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AN EVALUATION OF THE PRESSURE-LEAKAGE RESPONSE OF SELECTED WATER DISTRIBUTION NETWORKS IN SOUTH AFRICA

A dissertation submitted in fulfilment of:

Masters of Science in Civil Engineering

By

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ABSTRACT

Pressure is one of the major factors influencing leakage in water distribution systems. For this reason, pressure management has become standard practice in reducing leakage in water distribution networks around the world. A range of N1 values have been published following studies of the impact of pressure management. Further studies have contributed towards the development of leakage parameters which represent physical properties of the pressure management system. This study aims to add to, and improve, the information on leakage parameters and their relationships.

This study will seek to add to previously published data on the impact of pressure on leakage in field studies and determine the respective leakage parameters and identify relationships with respect to the latest findings on pressure and leakage behaviour. Significant research and investigations have been done at laboratory scale however theoretical developments have not been applied on field studies, and hence there is a lack of reports published in peer reviewed journals.

The principal aims of this dissertation were to consolidate information from pressure management zones collected around South Africa and the analysis of results using a conventional methodology as well as alternative methodologies that used different pressure and flow inputs that represented the extreme range of pressure and flow. The relationships between the calculated leakage parameters were then studied and where leakage parameters were determined to be not physically possible, these were studied for errors.

The dissertation is the result of research collected and conducted since February 2015 on 141 pressure management zones (PMZs) across South Africa. The data, collected from the field, consists of the zone characteristics, measurement data such as flow and pressure logging, and consumption data, including night time usage. From the 141 PMZs, only 107 were considered for this study due to exclusion of 34 PMZs for various reasons.

From the analysed data, the significant results were that when using the conventional method (AZP as pressure input and Q_{RL} as flow input), 12% of head-area slope ($\overline{m}$) values and 39% of initial leak area ($\overline{A_0}$) values were negative. The calculated FAVAD N1 values ranged between -0.34 and 2,20 (outliers were determined as N1=-31,88 and N1=6,77 but these are not impossible and can be explained through physical issues with the pressure management zone). The relationship between the calculated Leakage Exponent (N1) and the Leakage Number (L_N) were determined to be consistent with theoretical studies. The Infrastructure Leakage Index (ILI) was determined for each PMZ for before and after pressure management and it was found that although leakage reduces with pressure management, the ILI is not always reduced In fact, the ILI increased after pressure management for 39% of the PMZs.

The relationships for the various leakage parameters were studied and illustrated. The only notable relationships revealed was that when N1 < 0,5 then $\overline{m} < 0$ and when N1 > 1,5 then $\overline{A_0} < 0$. Whilst this can be explained mathematically, a negative $\overline{m}$ and $\overline{A_0}$ are not physically possible. Therefore possible errors such as assumption errors and data errors were explored. For $\overline{m}$, it was determined that four PMZs could not be explained from the correction of possible assumption or data errors. For $\overline{A_0}$, it was determined that 11 PMZs could not be explained from the correction of possible assumption or data errors however the errors may be the result the presence of leaking/open boundary valves.

The research undertaken is the first systematic study that is published where the parameters are explored to this extent in this detail, and using such a range of the latest conventional and the latest leakage theory. The result is that various pressure management zones can be analysed using standardised methodologies and calculations and these water distribution systems of different locations, sizes and characteristics can be compared and scrutinised. Furthermore, there are significant benefits of using the modified orifice equation which include determination of errors in assumptions or data collection or identifying the possibility of an open/leaking boundary valve. Finally, N1 values that fall outside of the typical range can often be explained by assessing the physical properties of the leakage parameters calculated from the modified orifice equation.

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List of Acronyms, Abbreviations and Symbols

$\overline{A_0}$	Leak Area
ANN	Artificial Neural Networks
AWWA	American Water Works Association
AZP	Average Zone Pressure
BABE	Burst and Background Estimate
C	Leakage Coefficient
CARL	Current Annual Real Losses
CoCT	City of Cape Town
CP	Critial Point
DEA	Data Envelopment Analysis
DMA	District Metered Area
DMS	District Metered System
DWA	Department of Water Affairs
FAVAD	Fixed Area Variable Area Discharge
GIS	Geographical Information System
ILI	Infrastructure Leakage Index
IWA	International Water Association
L_N	Leakage Number
$\overline{m}$	Head Area Slope
MNF	Minimum Night Flow
N1	Leakage Exponent
NRW	Non-Revenue Water
PIs	Performance Indicators
PMZ	Pressure Management Zone
PRV	Pressure Reducing Valve
SABS	South African Bureau of Standards
SIV	System Input Volume
SONA	State of the Nation Address
TWL	Top Water Level
UARL	Unavoidable Annual Real Losses
uPVC	Unplasticized Polyvinyl Chloride
UWDM	Urban Water Demand Management
WDM	Water Demand Management
WDS	Water Distribution System
WLTF	Water Loss Task Force

WRC	Water Research Commission
WSAA	Water Services Association of Australia
WWTP	Waste Water Treatment Plan

1. INTRODUCTION

1.1. Background

With the increasing international trend towards sustainability, economic efficiency and protection of the environment, the problem of losses from water supply systems is of major interest worldwide. Both the technical and financial aspects are receiving increasing attention, especially during water shortages or periods of rapid development.

However, particular problems and unnecessary misunderstandings arise because of differences in the definitions used by individual countries for describing and calculating losses. Also, traditional performance indicators also give conflicting impressions of true performance in controlling water losses (for example, the use of percentages).

In 1996, the Operations and Maintenance Committee of the IWA's Distribution Division set up a task force to review existing methodologies for international comparisons of water losses from water supply systems. The main objectives were:

- To prepare a recommended basic standard terminology for calculation of real and apparent losses;
- To recommend how the annual volume of real and apparent losses should be calculated from a water balance; and
- To review and recommend preferred performance indicators for international comparisons of losses.

The resulting publication "Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures" (Lambert, 2000) summarises the conclusions of the Water Losses Task Force, with particular reference to the preferred Performance Indicators for assessing operational performance in control of real losses in supply systems.

Following a study of 132 of 237 municipalities in South Africa, McKenzie determined that the level of Non-Revenue Water is 36.8% (McKenzie et al., 2012). With every year, the need to reduce the Non-Revenue Water becomes paramount in order to enable the sustainability of consumptions and water resources. It is a subject of considerable media and political debate and targets have been set by the presidency to alleviate these losses in the distribution system (McKenzie, 2012).

Pressure is one of the major factors influencing leakage in the water distribution systems (Van Zyl & Clayton, 2007). Pressure management is widely recognised as an important technique to reduce leakage in water distribution systems.

In recent years, publications on pressure and leakage relationship have been on the rise, the studies focused on a variety of areas namely, soil and leakage hydraulics, laboratory experiments on leakage and pressure relationship, leakage-pressure relationship field studies, modelling studies on leakage in water distribution systems and leakage in different pipe materials and the development of an empirical power equation to estimate the leakage exponent (N1) to name but a few.

Values of leakage exponent ranging from 0.5 to 2.79 have been reported from experiments and field studies (Al-Ghamdi, 2011). Cassa and van Zyl (2011) gave reasons as to why leakage exponents obtained from field studies were significantly higher than the theoretical values. They established that the most important reason for this behaviour is that leak areas are not fixed, but vary as a function of pressure.

The relationship between pressure and leakage in a distribution network has been established through the power equation (also referred to as the N1 equation or conventional leakage equation). The power equation denotes a factor, N1, which represents the relationship between the pressure and leakage. An alternate equation, the modified orifice equation (also referred to as the FAVAD equation), was derived from initial work done by Ledochowski (1956) and May (1994).

Understanding the relationship between pressure and leakage can assist in the development of pressure management strategies which could help water utilities, municipalities and government departments to save millions of Rands which in turn could be used to increase coverage of areas supplied with potable water or to maintain the aging infrastructure and respond to service delivery protests.

This study will seek to address the lack of published data on the impact of pressure on leakage in field studies and determine the respective leakage parameters and identify relationships with respect to the latest findings on pressure and leakage behaviour. Significant research and investigations have been done at laboratory scale however theoretical developments have not been applied on field studies, and hence there is a lack of reports published in peer reviewed journals.

1.2. Goals and Objectives

The goal of the research was to investigate and analyse pressure and leakage parameters and relationships in successfully pressure managed zones within South African distribution networks. The collected field information was analysed using common methods and put in context of latest findings on pressure and leakage behaviour. The detailed objectives of the study in order to successfully accomplish the stated goal were as follows:-

i. To identify and collect recorded field data from operational pressure management zones in South Africa;
ii. To investigate different methods (conventional methodology and eight variations of this methodology) that can be used for calculating the various parameters in pressure and leakage;

iii. To verify data and recalculate pressure and leakage parameters using a standard methodology to develop a standard data set;

iv. To analyse pressure and leakage parameters (N1, L_N, $\overline{m}$, $\overline{A_0}$, C) and their relationships.

Furthermore, the study aims to analyse the determined leakage parameters to scrutinise the results against possible reasons for when the leakage parameters fall outside of theoretical ranges. All the data will be consolidated into a database which can be used for further analysis or alternative studies/research moving forward.

1.3. Organisation/Structure of this proposal

This research proposal is divided into four channels; as detailed below.

- **Section 1** presented the background to the research topic, stated the goals of the research paper and the objectives required to accomplish the goals.
- **Section 2** presents relevant literature that supports and contributes towards the objectives on the study.
- **Section 3** outlines the methodology followed during the study in order to achieve the objectives outlined in this Section.
- **Section 4** provides and discusses the results of the study.
- **Section 5** concludes the research proposal and provides recommendations.

2. LITERATURE REVIEW

This Section summarizes the literature found relevant to the subject of water losses and pressure. It begins by analysing the difference between Apparent Losses and Real Losses and where leakage is located in the Water Balance of a Distribution System. It then considers how zones are created to restrict leakage through the introduction of pressure management and provides methodology for the determination of the Average Zone Pressure. It then details the developments in the relationship between pressure and leakage and provides the resultant pressure-leakage parameters that were developed empirically. Finally, it looks at case studies detailing results of pressure-leakage site investigations.

2.1. Water Balance

The IWA use a Water Balance to track and account for every component of water. This provides for water supplied as well as water extracted from a water supply system over a known period of time. The Water Balance is considered as standard international 'best practice' since being introduced by the IWA Water Loss Task Force in 2000 (Lambert, 2000) and is presented in Figure 2-1.

<table>
<tr><th>A</th><th>B</th><th>C</th><th>D</th><th>E</th></tr>
<tr><td rowspan="9">System Input Volume
(m³/year)</td><td rowspan="4">Authorised Consumption
(m³/year)</td><td rowspan="2">Billed Authorised Consumption
(m³/year)</td><td>Billed Metered Consumption (including water exported)</td><td rowspan="2">Revenue water
(m³/year)</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Unauthorised Consumption
(m³/year)</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-revenue water
(NRW)
(m³/year)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses
(m³/year)</td><td rowspan="2">Apparent Losses
(m³/year)</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses
(m³/year)</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflow at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer metering</td></tr>
</table>

Figure 2-1: IWA Water Balance (Lambert, 2002).

The template that has been adopted for use in South Africa was modified from the water balance originally produced by the Water Loss Task Force of the International Water Association (IWA). This water balance has been modified for South Africa's unique situation through the inclusion of Free Basic Water and the modified water balance template for reporting purposes was included in Figure 2-2.

<table>
<tr><td rowspan="7">System Input Volume

(allow for bulk errors)</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption includes free-basic-water, billed at a zero rate</td><td rowspan="2">Potential Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="5">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="3">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Under-registration</td></tr>
<tr><td>Real Losses</td><td>Leakage on Mains
Leakage and Overflows at Service Reservoirs
Leakage on Service Connections
Up to the Street/Property boundary</td></tr>
</table>

Figure 2-2: Modified IWA Water Balance for South Africa (Seago & McKenzie, 2007)

The definitions for the terms referenced in the modified Water Balance are as follows:

System Input Volume: the volume input to the water supply system from the Water Service Authority's own sources, allowing for all known errors (i.e. errors on bulk meters), as well as any water imported from the sources – also corrected for any known bulk metering errors.

Authorised Consumption: volume of metered (authorised metered) and/or unmetered (authorised unmetered) water taken by registered consumers, the water supplier and others who are implicitly authorised to do so by the water supplier, residential, commercial and industrial purposes. Authorised consumption includes Free-Basic-Water that is billed at zero rate.

Note 1: for service connections, Authorised Consumption is the volume of water passing the street/property boundary, where a customer's water meter would normally be situated; authorised consumption therefore includes real losses on customers' underground supply pipes and plumbing. Furthermore, authorised consumption is measured through the customer's water meter. If the meter is not functional or inaccurate, the water demand is estimated.

Note 2: authorised consumption may include items such as fire fighting and training, flushing of mains and sewers, street cleaning, water of municipal gardens, public fountains, building water, etc. these may be billed or unbilled, metered or unmetered, according to local practice.

Billed Authorised Consumption: is the volume of authorised consumption that is billed by the Water Services Authority (WSA) and paid for by the customer. It is equal to billed metered consumption (including Free-Basic-Water billed at zero rate) and billed unmetered consumption.

Unbilled Authorised Consumption: the volume of authorised consumption that is not billed or paid for. Equal to unbilled metered consumption and unbilled unmetered consumption.

Water Losses: the sum of the real losses and apparent losses, calculated as the difference between system input volume and authorised consumption. Water losses can be considered as a total volume for the whole system, or for partial systems such as raw water mains, transmission or distribution systems, or individual zones within a distribution system. In each case the components of the calculation would be adjusted accordingly.

Apparent Losses: consist of unauthorised consumption (theft or illegal use) plus all technical and administrative inaccuracies associated with customer metering.

Real Losses: physical water losses from the pressurized system, and overflows from service reservoirs, up to the point of measurement (or estimation) of customer consumption. The annual volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average duration of individual leaks and overflows.

Note: although physical losses after the point of customer flow measurement or assumed consumption are excluded from the assessment of real losses, this does not necessarily mean that they are not significant or worthy of attention for demand management purposes. Leakage on sections of private pipework can be substantial.

Potential Revenue Water: those components of system input volume that are billed and produce revenue (also known as billed authorised consumption). Equal to billed metered consumption (including Free-Basic-Water billed at zero rate) and billed unmetered consumption.

Note: Potential Revenue Water is measured using the consumption that is billed and therefore the potential revenue, and is not affected by actual revenue collected.

Non-Revenue Water: those components of system input which are not billed and do not produce revenue. Equal to the sum of the unbilled authorised consumption, apparent losses and real losses.

Although understanding the Water Balance is important to managing pressure and leakage, it is not imperative to this study. The important components that do form an important part of this study is the Real Losses component as these are directly affected by changes in pressure.

2.2. Real Losses (Leakage) in Water Distribution Systems

Real losses form the component of the Water Balance for which leakage and bursts are mainly attributed. Real losses are categorised into three components, namely background leakage, unreported leakage and reported leakage which are illustrated in Figure 2-3 (Kunkel & Sturm, 2011).

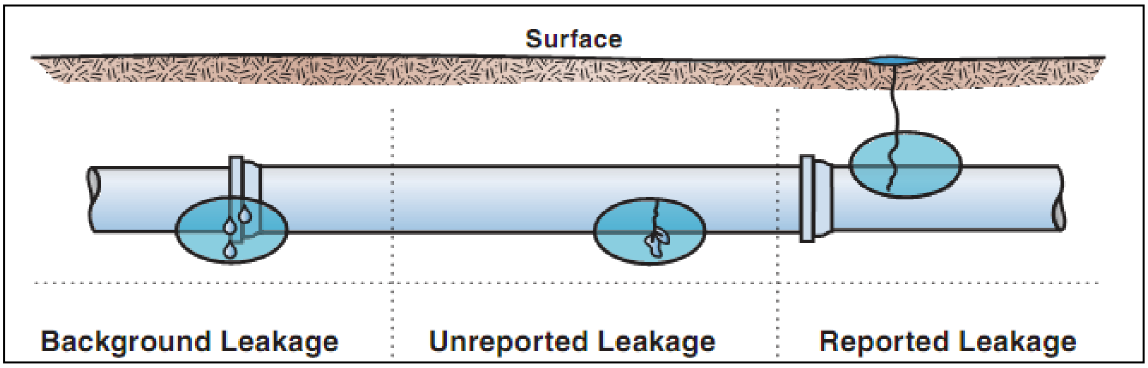

Figure 2-3: Components of leakage (Kunkel & Sturm, 2011)

Figure 2-3 presents the various categories of leakage and an example of how these leaks form. For example, background leakage occurs at pipe connections and unreported leakage can occur in small leaks that sink into the soil but don't rise to the surface. The volume of leakage in the system is dependent on a number of factors such as number of service connections, length of service mains, length of reticulation mains and system pressure.

In order to understand the distinction between the three categories as well as determine or estimate leakage, Thornton (2002) stipulated the following values which have been presented in Table 2-1.

Table 2-1: Values used to distinguish and estimate background losses, reported leaks and unreported leaks (Thornton, 2002)

Infrastructure Component	**Background (Undetectable Losses)**	**Reported Breaks or Bursts/Leaks**	**Unreported Breaks or Bursts/Leaks**
Mains	0.03 m^3/km/hr	0.3 breaks/km/year at 7.2 m^3/hour for 3 days duration	0.02 breaks/km/year at 3.6 m^3/hour for 50 days duration
Service lines, main to the kerb	0.00078 m^3/service line/hour	2.25/1000 service lines at 1.2 m^3/hour for 8 days duration	0.75/1000 service lines at 1.2 m^3/hour for 100 days duration
Underground pipes, kerb to meter (for 15 m avg. length)	0.00031 m^3/service line/hour	1.5/1000 service lines at 1.2 m^3/hour for 9 days duration	0.50/1000 service lines ,at 1.2 m^3/hour for 101 days duration
Note: All flow rates are at a reference pressure of 50m			

Table 2-1 provides estimates of the volume of water lost through the various categories of leaks/bursts. It is important to note the duration of time attributed to reported and unreported leaks as well as reference pressure (50m) for which these leakage rates were established. The pressure of a water distribution system plays a significant role in the level of leakage. From Table 2-1, it is evident that reported breaks or bursts/leaks are the most significant with regards to flow rates however they are for typically of a shorter time period. Unreported breaks or bursts/leaks can therefore become for more considerable with regards to water wastage as the durations of these bursts/leaks are significantly longer than reported bursts or leaks.

2.2.1.Minimum recommended pressure head in South Africa

Pressure is widely regarded as the main driver that affects leakage (Van Zyl and Cassa, 2014). There are other components which also have an effect on leakage and these are pipe materials, infrastructure condition, and age of infrastructure, to name a few. South Africa has no legislation stipulating the minimum pressure head in a system which leaves the topic open for debate. For each municipality, minimum pressure head is chosen based on system operation and guidelines exist on the topic and are widely accepted to be a minimum pressure head of 24m (Boutek, 1998). The history of the design criteria with regards to minimum pressure can be traced back to 1957. Jacobs and Strijdom (2009) provide a historical account of design criteria for minimum pressure head in South Africa. In 1957, the design criterion for minimum absolute pressure was 12 m for low income areas and 15 m for high income areas, by the mid 1970's the minimum pressure head design criterion had been increased to 25 m, later in the 1980's, the criterion of 24 m has been introduced and has be accepted as a guideline practicing engineers are using when designing water distribution systems.

Although these guidelines are widely accepted in terms of design, it is not uncommon to find systems with minimum pressure head in excess of 80m and maximum pressure head of 140m. In larger systems, it is more difficult to enforce these guidelines as the system is more complicated and pressures deplete over long distances due to frictional head losses. It is thus recommended that in larger systems, zones are formed to simplify system operation and monitoring of flows. These zones are called District Metered Areas (DMA's) and are discussed in more detail in the following Section.

2.3. Estimating real losses in water distribution systems through DMAs

2.3.1. What are DMAs

District Metered Areas (DMAs) are discrete systems with measured flow of all inlet supplies. Typically DMAs are defined by having an inlet, or multiple inlets, that are metered and the zone is separated from other areas by divisional valves. Farley (2010) describes DMAs as a discrete zone with a defined and permanent boundary. DMAs can principally be categorised into three different categories: single inlet DMAs, multiple inlet DMAs and cascading DMAs as shown in Figure 2-4 (Kunkel & Sturm, 2011).

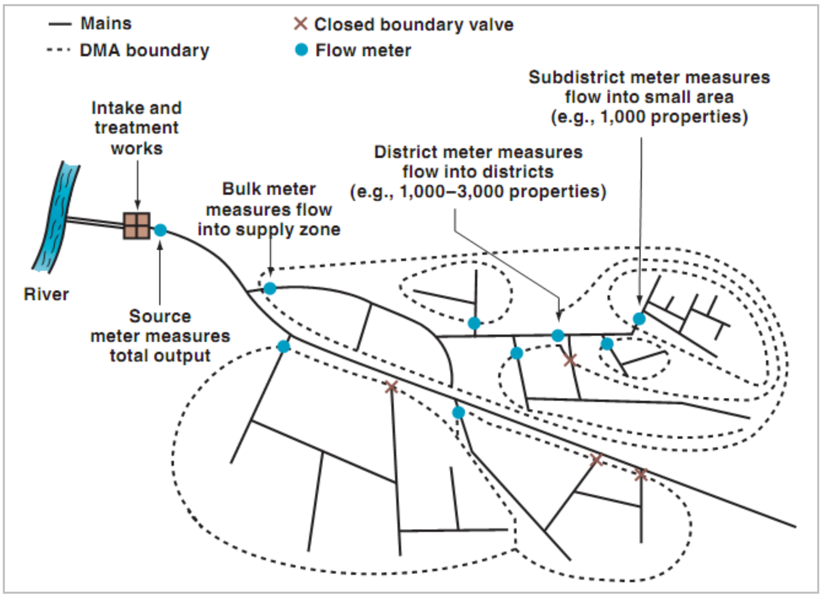

Figure 2-4: Conceptual diagram of DMA configurations (Kunkel & Sturm, 2011)

According to Farley, (2010) district metered areas (DMAs) were introduced by the UK Water Research Centre in 1982, at the time they were known as district metering systems. The concept of DMAs had since been promoted by the Water Loss Task Force (WLTF) and have been widely accepted and implemented in various parts in the world.

Water District Metering is an important methodology for Water Distribution System (WDS) management (AWWA 1999, Lambert and Hirner 2000). DMA planning is simpler for branched networks such as in rural areas and is much more complicated with looped networks that are typical of residential areas (Di Nardo & Di Natale, 2011). In South Africa, at this juncture, there was no documented method or guideline on DMA design, thus there is a need for a standard methodology which could be applicable for water distribution systems in South Africa.

Di Nardo & Di Natale, (2011) stated that the aims of designing and implementation of DMAs are:

- to simplify th**e** network water balance calculation by monitoring night flows in each district in order to detect unreported bursts and to enable leakage identification and location (using acoustic methods, step tests, etc.);
- to carry out pressure management in order to reduce hydraulic head and water leakage;
- to improve water system management with district hydraulic data continuous monitoring in order to prevent water shortages and to plan better maintenance operations.

DMA selection and design is usually the first thing done when implementing pressure management in water distribution systems however, by and large, this process is still done using a variety of methodologies, whether using a scientific approach or trial and error approach, without a standard methodology being adopted.

2.3.2.Design of DMAs

In South Africa, there was no standard, by-law or policy in place for the method or guideline for DMA design. Thus DMA design in South Africa was based on international guidelines, with these guidelines requiring modification to account for South African topography, water network designs, state of the water infrastructure, level of maintenance, skill set, etc.

Implementing DMAs effect new and permanent changes in water distribution systems such as the original topological layout of water systems and reduces network water pressure, especially during peak demands. Though this was positive in terms of water loss reduction during night flow, it could lead to insufficient supply to the customers during peak demand hours (Di Nardo & Di Natale, 2011). The design of DMAs must therefore consider various factors and the resultant effect on the system before implementation, to ensure efficient operation of the DMA and continued supply to the customer under all circumstances.

Charalambous (2005) highlights key factors for good DMA design, these include the following:

- minimum variation in ground level across the DMA,
- easily identifying boundaries that are robust,
- correctly sizing and location of water meters,
- single entry point into the DMA,
- DMA should have discrete boundaries,

- pressure optimisation to maintain standard of service to customers,
- main highways and physical feature such as streams are usually chosen to form discrete boundaries between DMAs.

2.3.3.Benefits and challenges of DMAs

The benefits of implementing DMAs include the following (Charalambous, 2005):

- Estimation of leakage in the pressure management zone (PMZ);
- Efficient leakage management through analysis of minimum night flows;
- System pressure and flow measurement;
- Increased reliability and the water distribution system management is improved;
- Creates a platform for accurate water balances to be calculated as actual supply volumes are measured;
- Continuous monitoring of system characteristics allows local operations personnel to maintain the DMA more effectively.

The challenges associated to implementing DMAs include the following:

- Implementation costs;
- Affecting consumers with regards to changing system characteristics and thus possibly altering supplied pressure head to the consumer. The reduction of pressure head may be in the interest of increased efficiency of the DMA however the consumer may not appreciate reduced pressure, even if it meets the minimum requirements for household instruments.

2.3.4.DMA Design Models

In trying to do away with manually selection of DMA, scientific models have been developed to deal with this simple problem. Table 2-2 below summarises models developed as discussed by Diao et al., (2013).

Table 2-2: Models and methods developed for DMA selection and partitioning (Diao et al., 2013)

Model and Theory	Application	Source
Graph theory–based algorithms	WDS sectorisation into DMAs	Tzatchkov et al. (2006) and Nardo (2010) in Diao et al., (2013)
DMA-partitioning methods based on machine learning, with both graphical and vector information considered	WDS sectorisation into DMAs	Izquierdo et al. (2009) and Herrera et al. (2010) in Diao et al., (2013)

Topological clustering tools	WDS analysis	Deuerlein (2008) and Perelman and Ostfeld (2011) in Diao et al., (2013)
DMA generation	Automated creation of DMA	Diao et al., (2013)
Heuristic design support methodology	Definition of a permanent water district metering of a water supply network compatible with system hydraulic performances	(Di Nardo & Di Natale, 2011)

As shown in the Table 2-2 there is a growing awareness on the challenges of DMA selection and water distribution system sectorisation and their implications. In all the models discussed above, there are some shortfalls as they don't consider certain things, for example water quality. It is evident that there is still a need for further development of models for DMAs selection. The application of these models has not been reported except where applied in a form of case studies, which has hindered the development and adoption of a single standard methodology.

Pressure-leakage relationship studies were performed in a manageable manner in DMAs and make it possible to estimate a variety of parameters. Understanding the fundamental principles and theories that govern leakage in relation to pressure are discussed in the next section.

2.4. Assessing Leakage Reduction from Pressure Management and Calculation of Average Zone Pressure in a System

It is widely accepted that pressure has a direct relationship with leakage (May, 1994). In order to establish a relationship between pressure and leakage, the average zone pressure must be determined. Pressure is a parameter that is variable in both space (relation to elevation) and time (head losses are related to flow rate, a function of demand in the system). It was thus necessary to define what was meant by the concept Average Zone Pressure and recognise different ways to calculate it (Renaud et al., 2012).

2.4.1. Water Services Association of Australia (WSAA) approach

The WSAA developed a guide for estimating the average zone pressure (WSAA, 2009). This method involved the methodical identification of an AZP which was made up of a 4-step approach. The approach was as follows:

- Step 1 – Calculation of the weighted average elevation of each zone
- Step 2 – Identification of a hydrant AZP representative of each zone
- Step 3 – Evaluate the pressure at the AZP for each zone

- Step 4 – Calculate the average pressure of the network from these zones

As a result of studies on this approach, three different methods were adapted from the WSAA approach to assess the pressure characterising a service zone. The methods were the topographic method, hydraulic model method and the measurement method. The results of each method revealed that each method had advantages and disadvantages and none of them could be discounted. A summary of the three methods was presented by Renaud et al. (2012) is presented in Table 2-3.

Table 2-3 - Comparison of the three pressure evaluation methods (Renaud et al., 2012)

	"Topographic" method	**"Hydraulic model" method**	**"Measurement" method**
Basic principles	The mean pressure is assumed to be similar to the static pressure which can be estimated from the elevation of the system components.	The mean pressure is calculated from a hydraulic model assumed to be reliable for mean daily demand.	The mean pressure is deduced from measurements taken at a point that is assumed to be representative of the whole DMA.
Necessary Information	Plan of the network with background topography (contour lines).	Existence of a calibrated hydraulic model with recent reliable demand information.	Topographic information and a measurement point with ground elevation known precisely.
Application scope	Well adapted to distribution DMAs. To be applied with caution in other cases.	Applicable for all types of DMA as long as the operation conditions are well known.	Only applicable to DMAs where all consumers are subjected to the same pressure regime.
Advantages	Easy to implement even for networks for which knowledge is limited.	Applicable for all types of DMA. Easy to simulate different configurations.	Quite simple to implement and allows adaption to changes in operation or demand.
Disadvantages	Not suitable for complicated networks.	Does not permit a simple and realistic adaption to the	Not suitable when there are many pressure regimes and

		possible changes in demand,	requires installation of measuring equipment.
Precautions	Besides simple distribution networks, precautions must be taken and corrections implemented.	The quality of the model is paramount; it is useful to test for coherence with other methods.	The elevation of the measurement point must be known precisely; the representativeness of the point should be checked.

2.4.2. Weighted Average System Pressure approach

Lambert et al. (2013) created a guideline and described the Average Pressure (P_{AV}) for a whole system is the weighted average pressure of all the Zones in that system. The method for weighting the system is based on the IWA Water Loss Task Force's conclusions that in most systems, if the density of connections is greater or equal to 20km, then the majority of the real losses would occur on the service connections, thus the preferred weighting factor is service connections. Alternatively, if the density of connections is less than 20 per km, most of the real losses would be expected on the mains and thus the preferred weighting factor would be mains length in km's (Lambert et al., 2013). The weighted average system pressure is a 6-step approach as follows:

- Always define an Average Zone Point (AZP) for each zone;
- Use a Systematic and Auditable approach for each zone;
- Calculate a Weighted Average Ground Level for each zone;
- Select a hydrant to represent the Average Zone Point;
- Obtain AZP pressures by measurement or indirect assessment;
- Record calculations and methods used to define AZP.

Lambert et al. (2013) further explained that the accurate and systematic approach to determining the Average Zone Pressure is fundamental to calculating the precise relationship between leakage and pressure.

2.5. Leakage-pressure relationship of a single leak

May (1994) first described the leakage-pressure relationship which was simplified to the N1 Power Law approximation (Power equation). Whilst May described this relationship, no conclusive proof was provided to corroborate this theory. The following sections use the work developed by May as the basis of their studies to develop further research and equations.

2.5.1. Orifice flow equation

A leak in a pipe happens through a hole or an opening, this opening resembles an orifice. A classical definition of an orifice can found in Brater et al., (1996, pp. 4.1), they define an orifice as "an opening with closed perimeter and of regular form through which water flows". Furthermore, the stream of water flowing through an orifice is termed the jet, and the depth of water producing discharge is the head. An orifice with a sharp upstream edge is called a sharp-edged orifice. If the jet discharges into the air, the orifice is said to have free discharge. If the jet discharges under water, the orifice is called a submerged orifice.

2.5.2. Small Orifice

Featherstone and Nalluri, (1995), classified a small orifice as an opening (a diameter, d) through which water flows caused by the head, h, where h is greater than d (see Fig. 2-5). In water distribution systems, small leak openings (small orifice) are common more especially on background leaks as discussed in Section 2.2 above.

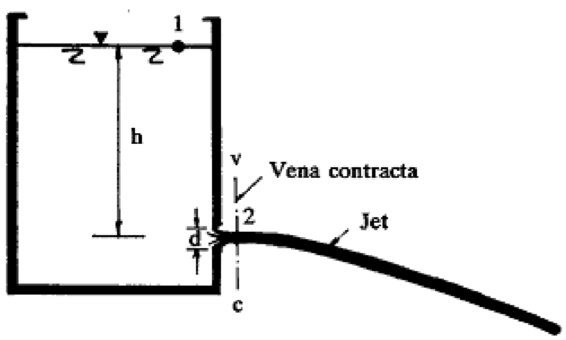

Figure 2-5: Small orifice (h >> d) adapted from Featherstone and Nalluri, (1995)

Applying Bernoulli's equation on the above diagram:

$$\mathrm{h} + \frac{\mathrm{p}_1}{\rho g} + \frac{{v_1}^2}{2g} = 0 + \frac{\mathrm{p}_2}{\rho g} + \frac{{v_2}^2}{2g} + losses \qquad 2\text{-}1$$

Where h = elevation

p = pressure

v = velocity

and ρ = density of the liquid and g = gravity

with both $p_1 = p_2$ opened to the atmosphere and assuming $v_1 \approx 0$ and ignoring losses we get

$$\frac{{v_2}^2}{2g} = h$$

$\therefore\ v_2 = \sqrt{2gh}$ where v_2 = velocity (m/s) 2-2

g = acceleration due to gravity (m/s^2)

h = pressure head (m)

Equation 2-2 is called Torricelli's theorem and the velocity is called theoretical velocity.
The actual velocity = $C_v\sqrt{2gh}$ where C_v is the coefficient of velocity.

The coefficient of velocity is expressed by Featherstone and Nalluri, (1995, pg. 62) in Equation 2-3 as:

$$C_v = \frac{actual\ velocity}{theoretical\ velocity} \qquad \text{2-3}$$

The jet is less than the area of the orifice due to contraction (see Fig. 2-6) and the corresponding coefficient of contraction is defined as (Featherstone & Nalluri, 1995):

$$C_c = \frac{area\ of\ jet}{area\ of\ orifice} \qquad \text{2-4}$$

A vena contracta is a point in a jet where the diameter of the jet is the least, and fluid velocity is at its maximum (Falkovich, 2011). Brater et al. (1996) expressed the area at the vena contracta where a_1 is related to the area of an orifice a as follow:

$a_1 = C_c a$ where a_1 = jet area (m^2) 2-5

C_c = coefficient of contraction

a = orifice area (m^2)

The contraction shown is caused by the fact that those elements of the fluid with approach from the side of the orifice have transverse velocity components directed toward the centre of the orifice (Brater et al., 1996). Figure 2-6 (Leung, 2004), provides a representation of the vena contracta with reference to the orifice.

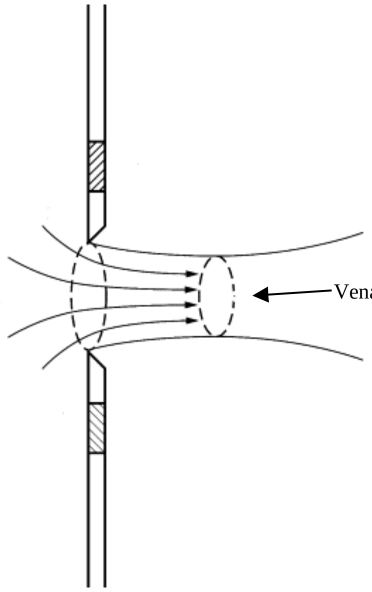

Figure 2-6: Vena contracta represented for a sharp edged orifice adapted from Leung (2004)

Therefore the nearness of boundaries, such as orifices in pipes, would tend to reduce the amount of contraction and increase the coefficient of contraction C_c. Rounding the inner edge of the orifice reduces contraction, and the contraction can be eliminated completely by shaping the orifice as shown in Figure 2-7 (Brater et al., 1996).

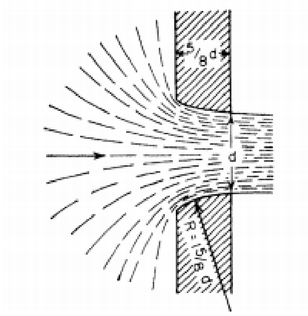

Figure 2-7: Bell-mouthed orifice with rounded upstream edge (Brater et al., 1996)

2.5.3.Discharge Coefficient

Featherstone and Nalluri, (1995) explains that at a section very close to the orifice, known as the vena-contracta, the velocity is normal to the cross-section of the jet and hence the discharge can be written as: Equation 2-3: Coefficient of discharge

$$Q = \text{area of jet} \times \text{velocity of jet (at vena-contracta)}$$

$$Q = C_c\, a \times C_v \sqrt{2gh}$$

$$Q = C_d\, a \sqrt{2gh} \qquad 2\text{-}6$$

where C_d is called the coefficient of discharge and defined as:

$$C_d = \frac{actual\ discharge}{theoretical\ discharge}$$

$$C_d = C_c C_v \qquad 2\text{-}7$$

In principle the product of the coefficient of contraction and coefficient of velocity is a coefficient of discharge. Some typical orifices and mouthpieces (short pipe lenghts attached to orifice) and their coefficients, C_c, C_v and C_d are shown in Fig. 2-8 below (Schwaller and van Zyl, 2014).

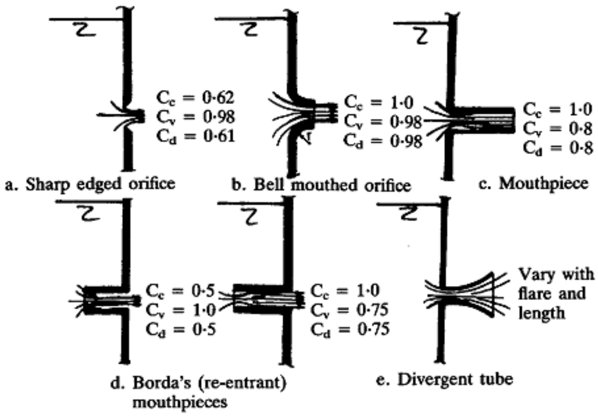

Figure 2-8: Hydraulic coefficients for some typical orifices and mouthpieces adapted from (Featherstone & Nalluri, 1995)

Brater et al., (1996) reported different experiments which showed that values of C_d decreased with increasing pressure and decreasing area. As reported above, C_d also increased when the contraction was suppressed at some points of the orifice perimeter. Furthermore they were able to show that the coefficient C_d varies with the pressure head (see Fig. 2-9).

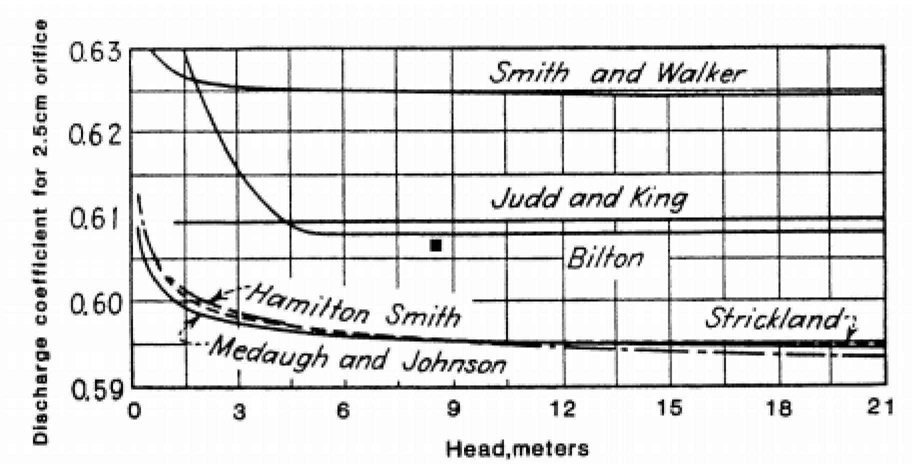

Figure 2-9: Orifice coefficients (Brater et al., 1996)

Since the velocity of the flow through the orifice depends on the pressure head and the orifice diameter, C_d can be determined as a function of the Reynolds number (Re) (Schwaller and van Zyl, 2014):

$$\mathrm{R_e} = \frac{d\sqrt{gh}}{\upsilon} \quad \text{where} \quad \begin{array}{ll} \mathrm{R_e} & = \text{Reynolds number (-)} \\ d & = \text{orifice's hydraulic diameter (m)} \\ \upsilon & = \text{kinematic viscosity due to gravity (m/s}^2\text{)} \\ h & = \text{pressure head (m)} \end{array} \qquad 2\text{-}8$$

The data shown in Brater et al., (1996) demonstrate how C_d increased 'linearly' (with reference to a log scale) with the Reynolds number in the laminar area from a value of 0 to approximately 0,4, however it should be noted that the diagram shown is Figure 2-10 is in log scale, therefore the observed relationship between C_d and R_e may not be necessarily a perfect linear relationship. For a flow in the transitional area, C_d took uniform values from 0,25 to 0,8 (see Fig. 2-10). For a flow turbulent zone where a Reynolds number is 10 000, the flow and the discharge coefficient approximated values of 0,66 to 0,6.

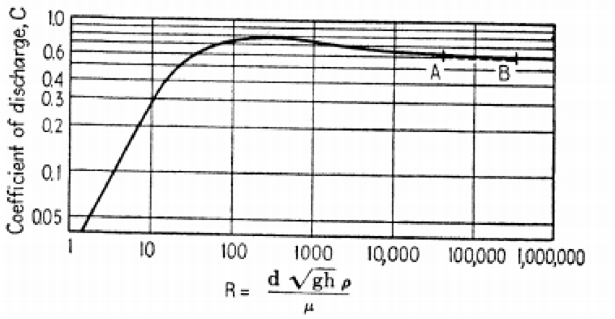

Figure 2-10: Orifice coefficients and Reynolds number (Brater et al., 1996)

Lambert (2001) also showed that the assumption that C_d is constant is not necessarily valid; for individual leaks, C_d can change depending upon whether the flow is laminar, transitional or turbulent. This depends upon the Reynolds number ($R_e = V \times H_d / \upsilon$), where H_d is the hydraulic diameter of the orifice and υ is the kinematic viscosity (which varies with temperature).

In Figure 2-11, Lambert (2001) shows the relationship between C_d and Reynolds Number for discharges through a 1 mm orifice drilled into the side of a 15 mm diameter copper pipe. For this particular set of test data, in the Laminar flow range (R < 2000, L < 10 l/hour), C_d rises rapidly to 0.80 as R_e increases, implying that discharge rates of small leaks may be very sensitive to changes in pressure because of changes in C_d. In the fully turbulent flow range (R >4000, L > 30 l/hour), C_d remains steady at around 0.75, whilst in the Transitional flow range, (10 < L < 30 l/hr), C_d oscillates between 0.70 and 0.85. Linking this to Equation 2-6, it is evident that there are others factor which influence the leakage flow rate i.e. C_d and a and they are not constant.

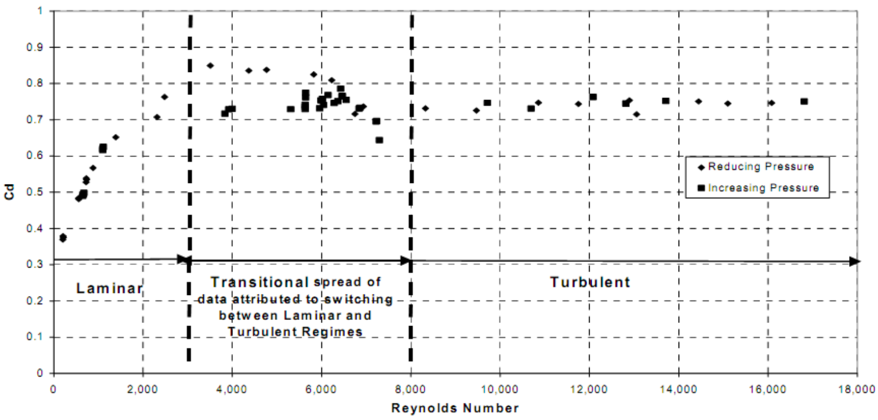

Figure 2-11: Discharge Coefficient of 1 mm Diameter Orifice vs Reynolds Number (Lambert, 2001)

2.5.4.The Power Equation

The power equation (Equation 2-9) developed by practitioners to analyse the leakage flow rate in water distribution systems is considered and applied as the best practice (Thornton, 2003). Writing the orifice equation (Equation 2-9) in a more general form, as follows:

$Q = Ch^{N1}$ where Q = leak flow rate 2-9

C = leakage coefficient

h = the pressure head differential over the orifice

$N1$ = the leakage exponent

Applying Equation 2-9 where there has been a pressure reduction in a DMA. The ratio of leakage flow rate before and after pressure reduction in a DMA gives the Equation 2-10.

$$Q_a = C{h_a}^{N1}$$

$$Q_b = C{h_b}^{N1}$$

where:

$$\frac{Q_a}{Q_b} = \frac{C{h_a}^{N1}}{C{h_b}^{N1}}$$

Q_a = Flow after pressure reduction

Q_b = Flow before pressure reduction

h_a = Pressure after pressure reduction

$$\frac{Q_a}{Q_b} = \left(\frac{h_a}{h_b}\right)^{N1} \qquad 2\text{-}10$$

h_b = Pressure before pressure reduction

N1 = Leakage exponent

Pressure management projects or schemes have been implemented successfully in the world based on the power equation in Equation 2-10 (Marunga et al., 2006; McKenzie et al., 2004; McKenzie & Wegelin, 2010; Meyer et al., 2009; Nazif et al., 2010).

The main parameter of the power equation is the leakage exponent, N1. The leakage exponent can be traced back to a study done by Ledochowski, (1956) cited in Gebhardt (1975). The leakage exponent

(N1) is used by practitioners to determine the leakage-pressure relationship in water distribution systems, it is also used in laboratory studies to describe the behaviour of individual leaks (Ferrante, 2012; Greyvenstein & van Zyl, 2007; Lambert, 2001; van Zyl & Clayton, 2007).

N1 value is used to predict leakage reduction when implementing pressure management projects (see Equation 2-9 & 2-10). A leakage coefficient [C] can also be derived from the power equation (see below).

$$Q_a = C{h_a}^{N1} \qquad 2\text{-}11$$

$$C = \frac{Q_a}{{h_a}^{N1}}$$

Greyvenstein and van Zyl, (2007), did experiments to determine values of leakage exponent on different types of pipe materials (uPVC, steel and asbestos cement). They were able to show that, leakage exponents vary with the type of pipe of materials and type of cracks. The resulting exponents from their study were between 0.42 and 2.4 (see Table 2-4).

Table 2-4: Summary of leakage exponents found adapted from (Greyvenstein & van Zyl, 2007)

Leakage exponent for pipe material			
Failure type	**uPVC**	**Asbestos cement**	**Mild steel**
Round hole	0.524	-	0.518
Longitudinal crack	1.38 - 1.85	0.79 - 1.04	-
Circumferential crack	0.41 - 0.53		
Corrosion cluster	-	-	0.67 - 2.3

In another experiment done in Italy, Paola and Giugni (2012) reported leakage exponent values ranging from 0.54 - 1.61. Hiki (1981) found leakage exponent of 0.5 which was proportional to the square of pressure head. Walski et al. (2009) reported leakage exponent values respectively ranging from 0.66 - 0.76. From above the leakage exponent values it can be concluded that leakage exponents obtained from the laboratory environment vary from roughly 0.5 to 1.61.

2.5.5.Pressure Head Relationship and N1

Pressure management projects have been implemented worldwide applying the power equation(s) discussed in Section 2.5.4. The leakage exponents reported above show that N1 varies from 0.42 to 2.4

in laboratory experimental studies, however N1 exponents found in field studies range from 0.3 to 2.95 (Walski et al., 2009; Wu et al., 2011).

Considering a leak as an orifice, N1 should be 0.5 when applying Torricelli equation (see Equation 2-2) which describes the relationship between flow rate and pressure head. Laboratory studies discussed above showed the leakage exponent was rather a complex phenomenon than an orifice as leakage exponents can be greater than 0.5 (Cassa et al., 2010; Ferrante, 2012; Massari et al., 2012; van Zyl & Clayton, 2007). Van Zyl and Clayton (2007) mentioned four mechanisms that may be responsible for the range of leakage exponents observed, i.e. leak hydraulics, pipe material behaviour, soil hydraulics and water demand. They concluded that material behaviour was likely to be the main mechanism, and can explain the range of exponents observed in the field. This was confirmed by Greyvenstein and van Zyl (2007) in an experimental study of failed pipes taken from the field (Cassa et al., 2010).

In a quest to understand and explain the leakage exponent (N1) variation as discussed above, Cassa et al., (2010) investigated the behaviour of different types of leaks in different pipe materials (uPVC, steel, cast iron and asbestos cement) under the influence of pressure using finite element analysis. In their study, three different leak openings were investigated i.e. circular holes and longitudinal and circumferential cracks.

Cassa et al., (2010) proposed a linear equation to explain the increase of leak area due to an increase pressure (see Equation 2-12).

$$A(h) = \bar{m}h + A_0 \qquad \text{2-12}$$

with h the pressure head, A the leak area, $\overline{A_0}$ the initial leak opening without any pressure in the pipe, and $\bar{m}$ the slope of the pressure area line.

Substituting Equation 2-12 into Equation 2-6 results in the following equation for the leakage rate as a function of pressure:

$$Q = C_d\sqrt{2g}\,(A_0h^{0.5} + \bar{m}h^{1.5}) \qquad \text{2-13}$$

Ferrante (2012) in a laboratory study, studied leak area in different pipe materials. Two steel pipes of different thicknesses and a polyethylene pipe were studied. His results concluded that Torricelli's formula cannot be used to interpret all the data unless the variation of the leak area and the pressure head was considered. His results confirmed the findings by Cassa et al. (2010) that a linear variation of the area was expected in an elastic material pipe.

Cassa and van Zyl (2013) offer an explanation on why leakage exponent varies. They claim that the most important reason for this behaviour was the fact that leak areas are not fixed but increase as a function of pressure. In their study, they used finite element analysis to investigate the relationship between pressure head and leak area in pipes with longitudinal, spiral and circumferential cracks. It was found that there was a linear relationship between crack area and pressure head for all crack types, pipe materials and loading conditions tested. With these relationships, it will be possible to predict the behaviour of different types of leak openings in different pipes and pipe materials.

The behaviour of similar pipe materials in field studies or water distribution systems cannot be inferred from the findings of Cassa et al., (2010) and that of Cassa and van Zyl (2013), as in water distribution systems there are a lot of factors at play, such as pipe age, pipe condition, surrounding soils, water demand placed on the systems to name but a few, however the head-area slope (m) can be expected to play a dominant role. Therefore a detailed investigation and analysis on water distribution systems was required.

Cassa et al., (2010) and Cassa and van Zyl (2013), showed that leak areas are not fixed but increase as a function of pressure. This phenomenon is called the head-area slope relationship (m) and it explains elastic behaviour of leak area expansion. Ferrante (2012) has confirmed this theory in a laboratory environment on different material type however it has not been done on field studies.

The following Table 2-5 (van Zyl and Cassa, 2014) states the range for $\bar{m}$ when determined for a single leak:

Table 2-5 – Range of $\bar{m}$ for various crack formations for a single leak (Van Zyl and Cassa, 2014)

Crack formation	**Range for $\bar{m}$**
Round holes	Very small; typically < 0.001 mm^2/m
Circumferential cracks	Range between small positive and negative values, say between 0.5 mm^2/m and -0.5 mm^2/m
Longitudinal cracks	Large values (say > 0.1 mm^2/m) except for virgin metal pipes where $\bar{m}$ is similar to round holes. $\bar{m}$ can be calculated as function of pipe and crack properties using equation (Cassa & van Zyl, 2013): $$\bar{m}_{long} = \frac{2.93157 d^{0.3379} {L_c}^{4.80} 10^{0.5997(\log L_c)^2} \rho g}{E t^{1.746}}$$

2.5.6. Power and FAVAD Equations

Cassa and van Zyl (2013) proposed a method for modelling the pressure-leakage behaviour of individual leaks on a new dimensionless Leakage Number (L_N) and illustrated how the model can be combined to earlier work by Cassa and van Zyl (2013).

Cassa and van Zyl (2013) investigated the relationship between the power equation (Eq. 2-11) and FAVAD (Eq. 2-13) equations. Shown below is how an analytical exploration was done.

2.5.6.1. *Analytical Exploration*

First, consider the relationship between the Power and the FAVAD equation:

$$Ch^{N1} = C_d\sqrt{2g}\,(A_0 h^{0.5} + \bar{m}h^{1.5}) \qquad 2\text{-}14$$

Dividing both sides by the orifice equation results in:

$$C'h^{N1-0.5} = 1 + \frac{\bar{m}h}{A_0} \qquad \text{with } C' = \frac{C}{C_d\sqrt{2g}A_0} \qquad 2\text{-}15$$

The term $\bar{m}h/\overline{A_0}$ on the very right of the equation represents the ratio between the variable and fixed portions of the leakage, and is now defined as the dimensionless Leakage Number L_N:

$$L_N = \frac{\bar{m}h}{A_0} \qquad 2\text{-}16$$

Through further manipulation, expression can be found for *N1* in the form:

$$N1 = \frac{\ln(L_N + 1) - \ln(C')}{\ln(h)} + \frac{1}{2} \qquad 2\text{-}17$$

They concluded that the equation above confirms that the leakage exponent is a function of *h*. In addition, by exploring the limits of *h* it can be shown that:

- In the limit as *h* reduces to zero, the leakage exponent *N1* = 0.5 and C = $C_d\sqrt{2g}A_0$. Thus, at a pressure of zero the leak behaviour can be described by the orifice equation.
- In the limit as *h* increases to infinity, the leakage exponent N1 = 1.5 and C = $C_d\sqrt{2g}$. Thus, if the pressure is sufficiently high the leak behaviour can be described by the variable area part of Equation 2-13.

2.5.7.Leakage Number

On previous work done, the leakage exponent and Leakage Numbers were calculated for cracks with $\overline{m}/\overline{A_0}$ ratios of 0.0001, 0.001, 0.01, 0.1, 1 and 10 pressures between 0.00001 and 200 m, the results are presented in Figure 2-12 (Cassa & van Zyl, 2013).

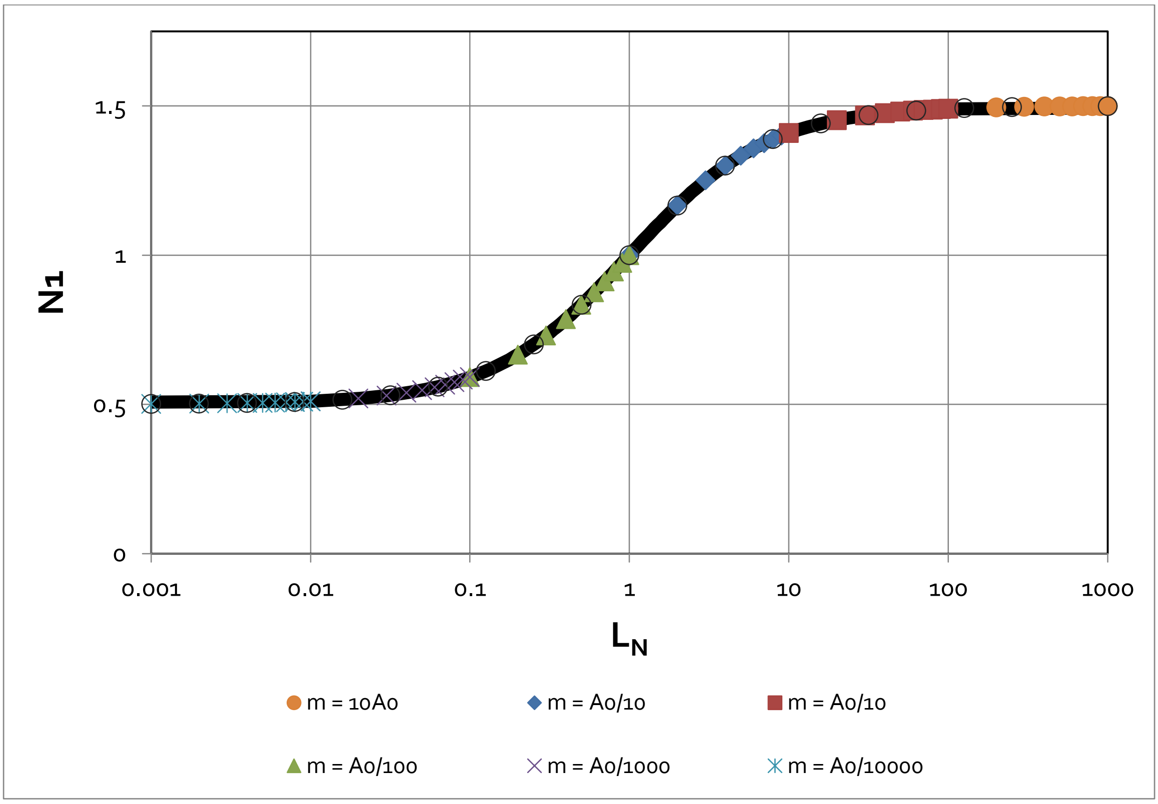

Figure 2-12: Relationship between leakage exponent (N1) and leakage number (L_N) for different $\overline{m}/\overline{A_0}$ ratios adapted (Cassa & van Zyl, 2013)

Based on this curve, they concluded that the relationship between *N1* and L_N display the following characteristics:

N1 = 1 when $L_N = 1$

N1 > 1 when $L_N > 1$

N1 < 1 when $L_N < 1$

N1 is practically 0.5 for all $L_N < 0.01$

N1 is practically 1.5 for all $L_N > 100$

The following derived are formulas for N1 and L_N

$$L_N = \frac{N1 - 0.5}{1.5 - N1} \quad \text{2-18}$$

$$N1 = \frac{1.5L_N + 0.5}{L_N + 1} \quad \text{2-19}$$

The leakage number equation has not been applied extensively on field studies to predict N1, this research will seek to apply it on water distribution systems.

Using the leakage number L_N, defined as the ratio between variable and fixed leaks (Cassa and van Zyl, 2011), it was possible to convert any pressure-area slopes into an equivalent leakage exponent N1 (see Equation 2-19).

The Leakage number has not been estimated in real water distribution systems. Using the leakage number (L_N) to predict N1 was the only theoretical approach available so far as opposed to the practitioners approach.

From Equation 2-16, it can be seen that a large leakage number (and thus high N1) may be obtained from a leak in a very flexible material (high m) or by a very small initial $\overline{A_0}$, such as a crack that only opens under pressure. This means that laboratory tests of machined 'cracks' in pipes produce lower leakage exponents of similar length, but narrower cracks, found in real systems (Lambert et al., 2013).

2.6. Effect of Pressure Management on Leakage Reduction

Leakage reduction in water distribution is one of the main concerns for water system managers, especially in these last decades, as water losses represent a major problem for water undertakings, consumers and the environment (Araujo et al., 2006; Gopan et al., 2010). Pressure management was recognised as an important and effective technique amongst others to control leakage in water distribution systems and has been in use for over 20 years in some countries (Thornton, 2003). Pressure management projects have been implemented in different parts in the world. For any leak, reducing pressure in water distribution systems may reduce the rate of water loss through leakage, as indicated by numerous studies (Walski et al., 2006). Pressure reductions in water distribution systems are normally achieved through installation of pressure reducing valves.

2.7. Field studies on leakage-pressure relationship on Water Distribution Systems

In Saudi Arabia, Al-Ghamdi (2011) conducted field investigation in seven water distribution systems in the Holy City of Makkah to identify the relationship between leakage rate and pressure. Out of seven areas, he studied two areas namely; Aziziah (Area 2) and Al-Hindawiah (Area 3). In Area 2, the network consisted of uPVC pipes (76.5%) and ductile iron pipes (23.5%), while in Area 3 consisted 100% asbestos cement pipe, the age of the network was estimated at 19 years and 32 year respectively.

Pressure tests were performed in the said areas during non-pumping period by plugging all the property connections at each service meter and adjusting the inlet pressure to the study zone with valves and pumps. He applied the procedures for field pressure testing found in Al-Dhowalia et al. (2002) and Al-Ghamdi & Gutub (2002). He found leakage exponent of 1.16 for the network of mixed pipes network in Area 2 and 0.50 for the network Area 3 which consisted solely of asbestos-cement pipes. He concluded that the high leakage exponent can be attributed to the older age of the network but the older network was in fact Area 3 not Area 2.

There are further field studies completed internationally including Japan, Brazil and the United Kingdom. Puust et al. (2010) summarised these and the resultant calculated leakage exponent as presented in Table 2-6.

Table 2-6: Leakage exponents from other field studies adapted from (Puust et al., 2010)

Country	**Number of zones tested**	**Range of Leakage Exponent**
Brazil (1998)	17	0.73 to 2.42
Brazil (2006)	13	0.52 to 2.79
Cyprus (2005	15	0.64 to 2.83
Japan (1979)	20	0.63 to 2.12
United Kingdom (1970's)	17	0.7 to 1.68
United Kingdom (2003)	75	0.36 to 2.95
Totals	157	0.36 to 2.95

Gebhardt, (1975), conducted field studies in South Africa in the following areas, Northcliff and Hillbrow in Johannesburg, Diepkloof in Soweto, and the purpose of the study was to investigate the effect of pressure on excessive use (demand) and the effect of pressure on leakage. He found leakage exponents varying from 0.52 to 1.02.

The pressure-leakage behaviour of leaks in water pipes was further studied by van Zyl & Malde (2017) where an experimental study was undertaken and concluded that the power equation produces good results when used within its calibrated range, but can result in substantial errors when used outside this range.

Deyi et al. (2014) advanced the work on the FAVAD concept and leakage number by applying the FAVAD calculation to real networks for information obtained from Kwadabeka, KwaZulu Natal, South Africa.

The results of the study found that the pressure-leakage parameters provided insights into the behaviour of the 9 zones analysed and provided possible reasoning for anomalies that were discovered. The study further found that certain zones had calculated N1 values that fell outside the 0,5 to 1,5 range.

3. RESEARCH METHODOLOGY

3.1. Introduction

The research required as part of this study was defined as part of the research methodology. This section aimed to specify the activities, methods and steps required.

This Section discusses the systematic approach that was followed during the study, so as to accomplish the stated research objectives. The research methodology comprised of five essential steps, which were logically organised to allow systematic completion of the research process. The abovementioned steps were as follows:

- Description of the Source Data
- Definition of the Input Information
- Selection of Study Areas
- Data Analysis and Interpretation for PMZ Validation
- Description of the Calculation Methodologies

3.1.1. Research Flow Diagram

The sequential steps of the research and methodology followed during the study, were arranged in the flow diagram shown in Figure 3-1.

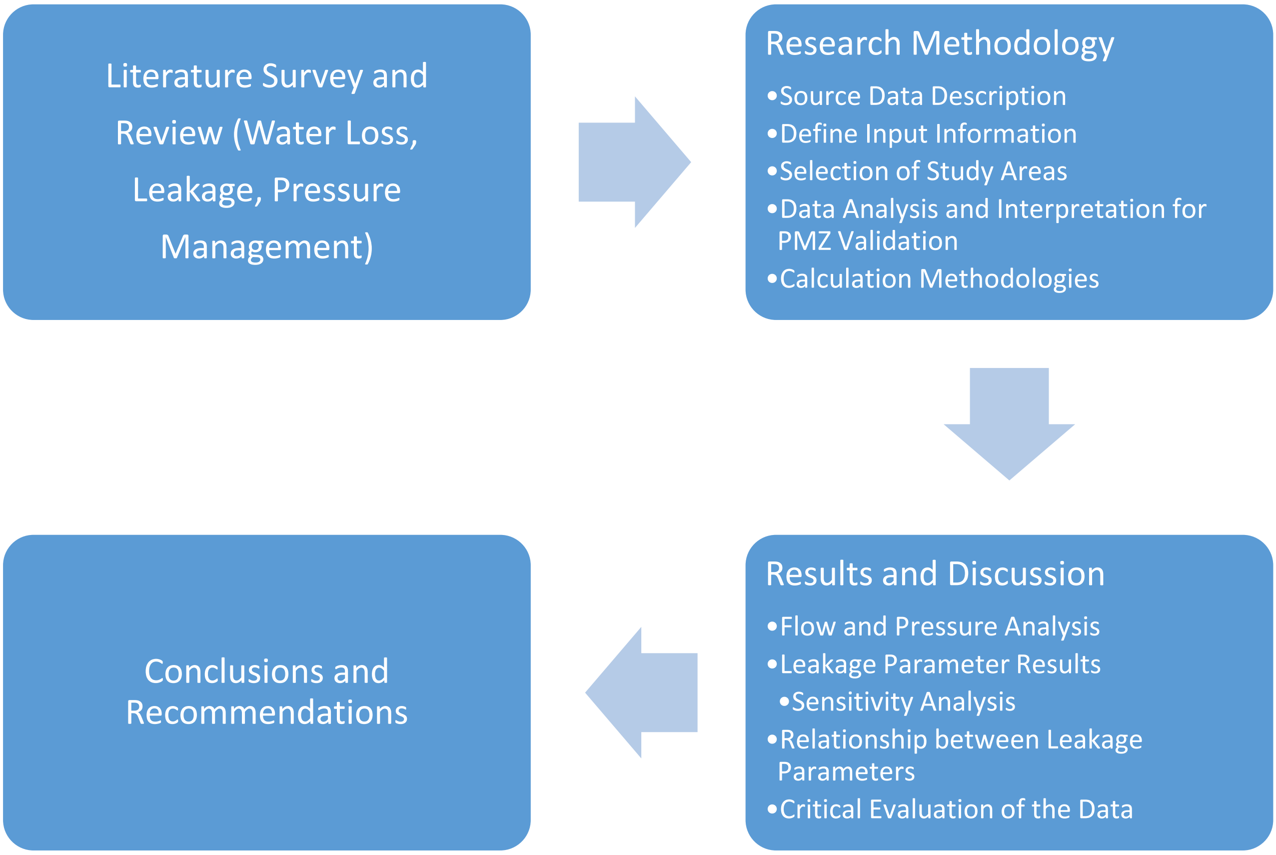

Figure 3-1: Flow diagram of research

3.2. Source Data Description

Information was obtained by an engineering company, JOAT Consulting. The information provided was collected from various pressure management programmes in the Free State and Kwa-Zulu Natal as presented in Figure 3-2.

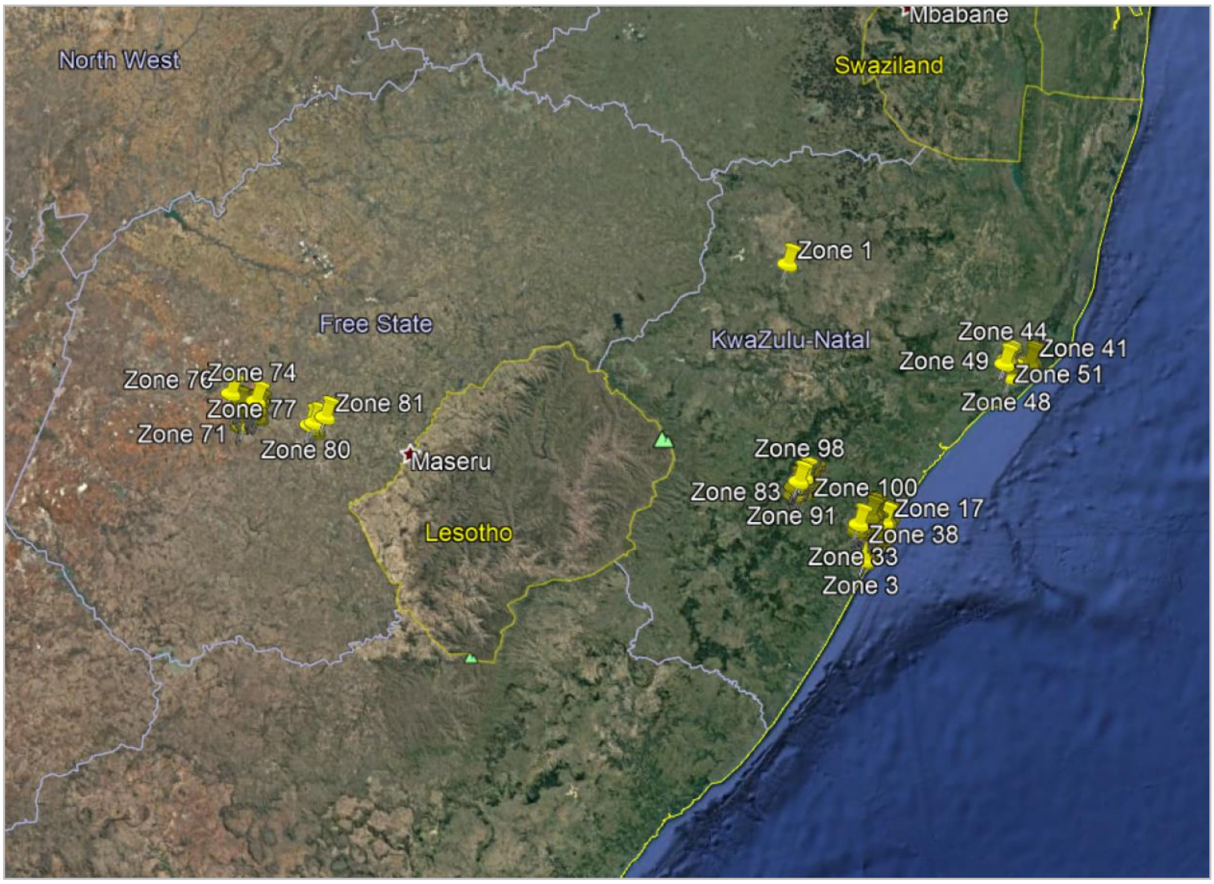

Figure 3-2: Distribution of study areas provided by JOAT Consulting

JOAT Consulting, when undertaking pressure management, followed the general methodology for establishment of PMZs. Firstly, an outline was drawn, of provisional zonal boundaries using local knowledge, maps, and mains records. Site and street surveys were used to verify existing local knowledge and generate additional information. This was followed by establishing information on consumption and property counts, to estimate flow meter size. Afterwards, the DMA boundaries were defined and the flow meter and pressure reducing valves installed. Boundary valves were then installed and closed, for subsequent operation of the PMZ.

This process ensured the PMZs was hydraulically isolated from the supply network to form representative zones. This facilitated better analysis and measurement of the pressure and flow profiles. The PMZs were created as discrete pressure areas separated by mode of supply i.e. areas that were supplied by gravity were separated from areas supplied by pump. Zone boundaries were created, by following as much as possible, existing natural hydraulic and geographical boundaries, to minimize the number of mains crossing them. These boundaries included main transport routes (roads or train lines), natural wetlands, and cliffs/mountains. Where this was not applicable, boundary valves and flow meters were installed to create artificial hydraulic boundaries. However, the number of valves required for this purpose was restricted as far as the technical requirements for PMZ formation allowed.

3.2.1. Data Quality

The consultant is known to be successful in the field of pressure management and water loss reduction and has appropriate theoretical knowledge of data collection process and undertakes methodical approach to data collection and interpretation. It was therefore assumed that the quality of data provided was valuable and usable although may contain minor errors.

