A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

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ABSTRACT

In South Africa, as is mostly the norm globally, national legislation recommends that potable water distribution systems (WDSs) maintain the capacity, both in flow and pressure head, to provide specified quantities for fire-fighting purposes. As a result, a limiting requirement and thus dominant constraint in the design of WDSs, is the provision for fire-flow. It is therefore pertinent that fire-fighting requirements are defined as accurately as possible. Fire-flow is defined as: 'the rate of flow of water required by the fire-fighting service for the extinguishing of fires'. Contrary to this, there is a view that the demand by emergency services for water supplies were historically based on instinct and strongly characterised by what was available rather than a technical analysis of what was needed (Davis, 2000). Furthermore, the typical implementation approach to designing WDSs has remained largely unchanged for 60 years. Despite this, the condition of WDS infrastructure, development of fire-fighting technologies and techniques, and the growth in fire safety awareness have dramatically evolved. It is therefore logical that the provision and requirements for fire-flows be amended to more appropriate levels. This study therefore investigates the question: Are the current South African standards and design guidelines pertaining to fire-flow provision appropriate for modern fire-fighting techniques and do they ensure the most efficient balance between providing sufficient fire protection and promoting sustainable water use? To answer this question, the study: (1) reviewed design guidelines and standards locally and internationally; (2) conducted interviews on key role players within the City of Johannesburg's fire department, including active and experienced fire-fighters, trainers, and heads of various directives; and (3) captured and analysed information contained within 10 years of billable (incidents that the fire department can charge the property owner for their services rendered) fire incident reports representing 3859 fire events within the City of Johannesburg. The review of literature revealed a lack of uniformity in design requirements for fire-fighting. This suggests that a large element of uncertainty exists on the topic of water provision for

fire-fighting. This is further emphasized by the fact that nowhere in any of South Africa's national guidelines are theoretical or empirical methods referenced or identified to be the source of the fire-flow values quoted. This problem is further compounded by the fact that water provision is never guaranteed by water services provider nor can they be held liable for failure to meet any recommendations in the guidelines. The review of South African metropolitan, district and local by-laws also identified that different expectations are held regarding the role and provision of water for firefighting. As regards the interviews conducted, the dominant opinion expressed is that the biggest infringements to firefighting in the City of Johannesburg are the frequent occurrences of fire hydrant related problems and the shortage of first response pumping appliances. From the fire incident reports, this study reports that 75% of fire incidents required less than 6.6 kl of fire-flow volume - this is less than the capacity (6.9 kl) of a conventional pumping tanker. This means that 75% of fire incidents in the City of Johannesburg can be managed without the use of municipal fire hydrants if a suitable first response appliance is dispatched. Furthermore, the data shows that 99.9% of all fire incidents within the city demand an average fire flow rate less than 1200 L/min, which is the minimum hydrant flow rate for the lowest fire risk category in SANS 10090. Likewise, 98% of all fire incidents required an average fire flow rate less than 350 L/min, which is the minimum hydrant flow rate for the lowest fire risk category in the South African '*Guidelines for Human Settlement Planning and Design'* manual.

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Chapter 1

1 INTRODUCTION

This introductory chapter presents the rationale, scope and objectives of the study contained in this research report.

1.1 BACKGROUND

Water conservation has become a primary concern for many water scare countries around the world, including South Africa. With the majority of potable water supply to the public being delivered via municipal water systems, it is of critical importance that these systems be designed, constructed and maintained in such a manner that they promote the most efficient use of water. Inseparable to the topic of efficient potable water use, is the efficient or inefficient use of potable water for firefighting and the impact that this provision has on water distribution systems and water conservation.

A global consensus on the ideal design philosophy for providing water as a means of firefighting remains to be established. Likewise, the civil infrastructure standards linked to firefighting remain scattered and widely debated as engineers face the challenge of balancing emergency protection services against efficient water use. Insufficient water supply during a fire can result in devastating amounts of destruction and potentially, the loss of life. According to the National Fire Statistics published by the Fire Protection Association of Southern Africa (2017), 436 fatalities were recorded in 2015 with the total direct financial losses estimated to be 2.7 billion Rand. The residential sector accounted for 43% of these financial losses and 70% of deaths.

Potable water on the other hand is arguably humanity's single most valuable natural resource which ought to be managed and conserved. It is due to this complex trade-off between ensuring adequate supply for firefighting and minimizing water use that makes this topic so highly contested and critically needed.

In South Africa, national standards (SANS, 2003) recommend that potable water distribution mains have and maintain the capacity, both in flow and pressure head, to provide specified quantities of water for emergency firefighting purposes. As a result, a dominant design constraint on a water distribution system (WDS) is ensuring the provision of fire flow which is defined as the rate of flow of water required by the firefighting service for the extinguishing of fires (SANS, 2003).

Since fire flows significantly influence the sizing of a reticulated network, it is important that these requirements are defined as accurately as possible. Contrary to this, there is a view that the demand by emergency services for water supplies were historically based on instinct and strongly characterised by what was available rather than a technical analysis of what was needed (Davis, 2000). Within South Africa, the recommended and typically implemented approach to designing reticulation mains within a WDS has remained largely unchanged over the past 60 years. The condition of infrastructure, development of firefighting technologies and techniques, and the growth in fire safety awareness have all progressed with time and evolved dramatically since 1966 when the national codes for the provision of water for firefighting in South Africa were first published. It was concluded by Van Zyl and Haarhoff (1997) that the provision and requirements for fire flows should be amended to more appropriate levels.

The consequences of inaccurate design standards for emergency water provision will have significant and far reaching quantity, quality, and economic impacts (Snyder et al., 2002). Furthermore, given the high costs for upgrading and maintaining water systems within South Africa, inappropriate infrastructure and water losses should be especially avoided. Greater emphasis needs to be placed on ensuring that design codes and municipal legislation promote the most optimal use of water resources. In light of this, the following study focuses on how water provision for firefighting is implemented in South Africa and aims to present recommendations that refine design guidelines for firefighting and thus achieving more efficient water use.

1.2 RESEARCH QUESTION

This investigation raises the question: Are the current national standards and design guidelines pertaining to fire flow provision appropriate for modern firefighting techniques and do they ensure the most efficient balance between providing sufficient fire protection and promoting sustainable water use?

1.3 MOTIVATION

As is common practice in South Africa, the municipal WDS is not only used to supply sufficient quantity and quality of water to its users (domestic, commercial, industrial, agricultural and environmental), but also for effective and efficient firefighting.

Flow rate and minimum residual pressure head are two common design criteria of a WDS and these significantly influence its construction and maintenance costs. These two design criteria are typically increased to satisfy minimum fire flow provision levels as recommended in design standards. A WDS that is 'over' designed with unnecessarily high flow rates and residual pressure heads, could potentially experience higher leakage rates, higher non-revenue water (NRW) volumes, and increased damages to consumer fixtures due to increased operating pressures (Snyder et al., 2002).

The operational efficiency with which a utility appropriates its water resource is commonly gauged by its quantity of NRW. NRW is the discrepancy between input water volume and water that is delivered to customers and accounted for. It has been observed by Babić et al (2014) that water lost from underperforming WDSs amounts to 48 billion m³ per year worldwide. Furthermore, approximately 55% of the global non-revenue water by volume occurs in developing countries of which South Africa is one. In support of this notion, Van Vuuren (2013) states that:

> *"The current volume of nonrevenue water* (in South Africa) *is around 1 580 million m³ of water per annum – roughly equal to the annual supply of Africa's largest water utility, Rand Water. At a nominal production cost of R4,5/m³, this loss represents about R7,2-billion a year*."

These relatively high levels of water losses in South Africa's WDSs could arise from a variety sources. However, the ability to pursue and implement corrective action lies with proactive governance and efficient design by the responsible engineer. This paper will focus on addressing engineering design and the potential to reduce inefficiencies through an improved understanding of the firefighting process.

Investigations carried out by Myburgh (2012) and quoted below, focusing on required fire flows in a rural environment, substantiated that the fire flows actually required to extinguish fires in rural areas, were significantly lower than the minimum fire flows recommended in the South African National Standards – SANS 10090 (2003). The national standards recommend a minimum fire flow of 1900 L/min in the lowest risk rural area fire category (SANS, 2003). Table 1-1 reveals that all 3 of the rural municipalities investigated by Myburgh made use of fire flows substantially less than that provided by the national guidelines.

> *"In our study for rural areas, 99.8% of the fires could be extinguished using 1 200 ℓ/min or less, 98.6% of the fires could be extinguished using 600 ℓ/min or less and 97.7% of the fires could be extinguished with less than 400 ℓ/min."*
> (Myburgh, 2012)

The study concluded that on average, only 11% of fires being extinguished in these rural towns covered by the data were making use of the WDS already implemented within those towns.

Table 1-1 - Average required fire flow for each category in L/min (Myburgh, 2012)

	Informal Settlements	**Automobile accidents**	**Structural fires (residential and industrial)**	**Veld, grass, and refuse**	**Special Services**
Municipality 1	130.4	96.7	143.9	74.2	0
Municipality 2	90.21	74.3	75.02	87.26	169.6
Municipality 3	57.2	37.9	53.8	44.6	58.4
Average	92.6	69.6	90.9	68.7	76.0

While there are numerous methods for firefighting, water remains the most practical and cost-effective firefighting agent in most situations. However, the associated processes that involve treatment, storage and supply of water for fire protection have significant financial implications. In light of this, a 1990 study by the National Research Council of Canada (NRCC) was conducted to evaluate the costs of designing a WDS to provide fire flow in addition to the annual average daily demand (AADD). The study indicated that instead of increasing the size of the reticulation system to be able to provide fire flow, it was more cost effective to provide a tanker supply for firefighting. This conclusion also motivates the need for this study's investigation into the suitability of existing fire flow design guidelines.

1.4 PURPOSE OF THE STUDY

Robust design guidelines and standards that promote the physical and hydraulic integrity of a WDS are indispensable to ensure that capital investment on new infrastructure result in a sustainable service provision. Without sound design guidelines, no matter the system's level of governance or sophisticated maintenance program, it will continue to exhibit inefficiencies and unnecessary water losses. Thus, this research aims to better understand how design guidelines and standards can be improved to enable more efficient WDS design and reduce system inefficiencies whilst maintaining acceptable levels of water provision for firefighting.

This study will attempt to understand if modern firefighting procedures and technologies present opportunities to reduce fire flow demands currently present in the South African design guidelines and standards.

The intended results and thus contribution of this paper is to present revised and more optimal design criteria for fire flows. The design recommendations put forward will specifically aim to optimize the balance between ensuring sufficient water volumes to quickly control and extinguish fires, and minimizing the typical overdesign effects that fire flow provision guidelines have on the hydraulic properties of a WDS.

1.5 RESEARCH OBJECTIVES

The primary research objectives for this study are as follows:

I. To present a critical analysis of both local and international design guidelines pertaining to water provision for firefighting and their influence in WDS design.

II. To report on the firefighting status quo within the city Johannesburg; identify and discuss the discrepancies that exist between guideline stipulations and current firefighting practice; and present the sentiments and opinions of firefighters.

III. To present actual fire flow volume and flow rate data recorded in the city of Johannesburg and compare the data to the requirements specified in the South African design standards and municipal by-laws.

IV. To recommend practical adjustments to the South African design guidelines and municipal by-laws (based on the already well-established national fire risk categories) formed from the observations and conclusions made from objectives I, II and III

1.6 LIMITATIONS

The conclusions drawn from this research report will be limited to the urban firefighting procedures currently implemented in Johannesburg and the associated equipment and procedures employed in this area. The extent of the data generated will also be limited to the detailed information that can be provided by the local fire authorities during the time of this study. A notable limitation of the data recorded within the incident reports is that no indication is made within the reports as to whether or not the volumes and flow rates of water released during the firefighting process was indeed sufficient for the specific incident. Furthermore, the scope of this research is limited to the manual use of water as a means of firefighting and does not account for the use of sprinkler systems or other firefighting agents such as foam, gas, sand, etc.

1.7 STRUCTURE OF THE REPORT

Chapter 1 presents the rational, scope and objectives of the study. Chapter two provides an introductory knowledge base on the fundamentals of fire by presenting concepts that portrays current understanding on the fundamentals of fire growth and containment with a focus on water use within the firefighting process. Chapter three reviews publicised design guidelines such as SANS and the South African *Guidelines for Human Settlement Planning and Design* manual (most commonly referred to as 'The Red Book') which are enforced by directives laid out in municipal by-laws. The fourth chapter presents findings from the anonymous discussion styled interviews that were conducted on key role players within the fire department, including active and experienced firefighters, trainers, and heads of various directives within the City of Johannesburg Fire Department. The fifth chapter deals with the capturing and analysis of the information contained within fire incident reports. Chapter 6 puts forward five concluding recommendations regarding: legislation; fire-risk categories; hydrant reliability and spacing; design fire flow and minimum hydrant flow; and pumping appliances. The chapter completes with a note on future research opportunities to investigation into the rate of water use during a fire emergency.

Chapter 2

2 LITERATURE REVIEW

This review of literature serves three purposes. First, to provide an introductory knowledge base on the fundamentals of fire by presenting concepts that accurately portrays current understanding on the fundamentals of fire growth and containment with a focus on water use within the firefighting process. Second, to identify the essential processes and equipment needed by fire fighters to control and extinguish fires. Third, to identify the impacts that the provision of water for fire flow has on a WDS.

2.1 FUNDAMENTALS OF FIRE

Before focusing on the various topics closely associated with fire flow provision, this section will introduce the fundamental components of combustion and the role water plays in fire suppression.

2.1.1 Principles of combustion

Combustion is an exothermic reaction which can be broadly described in three essential and consecutive phases. Firstly, combustion begins with endothermic pyrolysis which is the heating of a fuel or reductant to the point where it gives off inflammable vapour. Secondly, an oxidant (which is usually the surrounding atmospheric oxygen) mixes with the fuel vapour. Thirdly, the ignition of the inflammable gaseous mix requires activation energy which can be by a spark or through sufficient heat. The minimum temperature to which a solid, liquid or gas will self-ignite without an ignition source is referred to as the auto-ignition temperature. Table 2-1 below identifies auto-ignition temperatures of common solids.

Table 2-1 - Approximative auto-ignition temperature of solids (Grimwood & Desmet, 2003)

Solid	Auto-ignition Temperature °C
Polyvinylchloride (PVC)	470
Polystyrene (PS)	490
Nylon	450
Wood	250-350
Paper	200-350
Wool	570
Coal	350
Teflon	600

Once combustion is achieved, the heat released from the initial reaction is often sufficient to drive a continuous chain reaction whereby the fuel is constantly heated and additional vapour released. The presence of heat also draws in surrounding oxygen, once again raising the temperature and sustaining the chain reaction (Home Office Civil Defence, 1949). This chain reaction combined with the continuous supply of fuel, oxygen, and heat is commonly known as the fire tetrahedron, without which fire cannot be sustained.

When all of the tetrahedron elements are present, fire will spread to unignited fuel at the neighbouring fire front as energy is transferred via three heat transfer mechanisms, namely (Morais, 2001):

- **Radiation** – Electromagnetic waves transmit heat which are absorbed by other objects.
- **Convection** – Gasses or liquids transfer heat as a consequence of varying density
- **Conduction** – Transfer of heat within a material due to direct contact.

Through these mechanisms, the spread of fire within a building can be divided into five different phases; ignition, smouldering, flame growth, fully developed and decay. Figure 2-1 shows the stylised fire progression a building can expect to follow.

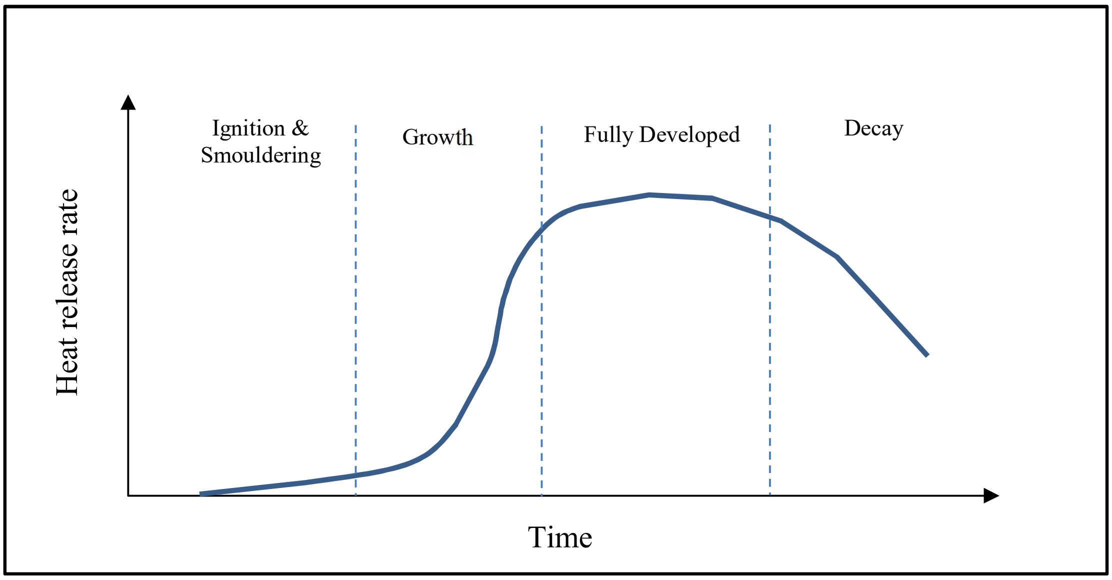


Figure 2-1 - Stylised fire progression (Grimwood & Desmet, 2003)

It is evident from the phases identified in figure 2-1 that the least productive time to start the fire extinguishing process would be in the fully developed phase (Myburgh, 2012). The duration and rate of heat release from a fire in each of these phases is significantly dependant on the fuel type. Fires are generally classified according to their fuel type as shown in Table 2-2.

Table 2-2 - Fire Classification

	Class A	**Class B**	**Class C**	**Class D**	**Class F**
Category	Ordinary	Flammable Liquid	Electrical	Metals	Cooking
Fuel Material	Wood, Coal, Paper, Organic solids	Gasoline, Varnishes, Alcohol	Electrical Equipment	Magnesium, Aluminium, Sodium	Cooking oils, fats

The correct classification of fires is important as different fuel types require specific methods to effectively suppress and extinguish the fire.

2.1.2 Fire suppression and extinction

While it is well understood in theory that a fire is extinguished by removing any one of its four critical elements, the practical implementation of this theory for large fires can at times be near impossible. So it is essential to the effectiveness of firefighting that the appropriate extinguishing agent is used. Selection of the agent depends on the fire class and the characteristics of the combustible element. Table 2-3 presents a global view of the link between fire classes and the efficiency of extinguishing agents and devices available. Once the extinguishing agent has been determined, four general methods can be employed to extinguish or control a fire. These include:

- **Cooling** - It is the most common method and consists in lowering the temperature of the combustible element and the environment, below the ignition point.
- **Smothering** - It is the method which consists in isolating the combustible element and oxygen, or reduces their concentration within the environment.
- **Dilution or elimination of combustible element** - It is the method which consists in separating the combustible element from the heat source or the environment of the fire.
- **Control of flames or interruption of the chain reaction** - This method modifies the chemical reaction, altering the release of free radicals produced in the combustion and therefore delaying the development (Epralima , 2008).

