

# **NON-REVENUE WATER REDUCTION STRATEGY THE BAHAMIAN EXPERIENCE**

BY

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## **ABSTRACT**

A comprehensive strategy is required to reduce both the commercial and physical aspects of Unaccounted-for-Water, or Non-Revenue Water (NRW) as it is now called. The NRW in New Providence (NP), Bahamas is estimated at 50% and the Water and Sewerage Corporation WSC is developing and implementing a \$25Mn comprehensive strategy for NRW reduction to 30% over the next 3-4 years. The projected payback period is 10 years and this program is designed to address both commercial and physical aspects of NRW. It involves; (i) establishing the actual level of NRW; (ii) pressure management through system optimization; (iii) commercial/metering audits; (iv) infrastructure management utilizing GIS and telemetry, and; (v) twinning with a utility which has successfully implemented similar strategies. NRW reduction is a major focus for most water utilities and a never-ending problem for some. NRW is considered a reflection of the state of a utilities infrastructure and, its operational and business efficiency. Depending on the marginal cost of water it is a very expensive reality that utilities face as it increases operational expenses and capital expenditure for water production facilities to offset the losses.

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## **1.0 INTRODUCTION**

The Corporation (WSC) has had several consultancies and invested considerable amounts of its resources in NRW reduction over the past 12 years. However, Non-Revenue Water (NRW) has continued to increase due to a lack of financial and national commitment in addition to fragile infrastructure, poor infrastructure management, and an erosion of the customer base. The present strategy marks the first time that a comprehensive approach is being developed. As the island of New Providence (NP) faces severe water shortages, and competition for Government funds increases, the implementation of this program will require significant capital investment but should also result in deferment of future capital expenditure for water production, reduction in expenses, and increased revenue from additional water sales.

The paper will focus on the challenges of NRW Reduction and present solutions and concepts as it relates to the WSC experience. The components of NRW will be identified along with the strategy and activities developed proposed to address these components, all within the Bahamian context.

Consulting visits were made to the Corporation between Jun-01 and Oct-01 by LYSA (France); Mr. Allan Lambert, ONTAP Partnership (UK), and; THAMES WATER (UK). Additionally, WSC representatives visited THAMES WATER and LYSA in Sep-01 to review their operation. The main outputs of these visits were a report by Mr. Lambert and draft proposals for assistance by both THAMES and LYSA. Mr. Lambert is an internationally renowned expert on NRW and his report has been used by WSC in developing a NRW Reduction strategy following the International Water Association (IWA) standards to a large extent.

A basic outline IWA terminology and concepts is presented and then applied to NP to indicate the status of NRW.

## **2.0 IWA TERMINOLOGY**

Under the IWA, water supply or system input is divided into Authorized Consumption and Water Losses. Authorised Consumption consists of billed and unbilled amounts and these can either be metered or un-

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metered. Water Losses are also divided into two main categories: Real Losses and Apparent Losses. Both loss components are described in more detail below.

Logically, NRW consists of Unbilled Authorized Consumption (UAC) and water losses as these are the components for which the utility does not receive revenue. Utilities and countries will have differing levels of concern with the various categories. In the case of New Providence the focus has been on Water Losses but it is recognized that a comprehensive strategy must address UAC.

### ***WATER LOSSES***

As indicated, the two main categories of water losses are Real Losses, and Apparent Losses.

**REAL LOSSES:** This consists of all physical losses up to the customer's meter due to leaks, bursts, and storage overflows. Key local factors influencing Real Losses are as follows:

- Number and average length of service connections
- Length of mains, materials, and condition of infrastructure
- Soil/ground conditions
- Continuity of supply

Four components must be addressed for a successful reduction of Real Losses and therefore NRW:

- Pressure management
- Speed and quality of repairs
- Pipe material management
- Active leakage control

**APPARENT LOSSES:** This is due to meter inaccuracies (customer and production meters) and unauthorized consumption (theft or illegal use). These losses are predominantly related to meter inaccuracies and are therefore affected by the following:

- Proper sizing
- Calibration and testing, and;
- Repair/replacement practices

The illegal/theft aspect is a difficult issue which can be affected by penalties imposed, disconnection practice, and the number of pressurized, unconnected/un-metered laterals existing in the system

### ***PERFORMANCE INDICATORS***

IWA has also developed more meaningful and universal indicators for NRW that take into consideration the differing nature of distribution systems and utilities in general. These indicators address both the operational and financial aspects of NRW, and there are various levels which provide either a basic or detailed indication of performance.

Detailed Financial Performance Indicators can be developed once the marginal costs of the components of NRW are known. IWA also categorises NRW percentage as a basic FPI. This is significant as the percentage was used for years as the main measurement of NRW.

