 19: OVERFLOW IN RESERVOIR/WATER TANK

PHOTO 20: LEVEL SENSOR

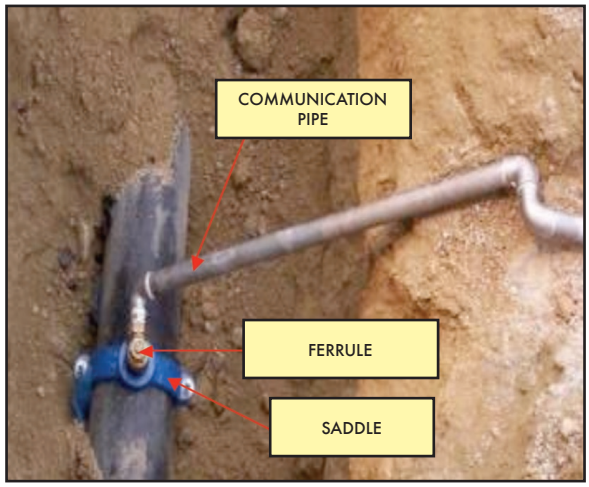


B2.3.2.4 Leakage on Service Connections up to the Customer Meter

The most apparent of water leakages occurs at the saddle and ferrule connection of service connection pipes, mostly small sized measuring 25 mm or less (photos 21 and 22). Poor condition of service connection pipes such as old and rusting pipes, low quality materials and poor workmanship are the main causes of leakage in service connection pipelines, joints and fittings.

PHOTO 21: LEAKAGE AT SADDLE AND FERRULE

PHOTO 22: TYPICAL STANDARD INSTALLATION OF PIPES



Source: MWA – Workshop on NRW Management

B2.4 Revenue Water

All components of authorised consumption which are billed to the customer are categorised as revenue water.

B2.5 Non-Revenue Water

All components of unbilled system input volume are categorised as non-revenue water. This is equivalent to unbilled consumption plus physical and commercial losses.

B3 METHOD OF CALCULATING NRW

The common methods of calculating NRW levels are:

B3.1 Difference between volume of water supplied and billed consumption in an area

The volume of water supplied by the WTP is obtained from the production meter readings, whereas the consumption volume is obtained from customer meter readings and billed unmetered consumption volume. The difference between the two quantities is the non-revenue water or water loss from the water supply system during the period. These readings are taken on a monthly basis for monitoring. This method is suitable for determining physical and commercial losses.

B3.2 Minimum Night Flow (MNF)

Minimum night flow (MNF) readings as shown in Graph 1 are a more focused method of determining water loss caused by leakage in a particular zone or area. However, this method is used only for determining physical losses and is not exhaustive, unless all district metering zones (DMZ) have been established in the area.

Night flow is when water consumption is at the minimum. It is crucial in controlling and detecting leakages in the distribution system.

MNF is the lowest flow that normally occurs after midnight. In Malaysia, the minimum flow rate usually occurs between 2 and 4 am.

MNF consists of two components, namely Legitimate Night Flow (LNF) and Net Night Flow (NNF).

B3.2.1 Legitimate Night Flow (LNF)

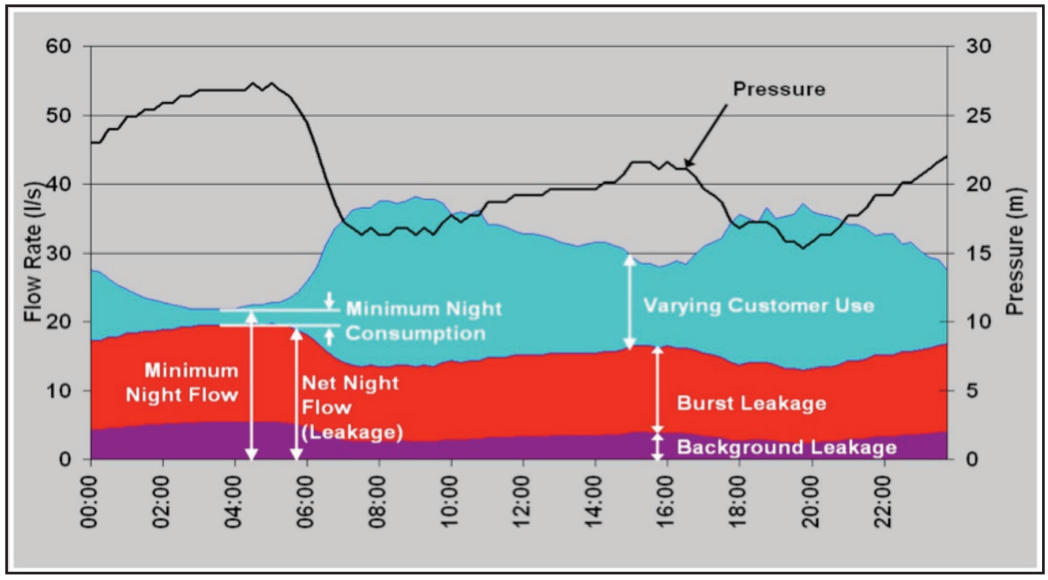
Legitimate Night Flow (LNF) is the estimated volume of water consumption in the early morning. Total water flow can be obtained from the meter reading at the customer's premises. Typically, meter readings from 10% of premises in a particular zone or area are taken to obtain the average hourly flow. The result of this calculation can then be used to calculate the Net Night Flow (NNF).

B3.2.2 Net Night Flow (NNF)

Net Night Flow (NNF) is the volume of water lost through leakage. NNF is obtained by subtracting the legitimate night flow (LNF) from the Minimum Night Flow (MNF). It represents the volume of water lost within the chosen zone. It is derived from the following formula:

NNF = MNF - LNF

GRAPH 1: 24-HOUR VARIATION OF PRESSURE, FLOW AND LEAKAGE



Source: Water Loss Control Manual

B4 CONTROL OF NRW

The most important step in NRW control is in determining the extent of leakages. This is because leakage in the water supply distribution network is a major contributor of water loss. By reducing the number and volume of leakages, NRW level can be reduced and this in turn will reduce water wastage and operating costs.

There are several steps in the implementation of NRW control, namely:

B4.1 Mapping

PHOTO 23: LOCATION INFORMATION FROM SATELLITE IMAGE

Source: Ministry of Energy, Water and Communications

One important aspect in addressing the problem of water loss is ensuring that all on-site information on the water supply system and its components is accurate and current. A mapping of the distribution system using a complete and latest set of data is therefore necessary. Base maps and schematic layouts must be reviewed and updated. These maps and layouts must be incorporated with information such as location of reservoirs/ water tanks, pump houses, pipelines, types and sizes of pipes, valves, fire hydrants, installation levels and number of connections to customers' premises.

In reality, most water supply entities keep paper maps and schematic layouts of water supply systems. Some do not keep complete sets of maps and schematic layouts. Presently, computerised mapping software, using the Geographic Information System (GIS), is being used extensively. The GIS incorporates satellite images and is used widely and for field work reference information facility (Diagram 23). In cases where records of the water supply system are unavailable, a field survey will be carried out and the results entered into the GIS.

The GIS is user-friendly and has become increasingly popular as a facility that manages mapping systems. It has the facility to interact directly with other database systems such as financial, billing, telemetry and Supervisory Control and Data Acquisition (SCADA) systems, complaint handling and daily maintenance of records such as locations of leakage and repair work. The GIS is used to mark the locations of leakage on layouts for purpose of repair and monitoring of leakage frequency. These applications can be accessed by completing the process of geocoding into the mapping system.

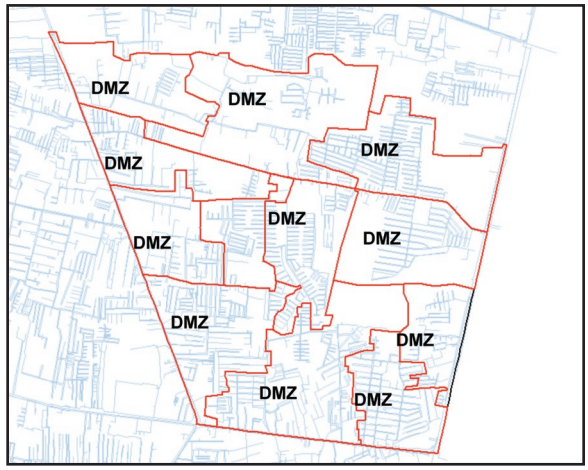
Additionally, the GIS supports the hydraulic modelling system which is used to evaluate the efficiency of the distribution system. The Global Positioning System (GPS) is used to locate and record accurately the locations of distribution system components and primary water supply facilities through the use of coordinates and location levels. The system is usually used in conjunction with the GIS to provide the locations of water supply system components on a digital map.

B4.2 Design and Establishment of District Metering Zone (DMZ)

Water supply from plants is channelled to the supply area via a network of pipelines. There could be more than one connection into the area. NRW management can be simplified if the area is divided into smaller areas called zones (Figure 4). NRW is monitored and measured in each established zone. The NRW reduction programme will have a higher chance of success through the monitoring of water flow and pressure in distribution systems with established boundaries.