Table 2-3 – Global view of the link between fire classes and the efficiency of extinguishing agents and devices available (Epralima, 2008)

<table>
<tr><th colspan="2"></th><th colspan="8">Extinguishing Agents</th></tr>
<tr><th rowspan="2">Fire Classes</th><th rowspan="2">Extinction Method</th><th colspan="3">Dry Chemical</th><th rowspan="2">CO_2</th><th rowspan="2">Foam</th><th colspan="2">Water</th><th rowspan="2">Halons</th></tr>
<tr><th>ABC</th><th>BC</th><th>Special (Metal Powder)</th><th>Jet</th><th>Pulverizing</th></tr>
<tr><td rowspan="2">A</td><td rowspan="2">Cooling or Flame Control</td><td>Yes Excellent</td><td>No</td><td>No</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes Excellent</td><td>Yes</td></tr>
<tr><td>Fast Reduction of Flames</td><td>Only Controls Small Surfaces</td><td>-</td><td>Only Controls Small Surfaces</td><td>Has an extinguishing and cooling action</td><td colspan="2">Good penetration, fast cooling of combustibles and cinder</td><td>Fast Reduction of Flames</td></tr>
<tr><td rowspan="3">B</td><td rowspan="3">Flame Control, Extinguishing, Cooling</td><td colspan="2">Yes Excellent</td><td>No</td><td>Yes</td><td>Yes Excellent</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td colspan="2">Cloud powder protects operator</td><td rowspan="2">-</td><td rowspan="2">Does not leave residues, does not contaminate food</td><td rowspan="2">Foam cover prevents fire from reigniting and cools off the liquid combustibles</td><td rowspan="2">Jet spreads the fire</td><td rowspan="2">Forms a Vapour Cloud which cools and inhibits</td><td rowspan="2">Fast Reduction of Flames</td></tr>
<tr><td colspan="2">Fast Reduction of Flames</td></tr>
<tr><td>C</td><td>Flame Control</td><td>Yes</td><td>Yes</td><td>No</td><td>Yes</td><td>No</td><td>No</td><td>No</td><td>Yes</td></tr>
<tr><td rowspan="2">D</td><td rowspan="2">Lack of O_2 or Cooling</td><td>No</td><td>No</td><td>Yes Excellent</td><td>No</td><td>No</td><td>No</td><td>No</td><td>No</td></tr>
<tr><td colspan="2">Danger Explosion</td><td>Forms a Crust on The Metals and Eliminates O_2</td><td colspan="5">Danger Explosion</td></tr>
</table>

The majority of fires fought by public fire services in South Africa are class A and thus water is the most commonly used agent due to its suitability, accessibility and comparative cost. Understanding the physical and chemical properties of water is fundamental to its effectiveness in firefighting as well as developing standards that seek to exploit its beneficial characteristics and defend against its disadvantages. Table 2-4 identifies the pros and cons of using water as an extinguishing agent.

Table 2-4 - Water as an extinguishing agent

Advantages	Disadvantages
Water is usually readily available, and is considered inexpensive	Water can react readily with some materials like combustible metals
Water has greater heat absorbing capability (higher specific heat) than most all other common extinguishing agents	Water allows radiant heat to pass through it and readily conducts electricity
Water vaporises at 100°C (expands to 1700 times its original volume when converted to steam) and takes a relatively large amount of heat to completely convert to steam (high latent heat of vaporization).	At 0°C water freezes and expands
Water can be stored easily and can be applied in many different ways such as a solid or broken stream or from a fog nozzle as a narrow pattern fog stream or wide pattern fog stream	Water has high surface tension which means that fuel surfaces are not as readily wetted compared to other agents. However, this can be overcome by the inclusion of small quantities of additives.

As already demonstrated, various methods are avaliable to extinguish or control a fire. With the knowledge of water properties and the processes required for sustained combustion, the three main mechanisms for extinguishment by water will now be discussed in greater detail. Davis (2000) describes these mechanisms as follows:

- **Fuel Surface Cooling** - The wetting (and thus cooling) of the solid fuel surface reduces the rate at which pyrozlates are generated. This reduces the heat release rate and in turn less material burns, reducing further the flame size and thermal feedback process. The buoyant plume released from combustion inhibits the penetration of small droplets of water to the fuel surface. Thus, this mechanism is most effectively achieved by the application of a direct and solid stream of water.
- **Flame Zone Cooling** – The placement of water droplets in the flame zone absorbs the heat from combustion. This heat removal reduces the heat available to initiate further combustion and thus slows the heat release rate. This mechanism is best

achieved by the use of fine water mist because the high surface area per unit mass enables more energy per unit mass to be absorbed.

- **Inerting** - Water in the presence of a hot fuel surface or flame will invariably produce steam. Water expands approximately 1700 times when converting from a liquid to gaseous state. This volume increase reduces the oxygen partial pressure and hence impedes the combustion process by starving the reaction of vital oxygen. Inerting is most effective in an enclosed area and is the main suppression mechanism associated with water mist systems.

While the extinguishing mechanisms employed in a firefighting emergency are important, they play but a small role in the entire firefighting process as is revealed in the following section.

2.2 FIREFIGHTING

Effective firefighting relies on the coordination and operation of numerous depending linkages without which the fraternity would cease to function. Primary features of the firefighting process include: water provision, equipment availability, firefighter expertise, and fire department management and coordination. A detailed investigation into the numerous technical and organisational structures of the firefighting service is beyond the scope of this study. However, an introduction and high-level understanding of fundamental firefighting features is considered relevant and is accordingly presented in the next section.

2.2.1 Coordination and Management

It is stated in SANS10090 (2003) that, "*Two essentials for protection against fire are an efficient fire service and an adequate water supply.*" This supports the notion that the ability for firefighters to add meaningful value to the communities they serve is heavily dependent on the management and organisation of the various structures within which they operate. A fire department or service is usually organised by a system of functions such as administration, training, and operations. Within this system exists a chain of command with which all emergency incidents are managed and coordinated. Specifically, all emergency incidents should be dealt with using an incident command system (ICS) which provides a standard, professional, and organized approach to managing emergency incidents. Characteristics of a well-functioning and correctly implemented ICS include (Schottke, 2012):

- **Organized approach**: An ICS imposes "order on chaos" on the fire ground and enables a safer and more efficient operation than would be possible if personnel and units worked independently of one another.
- **Terminology**: The ICS uses standard terminology for effective communication.
- **Integrated communications**: Everyone responding to the incident can communicate up and down the chain of command as needed.
- **Incident action plan**: Every incident has a plan that outlines the strategic objectives. Large incidents will have formal plans.

Central to the effective delivery of the ICS is a functional communications system. In most fire departments, the communications centre is the central processing point for all information relating to an emergency incident and all information relating to the location, status, and activities of fire department units. Amongst others, communications centres perform the following essential functions:

- Receiving calls for emergency incidents and dispatching fire department units;
- Supporting the operations of fire department units delivering emergency services;
- Coordinating fire department operations with other agencies;
- Keeping track of the status of each fire department unit at all times;
- Monitoring the level of coverage and deployment of available units, and;
- Notifying designated individuals and agencies of particular events and situations.

While the above speaks to the ability of a fire department to manage an ongoing emergency incident, it is obvious that pre-incident planning is a crucial element of good firefighting practice. Pre-incident planning assembles important information before the emergency occurs which enables a department to make better command decisions when an emergency arises. In brief, it is the process of obtaining unique information about a building or a property and storing the information in an accessible system. A fire department should aim to prepare a pre-incident plan for every property that poses a high life-safety hazard to the occupants or presents safety risks for responding fire fighters. Occupancies such as high-rise buildings, healthcare facilities and public-assembly venues involve unique considerations and the pre-incident planning should anticipate the types of incidents that could occur at such locations (Schottke, 2012).

2.2.2 Firefighting Expertise

The need for decisive, experienced based decision making and action is required throughout the firefighting process, however, its influence is directly felt in the heat of an emergency response. Firefighters are required to undergo a systematic process of gathering information and evaluating the incident. This is essential for determining the appropriate strategy and tactics needed to handle the incident. An on site incident action plan prioritises and defines the steps needed to bring the situation under control. This is based on the following five basic objectives (Schottke, 2012):

- **Save lives**—Protecting lives is the first consideration at a fire or any other emergency incident. Often the best way to protect lives is to quickly extinguish the fire.
- **Protect exposures**—The first priority in protecting property is to keep the fire from spreading.
- **Confine the fire**—Once the exposures are protected, the IC will focus on confining the fire to a specific area.
- **Extinguish the fire**—Depending on the size of the fire and the risk involved, the IC will mount either an offensive attack or a defensive strategy to extinguish a fire.
- **Salvage property and overhaul the fire**—Salvage is the removal or protection of property that could be damaged during firefighting operations. Overhaul operations completely extinguish any remaining pockets of fire.

The incident action plan also outlines specific techniques to be employed such as how to rescue occupants and attack the fire. Two broad firefighting attack strategies or 'postures' can be embraced on site, namely offensive and defensive.

- **Offensive -** The type of attack involves entering the structure, proceeding to the seat of the fire, and attempting to extinguish it with a direct agent inundation. It usually requires forcible entry equipment, including bolt cutters, sledge hammers, pry bars, etc.
- **Defensive** – A defensive posture is used when conditions do not allow fire fighters to directly enter the critical area. This could be due to threatened structural integrity or excessive heat. This often resorts in the use of a fog spray introduced from outside the building by any available penetration. Compartment venting is another means of cooling the area so fire fighters may enter safely.

Based on the decisions made, the need for specialised equipment will be required to carry out the actions defined in the incident plan.

2.2.3 Essential Equipment

A wide variety of apparatus, tools and protective gear are used in all fire suppression and rescue operations. This equipment is vital to the survival of both those doing the saving and those being saved. Essential firefighting items include:

- **Ladders** - The primary function of ladders is to provide safe access to and egress from otherwise inaccessible areas. Ladders can be used for several secondary functions, including channelling debris, serving as a lift point, and holding other firefighting equipment.
- **Hand tools** - Hand and power tools are used to extend or multiply the actions of a fire fighter to increase their effectiveness in performing specific functions. The interior attack team who are responsible for advancing a hose line, finding the fire, and applying water to extinguish the flames need the basic tools that will allow them to make a forcible entry if necessary and allow them to reach the source of the fire. A commonly used forcible entry tool is a pike pole. This is a long pole

with a metal hook on the end. It is used by firefighters to search behind walls and ceilings for fire and to ventilate structures by breaking windows and walls (Schottke, 2012).

- **Bunker Gear** – This is the term given to the personal protective equipment that enables firefighters to survive within the flames. The protective ensemble is made up of three main components: an outer shell, a moisture barrier, and a thermal barrier. Additionally, a fireman wears specialised fire retardant boots, hood, helmet and gloves. If conditions warrant, personal breathing apparatus (PBA) can be worn which provides the firefighter with clean oxygen. It is made up of a high-pressure tank, a pressure regulator, and an inhalation connection. In high risk environments a PASS device, or personal alert safety system, is attached to the PBA. A firefighter can activate the alarm when in danger or it is triggered automatically when the firefighter does not move for about 30 seconds (Walker, 2007).

An obvious exclusion from this list are firefighters use of water discharging apparatus. This will be a central focus for the remainder of this research report and is thus covered in greater detail below.

2.2.4 Water Discharging Apparatus

In metropolitan areas of South Africa, municipal water distribution systems make clean water available to the population. Most municipal water supply systems use both pumps and gravity to deliver water via underground water mains. Within this complex WDS, the smaller pipes carry water to the users and hydrants. It is these hydrants which make a portion of this water supply available to the fire department. Fire hydrants are distributed according to local standards and nationally recommended practices. Fire fighters must be proficient in operating fire hydrants, including the tasks of opening and shutting the hydrant, and inspecting its condition and functionality.

In addition to public hydrants, standpipe systems are used for manual fire suppression most commonly in multi-storey buildings. A standpipe system consists of a network of rigid water piping that supplies water for automatic sprinkler fire systems, as well as the manual application of water for firefighting. A standpipe system that is already installed for the purpose of extinguishing fires most notably reduces the time that would be forgone by firefighters to lay hoses up the stairs and into buildings from external hydrants. This also enables stairwells to be kept empty, allowing safe passage for evacuating building occupants and arriving firefighters. A standpipe network can be designed to operate as either a wet or dry system (Myburgh, 2012):

- **Dry standpipes** – Also referred to as a 'riser' in SANS 10252-1 (2012), are empty pipes which are fixed into buildings and have a vertically positioned intake located near the building entrance. They are only charged with water when connected to an arriving fire truck. Once filled, firefighters connect their hoses to pipes inside the building and begin their attack.
- **Wet standpipes** - These pipes are connected directly to the WDS and are always pressurized and filled with water, thus not limited for firefighting use only. They are mainly intended for use by the occupants of a building, as a 'first-aid' measure at the time of the outbreak of a fire and until such time as the fire brigade arrives (SANS, 2012).

If it is identified that the building on fire has a functioning built-in sprinkler system, the first action that should be taken by the fire department is to ensure its water supply is maintained. If necessary, action can be taken to provide additional water and pressure to the system by linking pumpers to the existing sprinkler network, this is commonly referred to as boosting. In the absence of a sprinkler system, hoses are used to transfer water (Myburgh, 2012).

Firefighting hoses can be used to serve one of two functions, supply or attack. Supply hoses, which can either be soft suction or hard suction, are used to deliver water from a static source or from a fire hydrant to an attack engine. A hard suction hose is a special type of supply hose that is used to draft water from a static source such as a river, lake, or portable drafting basin. It is designed to remain rigid and will not collapse when a vacuum is created in the hose to draft the water into the pump. It can also be used to carry water from a fire hydrant to the pumper. Soft suction hoses are short sections of large diameter hose that are used to connect fire department engines directly to a hydrant. It has a female connection on each end, with one end matching the local hydrant threads and the other end matching the threads on a large-diameter inlet to the engine (Schottke, 2012).

Attack hoses are used to carry water from the attack engine to a hand-held nozzle that is used to direct the water directly onto the fire. For larger fires, a large diameter hose can be used, however, these usually require two firefighters to safely control and operate due to their significant weight when fully charged. Another attack hose, commonly referred to as a booster hose, contains a steel wire or ribbing that gives it a rigid shape so that the hose can transfer water safely without pushing the unrolled hose off the reel. In most situations the attack engine will be positioned close to the fire, and attack lines are stretched manually by fire fighters towards the fire. Alternatively, an engine can drop the nozzle end of an attack line at the fire and drive from the fire towards a hydrant or water source. Preconnected rolled hose lines can be placed in several different locations on a fire engine. For example, a transverse hose bed installed above the pump and loaded so that the hose can be pulled off from either side of the apparatus. Preconnected lines can be loaded into special trays that are mounted on the side of fire apparatus. Many engines include a special compartment in the front bumper that can store a short preconnected hose line (Schottke, 2012).

At the discharge end of attack hoses, nozzles are connected to give the fire stream specific shape and direction. Nozzles are used on all sizes of handline and master stream devices and can be classified as (Jones & Bartlett Learning, 2014) :

- Low-volume nozzles are used for flow of approximately 150 L/min or less. They are primarily used for booster hoses; their use is limited to small outside fires.
- Handline nozzles are used on hose lines ranging from 38 mm to 65 mm in diameter. These nozzles operate ideally with flow between 150 and 1300 L/min.
- Master stream nozzles, 100mm or more in diameter, are used on deluge deck guns, portable monitors, and ladder pipes that flow more than 1300 L/min.

Apart from the different operating flow rates, nozzles are also manufactured for the fire service to deliver two different fire streams, namely (Jones & Bartlett Learning, 2014):

- Smooth-bore nozzles which produce a solid column of water.
- Fog-stream nozzles which separate the water stream into droplets.

Most modern nozzles have the capacity to vary the size of the water droplets and the discharge pattern so as to suite the need determined by the firefighter. With the trend to make use of lighter and stronger hoses as materials and manufacturing methods continue to evolve, nozzles are able to produce more efficient flow streams with lower supplied flow rates and pressures. However, to get the best functionality out firefighting equipment, both pre-incident as well as on site emergency calculations of the optimal required fire flow are crucial elements to successful firefighting.

2.2.5 The Impact of Fire Flow Provision

A widely embraced design philosophy for the provision of water for firefighting is to ensure the provision of fire flow over and above the normal public water demand. As is the case in South Africa, most public urban WDSs are used to provide the water for firefighting systems such as automatic sprinkler systems, fire hose reels, standpipe systems and the fire hydrants located on the public main. A key feature of this philosophy is that it enables effective firefighting to take place even when the WDS system is experiencing normal peak demand usage. This approach is most clearly seen in section 11.4.3 of SANS 10090 (2003), an extract of which is shown in figure 2-2.

11.4.3 The minimum quantity of water available should be based on the highest daily consumption plus the required fire flow and must be sustainable for the minimum duration period at the required residual pressure.

The supply requirements should be calculated in accordance with the following formula:

$$SR = \frac{(FF + HDC) \times D}{1\ 000}$$

where

SR is the supply requirement expressed in cubic meter (m^3)

FF is the required fire flow in relation to risk as given in 11.3

HDC is the highest daily consumption as given in 11.2

D is the duration

Figure 2-2 - Minimum water supply calculation (SANS, 2003)

The Red Book also recommends that the mains supplying fire-risk areas should be designed so that the supply is also assured:

> *"Trunk mains serving fire-risk areas should be sized for a design flow equivalent to the sum of the design instantaneous peak domestic demand for the area served by it, and the fire flow given in Table 9.18. Where an area served by the trunk main incorporates more than one risk category, then the fire flow adopted should be for the highest risk category pertaining to the area.* (CSIR, 2005)*"*

Beyond determining the magnitude of adequate fire flow provision, table 2-5 identifies six additional design considerations to be considered.

Table 2-5 - Design considerations for fire flow provision (Davis, 2000)

Consideration	Description
Adequacy (i.e. required fire flow for sufficient time)	Adequacy of water supply is considered in terms of sufficient water flow for the duration of a fire
Reliability	Reliability is a function of the amount of redundancy in the system arising from multiple storage facilities, interconnection and the type of delivery system. It reflects the ability of the system to remain in service despite continued maintenance or equipment failure.
Type of delivery system (e.g. gravity vs pump)	Gravity systems are inherently more reliable than pumped system unless redundancy or standby power is incorporated into mechanically pumped systems.
Storage capacity	Storage is a function of tanks, reservoirs and other static supplies and their degree of interconnection.
Interconnection	Interconnection must also include sufficient valving to allow for isolation in the event of failures or the need to cross connect systems.
Alternative static supplies	Alternative non-potable supplies combined with adequate fire service resources can provide sufficient fire-fighting water. Distance to the risks and accessibility are important factors.

During a large firefighting emergency, regardless of its time of occurrence, where multiple hydrants flow simultaneously, the continual draw offs can significantly diminish water supplies and reduce water pressures. (Davis, 2000). These demands placed on a WDS in times of fire can be greater than those associated with normal consumption, and thus the design and operation of a WDS is often dictated by fire protection requirements.

In 2002, a panel of industry experts were convened by The American Water Works Association (AWWA) Research Foundation and KIWA of the Netherlands to study, explore, and evaluate the impacts of fire flow on distribution systems water quality, design and operations (Snyder et al., 2002). Following this study, an investigation by

Snyder *et al* (2002) found that by incorporating the need for additional fire flow and fire hydrants into the design of a WDS, their provision will typically lead to an increased diameter of water supply lines and in turn higher capital costs.

The provision for greater reliability consequently induces a greater redundancy in the distribution system under normal use conditions. The redundancy can potentially attract negative water quality implications due to increased water resident times in larger pipe sizes. This can increase the possibility of residual disinfectant loss, and enhance the formation of disinfection by-products and bacterial growth in the water mains. Furthermore, the deposit of sediments can become problematic as water flow velocities slow in the larger diameter pipes (Hickey, 2008).

Due to the increased capital costs derived from larger pipelines, storage facilities and pumping requirements, the economic implications of fire flow provision are significant. Davis reported in his study in 2000 that:

> "*Auckland Regional Council Lifelines Project stated that the total cost of the national water infrastructure of New Zealand was $3 billion NZD, of which $0.9 billion NZD could be due to the provision for fire flow. However, the sum of insurance claims for the same year due to fire losses in New Zealand was only $120 million NZD.*"

A study by Myburgh (2012) calculated the cost savings that would be achieved if a rural WDS was designed and constructed based on historical fire flow use data as opposed to the minimum fire flow requirements laid out in the South African guidelines. The results of the study, shown in table 2-6, give unique insights into the financial impact of increased fire flow provision.

Table 2-6 - Cost Comparison for different fire flow conditions (Myburgh, 2012)

	Pipe costs (R millions)	Tank costs (R millions)		Total Costs (R millions)
		Node 24	Node 25	
Fire flow according to CSIR (2003)	20.627	2.967	3.847	27.441
Fire flow according to rural town requirements	17.712	2.266	3.363	23.340

Myburgh (2012) thus observed that, "*the cost of designing a network to provide the recommended fire flow of 12 000 ℓ/min for a high-risk area, is 14.94% (R 4.1 million) higher than the costs required to provide rural fire flow (1 200 ℓ/min). Note that even though the recommended fire flow is 10 times higher, the costs are only 1.5 times higher.*" These results are similar to those observed by Snyder *et al*. (2001) and are due to the fact that a significant portion of the costs are fixed and irrespective of small changes in size. (Myburgh, 2012)

Another recent study conducted in South Africa, this time by Strijdom (2016), confirmed that there are aspects of current WDS design criterion that are too stringent. Recommendations were made in this study to water providers to relax the current design criterion guidelines. In the case of Strijdom's study however, the focus was not on fire flows but rather the minimum residual pressure heads under instantaneous peak demand which is set at 24 meters for house connections. Table 2-7 displays the significant cost savings on required infrastructure upgrades in Nigel, Gauteng province, if the minimum residual pressure head were to be reduced from 24m to 15m.

