PAPER 2

Financial Feasibility and Bankability of City-wide Water Loss Intervention Programme – City of Tshwane

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ABSTRACT

The study described in this paper designed a programme for reducing water losses in City of Tshwane (CoT) and improving revenue and financial viability based on risk principles, proving the bankability of such a program with a view to attracting potential funders.

Water security is one of the key challenges facing South Africa and the reduction of water losses forms an integral part of ensuring sustainable water supply. Few studies have been undertaken where the potential for water loss reduction and potential savings have been analysed separately and in detail for each water Distribution Management Zone (DMZ).

The CoT system is being operated in 240 primary DMZ's, all of which are either supplied by a reservoir, a water tower, or a direct connection to a bulk pipeline. These DMZ's were the core subjects of this water loss reduction feasibility study. A DMZ database was compiled and populated with all the requisite water use/billing-, water loss-, water pressure-, customer debt- and water system condition information. This database was used to develop a set of rules-based decision-trees to determine first order optimal water loss interventions and costs for each DMZ.

Each DMZ was then considered a "sub-project" and a detailed Terms of Reference and capex and recurring opex costing for the indicated interventions in each DMZ were done. The potential benefits (decrease in System Input Volume, decrease in Annual Average Daily Demand, increase in billed/metered demand) for each intervention were calculated.

A financial model was developed for each of the 240 DMZ's to evaluate the impact of the capital and operating costs of the proposed water loss interventions against the potential achievable savings. The capex and opex associated with each intervention selected per DMZ were formulated in a 20-year cash flow model against the incremental benefits in bulk purchases and increases. These incremental cash flows were then discounted to Net Present Value (NPV) terms. Each DMZ model considered the unique characteristics of the particular DMZ including average tariff earned, collection rate and water balance.

City-wide modelling was performed to evaluate the impact of four DMZ-based intervention implementation strategies. The evaluation was based on the projected cash flows of CoT Water Services as a whole, considering its ability to service the resultant debt and ability to generate future excess cash to allow future interventions to be implemented without the need for external funding. The results revealed positive city-wide NPV's achieved both pre- and post-funding, with all debt covenants met.

INTRODUCTION

The City of Tshwane (CoT), located in Gauteng, South Africa, was established through the amalgamation of various municipalities. It is currently the third largest city in the world by area (CoT, 2021) with over 3 million residents. As a legacy of the amalgamations, the CoT has a vast and complex water distribution system with integration between various bulk facilities and water resources.

As water security within this complex and water scarce environment is a key challenge for the CoT, the reduction of water losses has been identified by the CoT as an integral part of ensuring sustainable water supply. The purpose of the study was to design a programme for reducing water losses and improving revenue and financial viability based on risk principles, and to prove the bankability of such a program with a view to attracting a potential funder such as the Development Bank of South Africa (DBSA). In addition to updating the water resources master plan, the project followed the recommendations made by Bruinette and Claasens (Bruitnette & Claasens, 2016) for an integrated and holistic approach to turn around a municipal supply system and re-establish financial viability and sustainability.

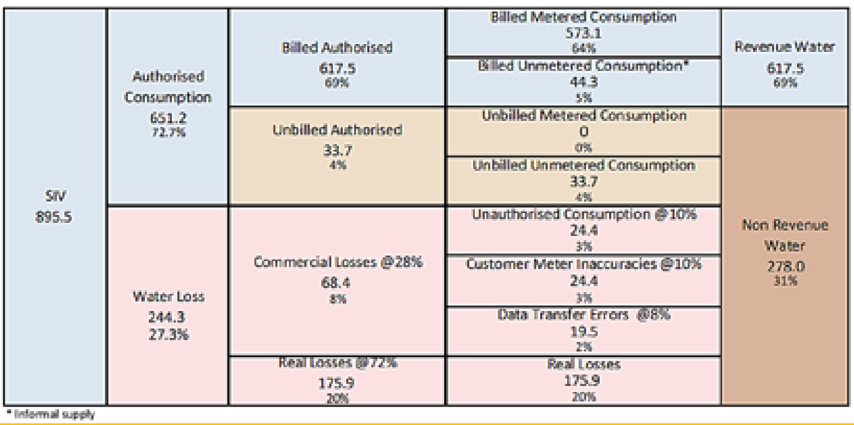

FIGURE 1: CoT FY 2017/18 Water Balance

WATER RESOURCES

The city has 13 Water Treatment Plants (WTPs) and various fountains and boreholes. Water purchases are made from Magalies Water from the Crocodile River, but most water is purchased from Rand Water and is supplied from the Vaal River System. The Vaal River System is under pressure and municipal customers are required to limit their demand from the system. However, in an interesting conundrum, increases in CoT's sewer return flows are required to generate sufficient yield in the downstream Crocodile River System which supplies several strategic power stations. This is compounded by the fact that augmenting CoT's own resources will reduce the load on the Vaal River System, but will also decrease the return flows to the Crocodile River System. To ensure holistic consideration of any proposed interventions the CoT Water Resource Master Plan (WRMP) (Mouton et al. 2015) was updated in this study.