A reduced area having a boundary valve is called a district metering zone (DMZ). An area with more than one DMZ is called a district metering area (DMA). Zone proving is required to set the boundary of a chosen zone and to ensure that it can be isolated from the supply mains of alternate sources without affecting water pressure and customer requirements. A zero pressure test (ZPT) must be carried out for zone proving. Boundary valves need to be identified and closed once zone boundaries have been established.

FIGURE 4: DISTRICT METERING ZONE BOUNDARIES



The implementation of the zoning system to monitor leakage was first introduced in the United Kingdom in the early 1980s. This method has been implemented by all water supply entities to improve the management of leakage and water pressure. The criteria for the design of DMZ include the following:

1. Size of DMZ (having 500 to 3000 connections)

2. Boundary valves must remain closed to isolate the DMZs

3. Establishing an inflow system and installing a flow meter to measure input volume

4. Terrain and level of water supply system network

5. Topographic map information that can help determine DMZ boundaries such as roads, rivers, railways and highways

B4.3 Installing Bulk Meters in DMZ and DMA

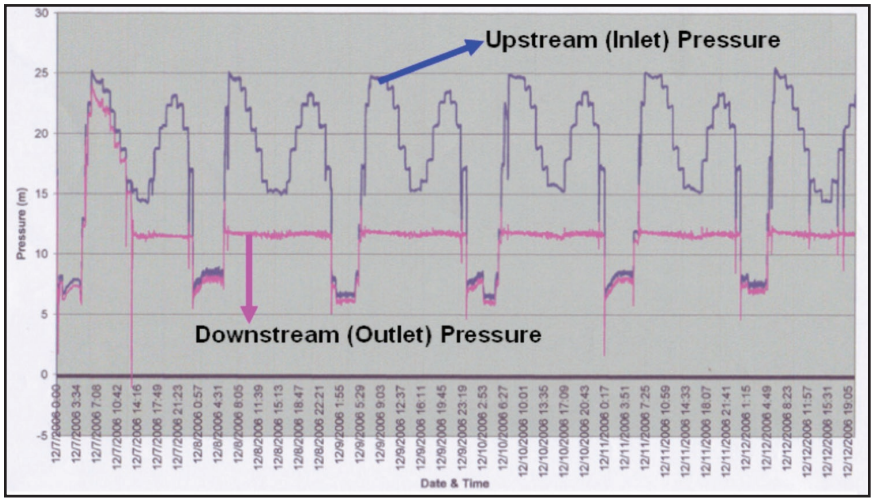
PHOTO 24: BULK METER

Bulk meters are installed in the reticulation pipelines. They record the amount of water flowing into the DMZ. The types of meters that can be used include those which are mechanical, ultrasonic and electromagnetic. However, the electromagnetic meter (photo 24) is more popularly used on site as it uses batteries instead of electrical power. The telemetry system can be connected to the DMZ and DMA bulk meters to monitor flow and pressure data remotely.

B4.4 Water Pressure Management

Water pressure management is an elementary component of leakage management strategy. Studies showed that the rate of leakage in distribution and reticulation pipeline systems vary according to pressure caused by gravity or pumps. The resulting pressure will affect the rate of leakages and frequency of burst pipes.

FIGURE 5: TYPICAL RESULTS OF PRESSURE REDUCTION USING PRV



Source: Singer Valve (Inc Canada)

In determining the appropriate pressure management in a pipeline network system, the following steps must first be taken:

1. Identify potential zones for the installation of pressure control valves (PRV)

2. Identify categories of supplies and pressure control levels by analysing water demands

3. Obtain flow and pressure data from field work

4. Use an appropriate and specific pressure control design model

5. Identify the correct control valves and equipment

6. Analyse the costs and benefits.

There are various methods of reducing pressure in the pipeline system, including the use of variable speed pump controllers and monitoring the depth of the reservoir/water tank. However, the PRV and bypass pipe assembly is more effective and widely used.

The PRV (photo 25) is a device which is installed at strategic locations in the pipeline network system to reduce or maintain the pressure at specified levels. The downstream valve controls the input pressure from the upstream or high-low flow rate (Figure 5).

For complex areas or zones, the selection of the PRV assembly must take into account the determined pressure duration and the pressure to be determined. The minimum pressure that must be determined in the supply area shall not be less than the prescribed limits as set out by SPAN or the operational requirements of the design.

Most PRVs are installed downstream of the DMZ and DMA flow meters to avoid any turbulent flow from the valve which can affect the accuracy of the flow meters. The best practice is to install a PRV with a bypass pipe assembly in order to facilitate maintenance work (photo 6).

PHOTO 6: PRV WITH BYPASS PIPE ASSEMBLY

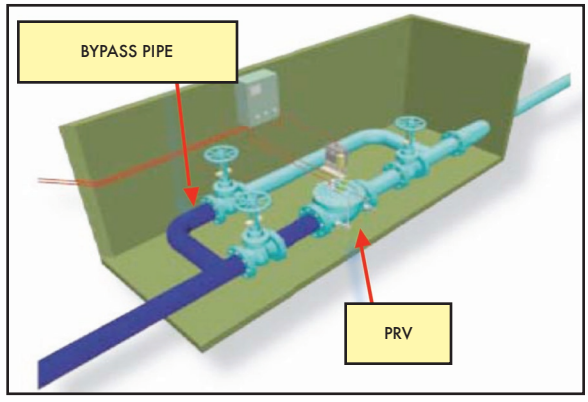
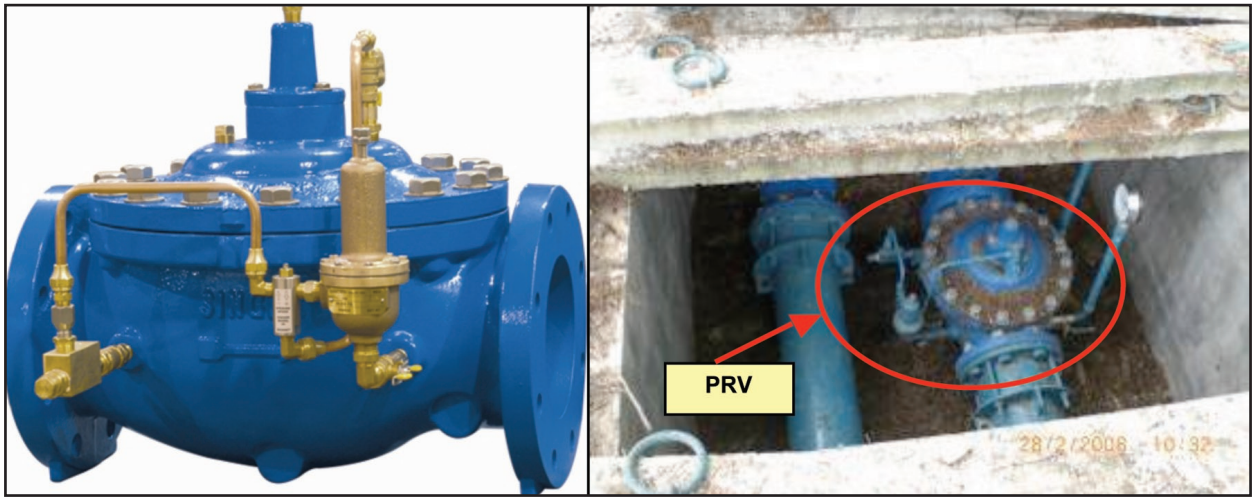


PHOTO 25: PRESSURE REDUCING VALVE (PRV)



The PRV must be maintained so that it can function effectively at optimum capacity. Two (2) types of maintenance work need to be carried out in accordance with supplier specifications, namely:

i) Regular service – To be carried out twice a year depending on water quality. The work involves cleaning of strainers and checking the sensing line.

ii) Overhaul – To be carried out in 8-10 years to replace the internal parts of the valve.

B4.5 Hot Tapping

Hot tapping is a method of installing a tee connection to a pipe while the water mains are under pressure (photo 26). The advantages of using this method as compared to conventional methods are as follows:

- Water supply does not have to be disconnected
- It saves time as tee connection work can be completed faster
- No wastage of water as the mains do not need to be emptied before installing the tee connection
- Tee connection work can be carried out at any time as it does not interrupt the water supply to consumers.

PHOTO 26: TEE CONNECTION INSTALLATION THROUGH THE HOT TAPPING METHOD

B5 WATER LOSS AND LEAK DETECTION

There are two (2) methods of obtaining information on leakages, namely the passive method where information is obtained from consumer complaints and active method which entails effort to search for leaks.

B5.1 Passive Method

The passive method involves taking action based on consumer complaints. The Customer Service Centre receives complaints from consumers on burst pipes, leaking pipes and other water supply disruptions and the subsequent action that is taken is regarded as passive-based action.

The Customer Service Centre functions as a facility for customer complaints and inquiries on all issues relating to the water supply services such as water disruption, billing and water meters. It also records data such as the number of complaints on burst pipes and leakages per day according to region. Complaints received by the Customer Service Centre are submitted to the Maintenance Unit for further action.

