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Analysis of Domestic Consumption and Background Leakage Trends for Alexandra Township, South Africa

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ABSTRACT: Water is a scare resource whose conservation through water loss reduction is significant. This paper seeks to introduce the significance of comparative method that combines hydraulic flow data preparation techniques, minimum night flow method as well as classical linear regression methods to analyze customer consumption and background leakage trend. The authors selected Alexandra, a socio-economic township in Johannesburg, South Africa, as a case study. Existing challenges in Alexandra are high population, high water demand exacerbated by ageing infrastructure and exponential background domestic leakages. The results showed the minimum night flow of 14.01 % measured at a flow rate of 196.39 l/s and a linear regression value (R^2) of 0.096. Two comparative property consumption results show linear regression values (R^2) of 0.0088 and 2 x 10^{-5} and a combined flowrate of 364.41 kl per year. The study demonstrated that combination of hydraulic flow data, minimum night flow and linear regression methods are viable alternative methods for analyzing water loss trend. The authors suggest that reduction of static pressure in water distribution systems will proportionally reduce water losses and improves the objective of water loss reduction. These results will assist policymakers and managers to improve their leakage analysis method and operational approach to minimize water leakages in socio-economic urban cities.

Keywords: Bulk Flow Logging, Customer Consumption Trends, Background Leakages, Minimum Night Flows, Water Loss Reduction

I. INTRODUCTION

Water is globally considered as a finite resource whose projected demand far surpasses what is readily available. Climate change has led to reduced rainfall levels in different parts of the world and this has negatively impacted the available quantity of fresh water [45, 47]. Despite its finite nature, water managers around the world are confronted with a duty to balance physical losses and growing consumption demand [39]. To balance consumption against available water resources without putting strain on existing infrastructure [47], there is a need for a paradigm shift by water utilities to look at protecting the available water resources through strategies such as integrated water loss management [34,39]. In the year 2012, a report published by the world bank estimated that, almost 700 million people in 43 countries suffered water scarcity [44]. The report further outlined that, by year 2025, an estimated 1.8 billion people will be living in countries or regions with absolute water scarcity, while by year 2030 almost half the world's population will be living in areas of high-water stress, including almost 250 million people in Africa [34, 44 - 45]. According to McKenzie *et al.* [7]. Developing countries like South Africa normally experience long hot summer seasons and shorter rainfall periods, yet the need for water is exponentially growing [49]. Specifically, in 2011, despite low rainfalls, some urban cities in South Africa, had an average water loss of 37% to 50% added, McKenzie *et al.,* [17]. By the year 2015, at least 27% of the country total system input volume (SIV) of 2158 million l/annum was attributed to Johannesburg municipality, which was 2.4% above the available resource allocation [40]. Of recent, in 2019, the Department of Water and Sanitation in South Africa published the country' National Water and Sanitation Mater Plan attested that the country' water losses were up to 41% of the country' total annual input volume [27]. The report further noted that 35% of the 41% was lost through leakage (NW&SMP, 2019).These losses equates to 1660 million m^3 in quantity and R9.9 billion South African Rand (ZAR) [27].

Many studies are of the common view that despite the water loss problem and existing water loss solutions, the perpetual challenge confronting water utilities in developing countries is how to curb high-water losses [2, 5, 17, 22, 29, 33]. Amongst other factors that contribute to high water losses in developing countries are; increasing urban population, socio-economic factors, poor infrastructure management, metering inaccuracies, substandard repair and maintenance strategies, financial challenges, ageing infrastructure, water theft as well as poor governance, added Mutikanga *et al.,* [22]. These findings were also recommended by other studies [2, 5, 15]. It is also important to highlight that the primary mandate of achieving water loss management strategies lies in the ability to understand ways in which water is lost in the distribution network between supplier and customers [2, 38, 41]. According to Dighade *et al.* [5], besides high consumption demand, most water in developing countries is lost through background leaks and unmonitored customer behavior. All these factors call for better development and implementation of water resource management strategies by water managers to avoid further depletion of this limited resource [5]. Because of this realization, there however, has been a significant global change on water resource management, specifically on conservation approaches. In practice, within the framework of water conservation lies the topic of water loss management. Some of the water loss management approaches in practice are pressure management, annual water balance, active leak detection, hydraulic modeling, meter error reduction, illegal water consumption, benchmarking, water audit, speed and quality of repairs and pipe network upgrading [7, 17, 23, 32, 39, 42].