Table 2-7 - Cost comparison for Minimum Pressure Head (MPH) criteria (Strijdom, 2016)

Description	**Infrastructure upgrade costs for different criteria**		**Cost Saving**
	MPH > 24m	MPH > 15m	
Total for the bulk system (ie. Treatment to storage)	R 57 351 937	R 39 339 884	31.4 %
Total for the reticulation system	R 8 417 751	R 5 074 512	39.7%
Sum of totals for the bulk and reticulation systems for the Nigel study area	R 65 769 688	R 44 414 396	32.5%

The installation of automatic sprinkler systems by property owners results in a significant transfer in the cost of water supplies to the private sector which then carries cost of the installation, maintenance, and periodic testing of their own systems. These outlays carried by commercial property owners with installed and maintained sprinkler systems can be offset in the form of insurance premium reductions. Notwithstanding the potential adverse impacts of excessive fire flow provision, inadequate water supply for firefighters will leave even the most experienced and well-equipped firefighters with very limited opportunity to save lives and extinguish hostile fires. While it is obvious that the magnitude of the impact that fire flow provision has on a WDS is proportional to the additional fire flow provision that is made available, determining the correct value of the required fire flow is much less obvious.

Chapter 3

3 DESIGN CRITERION FOR FIREFIGHTING

The chapter responds to the aim of objective I (i.e. present a critical analysis of both local and international design guidelines pertaining to water provision for firefighting and their influence in WDS design).

Design criterion or standards, in the context of civil infrastructure, can vary from as an author's recommendation to deemed-to-satisfy requirements for compliance. The function of design criterion is to identify the specifications and operating conditions of infrastructure that must be met for adequate levels of service and safety to be achieved. In support of this notion, the SANS (2003) describes the purpose of its own code as to, "*provide advice on the measures that may be taken to ensure that fire services are efficient.".* The point being that the design specifications and operating conditions of a WDS to supply adequate water for effective firefighting are indeed subject to the opinion of the various design authorities (e.g. author of the guidelines, design engineer, fire chief, etc.) In contrast to, for example, structural design, the design processes required for the provision of fire flow is not an exact science. Nonetheless, it does still require the implementation of sound engineering principles and technical justification. In light of this, the following chapter thus aims to:

- Review various global and national published design criterion pertaining to fire flows;
- Identify and compare various mathematical models for calculating required fire flow quantities and;
- Examine the adoption of South African guidelines in municipal and district by-laws.

3.1 GLOBAL FIREFIGHTING DESIGN TRENDS AND PRACTICES

The variation in standards, flow requirements and methodologies for firefighting that exist around the world can be attributed to factors such as:

- Differences in construction materials, design and budget allocation;
- Water availability and climatic conditions;
- The legacy of firefighting services in a community and the ease with which new technologies and techniques can be adopted.

The following review is of countries that readily provide literature on their firefighting processes and water supply requirements:

Germany

German law requires that cities with populations larger than 80 000 to 100 000 (varies according to the state) are to have a professional firefighting force which operates as a fulltime city department. Smaller cities and towns usually set up a smaller full or part-time force that occupy one large fire station. The German Institute for Standardization (*in German:* Deutsches Institut für Normung) prescribes the flow rate and flow pressures for fire hydrants in their standards as summarised in part in table 3-1:

Table 3-1 - German hydrant flow rates and pressures (KSB Aktiengesellschaft, 2013).

Required flow rates and pressures at outlet valve (landing valve)					
Category	**Flow rate (L/min)**	**Simultaneous use**	**Minimum flow pressure (Mpa)**	**Max. flow pressure**	**Max. static pressure**
Wall hydrant type S (for use by building occupants)	24	2	0.20	0.8 MPa	1.2 MPa
Wall hydrant type F (for use by firefighters)	100	3	0.30		
	200	3	0.45		
Surface hydrant DN 80	800	As per fire protection plan	0.15		
Surface hydrant DN 100	1 600				
Underground hydrant DN 80	800				

German fire water requirements are prescribed according to fire-risk categories that assign the level of risk according to four classes of building use and three classes of fire spread risk. The German approach to calculate fire flows is covered in their VdS 2034 method for non-public fire departments, and the German DVGW W405 method. The combined risk categories result in fire flow requirements ranging from 760L/min for the lowest risk area to 3200 L/min for the highest risk area. Their standards also require that all fire-risk flows should be maintained for at least 2 hours with the residual fire pressure (the minimum pressure required during fire-flow conditions) of 140 KPa for all categories of risk (Hickey, 2008).

United States of America

The two prominent methods for fire flow calculation in the USA are found in The International Fire Code (IFC) (International Code Council, 2014) and National Fire Protection Association (NFPA) (National Fire Protection Association, 2006) Fire Code . Although, in a similar fashion to South Africa, throughout the United States, it is generally left up to the local authorities to determine the fire-flow requirements for their jurisdiction. Table 3-2 below summarises some of the fire hydrant requirements for developments in the Santa Barbara County, California. This table applies to individual hydrant flow rates for buildings having a fire area which does not exceed 335 m^2 (3600 ft^2) (Santa Barbra County Fire Department, 2009).

Table 3-2 - Santa Barba hydrant requirements (Santa Barbra County Fire Department, 2009).

Area Type/Acres	Hydrant Spacing (m)	Minimum Hydrant Flow Rate (L/min) at 138 kpa (20 psi)
Commercial	91 (300 ft)	4731 (1250 gpm)
Urban and rural developed neighbourhood	152 (500 ft)	2839 (750 gpm)
Rural 5 to 10 Acres	183 (600 ft)	1893 (500 gpm)
Rural over 10 Acres	244 (800 ft)	1893 (500 gpm)

United Kingdom

Within the published document, *PD 7974-5, Application of Fire Safety Engineering Principles to the Design of Buildings,* drafted by the British Standards Institution, The recommended standards of "fire cover" within the UK Fire Service are addressed. The document also stipulates that the fire flow capacity should be related to the type and size of the building as well as the risk involved and agreed upon with the approving authority. The document, however, does not give a specific calculation method for fire flow values (Benfer & Scheffey, 2014).

Under current UK legislation, it is the duty of a water utility to install fire hydrants on mains as required by the governing fire authority. However, according to *The UK National Guidance Document on the Provision of Water for Firefighting*, the utility is not required to install a fire hydrant on a trunk main nor to provide any given pressure or flow at a hydrant. When a fire authroity is dealing with a fire it can instruct the utility to provide a greater supply by shutting off other mains in the area. The utility does however have a duty to maintain a supply and pressure that will ensure water to reach highest storey of every building in the area. Table 3-3 summarises the UK guidance on minimum flow requirments for fire fighting (Ratnayaka et al., 2009).

Table 3-3 - UK Guidelines on requirements for firefighting (Ratnayaka et al., 2009)

Category	Description	'Minimum' Requirements
Housing	Detached or semi-detached houses of not more than 2 floors	480 L/min through a single hydrant
	Multi-occupied housing with units of more than two floor	1500 – 2100 L/min through a single hydrant
Transportation	Lorry/coach parks – multi-story car parks – service stations	1500 L/min from any single hydrant on site or within 90m
Industry	Recommended for industrial estates:	Site mains normally at least 150mm diameter
	• Up to 1 ha • Between 1 and 2 ha • Between 2 and 3 ha • Over 3 ha	• 1200 L/min • 2100 L/min • 3000 L/min • 4500 L/min
Commercial	Shopping, offices, recreation, and tourism development	1200 – 4500 L/min
Institutional	Village halls	900 L/min through any single hydrant on site or within 100m of the complex
	Primary schools and single-story health centres	1200 L/min through any single hydrant on site or within 70m of the complex
	Secondary schools, colleges, large health, and community centres	2100 L/min through any single hydrant on site or within 70m of the complex

Australia

In Australia, under the Local Government (General) Regulations 2005, the local water utility has an obligation to install hydrants in its watermains at convenient distances and places to ensure the ready supply of water for firefighting. The local water utility has no prescribed standards that it must meet with respect to minimum flow levels or pressures at hydrant. The Australian standard AS24191 does not regulate the provision of infrastructure by a local water utility, it only provides a guidance to a number of areas of consideration. These guidelines have been summarised in table 3-4. The AS24191 further specifies that in assessing the capacity of a water supply system to provide for fire flow, the base demand level is defined as the 95th percentile demand. Fire flows are then superimposed on this base demand with a hydraulic model assessment then carried out to determine whether minimum residual pressures are achieved (Hunter Water Australia, 2011).

Table 3-4- Australia design criteria summary (Hunter Water Australia, 2011)

Item	**Criteria** *(AS24191)*
Fire Flow Provision* (4 hour duration)	
Residential buildings (3 storeys or less)	60 L/min
High-rise residential	120 L/min
Commercial areas	120 L/min
Industrial area	120 L/min
** In high-rise residential, commercial and industrial areas it is recommended that provision is made from two hydrants at 60 L/min*	
Residual Pressure	
Desirable booster assisted hydrants pressure	150 kPa
Desirable unassisted hydrant pressure	250 kpa
Minimum pressure in the main at the hydrant	Must be positive
Minimum Pipe Diameters	
Low-rise residential (3 storeys or less)	100 mm
High-rise residential	150 mm
Commercial areas	150 mm
Industrial area	150 mm
Hydrant spacing	
Urban	70 m
Rural residential	120 m
Rural	Not normally provided

New Zealand

In New Zealand the document which provides guidance on the supply of water for firefighting in urban areas is the *New Zealand Fire Service Firefighting Water Supplies Code of Practice, SNZ PAS 4509:2008*. The two methods for fire flow calculation put forward in this code both begin with fire water (FW) classification. This classification, FW1 through FW7, accounts for the use of the building, sprinkler protection, the fire hazard category (i.e. occupancy) of the building, and the largest fire cell of the building. Classification FW1 and FW2 account exclusively for sprinklered structures. Table 3-5 lists the fire flow requirements for buildings supplied by a municipal reticulation as well as the minimum water storage volume for buildings with non-reticulated supply (Benfer & Scheffey, 2014).

Table 3-5 - PAS 4509 Basic Required Fire Flow (Benfer & Scheffey, 2014)

Fire Water Classification	For reticulated water supply.		For non-reticulated water supply.	
	Required fire flow within 132m (L/min)	Additional required fire flow within 264m (L/min)	Firefighting time (min)	Minimum water storage within 90m (litres)
FW1	540	0	15	7 000
FW2	900	900	30	45 000
FW3	1800	1800	60	180 000
FW4	3600	3600	90	540 000
FW5	5400	5400	120	1 080 000
FW6	7220	7220	180	2 160 000
FW7	This classification requires Appendices H and J of PAS 4509 to calculate the required fire flow			

3.2 SOUTH AFRICAN NATIONAL STANDARDS AND GUIDELINES

Preceding the passing of South Africa's first national construction laws, the country's various provinces and municipalities had their own construction laws and regulations which were similar, although not the same. After several years of expert collaboration, in 1977, South Africa's first national construction laws, National Building Regulations and Building Standards Act No. 103 of 1977, were promulgated. On September 1, 1985, the laws came into effect. These National Building Regulations (NBR) relied on national standards published by the South African Bureau of Standards (SABS) that detail the code of practice (also known as deemed-to-satisfy rules) for the implementation of the NBR (Szymanowski & Swift, 2017).

The Water Services Act (Act 108 of 1997) of South Africa deals with water services and provision, such as water supply and sanitation, to the public. A requirement of the Act is a Water Services Development Plan which defines the minimum and desired level of water service for communities, which must be adhered to by the Water Services Provider in its area of jurisdiction. A Water Services Development Plan should also describe the present and future arrangements for water service provision in an area (CSIR, 2005). Additionally, water services are to be provided in accordance with local by-laws made in terms of the Water Services Act. Within the Water Services Development Plan as well as the local by-laws, certain design criterion for the provision of water for fire protection are stipulated. These are typically given by either making reference to recognised existing standards, such as the SABS or by defining new guidelines and detailing them within the publication.

The SABS is a statutory body that was established in terms of the Standards Act, 1945 (Act No. 24 of 1945). SABS operate as the national standardisation institution in South Africa and thus, develop, promote and maintain South African National Standards (SABS, 2017). The national code for the provision of water for fire-fighting in South Africa titled: *Community Protection Against Fire* was first published in 1966 and revised in 1972. This code was compiled with the assistance of organizations from the UK, USA, Canada, New Zealand and Germany (van Zyl & Haarhoff, 1997). A notable feature of this code is the absence of minimum water pressures for both water provision and pumping ability of response units. A summary of SANS 10090:2003 Edition 3 fire flow design values are shown in table 3-6. A significant feature of SANS 10090:2003 is its extensive reference to NFPA codes in section 2 titled 'Normative References' (SANS, 2003). SANS 10090:2003 refers to six NFPA publications, namely:

- NFPA 291, Fire flow testing and marking of hydrants
- NFPA 1201, Developing fire protection services for the public
- NFPA 1500, Fire department occupational health and safety program
- NFPA 1561, Fire department incident management system
- NFPA 1710, Standard for the organization and deployment of fire suppression, emergency medical operations and special operations to the public by career fire departments.
- NFPA 1901, Automotive fire apparatus.

The significance and implication of this NFPA reference will be discussed further in section 4.2.

A separate national code, titled SANS 10252-1:2012 *'Water supply and drainage for buildings Part 1: Water supply installations for buildings'* also provides recommendations for design pressures and flows for fire installations. As seen in figure 3-1, which is an extract from SANS 10252-1:2012, a minimum provision of 30 L/min per fire hose reel and 1200 L/min per hydrant is advised without any reference to fire risk category. It should be noted that SANS 10252-1:2012 does not make any reference to SANS 10090:2003 within it and provides far less detail regarding fire flow requirements. SANS 10252-1:2012 does, however, stipulate that a minimum pressure of 300kpa must be maintained in hoses and hydrants.

Table 3-6 – SANS 10090:2003 Fire Flow Summary (SANS, 2003)

FIRE RISK CATEGORY				
A	B	C	D	E
Central business districts and extensive commercial and industrial areas normally found in cities and large towns (areas where the risk to life and property due to fire occurrence and spread is likely to be high)	Limited central business districts, smaller commercial or industrial areas normally associated with small towns and decentralized areas of cities and large towns (areas where the risk to life and property due to fire occurrence and spread is likely to be moderate)	Residential areas of conventional construction.	Rural areas of limited buildings and remote from urban areas. D1 - Houses > 30m apart D2 - Houses 10.1m to 30m apart D3 - Houses 3m to 10m apart D4 - Houses < 3m apart	Special risk areas. Individual areas requiring a pre-determined attendance over and above the predominant risk category in an area. Includes large shopping/entertainment centres, informal settlements, harbours, hospitals, prisons, large airport buildings and petrochemical plants.

PROVISION OF WATER FOR FIREFIGHTING								
CATEGORY	WEIGHT OF RESPONSE AT FIRES			MINIMUM FIRE FLOW		FIRE HYDRANTS		
Fire-Risk Category	**Minimum number of pumping units**	**Minimum manning level per appliance**	**Minimum pumping capacity of each unit (L/min)**	**Possible Fire Sizes**	**Flow In (l/min)**	**Minimum Hydrant Flow (l/min)**	**Max. Distance between hydrants (m)**	**Maintenance Intervals**
A	2	5	3850	Non-residential buildings with divisions not greater than 5000 m²	13 000	2 000	85	Annually
B	2	4	3850	Non-residential buildings having divisions not greater than 2 500 m²	9 000	2 000	120	Biennially
C	1	4	2250	Non- residential premises not greater than 1 250 m²	6 000	2 000	200	Triennially
D1	1	4	2250	Houses > 30 m apart	1 900	1 200	300	Triennially
D2				Houses 10.1 m to 30 m apart	2 850	1 200	200	
D3				Houses 3 m to 10 m apart	3 800	1 400	200	
D4				Houses < 3 m apart	5 700	2 000	200	
E	* As determined by individual risk assessment							Annually

7.2.2 Fire installations and combined installations

7.2.2.1 A water gauge pressure of at least 300 kPa at the level of the highest protected point shall be maintained when one hose reel is in full operation in any combined installation.

7.2.2.2 A fire installation or combined installation shall

a) be so constructed as to provide

1) a supply of water sufficient for the effective operation of the number of hose reels and hydrants that can be operated or come into operation simultaneously in any division, and

2) a flow pressure, at any hose reel or hydrant, of at least 300 kPa and a flow rate of at least

i) 30 L/min per hose reel, and

ii) 1 200 L/min per hydrant, and

b) incorporate devices that limit the gauge pressure at any hydrant valve to 600 kPa under full flow conditions.

7.2.2.3 In a combined installation where a fire boosting system is installed (see 7.3.4), all branches to non-fire-related pipework (installations) shall be protected by a pressure control valve.

Figure 3-1 - SANS 10252-1:2012 Design pressures and flows (SANS, 2012)

SANS publications directly relating to the use of water for firefighting in the context of this investigation are listed in table 3-7.

Table 3-7- SANS Firefighting related publications

SANS Code	Year of Publication	Standard Title	Comment
10400-T	2011	The application of the National Building Regulations - Part T: Fire protection	Pre-empted by the NBR Act. No reference is made to SANS10090 or quantities of water supply for firefighting.
10400-W	2011	The application of the National Building Regulations - Part W: Fire installation	
10252-1	2012	Water supply and drainage for buildings Part 1: Water supply installations for buildings	Pre-empted by the Water Services Act. No reference is made to SANS10090. Limited reference is made to quantity of water supply for firefighting (Figure2-7)
10105-2	2010	The use and control of fire-fighting equipment - Part 2: Fire hose reels and above-ground hydrants	
1128-1	2010	Firefighting equipment - Part 1: Components of underground and above-ground hydrant systems	No relevance to water supply quantities.
1128-2	2010	Firefighting equipment Part 2: Hose couplings, connectors, and branch pipe and nozzle connections	
10090	2003	Community protection against fire	The only SANS publication to provide detailed guidance on the supply of water for firefighting.

Another industry recognised and respected reference providing national guidance on fire-fighting is the *Guidelines for the provision of Engineering services in residential townships* (1983). The document was later revised in 1994 in the *Guidelines for the provision of engineering services and amenities in residential township development*. The latest set of these South African guidelines, generally referred to as the '*Red Book*', is titled *Guidelines for Human Settlement Planning and Design* (CSIR, 2005). The Red

Book guideline still references the SABS Code of Practice 090 of 1972 despite the fact that they were revised in edition 3 which was published in 2003. The Red Book does however make amendments to this outdated 1972 code which is seen most notably in the lower fire risk categories. A summary of the latest Red Book guideline on fire flow design values can be seen in table 3-8.