The Maintenance Unit will then conduct repair work as quickly as possible. This unit must be equipped with adequate machinery, tools and equipment as well as trained personnel to ensure that repairs are carried out efficiently and effectively (photo 27).

PHOTO 27: PIPE REPAIR WORK

B5.2 Active Method

The active method involves the active detection of leakages through surveys conducted under the DMZ and DMA implementation programme.

There are two (2) methods of survey in the detection of leakages:

- Visual survey
- Acoustic survey
  (i) Correlation method
  (ii) Geophone method

B5.2.1 Visual Survey

Visual survey is the easiest way of detecting leakages without the use of sensors. Patrol teams will be on the lookout for surface run-offs, change in grass growth pattern or damp soil surfaces along pipeline routes that might indicate pipe leakage (photo 28).

PHOTO 28: LOCATING PIPE LEAKAGE BASED ON WATER RUN-OFFS ON SOIL SURFACE

B5.2.2 Acoustic Survey

Acoustic survey is a method of detecting underground leakage and water loss that are difficult to detect. This is accomplished by using high-technology leakage detection equipment. The advantage of using such tools is that they can locate leaks quickly and accurately. Skills and competence of the workforce are the two main criteria when using the equipment to locate leakages (Diagram 29).

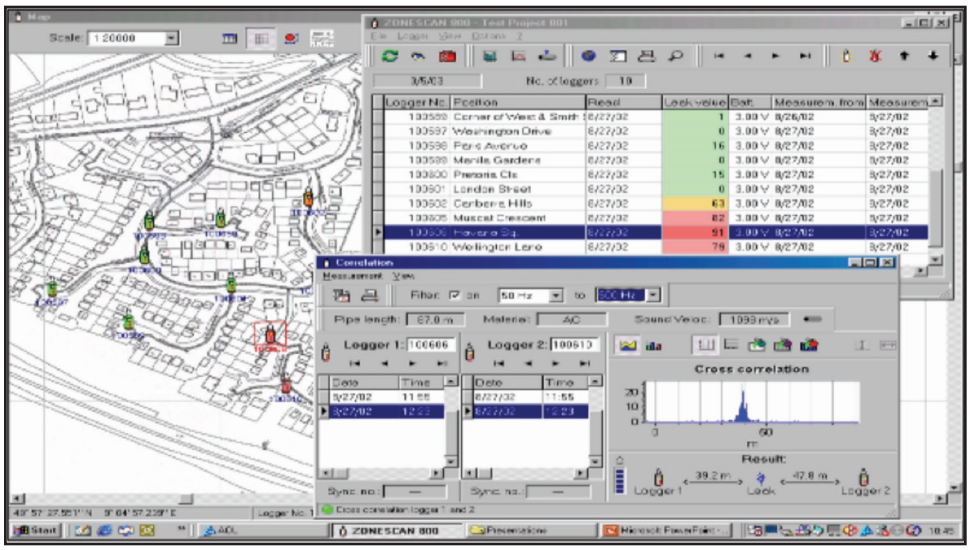
PHOTO 29: EQUIPMENT FOR DETECTING LEAKAGE

PHOTO 30: NOISE LOGGER INSTALLED ON A VALVE

There are three (3) strategic steps for detecting leakages in acoustic surveys:

1. Localise – Using the noise logger to locate the specific area (photo 30). Software is used to show the location of leakage (photo 31).
2. Locate – Using the leak-noise correlator to determine the location (Figure 7 and photo 32).
3. Pin-point – Using a sounding stick or geophone to verify the exact location of the leak.

DIAGRAM 31: TYPICAL SOFTWARE SHOWING THE LOCATION OF LEAKAGE



Source: Premier Amalgamated

(i) Correlation Method

The correlation method uses the leak-noise correlator technique to detect sound signals obtained from sensors connected to two (2) known points over a certain distance, for example from a fire hydrant to a valve or from a valve to a meter. A frequency peak is produced when water spurts out from a leak. This frequency peak will travel to the two selected points. The correlator measures the time delay between the signals from these two points.

The formula that is used to calculate the location of leakage is as follows:

$$L = TD*V + 2l$$

where:

L	=	Distance of pipe (metre)
TD	=	Time delay (second)
V	=	Velocity (metre/second)
l	=	Location of leakage (metre)

FIGURE 7: USING THE LEAK-NOISE CORRELATOR

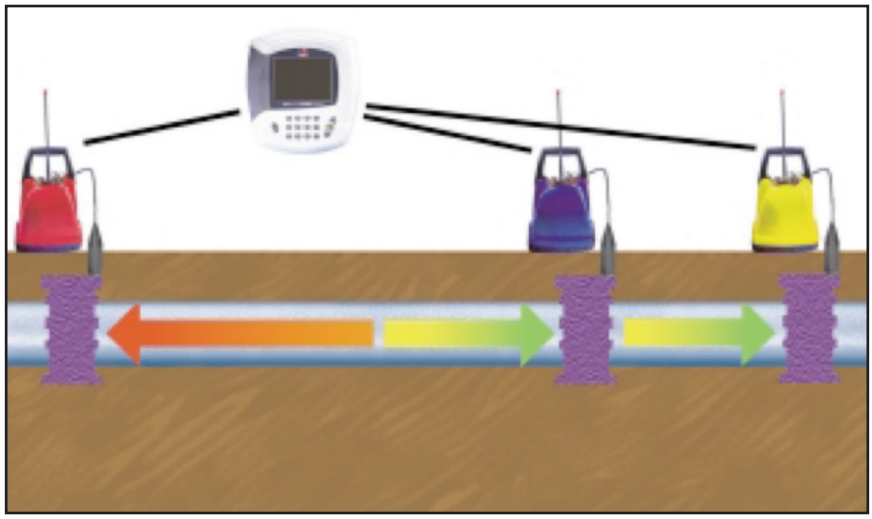


PHOTO 32: LOCATING A LEAK USING THE LEAK-NOISE CORRELATOR

Source: MWA – Workshop on NRW Management

(i) Geophone Method

The geophone (photo 33) method is used in acoustic surveys. The survey is carried out by using a geophone or sounding stick to detect leak sound along pipeline routes. Leak sound, however, depends on the soil type surrounding the pipe. A skilful geophone operator would be able to pin-point the exact location of a leak.

A sounding stick (photo 34) is used to detect vibrations from a leak by directly touching its point to the mains/pipe, fire hydrant, valve or service connection. The resulting vibration will then travel to a vibrating plate mounted at one end of a bar. Sounding sticks may be of a mechanical or electronic type and have an attached amplifier which amplifies leak sounds. The frequency at which leaks occur depends on the type of pipe, backfills and size of leakage.

PHOTO 33: USING A GEOPHONE

PHOTO 34: USING THE SOUNDING STICK TO DETECT A LEAK

B5.3 Speed and Quality of Repairs

Once a pipe leak has been located, repair work must be carried out promptly to prevent further water loss. The timeframe for action according to best practices is within 4 hours. Aside from speedy action, the materials used must be of high quality and certified by IKRAM or SIRIM. Repairs should be done by personnel who are skilled in pipe repair work to ensure high quality workmanship and to prevent recurrence of the problem.

B5.4 Repairing Leaks with Clamps

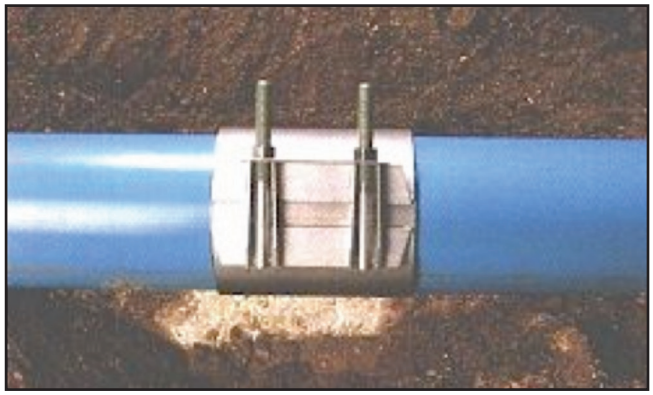
There have been cases of pipe leaks in locations that make repair work difficult such as the seabed, narrow areas and places where a network of cables obstruct the pipeline. Such conditions can slow down repair work and affect the quality of repairs.

Under these circumstances, it is most appropriate and convenient to use a clamp (photo 35 and 36). Clamps can speed up work as they are easy to install on a leaking pipe. Water wastage can therefore be minimised and the quality of installation is maintained.

PHOTO 35: CLAMP SIZES AND SHAPES

Source: Cascade catalogue

PHOTO 36: CLAMP INSTALLED ON A PIPE



B6 HOLISTIC APPROACH TO NRW MANAGEMENT

The NRW value is the difference between the actual volume system input and actual volume of billed authorised consumption. The concept of holistic NRW management consists of the following:

(i) Accuracy of data

Accurate data is essential for measuring and monitoring of overall data.