The WRMP indicated that there is sufficient surplus yield available in the Crocodile River basin for CoT to increase both the capacities of the Temba WTP and to increase the capacities and supply areas of the CoT's Rietvlei and Roodeplaat WTPs. Despite significant capital expenditure the latter can be achieved at a unit cost for water which is lower than the RW tariff.

There is no surplus yield available in the Olifants River basin for expansion of the Cullinan, Bronkhorstspruit and Bronkhorstbaai WTP's. Sufficient water resource availability can only be ensured through additional augmentation from RW to Cullinan and Bronkhorstspruit in combination with successful Water Conservation and Water Demand Management (WCWDM) initiatives.

WATER INFRASTRUCTURE

The water distribution system comprises inter alia of 658 km of bulk pipeline, 9 943 km of reticulation pipes, 183 pumping stations, 151 reservoirs and 31 water towers. The construction value of the system is estimated at more than R20bn. The CoT system is being operated in 240 primary Distribution Management Zones (DMZ's), all of which are either supplied by a reservoir, a water tower, or a direct connection to a bulk pipeline. These were the core subjects of this water loss reduction feasibility study and are shown on Figure 09 at the back of the paper.

The CoT has a system of dynamic master planning (Loubser et al, 2012) in which the relevant water information systems and master plans are updated regularly. The database of all 240 primary DMZ's was extracted from this information along with the requisite water use/billing-, water loss-, water pressure-, customer debt- and water system condition information for further analysis in the study.

CURRENT WATER DEMAND, WATER BALANCE AND RECOVERABLE REAL LOSSES

The current water demand and water balance was determined which included an analysis of the consumer base to establish the different consumption components, calculation of the unavoidable real losses and determination of the potential recoverable real losses for the city as a whole and for each DMZ. Data from the 2017/18 financial year (FY) was available as the basis for this study. The actual water balance for the CoT is in Figure 01. The invoices from RW and MW, bulk meter data and billing data (extracted from the SAP financial system) were input and spatially referenced within the Swift program (Jacobs & Fair, 2012). Stands with water consumption were mapped in Swift against aerial photographs to identify and quantify unbilled unmetered authorized consumption. It was assumed that informal water supply, being 5% of SIV, although free to the customers, is "billed" to National Treasury and paid in the form of the equitable share grant.

The total water loss for CoT is fairly accurately determined at 27.3%, or on average 244.3 ML/d (for 2017/18). The ratio of apparent loss to real loss was agreed with the CoT and was based on the typical parameters impacting apparent losses within the city: meter accuracy, meter reading errors, data transfer errors. The Unavoidable Real Loss (URL) for CoT is estimated per industry-standard formula as 35 ML/d, meaning that the estimated Recoverable real Loss (RRL) is: RRL = Total Loss – URL – Apparent loss = 244.3 ML/d – 35 ML/d – 68.4 ML/d = 140.9 ML/d.

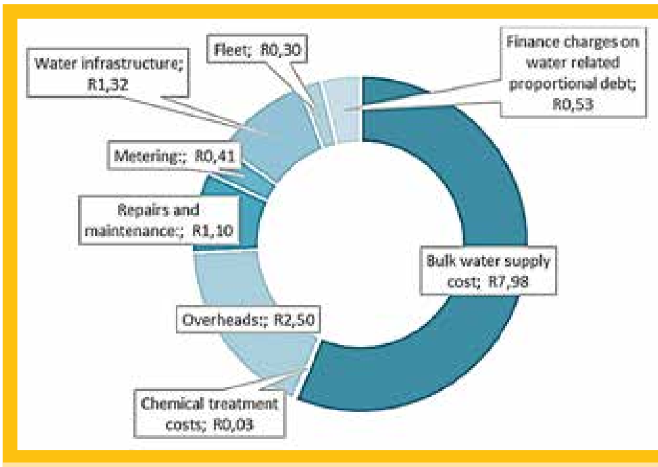

FIGURE 2: Breakdown of CoT unit water cost

COST OF WATER SUPPLY

Before financial modelling could be performed, the cost of water supply needed to be determined. This included determining the economic cost of water and the zero-based cost of water.