The design related information for the establishment of PMZs obtained from the consultant was provided to the author of this thesis to use. With this in mind, errors in collection or calculation may be present but these could not be scrutinised as own collection and calculation of the source data was not part of the scope of this thesis. Furthermore, the consultant's interpretation of the data and use thereof to implement the PMZs will not be scrutinised or corrected.

3.2.2. Data Limitations

The data, while comprehensive, also had limitations. Data collection errors may not be able to be identified directly, but following calculation of certain parameters, PMZs were excluded to ensure data confidence was as high as possible. A summary of the entire dataset of PMZs provided is included as Table 3-1.

Table 3-1: Summary of PMZ Dataset

No. of PMZs provided	141
No. of PMZs excluded from study	34
% of original PMZs excluded	24%
No. of PMZs studied	107

The 34 PMZs excluded from the study were excluded for various reasons. The excluded PMZs and specific reasoning are provided in Table 3-2.

Table 3-2: PMZs Excluded From Study

No.	PMZ Name	Reason
1	DV3141	MNF after > MNF before
2	DV3143	MNF after > MNF before
3	DV3066	SIV after > SIV before
4	DV2811	MNF after > MNF before
5	DV2930	No flow logging data
6	DV2931	No flow logging data
7	DV2932	No flow logging data
8	DV2934	No flow logging data
9	DV3151	No flow logging data
10	DV3154	No flow logging data

11	DV3216	No flow logging data
12	DV3214	No flow logging data
13	DV3215	No flow logging data
14	DV3056	Information poorly captured/incomplete
15	DV3187	Information poorly captured/incomplete
16	DV3189	Information poorly captured/incomplete
17	DV3193&DV3197	Information poorly captured/incomplete
18	DV3202	Information poorly captured/incomplete
19	DV3263	Information poorly captured/incomplete
20	DV3275	Information poorly captured/incomplete
21	DV3305	Information poorly captured/incomplete
22	DV3342	Information poorly captured/incomplete
23	Matshana 2 PRV	Information poorly captured/incomplete
24	PRV901	Information poorly captured/incomplete
25	COU 0038 Ngwelezane II	Information poorly captured/incomplete
26	903	MNF after pressure reduction went to zero (possible breach)
27	Corbet Rd	Information poorly captured/incomplete
28	Andres Pretorius PRV	Information poorly captured/incomplete
29	Grimthorpe Ave PRV	Information poorly captured/incomplete
30	Peter Brown Rd PRV	Information poorly captured/incomplete
31	Copesville PRV	MNF after pressure reduction went to zero (possible breach)
32	Twickenham Rd PRV	MNF after pressure reduction went to zero (possible breach)
33	Chase Valley Rd PRV	MNF after pressure reduction went to zero (possible breach)
34	Azalea Rd PRV	MNF after pressure reduction went to zero (possible breach)

The listed PMZs were excluded due to incomplete/poorly captured information, missing data or data that was clearly incorrect (for example, MNF must always be above zero due to background losses and MNF/SIV after pressure management should always be less than MNF/SIV before pressure management). The methodology for scrutinising the data is presented in Section 3.3.

3.2.3. Collected Data Overview

Data sets collected from the pressure management schemes implemented in different parts of South Africa were analysed and used to estimate pressure-leakage parameters.

Components listed herein were collected and others estimated for the purpose of the analysis and determination of pressure-leakage parameters.

<u>Components in the water distribution system include:</u>

- System Input Volume
- Upstream and Downstream Pressures in Pressure Management Zones (at PRV chambers).
- System flow rates
- Estimated Minimum Night Flows

- Population served in a PMZ
- Average Zone Pressure

Water Distribution System Information for purpose of analysis:

- Network and GIS Shape Files
- Population Data
- Cadastral Data
- Contour Maps

3.2.4.Field Data Collection Methodology

In order to understand the input information, it was important to understand how this information was sourced from the field.

Subsequent to zonal boundary establishment and PMZ formation, the newly isolated networks were monitored by installing flow meters and pressure data loggers, to obtain data on their hydraulic performance. Accurate measurement of pressure and effective metering of continuous inflows and outflows was ensured, as these properties are essential features of network monitoring. Since the PMZs were selected considering their potential for leakage reduction through pressure management, pressure monitoring points were selected for measurement of pressure at PMZ outlet, average zone point (AZP) and critical point.

The critical point was selected and considered to be the point in the network, which was furthest from the source and at which the desired minimum supply pressure was always equal to or greater than the standard level of service of 10m. A surrogate point for the measurement of pressure at the AZP was taken as the point in the network which was closest to the middle of the DMA and at which supply from the source was directly accessible through the mains.

Data logging at the various locations to provide PMZ performance was completed for 7 days, before and after pressure management was undertaken. During the measurement period, the PMZs were also monitored for unforeseen events that could have affected consumption and yield irregular performance data. Estimated consumer demands, based on land-use type and site specific information, and the GIS network database were used as additional sources for collecting data. Additionally, consumer consumption was calculated using a count of various types of consumers and applying a demand based on size and type of consumer, related to local design guidelines for water.

The following groups of field data were collected and recorded during the measurement periods in the PMZs;

(a) PMZ size and demand features

- Number of residential connections or properties
- Number of commercial and industrial connections

(b) PMZ network data (where available)

- Pipe lengths
- Pipe diameter
- Pipe material
- Junction (nodal) elevations
- Number of boundary valves

(c) PMZ pressure data

- Inlet point pressure (Upstream & Downstream)
- Average zone point (AZP) pressure
- Critical point pressure

(d) DMA flow data

- Inlet flow and outlet flow
- Diurnal flow profile – 24 hour flow pattern
- Minimum night flow – for the typical period from 00:00 – 03:00 Hours
- Target point flow

(e) Night water use data

- Industrial and commercial consumption – from billing records
- Customer night use – from sample of meters monitored at night

The groups of field data described above were processed and compiled in data collection forms that were prepared prior to the exercises. The processed data is presented in Appendix I.

3.3. Define Input Information

In order to move towards a standard methodology for analysing the information, and interpreting the calculated parameters, it was important to understand the various inputs and how they were collected. This sections aims to define the different inputs and present how they were determined.

Pressure management zones were provided for real distribution systems within South Africa. The information provided was made up of required information that formed the basis of the investigation. The individual information was made up of general information related to the site, consumption information of the zone and logging data as collected from loggers installed on the necessary infrastructure. The information provided could be analysed for accuracy however critical information such as logging data and consumption data could only be analysed for accuracy but could not be replaced as these were sourced directly from the site. The author had no experience with the site and thus could not draw conclusions based on the information without requiring feedback from the relevant authority on their method of calculation. The information collected was of a common template and consisted of the following:

General Data

- DV Number
- Reference Name
- Operational Area
- Town
- Area
- PRV Address
- X
- Y
- Z [masl]
- CP1 Address
- CP1 GL [masl]
- CP2 Address
- CP2 GL [masl]
- Lowest GL (masl)
- Supply
- Supply TWL [masl]
- Pipe Size
- Proposed PRV Size
- PRV Make
- Function
- Design Standard [mH2O]
- Length of mains [km]
- Average Length of service connections [m]
- Length of system pipe that is metal [km]

Consumption Data

- Night Usage
    - Domestic or Non-Domestic Use
    - Population Served
    - % Population Active at Night
    - Unit Use
    - Consumption

Logging Data

- Before PRV Control
    - Date
    - Time
    - Flow

  - Upstream (U/S) Pressure
  - Downstream (D/S) Pressure
  - AZP Point Pressure
  - Point in Zone Logged Pressure
- After PRV Control
  - Date
  - Time
  - Flow
  - Upstream (U/S) Pressure
  - Downstream (D/S) Pressure
  - AZP Point Pressure
  - Point in Zone Logged Pressure

Each input will be discussed with regards to the meaning and source of the information. Furthermore, each input will be described to how it contributes to the database.

3.3.1.General Data

The General Data provides information on the naming references for the installation and site, the location information, the installation specific information and general information on the PMZ.

Reference Number

The 'Reference Number' is a reference for each PMZ used for this study. The Reference Number has no effect on calculations.

DV Number

The 'DV number' is a reference name used by the relevant Municipality to identify a PRV installation. The DV number has no effect on calculations. The DV number is provided by the Municipality.

Company Reference Name

The 'Company Reference Name' input item refers to JOAT Consulting's reference name for the PRV installation. The reference name has no effect on calculations. The reference name is provided by the respective companies' PMZ designer.

Operational Area

The 'Operational Area' refers to the Municipality the PMZ falls within. This has no effect on calculations.

Town

The Town refers to the town within the Municipality that the PMZ falls within. This has no effect on calculations.

<u>Area</u>

The 'Area' refers to the particular area of the town that the PMZ falls within. This has no effect on calculations.

<u>PRV Address</u>

The 'PRV Address' provides a street address for the relevant PRV installation. This has no effect on calculations.

<u>X</u>

The 'X' input refers to the X coordinate (latitude) of the location of the PRV installation with reference to a coordinate system. The coordinate system adopted is typically that of Google Maps. The internal coordinate system of Google Earth is geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 (WGS84) datum. This has no effect on calculations.

<u>Y</u>

The 'Y' input refers to the Y coordinate (longitude) of the location of the PRV installation with reference to a coordinate system. The coordinate system adopted is typically that of Google Maps. The internal coordinate system of Google Earth is geographic coordinates (latitude/longitude) on the World Geodetic System of 1984 (WGS84) datum. This has no effect on calculations.

<u>Z</u>

The 'Z' input refers to the height of the PRV installation in metres above sea level. This input is used as an input into the determination of the Average Zone Pressure (AZP) and may have an effect on the final parameters. The height is typically collected through GPS, or geographic software such as GIS or Google Earth.

<u>CP1 Address</u>

The 'CP1 Address' input refers to the street address of the first critical point in the PMZ. Where a zone is deemed as big or particularly 'hilly', two critical points may be used in order to monitor the lowest pressures in the PMZ. The critical point is typically the highest point in the PMZ at which the lowest pressure in the PMZ is realised. The CP1 address does not affect calculations.

<u>CP1 GL</u>

The 'CP1 GL' refers to the ground level of the first critical point location in metres above sea level. This input is used as an input into the determination of the Average Zone Pressure (AZP) and may have an effect on the final parameters. The critical point is typically the highest point in the PMZ at which the lowest pressure in the PMZ is realised.

CP2 Address

The 'CP2 Address' input refers to the street address of the second critical point in the PMZ. Where a zone is deemed as big or particularly 'hilly', two critical points may be used in order to monitor the lowest pressures in the PMZ. The critical point is typically the highest point in the PMZ at which the lowest pressure in the PMZ is realised. The CP2 address does not affect calculations.

CP2 GL

The 'CP2 GL' refers to the ground level of the second critical point location in metres above sea level. This input is used as an input into the determination of the Average Zone Pressure (AZP) and may have an effect on the final parameters. The critical point is typically the highest point in the PMZ at which the lowest pressure in the PMZ is realised.

Lowest GL

The 'Lowest GL' refers to the height of the lowest point in the PMZ in metres above sea level. This input is used as an input into the determination of the Average Zone Pressure (AZP) and may have an effect on the final parameters.

Supply

The 'Supply' input refers to the source of water supply to the PRV whether it be a reservoir, pump station or another PRV. The name of the source is provided. This has no effect on calculations.

Source TWL

The 'Source TWL' input refers to the Top Water Level or maximum height of the source. In the case of a reservoir, the TWL would be the height of the top of the reservoir, in metres above sea level. For a pump station or PRV, the TWL would be the height of the point of installation in metres above sea level plus the maximum pressure head in metres resulting at the downstream side of the installation. This input is used as an input into the determination of the Average Zone Pressure (AZP) and may have an effect on the final parameters.

Pipe Size

The 'Pipe Size' input refers to the pipe diameter at the installation. The pipe size has no effect on the calculations and resulting parameters and is purely for information purposes.

Proposed PRV Size

The ‘Proposed PRV Size’ refers to the size of the PRV installation. The Proposed PRV Size has no effect on the calculations and resulting parameters and is purely for information purposes.

PRV Make

The ‘PRV Make’ input refers to the PRV manufacturer as per the installation. The PRV Make has no effect on the calculations and resulting parameters and is purely for information purposes.

Function

The ‘Function’ input refers to the function of the installation. In all cases in the database, the function of the valve is to reduce pressure however there are many types of valves that have different applications. This has no effect on the calculations and resulting parameters and is purely for information purposes.

Design Standard

The ‘Design Standard’ input refers to the design standard that the PMZ complied to. A design standard of 25-60m describes the pressure range in metres that the PRV will be designed to deliver on the downstream side. This has no effect on the calculations and resulting parameters and is purely for information purposes.

Length of mains

The ‘Length of mains’ input refers to the total length of the distribution network in the PMZ. The ‘mains’ does not include the length of service connections. Length of mains has an effect on the final parameters and has to be scrutinised for accuracy. The length of mains is provided in kilometres. The length of mains would be determined through Geographic Information Systems (GIS) software and calculating the sum of all the distribution mains length in the relevant PMZ. Possible errors in the determination of the input are that the GIS shapefiles may be inaccurate or outdated, or the determination of the boundary of the PMZ may be inaccurate and vary from the actual operation of the PMZ. The length of mains has a resulting effect on the Unavoidable Annual Real Losses (UARL) calculation and hence the Infrastructure Leakage Index (ILI). The input cannot be changed or deleted as it is an important factor in the calculation of the leakage parameters. The information will be scrutinised and where evident that the information is incorrect, the particular PMZ will be excluded in entirety from the database to ensure confidence in the database.

Average Length of Service Connections

The ‘Average Length of Service Connections’ input refers to the small diameter pipelines leading off the mains to feed the consumers. The average length of service connections has a resulting effect on the Unavoidable Annual Real Losses (UARL) calculation and hence the Infrastructure Leakage Index (ILI).

The average length of service connections is provided in metres. The average length of service connections is typically considered as zero in South African context because of the design of the mains and location of the household meters being outside of the consumers' property.

Length of system pipe that is metal

The Length of system pipe that is metal' input refers to the total length of metal pipes in the distribution network. This is significant because of the effect that rigid pipes have on the N1 value and is an important contribution in Thornton and Lambert (2005) N1 prediction equation. The length is provided in kilometres. Typically, the material of the pipelines is provided as part of the GIS database where distribution systems are comprehensively known and GIS systems are updated. This information however hasn't been provided by the supplying company which means at the time of submission, this information wasn't attainable. In future, as water systems are better understood and GIS information updated, this could be determined and used in the analysis. This parameter was therefore excluded from the analysis however if this information became available, it could be used to analyse the N1 values for PMZs with a specific percentage of metal pipes in the system. The exclusion of this parameter did not affect the findings or calculated parameters.

3.3.2.Consumption Data

Consumption data provides information on the typical consumption in the relevant PMZ.

Night Use

The 'Night Use' input refers to the submitted information that the provider has obtained. The night use is an indication of normal night usage by consumers. In domestic context, this refers to consumers using showers, flushing toilets, running water, etc. In non-domestic context, this refers to industrial or commercial usage at night such as laundry services, processing and manufacture plants, etc. Night use is considered as between 12am and 3am. The night use is determined through intricate knowledge of the consumers within the PMZ and thus this information cannot be scrutinised without this information being provided. Night use cannot be determined from monthly billing records thus night use for domestic consumers was typically estimated from a range of 2-10% of population active at night, and a range of 8-20 litres consumption per unit per hour. The exact value for the above are selected based on knowledge of the operation of the PMZ, and water use behaviours of the population. The input cannot be changed or deleted as it is an important factor in the calculation of the leakage parameters.

3.3.3.Logging Data

Logging data provides information on the pressure and flow into the PMZ from the supply points, as well as pressure within the zone (typically at the critical point or average zone pressure point). The information is provided for pre-pressure management and post-pressure management.

Date

The 'Date' input refers to the date of logging. Typically, a week's data is logged and logging is done simultaneously between the various points. The logger is programmed to timestamp a data point logged (Interval of data points logged is programmed into the logger when logging is initiated). The date has no effect on the calculations.

Time

The 'Time' input refers to the time of logging. The logger is programmed to timestamp a data point logged (Interval of data points logged is programmed into the logger when logging is initiated). Logging intervals are dependent on the duration of logging required. The shorter the intervals, the more comprehensive the logging information will be, but will require larger data storage space for the data and will use more energy. Typically, for weekly logging exercises, 15-30 minute intervals are adequate. This has no effect on the calculations.

Flow

The 'Flow' input refers to the flow rate at the indicated time and date. The flow rate logged was provided in m^3/hr (cubic metres per hour). The measured flow as a function of time can be used to produce a flow profile. The flow profile can then be analysed to determine Minimum Night Flow, Peak Flow, Average Flow and other important determinants. The input cannot be changed or deleted as it is an important factor in the calculation of the leakage parameters.

Upstream Pressure

The 'Upstream Pressure' input refers to the pressure measured on the upstream side of the PRV installation. Upstream refers to the side of the installation of which pressure is higher and comes from the source. This falls outside of the PMZ. Upstream pressure is measured in metres. This has no effect on the calculation of the parameters.

Downstream Pressure

The 'Downstream Pressure' input refers to the pressure measured on the downstream side of the PRV installation. Downstream refers to the side of the installation of which pressure is lower (as a result of the pressure reducing valve) and falls inside of the PMZ. Downstream pressure head was measured in metres. This will affect the calculation of leakage parameters and will be scrutinised accordingly.

AZP Point Pressure

The 'AZP Point Pressure' input refers to the pressure at the point where the AZP is located. The determination of the AZP point is subjective and thus it cannot be scrutinised without more information from the provider. The AZP can be determined based on the topography as well as the layout of the distribution network in the PMZ and the spread of consumers. A methodical approach to the determination of the AZP can be time consuming and is still open to subjective assumptions. The AZP can quickly be calculated by determining the average height between the Critical Point and the Lowest Ground Level point in the PMZ. This is a much quicker but less accurate determination of the AZP. The various methodologies for determining the AZP is discussed in Section 2.4. The information provided as collected from the field did not indicate the methodology used in calculating the AZP. Assumptions when determining the AZP point can lead to errors which can influence the leakage parameter results. The AZP information will be scrutinised and where evident that the information is incorrect, the particular PMZ will be excluded in entirety from the database to ensure confidence in the database.

Point in Zone Logged Pressure

The 'Point in Zone Logged Pressure' refers to the location and respective pressure logging information of an alternate logging point in the PMZ. The typical points in the zone to be logged could be the Critical Point or the AZP Point. It however could be the lowest point or any random point. The main reason for this point being logged is to measure the difference in pressure between the downstream of the PRV and the logged point. The difference in pressure should have a value approximately equal to the difference in height between the point being logged and the PRV location. Any variations can be attributed to pressure lost as a result of frictional losses, and leakage losses among others. Should the pressure between the point being logged and the PRV location be significantly different (considering elevation change), this could indicate an unknown second supply point into the zone (breach).

The information set out will provide the basis for all analysis from this point forwarded. A number of items in the listed information will be examined and scrutinised and furthermore, possibly recalculated where the information is deemed to be inaccurate. In order to evaluate how input information can affect final parameters, a matrix was created. The matrix aims to ascertain what information needs to be re-evaluated and each input item is asked the following questions:

- **Can the information provided be scrutinised?** – Where information is provided and human interpretation of that information is used, then scrutiny of this information can be completed. The interpretation of the information by the original designer could differ to that of the author and thus could result in drastically different results. The author then can interpret the information and scrutinise the original designers provided information.
- **Can the information provided be recalculated?** – Where information is provided and human interpretation of that information is used, then recalculation of this information can be completed. The interpretation of the information by the original designer could differ to that of

the author and thus could result in drastically different results. The author then can interpret the information and recalculate the original designers provided information.

- **Does the information affect the final parameters?** – Only information that is provided that affects the final parameters will be scrutinised and recalculated where necessary.

Each input was assessed against the above questions and a resulting comment provided as per Table 3-3.

Table 3-3: Matrix to outline sensitivity of input information

General Data	Does it affect final parameters?	Can it be scrutinised?	Can it be recalculated?	Comments
DV Number	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Company Reference Name	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Operational Area	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Town	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Area	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
PRV Address	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
X	☒	☑	☑	No further scrutiny or recalculations necessary as final parameter unaffected
Y	☒	☑	☑	No further scrutiny or recalculations necessary as final parameter unaffected
Z [masl]	☒	☑	☑	Information to be scrutinised and recalculated if necessary
CP1 Address	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
CP1 GL [masl]	☒	☑	☑	Information to be scrutinised and recalculated if necessary
CP2 Address	☒	☑	☑	No further scrutiny or recalculations necessary as final parameter unaffected
CP2 GL [masl]	☒	☑	☑	Information to be scrutinised and recalculated if necessary
Supply	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Supply TWL [masl]	☒	☑	☑	Information to be scrutinised and recalculated if necessary
Pipe Size	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Proposed PRV Size	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
PRV Make	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Function	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Design Standard [mH2O]	☒	☑	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Length of mains [km]	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Average Length of service connections [m]	?	☑	☑	Information to be assessed as to if final parameters are affected
Length of system pipe that is metal [km]	?	☑	☑	Information to be assessed as to if final parameters are affected
Consumption Data				
Billed Authorised Consumption				

Type of Consumption	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Units	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Average Consumption per Unit	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Unbilled Authorised Consumption				
Type of Consumption	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Units	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Average Consumption per Unit	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Night Usage				
Domestic or Non-Domestic Use	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Population Served	☑	☑	☑	Information to be scrutinised and recalculated if necessary
% Population Active at Night	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Unit Use	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Consumption	☑	☑	☑	Information to be scrutinised and recalculated if necessary
Logging Data				
Before PRV Control				
Date	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Time	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Flow	☑	☑	☒	Information to be scrutinised
Upstream (U/S) Pressure	☑	☑	☒	Information to be scrutinised
Downstream (D/S) Pressure	☑	☑	☒	Information to be scrutinised
AZP Point Pressure	☑	☑	☒	Information to be scrutinised
Point in Zone Logged Pressure	☑	☑	☒	Information to be scrutinised
After PRV Control				
Date	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Time	☒	☒	☒	No further scrutiny or recalculations necessary as final parameter unaffected
Flow	☑	☑	☒	Information to be scrutinised
Upstream (U/S) Pressure	☑	☑	☒	Information to be scrutinised
Downstream (D/S) Pressure	☑	☑	☒	Information to be scrutinised
AZP Point Pressure	☑	☑	☒	Information to be scrutinised
Point in Zone Logged Pressure	☑	☑	☒	Information to be scrutinised

If the input item was determined to be scrutinised but cannot be recalculated, the data was then assessed as to whether the PMZ would be discarded from the database. If the information collected was questionable, the PMZ was removed from the study to ensure confidence remained high in the results of the study. This would result in the nullification of inaccurate information supplied to the database which could possibly affect the results and thus the conclusions. This is discussed further in Section 3.4.2.

3.4. Selection of PMZs

A total of 107 PMZs were used in the final database. PMZs from the initial lists that were excluded were as a result of missing information or unreliable information. The PMZs were sourced from various municipalities, each with unique consumers, water demands, populations and landscapes. The final list of PMZs is presented in Table 3-4 and the comprehensive list of PMZ information is provided in Appendix II:

Table 3-4: List of Pressure Management Zones - Reference Names

No.	Reference Number	No.	Reference Number	No.	Reference Number
1	PRVA	37	DV3277	73	PRV-028
2	Dv 2876	38	DV3343	74	PRV-031
3	Dv 2877	39	DV3367	75	PRV-032
4	Dv 2824	40	Arboretum 1 PRV	76	PRV-036
5	Dv 3008	41	Arboretum 2 PRV	77	HV - 34
6	Dv 3067	42	Arboretum Ext PRV	78	HV - 06
7	Dv 3213	43	Gobandlovu 1 PRV	79	PRV - 012 - HV - 16
8	Dv 2885	44	Logan Rd. PRV	80	HV - 42
9	Dv 2823	45	Mandlazini PRV	81	PRV -016
10	Dv 3052	46	Union St PRV	82	DV 1507 Magazine Rd
11	DV 3145	47	EMP FARM PRV	83	1505 Braithwaite Rd PRV
12	Dv 2929	48	Gobandlovu 2 PRV	84	DV 0803 Haniville PRV
13	Dv 3148	49	Kildare Ext	85	DV 1007 Woodpecker Rd PRV 2
14	Dv 3149	50	Kuleka Industrial	86	PRV 0703 Chief Mhlabenzima Rd
15	Dv 3155	51	Matshana 1 PRV	87	DV 0708 Tamboville Prv 1
16	Dv 3156	52	PLOF-002	88	DV 0709 Tamboville PRV 2
17	Dv 2855	53	Birdswood PRV Zone	89	1602
18	Dv 3038	54	PLOF-001	90	1301
19	Dv 1292	55	PR101	91	Xulukhona PRV
20	Dv 2760	56	uMhlathuze Village PMZ	92	DV 0401 Bombay & Narandas Rd
21	Dv 2759	57	Veldenvlei PRV Zone	93	DV 0904 Khan Rd PRV
22	DV2820	58	PRV-01	94	DV 0203 Turbull Rd PRV
23	DV3188	59	PRV-03	95	DV 1601 Morcom Rd
24	DV3190	60	PRV-04	96	Ganges Rd PRV 1004
25	DV3191	61	PRV-05	97	DV 1003 Regina Rd
26	DV3193	62	PRV-06	98	Belfort PRV DV 1001
27	DV3194	63	PRV-007	99	DV 1604 Villiers Drive PRV
28	DV3195	64	PRV-009	100	DV 1005 Boundary Rd
29	DV3197	65	PRV - 11	101	DV 905 Simla Rd
30	DV3199	66	PRV-013	102	DV 1305 Mbubu Rd
31	DV3200	67	PRV-017	103	DV 0906 Springvale Rd
32	DV3203	68	PRV - 18	104	DV 1510 Old Howick Rd
33	DV3204	69	PRV-021	105	Kwapata PRV 4
34	DV3207	70	PRV-025	106	Kwapata PRV 3

35	DV3210	71	PRV-026	107	Montgomery Dr PRV
36	DV3262	72	PRV-027		

3.5. Data Analysis and Interpretation for PMZ Validation

Upon completion of collection of field data, the information was checked for consistency and reliability. It was necessary to subject the full range of data to this process in order to validate the integrity and performance of the PMZ, which primarily facilitated the calculation of the daily volume of leakage and the respective leakage parameters.

The flow profile, generated from flow logging data, was used to determine the period of minimum night consumption, from which the leakage component during this period, was determined. Deducting the calculated night consumption from the measured minimum flow yielded an estimate of the leakage in the PMZ.

Since leakage rate is influenced by system pressure, which varies during the day, the night leakage estimate was converted to the average leakage over the day, by multiplying it with the Night-Day Factor (NDF). Using the average volume of leakage over the day, as well as network data, pressure data, and flow data, the study proceeded to the next stage – calculation of the PMZ characteristics and the leakage parameters.

3.5.1. Calculation of PMZ Characteristics

The PMZ characteristics are the components that are derived from the data provided as described in Section 3.4. This includes the following:

- System Input Volume (SIV);
- Minimum Night Flow (MNF);
- Average Zone Pressure (AZP);
- Unavoidable Annual Real Losses (UARL);
- Current Annual Real Losses (CARL/Q_{RL});
- Infrastructure Leakage Index (ILI).

Each PMZ characteristic will be discussed with regards to the meaning, source and calculation of the information.

3.5.1.1. *System Input Volume (SIV)*

As defined in Section 2.1, the SIV is the volume input to the water supply system from the source. In relation to a PMZ, the SIV was the total volume of water through the pipes supplying the PMZ, and measured using a water meter and data logger. The SIV considers total volume of water supplied to the PMZ which included normal consumption, water losses and metering errors. The flow logging, typically collected for a period of seven days, and the average flow, per day, over the seven days is calculated to be the SIV. The SIV was calculated both pre-pressure management and post-pressure management.

3.5.1.2. *Minimum Night Flow (MNF)*

The Minimum Night Flow (MNF) was the measured rate of flow into any distribution network or district metered area when the consumption in the network is at its lowest, typically between midnight and 4am on a given night (Farley, 2001). This was measured at the supply water meter(s) with a data logger. The MNF was measured for a period of time pre-pressure management and post-pressure management. The flow logging, typically collected for a period of seven days, was analysed specifically during the periods of 00h00 and 04h00, and the average flow for these periods over the seven days is calculated to be the MNF. The MNF was calculated both pre-pressure management and post-pressure management.

3.5.1.3. *Average Zone Pressure (AZP)*

As discussed in Section 2.4, the Average Zone Pressure (AZP) was the average pressure experienced throughout the pressure managed zone. Based on the interpretation of ‘average pressure’, this could be determined using several different methodologies. Section 2.4 discussed the various methodologies for calculating the AZP, of which the most widely recognised version is the weighted average methodology as sourced from Alan Lambert (2018). The location of the AZP (where the AZP was measured) was determined by the company that provided the data without further background information on how this was determined. Considering that the PMZ designer for the company had intimate knowledge of the zone operation, it was assumed that the AZP provided was made consistently across all the PMZs, using the exact same methodology.

3.5.1.4. *Unavoidable Annual Real Losses (UARL)*

The Unavoidable Annual Real Losses (UARL) was defined as a theoretical reference value representing the technical low limit of leakage that could be achieved if all of today's best technology could be successfully applied (Lambert, 2000). The first IWA Water Loss Task Force developed a system-specific equation for the lowest technically achievable Annual Real Losses for well managed infrastructure in good condition. The calculation took into account length of mains, number of service connections, location of customer meters relative to property line (curb stop), and average operating pressure. The following equation applied:

UARL (litres/day) = (18 x Lm + Ns x (0.8 + 25 x Lp/1000)) x P

Where:

Lm = mains length (km),

Ns = number of service connections (main to property line)

Lp = average length, property line to meter (metres),

P = average pressure in the zone (metres)

The UARL was calculated both pre-pressure management and post-pressure management.

3.5.1.5. *Current Annual Real Losses (CARL / Q_{RL})*

The Current Annual Real Losses represents the volume of water being lost through all physical defects in the system, whether detected or not detected. This indicator presented a view of the current state of the real losses in the system. CARL was calculated through the determination of leakage in the PMZ. This was determined by using the MNF, night time usage and the NDF (see below) as presented in Equation 3-1:

$$CARL/Q_{RL} = (MNF - \text{Night Time Usage}) \times NDF \quad (3\text{-}1)$$

Normal night time usage was derived from the determination of typical water used during 00h00 and 03h00 such as toilet flushes, opening of taps, commercial/industrial water usage, etc. Night time usage was typically derived from the population and number of land-use types such as medical/industrial/commercial (that would be operational at night), as described in Section 3.3.2. The night time usage was determined by the company that provided the data without further background information on how this was calculated. Considering that the PMZ designer for the company had intimate knowledge of the zone operation, it was assumed that the night time usage provided was made consistently across all the PMZs, using the consistent methodology.

The Night Day Factor (NDF) converts the night leakage rate to daily leakage. It was derived from the fluctuation of pressure throughout night and day as determined from the pressure logging at the AZP of the PMZ. A full methodology for calculating the NDF is provided by Lambert (2011). The NDF was calculated by the PMZ Designer of the company that provided the data.

3.5.1.6. *Infrastructure Leakage Index (ILI)*

ILI (Infrastructure Leakage Index) represents an indicator defining the quality of water system operation (maintenance, repairs, rehabilitation) needed for real loss (leakage) control. Mathematically, it represents a ratio between the current annual real losses (CARL) and unavoidable annual real losses (UARL). A low ILI indicates that the PMZ was managed efficiently with low real losses as benchmarked by the UARL. A high ILI indicates that the PMZ was managed inefficiently with high real losses as benchmarked by the UARL. The ILI is a non-dimensional indicator, so it provides an indicator for benchmarking water system leakages across different PMZs, regardless of size, topography or population density. The ILI was calculated both pre-pressure management and post-pressure management.

3.5.2. Calculation of Leakage Parameters

The leakage parameters were derived from the PMZ characteristics as described in Section 3.6.1 and provided insight into the relationship between pressure and leakage in each of the PMZs. The leakage parameters determined were as follows:

- Leakage exponent (N1)
- Head-area slope ($\overline{m}$)
- Leakage number (L_N)
- Leak area and initial leak opening ($\overline{A_0}$)
- Leakage coefficient (C)

Each leakage parameter will be discussed with regards to the meaning, source and calculation of the information.

3.5.2.1. *Leakage Exponent (N1)*

As discussed in Section 2.5, the leakage exponent (N1) is used by practitioners to determine the leakage-pressure relationship in a water distribution systems, it was also used in laboratory studies to describe the behaviour of individual leaks (Ferrante, 2012; Greyvenstein & van Zyl, 2007; Lambert, 2001; van Zyl & Clayton, 2007). As the leakage exponent represents the relationship between pressure and leakage, it was calculated using measured pressure and flow, before and after pressure management.

$$N1 = \frac{\ln\left(\frac{Q_a}{Q_b}\right)}{\ln\left(\frac{h_a}{h_b}\right)} \tag{3-2}$$

Where:

Q_a - flow after pressure management, which is PMZ characteristic Q_{RLa};
Q_b - flow before pressure management, which is PMZ characteristic Q_{RLb};
h_a - pressure after pressure management, which is PMZ characteristic AZP_a;
h_b – pressure before pressure management, which is PMZ characteristic AZP_b.
The N1 value is a dimensionless quantity and therefore has no unit of measure.

3.5.2.2. *Head-area slope ($\overline{m}$)*

As discussed in Section 2.5, the head-area slope ($\overline{m}$) explained the elastic behaviour of leak area expansion.

Deriving equation for $\overline{m}$

Please note that a subscript a and b mean after and before, for example Q_a is the flow rate after pressure reduction and Q_b is the flow rate before pressure reduction, the same applies for h_a and h_b. Therefore using the FAVAD equation:

$$Q_a = C_d\sqrt{2g}\left(\overline{A_0}h_a^{0.5} + \overline{m}h_a{}^{1.5}\right)$$

Multiply by $C_d\sqrt{2g}$ across the equation on the right

$$Q_a = C_d\sqrt{2g}\left(\overline{A_0}h_a^{0.5} + \overline{m}h_a{}^{1.5}\right)$$

$$Q_a = C_d\overline{A_0}\sqrt{2g}h_a^{0.5} + C_d\sqrt{2g}\,\overline{m}h_a{}^{1.5}$$

Replace A_0 from Q_b with $A_0 = \left(\frac{Q_b h_b^{-0.5}}{C_d\sqrt{2g}} - \overline{m}h_b\right)$

$$\therefore\ \overline{m} = \left(\frac{\left(Q_a - Q_b h_a^{0.5}\, h_b^{-0.5}\right)}{C_d\sqrt{2g}h_a{}^{0.5}(h_a - h_b)}\right) \qquad 3\text{-}3$$

So in relation to the calculations made as part of this study, where Q_{RL} was flow and AZP was the pressure, $\overline{m}$ was calculated as follows:

$$\overline{m} = \left(\frac{\left(Q_{RLa} - Q_{RLb}AZP_a^{0.5}\, AZP_b^{-0.5}\right)}{C_d\sqrt{2g}AZP_a{}^{0.5}(AZP_a - AZP_b)}\right)$$

Where C_d was the coefficient of discharge equal to 0,65 (Schwaller and van Zyl, 2014) and g was gravity equal to 9,81m/s^2.

The unit of measure for $\overline{m}$ was m^2/m but often represented in mm^2/m.

3.5.2.3. *Leakage Number (L_N)*

As discussed in Section 2.5, the Leakage Number (L_N) was defined as the ratio between variable and fixed leaks. It can either be derived from the leakage exponent N1 or from other leakage parameters $\overline{m}$, h and A_0 as follows:

Leakage number (L_N) determined from N1:

$$L_N = \frac{N1 - 0.5}{1.5 - N1} \qquad 3\text{-}4$$

Leakage number (L_N) from leakage parameters:

$$L_N = \frac{\overline{m}h}{A_0} \qquad 3\text{-}5$$

$NB:\ h = average\ pressure\ before\ (h_b)\ and\ after\ (h_a)$

The L_N value is a dimensionless quantity and therefore has no unit of measure.

3.5.2.4. *Leak area and initial leak opening ($\overline{A_0}$)*

As discussed in Section 2.5, the estimation of $\overline{A_0}$ can give an indication of leakage opening and also could be used in real water distribution to predict the formation of new leaks in water distribution systems.

Deriving equation for $\overline{A_O}$

The equations to calculate the fixed leakage area ($\overline{A_0}$) was derived from the FAVAD equation:

$$Q = C_d\sqrt{2g}\left(\overline{A_0}h^{0.5} + \bar{m}h^{1.5}\right)$$

$$\frac{Q}{C_d\sqrt{2g}} = \overline{A_0}h^{0.5} + \bar{m}h^{1.5}$$

$$\therefore \overline{A_0} = \frac{Qh^{-0.5}}{C_d\sqrt{2g}} - \bar{m}h \qquad \text{3-6}$$

The unit of measure for $\overline{A_0}$ is m² but is often represented in mm².

3.5.2.5. *Leakage Coefficient (C)*

An investigation of the behaviour of the leakage coefficient C showed that when the leakage exponent approaches infinity, the leakage coefficient approaches zero (Van Zyl, 2017). This is recognised through the equation for the leakage coefficient in Equation 3-7.

$$C = \frac{Q_a}{{h_a}^{N1}} \qquad \text{3-7}$$

The unit of measure for C is $m^{3-\alpha}/s$. Note that α refers to the N1, and is referenced as α instead of N1 in some papers and software (EPANET).

3.6. Calculation Methodologies

3.6.1. Conventional Methodology

The conventional methodology for the determination of all leakage parameters used the measured Average Zone Pressure (h_{AZP}) and the Real Loss Flow (Q_{RL}), before and after pressure management as the pressure and flow inputs. These inputs were provided by the conventional methodology as described by Lambert (2017) for determination of the N1, and were used as the conventional inputs for all calculated parameters. The use of various other inputs for pressure and flow were considered under the Sensitivity Analysis section for each leakage parameter.

3.6.2. Sensitivity Analysis

The sensitivity analysis considered that the conventional methodology used the pressure as from the location of the average zone pressure point (h_{AZP}) and the real loss flow (Q_{RL}), and then used alternate locations from which pressure could be measured as well as alternate flow inputs. Each of these methods were linked to a possible scenario, such as the dominant leak in a PMZ located at the highest point (or Critical Point) in the PMZ rather than the AZP. The lowest point (LP) in the PMZ wasn't provided from the field studies however the pressure at the LP is critical as it provided the extent of the range of pressure, opposite to the CP. As a result, the LP was estimated using the following methodology:

LP = (AZP – CP) + AZP

This resulted in the LP being equal to the difference between the CP and the AZP, but on the reverse side of the AZP and therefore LP presented the location of the highest pressure in the PMZ.

The sensitivity analysis results were then used to consider how conventional results may vary. The various pressure and flow inputs to be used were presented in Table 3-5.

Table 3-5: Pressure and Flow Variables

	Input	**Description**
Pressure	Average Zone Pressure (AZP) location	The pressure at the location that represents the average for the respective PMZ. Refer to Section 3.5.1 for more detail.
	Critical Point (CP) location	Typically the location in the PMZ where the lowest pressure is realized. Refer to Section 3.3.1 for more detail.
	Lowest Point (LP) location	The pressure at the location of the highest pressure in the PMZ. Refer to Section 3.3.1 for more detail.
Flow	Minimum Night Flow (MNF)	The minimum flow into the PMZ during the time of least consumption (00h00 to 03h00). The minimum night flow is the highest of the flows represented as it includes night consumption, real loss flow and background leakage. Refer to Section 3.5.1 for more detail.

	Real Loss Flow (Q_{RL})	The flow attributed to leakage and bursts. The real loss flow is calculated as the summation of the background leakage, the burst leakage and the excess night flow.
	Excess Night Flow (ExNF)	Excess night flow is calculated by adding the night time usage flow and the background leakage, and subtracting both from the minimum night flow. If excess night flow is zero or negative, it indicates there is no leakage in the system.

The pressure and flow variables as per Table 3-5 were used to calculate various versions of the relevant leakage parameters. The various variables as listed in Table 3-5 resulted in 8 unique methodologies to determine the relevant leakage parameter, with exclusion of the conventional methodology. Each methodology consisted of unique combinations of the input variables discussed in Table 3-5. These unique methodologies are presented in Table 3-6, including the respective flow and pressure parameters:

Table 3-6: Various Methodologies Defined by their Inputs

No.	**Methodology Description**	**Pressure Input (h)**	**Flow Input (Q)**
	Conventional (h_{AZP}/Q_{RL})	Average Zone Pressure (AZP)	Real Losses Flow (Q_{RL})
1	Method 1 (h_{CP}/Q_{MNF})	Critical Point (CP)	Minimum Night Flow (MNF)
2	Method 2 (h_{CP}/Q_{RL})	Critical Point (CP)	Real Losses Flow (Q_{RL})
3	Method 3 (h_{CP}/Q_{ExNF})	Critical Point (CP)	Excess Night Flow (ExNF)
4	Method 4 (h_{AZP}/Q_{MNF})	Average Zone Pressure (AZP)	Minimum Night Flow (MNF)
5	Method 5 (h_{AZP}/Q_{ExNF})	Average Zone Pressure (AZP)	Excess Night Flow (ExNF)
6	Method 6 (h_{LP}/Q_{MNF})	Lowest Point (LP)	Minimum Night Flow (MNF)
7	Method 7 (h_{LP}/Q_{RL})	Lowest Point (LP)	Real Losses Flow (Q_{RL})
8	Method 8 (h_{LP}/Q_{ExNF})	Lowest Point (LP)	Excess Night Flow (ExNF)

The sensitivity analysis will discuss the findings of the relevant leakage parameters when calculated using the various pressure and flow inputs as per Table 3-6.

Each leakage parameter was discussed with regards to the findings of the conventional methodology and the sensitivity analysis in the following sections.

4. RESULTS AND DISCUSSION

Following the methodology provided in Section 3, the various pressure-leakage parameters were calculated and an analysis was completed to determine the errors present in measurements and how these errors affect the main leakage parameters. An analysis was also completed to determine the impact of different methods used, particularly for pressure and flow inputs, and how these affected the pressure-leakage parameters.

Furthermore, factors influencing any errors were further investigated and the impact of errors on estimation of pressure-leakage parameters discussed.

4.1. Pressure and Flow Analysis

The pressure and flow inputs contribute significantly to the results of the resultant leakage parameters. Therefore, the range of analysis parameters for flow and pressure were determined and are illustrated to provide understanding of the source information and the distribution of the pressure and flow across the 107 PMZs studied. The results are presented in Figures 4-1 to 4-4.

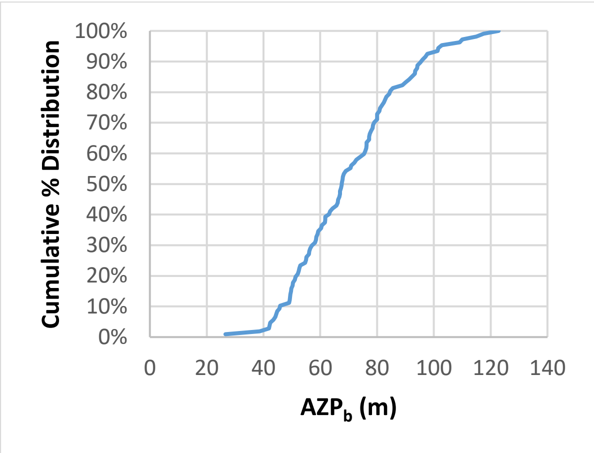

Figure 4-1: AZP_b Cumulative Distribution

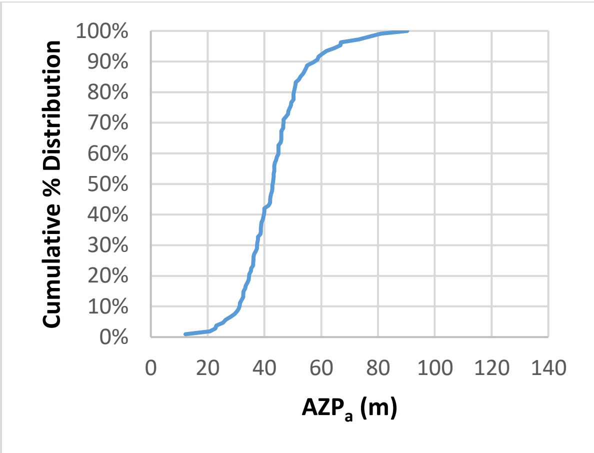

Figure 4-2: AZP_a Cumulative Distribution

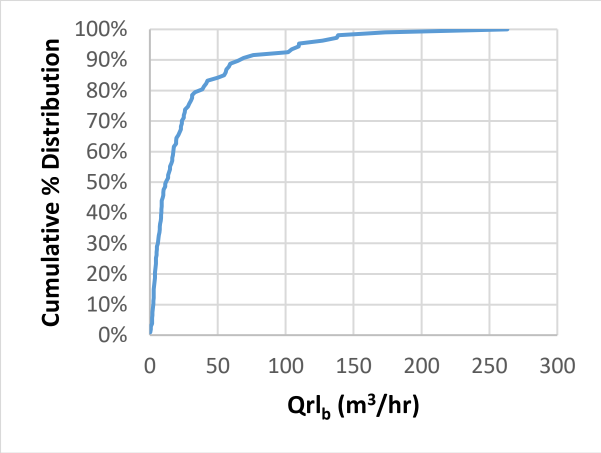

Figure 4-3: Qrl$_b$ Cumulative Distribution

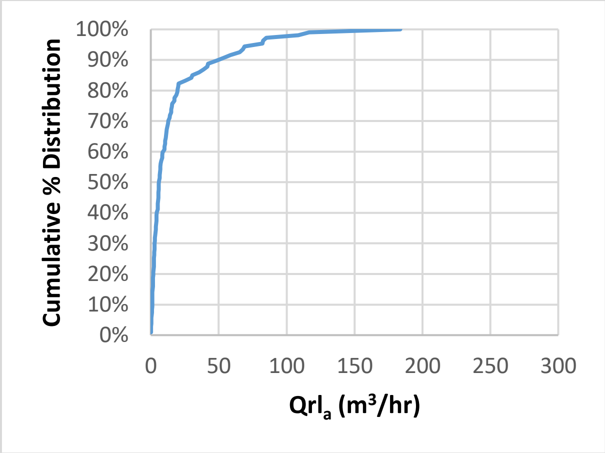

Figure 4-4: Qrl$_a$ Cumulative Distribution

The cumulative distribution graphs of the pressure and flow inputs for the conventional method (h_{AZP}; Q_{RL}) are presented in Figures 4-1 to 4-4. Figure 4-2 shows an increase in AZP figures between 20m and 60m in comparison with Figure 4-1. 93% of calculated AZPs being below 60m after pressure management compared to 36% of calculated AZPs being below 60m before pressure management. Similarly, Figure 4-4 shows an increase in the distribution with 91% of calculated Q_{RL} between 0m^3/hr and 50m^3/hr. Figure 4-3 presents the distribution of Q_{RL} before pressure management and 84% of calculated Q_{RL} are between 0m^3/hr and 50m^3/hr.

4.2. Leakage Parameter Results and Discussion

The leakage parameters were calculated using the standard methodology as detailed in Section 3.5.2, 'Calculation of Leakage Parameters'. This section aims to provide the results of the calculated leakage parameters and discuss the results.

The leakage parameters were determined for each of the PMZs listed in Section 3.4. This Section will present the results of the leakage parameters using a selected conventional methodology and the following will be determined:

- Maximum
- Median
- Average
- Minimum
- Distribution (histogram)
- Cumulative percentage distribution

Following this, the results of a sensitivity analysis using various methodologies for calculating the leakage parameters will be provided.

The results of the various methodologies for the determination of each parameter will then be discussed.

4.2.1. Results: Head-Area Slope ($\bar{m}$)

4.2.1.1. *Conventional Methodology*

Head-area slope ($\bar{m}$) varies depending on the nature of the cracks in the system. The system $\bar{m}$ represents the sum of all the individual leak $\bar{m}$ values. Cassa and van Zyl (2013) determined that the head-area slope is presented in the following equation:

$$\bar{m} = \left(\frac{\left(Q_a - \; Q_b h_a^{0.5} \, h_b^{-0.5}\right)}{C_d\sqrt{2g}{h_a}^{0.5}(h_a - h_b)} \right)$$

From the 107 PMZs analysed, $\bar{m}$ was determined using this equation above and using h_{AZP} and Q_{RL} as the conventional inputs for pressure and flow, the results for $\bar{m}$ values determined is presented in Table 4-1.

Table 4-1 - Summary of $\bar{m}$ Values Using Conventional Methodology (h_{AZP}/Q_{RL})

$\bar{m}$ (mm²/m)	
Max	0,2402
Median	0,0058
Average	0,0189
Min	-0,0835

The results of the $\bar{m}$ values determined for the 107 PMZs cannot be compared to the range for $\bar{m}$ as presented in Table 4-1 as this is relevant to single leaks and the determined $\bar{m}$ values represent the sum of the respective system's $\bar{m}$ values.

The distribution of the $\bar{m}$ values across the sites is represented through a histogram, presented in Figure 4-5.

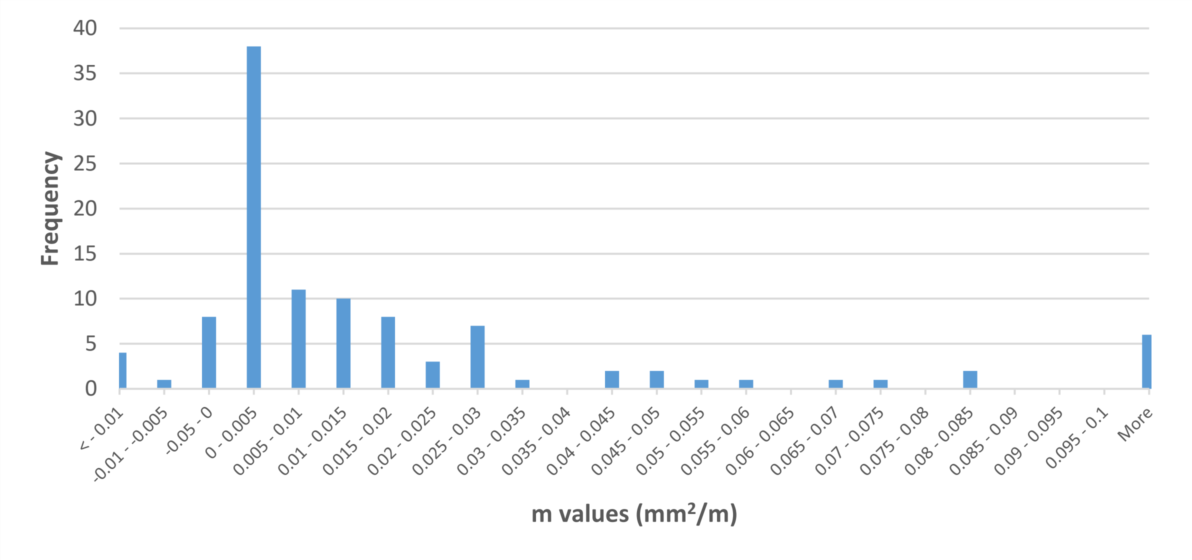

Figure 4-5: Histogram of $\overline{m}$ Values

The histogram for $\overline{m}$ was of a right-skewed distribution. Thirty-eight (38) percent of $\overline{m}$ values were between 0 and 0.005 mm^2/m with approximately twelve (12) percent of $\overline{m}$ values being negative. This indicated that approximately half of the systems analysed had relatively inelastic relationship to pressure, meaning that the change in pressure would not have a great impact on the leak area expansion.

The $\overline{m}$ value distribution was further represented through a cumulative % distribution chart as presented in Figure 4-6.

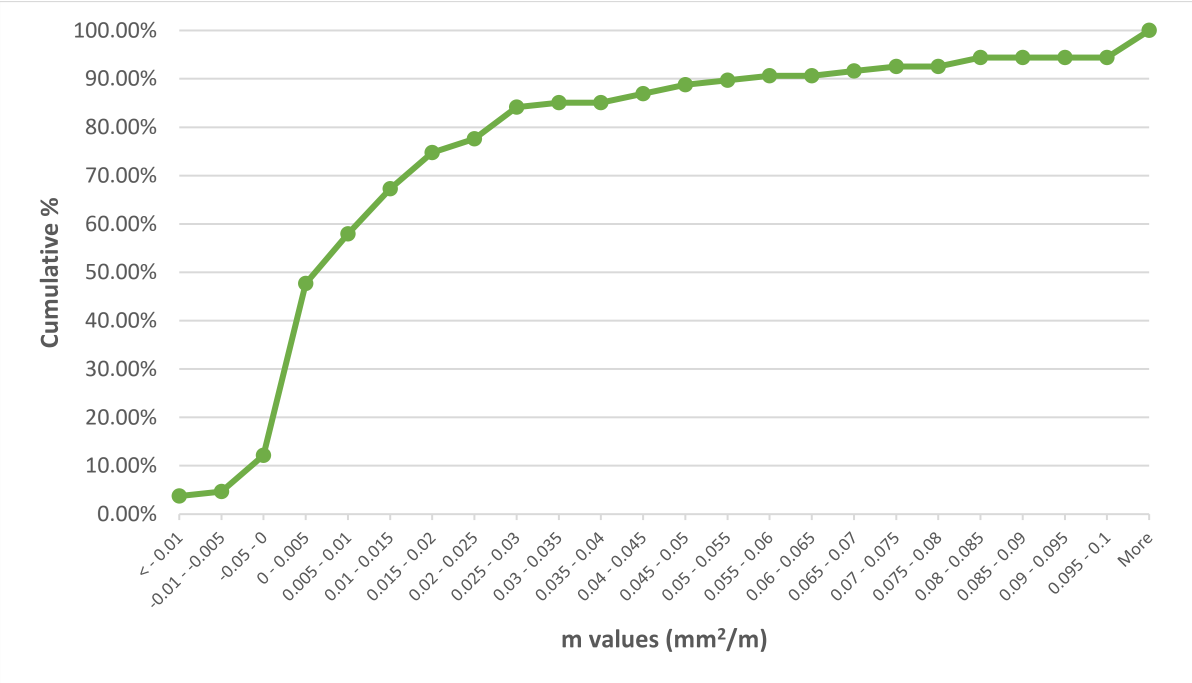

Figure 4-6: Cumulative % Distribution for $\overline{m}$ Values

From Figure 4-6 it is observed that 84% of calculated $\overline{m}$ values were below 0.03mm^2/m, of which 12% were negative.

4.2.1.2. *Sensitivity Analysis*

The sensitivity analysis aimed to use different input parameters for pressure and leakage to determine the respective $\bar{m}$ values for the 107 PMZs, other than the conventional methodology as in Section 4.2.1.1, but will then be compared to the conventional methodology. This provided insight into the sensitivity of the $\bar{m}$ value with respect to the changes in pressure locations (and therefore pressure readings) and flow inputs.

Using the methodologies as discussed in Section 3.6.2, the various inputs were used to determine the $\bar{m}$ values for each method. A five number summary (minimum, quartile 1 (Q1), median, quartile 3 (Q3) and maximum) is provided along with the average and range for each $\bar{m}$ methodology as presented in Table 4-2.

Table 4-2: Results of Sensitivity Analysis using Various Methodologies

	m (AZP/Qrl) (mm²/m)	m (CP/MNF) (mm²/m)	m (CP/Qrl) (mm²/m)	m (CP/ExNF) (mm²/m)	m (AZP/MNF) (mm²/m)	m (AZP/ExNF) (mm²/m)	m (LP/MNF) (mm²/m)	m (LP/Qrl) (mm²/m)	m (LP/ExNF) (mm²/m)
Min	-0.083	-0.095	-0.087	-0.064	-0.014	-0.020	-3.018	-1.262	-2.834
Q1	0.001	-0.003	-0.001	-0.004	0.001	0.000	0.001	0.001	0.000
Median	0.006	0.000	0.001	0.000	0.005	0.002	0.008	0.006	0.004
Q3	0.021	0.009	0.013	0.009	0.021	0.017	0.024	0.023	0.019
Max	0.240	0.302	0.171	0.297	0.357	0.341	1.106	1.174	1.064
Average	0.019	0.010	0.009	0.010	0.023	0.021	0.009	0.021	0.007
Range	0.324	0.397	0.258	0.361	0.371	0.361	4.124	2.436	3.898

The distribution of the results was presented as a box plot and whiskers diagram (Figure 4-7) which presents the distribution of the $\bar{m}$ values based on the 5 number summary (minimum, quartile 1, median, quartile 3 and maximum).

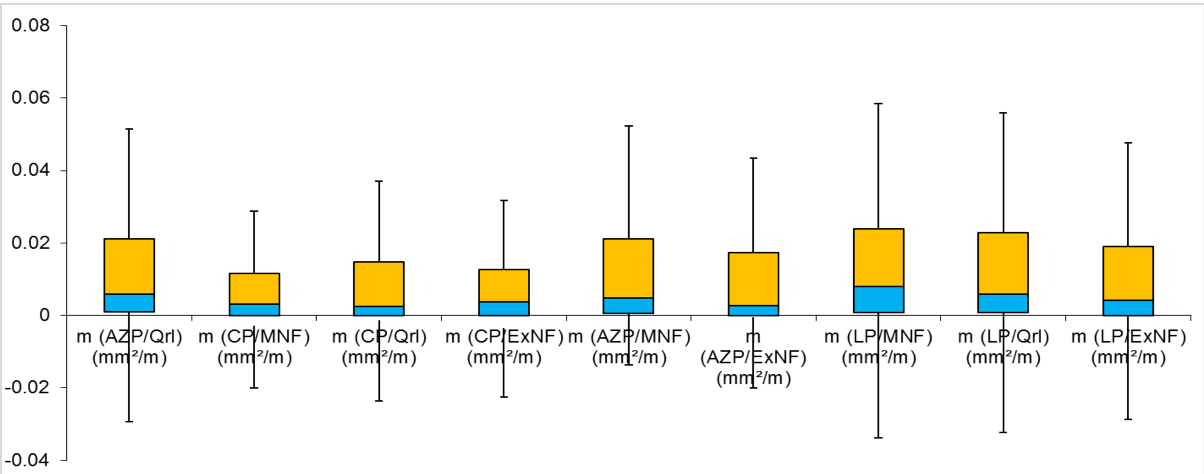

Figure 4-7: Box Plot Diagram (with whiskers) of various methodologies for $\bar{m}$ determination

The distribution of the $\overline{m}$ values for each of the methodologies was presented in Figure 4-8 as a Histogram and in Figure 4-9 as a Cumulative Distribution graph.

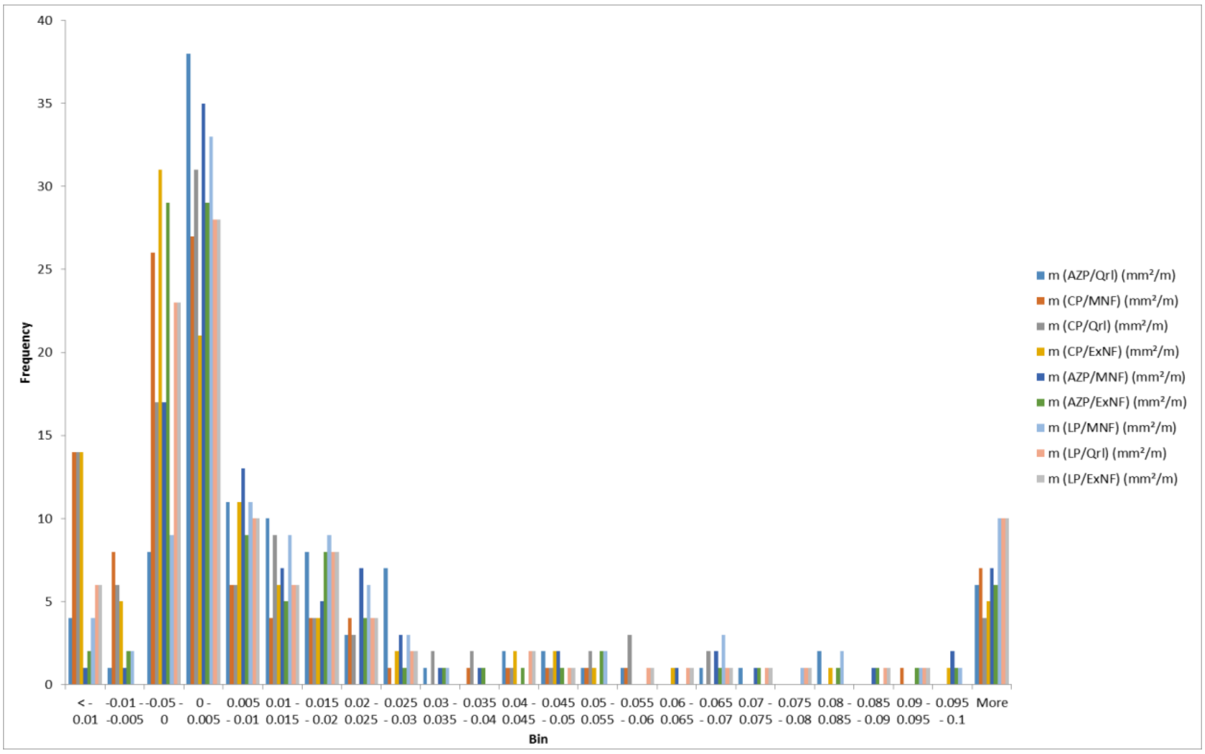

Figure 4-8: Histogram of $\overline{m}$ values for various methodologies

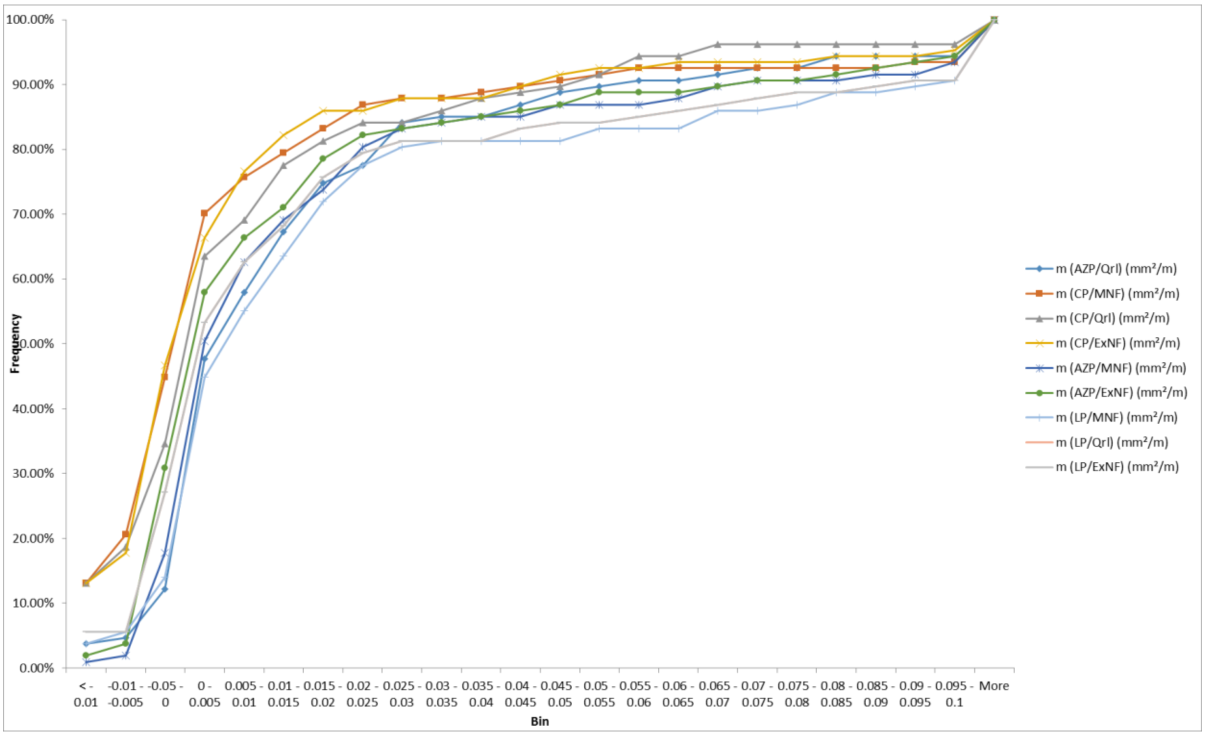

Figure 4-9: Cumulative Distribution of $\overline{m}$ values for various methodologies

Figure 4-7, 4-8 and 4-9 present the distribution of the various methodologies in different ways. From all three figures, it is observed that methodologies using the same pressure inputs (AZP, CP and LP) follow similar patterns of distribution. This is most notable in Figure 4-7 where the ranges of the box plots are similar for the pressure inputs and Figure 4-9 where the trend of distribution follows similar trends for the pressure inputs.

4.2.1.3. *Discussion*

The results for the $\overline{m}$ values determined were difficult to interpret as the $\overline{m}$ values represent the sum of $\overline{m}$ for the system and not necessarily the $\overline{m}$ value of a single leak in the system.

The $\overline{m}$ values for the various methodologies followed similar cumulative distribution patterns based on the pressure input. It was observed in Figure 4-9 that $\overline{m}$ (AZP/MNF), $\overline{m}$ (AZP/Qrl) and $\overline{m}$ (AZP/ExNF) each had very similar cumulative distribution patterns and relatively similar grouping. Similarly the other methodologies with the same pressure inputs had very similar cumulative distribution patterns and similar grouping despite the various flow inputs. This indicated that $\overline{m}$ was predominantly pressure dependent in comparison to flow.

4.2.2. Results: Leakage Area (A_0)

4.2.2.1. *Conventional Methodology*

The leak area (A_0) was defined as the area of the crack where the leak was occurring. For this reason, A_0 should always be greater or equal to zero. The leak area (A_0) was defined by the following equation:

$$\overline{A_0} = \frac{Qh^{-0.5}}{C_d\sqrt{2g}} - \overline{m}h$$

From the 107 PMZs analysed, A_0 was determined using this equation and using h_{AZP} and Q_{RL} as the conventional inputs for pressure and flow. The results for A_0 values determined are presented in Table 4-3.

Table 4-3 - Summary of $\overline{A_0}$ Values Using Conventional Methodology (h_{AZP}/Q_{RL})

A_0 (mm^2)	
Max	9,86
Median	0,06
Average	0,13
Min	-5,68
No. < 0	42

The results of the $\overline{A_0}$ values determined for the 107 PMZs showed that 42 of the 107 PMZs analysed had a negative leakage area using the conventional methodology. Considering the leakage area was the area of the crack where the leak was occurring, this implied that negative $\overline{A_0}$ was impossible. There was however reasons for negative $\overline{A_0}$ as explained by Deyi et al. (2014) which could be:

- measurement errors;
- plastic deformation playing a significant role in the leak behaviour; or
- leaking zone boundary valves.

The distribution of the $\overline{A_0}$ values across the sites was represented through a histogram, presented in Figure 4-10.

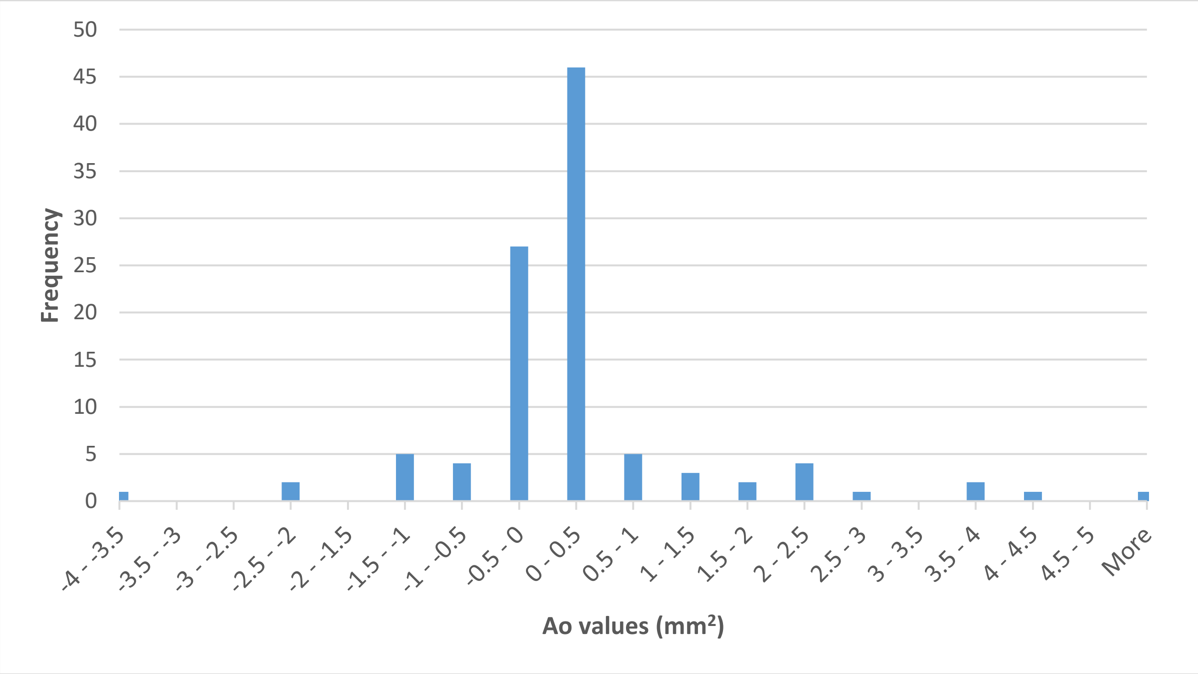

Figure 4-10: Histogram of $\overline{A_0}$ Values

Histograms typically take on a normal or lognormal distribution. The histogram for $\overline{A_0}$ was of a normal distribution with a peak at -0,5mm² < $\overline{A_0}$ < 0,5mm².

The $\overline{A_0}$ value distribution was further represented through a cumulative % distribution chart as presented in Figure 4-11.