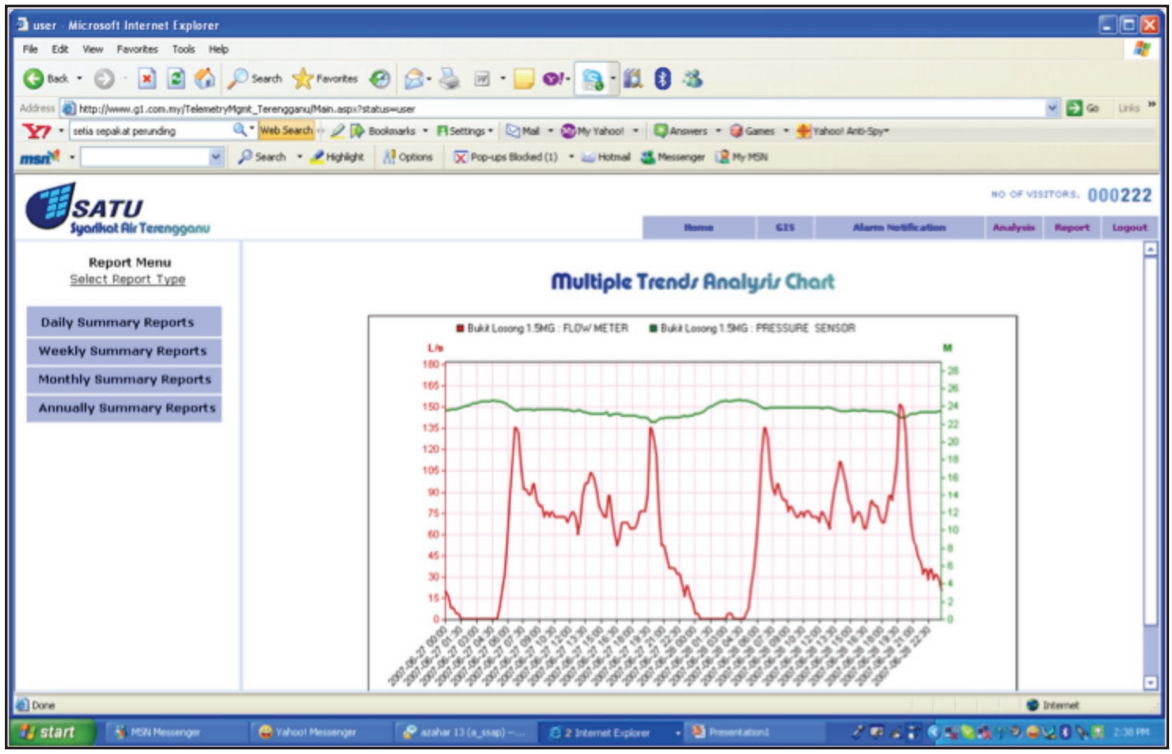
(ii) Use of the latest technology

The latest technology includes information and communication technologies such as GIS, network modelling, telemetry and SCADA (Figure 8).

(iii) NRW conventional approach

This approach refers to basic techniques such as zoning, pressure management, speedy detection and repair of pipe leakage and use of quality materials.

FIGURE 8: USING THE WEBSITE TO MONITOR DATA



B6.1 Geographic Information System (GIS)

The GIS combines all the information about a particular location to facilitate understanding of the area. A complete GIS requires software, hardware, data, trained personnel and robust analytical methods to interpret the results it produces. (Further information on the uses of the GIS is given in B4.1-Mapping.)

B6.2 Network Modelling

Network modelling is a technique of modelling a pipe network through the simulation-based calibration process of a water supply system. It has become a requirement of water supply entities with respect to software and analysis, as the results obtained can be used to address the issue of NRW.

The use of network modelling is based on a hydraulic design to calculate the rate of water flow and pressure head loss. The common methods of calculation include Hardy-Cross, Hazen-Williams and Colebrook-White. The different network modelling applications vary depending on the method and software used.

In the NRW reduction programme, the use of network modelling software helps in the design of DMZs through the simulation process of flow and pressure management. A model of a pipe network system can be used as a reference for asset replacement, flow and pressure requirement programme.

B6.2.1 Network Modelling Application Software

There are various types of software applications that are commonly used for network modelling, such as:

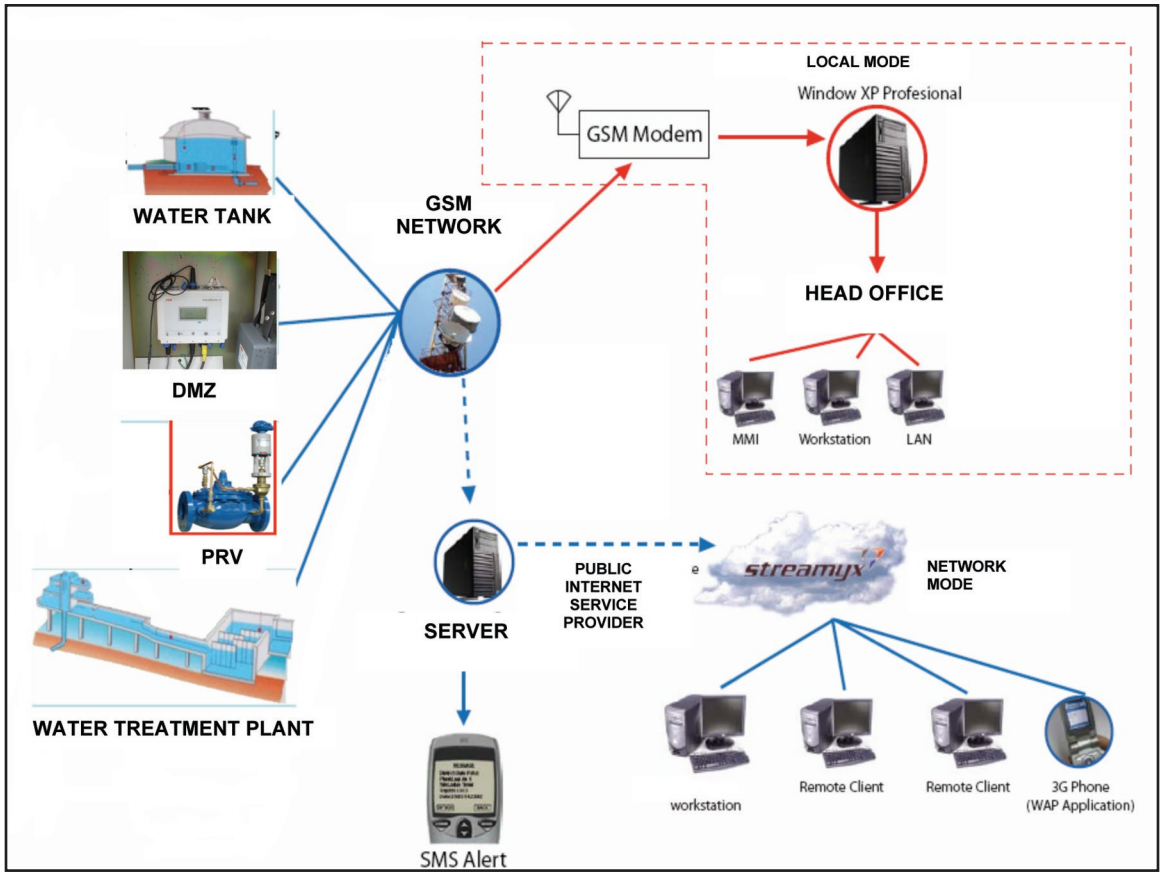
- InfoWorks WS
- AQUIS
- SynerGEE Water
- EPANET
- Water GEMS
- MWH Soft – H2oNET
- NETBASE

B6.3 Telemetry and SCADA (Supervisory Control and Data Acquisition)

The telemetry system is an information/data delivery system used for the remote monitoring of parameters such as water flow, pressure, depth and control valves and pumps. The SCADA system complements the telemetry system and is installed to control the pumps and valves.

The telemetry system makes monitoring and delivery of NRW data simple and cost-effective with the use of battery-operated electromagnetic meters (emf) equipped with pressure transducers and an integrated data storage device that uses a GSM/GPRS modem.

FIGURE 9: TYPICAL OF TELEMETRY SYSTEM INTERACTION



In Figure 9, the reservoir/water tank, DMZ, PRV and water treatment plant (WTP) provide data such as flow, pressure, water level, pump operation and water quality parameters which can be controlled and monitored by both the SCADA and telemetry systems. By using a SIM card, information from a remote terminal unit (RTU) can be sent to the centralised database on a daily basis. The information can also be sent to mobile phones and alarm systems. Furthermore, the data can be managed and displayed on a website using a web server. Other than the web server, a LAN network can also be used to display the relevant information.

The advantage of this system is that it receives real time information on any problems that occur on-site which allows proactive action to be taken to address the problem. Moreover, the system is equipped with the facility to store records and information on an ongoing basis, which can be used as reference materials.