Water economic cost

An analysis of the costs of water input by the City was conducted and revealed the actual current cost of water input to be R12.73/kL. The breakdown of this cost is shown in Figure 02. If this is adjusted to account for water losses (27.3%) and collection rate (86.3%) the total cost of water per kL billed and collected amounts to R20.39/kL. The CoT's actual cost (R12.73/kL), before adjusting for Non-Revenue Water (NRW) and collection risk, align with those of other South African metros', such as Cape Town, Johannesburg and Nelson Mandela Bay.

Water zero based cost

The zero-based cost of water (R14.17/kL) is the best practice costing for the CoT's water supply, taking into consideration the current network demands and operating landscape for CoT. The zero-based economic cost calculated (R22.70/kL = R14.17/kL when adjusted for 27.3% NRW and 86% collection risk) is 11% (or R2.31/kL) higher than the CoT's actual cost per kilolitre of

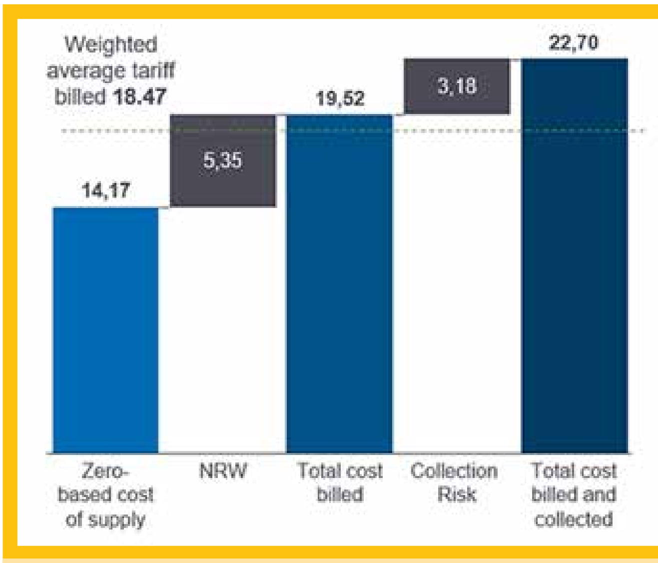

FIGURE 3: Zero-based cost of water supply vs. FY 2019 weighted average tariff (WAT) billed (R/kL)

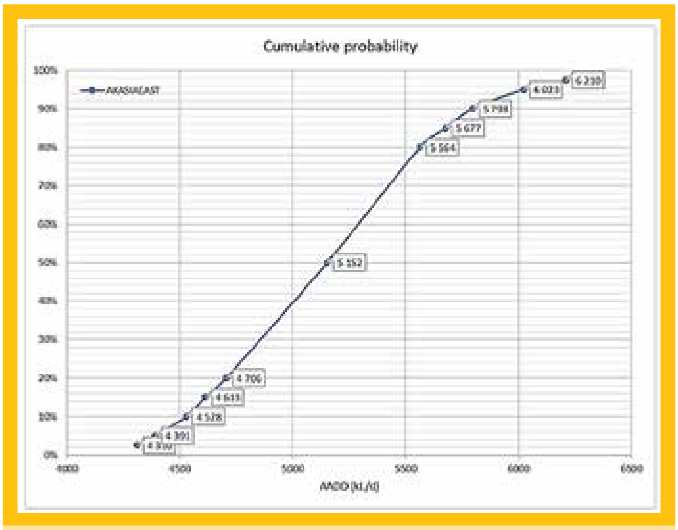

FIGURE 4: Cumulative empirical probability function for AADD in an example DMZ for total CoT

R20.39/kL and 22.9% (or R4.23/kL) higher than the equivalent weighted average tariff billed. As such, tariffs would need to be increased by 22.9% to cover zero-based costs unless the CoT's proportion of non-revenue water can be reduced, and collection rates improved.

Price elasticity and over consumption

A price elasticity analysis including stepped tariffs (similar to Hoffman & Du Plessis 2013) showed that the billed water consumption in CoT is likely to reduce to 476.5 ML/d should the water tariffs be increased by 40%. This represents the zero based demand "break-even" point where the zero based cost for water is covered by the billed and collected income. The current over consumption is therefore estimated at 98.9 ML/d which is 11% of the SIV. (Over consumptions are the difference between the actual billed water use and the water use at zero based prices.)

