Case Study

Reduction and Control of Unaccounted for Water

Swaziland Water Services Corporation

Swaziland

The implementation of a proper Integrated Management Information System by the Swaziland Water Services Corporation (SWSC) has resulted in an increase in the organisation's efficiency as well as a substantial reduction in Unaccounted for Water (UFW). By implementing the EDAMS Suite of Information Systems the Swaziland Water Services Corporation promises to emerge as a modern, efficient, productive and profitable Water Supply Authority.

BACKGROUND

The Swaziland Water Services Authority, like most water supply authorities in southern Africa, had long been challenged with the problem of UFW. Traditional attempts at controlling the problem failed and the organisation's management came to realise that UFW was not simply a problem, but a reflection of the overall performance of the organisation and the state of its network system.

Experience had taught the authority that reducing UFW was not a simple task and required an holistic approach. In the past, UFW was viewed as a leakage problem and leakage detection equipment was used in isolation. Subsequently this approach was found to be not cost effective and in the end did little to address the problem.

As a result, the SWSC recognised that the implementation and continuous use of an appropriate Integrated Management Information System together with appropriate field actions would result in operational improvement as well as reduce UFW.

This case study shows the continuous effort started by the SWSC to increase its efficiency as well as reduce UFW. It also describes the methodology adopted and in some cases makes reference to the results achieved.

COMPONENTS OF UNACCOUNTED FOR WATER

Twenty four different components were identified and grouped into six categories as seen in the table on the next page.

The table also gives estimates of both the present and desired UFW levels at the SWSC, as well as showing the effect on revenues/cost to the SWSC of each UFW component.

The first category, "Customer problems" is of particular interest as it refers to wasted water after the consumer's meter has been measured. Although this wastage does not strictly speaking contribute to UFW, it is important to address it, as it often results in consumers not paying for services received, thus creating an undesirable culture of non-payment.

Using the assumed present and desired levels of UFW, a detailed cost analysis was performed to study the expected effect of the integrated management system. The following reflect the findings:

- *Production:* Water production will drop by 17.2% from 16.2 million cubic meters per year to 13.4 million cubic meters per year, corresponding to an annual saving in production costs of 5.6 million SZL per year.

Problems contributing to UFW				Effect on Revenue	Present Level of %UFW		Desired Level of %UFW	
Category		#	Problem					
A	Customer problems	1	Wastage within the household	Water resources non-payment	n/a	n/a	n/a	n/a
		2	Internal leakage					
B	Connections (not in Billing db)	3	Illegal connections	Lost revenue for usage (2/3) Production cost for wastage (1/3)	10.0%	10.0%	0.5%	0.5%
		4	Unknown/lost connections					
C	Meter readings	5	Un-monitored government use		6.0%	6.0%	1.0%	1.0%
		6	Connections with no meters					
		7	Connections in the field not identifiable	Lost revenue				
		8	Incorrect readings					
		9	Not all meters are read					
		10	Fire-fighting/testing	Lost revenue or no effect				
D	Consumption meters	11	Broken meters	Lost revenue	5.0%	1.0%	1.5%	0.0%
		12	Slow/malfunctioning meters			2.5%		0.5%
		13	Wrong size/over-sized meters			0.5%		0.0%
		14	Meter inaccuracy			1.0%		1.0%
E	Bulk meters	15	Malfunctioning bulk meters	No effect	1.0%	1.0%	0.5%	0.5%
		16	Missing bulk meters					
F	Measurement methods	17	Timing in readings/zoning changes		n/a	n/a	n/a	n/a
G	Water network (Leakage)	18	Overflows	Production cost	18.0%	0.0%	5.5%	0.0%
		19	High and irregular pressures			1.5%		0.0%
		20	Bad circulation/wrong zoning			1.5%		0.0%
		21	Badly corroded pipes			0.5%		0.0%
		22	Visible bursts			1.5%		0.5%
		23	Major non-visible leaks			10.0%		2.0%
		24	Minor leaks			3.0%		3.0%
			Totals		**40.0%**	**40.0%**	**9.0%**	**9.0%**

- *Volumes Billed/Revenues:* Billed volumes of water will increase drastically by 25.2% from 9.72 million cubic meters per year to 12.21 million cubic meters per year, corresponding to an annual increase in revenues of 7.4 million SZL per year.