B7 NRW ECONOMIC LEVEL

In designing the NRW reduction programme, the water supply entity needs to identify the main target to be achieved within a stipulated period of time. Often, the target is chosen without considering actual cost implications or whether the target is achievable. Identifying the economic level of NRW is essential to setting the initial NRW target and it requires a comparison of the cost of water being lost against the cost of undertaking NRW reduction activities.

There are two (2) components for determining the economic level of NRW:

(1) Cost of Water Loss

The cost of water loss is the value of the water lost through both physical and commercial losses.

The cost of physical losses is the volume of physical losses multiplied by the variable operational costs (RM/m3), including manpower, chemicals and electricity.

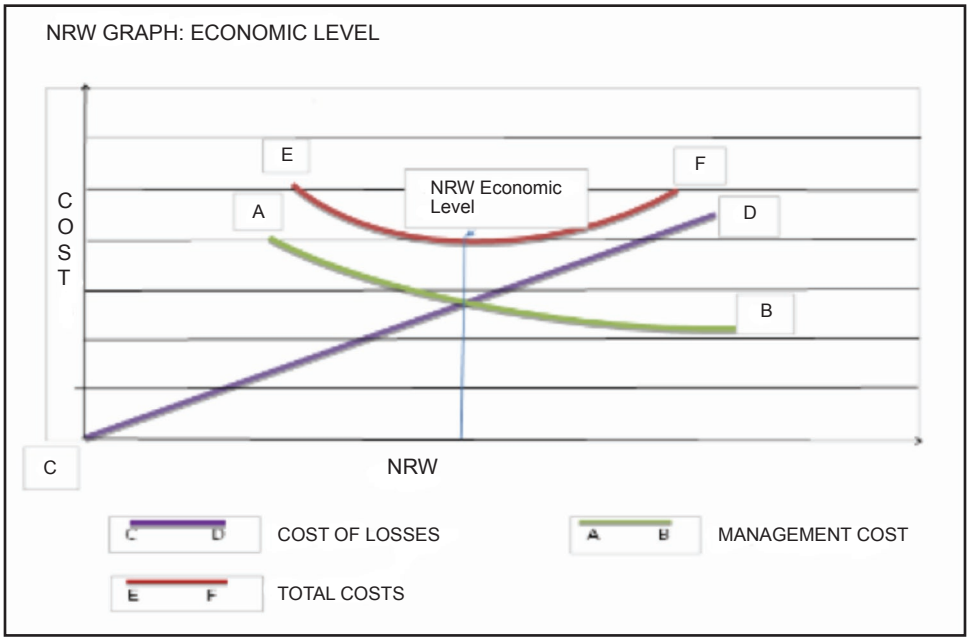
The cost of commercial losses is the volume of commercial losses (m3) multiplied by the average customer tariff.

As NRW increases, the cost of water loss also increases.

(2) Cost of NRW Management

The cost of NRW management is the cost of reducing NRW, including staff costs, equipment, transport, leakage repairs, DMZ provision and other factors.

FIGURE 10: IDENTIFYING THE ECONOMIC LEVEL OF NRW



Source: The Manager's Non-Revenue Water Handbook

In Figure 10, total costs are obtained by adding cost of water loss and cost of NRW management, and the intersection of the two component lines is the minimum total cost at the economic level of NRW.

Allowing the NRW value to exceed the economic level will reduce the cost of NRW management but increase the total operating costs. Similarly, reducing the NRW value lower than the economic level will increase the overall costs over potential savings.

The economic level of NRW will change with changes in water tariffs, cost of electricity and chemicals, salaries and equipment costs. The economic level of NRW should be assessed yearly and NRW targets adjusted accordingly to ensure the efficient use of resources.

B8 CONTINUOUS AND SUSTAINABLE EFFORT

Once the NRW target has been achieved, maintenance work must be continued so that NRW reduction is sustainable. Every aspect of leakage management requires continuous effort to ensure that the NRW level is further reduced. The problem of NRW will continue to worsen and if left unchecked, all efforts and investment in the NRW reduction programme will not result in any long-term benefits. Therefore, a number of issues need to be addressed:

1. Ensuring adequate and trained human capital to perform work in line with the objectives.

2. Adequate provisions for operations and maintenance in carrying out prompt repairs.

3. Ensuring that past mistakes are not repeated, especially in the implementation of new project development.

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C1 ORGANISATION OF NRW DIVISION

C1.1 Line of Inquiry: Organisational Structure

Audit sub-objectives:

- To determine whether the organisational structure is designed according to the organisation's objectives/functions
- To ensure that approved posts have been filled so that the organisation has responsible officers to ensure proper implementation of work

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Organisational chart has NRW divisions/ units at headquarters and regional levels	• Organisational chart • List of posts	• Document examination • Analysis	• Determine the number and grades of the actual posts filled • Check the position of the NRW division/unit within the organisation
2.	Organisational structure must be comprehensive and show clearly the functions of the division/unit and the responsibilities of the officer in charge of NRW programme implementation	• Standard operating procedure (SOP) • Desk file • Task list • Management report	• Document examination • Interview	• Check the SOP, desk file and task list of current officers • Ensure that the organisational structure clearly shows the functions of the division/unit and the grade of officers for the specified work • Ensure that the duties and responsibilities of the officer in charge of NRW programme implementation are specified clearly

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C1.2 Line of Inquiry: Laws, Regulations, Guidelines and Work Procedure

Audit sub-objectives:

- To ensure the adequacy of laws and regulations in regulating NRW activities
- To determine whether NRW activities are planned according to the requirements of the laws, regulations, guidelines and work procedures

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Requirements of the law, regulations and directives on NRW are observed during the course of work	• Acts • Regulations • Enactments • Concession agreements • NRW guidelines	• Document examination • Interview	• Obtain the list of work contracts and the list of NRW maintenance work • Obtain samples of contract and maintenance work documents • Check that the contract and maintenance work documents comply with applicable laws, enactments, concession agreements and related regulations • Ensure that the implementing agencies/ contractors who perform the work/supply the materials and equipment comply with the directives of the entity
2.	Entity issues complete and updated regulations or guidelines on NRW	• Regulations • NRW guidelines • Sample of NRW contract • Sample of maintenance work	• Document examination • Interview	• Ensure that the guidelines or work procedures are prepared and approved by the management • Check whether the guidelines are complete and updated in line with the requirements • Ensure that the policies, methods, concepts, scope and action for carrying out NRW maintenance are clear and observed

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C1.3 Line of Inquiry: Financial Allocations

Audit sub-objective:

- To ensure that the financial allocation for NRW implementation programmes is spent wisely

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Financial allocation for NRW projects is dispensed according to the NRW programmes which have been approved	• Allocation approval • NRW annual programmes • NRW project reports • Vote book	• Document examination • Interview • Analysis	• Ensure that the total expenditure is in accordance with the provisions of approved NRW programmes

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C1.4 Line of Inquiry: Human Capital – NRW Manpower Requirements and Training

Audit sub-objectives:

- To ensure that manpower and staffing are planned according to current needs based on the required qualifications, expertise and experience
- To ensure that training/course programmes designed to improve the efficiency and skills of officers are implemented, in particular NRW management programmes

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	All approved posts have been filled by qualified personnel	• List of positions • Employment files • Service book • Task list	• Document examination • Interview	• Obtain the number of positions filled and those vacant according to grade • Ensure that the officer in charge of NRW management has the appropriate qualifications
2.	Annual training plans are prepared according to personnel's area of work and subsequently implemented	• Training file • Annual training schedule • Service book • Annual report	• Document examination	• Ensure that the relevant officers/staff are given NRW work-related courses • Check the service records of the officers involved to ensure that course information has been recorded and updated

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C1.5 Line of Inquiry: System and Work Procedure

Audit sub-objective:

- To ensure that the establishment and implementation of systems and procedures are in order, reliable and effective

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	NRW work procedure manual and desk file of officers are complete, updated and easily accessed	• NRW SOP • Work procedure manual • Desk file	• Document examination • Interview	• Ensure that the NRW work procedure manual is prepared, complete and updated • Ensure that the work procedure manual and desk file contain a review programme/schedule and that continuous improvements are made to them
2.	Task list provided is complete and approved	• Desk file • Task list	• Document examination	• Ensure that a complete task list, approved by the officer in charge, is available to the staff
3.	NRW monthly and annual reports are available	• Scheduled reports	• Document examination • Analysis	• Check the NRW monthly and annual reports and ensure that they are submitted to the management
4.	Inspection of the maintenance of NRW work records is carried out	• Documents • Related files	• Document examination • Site visit	• Ensure that maintenance records are regularly checked and verified by the supervising officer

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C2 NRW PROGRAMME MANAGEMENT

C2.1 Line of Inquiry: NRW Strategic Management

Audit sub-objective:

- To ensure that the NRW strategic plan is comprehensive, clear and systematic

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	NRW strategic plan has been developed and approved	• Planning documents • Related files	• Document examination • Interview	• Ensure that the entity has an NRW work programme which is in accordance with the approved NRW strategic plan
2.	NRW master plan has NRW baseline data and target	• Planning documents • Baseline record	• Document examination • Interview	• Check baseline data and the review year • Check NRW target data and implementation period • Identify the implementation components of NRW programme, either holistic or piecemeal
3.	Financial allocation (project) is provided	• Documents	• Document examination	• Check the required allocation • Check the allocation breakdown according to components of the NRW programme