It is for the above literature background that the researchers draw interests to study the significance of comparative analysis method that combines hydraulic flow data preparation techniques, minimum night flow method as well as classical linear regression methods to analyze customer consumption and background leakage trend as contributing factors to water losses. In thus study, the approach followed by researchers agrees directly with the already existing empirical and scientific water loss hydraulic model developed by McKenzie [20] and adopted by others [12, 14]. The model is commonly known as a SANFLOW model, Night Flow Analysis (NFA) or Minimum Night Flow [20]. The model uses data logging devices designed to record pressure and flows in to a water distribution network. The data can be recorded at times where consumers are not using water, say between 12 midnight to 4 AM, added Mckenzie [16-20, 30]. The method allows researchers to analyze the water demand parameters where customer consumption is at a minimum while the leakage percentage is at its highest, and balances these two factors with the total system input volume [20]. Furthermore, the hydraulic minimum night flow model has also been used by other researchers in some parts of the world. According to Makaya and Hensel [15], the SANFLOW model has been used with great success in most developing countries including Europe, the Middle East, Malaysia and South America. Makaya and Hensel [15] further confirmed that apart from South Africa, the SANFLOW model was used in Malawi with great success. The drawbacks of this technique on reducing water losses is when the infrastructure is old, with non-existence of metering data, compounding illegal connections, over capacity problem and lack of zone discreetness ([14, 15]. The technique is however effective in a well-managed water distribution network where assets register is in a good state, added McKenzie [19] and Makaya and Hensel (15). Where poor zone discreetness and district metered area (DMA) are impossible to comprehend; data flow logging is often a good starting point for assessing water losses [20]. Finally, aaccording to McKenzie and Wegelin, [16] bulk-flow data logging in water distribution system allows water utilities to convert raw flow data into information upon which strategic operational decision can be based.

It can be deduced from the literature above that the integration of hydraulic modelling and data-flow methods are significant means of assessing water losses. A case in point is the Alexandra Township in Johannesburg, South Africa, wherein similar problems of excessive water losses have been documented. According to Wilson [43] and World Bank [44] Alexandra is a socio-economic deprived township with high unemployment rate. For example, the 2016' Water Conservation and Water Demand Management (WC/WDM) report produced by Johannesburg Water SOC LTD (the water utility servicing Alexandra township), indicated a 52% increase in consumption per month per household from an average 20 kl/month. The report further noted high percentage of illegal connections and attributed this to poverty [48]. The minimum night flow for the township was estimated above 70 %, which exceeded by far the 20-40% norm for similar township establishment in Johannesburg Municipal [48]. Alexandra socio-economic status are due to change in historic settlement pattern which then affects their affordability levels for services. Change in settlement pattern is similar to what was reported by Ummer and Vedh [50], who cited Goswami and Challa [51] about India, where change in settlement arrangement resulted in socio-economic exclusion and poverty. The authors therefore located Alexandra township as a suitable case study area to demonstrate the significance of using comparative analysis method that combines hydraulic flow data preparation techniques, minimum night flow method as well as classical linear regression methods to analyze customer consumption and background leakage trends.

II. STUDY AREA

Figure 1 show location for Alexandra township in Region E, North-East part of the City of Johannesburg municipality- South Africa. Its coordinates are 26° 6'1.68"S and 28° 7'3.50"E. Alexandra is subdivided into 5 Blocks in line with the water provision district metered area. The Johannesburg Water's internal Infrastructure Management Query System/Software (IMQS) confirmed that Alexandra is supplied through three reservoir outlets systems: 600DN pipe from Linbro Park Reservoir in the east, 650DN pipe from Ranjieslaagte Reservoir in the south, and 110DN uPVC mains from Marlboro Reservoir in the north of Alexandra.