Table 3-8 - Red Book Fire Flow Summary (CSIR, 2005)

<table>
<tr><th colspan="7">FIRE RISK CATEGORY</th></tr>
<tr><th colspan="2">High-risk</th><th>Moderate-risk</th><th>Low-risk (Group 1)</th><th>Low-risk (Group 2)</th><th>Low-risk (Group 3)</th><th>Low-risk (Group 4)</th></tr>
<tr><td colspan="2">These areas in which the risk of fire and of the spread of fire is high, such as congested industrial areas, congested commercial areas, warehouse districts, central business districts, and general residential areas with floor space ratio of 1,0 and greater where buildings are four storeys and more in height (residential zone IV).</td><td>These are areas in which the risk of fire and of spread of fire is moderate, such as industrial areas, areas zoned "general residential" with a floor space ratio of less than 1,0 (residential zones II and III) where buildings are not more than three storeys in height</td><td>Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally likely to be more than 200 m2.</td><td>Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is likely to vary between 100 m2 and 200 m2.</td><td>Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally likely to be less than 100 m2 but more than 55 m2.</td><td>Residential areas (residential zone 1) where the gross floor area of the dwelling house, including outbuildings, is generally not more than 55 m2. This group includes low-cost housing schemes.</td></tr>
<tr><th colspan="7">PROVISION OF WATER FOR FIREFIGHTING</th></tr>
<tr><td>CATEGORY</td><td>HYDRANT LOCATION</td><td>DURATION OF DESIGN FIRE FLOW</td><td colspan="2">DESIGN FIRE FLOW</td><td colspan="2">FIRE-FLOW DESIGN CRITERIA FOR RETICULATION MAINS</td></tr>
<tr><th>Fire-Risk Category</th><th>Maximum Distance Apart (m)</th><th>Duration of Design Fire Flow (hours)</th><th>Minimum Design Fire Flow (ℓ/min)</th><th>Maximum Number of Hydrants Discharging Simultaneously</th><th>Minimum Hydrant Flow Rate For Each Hydrant (ℓ/min)</th><th>Minimum Residual Head (m)</th></tr>
<tr><td>High-risk</td><td>120</td><td>6</td><td>12 000</td><td rowspan="2">All hydrants within a radius of 270 m of the fire</td><td rowspan="2">1 500*</td><td rowspan="2">15</td></tr>
<tr><td>Moderate-risk</td><td>180</td><td>4</td><td>6 000</td></tr>
<tr><td>Low-risk (Group 1)</td><td>240</td><td>2</td><td>900</td><td>1</td><td>900</td><td>7</td></tr>
<tr><td>Low-risk (Group 2)</td><td>240</td><td>1</td><td>500</td><td>1</td><td>500</td><td>6</td></tr>
<tr><td>Low-risk (Group 3)</td><td>240</td><td>1</td><td>350</td><td>1</td><td>350</td><td>6</td></tr>
<tr><td>Low-risk (Group 4)</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
<tr><td></td><td></td><td>Red Book: Table 9.19</td><td colspan="2">Red Book: Table 9.18</td><td colspan="2">Red Book: Table 9.20</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td><td colspan="2">*With a design maximum of 1 600 l/min per hydrant</td></tr>
</table>

The Red Book further provides the following guidelines when designing specific elements of a WDS as quoted below (CSIR, 2005):

- **Design of trunk mains –** *"The mains supplying fire-risk areas should be designed so that the supply is assured at all times. Trunk mains serving fire-risk areas should be sized for a design flow equivalent to the sum of the design instantaneous peak domestic demand for the area served by it, and the fire flow given in Table 9.18* (Table 3-8)*."*

- **Ground reservoirs –** "*The storage capacity of reservoirs serving fire areas should, over and above the allowance for domestic demand, include for the design fire flow obtained from Table 9.18* (Table 3-8) *for a duration at least equal to that given in Table 9.19* (Table 3-8). *Where an area served incorporates more than one risk category, then the design fire flow and duration used should be for the highest risk category pertaining to the area served by the reservoir."*
- **Elevated storage** – *"There need be no provision for storage of water for fire-fighting when the pumping plant serving the elevated storage facility is sized to deliver the sum of the instantaneous peak demand and the fire flow obtained from Table 9.18* (Table 3-8)*, or the instantaneous peak demand plus an allowance of 20%, whichever is the greater. A standby pumping plant should also be provided."*
- **Reticulation mains –** *"Reticulation mains in fire areas should be designed according to the design domestic demand required. The mains should, however, have sufficient capacity to satisfy the criteria given in Table 9.20* (Table 3-8). *The minimum residual head should be obtained with the hydrant discharging at the minimum hydrant flow rate, assuming the reticulation is operating under a condition of instantaneous peak domestic demand at the time."*

A notable distinction between SANS10090 and the Red Book is their differing fire-risk categories. The Red Book presents a single set of fire-risk categories whereby all its various recommendations are in relation to. The SANS10090 guidelines, however, present two category sets. The main set is titled, 'Fire Risk Categories', and the subset is titled, 'Possible Fire Sizes'. The 'Possible Fire Size' categorisation is used exclusively for the determination of minimum fire flow rates.

3.3 METHODS FOR CALCULATING REQUIRED FIRE FLOWS

The scope of this study does not allow for a detailed mathematical analysis of the various methods employed to size a conventional WDS. The study will, however, look at the numerous methods developed for determining fire flows. Across the world, many methods have been developed to calculate fire flow rates. These methods generally form the basis on which fire protection codes are established which regulate the design of various WDS features such as:

- Spacing of fire hydrants;
- Minimum size of reticulation pipes;
- Minimum flow rate and pressures; and
- Storage requirements and flow durations.

In a report conducted by The Fire Protection Research Foundation, titled: *Evaluation of Fire Flow Methodologies,* sixteen fire flow calculation methods were evaluated. The methods identified were from the USA, UK, France, Germany, the Netherlands, New Zealand, and Canada and are listed in table 3-1. Eleven of the methods evaluated are geared towards pre-incident infrastructure and building planning and five are best suited for on-scene firefighting (Benfer & Scheffey, 2014) :

- **Infrastructure and Building planning** - These methods are necessarily predictive in nature, are more complicated and involve several steps and multiple-calculations. Typical variables accounted for include: building construction, occupancy, fire size, heat release, sprinkler contribution, etc. The inclusion of a variety of variables enables adjustments to be made to the building type or protection features (e.g. adding a sprinkler system) to reduce the required fire flow.
- **On-scene firefighting -** These methods, by comparison, are much simpler, allowing fire fighters on the scene to assess whether they need more hose lines or apparatus to fight the fire. They typically consist of one equation with one variable, either the volume or area of the fire.

Table 3-9 - Names of fire flow calculation methods (Benfer & Scheffey, 2014)

Infrastructure and Building Planning Methods	
Name (Acronym)	**Origin**
ISO Method (Insurance Service Office)	USA
IFC/NFPA 1 Method (International Fire Code/ National Fire Protection Association)	USA
NFPA 1142 Method (National Fire Protection Association)	USA
IWUIC Method (International Wildland-Urban Interface Code)	USA
Ontario Building Code Method	Canada
FIERA system Method (Fire Evaluation and Risk Assessment)	Canada
TP 2004/1 and TP 2005/2 Methods (Technical Publication)	New Zealand
FEDG Method (Fire Engineering Design Guide)	New Zealand
SNZ PAS 4509 (New Zealand Fire Service Firefighting Water Supplies Code of Practice)	New Zealand
D9 Method (Technical Document: External Fire Control – Determination of Water Supply)	France
UK National Guidance Document on the Provision of Water for Firefighting	UK
On-scene Methods	
ISU Method (Iowa State University)	USA
Särdqvist, Thomas, and Baldwin Methods	UK, UK, and USA respectively
IIT Method (Illinois Institute of Technology)	USA
NFA Method (National Fire Academy)	USA
3D Firefighting Method by Oklahoma State University	UK/USA/Australia

The sixteen fire flow calculation equations and methods that were evaluated by Benfer & Scheffey (2014) were simulated in two different sized non-residential buildings and two different sized single-family residential buildings. The study by Benfer & Scheffey

(2014) included both sprinklered and non-sprinklered calculations. Figures 3-2 and 3-3 show the maximum and minimum fire flow requirements for a non-sprinklered, non-residential building of 50 000 ft^2 (4 645 m^2) and 10 000 ft^2 (929 m^2) respectively. It is noted that the values quoted are not total water supply values and do not include water required for daily consumption.

To allow for a comparison of South African fire flow requirements to other international requirments, the minimum fire flow requirments for a simlar structure as defined in SANS 10090 and the Red Book are superimposed on results presented by Benfer & Scheffey (2014). An important consideration to note is that the SANS 10090 fire flow values presented in figures 3-2 to 3-5 are not explicitly intended to deal with a single incident, however, as seen from figure 2-2 and SANS 10090 - clause 11.4.1: "The required fire flow should be available to the fire-fighting team on arrival at the fire (SANS, 2003)." This is assumed to imply that a comparison between the values calculated for the methods presented in table 3-9 to the SANS 10090 and Red Book fire flows is indeed fair. Where applicable, both the design 'Fire Flow In' and minimum flow per hydrant for SANS 10090 and the Red Book have been shown.

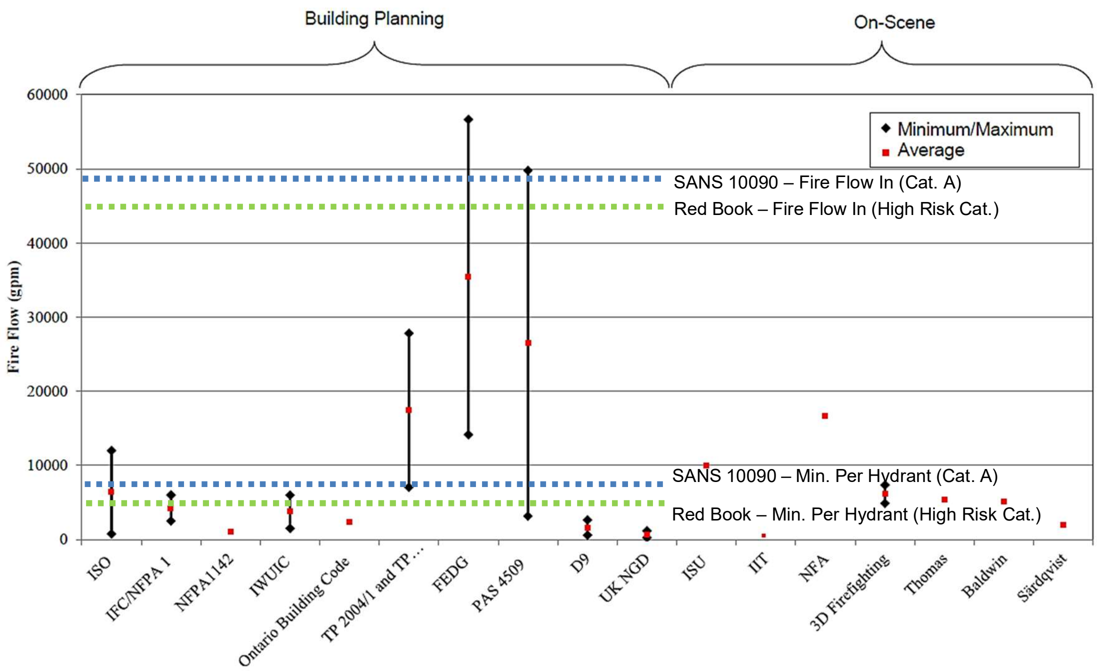


Figure 3-2 - Maximum and minimum fire flow calculations for a non-sprinklered, non-residential building of 50 000 ft^2 (Benfer & Scheffey, 2014)

The minimum fire flow requirments for a simlar structure as defined in SANS 10090 and the Red Book has been superimposed on results presented in figure 3-2. Assuming Risk Category A - 'Non-residential buildings with divisions not greater than 5000 m² (53 800 ft^2)' a minimum flow of 13 000 L/min (49 242 gpm) is required by SANS 10090. As shown in figure 3-2, the SANS requirement falls with the maximum range of the FEDG and PAS 4509 method however is an order of magnitude greater than other fire flows presented. The minimum fire flow requirement in The Red Book for a similar 'Hight-risk' category is 12 000 L/min (45 330 gpm). The corresponding minimum flow per hydrant for SANS 10090 and the Red Book are 2 000 L/min (7 570 gpm) and 1 500 L/min (5 678 gpm) respectively. It is seen in figure 3-2 that these individual hydrant recommendations are in closer agreement with the other methods presented.

Figure 3-3 displays a similar situation however for a building a fifth of the size. Assuming Risk Category C - 'Non- residential premises not greater than 1 250 m² (13 450 ft^2)' a minimum flow of 6 000 L/min (22 667 gpm) is required by SANS 10090. The minimum fire flow requirement in The Red Book for a similar 'Moderate-risk' category is also 6 000 L/min (22 667 gpm). SANS 10090 and the Red Book recommendation is once again an order of magnitude greater than many other fire flows presented. The corresponding minimum flow per hydrant for SANS 10090 and the Red Book remain the same at 2 000 L/min (7 570 gpm) and 1 500 L/min (5 678 gpm) respectively, despite the change in risk category. It is seen in figure 3-3 that these individual hydrant recommendations are higher than most other methods presented however are much closer than the design fire flow requirements.

It is seen from figures 3-2 and 3-3 that the range of flow rates calculated is extremely large not only between the various methodologies but also with in them depending on the assumptions made. The *FEDG* and *PAS 450*9 methods produced the largest min-max range of values for the same size non-sprinklered building. Furthermore, the building planning methods tend to recommend fire flows that are higher than the on-scene methods. It is also reported by Benfer & Scheffey (2014) that many of the on-scene methods do not accommodate a variation for sprinkler protection system in their calculations. Given the wide variety of variables and approaches present in the fire flow calculation methods, it is problematic to devise a single building case that can be used to compare all the methods without introducing biases to several of the methods (Benfer & Scheffey, 2014).

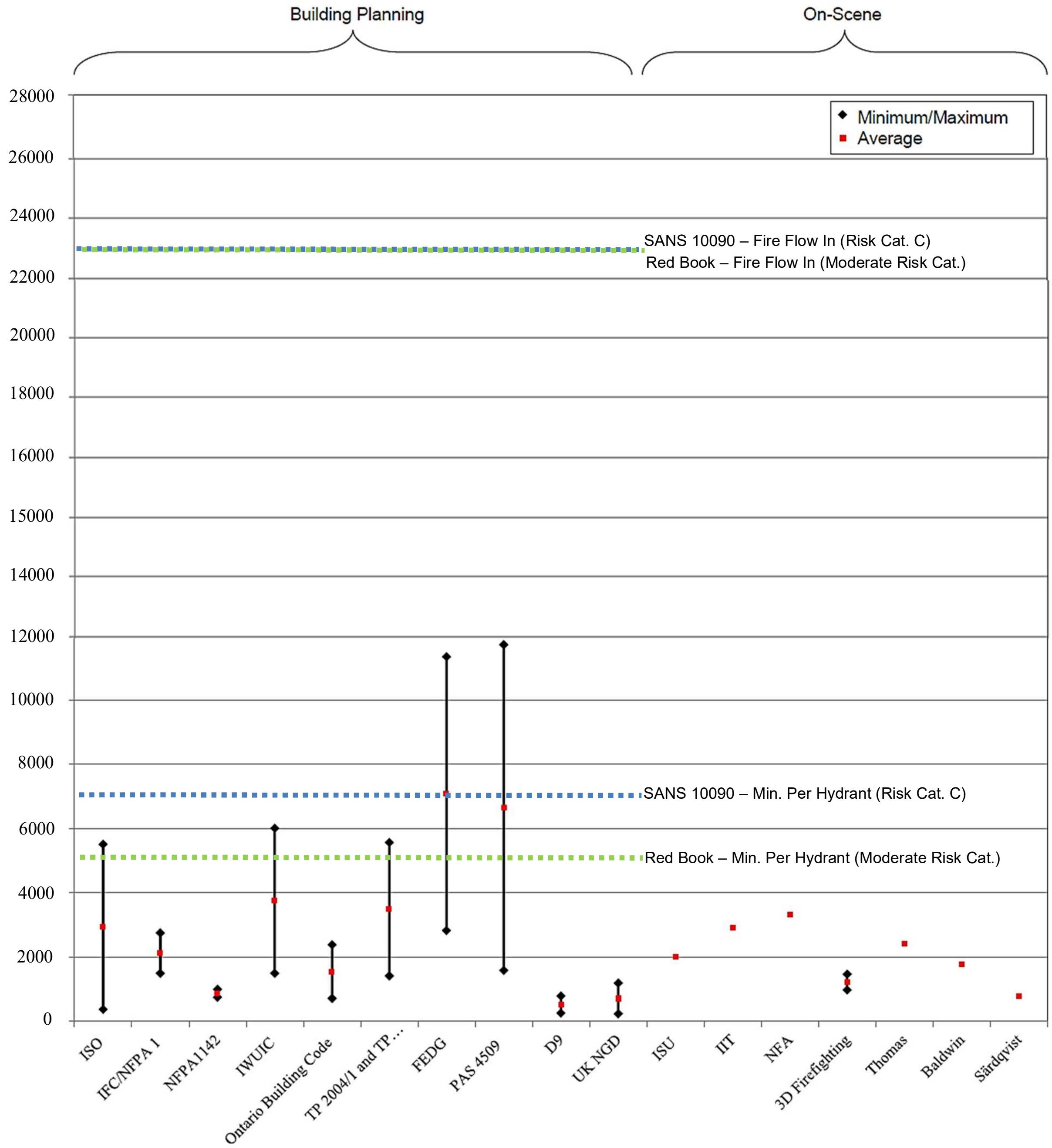


Figure 3-3 -Maximum and minimum fire flow calculations for a non-sprinklered, non-residential building of 10 000 ft² (Benfer & Scheffey, 2014)

Figures 3-4 and 3-5 show the sprinkled and non-sprinkled fire flow calculations for a residential building of 3 500 ft^2 (325 m^2) and 1 500 ft^2 (140 m^2) respectively.

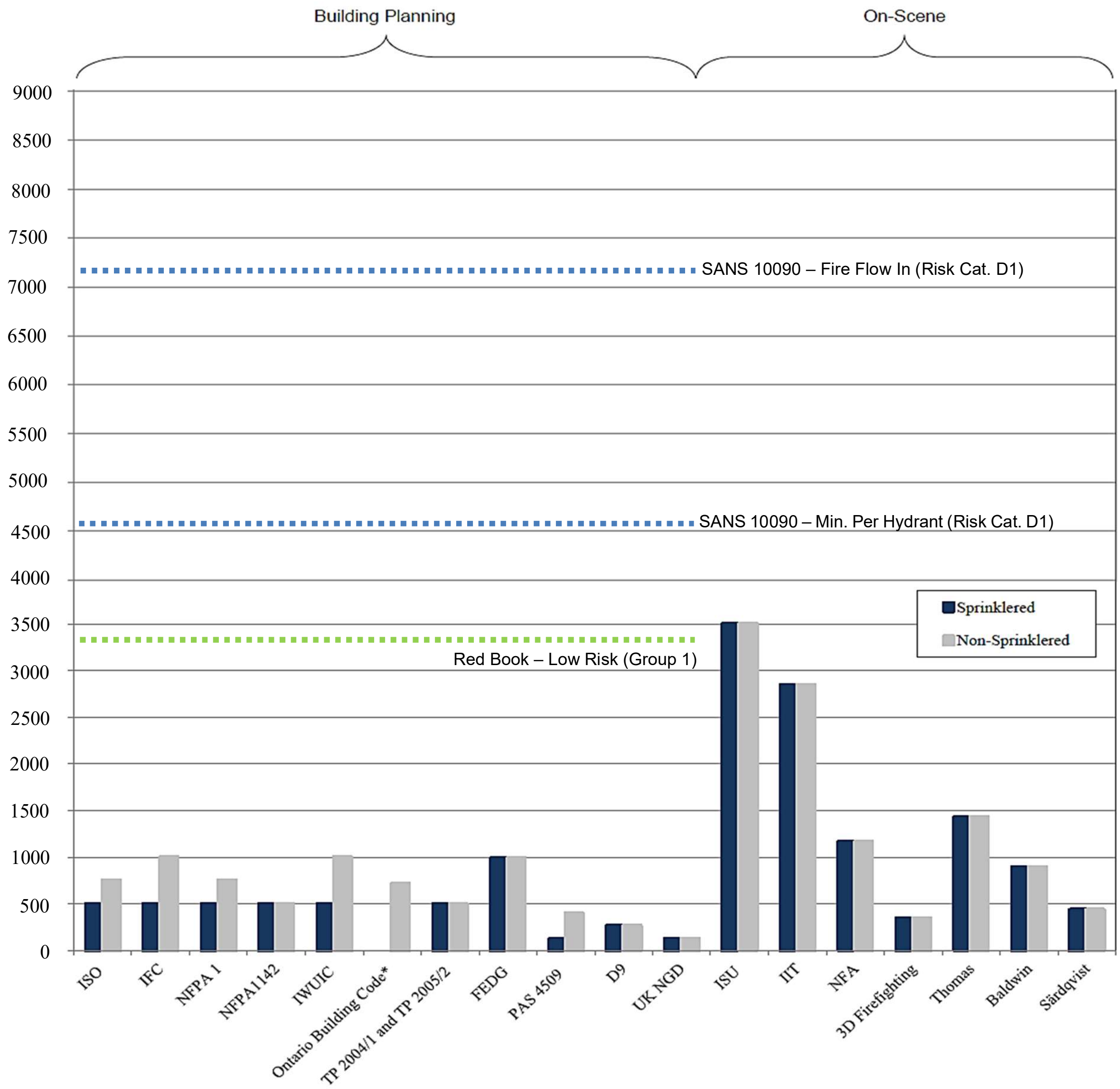


Figure 3-4 - Fire flow calculations for a 3 500 ft^2 single-family home; sprinklered vs. non-sprinklered (Benfer & Scheffey, 2014).

As is seen from figure 3-4, assuming risk category D1 - 'House > 30m apart', a minimum flow of 1 900 L/min (7 191 gpm) is required by SANS 10090. The minimum hydrant flow for this SANS 10090 risk category is 1 200 L/min (4 542 gpm). Appling the Red Book category: Low-risk (Group 1), which is residential greater than 200 m^2 (2 152 ft^2), the design fire flow and the minimum hydrant flow are both set to 900 L/min (3 407 gpm). Figure 3-4 shows that in all three cases, the South African design guide lines require significantly larger fire flows compared to the other methods presented.