- *Capital Cost Savings:* In addition to direct cost savings and the generation of extra revenue, the reduction of UFW also reflects directly on capital works. According to the analysis done for the SWSC, the amount of water produced would be reduced by 17.2%. This potentially extends the life cycle of all system components, as they have to cope with less water in the system. If one assumes an annual growth rate in demand of 5%, then the saving of 17% water implies that the system is given an added design life of *4 years*.

The Importance of Software Technology in the Reduction and Control of UFW

It would be naïve to think that the UFW of an organisation can effectively be addressed and sustained at low levels without also looking at its modus operandi, to ensure that it is operating internally with efficiency and purpose. The use of appropriate software technology is essential to help the organisation achieve these competent and efficient operation levels.

Appropriate software, accompanied by the relevant procedures and methodologies, can not only be used for the efficient operation of a Water Utility, but also to solve major problems like UFW by effectively quantifying, narrowing down, identifying and finally eliminating all UFW components in a progressive and organised manner that are caused by leakage and other problems. Utilities will therefore be able to effectively monitor and maintain UFW at low levels.

The software needed for all core-business departments basically consists of operational systems - Commercial, Operations & Maintenance, Design and Planning, Corporate Services-GIS Department. The table below illustrates the nature of the software required for this task:

Methodology in Reducing UFW

The implementation by the SWSC of the EDAMS Suite of Information Systems as an Integrated Management Information System was executed in eight main steps:

- Implementing the Billing and Customer Services System
- Commercial Data Validation
- Implementing the Network Asset Management System
- Network Data Validation
- Data Analysis & Reports
- System Rehabilitation
- Testing and Commissioning/Leakage Detection

Table 2: Use of Software Technology to reduce and control UFW

Nature of Software	Problems contributing to UFW: Category	#	Problem	Activity
Billing & Customer Services (Commercial department)	A. Customers	1	Wastage within the household	Lists connections with abnormally high consumption
		2	Internal leakage	Imports, analyses information from HHU and Lists connections with suspected internal leakage
	B. Connections (not in Billing db)	3	illegal connections	Keeps properties (mun) and plots (SG) database
		4	Unknown/lost connections	Reconciles plots with properties; properties with connections and lists all discrepancies
				Initiates illegal connections procedures
	C. Meter Readings	5	Unmonitored government use	Lists unmetered connections & proposed meter sizes
		6	Connections with no meters	
		7	Connections not identifiable	Reads info from HHU, Lists connections without TAG
		8	Incorrect readings	Identifies through use of proper activity cycle and issuance of discrepancy reports
		9	Not all meters are read	Keeps Walk Routes up to date - use of GIS
	D. Consumption Meters	11	Broken meters	Lists broken meters
				Lists meters with persistently no consumption
		12	Slow meters	Lists connections with slow meters by analysing historical recording trends
		13	Over/under sized meters	Lists connections with wrong size meters
				Performs Customer Services
				Controls Debt Management
				Requests action from O&M department
				Invoices for work done (when applicable)
Operations & Maintenance	A .Customers	2	Internal leakage	Receives Request for maintenance from Billing
	B .Connections (not in Billing db)	3	Illegal connections	Prepares Work Order & Job Card
		4	Unknown/lost connections	Reports Completion to Billing
	C .Meter Readings	5	Un-monitored government use	Performs Job Costing of operations (budgeting/pricing)
		6	Connections with no meters	Controls: Disconnections, Reconnections, Meter replacements, Meter repairs
		7	Connections not identifiable	
		10	Fire fighting/testing	Record fire usage details
	D Consumption Meters	11	Broken meters	as above "controls….
		12	Slow meters	
		13	Over/under sized meters	
		14	Meter inaccuracy	Lists Meter types Statistics of effective life span
	E. Bulk Meters	15	Malfunctioning bulk meters	Record and Analyse readings-> reactive maintenance
				Routine Maintenance for periodic calibration
		16	Missing bulk meters	Handles procurement, installation and calibration
	G. Network Problems (Leakage)	18	Overflows	Handles Maintenance of reservoir level controls
		19	High/irregular pressures	Receives Request for maintenance
		20	Bad circulation/wrong zoning	Prepares Work Order & Job Card
				Performs Job Costing of operations (budgeting/pricing)
		21	Badly corroded pipes	Log all leaks (use GIS) / attach to element
				Perform leak frequency of occurrence analysis
		22	Visible bursts/leaks (at connections, valves, hydrants)	Records the problem in system
				Initiates investigation, handles repairs process
		23	major non-visible leaks	Analysis of bulk meter readings - night flows
				Records leakage detection exercises (Pressure Method, Step Method, correlators, etc)
Demand Management Systems	E. Bulk Meters	15	Malfunctioning bulk meters	Mass Balancing Analysis.UFW calculations per DMZ
		16	Missing bulk meters	Checks sizing / calculates required size, through System Component (demand) Analysis
	F Methods of measurement	17	b) Problems with reading meters at different times	All meter readings are reduced to daily flow rates between reading times
			a) Problems with zoning changes	When calculating UFW per DMZ it accounts for zoning changes and uses daily consumption rates.
	G. Network Problems (Leakage)	19	high/irregular pressures	Calculation of design flows for different scenarios (static and dynamic)
		20	Bad circulation/wrong zoning	
		23	major non-visible leaks	UFW report / Mass Balancing
Network Asset Management	E .Bulk Meters	16	Missing bulk meters	Rezoning - definition of District Meter Zones, district junctions and flow control points
	F. Methods of measurement	17	a) Problems with zoning changes	Keeps track of zoning changes. (with date) automatically terminates old zones and creates new ones.
Network Analysis	G. Network Problems (Leakage)	19	High/irregular pressures	Static mode: Network Analysis and Evaluation
		20	Bad circulation/wrong zoning	Dynamic Mode: Studies pressure and flow variations
				Design Mode: Calculates system upgrades / reinforcements. Compiles pipe replacement programme
		23	Major non-visible leaks	performs network calibration (pressure method)