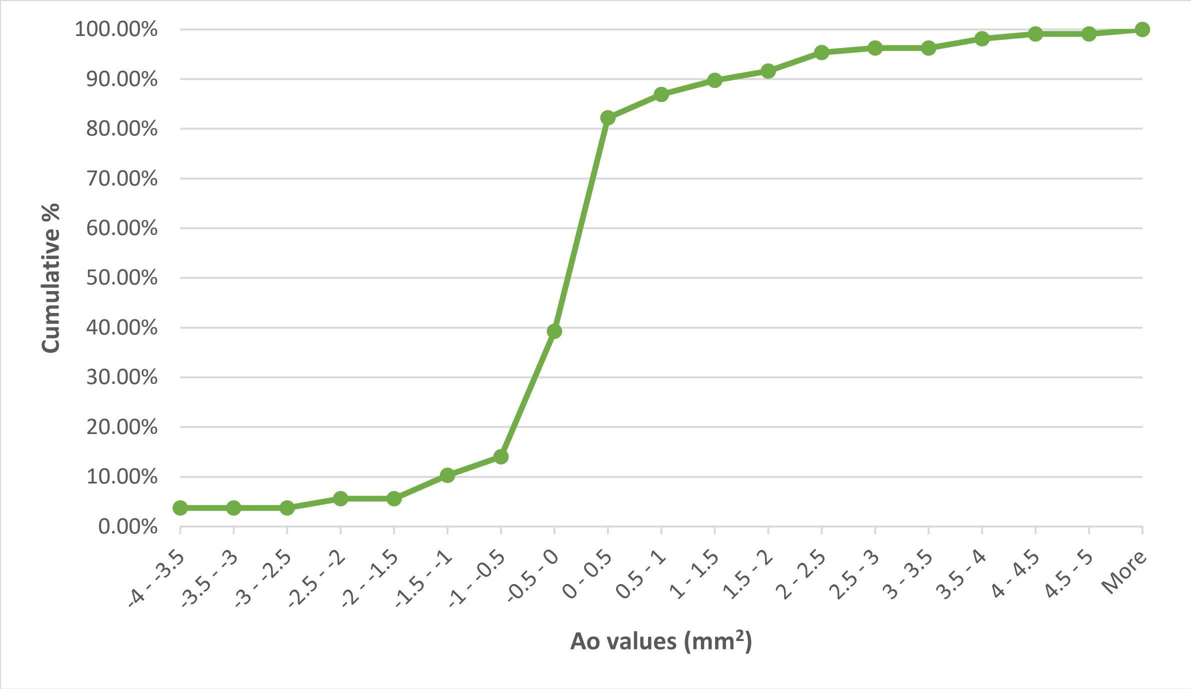

Figure 4-11: Cumulative % Distribution for $\overline{A_0}$ Values

It is observed that most $\overline{A_0}$ values were close to zero with few $\overline{A_0}$ values outside of -0,5 to 0,5 range.

4.2.2.2. *Sensitivity Analysis*

The sensitivity analysis aimed to use different input parameters for pressure and leakage to determine the respective $\overline{A_0}$ values for the 107 PMZs, other than the conventional methodology as in Section 4.2.2.1, but will then be compared to the conventional methodology. This provided insight into the sensitivity of the $\overline{A_0}$ value with respect to the changes in pressure locations (and therefore pressure readings) and flow inputs.

Using the methodologies as discussed in Section 3.6.2, the various inputs were used to determine the various $\overline{A_0}$ values for each method. A 5 number summary (minimum, quartile 1 (Q1), median, quartile 3 (Q3) and maximum) was provided along with the average and range for each $\overline{A_0}$ methodology as presented in Table 4-4.

Table 4-4: Results of Sensitivity Analysis using Various Methodologies

	Ao (AZP/Qrl) (mm²)	Ao (CP/MNF) (mm²)	Ao (CP/Qrl) (mm²)	Ao (CP/ExNF) (mm²)	Ao (AZP/MNF) (mm²)	Ao (AZP/ExNF) (mm²)	Ao (LP/MNF) (mm²)	Ao (LP/Qrl) (mm²)	Ao (LP/ExNF) (mm²)
Min	-5.68	-2.50	-3.66	-2.89	-8.89	-9.35	-62.01	-66.29	-59.82
Q1	-0.17	0.17	0.09	0.05	-0.10	-0.21	-0.81	-1.01	-0.76
Median	0.06	0.56	0.40	0.37	0.14	0.05	-0.01	-0.04	0.01
Q3	0.34	1.54	1.06	1.14	0.43	0.38	0.25	0.16	0.25
Max	9.86	11.89	10.61	9.44	6.03	5.92	172.90	72.28	161.80
Average	0.14	1.37	1.15	1.04	0.14	0.02	0.30	-0.53	0.22
Range	15.54	14.39	14.27	12.33	14.91	15.27	234.91	138.57	221.62

No. of negative Ao values	42	10	17	18	36	44	55	61	52

The distribution of the results was presented as a box plot and whiskers diagram (Figure 4-12) which presents the distribution of the $\overline{A_0}$ values based on the 5 number summary (minimum, quartile 1, median, quartile 3 and maximum).

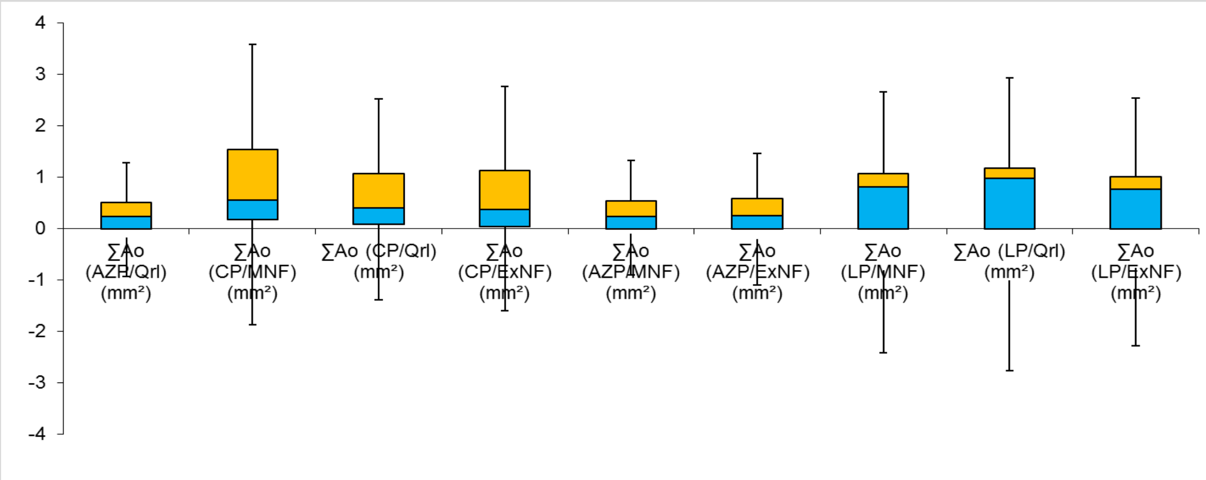

Figure 4-12: Box Plot Diagram of various methodologies for $\overline{A_0}$ determination

The distribution of the $\overline{A_0}$ values for each of the methodologies was presented in Figure 4-13 as a Histogram and in Figure 4-14 as a Cumulative Distribution graph.

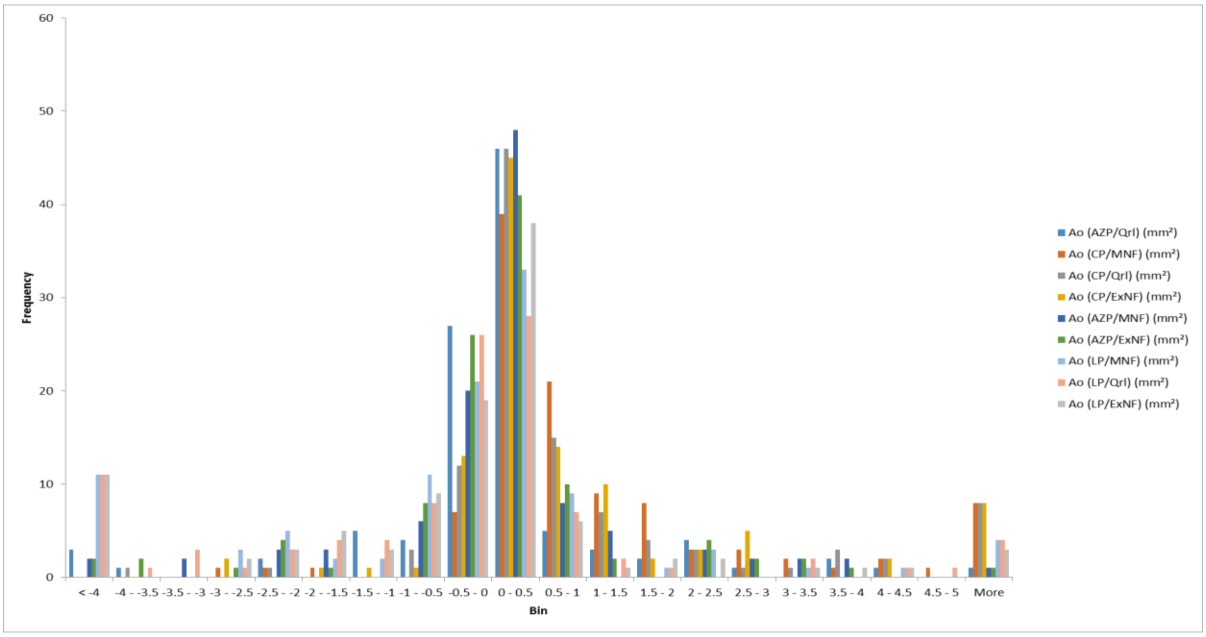

Figure 4-13: Histogram of $\overline{A_0}$ values for various methodologies

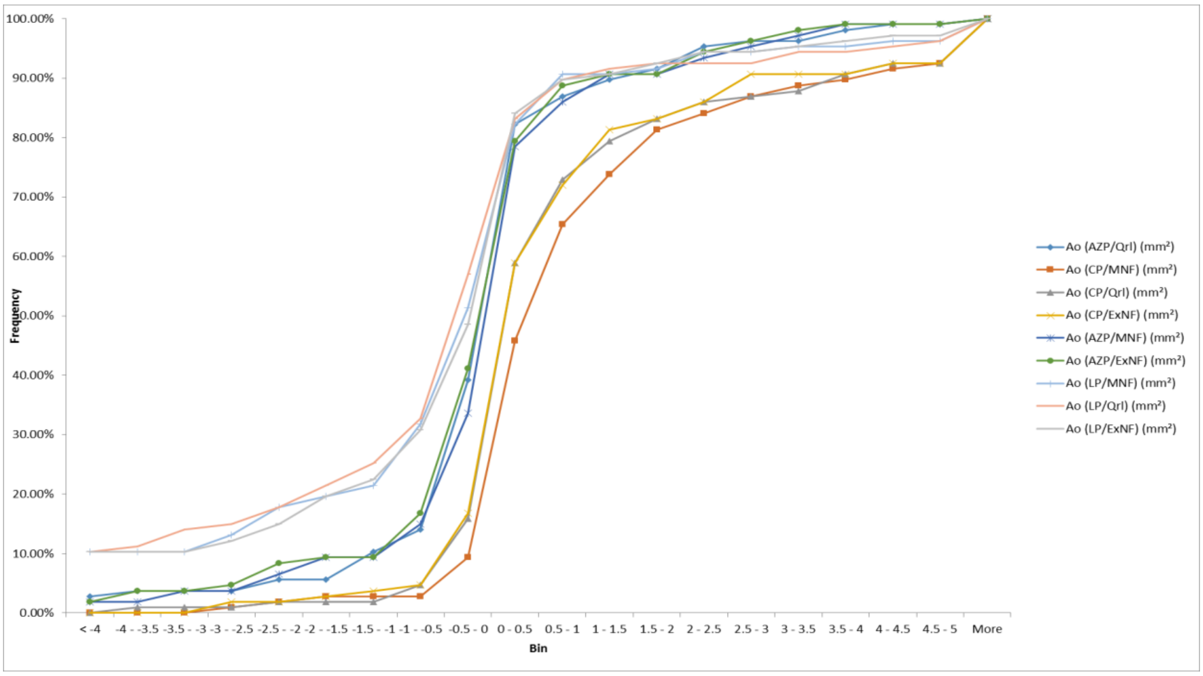

Figure 4-14: Cumulative Distribution of $\overline{A_0}$ values for various methodologies

From the distribution as represented in Figure 4-13 and Figure 4-14, it was evident that methodologies that have LP as the pressure inputs had the most negative $\overline{A_0}$ values. The grouping for the methodologies had a very similar pattern for each of the pressure inputs indicated that pressure had a greater influence over $\overline{A_0}$ values than flow. It was observed that the results for LP pressure inputs (approximately 55% results are negative) were vastly different from the results for CP pressure inputs (approximately 15% results are negative).

4.2.2.3. *Discussion*

The results for the $\overline{A_0}$ values determined were difficult to interpret as the $\overline{A_0}$ values represented the sum of all $\overline{A_0}$ for the system and not necessarily the $\overline{A_0}$ value of a single leak in the system. That being said, a large proportion (39%) of $\overline{A_0}$ values determined using the conventional methodology (h_{azp}/Q_{RL}) were negative. Similar distributions were observed for methodologies that used the same pressure inputs.

4.2.3. Results: Leakage Exponent (FAVAD N1)

4.2.3.1. *Conventional Methodology*

The conventional methodology for determination of the FAVAD N1 used the measured Average Zone Pressure (AZP) and the Real Loss Flow (Q_{RL}), before and after pressure management, as described in Section 3.6.1. In essence, this approach used the average zone pressure as the pressure that characterised the system pressure of the PMZ, and similarly used the real loss flow as the flow that represented the total leakage in the PMZ.

From the 107 PMZs analysed, the FAVAD N1 was determined using this conventional methodology. The summary of results for the FAVAD N1 values determined was presented in Table 4-5.

Table 4-5 - Summary of FAVAD N1 Values Using Conventional Methodology (h_{AZP}/Q_{RL})

FAVAD N1	
Max	6.77
Median	1.39
Average	1.05
Min	-31.88
Total	107
No. within 0,5-1,5	52
% fraction within 0,5-1,5	49%

The results of the N1 values determined for the 107 PMZs differ from the notion that N1 values fall within the range of 0,5 to 1,5. A total of 55 determined N1 values were outside of this range which equates to 51%. The average N1 value was 1,05 and median for the dataset was 1,39. The determined N1 values range from -31,88 to 6,77 but these are outliers thus if these two were removed, the range would be -0.34 to 2,20. These results, whilst different, can be compared to previously published findings as per Section 2.7 where Puust et al. (2010) established a range of 0,36 to 2,95 for N1 in various countries but significantly different to results published by Gebhardt (1975) who established a range of 0,52 to 1,02.

Following this initial analysis, the N1 values that fell between 0,5 and 1,5 were analysed as a separate dataset. The summary of results was presented in Table 4-6.

Table 4-6 - Summary of N1 Values for $0,5 \leq N1 \geq 1,5$

N1	
Average	1,11
Median	1,07

For the N1 values that fall within the 0,5 and 1,5 range, the average was determined to be 1,11 and the median 1,07.

The distribution of the N1 values across the sites was represented through a histogram, presented in Figure 4-15.

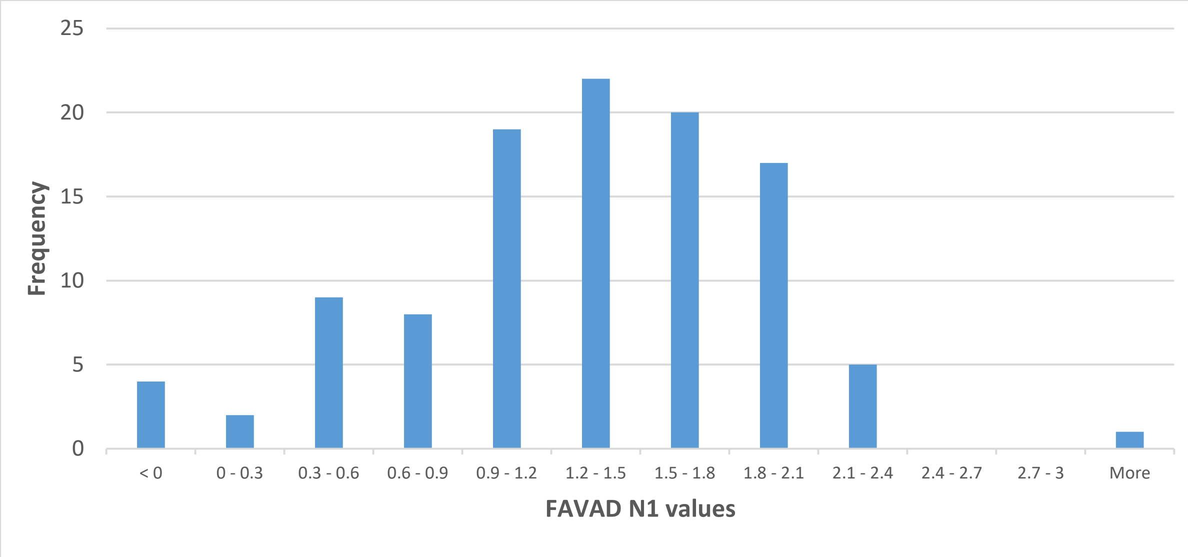

Figure 4-15: Histogram of N1 Values

For N1, a normal distribution is expected with peak at N1=1 which is considered an average N1 value for mixed material distribution networks. Figure 4-15 presents a left-skewed histogram with a peak frequency of N1 between 1,2 and 1,5. The majority of N1 values determined fell between 0.3 and 2.1 (93%). A total of 77 N1 values were determined to be greater than 1 which amounts to 72% of total N1 values determined.

The N1 distribution was further represented through a cumulative % distribution chart as presented in Figure 4-16.

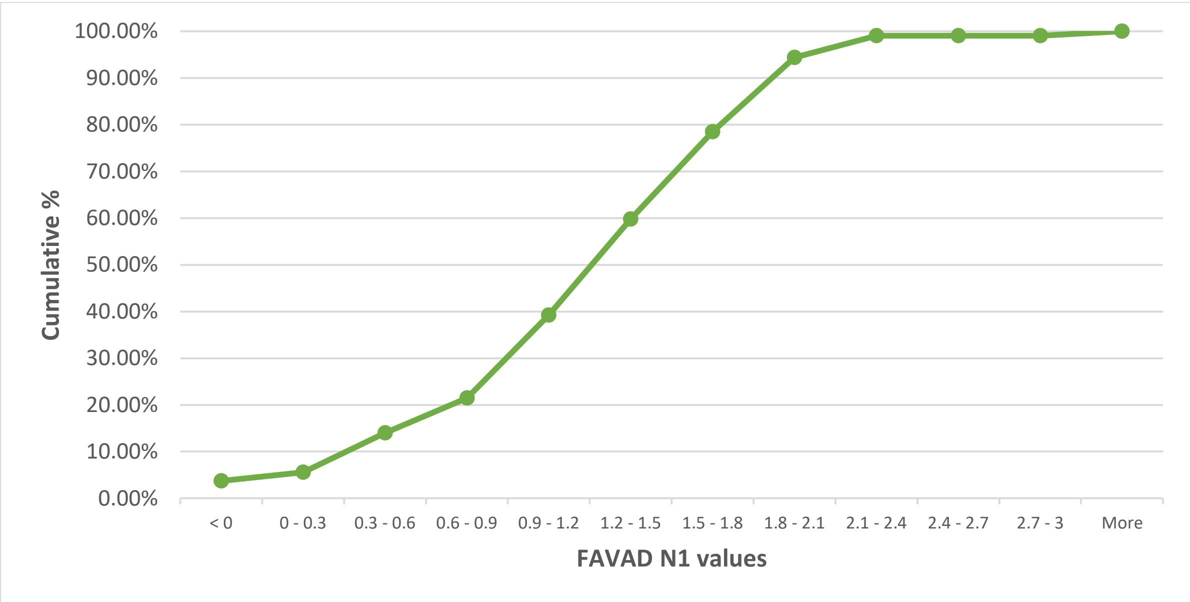

Figure 4-16: Cumulative % Distribution for N1 Values

4.2.3.2. *Sensitivity Analysis*

The sensitivity analysis aimed to use different input parameters for pressure and leakage to determine the respective N1 values for the 107 PMZs, other than the conventional methodology as in Section 4.2.3.1, but will then be compared to the conventional methodology. This provided insight into the sensitivity of the N1 value with respect to the changes in pressure locations (and therefore pressure readings) and flow inputs.

The various inputs were used to determine the various N1 values for each method. A 5 number summary (minimum, quartile 1 (Q1), median, quartile 3 (Q3) and maximum) was provided along with the average and range for each N1 methodology as presented in Table 4-7.

Table 4-7: Results of Sensitivity Analysis using Various Methodologies

	FAVAD N1 (h_{AZP}/Q_{RL})	FAVAD N1 (h_{CP}/Q_{MNF})	FAVAD N1 (h_{CP}/Q_{RL})	FAVAD N1 (h_{CP}/Q_{ExNF})	FAVAD N1 (h_{AZP}/Q_{MNF})	FAVAD N1 (h_{AZP}/Q_{ExNF})	FAVAD N1 (h_{LP}/Q_{MNF})	FAVAD N1 (h_{LP}/Q_{RL})	FAVAD N1 (h_{LP}/Q_{ExNF})
Min	-31.89	-1.28	-8.43	-1.90	-0.29	-1.69	-0.35	-0.40	-1.60
Q1	0.96	0.11	0.16	-0.25	0.72	0.47	1.01	1.24	0.77
Median	1.39	0.56	0.89	0.62	1.27	1.32	1.61	1.69	1.67
Q3	1.74	1.10	1.21	1.25	1.61	1.76	1.97	2.12	2.08
Max	6.77	2.08	11.01	1.99	2.10	2.21	5.80	15.85	4.75
Average	1.05	0.56	0.75	0.50	1.17	1.06	1.55	1.79	1.40
Range	38.65	3.35	19.44	3.89	2.39	3.90	6.15	16.26	6.34

The distribution of the results was presented as a box plot and whiskers diagram (Figure 4-17) which presents the distribution of the N1 values based on the 5 number summary (minimum, quartile 1, median, quartile 3 and maximum).

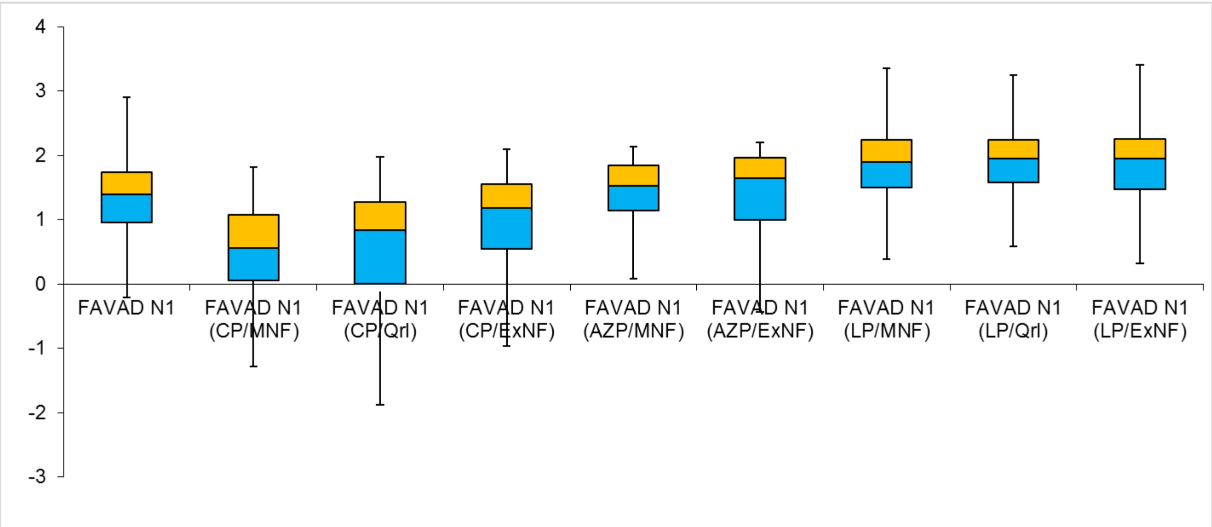

Figure 4-17: Box Plot Diagram of various methodologies for N1 determination

The distribution of the N1 values for each of the methodologies was presented in Figure 4-18 as a Histogram and in Figure 4-19 as a Cumulative Distribution graph.

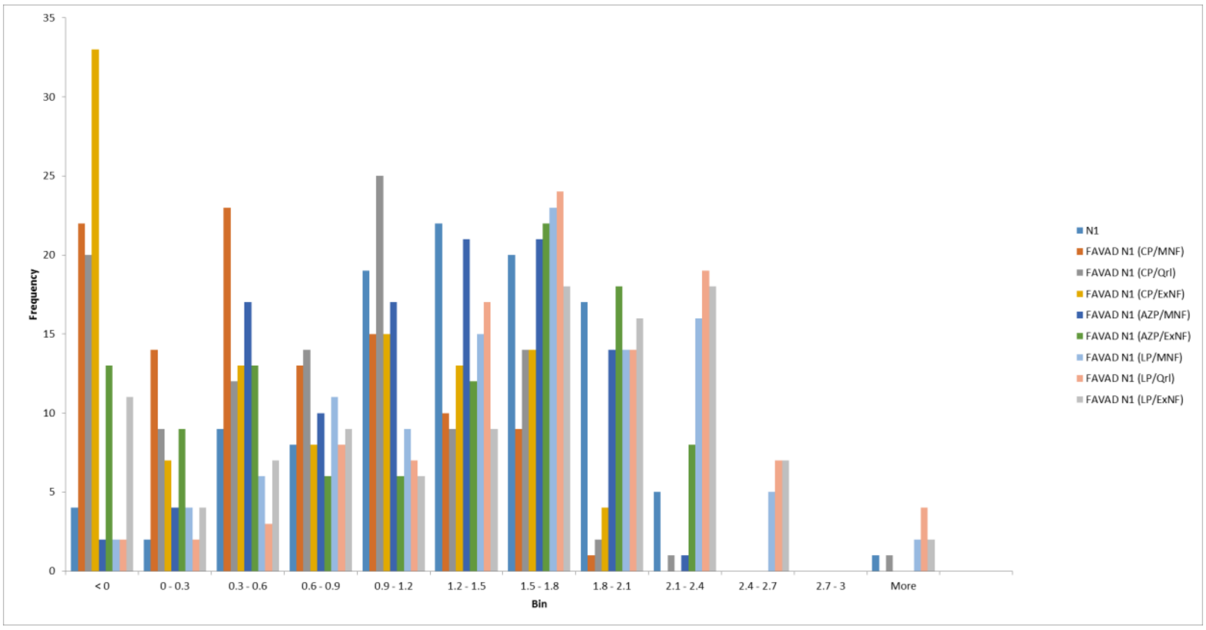

Figure 4-18: Histogram of FAVAD N1 values for various methodologies

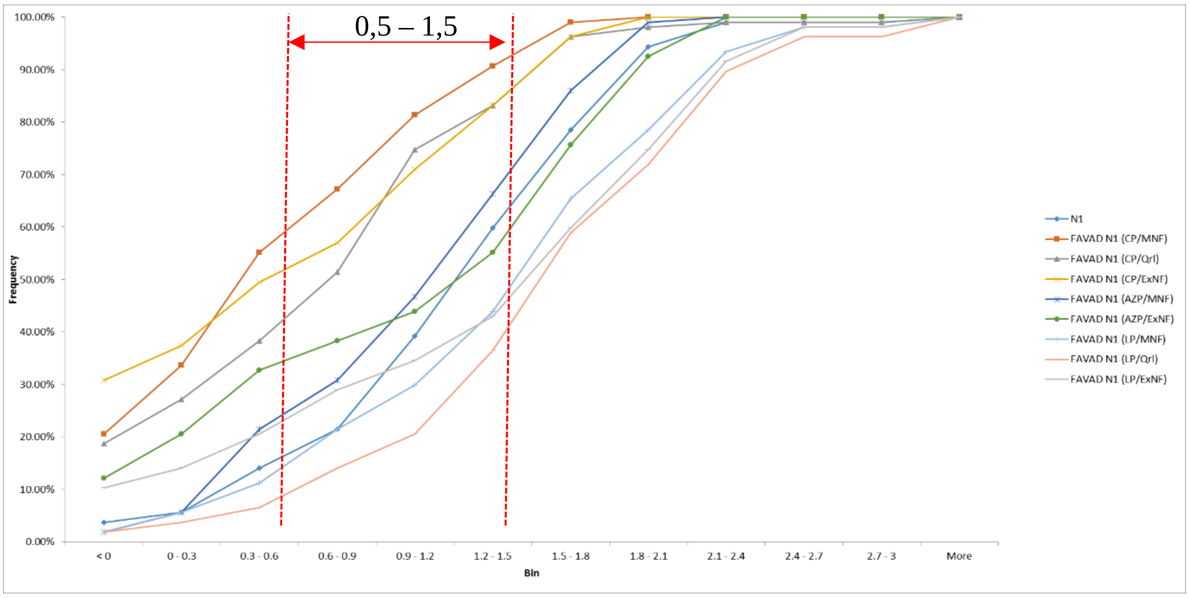

Figure 4-19: Cumulative Distribution of FAVAD N1 values for various methodologies

From Figure 4-17, Figure 4-18 and Figure 4-19, it is evident that each methodology produces FAVAD N1 values that fall outside of the 0,5 to 1,5 range. It was observed that the methodologies with the same pressure inputs followed the same trends/groupings regardless of the flow inputs. This showed that the FAVAD N1 is predominantly pressure dependent.

From Figure 4-17, it was observed that the overall results for the boxplots for the CP locations were considerably lower than the boxplots for the LP locations.

4.2.3.3. *Discussion*

The results for the FAVAD N1 values determined using the conventional methodology and the variations to this as described in the sensitivity analysis sections provided similarities to the published findings for N1 values. Published findings, as per Section 2.7, show N1 value range between 0.36 and 2.95 (Puust. et al., 2010). Using the conventional method, it was found that the determined N1 values across the 107 PMZs fell within the 0,5 to 1,5 range 49% of the time and the average N1 value across the 107 PMZs was 1,05. More importantly, the minimum N1 value, when excluding the outliers, determined was -0,22 and the maximum was 2.14 which are similar to the published N1 ranges. However it is important to note that the outliers are important in establishing problems, such as a high N1 value can be the result of an error in data collection or a physical error with the zone such as an open boundary valve.

4.2.4. Results: Leakage Number (L_N)

4.2.4.1. *Conventional Methodology*

The leak number (L_N) was defined as the ratio between variable and fixed leaks. It could either be derived from the leakage exponent N1 or from other leakage parameters $\overline{m}$, h and $\overline{A_0}$.

From the 107 PMZs analysed, L_N was determined and using h_{AZP} and Q_{RL} as the conventional inputs for pressure and flow, the results for L_N values determined is presented in Table 4-8.

Table 4-8 - Summary of L_N Values Using Conventional Methodology (h_{AZP}/Q_{RL})

L_N	
Median	-0,03
Average	2.66
Min	-86.62
Max	410.47

The results of the L_N values determined for the 107 PMZs showed that the median for all L_N values determined was approximately 0. To determine the spread of L_N values, a histogram is presented in Figure 4-20.

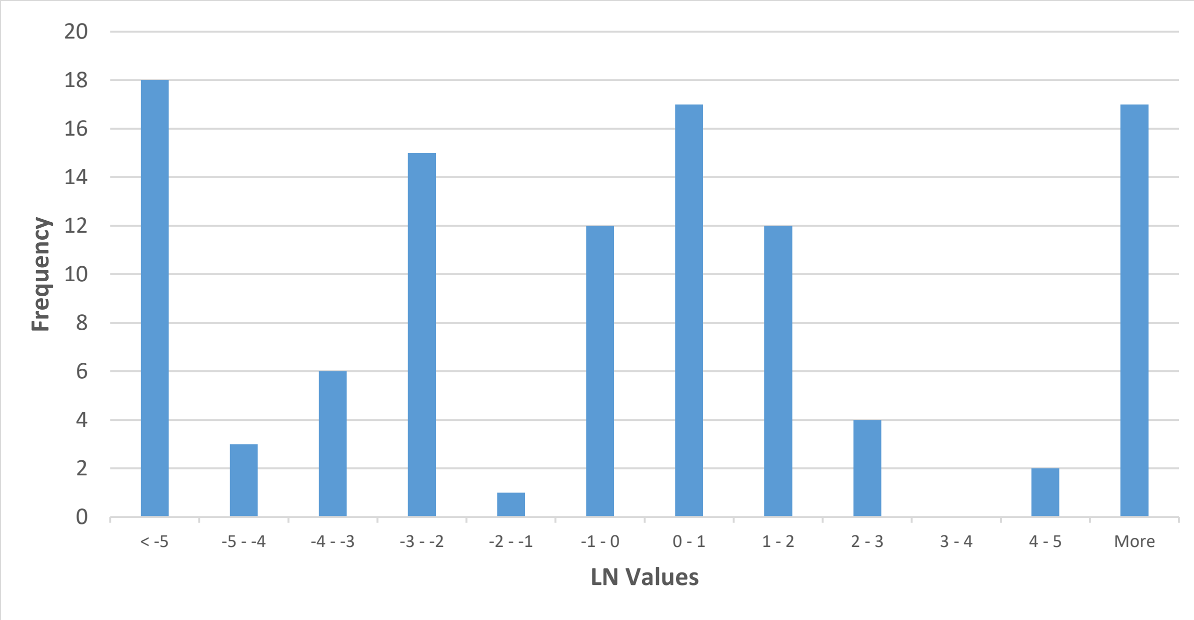

Figure 4-20: Histogram of L_N Values

The histogram for L_N had a left-skewed distribution with three peaks, when $L_N < -5$, when $0 < L_N < 1$ and when $L_N > 5$.

The L_N value distribution was further represented through a cumulative % distribution chart as presented in Figure 4-21.

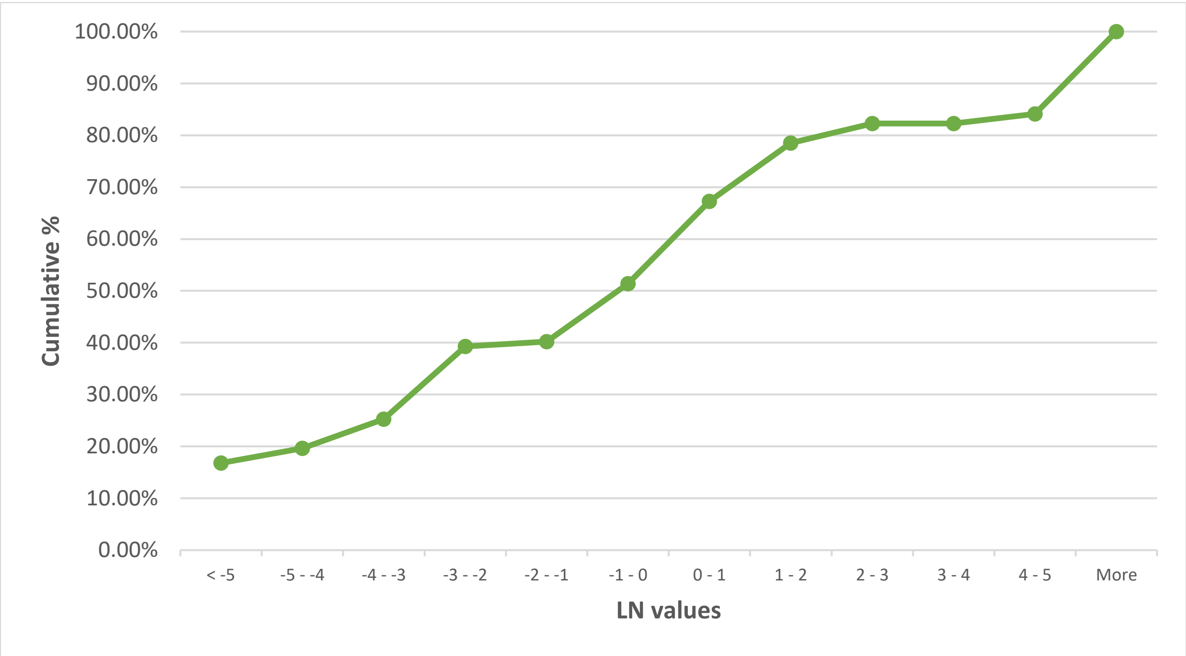

Figure 4-21: Cumulative % Distribution for L_N Values

Figure 4-21 presents the cumulative % distribution graph for L_N values. It is observed that the majority (62%) of L_N values fall between -5 and 3. It is also observed that there is minimal values that fall between -3 and -1.

4.2.4.2. *Sensitivity Analysis*

The sensitivity analysis aimed to use different input parameters for pressure and leakage to determine the respective L_N values for the 107 PMZs, other than the conventional methodology as in Section 4.2.4.1, but was then compared to the conventional methodology. This provided insight into the sensitivity of the L_N value with respect to the changes in pressure locations (and therefore pressure readings) and flow inputs.

Using the methodologies as discussed in Section 3.6.2, the various inputs were used to determine the various L_N values for each method. A 5 number summary (minimum, quartile 1 (Q1), median, quartile 3 (Q3) and maximum) was provided along with the average and range for each L_N methodology as presented in Table 4-9.

Table 4-9: Results of Sensitivity Analysis using Various Methodologies

	LN (AZP/Qrl)	LN (CP/MNF)	LN (CP/Qrl)	LN (CP/ExNF)	LN (AZP/MNF)	LN (AZP/ExNF)	LN (LP/MNF)	LN (LP/Qrl)	LN (LP/ExNF)
Min	-86.6	-36.3	-294.0	-428.4	-80.8	-2159.4	-86.8	-149.4	-771.2
Q1	-3.0	-0.4	-0.5	-0.6	-3.2	-3.7	-3.8	-4.1	-3.3
Median	0.0	0.0	0.0	-0.3	0.0	-0.5	-2.1	-2.2	-2.1
Q3	1.5	0.6	0.8	0.8	1.4	0.1	0.6	0.3	0.0
Max	410.5	675.5	13.8	39.1	28.1	24.7	29.4	158.6	22.7
Average	2.7	6.9	-3.2	-4.5	-1.4	-25.4	-2.1	-2.6	-8.7
Range	497.1	711.8	307.9	467.5	108.8	2184.1	116.2	308.0	794.0

The distribution of the results was presented as a box plot and whiskers diagram (Figure 4-22) which presents the distribution of the L_N values based on the five number summary (minimum, quartile 1, median, quartile 3 and maximum).

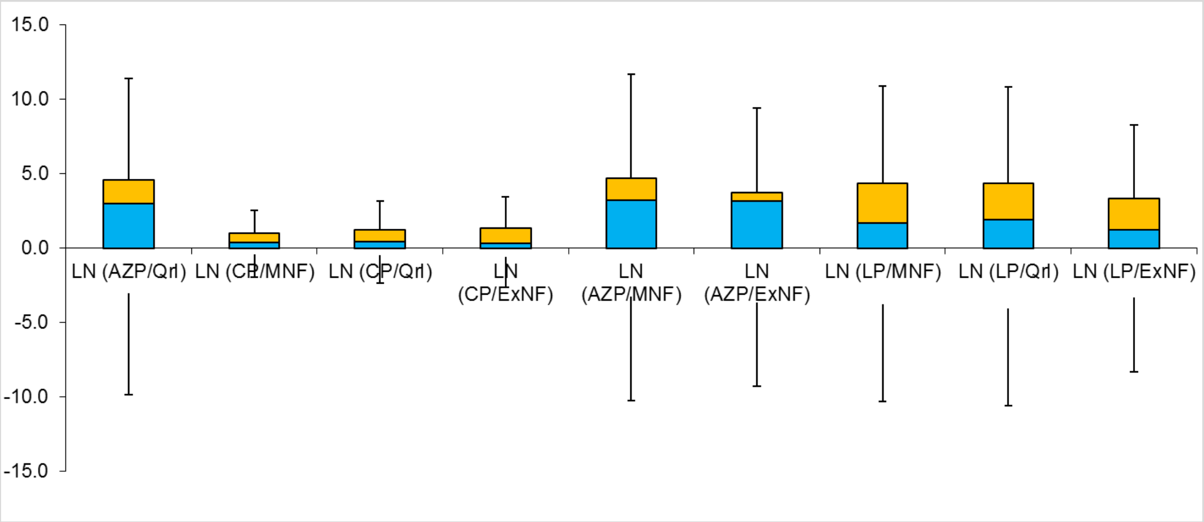

Figure 4-22: Box Plot Diagram of various methodologies for L_N determination

The distribution of the L_N values for each of the methodologies is presented in Figure 4-23 as a Histogram and in Figure 4-24 as a Cumulative Distribution graph.

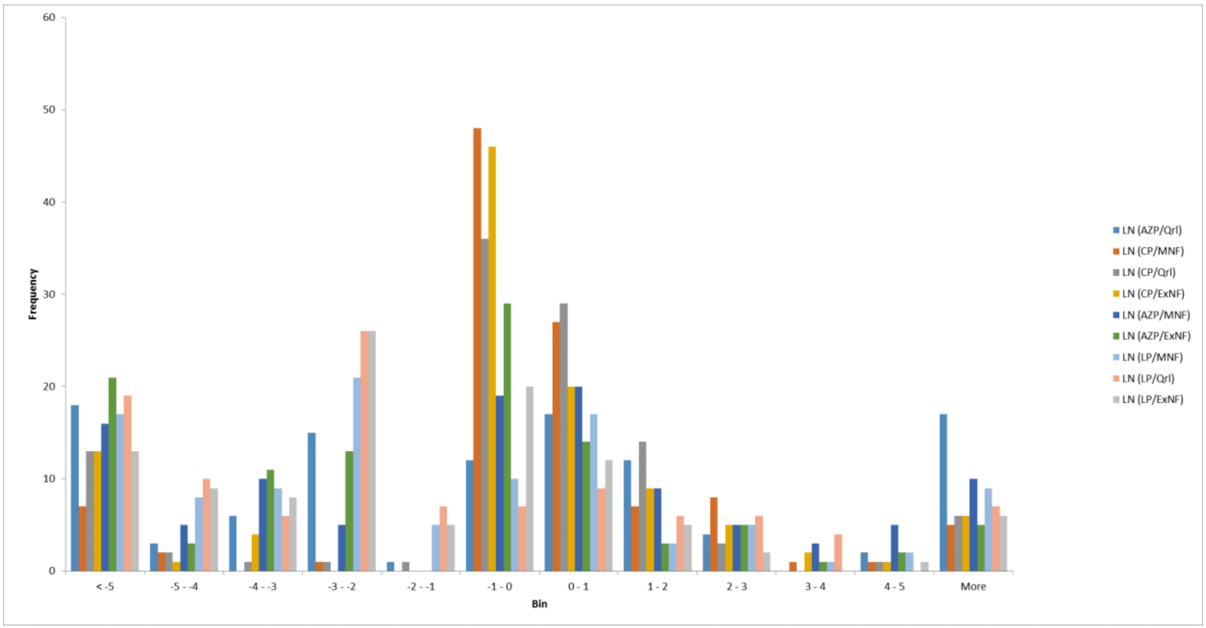

Figure 4-23: Histogram of L_N values for various methodologies

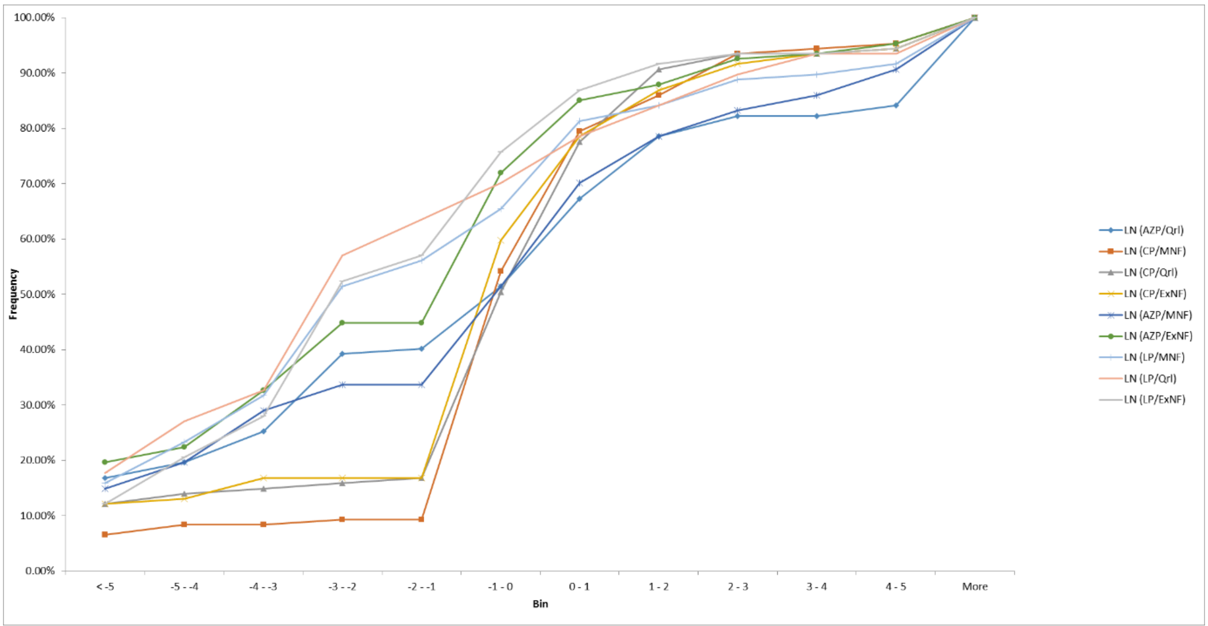

Figure 4-24: Cumulative Distribution of L_N values for various methodologies

From the distribution as represented in Figure 4-23 and Figure 4-24, the majority of methodologies used have an even distribution of negative and positive L_N values.

4.2.4.3. *Comparison of L_N using Leakage Parameters and Conventional N1*

The leakage number, calculated using the modified orifice equation, and the conventional leakage exponent N1, were plotted for the 107 PMZs to distinguish the relationship. The results are presented in Figure 4-25.

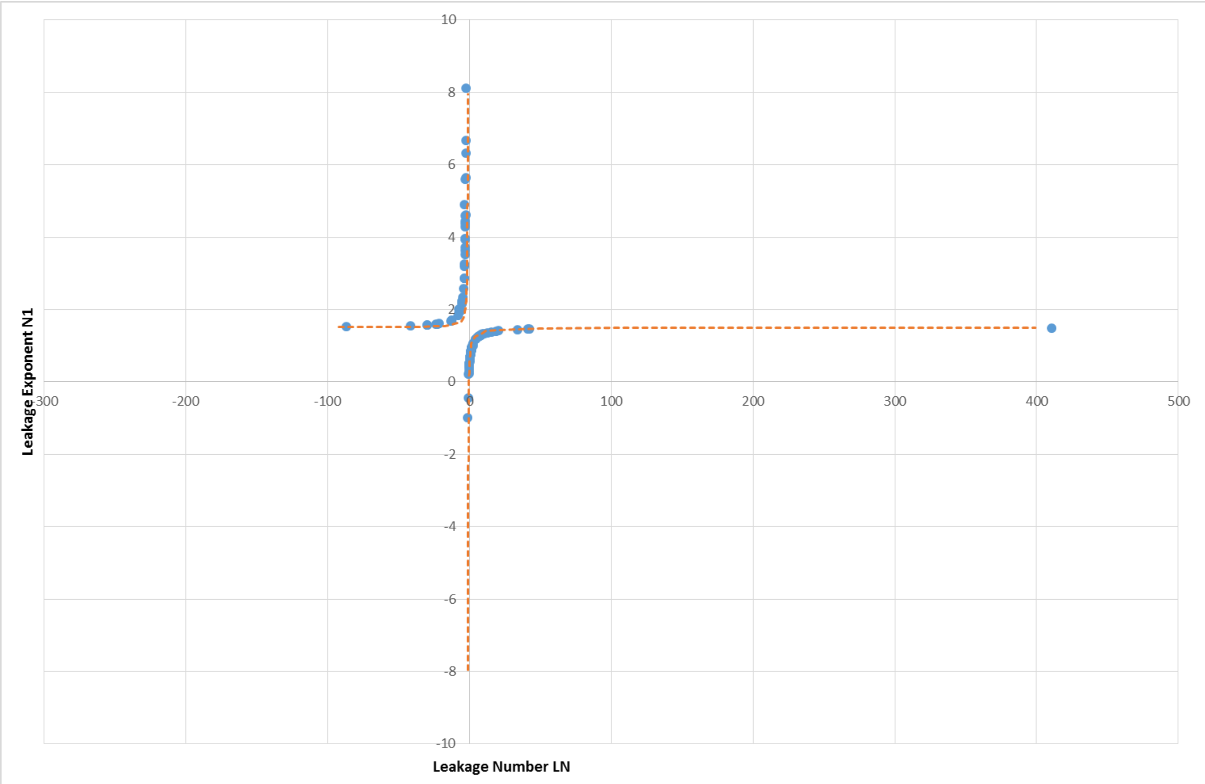

Figure 4-25: Relationship between Leakage Number and Leakage Exponent for 107 PMZs

It is observed in Figure 4-25 that the leakage number as calculated from the modified orifice equation follows the theoretical trend of the leakage number vs leakage exponent very closely and conforms to hyperbolic function with asymptotes of N1=1,5 and LN=-1.

4.2.4.4. *Discussion*

The methodologies that used the same pressure inputs follow similar trends of distribution regardless of the various flow inputs. This provided evidence that L_N was influenced by pressure more than flow.

4.2.5. Results: Infrastructure Leakage Index (ILI)

4.2.5.1. *Conventional Methodology*

The conventional methodology for the determination of the Infrastructure Leakage Index (ILI) was expressed as the following:

$$ILI = \frac{CARL}{UARL}$$

The conventional methodology for determination of ILI was defined, and as such, only h_{AZP} and Q_{RL} (before and after pressure management) were used, therefore a sensitivity analysis for different pressure and flow inputs was not undertaken. However, a comparison between the ILI determined before

Pressure Management (PM) and after Pressure Management (PM) was completed. Table 4-10 provides the results of the comparison.

Table 4-10: Comparison of ILI before and after PM

	ILI Before PM	ILI After PM
Max	93.6	141.3
Median	9.7	7.5
Average	13.5	11.9
Min	0.7	0.7
No. < 1	1	1
No. > 10	49	44
Avg. % ILI reduction after PM	9%	
No. ILI increased after PM	42	
% ILI increased after PM	39%	

4.2.5.1. *Discussion*

Table 4-10 showed a reduction in ILI as a result of pressure management such that the ILI had reduced by 9% on average across the 107 PMZs. It was observed that the ILI decreased for 65 PMZs after pressure management as compared to before pressure management. This represented 61% of the PMZs. Therefore the reduction in pressure, which decreased water losses in the PMZ, had a negative effect for 39% of the PMZs if measured using the ILI.

4.3. Relationship between Leakage Parameters

The determination of the relevant leakage parameters in a zone can provide significant information on the leakage and leakage-pressure relationship in the zone. Further information may be collected from the relationship between the determined leakage parameters. This section aimed to examine the relationship between leakage parameters, specifically for leakage parameter values that fall in certain ranges, and the resultant significance. The analysis considered the leakage parameters using the conventional methodology.

In order to observe trends or patterns in the relationship between parameters, two outliers were removed from the dataset (Zone 60 and Zone 61).

4.3.1. Head-Area Slope ($\overline{m}$) and Leakage Area ($\overline{A_0}$)

The relationship between the head-area slope and leakage area values using the conventional methodology for the 105 zones (two zones were excluded) is presented in Figure 4-25.

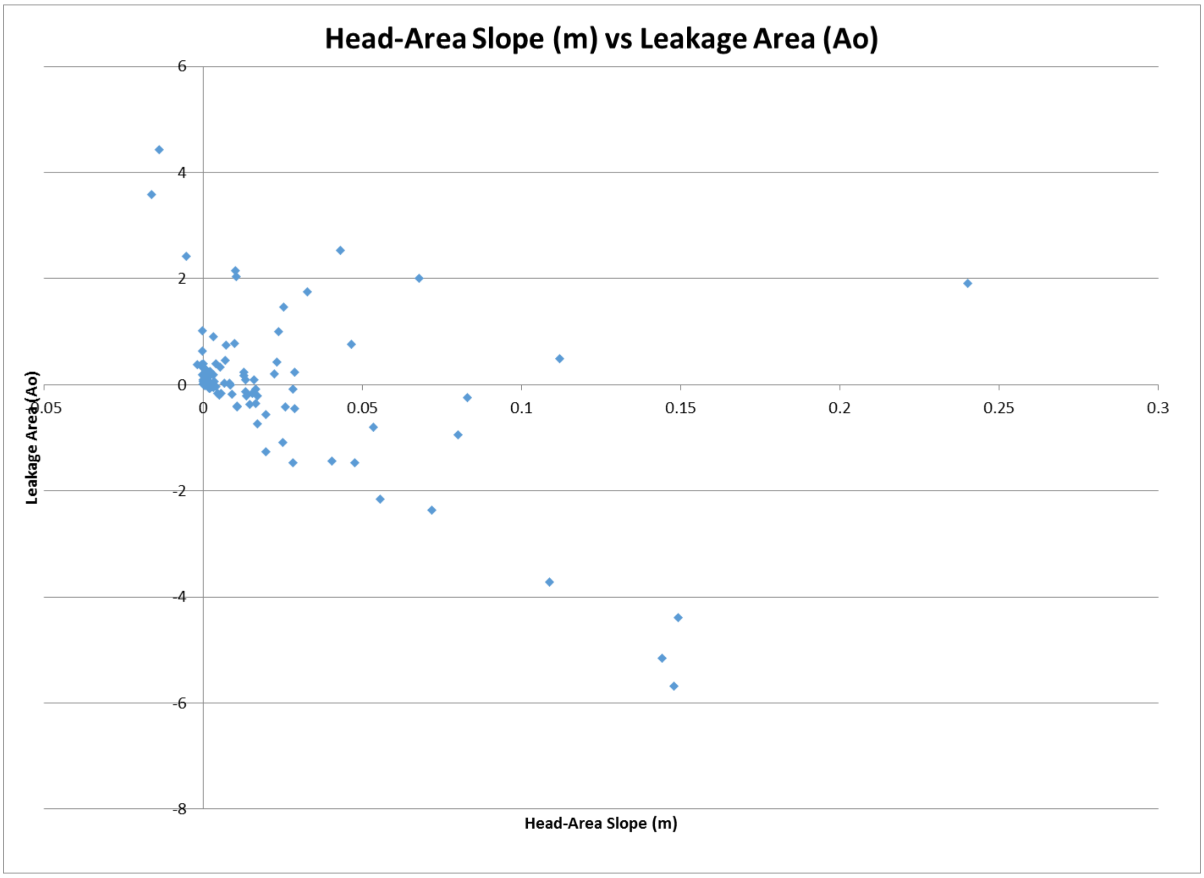

Figure 4-26: Head-Area Slope vs Leakage Area

Figure 4-25 showed no significant relationship between the head-area slope values and the leakage area values.

4.3.2.Head-Area Slope ($\bar{m}$) and Leakage Exponent (N1)

The relationship between the head-area slope and leakage exponent values using the conventional methodology for the 105 zones (two zones were excluded) is presented in Figure 4-26.

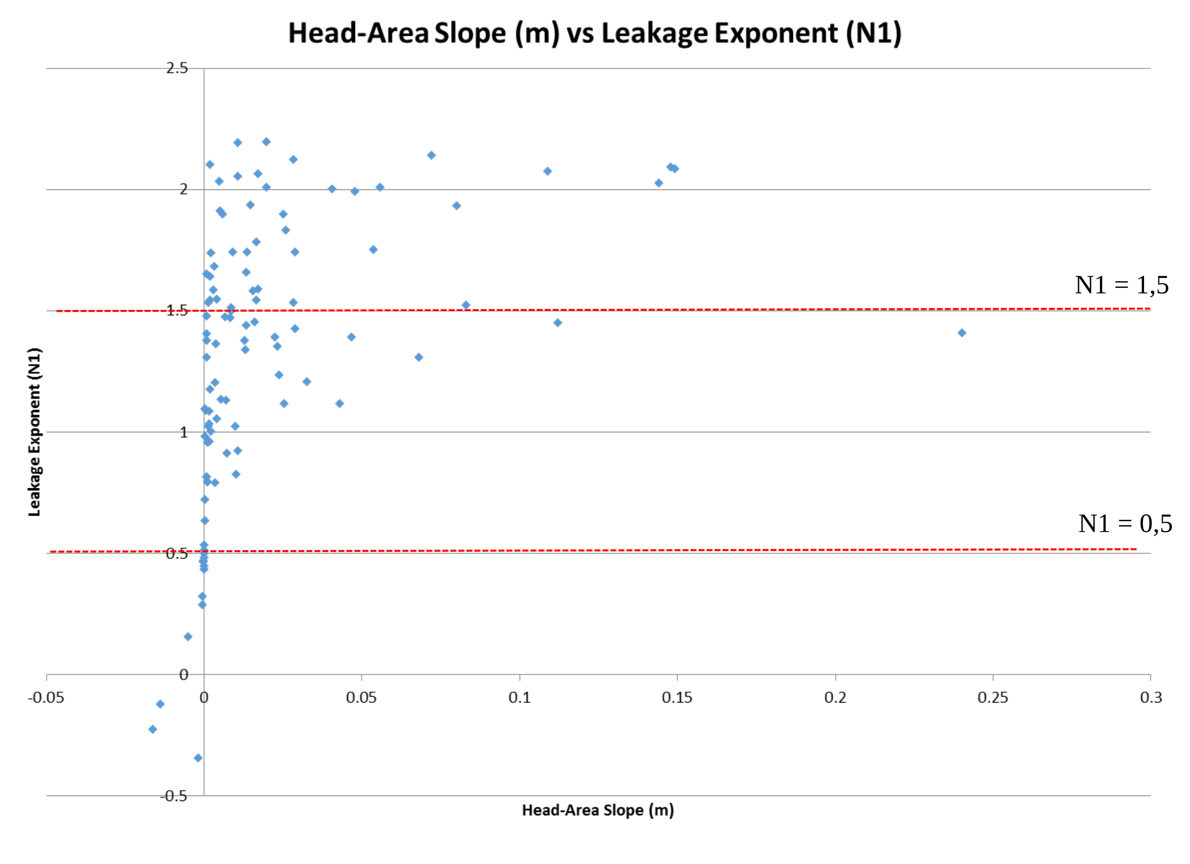

Figure 4-27: Head-Area Slope vs Leakage Exponent

From Figure 4-26, it was observed that for all negative $\overline{m}$ values determined, the respective leakage exponent (N1) value was always less than 0,5. Only 12 zones had N1 values less than 0,5 from the 105 zones analysed (Zone 60 and Zone 61 were excluded as they were outliers), of which all 12 had a corresponding negative $\overline{m}$ value.

4.3.3.Head-Area Slope ($\overline{m}$) and Leakage Number (L_N)

The relationship between the head-area slope and leakage number values using the conventional methodology for the 105 zones is presented in Figure 4-27.

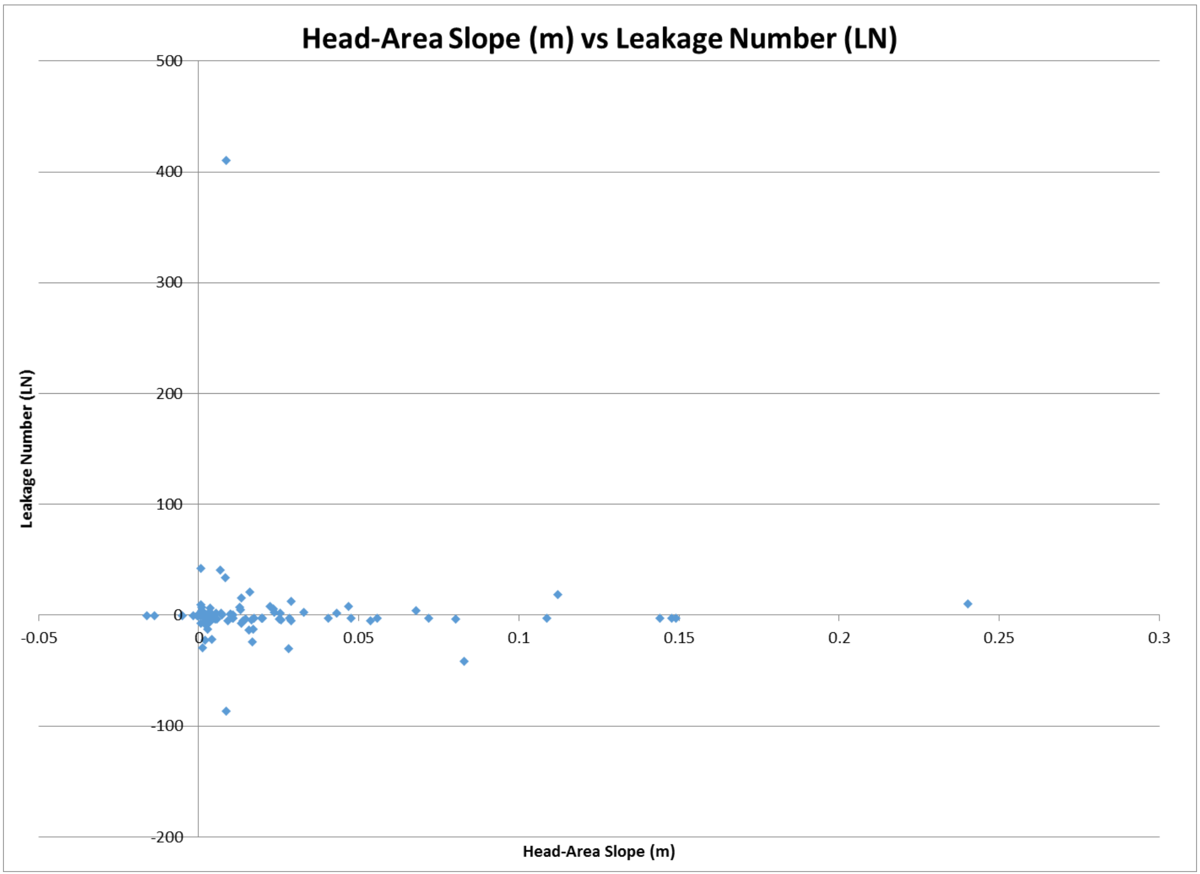

Figure 4-28: Head-Area Slope vs Leakage Number

From Figure 4-27, no trend or pattern was observed that could describe the relationship between Head-Area Slope and Leakage Number for the 105 zones analysed.

4.3.4.Head-Area Slope ($\bar{m}$) and Infrastructure Leakage Index (ILI)

The relationship between the head-area slope and the infrastructure leakage index (after pressure management) values using the conventional methodology for the 105 zones is presented in Figure 4-28.

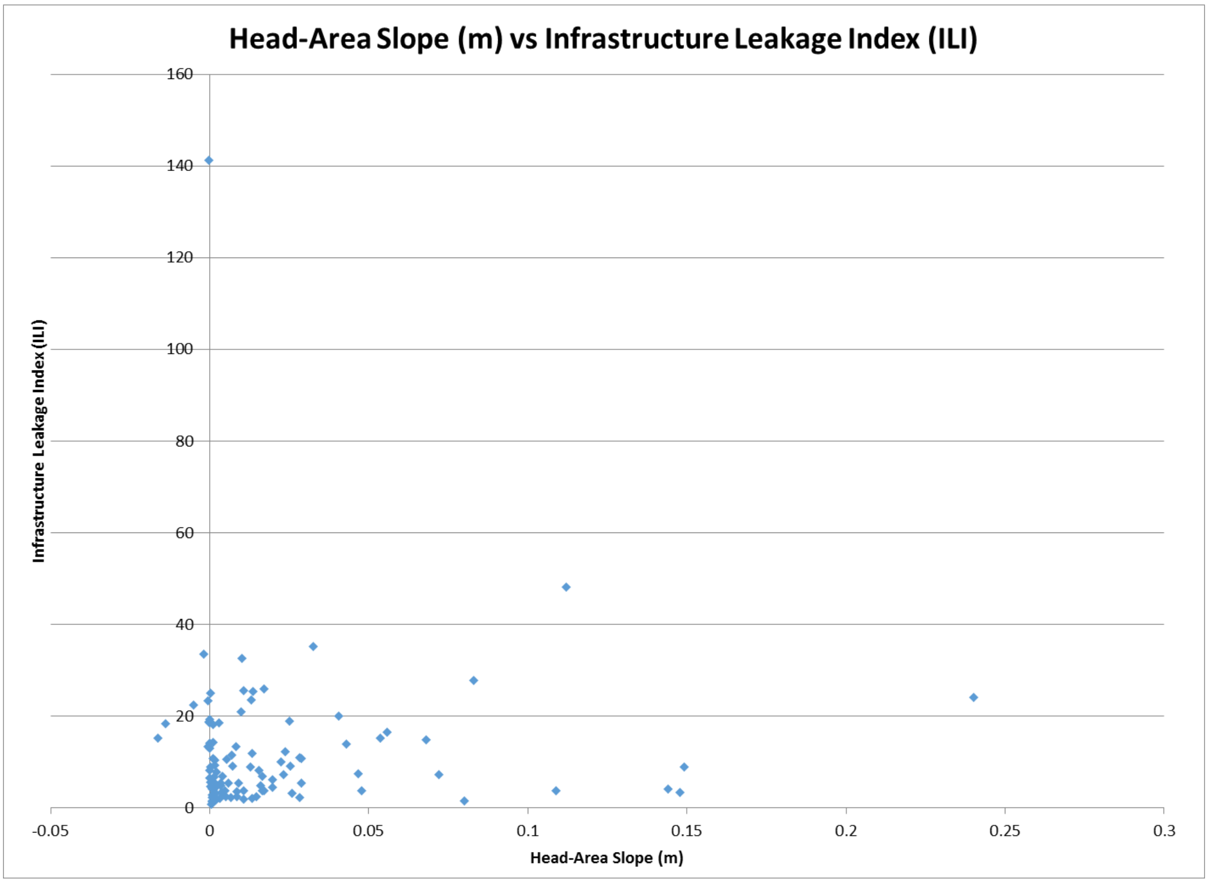

Figure 4-29: Head-Area Slope vs Infrastructure Leakage Index (after PM)

From Figure 4-28, there was no relationship observed between the Infrastructure Leakage Index (after PM) and Head-Area Slope.

4.3.5.Leakage Area ($\overline{A_0}$) and Leakage Exponent (N1)

The relationship between the leakage area and the leakage exponent values using the conventional methodology for the 107 zones is presented in Figure 4-29.

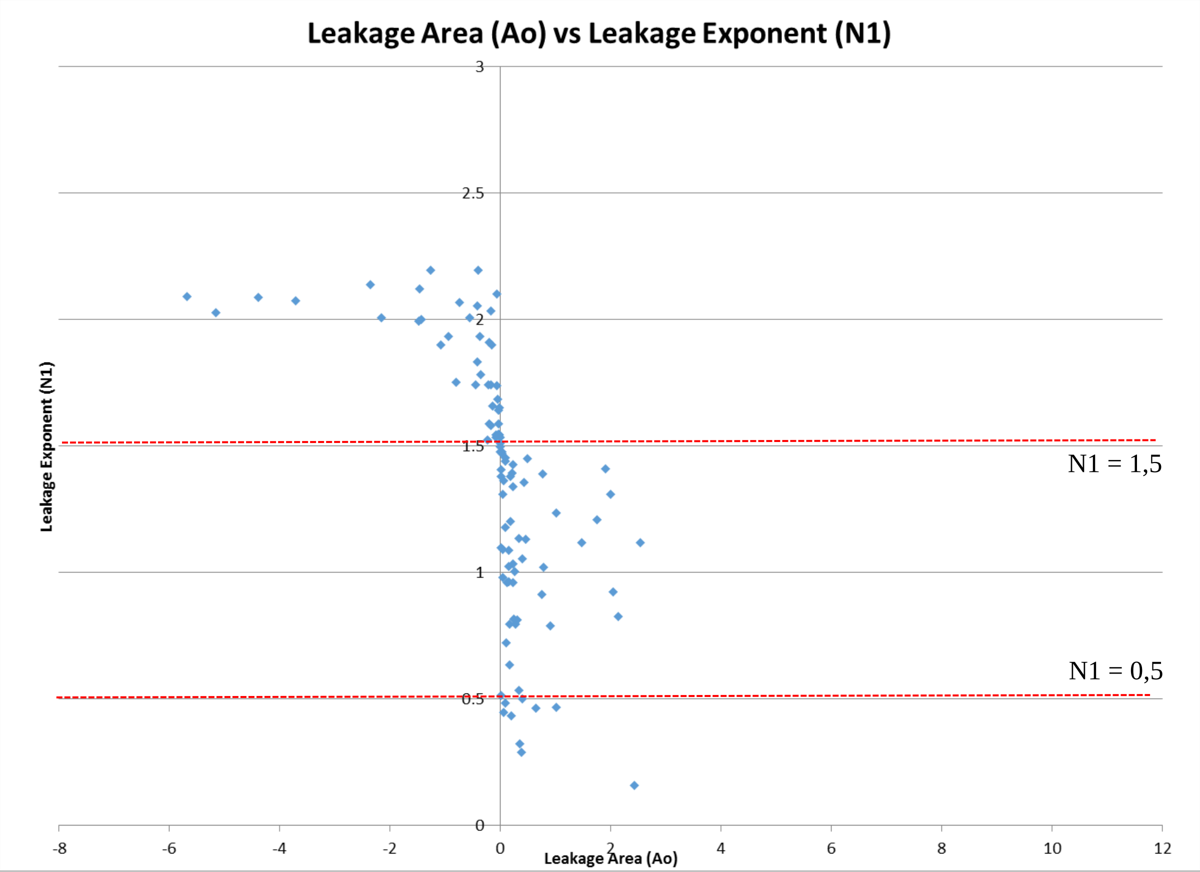

Figure 4-30: Leakage Area vs Leakage Exponent

From Figure 4-29, it was observed that $\overline{A_0}$ tended to be negative when N1 > 1,5 and $\overline{A_0}$ tended to be positive when N1 < 1,5 with 39% of calculated $\overline{A_0}$ values being negative.

4.3.6. Leakage Area ($\overline{A_0}$) and Leakage Number (L_N)

The relationship between the leakage area and the leakage number values using the conventional methodology for the 107 zones is presented in Figure 4-30.