WATER DEMAND AND COST RECOVERY RISK

Using bootstrap techniques on the empirical data, rather than fitted probability density functions, the actual empirical distribution of demand in each DMZ was determined, with confidence bands for Annual Average Daily Demand (AADD) and billed income for stress-testing the financial modelling of the Net Present Value (NPV) of water loss interventions in each DMZ.

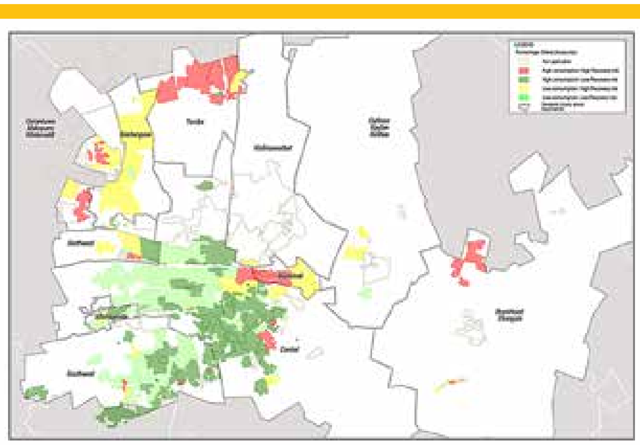

FIGURE 5: DMZ recovery risk categorization

Cost recovery and recovery risk

Using bootstrap techniques on the empirical data, rather than fitted probability density functions, the actual empirical probability density function (PDF) of current billed income was determined, with confidence bands for billed income for stress-testing the financial modelling of the NPV of water loss interventions in each zone.

The various DMZ's were categorized into a cost recovery risk matrix shown in Figure 05 as High Consumption/Low Recovery Risk (Green); Low Consumption/Low Recovery Risk (Light Green); Low Consumption/High Recovery Risk (Yellow); and High Consumption/High Recovery Risk (Red).

Future water demand and risk

The available CoT Spatial Development Framework (SDF) at the time of this study represents more than a doubling of the City over ±45 years at a rate of ±2% p.a. For this study a 20y horizon was considered. Using assumptions about the probabilities of developments occurring over time, a 95% confidence band for the additional future anticipated 20y AADD was established as between 304 ML/d and 612 ML/d as shown n Figure 06. This information was requisite input into the stress testing of the financial viability of proposed water loss reduction interventions in each DMZ, and was also aggregated input to a city-wide analysis.

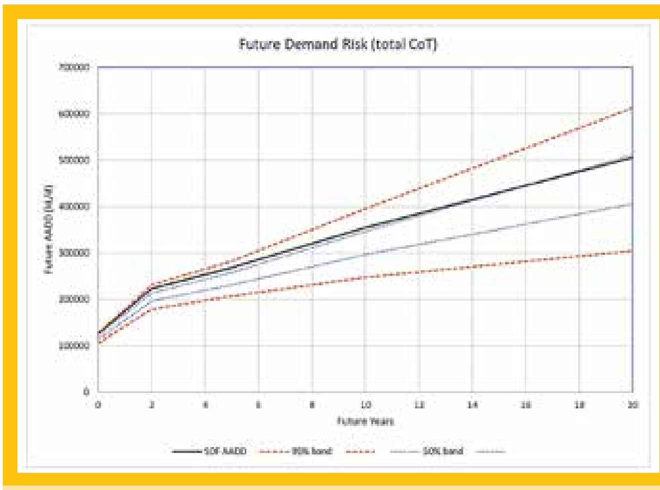

FIGURE 6: Additional future demand timeline and confidence bands for total CoT

INTERVENTION PROGRAMME

DMZ database and decision tree analysis

A comprehensive geo-database was developed for all ± 240 "Level 4" DMZ's in CoT, with requisite fields to allow in-depth analysis of the water losses and potential remedies in each. This database was used to develop a set of rules-based decision-trees to determine first order optimal water loss interventions for each zone, and a first order associated cost.

Possible interventions

The possible interventions considered in this feasibility study are listed in Table 1 and the workflow to use the decision trees in order to determine the first order interventions is shown in Figure 8.

Potential benefits per DMZ

In order to evaluate the bankability of each intervention sub-project, an estimation of the benefits of the intervention was required (McKenzie et al. 2002) (Wegelin et al. 2009) (WRC, 2020).