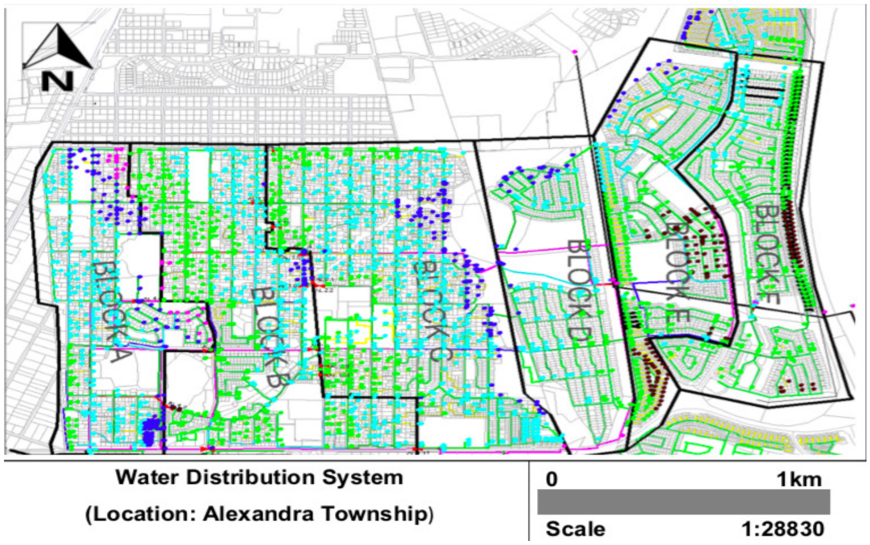

Fig. 1. Locality Map *(Source IMQS: JW 2021).*

Table 1 shows the population dynamics for Alexandra township. Alexandra accounts for over 13.5% of the entire 5.5 million residents of Johannesburg [48]. The population growth for Alexandra remains complex and is estimated to be 2.5% per annum since last verified by Statistics South Africa in 2015 [48]. According Wilson [43], the township is characterized by sizeable houses stands with 3 to 6 additional separate backyard rooms built in the original gardens each housing an additional family or renting backyard shacks. Prior to the current state, according to World Bank [44, 45], the socio-political problems such as unemployment, have resulted in Alexandra' informal settlement patterns outpacing the formal housing accommodation [44]. The informal backyard yard dwellings are estimated to rise by over 400 000 in the next decades, added Wilson [43].

Table 1: Population Alexandra Township.

Base Year- 2018				2019	2020
Dwelling Classification	**2.5 %Growth Population Category**			**2.5 % Growth**	**2.5% Growth**
Block	**Formal**	**Informal**	**Total**		**2.5%**
A	8566	58431	66997	68672	70389
B	14963	102062	117025	119951	122949
C	19371	132132	151503	155291	159173
D	6370	43440	49810	51055	52332
E	16390	3281	19671	20163	20667
F	19108	3825	22933	23506	24094
Hostels (Block B)	11262		11262	11544	11832
Flats (Block B)	2815		2815	2885	2958
RCA Flats (Block D)	1126		1126	1154	1183
Informal Dwellers	11000		11000	11275	11557
Sub-Total			**454142**	**465496**	**477133**

Source: City of Johannesburg: Region E

III. MATERIALS AND METHODOLOGY

Fig. 2 and Table 2 shows the 6 hydraulic data logging and simulation process points used to measure flows and pressure. Data recording process was done using ultra-sonic flow loggers for a period of 7 days of uninterrupted flows. The average zonal pressure (AZP) at the 6 critical bulk feeding points were monitored using the Supervisory Control and Data Acquisition (SCADA), the Water Distribution and System Optimization (WADISO) and Infrastructure Monitoring Query System (IMSQ). The existing hydraulic model was verified for each district metered area using the data provided by Johannesburg Water' SCADA and its results were compared with the existing hydraulic pressures and flows logged at each DMA.