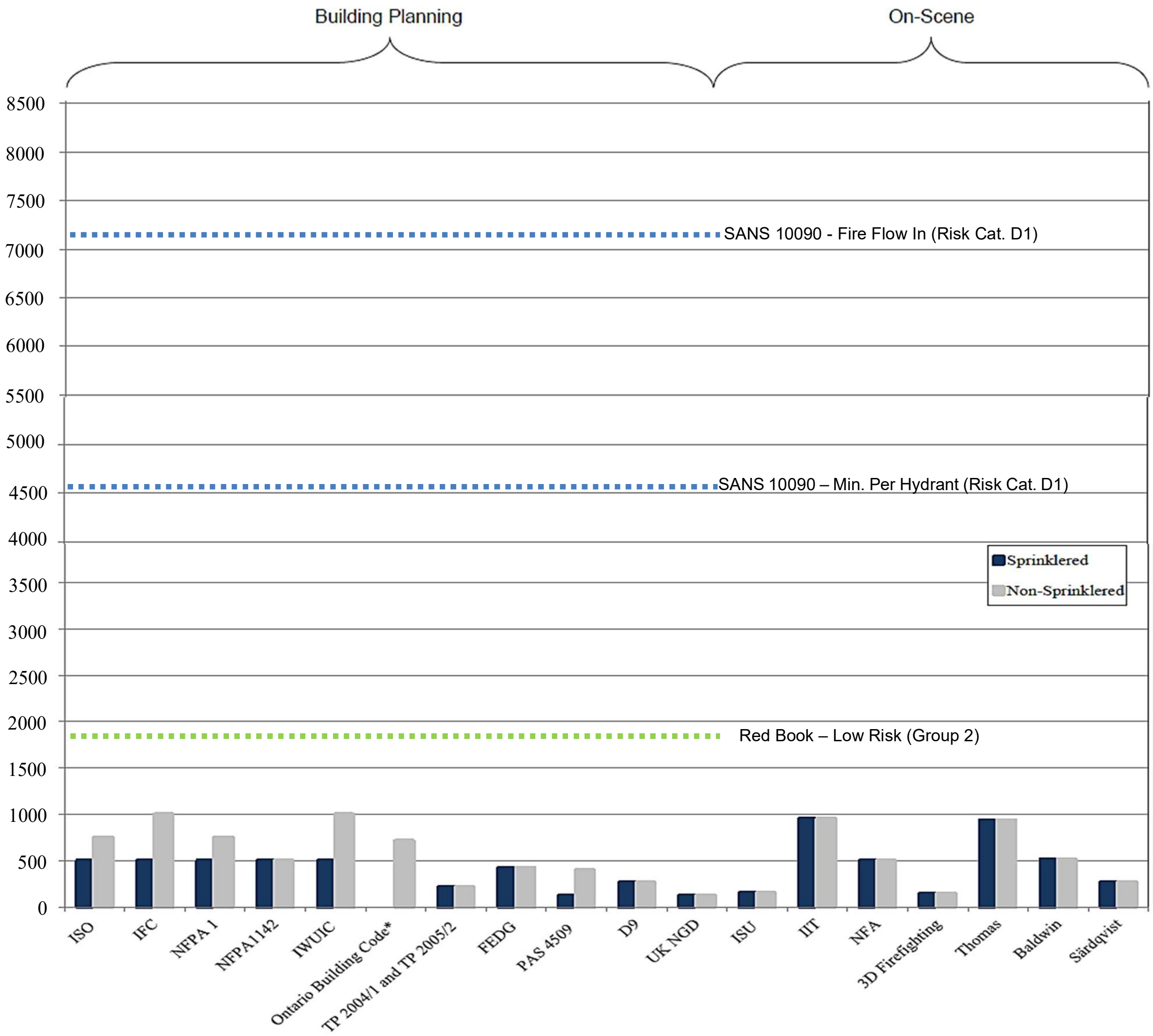


Figure 3-5 - Fire flow calculations for a 1 500 ft^2 single-family home; sprinklered vs. non-sprinklered (Benfer & Scheffey, 2014).

Seen in figure 3-5, again assuming risk category D1 - ‘House > 30m apart’, which is the lowest SANS 10090 risk profile, the recommend fire flow is more than 700% greater than all other fire flows presented in the study. Appling the Red Book category: Low-risk (Group 2), which is residential between 100 m^2 - 200 m^2 (1076-2152 ft^2), the design fire flow and the minimum hydrant flow are both set to 500 L/min (1 892 gpm) which is more than double the other methods calculated with the exception of the IFC and IWUIC methods.

For buildings fitted with sprinklers, it is surprising that 12 out of the 18 methodologies required the same fire flow compared to non-sprinkler fitted buildings. The large degree of variance observed within figures 3-4 and 3-5 further suggests the need for continued investigation into this topic. Detailed field data from real firefighting cases would provide the much-needed validation of these different methodologies and potentially identify their various strengths and weakness or suitability to particular conditions. Considering this, table 3-10 provides a summarised comparison of the sixteen fire flow calculation methods evaluated by Benfer & Scheffey (2014) and indicates the important factors used in their respective calculations. Variation in fire flow calculations and lack of consistency in approach is translated to fire flow requirements that vary greatly all over the world.

Another important observation to be taken from figures 3-2 to 3-5 is the significant ranges in fire flow that is calculated for different building sizes and types by the 10 building planning methods presented. Using the median values in figures 3-2 and 3-3 and the non-sprinklered values in figures 3-4 and 3-5, the following is noted:

- A 500% increase in non-residential building size (10 000 ft^2 to 50 000 ft^2) showed an average increase of 328% in fire flow (3040 gpm to 9975 gpm).
- A 233% increase in residential building size (1 500 ft^2 to 3 500 ft^2) showed an average increase of 113% in fire flow (570 gpm to 643 gpm).
- A 286% increase in residential to non-residential building size (3 500 ft^2 to 10 000 ft^2) showed an average increase of 473% in fire flow (643 gpm to 3040 gpm).

Table 3-10 - Comparison of fire flow calculation methods (Benfer & Scheffey, 2014).

Method	Flow, duration, and/or volume	Empirical (loss data) or theoretical basis	Explicitly addresses residential	Building construction	Building occupancy and use	Exposure protection	Building or fire area	Building volume (height)	Heat release rate	Efficiency of water application or cooling	Human intervention	Reduction for sprinkler protection
Building Planning Methods												
ISO Method	Flow Duration*	Empirical	Yes	Yes	Yes	Yes	Yes	-	-	-	-	Yes
IFC/NFPA 1 Methods	Flow Duration	Empirical	Yes	Yes	-	-	Yes	-	-	-	-	Yes
NFPA1142	Flow Volume	Unknown	-	Yes	Yes	Yes	-	Yes	-	-	-	Yes
IWUIC Method	Flow Duration	Unknown	Yes	-	Yes	-	Yes	-	-	-	-	Yes
Ontario Building Code Method	Flow Duration Volume	Unknown	-	Yes	Yes	Yes	-	Yes	-	-	-	Yes
FIERAsystem Method	Flow Duration	Unknown	-	-	Yes	Yes	Yes	Yes	Yes	Yes	-	-
TP 2004/1 and TP 2005/2 Methods	Flow Volume	Theoretical	-	-	-	Yes	Yes	-	Yes	Yes	-	-
FEDG Method (NZ)	Flow	Theoretical	-	-	-	-	-	-	Yes	Yes	-	-
PAS 4509 Method	Flow Duration Volume	Unknown	Yes	-	Yes	Yes	Yes	Yes	Yes	-	Yes	Yes
D9 Method	Flow Duration	Unknown	Yes	Yes	Yes	-	Yes	(Yes)	-	-	Yes	Yes
UK National Guidance Document on the Provision of Water for Firefighting	Flow	Unknown	Yes	-	Yes	-	Yes	-	-	-	-	-
SANS 10090	Flow Duration	Unknown	Yes	-	Yes	-	Yes	-	-	-	Yes	-
Red Book	Flow Duration	Unknown	Yes	-	Yes	-	Yes	Yes	-	-	-	-

Table 3-10 - Comparison of fire flow calculation methods (continued) (Benfer & Scheffey, 2014).

Method	Flow, duration, and/or volume	Empirical (loss data) or theoretical basis	Explicitly addresses residential	Building construction	Building occupancy and use	Exposure protection	Building or fire area	Building volume (height)	Heat release rate	Efficiency of water application or cooling	Human intervention	Reduction for sprinkler protection
On-Scene Methods												
Thomas, Baldwin, and Särdqvist Methods	Flow	Empirical	-	-	-	-	Yes	-	-	-	-	-
ISU Method	Flow	Empirical	-	-	-	-	-	Yes	-	-	-	-
IIT Method	Flow	Empirical	Yes	-	Yes	-	Yes	-	-	-	-	-
NFA Method	Flow	Empirical	-	-	-	-	Yes	-	-	-	-	-
3D Firefighting Method	Flow	Empirical	-	-	-	-	Yes	-	-	-	-	-

3.4 MUNICIPAL BY-LAWS

In terms of Section 13(a) of the Local Government: Municipal Systems Act 2000 (Act No. 32 of 2000), municipal councils are enabled to publish their own by-laws. The passing of these by-laws enables municipalities to regulate the affairs and the services it provides within its area of jurisdiction. These by-laws enable each municipality to, at its own discretion, specify the design criteria to be satisfied for developments to be granted authorisation for connect to the municipality's water mains. The adoption and enforcement of SANS or the Red Book's guidelines should thus be clearly stipulated within the local municipal by-laws. Metropolitan municipalities encompass the largest metropolitan regions within the country. The following section reviews South Africa's eight metropolitan municipality by-laws to identify their individual stance and level of detail that is given to the provision of water for firefighting.

3.4.1 City of Johannesburg Metropolitan Municipality

Under the title of '*Special provisions for fire services',* section 51 (1) of the '*Water Services'* by-laws states that, "*Any water installation for the provision of water for firefighting purposes, must comply with the provisions of SABS Code 10252-1:1994* (Figure2-6) *or any revision or substitution thereof.*" (City of Johannesburg Metropolitian Municipality, 2011). Differently, in '*Part 5: Water supply for fire-fighting purposes'* of Johannesburg's '*Emergency Services*' by-laws, a more descriptive yet contradictory (in relation to minimum volume in the second column for the different fire risk categories) provision is made as seen in figure 3-6.

Township development fire-extinguishing stream requirements

26. Every person who develops or redevelops a township must ensure that the water supply provides a fire-extinguishing stream that is immediately available to members of the Service in an emergency, of the following volume and duration:

Fire risk category	Minimum volume of extinguishing stream (litres per minute)	Minimum duration of extinguishing stream (hours)
High risk	11 500	6
Moderate risk	5 750	4
Low risk	2 300	2

Township development fire hydrant requirements

27. (1) Every person who develops or redevelops a township must ensure that fire hydrants are plotted on a plan and installed in accordance with the following minimum delivery volumes and distance frequencies:

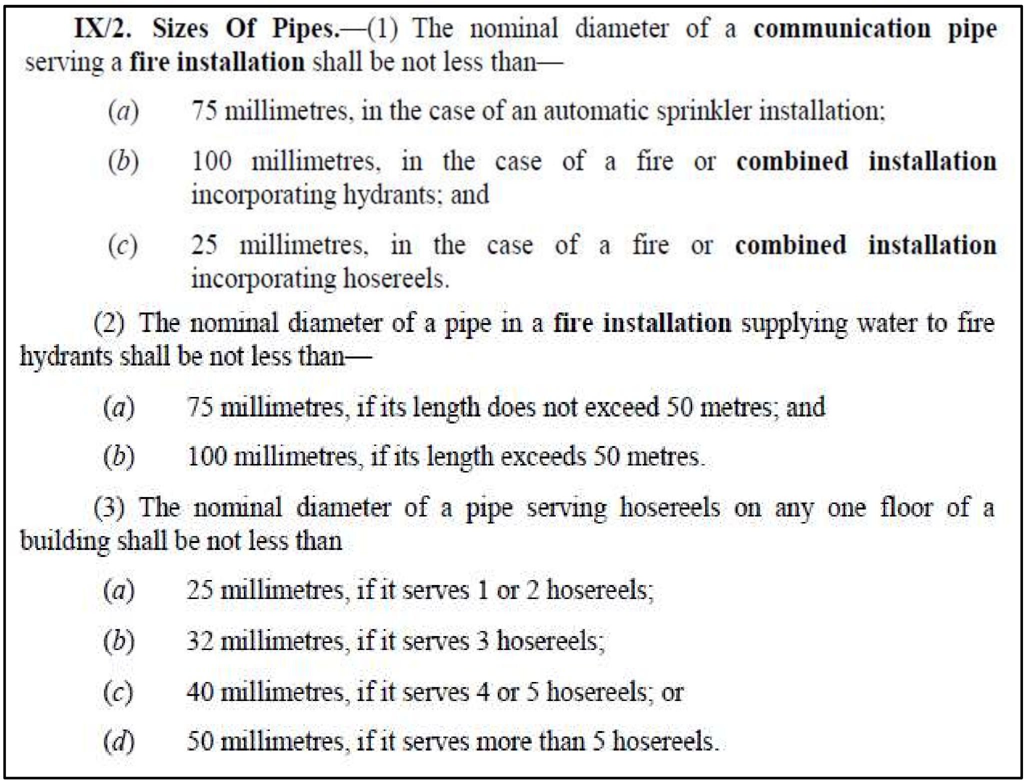
Fire risk category	Minimum fire hydrant delivery volume measured at peak consumption (litres per minute)	Minimum distance between fire hydrants (metres)
High risk	1980	120
Moderate risk	1 150	180
Low risk	900	240

(2) Every person who develops or redevelops a township must ensure that the position of fire hydrants are plotted accurately on a plan that is furnished to the Chief Fire Officer for operational fire-fighting purposes.

Figure 3-6 - Johannesburg Metropolitan Emergency Services By-Laws (City of Johannesburg Metropolitan Municipality, 2004)

3.4.2 eThekwini Metropolitan Municipality

eThekwini Municipality does not have a by-law publication dedicated to fire safety. The most recently promulgated by-law concerning the supply of water for firefighting is contained within '*Chapter IX: Fire Installations'* of the '*Water Supply'* municipal by-law (eThekwini Municipality, 1996). A revised version of this by-law was released in draft form in 2014 under the authority of the eThekwini Municipality. However, the chapter titled '*Fire Installations*' remains unchanged (eThekwini Municipality, 2011). Within this chapter, no provision is made for minimum fire flow supply rates or pressures, rather the by-laws prescribe detailed minimum pipe and fittings requirements such as nominal diameters for communication pipes serving a fire installation as well as number of pumping connections, non-return valves, pressure gauges, test valves, etc. Figure 3-7 provides an extract from the '*Water Supply*' by-laws showing these pipe requirements.



IX/2. Sizes Of Pipes.—(1) The nominal diameter of a **communication pipe** serving a **fire installation** shall be not less than—

(*a*) 75 millimetres, in the case of an automatic sprinkler installation;

(*b*) 100 millimetres, in the case of a fire or **combined installation** incorporating hydrants; and

(*c*) 25 millimetres, in the case of a fire or **combined installation** incorporating hosereels.

(2) The nominal diameter of a pipe in a **fire installation** supplying water to fire hydrants shall be not less than—

(*a*) 75 millimetres, if its length does not exceed 50 metres; and

(*b*) 100 millimetres, if its length exceeds 50 metres.

(3) The nominal diameter of a pipe serving hosereels on any one floor of a building shall be not less than

(*a*) 25 millimetres, if it serves 1 or 2 hosereels;

(*b*) 32 millimetres, if it serves 3 hosereels;

(*c*) 40 millimetres, if it serves 4 or 5 hosereels; or

(*d*) 50 millimetres, if it serves more than 5 hosereels.

Figure 3-7 - eThekwini Metropolitan Municipality By-Laws (eThekwini Municipality, 1996)

3.4.3 City of Cape Town Metropolitan Municipality

The municipal by-law '*Community Fire Safety*' published in 2002 makes numerous provisions in line with its title. However, none that deal directly with fire flow supply rates or pressures (Municipal Council of The City of Cape Town, 2002). The provincial '*Water'* by-law, in chapter 9 titled '*Fire Installations'*, requires all hose reel and hydrant installations comply with the relevant standard set by SANS 10252:1 (City of Cape Town Metropolitan Municipality, 2011).

3.4.4 City of Tshwane Metropolitan Municipality

Tshwane municipality, in its '*Water Supply'* by-laws '*Chapter III, Part 9: Fire services connections'*, states that, "*The Engineer is entitled at his or her absolute discretion to grant or refuse an application for the connection of a fire extinguishing installation to the Municipality's main.*" Additionally, in section 41 of the by-laws, states that, in general, the provisions of SANS 10252-1 and SANS 10400 apply to the supply of water for firefighting purposes with no additional requirements (City of Tshwane Metropolitan Municipality, 2003).

3.4.5 Nelson Mandela Bay Metropolitan Municipality

In both the '*Water and Sanitation*' (Nelson Mandela Bay Metropolitan Municipality, 2010) and '*Fire Safety*' (Nelson Mandela Bay Metropolitan Municipality, 2007) by-laws, it was found that no provision was made for minimum water supply quantities nor any reference to the relevant SANS documents.

3.4.6 City of Ekurhuleni Metropolitan Municipality

In Part III, '*Fire Protection and Firefighting*', section 21 (1) of the Ekurhuleni Metropolitan Municipality '*Emergency Services*' by-laws, reference to three different design criteria for water supply for firefighting is made. Figure 3-8 shows an extract from these by-laws. Furthermore, the by-laws go on to explicitly require that the size, working pressure and delivery flow of any water supply, must be calculated and designed according to the provisions of Part W of SANS 10400 and SANS 10252, Part 1 (City of Ekurhuleni Metropolitan Municipality, 2006).

21. (1) Every person who develops or redevelops a township must:

(a) design and develop that township with a sufficient water supply for purposes of firefighting by members of the Service as specified in:
(i) SANS 10090 (Community Protection against Fire)
(ii) SANS 11200 and
(iii) The Red Book

(b) ensure the position of all fire hydrants are plotted on a plan for operational use by the Service;

(c) space all fire hydrants in accordance with SANS 10090 (Community Protection Against Fire), SANS 11200 and The Red Book's specifications

(d) in the event that any risk area is developed or redeveloped in such a manner that the risk area falls into the high-risk category, adapt the water reticulation accordingly without delay.

Figure 3-8 - Ekurhuleni Emergency Services By-Laws (City of Ekurhuleni Metropolitan Municipality, 2006)

3.4.7 **Buffalo City Metropolitan Municipality**

The Buffalo City Municipality deals with the provision of water for firefighting in section 112 (1) of their '*Water Services*' by-laws which states that the approval of a connection of a fire safety installation to a water main is conditional upon the connection's design and installation "complying with the provisions of SANS." (Buffalo City Metropolitan Municipality, 2011) No further comment is made as to which specific SANS document is being referred to. While this unspecific approach prevents the by-laws from becoming outdated as SANS document numbers change, it does little to inform the reader which are the few actual pertinent standards out of hundreds of SANS publications. Other relevant requirements made by these by-laws include: hydrants to be within 90m from a premises; and dual-pipe installations to be installed where boosting is required and must handle pressures in excess of 1 015 KPa.

3.4.8 **Mangaung Metropolitan Municipality**

Section 18 of Mangaung Municipality '*Firefighting Services*' by-laws shares a very close similarity to those seen in the Ekurhuleni Metropolitan Municipality whereby township designs are required to supply sufficient water for firefighting as specified in SANS 10090 and the *Red Book*. The only notable difference is the exclusion of SANS 11200 from subpoint 1 (a) in the Mangaung by-laws (Mangaung Metropolitan Municipality, 2013).

From the above, it is seen that there are large differences in how fire safety is legislated in the different metropolitan municipalities. Moreover, it was found throughout the review that while each municipality may require certain design standards to be met, they do not in any way constitute an undertaking to maintain their water supply or pressure to any amount. Municipalities should be making use of modern firefighting statistics to update their legislation on present day firefighting water requirements to facilitate the planning and most optimal design of WDSs to cope with the high draw offs that can happen at any time when firefighting.