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Financial allocation (maintenance) is provided	• Documents	• Document examination • Analysis	• Check the requested allocation for maintenance work • Check the activities that are included in maintenance work • Check the approved allocation
5.	Method of implementation has been specified	• Documents	• Document examination	• Ensure that the implementation method is provided and encompasses the following: o Method of acquisition o Method of control and monitoring o Method of reporting
6.	Status of project implementation and maintenance is reported	• Periodic progress reports • Status of claims • Photos	• Document examination • Site visit • Analysis	• Obtain the relevant NRW programme documents (inhouse or outsourced) of completed and current programmes • Identify the methods used • Verify the actual progress report against the target

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C3 MAPPING USING GEOGRAPHIC INFORMATION SYSTEM (GIS)

C3.1 Line of Inquiry: Mapping Method

Audit sub-objective:

- To ensure that all information and data relating to the NRW control system are entered into the system and the applications used are easily accessed and maintained

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Base map of the entire installation area is prepared	• Map • Water supply system layout	• Document examination • Simulation • Interview	• Ensure that maps and layouts of the water supply system are prepared • Ensure that existing water supply system layouts are stored manually or in the computer system • Check the register and method of storage • Check base map details such as area, street name, river, related strategic locations and earth surface • Check the accuracy of maps that use coordinates and difference
2.	Level of GIS application development is identified	• Documentation • Computer application system	• Document examination • Test review	• Check whether the GIS is used throughout or part of the entity • Check the base maps that are used in the system, such as JUPEM, Telekom, satellite images • Ensure that the GIS is able to provide enquiry attributes/ layers for piping, valves, reservoirs/water tanks and fittings installation • Ensure that data (geocoding) is integrated with the billing system for each customer • Check use of the system operation is made online and is comprehensive • Check system testing through sampling to determine its functionality

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
3.	Security level of mapping system is under control	• Documentation • Computer system	• Document examination • Interview • Simulation	• Originals or hardcopies are stored in a secure and controlled location, such as a locked cabinet • Ensure that there is an officer in charge • Check whether the security levels, such as passwords for computer systems, are put in place according to the function and authority of the operator • Ensure that passwords are kept confidential • Ensure that passwords have limited validity period
4.	Information data is easily managed and updated	• Mapping documentation • Computer system	• Document examination • Interview • Simulation	• Ensure that on-site information is constantly updated • Data must be verified by an authorised officer • Ensure that the mapping system can be fully utilised for operations and maintenance work at the site • Check the records for the dates of updates • Ensure the use of uniform terms and terminology in the naming of information and data in the system
5.	Backup data service is provided	• SOP • Computer system	• Document examination • Computer laboratory	• Ensure that a backup data service is available in the event of data problems • Ensure that the backup system is placed in different premises

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C4 SYSTEM INPUT VOLUME (Qin)

C4.1 Line of Inquiry: Production Meter

Audit sub-objectives:

- To ensure that water production data from the water treatment plant (WTP) or other sources that feed into the supply system is measured accurately and monitored continuously
- To ensure that the standard operating procedure (SOP) for the production meter is prepared and observed

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Installation of production meter from the water supply entity and treated water producer	• Production meter installation documentation • Photos	• Document examination • Site visit • Interview	• Ensure that production meter list and basic record (type, size, age) are provided • Ensure that the on-site installation of production meters is carried out according to the list • Check the schematic layout of WTP and balancing reservoir pipe system • Ensure that a boundary meter is installed at each system input pipeline • Ensure that treated water purchase data and reports are provided
2.	Installation method of production meter and serial double flow meter system is followed	• Meter supply documentation • Photos • Specifications	• Document examination • Site visit	• Check supplier specifications • Check the on-site installation against the specifications • Indicate any serial connections (two units of production meters on one connection) • Ensure that the location of meter installation (sensor and converter) is suitable and safe and according to specifications

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
3.	Production meter monitoring and maintenance programme is implemented	• Maintenance documentation	• Document examination	• Ensure that there is a record on the monitoring and maintenance programme • Check records of functioning and faulty flow meters • For faulty meters, ensure that the average/estimated reading calculations are based on specified rules • Check the daily reading records • Check the implementation of maintenance schedule records • Check records of corrective action taken • Check method of daily readings recorded either manually or using telemetry • Check production water meter inspection records
4.	Production meter calibration/verification is done according to manufacturer's schedule	• Calibration/ verification certificate	• Document examination	• Check the calibration/ verification periodic schedule • Ensure that calibration/ verification is conducted by an independent party
5.	Reading of production meter is carried out	• Daily/monthly/ annual reading records	• Document examination • Analysis	• Obtain the daily, monthly and yearly reading records • Check and analyse the daily, monthly and yearly reading records • Obtain statistical analysis of the overall production meter reading trend
6.	Validity and accuracy of data are verified	• Photos • Selected meter sample	• Site visit	• Select a production meter sample • Make sure that the meter serial number is the same as in the record • Compare the on-site readings with the final reading record
7.	Standard operating procedure (SOP) is prepared	• SOP document • Work manual • Related files	• Document examination • Interview	• Obtain the relevant SOP • Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed and observed
8.	Reporting of Q_{in} is carried out	• Scheduled reports	• Document examination	• Obtain a summary of the treated water volume report (data and graph)

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C5 BILLED CONSUMPTION (Qbill)

C5.1 Line of Inquiry: Billed Metered Consumption

Audit sub-objective:

- To ensure that the volume of billed consumption is fully accounted for as revenue water

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Number of accounts and volume of daily, monthly, yearly consumption are provided	• Documentation	• Document examination	• Ensure that the billing report contains information on the number of users and volume of water consumed • Obtain a monthly summary report on total daily consumption of each area
2.	Validity and accuracy of data are verified	• Documentation	• Document examination • Site visit • Analysis	• Select a sample of accounts • Compare all information such as address, meter number, type of consumption, current readings and status
3.	Analysis of metered consumption data is carried out	• Documentation	• Record examination • Sample	• Check the total monthly consumption, taking into account the number of days for the billing period • Specify the average consumption volume (m^3/day) for all types of reading • Check the breakdown of the number of accounts for various types of reading, either normal or faulty and obstructed meters, and also average consumption by region • Find a method to calculate the average daily water consumption for the various types of readings as a sample

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Reporting of Q_{bill} is carried out	• Scheduled reports	• Record examination	• Obtain a summary of report (data and graph) on water consumption volume
5.	Calculation of Q_{bill} is carried out	• Documentation	• Record examination	• Check the calculation components that have been taken into account • Obtain the total annual metered consumption

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C5.2 Line of Inquiry: Billed Unmetered Consumption

Audit sub-objective:

- To determine the volume of billed unmetered consumption for all authorised consumption

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Work on pressure testing, leakage, cleaning and disinfecting of new pipe installation/water tank is recorded	• Documentation • Photos	• Document examination	• Ensure that the volume of water consumed is recorded • Check whether the cost of water usage has been charged to the contractor/ developer • If charged, make sure that payments have been made
2.	Sale of water tanks to industrial and domestic users is recorded	• Documentation	• Document examination	• Ensure that the volume of water usage for water tank sales is recorded • If charged, make sure that payments have been made

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C6 UNBILLED CONSUMPTION

C6.1 Line of Inquiry: Unbilled Metered Consumption

Audit sub-objective:

- To ensure that the volume of water loss is measured for each category of NRW

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	New individual water supply services (creation of new account)	• List of new applications	• Record examination	• Obtain the total number of new individual connections which have not been billed, if any • Obtain the duration between the time a new meter is installed and the time the customer is billed to assess delay in issue of the first bill • Check whether the calculation for the estimated NRW components has been made for the months in which the water bill was not issued
2.	Disconnection of water supply is not done on suspended accounts for which water bills are not being issued	• List of disconnected water supply	• Record examination • Analysis	• Obtain the number of suspended accounts for which water supply has not been disconnected • Check whether the calculation for the estimated NRW components has been made
3.	Reporting is carried out	• Scheduled reports	• Document examination	• Obtain a report summary on the estimated volume of unbilled water consumption (m^3) by month within the same year

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C6.2 Line of Inquiry: Unbilled Unmetered Consumption

Audit sub-objective:

- To ensure that the volume of water loss is measured for each category of NRW

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Pipe flushing carried out by the water supply entity for purpose of scheduled maintenance and repair work on burst pipes and dirty water complaints are recorded	• Record on pipe flushing • Record on burst pipes • Record on complaints of dirty water • Photos	• Document examination	• Ensure that the estimated volume of water used for flushing pipes has been recorded
2.	Reservoir cleaning work is recorded	• Record on reservoir cleaning • Photos	• Document examination	• Ensure that the estimated volume of water used for cleaning the reservoir has been recorded
3.	Fire hydrant use is recorded	• Report from the Fire Department	• Document examination	• Ensure that the water supply entity obtains the Fire Department's report on the estimated volume of water used for fire-fighting
4.	Delivery of water tanks to consumers is recorded	• Record on water tanker delivery	• Document examination	• Ensure that the volume of free water supplied has been recorded