IV. DATA SAMPLING

To establish consumption pattern and background leakage trends, the following data sampling methods were follows: • In Block A-E, at least 110 properties were randomly selected and inspected for plumbing defects that might likely contribute to water losses. Of the same sampled 110 properties, only 10 metering devices were verified and found to be functional, and were therefore used to measure daily consumptions.

• In Block F, 126 properties were also randomly selected as those of Blocks A-E. All sampled properties had proper metering devices, and consumption was manually recorded.

Sampling of information on all customer metering devices was manually conducted by Johannesburg Water' meter reading personnel. Equation 1 according to Makaya and Hensel [15] was used to determine sample size

$$n = \frac{N}{[(1+Ne^2)]} \quad (1)$$

where, n is the sample size, N is the total number of households; and e is the level of precision.

For this research, at a level of precision of 7± 2%, customer metering devices were manually inspected and readings were recorded each day for a period of 7 days. This level of precision was borrowed from Makaya and Hensel [15] in their study for customer meter consumption assessment.

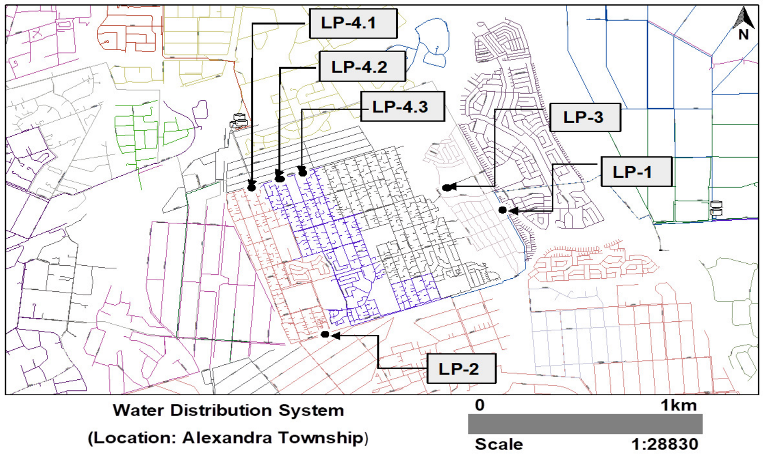

Fig. 2. Bulk Flow and Pressure Logging Points for Alexandra Township

Table 2: Flow Logging Points and Locations.

Logging Point	Latitude	Longitude	Pipe Diameter (mm)	Material Type
LP-1	26° 6'3.44"S	28° 6'41.64"E	600DN	Steel
LP-2	26° 7'20.57"S	28° 5'52.65"E	675DN	Steel
LP-3	26° 5'56.09"S	28° 7'24.59"E	600DN	Steel
LP4.1	26° 6'1.49"S	28° 5'17.58"E	110DN	uPVC
LP4.2	26° 5'56.09"S	28° 7'24.59"E	110DN	uPVC
LP4.3	26° 5'55.24"S	28° 5'38.39"E	110DN	uPVC

V. MATHEMATICAL FORMULATION

A. Conservation of Mass and Energy

The mathematical formulation adopted in this study was premised from the concept of conservation of mass and energy. When applying the theory of hydrodynamics in consideration of fluid as an incompressible fluid, scientific research has proven that the principle of conservation of energy and mass for frictionless laminar flow implies that in closed conduit, the relationship between speed and pressure has a direct influence on water leakage [25-26, 35-38,42]. Therefore, in closed conduit, pressure expresses the amount of force due to head difference between two points required to push a specific constant density of water at a particular rate of flow [8,10,13,14] The methodology followed in this study integrated the above parameters for total mass and energy into continuity equation as per Bernoulli's theory of hydrodynamics. The mathematical expressions are therefore presented in equation (2) – (8) as adopted from Serway and Jewett [28].

$$M_g(y_f - y_i) + \frac{1}{2}mV_f^2 + mgy_i = W = F.\ \Delta\mathbf{x} \quad (2)$$

$$\frac{1}{2}mV_f^2 + mgy_f = \left(\frac{1}{2}mV_i^2 + mgy_i\right) + F.\ \Delta\mathbf{x} \quad (3)$$

$$mgy_f + \frac{1}{2}mV_f^2 - \left(mgy_f + \frac{1}{2}mV_f^2\frac{1}{2}mV_f^2\right) = E_f - E_i = W = F \cdot \Delta x \quad (4)$$

Where *m* is the mass, *v* is the speed of flow; *y* is the height from the ground; *g* is the gravitational force, *f* is the friction, E kinetic energy $(K = \frac{1}{2}mV^2)$, F is the constant force due to pressure head, W, the work done by conservative forces like gravity.

