Water Balance - The Next Stage

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Summary

Have you ever wondered what you do with the water balance after the various components have been calculated? Or how you can use the numbers to work out an investment strategy and an action plan and how to prioritise your actions in order to get the best return on your investment? This paper shows how the water balance can be used to derive an action plan for reducing non-revenue water as well as the relevant returns on investment for each action. Also it gives a full working model of how the Water Balance is taken to the next stage.

Furthermore it details the actions that are appropriate to be taken for each one of the above main components of the water balance in order to reduce non-revenue water and provides justification for each action proposed. It also expands on current thinking and knowledge in the planning and prioritisation of non- revenue water reduction options that are available to water utilities and recommends a basic action plan matrix.

Introduction

Most water utilities use the water balance to calculate non-revenue water and to find the amount of water being lost. It is obvious that this is extremely useful and must be worked out in order to have a clear picture and to account for each constituent component of the water balance.

The planning of non-revenue reduction activities to be carried out and ultimately the compilation of an action plan are based on the findings of the water balance and in particular on the main components, namely, Authorised Billed Consumption, Unbilled Authorised Consumption, Apparent Losses and Real Losses. Depending on the amount of water which is being lost in each one of the above components which comprise the Non-Revenue Water, the action plan is targeted in order to provide the best return with the minimum of investment in the shortest time possible.

Accountability of water is extremely important in this process. This is achieved through a validated Water Audit which could be carried out internally by experience water utility personnel or by external auditor.

Water Audit

A water audit is a thorough accounting of all water into and out of a utility as well as an in-depth record and field examination of the distribution system that carries the water, with the intend to determine the operational efficiency of the system and to identify sources of water loss and revenue loss. It should include but not limited the following (Manual 2, Water Audits p9):

- A thorough accounting of all water into and out of a distribution system.
- A Water Balance calculation including inspection of system records and data verification.
- A meter testing and calibration program.

A water audit is a critical first step in the establishment of an effective water loss management program. With the successful completion of a system water audit, the utility gains a quantified understanding of the integrity of the distribution system and begin to formulate an economically sound plan to address losses. Water loss in a public water system can be a major operational issue. Non-revenue water components can significantly affect the financial stability of the utility. Addressing the issues associated with the non-revenue components will certainly entail a significant cost for the utility. The economic trade-offs between value of lost water given it generates no revenue and the investment to reduce this loss requires careful planning and economic judgment. The utility needs to clearly understand the type of loss as well as its magnitude. Water resource, financial and operational consequences must be weighed when considering these issues and the decision taken is unique to every system.

A brief summary of the main steps to perform an initial water audit is given below for ease of reference:

1. The amount of water put into the distribution system is determined.
2. The authorised consumption (billed + unbilled) is obtained from records.
3. Water losses are calculated (water losses = system input – authorised consumption).
4. Apparent losses are estimated (theft + meter error + billing errors and adjustments).
5. Real losses are calculated (real losses = water losses – apparent losses).

The above steps are an example of a **top down** audit, which starts at the “top” with existing information and records. It may also be known as a desktop audit or paper audit since no additional field work is required. Distribution systems are dynamic. The audit process and water balance has to be periodically performed to be meaningful to a utility’s water loss management program.

After performing an initial top down audit it may become evident that some of the numbers are approximate estimates and inspire little confidence in their accuracy. The next action in the audit process is to refine the quantities that may have been initially estimated and begin reducing non-revenue water losses. A **bottom up** approach is often implemented after top down audit has been completed which can help in identifying the real losses component more accurately thus adjusting the initial Apparent losses estimate. A bottom up approach will help with finding real losses and begins by looking at components or discrete areas in the distribution system. It also assesses and verifies the accuracy of the water loss data associated with individual components of the distribution system.

It is important to stress that although utility personnel are well experienced and are familiar with the operational characteristics of the network it may be worth while having an external or independent audit carried out. External audits are usually an excellent way of helping water utilities to analyse and improve their data. It must stressed the external audits are an independent process, ensure accurate reporting, improve data collection and accuracy by identifying statistical and reporting errors and is an excellent method of helping utilities to improve their performance.

There are many types of audits that will analyse water use, from distribution system balances to household reviews. The accuracy of results depends on the methods used to generate the data. Audits have an important part to play in the development of strategic action plans for water efficiencies and financial savings as well as short and long term management. Therefore it is vital they are undertaken in ways which ensure that the most accurate data possible is generated (Queensland Environmental Protection Agency / Wide Bay Water, Manual 2, Water Audits p43).

Assessing Losses – IWA Water Balance

A significant contribution to reaching the point of water accountability was the establishment of the IWA Water Balance (Figure 1) which is a useful tool in analysing the various components of water production, storage and distribution. Through this analysis the utility will gain an understanding of the magnitude of the water loss problem and will set priorities for rectifying the situation based on the component analysis of the Revenue and Non-Revenue Water elements.