Potential benefits considered were:

POSSIBLE WATER LOSS INTERVENTION	WHEN APPROPRIATE
Install bulk meter(s) for SIV/Water Loss calculation	No bulk meter / for loss calculation
Log bulk meter	No logging / determine MNF / calibrate AADD
Pressure management	High static and/or dynamic pressures
Leak detection and fixing	Indication of high real losses / high MNF
Pipe replacement	Indication of deteriorating pipe condition
Meter audit/replacement	Indication of old an/or improperly sized meters
Connection replacement	Indication of old and/or deteriorating connections
Retrofitting	Indication of high MNF/UWD's and cost recovery risk
Water management devices	Indication of excessive UWD's
Billing data cleanup	Indication of many unbilled stands/areas
Check DMZ boundary discreteness	Indication of cross-boundary flows
Rezoning/Sectorization	Large zone or potential PRV sub-zone
Punitive tariffs	Indication of excessive UWD's

TABLE 1: Possible water loss interventionsfor total CoT

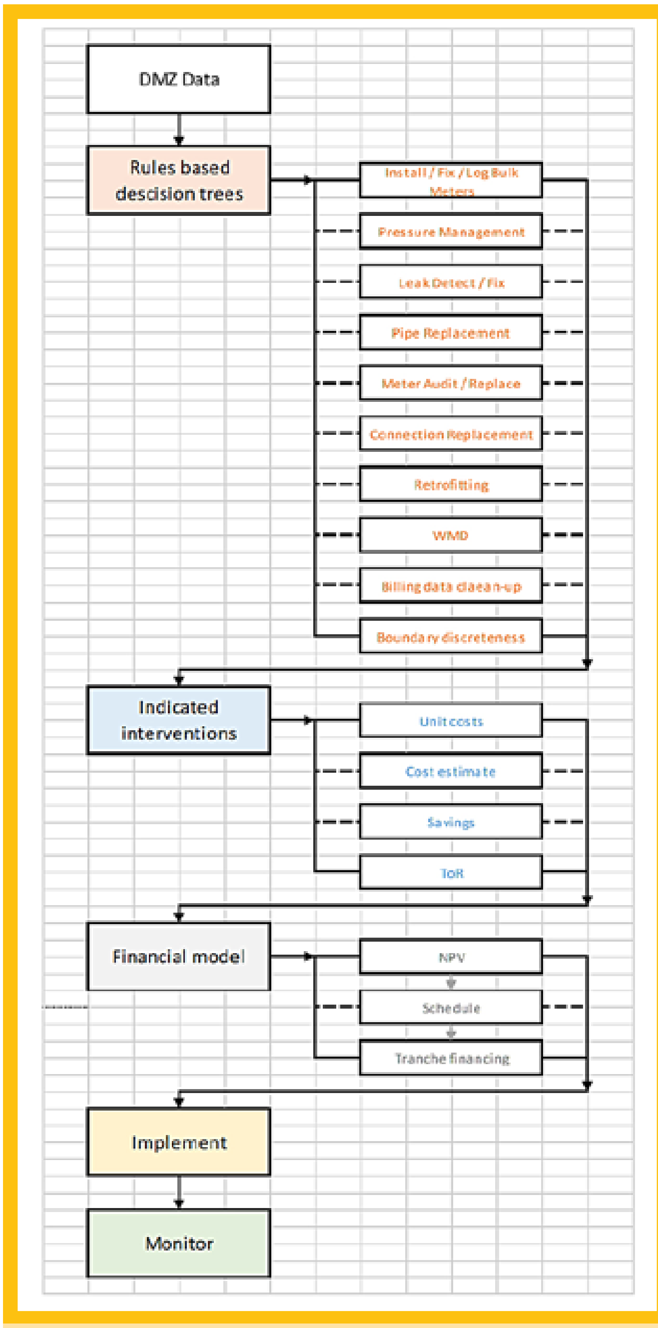

FIGURE 7: Workflow for decision-tree based first order interventions

- Reduction in SIV
- Reduction in water demand
- Increase in metered/billable water consumption

Table 2 lists the (high level view) potential benefits of each water loss intervention, together with notes on the quantification thereof. Most of the formulae use data which was readily available from the fully populated DMZ database. In all cases a range (min/max) of potential benefits was calculated, in order to allow "stress-testing" of the NPV of each intervention.

These potential benefits (decrease in SIV, decrease in AADD, increase in billed/metered AADD) for each intervention in each DMZ were calculated on a detailed level.

Summary of interventions and benefits

Table 3 summarises the indicated interventions and potential range of benefits determined in this manner for all the DMZ's. The full details with Scope of Work (SoW) maps, Bill of Quantities (BoQ) tables, and cost summaries were provided in electronic media with the project report.