3.5 LOCAL AND DISTRICT MUNICIPALITIES

Beyond the eight metropolitan municipalities within South Africa, the remainder of the country is divided into 44 district municipalities. District municipalities are themselves further divided into several local municipalities of which there are 205 in the country. The roles and responsibilities of local and district municipalities regarding the provision of fire brigade services are described in section 84, '*Functions and Powers of municipalities*', of the Local Government Municipal Structures Act, (Act 117 of 1998) (Government Gazette No. 19614, 1998). Section 84(1) of the Act states that, "*A district municipality has the following functions and powers:*

> *(j) Firefighting services serving the area of the district municipality as a whole, which includes -*
>
> *i. Planning, co-ordination and regulation of fire services;*
> *ii. Specialised firefighting services such as mountain, veld and chemical fire services;*
> *iii. Co-ordination of the standardisation of infrastructure, vehicles, equipment and procedures;*
> *iv. Training of fire officers."*

Section 84(2) further provides that, "*A local municipality has the functions and powers referred to in section 83 (1), excluding those functions and powers vested in terms of subsection (1) of this section in the district municipality in whose area it falls*" (Government Gazette No. 19614, 1998). According to Act 117, the only basis upon which a district municipality can escape responsibility for performing this function is if the MEC has acted in terms of Section 85 of the Structures Act by allocating that function to a Local Municipality having followed the relevant procedures. Thus, in the absence of an adjustment in terms of Section 85 of the Act by the MEC, the district municipality is obliged to provide the firefighting service (RM Emergency Managment Services (PTY) Ltd, 2009).

Table 3-11 identifies the by-laws pertaining to fire protection of the eight local and district municipalities around South Africa that were investigated for the purpose of this study.

Table 3-11 – List of Local and District Municipalities Investigated

Province	Name
Eastern Cape	Kou-Kamma Local Municipality
Free Sate	Thabo Mofutsanyane District Municipality
Gauteng	Emfuleni Local Municipality
Western Cape	Knysna Local Municipality
North West	Bojanala Platinum District Municipality
Northern Cape	Hantam Local Municipality
Limpopo	Vhembe District Municipality
Gauteng	Midvaal Local Municipality

Of the five local municipality by-laws examined only two provided information regarding the supply requirements of water for firefighting. The way these fire flow requirements are defined is notably different, yet equally valid. Emfuleni Local Municipality by-laws provide a comprehensive reference to SANS for water supply for firefighting. Within its fire safety by-laws, Part 5: *Water Supply for Firefighting Purposes,* it states, "*Water supply for firefighting purposes must comply with both SANS 10090 and SANS 10400 (Parts A, D, F, K, M, O, S, T, V and W)*". A very different approach is seen in Part 5: *Water supply for fire-fighting purposes Township development water supply requirements,* of the Midvaal fire safety by-laws. The Midvaal by-laws make no reference to SANS 10090 or the Red Book but rather define their own. Clause 26 and 27 of the by-laws provide minimum stream and hydrant requirements for three risk categories which are later defined under clause number 28 (Midvaal Local Municipality, 2015). These requirements are identical to those seen in figure 3-6 which is an extract of the Johannesburg Metropolitan Emergency Services By-Laws.

Of the three district municipality by-laws examined, only two provided information regarding the supply requirements of water for firefighting. The Vhembe district municipality Water and Sanitation By-laws give no recommendation or comment to specify a minimum water supply for firefighting (Limpopo Province, 2014). The Bojanala and Thabo Mofutsanyana district municipality by-laws (titled 'Fire Services' and 'Emergency Services: Fire' respectively) prescribe the same guidelines seen in the Midvaal and Johannesburg (figure3-6) by-laws (North West Province , 2012). A unique feature of the Thabo Mofutsanyana Emergency Services by-laws is the intricate selection between SANS 10090 and its own guidelines. An example of such can be seen in figure 3-9 which shows an extract from Part 3, section 22: 'Water Supply for Fire-Fighting', clause 4. In this clause it is seen that there is a distinct selection of the SANS10090 fire hydrant inspection intervals only and thereafter its specification of fire flow rates and durations which are different to those that SANS10090 recommends (Thabo Mofutsanyana District Municipality, 2016).

4. The Service must inspect fire hydrants at the intervals as provided for in SANS 10090, and a flow and pressure test must be conducted on the stream to determine whether the stream complies with the following volume and duration:

Fire Risk Category	Minimum volume of extinguishing stream (Litres per minute)	Minimum duration of extinguishing stream (hours)
High Risk	11 500	6
Moderate Risk	5 750	4
Low Risk	2 300	2

Figure 3-9 - Thabo Mofutsanyana Emergency Services By-laws (Thabo Mofutsanyana District Municipality, 2016)

Chapter 4

4 A FIRE FIGHTERS PERSPECTIVE

This chapter responds to the aim of objective II (i.e. to report on the firefighting status quo within the city Johannesburg; identify and discuss the discrepancies that exist between guideline ideals and current firefighting practice; and present the sentiments and opinions of firefighters)

Interviews with nine key role players within the fire department, including active and experienced firefighters, trainers, and heads of various directives, were conducted to understand internal viewpoints of urban firefighting within Johannesburg. The information gathered from the interviews provides a valuable perspective and explains the challenges relating to water provision for firefighting currently experienced. The insights gained from the interviews, in light of the review of design considerations made in chapter three, form the basis of the status quo report presented in this chapter.

Before undertaking the interview process, a non-medical ethics clearance application was made to the relevant ethics committee within the school of Civil and Environmental Engineering of the University of the Witwatersrand. Clearance to proceed was obtained and is shown in appendix A. Permission was applied for and obtained from the City of Johannesburg Department of Emergency Management Services (EMS). The letter of authorisation granted is showed in appendix B. Within the EMS department, there are five directorates. This study closely engaged with three of the directorates, namely:

- **Operations** - The core department dealing with the saving of lives and property when disasters or accidents happen.
- **Proactive services and fire safety** - focuses on preventing fires. The directorate focuses on fire safety, looking at code application, code enforcement and events management, among others.
- **Corporate services and academy** - supports the EMS with a wide range of services, including training, fleet management, human resources, finance, and administration.

4.1 METHODOLOGY FOR EVALUATING THE STATUS QUO

The general interview process was structured into three discussion topics: firefighting procedure, equipment and code applicability. The procedure component included the following discussion points and was crafted so as to better understand and reveal the crucial elements of effective firefighting:

- The order of proceedings after an emergency call is received;
- The rational for sizing a fire and the mechanisms for decision making on the firefighting equipment and water needed;
- The connection process to fire hydrants in a WDS;
- The use of multiple hydrants and their configuration;
- The refilling of tankers and the time dependency of the refilling rate;
- The occurrence of non-performing hydrants and the resulting consequences;
- The effect that hydrant pressures and spacing have on their efficiency;
- The relationship between water supply and time elapsed to control fire; and
- External factors affecting firefighting processes and efficiency.

Fire truck specification sheets and equipment registers were examined at the participating fire stations to accurately record the various water use equipment items and tools used.

Specific attention was given to:

- Water Tank Capacity;
- Pump capacity; and
- Hose carrying capacity and variety.

These details enable a comparison to be made between the recommendations made in the national guidelines to the actual tools and equipment currently used in practice within a metropolitan municipality. Understanding the pumping capacity and efficiencies of fire trucks is an important consideration when determining appropriate fire flow supply quantities and pressures. Likewise, standard hose sizes, lengths and quantities carried by trucks ought to be considered when prescribing hydrant spacing and flow rate capabilities.

The objective of interrogating code applicability is to identify any inconsistencies that became apparent in light of the interview findings. The comparison focuses on the following items which are design considerations stipulated in the national standards and Red Book guidelines:

- Minimum number of pumping units per fire risk area;
- Minimum manning level per appliance;
- Minimum pumping capacity;
- Minimum fire flow, hydrant flow and residual head; and
- Maximum distance between hydrants.

From this, recommendations to adjust the current guidelines (where they do not match or support the observations made in this chapter) are motivated and detailed. The full questionnaire, including the participant information sheet and signed (anonymised) consent forms from the nine interviewees can be found in Appendix C.

4.2 OBSERVATIONS AND RECOMMENDATIONS

The survey process began with interviewing experienced firefighters. It was soon identified that one of the biggest infringements to the firefighting process is the frequent occurrence of fire hydrant related problems and shortage of pumping appliances. These two topics thus form the focus of this section which: identifies aspects of South African design code which fail to fully address the problems identified; highlights elements of design code which are not being put into practice; and puts forward recommendations for corrective changes to the codes.

4.2.1 Fire Hydrants

Specifically, four common problems were identified regarding fire hydrants:

- **Hydrant usability** – Fire hydrants have been vandalised beyond useabilty.
- **Hydrant visibility and accessibility** – Buried hydrants do not have correct road markings to clearly identify their location. This also applies to hydrants that have been covered by vegetation.
- **Hydrant serviceability** – Hydrants provide insufficient or no water supply due to inadequate maintenance.
- **Hydrant spacing** – Hydrants are not readily found 'close enough' to the emergency site.

The occurrence of either of the above four situations results in valuable time lost during a fire incident as fire fighters go in search of the nearest operational hydrant or are forced to ration water release rates until additional water supplies arrive. Figure 4-1, which provides an extract of the SANS 10090 hydrant maintenance requirements, refers to the NFPA 291 (National Fire Protection Association, 2016), '*Fire flow testing and marking of hydrants'* which prescribes in detail, the installation and maintenance steps to be carried out that ensure hydrant reliability. However, no clarity is given in the Johannesburg Water Supply nor the Emergency Services by-laws to ensure that the authority having jurisdiction shall ensure that hydrants are indeed serviced and maintained in accordance with national standards. It is thus a recommendation of this study that the enforcement of SANS 10090, clause 11.5.2 and 11.5.3, be improved. Furthermore, that these sections pertaining to hydrant serviceability and maintenance, be added to and clearly articulated within the City of Johannesburg's municipal by-laws.

11.5.2 Authority having jurisdiction shall ensure that hydrants are serviced (and the flow measured for conformity with table 8) at intervals as given in table 10 and shall include the following:

a) hydrant markings in accordance with NFPA 291;

b) positions as indicated on water reticulation drawings;

c) hydrant serviceability including condition, access and operation;

d) individual flow and pressure tests; and

e) availability of suitable accurate records.

11.5.3 The location of hydrants should be adequately indicated.

Table 10 — Hydrant maintenance intervals

1	2
Risk category	**Interval**
A & E	Annually
B	Biennially
C & D	Triennially

Figure 4-1- SANS 10090 Hydrant Maintenance Requirements (SANS, 2003)

Hydrants spaced further than 90m apart are cause for frustration for many of the fire fighters interviewed. Interviewees indicate that this is due to the difficulty of laying the 100mm hydrant supply lines (which are typically 15m in length) further than 90 m. Hydrants spaced more than 90m apart require a minimum of six 15m long hydrant supply lines. As seen from the international standards presented in section 3.1, the spacing of hydrants in residential areas in South Africa is notably higher than the other countries referenced. SANS 10090 and the Red Book recommend 200 m and 180 m – 240 m respectively for residential areas. Whereas, residential spacing requirements in other countries are: USA – 152 m; Australia - 120 m; New Zeeland – 132 m. It is therefore recommended that hydrant spacing be reduced and limited to a maximum of 180 m for medium to low risk areas in the South African design guidelines to ensure hydrant connection lengths are not greater than 90 m. This recommendation is in line with clause 4.35.4 of SANS 10400-T:2011 which states, "*In any industrial park, permanent amusement park or exhibition ground, shopping centre or group housing, cluster housing, or townhouse complex there shall be installed ground or raised hydrants so placed that* *no point in such amusement park or exhibition ground or shopping centre or in any building in such housing complex shall be at a distance greater than 90 m from any hydrant* (SANS, 2011)."

Another common view expressed by firefighters is that it is extremely uncommon for multiple hydrants to be used during a single incident due to the aforementioned reasons. A consequence of this is that according to SANS 10090, fire hydrants are designed to provide a minimum flow well below that of the minimum fire flow and that only when multiply hydrants are connected to discharge at the emergency site can the design fire flow be achieved. This problem would appear to have been resolved in part by the Red Book's guidelines where, apart from the high and moderate risk categories, the design minimum fire flow is equal to the minimum individual hydrant flow. A recommendation of this study is to reconcile the SANS 10090 recommended 'Flow In' to match the 'Minimum Hydrant Flow' in the lower risk categories.

Pumping Appliances

Effective firefighting of any large fire requires a pumping appliance, which is defined as a, "*self-propelled vehicular appliance equipped to project one or more streams of water on to a fire*" (SANS, 2003). As revealed in section 3.3, SANS 10090 section 5.2.2.2.1 requires that firefighting appliances should comply with NFPA1901, '*Automotive Fire Apparatus*'. A fire pump is defined in the NFPA 1901 (2003) as a water pump with a rated capacity of 1000 L/min or greater at 1000 kPa net pump pressure that is mounted on a fire apparatus and used for firefighting (National Fire Protection Association, 2003).

Table 4-1 shows the SANS 10090 'Weight of response at fires' requirements. Additionally, according to clause 5.2.2.2.3 of SANS 10090, "*In the case of brigades which have more than one station, the number (see Table 4-1) of appliances allotted to any particular substation will depend on the fire-risk category in the area assigned to the station* (SANS, 2003)."

Table 4-1 - Weight of response at fires (SANS, 2003)

Risk Category	Minimum Number of Pumping Units	Minimum Manning level per appliance	Minimum pumping capacity of each unit (L/min)
A - Central business districts and extensive commercial and industrial areas normally found in cities and large towns (areas where the risk to life and property due to fire occurrence and spread is likely to be high).	2	5	3850
B - Limited central business districts, smaller commercial or industrial areas normally associated with small towns and decentralized areas of cities and large towns (areas where the risk to life and property due to fire occurrence and spread is likely to be moderate).	2	4	3850
C - Residential areas of conventional construction.	1	4	2250
D - Rural areas of limited buildings and remote from urban areas.	1	4	2250
E - Special risk areas.	As determined by individual risk assessment		

Interviews with personnel involved in the fire department's fleet management indicated that there is currently a severe shortage of operational pumping appliances within the City of Johannesburg. Daily, the fire department produces a detailed fleet allocation inventory, commonly referred to as a 'Fire Engine Strength Report', for the city. This report records the following appliance information for each station and district: fleet number; vehicle registration; product code; vehicle class; vehicle status; licence expiry date; problem/discretion notes; dates of admission for repairs or maintenance; general comments; and the name of the service provider. The full Fire Engine Strength Report for the 9th of January can be found in Appendix D. In this report, it is observed that within the 28 stations recorded, only 11 'first turn out' (pumping units) vehicles are in operation with 2 on standby in the reserve fleet. Of the 104 registered vehicles, only 32 are currently operational with 61 as recorded 'breakdown/repairs' and 11 as 'panel beaters'.

Assuming Midrand, Sandton, Berea, Central, Randburg, and Rosebank stations are classified as either risk category A or B stations, table 4-1 shows that SANS 10090 requires a minimum of 34 active pumping units within the City of Johannesburg. Additionally, clause 5.34.3 of SANS10090 requires the presence of a reserve fleet that would total 8 additional standby pumping appliances (SANS, 2003). By comparing the fleet on the ground with what is expected, as articulated in SANS 10090, there is only a 31% realisation of the required number of pumping units at the time of this study. Early in 2017, it was publicly announced that the city will be purchasing 29 new fire engines to address this well publicized shortage. The order included (Manda, 2018):

- 6 x P410 CP31 Scania Pumpers
- 6 x P360 CP28 Scania Pumpers
- 11 x 1828 Mercedes-Benz Pumpers
- 6 x Pierce PUC.

However, on the 19th of November 2017, the City of Johannesburg cancelled the order after it was alleged that the bid evaluation committee had forged documents (African News Agency, 2017). The city is unquestionably facing a firefighting equipment shortage crisis which will continue to cripple the city's entire fire department until resolved through the purchase of additional pumping appliances.

In consultation with the firefighting department's directive, 'Corporate services and academy', it was noted that in 2003 the City of Johannesburg acquired a fleet of 15 brand new pumping units. It is the majority of this fleet which make up the 13 currently operational appliances discussed above. Table 4-2 shows the 2003 fleet's water tank volumes and pumping capacities of each vehicle type. More detailed specification sheets can be found in Appendix E.

The 2003 edition of NFPA 1901 (National Fire Protection Association, 2003) is a general update of the 1999 edition. However, a significant change in the editions is that the minimum pump size for a fire pump on pumper was raised in the 2003 edition to 2840 *L/min* (750 gpm), and the minimum water tank size was set at 1900 L (500 gal). It is noted that the 2003 fleet of pumping appliances generously exceeds the NFPA 1901 and SANS

10090 performance requirements. However, according to clause 5.3.2.2 of SANS 10090, pumping appliances should not be operational after 15 years in service. This makes the current and entire fleet due for replacement now (2018) (SANS, 2003). Should replacement of the entire fleet not be realised in 2018, the city's entire fleet will legally absolve and the firefighting capability severely compromised.

Table 4-2 - 2003 Pumping Unit Feet Specifications

Vehicle type	Qty.	Tank Volume (litres)	Pump Capacity (L/min)
Industrial	2	3 800	5 700
Tanker	6	6900	4700
Tele-Squirt Boom	7	1900	4700

As regards understanding the history and formation of fire flow design values, anonymous interviews within the 'Proactive services and fire safety' directorate revealed that there is no clear understanding as to where the current fire flow values presented in the Johannesburg 'Emergency Services' by-laws were derived from. Respondents indicated that the fire flow values may have been derived heuristically a long time ago.

Fire brigade services need to insist on the empowerment of active task teams whose responsibility it is to enforce the applicable fire safety legislation. Furthermore, specific water supply quantities cannot be enforced due to noncommitment disclaimers present in municipal by-laws. These disclaimers, which protect water services providers from legal action, undermine the important influence of design standards.

It is recommended from this study that a firmer stance be taken in local by-laws to hold water providers accountable to their supply volumes and reliability. It is essential that high ranking community officials, from the municipal council, to the relevant water and fire departments provide the means and opportunity to both regularly monitor the WDS performance and enforce local by-laws which ensure that the correct design criteria are used for WDS design.

Chapter 5

5 FIRE INCIDENT REPORTS

This chapter responds to the aim of objective III (i.e. to present actual fire flow volume and flow rate data recorded in the city of Johannesburg and compare them to the requirements specified in South African design standards and municipal by-laws).

A fire incident report (or call slip) is a physical document that is filled out and submitted to the central EMS headquarters after every fire incident that is responded to by the fire brigade. This chapter deals with the capturing and analysis of the information contained within these reports. Details captured within these slips include: a description of the fire type; the duration of the call out; the quantity of water used; and the appliances from each station used during the incident. On site calculations are carried out to estimate the total fire flow volume released during the response. These calculations account for water derived from fire trucks, water tankers, and hydrants. The volume or flow rate is determined by reading meters installed on the pumping appliance(s). An example of a typical fire incident report slip can be found in Appendix F. The fire incident report data presented in this chapter was obtained from the Corporate Services and Academy directive who use the information for billing purposes. The reports are exclusively from fire incidents within the City of Johannesburg and account for the past 10 years of billable (incidents that the fire department can charge the property owner for their services rendered) fire incidents.

5.1 PREVIOUS FINDINGS

While limited data on actual fire flow measurements has been published in South Africa, the majority of what has been has almost all come out of the Western Cape. van Zyl *et al.* (2011) reports on a study which examined water used for fire fighting between January

2005 and April 2010. The data presented by van Zyl *et al.* (2011) was obtained from the fire services of the greater Cape Town area and consisted of 23 747 fire event records. Of these, 66.3% of the events were classiffied as vegetation fires, 30.0% as residential, 2.5 % as commercial and 1.2% as industrial. The paper shows that fires in industrial areas have the longest durations and require the greatest fire flow volumes and flow rates to extinguish while commercial areas have lower. Residential areas exhibit the lowest flow rate and volume values for these parametes (van Zyl, et al., 2011). Figure 5-1 persents the cumulative probability plot for all fire flow rates and volumes from the greater Cape Town Area as presented in the paper by van Zyl *et al.* (2011).

A report by Myburgh in 2012 presents fire flow data from 2010 and 2011 that was obtained from 3 rural municipalities within the Western Cape. The data was sorted into five different fire categories. Table 5-1 shows the average required fire flow for each category in L/min. The three highest flows that were reported over the study duration were 1 200 L/min, followed by 555 L/min and 416 L/min, all of which were structural fires, both residential and industrial (Myburgh, 2012).