System Input Volume	Authorised Consumption	Billed Authorised Consumption	Billed Metered Consumption	Revenue Water
			Billed Unmetered Consumption	
		Unbilled Authorised Consumption	Unbilled Metered Consumption	Non-Revenue Water
			Unbilled Unmetered Consumption	
	Water Losses	Apparent Losses	Unauthorised Consumption	
			Metering Inaccuracies and Data Handling Errors	
		Real Losses	Leakage on Transmission and/or Distribution Mains	
			Leakae and Overflows at Utility's Storage Tanks	
			Leakage on Service Connections up to Point of Customer Metering	

Figure 1, IWA Water Balance

The findings from the water balance and in particular its main components should:

- Assist in estimating the best return with the minimum of investment in the shortest time possible
- Form the basis for planning NRW reduction activities
- Provide sufficient information for an effective action plan

It is strange however, that for a number of reasons instead of following the above desired results a different approach is adopted which follows the steps below:

- Limited and / or unreliable data is used
- Calculate non-revenue water
- Find the amount of water lost
- Do not like the outcome
- Change assumptions made to suit
- Management 'blaming' staff for not doing their job
- Employees pointing out lack of funding, commitment and support by management
- Finally, work out figures to suit management and employees

Obviously the above approach will result in serious problems for the utility and it must be avoided at any cost. The Water Balance is a useful tool which if used correctly it will certainly point the way to the actions and measures that need to be taken to reduce NRW. Answers to the questions below will take you to the next stage from the desk top to the field environment.

- Have you ever wondered what you do with the water balance after the various components have been calculated?
- Or how you can use the numbers to work out an investment strategy and an action plan?
- Or how to prioritise your actions in order to get the best return on your investment?

Answers to the above questions and what could be done with the water balance will be demonstrated using examples from case studies.

Case Study Examples

Top Down Approach

In this example the constituent components of the water balance are entered into the water balance using absolute volume figures and working out the corresponding percentage figures. It is this percentage figures which are usually quoted and has to be stressed that they could be misleading as a performance indicator since they are strongly influenced by consumption as well as changes in consumption.

System Input Volume 11.985.560 100,00%	Authorised Consumption 10.276.626 85,74%	Billed Authorised Consumption 10.216.698 85,24%	Billed metered consumption (including water exported) 10.216.698 (85,24%)	Revenue water 10.216.698 85,24%
			Billed unmetered consumption Zero	
		Unbilled Authorised Consumption 59.928 0,50%	Unbilled metered consumption Zero	Non-revenue water 1.768.862 14,76%
			Unbilled unmetered consumption 59.928 (0,50%)	
	Water Losses 1.708.934 14,26%	Apparent Losses 299.639 2,50%	Unauthorised use 59.928 (0,50%)	
			Metering inaccuracies 239.711 (2,00%)	
		Real Losses 1.409.295 11,76%	Real losses on raw water mains and at the treatment works Zero	
			Leakage on transmission and/or distribution mains 80.458 (0,67%)	
			Leakage and overflows at storage tanks 11.986 (0,10%)	
			Leakage on service connections up to the metering point 268.913 (2,24%)	
			Detectable Losses 1.047.938 (8,74%)	

Figure 2, Top down approach using the IWA Water Balance

The Non Revenue Water is often expressed as a percentage of the System Input Volume. However, a true financial performance indicator needs to reflect costs as well as volumes. An improved financial indicator can be used by converting the Non Revenue Water Volume to values. An example is shown in Table 1 below where the NRW volumes in the above Water Balance were converted to values using the corresponding unit value for water. The unit value for Unbilled Authorised Consumption and Apparent Losses is usually the average sale price of water to customers. The unit value for Real Losses is usually taken as the marginal cost of water that is the unit cost of producing and distributing water into the network or bulk charge whichever is the higher.

Table 1: Converting NRW Volume Components to Values

	Components of Non- Revenue Water	Assessed unit value of NRW component	Assessed total value of NRW component	
Non-Revenue Water 1 768 862 m^3	Unbilled Authorised Consumption **59 928m^3**	1,2 € / m^3	€ 71 914	Assessed total value of Non-Revenue Water € 1 127 436
	Apparent Losses **299 639m^3**	1,2 € / m^3	€ 359 567	
	Real Losses **1 409 295m^3**	0,8 € / m^3	€ 1 127 436	

From Table 1 it can be seen that the Real Losses have the biggest financial loss for the utility and it is evident that this area is critical and should be examined further. This examination should provide proof that repairing the leaks and savings this amount of water which is being lost makes financial sense for the utility. In order to arrive at this result the following methodology needs to be followed.