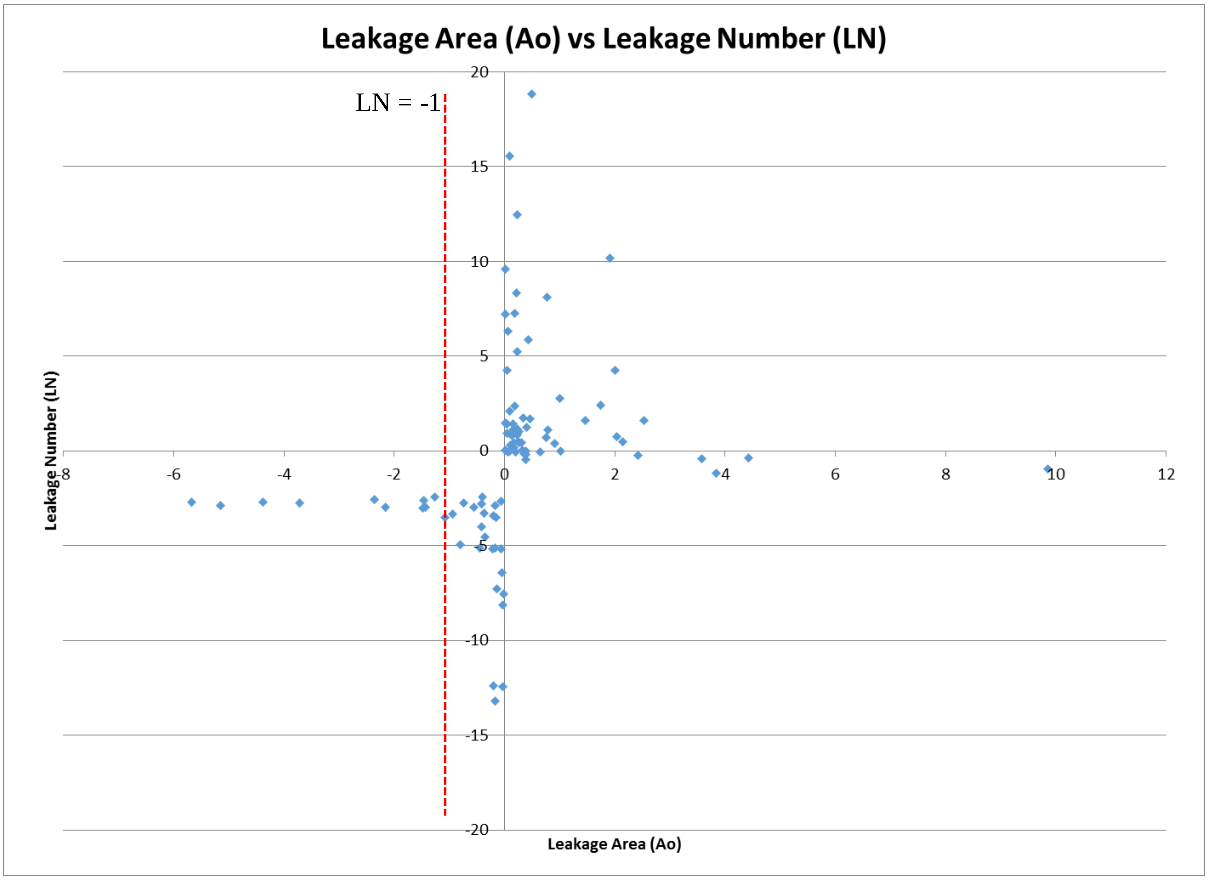

Figure 4-31: Leakage Area vs Leakage Number

From Figure 4-30, it was observed that the resultant Leakage Number and Leakage Area were mostly either both negative or both positive, for the 107 zones analysed. There were a few exceptions where 6 (6%) PMZs registered a negative Leakage Number and a Positive Leakage Area.

4.3.7.Leakage Area ($\overline{A_0}$) and Infrastructure Leakage Index (ILI)

The relationship between the leakage area and the infrastructure leakage index values using the conventional methodology for the 107 zones is presented in Figure 4-31.

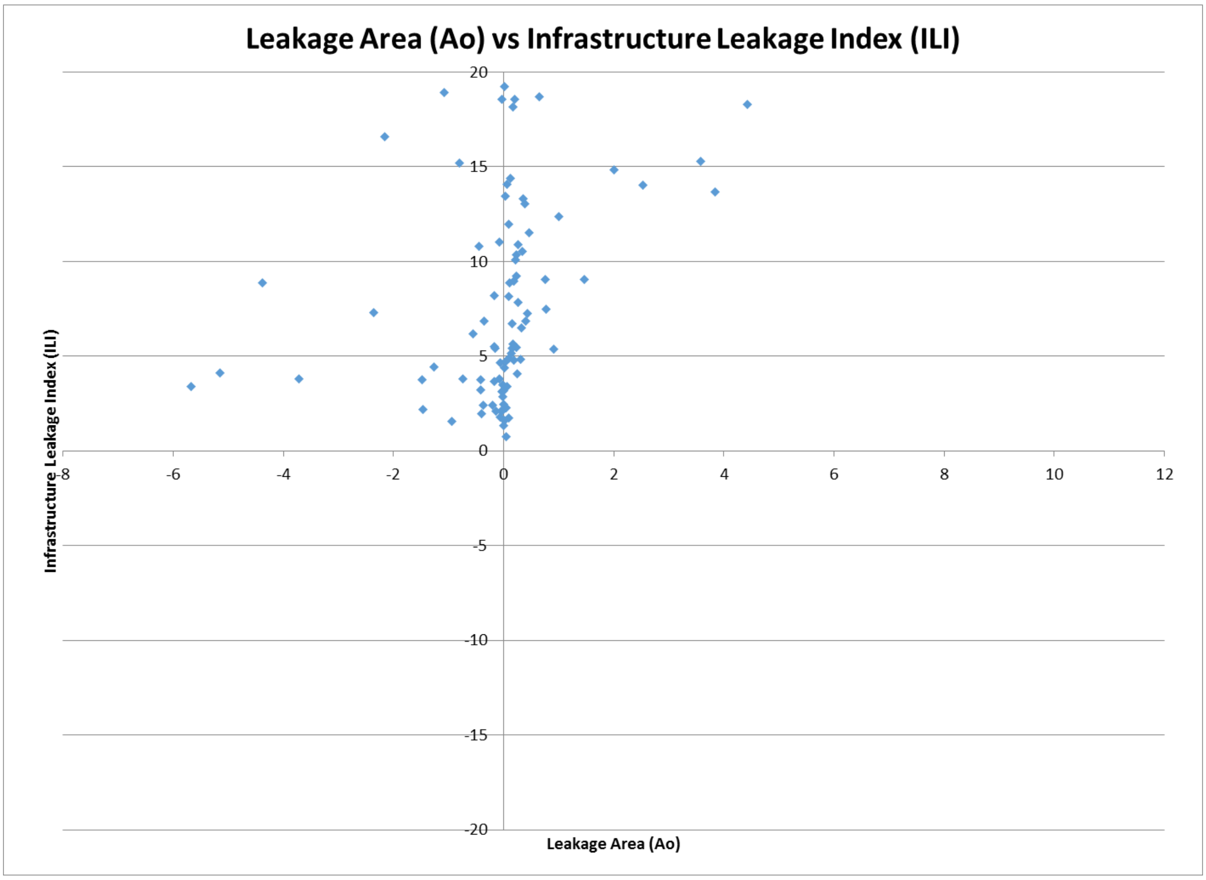

Figure 4-32: Leakage Area vs Infrastructure Leakage Index

From Figure 4-31, there was no relationship between the Infrastructure Leakage Index and Leakage Area observed.

4.3.8.Leakage Exponent (N1) and Leakage Number (L_N)

The relationship between the leakage exponent and the leakage number values using the conventional methodology for the 107 zones is presented in Figure 4-32.

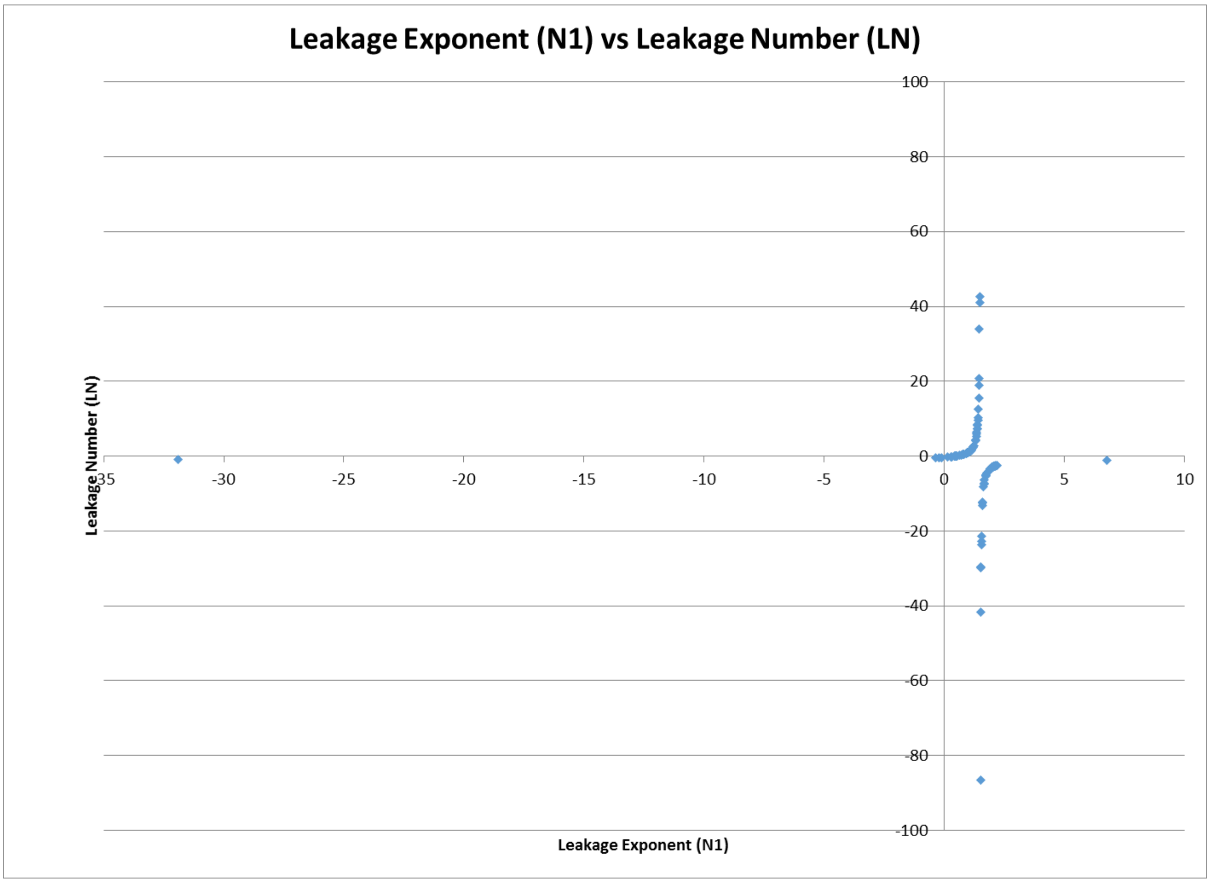

Figure 4-33: Leakage Exponent vs Leakage Number

In order to see the majority of the data points, Figure 4-33 provides a zoomed-in look at the relevant information.

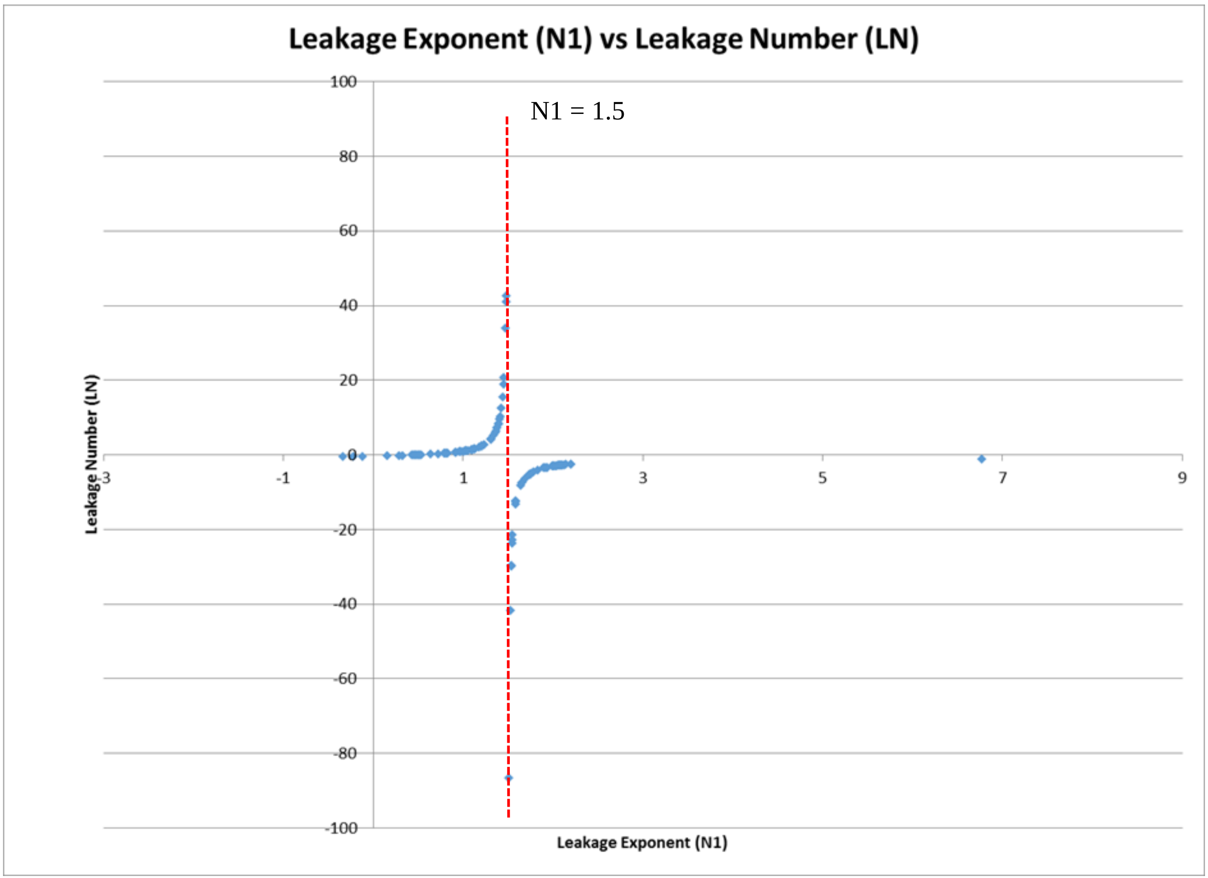

Figure 4-34: Leakage Exponent vs Leakage Number - Zoomed In

The relationship between N1 and LN was clear and showed a hyperbolic relationship. This emulated the relationship as described by Cassa and van Zyl (2010).

4.3.9. Leakage Exponent (N1) and Infrastructure Leakage Index (ILI)

The relationship between the leakage exponent and the infrastructure leakage index values using the conventional methodology for the 107 zones is presented in Figure 4-34.

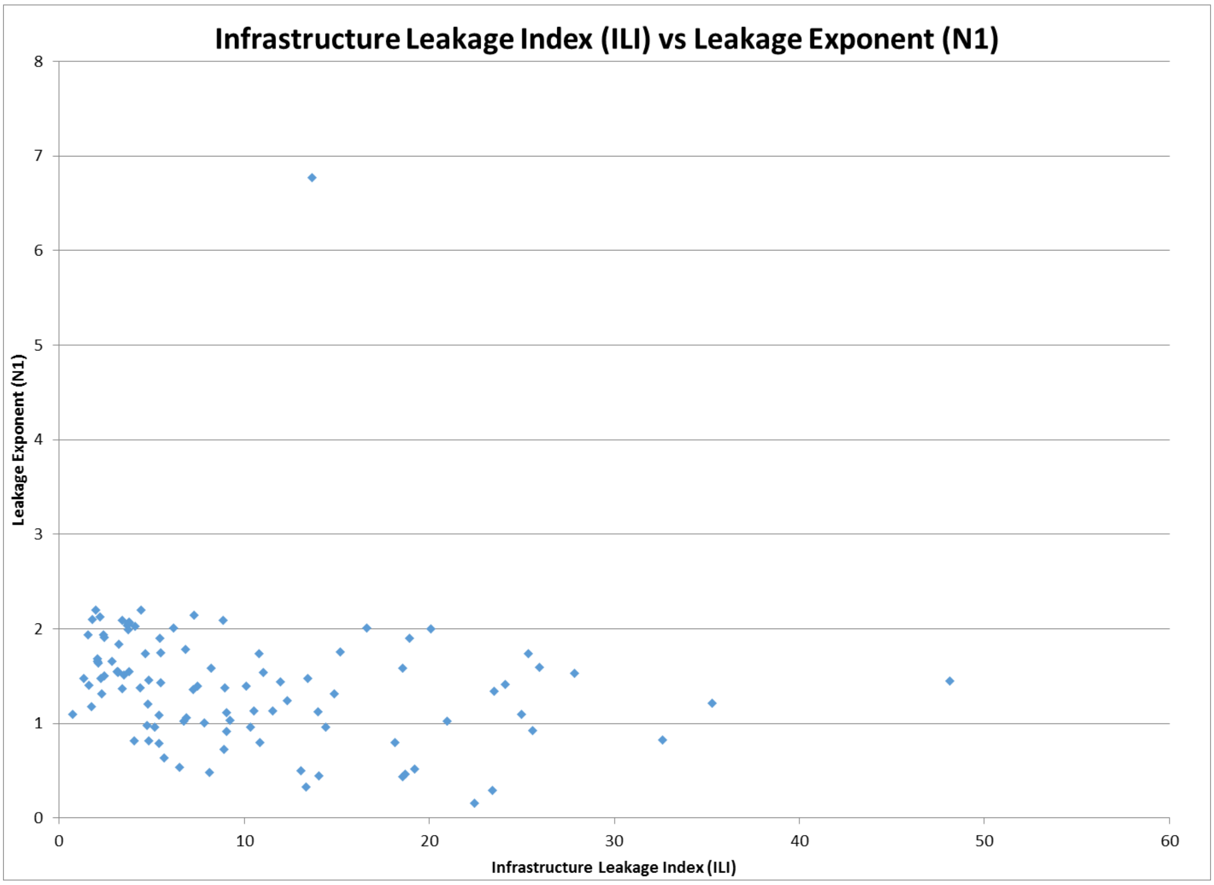

Figure 4-35: Infrastructure Leakage Index vs Leakage Exponent

From Figure 4-34, there was no relationship between the Infrastructure Leakage Index and Leakage Exponent.

4.3.10. Leakage Number (L_N) and Infrastructure Leakage Index (ILI)

The relationship between the leakage number and the infrastructure leakage index values using the conventional methodology for the 107 zones is presented in Figure 4-35.

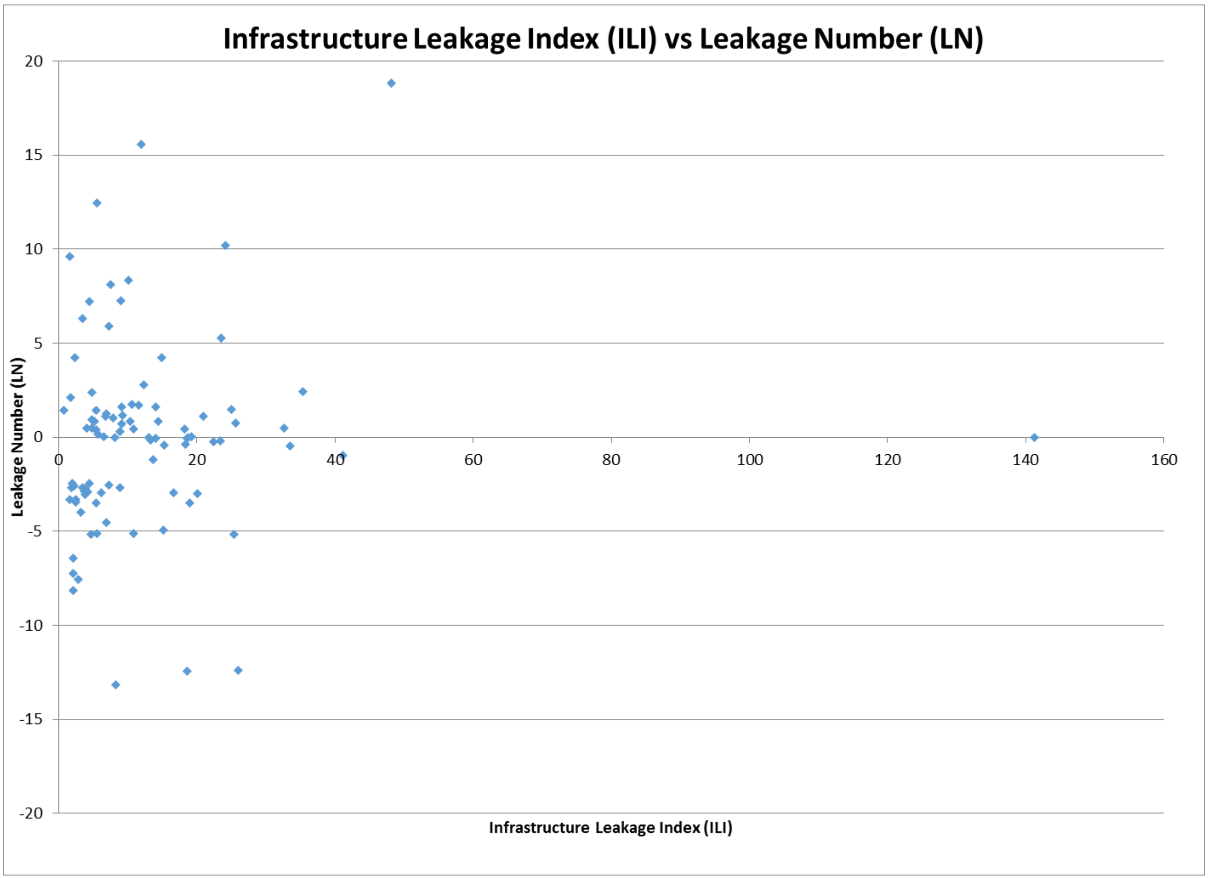

Figure 4-36: Infrastructure Leakage Index vs Leakage Number

From Figure 4-35, there was no relationship between the Infrastructure Leakage Index and Leakage Exponent.

4.3.11. Infrastructure Leakage Index (ILI) – Before PM and after PM

The relationship between the infrastructure leakage index values, before and after pressure management, using the conventional methodology for the 107 zones is presented in Figure 4-36.

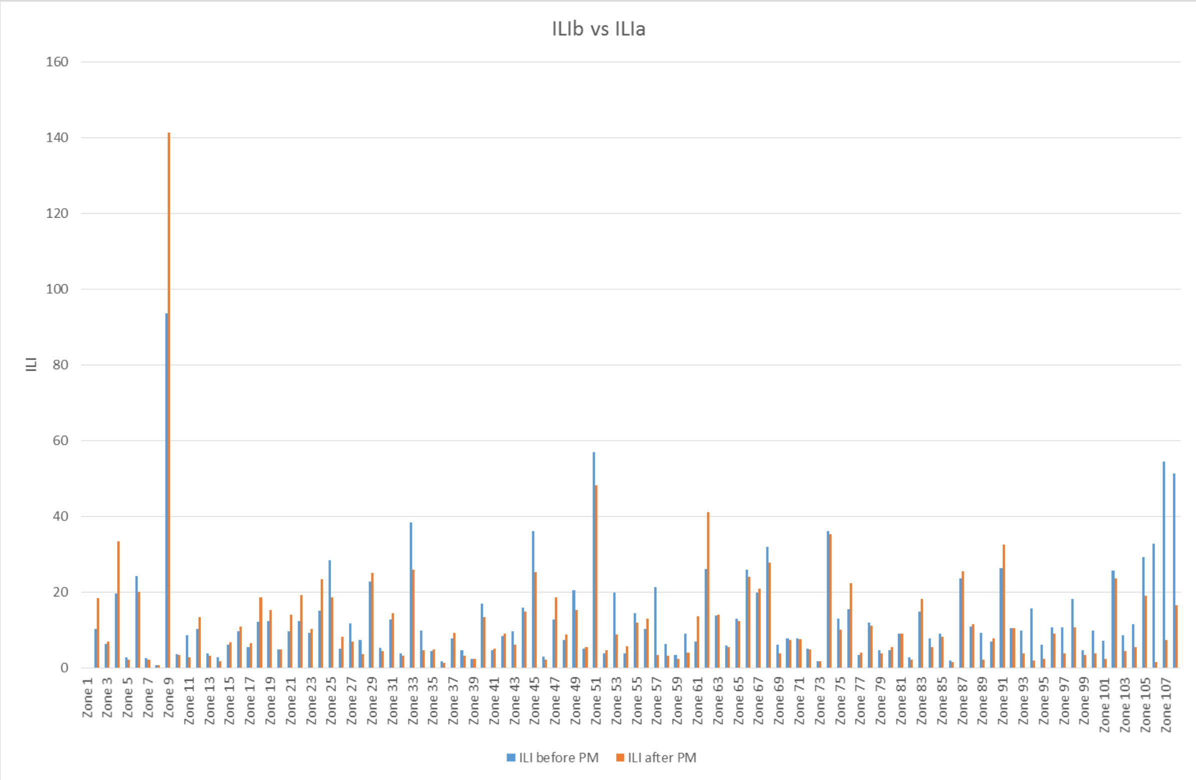

Figure 4-37: Infrastructure Leakage Index Before vs Infrastructure Leakage Index After Pressure Management

Figure 4-36 showed the ILI for before and after pressure management for each PMZ. The average ILI for the 107 zones before pressure management was 12,8 and the average ILI after pressure management was 11,9 which is an average percentage ILI reduction of 9% post pressure management.

4.4. Critical Evaluation of the Data

Following the calculation of the leakage parameters, an analysis of the leakage parameters per zone to identify and understand trends was required. This analysis considers leakage parameters that fell outside of the typical range for the relevant parameters and aimed to determine reasoning for this using an understanding of the relationship between the equations or parameters. Furthermore, it considered operational possibilities and reasoning for the parameters not falling within the known range.

Considering the N1 factor had research stating that N1 should fall between 0,5 and 1,5, the zones were assessed for when N1 fell outside of this range. From the analysis, two trends were noted:

- When N1 > 1,5, $\overline{A_0}$ was always less than 0; and
- When N1 < 0,5, $\overline{m}$ was always less than 0.

This means that when N1 fell outside the 0,5 to 1,5 range, either $\overline{A_0}$ or $\overline{m}$ was negative. The relationship between a negative $\overline{m}$ and N1<0,5 and a negative $\overline{A_0}$ and N1>1,5 was explained through the equation:

$$L_N = \frac{\overline{m}h}{\overline{A_0}}$$

Such that when $\overline{m}$ or $\overline{A_0}$ were negative, then L_N was negative. Subsequently, a negative L_N resulted in N1 being either less than 0,5 or greater than 1,5 as can be seen in Figure 4-37.

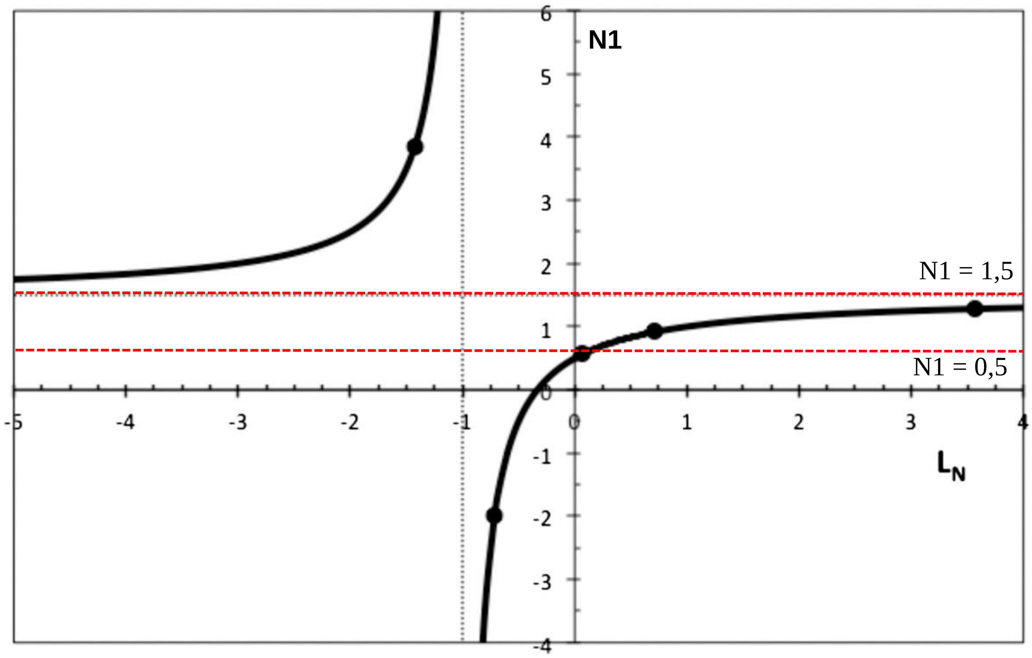

Figure 4-38: Relationship between N1 and L_N (Van Zyl et al., 2017)

Figure 4-37 (Van Zyl et al., 2017) presents the relationship between N1 and L_N and showed that when L_N is negative, N1 was either greater than 1,5 or less than 0,5.

As $\overline{A_0}$ < 0mm (initial leak area less than zero for any system) is considered impossible, and a negative $\overline{m}$ (where leak area decreases with increased pressure) is unlikely, further investigation was undertaken to determine which fraction of physically impossible leakage parameter ranges based on standard analysis can be explained from data.

4.4.1. Critical Evaluation of Head-Area Slope (m)

From the PMZs analysed, 12% of the results for $\overline{m}$ were negative. Negative head-area slopes are not common but have been shown to occur, for example, in circumferential cracks (Cassa et al. 2010; van Zyl & Malde, 2017). Whilst this is possible, additional reasons for negative $\overline{m}$ were investigated and were as follows:

- Assumption error
- Data error

4.4.1.1. *Assumption Error*

An assumption error considered where the assumptions for the operation and characteristics of a PMZ were incorrect. An example of an assumption error would be the assumption that the average zone pressure was the location of the average of all leaks, however if a dominant leak was located at the lowest point in the zone, the assumption would produce an error which would result in a negative leakage head-area slope for the zone. This example is illustrated in Figure 4-38.

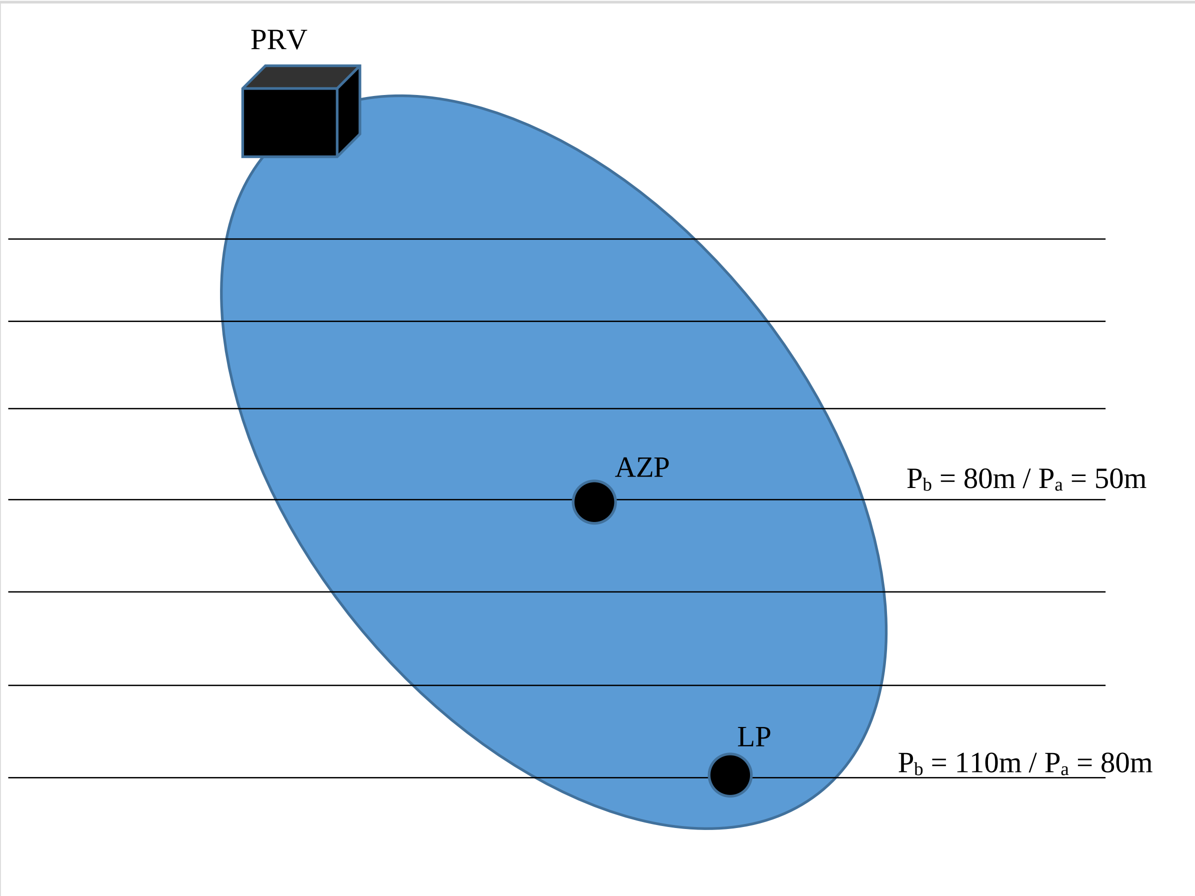

Figure 4-39: Example of PMZ for Simulation of Measurement Error on m

Figure 4-38 shows a PMZ with an AZP which had a pressure of 80m before pressure management. Following the introduction of pressure management, the AZP pressure dropped to 50m. Similarly, the PMZ had a LP at 110m pressure before pressure management which resulted in a LP at 80m pressure after pressure management. The ratio of pressure change at the AZP is 50m/80m = 0,625 while the ratio of pressure change at the LP is 0,727. This difference in the pressure ratio for before and after pressure management will result in different $\overline{m}$ values being determined at CP and LP locations. The assumption error study therefore considered the results for the different locations (CP/LP) which were completed in the sensitivity analysis for m.

From the results of the sensitivity analysis, it was observed that of the 13 $\overline{m}$ values (using the conventional method) that were negative, 8 of the $\overline{m}$ values were positive when calculated using the CP or LP pressure input. These 8 results may mean that a dominant leak in the PMZ was located at/closer to the CP or LP as compared to the assumption that it occurs at the AZP. The PMZs that remained negative regardless of the location of the various pressure inputs were Zone 1, Zone 3, Zone 18 and Zone 60 and Zone 61.

4.4.1.2. *Data Error*

A data error considered where information collected from the field was incorrect. For example, if the identified AZP location had a pressure of 70m, but the location of the AZP was determined incorrectly and the correct AZP location should have had a pressure of 65m. Whilst this error may be impossible to determine for all the PMZ info provided, the error may exist and the resulting leakage parameters may be giving an impossible value (such as negative $\overline{m}$ values).

The data error was studied by considering a 10% error on the pressure and flow inputs for the conventional method (h_{AZP} and Q_{RL}). The zones with negative $\overline{m}$ values were considered and are presented in Table 4-11.

Table 4-11: PMZs with negative $\overline{m}$ values

	AZPb (m)	AZPa (m)	Qrlb (m^3/hr)	Qrla (m^3/hr)	$\overline{m}$ (mm^2/m)
Zone 1	84.6	37.7	86.21113	69.03167	-0.01385
Zone 3	67	34	6	5	-0.00175
Zone 8	80	36	26	17	-0.00028
Zone 11	66.7	42	7.503653	6.17683	-0.00048
Zone 17	101.3	45	5.430875	3.711138	-8.4E-05
Zone 18	53	40	57.10363	53.43735	-0.01617
Zone 20	94.2	46	1.73	1.23	-2.2E-05
Zone 23	97.07	45.94	9.529667	7.020625	-0.00047
Zone 25	102.77	39.7	2.480555	1.552653	-9.5E-06
Zone 46	92.3	43.5	17.39635	12.08961	-0.00016
Zone 60	67.9	48.4	27.84833	38.87292	-0.03933
Zone 61	66.3	48.3	101.4525	116.66	-0.08348
Zone 75	76.3	43.2	51.11792	41.705	-0.00517

The data was then applied a 10% adjustment to each of the pressure and flow inputs (resulting in 8 different scenarios) and the $\overline{m}$ values recalculated for each scenario. The results for selected scenarios are presented in Table 4-12 and 4-13.

Table 4-12: PMZs with 10% increase of Qrl_b

	AZP_b (m)	AZP_a (m)	Qrl_b (m^3/hr)	Qrl_a (m^3/hr)	$\overline{m}$ (mm^2/m)
Zone 1	84.6	37.7	94.83224	69.03167	-0.00691
Zone 3	67	34	6.973069	5	-0.00093
Zone 8	80	36	28.11188	17	0.001979
Zone 11	66.7	42	8.254019	6.17683	0.000809
Zone 17	101.3	45	5.973963	3.711138	0.000249
Zone 18	53	40	62.814	53.43735	0.004782
Zone 20	94.2	46	1.903	1.23	0.000106

Zone 23	97.07	45.94	10.48263	7.020625	0.000191
Zone 25	102.77	39.7	2.728611	1.552653	0.000125
Zone 46	92.3	43.5	19.13598	12.08961	0.00113
Zone 60	67.9	48.4	30.63317	38.87292	-0.03331
Zone 61	66.3	48.3	111.5978	116.66	-0.05944
Zone 75	76.3	43.2	56.22971	41.705	0.000966

Table 4-13: PMZs with 10% decrease of AZP_b

	AZPb (m)	AZPa (m)	Qrl_b (m^3/hr)	Qrl_a (m^3/hr)	m (mm^2/m)
Zone 1	76.14	37.7	86.21113	69.03167	-0.01231
Zone 3	60.3	34	6	5	-0.00164
Zone 8	72	36	26	17	0.001153
Zone 11	60.03	42	7.503653	6.17683	0.000296
Zone 17	91.17	45	5.430875	3.711138	0.000117
Zone 18	47.7	40	57.10363	53.43735	-0.00817
Zone 20	84.78	46	1.73	1.23	5.85E-05
Zone 23	87.363	45.94	9.529667	7.020625	-0.00014
Zone 25	92.493	39.7	2.480555	1.552653	7.57E-05
Zone 46	83.07	43.5	17.39635	12.08961	0.000664
Zone 60	61.11	48.4	27.84833	38.87292	-0.05534
Zone 61	59.67	48.3	101.4525	116.66	-0.11157
Zone 75	68.67	43.2	51.11792	41.705	-0.00241

Table 4-12 and Table 4-13 provide the results for the simulation of a 10% error on Qrl_b (+10%) and AZP_b (-10%) respectively. The resultant $\overline{m}$ values were determined to be positive with only four PMZs, Zone 1, Zone 3, Zone 60 and Zone 61, not being positive for either of the scenarios. The simulation proves that a 10% error in the capturing/collection of the field data (See Table 5-1 for critical field data) may result in $\overline{m}$ values that are physically impossible. Additionally, of the $\overline{m}$ values that changed from negative to positive as a result of this simulation, all of them produced a positive $\overline{A_0}$ value subsequent to the simulation (whether they were positive to start off with or were negative before the simulation).

From the various possibilities for errors, it was established that the presence of an error can result in physically impossible $\overline{m}$ values being determined. The simulations undertaken for an estimation error and a data error resolved that the $\overline{m}$ values can become positive with exception of four Zones. It is important to note that these four Zones with negative $\overline{m}$ values have corresponding N1 values that are outside the normal range for N1 (0.3 – 2.3). This may imply that there is an error in the field data collected or there may be a physical defect in the Zone that may be affecting the results such as a dominant leak with a circumferential crack. This is supported by the Schwaller and van Zyl (2012) paper that individual leak behaviour can characterise the pressure-leakage response in a water distribution network.

4.4.2. Critical Evaluation of Initial Leak Area ($\overline{A_0}$)

From the PMZs analysed, 42 of the 107 (39%) PMZs had a resultant $\overline{A_0}$ that was negative. A negative initial area is not physically possible, however it may occur in the mathematical model when a leak opening remains closed at head differentials above zero, for instance as a result of external forces (Van Zyl, 2017).Whilst this is possible, additional reasons for negative $\overline{A_0}$ were investigated and were as follows:

- Measurement error
- Data error

4.4.2.1. *Assumption Error*

An assumption error considered where the assumptions for the operation and characteristics of a PMZ were incorrect. An example of an assumption error would be the assumption that the average zone pressure was the location of the average of all leaks, however if a dominant leak was located at the lowest point in the zone, the assumption would produce an error which would result in a negative leakage initial leak area for the zone. This example is illustrated in Figure 4-39.

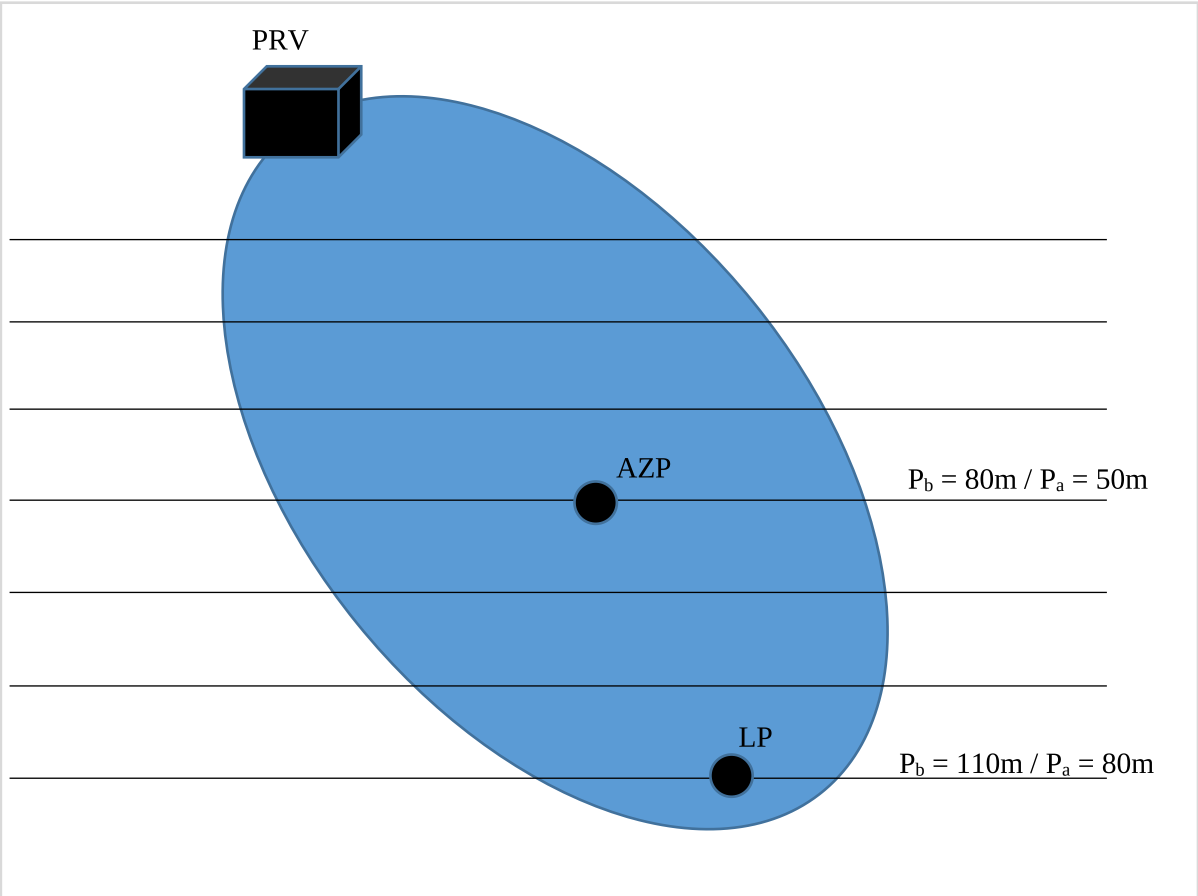

Figure 4-40: Example of PMZ for Simulation of Measurement Error on $\overline{A_0}$

Figure 4-39 shows a PMZ with an AZP which had a pressure of 80m before pressure management. Following the introduction of pressure management, the AZP pressure dropped to 50m. Similarly, the PMZ had a LP at 110m pressure before pressure management which resulted in a LP at 80m pressure after pressure management. The ratio of pressure change at the AZP is 50m/80m = 0,625 while the ratio of pressure change at the LP is 0,727. This difference in the pressure ratio for before and after pressure management would result in different $\overline{A_0}$ values being determined at CP and LP locations. The assumption error study therefore considered the results for the different locations (CP/LP) which were completed in the sensitivity analysis for $\overline{A_0}$.

The analysis considered where the Conventional Method (h_{AZP}/Q_{RL}) provides an $\overline{A_0}<0$, then the alternate methods, Method 2 (h_{CP}/Q_{RL}) and Method 7 (h_{LP}/Q_{RL}), were observed. If either of these methods were positive, then it could indicate a dominant leak closer to the location of the respective pressure location (the CP or LP). The results of the analysis for each zone are presented in Table 4-14.

Table 4-14: Analysis of PMZs with negative $\overline{A_0}$ values

Ref.	Ao (CP/Qrl) (mm²)	**Ao (AZP/Qrl) (mm²)**	Ao (LP/Qrl) (mm²)
Zone 4	0.019855	**-0.04989**	-0.08874
Zone 5	-0.58779	**-1.43487**	-1.85427
Zone 6	-0.01251	**-0.03058**	-0.03213
Zone 10	-0.01494	**-0.01161**	-0.00898
Zone 12	-0.26625	**-0.03773**	-0.00516
Zone 13	-0.00573	**-0.06932**	-0.35707
Zone 24	0.136146	**-0.02726**	-0.11674
Zone 26	0.645977	**-0.35449**	12.3733
Zone 27	-0.07834	**-0.16551**	-0.30256
Zone 31	0.159259	**-0.01147**	-0.09697
Zone 32	0.666032	**-0.2026**	-0.75876
Zone 33	0.015546	**-0.06211**	-0.11636
Zone 37	0.071751	**-0.00565**	-0.04929
Zone 42	0.16295	**-0.56069**	-2.61618
Zone 44	-0.16306	**-0.21049**	-0.2348
Zone 45	0.378459	**-0.13707**	-2.45524
Zone 48	2.403024	**-0.80695**	-12.6532
Zone 52	0.628183	**-4.38645**	-66.2862
Zone 56	-0.96989	**-5.68049**	-9.67616
Zone 57	0.411898	**-0.41266**	-12.0872
Zone 59	-3.65729	**-5.15549**	-6.39707
Zone 67	3.279909	**-0.23768**	-3.70133
Zone 68	-0.1765	**-3.71512**	72.28389
Zone 77	-0.32485	**-0.07678**	0.011647
Zone 78	0.401002	**-0.08036**	-0.53976

Zone 83	0.237828	**-0.1546**	-1.11019
Zone 84	3.682109	**-0.16899**	14.79455
Zone 88	0.463215	**-1.46953**	-8.67749
Zone 92	-0.15758	**-1.47486**	-3.28406
Zone 93	-0.07302	**-0.39568**	-0.8898
Zone 94	0.190582	**-0.36981**	-0.95529
Zone 96	0.162058	**-0.41781**	0.580269
Zone 97	0.863749	**-0.45151**	-1.65353
Zone 98	1.04589	**-0.00975**	-0.58595
Zone 99	0.423723	**-0.73387**	-2.3781
Zone 100	0.123743	**-0.19597**	-0.48513
Zone 102	0.542215	**-1.2689**	-2.06997
Zone 103	0.371832	**-0.17591**	-0.70754
Zone 104	1.148725	**-1.08501**	-3.27552
Zone 105	-0.53061	**-0.9396**	-1.52747
Zone 106	0.17235	**-2.3549**	-9.10667
Zone 107	0.973962	**-2.15401**	-5.9279

Of the 42 PMZs with negative $\overline{A_0}$ values when determined using the conventional methodology (h_{AZP}/Q_{RL}), 30 of the PMZs had positive $\overline{A_0}$ values when using either h_{CP} or h_{LP}. These results may provide evidence that the AZP may not be at the location of the dominant leak for the respective PMZs and the dominant leak was located at/closer to the CP/LP.

4.4.2.2. *Data Error*

A data error considered where information collected from the field was incorrect. For example, if the identified AZP location had a pressure of 70m, but the location of the AZP was determined incorrectly and the correct AZP location should have had a pressure of 65m. Whilst this error may be impossible to determine for all the PMZ info provided, the error may exist and the resulting leakage parameters may be giving an impossible value (such as negative $\overline{A_0}$ values).

The data error was studied by considering a 10% error on the pressure and flow inputs for the conventional method (h_{AZP} and Q_{RL}). The zones with negative $\overline{A_0}$ values were considered and are presented in Table 4-15.

Table 4-15: PMZs with negative $\overline{A_0}$ values and simulated errors on pressure and flow inputs

Ref.	Ao (Conventional Method) (mm2)	Ao (AZPb + 10%) (mm2)	Ao (AZPb - 10%) (mm2)	Ao (AZPa + 10%) (mm2)	Ao (AZPa - 10%) (mm2)	Ao (Qrlb + 10%) (mm2)	Ao (Qrlb - 10%) (mm2)	Ao (Qrla + 10%) (mm2)	Ao (Qrla - 10%) (mm2)
Zone 4	-0.050	-0.074	-0.025	-0.050	-0.050	-0.037	-0.063	-0.050	-0.050
Zone 5	-1.435	-1.695	-1.169	-1.435	-1.435	-1.356	-1.514	-1.435	-1.435
Zone 6	-0.031	-0.049	-0.011	-0.031	-0.031	-0.020	-0.041	-0.031	-0.031
Zone 10	-0.012	-0.021	-0.002	-0.012	-0.012	-0.006	-0.017	-0.012	-0.012
Zone 12	-0.038	-0.105	0.033	-0.038	-0.038	0.006	-0.081	-0.038	-0.038
Zone 13	-0.069	-0.080	-0.058	-0.069	-0.069	-0.066	-0.072	-0.069	-0.069
Zone 24	-0.027	-0.058	0.005	-0.027	-0.027	-0.008	-0.046	-0.027	-0.027
Zone 26	-0.354	-0.479	-0.225	-0.354	-0.354	-0.294	-0.415	-0.354	-0.354
Zone 27	-0.166	-0.197	-0.134	-0.166	-0.166	-0.156	-0.175	-0.166	-0.166
Zone 31	-0.011	-0.033	0.011	-0.011	-0.011	0.002	-0.025	-0.011	-0.011
Zone 32	-0.203	-0.427	0.032	-0.203	-0.203	-0.063	-0.342	-0.203	-0.203
Zone 33	-0.062	-0.090	-0.033	-0.062	-0.062	-0.047	-0.077	-0.062	-0.062
Zone 37	-0.006	-0.022	0.011	-0.006	-0.006	0.005	-0.016	-0.006	-0.006
Zone 42	-0.561	-0.667	-0.452	-0.561	-0.561	-0.526	-0.595	-0.561	-0.561
Zone 44	-0.210	-0.292	-0.125	-0.210	-0.210	-0.169	-0.252	-0.210	-0.210
Zone 45	-0.137	-0.217	-0.053	-0.137	-0.137	-0.092	-0.183	-0.137	-0.137
Zone 48	-0.807	-1.099	-0.504	-0.807	-0.807	-0.663	-0.951	-0.807	-0.807
Zone 52	-4.386	-5.148	-3.608	-4.386	-4.386	-4.166	-4.607	-4.386	-4.386
Zone 56	-5.680	-6.755	-4.580	-5.680	-5.680	-5.335	-6.026	-5.680	-5.680
Zone 57	-0.413	-0.540	-0.281	-0.413	-0.413	-0.354	-0.471	-0.413	-0.413
Zone 59	-5.155	-6.154	-4.133	-5.155	-5.155	-4.826	-5.485	-5.155	-5.155
Zone 67	-0.238	-1.041	0.606	-0.238	-0.238	0.294	-0.770	-0.238	-0.238
Zone 68	-3.715	-4.344	-3.073	-3.715	-3.715	-3.539	-3.891	-3.715	-3.715
Zone 77	-0.077	-0.253	0.108	-0.077	-0.077	0.038	-0.192	-0.077	-0.077
Zone 78	-0.080	-0.242	0.089	-0.080	-0.080	0.024	-0.185	-0.080	-0.080
Zone 83	-0.155	-0.191	-0.117	-0.155	-0.155	-0.140	-0.169	-0.155	-0.155
Zone 84	-0.169	-0.335	0.005	-0.169	-0.169	-0.067	-0.271	-0.169	-0.169
Zone 88	-1.470	-1.725	-1.209	-1.470	-1.470	-1.396	-1.544	-1.470	-1.470
Zone 92	-1.475	-1.791	-1.150	-1.475	-1.475	-1.360	-1.590	-1.475	-1.475
Zone 93	-0.396	-0.458	-0.332	-0.396	-0.396	-0.380	-0.411	-0.396	-0.396
Zone 94	-0.370	-0.460	-0.277	-0.370	-0.370	-0.334	-0.406	-0.370	-0.370
Zone 96	-0.418	-0.497	-0.337	-0.418	-0.418	-0.392	-0.443	-0.418	-0.418
Zone 97	-0.452	-0.638	-0.258	-0.452	-0.452	-0.355	-0.548	-0.452	-0.452
Zone 98	-0.010	-0.088	0.072	-0.010	-0.010	0.043	-0.062	-0.010	-0.010
Zone 99	-0.734	-0.869	-0.595	-0.734	-0.734	-0.692	-0.776	-0.734	-0.734
Zone 100	-0.196	-0.248	-0.142	-0.196	-0.196	-0.174	-0.218	-0.196	-0.196
Zone 102	-1.269	-1.450	-1.085	-1.269	-1.269	-1.232	-1.306	-1.269	-1.269
Zone 103	-0.176	-0.253	-0.096	-0.176	-0.176	-0.135	-0.217	-0.176	-0.176
Zone 104	-1.085	-1.345	-0.817	-1.085	-1.085	-0.981	-1.189	-1.085	-1.085
Zone 105	-0.940	-1.208	-0.662	-0.940	-0.940	-0.820	-1.059	-0.940	-0.940
Zone 106	-2.355	-2.765	-1.936	-2.355	-2.355	-2.236	-2.474	-2.355	-2.355
Zone 107	-2.154	-2.611	-1.685	-2.154	-2.154	-1.989	-2.319	-2.154	-2.154

From Table 4-15 it was observed that 10 of the 42 (24%) PMZs became positive in one of the various methods when a 10% error was simulated on the flow and/or pressure inputs.

The simulation proved that a 10% error in the capturing/collection of the field data may result in $\overline{A_0}$ values that are physically impossible (i.e. $\overline{A_0}$ being negative).

If the results of the above are considered, only 11 PMZs had resulting negative $\overline{A_0}$ values that cannot be attributed to assumption errors or data errors. The 11 PMZs are listed in Table 4-16.

Table 4-16: List of PMZs with negative $\overline{A_0}$ values

No.	**PMZ**
1	Zone 5
2	Zone 6
3	Zone 10
4	Zone 13
5	Zone 27
6	Zone 44
7	Zone 56
8	Zone 59
9	Zone 92
10	Zone 93
11	Zone 105

Alternate errors proposed by Deyi et al. (2014) for $\overline{A_0}<0$ were plastic deformation playing a significant role in the leak behaviour and a leaking boundary valve in the PMZ. Plastic deformation may be the result if poor water infrastructure or conditions for the pipe. A leaking boundary valve may indicate that the PMZ is not discreet, which would jeopardise the pressure management of the zone.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The research aimed to collect, analyse and scrutinise real distribution network data for 107 PMZs. It further calculated leakage parameters and aimed to establish the relationship between the various parameters consistent with developments made on pressure and leakage behaviour.

The leakage parameters were calculated using conventional methodology and alternative methodologies to analyse sensitivity of the results against various pressure and flow inputs. The relationships between the calculated leakage parameters were then studied and where leakage parameters were determined to be physically impossible, these were studied for errors.

From the analysed data, the significant results were that when using the conventional method (AZP as pressure input and Q_{RL} as flow input), 12% of head-area slope ($\overline{m}$) values and 39% of initial leak area ($\overline{A_0}$) values were negative. The calculated FAVAD N1 values ranged between -0.34 and 2,20 (two outliers were determined as N1=-31,88 and N1=6,77 but these are not impossible and can be explained through physical issues with the pressure management zone). The relationship between the calculated Leakage Exponent (N1) and the Leakage Number (L_N) were determined to be consistent with theoretical studies. The Infrastructure Leakage Index (ILI) was determined for each PMZ for before and after pressure management and it was found that although leakage reduces with pressure management, the ILI is not always reduced (ILI increased for 39% of the PMZs after pressure management).

The relationships for the various leakage parameters were studied and illustrated. The only notable relationships revealed was that when N1 < 0,5 then $\overline{m} < 0$ and when N1 > 1,5 then $\overline{A_0} < 0$. Whilst this can be explained mathematically, a negative $\overline{m}$ and $\overline{A_0}$ are not physically possible. Therefore possible errors such as assumption errors and data errors were explored. For $\overline{m}$, it was determined that four PMZs could not be explained from the correction of possible assumption or data errors. For $\overline{A_0}$, it was determined that 11 PMZs could not be explained from the correction of possible assumption or data errors however the errors may be the result the presence of leaking/open boundary valves.

5.2. Recommendations

The following recommendations are made as a result of the findings from the study:

- The study of pressure management zones and the resultant leakage parameters must be completed with more sets of data. This will enable further analysis and understanding between the leakage parameters and their behaviour.
- Data must be collected and captured precisely by field technicians with intimate knowledge of the pressure management zones to ensure errors are minimised/eliminated. Retrieving information from companies may be practical but miscalculation/incorrect collection/poor

measurement techniques, whether measured/collected by the researcher or by consultants, requires accurate and structured methodologies. Any errors in measurement, calculation or collection may have considerable influence on the subsequent leakage parameter results.

- The accurate collection of the parameters in Table 5-1 is critical for the continued comparison of results to this study.

Table 5-1: Priority Parameters to Collect from the Field

No.	Parameter	Source
1.	Average Zone Pressure (AZP) Elevation	Using consistent methodology described by Lambert et al. (2013). See Section 2.4.2 and Section 3.5.1.3.
2.	Critical Point Elevation (CP)	Point in the PMZ with lowest pressure. See Section 3.3.1.
3.	Lowest Point Elevation (LP)	Point in the PMZ with highest pressure.
4.	Pressure Logging at AZP, CP, LP	Data collected from pressure logging at location of AZP, CP, LP.
5.	Flow Logging at Supply Inlets	Data collected from flow logging at location one or more inlet supply points.
6.	Minimum Night Flow (MNF)	Calculated from Flow Logging data. See Section 3.5.1.2.
7.	From Flow Logging: System Input Volume (SIV)	Calculated from Flow Logging data. See Section 3.5.1.1.
8.	Night Time Usage	Calculated from population or no. of connections (considering various land use types). See Section 3.5.1.5.
9.	Unavoidable Annual Real Losses (UARL)	See Section 3.5.1.4.
10.	Night Day Factor (NDF)	See Section 3.5.1.5.

- Interpretation and application of flow and pressure logging information, as well as using a standard methodology for calculating parameters (such as AZP) will provide robust results that can be compared to other PMZs collected by, and calculated by, other companies/researchers.
- Further study to be undertaken on the practical applications of the leakage area ($\overline{A_0}$) and head-area slope ($\overline{m}$) parameters.
- Development of a new indicator to measure the performance of a PMZ/DMA. The ILI is influenced by pressure thus the ILI may increase after pressure management despite the reduction in real losses. Furthermore, the Unavoidable Annual Real Loss calculation that is an

input to calculate the ILI was created using N1=1. It was observed that in a system where N1>1, then the ILI will decrease after pressure management, and in a system where N1<1, then the ILI will increase after pressure management. This is a weakness in the ILI being used as an indicator.

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Appendix I

Example of Field Data Collection Sheet

CITY of Umhlathuze

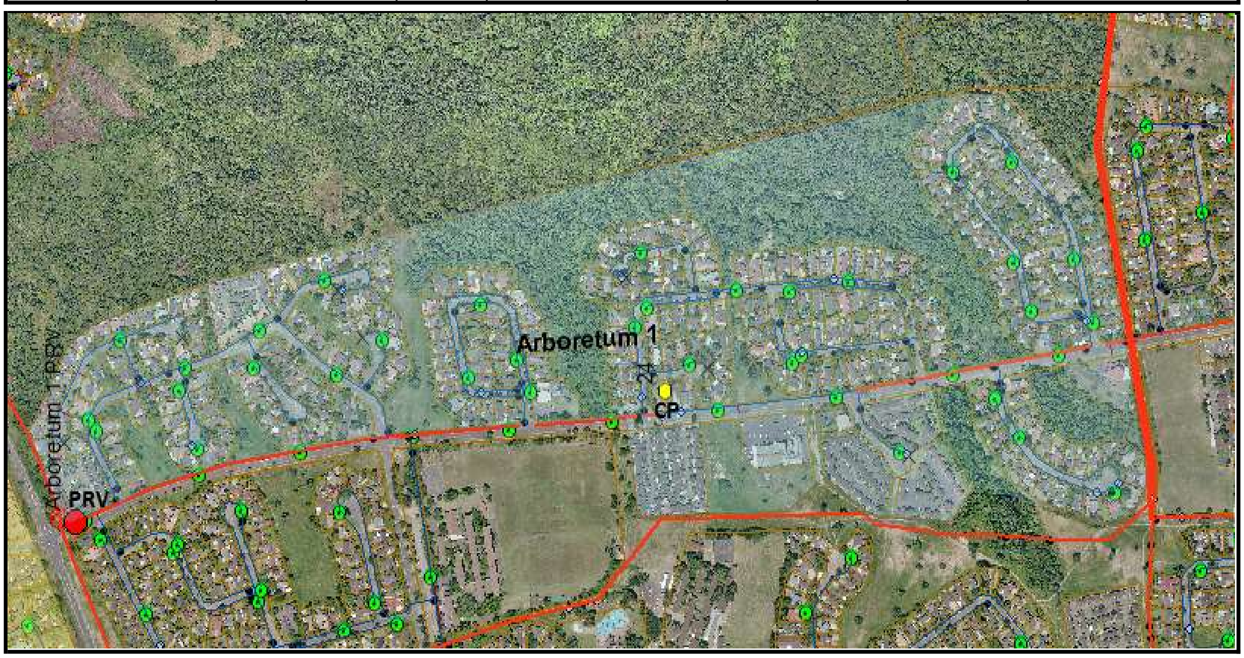
Pressure Reduction Program

Operational Area:	City of Umhlathuze	Designed by:	Aren Govender	PRV Number:	**Arboretum 1 PRV**
Town:	Richards Bay	Approved by Ops:		Ops Area Manager:	Steve Schamrel
Area:	Arboretum	Approved by NRW:		NRW Area Manager:	Sabelo Hlela
Consultant:	JOAT Sales & Service	Approved by Municipality:		Municipality Area Manager:	1900/01/00

Supply:	Mandlazini Reservoir		Pipe Size:	200	mm	AZP before PRV	49.7	mH2O
Supply TWL:	77	AMSL	Length of Mains:	8.90	Km	AZP after PRV	29.5	mH2O
			Number of Connections:		376	ΔAZP	20.2	mH2O

Joat PRV No:	PMAN - 001		Proposed PRV Size:	100	mm	GIS Reference:	X:	28°44'41.48"S	
Address	Essonwood Way		Design Standard:	25-60	m H_2O		Y:	32° 3'53.91"E	
PRV Maker:	CLA-VAL		Function:	Reducing			Z	20	AMSL
Upstream Pressure	46.2	mH2O	Cavitation Checked:	ok		Maximum Flow Logged		39.83	m^3/h
Downstream Pressure	25.5	mH2O	Fire-Risk Categorie	High-Risk		Minimum Flow Logged		4.62	m^3/h

CP1 Details	Address:	1 Haakdoringrug						
	Elevation:	24	AMSL	Measured Pressure:		Kpa	Date:	
CP2 Details	Address:	-						
	Elevation:	-	AMSL	Measured Pressure:		Kpa	Date:	



Comments:

Submitted By:	Aren Govender	Date:

PRV - GENERAL DATA

GENERAL DATA		
	PRV Number	*Arboretum 1 PRV*
	JOAT Name	*PMAN - 001*
	Operational Area	*City of Umhlathuze*
	Town	*Richards Bay*
	Area	*Arboretum*
	Designed by	*Aren Govender*
	Submitted by	*Aren Govender*
	Ops Area Manager	*Steve Schamrel*
	NRW Area Manager	*Sabelo Hlela*
	Municipality Area Manager	*0*
	PRV Address	*Essonwood Way*
	X	*28°44'41.48"S*
	Y	*32° 3'53.91"E*
	Z [amsl]	*20*
	CP1 Address	*1 Haakdoringrug*
	CP1 GL [amsl]	*24*
	CP2 Address	*-*
	CP2 GL [amsl]	*-*
	Supply	*Mandlazini Reservoir*
	Supply TWL [amsl]	*77*
	Pipe Size	*200*
	Proposed PRV Size	*100*
	PRV Maker	*CLA-VAL*
	Function	*Reducing*
	Design Standard [mH2O]	*25-60*
	Length of mains [km]	*8.9*
	Average Length of service connections [m]	*4.2*
	Length of system pipe length that is metal [km]	*0*

Billed Authorized Consumption

Type of consumption	***Units***	***ACU [l/day]***	***Consumption [m3/day]***
A - Domestic	*317*	*1035*	*328.0*
D - Commercial	*2*	*3085*	*6.2*
G - Governamental	*0*		*4.0*
B - Flats	*7*	*17571*	*123.0*

Unbilled Authorized Consumption

Type of consumption		***Units***	***ACU [l/day]***	***Consumption [m3/day]***
A - Domestic		*50*	*500*	*25.0*
D - Commercial		*0*		*0.0*
N - Education		*0*		*0.0*
Outlet Devices				
Consumption per Capita [l/day]	*0*			
Habitants per House	*0*	*0*		
Houses supplied by Ods	*0*			

Night Use

Domestic Use		***Non Domestic Use***	
Population	*1675*	*Description*	*2*
% Active	*6*	*No of Units*	*50*
Unit Use [l/hour]	*10*	*Unit Use [l/hour]*	*200*
Consumption [m3/hour]	*1.0*	*Consumption [m3/hour]*	*10*

AVERAGE ZONE PRESSURE (AZP)

Analysis of AZP before pressure management

DV No	Name	Supply GL [amsl]	d/s [mH20]	Nc	Lm [km]	AZP [amsl]	AZP [mH2O]	AZP using Nc [mH2O]	AZP using Lm mH2O]
boretum 1 P	Arboretum	20	45.721905	369	8.9	16	49.721905	49.7	49.7

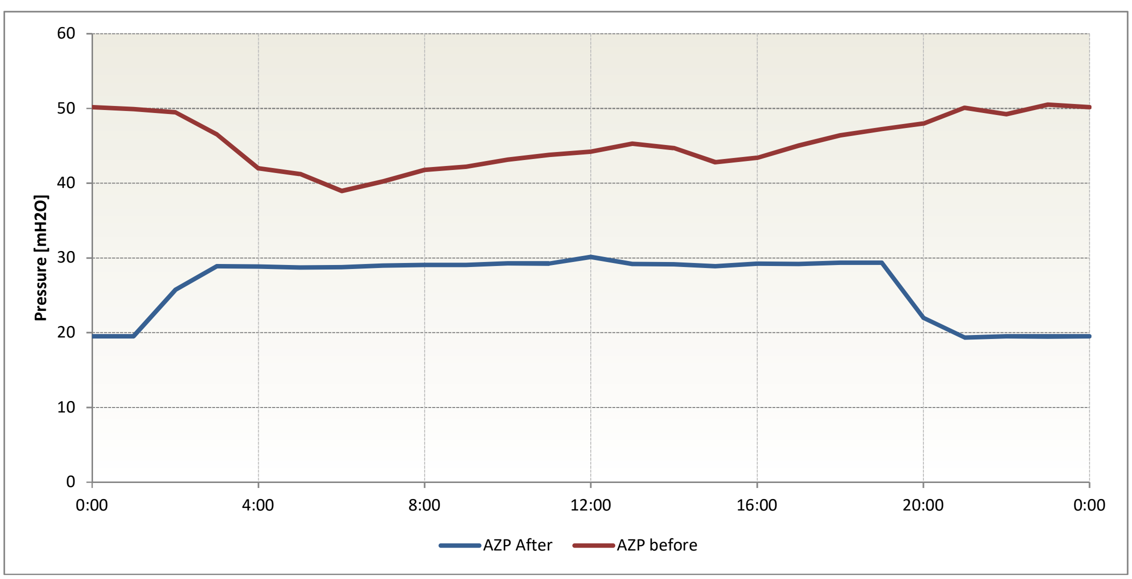
Analysis of AZP after pressure management

DV No	Name	Supply GL [amsl]	d/s [mH20]	Nc	Lm [km]	AZP [amsl]	AZP [mH2O]	AZP using Nc [mH2O]	AZP using Lm mH2O]
boretum 1 P	Arboretum	20	25.532872	376	8.9	16	29.532872	29.5	29.5

Selection of AZP

AZP Before Pressure Reduction / Using Nc Analysis *49.7* *mH2O*
AZP After Pressure Reduction / Using Nc Analysis *29.5* *mH2O*

Graph



NIGHT DAY FACTOR ANALYSIS

Analysis of Favad N1 Value

A) IWA Simpler Practical Approach

Length of mains Lm	*8.90*	*km*
Length of service connections	*1.58*	*km*
Length of system pipe length that is metal	*0.00*	*km*
% of system pipe length that is metal	*0.00*	*%*
Infrastructure Leakage Index ILI	*-9.7*	
Favad N1 Value	*1.50*	

B) Calculated from logging data (commiossioning the PRV)

Leak flow rate before the change in the pressure	*6.18*	*m3/h*
Leak flow rate after the change in the pressure	*4.62*	*m3/h*
AZP before the change in the pressure	*49.7*	*mH20*
AZP after the change in the pressure	*29.5*	*mH20*
Favad N1 Value	*0.56*	

C) Test

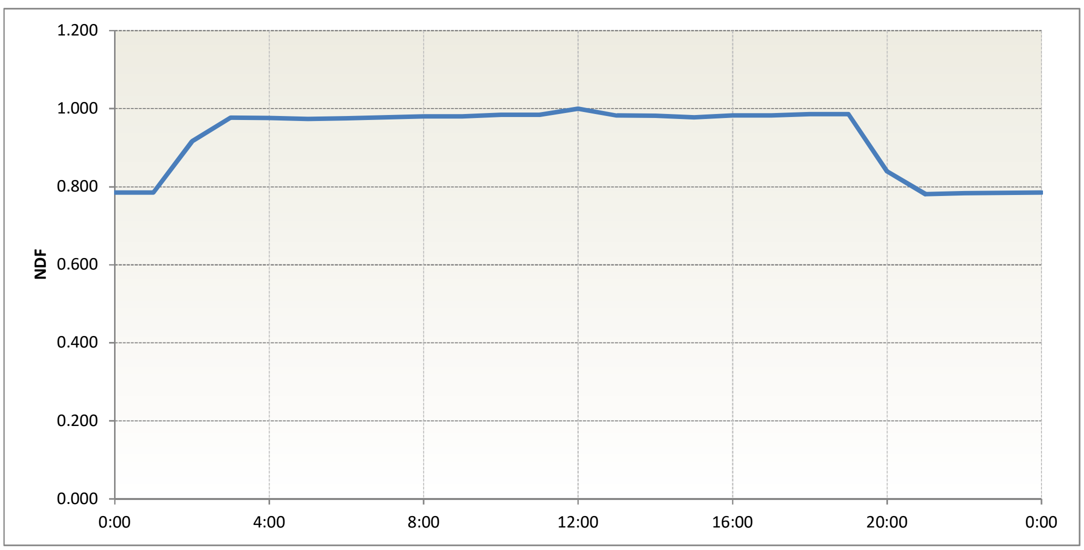
Test Not Performed	*0.00*	*N1*

Selection of Favad N1 Value

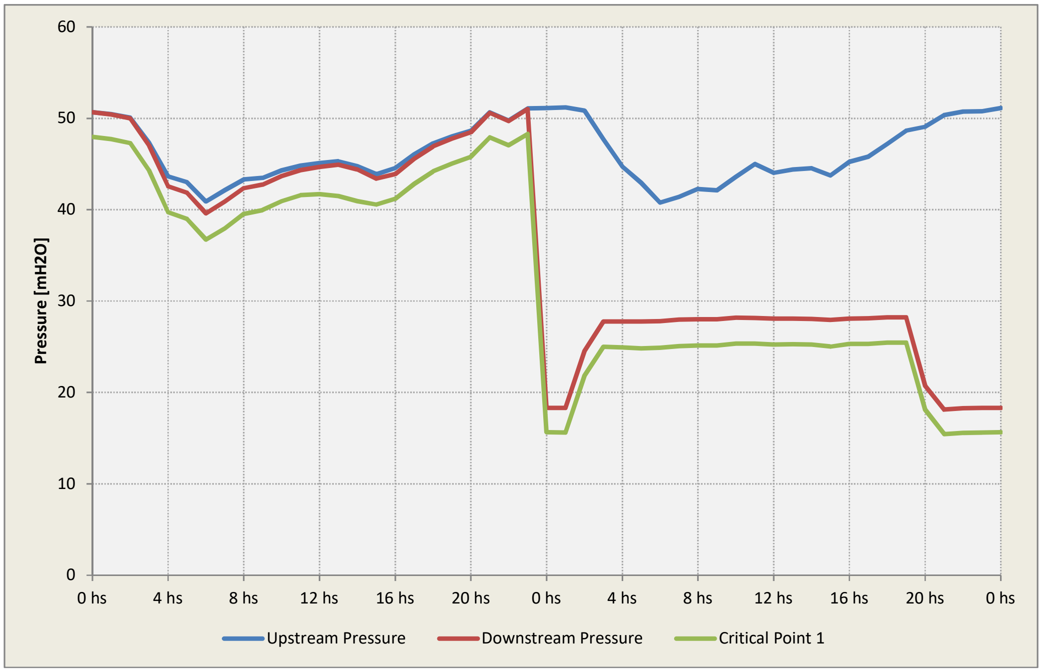
Favad N1 Value Calculated with Logging Data *0.56*

Night Day Factor (NDF)

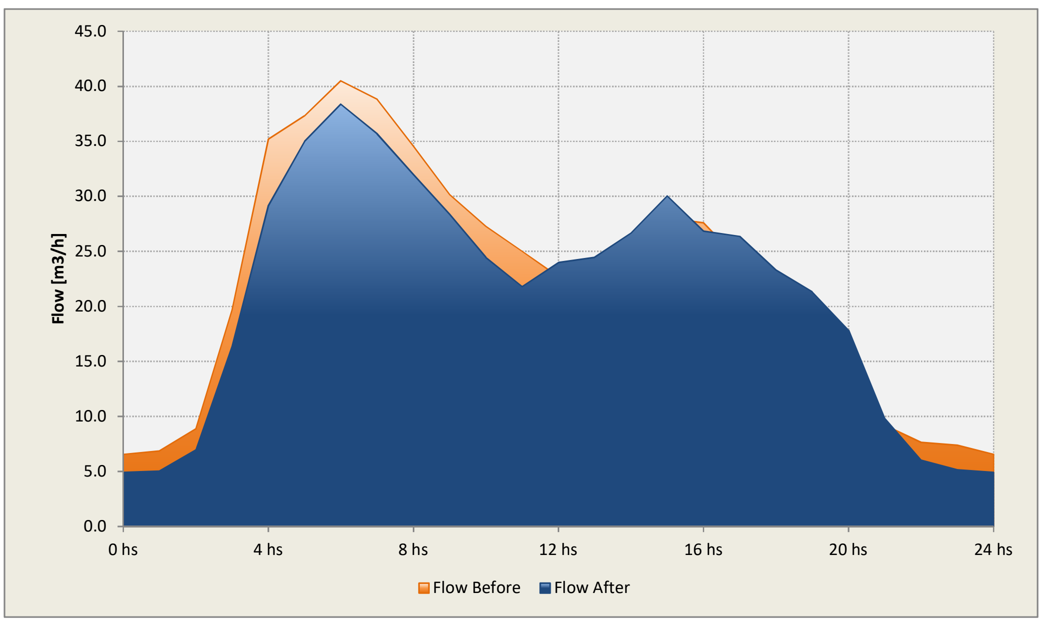
Night Day Factor in Hours *22.4*



PRV SETTING



FLOW BEFORE VS FLOW AFTER



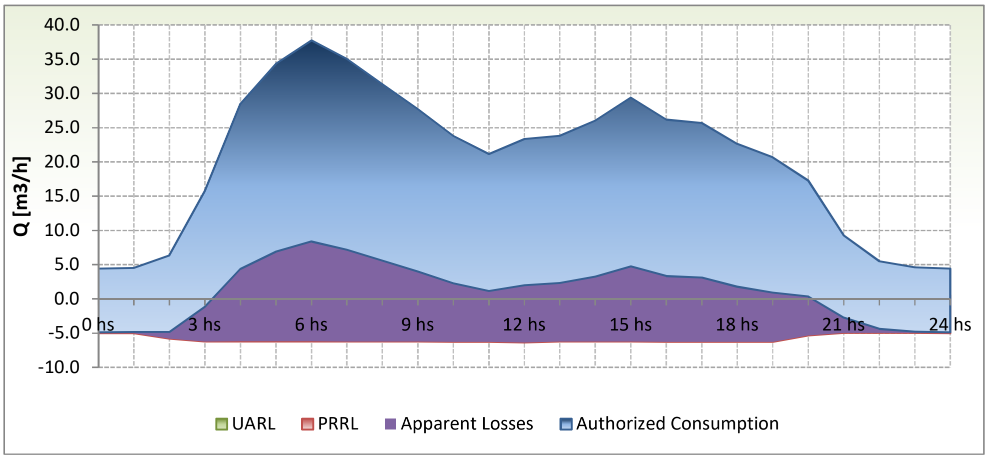
SIMPLIFIED WATER BALANCE

System Input Value (SIV)	Authorized Consumption 486.2 m3/day	
519.9 m3/day	Water Losses 33.7 m3/day	Apparent Losses 176.5 m3/day
		Real Losses -142.8 m3/day

AZP Values		
Pave	*26.7*	*mH2O*
Pmax	*30.1*	*mH2O*
Pmin	*19.3*	*mH2O*

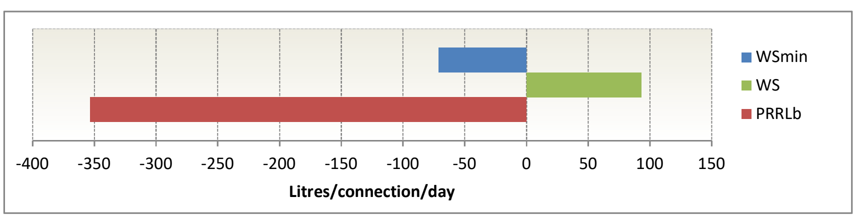
Flow Values		
Qave	*21.7*	*m3/h*
Qmax	*39.8*	*m3/h*
Qmin	*4.6*	*m3/h*

IWA Factors		
TIRL	*-380*	*l/conn/day*
UARL	*39*	*l/conn/day*
ILI	*-9.7*	

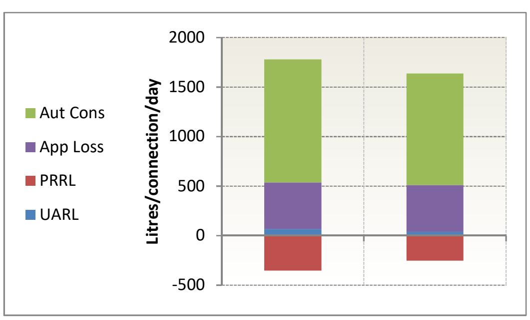


Water Savings (Cost of Water = 4.105 Rands/m3)

A) Minimum Estimated Water Saving from Design (Wsmin)	*-1.1 m3/h*	=	*-71 l/conn/day*	=	*-40 111*	*Rands/year*
B) Potential Recovery Real Losses Before Pressure Management (PRRLb)	*-5.5 m3/h*	=	*-353 l/conn/day*	=	*-199 116*	*Rands/year*
C) Real Water Savings (WS)	*1.5 m3/h*	=	*93 l/conn/day*	=	*52 383*	*Rands/year*



Situation Before vs Situation After Pressure Management



	Before	After
SIV	*1424*	*1383*
Aut Cons	*1242*	*1127*
App Loss	*469*	*469*
TIRL	*-287*	*-214*
PRRL	*-353*	*-254*
UARL	*67*	*40*

Values are in l/conn/day. SIV: System Input Value; Aut Cons: Authorized Consumption; App Loss: Apparent Losses; TIRL: Technical Indicator for Real Losses; Potential Recovery Real Losses; UARL: Unavoidable Annual Real Losses.