Table 5-1 - Average required fire flow for each category in L/min (Myburgh, 2012)

	Informal Settlements	**Automobile accidents**	**Structural fires (residential and industrial)**	**Veld, grass, and refuse**	**Special Services**
Municipality 1	130.4	96.7	143.9	74.2	0
Municipality 2	90.21	74.3	75.02	87.26	169.6
Municipality 3	57.2	37.9	53.8	44.6	58.4

In 2014, another paper out of the Western Cape by Myburgh & Jacobs, reported on actual fire flow data from five small towns in three municipalities. Figure 5-2 shows the cumulative probability plots for all 554 fire flow volumes and all 546 fire flow rates that were obtained. The flow rates are notably and expectantly lower for the small towns than those of urban Cape Town presented by Van Zyl *et al.* (2011).

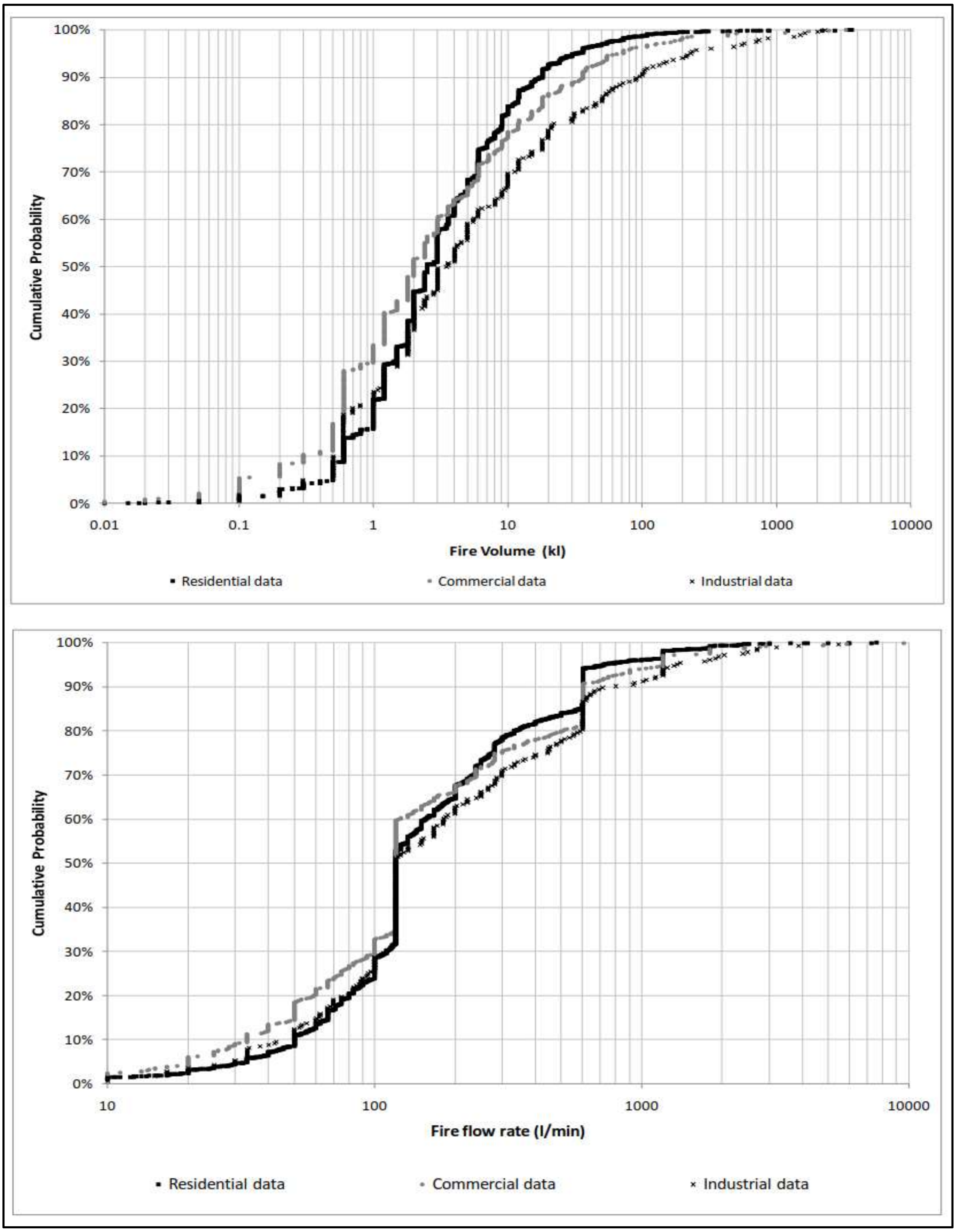


Figure 5-1 - Cumulative probability plot for all fire flow rates and volumes in the greater Cape Town Area from 2005 to2010 (van Zyl, et al., 2011)

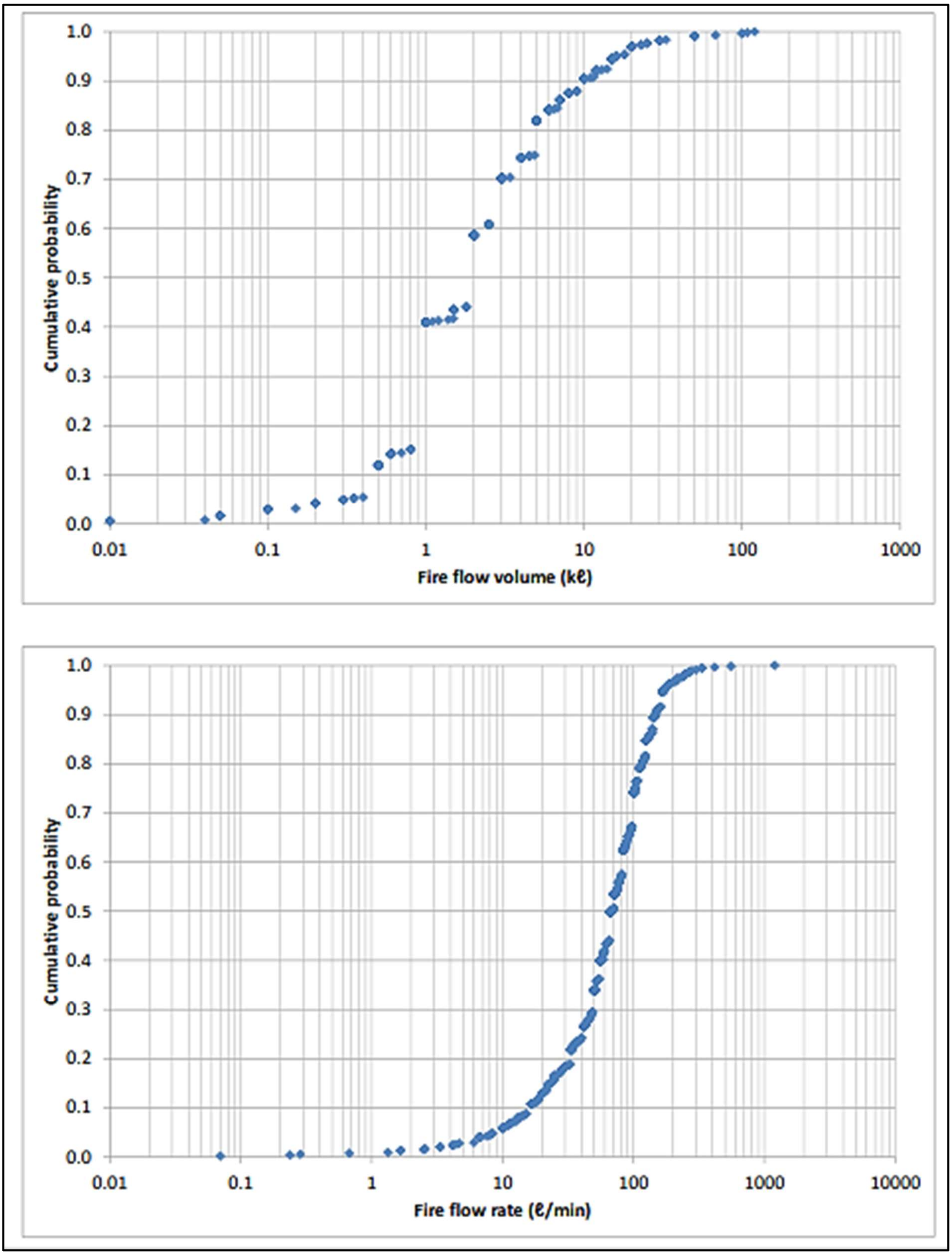


Figure 5-2 - Cumulative probability plot for all fire flow rates and volumes from three rural municipalities in the Western Cape (Myburgh & Jacobs, 2014)

5.2 METHODOLOGY

Every callout responded to by the fire department is captured in a fire incident slip and submitted to EMS headquarters. Not all reports are digitally captured. It is an observation of this study that only billable callouts are digitally captured in spreadsheets by EMS. It is these billable incidents that have been consolidated and presented in this chapter. Figure 5-3 identifies some of the 30 firestations in operation within the greater Johannesburg region from which fire report slips were obtained.

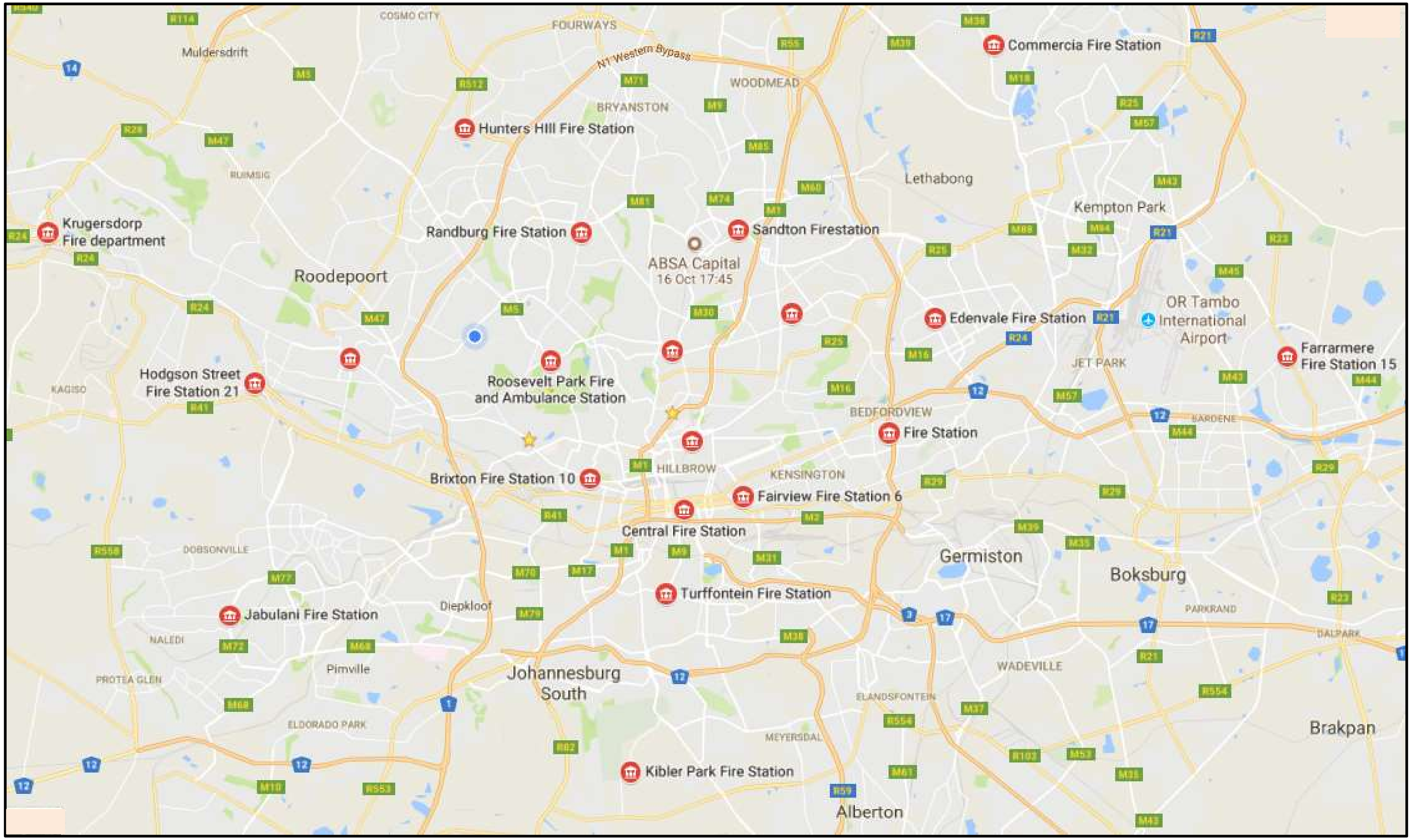


Figure 5-3 - Johannesburg Fire Stations from whom fire incident reports were received (Google Maps, 2017)

Table 5-2 shows a typical example of the information captured from a single billable incident report slip which was used for invoicing purposes. In the example presented in table 5-2, four different stations responded to the emergency with a total of 30 kl of water being released. The Malvern unit was onsite for the longest duration of 2 hours and 27 minutes. These are not precisely measured values. However, they give a reasonably accurate indication of the volume of water used and the time over which it was released. Using VBA macros, the following information was extracted from individual invoices and consolidated in a single data file for analysis: date of incident (month and year); arrival and release time; and total water volume applied

More detailed information describing actual and changing flow rates, from the fire hose and the reticulation main, over the duration of the fire attack is not captured on incident reports. An assumption was made to enable a consistent flow rate calculation for the available information and this was that fire flow rates were assumed to be constant over the on-scene duration. This produces what is expected to be an average flow rate per incident and would most likely underestimate the actual peak flow rate during the attack. This average fire flow rate per incident was calculated as follows:

$$Average\ Fire\ Flow\ Rate\ = \frac{Total\ Fire\ Flow\ Volume}{Release\ Time - Arrival\ Time}$$

This study obtained 4556 billable incidents, from 1 January 2006 to 30 September 2017, from Johannesburg EMS. Of these incidents, 697 are recorded as no water use incidents. The remaining 3859 billable water use incidents (2006/01/01 – 2017/09/30) are those on which this study provides an analysis on. Incidents such as shack and veld fires, whereby no client can be charged for the water used or services rendered, are classified as non-billable and thus not included in data set analysed.

Table 5-2 - Typical information captured from a billable fire incident report slip to be used for invoicing

Vehicles							Personnel				Water			Total Amount
Stations	**Vehicle Description**	**Arrival Time**	**Release Time**	**Hours**	**Rate per hour**	**Amount**	**Hours**	**Rate**	**No of Personnel**	**Amount**	**Rate per kilo litre**	**No of kilo litre**	**Amount**	
Turffontein	TP 02	17h15	19h33	2	R 687,94	R 1 375,88	2	R 296,80	4	R 2 374,40	R 17,60	30	R 528,00	**R 4 278,28**
Malvern	BP 07	17h33	20h00	2	R 687,94	R 1 375,88	2	R 296,80	4	R 2 374,40	R 17,60	0	R 0,00	**R 3 750,28**
Kibler Park	Eng 03	17h19	19h33	2	R 687,94	R 1 375,88	2	R 296,80	4	R 2 374,40	R 17,60	0	R 0,00	**R 3 750,28**
Turffontein	SC 02	17h18	19h33	2	R 269,24	R 538,48	2	R 296,80	1	R 593,60	R 17,60	0	R 0,00	**R 1 132,08**
						R 4 666,12				**R 7 716,80**			**R 528,00**	**R 12 910,92**

Vehicles	R 4 666,12
Personnel	R 7 716,80
Water/Foam	R 528,00
Grand Total	**R 12 910,92**

5.3 RESULTS AND DISCUSSION

The scatter plot seen in figure 5-4 shows the magnitude and distribution of the 3859 fire flow volumes recorded from January 2006 to September 2017. Similarly, figure 5-5 shows the scatter of fire flow rates for the same period. To gauge the validity of the incidents with extremely large fire flow volumes (taken to be greater than 300 kl) and fire flow rates (taken to be greater than 1000 L/min) the fire event characteristics (such as: duration; number of responding stations; presence of fire safety officials; and fire location) were individually examined. This exercise identified the incident circled in figures 5-4 and 5-5 as a likely data capture error. Unlike the other high fire flow incidents examined, the incident in question did not bare the same characteristics as the other high fire flow incidents. The erroneous data point identified is a suburban residential property which was responded to by only a single fire truck that was on the scene for less than 2 hours. In contrast, the 800kl incident in September 2016 (the largest fire flow volume in the data set) was responded to by 6 different fire stations with fire safety officials also deployed and was recorded to have lasted over 15 hours. It is thus assumed to be an accurate and valid data point despite its extreme magnitude because its various event characteristics all match those of an extremely large fire incident.

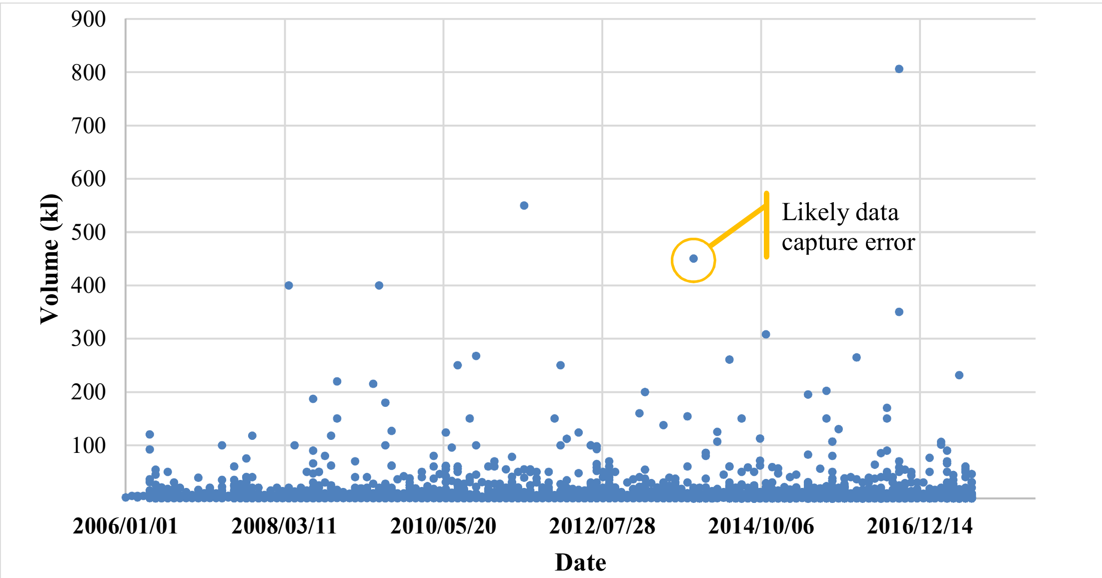


Figure 5-4 - Scatter plot of 3859 fire flow volumes for all incidents that took place from January 2006 to September 2017

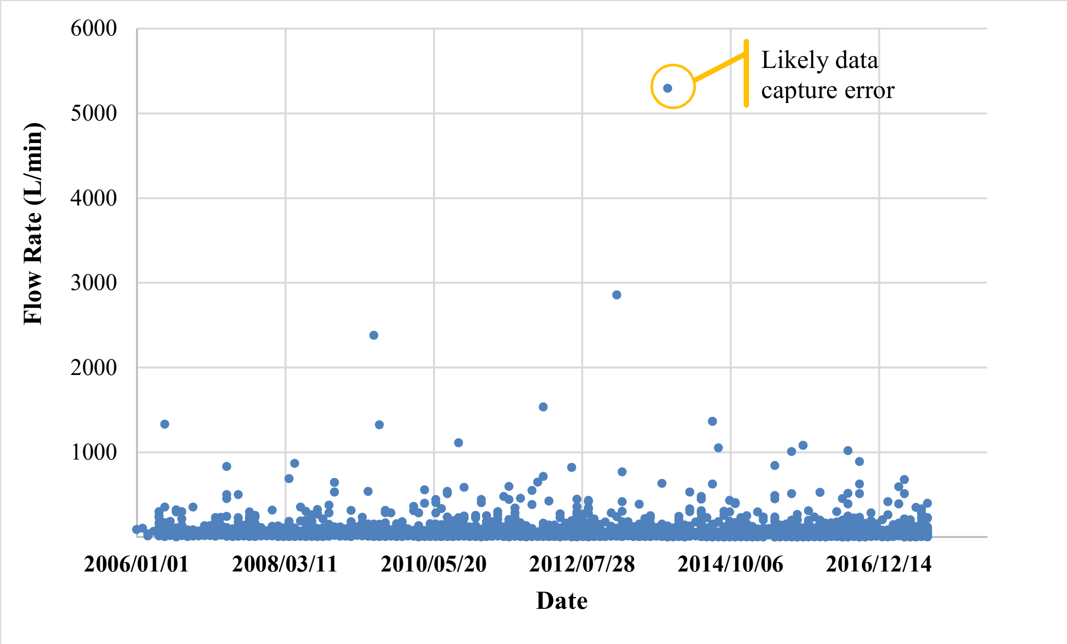


Figure 5-5 - Scatter plot of average fire flow rates for all incidents that took place from January 2006 to September 2017

Figure 5-6 presents the same scatter plot shown in figure 5-5 with the addition of South African guideline recommendations super imposed. Presented on the left-hand side of figure 5-6 are the SANS 10090 'fire flow in' as well as the 'minimum flow per hydrant' requirements for the various SANS risk categories. Similarly, down the right-hand side of figure 5-6 are the Red Book 'fire flow in' and 'minimum flow per hydrant' requirements for the its various risk categories. In both cases the superimposed solid line indicates fire flow in whereas the dashed line indicates minimum flow per hydrant. Figure 5-6 reveals that over the ten-year period not a single fire incident in the City of Johannesburg recorded an average flow rate greater than 6000 L/min. Consequently, this implies that there has not been an incident whose average fire flow rate would be classified within the fire flow in SANS 10090 risk category A, B or C nor the fire flow in the Red Book high risk or medium risk categories. Over the ten year period only two incidents required average flow rates greater than 2000 L/min and are thus between the fire flow recommended for category C and the minimum fire flow per hydrant for categories A, B and C.