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C7 COMMERCIAL LOSS

C7.1 Line of Inquiry: Unauthorised Consumption

Audit sub-objectives:

- To determine the volume of water loss of unmetered consumption
- To ensure that the standard operating procedure (SOP) relating to control of unauthorised consumption is prepared and observed

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Unauthorised connections are recorded	• Documentation • Photos	• Document examination • Site visit	• Ensure that a list of statistical records on water theft and problematic locations is provided
2.	Water supply has been disconnected from occupied houses, but payments have not been made	• List of disconnected water supply	• Record examination • Analysis	• Obtain the number of accounts for which water supply has been cut but payment remains overdue for more than a week • Check whether estimates for the NRW components have been made
3.	Method of monitoring and control is specified	• Documentation	• Document examination	• Check the records on corrective measures that have been taken • Obtain an analysis and volume of water loss • Obtain and check the method of calculating volume of water loss

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Actions taken by the water supply entity	• Documentation	• Document examination	• Obtain the corrective action report on water theft cases • Obtain programmes on addressing water theft, such as the water formation of the water Task Force programme, whereby authorised water is supplied to consumers
5.	Standard operating procedure (SOP) is provided	• SOP • Related files	• Document examination • Interview	• Ensure that the relevant SOP is provided • Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed • Ensure compliance of the SOP
6.	Reporting is camed out	• Scheduled reports	• Document examination • Analysis	• Obtain a summary report on unauthorised consumption • Obtain an estimate of the annual water loss volume (m^3/year)

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C7.2 Line of Inquiry: Customer Metering Inaccuracies

Audit sub-objectives:

- To ensure that the volume of estimated water loss is due to metering inaccuracies
- To measure the performance of the meter replacement programme

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Age of customer meter is analysed by the billing system	• Documentation	• Document examination	• Obtain the age statistics of domestic and commercial meters • Obtain the schedule for the meter replacement programme
2.	Analysis of under-registration percentage based on sample is carried out	• Documentation	• Document examination	• Check the metering inaccuracy sample test record • Obtain statistics on meter sample record and analysis
3.	Scheduled meter replacement programme is carried out	• Documentation • Photos	• Document examination	• Check the implementation schedule • Check the statistics and analysis of water usage before and after replacement work • Check the record/trend percentage (%) of increased consumption
4.	Faulty meter replacement programme is carried out	• Documentation	• Document examination	• Obtain the complaints statistics • Check the duration before corrective action is taken to replace a faulty meter • Find the method of calculating the volume of water loss based on the calculation method for newly replaced meters
5.	Cost of meter replacement is provided	• Documentation	• Document examination	• Obtain records on the overall cost of meter replacement • Obtain per unit cost of meter replacement (RM/unit)
6.	Reporting is camed out	• Scheduled reports	• Document examination	• Obtain a report summary on volume of water loss (m^3/year)

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C7.3 Line of Inquiry: Data Handling Errors

Audit sub-objective:

- To ensure that data handling errors due to human negligence are taken into account and adjusted accordingly

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Data management controls are established and taken into account in the adjustment of water volume	• Debit and credit notes	• Document examination	• Obtain the number of debit/ credit notes for the year • Obtain the total water volume adjustments in the debit and credit notes for the period being measured • Check whether the water volume adjustment data in the debit and credit notes has been entered into the billing system and taken into account in the calculation for total water consumption
2.	Reporting is camed out	• Scheduled reports	• Document examination	• Check the water volume data which has been taken into account in the calculations for the NRW component

CHAPTER C: AUDIT PROGRAMME

C8 PHYSICAL LOSS

C8.1 Line of Inquiry: Leakage from Transmission, Distribution and Reticulation Mains

Audit sub-objectives:

- To ensure that every incident of leakage is promptly acted upon and volume of water loss measured
- To ensure that complaints are recorded and updated
- To ensure that the standard operating procedure (SOP) on leakage control of mains and service connections is prepared and observed

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Records of burst pipes and leakages are prepared	• Documentation	• Document examination	• Ensure that the daily, monthly and yearly records on the number of burst pipes and leakages are available • Identify the causes of burst pipes and leakages based on the records • Check the frequency of burst pipes and leakages at the same location
2.	Procedure for repairing burst pipes and leakages has been set	• Documentation • Photos	• Document examination • Analysis	• Ensure that reports on burst pipe and leakage repair work are provided • Obtain an analysis and examination of the report on burst and pipe leakage repair (type of material used) • Check the implementation of repair works, either in-house or outsourced • Obtain the cost of repairs and conduct a cost analysis

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
3.	Monitoring of burst pipes and leaks is carried out	• Documentation • Photos	• Document examination • Interview	• Ensure that patrol surveilance is conducted to detect leaks • Check the record for number of burst pipes and leakages throughout the patrol programme • Check the record for number of burst pipe and leakage repair works throughout the patrol programme
4.	Method of measuring water loss has been determined	• Documentation	• Document examination	• Check and analyse the record on burst pipes (pipe type, size and age) • Check the record for the time lapse before action is taken to repair burst pipes and leaks • Obtain and review the method used to measure water loss
5.	Standard operating procedure (SOP) is provided	• SOP • Related files	• Document examination • Interview	• Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed • Ensure that the SOP is observed
6.	Reporting is camed out	• Scheduled reports	• Document examination • Analysis	• Obtain a report summary on burst pipes and leaks and repair work • Check the water volume data that was taken into account in the NRW component calculation

C8.2 Line of Inquiry: Leakage on Service Connections up to the Customer's Meter

Audit sub-objectives:

- To ensure that every leakage is promptly acted upon and volume of water loss measured
- To ensure that complaints and data are recorded and updated

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Record of pipe leaks is prepared	• Document	• Document examination	• Ensure that the daily, monthly and yearly records of the number of burst pipes are provided • Identify the causes of leakage based on the records • Check the frequency of leaks at the same location
2.	Method of repairing pipe leaks has been determined	• Document • Photos	• Document examination • Analysis	• Ensure that reports on leakage repair work are provided • Obtain an analysis and review report on pipe leakage repair (type of material used) • Check the implementation of improvement works, either in-house or outsourced • Obtain the cost of repairs and conduct a cost analysis
3.	Method of monitoring pipe leaks has been determined	• Document • Photos	• Document examination • Interview	• Ensure that patrols are conducted to detect leaks • Check the record for number of pipe leaks throughout the patrol programme • Check the record for number of pipe leakage repair works throughout the patrol programme

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Method of measuring water loss has been determined	• Document	• Document examination	• Check and analyse the record of pipe leaks (pipe type, size and age) • Check the record for the time lapse before action is taken to repair pipe leaks • Obtain and review the method of measuring water loss that was used
5.	Standard operating procedure (SOP) is prepared	• SOP	• Document examination • Interview	• Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed • Ensure that the SOP is observed
6.	Reporting is camed out	• Scheduled reports	• Document examination • Analysis	• Obtain a report summary on pipe leaks and repair work • Check the water volume data that was taken into account in the NRW component calculation

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C8.3 Line of Inquiry: Leakage and Overflows from the Utility's Reservoirs/ Storage Tanks

Audit sub-objectives:

- To ensure that water levels in reservoirs are monitored to avoid overflow
- To ensure no leaks in the structure of water tanks
- To ensure that the standard operating procedure (SOP) on control of leakage/overflow is provided and observed

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	The entity has a complete list of reservoirs	• Reservoir/ water tank records • Photos	• Document examination	• Ensure that a complete list of reservoirs and details such as type of reservoir, TWL, BWL, and year of construction • Ensure that schematic and structural drawings of reservoirs/water tanks have been provided
2.	Monitoring method has been determined	• Documentation	• Document examination • Site visit • Interview	• Ensure that reservoirs/water tanks are equipped with an overflow control system • Check method of monitoring o Manual o Telemetry (sms, radio-based, web-based, SCADA) • Check the reservoir/water tank monitoring reports (overflow/leakage)

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
3.	Method of control and maintenance is provided and observed	• Documentation • Photos	• Document examination • Site visit	• Check the control system of input volume into the reservoir/water tank (float valve, altitude valve, electrodes, pressure control system) that is used • Check the status of reservoir/ water tank level indicator • Check the inspection/ maintenance programme • Check record on implementation • Check record on corrective action (time period) • Check the method of leakage inspection
4.	Method of measuring leakage/overflow is specified	• Documentation	• Document examination • Analysis	• Check record on overflow volume and frequency • Check record on the analysis of overall overflow level • Check the method of calculating water loss volume from leakages
5.	Standard operating procedure (SOP) is prepared	• SOP • Related files	• Document examination • Interview	• Obtain the relevant SOP • Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed • Ensure that the SOP is observed
6	Reporting is camed out	• Scheduled reports	• Document examination	• Ensure that a report on the estimated volume of overflow water has been prepared and submitted to the entity's management