Operational Performance Indicators (OPI) also varies and the basic indicator applied is dependent on the density of service connections. In the case of NP, the density is 93 connections/mile of main. This exceeds the cutoff of 32 connections/mile of main set by IWA and therefore the basic OPI used is volume per service connection per day or *Igal<sup>1</sup>/service connection/day*. The detailed OPI is the *Infrastructure Leakage Index (ILI)* which is described below.

#### ***Infrastructure Leakage Index***

Under the IWA approach there is a level of Real Losses (RL) referred to as the Unavoidable Annual Real Losses (UARL). This allows for local conditions and represents the absolute best level of RL that could be obtained if; (i) all aspects of leakage control were being managed to the highest technical standards; (ii) infrastructure is in good condition, and; (iii) there are no economic or financial constraints.

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<sup>1</sup> Igal – imperial gallons

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The UARL is compared to the Current/Actual Annual Real Losses (CARL) and the ratio is called the Infrastructure Leakage Index (ILI). The target ILI is based on several factors mentioned previously such as; (i) connection density and length; (ii) average system pressure, and; (iii) marginal cost NRW components. It is considered “the most reliable measure of annual performance in managing Real Losses”. The ILI can have a wide range of values and the highest ILI identified to date is in excess of 50. This means that the actual level of Real Losses is more than 50 times the unavoidable amount.

### 3.0 STATUS OF NRW IN NEW PROVIDENCE

During Mr. Lambert’s visit, the IWA approach was applied to WSC based on information available at the time and the following performance indicators were determined:

- a) NRW had varied between 48.3% and 52.7% from 1995 to 2000
- b) Based on an average system input volume of 8.1Migd, NRW could be broken down by volume and in financial terms<sup>2</sup> as follows:

Real Losses (CARL)	3.69Migd	45.5%	\$7.5Mn
Apparent Losses	0.45Migd	5.5%	\$2.5Mn
UAC	0.02Migd	0.2%	\$<.1Mn
- c) Preliminary calculations show that the UARL (volume/day) for New Providence is 0.24Migd.
- d) The ILI for NP is approximately 15.2
- e) Based on the marginal cost of water in NP and other factors related to the system, it was determined that the long-term target or economic level of leakage should be an ILI of 1.5 (or 0.4Migd)<sup>3</sup>.

It was further concluded that the NP infrastructure is “in “comparatively fragile condition”. This was also confirmed through the Corporate Business Plan (CBP) produced in 2002 by THAMES, which identified a backlog of mains renewals requiring an investment of over \$15Mn in the next five years.

### 4.0 STRATEGY FOR NRW REDUCTION

Any strategy for NRW reduction must obviously address both components of water losses (real and apparent), and Unbilled Authorised Consumption. A clear understanding of the magnitude of each must be determined and a strategy for reduction created. This report addresses the water losses only but some initiatives will overlap and simultaneously address UAC.

Mr. Lambert’s report made several recommendations which WSC proposes to adopt and implement along with those made by THAMES under a System Optimisation consultancy. These have been assigned where possible, to each of the components of water losses. The recommendations focus on Real Losses as this is by far the largest component of NRW (89% of NRW). Additionally, WSC has reviewed several options regarding metering, data logging, and other equipment, and initiated purchases to aid its efforts. Other ongoing projects related and integral to NRW Reduction are also listed.

Table 1 below show the relationship between the recommendations made, the NRW component being targeted, and the project addressing the recommendation. Table 2 provides project briefs including proposed (or actual) start and completion dates, and estimated costs.

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<sup>2</sup> Following assumptions made: (i) overall 10% under-registration of billed authorized metered consumption; (ii) Real Losses - \$5.5/tig, and; (iii) UAC and Apparent Losses - \$15/tig

<sup>3</sup> It must be noted that the figures presented in Mr. Lambert’s report are preliminary and based on information available at the time. The confidence level in these figures must be established and improved through implementation of the various recommendations made in the report

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**TABLE 1 – RECOMMENDATIONS**