The ToR, costing and benefits were used as inputs into a financial model, which determined the NPV for each DMZ sub-project. This allowed for the sub-projects to be ranked in accordance with their "bankability" (i.e. their NPV).

FINANCIAL MODELLING

DMZ level financial modelling

A financial model was developed in order to evaluate the impact of the capital and operating expenditure cost of the proposed water loss interventions against the savings envisaged to be achieved on each of the 240 DMZ's included in this study.

The DMZ level intervention financial modelling was conducted on an incremental cash flow approach. Therefore, the capital and annual operating expenditure associated with each intervention selected per DMZ was formulated in a 20-year cash flow forecasting model against the incremental savings in bulk water purchases and increased billing potential. These incremental cash flows were then discounted at an assumed weighted average cost of capital for CoT to NPV terms. Each DMZ model considered the unique characteristics of the particular DMZ including average tariff earned, collection rate and water balance.

The DMZ level financial model calculates both a project and equity NPV based on the net incremental cash flows. Project NPV is based on only the present value of incremental cash flows between costs and revenue potential of the interventions, i.e. project cash flows. The equity NPV is based on project cash flows after indicative funding terms for the capital expenditure required for interventions per DMZ. All interventions were assumed to be implemented in project year 1 for comparability across the results of the 240 DMZ's evaluated. These project NPV results were used to rank the financial preference of each DMZ for implementation of the technical suite of interventions.

The results of the 240 DMZ's with all the technical interventions, as recommended based on the technical decision-trees explained earlier, revealed an aggregate funding requirement of R3 422 million. The majority of the DMZ's however do not achieve a financial viable cash flow profile that can be expected to settle the debt required to fund its interventions. This

POSSIBLE WATER LOSS INTERVENTION	POTENTIAL BENEFIT	BENEFIT ESTIMATION
Install bulk meter(s) for SIV/Water Loss calculation	Knowledge of water loss and MNF w/o which sensible interventions cannot be determined	Not applicable
Log bulk meter	Knowledge of MNF w/o which sensible interventions cannot be determined	Not applicable
Pressure management	Reduction in SIV and unit water demands due to drop in pressure	Dependent on land use, SIV and UWD are reduced as a funtion of the % reduction in ave.pressure
Leak detection and fixing	Reduction in real losses due to minimisation of leakage	Real loss will reduce with 5% to 10%
Pipe replacement	Reduction in real losses due to improved reticulation condition	Based on reduced number of leaks, and the ave. leak report time, leak run/fix time, and leak flow rates
Rezoning/Sectorization	Improved information on water losses	Not applicable
Check DMZ boundary discreteness	Improved information on water losses since cross-boundary flows prevented	Not applicable
Meter audit/replacement	Increase in metered and billable water consumption	Bus/Comm customers increase = 25 kL/m (or 1255 kL/m if previously audited); Residential customers increase = 19%
Connection replacement	Reduction in real losses due to minimisation of leakage	Based on reduced number of leaks, and the ave. leak report time, leak run/fix time, and leak flow rates
Retrofitting	Reduction in on-site wastage will lead to reduction in SIV and concomitant reduction in AADD	Based on observed values retrofitting results in reduction of between 2.9 and 10.5 kL/month per household
Billing data clean-up	Increased billed income	Estimated demand for all identified unbilled/unmetered users will increase billing income accordingly
Punitive tariffs	Decrease in water consumption whilst not compromising revenue	Over-consumption is reduced in accordance with assumed price elasticity
Water management devices	Limit indigent users to FBW amount	If WMD is set to 0.4 kL/d then all excess consumption by indigent and non-paying customers is reduced to this level

TABLE 2: Potential benefits from water loss interventions

funding requirement is significantly reduced with the exclusion of the pipe replacement intervention. The number of DMZ's with a positive project NPV increased and ability to settle debt funding is also improved as a result. Table 04 below shows a summarised comparison of the key results of the DMZ modelling including and excluding the pipe replacement intervention.

Programme-wide financial modelling

The programme-wide modelling aimed to evaluate the impact of four DMZ-based intervention implementation strategies. The evaluation was based on the projected cash flows of CoT Water Services as a whole, considering its ability to service the resultant debt and ability to generate future excess cash to allow future interventions to be implemented without the need for external funding. These four implementation strategies considered the roll-out of the suite of technical interventions in DMZ's that either only revealed a positive project NPV or to all DMZ's identified, and whether the suite of interventions should include pipe replacement or not.