From the top down analysis in Figure 1 the amount of detectable losses are 1047938 m^3. This figure is equivalent to a Night Line reduction of 1047938 m^3 / 365 days / 20 hrs= 144 m^3/hr. Assuming an average leak of the order of 1.6 m^3/hr then the number of equivalent leaks that should be located and repaired is 90. Given that the network length is 345 km it works out that there is on average 1 leak every 3.83 km. Assume a leakage detection team comprises 2 technicians with an average output of 2.5 km per day, 5 day working week and a weekly charge of €5000/week. The average number of leaks found by the team per week is 5 x 2.5 /3.83= 3.26, say 3 leaks found per week. The total time required to find all leaks will be 90 leaks / 3= 30 weeks. Based on the above the following financial calculations can be made

- Total Cost for locating leaks= 30 x €5000 = €150000
- Total Cost for repairing leaks= 90 x €1500= €135000
- Water Saving = 1047938 m^3 x €0.8/m^3= €838350
- NET SAVING = € 838350 - € 150000 - €135000 = €553350

It obvious from the above calculation that the utility will have a considerable saving by moving forward with repairing the leaks first and an action plan to this effect should be work out.

In order to highlight a different approach to the above the apparent losses in Table 1 are increased with the corresponding reduction in the real losses. The revised figures are shown in Table 2 below.

Table 2: Converting NRW Volume Components to Values (Revised)

	Components of Non- Revenue Water	Assessed unit value of NRW component	Assessed total value of NRW component	
Non-Revenue Water 1 768 862 m^3 (14,76%)	Unbilled Authorised Consumption **59 928m^3** (0,50%)	1,2 € / m^3	€ 71 914	Assessed total value of Non-Revenue Water € 1 678 917
	Apparent Losses **599 639m^3** (5,00%)	1,2 € / m^3	€719 567	
	Real Losses **1 109 295m^3** (9,26%)	0,8 € / m^3	€ 887 436	

In this instance the action plan needs to be different to the above for the following reasons:

- The Apparent Losses are almost equal to Real Losses in terms of revenue loss
- Need to deploy a strategy that will maximise benefits
- Tackle apparent losses with the minimum expenditure; reduce unauthorised consumption, meter reading and accounting errors at the first instance which will increase revenue.
- Simultaneously reduce leakage in order to save money in producing / buying less water.
- Invest savings in further reducing Apparent and Real Losses.

Bottom Up Audit – Case study to show bottom up and top down comparisons

It this example it is explained how the bottom up audit is extremely useful in complementing the top down approach. The case study data used are of the area of 'Sky' in Piraeus, Greece (Kanellopoulou, S., 2011). The main characteristics of the area are as follows:

- Length of network= 56km
- Number of consumers= 16840
- Service connections= 4000

A top down approach is carried out and the result is given in the table below. It should be noted that under the Real Losses the two main constituent components are included:

- Background Leakage on mains and service connections, and
- Detactable Losses

Table 3: Top down approach for the area of Sky, Piraeus, Greece

Description	M^3 / year	Average Daily Volume (m^3)
Input volume	2 898 100	7940
Construction	1 881 575	5155
Non-revenue water	1 016 525	2785
Unbilled Authorised Consumption (measured)		26
Apparent Losses (assumed 2.5% of consumption)		129
Real Losses		**2630**

In order to verify the assumption made for the Apparent Losses a bottom up audit will be carried out based on measured values. The Minimum Night Flow (MNF) as measured is shown in Figure 3. The Minimum Night Flow is 55 lit/sec (198 m^3/hr). Based on this measured figure a bottom up audit is carried out of the constituent components of the MNF in order to arrive at the amount of potentially detectable losses as shown in Table 4.