C8.4 Line of Inquiry: Distribution and Reticulation Pipe Replacement Programme

Audit sub-objectives:

- To ensure the effectiveness of the pipe system replacement programme in controlling and reducing burst pipes and leaks
- To ensure that the standard operating procedure (SOP) on the pipe system replacement programme is prepared and observed

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Method of determining the selection of areas or locations designated for pipeline replacement has been determined	• Documentation • Photos	• Document examination	• Ensure that the daily, monthly and yearly records on the number of burst pipes are available • Check the type and age of the pipe before its replacement • Check the frequency of complaints from customers
2.	Duration and cost of pipe replacement work have been specified	• Documentation	• Document examination	• Check work commencement and completion dates • Check the work progress report • Check replacement costs and conduct a cost analysis
3.	Standard operating procedure (SOP) is prepared	• SOP • Related files	• Document examination • Interview	• Obtain the relevant SOP • Ensure that the SOP has been approved and communicated to the staff • Ensure that the SOP is easily accessed • Ensure that the SOP is observed
4.	Reporting on programme effectiveness is made	• Scheduled reports	• Document examination	• Check the effectiveness of mains replacement work by comparing against the record on the number of burst or leaking pipes

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C 9 CONTROL OF NRW

C9.1 Line of Inquiry: Developing and Establishing District Metering Zone (DMZ)

Audit sub-objective:

- To ensure that NRW monitoring methods are implemented effectively

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Zone selection is done according to prescribed guidelines	• Documentation	• Document examination	• Obtain NRW baseline data record of each zone • Obtain record on zone size based on connections
2.	Zone proving is done according to the SOP	• Documentation	• Document examination	• Ensure that all zone proving has been documented and verified • Ensure that site plans and pressure profiles are provided
3.	Installation of district zone meters is in accordance with the guidelines	• Photos	• Document examination • Site visit	• Obtain a list of zone meters, type and size of meters • Check whether the location of the zone meter is secure against trespassers • Ensure that the flow meter sensor is mounted above ground level • Ensure that each meter chamber/cabinet is tagged in every zone

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Continuous monitoring of zone meters is carried out	• Scheduled monitoring report • Photos	• Document examination • Site visit	• Ensure that zone meters are fully operational • Ensure that boundary valves are closed and marked
5.	Data transmission system is established	• Documentation	• Document examination	• Obtain the method of data transmission • Ensure that the system is functioning • Check data records
6.	Zone meter maintenance and calibration are carried out	• Certification	• Document examination	• Obtain record on maintenance and calibration of zone meters
7.	Reporting is camed out	• Scheduled reports	• Document examination	• Obtain a report summary on the installation and status of district zone meters

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C9.2 Line of Inquiry: Water Pressure Management

Audit sub-objective:

- To ensure that high pressure areas can be reduced to an optimum level which would reduce leakage

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Selection of the PRV installation area is carried out	• Documentation • Computer	• Document examination	• Ensure that record of pressure of PRV installation area is available • Obtain record of burst pipes before and after installation for purpose of cost reduction analysis • Obtain the economic level and status of the installation area
2.	Effectiveness of PRV installation is reviewed	• Documentation	• Document examination	• Ensure that analysis or trend between pressure and frequency of burst pipes in an area is carried out
3.	PRV maintenance programme is carried out	• Documentation	• Document examination	• Obtain maintenance and monitoring record
4.	Monitoring method is established	• Documentation	• Document examination	• Check method of monitoring o Manual o Telemetry/SCADA • Obtain the daily or monthly pressure readings
5.	Reporting is camed out	• Scheduled reports	• Document examination	• Obtain a report summary on pressure management

CHAPTER C: AUDIT PROGRAMME

C10 LEAK DETECTION AND REPAIR

C10.1 Line of Inquiry: Active Detection Method

Audit sub-objectives:

- To ensure the implementation of leakage location verifying method
- To ensure that the detected leaks are repaired promptly

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Zone leakage levels are obtained	• Scheduled monitoring report	• Document examination	• Obtain the list of base leakage levels per zone • Check the record of locations of leakages
2.	Leak detection work is carried out	• Record on detection work	• Document examination	• Obtain records and reports on leakage detection programmes and their implementation • Ensure that the programme is implemented
3.	Use and maintenance of leak detectors	• Equipment list	• Document examination	• Obtain the list of equipment used • Check the record of detecting effectiveness • Check the maintenance record

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
4.	Repairs and monitoring are carried out	• Work order	• Document examination	• Obtain record of repair work and accuracy of location • Obtain a report on duration of repairs as compared to the prescribed norms • Check the list of approved materials used as substitute for repair work
5.	Method of record-keeping is established	• Paper maps • GIS	• Document examination	• Ensure that information on leakages has been incorporated in the plan, either manually or by geocoding • Obtain the level of updates in the GIS
6.	Reporting is camed out	• Scheduled reports	• Document examination	• Obtain a report summary on leak detection and repairs

CHAPTER C: AUDIT PROGRAMME

C11 QUALITY CONTROL AND WORK MATERIALS

C11.1 Line of Inquiry: Approval of Quality of Materials and Workmanship

Audit sub-objectives:

- To ensure that the materials used have certificates of approval
- To ensure that high quality work is maintained

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Pipe materials, valves and joints used are approved	• Certificate	• Document examination	• Ensure that the list of SIRIM or IKRAM-approved materials is prepared
2.	Validity of materials used is verified	• Documentation	• Site visit	• Select a pipe installation project sample • Compare all information on approvals and on-site installation
3.	Data analysis of materials is carried out	• Documentation	• Record checks • Analysis	• Analyse the materials used and check materials that have problems
4.	Reporting is camed out	• Documentation	• Document examination	• Obtain a report summary on quality of workmanship and materials
5.	Hot tapping method is used for tee connections in DMZ flow meter installation	• Documentation • Photos	• Document examination • Site visit	• Ensure that the hot tapping method is used for tee connections
6.	Repair method using repair clamps is employed	• Documentation • Photos	• Document examination • Interview • Site visit	• Check whether repairs using repair clamps are implemented

CHAPTER C: AUDIT PROGRAMME

C12 NRW ECONOMIC LEVEL

C12.1 Line of Inquiry: Calculation of NRW Economic Level

Audit sub-objective:

- To ensure optimum resource use and costs to achieve NRW economic level

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Cost of water loss is calculated	• Documentation	• Document examination	• Obtain record of the cost of water loss based on the production costs of each plant and the operating costs of distribution
2.	Cost of NRW management is calculated	• Documentation	• Document examination	• Obtain records of management, personnel, equipment and transport costs
3.	Data analysis is carried out	• Documentation	• Document examination	• Obtain a graph on cost of water loss, management costs and the economic level of NRW • Check and obtain the optimum NRW level, which comprises total management cost and lowest NRW cost

CHAPTER C: AUDIT PROGRAMME

C13 NRW PROGRAMME PERFORMANCE

C13.1 Line of Inquiry: Calculation of NRW Level in accordance with IWA Water Balance

Audit sub-objectives:

- To ensure that the NRW programme as a whole is implemented in accordance with best practices
- To ensure that the NRW level achievement is obtained through the prescribed performance indicators

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
1.	Water production volume is obtained	• Plant production record • Record of state and district boundary meters	• Document examination	• Ensure that every WTP and water input source into the distribution system has a meter • Ensure that meters are functioning • Ensure that the summary of monthly report on production volume (data and graph) is available
2.	Water consumption volume is obtained	• Calculated billed water consumption report	• Document examination	• Ensure that the summary of monthly report on water consumption (data and graph) is available
3.	Calculation of NRW rate is carried out	• Water balance	• Document examination	• Ensure that accurate calculation of NRW rates is done according to district and state
4.	Key performance indicators (KPIs) are measured using several methods	• NRW performance indicator report	• Document examination • Test review • Analysis	• Ensure that the performance indicators for the rate of water loss is calculated based on: i. Percentage (%) ii. Infrastructure Leakage Index (ILI) iii. Physical losses (litre/ connection/day) iv. Physical losses (litre/ km/day)

NO	AUDIT CRITERIA	TYPE/ SOURCE OF EVIDENCE	AUDIT TECHNIQUE	AUDIT PROCEDURE
				• Verify the data calculations using WB-EasyCalc software • Obtain an analysis of the outcome based on performance indicators
5.	Monitoring is carried out	• Documentation	• Document examination	• Ensure that the organisation has a customer service centre to receive and respond to complaints on burst pipes and leakages
6.	Implementation is camed out	• Documentation	• Document examination	• Ensure that the maintenance team has the capability to repair broken and leaking pipes (physical losses) • Ensure that corrective action is taken according to the prescribed timeframe
7.	Continued effectiveness and sustainability	• Documentation	• Document examination	• Ensure that the organisation has a competent team • Ensure that there are adequate succession teams • Ensure that there are adequate equipment and facilities • Ensure that continuous training is provided, both internal and external • Ensure that financial allocations are made for the monitoring and maintenance of NRW control