FIRE FIGHTING ANALYSIS

A) PRV Details

PRV Maker	CLA-VAL	
Type	CLA-VAL / 90_01	
PRV Size	200	mm
Reduced Bore	no	
Flow capacity (Qprv)	885.6	m3/h

B) Logging Data

Differential Pressure	2.1	bar
Maximum Flow Logged (Qlog)	39.8	m3/h
Demand Factor (F)	1.2	
Maximum Flow (Qmax = Qlog x F)	47.8	m3/h

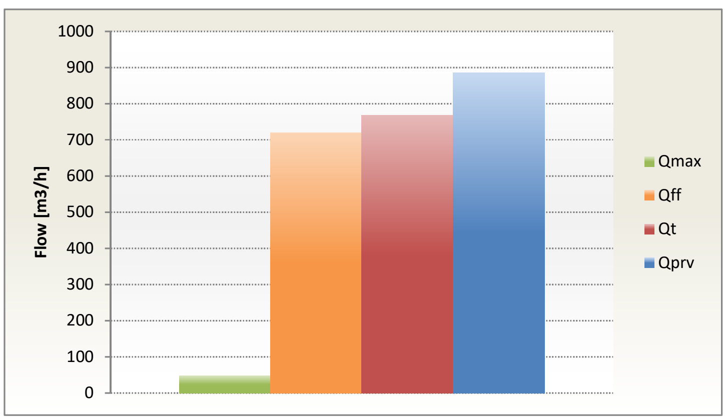
C) Red Book Guidelines

Fire-Risk Category	High-Risk	
Duration of design fire flow	6	h
Minimum design fire flow (Qff)	12000	l/min
Maximum number of hydrants discharging simultaneously	8	
Minimum hydrrant flow rate (for each hydrant)	1500	l/min
Minimum residual head	1.5	bar

D) Verification

Total Flow Demanded (Qt = Qmax + Qff)	767.8	m3/h

Fire Fighting Analysis has been Succesfull, the PRV can supply the required flow



Appendix IIa

Consolidated Data and Calculated Parameters

Ref No.	DV Number	Company Ref Name	Operations Area	Town	Area	Designed By
Zone 1	PRVA	PRVA	Uthukela Water	Dundee	Dundee	Mauro Raul Iriart
Zone 2	Dv 2876	Almond Road 1	Toti	Toti/Durban	Amanzintoti	CBI
Zone 3	Dv 2877	Almond Rd Prv 2	Toti	Toti Durban	Kingsburgh	CBI Consulting
Zone 4	Dv 2824	Bluff 1 Beacon Road Prv	South Central	Durban	Bluff	Vishal Poona
Zone 5	Dv 3008	Cato Manor Hl Prv	South Central	Durban	Pigeon Vally	Vishal Poona/Brett Nichol
Zone 6	Dv 3067	Chatsworth Prv Zone 7	South Central	Durban	Umhlatuzana	Brett Nichol
Zone 7	Dv 3213	Chats 4 - Papaver Plc	South Central	Durban	Crossmore	Brett Nichol
Zone 8	Dv 2885	Doonside Prv 1	Toti	Toti/Durban	Amanzintoti	CBI
Zone 9	Dv 2823	Lamont Prv	South Central	Durban	Mobeni Heights	V.Poona
Zone 10	Dv 3052	Lewis Drive 3	Toti	Toti/Durban	Amanzintoti CBD	CBI
Zone 11	DV 3145	N.Ridge Prv Zone 1	South Central	Durban	Windermere	SSI
Zone 12	Dv 2929	Northdene Prv 1	South Central	Durban	Malvern	Brett Nichol
Zone 13	Dv 3148	Ridge End Prv Zone 1	South Central	Durban	Morningside	SSI/Joat
Zone 14	Dv 3149	Ridge End Prv Zone 2	South Central	Durban	Morningside	SSI/Joat
Zone 15	Dv 3155	S.Ridge prv Zone 2	South	Durban Central	Westridge	SSI/Joat
Zone 16	Dv 3156	S.Ridge prv Zone 3	South	Durban Central	Glenwood	SSI/Joat
Zone 17	Dv 2855	Sherwood 12&3 Prv 8	South Central	Durban	Springfield	Brett Nichol
Zone 18	Dv 3038	St Thomas Hl Prv	South Central	Durban	Musgrave	Vishal Poona/Brett Nichol
Zone 19	Dv 1292	Woodlands 1&2 Beaunoir	South Central	Durban	Austerville	Vishal poona
Zone 20	Dv 2760	Falconhaven Prv	South Central	Durban	Austerville	V.Poona
Zone 21	Dv 2759	Genoa Road Prv	South Central	Durban	Austerville	V.Poona
Zone 22	DV2820	KWD3-5	West	Durban	Kwadabeka	Mauro Raul Iriart
Zone 23	DV3188	GEOR-2	West	Durban	Mlaba Village	Juan Bazet
Zone 24	DV3190	INT-4	West	Durban	Luganda	Juan Bazet
Zone 25	DV3191	INT-6	West	Durban	Luganda	Juan Bazet
Zone 26	DV3193	KWD3-3	West	Durban	Kwadabeka	Mauro Raul Iriart
Zone 27	DV3194	KWD3-4	West	Durban	Kwadabeka-D	Juan Bazet
Zone 28	DV3195	KWD3-6	West	Durban	Kwadabeka	Mauro Raul Iriart
Zone 29	DV3197	KWD3-2	West	Durban	Kwadabeka	Mauro Raul Iriart
Zone 30	DV3199	KWD3-1	West	Durban	Kwadabeka-D	Juan Bazet
Zone 31	DV3200	MPU4-1	West	Durban	Mlaba Village	Juan Bazet
Zone 32	DV3203	TSHE1-3	West	Durban	Marian Heights	Juan Bazet
Zone 33	DV3204	INT-1	West	Durban	Luganda	Juan Bazet
Zone 34	DV3207	WASH-2	West	Durban	Savannah Park	Mauro Raul Iriart
Zone 35	DV3210	WASH-5	West	Durban	Savannah Park	Mauro Raul Iriart
Zone 36	DV3262	PTN-4	West	Durban	Nazareth	Juan Bazet
Zone 37	DV3277	WYEB-3	West	Durban	Berkshire	Juan Bazet
Zone 38	DV3343	TSHE2-1	West	Durban	Tshelimnyama	Mauro Raul Iriart
Zone 39	DV3367	KWD1-5	West	Durban	Kwadabeka	Mauro Raul Iriart
Zone 40	Arboretum 1 PRV	PMAN - 001	City of Umhlathuze	Richards Bay	Arboretum	Aren Govender
Zone 41	Arboretum 2 PRV	PMAN - 002	City of Umhlathuze	Richards Bay	Arboretum	Aren Govender
Zone 42	Arboretum Ext PRV	PMAN - 003	City of Umhlathuze	Richards Bay	Arboretum	Aren Govender
Zone 43	Gobandlovu 1 PRV	PFOR - 002	City of Umhlathuze	Esikhawini	Gobandlovu	Aren Govender
Zone 44	Logan Rd. PRV	PMAG - 001	City of Umhlathuze	Empangeni	Central Empangeni	Aren Govender
Zone 45	Mandlazini PRV	PMAN - 004	City of Umhlathuze	Richards Bay	Mandlazini	Aren Govender
Zone 46	Union St PRV	PMAG - 002	City of Umhlathuze	Empangeni	Noordsig	Aren Govender
Zone 47	EMP FARM PRV	PMAG - 002	City of Umhlathuze	Empangeni	Mandosi Emp Farm	Aren Govender
Zone 48	Gobandlovu 2 PRV	PFOR03	City of Umhlathuze	eSikhaleni	Gobandlovu	Aren Govender
Zone 49	Kildare Ext	PFOR03	City of Umhlathuze	Empangeni	Kildare Extension	Aren Govender
Zone 50	Kuleka Industrial	PPCE002	City of Umhlathuze	Empangeni	Kuleka Industrial	Shaym Natha
Zone 51	Matshana 1 PRV	PR12-001	City of Umhlathuze	Ngwelezane	Matshana	Aren Govender
Zone 52	PLOF-002	EMP4 - Nyala Park PMZ	City of Umhlathuze	Empangeni	Nyala Park	Shaym Natha
Zone 53	Birdswood PRV Zone	RBAY 1	City of Umhlathuze	Richards Bay	Birdswood	Shaym Natha
Zone 54	PLOF-001	CoU 0035 Kildare	City of Umhlathuze	Empangeni	Kildare	Shaym Natha
Zone 55	PR101	NGW 8 - Ndabayakhe	City of uMhlathuze	Ndabayakhe	Ngwelezane	Shaym Natha
Zone 56	uMhlathuze Village P	uMhlathuze Village PRV Zo	City of Umhlathuze	Ngwelezane	Ngwelezane	Shaym Natha
Zone 57	Veldenvlei PRV Zone	PMAN - 005	City of Umhlathuze	Richards Bay	Veldenvlei	Aren Govender
Zone 58	PRV-01		Mangaung	Bloemfontein	Ashbury	Lyle Goldman
Zone 59	PRV-03		Mangaung	Bloemfontein	Bloemside Phase 2&3	Lyle Goldman
Zone 60	PRV-04	PRV - 04	Mangaung Municipa	Bloemfontein	Heidedal	Robison de Melo
Zone 61	PRV-05	PRV - 05	Mangaung Municipa	Bloemfontein	Heidedal	Robison de Melo
Zone 62	PRV-06		Mangaung	Bloemfontein	Batho	Robison de Melo
Zone 63	PRV-007	PRV-007	Mangaung Municipa	Bloemfontein	Bochabela	Robison de Melo

Ref No.	DV Number	Company Ref Name	Operations Area	Town	Area	Designed By
Zone 64	PRV-009		Mangaung	Bloemfontein	Heidedal	Lyle Goldman
Zone 65	PRV - 11	PRV - 11	Mangaung Municipa	Bloemfontein	Freedon Square	Robison de Melo
Zone 66	PRV-013		Mangaung	Bloemfontein	Ooseinde	Robison de Melo
Zone 67	PRV-017	PRV-017	Mangaung Municipa	Bloemfontein	Universitas	Robison de Melo
Zone 68	PRV - 18	PRV - 18	Mangaung Municipa	Bloemfontein	Langenhovenpark	Robison de Melo
Zone 69	PRV-021	PRV-021	Center	Bloemfontein	Fichard Park	Robison de Melo
Zone 70	PRV-025	PRV-025	Mangaung Municipa	Bloemfontein	Fairview	Robison de Melo
Zone 71	PRV-026	PRV-026	Mangaung Municipa	Bloemfontein	Driehoek and Bainsvlei	Robison de Melo
Zone 72	PRV-027	PRV-027	Mangaung Municipa	Bloemfontein	Bainsvlei	Robison de Melo
Zone 73	PRV-028	PRV-028	Mangaung Municipa	Bloemfontein	Groenvlei	Robison de Melo
Zone 74	PRV-031	PRV-031	Mangaung Municipa	Bloemfontein	Estoire	Robison de Melo
Zone 75	PRV-032	PRV-032	Mangaung Municipa	Bloemfontein	Estoire	Robison de Melo
Zone 76	PRV-036	PRV-036	Mangaung Municipa	Bloemfontein	Hartebeesfontein	Robison de Melo
Zone 77	HV - 34	PRV - 001	Mangaung Municipa	Botshabelo	Botshabelo H	Shravan Sewlal
Zone 78	HV - 06	PRV - 006	Mangaung Municipa	Botshabelo	Botshabelo C	Shravan Sewlal
Zone 79	PRV - 012 - HV - 16	PRV - 012	Mangaung Municipa	Botshabelo	Botshabelo L	Shravan Sewlal
Zone 80	HV - 42	PRV - 013	Mangaung Municipa	Botshabelo	Botshabelo F	Shravan Sewlal
Zone 81	PRV -016	PRV - 016	Mangaung Municipa	Thaba Nchu	Bultfontein Zone 1	Shravan Sewlal
Zone 82	DV 1507 Magazine Rd	DV 1507 Magazine Rd	Msunduzi Municipal	Pietermaritzburg	Blackridge	Shaym Natha
Zone 83	1505 Braithwaite Rd F	Braithwaite Rd PRV	Msunduzi Municipal	Pietermaritzburg	Montrose	Shaym Natha
Zone 84	DV 0803 Haniville PRV	DV 0803 Haniville PRV	Msunduzi Municipal	Pietermaritzburg	Whispers	Shaym Natha
Zone 85	DV 1007 Woodpecker	DV 1007 Woodpecker Rd P	Msunduzi Municipal	Pietermaritzburg	Mount View	Shaym Natha
Zone 86	PRV 0703 Chief Mhlab	DV 0703 Chief Mhlabenzim	Msunduzi Municipal	Pietermaritzburg	Willowton	Shaym Natha
Zone 87	DV 0708 Tamboville P	DV 0708 Tamboville Prv 1	Msunduzi Municipal	Pietermaritzburg	Eastwood	Existing
Zone 88	DV 0709 Tamboville P	DV 0709 Tamboville PRV 2	Msunduzi Municipal	Pietermaritzburg	Eastwood	Wesley Moonsamy
Zone 89	1602	Stott Rd Prv	Msunduzi Municipal	Pietermaritzburg	Prestbury	Existing
Zone 90	1301	Albany Rd Prv	Msunduzi Municipal	Pietermaritzburg	Sweetwaters Res	Existing
Zone 91	Xulukhona PRV	Xulukhona PRV	Msunduzi Municipal	Pietermaritzburg	Ashdown	Shaym Natha
Zone 92	DV 0401 Bombay & N	DV 0401 Bombay and Nara	Msunduzi Municipal	Pietermaritzburg	Haythorns	Existing
Zone 93	DV 0904 Khan Rd PRV	Khan Rd Prv	Msunduzi Municipal	Pietermaritzburg	Belfort	Existing
Zone 94	DV 0203 Turbull Rd PI	Turnbull Rd PRV	Msunduzi Municipal	Pietermaritzburg	Bisley	Existing
Zone 95	DV 1601 Morcom Rd	Morcom Rd Prv 1601	Msunduzi Municipal	Pietermaritzburg	Black Ridge	Existing
Zone 96	Ganges Rd PRV 1004	Belfort Prv 1004	Msunduzi Municipal	Pietermaritzburg	Belfort	Existing
Zone 97	DV 1003 Regina Rd	DV 1003 Regina Rd PRV	Msunduzi Municipal	Pietermaritzburg	Northdale	Existing
Zone 98	Belfort PRV DV 1001	Belfrot PRV DV 1001	Msunduzi Municipal	Pietermaritzburg	Belfort	Existing
Zone 99	DV 1604 Villiers Drive	Villers Drive Prv	Msunduzi Municipal	Pietermaritzburg	Clarendon	Existing
Zone 100	DV 1005 Boundary Rd	DV 1005 Boundary Rd Prv	Msunduzi Municipal	Pietermaritzburg	Belfort	Existing
Zone 101	DV 905 Simla Rd	Simla Rd Prv	Msunduzi Municipal	Pietermaritzburg	Bombay Hights	Existing
Zone 102	DV 1305 Mbubu Rd	DV 1305 Mbubu Rd Prv	Msunduzi Municipal	Pietermaritzburg	Blackridge	Existing
Zone 103	DV 0906 Springvale R	Springvale Rd Prv	Msunduzi Municipal	Pietermaritzburg	Northdale	Existing
Zone 104	DV 1510 Old Howick F	Old Howick Rd Prv	Msunduzi Municipal	Pietermaritzburg	Wembly	Existing
Zone 105	Kwapata PRV 4	Kwapata PRV 4	Msunduzi Municipal	Pietermaritzburg	Edendale H	Shaym Natha
Zone 106	Kwapata PRV 3	Kwapata PRV 3	Msunduzi Municipal	Pietermaritzburg	Edendale H	Shaym Natha
Zone 107	Montgomery Dr PRV	Montgomery Dr PRV	Msunduzi Municipal	Pietermaritzburg	Athlone	Existing

General Info

Ref No.	Submitted By	Ops Area Manager	NRW Area Manager	Municipality Area Manager	PRV Address	X	Y	Z (masl)
Zone 1	Mauro Raul Iriart				Union St	-76002	-3116815	1241
Zone 2	Brett Nichol	D.Davids	S.Scruton	S.Scruton	2 Hawthorne Road	-13186.6	-3329768.1	28.0
Zone 3	Brett Nichol	D.Davids	S.Scruton	S.Scruton	40 San Raphael Avenue	-13792.9	-3328683.7	34.0
Zone 4	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	132 Beacon Road	1297.6	-3310523.7	45.0
Zone 5	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	Cato Manor Reservoir	-1995.5	-3305648.4	138.0
Zone 6	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	12 42nd Avenue	-7587.1	-3310657.1	159.0
Zone 7	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	Behind 148 Crossmoor Dr	-12817.5	-3308486.5	252.0
Zone 8	Brett.Nichol	D.Davids	S.Scruton	S.Scruton	2 Rockview Road	-11996.4	-3327733.9	21.0
Zone 9	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	24 Jacaranda Ave	-5779.0	-3312698.0	90.0
Zone 10	Brett Nichol	D.Davids	S.Scruton	S.Scruton	Opp 27 Commercial Road	-11408.8	-3326553.4	2.0
Zone 11	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	701 Currie Road	1186.2	-3301529.2	67.0
Zone 12	Brett Nichol	Prashan	S.Scruton	S.Scruton	97 Main Road	-7603.8	-3306687.0	169.0
Zone 13	Brett Nichol	Prashan	S.Scruton	S.Scruton	45 Tremation Drive	1871.5	-3300094.7	86.0
Zone 14	Brett Nichol	Prashan	S.Scruton	S.Scruton	560 Windermere Road	2111.7	-3299951.3	66.0
Zone 15	Brett Nichol	Prashan	S.Scruton	S.Scruton	Street 120136	-2141.9	-3303944.6	82.0
Zone 16	Brett Nichol	Prashan	S.Scruton	S.Scruton	30 Ellis Brown Road	-1281.1	-3304835.4	116.0
Zone 17	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	Nxt 122 Hendry Road	-185.7	-3300780.7	47.0
Zone 18	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	St Thomas Reservoir	-445.4	-3302561.9	142.0
Zone 19	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	Beanoir Road	-1199.5	-33130963.9	45.0
Zone 20	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	2 Falconhaven Road	-1117.9	-3313080.5	42.0
Zone 21	Brett Nichol	Prashan Shukla	S.Scruton	S.Scruton	Outside 297 Quality St	-1199.1	-3312990.8	56.0
Zone 22	Mauro Raul Iriart	Sfiso Ngcobo	Devashan Govender	Bhavna Soni	Isomi Drive	-7302.8	-3294110.2	126.0
Zone 23	Juan Bazet	Mark Backman			STR 76107	-34589.16	-3296725.25	654.0
Zone 24	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	39 Ekuthuleni Rd	-19455.72	-3307350.32	240.0
Zone 25	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	16, STR 40527	-15736.52	-3307730.47	340.0
Zone 26	Mauro Raul Iriart	Sfiso Ngcobo	Devashan Govender	Bhavna Soni	27 Isomi Drive	-7426.2	-3294046.9	136.0
Zone 27	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	Kunempunzi Way	-7705.85	-3293958.93	146.0
Zone 28	Mauro Raul Iriart	Sfiso Ngcobo	Devashan Govender	Bhavna Soni	Kunempisi Ave	-7683.85	-3294133.95	156.0
Zone 29	Mauro Raul Iriart	Sfiso Ngcobo	Devashan Govender	Bhavna Soni	2 Sinoshaka Place	-7421.3	-3294057.7	138.0
Zone 30	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	Kunempunzi Way	-7705.85	-3293958.93	146
Zone 31	Juan Bazet	Mark Backman			STR 400178	-38129.12	-3298902.24	569
Zone 32	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	John Rose Drive	-17121.31	-3304711.23	324
Zone 33	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	39 Mango Dr	-19785.53	-3308063.84	287
Zone 34	Mauro Raul Iriart	Vernon Dollman	Devashan Govender	Bhavna Soni	Ngena Road	-15119.85	-3306914.85	330
Zone 35	Mauro Raul Iriart	Vernon Dollman	Devashan Govender	Bhavna Soni	Ngena Road	-15021.6	-3306637.43	306
Zone 36	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	Mkhize Rd	-13875.0	-3303836.32	232
Zone 37	Juan Bazet	Vernon Dollman	Devashan Govender	Bhavna Soni	Dinkelmann Rd	-10885.85	3296328.46	332
Zone 38	Mauro Raul Iriart	Vernon Dollman	Devashan Govender	Bhavna Soni	116 Tshelimnyama Road	-18676.77	-3302796.61	376
Zone 39	Mauro Raul Iriart	Sfiso Ngcobo	Devashan Govender	Bhavna Soni	Kwululeka Drive	-9273.64	-3294964.77	308
Zone 40	Aren Govender	Steve Schamrel	Sabelo Hlela		Essonwood Way	28°44'41.48"S	32° 3'53.91"E	20.0
Zone 41	Aren Govender	Steve Schamrel	Sabelo Hlela		Albizia Ave	28°44'53.38"S	32° 3'29.97"E	26.0
Zone 42	Aren Govender	Steve Schamrel	Sabelo Hlela		Cnr R619 and Saligna Rd	28°45'42.77"S	32° 3'33.70"E	26.0
Zone 43	Aren Govender	Bonga Mhlongo	Sabelo Hlela		Off Gobandlovu Main Rd	28°51'28.57"S	31°53'38.40"E	60.0
Zone 44	Aren Govender	Kevin Groenewald	Sabelo Hlela		Logan Rd	28°44'27.23"S	31°53'18.18"E	124.0
Zone 45	Aren Govender	Steve Schamrel	Sabelo Hlela		Off Nkoninga Rd near airport	28°44'13.52"S	32° 5'55.21"E	32.0
Zone 46	Aren Govender	Kevin Groenewald	Sabelo Hlela		Union Street	28°44'19.08"S	31°53'47.70"E	112.0
Zone 47	Aren Govender	Kevin Groenewald	Sabelo Hlela		Ukhula St	28°44'12.76"S	31°53'35.48"E	112
Zone 48	Aren Govender	Bongani Mhlongo	Sabelo Hlela	TJ Hlatswayo	Gobandlovu	28°51'10.13"S	31°54'23.84"E	46
Zone 49	Aren Govender	Kevin Groenewald	Sabelo Hlela	TJ Hlatswayo	Intrepid Avenue	28°45'26.40"S	31°53'15.83"E	106
Zone 50	Aren Govender	Kevin Groenewald	Sabelo Hlela	TJ Hlatswayo	102	28°45'55.68"S	31°54'21.91"E	59
Zone 51	Aren Govender		Sabelo Hlela		Thandaza Crescent	28°45'40.10"S	31°51'48.18"E	99
Zone 52	Aren Govender	Kevin Groenewald	Sabelo Hlela		Segar Rd	28°45'16.14"S	31°53'57.47"E	97
Zone 53	Shaym Natha	Steve Schamrel	Sabelo Hlela		Wag Tail Walk	28°44'23.14"S	32° 4'27.66"E	24
Zone 54	Shaym Natha	Kevin Groenewald	Sabelo Hlela		Farewell Road	28°45'30.21"S	31°53'33.65"E	87
Zone 55	Shaym Natha	Kevin Groenewald	Sabelo Hlela	Sabelo Hlela		28°48'38.48"S	31°51'46.38"E	78
Zone 56	Shaym Natha	Kevin Groenewald	Sabelo Hlela			28°45'50.67"S	31°52'50.73"E	77
Zone 57	Aren Govender	Steve Schamrel	Sabelo Hlela		Via Verbena	28°44'53.38"S	32° 3'29.97"E	26.0
Zone 58		Mr. M Gabusa		Mr. M Gabusa	Meadoes Str (Old Bloem Rd 3)	-460760.9	-3234921.6	1383.0
Zone 59		Mr. M Gabusa		Mr. M Gabusa	Dr. Belcher Rd	-461824.5	-3236342.0	1406.0
Zone 60	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29° 7'54.56"S	26°14'13.57"E	1372.0
Zone 61	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29° 8'22.91"S	26°14'45.10"E	1382.0
Zone 62		Mr. M Gabusa		Mr. M Gabusa	Lovedale Str	-464468.3	-3233129.5	1385.0
Zone 63	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Dr Belcher Rd with Mkuhlane S	26° 14' 19.18" E	29° 08' 01.32" S	1380.0

Ref No.	Submitted By	Ops Area Manager	NRW Area Manager	Municipality Area Manager	PRV Address	X	Y	Z (masl)
Zone 64		Mr. M Gabusa		Mr. M Gabusa	Doctor Belcher Road	-461963.7	-3236011.8	1404.0
Zone 65	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°10'0.53"S	26°14'54.60"E	1428.0
Zone 66		Mr. M Gabusa		Mr. M Gabusa	Mackenzie Street EB	-460928.7	-3233386.7	1374.0
Zone 67	Robison de Melo	Meshack Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Van Schalkwyk Street	26° 10' 04.77" E	29° 07' 32.50" S	1429
Zone 68	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29° 6'6.83"S	26° 9'44.57"E	1432
Zone 69	Robison de Melo	Meshack Gabusa	Koki Mokhoabane	Mosiuoa Tsomel	Castelyn Dr	26° 10' 46.70"	29° 08' 51.70"	1443
Zone 70	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomela		26° 16' 46.40" E	29° 09' 42.61" S	1391
Zone 71	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Coordinates	26° 11' 24.80" E	29° 12' 32.00" S	1408
Zone 72	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Coordinates	26° 09' 44.60" E	29° 13' 33.30" S	1404
Zone 73	Robison de Melo	Meshack Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Bankovs Blv with Du Plessis	26° 08' 47.63" E	29° 05' 51.46" S	1406
Zone 74	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomela		26° 16' 34.22" E	29° 03' 39.42" S	1365
Zone 75	Robison de Melo	Meshake Gabuza	Koki Mokhoabane	Mosiuoa Tsomela		26° 17' 09.00" E	29° 06' 44.26" S	1362
Zone 76	Robison de Melo	Meshack Gabuza	Koki Mokhoabane	Mosiuoa Tsomel	Coordinates	26° 05' 11.24" E	29° 00' 29.86" S	1328
Zone 77	Robison de Melo	Luzuko Ntlabezo	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°12'31.09" S	26°43'07.98" E	1433
Zone 78	Robison de Melo	Luzuko Ntabezol	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°14'57.746" S	26°43'13.834" E	1424
Zone 79	Robison de Melo	Luzuko Ntabezol	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°16'04.4" S	26°43'26.7" E	1445
Zone 80	Robison de Melo	Luzuko	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°13'15.60" S	26°40'57.44" E	1416
Zone 81	Robison de Melo	William Makhotsi	Koki Mokhoabane	Mosiuoa Tsomel	Refer to GPS Coordinates	29°10'17.70" S	26°48'00.29" E	1487
Zone 82	Shaym Natha	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivpras	2 Magazine Rd	29°36'37.5"S	30°20'52.5"E	695
Zone 83	Shaym Natha	Vish Devsaran	Clifford Enoch	Brenden Sivprasad		29°34'28.93"S	30°20'50.58"E	762
Zone 84	Shaym Natha	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivprasad		29°33'28.38"S	30°26'45.74"E	893
Zone 85	Shaym Natha	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivprasad		29°33'20.53"S	30°22'54.15"E	799
Zone 86	Shaym Natha	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivprasad		29°35'1.30"S	30°25'7.30"E	676
Zone 87	Wesley Moonsamy	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivpras	29°35'19.43"S 30°26'15.96"E	29°35'19.43"S	30°26'15.96"E	669
Zone 88	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivprasad		29°34'57.82"S	30°26'29.24"E	697
Zone 89	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	93 Stott Rd	29º36'44,52 S	30º20'02.74 E	745
Zone 90	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	19 Albany Rd	29º36'41.49 S	30º18'58.01 E	912
Zone 91	Shaym Natha	Vish Devsaran	Clifford Enoch	Brenden Sivprasad		29°38'01.4"S	30°19'34.5"E	743
Zone 92	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	79 Bombay Road	29º34'08.06 S	30º23'32.90 E	701
Zone 93	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	436 Khan Rd	29º32'48.64 S	30º24'10.43	774
Zone 94	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	23 Turnbull Rd	29°38'58.96"S	30°22'35.02"E	724
Zone 95	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	123 Morcom Rd	29°36'55.55"S	30°20'15.15"E	776
Zone 96	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	47 Boundary Rd	29°32'46.05"S	30°23'06.20"E	814
Zone 97	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	170 Regina Rd	29°32'40.86"S	30°23'31.34"E	819
Zone 98	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivprasad		29°32'38.96"S	30°22'57.62"E	871
Zone 99	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	77 Villers Drive	29°36'03.14"S	30°21'02.16"E	783
Zone 100	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	35 Boundary Rd	29°32'47.86"S	30°23'03.36"E	820
Zone 101	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	569 Regina Rd	29°32'43.94"S	30°24'18.34"E	781
Zone 102	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	50 Sweetwaters Rd	29°36'25.96"S	30°19'31.81"E	789
Zone 103	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	169 Springvale Rd	29°32'40.01"S	30°24'31.19"E	786
Zone 104	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	19 Old Howick Rd	29°35'12.32"S	30°20'40.45"E	845
Zone 105	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	29°39'50.30"S 30°18'59.06"	29°39'50.30"S	30°18'59.06"E	836
Zone 106	Wesley Moonsamy	Vish Devsaran	Clifford Enoch	Brenden Sivpras	29°39'49.99"S 30°18'42.36"E	29°39'49.99"S	30°18'42.36"E	880
Zone 107	Wesley Moonsamy	Dhamendra Ragoon	Lungelo Nqashi	Brenden Sivpras	41 Montgomery Drive	29°34'53.19"S	30°21'27.43"E	755

Ref No.	CP1 Address	CP1 GL (masl)	CP2 Address	CP2 GL (masl)	Lowest GL (masl)	Supply	Supply TWL (masl)	Pipe Size (mm)	Proposed PRV Size (mm)
Zone 1	Anne St	1251	Nightingale St	1240		WTW	1325	300 AC	
Zone 2	4 Araucaria Road	38.0				Almond Road	96.0	100.0	100.0
Zone 3	59 Berrio Avenue	37.0				Almond Road Reservoir	96.0	100.0	80.0
Zone 4	114 Watsonia Road	51.0				Bluff 1 Reservoir Zone	90.0	150.0	150.0
Zone 5	University King George	138.0				Cato Manor Prv	190.0	225.0	200.0
Zone 6	20 40th Avenue	162.0				Chatswoth 1 Reservoir	203.9	150.0	100.0
Zone 7	End Str 105896	254.0				Chatsworth 4 Reservoir	320.6	75.0	50.0
Zone 8	2 Leslie Road	28.0	2 Rockview Road	24.0		Doonside Reservoir	96.0	150.0	100.0
Zone 9	19 Primrose Terrace	90.0				Lamont Reservoir	123.2	300.0	200.0
Zone 10	377 Andrew Zondo Road	4.0				Lewis Drive Reservoir	99.0	150.0	80.0
Zone 11	741 Musgrave Road	112.0				N.Ridge Reservoir	148.7	300.0	150.0
Zone 12	13 Fourth Avenue	176.0				Northdene Reservoir	235.0	200.0	100.0
Zone 13	3 Morningside Road	96.0	1 Morningside Road	92.0		Ridge End Reservoir	127.4	200.0	80.0
Zone 14	48 Maple Road	66.0				Ridge End Reservoir	127.4	150.0	100.0
Zone 15	44 Thulacrest Drive	90.0	51 Street 109738	90.0		Southridge Reservoir	148.7	150.0	80.0
Zone 16	322 Cato Road	104.0				Southridge Reservoir	148.7	400.0	150.0
Zone 17	26 Arnold road	72.0				Sherwood 12&3 Res	153.3	250.0	80.0
Zone 18	15 Pincent Road	148.0				St Thomas High Level	185.0	500.0	250.0
Zone 19	18 Wynberg Place	60.0				Woodlands 1&2	139.2	150.0	150.0
Zone 20	34 Finchaven Place	66.0				Woodlands 1&2 Res LL	139.2	100.0	50 Braukm
Zone 21	19 Genoa Rd	68.0				Woodlands 1&2	139.2	100.0	50.0
Zone 22	PRV location	126.0	-	-		Kwadabeka-3 Reservoir	210.0	200.0	100.0
Zone 23	85, STR 400170	672.0				DV3187	720.0	80.0	80x50
Zone 24	18, STR 200112	242.0				DV0036	283.0	75.0	50.0
Zone 25	10, STR 40562	338.0				Proposed INT-5	396.0	100.0	80x50
Zone 26	Khulugqame Drive	160.0	Locilo Walk	144.0		Kwadabeka-3 Reservoir	210.0	150.0	100.0
Zone 27	8 Siphumelele Gr.	150.0				Kwadabeka-3 Reservoir	210.0	100.0	80x50
Zone 28	Prv Location	156.0				Kwadabeka-3 Reservoir	210.0	100.0	50
Zone 29	PRV location	138.0	-	-		Kwadabeka-3 Reservoir	210.0	150.0	80.0
Zone 30	8 Siphumelele Gr.	150				Kwadabeka-3 Reservoir	210.0	100.0	80x50
Zone 31	45, Meyiwa Main	580				Mpumalanga	621.8	150.0	80x50
Zone 32	11, Cross Street	326				Tshelimnyama	387.5	150.0	100x80
Zone 33	101 Mango Dr	288				DV0034	348.0	75.0	50
Zone 34	38 Ngcamu Place	358				Washington Heights Reservoir	402.0	100.0	100x80
Zone 35	5 Goba Road	316				WASH-2	383.0	75.0	80x50
Zone 36	Prv Location	232				DV0263	282.0	100.0	80x50
Zone 37	30 Majuba Rd	374				Wyebank Reservoir	437.0	150.0	50
Zone 38	30, STR 200505	386				Tshelimnyama 2 Reservoir	446.0	150.0	100x80
Zone 39	33 Paradise Road	330				Kwadabeka-1 Reservoir	386.0	100.0	100x80
Zone 40	1 Haakdoringrug	24.0	-	-	8.0	Mandlazini Reservoir	77.0	200.0	100.0
Zone 41	25 Vaarlandswilg	30.0	-	-	8.0	Mandlazini Reservoir	77.0	200.0	200.0
Zone 42	25 Vaarlandswilg	30.0	-	-	10.0	Mandlazini Reservoir	77.0	200.0	100.0
Zone 43	PRV Point	60.0	-	-	4.0	Forest Reservoir	125.6	300.0	200.0
Zone 44	PRV Address	124.0	-	-	104.0	Magazulu Reservoir	202.0	110.0	100.0
Zone 45	PRV Address	32.0	-	-	6.0	Mandlazini Reservoir	77.0	150.0	150 NGE
Zone 46	Schweitzer Crescent	124.0	-	-	90.0	Magazulu Reservoir	202.0	160.0	100.0
Zone 47	PRV Address	106	-	-	60	Magazulu Reservoir	202	160	50
Zone 48	-	46	-	-	4	Gobandlovu 1 PRV	65.5	100	80
Zone 49	-	108	-	-	62	Loftheim Reservoir	151	150	100
Zone 50	6th Street	82	-	-	50	Pierce Crescent	132	300	200
Zone 51	PRV Address	99	-	-	90	Magazulu Reservoir	178	110	80
Zone 52	23 Crane Place	111	-	-	62	Loftheim Resevoir	152	200	150
Zone 53	Robbin Rif Rd	31	-	-	10	Mandlazini Reservoir	77	150	100
Zone 54	Kelly Road	109	-	-	65	Loftheim Resevoir	152	150	100
Zone 55	28°48'45.06"S 31°51'35	76	-	-	34	Reservoir 9 - Ndabayakhe	118	110	100
Zone 56		93	-	-	48	uMhlathuze BPT	136	350	150
Zone 57	25 Vaarlandswilg	34.0	-	-	12.0	Mandlazini Reservoir	77.0	200.0	200.0
Zone 58	Road 2 with Road 3	1386.0			1374.0	Longridge Reservoir	1480.0	250.0	200.0
Zone 59	Bloem Rd 82	1408.0			1384.0	Longridge Reservoir	1480.0	300.0	300.0
Zone 60	29° 8'14.97"S - 26°14'43.	1388.0			1370.0	Arboretum	1480.0	200.0	
Zone 61	29° 8'14.97"S - 26°14'43.	1388.0			1370.0	Arboretum	1480	150.0	
Zone 62	Mlamleli Road	1396.0			1376.0	Arboretum	1480.0	150.0	100.0
Zone 63	26° 14' 36.5", 29° 09' 02.5	1402.0			1376.0	Arboretum	1480.0	300	150

Ref No.	CP1 Address	CP1 GL (masl)	CP2 Address	CP2 GL (masl)	Lowest GL (masl)	Supply	Supply TWL (masl)	Pipe Size (mm)	Proposed PRV Size (mm)
Zone 64		1404.0	Da Vinci Cres	1390.0	1384.0	Longridge Reservoir	1480.0	300.0	250.0
Zone 65	29°10'19.83"S - 26°14'46	1442.0			1406.0	Longridge Reservoir	1480.0	400.0	
Zone 66	Mackenzie Street EB	1374.0			1364.0	Longridge Reservoir	1480.0	300.0	200.0
Zone 67	26° 10' 20.95", 29° 06' 47.	1440			1404.0	Brandkop	1475.0	375.0	200.0
Zone 68	29° 5'44.58"S - 26° 9'26	1438			1406.0	Governor Brandkop	1493.0	400.0	200.0
Zone 69	Gustav Cres	1451			1418.0	Brandkop	1485.0	350.0	200.0
Zone 70	26° 23' 38.23", 29° 10' 38.	1409			1345.0	Rodenbeck	1444.0	300.0	200.0
Zone 71	26° 10' 13.4", 29° 13' 47.2	1422	26° 11' 28.7", 29° 11'	1422	1388	Slypsteenberg Reservoir	1461.0	250.0	100.0
Zone 72	26° 09' 31.2", 29° 13' 51.4	1408			1388.0	PRV-026	1450.0	110.0	100.0
Zone 73	Pretty Gardens	1414			1364.0	Governor Brandkop	1493.0	300.0	200.0
Zone 74	26° 16' 43.42", 29° 03' 29.	1363			1376.0	Rodenbeck	1444.0	200.0	100.0
Zone 75	26° 21' 33.22", 29° 03' 29.	1359			1343.0	Rodenbeck	1444.0	200.0	100.0
Zone 76	26° 04' 40.8", 29° 01' 04.8	1326			1304.0	Ednau Reservoir	1405.0	150.0	100.0
Zone 77	7th Street, Parcel no. 301	1437			1410.0	Botshabelo Res. 1/2	1485.0	100.0	100.0
Zone 78	Parcel no. 2679	1434			1398	Botshabelo Res. 4,5 & 6	1503.0	140.0	100.0
Zone 79	Parcel no. 342	1456			1418	Botshabelo Res. 4,5 & 6	1503.0	100.0	100.0
Zone 80	Parcel no. 307 Road 86	1422			1388	Botshabelo Res. 4,5 & 6	1503.0	100.0	100.0
Zone 81	29°10'17.70" S ; 26°48'00.	1490			1466	OK Reservoir (1,2 &3) - pumplin	1531.0	200.0	100.0
Zone 82	29°36'37.00"S 30°20'36.1	709			684	Masons Reservoir	778.0	100.0	80.0
Zone 83	29°34'50.81"S 30°20'57.1	760			714	Clarendon Reservoir	969.0	100.0	80.0
Zone 84	29°33'12.29"S 30°26'38.1	903			795	Whispers Tank	934.8	100	80
Zone 85	29°33'33.72"S 30°23'0.2	802			721	Belfort BPT	866	150	100
Zone 86	29°35'12.30"S 30°24'2	668			608	Pailman Rd PRV	750	225	200
Zone 87	29°35'07.74"S 30°26'17.	682	-	-	643	Eastwood Upper Res	793	150	150
Zone 88	29°34'48.97"S 30°26'37.	749	-	-	670	Eastwood BPT	734	250	100
Zone 89	90 Stott Rd	745			692	Masons Reservoir	777	100	100
Zone 90	29º36'41.49 S 30º18'58.01 E				869	Sweetwaters Res	971	150	100
Zone 91	29°38'00.3"S 30°20'06.2	735	-	-	690	Reservoir	806	100	100
Zone 92	29º34'08.06 S 30º23'32.9	701			668	Haythorns	788	300	150
Zone 93	436 Khan Rd	774	-	-	725	Belfort Res	937	100mm	80mm
Zone 94	29°39'01.94"S 30°22'34.	729	-	-	686	Bisley	778	150	80
Zone 95	29°36'56.52"S 30°20'01.	780	-	-	733	Balancing Tanks	864	200	150
Zone 96	29°32'46.05"S 30°23'06.	814	-	-	752	Belfort Res	940	100	80
Zone 97	29°32'40.86"S 30°23'31.	819	-	-	779	Belfort Res	940	200	100
Zone 98	29°32'38.96"S 30°22'57.	871	-	-	816	Belfort Res	940	200	150
Zone 99	29°36'03.14"S 30°21'02.	783	-	-	705	Balancing Tanks	864	225	150
Zone 100	29°32'47.86"S 30°23'47.	820	-	-	751	Prv 1001	864	150	80
Zone 101	29°32'43.94"S 30°24'18.	781	-	-	732	Northdale BPT	864	300	100
Zone 102	29°35'55.99"S 30°19'41.	785	-	-	711	Prv 1302	879	150	80
Zone 103	29°32'40.01"S 30°24'31	786	-	-	743	Northdale BPT	864	200	100
Zone 104	29°35'06.33"S 30°21'19.	827	-	-	779	Clarendon	980	150	150
Zone 105	29°39'50.30"S 30°18'59.0	836	-	-	836	Kwapata Prv 3	895	150	80
Zone 106	29°39'49.99"S 30°18'42.3	880	-	-	835	Kwapata Prv 2	929	150	80
Zone 107	29°34'58.42"S 30°21'29.	765	-	-	699	Symonds Res	838	150	100

Ref No.	PRV Make	Function	Design Standard (mH20)	Length of Mains (km)	Average Length of service connections (m)	Length of system pipe length that is metal (km)	Number of Connections (No.)	Domesti	
								Units	ACU (l/day)
Zone 1			20-60	47.79	6.0	Not Provided	1866	1865	655
Zone 2	Bermad	Reducing	25-60	16.3	10.0	Not Provided	723	600	629
Zone 3	CLA-VAL	Reducing	25-60	2.1	15.0	Not Provided	94	89	782
Zone 4	CLA-VAL	Reducing	25-60	7.4	10.0	Not Provided	380	371	849
Zone 5	CLA-VAL	Reducing	25-60	5.8	10.0	Not Provided	242	221	848
Zone 6	CLA-VAL	Reducing	25-60	4.8	10.0	Not Provided	306	276	1013
Zone 7	Braukmann	Reducing	25-60	3.8	15.0	Not Provided	1023		
Zone 8	Bermad	Reducing	25-60	2.2	15.0	Not Provided	51	24	1223
Zone 9	CLA-VAL	Reducing	25-60	10.4	10.0	Not Provided	631	612	673
Zone 10	CLA-VAL	Reducing	25-60	1.3	10.0	Not Provided	25		
Zone 11	CLA-VAL	Reducing	25-60	4.4	12.0	Not Provided	224	174	1279
Zone 12	CLA-VAL	Reducing	25-60	12.0	10.0	Not Provided	620	601	786
Zone 13	CLA-VAL	Reducing	25-60	1.9	10.0	Not Provided	76	76	1105
Zone 14	CLA-VAL	Reducing	25-60	4.3	10.0	Not Provided	296	221	1122
Zone 15	CLA-VAL	Reducing	20-60	3.1	5.0	Not Provided	307	307.0	384.0
Zone 16	CLA-VAL	Reducing	25-60	11.7	10.0	Not Provided	360	360	1122
Zone 17	CLA-VAL	Reducing	25-60	2.1	12.0	Not Provided	83	78	944
Zone 18	CLA-VAL	Reducing	25-60	30.6	15.0	Not Provided	1875	1584	1006
Zone 19	CLA-VAL	Reducing	25-60	10.5	10.0	Not Provided	671	637	934
Zone 20	Braukmann	Fixed outlet	25-60	0.4	10.0	Not Provided	46	45	751
Zone 21	Braukmann	Fixed outlet	25-60	0.2	10.0	Not Provided	5	5	920
Zone 22	CLA-VAL	Reducing	20-60	6.0	12.0	Not Provided	229	227.0	200.0
Zone 23		Reducing	25-60	8.7	6	Not Provided	0		
Zone 24	Braukmann	Reducing	15-60	1.3	6	Not Provided	35	35	
Zone 25	CLA-VAL	Reducing	25-60	2.0	6	Not Provided	97	97	
Zone 26	CLA-VAL	Reducing	20-60	7.4	12.0	Not Provided	402	402	398
Zone 27		Reducing	15-60	2.5	6	Not Provided	97	97	
Zone 28	Braukmann	Reducing	25-60	0.553	6	Not Provided	0		
Zone 29	CLA-VAL	Reducing	20-60	2.1	12.0	Not Provided	123	123	302
Zone 30		Reducing	15-60	2.505	6	Not Provided	97	97	
Zone 31		Reducing	25-60	5.092	6	Not Provided	231	231	
Zone 32		Reducing	25-60	3.871	6	Not Provided	230	230	
Zone 33	Braukmann	Reducing	15-60	1.09	6	Not Provided	104	104	
Zone 34	CLA-VAL	Reducing	25-60	30.704	6	Not Provided	0		
Zone 35	CLA-VAL	Reducing	25-60	7.434	6	Not Provided	238	238	
Zone 36		Reducing	15-60	5.611	6	Not Provided	295	295	
Zone 37	Braukmann	Reducing	15-60	2.325	6	Not Provided	149	149	
Zone 38	CLA-VAL	Reducing	25-60	5.902	6	Not Provided	330	330	
Zone 39	CLA-VAL	Reducing	25-60	4.736	6	Not Provided	314	314	
Zone 40	CLA-VAL	Reducing	25-60	8.9	4.2	Not Provided	376	317	1035
Zone 41	CLA-VAL	Reducing	25-60	29.6	4.2	Not Provided	974	933	1029
Zone 42	CLA-VAL	Reducing	25-60	6.0	4.2	Not Provided	307	299	959
Zone 43	Bermad	Reducing	25-60	49.0	10.0	Not Provided	3230		
Zone 44	CLA-VAL	Reducing	25-60	2.3	10.0	Not Provided	92	59	869
Zone 45	CLA-VAL	Reducing	25-60	20.7	18.0	Not Provided	1484	702	528
Zone 46	CLA-VAL	Reducing	25-60	5.7	6.0	Not Provided	308	256	1258
Zone 47	CLA-VAL	Reducing	25-60	6.4	8	0	8	4	47250
Zone 48	CLA-VAL	Reducing	25-60	16.4	3	0	556	550	36
Zone 49	CLA-VAL	Reducing	25-60	8.6	11	0	329	327	1199
Zone 50	CLA-VAL	Reducing	25-60	18.7	2	0	852	50	800
Zone 51	CLA-VAL	Reducing	25-60	5.5	16.3	0	51	51	5788
Zone 52	CLA-VAL	Reducing	25-60	27.9	4.2	0	786	780	600
Zone 53	CLA-VAL	Reducing	25-60	7.6	4.2	0	390	390	33
Zone 54	CLA-VAL	Reducing	25-60	9.8	4.2	0	476	474	600
Zone 55	CLA-VAL	Reducing	25-60	6.6	4.2	0	267	267	600
Zone 56	CLA-VAL	Reducing	25-60	12.8	4.2	0.1	1447	1447	600
Zone 57	CLA-VAL	Reducing	25-60	18.3	6.0	Not Provided	863	855	1087
Zone 58	Bermad	Reducing	30-60	26.4	3.0	Not Provided	1235		
Zone 59	Bermad	Reducing	30-60	64.1	3.0	Not Provided	2582		
Zone 60	Bermad	Reducing	25-60	21.5	3.0	Not Provided	1241	653	1891
Zone 61	Bermad	Reducing	25-60	21.5	6.0	Not Provided	1241	653	1891
Zone 62	Bermad	Reducing	30-60	68.8	3.0	Not Provided	2498		
Zone 63	CLA-VAL	Reducing	25-60	47.631	4.0	Not Provided	2481	1923	2314

Ref No.	PRV Make	Function	Design Standard (mH20)	Length of Mains (km)	Average Length of service connections (m)	Length of system pipe length that is metal (km)	Number of Connections (No.)	Domesti	
								Units	ACU (l/day)
Zone 64	Bermad	Reducing	30-60	26.3	3.0	Not Provided	1524		
Zone 65	Bermad	Reducing	25-60	59.4	4.0	Not Provided	4826.0	3563.0	207.0
Zone 66	Baker	Reducing	30-60	21.2	3.0	Not Provided	293.0		
Zone 67	CLA-VAL	Reducing	25-60	50.8	10.0	Not Provided	596.0	467.0	9530.0
Zone 68	CLA-VAL	Reducing	25-60	32.5	4.0	Not Provided	2631.0	2549.0	0.0
Zone 69	CLA-VAL	Reducing	25-60	46.4	4.0	Not Provided	1545.0	1225.0	2363.0
Zone 70	CLA-VAL	Reducing	25-60	114.5	20.0	Not Provided	2700.0	2571.0	1731.0
Zone 71	CLA-VAL	Reducing	25-60	91.3	4.0	Not Provided	225.0	192.0	3696.0
Zone 72	CLA-VAL	Reducing	25-60	43.9	4.0	Not Provided	225.0	192.0	1355.0
Zone 73	Bermad	Reducing	25-60	47.7	4.0	Not Provided	95.0	92.0	2007.0
Zone 74	CLA-VAL	Reducing	25-60	30.0	20.0	Not Provided	596.0	467.0	9530.0
Zone 75	CLA-VAL	Reducing	25-60	30.0	20.0	Not Provided	596.0	467.0	9530.0
Zone 76	CLA-VAL	Reducing	25-60	36.2	4.0	Not Provided	45.0	44.0	833.0
Zone 77	Baker	Reducing	25-60	12.9	4.0	1.3	934.0	842.0	249.0
Zone 78	Baker	Reducing	25-60	22.2	4.0	1.0	1780.0	1774.0	304.0
Zone 79	Baker	Reducing	25-60	13.3	6.0	0.0	2192.0	336.0	0.0
Zone 80	Baker	Reducing	25-60	34.4	4.0	6.5	2855.0	1677.0	300.0
Zone 81	Bermad	Reducing	25-60	27.6	4.0	0.0	1380.0	1379.0	152.0
Zone 82	Bermad	Reducing	25-60	2.1	1.0	0.0	136.0	136.0	1271.0
Zone 83	CLA-VAL	Reducing	25-60	3.2	0.0	0.0	143.0	143.0	0.0
Zone 84	Bermad	Reducing	25-60	7.2	0	0	929	929	956
Zone 85	Bermad	Reducing	25-60	4.2	0	0	254	254	1195
Zone 86	Bermad	Reducing	25-60	15		2	810	781	4670
Zone 87	Bermad	Reducing	25-60	9.1	1.5	0.1	685	685	1034
Zone 88	Bermad	Reducing	25-60	5.5	1	0.1	637	878	559.2
Zone 89	Bermad	Reducing	25-60	6	0	0	436	436	0
Zone 90	Bermad	Reducing	25-60	14.6	1.5	0.5	773	773	
Zone 91	Bermad	Reducing	25-60	5.8	1.5	1	557	557	1099
Zone 92	Bermad	Reducing	25-60	12.3	1.5	0.5	1047	1047	
Zone 93	Bermad	Reducing	25-60	1.3	0	0	87	87	
Zone 94	Bermad	Reducing	25-60	6.3	1.5	0.1	574	574	
Zone 95	Bermad	Reducing	25-60	18	1.5	0.1	595	595	1595
Zone 96	Bermad	Reducing	25-60	2.6	1.5	0.1	197	197	1425
Zone 97	Bermad	Reducing	25-60	1.9	1.5	0.1	589	589	1072
Zone 98	Bermad	Reducing	25-60	7.1	1.5	1	1034	517	1238
Zone 99	Bermad	Reducing	25-60	6.6	1.5	0.1	290	290	1183
Zone 100	Bermad	Reducing	25-60	3.1	1.5	0.1	223	223	1130
Zone 101	Bermad	Reducing	25-60	2.4	1	0.1	366	366	2328
Zone 102	Bermad	Reducing	25-60	5.4	1.5	0.1	283	283	1136
Zone 103	Bermad	Reducing	25-60	2.5	1	0.1	316	316	949
Zone 104	Bermad	Reducing	25-60	7.7	1.5	0.1	156	156	4708
Zone 105	Bermad	Reducing	25-60	3.3	1	0.1	520	520	858
Zone 106	Bermad	Reducing	25-60	2.1	1	0.1	215	215	2869
Zone 107	Bermad	Reducing	25-60	5.2	1	0.1	212	206	5184

Bill

Ref No.	c	Flats			Commercial			Commercial/Flats			Industria	
	Consumption (m^3/day)	Units	ACU (l/day)	Consumption (m^3/day)	Units	ACU (l/day)	Consumption (m^3/day)	Units	ACU (l/day)	Consumption (m^3/day)	Units	ACU (l/day)
Zone 1	1222											
Zone 2	377.4	26	10192	264.992	94	3787	355.978					
Zone 3	69.598	2	4641	9.282	3	3539	10.617					
Zone 4	314.979				6	2567	15.402					
Zone 5	187.408				6	15970	95.82					
Zone 6	279.588	3	667	2.001	24	2675	64.2					
Zone 7												
Zone 8	29.352	12	29427	353.124	15	3387	50.805					
Zone 9	411.876	1	1371	1.371	18	5029	90.522					
Zone 10					25	3028	75.7					
Zone 11	222.546	28	2381	66.668	21	2852	59.892					
Zone 12	472.386	6	11633	69.798	8	7186	57.488	5	2926	14.63		
Zone 13	83.98											
Zone 14	247.962	43	3285	141.255	30	6424	192.72					
Zone 15	117.888											
Zone 16	403.92											
Zone 17	73.632				4	4422	17.688					
Zone 18	1593.504	168	3820	641.76	117	4664	545.688					
Zone 19	594.958	3	48872	146.616	24	4984	119.616					
Zone 20	33.795				1	962	0.962					
Zone 21	4.6											
Zone 22	45.4											
Zone 23	0											
Zone 24	0											
Zone 25	0											
Zone 26	159.996											
Zone 27	0											
Zone 28	0											
Zone 29	37.146											
Zone 30	0											
Zone 31	0											
Zone 32	0											
Zone 33	0											
Zone 34	0											
Zone 35	0											
Zone 36	0											
Zone 37	0											
Zone 38	0											
Zone 39	0											
Zone 40	328.095	7	17571	122.997	2	3085	6.17					
Zone 41	960.057				16	25125	402					
Zone 42	286.741	2	52700	105.4								
Zone 43												
Zone 44	51.271	17	10824	184.008								
Zone 45	370.656											
Zone 46	322.048											
Zone 47	189				2	4000	8					
Zone 48	19.8				4	1250	5					
Zone 49	392.073	2	16000	32								
Zone 50	40				800	4500	3600					
Zone 51	295.188											
Zone 52	468				6	2000	12					
Zone 53	12.87											
Zone 54	284.4				2	2000	4					
Zone 55	160.2											
Zone 56	868.2											
Zone 57	929.385	7	24563	171.941	1	60180	60.18					
Zone 58												
Zone 59												
Zone 60	1234.6				28	1493	41.8					
Zone 61	1234.6				28	1493	41.8					
Zone 62												
Zone 63	4450.6				66	5190	342.5					

Ref No.	c	Flats			Commercial			Commercial/Flats			Industria	
	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)
Zone 64												
Zone 65	738.6				13.0	1692.0	22.0					
Zone 66												
Zone 67	4450.6				10.0	34254.0	342.5					
Zone 68					48.0							
Zone 69	2894.3				66.0	5672.0	374.3					
Zone 70	4450.6				10.0	34254.0	342.5					
Zone 71	709.6				13.0	7442.0	96.7					
Zone 72	123.3				13.0	3392.0	20.4					
Zone 73	184.7				1.0	6183.0	6.2					
Zone 74	4450.6				10.0	34254.0	342.5					
Zone 75	4450.6				10.0	34254.0	342.5					
Zone 76	36.7				1.0	3967.0	4.0					
Zone 77	210.0											
Zone 78	540.0				2.0	6750.0	13.5					
Zone 79	0.0											
Zone 80	503.0											
Zone 81	210.0											
Zone 82	172.8											
Zone 83	0.0											
Zone 84	888											
Zone 85	303.6											
Zone 86	3647				29	0	0					
Zone 87	708											
Zone 88												
Zone 89	0											
Zone 90												
Zone 91	612											
Zone 92												
Zone 93												
Zone 94												
Zone 95	949.2											
Zone 96	280.8											
Zone 97	631.2											
Zone 98												
Zone 99	343.2											
Zone 100	252											
Zone 101	852											
Zone 102	321.6											
Zone 103	300											
Zone 104	734.4											
Zone 105	446.4											
Zone 106	616.8											
Zone 107	1068				6	800	4.8					

ed Authorised Consumption Info

Ref No.	l	Hospital			Hotel			Education			Governmer	
	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)
Zone 1												
Zone 2		3	17956	53.868								
Zone 3												
Zone 4								3	923	2.769		
Zone 5								13	38348	498.524		
Zone 6					3	2356	7.068					
Zone 7												
Zone 8												
Zone 9												
Zone 10												
Zone 11												
Zone 12												
Zone 13												
Zone 14												
Zone 15												
Zone 16												
Zone 17								1	47590	47.59		
Zone 18		6	28423	170.538								
Zone 19								7	1947	13.629		
Zone 20												
Zone 21												
Zone 22												
Zone 23												
Zone 24												
Zone 25												
Zone 26												
Zone 27												
Zone 28												
Zone 29												
Zone 30												
Zone 31												
Zone 32												
Zone 33												
Zone 34												
Zone 35												
Zone 36												
Zone 37												
Zone 38												
Zone 39												
Zone 40												
Zone 41												
Zone 42												
Zone 43												
Zone 44											1	130600
Zone 45												
Zone 46											2	101480
Zone 47											2	2000
Zone 48											2	2250
Zone 49												
Zone 50											2	2250
Zone 51												
Zone 52												
Zone 53												
Zone 54												
Zone 55												
Zone 56												
Zone 57												
Zone 58												
Zone 59												
Zone 60								9	10578	95.2	227	22730
Zone 61								9	10578	95.2	227	22730
Zone 62												
Zone 63								3	33	0.1	6	13502

Ref No.	I	Hospital			Hotel			Education			Governmer	
	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)
Zone 64												
Zone 65											3.0	2122.0
Zone 66												
Zone 67												
Zone 68								4.0			12.0	
Zone 69								155.0	3609.0	559.4	21.0	115438.0
Zone 70												
Zone 71								11.0	976.0	10.7	1.0	2018.0
Zone 72								11.0	489.0	1.5	1.0	0.0
Zone 73								1.0	1600.0	1.6		
Zone 74										0.1		
Zone 75										0.1		
Zone 76												
Zone 77												
Zone 78												
Zone 79												
Zone 80												
Zone 81												
Zone 82												
Zone 83												
Zone 84												
Zone 85												
Zone 86												
Zone 87												
Zone 88												
Zone 89												
Zone 90												
Zone 91												
Zone 92												
Zone 93												
Zone 94												
Zone 95												
Zone 96												
Zone 97												
Zone 98												
Zone 99												
Zone 100												
Zone 101												
Zone 102												
Zone 103												
Zone 104												
Zone 105												
Zone 106												
Zone 107												

					Unbilled Authorised Consumption Info							
Ref No.	ntal	Recreational			Domestic			Flats			Dom	
	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Population	% Active
Zone 1											9325	4
Zone 2											3108	6
Zone 3											392	6
Zone 4											1500	10
Zone 5		2	10680								9050	10
Zone 6											1407	10
Zone 7					1023	82	83.886				2046	6
Zone 8											1000	2
Zone 9											3065	6
Zone 10											50	6
Zone 11		1	8320								896	6
Zone 12											2308	10
Zone 13											304	6
Zone 14		2	1775								1056	6
Zone 15											1535	6
Zone 16											1440	6
Zone 17											555	6
Zone 18											7178	6
Zone 19											3915	6
Zone 20											225	6
Zone 21											25	6
Zone 22											916	6
Zone 23											0	6
Zone 24											140	6
Zone 25											388	6
Zone 26					23	241	5.543				28	2
Zone 27											388	6
Zone 28											0	6
Zone 29					11	255	2.805				7	3
Zone 30											388	6
Zone 31											924	6
Zone 32											920	6
Zone 33											416	6
Zone 34											0	6
Zone 35											952	6
Zone 36											1180	6
Zone 37											596	6
Zone 38											1320	6
Zone 39											1256	6
Zone 40					50	500	25				1675	6
Zone 41					25	500	12.5				4900	6
Zone 42											1495	6
Zone 43					3230	300	969				19400	6
Zone 44	130.6				15	500	7.5				552	6
Zone 45					782	300	234.6				8202	6
Zone 46	202.96				50	300	15				1848	6
Zone 47	4				1	500	0.5				200	6
Zone 48	4.5										500	6
Zone 49											1500	6
Zone 50	4.5										250	6
Zone 51											1055	6
Zone 52					1	500	0.5				3650	6
Zone 53					5	33	0.165				1700	6
Zone 54					1	500	0.5				2370	6
Zone 55											1335	6
Zone 56											7235	6
Zone 57											4435	6
Zone 58											4940	6
Zone 59											10328	6
Zone 60	5159.7				324	35	11.2				2612	6
Zone 61	5159.7				324	35	11.2				2612	6
Zone 62											9992	6
Zone 63	81				483	1855	895.8				7692	6