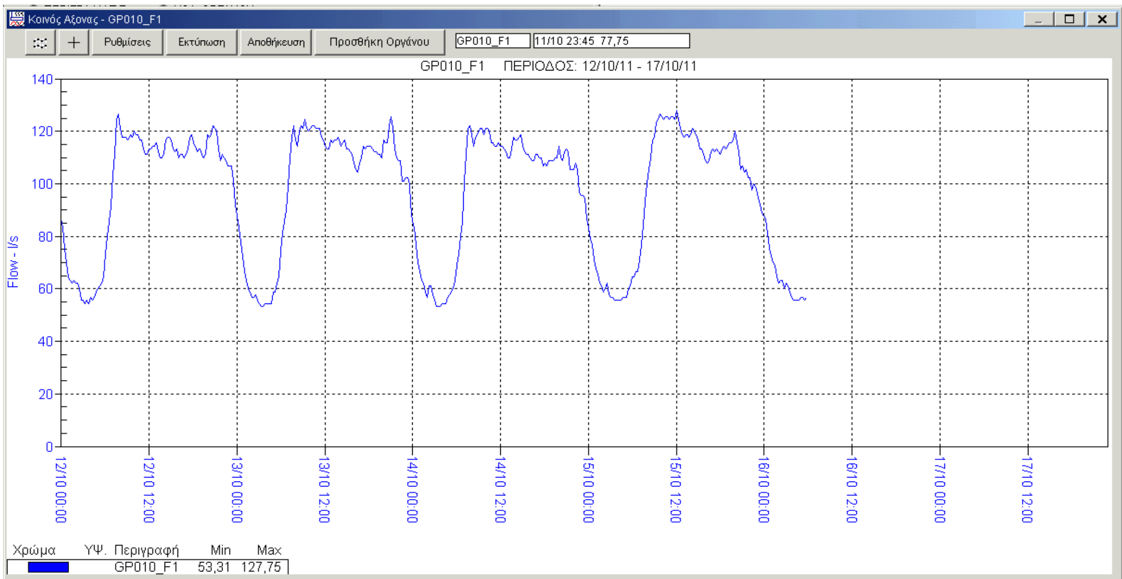

Figure 3, Minimum Night Flow Diagram for the area of Sky, Piraeus, Greece

As it can be seen from Table 4 below the potentially Detectable Losses are 2352 m^3 per day compared to the overall figure of 2631 m^3 per day estimated for all Real Losses in the system using the Top Down approach (Table 3).

This exercise shows that the initial assumption for Apparent Losses is reasonable and the NRW reduction plan should concentrate on reducing the Real Losses particularly in locating and repairing the leaks in the distribution network. The potentially detectable losses comprise 89% of the overall Real Losses which is of the right order considering that apart from a small percentage of Background Losses and Customer Night Use the remainder is attributed to losses in the distribution network which could potentially be located and repaired. Of course the Economic Level of Leakage must be taken into consideration in deciding how much of the amount of potentially detectable losses is financially worthwhile recovering.

Table 4: Bottom up audit for the area of Sky, Piraeus, Greece

Description	m^3 / hr	Daily (m^3)
Minimum Night Flow (measured)	198	198 x 20hr=3960
Background Losses (calculated)	21	21 x 24= 504
Customer Night Use	46	46 x 24= 1104
Potentially Detectable Losses	3960-504-1104	**2352**

Benchmarking of Non-Revenue Water

It is extremely useful to have a matrix which could be used to benchmark the performance of a utility based on the NRW figures.

The authors have developed and are proposing for use an action plan matrix which is based on the percentage of System Input Volume for each constituent component of the Non Revenue Water. The action plan matrix which is shown in Table 5 provides guidance as to the general actions that could be taken depending on the percentage figure in order to reduce the NRW in each component.

Of course the proposed matrix is only a guideline and much more investigation and development of this Matrix is required. The intention is to provide a guideline as to the general actions required which could be carried out by the utility whilst collecting and validating further data and information for more detailed analysis which will result in specific water loss management strategies.

Table 5: Proposed Action Plan Matrix for NRW

Water Balance Component	% of System Input Volume	Suggested Action
Unbilled Authorised Consumption	Up to 1%	Considered within acceptable limits
	1% to 5%	Introduce new tariffs
	5% and above	Review overall billing policy
Apparent Losses	Up to 2%	Considered within acceptable limits
	2% to 5%	Reduce unauthorised consumption, meter reading and accounting errors
	5% and above	Review metering accuracy / policy
Real Losses	Up to 5%	Considered acceptable, may be uneconomic to reduce
	5% to 10%	Reduce visual leakages and overflows at storages and fix visual network leaks
	10% and above	Improve active leakage control, effective maintenance, pressure management

Conclusions

It could not be stressed enough that utilities must target their actions and investments in order to get the maximum benefit. To achieve this it is important to have the necessary knowhow either internally or externally in order to be in a position to justify a proposed NRW reduction action plan which above all should be financially viable and sustainable. Needles to say in order to carry out such a plan the right level of knowledge and experience are required.

So, tackle first whatever gives you the quickest revenue return which will provide money for the longer term savings – think of the returns and not get caught up in the expensive solutions because it may be more attractive.

It is important to be understood that the Water Balance is the starting point for any NRW work. This paper aims to show that this could be done at the very early stages without having to wait until DMAs, pressure management, etc. are set up and data collected and analysed.

The Water Balance provides sufficient information to assist in the drafting of a NRW master plan in order to move ahead with water loss reduction and in parallel to make strategic improvements to the network. In the past it was thought necessary, mostly in developing countries, to develop DMAS in order to drive a NRW reduction master plan. The authors are suggesting that this could be done in parallel and that in the initial stages the Water Balance is the vehicle for driving a NRW Master Plan.

References

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