POSSIBLE WATER LOSS INTERVENTION	Number of DMZ's	Estimated capex (R million)	Estimated PV of opex (R million)	Potential SIV saving (kL/d)		Potential AADD saving (kL/d)		Potential increase in AADD (kL/d)		Potential Billing clean-up (kL/d)	
				Min	Max	Min	Max	Min	Max	Min	Max
Install bulk meter(s) for SIV/Water Loss calculation	129	R39.68	R7.32	0	0	0	0	0	0	0	0
Log bulk meter	55	R6.205	R11.337	0	0	0	0	0	0	0	0
Pressure management	111	R96.259	R37.202	11970	23156	4781	9270	0	0	0	0
Leak detection and fixing	15	R6.373	R10.042	2810	5619	0	0	0	0	0	0
Pipe replacement	36	R3 006.325	R0.000	6208	15219	0	0	0	0	0	0
Meter audit/replacement	97	R63.439	R0.000	0	0	0	0	8912	11691	0	0
Connection replacement	41	R139.729	R0.000	2789	5578	0	0	0	0	0	0
Retrofitting	13	R23.531	R70.594	3250	11766	3250	11765	0	0	0	0
Water management devices	13	R33.616	R53.786	7165	10236	7165	10236	0	0	0	0
Billing data cleanup	71	Internal	Internal	0	0	0	0	0	0	9890	24514
Check DMZ boundary discreteness	21	R7.409	R0.000	0	0	0	0	0	0	0	0
Rezoning/Sectorization	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Punitive tariffs	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		R3 422.57	R190.28	34177	71549	15197	31271	8913	11689	9890	24514

TABLE 3: Summary of interventions and benefits (with costs)

TABLE 4: Comparison in NPV and funding requirement between including and excluding pipe replacement

	Incl. PRP	Excl. PRP	Comment
Full funding requirement	R 3 435 mil	R 416 mil	88% reduction funding requirement
DMZ's with project NPV>=0	106	143	29% increase in DMZ's with pos. NPV
DMZ's with Project NPV<0	134	97	25% reduction in DMZ's with neg. NPV

TABLE 5: Recommended feasibility scenario – key outputs

Key outputs	
Total funding draw-down	R471 391 413
Number of active DMZ's	240
Active DMZ's with project NPV – positive	143
Active DMZ's with project NPV - negative	97
NPV: Consolidated cash flows	R2 311 164 320
NPV: Interventions (pre-funding)	R780 144 319
NPV: Interventions (post funding)	R778 857 708
Project IRR: Active DMZ's	36%
Equity IRR: Active DMZ's funded	N/A
Debt Service Cover Ratio	12.58
Loan Life Cover Ratio	5.86
Project Life Cover Ratio	10.49
Debt repayment period met?	Yes

A recommended feasibility scenario was developed after rigorous financial analysis and consultation on these four strategies with CoT officials, engagement with the technical work stream members on the practical roll-out recommendations of interventions and consideration of the funding implications of staggered implementation over a 5-year period. This final selected scenario is based on the roll-out of interventions, excluding pipe replacement, to all 240 identified DMZ's in CoT. The aggregate capital expenditure requirement of this scenario amounts to R471.4 million.

Table 05 sets out the key outputs of the recommended feasibility scenario. These results reveal positive NPV's achieved both pre- and post-funding, with all assumed debt covenants met. It is worth noting that the deferral in project cash flows to accommodate a 5-year staggered roll-out period results in one DMZ which held a positive project NPV (without staggered roll-out) to turn negative over the fixed 20-year evaluation period. The recommended scenario therefore has 143 DMZ's with a project NPV of zero and greater cross subsidising the project cash flows of the 97 DMZ's with a negative project NPV.

The profile for the five consecutive tranches of project finance to fund the capital expenditure requirements of the suite of recommended interventions shows a funding peak of R404.4 million in 2024/25 (see Figure 08). Once all the facilities have been drawn, the maximum

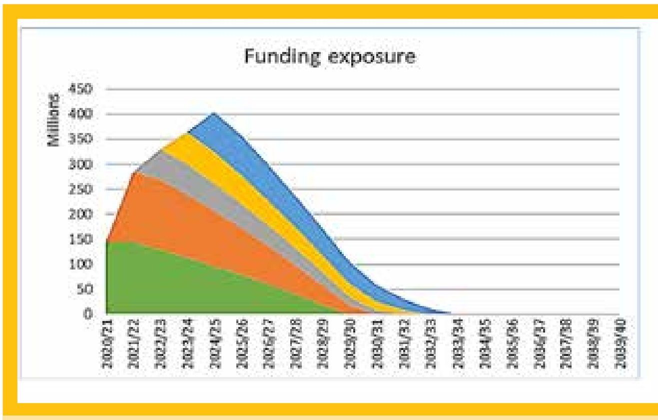

FIGURE 8: Recommended feasibility scenario – Funding exposure

required repayment per annum occurs in 2026/27 at R95.2 million. All funding tranches are projected to be repaid by the close of 2033/34.