- Implementing the Integrated Management Information Systems

Step 1: Implementing the Billing and Customer Services Systems

After a comprehensive tender process, the EDAMS Billing System was selected; implementation began mid-1999 and the first statements were printed in the middle of October 1999. The system was chosen as it was more than a billing system – it geared towards problem solving by addressing customer services, meter reading operations, meter and connections management, data validation and debt management.

The conversion process from the existing government mainframe legacy system revealed many data problems:

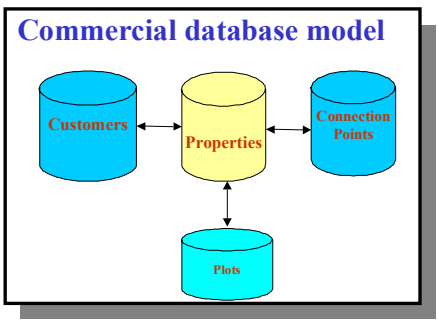
- Out of 31 254 customer records only 24 541 were active; many were duplicate
- Out of 21 417 properties, 3 181 were without an owner and were forwarded for investigation
- Only 18 000 water connections were valid and subsequently billed

Even though the present billed volumes are only slightly higher than before, the system has inspired confidence in its abilities, especially as it has succeeded in replacing a high wrongly billed volume quantity with an almost equal volume of correct billings. This is reflected in the very high increase of billed revenues (and collectibles) that rose, for water charges, from SZL 29.2 million to 42.2 million for the last 12 months – an increase of 45%. Once the commercial data validation exercise has been completed, the billed volumes and revenues are expected to increase even more.

Step 2: Commercial Data Validation

This process, in which the data found in the billing system is validated, is recommended when the billing data is thought to be erroneous and incomplete. The validation process involves collecting data from other sources, e.g. field surveys, and comparing it with the data in the Billing system. The discrepancy reports that arise out of the comparison are then investigated in the field and corrected in the system. The main objective of this exercise is to rectify the contents of the commercial data model shown in the adjoining diagram.

Plot information was obtained from the Surveyor General in Swaziland in GIS format as it was considered quite reliable,



but numerous mistakes were found in the setting of the GIS system of the SWSC, which were forwarded to the SG for correction.