Ref No.	ntal	Recreational			Domestic			Flats			Dom	
	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Units	ACU (l/day)	Consumption (m³/day)	Population	% Active
Zone 64											6096	6
Zone 65	6.4				1245.0	197.0	244.9	2.0	20000.0	40.0	14252.0	6.0
Zone 66											1172	6
Zone 67					119.0	7528.0	895.8				1868.0	6.0
Zone 68					18.0	0.0					10196.0	6.0
Zone 69	2424.2				78.0	1289.0	100.5				4900.0	6.0
Zone 70					119.0	7528.0	895.8				10284.0	6.0
Zone 71	2.0				8.0	388.0	3.1				768.0	6.0
Zone 72	0.0				8.0	333.0	0.3				768.0	6.0
Zone 73					1.0	1833.0	1.8				368.0	6.0
Zone 74	81.0				119.0	7528.0	895.8				1868.0	6.0
Zone 75	81.0				119.0	7528.0	895.8				1868.0	6.0
Zone 76											176.0	6.0
Zone 77					90.0	250.0	22.5			112.5	4210.0	6.0
Zone 78										40.0	8870.0	6.0
Zone 79											2295.0	6.0
Zone 80					1173.0	300.0	352.0	5.0	10000.0	50.0	14250.0	6.0
Zone 81							22.5	1.0	90000.0	90.0	6895.0	6.0
Zone 82											680.0	6.0
Zone 83											572	6
Zone 84											3716	6
Zone 85											1016	6
Zone 86											3760	6
Zone 87											2740	6
Zone 88											2548	6
Zone 89											1744	6
Zone 90											3092	6
Zone 91											2228	6
Zone 92											4188	6
Zone 93											348	6
Zone 94											2296	6
Zone 95											2380	6
Zone 96											788	6
Zone 97											2356	6
Zone 98					517	1207	624				2585	6
Zone 99											1160	6
Zone 100											892	6
Zone 101											1464	6
Zone 102											1132	6
Zone 103											1264	6
Zone 104											624	6
Zone 105											2080	6
Zone 106											860	6
Zone 107											848	6

	Normal Night Use						PMZ/DMA Characteristics			
Ref No.	estic Use		Non-Domestic Use				System Input Volume (SIV)		Minimum Night Flow (MNF)	
	Average Night Use (l/hour)	Consumption (m^3/hour)	Description	No. of Units	Unit Use (l/hour)	Consumption (m^3/hour)	SIV Before (m^3/day)	SIV After (m^3/day)	MNF Before (m^3/hr)	MNF After (m^3/hr)
Zone 1	10	3.7					3376.2	3180.6	93.3	62.9
Zone 2	20	3.7	Not Registered	3	1000	3	1414.6	1200.1	26.5	17.9
Zone 3	20	0.5					225.4	214.9	7	6
Zone 4	20	3.0					425.9	355.6	5.9	4.7
Zone 5	20	18.1					1322.9	1135	35.4	31.3
Zone 6	20	2.8					420.8	400.4	5.6	4.6
Zone 7	10	1.2					74.3	61.5	3.4	2.4
Zone 8	20	0.4					1414.6	1200.1	26.5	17.9
Zone 9	20	3.7					648	680.2	10.3	9.2
Zone 10	10	0.0					70.4	35.6	1.6	0.2
Zone 11	10	0.5					562.8	537.6	8.3	6.9
Zone 12	20	4.6					1021.5	827.2	19.9	12.5
Zone 13	20	0.4					81.8	80.5	1	0.7
Zone 14	20	1.3					519.6	479.2	8	5.7
Zone 15	20	1.8					377.4	341	9.8	8.3
Zone 16	20	1.7					641.6	609.2	10	8.6
Zone 17	10	0.3					239.4	196.5	6	4.4
Zone 18	20	8.6					4023	3389.8	68.2	62.5
Zone 19	20	4.7					1196.2	1044.5	20.4	10.9
Zone 20	20	0.3					48.2	34.8	2	1.5
Zone 21	20	0.0					6	4.6	0.3	0.2
Zone 22	10	0.5					273.9	198.8	9.3	6.3
Zone 23	10	0.0					326.51	264.57	10.12	7.05
Zone 24	10	0.1					129.12	53.82	5	1.86
Zone 25	10	0.2					98.03	71.25	2.81	1.76
Zone 26	0	0.6					486.7	293.4	14.8	5.8
Zone 27	10	0.2					81.7	52.2	2.5	1.1
Zone 28	10	0.0					27.5	18.3	0.7	0.3
Zone 29	0	0.2					120.6	76.7	3.4	1.5
Zone 30	10	0.2					170	145.8	5.1	3.2
Zone 31	10	0.6					217.68	226.56	4.13	2.81
Zone 32	10	0.6					1464.54	604.23	40.4	15.6
Zone 33	10	0.2					162.19	96.63	4.42	1.32
Zone 34	10	0.0					400.81	364.98	11.41	10.05
Zone 35	10	0.6					124.32	79.22	3.5	1.77
Zone 36	10	0.7					387.77	209.08	14.17	6.44
Zone 37	10	0.4					115.44	65.44	3.24	1.39
Zone 38	10	0.8					186.01	184.01	5.03	3.6
Zone 39	10	0.8					658.85	370.01	23.91	11.46
Zone 40	10	1.0		2	200	0.4	535.5	519.9	6.2	4.6
Zone 41	10	2.9		16	200	3.2	1598.2	1564.1	28	24
Zone 42	10	0.9		0	200	0	553.8	381.6	8	4.5
Zone 43	10	11.6					5549	4021.8	200	129.7
Zone 44	10	0.3					339.4	247.4	8.4	4.9
Zone 45	10	4.9		0	200	0	840.6	779.8	15.4	9.7
Zone 46	10	1.1					666.7	511.4	18.8	13.3
Zone 47	10	0.1					141.5	58.9	3.5	2.4
Zone 48	10	0.3					1198.1	871.9	38.9	19.6
Zone 49	10	0.9					443.2	380.8	10.3	5.4
Zone 50	10	0.2		802	10	8.02	3878.2	3172	141.1	90.3
Zone 51	10	0.6					128.7	116.1	2.5	1.4
Zone 52	10	2.2					1851.1	1254.7	49.1	23.4
Zone 53	10	1.0					433.3	357.6	4.9	3.4
Zone 54	10	1.4					1846.5	1493.7	25.3	14.4
Zone 55	10	0.8					942.8	722.1	9.6	7.7
Zone 56	10	4.3					2102.4	1173.4	85.2	16
Zone 57	10	2.7		1	200	0.2	1196.2	1018.4	15.4	7.4
Zone 58	10	3.0					1009.84	642.56	19.93	9.03
Zone 59	10	6.2					2365.69	2016.23	82.94	40.77
Zone 60	10	1.6	255	0	0	0	1540.8	1395	45	41.3
Zone 61	10	1.6	255	0	0	0	4563.1	4404.2	147.4	124.4
Zone 62	10	6.0					3543.95	3166.01	132	100.46
Zone 63	10	4.6	72	5	100	0.5	2003	1554.1	77.7	49.7

Ref No.	estic Use		Non-Domestic Use				System Input Volume (SIV)		Minimum Night Flow (MNF)	
	Average Night Use (l/hour)	Consumption (m³/hour)	Description	No. of Units	Unit Use (l/hour)	Consumption (m³/hour)	SIV Before (m³/day)	SIV After (m³/day)	MNF Before (m³/hr)	MNF After (m³/hr)
Zone 64	10	3.7					2657.5	1854.18	80	39.33
Zone 65	10.0	8.6	16.0	0.0	0.0	0.0	7377.5	5968.0	277.4	196.2
Zone 66	10	0.7					931.4	701.2	26.5	20.5
Zone 67	10.0	1.1	10.0	5.0	0.0	0.0	4609.2	3478.2	149.3	92.7
Zone 68	10.0	6.1	60.0	0.0	0.0	0.0	3540.1	3377.9	85.8	45.1
Zone 69	10.0	2.9	87.0	5.0	100.0	0.5	2061.7	1936.1	47.3	35.0
Zone 70	10.0	6.2	10.0	5.0	0.0	0.0	5141.3	4753.4	124.3	102.1
Zone 71	10.0	0.5	14.0	5.0	100.0	0.5	1041.6	841.7	26.5	22.2
Zone 72	10.0	0.5	14.0	5.0	100.0	0.5	255.5	215.5	5.6	3.8
Zone 73	10.0	0.2	1.0	5.0	100.0	0.5	5337.0	3651.0	133.3	69.0
Zone 74	10.0	1.1	10.0	5.0	0.0	0.0	1057.1	555.2	34.2	11.8
Zone 75	10.0	1.1	10.0	5.0	0.0	0.0	1962.3	1577.2	59.8	45.0
Zone 76	10.0	0.1	1.0	5.0	100.0	0.5	350.1	252.3	9.5	6.7
Zone 77	10.0	2.5					890.6	823.3	24.6	20.0
Zone 78	10.0	5.3	2.0	0.0	0.0	0.0	994.8	568.6	34.1	19.5
Zone 79	10.0	1.4					954.4	788.4	30.7	21.9
Zone 80	10.0	8.6					2168.8	1963.8	65.4	58.6
Zone 81	10.0	4.1					816.6	746.7	24.1	14.4
Zone 82	10.0	0.4					184.7	160.8	4.4	3.2
Zone 83	10	0.3					165.3	165.1	3.3	2.2
Zone 84	10	2.2					875.4	833.9	29.1	24.4
Zone 85	10	0.6					227.8	190	2.8	1.7
Zone 86	10	2.3					3129.1	3078	81.7	69.7
Zone 87	10	1.6					685.3	529	28.6	14
Zone 88	10	1.5					507	392.2	20.9	7.9
Zone 89	10	1.0					642.6	441.5	14.7	8.4
Zone 90	10	1.9					1567.7	1204.4	69.5	45.9
Zone 91	10	1.3					611.7	535.6	16.7	13.6
Zone 92	10	2.5					1013.1	967.2	27.9	12.1
Zone 93	10	0.2					92	89.5	3.5	0.8
Zone 94	10	1.4					260.3	216.2	8.9	3.7
Zone 95	10	1.4					802.9	728.9	27.5	13.1
Zone 96	10	0.5					207.2	189	6.5	2.9
Zone 97	10	1.4					567.3	520.6	21	10.1
Zone 98	10	1.6					482.5	449	14.2	7.4
Zone 99	10	0.7					322.2	291.7	10.7	4.1
Zone 100	10	0.5					193.4	166.3	6.3	2.1
Zone 101	10	0.9					730.4	761.1	21.8	14.6
Zone 102	10	0.7					272.9	255.9	10.7	6.2
Zone 103	10	0.8					300.9	248.1	10.2	3.6
Zone 104	10	0.4					695.3	592.5	27.9	17.3
Zone 105	10	1.2					447.6	185	19.5	2.6
Zone 106	10	0.5					617.5	318.1	24.6	3.7
Zone 107	10	0.5					955.9	609.6	39.9	11.8

			Calculations			Performance Indicators					
Ref No.	Average Zone Pressure (AZP)		Assumed Constants		UARL before PM	UARL after PM	NDF before PM	NDF after PM	Qrl before	Qrl after	CARL before PM
	AZP Before (m)	AZP After (m)	Cd	g	l/km/day	l/km/day	hrs	hrs	m³/annum	m³/annum	l/day
Zone 1	84.6	37.7	0.65	9.81	203012.1	90467.56	23.1	28	755209.5	604717.4	2069067
Zone 2	79	43	0.65	9.81	70270.26	38248.37	22.6	23.5	163086	95814.106	446811.04
Zone 3	67	34	0.65	9.81	7745.334	3930.468	23.3	23.8	55530.98	48035.635	152139.68
Zone 4	57	43.5	0.65	9.81	25453.69	19425.19	23.8	23.9	25192.3	14829.95	69020
Zone 5	55	51	0.65	9.81	16713.84	15498.29	23.5	23.6	148390.8	113704.8	406550
Zone 6	74	59	0.65	9.81	25030.94	19957.1	23	23.7	23388.47	15449.793	64078
Zone 7	78.6	37	0.65	9.81	71646.18	33726.57	22.5	21.1	17840.84	9029.2386	48879
Zone 8	80	36	0.65	9.81	6551.28	2948.076	23.5	23.8	223872.8	152022.5	613350
Zone 9	58.2	50.2	0.65	9.81	41163.17	35505	22.1	22	53416.36	44341.66	146346.2
Zone 10	96	32	0.65	9.81	4264.416	1421.472	23.4	23.8	13409.37	1476.79	36738
Zone 11	66.7	42	0.65	9.81	17664.03	11122.78	23.2	23.3	65732	54109.031	180087.68
Zone 12	115	81	0.65	9.81	83637.66	58910	21.1	23.3	117709.7	67049.478	322492.4
Zone 13	52.4	46	0.65	9.81	5062.469	4444.152	22.8	23.7	5286.134	2899.6476	14482.56
Zone 14	77.4	42.8	0.65	9.81	24937.82	13789.9	22.7	20.9	55784.61	33815.615	152834.56
Zone 15	60.5	42	0.65	9.81	18653.3	12949.4	22.6	21.8	65645.54	51386.306	179850.8
Zone 16	70.7	49.4	0.65	9.81	35884.77	25073.66	23.7	23.7	71556.94	59446.236	196046.4
Zone 17	101.3	45	0.65	9.81	10791.19	4793.715	23	21.9	47574.47	32509.565	130341
Zone 18	53	40	0.65	9.81	111137.7	83877.48	23	23.8	500227.8	468111.16	1370487.2
Zone 19	95.2	36	0.65	9.81	70665.72	26722.33	21.8	20.6	124940.8	46632.838	342303.6
Zone 20	94.2	46	0.65	9.81	4300.607	2100.084	24	24	15154.8	10774.8	41520
Zone 21	77.2	31	0.65	9.81	528.2796	212.133	24	24	2365.2	1489.2	6480
Zone 22	76.2	44.4	0.65	9.81	22574.94	13153.9	23.9	23.7	76334.11	49743.835	209134.56
Zone 23	97.07	45.94	0.65	9.81	15213.39	7199.992	22.6	23.9	83479.88	61500.675	228712
Zone 24	77.18	42.3	0.65	9.81	4097.1	2245.496	23.7	23.5	42525.86	15233.64	116509.2
Zone 25	102.77	39.7	0.65	9.81	11857.29	4580.467	23.1	24.4	21729.66	13601.243	59533.32
Zone 26	58.5	39	0.65	9.81	27207.41	18138.28	22.6	23.7	117465.8	45328.62	321824
Zone 27	56.5	44.9	0.65	9.81	7068.998	5617.664	22.7	23.9	18784.89	7565.0192	51465.44
Zone 28	72	28	0.65	9.81	716.688	278.712	23.3	23.2	5953.15	2540.4	16310
Zone 29	101.6	50.5	0.65	9.81	14110.11	7013.39	23.4	23.8	27245.79	11206.23	74646
Zone 30	69	39.4	0.65	9.81	8632.935	4929.531	22.7	23.9	40327.19	25884.369	110485.44
Zone 31	79.98	60.42	0.65	9.81	22572.84	17052.4	23.7	24	30930.73	19759.056	84741.72
Zone 32	93.3	53.64	0.65	9.81	24204.63	13915.72	23.3	24	338887.3	131820.48	928458.4
Zone 33	94.1	50.66	0.65	9.81	9920.022	5340.577	23.7	23.3	36076.05	9103.2168	98838.48
Zone 34	109.99	90.31	0.65	9.81	60788.39	49911.81	24.2	24	100784.5	88038	276122
Zone 35	117.61	64.71	0.65	9.81	38830.35	21364.78	23.3	23.9	24907.98	10457.732	68241.04
Zone 36	122.82	43.27	0.65	9.81	42295.89	14901.02	24.5	24	120383.9	50212.32	329819
Zone 37	88.92	45.78	0.65	9.81	14651.79	7543.4	23.6	23.1	24828.99	8704.6806	68024.64
Zone 38	109.06	77.12	0.65	9.81	41277.68	29188.84	23.8	23.9	36815.51	24495.588	100864.4
Zone 39	91.34	54.63	0.65	9.81	31448.18	18809	22.9	23.6	193552.8	92224.93	530281.56
Zone 40	49.7	29.5	0.65	9.81	23378.88	13876.8	22.6	22.4	39553.96	26122.32	108367
Zone 41	42.4	31.3	0.65	9.81	56661.24	41827.76	21.8	21.2	173940	138200.68	476548
Zone 42	45.9	38.7	0.65	9.81	16582.52	13981.34	22.6	24	58592.65	31562.28	160527.8
Zone 43	75.4	49.5	0.65	9.81	267425	175564.1	22.7	22.1	1560657	952330.99	4275772
Zone 44	45.6	33.5	0.65	9.81	5348.88	3929.55	24	21.8	70682.69	36353.942	193651.2
Zone 45	44.5	30.4	0.65	9.81	71062.05	48545.76	20	21.3	76495.24	37152.781	209576
Zone 46	92.3	43.5	0.65	9.81	32923.41	15516.45	23.6	23.8	152392	105904.95	417512.32
Zone 47	81.7	50.3	0.65	9.81	9951.06	6126.54	21.8	23.9	26894.66	19889.58	73684
Zone 48	41.9	32.7	0.65	9.81	31588.41	24652.53	16.7	19.4	235286.3	136663.3	644620
Zone 49	97.7	43.7	0.65	9.81	41642.18	18626.03	22.1	22.4	75825.1	36792	207740
Zone 50	49.4	32.5	0.65	9.81	51351.3	33783.75	22	19.8	1067428	593553.51	2924460
Zone 51	75.9	26.3	0.65	9.81	10707.59	3710.273	21.9	23	14923.86	6438.965	40887.3
Zone 52	44.2	35.3	0.65	9.81	50858.73	40617.95	21.6	17	369838.4	131608.05	1013256
Zone 53	49.5	20.8	0.65	9.81	22698.23	9537.84	22.8	22.7	32289.36	19719.49	88464
Zone 54	66.2	40	0.65	9.81	37674.42	22764	22.9	21	199584.3	99476.37	546806.2
Zone 55	60.3	37.4	0.65	9.81	20446.22	12681.41	23.9	24	76758.08	60435.24	210296.1
Zone 56	61.8	41.5	0.65	9.81	88014.02	59103.26	23.2	17.3	684714	73620.756	1875928.8
Zone 57	38.6	25.5	0.65	9.81	40183.18	26545.88	20	18.9	91534.7	31312.292	250780
Zone 58	72.64	37.4	0.65	9.81	108508.7	55867.63	21.7	22.5	134379.2	49817.025	368162.2
Zone 59	58.63	44.9	0.65	9.81	192517.9	147434	22.7	17.6	635855.8	222098.24	1742070.6
Zone 60	67.9	48.4	0.65	9.81	95795.02	68283.93	15.4	23.5	243951.4	340526.75	668360
Zone 61	66.3	48.3	0.65	9.81	93537.7	68142.85	16.7	22.8	888723.9	1021941.6	2434860
Zone 62	52.64	42.7	0.65	9.81	173659.3	140867.2	19.1	20.9	878442.5	720624.73	2406691.7
Zone 63	56.1	46	0.65	9.81	162924.7	133592.4	13.2	16.4	349786.8	266975.6	958320

Ref No.	Average Zone Pressure (AZP)		Assumed Constants		UARL before PM	UARL after PM	NDF before PM	NDF after PM	Qrl before	Qrl after	CARL before PM
	AZP Before (m)	AZP After (m)	Cd	g	l/km/day	l/km/day	hrs	hrs	m³/annum	m³/annum	l/day
Zone 64	78.48	39.9	0.65	9.81	135757.5	69020.46	23	23.9	640894.4	311188.18	1755875.2
Zone 65	44.8	36.2	0.65	9.81	226287.7	182848.5	21.8	23.5	2138842	1609139	5859840
Zone 66	50.4	36.2	0.65	9.81	31428.83	22560.46	24.3	23.94	228893.4	172636.89	627105.24
Zone 67	67.0	52.2	0.65	9.81	94194.23	73387.14	20.3	22.3	1098088	745578.2	3008460
Zone 68	50.3	43.3	0.65	9.81	138626.2	119334.3	10.8	11.6	314177.4	165126	860760
Zone 69	61.6	46.8	0.65	9.81	129965.2	98739.81	23	22.7	368540.5	261821.8	1009700
Zone 70	70.9	61.8	0.65	9.81	304054.7	265029.3	20.1	20.7	866440.7	724572.45	2373810
Zone 71	59.1	52.7	0.65	9.81	108095.4	96389.62	21.6	22.1	201042	171009.8	550800
Zone 72	59.3	38.8	0.65	9.81	57866.42	37862.01	22.2	23.8	37273.8	24323.6	102120
Zone 73	82.4	47.5	0.65	9.81	77206.74	44506.31	21	23	1016379	573378.5	2784600
Zone 74	54.7	23.1	0.65	9.81	56433.99	23832.27	22.1	22.5	267001.2	87873.75	731510
Zone 75	76.3	43.2	0.65	9.81	78718.71	44569.44	20.9	22.8	447793	365335.8	1226830
Zone 76	90.1	50.2	0.65	9.81	62054.12	34574	23.5	23	76339.75	51209.5	209150
Zone 77	43.5	37.5	0.65	9.81	43619.63	37603.13	23.7	23.7	191176.1	151383.75	523770
Zone 78	67.5	46.8	0.65	9.81	126096.8	87427.08	20.6	23.3	216547.2	120763.9	593280
Zone 79	65.7	44.2	0.65	9.81	134540.5	90512.76	21.7	23.8	232070.7	178083.5	635810
Zone 80	51.0	42.8	0.65	9.81	151703.3	127311.8	24	23.1	497568	421575	1363200
Zone 81	85.5	55.1	0.65	9.81	139818.2	90105.03	19.3	19.8	140890	74438.1	386000
Zone 82	42.2	22.7	0.65	9.81	6330	3405	23.4	22.1	34164	22586.2	93600
Zone 83	51.3	42.1	0.65	9.81	9006.998	7391.708	23.9	21.6	25793.64	14639.011	70667.52
Zone 84	76.3	66.8	0.65	9.81	68366.71	59854.47	22.9	22.2	224596.2	179646.75	615332.16
Zone 85	93.4	54.2	0.65	9.81	26633.01	15455.13	23.5	23	18788.16	9153.908	51474.4
Zone 86	83.3	58.7	0.65	9.81	78156.23	55075.28	23.2	20.9	672359.2	514160.9	1842080
Zone 87	81	32.6	0.65	9.81	59042.93	23762.96	23.9	22.2	235150.7	100120.67	644248.4
Zone 88	77.9	57.1	0.65	9.81	48650.5	35660.38	23.3	12.3	164742.4	28603.502	451348.96
Zone 89	80.8	43.5	0.65	9.81	37790.16	20344.95	19.5	21.7	97179.5	58244.189	266245.2
Zone 90	68	34.5	0.65	9.81	61235.7	31068.11	23.9	23	590099.4	369756.1	1616710.7
Zone 91	61.8	45	0.65	9.81	34850.57	25376.63	23.6	21.8	132338.6	97578.282	362571.52
Zone 92	55.1	38.6	0.65	9.81	59793.14	41887.76	23.3	16.4	215905.4	57388.979	591521.76
Zone 93	52.1	38.9	0.65	9.81	4958.618	3702.308	23.8	12.4	28590.65	2675.7712	78330.56
Zone 94	49.8	33.2	0.65	9.81	29230.11	19486.74	23.5	20.3	64523.39	17207.823	176776.4
Zone 95	67.6	34.7	0.65	9.81	55085.55	28276.16	22.7	21.7	216019.6	92448.076	591834.4
Zone 96	63.4	46.6	0.65	9.81	13271.21	9754.545	23.4	15.1	51478.32	13377.513	141036.48
Zone 97	49	31.4	0.65	9.81	25486.13	16331.93	23.8	20.3	170147.1	64361.881	466156.32
Zone 98	63.1	36.4	0.65	9.81	61891.64	35702.94	22.9	21.5	105317.1	45515.5	288540
Zone 99	67.3	50.9	0.65	9.81	24096.77	18224.75	23.9	20.3	87269.89	25221.938	239095.6
Zone 100	80	48.9	0.65	9.81	19182	11725	23.7	18.2	49868.4	10394.966	136625.76
Zone 101	56	37.7	0.65	9.81	19328.4	13012.16	23.7	22.3	180982.3	111686.96	495841.92
Zone 102	82.8	73.2	0.65	9.81	27379.89	24205.41	23.3	19.4	85221.89	39092.785	233484.64
Zone 103	64.3	35.4	0.65	9.81	19656.51	10821.78	23.9	21	82363.8	21780.864	225654.24
Zone 104	84.3	66.9	0.65	9.81	22533.39	17882.37	23.9	20	240119.6	123556.88	657861.84
Zone 105	26.6	12.2	0.65	9.81	12991.44	5958.48	23.3	6.9	155224.1	3405.012	425271.6
Zone 106	49.3	34.6	0.65	9.81	10608.13	7445.055	24	17.1	210975.8	19872.936	578016
Zone 107	68.3	46.6	0.65	9.81	18338.55	12512.1	23.9	18.4	343629.1	75831.699	941449.68

Ref No.	CARL after PM l/day	ILI before PM	ILI after PM	% ILI Change	CP before (m)	AZP before (m)	PRV before (m)	LP before (m)	CP after (m)	AZP after (m)	PRV after (m)
Zone 1	1656760	10.1918417	18.3133	-80%	59.16	84.6	74.5	110.04	11.33	37.7	23.96
Zone 2	262504.4	6.35846546	6.863152	-8%	60.7	79	62.24	97.3	29.47	43	30.82
Zone 3	131604.48	19.6427527	33.48316	-70%	51.9	67	54.18	82.1	28.1	34	29.7
Zone 4	40630	2.71159092	2.091614	23%	37.72	57	43.72	76.28	25.51	43.5	31.51
Zone 5	311520	24.3241529	20.10028	17%	30.07	55	35.83	79.93	26.5	51	32.06
Zone 6	42328.2	2.55995139	2.120959	17%	37.67	74	41.07	110.33	29.05	59	32.35
Zone 7	24737.64	0.68222759	0.733476	-8%	66.18	78.6	61.24	91.02	30.95	37	26.31
Zone 8	416500	93.6229256	141.2786	-51%	60.7	80	62.24	99.3	29.47	36	30.82
Zone 9	121484	3.55527021	3.421602	4%	20.18	58.2	30.98	96.22	19.65	50.2	25.58
Zone 10	4046	8.61501317	2.846345	67%	89.06	96	90.17	102.94	31.67	32	33.24
Zone 11	148243.92	10.1951652	13.32796	-31%	33.08	66.7	68.42	100.32	23.54	42	58.32
Zone 12	183697.2	3.85582763	3.118268	19%	50.29	115	55.15	179.71	37.96	81	40.62
Zone 13	7944.24	2.86077022	1.787572	38%	36.34	52.4	45.69	68.46	25.55	46	34.87
Zone 14	92645.52	6.1286266	6.718359	-10%	34.2	77.4	32.18	120.6	25.8	42.8	23.71
Zone 15	140784.4	9.64176874	10.87189	-13%	51.46	60.5	53.84	69.54	28.4	42	34.75
Zone 16	162866.4	5.46321946	6.495517	-19%	42.55	70.7	23.18	98.85	30.86	49.4	11.46
Zone 17	89067.3	12.0784695	18.58002	-54%	59.5	101.3	82.02	143.1	28.11	45	50.81
Zone 18	1282496.32	12.3314382	15.29012	-24%	33.59	53	40.03	72.41	26.42	40	32.71
Zone 19	127761.2	4.84398359	4.781065	1%	73.48	95.2	89.4	116.92	25.86	36	41.33
Zone 20	29520	9.65445155	14.05658	-46%	70.2	94.2	93.6	118.2	25	46	49
Zone 21	4080	12.2662317	19.23322	-57%	69.8	77.2	81.8	84.6	25	31	37
Zone 22	136284.48	9.26401571	10.36077	-12%	74.96	76.2	74.96	77.44	21.38	44.4	21.38
Zone 23	168495	15.0335959	23.40211	-56%	68.07	97.07	74.54	126.07	16.94	45.94	34.94
Zone 24	41736	28.4369899	18.58654	35%	48.18	77.18	42.6	106.18	13.3	42.3	10.22
Zone 25	37263.68	5.02081829	8.135345	-62%	86.77	102.77	82.54	118.77	23.7	39.7	19.4
Zone 26	124188	11.8285406	6.846737	42%	48.68	58.5	71.46	68.32	7.66	39	29.67
Zone 27	20726.08	7.28044394	3.689448	49%	49.05	56.5	53.05	63.95	34.39	44.9	38.89
Zone 28	6960	22.7574621	24.97201	-10%	58.23	72	47.04	85.77	22.27	28	10.65
Zone 29	30702	5.29025068	4.377627	17%	70.68	101.6	68.99	132.52	21.62	50.5	21.03
Zone 30	70916.08	12.7981318	14.38597	-12%	49.05	69	53.05	88.95	34.39	39.4	38.39
Zone 31	54134.4	3.75414602	3.174592	15%	38.98	79.98	49.98	120.98	19.42	60.42	30.42
Zone 32	361152	38.3587069	25.95281	32%	64.3	93.3	66.3	122.3	24.64	53.64	26.64
Zone 33	24940.32	9.96353436	4.669967	53%	68.1	94.1	58.33	120.1	24.66	50.66	16.08
Zone 34	241200	4.5423474	4.832524	-6%	40.99	109.99	68.42	178.99	21.31	90.31	49.54
Zone 35	28651.32	1.75741488	1.341054	24%	80.61	117.61	88.98	154.61	27.71	64.71	34.58
Zone 36	137568	7.79789681	9.23212	-18%	99.68	122.82	99.68	145.96	20.26	43.27	20.26
Zone 37	23848.44	4.64275191	3.161498	32%	58.92	88.92	99.09	118.92	15.78	45.78	57.7
Zone 38	67111.2	2.44355769	2.299207	6%	56.06	109.06	64.53	162.06	24.12	77.12	33.05
Zone 39	252671.04	16.8620751	13.43352	20%	64.34	91.34	69.42	118.34	27.63	54.63	27.88
Zone 40	71568	4.63525199	5.157385	-11%	47.34	49.7	50.04	52.06	19.42	29.5	22.12
Zone 41	378632	8.41047601	9.052171	-8%	41.07	42.4	42.97	43.73	15.85	31.3	17.66
Zone 42	86472	9.68054167	6.184814	36%	26.2	45.9	44.2	65.6	14.71	38.7	32.71
Zone 43	2609126	15.9886802	14.86138	7%	45.6	75.4	45.6	105.2	15.8	49.5	15.8
Zone 44	99599.84	36.2040652	25.34637	30%	35.59	45.6	35.59	55.61	25.29	33.5	25.29
Zone 45	101788.44	2.94919722	2.096752	29%	36.76	44.5	36.76	52.24	12.34	30.4	12.34
Zone 46	290150.56	12.6813207	18.69955	-47%	71.58	92.3	84.62	113.02	27.02	43.5	38.82
Zone 47	54492	7.4046383	8.894417	-20%	60.09	81.7	60.09	103.31	21.29	50.3	21.29
Zone 48	374420	20.4068518	15.18789	26%	21.78	41.9	21.78	62.02	5.55	32.7	5.55
Zone 49	100800	4.98869145	5.411781	-8%	54.2	97.7	85.62	141.2	5.55	43.7	20.58
Zone 50	1626174	56.9500675	48.1348	15%	36.24	49.4	60.52	62.56	15.58	32.5	32.96
Zone 51	17641	3.81853344	4.754637	-25%	71.17	75.9	71.17	80.63	22.58	26.3	22.56
Zone 52	360570	19.9229513	8.877111	55%	30.32	44.2	31.92	58.08	12.57	35.3	22.01
Zone 53	54026	3.89739726	5.664385	-45%	43.17	49.5	52.17	55.83	6.95	20.8	15.25
Zone 54	272538	14.5139912	11.97232	18%	41.63	66.2	68.05	90.77	13.07	40	37.89
Zone 55	165576	10.2853278	13.0566	-27%	35.4	60.3	37.42	85.2	12.43	37.4	14.43
Zone 56	201700.7	21.3139782	3.412683	84%	33.45	61.8	56.45	90.15	10.94	41.5	30.66
Zone 57	85787.1	6.24091986	3.231654	48%	32.13	38.6	40.12	45.07	7.19	25.5	15.19
Zone 58	136485	3.39292833	2.443007	28%	69.89	72.64	72.64	75.39	31.43	37.4	34.4
Zone 59	608488.32	9.04887444	4.127191	54%	46.63	58.63	57.82	70.63	32.94	44.9	40.95
Zone 60	932950	6.97698082	13.6628	-96%	62.15	67.9	79.84	73.65	39.75	48.4	55.86
Zone 61	2799840	26.0307883	41.0878	-58%	62.15	66.3	69.19	70.45	39.75	48.3	45.47
Zone 62	1974314.32	13.858701	14.01543	-1%	42.64	52.64	61.81	62.64	32.71	42.7	56.86
Zone 63	731440	5.88198228	5.475161	7%	44.83	56.1	75.8	67.37	36.72	46	55.87

Ref No.	CARL after PM l/day	ILI before PM	ILI after PM	% ILI Change		CP before (m)	AZP before (m)	PRV before (m)	LP before (m)	CP after (m)	AZP after (m)	PRV after (m)
Zone 64	852570.36	12.9339066	12.35243	4%		68.48	78.48	68.48	88.48	29.9	39.9	29.9
Zone 65	4408600	25.8955341	24.11067	7%		29.4	44.8	42.42	60.2	20.45	36.2	32.37
Zone 66	472977.792	19.9531823	20.9649	-5%		45.43	50.43	49.86	55.43	31.16	36.2	36.73
Zone 67	2042680	31.9388997	27.8343	13%		49.62	67	63.87	84.38	32.54	52.2	46.3
Zone 68	452400	6.20921377	3.79103	39%		44.62	50.3	50.62	55.98	29.99	43.3	39.9
Zone 69	717320	7.76900158	7.26475	6%		43.97	61.6	54.64	79.23	29.36	46.8	40
Zone 70	1985130	7.80718203	7.490228	4%		32.35	70.9	61.71	109.45	18.09	61.8	49.27
Zone 71	468520	5.09550004	4.860689	5%		39.38	59.1	56.94	78.82	32.28	52.7	49.8
Zone 72	66640	1.76475399	1.760076	0%		58.75	59.3	58.75	59.85	33.21	38.8	33.21
Zone 73	1570900	36.0667993	35.29612	2%		70.41	82.4	73.64	94.39	24.5	47.5	30.61
Zone 74	240750	12.9622237	10.10185	22%		64.48	54.7	61.31	44.92	30.85	23.1	27.67
Zone 75	1000920	15.5849861	22.45754	-44%		74.15	76.3	77.66	78.45	31.34	43.2	33.48
Zone 76	140300	3.37044489	4.057963	-20%		74.94	90.1	80.58	105.26	34.19	50.2	37.25
Zone 77	414750	12.0076686	11.02967	8%		30.39	43.5	34.39	56.61	26.61	37.5	27.96
Zone 78	330860	4.70495869	3.784411	20%		54.94	67.5	62.96	80.06	32.16	46.8	38.65
Zone 79	487900	4.72579029	5.3904	-14%		54.9	65.7	65.9	76.5	25.32	44.2	36.32
Zone 80	1155000	8.98595993	9.072214	-1%		32.71	51	40.04	69.29	26.47	42.8	29.05
Zone 81	203940	2.76072885	2.263359	18%		71.04	85.5	77.33	99.96	37.16	55.1	38.26
Zone 82	61880	14.7867299	18.17327	-23%		35.04	42.2	43.99	49.36	7.05	22.7	15.87
Zone 83	40106.88	7.84584652	5.425929	31%		21.44	51.3	26.44	81.16	6.21	42.1	11.21
Zone 84	492182.88	9.00046503	8.222993	9%		25.03	76.3	33.85	127.57	4.56	66.8	11.75
Zone 85	25079.2	1.93272935	1.62271	16%		53.63	93.4	57.24	133.17	7.21	54.2	9.62
Zone 86	1408660	23.5692039	25.57699	-9%		48.6	83.3	44.7	118	14.35	58.7	10.32
Zone 87	274303.2	10.9115258	11.54331	-6%		62.75	81	74.75	99.25	5.85	32.6	17.85
Zone 88	78365.76	9.27737604	2.197558	76%		39.98	77.9	92.12	115.82	4.6	57.1	42.01
Zone 89	159573.12	7.04535784	7.843377	-11%		56.43	80.8	56.43	105.17	9.24	43.5	9.24
Zone 90	1013030.4	26.401441	32.60676	-24%		46.45	68	46.45	89.55	7.15	34.5	7.15
Zone 91	267337.76	10.4036052	10.5348	-1%		38	61.8	35.9	85.6	10.38	45	11.81
Zone 92	157230.08	9.89280267	3.753605	62%		38.71	55.1	38.71	71.49	17.65	38.6	17.65
Zone 93	7330.88	15.7968547	1.980084	87%		27.99	52.1	27.99	76.21	10.33	38.9	10.33
Zone 94	47144.72	6.04775008	2.419323	60%		27.76	49.8	32.76	71.84	6.76	33.2	11.76
Zone 95	253282.4	10.7439138	8.957453	17%		49.65	67.6	47.37	85.55	8.32	34.7	7.95
Zone 96	36650.72	10.627255	3.757297	65%		83.92	63.4	31.76	42.88	9.83	46.6	9.83
Zone 97	176333.92	18.2905922	10.79689	41%		29.15	49	29.15	68.85	7.1	31.4	7.1
Zone 98	124700	4.66201935	3.49271	25%		36.96	63.1	36.96	89.24	3.16	36.4	3.16
Zone 99	69101.2	9.92231115	3.791614	62%		28.33	67.3	28.3	106.27	4.7	50.9	4.7
Zone 100	28479.36	7.12260244	2.428944	66%		45.43	80	45.43	114.57	7.41	48.9	7.41
Zone 101	305991.68	25.6535419	23.51583	8%		28.61	56	31.59	83.39	3.65	37.7	6.82
Zone 102	107103.52	8.52759598	4.424776	48%		15.49	82.8	42.61	150.11	5.58	73.2	24.85
Zone 103	59673.6	11.4798731	5.514213	52%		42.88	64.3	42.88	85.72	4.99	35.4	4.99
Zone 104	338512	29.1949787	18.92993	35%		36.48	84.3	42.34	132.12	13.94	66.9	12.98
Zone 105	9328.8	32.7347546	1.565634	95%		25.68	26.6	25.68	27.52	8.49	12.2	8.49
Zone 106	54446.4	54.4880329	7.313096	87%		27.2	49.3	27.2	71.4	4.11	34.6	4.11
Zone 107	207758.08	51.337193	16.60457	68%		35.26	68.3	45.26	101.34	6.21	46.6	16.21

Ref No.	LP after (m)	MNF before (m³/hr)	Qrl before (m³/hr)	ExNF before (m³/hr)	MNF after (m³/hr)	Qrl after (m³/hr)	ExNF after (m³/hr)	m (CP/MNF) (mm²/m)	m (CP/Qrl) (mm²/m)	m (CP/ExNF) (mm²/m)	m (AZP/MNF) (mm²/m)
Zone 1	64.07	93.300	86.211	67.070	62.900	69.032	51.167	-0.04761	-0.06753	-0.047063	-0.0007446
Zone 2	56.53	26.500	18.617	17.598	17.900	10.938	13.209	0.001157	0.00417	-0.001941	0.002429
Zone 3	39.9	7.000	6.339	6.050	6.000	5.484	5.507	-0.00234	-0.00225	-0.002903	-0.0018293
Zone 4	61.49	5.900	2.876	2.790	4.700	1.693	2.327	0.000856	0.00379	-0.000181	0.0017717
Zone 5	75.5	35.400	16.940	28.586	31.300	12.980	24.634	0.036518	0.05523	0.0416029	0.0339041
Zone 6	88.95	5.600	2.670	2.209	4.600	1.764	1.942	0.002375	0.00434	-2.15E-05	0.0012068
Zone 7	43.05	3.400	2.037	-6.189	2.400	1.031	-1.528	-0.00013	0.00064	-0.004792	-9.23E-05
Zone 8	42.53	26.500	25.556	25.308	17.900	17.354	17.121	0.001157	0.00093	0.0010506	-0.0001622
Zone 9	80.75	10.300	6.098	4.770	9.200	5.062	4.404	0.142491	0.14123	0.0447573	0.0022424
Zone 10	32.33	1.600	1.531	1.163	0.200	0.169	0.092	0.000811	0.0008	0.0006474	0.0006943
Zone 11	60.46	8.300	7.504	6.108	6.900	6.177	5.536	0.000763	0.00115	-0.002876	-0.0006807
Zone 12	124.04	19.900	13.437	8.192	12.500	7.654	5.013	0.021897	0.01838	0.0096213	0.0047685
Zone 13	66.45	1.000	0.603	0.411	0.700	0.331	0.183	0.000882	0.00111	0.0010281	0.0018959
Zone 14	59.8	8.000	6.368	4.752	5.700	3.860	3.991	0.010163	0.0136	0.0011079	0.000382
Zone 15	55.6	9.800	7.494	7.082	8.300	5.866	6.339	-0.00288	-0.00084	-0.003048	-0.0003902
Zone 16	67.94	10.000	8.169	5.928	8.600	6.786	5.862	-0.00045	0.00091	-0.004353	-0.0005592
Zone 17	61.89	6.000	5.431	4.466	4.400	3.711	3.711	-0.00058	4.5E-05	-0.00134	-0.0003688
Zone 18	53.58	68.200	57.104	54.374	62.500	53.437	51.952	-0.01899	-0.02633	-0.035144	-0.0137361
Zone 19	46.14	20.400	14.263	9.898	10.900	5.323	6.655	0.001724	0.0045	-0.001124	0.0016083
Zone 20	67	2.000	1.730	1.345	1.500	1.230	1.188	-0.00047	-0.0003	-0.000592	-0.0001088
Zone 21	37	0.300	0.270	0.235	0.200	0.170	0.172	-3.2E-05	-1.3E-05	-4.9E-05	-1.336E-05
Zone 22	67.42	9.300	8.714	6.578	6.300	5.679	4.784	-0.00187	-0.00144	-0.001782	0.0013097
Zone 23	74.94	10.120	9.530	9.178	7.050	7.021	6.743	-0.0033	-0.00374	-0.003573	-8.82E-05
Zone 24	71.3	5.000	4.855	4.544	1.860	1.739	1.625	0.002094	0.00222	0.0020817	0.0028196
Zone 25	55.7	2.810	2.481	1.202	1.760	1.553	1.197	-0.00033	-0.00029	-0.000643	-1.18E-05
Zone 26	70.34	14.800	13.409	12.373	5.800	5.175	4.471	0.000217	0.00044	0.0013365	0.0179232
Zone 27	55.41	2.500	2.144	1.681	1.100	0.864	0.452	0.004013	0.00377	0.0038607	0.0050432
Zone 28	33.73	0.700	0.680	0.662	0.300	0.290	0.291	0.000272	0.00027	0.0002426	0.0002037
Zone 29	79.38	3.400	3.110	1.730	1.500	1.279	0.912	0.000579	0.00067	6.811E-05	0.000858
Zone 30	44.41	5.100	4.604	4.076	3.200	2.955	2.626	0.004324	0.00364	0.0031797	0.0012223
Zone 31	101.42	4.130	3.531	1.294	2.810	2.256	0.758	0.000424	0.00095	0.000628	0.001781
Zone 32	82.64	40.400	38.686	37.108	15.600	15.048	13.854	0.0166	0.0157	0.0160859	0.0179753
Zone 33	76.66	4.420	4.118	2.984	1.320	1.039	0.602	0.002157	0.00232	0.0019222	0.0021603
Zone 34	159.31	11.410	11.505	7.403	10.050	10.050	7.069	-0.00697	-0.00671	-0.006618	0.0005366
Zone 35	101.71	3.500	2.843	-1.578	1.770	1.194	-0.641	0.000352	0.00059	-0.000355	0.0006743
Zone 36	66.28	14.170	13.742	8.055	6.440	5.732	4.601	-5E-05	0.00045	-0.000942	0.001308
Zone 37	75.78	3.240	2.834	1.248	1.390	0.994	0.429	0.000581	0.00096	0.0004404	0.0011123
Zone 38	130.12	5.030	4.203	-0.775	3.600	2.796	-0.173	-0.00067	-8.8E-05	-0.000743	0.0007799
Zone 39	81.63	23.910	22.095	19.587	11.460	10.528	9.056	0.007575	0.00711	0.0068045	0.0090005
Zone 40	39.58	6.200	4.515	3.352	4.600	2.982	2.752	-0.00178	-0.00025	-0.001709	0.0005593
Zone 41	46.75	28.000	19.856	21.093	24.000	15.776	18.544	-0.02285	-0.0119	-0.018819	0.0003206
Zone 42	62.69	8.000	6.689	5.812	4.500	3.603	2.603	0.011778	0.0111	0.0138038	0.0220675
Zone 43	83.2	200.000	178.157	160.805	129.700	108.714	103.403	-0.03511	-0.01127	-0.025649	0.0616593
Zone 44	41.71	8.400	8.069	7.668	4.900	4.150	4.317	0.014624	0.01778	0.0143997	0.0114055
Zone 45	48.46	15.400	8.732	4.800	9.700	4.241	1.572	-0.00315	0.00331	0.004894	0.0135304
Zone 46	59.98	18.800	17.396	14.029	13.300	12.090	11.006	-0.00262	-0.0021	-0.003579	-0.0004249
Zone 47	79.31	3.500	3.070	2.778	2.400	2.271	1.989	-0.00061	-0.00086	-0.000651	0.00054
Zone 48	59.85	38.900	26.859	36.391	19.600	15.601	17.777	0.000333	-0.01855	0.0053881	0.0974786
Zone 49	81.85	10.300	8.656	4.866	5.400	4.200	3.144	-0.00638	-0.00433	-0.004808	0.0014484
Zone 50	49.42	141.100	121.853	136.869	90.300	67.757	87.972	0.009438	0.0517	0.0075364	0.0870514
Zone 51	30.02	2.500	1.704	1.074	1.400	0.735	0.605	1.23E-05	0.00034	-4.55E-07	9.78E-05
Zone 52	57.03	49.100	42.219	43.369	23.400	15.024	18.683	0.045336	0.06711	0.0510055	0.134515
Zone 53	34.65	4.900	3.686	2.044	3.400	2.251	1.880	-0.00522	-0.00281	-0.003855	-0.0005935
Zone 54	66.93	25.300	22.784	20.380	14.400	11.356	11.335	-0.00075	0.00474	0.0002834	0.0110384
Zone 55	62.37	9.600	8.762	7.035	7.700	6.899	6.037	-0.00863	-0.00732	-0.008015	-0.0003461
Zone 56	72.06	85.200	78.164	72.202	16.000	8.404	6.895	0.152662	0.16932	0.160459	0.1429378
Zone 57	43.81	15.400	10.449	9.902	7.400	3.574	3.215	-0.0006	0.00711	0.007627	0.026866
Zone 58	43.37	19.930	15.340	6.468	9.030	5.687	2.187	0.006983	0.00741	0.0034629	0.0084943
Zone 59	56.86	82.940	72.586	60.374	40.770	25.354	23.603	0.127928	0.15761	0.1199745	0.1200966
Zone 60	57.05	45.000	27.848	34.216	41.300	38.873	34.186	-0.01306	-0.04083	-0.016778	-0.0084674
Zone 61	56.85	147.400	101.453	136.940	124.400	116.660	117.303	-0.01603	-0.08737	-0.019151	0.0039141
Zone 62	52.69	132.000	100.279	112.239	100.460	82.263	84.408	0.09267	0.03404	0.0849912	0.0985287
Zone 63	55.28	77.700	39.930	59.026	49.700	30.477	34.646	0.145742	0.04001	0.132689	0.1047472

Ref No.	LP after (m)	MNF before (m³/hr)	Qrl before (m³/hr)	ExNF before (m³/hr)	MNF after (m³/hr)	Qrl after (m³/hr)	ExNF after (m³/hr)	m (CP/MNF) (mm²/m)	m (CP/Qrl) (mm²/m)	m (CP/ExNF) (mm²/m)	m (AZP/MNF) (mm²/m)
Zone 64	49.9	80.000	73.161	62.290	39.330	35.524	30.578	0.022279	0.02111	0.0174214	0.0252443
Zone 65	51.95	277.400	244.160	250.461	196.200	183.692	174.293	0.301688	0.17113	0.2968794	0.3568171
Zone 66	41.24	26.510	26.129	23.761	20.460	19.707	18.513	0.006519	0.00843	0.0050836	0.0081155
Zone 67	71.86	149.300	125.353	141.330	92.700	85.112	86.869	0.100542	0.05846	0.0983208	0.1269469
Zone 68	56.61	85.800	35.865	67.751	45.100	18.850	29.453	0.109425	0.04575	0.1131102	0.2601915
Zone 69	64.24	47.300	42.071	33.371	35.000	29.888	24.783	0.016019	0.0197	0.0109074	0.0213654
Zone 70	105.51	124.300	98.909	92.160	102.100	82.714	74.795	-0.05239	-0.05011	-0.033667	0.0677254
Zone 71	73.12	26.500	22.950	20.190	22.200	19.522	16.814	0.015433	0.01082	0.012619	0.0211117
Zone 72	44.39	5.600	4.255	1.709	3.800	2.777	1.524	0.000968	0.001	-0.000564	0.001985
Zone 73	70.5	133.300	116.025	128.239	69.000	65.454	66.661	0.014721	0.00457	0.0137333	0.0465076
Zone 74	15.35	34.200	30.480	28.978	11.800	10.031	9.554	0.022046	0.02055	0.0195062	0.0238404
Zone 75	55.06	59.800	51.118	51.923	45.000	41.705	41.001	-0.00887	-0.01228	-0.010499	-5.248E-06
Zone 76	66.21	9.500	8.715	5.456	6.700	5.846	4.957	-0.00041	5.9E-05	-0.001853	0.0004805
Zone 77	48.39	24.600	21.824	18.624	20.000	17.281	14.712	0.053781	0.05593	0.0483546	0.0268515
Zone 78	61.44	34.100	24.720	16.217	19.500	13.786	6.926	0.017717	0.01379	0.0147366	0.0218141
Zone 79	63.08	30.700	26.492	15.315	21.900	20.329	12.793	-0.00245	-0.00546	-0.005583	0.0079716
Zone 80	59.13	65.400	56.800	43.668	58.600	48.125	39.916	0.002511	0.03214	-0.00685	0.0084951
Zone 81	73.04	24.100	16.083	5.151	14.400	8.498	2.600	0.005096	0.00527	0.0018925	0.007614
Zone 82	38.35	4.400	3.900	3.505	3.200	2.578	2.600	-0.00573	-0.00387	-0.004803	0.0001012
Zone 83	77.99	3.300	2.944	2.229	2.200	1.671	1.316	-0.00388	-0.00079	-0.001063	0.0045936
Zone 84	129.04	29.100	25.639	19.323	24.400	20.508	15.987	-0.09519	-0.076	-0.0615	0.0126513
Zone 85	101.19	2.800	2.145	-0.832	1.700	1.045	-0.246	-0.00188	-0.00072	-0.000165	0.0005211
Zone 86	103.05	81.700	76.753	71.187	69.700	58.694	62.559	-0.06774	-0.04548	-0.063921	-0.0020578
Zone 87	59.35	28.600	26.844	20.556	14.000	11.429	10.722	-0.01329	-0.00816	-0.011219	0.0052083
Zone 88	109.6	20.900	18.806	13.988	7.900	3.265	2.993	-0.00371	0.01425	0.0080178	0.0220838
Zone 89	77.76	14.700	11.094	9.578	8.400	6.649	5.744	-0.00594	-0.00523	-0.004523	0.0033685
Zone 90	61.85	69.500	67.363	61.815	45.900	42.210	41.938	-0.06158	-0.05216	-0.058454	0.0063615
Zone 91	79.62	16.700	15.107	11.983	13.600	11.139	10.163	-0.01902	-0.01266	-0.015222	0.0020046
Zone 92	59.55	27.900	24.647	19.973	12.100	6.551	6.413	0.026456	0.03961	0.0277699	0.0381228
Zone 93	67.47	3.500	3.264	2.866	0.800	0.305	0.317	0.008116	0.01026	0.0087152	0.0093838
Zone 94	59.64	8.900	7.366	4.990	3.700	1.964	0.944	0.004401	0.01063	0.0096597	0.0129521
Zone 95	61.08	27.500	24.660	21.199	13.100	10.553	9.880	-0.00537	-0.00134	-0.003502	0.011833
Zone 96	83.37	6.500	5.877	4.754	2.900	1.527	1.625	-0.00101	0.00072	3.427E-06	0.0080943
Zone 97	55.7	21.000	19.423	17.227	10.100	7.347	7.476	0.001561	0.01323	0.0060646	0.0236335
Zone 98	69.64	14.200	12.023	6.383	7.400	5.196	3.104	-0.01878	-0.00971	-0.007152	0.0072987
Zone 99	97.1	10.700	9.962	7.780	4.100	2.879	1.941	0.001751	0.00799	0.0083231	0.0154521
Zone 100	90.39	6.300	5.693	3.709	2.100	1.187	0.582	0.001491	0.00373	0.0030728	0.0045125
Zone 101	71.75	21.800	20.660	19.073	14.600	12.750	12.700	-0.04963	-0.03911	-0.042885	0.0101599
Zone 102	140.82	10.700	9.729	7.148	6.200	4.463	3.133	0.003295	0.02042	0.0171709	0.0163255
Zone 103	65.81	10.200	9.402	7.452	3.600	2.486	2.029	-0.00049	0.00296	0.0021061	0.0080156
Zone 104	119.86	27.900	27.411	25.485	17.300	14.105	15.483	-0.00022	0.01172	0.0011182	0.0184364
Zone 105	15.91	19.500	17.720	17.394	2.600	0.389	1.085	0.05972	0.06796	0.0618248	0.0732402
Zone 106	65.09	24.600	24.084	23.160	3.700	2.269	2.641	0.043499	0.05263	0.0472053	0.0679189
Zone 107	86.99	39.900	39.227	37.705	11.800	8.657	10.341	0.023724	0.03745	0.0263046	0.0496079

Ref No.	**m (AZP/Qrl) (mm²/m)**	m (AZP/ExNF) (mm²/m)	m (LP/MNF) (mm²/m)	m (LP/Qrl) (mm²/m)	m (LP/ExNF) (mm²/m)	Ao (CP/MNF) (mm²)	Ao (CP/Qrl) (mm²)	Ao (CP/ExNF) (mm²)	Ao (AZP/MNF) (mm²)	**Ao (AZP/Qrl) (mm²)**	Ao (AZP/ExNF) (mm²)
Zone 1	**-0.01384781**	-0.0077116	0.0078274	-0.00307	1.0613E-05	7.029867	7.888274	5.8129147	3.5861627	**4.427007**	3.1850898
Zone 2	**0.004115902**	-0.0003323	0.0026049	0.003686	0.00023172	1.111158	0.576974	0.9023322	0.843659	**0.402349**	0.71394927
Zone 3	**-0.00174679**	-0.0021596	-0.0014594	-0.00139	-0.00167905	0.458829	0.422651	0.4423776	0.4195918	**0.386022**	0.40143004
Zone 4	**0.003196275**	0.00043177	0.0017886	0.002663	0.00053407	0.301367	0.019855	0.1646213	0.170441	**-0.04989**	0.10374054
Zone 5	**0.040512907**	0.0351717	0.0280172	0.031432	0.02840803	1.144106	-0.58779	0.5596053	-0.2068213	**-1.43487**	-0.595664
Zone 6	**0.001870016**	8.9546E-05	0.0007376	0.001091	7.0117E-05	0.227431	-0.01251	0.1257989	0.1368021	**-0.03058**	0.08255054
Zone 7	**0.000503194**	-0.0037308	-6.811E-05	0.000408	-0.00301054	0.153943	0.044494	0.0529191	0.1404553	**0.040237**	0.05078947
Zone 8	**-0.00027696**	-0.0001896	-0.0005227	-0.00059	-0.00052403	1.111158	1.082982	1.0644661	1.0420268	**1.014562**	0.99793969
Zone 9	**0.00368487**	0.00015834	0.000589	0.00131	-8.6099E-05	-2.07909	-2.37856	-0.534377	0.3384304	**0.063157**	0.2079643
Zone 10	**0.000686131**	0.00055632	0.0006027	0.000596	0.00048462	-0.01334	-0.01494	-0.014841	-0.0099393	**-0.01161**	-0.0121705
Zone 11	**-0.00048273**	-0.0014948	-0.0005116	-0.00039	-0.00088981	0.476	0.415151	0.4639833	0.3983855	**0.351313**	0.35945812
Zone 12	**0.004112479**	0.00211381	0.0022592	0.001966	0.00100443	-0.12653	-0.26625	-0.082632	0.0961456	**-0.03773**	0.02223805
Zone 13	**0.001875413**	0.00161528	0.0060459	0.005586	0.00469933	0.025564	-0.00573	-0.013706	-0.0513655	**-0.06932**	-0.0649398
Zone 14	**0.001342947**	-0.0007021	-4.923E-05	0.000461	-0.00047654	0.127565	-0.08695	0.2443484	0.2862647	**0.147463**	0.24195868
Zone 15	**0.001094382**	-0.0012717	0.0015466	0.002789	-2.3928E-05	0.622795	0.406312	0.499736	0.4612136	**0.268417**	0.39316188
Zone 16	**9.7497E-05**	-0.0021045	-0.0004221	-1.9E-05	-0.00129206	0.551521	0.396149	0.5008631	0.4526057	**0.33053**	0.39365994
Zone 17	**-8.41E-05**	-0.0006759	-0.0002469	-7.6E-05	-0.00042104	0.304432	0.241842	0.280783	0.2444102	**0.195933**	0.22257279
Zone 18	**-0.01617467**	-0.0199168	-0.0096614	-0.01088	-0.01305074	4.725072	4.306504	4.439023	3.9817604	**3.581608**	3.6497233
Zone 19	**0.003370871**	-0.0005559	0.0013836	0.002627	-0.00031594	0.699888	0.247207	0.4835947	0.573076	**0.186807**	0.40525755
Zone 20	**-2.2391E-05**	-0.0002632	4.782E-06	6.01E-05	-0.000145	0.115973	0.093034	0.0972811	0.0818201	**0.064019**	0.07291944
Zone 21	**1.4778E-06**	-3.152E-05	-1.922E-06	1.03E-05	-2.0211E-05	0.014686	0.012135	0.0131938	0.0128905	**0.010559**	0.01172478
Zone 22	**0.001595085**	0.0003887	0.0100368	0.010352	0.00571467	0.513194	0.457264	0.3974778	0.2702377	**0.225171**	0.23212335
Zone 23	**-0.00046578**	-0.0004303	0.0005905	0.000256	0.00026117	0.650896	0.655829	0.6295752	0.3653212	**0.381162**	0.36532116
Zone 24	**0.002839962**	0.00266258	0.0026383	0.00264	0.00247491	0.149289	0.136146	0.1270941	-0.0199378	**-0.02726**	-0.0258364
Zone 25	**-9.5391E-06**	-0.0003931	0.0001213	0.000108	-0.00027575	0.13338	0.117644	0.1006546	0.097487	**0.085967**	0.08159685
Zone 26	**0.016468732**	0.01606107	-0.188966	-0.17286	-0.16571937	0.726205	0.645977	0.5508732	-0.3764301	**-0.35449**	-0.3777074
Zone 27	**0.004683111**	0.00467655	0.0067044	0.006188	0.00607981	-0.07286	-0.07834	-0.106013	-0.1694241	**-0.16551**	-0.1865609
Zone 28	**0.000199593**	0.00018194	0.0001597	0.000156	0.00014281	0.016022	0.015406	0.0159951	0.0139888	**0.013447**	0.01398882
Zone 29	**0.000873758**	0.0002942	0.00083	0.000827	0.00031313	0.099524	0.081043	0.0666544	0.0299841	**0.018399**	0.029719
Zone 30	**0.000979305**	0.00084901	0.0004723	0.000349	0.00029744	0.040811	0.049982	0.0461616	0.1289099	**0.124917**	0.11183856
Zone 31	**0.001857975**	0.0008389	0.0017128	0.001723	0.00075347	0.213248	0.159259	0.0475177	0.0179518	**-0.01147**	-0.0168327
Zone 32	**0.017081137**	0.01707898	0.0169644	0.016139	0.01603998	0.682521	0.666032	0.5729964	-0.2243903	**-0.2026**	-0.2591278
Zone 33	**0.002227072**	0.00178346	0.0020193	0.002056	0.00162748	0.039128	0.015546	-0.005319	-0.0450276	**-0.06211**	-0.0609898
Zone 34	**0.000696651**	-0.0006699	0.000999	0.001124	-0.00011834	0.904683	0.899097	0.6728728	0.3188479	**0.304398**	0.31884788
Zone 35	**0.000747066**	-0.0004326	0.0006958	0.000724	-0.00041632	0.107037	0.062411	-0.032431	0.0327884	**0.003202**	0.00033505
Zone 36	**0.001609501**	0.00011931	0.0016645	0.001889	0.00044263	0.497957	0.433182	0.3741521	0.2834423	**0.233013**	0.23779429
Zone 37	**0.001237574**	0.00055566	0.0011065	0.001174	0.00052511	0.112363	0.071751	0.0305393	0.020431	**-0.00565**	-0.0034284
Zone 38	**0.000913589**	-0.0005928	0.0008648	0.000924	-0.00049709	0.270652	0.199872	0.0056954	0.0822399	**0.04014**	0.03888352
Zone 39	**0.00839683**	0.00779912	0.0087945	0.008192	0.00755292	0.547932	0.499143	0.4103548	0.0468293	**0.036008**	-0.0005272
Zone 40	**0.001572463**	-0.0005376	0.0035656	0.004225	0.00075388	0.397033	0.239963	0.2500916	0.2776619	**0.144305**	0.19184768
Zone 41	**0.007180736**	-0.0023545	-0.0832734	-0.07997	-0.05492426	2.455967	1.565019	1.9160798	1.4799308	**0.754668**	1.22493859
Zone 42	**0.01968609**	0.02119418	0.0500558	0.044253	0.04640057	0.234258	0.16295	0.0327041	-0.6027701	**-0.56069**	-0.6748639
Zone 43	**0.067927045**	0.05125135	0.0833604	0.086063	0.06854546	11.88779	9.677406	9.4405039	3.350733	**2.004448**	2.56771071
Zone 44	**0.013717263**	0.01118833	0.0091883	0.01098	0.00899355	-0.03142	-0.16306	-0.066045	-0.0880426	**-0.21049**	-0.1157797
Zone 45	**0.01329722**	0.01069956	0.0677442	0.055032	0.04026578	0.997914	0.378459	0.0950468	0.1997199	**-0.13707**	-0.2262339
Zone 46	**-0.00015855**	-0.001484	0.0003346	0.000493	-0.00066471	0.959561	0.864585	0.8321388	0.7188781	**0.643553**	0.64416989
Zone 47	**0.000215993**	0.00029741	0.0010833	0.000682	0.00072317	0.19374	0.189211	0.1636127	0.0903705	**0.100328**	0.08246649
Zone 48	**0.053654918**	0.0948802	0.385098	0.223119	0.37181918	2.887813	2.403024	2.5909575	-1.9970769	**-0.80695**	-2.0228489
Zone 49	**0.001546045**	0.00010764	0.0015796	0.001546	0.00036292	0.831518	0.643267	0.4901565	0.2204264	**0.153109**	0.16046547
Zone 50	**0.112037734**	0.08307075	0.132012	0.15245	0.12662417	7.798819	5.15675	7.6236032	2.672356	**0.486883**	2.65989756
Zone 51	**0.000365675**	3.6812E-05	0.0001571	0.000381	6.273E-05	0.102053	0.046099	0.0442498	0.0922451	**0.040165**	0.04002336
Zone 52	**0.149142289**	0.13185958	1.1061878	1.17442	1.0640682	1.722497	0.628183	1.1891282	-3.3804432	**-4.38645**	-3.5624615
Zone 53	**0.000366962**	-0.0014726	0.0012822	0.001818	-0.0007513	0.484194	0.316096	0.2744606	0.2712765	**0.163801**	0.17379345
Zone 54	**0.013319351**	0.00944659	0.0130445	0.014618	0.01097914	1.393291	1.02897	1.08529	0.3492683	**0.09085**	0.24462763
Zone 55	**4.37277E-06**	-0.0012326	0.0009896	0.001152	-3.522E-05	0.865793	0.770642	0.6943839	0.4502555	**0.391657**	0.3889791
Zone 56	**0.147797691**	0.13883028	0.1360995	0.139051	0.13040867	0.010032	-0.96989	-1.031365	-5.0692733	**-5.68049**	-5.3897014
Zone 57	**0.025824178**	0.02537216	0.3241445	0.280182	0.27264792	0.962821	0.411898	0.3616583	-0.1761062	**-0.41266**	-0.4258307
Zone 58	**0.008574356**	0.00395381	0.0100248	0.009797	0.00447682	0.339957	0.119416	0.0266833	0.1951614	**0.002299**	-0.023638
Zone 59	**0.144090648**	0.11035408	0.1125506	0.133044	0.10224789	-1.74668	-3.65729	-2.523576	-3.2790672	**-5.15549**	-3.7314556
Zone 60	**-0.03932791**	-0.013564	-0.0046944	-0.03979	-0.01127938	2.794469	3.764441	2.550217	2.4717091	**3.844185**	2.36322689
Zone 61	**-0.08348154**	-0.00117	0.0271325	-0.08646	0.0193436	7.490378	9.899587	7.2234328	6.0279932	**9.862387**	5.91888661
Zone 62	**0.04306209**	0.08919473	0.0990797	0.046681	0.08911791	3.069617	3.882212	2.3459403	1.1325181	**2.533733**	0.67785922
Zone 63	**0.028803066**	0.09533719	0.0799197	0.021999	0.07272569	-2.50298	0.277575	-2.886507	-2.2732117	**0.235781**	-2.6112602