RECOMMENDATIONS		NRW COMPONENT	PROJECT ACTIVITY
REF. NO	DESCRIPTION	<i>RL-Real Losses, AL-Apparent Losses</i>	
1a	Adopt IWA Approach	RL, AL	<ul style="list-style-type: none"> <li>○ Twinning/Technical assistance (Malta Water Authority)</li> </ul>
1b	Calculate NRW and Set Targets	RL, AL	<ul style="list-style-type: none"> <li>• Meter/Loggers Purchase</li> <li>• Meter Sizing/Calibration</li> <li>• Baseline Survey/Pilot Project</li> <li>• GIS – HTE/WATERCAD<sup>4</sup> Integration</li> <li>• Infrastructure Audit/District Improvement Plan</li> </ul>
1c	Monitor NRW trends ( <i>Ig/service/day</i> )	RL, AL	
1d	Calculate ILI for each DMA <sup>5</sup>	RL	
2a	Delineate Leak repairs in DMAs ( <i>mains, valves, hydrants, service, meters</i> )	RL	<ul style="list-style-type: none"> <li>○ GIS – WOMS<sup>6</sup> Integration</li> </ul>
2b	Determine cause for leak frequency on Customer meters	RL	
3a	'Best Practice' Pressure Management/Surge recording ( <i>pumped flows, station pressures</i> )	RL	<ul style="list-style-type: none"> <li>○ Meter/Logger Purchase</li> <li>○ Telemetry</li> <li>○ Twinning/Technical assistance (Malta Water Authority)</li> </ul>
3b	Surge reduction ( <i>electrical/mechanical improvements</i> )	RL	<ul style="list-style-type: none"> <li>○ Twinning/Technical assistance (Malta Water Authority)</li> <li>○ System optimization – Pump/Surge Control Valves</li> </ul>
3c	Maximise gravity water supply	RL	<ul style="list-style-type: none"> <li>○ Telemetry</li> <li>○ GIS – WATERCAD integration</li> <li>○ System Optimisation – Network Analysis</li> </ul>
4a	Permanent flow/pressure monitoring ( <i>DMA inlets and critical points</i> )	RL	<ul style="list-style-type: none"> <li>○ Meter/Logger Purchase</li> <li>○ Telemetry</li> <li>○ GIS – WATERCAD integration</li> <li>○ System Optimisation – Network Analysis</li> </ul>
4b	Pressure Control ( <i>following Active Leakage Control activities</i> )	RL	<ul style="list-style-type: none"> <li>○ Meter/Logger Purchase</li> <li>○ Telemetry</li> <li>○ GIS – WATERCAD integration</li> <li>○ System Optimisation – Pressure Relief Valves</li> </ul>
5	Twinning/Technical Assistance	RL, AL	<ul style="list-style-type: none"> <li>○ Twinning/Technical assistance (Malta Water Authority)</li> </ul>
6	NRW Reduction	RL, AL	<ul style="list-style-type: none"> <li>○ Baseline Survey/Pilot Project</li> <li>○ Performance-based Contract</li> </ul>

<sup>4</sup> GIS – Geographic Information System; THE – Existing customer and financial information system; WATERCAD – Hydraulic network analysis software

<sup>5</sup> DMA – District Metered Areas

<sup>6</sup> WOMS – Work Order Management System

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**TABLE 2 – PROJECTS**

PROJECT NAME	DESCRIPTION	ESTIMATED COST (\$ Mn)	START DATE	COMPLETION DATE
GIS	This will provide immediate digital data on all NP assets and will be integrated with; (i) the HTE Customer Service module; (ii) hydraulic network analysis software, and; (iii) a Work Order Management software. Phase I – Software Review, Phase II – Implementation/User Needs Assessment	\$0.10	Sep-02	Dec-02
		\$0.40	Mar-03	Dec-03
TELEMETRY	SCADA system for level and pump controls, flow and pressure recording. Main pumping stations will be addressed first and are expected to save \$0.05Mn/year in overtime expenses. The second phase will address remote readout for flow and pressure in DMAs.	\$0.20	Jul-03	Dec-03
		\$0.30	Jan-04	May-04
NRW EQUIPMENT	All DMA meters (90no) are being replaced and strainers installed to minimize damage and extend life. Data Loggers for pressure, flow, surge being purchased along with leak correlators and, leak and pipe detection equipment.	\$0.90	Oct-02	Dec-03
METER SIZING / CALIBRATION	The economic life of domestic meters will be determined and form the basis for a meter replacement policy. A testing and calibration program for new meters will also be established. Field calibration equipment for district meters will also be purchased	\$0.25	Jun-03	Dec-03
SYSTEM OPTIMISATION	Based on network analysis assistance from THAMES, recommendations related to operation of the distribution system and pressure management were made. This was expanded to include surge reduction. The project includes maximizing gravity flows and strategic installation of (i); surge relief; (ii) pressure relief; (iii) flow control, and; (iv) pump control valves. Updated GIS compatible network analysis software is also included	\$0.20	Jun-02	Sep-03
<i>NRW REDUCTION:</i> BASELINE SURVEY/ PILOT PROJECT	This includes; (i) establishing the true level of NRW in NP; (ii) reducing NRW in 5 specified DMAs while ensuring the overall level of NRW in NP does not increase; (iii) establishing new DMAs or realigning existing DMAs as required for system optimization, and; (iv) preparing detailed Terms of Reference for a performance based contract to reduce NRW to an agreed level. This is detailed further in Annex 2 of the (THAMES) CBP	\$0.60	Aug-03	Jan-04