The expression of equations (2) to (4) can be also expressed as follows:

$$\Delta U = (mgy_2 + U_{gray}) - (mgy_1 + U_{gray}) = mgy_2 - mgy_1 \quad (5)$$

Where U_{gray} is the expression of potential gravitational energy. The change in mechanical energy of equation (7) due to total work done is expressed as; $W = \Delta K + \Delta U$

dividing each term by the portion volume *V* and recalling that the density $\rho = \frac{m}{V}$ this expression reduces to;

$$mgy_f + \frac{1}{2}mV_f^2 = \left(mgy_f + \frac{1}{2}mV_f^2\frac{1}{2}mV_f^2\right) \quad (6)$$

We assume here that the density at the two points is the same. Therefore, density is denoted by ρ. For an incompressible and frictionless fluid, the combination of pressure and the sum of kinetic and potential energy densities is constant not only over time, but also along a streamline as shown in equation (7).

$$(P_1 - P_2) = \frac{1}{2}\rho V_2^2 - \frac{1}{2}\rho V_1^2 + \rho g y_2 - \rho g y_1 \quad (7)$$

$$P_1 + \frac{1}{2}\rho V^2 + \rho g y = \text{Costant} \quad (8)$$

Therefore, considering head loss, friction and pressure within a closed conduit, the effect of these factors in terms of water loss can be modeled using equation (9).

$$Q = \rho + \frac{1}{2}\rho V^2 + \rho g y \quad (9)$$

where Q is the volumetric flow rate (discharge); ρ is the density, V is speed of flow (velocity), g is the gravitational constant; and y is the height from the ground. Conservation of energy and mass are crucial to consider when analyzing minimum night flows in water distribution system [10,11,36,37]. It is for this reason that integrating this mathematical formulation was critical for this research.

B. Bulk Flow Logging Formulation

Pressure and flow simulation were implemented at each logging point (LP) supplying a specific district metered area (DMA) for a period of seven days. The derived and adopted mathematical equations for this study are presented below.

$$LP_1(Average) = \sum_{i=1}^{n}\left(\frac{\text{(Flow in l/s X 24hrs)}}{1000}\right) \text{x 7 days: } (kl) \quad (10)$$

$$Total\ Ave\ Flow(LP_1{:}\,LP_7) = \sum_{i=1}^{n}(LP_1d_1{+}LP_2d_1{+}\ldots..LP_7d_7) : (kl) \quad (11)$$

$$SIV = AADD{:}\sum_{i=1}^{n}(LP_1d_1{+}LP_2d_1{+}\ldots..LP_7d_7)\ x\ 365\ days{:}\,(kl/year) \quad (12)$$

Where: LP is the Logging Point Position (e.g. 1, 2, 3), n is the Sample number or position (e.g. 1, 2 or 3), i is the index of summation used to generate the first term in the series and SIV is total measured system flows (kl/day/year)

C. Minimum Night Flow Formulation

The methodology considered in this research for calculating normal domestic night use was based on the SANFLOW model, which states that minimum night flow is the consumption measured between 12 AM and 4 AM in any district metered area [16, 20, 41]. As a default consideration, in the SANFLOW model, it is assumed that 6% of the population of a supply zone are active per hour, and that, typical water use is 10 l/capita/hour [19, 20, 32, 37]. In practice, the mathematical formulation is therefore given as follows [19, 20, 30, 37, 38]

$$\text{QL (tMNF)} = \text{QDMA (tMNF)} - \text{Legitimate Night} - \text{Time Uses} \quad (13)$$