Ref No.	**m (AZP/Qrl) (mm²/m)**	m (AZP/ExNF) (mm²/m)	m (LP/MNF) (mm²/m)	m (LP/Qrl) (mm²/m)	m (LP/ExNF) (mm²/m)	Ao (CP/MNF) (mm²)	Ao (CP/Qrl) (mm²)	Ao (CP/ExNF) (mm²)	Ao (AZP/MNF) (mm²)	**Ao (AZP/Qrl) (mm²)**	Ao (AZP/ExNF) (mm²)
Zone 64	**0.023719516**	0.01972005	0.0264428	0.024749	0.02064644	1.832039	1.625346	1.4213898	1.1553451	**1.006895**	0.89453973
Zone 65	**0.240211753**	0.34132075	0.3591776	0.251877	0.34096511	8.899653	10.60895	7.3153838	-1.590641	**1.908398**	-2.2943372
Zone 66	**0.009860423**	0.00656712	0.0091717	0.010789	0.00755653	1.069901	0.963649	0.9934673	0.8873222	**0.780712**	0.83095366
Zone 67	**0.082936099**	0.12303634	0.1475249	0.100036	0.14253735	2.372625	3.279909	2.0898862	-2.1702562	**-0.23768**	-2.2464338
Zone 68	**0.108777815**	0.25190484	-3.0175301	-1.2615	-2.83411251	-0.42127	-0.1765	-1.52418	-8.8857832	**-3.71512**	-9.352876
Zone 69	**0.023265048**	0.0147656	0.0219452	0.02311	0.0152231	1.773201	1.337509	1.2683528	0.777079	**0.428651**	0.56722198
Zone 70	**0.046753244**	0.05460487	0.1711462	0.123569	0.134655	9.285453	7.661026	6.7169518	0.3255264	**0.765088**	-0.0699856
Zone 71	**0.01607348**	0.01683173	0.0236855	0.018406	0.01875767	0.858946	0.844118	0.6205084	-0.0504382	**0.086932**	-0.0825962
Zone 72	**0.001809209**	-0.0003847	0.0034488	0.002994	-0.00017544	0.196867	0.134243	0.1105502	0.1348701	**0.084629**	0.09988206
Zone 73	**0.032688363**	0.04433667	0.0800003	0.060289	0.07647698	4.481096	4.481093	4.3411403	1.2681669	**1.745887**	1.25339351
Zone 74	**0.022356279**	0.02121699	0.0245602	0.023343	0.02214305	0.057785	-0.00666	-0.004341	0.3020206	**0.208483**	0.20029346
Zone 75	**-0.00517448**	-0.0030832	0.0102026	0.002241	0.00499971	3.069995	2.972274	2.8728351	2.3782044	**2.427394**	2.2998416
Zone 76	**0.000809649**	-0.0010859	0.0009122	0.001165	-0.00068778	0.412097	0.345229	0.3577764	0.3043221	**0.245926**	0.29749398
Zone 77	**0.028185039**	0.02438229	0.0166674	0.01759	0.01522321	-0.0845	-0.32485	-0.296127	0.127429	**-0.07678**	-0.0798855
Zone 78	**0.016672648**	0.0161314	0.0246841	0.018728	0.01732506	0.624526	0.401002	-0.049718	-0.0308688	**-0.08036**	-0.4032939
Zone 79	**0.003402035**	-0.000563	0.0194786	0.012146	0.00362897	1.573744	1.54135	1.0244225	0.7917706	**0.911682**	0.6932438
Zone 80	**0.025306925**	0.0005696	0.0080699	0.01932	0.00188461	3.889543	2.398113	2.8759872	2.7475019	**1.471835**	2.09476908
Zone 81	**0.006793553**	0.00236256	0.0093612	0.007927	0.00272189	0.631099	0.288264	0.0778218	0.2542558	**0.023281**	-0.0085158
Zone 82	**0.001054353**	-0.0001091	0.0034556	0.004377	0.0024942	0.459	0.364586	0.3739536	0.2309804	**0.164025**	0.19200759
Zone 83	**0.005796919**	0.00409382	0.0128399	0.015078	0.0107863	0.330725	0.237828	0.1900171	-0.0756243	**-0.1546**	-0.1019063
Zone 84	**0.015576172**	0.00935937	-0.101236	-0.10979	-0.07167955	4.40271	3.682109	2.8807846	0.1917967	**-0.16899**	0.05419311
Zone 85	**0.000708703**	-0.0004673	0.0007998	0.00089	-0.00051799	0.233425	0.140362	-0.030612	0.0519595	**0.010888**	0.01372703
Zone 86	**0.010571659**	-0.0051627	0.0152177	0.029826	0.00907454	7.362746	6.034113	6.6531864	3.28053	**2.040249**	3.13907818
Zone 87	**0.007038924**	0.00291443	0.0091708	0.010541	0.00584611	2.088192	1.688999	1.6053074	0.6818486	**0.465792**	0.55721518
Zone 88	**0.028364454**	0.01985054	0.0663055	0.080163	0.05661536	1.296407	0.463215	0.4478343	-0.8978687	**-1.46953**	-0.9958882
Zone 89	**0.00210482**	0.0018128	0.0060929	0.004153	0.0035811	1.014649	0.808036	0.6980672	0.2958265	**0.25858**	0.2236102
Zone 90	**0.010188754**	0.00369247	0.018908	0.02196	0.01504173	6.402387	5.855635	5.865361	2.4947171	**2.144455**	2.35250906
Zone 91	**0.00540002**	0.00019227	0.0163127	0.022332	0.00907305	1.663527	1.332252	1.25361	0.6139493	**0.333739**	0.51754086
Zone 92	**0.047697044**	0.03491311	0.0503756	0.060099	0.04454277	0.5334	-0.15758	0.040021	-0.7951017	**-1.47486**	-0.9891486
Zone 93	**0.010609091**	0.00911061	0.0120622	0.013379	0.01151311	0.002617	-0.07302	-0.055803	-0.3204809	**-0.39568**	-0.3367659
Zone 94	**0.014705575**	0.01136698	0.0162541	0.017499	0.01328058	0.464518	0.190582	0.0607742	-0.2069773	**-0.36981**	-0.3204946
Zone 95	**0.012749921**	0.00951319	0.0184096	0.018676	0.01458814	1.622085	1.281898	1.2187896	0.3617991	**0.17983**	0.25242167
Zone 96	**0.010633264**	0.00742225	-0.0057903	-0.00626	-0.00470075	0.331188	0.162058	0.1799412	-0.2296412	**-0.41781**	-0.263217
Zone 97	**0.028882665**	0.02223748	0.0311023	0.035825	0.02837838	1.305443	0.863749	0.9314405	-0.1160642	**-0.45151**	-0.2348677
Zone 98	**0.0084853**	0.00376081	0.0109234	0.011519	0.00538277	1.505186	1.04589	0.6289833	0.1603347	**-0.00975**	0.04177191
Zone 99	**0.017171625**	0.01432251	0.0235544	0.025536	0.0211241	0.64863	0.423723	0.2719087	-0.5869133	**-0.73387**	-0.6345032
Zone 100	**0.005212953**	0.00370088	0.0052817	0.005847	0.00409728	0.256896	0.123743	0.0515083	-0.1163569	**-0.19597**	-0.1520587
Zone 101	**0.012988461**	0.00911482	0.0198023	0.022596	0.01758232	2.835398	2.46064	2.4654162	0.4428545	**0.23155**	0.37479093
Zone 102	**0.019809665**	0.01517285	0.0131178	0.015627	0.01194211	0.89323	0.542215	0.3648433	-0.9433306	**-1.2689**	-0.9834666
Zone 103	**0.009069417**	0.00707092	0.0114773	0.012369	0.00967854	0.56221	0.371832	0.3049721	-0.0735996	**-0.17591**	-0.1318641
Zone 104	**0.025171193**	0.01762053	0.0239981	0.031061	0.02274793	1.612417	1.148725	1.4247532	-0.4987606	**-1.08501**	-0.521332
Zone 105	**0.080184238**	0.07384875	0.0917023	0.098135	0.09105033	-0.1971	-0.53061	-0.395512	-0.6349884	**-0.9396**	-0.7930241
Zone 106	**0.07193222**	0.06732786	0.1350048	0.141409	0.13285074	0.455117	0.17235	0.25838	-2.1315207	**-2.3549**	-2.1736247
Zone 107	**0.055674923**	0.04877806	0.065311	0.07185	0.06382019	1.497324	0.973962	1.2779553	-1.7113476	**-2.15401**	-1.746908

Ref No.	Ao (LP/MNF) (mm²)	Ao (LP/Qrl) (mm²)	Ao (LP/ExNF) (mm²)	C (CP/MNF)	C (CP/Qrl)	C (CP/ExNF)	C (AZP/MNF)	**C (AZP/Qrl)**	C (AZP/ExNF)	C (LP/MNF)	C (LP/Qrl)
Zone 1	2.2278575	3.191877	2.21954115	171.654	824.8996	383.14778	11.2603299	106.5506478	38.3651908	2.5833776	19.887856
Zone 2	0.6796417	0.296923	0.59711398	2.466383	0.530475	5.4913995	1.02685947	0.206703568	2.52635947	0.67648023	0.1029866
Zone 3	0.38814659	0.356847	0.36977591	11.24167	12.40064	41.482126	16.4946058	18.29901291	62.7348526	20.4321274	24.093568
Zone 4	0.09819703	-0.08874	0.07021231	0.568254	0.016839	0.5870845	0.10368477	0.002948901	0.11594526	0.04800133	0.0009432
Zone 5	-0.8641516	-1.85427	-1.160111	0.737837	0.044524	0.3389036	0.06759578	0.004955359	0.03202447	0.03246751	0.0014046
Zone 6	0.10379359	-0.03213	0.06529744	0.213965	0.009675	0.3746807	0.06627046	0.002197222	0.15123572	0.05487777	0.0009657
Zone 7	0.1299782	0.03699	0.04871679	0.590316	0.025011	-0.005714	0.53093605	0.020047444	-0.00419271	0.51832305	0.0166404
Zone 8	0.97556065	0.949355	0.93414351	2.466383	2.508045	2.3919954	3.18649435	3.251964234	3.09361789	4.00595715	3.8240418
Zone 9	0.30803303	0.089875	0.17719164	0.018881	0.006557	0.0141314	0.25265747	0.02429102	0.46118706	0.48244747	0.023792
Zone 10	-0.0072679	-0.00898	-0.0100649	0.000651	0.000503	0.000229	0.00071414	0.00054943	0.00024802	0.00078703	0.0005933
Zone 11	0.33914693	0.299733	0.30106935	1.093614	0.830089	6.2957479	2.49739685	1.837228738	18.6452811	3.52384287	2.3848456
Zone 12	0.10959537	-0.00516	0.03174162	0.041425	0.016024	0.0144821	0.02583426	0.00846154	0.00860165	0.0314057	0.0053123
Zone 13	-0.3719229	-0.35707	-0.3044801	0.015237	0.001911	0.0005816	0.00052386	0.000106021	4.1617E-05	9.0629E-05	1.396E-05
Zone 14	0.25895684	0.145815	0.20777062	0.076325	0.019992	0.3921148	0.51836692	0.082852199	4.56353588	0.99562677	0.1129815
Zone 15	0.30062061	0.118164	0.296621	11.07363	2.143442	28.551426	1.82629737	0.300806514	6.24424766	0.29626905	0.0390932
Zone 16	0.39106393	0.287252	0.33480942	1.924136	0.744118	445.05416	2.41390404	0.844904468	910.660116	2.88061542	0.8632137
Zone 17	0.20953845	0.168541	0.18991209	1.610116	0.663233	7.6826058	1.92817193	0.713956587	11.5999999	2.2044971	0.7175176
Zone 18	3.48327732	3.1184	3.16437785	34.42973	69.32151	195.72269	56.4459423	122.1480622	367.69157	71.683084	165.5328
Zone 19	0.49350872	0.150991	0.35486696	1.130798	0.128893	3.4727453	0.69254518	0.071431964	2.43543547	0.5902361	0.0461075
Zone 20	0.06332852	0.048167	0.06010484	2.28205	1.050031	19.845031	0.53175035	0.2209347	8.83755385	0.20978766	0.0682659
Zone 21	0.01149112	0.009327	0.01058544	0.09163	0.04899	0.1984666	0.05542781	0.02900821	0.12658866	0.03857537	0.0182488
Zone 22	-0.4101902	-0.45773	-0.1829059	7.133346	4.640404	10.618059	0.23332962	0.148444787	0.37961017	0.00479562	0.0016129
Zone 23	0.23860988	0.262469	0.25097964	14.66531	24.48332	22.904844	1.19272333	2.329593125	2.1603793	0.29170576	0.3993584
Zone 24	-0.1116065	-0.11674	-0.1096112	0.15387	0.130693	0.1216449	0.00534189	0.004557288	0.00424265	0.00209444	0.0007013
Zone 25	0.07515308	0.066254	0.07107059	1.18707	1.041986	493.4531	0.29796951	0.261432729	600.456692	0.12442659	0.0855403
Zone 26	13.5320615	12.3733	11.8418666	2.026239	1.733339	1.2646791	0.00870976	0.007524741	0.00572899	0.00047589	9.375E-05
Zone 27	-0.3201675	-0.30256	-0.3158033	0.002039	0.001322	0.000395	0.00055516	0.000374952	0.00012732	0.00028915	0.0001291
Zone 28	0.01255423	0.012065	0.01256968	0.010593	0.010092	0.0111876	0.00786382	0.007484677	0.00835199	0.00759638	0.0058831
Zone 29	-0.0074122	-0.01581	0.01069768	0.110198	0.072632	0.1504993	0.00869731	0.005743209	0.01215745	0.00351734	0.0011724
Zone 30	0.14580676	0.138518	0.12363974	0.022731	0.024167	0.0219937	0.07919793	0.087057293	0.07966159	0.16830675	0.1708909
Zone 31	-0.0768022	-0.09697	-0.0502872	0.468488	0.237351	0.0472239	0.00787488	0.003977079	0.00081412	0.0021239	0.0004618
Zone 32	-0.8059088	-0.75876	-0.7962378	0.35125	0.346262	0.2831882	0.02743607	0.027000916	0.02229414	0.01194032	0.0053819
Zone 33	-0.1024401	-0.11636	-0.1008952	0.018208	0.010534	0.0044521	0.00189168	0.001129504	0.00049557	0.00093626	0.0002683
Zone 34	0.1174004	0.097418	0.21336894	36.65252	31.02003	193.71357	0.33979062	0.256783512	19.6097332	0.03739178	0.0140538
Zone 35	-0.0098124	-0.03254	0.02028023	0.140567	0.042223	-0.020071	0.00818112	0.002523913	-0.00120905	0.00266734	0.0004356
Zone 36	0.16442538	0.119319	0.16696749	1.484457	0.912241	3.7592587	0.19092306	0.116418344	0.52352102	0.07486501	0.0277923
Zone 37	-0.0283918	-0.04929	-0.0226857	0.162204	0.063043	0.0258136	0.00710034	0.002805482	0.00115208	0.00251145	0.0004581
Zone 38	-0.0029118	-0.03512	0.0594216	1.602087	0.639437	-0.001042	0.025583	0.009465649	-2.3998E-05	0.00505301	0.0009099
Zone 39	-0.2773435	-0.26399	-0.2684244	0.340144	0.304878	0.2321031	0.03257135	0.029226928	0.02238545	0.01341953	0.0061275
Zone 40	0.11282975	-0.00259	0.12209696	3.689317	0.847971	7.5174924	0.53165843	0.114476792	1.33039773	0.06843749	0.0116824
Zone 41	5.11218165	4.539775	3.50970247	135.2478	32.67074	154.74656	4.06384393	0.681975193	5.85142026	9.5658E-05	7.604E-05
Zone 42	-2.9405995	-2.61618	-2.7946496	0.1922	0.129871	0.0534608	0.00327033	0.002340428	0.00119046	0.000852	0.0002113
Zone 43	-1.9968502	-3.02081	-1.7656044	60.13129	33.82812	45.205907	1.21563089	0.658005255	0.90733476	0.21095153	0.0520547
Zone 44	-0.1197241	-0.2348	-0.1429801	0.034234	0.0184	0.0260858	0.01728649	0.009192206	0.01312271	0.01468513	0.0053878
Zone 45	-2.7989177	-2.45524	-1.8728423	4.376256	0.567253	0.07393	0.10152817	0.014673538	0.00244848	0.00537978	0.0005737
Zone 46	0.57639915	0.51259	0.53347574	8.636389	6.573812	23.99342	2.80274378	2.088737719	9.29822352	1.42920316	0.8701686
Zone 47	0.0076862	0.034484	0.02023398	1.507029	2.958103	1.8651507	0.06013022	0.134521833	0.07927831	0.00778927	0.0083005
Zone 48	-22.16816	-12.6532	-21.455276	8.275087	10.4725	6.8814523	0.02799101	0.03458509	0.02354963	0.00461989	0.000957
Zone 49	0.07801642	0.03469	0.09098223	9.763683	5.657525	15.109016	0.13245127	0.068901899	0.34282644	0.03707346	0.0084833
Zone 50	-2.0626108	-4.18642	-1.9113579	19.45489	6.71321	19.496037	1.25909583	0.435823668	1.26318889	0.27714384	0.0549211
Zone 51	0.08403126	0.035146	0.03648462	0.284553	0.043469	0.1277556	0.19830477	0.029643386	0.08911476	0.15585606	0.0209672
Zone 52	-62.009672	-66.2862	-59.824538	1.724278	0.53053	1.0222906	0.02148532	0.008836748	0.01422399	0.00378704	0.0007131
Zone 53	0.15618882	0.069813	0.13695324	12.54665	4.049367	71.65427	1.2942743	0.326602731	36.048155	0.20450125	0.0317333
Zone 54	-0.2617206	-0.49626	-0.253604	4.307709	1.871787	3.0239189	0.13274614	0.05608047	0.09234246	0.03324571	0.0065457
Zone 55	0.27691989	0.231564	0.26771343	21.66413	15.95092	38.231613	1.68948185	1.123664155	5.00815886	0.36056468	0.1518462
Zone 56	-9.1526815	-9.67616	-9.1151284	0.443741	0.162942	0.1270858	0.00853328	0.003457002	0.00273679	0.00427721	0.0005524
Zone 57	-13.812457	-12.0872	-11.775977	2.899252	0.60052	0.4903474	0.03973763	0.009469341	0.00791631	0.00291086	0.0003488
Zone 58	0.04147132	-0.12498	-0.078792	0.1569	0.0518	0.0158399	0.07380058	0.025083542	0.00776729	0.04459904	0.0126495
Zone 59	-4.5217164	-6.39707	-4.7266304	0.104564	0.031814	0.0355635	0.03468582	0.011300805	0.01239475	0.0235368	0.00512
Zone 60	2.16696513	4.057429	2.21551177	186.7273	9.74E-17	9710.3369	77.509042	1.53366E-10	11859.7077	27.4787842	5.247E-08
Zone 61	4.18801647	10.28893	4.30390252	55.112	3.55E+15	72.721821	13.6841943	5.77904E+55	18.4657356	3.10276887	1.769E-26
Zone 62	-0.4135969	1.476573	-0.6567976	1.557769	3.591147	1.1493624	0.53922372	1.235322454	0.39912625	0.31269546	0.5048784
Zone 63	-2.0962436	0.207601	-2.4017866	0.085413	0.181676	0.0419747	0.05667489	0.129792331	0.02728549	0.056221	0.098767

Ref No.	Ao (LP/MNF) (mm^2)	Ao (LP/Qrl) (mm^2)	Ao (LP/ExNF) (mm^2)	C (CP/MNF)	C (CP/Qrl)	C (CP/ExNF)	C (AZP/MNF)	**C (AZP/Qrl)**	C (AZP/ExNF)	C (LP/MNF)	C (LP/Qrl)
Zone 64	0.61430123	0.511695	0.47322857	1.13	0.965912	0.8727708	0.43615461	0.372928926	0.33688036	0.26509496	0.1675349
Zone 65	-9.204672	-4.23316	-9.314224	6.515253	10.5818	5.1145134	0.73089671	1.162123849	0.57830573	0.3111465	0.244512
Zone 66	0.72833878	0.620942	0.68962231	1.22701	0.888685	1.259279	0.6958232	0.502210655	0.71556138	0.47403177	0.298168
Zone 67	-6.8029807	-3.70133	-6.683482	1.086238	1.883921	0.9574079	0.12675836	0.204723965	0.11263358	0.04691554	0.0370845
Zone 68	172.904315	72.28389	161.798728	0.22822	0.095347	0.0847443	0.0181699	0.0075925	0.00867846	0.00318763	0.0006751
Zone 69	0.10695263	-0.18942	0.09602726	1.680067	0.953962	1.2377875	0.28728747	0.163222815	0.21174591	0.1240432	0.0451087
Zone 70	-14.60528	-10.2409	-11.678351	75.95695	80.9053	46.840537	0.24274333	0.267738472	0.14788559	0.01391319	0.0041032
Zone 71	-0.830162	-0.55291	-0.6886268	0.552808	0.651026	0.3769779	0.05321564	0.061270446	0.0366353	0.01767485	0.0108421
Zone 72	0.04500336	0.011863	0.08721406	0.221483	0.116298	5.830093	0.07025579	0.037434083	2.25610707	0.02362109	0.0107876
Zone 73	-2.7857711	-1.5428	-2.6341489	6.517544	9.974025	6.4343532	0.41182019	0.615780621	0.40598186	0.07497585	0.0505978
Zone 74	0.66908119	0.530968	0.5070513	0.075483	0.057862	0.0553103	0.16497303	0.126442081	0.12086802	0.28245828	0.3525223
Zone 75	1.54459767	1.828743	1.64388066	36.42771	106.569	63.59618	6.85333602	22.98642415	12.7949955	1.17234293	3.1990335
Zone 76	0.22559499	0.172399	0.25711126	1.76773	0.937232	83.577972	0.46483957	0.23940926	42.6692158	0.19027449	0.0756836
Zone 77	0.19206018	0.011647	-0.0020726	0.132761	0.086763	0.0722063	0.1064387	0.066336015	0.05498954	0.12463528	0.0526016
Zone 78	-0.6525259	-0.53976	-0.7575392	0.290625	0.180233	0.0330211	0.05804011	0.036352126	0.00737102	0.02517344	0.0099837
Zone 79	-0.2709945	0.122856	0.33055202	6.906291	14.55065	31.298329	0.45022904	1.015937176	2.78951183	0.04899465	0.0536911
Zone 80	2.16968354	1.031347	1.69149429	10.09627	2.196248	13.280338	3.84940809	0.723780897	5.55709891	2.65958932	0.3506851
Zone 81	-0.0985198	-0.23363	-0.0931378	0.437727	0.126261	0.0310643	0.07599763	0.022855557	0.00572075	0.02715518	0.0056399
Zone 82	0.04695233	-0.02326	0.05016494	10.48727	4.716085	9.7478008	0.61607714	0.215849254	0.61499115	0.04497781	0.008581
Zone 83	-0.9148589	-1.11019	-0.7894678	2.121655	0.806839	0.7376359	0.00361772	0.001372323	0.00123772	0.00038846	5.701E-05
Zone 84	13.8095416	14.79455	9.73835135	169.0482	103.8041	101.04864	0.06683839	0.026610281	0.03448068	0.00037965	6.483E-05
Zone 85	-0.0222311	-0.05401	0.04392638	4.19398	0.954435	-0.05617	0.02130982	0.003815651	-0.00022848	0.00248947	0.0002047
Zone 86	0.81658732	-1.06538	1.2053205	719.5401	171.5594	973.25588	13.5474562	1.363224085	28.2410915	0.34336194	0.0229635
Zone 87	0.08689393	-0.11032	0.13642194	22.7693	11.3423	22.555527	0.48583386	0.221411751	0.51246471	0.0915393	0.0187324
Zone 88	-7.0049826	-8.67749	-6.1057406	4.604542	0.629831	0.7088787	0.00320364	0.000609518	0.0006343	0.00051667	3.713E-05
Zone 89	-0.1429275	-0.06106	-0.0522392	11.06439	11.31722	9.806354	0.13960642	0.151167032	0.13108574	0.01680839	0.0066279
Zone 90	0.85766075	0.5059	0.92180829	139.2757	95.22534	149.66113	3.75184239	2.253506943	4.37095194	0.51239191	0.1496153
Zone 91	-0.769438	-1.34447	-0.3268107	76.33587	25.31797	88.320606	0.7576829	0.148947259	1.3101408	0.00984401	0.0012749
Zone 92	-2.4552633	-3.28406	-2.3638934	0.347663	0.071044	0.092899	0.01772715	0.004518259	0.00548918	0.00579852	0.0007665
Zone 93	-0.7800091	-0.8898	-0.7633977	0.02457	0.005403	0.0059713	0.00036557	9.90399E-05	0.00010668	0.0001648	1.462E-05
Zone 94	-0.8029904	-0.95529	-0.7496086	0.888528	0.214821	0.0720918	0.00839064	0.002240195	0.00081391	0.00234925	0.000234
Zone 95	-0.5422781	-0.67172	-0.4519742	7.510345	4.193039	5.2307345	0.14494967	0.079348124	0.1003433	0.02627574	0.005809
Zone 96	0.59305493	0.580269	0.45370127	2.308927	0.248104	0.5160669	0.0023986	0.000567741	0.00082108	6.1474E-10	1.015E-08
Zone 97	-1.2623646	-1.65353	-1.232753	3.494045	1.369412	1.9297155	0.04587149	0.018172845	0.0252287	0.01084706	0.0016575
Zone 98	-0.4527126	-0.58595	-0.2456862	13.18126	5.789006	4.5833278	0.06455143	0.022686592	0.0202753	0.00947654	0.001212
Zone 99	-2.1426201	-2.3781	-1.9827215	1.666176	0.73328	0.4113071	0.00175623	0.000856299	0.00050686	0.00046939	6.307E-05
Zone 100	-0.4006934	-0.48513	-0.3490859	0.4821	0.127316	0.0467503	0.00232176	0.000699539	0.00027583	0.00062447	6.45E-05
Zone 101	-0.8221545	-1.09845	-0.7407709	40.96808	26.07488	34.806923	0.19967358	0.098392187	0.16598672	0.01674306	0.0029844
Zone 102	-1.6657755	-2.06997	-1.5899897	2.318622	0.882941	0.5634969	0.00079196	0.000358008	0.00023648	0.00035598	4.271E-05
Zone 103	-0.6011882	-0.70754	-0.5500733	1.72951	0.714425	0.6092471	0.01190335	0.004988049	0.00424012	0.00259692	0.0003677
Zone 104	-2.3275727	-3.27552	-2.2353661	4.718754	1.543631	3.7512211	0.012651	0.004822762	0.01017707	0.00227819	0.000343
Zone 105	-1.2325843	-1.52747	-1.3540982	0.083618	0.008339	0.0268075	0.02970521	0.00309047	0.00977964	0.01988483	0.0013058
Zone 106	-8.6281728	-9.10667	-8.533576	0.632685	0.311256	0.3910927	0.00218703	0.001154296	0.00141397	0.00080233	0.0001036
Zone 107	-5.2419786	-5.9279	-5.1666237	2.295402	1.130785	1.7897627	0.00713618	0.003870802	0.00570792	0.00213894	0.0003282

Ref No.	C (LP/ExNF)	CONV. N1 (CP/MNF)	CONV. N1 (CP/Qrl)	CONV. N1 (CP/ExNF)	CONV. N1 (AZP/MNF)	**CONV. N1 (AZP/Qrl)**	CONV. N1 (AZP/ExNF)	CONV. N1 (LP/MNF)	CONV. N1 (LP/Qrl)
Zone 1	6.37024658	0.23855031	0.1344597	0.16375542	0.487797282	**0.274948651**	0.334853667	0.728965593	0.410884017
Zone 2	1.39969686	0.54298342	0.7360772	0.39702226	0.645039836	**0.874426488**	0.471644551	0.722512224	0.979449317
Zone 3	84.8763277	0.2512442	0.2363266	0.15351101	0.227249574	**0.213756634**	0.138850215	0.213634789	0.200950226
Zone 4	0.03605592	0.58138138	1.3548008	0.46436433	0.841279976	**1.960446044**	0.671952057	1.05499596	2.458471276
Zone 5	0.00804216	0.9739717	2.1066348	1.17722297	1.630217356	**3.526049676**	1.970415889	2.158834706	4.669413184
Zone 6	0.09336944	0.75702779	1.5957463	0.49429533	0.868372116	**1.830450111**	0.566996732	0.913226371	1.924998834
Zone 7	-0.0032276	0.45829508	0.8960752	1.8404481	0.462280103	**0.90386683**	1.856451377	0.465204716	0.90958514
Zone 8	3.63056743	0.54298342	0.5356558	0.54084518	0.491346573	**0.484715771**	0.489411677	0.462704832	0.456460555
Zone 9	0.7408819	4.24353874	6.9958573	2.99777724	0.763780081	**1.259160531**	0.539559714	0.644345498	1.06226182
Zone 10	0.00026562	2.01118117	2.1336654	2.45680833	1.892789261	**2.008063195**	2.312183755	1.795484419	1.904832332
Zone 11	29.2035109	0.54297186	0.5719252	0.28911379	0.399394575	**0.420691791**	0.212663835	0.364810966	0.384264054
Zone 12	0.0057152	1.65316483	2.0008684	1.74615936	1.326715197	**1.605757947**	1.401346148	1.254223049	1.518018812
Zone 13	6.9864E-06	1.01247069	1.7045959	2.29648297	2.738067865	**4.609811776**	6.210477253	11.96901892	20.1510434
Zone 14	9.26341465	1.20267512	1.7760276	0.61896546	0.572159884	**0.844926236**	0.29446623	0.483233233	0.713605494
Zone 15	0.88574416	0.2794793	0.4119979	0.18628252	0.455174851	**0.671001622**	0.303389622	0.742569591	1.094668123
Zone 16	1450.03693	0.46953289	0.5772421	0.03468562	0.420711104	**0.517220759**	0.031079023	0.40221734	0.494484591
Zone 17	14.6643663	0.41362212	0.5077834	0.24677373	0.382235377	**0.469251422**	0.228047883	0.370031559	0.4542694
Zone 18	526.392972	0.36349615	0.2763678	0.18978702	0.310142658	**0.23580288**	0.161930325	0.289797885	0.220334656
Zone 19	1.87809701	0.60017483	0.9437137	0.38008681	0.64452159	**1.013444408**	0.408171318	0.67408645	1.059932134
Zone 20	4.32904746	0.27863413	0.330379	0.12054308	0.401354056	**0.475889139**	0.17363434	0.506763128	0.600873631
Zone 21	0.08440188	0.39489835	0.4505672	0.30250145	0.444388057	**0.507033439**	0.340411742	0.490274595	0.559388602
Zone 22	0.00261802	0.31045449	0.3413582	0.25383587	0.721068151	**0.792845713**	0.589564535	2.810767142	3.09056041
Zone 23	0.36915468	0.25990131	0.2196898	0.22162772	0.48320799	**0.40844681**	0.412049806	0.694965653	0.58744166
Zone 24	0.00065325	0.76823867	0.7975623	0.79884045	1.644393527	**1.707159876**	1.70989578	2.483082603	2.577861637
Zone 25	730.303695	0.36051453	0.3610126	0.00337502	0.491903974	**0.492583531**	0.004605042	0.617888665	0.618742268
Zone 26	8.2313E-05	0.50656541	0.5149142	0.55041072	2.310357277	**2.348434543**	2.510328176	-32.149316	-32.67917259
Zone 27	4.9675E-05	2.31213695	2.5614851	3.70025375	3.572543054	**3.957817451**	5.717358485	5.727447154	6.345113257
Zone 28	0.00660015	0.88153656	0.8860114	0.85577011	0.897122607	**0.901676611**	0.870900591	0.907869413	0.912477971
Zone 29	0.002367	0.69082317	0.750018	0.54042326	1.170569601	**1.27087257**	0.915723541	1.596743168	1.733563807
Zone 30	0.15679542	1.31265386	1.2487146	1.23835845	0.831797047	**0.791280288**	0.784717844	0.671009489	0.638324678
Zone 31	0.00010236	0.55270263	0.643188	0.76848945	1.373093593	**1.597888853**	1.909178431	2.183624345	2.5411152
Zone 32	0.00449735	0.99204575	0.9844016	1.02721062	1.719089085	**1.70584268**	1.780025328	2.427550026	2.408844591
Zone 33	0.00012178	1.18971672	1.3555901	1.57634135	1.951657284	**2.223762336**	2.585891261	2.6918862	3.067195862
Zone 34	1.8065882	0.1940185	0.2067049	0.07061642	0.643789797	**0.685885515**	0.234318549	1.089627099	1.160874943
Zone 35	-0.0002111	0.63847601	0.8127203	0.84434905	1.141139729	**1.452564311**	1.5090939	1.62802214	2.072320152
Zone 36	0.12484992	0.49494152	0.5488085	0.35143707	0.755898123	**0.838166339**	0.536731331	0.99892848	1.107646919
Zone 37	0.00018919	0.64236044	0.7955985	0.81118559	1.274713989	**1.578803028**	1.609734288	1.878025791	2.326037708
Zone 38	-3.999E-06	0.39660138	0.4830865	1.7792743	0.965228962	**1.175712299**	4.330310391	1.52378865	1.856074701
Zone 39	0.00474162	0.87004851	0.8770115	0.91272337	1.430789925	**1.442240452**	1.500968488	1.980353772	1.996202425
Zone 40	0.11578738	0.33498936	0.4656019	0.22121979	0.572248071	**0.795367907**	0.377900361	1.089100469	1.513741337
Zone 41	5.6118E-06	0.16190454	0.241573	0.13528033	0.50785934	**0.757761983**	0.424344961	-2.308339818	-3.444205948
Zone 42	0.0001347	0.99676433	1.0717469	1.39126716	3.372087334	**3.625755895**	4.70670372	12.68055068	13.63445748
Zone 43	0.06764724	0.40861797	0.4660349	0.41660637	1.029129424	**1.173737533**	1.049248694	1.845966869	2.105352881
Zone 44	0.00773417	1.57760165	1.9461059	1.68188635	1.747932674	**2.156223678**	1.863476816	1.873974354	2.311706813
Zone 45	0.00016663	0.42346716	0.6616101	1.02249528	1.213084298	**1.895279834**	2.929088937	6.154214378	9.615126027
Zone 46	4.37750886	0.35524451	0.373537	0.24908835	0.460056576	**0.483746135**	0.322579889	0.546272365	0.574401408
Zone 47	0.00503583	0.36361995	0.2907961	0.32195135	0.777847784	**0.622064625**	0.688711236	1.427144905	1.14132402
Zone 48	0.00096868	0.501366	0.3973706	0.52400669	2.764965566	**2.191445252**	2.889825913	19.24625619	15.25412008
Zone 49	0.04367512	0.28336029	0.3173261	0.19170022	0.802612848	**0.898820254**	0.542987372	1.184225093	1.326175503
Zone 50	0.13790515	0.52871877	0.6952107	0.52359014	1.065966997	**1.401636843**	1.055627001	1.893072498	2.489195412
Zone 51	0.06413335	0.50506537	0.7322202	0.49956431	0.547077161	**0.793126906**	0.541118514	0.58685669	0.850797408
Zone 52	0.0009134	0.84171222	1.1734747	0.95644155	3.29619728	**4.595399783**	3.745484471	40.62300181	56.63463617
Zone 53	10.5124029	0.20009798	0.2700006	0.0458026	0.421512661	**0.568764801**	0.096484612	0.766141149	1.033786547
Zone 54	0.01006243	0.48646996	0.6010492	0.50639104	1.118648393	**1.382125834**	1.164457373	1.849722152	2.285390823
Zone 55	0.82964522	0.21072329	0.2284411	0.14611673	0.461713611	**0.500534969**	0.320154843	0.707055848	0.766505835
Zone 56	0.000442	1.49639748	1.9953672	2.10146207	4.199826662	**5.600247638**	5.898016118	7.466933395	9.956762378
Zone 57	0.0003112	0.48953844	0.716524	0.75127138	1.767809414	**2.587494319**	2.712973094	25.84709441	37.8316856
Zone 58	0.0039748	0.99063271	1.2416903	1.35649753	1.192558099	**1.494789957**	1.632998884	1.431839752	1.794713132
Zone 59	0.00552739	2.04332582	3.0264211	2.70224916	2.661723155	**3.942344932**	3.520064734	3.274746453	4.850309116
Zone 60	14072.8954	0.19197163	-0.746239	0.00196851	0.253444047	**-0.985196377**	0.002598865	0.335948752	-1.305911492
Zone 61	3.57564938	0.3795754	-0.312509	0.34631059	0.535574853	**-0.440945025**	0.488638742	0.790946701	-0.651195648
Zone 62	0.168366	1.0299132	0.7469747	1.07490804	1.304690939	**0.946265247**	1.361690264	1.578476478	1.144836213
Zone 63	0.01921746	2.23922278	1.3538384	2.66987017	2.251198463	**1.36107888**	2.684149013	2.259231543	1.365935696

Ref No.	C (LP/ExNF)	CONV. N1 (CP/MNF)	CONV. N1 (CP/Qrl)	CONV. N1 (CP/ExNF)	CONV. N1 (AZP/MNF)	**CONV. N1 (AZP/Qrl)**	CONV. N1 (AZP/ExNF)	CONV. N1 (LP/MNF)	CONV. N1 (LP/Qrl)
Zone 64	0.15120266	0.85682804	0.8718252	0.8586051	1.049627746	**1.067999528**	1.051804672	1.239689544	1.261388005
Zone 65	0.13045476	0.95403502	0.7839005	0.99877336	1.624806719	**1.335052443**	1.701000112	2.349714833	1.930686581
Zone 66	0.4255055	0.6870677	0.7481112	0.66198652	0.781384829	**0.850808042**	0.752860629	0.876021241	0.953852556
Zone 67	0.02280744	1.12956213	0.9176197	1.15351517	1.909334539	**1.55108151**	1.949823118	2.967358056	2.410585531
Zone 68	0.00108816	1.61869445	1.6189769	2.09667968	4.291800327	**4.292549168**	5.55912854	-57.46826355	-57.47829072
Zone 69	0.05735642	0.74568294	0.8465169	0.73669411	1.096017521	**1.244225012**	1.082805591	1.435959321	1.630134984
Zone 70	0.00295467	0.33848374	0.3076308	0.35916292	1.432259381	**1.301708316**	1.519761195	5.366450186	4.877295918
Zone 71	0.00685051	0.89056003	0.8138061	0.92037881	1.544751733	**1.411615537**	1.596474925	2.358659969	2.155376161
Zone 72	0.62558237	0.67976553	0.7482706	0.20101834	0.914133739	**1.006257906**	0.270325046	1.29762456	1.428395995
Zone 73	0.03660841	0.62377504	0.5422715	0.61978028	1.195405061	**1.039211369**	1.187749487	2.256494584	1.9616571
Zone 74	0.33696284	1.44343411	1.5074935	1.50513073	1.234440524	**1.289224775**	1.287204143	0.991020829	1.035002157
Zone 75	1.73634364	0.33017287	0.2363159	0.27423418	0.499871578	**0.357775004**	0.415182112	0.803143131	0.574836717
Zone 76	21.2665243	0.44495983	0.5087816	0.1223907	0.596992999	**0.682621309**	0.164208954	0.75319842	0.861231694
Zone 77	0.04348687	1.55853038	1.757004	1.77485869	1.394786163	**1.572407489**	1.588386328	1.319465319	1.48749479
Zone 78	0.0022805	1.04363004	1.0904785	1.58860812	1.525983541	**1.594484846**	2.322844064	2.111260638	2.206034995
Zone 79	0.13118886	0.43644894	0.342141	0.23246579	0.852164626	**0.668028727**	0.453888427	1.751160291	1.372769232
Zone 80	3.11502468	0.51867611	0.7829898	0.42446207	0.62632842	**0.945500989**	0.512560062	0.692394352	1.045233656
Zone 81	0.00144601	0.79471534	0.9845702	1.05497224	1.172104488	**1.45211641**	1.555950462	1.641314775	2.033419497
Zone 82	0.02161394	0.19860377	0.2580873	0.1863081	0.513589244	**0.667413632**	0.48179263	1.261773308	1.639685247
Zone 83	4.679E-05	0.32722617	0.4571377	0.42541381	2.051502378	**2.8659661**	2.667077194	10.1768513	14.21714697
Zone 84	4.6011E-05	0.10345311	0.1311476	0.11127487	1.324774237	**1.67941719**	1.424936211	-15.3750513	-19.49096286
Zone 85	-1.762E-05	0.24867004	0.3583333	0.60776037	0.916908483	**1.321264222**	2.240964118	1.81698066	2.618267344
Zone 86	0.34064709	0.13022143	0.2199051	0.10590341	0.453856229	**0.766427738**	0.369101472	1.172608786	1.98018633
Zone 87	0.0395915	0.30106811	0.3598619	0.27430973	0.78488128	**0.938155934**	0.715122496	1.389271803	1.660574178
Zone 88	3.5106E-05	0.44992649	0.8097096	0.71307196	3.132060551	**5.636608526**	4.963887708	17.6247896	31.71842872
Zone 89	0.00574395	0.30927243	0.2829108	0.28260781	0.903748875	**0.826715421**	0.825830154	1.853333556	1.695359712
Zone 90	0.28298286	0.22170127	0.249803	0.20731982	0.611395808	**0.688893296**	0.57173542	1.120990049	1.263081166
Zone 91	0.00422173	0.15823233	0.2348059	0.12694734	0.647265038	**0.960496891**	0.51929068	2.835391111	4.207525802
Zone 92	0.00086426	1.06374009	1.6871047	1.44660258	2.34736512	**3.722949683**	3.192231334	4.57160647	7.250623567
Zone 93	1.547E-05	1.48065198	2.3764588	2.20968208	5.051521351	**8.107733843**	7.538743991	12.11650083	19.44708475
Zone 94	9.4613E-05	0.62136138	0.9356426	1.17888113	2.16472007	**3.259623605**	4.107026503	4.716002299	7.101330389
Zone 95	0.00687781	0.41513675	0.4751188	0.42738413	1.112024336	**1.272697771**	1.144831331	2.201060887	2.519086313
Zone 96	1.2402E-09	0.37636729	0.6284134	0.50065734	2.621590123	**4.377220078**	3.487333712	-1.21388488	-2.026800919
Zone 97	0.00208867	0.51827222	0.68831	0.59104616	1.644868784	**2.184526874**	1.875835424	3.453582183	4.586653453
Zone 98	0.0009655	0.26502316	0.3411276	0.29319994	1.184694358	**1.524892902**	1.310648947	2.628175713	3.382886448
Zone 99	4.0182E-05	0.53400065	0.6910041	0.7727828	3.434536327	**4.444336974**	4.970313426	10.62986733	13.75519368
Zone 100	2.7494E-05	0.60584939	0.864738	1.02114376	2.231821206	**3.18551208**	3.761677981	4.634471236	6.614850717
Zone 101	0.0042481	0.1946978	0.2344305	0.19748583	1.013133574	**1.219887556**	1.027641451	2.666535798	3.210705796
Zone 102	2.8835E-05	0.53446749	0.7632869	0.80790031	4.428164872	**6.323977538**	6.693607834	8.541706759	12.1986338
Zone 103	0.000308	0.4841788	0.6183789	0.60483565	1.744923673	**2.228565105**	2.17975684	3.940209086	5.032318954
Zone 104	0.00055332	0.49679762	0.69068	0.51803212	2.067281757	**2.874068123**	2.155643079	4.907473137	6.822684939
Zone 105	0.00404852	1.82043755	3.4509763	2.50641905	2.584947994	**4.900247398**	3.5590141	3.677064033	6.9705555
Zone 106	0.00012281	1.00244454	1.2500753	1.14902227	5.350386897	**6.672076585**	6.132722031	20.47418392	25.53185887
Zone 107	0.00043962	0.70153462	0.8701237	0.74495348	3.186626718	**3.952419857**	3.38385109	7.978862444	9.896300116

Ref No.	CONV. N1 (LP/ExNF)	LN (CP/MNF)	LN (CP/Qrl)	LN (CP/ExNF)	LN (AZP/MNF)	**LN (AZP/Qrl)**	LN (AZP/ExNF)	LN (LP/MNF)	LN (LP/Qrl)	LN (LP/ExNF)	LN from Conv. N1 (CP/MNF)
Zone 1	0.500406237	-0.47742	-0.60348	-0.570705	-0.0253931	**-0.38256**	-0.2961074	0.61171978	-0.16726	0.00083253	-0.207261
Zone 2	0.528291332	0.093877	0.651342	-0.193919	0.35124626	**1.24802**	-0.0567876	0.58958825	1.909439	0.05969528	0.044914
Zone 3	0.130531538	-0.40766	-0.42681	-0.525021	-0.4403326	**-0.45704**	-0.5433666	-0.4587229	-0.47411	-0.5539679	-0.199203
Zone 4	0.842652536	0.179621	12.05439	-0.069662	1.04465871	**-6.43912**	0.41828174	2.50937395	-4.13364	1.04795235	0.088591
Zone 5	2.609346656	1.805613	-5.31528	4.2056006	-17.37651	**-2.99286**	-6.2588977	-5.0392911	-2.63472	-3.8060674	0.9010384
Zone 6	0.596283964	0.696786	-23.1594	-0.011408	1.17325073	**-8.13286**	0.14427012	1.41617098	-6.76897	0.2139874	0.3459454
Zone 7	1.868196208	-0.08372	1.400514	-8.795664	-0.0759704	**1.445674**	-8.491507	-0.07025	1.479563	-8.2850884	-0.040035
Zone 8	0.460882725	0.093877	0.077257	0.0889996	-0.0180523	**-0.03167**	-0.0220443	-0.0759983	-0.08816	-0.079563	0.044914
Zone 9	0.455187142	-2.72975	-2.36496	-3.336001	0.71822986	**6.324511**	0.08253429	0.33838035	2.579224	-0.0859912	-1.364493
Zone 10	2.193318608	-7.33939	-6.46646	-5.266286	-8.9419257	**-7.56763**	-5.8509829	-11.21719	-8.98199	-6.5132704	-2.956254
Zone 11	0.194249256	0.090705	0.156599	-0.350958	-0.185734	**-0.14936**	-0.4520256	-0.2425488	-0.21135	-0.4751846	0.0449014
Zone 12	1.32477614	-15.2726	-6.09243	-10.27548	9.7210123	**-21.3649**	18.6305189	6.26140269	-115.625	9.61183689	-7.528914
Zone 13	27.14809253	2.13529	-12.0458	-4.642791	-3.6319993	**-2.66224**	-2.4475604	-2.1930594	-2.11044	-2.0821943	1.0511587
Zone 14	0.248699485	4.780069	-9.38565	0.2720579	0.16040343	**1.094665**	-0.3488128	-0.0342986	0.570293	-0.4137641	2.3633243
Zone 15	0.494948056	-0.36954	-0.16608	-0.487104	-0.0867114	**0.41791**	-0.3315297	0.6438265	2.953771	-0.0100948	-0.180678
Zone 16	0.029712841	-0.05962	0.168965	-0.638007	-0.1483725	**0.035426**	-0.6420603	-0.1800225	-0.0111	-0.6436592	-0.029566
Zone 17	0.220766885	-0.16574	0.016423	-0.417957	-0.2207385	**-0.0628**	-0.444251	-0.2415328	-0.09228	-0.4544668	-0.07951
Zone 18	0.151308001	-0.24121	-0.36688	-0.475096	-0.320828	**-0.41999**	-0.5075088	-0.3494507	-0.43946	-0.5196163	-0.120109
Zone 19	0.426894552	0.244715	1.808499	-0.23079	0.36820766	**2.367464**	-0.1799785	0.45713974	2.836928	-0.1451733	0.111327
Zone 20	0.219236558	-0.38664	-0.31075	-0.578923	-0.1864195	**-0.04904**	-0.5059882	0.01398466	0.230997	-0.4467885	-0.181245
Zone 21	0.375561914	-0.20477	-0.10191	-0.352309	-0.1121474	**0.015143**	-0.2909027	-0.0203379	0.133841	-0.2321773	-0.095106
Zone 22	2.298158118	-0.35089	-0.30269	-0.431921	0.58447338	**0.854317**	0.20194849	-3.5445317	-3.27616	-4.5259718	-0.159343
Zone 23	0.592623607	-0.43145	-0.48492	-0.482438	-0.0345288	**-0.17476**	-0.1684663	0.4974122	0.196327	0.209174	-0.193613
Zone 24	2.581992932	0.862471	1.000696	1.0070025	-16.89664	**-12.4464**	-12.313058	-4.1955803	-4.01447	-4.0073107	0.3665658
Zone 25	0.005784469	-0.27304	-0.2722	-0.706077	-0.0172447	**-0.01581**	-0.6864216	0.28150695	0.283831	-0.676942	-0.122411
Zone 26	-34.93197117	0.016816	0.038609	0.1366905	-4.6423404	**-4.52958**	-4.1459451	-1.9362919	-1.93714	-1.9404582	0.0066088
Zone 27	9.165982911	-4.59582	-4.01042	-3.038649	-3.0183685	**-2.86914**	-2.5418101	-2.4994497	-2.44101	-2.2979047	-2.231319
Zone 28	0.881333279	1.366595	1.393178	1.2209242	1.45593493	**1.48434**	1.30059389	1.5202054	1.549958	1.35773027	0.6169105
Zone 29	1.249114369	0.537202	0.764615	0.0943161	4.35238019	**7.223047**	1.50568959	-23.728846	-11.0877	6.20257083	0.2358238
Zone 30	0.633030763	8.841483	6.069066	5.7475949	1.02780843	**0.849816**	0.82290817	0.43197103	0.335716	0.32082813	4.3377133
Zone 31	3.036157567	0.11598	0.349654	0.7718208	13.9291567	**-22.7411**	-6.9971917	-4.9599237	-3.952	-3.3322941	0.0556347
Zone 32	2.513598957	2.163158	2.096756	2.4968377	-11.770969	**-12.3882**	-9.6847378	-4.3139879	-4.35902	-4.1284573	0.9686812
Zone 33	3.566673852	5.113911	13.82463	-33.51907	-6.9452213	**-5.19037**	-4.2330711	-3.8786307	-3.47593	-3.1738256	2.2228614
Zone 34	0.396588827	-0.47997	-0.46479	-0.612736	0.33711897	**0.458411**	-0.4208205	2.87878254	3.904851	-0.187629	-0.234292
Zone 35	2.152968841	0.356033	1.024546	1.1861293	3.7495074	**42.53499**	-235.43168	-18.17578	-5.70377	-5.2618513	0.1607338
Zone 36	0.709296922	-0.0121	0.124704	-0.302075	0.76645815	**1.147239**	0.08333124	2.14849096	3.360584	0.56264473	-0.005033
Zone 37	2.371608483	0.386363	0.998355	1.0771826	7.33345698	**-29.5204**	-21.831753	-7.5880015	-4.63607	-4.5067409	0.165991
Zone 38	6.836178862	-0.1972	-0.03518	-10.45548	1.76548727	**4.237516**	-2.8383931	-86.774892	-7.68909	-2.4442481	-0.093709
Zone 39	2.077487795	1.271502	1.310447	1.5250413	28.0550538	**34.03892**	-2159.3516	-6.3410045	-6.20531	-5.6267546	0.5874238
Zone 40	0.719218606	-0.29855	-0.07069	-0.456157	0.15952419	**0.863027**	-0.2219273	2.89594941	-149.413	0.5658223	-0.141639
Zone 41	-1.928747379	-0.52958	-0.43293	-0.55905	0.01596561	**0.701263**	-0.141664	-1.4738473	-1.59375	-1.4159454	-0.252669
Zone 42	17.69930288	2.056897	2.78766	17.267417	-3.0972217	**-2.97035**	-2.6568736	-2.1837943	-2.17005	-2.130045	0.9871405
Zone 43	1.882055144	-0.18133	-0.07151	-0.166818	2.29837608	**4.232631**	2.49299628	-7.8649327	-5.3675	-7.3141894	-0.083731
Zone 44	1.997850268	-28.3375	-6.63875	-13.27359	-10.247068	**-5.15475**	-7.6438038	-7.4688781	-4.55104	-6.1214969	-13.88632
Zone 45	14.85984221	-0.15487	0.429804	2.5281691	5.07423412	**-7.26632**	-3.5423398	-2.4373156	-2.2571	-2.1650325	-0.071092
Zone 46	0.383032193	-0.26955	-0.23965	-0.424095	-0.0802577	**-0.03346**	-0.3128546	0.10041332	0.166517	-0.2155589	-0.126451
Zone 47	1.263602921	-0.25807	-0.36968	-0.323827	0.78880151	**0.28418**	0.47605184	25.7383541	3.61032	6.52687328	-0.120013
Zone 48	20.11537885	0.00315	-0.211	0.0568348	-3.6412726	**-4.96025**	-3.4990568	-2.1170857	-2.14897	-2.1120028	0.0013679
Zone 49	0.80115746	-0.45817	-0.40257	-0.5861	0.92910548	**1.427811**	0.09484857	4.51623569	9.941243	0.88971954	-0.178064
Zone 50	1.874709487	0.062712	0.519532	0.0512271	2.66787422	**18.84618**	2.55780315	-7.1669887	-4.07779	-7.418482	0.0295679
Zone 51	0.580464773	0.011283	0.686975	-0.000965	0.10835439	**0.930469**	0.09400005	0.20690217	1.200676	0.1902458	0.0050912
Zone 52	46.160108	1.128868	4.582243	1.8396895	-3.163473	**-2.70305**	-2.9425824	-2.0534423	-2.03945	-2.0474022	0.5190925
Zone 53	0.17537037	-0.53991	-0.44532	-0.703953	-0.1538088	**0.157492**	-0.5956676	0.74275065	2.356828	-0.4963566	-0.230711
Zone 54	1.925468816	-0.02958	0.252197	0.0142819	3.35639071	**15.56975**	4.10103873	-7.8599873	-4.64519	-6.8272224	-0.013349
Zone 55	0.490276545	-0.47657	-0.45432	-0.55205	-0.0750916	**0.001091**	-0.3095817	0.52735659	0.73414	-0.019414	-0.224371
Zone 56	10.48616932	675.4871	-7.74966	-6.906163	-2.9127407	**-2.68771**	-2.6608465	-2.4120479	-2.33104	-2.3207122	276.58328
Zone 57	39.66630744	-0.02439	0.678512	0.8292146	-9.778831	**-4.01134**	-3.8192539	-2.0857956	-2.06024	-2.0578291	-0.010353
Zone 58	1.960653085	2.081253	6.287319	13.148898	4.78943954	**410.4686**	-18.405868	28.7075354	-9.30992	-6.747725	0.9632199
Zone 59	4.330773274	-5.82775	-3.42901	-3.782874	-3.7918092	**-2.89356**	-3.0617967	-3.1733682	-2.65149	-2.7579021	-2.840516
Zone 60	0.003444885	-0.47636	-1.1052	-0.670402	-0.3984135	**-1.18981**	-0.6675189	-0.2831408	-1.28166	-0.6654061	-0.235491
Zone 61	0.721630597	-0.21809	-0.8993	-0.270162	0.07441213	**-0.97005**	-0.0226527	0.82472515	-1.06967	0.57214127	-0.107481
Zone 62	1.647436943	2.274768	0.660745	2.7298599	8.29454991	**1.620352**	12.5451208	-27.628019	3.646111	-15.648608	1.1272667
Zone 63	2.693727016	-4.74845	11.75548	-3.748747	-4.7046582	**12.47254**	-3.7276741	-4.6760563	12.99693	-3.713821	-2.352772

Ref No.	CONV. N1 (LP/ExNF)	LN (CP/MNF)	LN (CP/Qrl)	LN (CP/ExNF)	LN (AZP/MNF)	**LN (AZP/Qrl)**	LN (AZP/ExNF)	LN (LP/MNF)	LN (LP/Qrl)	LN (LP/ExNF)	LN from Conv. N1 (CP/MNF)
Zone 64	1.242260658	1.196393	1.277532	1.2058048	2.58660277	**2.788689**	2.60967694	5.9566119	6.692867	6.0373676	0.5547942
Zone 65	2.459901937	1.689858	0.804096	2.0230569	-18.17015	**10.19554**	-12.050095	-4.3762307	-6.67303	-4.1054668	0.8316193
Zone 66	0.84404237	0.4667	0.66973	0.3919154	0.79232747	**1.09414**	0.68464687	1.21733557	1.67965	1.05926036	0.2301147
Zone 67	3.030282656	3.481614	1.464425	3.865298	-6.9724832	**-41.5928**	-6.5285397	-3.3881169	-4.2227	-3.3321008	1.699508
Zone 68	-74.4381005	-19.38	-19.339	-5.536845	-2.740774	**-2.74058**	-2.5209671	-1.9649233	-1.96493	-1.9721584	-9.424994
Zone 69	1.418649567	0.66244	1.079966	0.6306106	2.98040157	**5.883412**	2.82180778	29.4380025	-17.5046	22.7441523	0.3257025
Zone 70	5.694305694	-0.28461	-0.32992	-0.252816	27.6080878	**8.109078**	-103.53656	-2.5189244	-2.59375	-2.4785554	-0.139056
Zone 71	2.437635394	1.287575	0.918587	1.4573198	-46.795594	**20.67161**	-22.782981	-4.3350245	-5.05798	-4.138729	0.6408507
Zone 72	0.383729868	0.45234	0.682912	-0.468962	1.44380713	**2.097192**	-0.3778405	7.98843749	26.30506	-0.2096857	0.2191636
Zone 73	2.242043615	0.311791	0.096697	0.3002491	4.76383499	**2.432126**	4.59499179	-4.7352219	-6.4435	-4.7872345	0.1412594
Zone 74	1.033379975	36.36919	-294.026	-428.3741	6.14123987	**8.342716**	8.24131522	2.21235157	2.64963	2.63200466	16.6785
Zone 75	0.667072656	-0.30491	-0.43577	-0.385532	-0.0002637	**-0.25474**	-0.1602019	0.88188285	0.163594	0.40605826	-0.145173
Zone 76	0.207174833	-0.10933	0.018627	-0.565191	0.22152081	**0.461902**	-0.512131	0.69331857	1.158667	-0.4586861	-0.052169
Zone 77	1.502610744	-36.2799	-9.81448	-9.307526	17.0681263	**-29.7343**	-24.722462	9.11211943	158.578	-771.22429	-18.08515
Zone 78	3.213749761	2.470896	2.994202	-25.81699	-80.772563	**-23.7138**	-4.5718992	-5.3527353	-4.9095	-3.2361317	1.1912047
Zone 79	0.93272047	-0.12502	-0.28393	-0.437204	1.10648349	**0.410103**	-0.0892555	-10.03274	13.79926	1.53237968	-0.059754
Zone 80	0.56662556	0.038208	0.793143	-0.14095	0.29002356	**1.61281**	0.02550557	0.47764646	2.405631	0.14308172	0.0190315
Zone 81	2.178819814	0.873701	1.978751	2.6312133	4.21045576	**41.02834**	-39.007085	-16.43815	-5.86974	-5.0558126	0.4178672
Zone 82	1.183656175	-0.52557	-0.44726	-0.540584	0.02844238	**0.417177**	-0.0368808	6.45531519	-16.5039	4.36094381	-0.231595
Zone 83	13.23052232	-0.32439	-0.09197	-0.154699	-5.673322	**-3.50225**	-3.7520974	-2.2336448	-2.16145	-2.1744273	-0.147321
Zone 84	-16.53751011	-0.63973	-0.61071	-0.631699	9.43917551	**-13.1895**	24.7139585	-1.8811759	-1.90433	-1.8887888	-0.283948
Zone 85	4.440779574	-0.48904	-0.3123	0.3287077	1.48022519	**9.607761**	-5.0244837	-8.4311251	-3.86321	-2.7636515	-0.20085
Zone 86	0.953631574	-0.57919	-0.47442	-0.604794	-0.0890738	**0.735781**	-0.2335417	4.11941616	-6.18846	1.66422638	-0.269955
Zone 87	1.265795916	-0.43672	-0.33141	-0.479442	0.86774067	**1.716692**	0.59416815	16.7387139	-15.154	6.79650852	-0.165924
Zone 88	27.93288158	-0.1276	1.371687	0.7981421	-3.3204342	**-2.60574**	-2.6908878	-2.1337063	-2.08243	-2.0902025	-0.047686
Zone 89	1.693544279	-0.3842	-0.42502	-0.425479	1.41536838	**1.011792**	1.00769749	-7.7981649	-12.4428	-12.540216	-0.160177
Zone 90	1.048272998	-0.51557	-0.47742	-0.534175	0.26137538	**0.486999**	0.16088255	3.33777167	6.571999	2.47049045	-0.21771
Zone 91	2.274790222	-0.55302	-0.45972	-0.587472	0.34871639	**1.728063**	0.03967606	-3.5027896	-2.74432	-4.5869021	-0.254714
Zone 92	6.217024057	2.795373	-14.1683	39.107324	-4.4926439	**-3.03025**	-3.3072468	-2.6886003	-2.39808	-2.4691824	1.2922115
Zone 93	18.08231451	118.823	-5.38661	-5.984753	-2.6645252	**-2.4399**	-2.4618455	-2.2218935	-2.16045	-2.1668964	50.684873
Zone 94	8.947460091	0.327087	1.924664	5.4867366	-5.1939348	**-3.30047**	-2.9437599	-2.6614192	-2.40844	-2.32939	0.1381243
Zone 95	2.26599669	-0.19186	-0.06045	-0.166557	3.34580986	**7.253072**	3.85545274	-4.9778966	-4.07679	-4.7327014	-0.078225
Zone 96	-1.614753438	-0.28585	0.418758	0.0017853	-3.877213	**-2.79949**	-3.101806	-1.2326531	-1.36274	-1.308064	-0.110029
Zone 97	3.938521942	0.043343	0.555386	0.2360234	-16.371401	**-5.14309**	-7.6123416	-3.0686828	-2.69848	-2.8671823	0.0186123
Zone 98	2.907598662	-0.50044	-0.37263	-0.456187	4.52942367	**-86.6154**	8.95817809	-3.8335749	-3.12345	-3.480922	-0.190268
Zone 99	15.38308734	0.089152	0.622867	1.0110496	-3.1119472	**-2.76574**	-2.6681036	-2.2357035	-2.18382	-2.166723	0.0351974
Zone 100	7.811283605	0.306729	1.594208	3.1522239	-4.9989382	**-3.42876**	-3.1372311	-2.7016505	-2.47013	-2.4056486	0.1183798
Zone 101	2.704720077	-0.56463	-0.51281	-0.561152	2.14966052	**5.255962**	2.27875984	-3.736675	-3.1913	-3.6822729	-0.233894
Zone 102	12.911632	0.077722	0.793541	0.9916344	-2.6997685	**-2.43542**	-2.4067564	-2.2910339	-2.19633	-2.1851203	0.0356979
Zone 103	4.922105098	-0.04209	0.38091	0.3305841	-10.858211	**-5.14022**	-5.3461946	-2.892861	-2.64897	-2.6661716	-0.015575
Zone 104	5.117232069	-0.00687	0.514427	0.0395703	-5.5890122	**-3.5077**	-5.1104171	-2.598004	-2.38948	-2.564244	-0.003192
Zone 105	5.06266384	-10.3533	-4.37618	-5.341319	-4.4752291	**-3.31116**	-3.6131706	-3.2311229	-2.79022	-2.9202578	-4.120733
Zone 106	23.46792507	2.992511	9.561218	5.7202445	-2.673396	**-2.56279**	-2.598796	-2.135655	-2.11943	-2.1248769	1.0098262
Zone 107	8.472684366	0.657058	1.594593	0.8535902	-3.3306771	**-2.96984**	-3.2082966	-2.3464459	-2.28269	-2.3263271	0.2524024

Ref No.	LN from Conv. N1 (CP/Qrl)	LN from Conv. N1 (CP/ExNF)	LN from Conv. N1 (AZP/MNF)	**LN from Conv. N1 (AZP/Qrl)**	LN from Conv. N1 (AZP/ExNF)	LN from Conv. N1 (LP/MNF)	LN from Conv. N1 (LP/Qrl)	LN from Conv. N1 (LP/ExNF)	FAVAD N1 (CP/MNF)	FAVAD N1 (CP/Qrl)	FAVAD N1 (CP/ExNF)
Zone 1	-0.26769	-0.251634	-0.0120556	**-0.18371**	-0.1417387	0.29695898	-0.08182	0.0004064	-0.41357513	-1.02193338	-0.829401499
Zone 2	0.309033	-0.093363	0.16964514	**0.598533**	-0.0275736	0.28619386	0.921043	0.02911503	0.585820169	0.89443182	0.259429592
Zone 3	-0.20866	-0.257328	-0.2143	**-0.22254**	-0.265327	-0.2226158	-0.23021	-0.2697897	-0.18822273	-0.24462137	-0.605355165
Zone 4	5.887093	-0.034409	0.51809565	**-3.17181**	0.20765954	1.24717061	-2.04333	0.52126547	0.652270004	1.42339744	0.425121344
Zone 5	-2.64844	2.0981139	-8.6794679	**-1.49357**	-3.1257785	-2.5178314	-1.31552	-1.9014315	1.143571714	1.73173487	1.307899207
Zone 6	-11.4443	-0.005672	0.58321066	**-4.02618**	0.07180761	0.70423474	-3.35295	0.10654228	0.910650341	1.54512751	0.488460343
Zone 7	0.655835	-3.937305	-0.0363488	**0.677478**	-3.8054317	-0.0336253	0.693724	-3.7159432	0.408628786	1.08342251	1.628276432
Zone 8	0.036974	0.0425846	-0.0085792	**-0.01505**	-0.0104774	-0.0359542	-0.04172	-0.0376447	0.585820169	0.57171621	0.581726048
Zone 9	-1.18196	-1.667656	0.35828979	**3.152143**	0.04118914	0.16869601	1.284471	-0.0428908	2.078118334	2.23262419	1.928082059
Zone 10	-2.57812	-2.045141	-3.5458945	**-2.96826**	-2.2312485	-4.3842732	-3.47016	-2.4423383	1.657743885	1.68293361	1.734395894
Zone 11	0.077499	-0.174159	-0.0914092	**-0.07348**	-0.2232021	-0.1190894	-0.10373	-0.2341571	0.583161656	0.63539633	-0.040731958
Zone 12	-2.99653	-5.062409	4.7708465	**-10.4556**	9.1364516	3.06872978	-56.4976	4.70698534	1.570064548	1.69636978	1.60781111
Zone 13	-5.88768	-2.25552	-1.8077102	**-1.32156**	-1.2122927	-1.0955199	-1.05362	-1.0389893	1.181050234	1.5905319	1.774514798
Zone 14	-4.62283	0.1350293	0.07777189	**0.526546**	-0.1704919	-0.0164903	0.271626	-0.2008315	1.326991673	1.61925131	0.713872282
Zone 15	-0.08088	-0.238801	-0.0429021	**0.206275**	-0.1643061	0.3202533	1.467114	-0.0050265	-0.08615583	0.30085048	-0.449714202
Zone 16	0.083708	-0.317553	-0.073464	**0.017523**	-0.3192282	-0.0890729	-0.00549	-0.3198608	0.436594895	0.64454224	-1.262487269
Zone 17	0.007844	-0.202059	-0.1053573	**-0.02983**	-0.2138069	-0.1150195	-0.04373	-0.2182816	0.30133713	0.51615775	-0.21808748
Zone 18	-0.18276	-0.236765	-0.1595631	**-0.20898**	-0.2526548	-0.1736917	-0.21855	-0.2585409	0.182108756	-0.07948557	-0.405109861
Zone 19	0.797635	-0.107074	0.16893657	**1.055264**	-0.0841054	0.21078047	1.272377	-0.0681251	0.696603265	1.14393791	0.199965696
Zone 20	-0.14502	-0.275077	-0.0897887	**-0.02354**	-0.2460601	0.00680918	0.112191	-0.2192157	-0.13035892	0.04914587	-0.874865152
Zone 21	-0.0471	-0.164926	-0.0526822	**0.007083**	-0.1376249	-0.0096317	0.063138	-0.1106669	0.242495044	0.38652838	-0.043945749
Zone 22	-0.13692	-0.197537	0.28380936	**0.414119**	0.09837549	-1.762912	-1.62871	-2.2528846	-0.04056574	0.06592392	-0.26031915
Zone 23	-0.21894	-0.217755	-0.0165147	**-0.08387**	-0.0808403	0.24218302	0.09582	0.10207848	-0.25884836	-0.44144243	-0.432135373
Zone 24	0.423614	0.4262089	-7.9255182	**-5.82719**	-5.7642692	-2.0172085	-1.92776	-1.9242205	0.963078852	1.00017396	1.001744527
Zone 25	-0.12203	-0.33183	-0.008031	**-0.00736**	-0.3312803	0.13364375	0.134742	-0.3307525	0.124412758	0.12599599	-1.90224884
Zone 26	0.01514	0.0530869	-2.2340236	**-2.17864**	-1.9897774	-0.9702817	-0.97074	-0.9725516	0.516537454	0.5371742	0.620253086
Zone 27	-1.94208	-1.454493	-1.482499	**-1.40687**	-1.2371152	-1.2365494	-1.20639	-1.1304464	1.778100718	1.8321794	1.990520817
Zone 28	0.628695	0.5522409	0.65871205	**0.671337**	0.5895739	0.68881666	0.702064	0.61637917	1.077451946	1.08214551	1.049736988
Zone 29	0.333365	0.0421261	2.03554257	**3.364384**	0.71151856	-11.336647	-5.28149	2.98587993	0.84946753	0.93330429	0.586187261
Zone 30	2.979539	2.8220229	0.4965513	**0.410995**	0.39804969	0.20628643	0.16053	0.15344346	1.398389297	1.3585386	1.351799046
Zone 31	0.167117	0.3670343	6.8798228	**-11.2157**	-3.4439216	-2.4627917	-1.96051	-1.6509749	0.603926588	0.75906944	0.935608828
Zone 32	0.939494	1.1151067	-5.5643534	**-5.85808**	-4.5711055	-2.078109	-2.1003	-1.9865835	1.183860289	1.1770814	1.214027331
Zone 33	5.924732	-14.09906	-3.2140681	**-2.38167**	-1.9209025	-1.8390063	-1.63808	-1.4838693	1.33643857	1.43254467	1.530751187
Zone 34	-0.22678	-0.300398	0.1679375	**0.228328**	-0.2099118	1.43680808	1.948765	-0.0937195	-0.42296007	-0.36841963	-1.082220068
Zone 35	0.455012	0.5252018	1.78659992	**20.08117**	-110.96382	-8.8111489	-2.74727	-2.5314666	0.762554909	1.00606213	1.042570508
Zone 36	0.051313	-0.129347	0.343902	**0.510954**	0.03813197	0.99572309	1.548725	0.26469724	0.487753688	0.61087741	0.067182249
Zone 37	0.419645	0.4517699	3.43880201	**-13.6899**	-10.112922	-3.6453222	-2.2106	-2.1473041	0.77868834	0.99958853	1.018578669
Zone 38	-0.01663	-4.580709	0.86995916	**2.083682**	-1.3533181	-43.036854	-3.8084	-1.1874	0.25435636	0.46353921	1.605758808
Zone 39	0.605166	0.7027751	13.4487634	**16.31315**	-1033.5375	-3.081799	-3.01531	-2.7316383	1.05976266	1.06718329	1.103966873
Zone 40	-0.03325	-0.218005	0.07787434	**0.41918**	-0.1088135	1.43368494	-73.7731	0.28076822	0.074373707	0.42392944	-0.338764692
Zone 41	-0.20536	-0.267249	0.0079216	**0.347277**	-0.0703339	-0.7374184	-0.79774	-0.7083483	-0.62575059	-0.26345429	-0.767830903
Zone 42	1.335068	8.1968539	-1.5341631	**-1.47042**	-1.3118467	-1.089441	-1.08241	-1.0617311	1.172870877	1.23598473	1.445257724
Zone 43	-0.03285	-0.076974	1.12372582	**2.065017**	1.21851825	-3.8904502	-2.65193	-3.6174232	0.278511235	0.42297833	0.299782521
Zone 44	-3.24162	-6.497939	-5.033353	**-2.52387**	-3.7512071	-3.6739802	-2.23197	-3.0086361	1.536579849	1.67734424	1.581475732
Zone 45	0.192762	1.0942201	2.48534428	**-3.52985**	-1.6997465	-1.214859	-1.12323	-1.0748512	0.316745395	0.8006035	1.216566874
Zone 46	-0.11227	-0.200583	-0.0384092	**-0.01599**	-0.1506855	0.04851738	0.080382	-0.104719	0.130978109	0.18481359	-0.236396524
Zone 47	-0.17301	-0.151139	0.38474961	**0.139036**	0.23260674	12.725876	1.788032	3.2301707	0.152155904	-0.08650347	0.021088388
Zone 48	-0.09308	0.0245972	-1.7905354	**-2.44625**	-1.7195146	-1.0563499	-1.07271	-1.053719	0.503139931	0.23256653	0.553778291
Zone 49	-0.15446	-0.235649	0.43392375	**0.663396**	0.04491829	2.16681274	4.752929	0.4309375	-0.34558958	-0.1738256	-0.916041823
Zone 50	0.242561	0.0241601	1.30397226	**9.166408**	1.25036175	-3.54406	-2.01092	-3.6687341	0.559011585	0.84190252	0.548730753
Zone 51	0.302457	-0.000435	0.04940291	**0.414681**	0.04288175	0.09511835	0.540351	0.08750592	0.511157057	0.90722298	0.499034493
Zone 52	2.06255	0.8397286	-1.5567317	**-1.32306**	-1.4453382	-1.0255604	-1.01814	-1.0223913	1.030266689	1.32086054	1.147848825
Zone 53	-0.18699	-0.312335	-0.0727754	**0.073843**	-0.2875034	0.36265986	1.14494	-0.245072	-0.6734669	-0.30285055	-1.877842747
Zone 54	0.112408	0.0064322	1.62225197	**7.483623**	1.98024727	-3.8594128	-2.27325	-3.3503485	0.469522149	0.70140336	0.51408079
Zone 55	-0.21356	-0.261384	-0.0368746	**0.000535**	-0.1524312	0.26112286	0.363337	-0.0096298	-0.41047275	-0.33258042	-0.732390208
Zone 56	-3.0187	-2.662615	-1.3703941	**-1.24389**	-1.2273752	-1.1675903	-1.11825	-1.1112821	1.498521775	1.64815555	1.669314675
Zone 57	0.276363	0.3355974	-4.7339987	**-1.91955**	-1.8244206	-1.0410727	-1.02752	-1.0262011	0.474999406	0.90423421	0.953317288
Zone 58	2.871322	5.968521	2.25264707	**190.937**	-8.5188601	13.6713081	-4.39313	-3.170831	1.175456758	1.36277532	1.429323118
Zone 59	-1.65513	-1.831774	-1.8607903	**-1.40944**	-1.4950336	-1.5634608	-1.29848	-1.3532604	1.707135758	1.91169065	1.859340705
Zone 60	-0.55481	-0.332457	-0.1977897	**-0.59762**	-0.3321763	-0.1409313	-0.64361	-0.3317987	-0.40970577	11.0053472	-1.534000958
Zone 61	-0.44828	-0.133216	0.03688711	**-0.48479**	-0.0112336	0.41033121	-0.53514	0.28473704	0.221075492	-8.43077276	0.129832182
Zone 62	0.327977	1.3524321	4.12009016	**0.805919**	6.23014902	-13.742672	1.815602	-7.7825606	1.194634867	0.89786056	1.231893413
Zone 63	5.84174	-1.854796	-2.3312061	**6.19833**	-1.8444883	-2.3171213	6.459107	-1.8377125	1.766776815	1.42160232	1.863802084