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*TABLE 2 – PROJECTS*

PROJECT NAME	DESCRIPTION	ESTIMATED COST (\$ MN)	START DATE	COMPLETION DATE
<i>NRW REDUCTION: PERFORMANCE BASED CONTRACT</i>	NRW reduction from the level determined in the Baseline Survey to an agreed level within 3 years. This will include substantial capital works as outlined in Annex 2 of the CBP	\$23.0	May-04	May-07
INFRASTRUCTURE AUDIT	Also called 'District Improvement Plan'. This includes a full audit of infrastructure in NP through a systematic field exercise. It is an attempt to document exactly what assets exist, the condition of those assets, and the rehabilitation/replacement requirements. As the majority of infrastructure is underground, this will be an ongoing exercise in conjunction with the GIS and NRW Reduction projects.	\$0.30		May-07
TWINNING/TECHNICAL ASSISTANCE	Establish technical relationship with a water authority that has experienced similar problems (ie fragile infrastructure, direct pumping into distribution system, high marginal cost of water, vacant pressurized services) and which has substantially and rapidly reduced NRW in recent years.	\$0.15	Aug-03	Mar-04
	<b>TOTAL</b>	<b>\$ 26.40</b>		

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### 5.0 FINANCIAL ASPECTS

The total cost of the proposed strategy is \$26.4Mn. This cost does not include the in-house efforts of WSC staff, only the cash outlay required. Table 3 shows the potential benefits to be derived assuming a baseline NRW level of 52% with reduction to various levels.

**TABLE 3**

Reducing NRW to	45%	40%	35%	30%
Water Supplied (MG)	3,098	3,098	3,098	3,098
Water Billed for Consumption (MG)	1,493	1,493	1,493	1,493
<i>NRW</i>	<i>52%</i>	<i>52%</i>	<i>52%</i>	<i>52%</i>
(Present) Water Billed for Consumption (MG)	1,493	1,493	1,493	1,493
Additional Water	210	365	520	675
<b>(Projected) Water Billed for Consumption (MG)</b>	<b>1,704</b>	<b>1,859</b>	<b>2,014</b>	<b>2,168</b>
<i>NRW</i>	<i>45%</i>	<i>40%</i>	<i>35%</i>	<i>30%</i>

#### *If additional water is sold*

Water Billed for consumption (MG)	210	365	520	675
Water tariff (average) US\$/ ,000 g	\$ 16.66	\$ 16.66	\$ 16.66	\$ 16.66
<b>Additional Revenue per year</b>	<b>\$3,504,174</b>	<b>\$6,084,726</b>	<b>\$8,665,278</b>	<b>\$11,245,830</b>

#### *If additional water is saved*

Water Billed for consumption (MG)	210	365	520	675
Cost of production/ Purchase US\$/ ,000ig	\$ 6.46	\$ 6.46	\$ 6.46	\$ 6.46
Deduct Staffing & Administrative Expenses	\$ (3.16)	\$ (3.16)	\$ (3.16)	\$ (3.16)
<b>Savings per year</b>	<b>\$ 694,379</b>	<b>\$1,205,735</b>	<b>\$1,717,091</b>	<b>\$ 2,228,447</b>

#### *Payback Period*

Total investment US\$ Million	\$ 26.4	\$ 26.4	\$ 26.4	\$ 26.4
If additional water is sold	8	4	3	2
If additional water is saved	38	22	15	12

This gives an indication of the additional revenue possible if the water is sold and the reduction in expenses if the water is saved. These are basic financial indicators based on 2002 figures and are only meant to be an indication of the potential impact of this strategy. The payback period varies depending on whether the assumption is made that the water is sold or saved, and of course on the level of reduction.

It is worth noting that the deferred capital expenditure for additional water infrastructure is not addressed (ie supply increase, pipe/pump upgrades for higher flows due to NRW) but is an additional benefit of NRW Reduction.

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## **6.0 CONCLUSIONS**

The IWA has developed several terms, standards and indicators that reflect international best practices. These are encompassed in four main activities: Measure, Monitor, Mitigate, and Maintain.

Several visits, proposals, and recommendations have been made to WSC by various experts in the field of NRW. Each points to the need for a systematic and comprehensive strategy for NRW Reduction that must address commercial and physical losses, while ensuring operational efficiencies (ie pressure management, leak response times etc) are maintained or improved.

The need for technical assistance cannot be overemphasized in order to maximize technology transfer and minimize the learning curve for the technical aspects of implementing such a strategy. Implementation of the strategy requires dedication of substantial resources namely financial and human. However, the benefits of a successful strategy far outweigh the cost.

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