$$\text{NF} = \text{Measured MNF} - \text{EMNF} \quad (14)$$

Because in this study, flows were logged, the derived and adopted mathematical equations to compute minimum night flows were done as follows:

$$MNF_{DMA_1} = \sum_{t=i}^{n}(Measured_{MNF}) - \left\{(Measured_{MNF})\ X\ (DMA_{Pop}\ X \frac{6}{100}\%\right\} \quad (15)$$

$$tMNF_{DM1-6} = \sum_{t=i}^{n} MNF_{DMA_1}{:}\,MNF_{DMA_2}\ \ldots\ldots\ldots\ldots.MNF_{DMA_6}\ (kl) \quad (16)$$

Where: EMNF is estimated minimum night flow in (kl/day/year), Q_{DMA} is the logged bulk flow for districted metered area (kl/day/year), NF is total night flow using SANFLOW method, t is the period index measure between 12 AM and 12 AM, the $Measured\ Flow_{MNF}$ is the total average flow per logging point, DMA_{Pop} is the population size in the district metered area, n sample number or position, $tMNF$ is the total MNF for all logging points.

D. Linear Regression Method

The minimum night flow expressed as a percentage of system input volume (SIV) or percentage of system input volume (SIV) for a logged district metered area was used to analyze the regression linear outcome. According to Ncube [24] and Wegelin [42] linear regression method can be used as a primary rough guide to assess the level of leakage in an area, where a rigorous minimum night flow analysis procedure is not possible. To achieve the linear regression analysis of minimum night flow versus average flow, as adopted from Wegelin [42], equations below were used.

$$Y = mx + b \quad (17)$$

$$\text{\% Reduction in MNF} = m \text{ x } P_{Reduction}\ \text{(m)} + b \quad (18)$$

Where m is the coefficient value linear regression R^2, b is average constant value of minimum night flow (l/s), $P_{Reduction}$ is the hydraulic system pressure (m)

VI. RESULTS AND DISCUSSION

A. Bulk Flow Results

Table 3 present the outcome of the conducted flow data logging. As seen in the Table 3, the flow characteristics show the projected maximum flow of 30 488 090 m^3/year, average flow of 26 270 560 m^3/year and minimum night flow of 3 681 271 m^3/year. The results show that the proportion of minimum night flow (MNF) against system input volume (SIV) is approximately 14.01% As per night flow assessment model, this percentage preliminary suggests a high-water loss trend between 12 AM and 4 AM. Specially, when compared with the recommended 6% MNF losses according to McKenzie [20], the recorded losses are 15 times above the norm. The researchers thereby draw inferences that the physical losses during night times can be attributed to domestic background leakages.

Table 3: Measured Flow Characteristics (LP-1 to LP 4.3).

Description	Maximum flow (m^3)	Average flow (m^3)	Minimum night flow (m^3)
Average daily demand (m^3/day)	83 529	71 974	64 378
Peak weakly demand (m^3/week)	584 703	503 819	450 649
Average monthly demand (m^3/month)	2 589 399	2 231 198	1 995 729
System Input Volume (m^3/year)	**30 488 090**	**26 270 560**	**3 681 271**

Fig. 3 indicates results consolidated flow trend. It is evident from figure 3 that higher minimum night flows exhibited by LP-2, LP-3 and LP-4.3 are above 150 l/s. This further justify the inferences drawn by researchers that water loss pattern on the background domestic level is possible. Further findings are that the minimum night flow show a combined regression linear value (R^2) of 0.096. The linear regression analysis shows that the minimum night flow at a rate of 196.39 l/s is exhibited by the 6 logging points between 12 AM and 4 AM. The linear regression equation is given as follows: y = -20.63x + 196.39. Further inferences drawn from the linear regression equation is the pressure constant reduction value of -20.63x. The pressure reduction value preliminary suggests that, to reduce night time flows; pressure must be reduced by a factor of 20.63. The equation derived from this analysis is given below:

% Reduction AADD:(SIV)=-20.63 x Pressure Reduction (*m*) + 196.39 (19)

It can be summarily deduced that, reduction of pressure would have a direct linear proportional effect in the reduction of average flows and minimum night flow. The results finding of drawing inferences on the effect of pressure to water losses was previously studied and scientifically proven in other literature studies [9, 23, 24, 42].