Whilst pipe replacement has been excluded from the financial packaging of the recommended scenario, CoT is encouraged to consider the recommended pipe replacements in each of the DMZ's indicated should other sources of funding be available. The same applies to implementation of master plan items where required to eliminate capacity backlogs in parallel with the water loss interventions.

Stress tests have been performed on key assumptions to evaluate the financial implications of the roll-out of interventions for CoT Water Services should actual conditions differ to those projected in the base case. These stress tests indicate financial resilience to flexes on key economic assumptions, but with critical monitoring required on the balance between bulk water cost escalations and water tariff increases. Continued misalignment in the annual escalations of bulk water costs and that of the average water tariff charged, by as little as 0.5% will curtail long-term viability. Further, stress tests confirm that the average billing collection rate is a sensitive lever to the financial sustainability of quality water services in CoT. An average collection rate of less than 75% is likely to result in a financial inability to operate and maintain water services, even with the realisation of savings achieved through the suite of interventions.

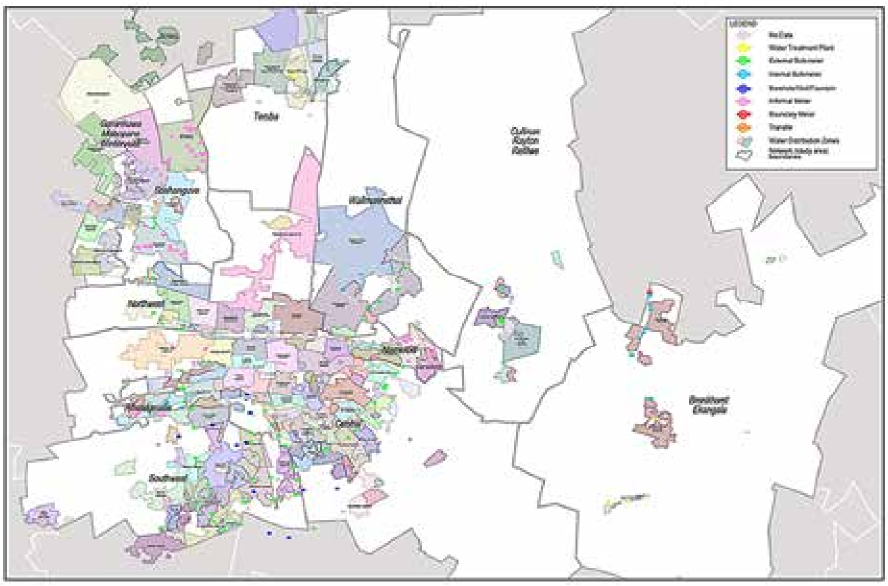

FIGURE 9: Study area and primary distribution management zones (DMZ's)

The financial viable realisation of this proposed project under the set of assumptions as set out in this study is therefore dependent on CoT's ability to roll-out the technical (and non-technical) interventions in accordance with the recommended DMZ prioritisation, monitoring and aligning the escalation of bulk water costs versus what is passed onto consumers, and ensuring improved collection of water tariffs charged.

MONITORING AND EVALUATION OF RESULTS

In November 2020 the CoT (CoT 2020) issued a press release approving the implementation of the water loss reduction strategy. This includes monitoring the success (or not) of the interventions in a database containing key performance indicators (KPIs) for each DMA, date stamped to monitor trends using the 2017/18 values collected from this study as the baseline. These will be added to the existing web-based platform on which all water and sanitation related information is stored, including models of existing systems, master planning of systems (based on SDF), and all billing and water balance related data.

The primary KPI's in this regard include the SIV, Authorised AADD (Billed, Unbilled), Minimum Night Flow (MNF), Water loss (Volume, %), SIV saving (kL/d, ZAR/a), Total billed amount (ZAR/a), Customers with 60d+ debt (%), Total collected revenue (ZAR/a), PRV / CP /Average pressures.

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