Property data was also investigated at the municipalities and the electricity authority, but was found to be unreliable and incomplete. As a result, it was decided to embark on a field exercise with the following objectives:

- To compile a reliable **property** database that relates to the plot database
- To compile a **connections** database for the verification/improvement of the existing (in the Billing system) connections database
- To establish the **geographical position** of a connection by linking it to a property, which in turn is linked to a plot
- To verify/improve the existing (in the Billing system) **meter** database
- To verify/enhance property characteristics in the existing database, e.g. consumer type (to apply the right tariff structure). To also establish if there is a sewer connection (so it can be billed) and a borehole supplying the property (so it can be billed for borehole licence fees)
- To establish various **connection/meter conditions** that might be contributing to UFW – faulty/broken meters, meters with damaged units, buried meters, or meters covered by sand, leaking connections
- To establish connection without meters
- To establish a means of easily identifying connections in the field, and adopting a numbering system and tagging process to permanently mark connections
- To identify connections in the field that were not included in the billing database (illegal and unknown/lost connections)

The field exercise has successfully been completed in Mbabane and is presently being carried out in Manzini-Matshapa.

The data validation process that is being adopted is shown below. It not only rectifies the problematic data in the system but also identifies illegal connections and prospective customers. The process is currently being carried out in Mbabane.

Step 3: Implementation of Network Asset Management

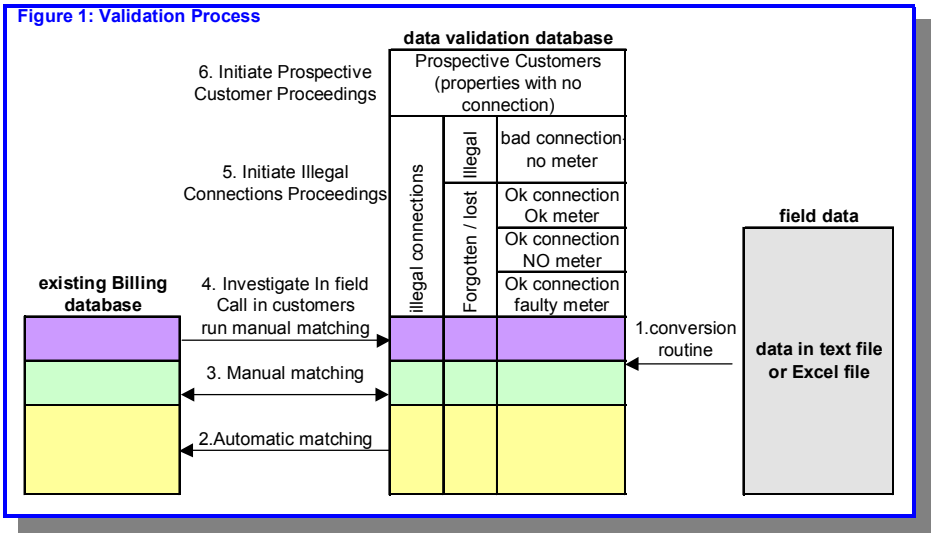
Before attempting to carry out any remedial work, it is extremely important to understand one's water network as the correction of the data in relation to positioning, connectivity and characteristics is of vital importance.

All network data was imported from the organization's CAD system to a GIS system to be featurised. Graphical and numerical attributes of the following elements were captured: pipes and nodes, reservoirs and towers, sources and treatment works, pumps and all pressure reducing valves, isolating valves showing and when available, the direction of opening and status (open/closed). Fire hydrants were also included.

Data capture and manipulation were also done and supervised by water experts. When capturing the data they noticed various suspect incidents in the network. The Asset Management System also provided exception reports where bad connectivity existed and network data was further manipulated to establish zoning and flow control points.

The exercise already completed provided the SWSC engineers with a good understanding of the existing network layout and operation for the first time. It highlighted a multitude of problem areas, as well as missing and questionable data that was documented for investigation in the next phase. Especially interesting was the observation of spaghetti networks and of networks with illogical pipe sizes – the obvious result of unplanned expansion that is frequently carried out without prior studying of the system.