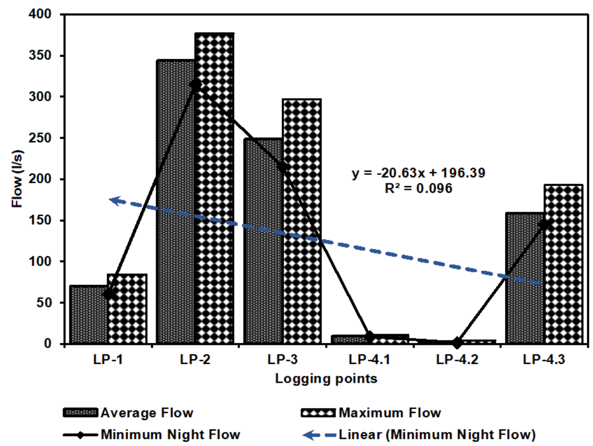

Fig. 3. Bulk Flow Loggings for Alexandra Township.

B. Customer Consumption and Leakage Analysis

Background Leakage Assessment for Block A-E. Fig. 4 presents the results for the visual condition assessment of 110 randomly sampled properties. The results show a combined 1160 leaking feature. Further to this, the results show that items such as leaking taps, meters, cisterns, stolen taps and wash basins were the most leaking items in most properties. Of critical important is that, blocks A-E represents the denser part of Alexandra with dominant backyard dwellers. As per Table 1, the estimated population for blocks A–E is above 437 000, and this equates to 36 400 households at a ratio of extra 10–15 dwellers per yard. In addition, during visual condition assessment, some residents confirmed that at least 12-15 people are housed from the backyards dwelling or rental arrangements. The findings further justify the existing socio-economic problems in the area. The researchers thereby draw preliminary inferences that the minimum night flow results of 14.01 % is somewhat justifiable.

Customer Consumption Trend for Block A–E: Fig. 5 shows the consumption trends on customers for the 110 properties sampled in blocks A-E. The results show that most properties under Block A-E consumes more than 400 kl of water annually. The results further show a linear increment value (R^2) of 0.0088 at a minimum constant consumption rate of 427.57 kl/year per property. The linear trend is therefore provided by equation y = 1.8961x + 427.57. Further findings to note is a consumption factor of 1.8961 on the linear equation. The factor of 1.8961 reveals that each property consumptions doubles every year circle. Despite the small sample size of 10 metering devices out of 110 properties, there is a meaningful linear trend that helps draw inferences in relations to background leaking items in Fig. 4 above. Equation 20 scientifically present the above analysis.

% Reduction AADD:(SIV)=1.8961 x Pressure Reduction (*m*) + 427.57 (20)

The researchers also draw further preliminary inferences that an increase or decrease in pressure would proportional consumptions pattern due to background leakages. This summation is agreed upon by Berardi *et al.*, [13], who collectively concluded that water consumption pattern, loss reduction, leakages and reduction of minimum night flow in distribution systems are directly proportional to hydraulic pressure.

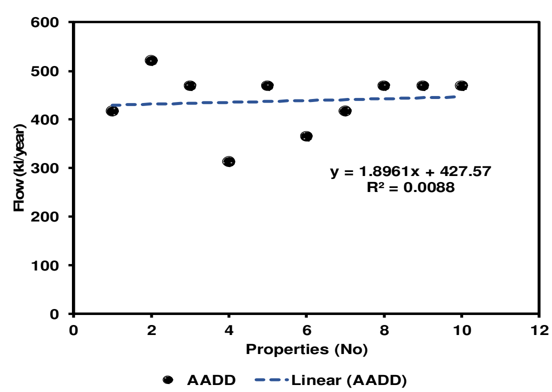

Fig. 5. Sample A: Household Average Consumption Trends for Blocks A–E.