Ref No.	LN from Conv. N1 (CP/Qrl)	LN from Conv. N1 (CP/ExNF)	LN from Conv. N1 (AZP/MNF)	**LN from Conv. N1 (AZP/Qrl)**	LN from Conv. N1 (AZP/ExNF)	LN from Conv. N1 (LP/MNF)	LN from Conv. N1 (LP/Qrl)	LN from Conv. N1 (LP/ExNF)	FAVAD N1 (CP/MNF)	FAVAD N1 (CP/Qrl)	FAVAD N1 (CP/ExNF)
Zone 64	0.591914	0.5591019	1.22038545	**1.314812**	1.23117007	2.84156678	3.190904	2.87988886	1.044708108	1.06092826	1.046650735
Zone 65	0.396454	0.9951055	-9.0123892	**5.062533**	-5.9751216	-2.1768654	-3.32187	-2.0417731	1.128233213	0.94570563	1.169209007
Zone 66	0.329984	0.1932982	0.39156539	**0.540376**	0.33843837	0.60261866	0.831007	0.52448871	0.818197285	0.90110075	0.781565523
Zone 67	0.717091	1.8861292	-3.4429895	**-20.5766**	-3.2230961	-1.6814969	-2.09819	-1.653474	1.276866081	1.09422586	1.294462743
Zone 68	-9.40499	-2.675941	-1.3581918	**-1.3581**	-1.2463583	-0.9830417	-0.98304	-0.9868314	1.55440694	1.55452873	1.720417509
Zone 69	0.530261	0.3100908	1.47535488	**2.909686**	1.39696405	14.615075	-8.68433	11.2924975	0.898474484	1.01922293	0.886732784
Zone 70	-0.16133	-0.123451	13.7621917	**4.043076**	-51.604227	-1.2586352	-1.29609	-1.2384185	0.102158651	0.00763515	0.161640918
Zone 71	0.457314	0.7252647	-23.345504	**10.31421**	-11.365388	-2.1646054	-2.52584	-2.0665126	1.062855854	0.97878315	1.09305256
Zone 72	0.330266	-0.230166	0.70687419	**1.025349**	-0.186777	3.94131106	12.9657	-0.1041595	0.811455943	0.90579197	-0.383104588
Zone 73	0.044137	0.13608	2.28304864	**1.170192**	2.20255679	-2.3218865	-3.16611	-2.3476297	0.737683655	0.58817075	0.730916608
Zone 74	-134.45	-195.9039	2.76563478	**3.744391**	3.69933961	0.96471694	1.150548	1.14307133	1.473239987	1.50341267	1.50233987
Zone 75	-0.20866	-0.184183	-0.0001284	**-0.12452**	-0.0781863	0.43501491	0.08089	0.20058491	0.06134666	-0.27233684	-0.127423266
Zone 76	0.008859	-0.274105	0.10741113	**0.223423**	-0.2513799	0.33904377	0.565513	-0.2265002	0.377247006	0.51828665	-0.79986096
Zone 77	-4.89099	-4.638233	8.50445326	**-14.8107**	-12.313967	4.53910194	78.96667	-384.03263	1.528344781	1.61344974	1.620372773
Zone 78	1.441874	-12.28565	-39.485901	**-11.5837**	-2.2152971	-2.6359633	-2.41636	-1.5835158	1.211889969	1.24963712	1.540294972
Zone 79	-0.13634	-0.211067	0.54360203	**0.201965**	-0.044079	-4.9815211	6.859734	0.76279937	0.357115931	0.10348486	-0.276842059
Zone 80	0.39468	-0.070233	0.14459486	**0.80343**	0.01271982	0.23822809	1.198931	0.07138138	0.536801642	0.94231993	0.33592377
Zone 81	0.940129	1.2470508	2.04975202	**19.88398**	-18.872953	-8.0764009	-2.8747	-2.473145	0.966296908	1.16428879	1.22460995
Zone 82	-0.19479	-0.238787	0.01377646	**0.201077**	-0.0178818	3.19768243	-8.15895	2.16111749	-0.6077801	-0.30917936	-0.676678322
Zone 83	-0.0411	-0.069409	-2.8132288	**-1.73208**	-1.8568414	-1.1152492	-1.07863	-1.0852477	0.019856324	0.39871897	0.316989527
Zone 84	-0.26946	-0.279915	4.70692337	**-6.5736**	12.3220027	-0.9407409	-0.95236	-0.94456	-1.27566837	-1.06879624	-1.21517013
Zone 85	-0.12409	0.1207751	0.71499665	**4.594851**	-2.349593	-4.1547666	-1.89424	-1.3400459	-0.4571178	0.04587295	0.747389026
Zone 86	-0.21881	-0.28269	-0.0441084	**0.363192**	-0.1157474	2.05444971	-3.08252	0.83026682	-0.87636304	-0.40266146	-1.030326183
Zone 87	-0.12291	-0.184133	0.39836921	**0.779853**	0.27408417	8.03112326	-7.22765	3.26978037	-0.2753307	0.00432583	-0.421014086
Zone 88	0.448666	0.2707642	-1.6127224	**-1.24174**	-1.288693	-1.0620163	-1.03309	-1.0378317	0.353735066	1.07835928	0.943870418
Zone 89	-0.17837	-0.178572	0.67714568	**0.485256**	0.48330574	-3.8301869	-6.11876	-6.1667763	-0.12390147	-0.23920279	-0.240580542
Zone 90	-0.20013	-0.226413	0.12536043	**0.232883**	0.07727907	1.63845315	3.220855	1.21372642	-0.56427381	-0.41360039	-0.646726795
Zone 91	-0.20961	-0.271696	0.17269731	**0.853557**	0.01967013	-1.7488443	-1.36934	-2.2906719	-0.73724828	-0.35089617	-0.924080356
Zone 92	-6.3446	17.727497	-2.1801288	**-1.44985**	-1.5909358	-1.3255625	-1.17389	-1.2119981	1.236521297	1.57594011	1.475066898
Zone 93	-2.14095	-2.409082	-1.2815695	**-1.15134**	-1.1655973	-1.094193	-1.05572	-1.0603052	1.49165436	1.72796643	1.70061176
Zone 94	0.771927	2.1141116	-2.5043927	**-1.5683**	-1.3835788	-1.3109451	-1.17853	-1.134274	0.746470152	1.15808042	1.345839278
Zone 95	-0.02428	-0.0677	1.57748125	**3.399429**	1.81556367	-2.4264096	-1.98127	-2.3054887	0.262585885	0.43566429	0.300158522
Zone 96	0.147333	0.0006578	-1.8915913	**-1.34756**	-1.5031868	-0.6315245	-0.71646	-0.6789473	0.099730528	0.79515817	0.501782078
Zone 97	0.231997	0.1001659	-7.9027983	**-2.46086**	-3.6607391	-1.5118802	-1.32398	-1.4100845	0.541542829	0.85707296	0.690953803
Zone 98	-0.13709	-0.171362	2.17152587	**-41.1721**	4.28119586	-1.8863867	-1.5311	-1.7104298	-0.50176459	-0.09395634	-0.338866687
Zone 99	0.2361	0.375105	-1.5169197	**-1.33964**	-1.2881584	-1.1095306	-1.0816	-1.0720301	0.581854348	0.8838066	1.002747227
Zone 100	0.574154	1.0883094	-2.366454	**-1.59329**	-1.4421496	-1.3190331	-1.19551	-1.1584464	0.734730429	1.11452595	1.259165205
Zone 101	-0.20984	-0.232254	1.05395145	**2.569995**	1.11703589	-1.857239	-1.58455	-1.8300683	-0.79690285	-0.55260162	-0.778693726
Zone 102	0.357381	0.4448786	-1.3415108	**-1.2073**	-1.1925444	-1.142011	-1.09347	-1.0876299	0.572116519	0.9424436	0.997899807
Zone 103	0.134274	0.1171133	-5.0829046	**-2.37256**	-2.4711143	-1.4098009	-1.2831	-1.2922178	0.456065293	0.77584002	0.748450382
Zone 104	0.235605	0.0183633	-2.7627925	**-1.72777**	-2.5252201	-1.2934726	-1.18788	-1.2764545	0.49308494	0.83968418	0.538064101
Zone 105	-1.51256	-1.993622	-1.9217032	**-1.2941**	-1.4856693	-1.4593342	-1.1828	-1.2806888	1.606913779	1.79619258	1.73034475
Zone 106	3.001206	1.8491837	-1.2597142	**-1.19335**	-1.2158558	-1.0527032	-1.04161	-1.0455209	1.249531033	1.40531395	1.35119589
Zone 107	0.587613	0.3244217	-1.5928994	**-1.40776**	-1.5308275	-1.1543481	-1.1191	-1.1434168	0.896520945	1.11458308	0.960506425

Ref No.	FAVAD N1 (AZP/MNF)	**FAVAD N1 (AZP/Qrl)**	FAVAD N1 (AZP/ExNF)	FAVAD N1 (LP/MNF)	FAVAD N1 (LP/Qrl)	FAVAD N1 (LP/ExNF)
Zone 1	0.473945271	-0.119585606	0.079328686	0.879544748	0.299149793	0.500831839
Zone 2	0.759942449	1.055164161	0.439793362	0.870906272	1.156291114	0.556332496
Zone 3	-0.286775538	-0.341740409	-0.689940761	-0.34748264	-0.401531901	-0.741990968
Zone 4	1.010920823	1.683853232	0.794921476	1.21504889	1.819117566	1.01170739
Zone 5	1.56106307	2.001791583	1.690153919	1.747568192	2.111726687	1.856370627
Zone 6	1.039859813	1.640196145	0.626080471	1.086122005	1.673341152	0.676268221
Zone 7	0.417783639	1.091114733	1.633484491	0.424442027	1.096703207	1.637266694
Zone 8	0.481615803	0.467298615	0.477458833	0.417750875	0.403317364	0.413559556
Zone 9	0.91800569	1.363472114	0.57624173	0.752828242	1.220609846	0.405918577
Zone 10	1.625914046	1.652261968	1.70614379	1.597874272	1.625282005	1.681380546
Zone 11	0.27190003	0.324412536	-0.324902632	0.179782956	0.232002683	-0.405431947
Zone 12	1.406725226	1.549104044	1.449058912	1.362285561	1.508724081	1.405765608
Zone 13	1.879939316	2.101598347	2.190817456	2.338181246	2.400544516	2.424048522
Zone 14	0.638230745	1.022596778	-0.035656775	0.464483243	0.863176053	-0.205798061
Zone 15	0.405055836	0.794736867	0.004047303	0.891663294	1.247076875	0.489802274
Zone 16	0.325777689	0.534214	-1.293766299	0.280454397	0.488777615	-1.306302181
Zone 17	0.216733733	0.432996505	-0.299373398	0.181551459	0.398340204	-0.333068956
Zone 18	0.027618997	-0.224112516	-0.530492936	-0.037162569	-0.284001399	-0.58166937
Zone 19	0.769116792	1.203040637	0.280519725	0.813724022	1.239374859	0.330172198
Zone 20	0.270865347	0.448436427	-0.524243079	0.513791791	0.687650516	-0.307626806
Zone 21	0.373686862	0.514917334	0.089756327	0.479239833	0.618041975	0.197616052
Zone 22	0.868875481	0.96071784	0.668017588	1.892999628	1.939335894	1.783609757
Zone 23	0.464236305	0.288231438	0.29740287	0.832181213	0.664108341	0.672989162
Zone 24	1.562906374	1.587363358	1.588393432	1.812932211	1.831732916	1.832523003
Zone 25	0.48245273	0.483937414	-1.688995051	0.719668688	0.721081535	-1.595419294
Zone 26	1.774548748	1.783319674	1.817869505	2.568042933	2.567074122	2.563311447
Zone 27	1.995449678	2.035005244	2.148588319	2.166911314	2.19395794	2.270472602
Zone 28	1.092823088	1.097478569	1.06532963	1.103206945	1.10783668	1.075863272
Zone 29	1.313167233	1.378390576	1.100908267	1.543996954	1.599131078	1.361160685
Zone 30	1.00685677	0.959405795	0.951426014	0.801661851	0.751337853	0.742899227
Zone 31	1.43301698	1.545995795	1.666744713	1.752530117	1.83875309	1.928762397
Zone 32	1.592842155	1.587810415	1.615144524	1.801751252	1.797705591	1.81964636
Zone 33	1.668202316	1.738642293	1.809303439	1.847387389	1.903887857	1.960018511
Zone 34	0.752123391	0.814322104	-0.226580345	1.242187145	1.296120216	0.269035344
Zone 35	1.289451849	1.477029973	1.504265635	1.558221519	1.712595261	1.734639814
Zone 36	0.933895446	1.034285734	0.576921293	1.182387527	1.270672904	0.860059276
Zone 37	1.380001781	1.535062599	1.548003641	1.6517911	1.775021896	1.785165063
Zone 38	1.138400071	1.309069794	2.043953299	1.511658423	1.649497252	2.192401798
Zone 39	1.46558258	1.471460309	1.500463317	1.687230698	1.692111374	1.71613422
Zone 40	0.637577285	0.963239204	0.214773045	1.243323156	1.506737945	0.861357926
Zone 41	0.515714714	0.912201305	0.334955064	3.610384378	3.184224444	3.904161419
Zone 42	1.976821305	2.007524694	2.103546333	2.344741319	2.354664151	2.384920535
Zone 43	1.196820504	1.308891564	1.213712836	1.645667852	1.728963774	1.658373457
Zone 44	1.608142382	1.740688286	1.650516186	1.654586311	1.781607458	1.695255415
Zone 45	1.335370191	1.659583385	1.893338446	2.195741416	2.295483104	2.358345144
Zone 46	0.412738894	0.465384963	0.044703829	0.591250549	0.642747245	0.225207107
Zone 47	0.940966483	0.721292796	0.822517018	1.46260054	1.28309534	1.367142708
Zone 48	1.878605369	1.752509213	1.900150973	2.395186434	2.3703426	2.399278278
Zone 49	0.981625029	1.088106245	0.586631682	1.318716956	1.408602708	0.970820945
Zone 50	1.227362515	1.449612461	1.218927676	1.662153694	1.824908109	1.655800079
Zone 51	0.597761498	0.981991267	0.585923258	0.671432426	1.04559426	0.659837407
Zone 52	1.962219765	2.087180939	2.014778683	2.449268902	2.462045767	2.454743072
Zone 53	0.318234016	0.636063335	-0.973212735	0.926194446	1.20209975	-0.48553186
Zone 54	1.270452178	1.439649072	1.303961496	1.645772865	1.774334175	1.671608345
Zone 55	0.418811805	0.50108961	0.051602804	0.845274046	0.92334519	0.480201624
Zone 56	2.022810026	2.092519091	2.102102614	2.208191276	2.251294203	2.257167228
Zone 57	1.613910383	1.83207775	1.85470378	2.420983621	2.443180177	2.445332317
Zone 58	1.327271709	1.497569681	1.55745189	1.466338507	1.620338057	1.673981879
Zone 59	1.858190665	2.02810655	1.985013878	1.96011532	2.10551236	2.068859881
Zone 60	-0.16227146	6.768524753	-1.507689929	0.105025982	5.050370605	-1.488697763
Zone 61	0.569258459	-31.88635367	0.476822309	0.95197226	15.85381057	0.863924845
Zone 62	1.392410067	1.118371899	1.426172678	1.537554428	1.284766225	1.568265874
Zone 63	1.769930435	1.425774931	1.86661271	1.772030657	1.428555752	1.868484148

Ref No.	FAVAD N1 (AZP/MNF)	**FAVAD N1 (AZP/Qrl)**	FAVAD N1 (AZP/ExNF)	FAVAD N1 (LP/MNF)	FAVAD N1 (LP/Qrl)	FAVAD N1 (LP/ExNF)
Zone 64	1.221184624	1.236056478	1.222966898	1.356251863	1.370009452	1.357901412
Zone 65	1.55824061	1.410678739	1.590496964	1.796188289	1.676272755	1.822012782
Zone 66	0.942066242	1.02247695	0.90640379	1.049008272	1.12681696	1.014388749
Zone 67	1.667434543	1.524634908	1.68087959	1.918739977	1.810298815	1.92879794
Zone 68	2.0744571	2.074519818	2.157476402	2.536351805	2.536345832	2.528638903
Zone 69	1.248769067	1.354723217	1.238343722	1.467146333	1.560589137	1.457884367
Zone 70	1.46504485	1.390219404	1.509752619	2.158360608	2.12745055	2.176335851
Zone 71	1.521836162	1.453856674	1.545907398	1.79984787	1.746427784	1.818600298
Zone 72	1.090802406	1.17712689	-0.107304826	1.388745958	1.463376751	0.234680615
Zone 73	1.326504402	1.208635417	1.321268728	1.767721712	1.683705403	1.764044909
Zone 74	1.359968294	1.392964748	1.391790294	1.18870157	1.225999643	1.224669957
Zone 75	0.499736234	0.158189716	0.309237603	0.968617296	0.640594059	0.788791917
Zone 76	0.681348371	0.815959577	-0.54973058	0.90944367	1.036751242	-0.347357077
Zone 77	1.444653918	1.534801644	1.54215414	1.401108763	1.493733472	1.501298323
Zone 78	1.512535638	1.544026109	1.779963108	1.729740593	1.755787181	1.94720085
Zone 79	1.025275178	0.790832085	0.401997207	1.610708383	1.432429044	1.105114506
Zone 80	0.724820361	1.117270273	0.524871217	0.823248132	1.206368624	0.625171908
Zone 81	1.308078209	1.476206528	1.526310884	1.5647746	1.705349837	1.746559717
Zone 82	0.527655783	0.79437166	0.461706969	1.365867509	1.564499851	1.313465681
Zone 83	1.713980549	1.899640089	1.86335923	2.310606126	2.360989429	2.351478819
Zone 84	1.404206994	1.58203805	1.461110616	2.634847178	2.605796352	2.625126678
Zone 85	1.096810804	1.4057294	1.748479075	1.634569125	1.849258808	2.067005453
Zone 86	0.402216272	0.923890359	0.195297588	1.304665226	1.692735251	1.124656521
Zone 87	0.964593764	1.131905263	0.8727136	1.443626127	1.570651535	1.371737458
Zone 88	1.930953831	2.122766465	2.091405295	2.382062678	2.423848766	2.417260788
Zone 89	1.085984478	1.002930842	1.001916995	1.64709852	1.587391572	1.586653488
Zone 90	0.707214589	0.827504575	0.638586417	1.269466889	1.367934476	1.211856288
Zone 91	0.758554278	1.133439611	0.538161941	1.899554155	2.07328985	1.778792106
Zone 92	1.786316051	1.992549187	1.933417002	2.092206469	2.215267351	2.180650668
Zone 93	2.100771911	2.194493839	2.184066816	2.318401941	2.361734236	2.356974117
Zone 94	1.738439567	1.934693519	2.014466846	2.101895047	2.210004229	2.252224729
Zone 95	1.269893292	1.378833	1.294045982	1.751389138	1.825014476	1.767902493
Zone 96	1.847558561	2.055712239	1.97578131	5.798244645	4.256833376	4.746078793
Zone 97	1.565055879	1.74136554	1.651232357	1.983399382	2.088762416	2.035566347
Zone 98	1.319149326	1.511680141	1.399580025	1.852911081	1.970930713	1.90307595
Zone 99	1.973496689	2.066333875	2.099483159	2.309255624	2.344724177	2.357101464
Zone 100	1.750066378	1.911732777	1.967895124	2.087664744	2.180212697	2.211415359
Zone 101	1.182505465	1.340152475	1.195006634	1.865406926	1.956349884	1.872818146
Zone 102	2.088315409	2.196661332	2.21085513	2.274573018	2.335886414	2.343796179
Zone 103	1.601438282	1.74153299	1.730086339	2.028300807	2.106439752	2.100178294
Zone 104	1.717911821	1.898771448	1.743284315	2.125780677	2.219693965	2.139286437
Zone 105	1.78775081	1.932683819	1.882676885	1.948204803	2.058591575	2.020763408
Zone 106	2.097587193	2.139881575	2.125470681	2.380549081	2.393310638	2.388986192
Zone 107	1.92905986	2.007656427	1.952837717	2.242695991	2.279608884	2.253961851

Appendix IIb

SANFLOW Analysis Data

								SANFLOW Analysis Before PM	
Sub-district, Zone, Year and Night Flow Test Number	Ave. Zone Night Press. Metres (AZNP)	Exceptional night use > 0.25 m3/hr	Measured Min. Night Flow in l/sec	**Measured Min. Night Flow in m3/hr**	**Excess night flow in m3/hr**	Excess as equivalent number of Service bursts ESPB's	Marginal cost of water supply cents/m3	Daily Cost of excess night flow due to bursts (Rand/day)	Length of Mains in Metres (L)
PRVA	84.6	0	25.92	**93.3**	**67.07**	32.23	123	1649.93	47790.00
Dv 2876	79	0	7.36	**26.5**	**17.60**	8.75	123	432.92	16279.00
Dv 2877	67	0	1.94	**7**	**6.05**	3.27	123	148.84	2114.00
Dv 2824	57	0	1.64	**5.9**	**2.79**	1.63	123	68.63	7392.00
Dv 3008	55	0	9.83	**35.4**	**28.59**	17.03	123	703.22	5791.00
Dv 3067	74	0	1.56	**5.6**	**2.21**	1.13	123	54.33	4767.00
Dv 3213	78.6	0	0.94	**3.4**	**-6.19**	-3.08	123	-152.24	3753.00
Dv 2885	80	0	7.36	**26.5**	**25.31**	12.50	123	622.58	2212.00
Dv 2823	58.2	0	2.86	**10.3**	**4.77**	2.76	123	117.35	10372.00
Dv 3052	96	0	0.44	**1.6**	**1.16**	0.52	123	28.62	1322.00
DV 3145	66.7	0	2.31	**8.3**	**6.11**	3.31	123	150.25	4446.00
Dv 2929	115	0	5.53	**19.9**	**8.19**	3.38	123	201.52	11988.00
Dv 3148	52.4	0	0.28	**1**	**0.41**	0.25	123	10.10	1884.00
Dv 3149	77.4	0	2.22	**8**	**4.75**	2.39	123	116.90	4333.00
Dv 3155	60.5	0	2.72	**9.8**	**7.08**	4.02	123	174.21	3058.00
Dv 3156	70.7	0	2.78	**10**	**5.93**	3.12	123	145.83	11698.00
Dv 2855	101.3	0	1.67	**6**	**4.47**	1.96	123	109.86	2114.00
Dv 3038	53	0	18.94	**68.2**	**54.37**	33.01	123	1337.60	30559.00
Dv 1292	95.2	0	5.67	**20.4**	**9.90**	4.48	123	243.48	10484.00
Dv 2760	94.2	0	0.56	**2**	**1.34**	0.61	123	33.08	428.00
Dv 2759	77.2	0	0.08	**0.3**	**0.24**	0.12	123	5.78	151.00
DV2820	76.2	0	2.58	**9.3**	**6.58**	3.33	123	161.83	5963.00
DV3188	97.07	0	2.81	**10.12**	**9.18**	4.12	123	225.78	8707.00
DV3190	77.18	0	1.39	**5**	**4.54**	2.29	123	111.79	1345.00
DV3191	102.77	0	0.78	**2.81**	**1.20**	0.52	123	29.58	1964.00
DV3193	58.5	0	4.11	**14.8**	**12.37**	7.15	123	304.37	7413.00
DV3194	56.5	0	0.69	**2.5**	**1.68**	0.99	123	41.35	2505.00
DV3195	72	0	0.19	**0.7**	**0.66**	0.34	123	16.28	553.00
DV3197	101.6	0	0.94	**3.4**	**1.73**	0.76	123	42.56	2078.00
DV3199	69	0	1.42	**5.1**	**4.08**	2.17	123	100.26	2505.00
DV3200	79.98	0	1.15	**4.13**	**1.29**	0.64	123	31.84	5092.00
DV3203	93.3	0	11.22	**40.4**	**37.11**	16.98	123	912.86	3871.00
DV3204	94.1	0	1.23	**4.42**	**2.98**	1.36	123	73.40	1090.00
DV3207	109.99	0	3.17	**11.41**	**7.40**	3.12	123	182.11	30704.00
DV3210	117.61	0	0.97	**3.5**	**-1.58**	-0.64	123	-38.83	7434.00
DV3262	122.82	0	3.94	**14.17**	**8.06**	3.21	123	198.15	5611.00
DV3277	88.92	0	0.90	**3.24**	**1.25**	0.59	123	30.71	2325.00
DV3343	109.06	0	1.40	**5.03**	**-0.77**	-0.33	123	-19.06	5902.00
DV3367	91.34	0	6.64	**23.91**	**19.59**	9.06	123	481.85	4736.00
Arboretum 1 PRV	49.7	0	1.72	**6.2**	**3.35**	2.10	123	82.45	8900.00
Arboretum 2 PRV	42.4	0	7.78	**28**	**21.09**	14.32	123	518.89	29600.00
Arboretum Ext PRV	45.9	0	2.22	**8**	**5.81**	3.79	123	142.97	6000.00
Gobandlovu 1 PRV	75.4	0	55.56	**200**	**160.80**	81.84	123	3955.80	49000.00
Logan Rd. PRV	45.6	0	2.33	**8.4**	**7.67**	5.02	123	188.64	2300.00
Mandlazini PRV	44.5	0	4.28	**15.4**	**4.80**	3.18	123	118.07	20700.00
Union St PRV	92.3	0	5.22	**18.8**	**14.03**	6.45	123	345.12	5700.00
EMP FARM PRV	81.7	0	0.97	**3.5**	**2.78**	1.36	123	68.35	6400.00
Gobandlovu 2 PRV	41.9	0	10.81	**38.9**	**36.39**	24.85	123	895.21	16400.00
Kildare Ext	97.7	0	2.86	**10.3**	**4.87**	2.18	123	119.70	8600.00
Kuleka Industrial	49.4	0	39.19	**141.1**	**136.87**	86.06	123	3366.97	18700.00
Matshana 1 PRV	75.9	0	0.69	**2.5**	**1.07**	0.54	123	26.42	5500.00
PLOF-002	44.2	0	13.64	**49.1**	**43.37**	28.83	123	1066.89	27900.00
Birdswood PRV Zone	49.5	0	1.36	**4.9**	**2.04**	1.28	123	50.28	7600.00
PLOF-001	66.2	0	7.03	**25.3**	**20.38**	11.07	123	501.35	9800.00
PR101	60.3	0	2.67	**9.6**	**7.03**	4.00	123	173.06	6600.00
uMhlathuze Village PMZ	61.8	0	23.67	**85.2**	**72.20**	40.59	123	1776.17	12800.00
Veldenvlei PRV Zone	38.6	0	4.28	**15.4**	**9.90**	7.04	123	243.58	18280.00
PRV-01	72.64	0	5.54	**19.93**	**6.47**	3.35	123	159.10	26384.00
PRV-03	58.63	0	23.04	**82.94**	**60.37**	34.85	123	1485.21	64081.00
PRV-04	67.9	0	12.50	**45**	**34.22**	18.35	123	841.72	21500.00
PRV-05	66.3	0	40.94	**147.4**	**136.94**	74.33	123	3368.72	21500.00
PRV-06	52.64	0	36.67	**132**	**112.24**	68.37	123	2761.08	68786.00
PRV-007	56.1	0	21.58	**77.7**	**59.03**	34.83	123	1452.04	47631.00
PRV-009	78.48	0	22.22	**80**	**62.29**	31.07	123	1532.33	26252.00
PRV - 11	44.8	0	77.06	**277.4**	**250.46**	165.37	123	6161.33	59423.00
PRV-013	50.43	0	7.36	**26.51**	**23.76**	14.79	123	584.52	21194.00
PRV-017	67	0	41.47	**149.3**	**141.33**	76.31	123	3476.72	50788.00
PRV - 18	50.3	0	23.83	**85.8**	**67.75**	42.22	123	1666.67	32523.00
PRV-021	61.6	0	13.14	**47.3**	**33.37**	18.79	123	820.93	46400.00
PRV-025	70.9	0	34.53	**124.3**	**92.16**	48.37	123	2267.13	114500.00
PRV-026	59.1	0	7.36	**26.5**	**20.19**	11.61	123	496.66	91300.00
PRV-027	59.3	0	1.56	**5.6**	**1.71**	0.98	123	42.03	43900.00
PRV-028	82.4	0	37.03	**133.3**	**128.24**	62.43	123	3154.67	47700.00
PRV-031	54.7	0	9.50	**34.2**	**28.98**	17.32	123	712.86	30000.00
PRV-032	76.3	0	16.61	**59.8**	**51.92**	26.27	123	1277.31	30000.00
PRV-036	90.1	0	2.64	**9.5**	**5.46**	2.54	123	134.23	36200.00
HV - 34	43.5	0	6.83	**24.6**	**18.62**	12.48	123	458.14	12900.00
HV - 06	67.5	0	9.47	**34.1**	**16.22**	8.72	123	398.94	22200.00
PRV - 012 - HV - 16	65.7	0	8.53	**30.7**	**15.32**	8.35	123	376.75	13300.00
HV - 42	51	0	18.17	**65.4**	**43.67**	27.02	123	1074.24	34400.00
PRV -016	85.5	0	6.69	**24.1**	**5.15**	2.46	123	126.71	27600.00
DV 1507 Magazine Rd	42.2	0	1.22	**4.4**	**3.51**	2.38	123	86.22	2100.00
1505 Braithwaite Rd PRV	51.3	0	0.92	**3.3**	**2.23**	1.38	123	54.84	3200.00
DV 0803 Haniville PRV	76.3	0	8.08	**29.1**	**19.32**	9.78	123	475.33	7200.00
DV 1007 Woodpecker Rd PRV 2	93.4	0	0.78	**2.8**	**-0.83**	-0.38	123	-20.48	4200.00
PRV 0703 Chief Mhlabenzima Rd	83.3	0	22.69	**81.7**	**71.19**	34.47	123	1751.19	15000.00
DV 0708 Tamboville Prv 1	81	0	7.94	**28.6**	**20.56**	10.09	123	505.67	9100.00
DV 0709 Tamboville PRV 2	77.9	0	5.81	**20.9**	**13.99**	7.00	123	344.11	5500.00
1602	80.8	0	4.08	**14.7**	**9.58**	4.71	123	235.62	6000.00
1301	68	0	19.31	**69.5**	**61.81**	33.13	123	1520.64	14600.00
Xulukhona PRV	61.8	0	4.64	**16.7**	**11.98**	6.74	123	294.78	5800.00
DV 0401 Bombay & Narandas Rd	55.1	0	7.75	**27.9**	**19.97**	11.89	123	491.34	12300.00
DV 0904 Khan Rd PRV	52.1	0	0.97	**3.5**	**2.87**	1.75	123	70.50	1300.00
DV 0203 Turbull Rd PRV	49.8	0	2.47	**8.9**	**4.99**	3.12	123	122.75	6300.00
DV 1601 Morcom Rd	67.6	0	7.64	**27.5**	**21.20**	11.39	123	521.49	18000.00
Ganges Rd PRV 1004	63.4	0	1.81	**6.5**	**4.75**	2.64	123	116.94	2600.00
DV 1003 Regina Rd	49	0	5.83	**21**	**17.23**	10.88	123	423.78	1900.00
Belfort PRV DV 1001	63.1	0	3.94	**14.2**	**6.38**	3.55	123	157.01	7100.00
DV 1604 Villiers Drive PRV	67.3	0	2.97	**10.7**	**7.78**	4.19	123	191.40	6600.00
DV 1005 Boundary Rd	80	0	1.75	**6.3**	**3.71**	1.83	123	91.23	3100.00
DV 905 Simla Rd	56	0	6.06	**21.8**	**19.07**	11.26	123	469.18	2400.00
DV 1305 Mbubu Rd	82.8	0	2.97	**10.7**	**7.15**	3.47	123	175.84	5400.00
DV 0906 Springvale Rd	64.3	0	2.83	**10.2**	**7.45**	4.11	123	183.33	2500.00
DV 1510 Old Howick Rd	84.3	0	7.75	**27.9**	**25.49**	12.27	123	626.94	7700.00
Kwapata PRV 4	26.6	0	5.42	**19.5**	**17.39**	14.90	123	427.88	3300.00
Kwapata PRV 3	49.3	0	6.83	**24.6**	**23.16**	14.58	123	569.73	2100.00
Montgomery Dr PRV	68.3	0	11.08	**39.9**	**37.71**	20.16	123	927.55	5200.00

Sub-district, Zone, Year and Night Flow Test Number	Number of Connections (C)	Number of Properties (N)	Estimated Population (P)	% of Commercial Properties	Mains Length per Connection L/C in metres	Estimated minor night use m3/hr	Estimated background night flow in m3/hr
PRVA	1866	1866	9325	0.00	25.61	**5.60**	**26.23**
Dv 2876	723	723	3108	0.41	22.52	**1.86**	**8.90**
Dv 2877	94	94	392	0.00	22.49	**0.24**	**0.95**
Dv 2824	380	380	1500	0.00	19.45	**0.90**	**3.11**
Dv 3008	242	242	9050	0.00	23.93	**5.43**	**6.81**
Dv 3067	306	306	1407	0.00	15.58	**0.84**	**3.39**
Dv 3213	1023	1023	2046	0.00	3.67	**1.23**	**9.59**
Dv 2885	51	51	1000	0.00	43.37	**0.60**	**1.19**
Dv 2823	631	631	3065	0.00	16.44	**1.84**	**5.53**
Dv 3052	25	25	50	0.00	52.88	**0.03**	**0.44**
DV 3145	224	224	896	0.00	19.85	**0.54**	**2.19**
Dv 2929	620	620	2308	0.00	19.34	**1.38**	**11.71**
Dv 3148	76	76	304	0.00	24.79	**0.18**	**0.59**
Dv 3149	296	296	1056	0.00	14.64	**0.63**	**3.25**
Dv 3155	307	307	1535	0.00	9.96	**0.92**	**2.72**
Dv 3156	360	360	1440	0.00	32.49	**0.86**	**4.07**
Dv 2855	83	83	555	0.00	25.47	**0.33**	**1.53**
Dv 3038	1875	1875	7178	0.00	16.30	**4.31**	**13.83**
Dv 1292	671	671	3915	0.00	15.62	**2.35**	**10.50**
Dv 2760	46	46	225	0.00	9.30	**0.14**	**0.66**
Dv 2759	5	5	25	0.00	30.20	**0.02**	**0.06**
DV2820	229	229	916	0.00	26.04	**0.55**	**2.72**
DV3188	0	0	0	0.00	#DIV/0!	**0.00**	**0.94**
DV3190	35	35	140	0.00	38.43	**0.08**	**0.46**
DV3191	97	97	388	0.00	20.25	**0.23**	**1.61**
DV3193	402	402	28	0.00	18.44	**0.02**	**2.43**
DV3194	97	97	388	0.00	25.82	**0.23**	**0.82**
DV3195	0	0	0	0.00	#DIV/0!	**0.00**	**0.04**
DV3197	123	123	7	0.00	16.89	**0.00**	**1.67**
DV3199	97	97	388	0.00	25.82	**0.23**	**1.02**
DV3200	231	231	924	0.00	22.04	**0.55**	**2.84**
DV3203	230	230	920	0.00	16.83	**0.55**	**3.29**
DV3204	104	104	416	0.00	10.48	**0.25**	**1.44**
DV3207	0	0	0	0.00	#DIV/0!	**0.00**	**4.01**
DV3210	238	238	952	0.00	31.24	**0.57**	**5.08**
DV3262	295	295	1180	0.00	19.02	**0.71**	**6.11**
DV3277	149	149	596	0.00	15.60	**0.36**	**1.99**
DV3343	330	330	1320	0.00	17.88	**0.79**	**5.80**
DV3367	314	314	1256	0.00	15.08	**0.75**	**4.32**
Arboretum 1 PRV	376	376	1675	0.53	23.67	**1.01**	**2.85**
Arboretum 2 PRV	974	974	4900	1.64	30.39	**2.94**	**6.91**
Arboretum Ext PRV	307	307	1495	0.00	19.54	**0.90**	**2.19**
Gobandlovu 1 PRV	3230	3230	19400	0.00	15.17	**11.64**	**39.20**
Logan Rd. PRV	92	92	552	0.00	25.00	**0.33**	**0.73**
Mandlazini PRV	1484	1484	8202	0.00	13.95	**4.92**	**10.60**
Union St PRV	308	308	1848	0.00	18.51	**1.11**	**4.77**
EMP FARM PRV	8	8	200	0.00	800.00	**0.12**	**0.72**
Gobandlovu 2 PRV	556	556	500	0.00	29.50	**0.30**	**2.51**
Kildare Ext	329	329	1500	0.00	26.14	**0.90**	**5.43**
Kuleka Industrial	852	852	250	94.13	21.95	**0.15**	**4.23**
Matshana 1 PRV	51	51	1055	0.00	107.84	**0.63**	**1.43**
PLOF-002	786	786	3650	0.00	35.50	**2.19**	**5.73**
Birdswood PRV Zone	390	390	1700	0.00	19.49	**1.02**	**2.86**
PLOF-001	476	476	2370	0.00	20.59	**1.42**	**4.92**
PR101	267	267	1335	0.00	24.72	**0.80**	**2.57**
uMhlathuze Village PMZ	1447	1447	7235	0.00	8.85	**4.34**	**13.00**
Veldenvlei PRV Zone	863	863	4435	0.12	21.18	**2.66**	**5.50**
PRV-01	1235	1235	4940	0.00	21.36	**2.96**	**13.46**
PRV-03	2582	2582	10328	0.00	24.82	**6.20**	**22.57**
PRV-04	1241	1241	2612	0.00	17.32	**1.57**	**10.78**
PRV-05	1241	1241	2612	0.00	17.32	**1.57**	**10.46**
PRV-06	2498	2498	9992	0.00	27.54	**6.00**	**19.76**
PRV-007	2481	2481	7692	0.20	19.20	**4.62**	**18.67**
PRV-009	1524	1524	6096	0.00	17.23	**3.66**	**17.71**
PRV - 11	4826	4826	14252	0.00	12.31	**8.55**	**26.94**
PRV-013	293	293	1172	0.00	72.33	**0.70**	**2.75**
PRV-017	596	596	1868	0.84	85.21	**1.12**	**7.97**
PRV - 18	2631	2631	10196	0.00	12.36	**6.12**	**18.05**
PRV-021	1545	1545	4900	0.32	30.03	**2.94**	**13.93**
PRV-025	2700	2700	10284	0.19	42.41	**6.17**	**32.14**
PRV-026	225	225	768	2.22	405.78	**0.46**	**6.31**
PRV-027	225	225	768	2.22	195.11	**0.46**	**3.89**
PRV-028	95	95	368	5.26	502.11	**0.22**	**5.06**
PRV-031	596	596	1868	0.84	50.34	**1.12**	**5.22**
PRV-032	596	596	1868	0.84	50.34	**1.12**	**7.88**
PRV-036	45	45	176	11.11	804.44	**0.11**	**4.04**
HV - 34	934	934	4210	0.00	13.81	**2.53**	**5.98**
HV - 06	1780	1780	8870	0.00	12.47	**5.32**	**17.88**
PRV - 012 - HV - 16	2192	2192	2295	0.00	6.07	**1.38**	**15.38**
HV - 42	2855	2855	14250	0.00	12.05	**8.55**	**21.73**
PRV -016	1380	1380	6895	0.00	20.00	**4.14**	**18.95**
DV 1507 Magazine Rd	136	136	680	0.00	15.44	**0.41**	**0.89**
1505 Braithwaite Rd PRV	143	143	572	0.00	22.38	**0.34**	**1.07**
DV 0803 Haniville PRV	929	929	3716	0.00	7.75	**2.23**	**9.78**
DV 1007 Woodpecker Rd PRV 2	254	254	1016	0.00	16.54	**0.61**	**3.63**
PRV 0703 Chief Mhlabenzima Rd	810	810	3760	0.00	18.52	**2.26**	**10.51**
DV 0708 Tamboville Prv 1	685	685	2740	0.00	13.28	**1.64**	**8.04**
DV 0709 Tamboville PRV 2	637	637	2548	0.00	8.63	**1.53**	**6.91**
1602	436	436	1744	0.00	13.76	**1.05**	**5.12**
1301	773	773	3092	0.00	18.89	**1.86**	**7.69**
Xulukhona PRV	557	557	2228	0.00	10.41	**1.34**	**4.72**
DV 0401 Bombay & Narandas Rd	1047	1047	4188	0.00	11.75	**2.51**	**7.93**
DV 0904 Khan Rd PRV	87	87	348	0.00	14.94	**0.21**	**0.63**
DV 0203 Turbull Rd PRV	574	574	2296	0.00	10.98	**1.38**	**3.91**
DV 1601 Morcom Rd	595	595	2380	0.00	30.25	**1.43**	**6.30**
Ganges Rd PRV 1004	197	197	788	0.00	13.20	**0.47**	**1.75**
DV 1003 Regina Rd	589	589	2356	0.00	3.23	**1.41**	**3.77**
Belfort PRV DV 1001	1034	1034	2585	0.00	6.87	**1.55**	**7.82**
DV 1604 Villiers Drive PRV	290	290	1160	0.00	22.76	**0.70**	**2.92**
DV 1005 Boundary Rd	223	223	892	0.00	13.90	**0.54**	**2.59**
DV 905 Simla Rd	366	366	1464	0.00	6.56	**0.88**	**2.73**
DV 1305 Mbubu Rd	283	283	1132	0.00	19.08	**0.68**	**3.55**
DV 0906 Springvale Rd	316	316	1264	0.00	7.91	**0.76**	**2.75**
DV 1510 Old Howick Rd	156	156	624	0.00	49.36	**0.37**	**2.41**
Kwapata PRV 4	520	520	2080	0.00	6.35	**1.25**	**2.11**
Kwapata PRV 3	215	215	860	0.00	9.77	**0.52**	**1.44**
Montgomery Dr PRV	212	212	848	0.00	24.53	**0.51**	**2.19**

Sub-district, Zone, Year and Night Flow Test Number	Date of Measurement	Ave. Zone Night Press. Metres (AZNP)	Exceptional night use > 0.25 m3/hr
PRVA		37.7	0
Dv 2876		43	0
Dv 2877		34	0
Dv 2824		43.5	0
Dv 3008		51	0
Dv 3067		59	0
Dv 3213		37	0
Dv 2885		36	0
Dv 2823		50.2	0
Dv 3052		32	0
DV 3145		42	0
Dv 2929		81	0
Dv 3148		46	0
Dv 3149		42.8	0
Dv 3155		42	0
Dv 3156		49.4	0
Dv 2855		45	0
Dv 3038		40	0
Dv 1292		36	0
Dv 2760		46	0
Dv 2759		31	0
DV2820		44.4	0
DV3188		45.94	0
DV3190		42.3	0
DV3191		39.7	0
DV3193		39	0
DV3194		44.9	0
DV3195		28	0
DV3197		50.5	0
DV3199		39.4	0
DV3200		60.42	0
DV3203		53.64	0
DV3204		50.66	0
DV3207		90.31	0
DV3210		64.71	0
DV3262		43.27	0
DV3277		45.78	0
DV3343		77.12	0
DV3367		54.63	0
Arboretum 1 PRV		29.5	0
Arboretum 2 PRV		31.3	0
Arboretum Ext PRV		38.7	0
Gobandlovu 1 PRV		49.5	0
Logan Rd. PRV		33.5	0
Mandlazini PRV		30.4	0
Union St PRV		43.5	0
EMP FARM PRV		50.3	0
Gobandlovu 2 PRV		32.7	0
Kildare Ext		43.7	0
Kuleka Industrial		32.5	0
Matshana 1 PRV		26.3	0
PLOF-002		35.3	0
Birdswood PRV Zone		20.8	0
PLOF-001		40	0
PR101		37.4	0
uMhlathuze Village PMZ		41.5	0
Veldenvlei PRV Zone		25.5	0
PRV-01		37.4	0
PRV-03		44.9	0
PRV-04		48.4	0
PRV-05		48.3	0
PRV-06		42.7	0
PRV-007		46	0
PRV-009		39.9	0
PRV - 11		36.2	0
PRV-013		36.2	0
PRV-017		52.2	0
PRV - 18		43.3	0
PRV-021		46.8	0
PRV-025		61.8	0
PRV-026		52.7	0
PRV-027		38.8	0
PRV-028		47.5	0
PRV-031		23.1	0
PRV-032		43.2	0
PRV-036		50.2	0
HV - 34		37.5	0
HV - 06		46.8	0
PRV - 012 - HV - 16		44.2	0
HV - 42		42.8	0
PRV -016		55.1	0
DV 1507 Magazine Rd		22.7	0
1505 Braithwaite Rd PRV		42.1	0
DV 0803 Haniville PRV		66.8	0
DV 1007 Woodpecker Rd PRV 2		54.2	0
PRV 0703 Chief Mhlabenzima Rd		58.7	0
DV 0708 Tamboville Prv 1		32.6	0
DV 0709 Tamboville PRV 2		57.1	0
1602		43.5	0
1301		34.5	0
Xulukhona PRV		45	0
DV 0401 Bombay & Narandas Rd		38.6	0
DV 0904 Khan Rd PRV		38.9	0
DV 0203 Turbull Rd PRV		33.2	0
DV 1601 Morcom Rd		34.7	0
Ganges Rd PRV 1004		46.6	0
DV 1003 Regina Rd		31.4	0
Belfort PRV DV 1001		36.4	0
DV 1604 Villiers Drive PRV		50.9	0
DV 1005 Boundary Rd		48.9	0
DV 905 Simla Rd		37.7	0
DV 1305 Mbubu Rd		73.2	0
DV 0906 Springvale Rd		35.4	0
DV 1510 Old Howick Rd		66.9	0
Kwapata PRV 4		12.2	0
Kwapata PRV 3		34.6	0
Montgomery Dr PRV		46.6	0

Sub-district, Zone, Year and Night Flow Test Number	Measured Min. Night Flow in l/sec
PRVA	17.47
Dv 2876	4.97
Dv 2877	1.67
Dv 2824	1.31
Dv 3008	8.69
Dv 3067	1.28
Dv 3213	0.67
Dv 2885	4.97
Dv 2823	2.56
Dv 3052	0.06
DV 3145	1.92
Dv 2929	3.47
Dv 3148	0.19
Dv 3149	1.58
Dv 3155	2.31
Dv 3156	2.39
Dv 2855	1.22
Dv 3038	17.36
Dv 1292	3.03
Dv 2760	0.42
Dv 2759	0.06
DV2820	1.75
DV3188	1.96
DV3190	0.52
DV3191	0.49
DV3193	1.61
DV3194	0.31
DV3195	0.08
DV3197	0.42
DV3199	0.89
DV3200	0.78
DV3203	4.33
DV3204	0.37
DV3207	2.79
DV3210	0.49
DV3262	1.79
DV3277	0.39
DV3343	1.00
DV3367	3.18
Arboretum 1 PRV	1.28
Arboretum 2 PRV	6.67
Arboretum Ext PRV	1.25
Gobandlovu 1 PRV	36.03
Logan Rd. PRV	1.36
Mandlazini PRV	2.69
Union St PRV	3.69
EMP FARM PRV	0.67
Gobandlovu 2 PRV	5.44
Kildare Ext	1.50
Kuleka Industrial	25.08
Matshana 1 PRV	0.39
PLOF-002	6.50
Birdswood PRV Zone	0.94
PLOF-001	4.00
PR101	2.14
uMhlathuze Village PMZ	4.44
Veldenvlei PRV Zone	2.06
PRV-01	2.51
PRV-03	11.33
PRV-04	11.47
PRV-05	34.56
PRV-06	27.91
PRV-007	13.81
PRV-009	10.93
PRV - 11	54.50
PRV-013	5.68
PRV-017	25.75
PRV - 18	12.53
PRV-021	9.72
PRV-025	28.36
PRV-026	6.17
PRV-027	1.06
PRV-028	19.17
PRV-031	3.28
PRV-032	12.50
PRV-036	1.86
HV - 34	5.56
HV - 06	5.42
PRV - 012 - HV - 16	6.08
HV - 42	16.28
PRV -016	4.00
DV 1507 Magazine Rd	0.89
1505 Braithwaite Rd PRV	0.61
DV 0803 Haniville PRV	6.78
DV 1007 Woodpecker Rd PRV 2	0.47
PRV 0703 Chief Mhlabenzima Rd	19.36
DV 0708 Tamboville Prv 1	3.89
DV 0709 Tamboville PRV 2	2.19
1602	2.33
1301	12.75
Xulukhona PRV	3.78
DV 0401 Bombay & Narandas Rd	3.36
DV 0904 Khan Rd PRV	0.22
DV 0203 Turbull Rd PRV	1.03
DV 1601 Morcom Rd	3.64
Ganges Rd PRV 1004	0.81
DV 1003 Regina Rd	2.81
Belfort PRV DV 1001	2.06
DV 1604 Villiers Drive PRV	1.14
DV 1005 Boundary Rd	0.58
DV 905 Simla Rd	4.06
DV 1305 Mbubu Rd	1.72
DV 0906 Springvale Rd	1.00
DV 1510 Old Howick Rd	4.81
Kwapata PRV 4	0.72
Kwapata PRV 3	1.03
Montgomery Dr PRV	3.28

SANFLOW Analysis After PM

Sub-district, Zone, Year and Night Flow Test Number	**Measured Min. Night Flow in m3/hr**	**Excess night flow in m3/hr**	Excess as equivalent number of Service bursts ESPB's	Marginal cost of water supply cents/m3	Daily Cost of excess night flow due to bursts (Rand/day)	Length of Mains in Metres (L)	Number of Connections (C)	Number of Properties (N)	Estimated Population (P)	% of Commercial Properties	Mains Length per Connection L/C in metres
PRVA	**62.9**	**51.17**	36.83	123	1258.70	47790.00	1866.00	1866.00	9325.00	0.00	25.61
Dv 2876	**17.9**	**13.21**	8.90	123	324.95	16279.00	723.00	723.00	3108.00	0.41	22.52
Dv 2877	**6**	**5.51**	4.17	123	135.46	2114.00	94.00	94.00	392.00	0.00	22.49
Dv 2824	**4.7**	**2.33**	1.56	123	57.23	7392.00	380.00	380.00	1500.00	0.00	19.45
Dv 3008	**31.3**	**24.63**	15.24	123	606.00	5791.00	242.00	242.00	9050.00	0.00	23.93
Dv 3067	**4.6**	**1.94**	1.12	123	47.78	4767.00	306.00	306.00	1407.00	0.00	15.58
Dv 3213	**2.4**	**-1.53**	-1.11	123	-37.59	3753.00	1023.00	1023.00	2046.00	0.00	3.67
Dv 2885	**17.9**	**17.12**	12.61	123	421.18	2212.00	51.00	51.00	1000.00	0.00	43.37
Dv 2823	**9.2**	**4.40**	2.75	123	108.35	10372.00	631.00	631.00	3065.00	0.00	16.44
Dv 3052	**0.2**	**0.09**	0.07	123	2.26	1322.00	25.00	25.00	50.00	0.00	52.88
DV 3145	**6.9**	**5.54**	3.77	123	136.18	4446.00	224.00	224.00	896.00	0.00	19.85
Dv 2929	**12.5**	**5.01**	2.46	123	123.32	11988.00	620.00	620.00	2308.00	0.00	19.34
Dv 3148	**0.7**	**0.18**	0.12	123	4.50	1884.00	76.00	76.00	304.00	0.00	24.79
Dv 3149	**5.7**	**3.99**	2.70	123	98.19	4333.00	296.00	296.00	1056.00	0.00	14.64
Dv 3155	**8.3**	**6.34**	4.32	123	155.95	3058.00	307.00	307.00	1535.00	0.00	9.96
Dv 3156	**8.6**	**5.86**	3.69	123	144.21	11698.00	360.00	360.00	1440.00	0.00	32.49
Dv 2855	**4.4**	**3.71**	2.45	123	91.30	2114.00	83.00	83.00	555.00	0.00	25.47
Dv 3038	**62.5**	**51.95**	36.30	123	1278.02	30559.00	1875.00	1875.00	7178.00	0.00	16.30
Dv 1292	**10.9**	**6.66**	4.90	123	163.71	10484.00	671.00	671.00	3915.00	0.00	15.62
Dv 2760	**1.5**	**1.19**	0.77	123	29.21	428.00	46.00	46.00	225.00	0.00	9.30
Dv 2759	**0.2**	**0.17**	0.14	123	4.24	151.00	5.00	5.00	25.00	0.00	30.20
DV2820	**6.3**	**4.78**	3.17	123	117.69	5963.00	229.00	229.00	916.00	0.00	26.04
DV3188	**7.05**	**6.74**	4.40	123	165.88	8707.00	0.00	0.00	0.00	0.00	#DIV/0!
DV3190	**1.86**	**1.63**	1.10	123	39.98	1345.00	35.00	35.00	140.00	0.00	38.43
DV3191	**1.76**	**1.20**	0.84	123	29.45	1964.00	97.00	97.00	388.00	0.00	20.25
DV3193	**5.8**	**4.47**	3.16	123	109.99	7413.00	402.00	402.00	28.00	0.00	18.44
DV3194	**1.1**	**0.45**	0.30	123	11.11	2505.00	97.00	97.00	388.00	0.00	25.82
DV3195	**0.3**	**0.29**	0.24	123	7.15	553.00	0.00	0.00	0.00	0.00	#DIV/0!
DV3197	**1.5**	**0.91**	0.57	123	22.44	2078.00	123.00	123.00	7.00	0.00	16.89
DV3199	**3.2**	**2.63**	1.85	123	64.59	2505.00	97.00	97.00	388.00	0.00	25.82
DV3200	**2.81**	**0.76**	0.43	123	18.64	5092.00	231.00	231.00	924.00	0.00	22.04
DV3203	**15.6**	**13.85**	8.36	123	340.80	3871.00	230.00	230.00	920.00	0.00	16.83
DV3204	**1.32**	**0.60**	0.37	123	14.80	1090.00	104.00	104.00	416.00	0.00	10.48
DV3207	**10.05**	**7.07**	3.29	123	173.89	30704.00	0.00	0.00	0.00	0.00	#DIV/0!
DV3210	**1.77**	**-0.64**	-0.35	123	-15.76	7434.00	238.00	238.00	952.00	0.00	31.24
DV3262	**6.44**	**4.60**	3.09	123	113.19	5611.00	295.00	295.00	1180.00	0.00	19.02
DV3277	**1.39**	**0.43**	0.28	123	10.55	2325.00	149.00	149.00	596.00	0.00	15.60
DV3343	**3.6**	**-0.17**	-0.09	123	-4.25	5902.00	330.00	330.00	1320.00	0.00	17.88
DV3367	**11.46**	**9.06**	5.41	123	222.77	4736.00	314.00	314.00	1256.00	0.00	15.08
Arboretum 1 PRV	**4.6**	**2.75**	2.24	123	67.70	8900.00	376.00	376.00	1675.00	0.53	23.67
Arboretum 2 PRV	**24**	**18.54**	14.65	123	456.18	29600.00	974.00	974.00	4900.00	1.64	30.39
Arboretum Ext PRV	**4.5**	**2.60**	1.85	123	64.04	6000.00	307.00	307.00	1495.00	0.00	19.54
Gobandlovu 1 PRV	**129.7**	**103.40**	64.95	123	2543.70	49000.00	3230.00	3230.00	19400.00	0.00	15.17
Logan Rd. PRV	**4.9**	**4.32**	3.30	123	106.19	2300.00	92.00	92.00	552.00	0.00	25.00
Mandlazini PRV	**9.7**	**1.57**	1.26	123	38.67	20700.00	1484.00	1484.00	8202.00	0.00	13.95
Union St PRV	**13.3**	**11.01**	7.38	123	270.76	5700.00	308.00	308.00	1848.00	0.00	18.51
EMP FARM PRV	**2.4**	**1.99**	1.24	123	48.94	6400.00	8.00	8.00	200.00	0.00	800.00
Gobandlovu 2 PRV	**19.6**	**17.78**	13.74	123	437.31	16400.00	556.00	556.00	500.00	0.00	29.50
Kildare Ext	**5.4**	**3.14**	2.10	123	77.33	8600.00	329.00	329.00	1500.00	0.00	26.14
Kuleka Industrial	**90.3**	**87.97**	68.20	123	2164.11	18700.00	852.00	852.00	250.00	94.13	21.95
Matshana 1 PRV	**1.4**	**0.61**	0.52	123	14.89	5500.00	51.00	51.00	1055.00	0.00	107.84
PLOF-002	**23.4**	**18.68**	13.90	123	459.60	27900.00	786.00	786.00	3650.00	0.00	35.50
Birdswood PRV Zone	**3.4**	**1.88**	1.82	123	46.24	7600.00	390.00	390.00	1700.00	0.00	19.49
PLOF-001	**14.4**	**11.34**	7.92	123	278.84	9800.00	476.00	476.00	2370.00	0.00	20.59
PR101	**7.7**	**6.04**	4.36	123	148.52	6600.00	267.00	267.00	1335.00	0.00	24.72
uMhlathuze Village PMZ	**16**	**6.90**	4.73	123	169.62	12800.00	1447.00	1447.00	7235.00	0.00	8.85
Veldenvlei PRV Zone	**7.4**	**3.22**	2.81	123	79.10	18280.00	863.00	863.00	4435.00	0.12	21.18
PRV-01	**9.03**	**2.19**	1.58	123	53.81	26384.00	1235.00	1235.00	4940.00	0.00	21.36
PRV-03	**40.77**	**23.60**	15.57	123	580.64	64081.00	2582.00	2582.00	10328.00	0.00	24.82
PRV-04	**41.3**	**34.19**	21.72	123	840.98	21500.00	1241.00	1241.00	2612.00	0.00	17.32
PRV-05	**124.4**	**117.30**	74.59	123	2885.66	21500.00	1241.00	1241.00	2612.00	0.00	17.32
PRV-06	**100.46**	**84.41**	57.09	123	2076.43	68786.00	2498.00	2498.00	9992.00	0.00	27.54
PRV-007	**49.7**	**34.65**	22.58	123	852.30	47631.00	2481.00	2481.00	7692.00	0.20	19.20
PRV-009	**39.33**	**30.58**	21.39	123	752.22	26252.00	1524.00	1524.00	6096.00	0.00	17.23
PRV - 11	**196.2**	**174.29**	128.02	123	4287.60	59423.00	4826.00	4826.00	14252.00	0.00	12.31
PRV-013	**20.46**	**18.51**	13.60	123	455.41	21194.00	293.00	293.00	1172.00	0.00	72.33
PRV-017	**92.7**	**86.87**	53.14	123	2136.98	50788.00	596.00	596.00	1868.00	0.84	85.21
PRV - 18	**45.1**	**29.45**	19.78	123	724.54	32523.00	2631.00	2631.00	10196.00	0.00	12.36
PRV-021	**35**	**24.78**	16.01	123	609.66	46400.00	1545.00	1545.00	4900.00	0.32	30.03
PRV-025	**102.1**	**74.80**	42.05	123	1839.97	114500.00	2700.00	2700.00	10284.00	0.19	42.41
PRV-026	**22.2**	**16.81**	10.24	123	413.61	91300.00	225.00	225.00	768.00	2.22	405.78
PRV-027	**3.8**	**1.52**	1.08	123	37.48	43900.00	225.00	225.00	768.00	2.22	195.11
PRV-028	**69**	**66.66**	42.75	123	1639.85	47700.00	95.00	95.00	368.00	5.26	502.11
PRV-031	**11.8**	**9.55**	8.78	123	235.02	30000.00	596.00	596.00	1868.00	0.84	50.34
PRV-032	**45**	**41.00**	27.57	123	1008.62	30000.00	596.00	596.00	1868.00	0.84	50.34
PRV-036	**6.7**	**4.96**	3.09	123	121.93	36200.00	45.00	45.00	176.00	11.11	804.44
HV - 34	**20**	**14.71**	10.62	123	361.92	12900.00	934.00	934.00	4210.00	0.00	13.81
HV - 06	**19.5**	**6.93**	4.47	123	170.39	22200.00	1780.00	1780.00	8870.00	0.00	12.47
PRV - 012 - HV - 16	**21.9**	**12.79**	8.50	123	314.72	13300.00	2192.00	2192.00	2295.00	0.00	6.07
HV - 42	**58.6**	**39.92**	26.96	123	981.93	34400.00	2855.00	2855.00	14250.00	0.00	12.05
PRV -016	**14.4**	**2.60**	1.55	123	63.96	27600.00	1380.00	1380.00	6895.00	0.00	20.00
DV 1507 Magazine Rd	**3.2**	**2.60**	2.41	123	63.96	2100.00	136.00	136.00	680.00	0.00	15.44
1505 Braithwaite Rd PRV	**2.2**	**1.32**	0.90	123	32.37	3200.00	143.00	143.00	572.00	0.00	22.38
DV 0803 Haniville PRV	**24.4**	**15.99**	8.64	123	393.29	7200.00	929.00	929.00	3716.00	0.00	7.75
DV 1007 Woodpecker Rd PRV 2	**1.7**	**-0.25**	-0.15	123	-6.05	4200.00	254.00	254.00	1016.00	0.00	16.54
PRV 0703 Chief Mhlabenzima Rd	**69.7**	**62.56**	36.09	123	1538.96	15000.00	810.00	810.00	3760.00	0.00	18.52
DV 0708 Tamboville Prv 1	**14**	**10.72**	8.30	123	263.76	9100.00	685.00	685.00	2740.00	0.00	13.28
DV 0709 Tamboville PRV 2	**7.9**	**2.99**	1.75	123	73.63	5500.00	637.00	637.00	2548.00	0.00	8.63
1602	**8.4**	**5.74**	3.85	123	141.29	6000.00	436.00	436.00	1744.00	0.00	13.76
1301	**45.9**	**41.94**	31.55	123	1031.67	14600.00	773.00	773.00	3092.00	0.00	18.89
Xulukhona PRV	**13.6**	**10.16**	6.70	123	250.01	5800.00	557.00	557.00	2228.00	0.00	10.41
DV 0401 Bombay & Narandas Rd	**12.1**	**6.41**	4.56	123	157.75	12300.00	1047.00	1047.00	4188.00	0.00	11.75
DV 0904 Khan Rd PRV	**0.8**	**0.32**	0.22	123	7.79	1300.00	87.00	87.00	348.00	0.00	14.94
DV 0203 Turbull Rd PRV	**3.7**	**0.94**	0.72	123	23.22	6300.00	574.00	574.00	2296.00	0.00	10.98
DV 1601 Morcom Rd	**13.1**	**9.88**	7.41	123	243.04	18000.00	595.00	595.00	2380.00	0.00	30.25
Ganges Rd PRV 1004	**2.9**	**1.62**	1.05	123	39.97	2600.00	197.00	197.00	788.00	0.00	13.20
DV 1003 Regina Rd	**10.1**	**7.48**	5.90	123	183.91	1900.00	589.00	589.00	2356.00	0.00	3.23
Belfort PRV DV 1001	**7.4**	**3.10**	2.27	123	76.35	7100.00	1034.00	1034.00	2585.00	0.00	6.87
DV 1604 Villiers Drive PRV	**4.1**	**1.94**	1.20	123	47.76	6600.00	290.00	290.00	1160.00	0.00	22.76
DV 1005 Boundary Rd	**2.1**	**0.58**	0.37	123	14.32	3100.00	223.00	223.00	892.00	0.00	13.90
DV 905 Simla Rd	**14.6**	**12.70**	9.14	123	312.43	2400.00	366.00	366.00	1464.00	0.00	6.56
DV 1305 Mbubu Rd	**6.2**	**3.13**	1.62	123	77.07	5400.00	283.00	283.00	1132.00	0.00	19.08
DV 0906 Springvale Rd	**3.6**	**2.03**	1.51	123	49.91	2500.00	316.00	316.00	1264.00	0.00	7.91
DV 1510 Old Howick Rd	**17.3**	**15.48**	8.37	123	380.89	7700.00	156.00	156.00	624.00	0.00	49.36
Kwapata PRV 4	**2.6**	**1.09**	1.37	123	26.70	3300.00	520.00	520.00	2080.00	0.00	6.35
Kwapata PRV 3	**3.7**	**2.64**	1.98	123	64.96	2100.00	215.00	215.00	860.00	0.00	9.77
Montgomery Dr PRV	**11.8**	**10.34**	6.69	123	254.39	5200.00	212.00	212.00	848.00	0.00	24.53

Sub-district, Zone, Year and Night Flow Test Number	**Estimated minor night use m3/hr**	**Estimated background night flow in m3/hr**
PRVA	**5.60**	**11.73**
Dv 2876	**1.86**	**4.69**
Dv 2877	**0.24**	**0.49**
Dv 2824	**0.90**	**2.37**
Dv 3008	**5.43**	**6.67**
Dv 3067	**0.84**	**2.66**
Dv 3213	**1.23**	**3.93**
Dv 2885	**0.60**	**0.78**
Dv 2823	**1.84**	**4.80**
Dv 3052	**0.03**	**0.11**
DV 3145	**0.54**	**1.36**
Dv 2929	**1.38**	**7.49**
Dv 3148	**0.18**	**0.52**
Dv 3149	**0.63**	**1.71**
Dv 3155	**0.92**	**1.96**
Dv 3156	**0.86**	**2.74**
Dv 2855	**0.33**	**0.69**
Dv 3038	**4.31**	**10.55**
Dv 1292	**2.35**	**4.24**
Dv 2760	**0.14**	**0.31**
Dv 2759	**0.02**	**0.03**
DV2820	**0.55**	**1.52**
DV3188	**0.00**	**0.31**
DV3190	**0.08**	**0.23**
DV3191	**0.23**	**0.56**
DV3193	**0.02**	**1.33**
DV3194	**0.23**	**0.65**
DV3195	**0.00**	**0.01**
DV3197	**0.00**	**0.59**
DV3199	**0.23**	**0.57**
DV3200	**0.55**	**2.05**
DV3203	**0.55**	**1.75**
DV3204	**0.25**	**0.72**
DV3207	**0.00**	**2.98**
DV3210	**0.57**	**2.41**
DV3262	**0.71**	**1.84**
DV3277	**0.36**	**0.96**
DV3343	**0.79**	**3.77**
DV3367	**0.75**	**2.40**
Arboretum 1 PRV	**1.01**	**1.85**
Arboretum 2 PRV	**2.94**	**5.46**
Arboretum Ext PRV	**0.90**	**1.90**
Gobandlovu 1 PRV	**11.64**	**26.30**
Logan Rd. PRV	**0.33**	**0.58**
Mandlazini PRV	**4.92**	**8.13**
Union St PRV	**1.11**	**2.29**
EMP FARM PRV	**0.12**	**0.41**
Gobandlovu 2 PRV	**0.30**	**1.82**
Kildare Ext	**0.90**	**2.26**
Kuleka Industrial	**0.15**	**2.33**
Matshana 1 PRV	**0.63**	**0.79**
PLOF-002	**2.19**	**4.72**
Birdswood PRV Zone	**1.02**	**1.52**
PLOF-001	**1.42**	**3.06**
PR101	**0.80**	**1.66**
uMhlathuze Village PMZ	**4.34**	**9.10**
Veldenvlei PRV Zone	**2.66**	**4.18**
PRV-01	**2.96**	**6.84**
PRV-03	**6.20**	**17.17**
PRV-04	**1.57**	**7.11**
PRV-05	**1.57**	**7.10**
PRV-06	**6.00**	**16.05**
PRV-007	**4.62**	**15.05**
PRV-009	**3.66**	**8.75**
PRV - 11	**8.55**	**21.91**
PRV-013	**0.70**	**1.95**
PRV-017	**1.12**	**5.83**
PRV - 18	**6.12**	**15.65**
PRV-021	**2.94**	**10.22**
PRV-025	**6.17**	**27.30**
PRV-026	**0.46**	**5.39**
PRV-027	**0.46**	**2.28**
PRV-028	**0.22**	**2.34**
PRV-031	**1.12**	**2.25**
PRV-032	**1.12**	**4.00**
PRV-036	**0.11**	**1.74**
HV - 34	**2.53**	**5.29**
HV - 06	**5.32**	**12.57**
PRV - 012 - HV - 16	**1.38**	**9.11**
HV - 42	**8.55**	**18.68**
PRV -016	**4.14**	**11.80**
DV 1507 Magazine Rd	**0.41**	**0.60**
1505 Braithwaite Rd PRV	**0.34**	**0.88**
DV 0803 Haniville PRV	**2.23**	**8.41**
DV 1007 Woodpecker Rd PRV 2	**0.61**	**1.95**
PRV 0703 Chief Mhlabenzima Rd	**2.26**	**7.14**
DV 0708 Tamboville Prv 1	**1.64**	**3.28**
DV 0709 Tamboville PRV 2	**1.53**	**4.91**
1602	**1.05**	**2.66**
1301	**1.86**	**3.96**
Xulukhona PRV	**1.34**	**3.44**
DV 0401 Bombay & Narandas Rd	**2.51**	**5.69**
DV 0904 Khan Rd PRV	**0.21**	**0.48**
DV 0203 Turbull Rd PRV	**1.38**	**2.76**
DV 1601 Morcom Rd	**1.43**	**3.22**
Ganges Rd PRV 1004	**0.47**	**1.28**
DV 1003 Regina Rd	**1.41**	**2.62**
Belfort PRV DV 1001	**1.55**	**4.30**
DV 1604 Villiers Drive PRV	**0.70**	**2.16**
DV 1005 Boundary Rd	**0.54**	**1.52**
DV 905 Simla Rd	**0.88**	**1.90**
DV 1305 Mbubu Rd	**0.68**	**3.07**
DV 0906 Springvale Rd	**0.76**	**1.57**
DV 1510 Old Howick Rd	**0.37**	**1.82**
Kwapata PRV 4	**1.25**	**1.51**
Kwapata PRV 3	**0.52**	**1.06**
Montgomery Dr PRV	**0.51**	**1.46**