Figure 1: Validation Process



Step 4: Network Data Validation

In the previous phase, maps with marked queries were prepared, to

be used by experts in the field for carrying out a network inspection for network data capture validation. The inspection activities include walking through the whole system using the following equipment: metal detectors, cover locators, pipe and cable locators, water pipe locators, measuring wheels and listening sticks, to be used for the following:

- *Visible leaks:* to record them (including ones on valves, hydrants and meter chamber)
- *Isolating valves:* to - record the type of valve and the pipe external diameter (OD); test that the valve can close properly (condition); ascertain status (open/close/partly open); record the opening direction (clockwise/anticlockwise); record missing valves (shown on the drawing but not found, and record not recorded valves (not shown in the drawing but found)
- *Hydrants:* to – record the **type** of hydrant, outlet nozzle size and the pipe external diameter (OD); **open/clean/check** packing in each hydrant; record **missing hydrant** (shown on drawing but not found); record **not recorded hydrant** (not shown on drawing but found)
- *Chambers (ALL):* to – record/confirm position; record incoming and outgoing pipes and their external position (O.D.); check bulk meters/ types; take pressure readings (with date and time) on hydrants where possible.
- *Sounding (for hot spots):* sounding of pipes and valves is also carried out, using electronic amplified equipment to indicate water leaks in the immediate area. This is used purely as an attempt to localise leak areas, making further investigation easier. This exercise is primarily done to get a feel for the system, the results of which will be used as reference at a later stage when proper leak localisation is carried out.

The information recorded in Network Data Validation is captured in the Network Asset Management System. The data is corrected and is stored for use in subsequent exercises.

Step 5: Data Analysis and Reports

At this stage, the Billing system should contain accurate data of consumers and their consumption with an accurate geographical position that can be related to the network; the data should also be more accurate. Various studies and analyses are carried out to give further understanding of the system's behaviour, including: ***Zoning***, setting the ***Demand Management Model***, the ***Demand Management Model***, ***Engineering Analysis*** and the preparation of ***Rehabilitation Programmes***.

Zoning is extremely important and its objectives are to:

- Define pressure zones
- Provide lower pressures
- Stabilise pressure fluctuations
- Perform water balancing (define District Meter Zones)
- Locate bulk meters
- Monitor system behaviour for easy calibration on demand
- Define waste-water areas for isolation tests and maintenance purposes
- Apply effective demand management for sizing major system components
- Improve bulk supply operation by optimising reservoir operating storage, reduce pump operation costs and maximise the use of existing assets (pipes, reservoirs, pumps, etc)
- Improve district network supply operation by achieving pressure equalisation, to improve water reticulation within the system and minimise the risk of failure
- Separate the bulk supply system from district networks
- Allow for easier system maintenance

Setting the Demand Management model is essential as it gives functionality in terms of Water Balancing and Demand Management. Demand areas and balancing areas of interest are defined and their connections are related to them.

Demand Management and Analysis is carried out to size major system components, specifically for sizing bulk meters and producing design flows for use in Analysis. To do this, Policy & Design Standards are revisited, present and future land use is investigated through town master plans, and mass balancing is also carried out for all meter zones.

Engineering Analysis is carried out to provide an understanding of system behaviour and recommend appropriate remedial work to render the networks functional.

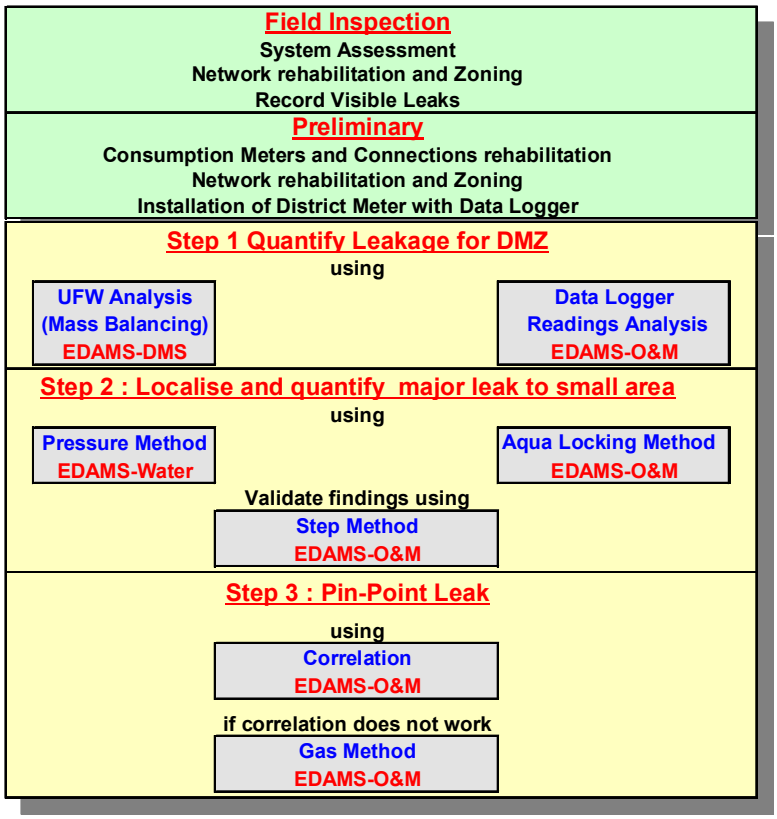
Preparing the Rehabilitation Programmes uses the results of previous phases and formulates rehabilitation