Customer Consumption Trend for Block F: Fig. 6 shows the consumption analysis for Block F. A per table 1, block F represents the less dense part of the township and has an estimated population of around 23 500. The settlement pattern also constitutes rental arrangements from the backyard dwellers as well as mild populated formalized municipal houses. The results show that 85 % of the properties recorded annual consumption below 300 kl. Further results show that 13 % of the properties consumed between 400 to 900 kl annually, while a further 2 % between 1200 and 1400 kl annually. The researchers identified the higher consumption properties of above 1000 kl per year were either municipal properties or rental flats with metering devices between 100 to 150mm. Despite the small sample size of 126 households, there is meaningful upwards linear trend which suggest the viability of the findings. Also, to note the linear regression value (R^2) value of 2E-05 or (2×10^{-5}) given by equation $y = 0.0347x + 301.25$. Although the linear regression value looks insignificant, the annual average constant consumption per property is 301.25 kl.

% Reduction AADD:(SIV)=0.0347 × Pressure Reduction (m) + 301.25 (21)

The researchers thereby draw inferences that average consumptions for properties in Block F presents a less worrying water loss problem for the water entity. It is also the researcher' preliminary assertion that the static pressure does in the DMA does not negatively affect water consumption.

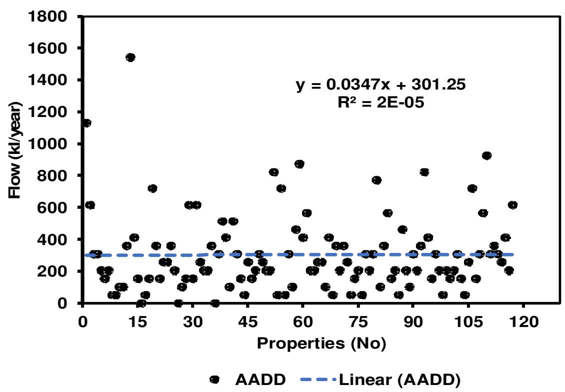

Fig. 6. Sample B: Household Average Consumption Trends for Block F.

VII. CONCLUSION

The purpose of this study was to analyze the significant impact of domestic consumption and domestic background leakage trends. The study results agree with the scientific principle of conservation of mass and energy as well as the concept of water conservation, that to further improve these two concepts, there should be mechanisms through which water losses can be traced, assessed, understood and minimized. From the analysis, the results show that the denser part of Alexandra exhibits more consumption at a linear average value of 427.57 kl per year, while the formalized area show a consumption average of 301.25 kl per year. The results show that each property consumption is at least 364.41 kl per year. The results also showed that the comprehensive minimum night flow of 196 l/s equates to a projected 14.01 % of the total system input volume per year. Through the findings, the authors further draw inferences on the linear regression analysis and suggested that reduction in static pressure would proportionally reduce water losses. The direct and relationship between pressure and water leakage has long been studied and scientifically proven by other researchers. The results of this study corelates well with other similar research findings conducted in other areas around the world, where combination of hydraulic flow data, minimum night flow and regression analysis methodologies were implemented and used to assess water losses. Specifically, it can therefore be concluded that, the study findings are essential to persuade various water managers, policy makers and strategic decision makers in the water utility to invest more resources towards reduction of water losses. Besides attending to physical losses, water utilities should integrate hydraulic modelling that aims to reduce domestic background leakages during night times. Finally, the authors of this paper finally recommend a need for an integrated metrics, that can adequately portray the complexity of socio-technical approaches required to curb water losses in developing countries. This approach will somewhat guarantee sustainable water provision to customers while improving conservation of this finite resource

VIII. FUTURE SCOPE

The current study will be useful to policymakers in the water sector industries in the developed and developing countries such as governments and research institutions to understand the scientific and practical approach in the analysis of domestic consumption and background leakage trends in socio-economic areas.

This study can further contribute to the future water leakage mitigation policies and service delivery approaches by water managers in some parts of the world.

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CONFLICT OF INTERESTS

The authors hereby confirm that there are no conflicts of interest.

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