programmes to be implemented in System Rehabilitation – the next phase.

Step 6: System Rehabilitation

This will either be carried out directly by the SWSC for small activities, or by suitable contractors. Rehabilitation will be carried out according to the following programmes:

- *Connections and Consumption meters rehabilitation* – by installing new connections and tagging to existing connections and installing and replacing existing consumption meters
- *Network Rehabilitation (Stage 1):* to – fix visible leaks (connections/pipe work); isolate valve rehabilitation; rehabilitate hydrants and embark on remedial work to achieve zoning for pipe work.
- *Network Rehabilitation (Stage 2):* to – procure, supply and install bulk supply meters; replace pipes and install new pipes for network upgrading; install/rehabilitate pressure breaking tanks.



- Network Rehabilitation (Stage 3), after the leakage detection exercise: to – fix major non-visible leaks and replace/refurbish badly corroded pipes.

Step 7: Testing & Commissioning Leak Detection

Leakage detection is included in the final stage of the project, as it is first advisable to sort out basic zoning and pressure problems for each district.

Testing District Meter Zones (DMZ)

- Survey the elevation of all points where pressure measurements will be taken during the leakage detection exercises as well as the zooming isolation tests. These include predefined pressure control points (PCP) for calibration, zone boundary valves and pressure reducing valves.
- Check if DMA is isolated: the zones are checked for isolation by ensuring there is no flow across known "closed" boundary valves and no other link between DMZs.
- Check the operation of pressure reducing valves (PRV).

Leakage Detection

The leak detection methodology is shown in the adjoining diagram. Three steps are used -each one quantifying and narrowing the problems down to a smaller area. The pressure method is particularly interesting as it is quite unique to this type of work. It is based on calibrating the network by using pressure readings. It is the only method that is noise-dependent and has been quite successful in localizing and quantifying leakage.

Commissioning District Meter Zones (DMZ)

Once leak detection and fixing have been completed, the district is commissioned and handed over to the SWSC staff. Operational Manuals will be compiled for each district with instructions, procedures and reference to software tools used to handle its Operations with special reference to the control and further reduction of UFW.

Implementation of Integrated Management Information Systems

As the final step, the systems used in the project will be implemented at the organization, to assist the organization in sustaining the low levels of UFW achieved and improve its operations efficiency. The implementation of the Operations and Management System will be particularly significant at this stage.

SUMMARY

The SWSC has embarked on an ambitious programme to address the reduction and control of UFW and it adopted an holistic approach in which both its operational efficiency and the state of its networks had to be addressed first before any meaningful results could be expected. This was because they realised that UFW is not a problem but merely an index, reflecting both upon the overall performance of the organisation and the state of the network system.

The traditional approach of addressing UFW through leakage detection is part of a process, rather than an exercise in itself. The methodology adopted argues that system rehabilitation must be done first, for any meaningful and cost effective leakage detection and repairs to be carried out. In fact, it should be noted that the repairs are only carried out at the last step of the implementation methodology.

This new approach, of adopting technology as the centre of future operations and activities promises to render the

Swaziland Water Services Corporation as a modern, efficient, productive and most profitable Water Supply Authority. The first signs are most encouraging.