Regarding the Red Book, only three incidents recorded average flow rates greater than 1500 L/min and are thus the same value as the minimum fire flow per hydrant for the Red Book high & moderate risk category. The study data also clearly shows in figure 5-6 that the vast majority of billable average flow rates fall well below both the SANS 10090 and Red Book minimum flow rates per hydrant.

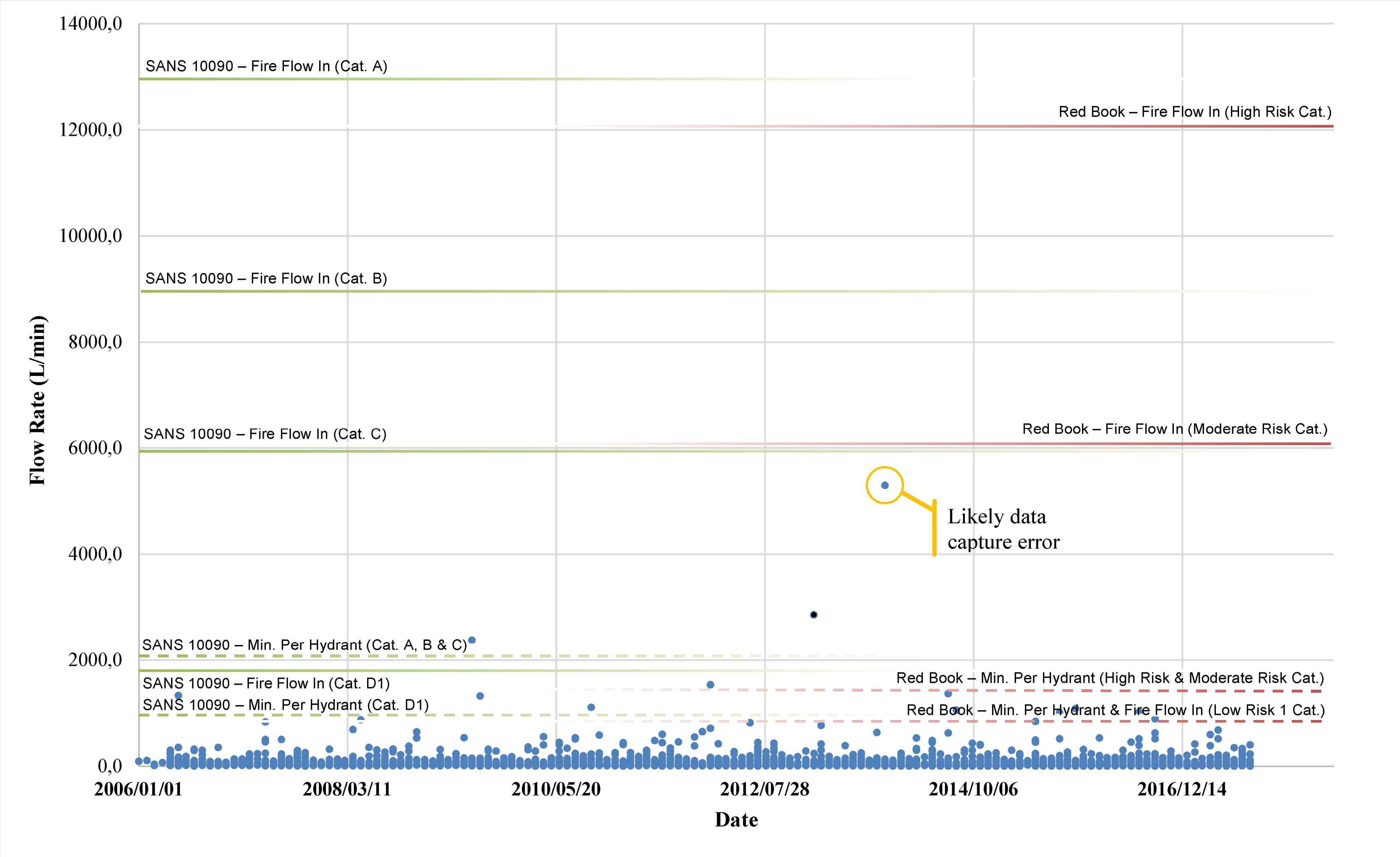


Figure 5-6 - Scatter plot of average fire flow rates for all incidents that took place from January 2006 to September 2017

Table 5-3 provides an indication of the high degree of spread observed in the fire flow incident reports. The significantly higher standard deviation of the fire flow rate when compared to the fire flow volume can be attributed to the fact that an additional factor influences fire flow rates - the duration of the actual firefighting.

Table 5-3 - Measure of central tendency

	Fire Flow Volume (kl)	Average Fire Flow Rate (L/min)
Mean	55,14	94,90
Median	18,75	46,15
Standard Deviation	96,81	170,93
Max	806,00	2857,14
Number of Standard Deviations from Median to Max	7,33	16,45

*The erroneous data point identified in figures 5-4 & 5-5 has been omitted from the data set represented by this table

Table 5-4 provides an indication of how the large spread of results (shown in table 5-3) skews the average fire flow volume and rate recorded. By removing the three highest incidents, which account for 0.08 % of the total data size, a decrease in the average volume and flow rate is observed to be approximately 5%. Removing the seven highest values, accounting for 0.18% of the data, further deceases the average volume and flow rate by 9.35% and 6.44 % respectively.

Table 5-4 - Outlier Sensitivity Analysis

Sensitivity Test	Most Extreme Incidents removed	% Reduction in number of events	Average fire flow volume (L/min)	Average Flow rate (L/min)	% Decrease in Average fire flow volume	% Decrease in Average fire flow rate
Base Line	0	0	8,89	63,23	0	0
1	3	0,08	8,43	60,54	5,19	4,25
2	5	0,13	8,23	59,82	7,48	5,39
3	7	0,18	8,06	59,16	9,35	6,44

Figure 5-7 and figure 5-8 present the cumulative probability plots for all 3859 incidents. The curves observed are similar to those presented by van Zyl *et al.* (2011), as shown in figure 5-1, for a similarly large metropolitan municipality. However, when compared to the plots by Myburgh & Jacobs (2014) (figuer 5-2), it is seen that the smaller rural municpalities have comparatively lower fire flow volumes. It is noted that the shorter duration of the data period presented by Myburgh & Jacobs (2014) most likely statisticly exludes the occurence of high fire flow volume incidents. Furthermore, the fewer number of large structures in small Western Cape towns would expectantly result in fewer large fires reported by Myburgh & Jacobs (2014) compared to the City of Johannesburg.

Fire flow volumes recorded within the incident report slips are commonly rounded to whole numbers. For this reason some data points overlap or bunch near round numbers as shown in figure 5-7. Different, figure 5-8 graphically shows more data points because the rounded values have been devived by time producing more unique values. The two volumes that represent most of these overlapping points are 1 kl with 964 instances, and 2 kl with 565 instances.

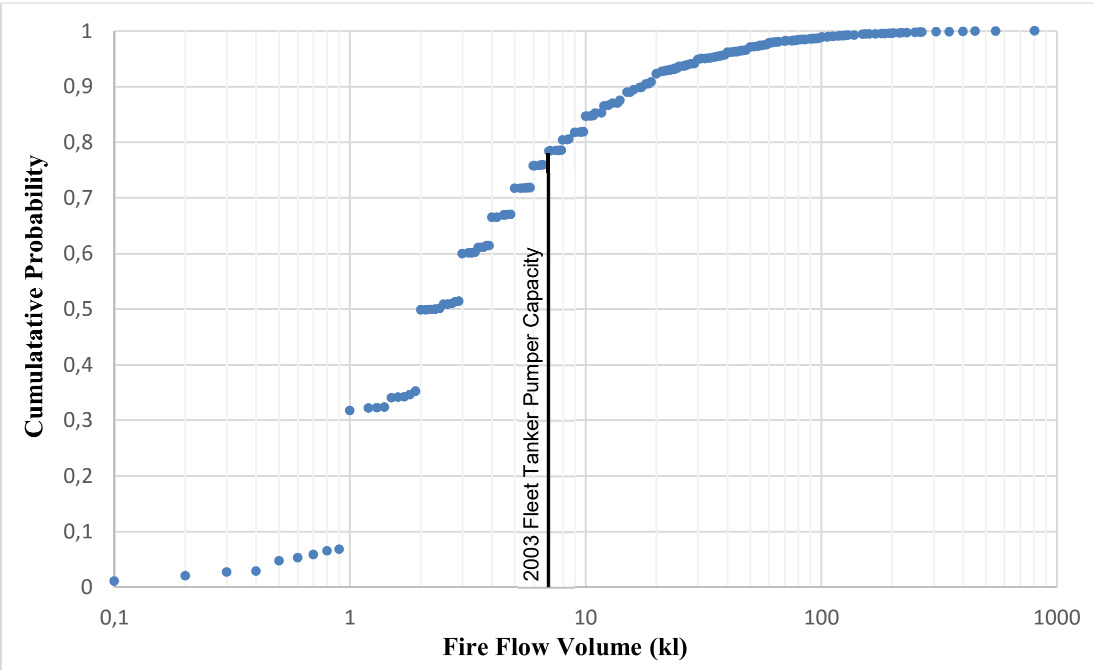


Figure 5-7 - Cumulative probability plot for all fire flow volumes

Figure 5-7 indicates that 75% of fire incidents require less than 6.6 kl of fire flow volume which is less than the capacity (6.9 kl) of a conventional pumping tanker appliance from the 2003 fleet (table 4-2). This observation thus infers that 75% of fire incidents in the City of Johannesburg can be managed without the use of municipal fire hydrants if a suitable first response appliance is dispatched. This observation further emphasises the importance of maintaining a sufficiently large fleet of first responding pumping appliances within the City of Johannesburg.

A comparison between the data presented by van Zyl, *et al* (2011) and the cumulative fire volumes obtained from Johannesburg is presented in Figure 5-8. Figure 5-8 shows that the data captured from the Johannesburg fire department resembles a distribution most like that of the residential data captured in Cape Town (CPT). This is especially the case the upper probability range of 50% to100%. While the details of the Johannesburg data do not enable the fire event volumes to be classified as was done by Zyl, *et al* (2011) it is believed that the vast majority of events were indeed of the residential type.

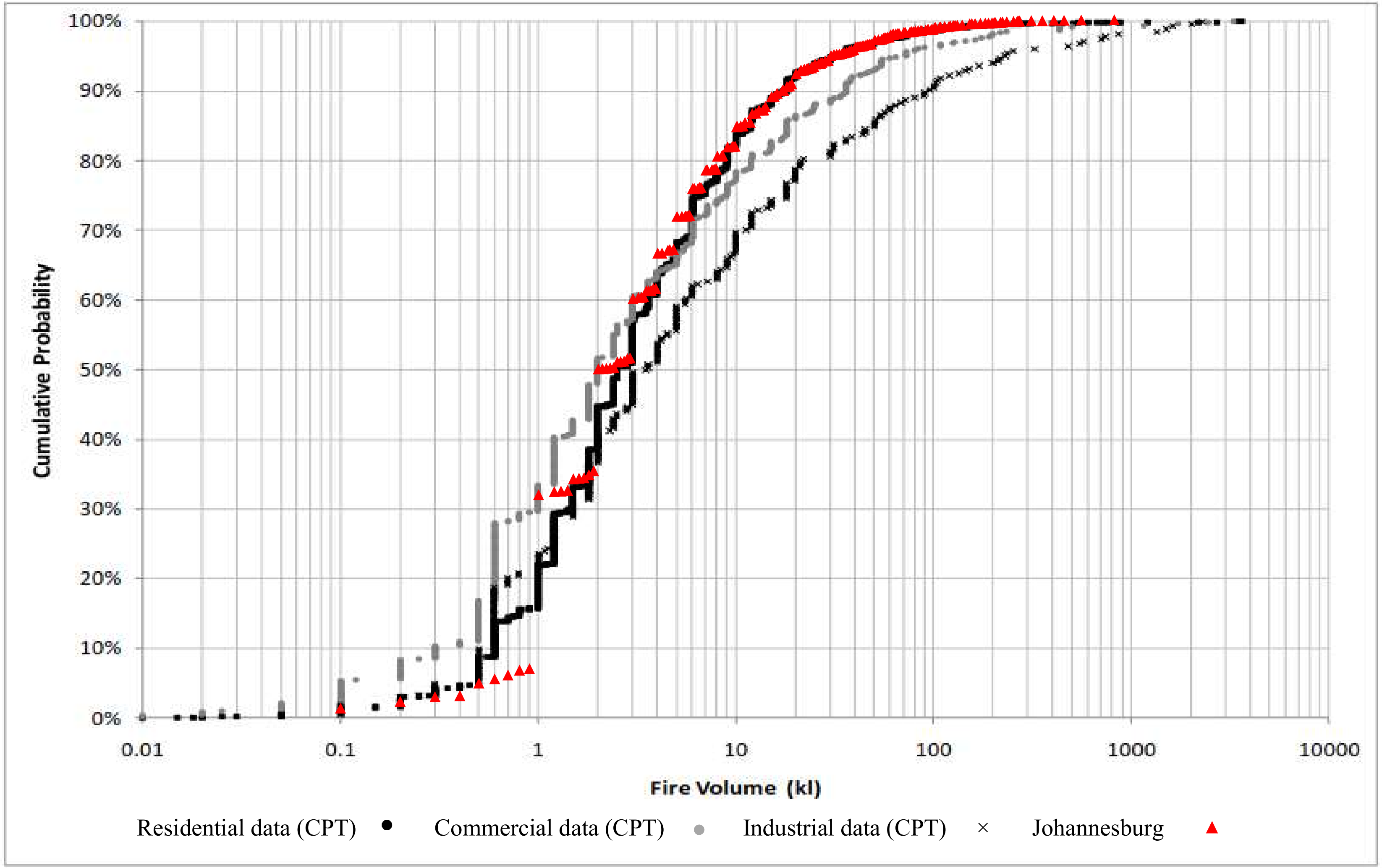


Figure 5-8 - Cumulative probability plot for all fire flow volumes in the greater Cape Town Area from 2005 to2010 (van Zyl, et al., 2011) VS plot for fire flow volumes in Johannesburg from 2006 to 2017.

Figure 5-9 presents the cumulative probability plot of each event's average flow rate, with the South African design guideline recommendations superimposed. The lables above the figure indicate SANS 10090 recommendations and the lables below indicate the Red Book's. Figure 5-9 indicates that 99.9% of all fire incidents demand an average fire flow rate less than 1200 L/min, which is the minimuim hydrant flow rate for the lowest fire risk categoty in SANS 10090. Likewise, 98% of all fire incidents demand an average fire flow rate less than 350 L/min, which is the minimuim hydrant flow rate for the lowest fire risk categoty in the Red Book. Both of these extremely high percentage numbers, along with the observaions made in section 3.3, suggest that there existes scope within the South African guidelines to reduce the current minimum fire flow requirements whilst maintaining adequate levels of safety.

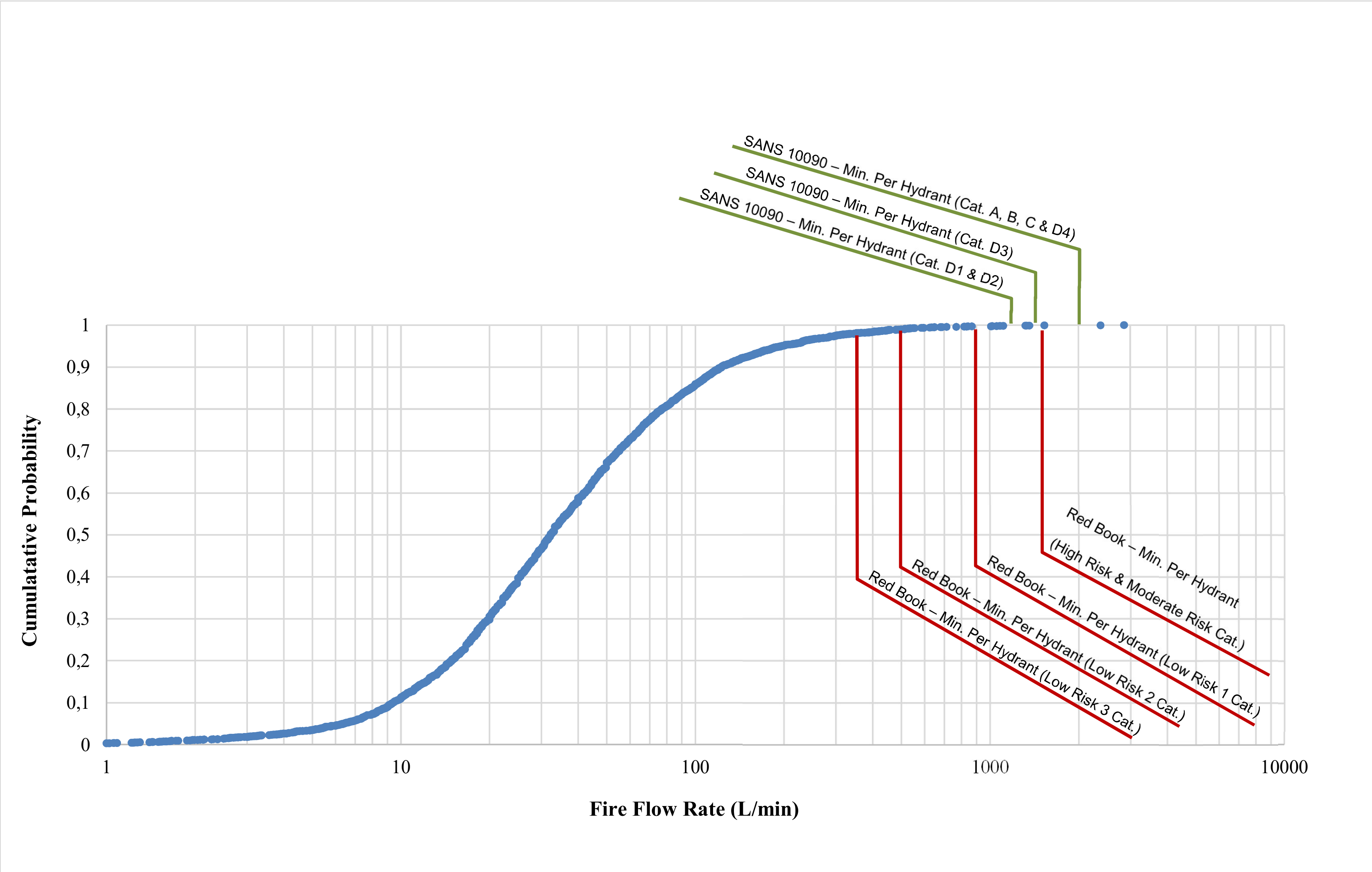


Figure 5-9 - Cumulative probability plot for all fire flow rates

To better understand the need for safey factors in firefighting, the following results, presenetd in figures 5-10, 5-11 and 5-12, concerning the size of a fire in relation to its duration and frequncy, provide meaningful insight. Figure 5-10 displays the variation of incidents throughout a year. The values indicated are the averaged number per month over the period January 2006 to September 2017. The green bars represent the average number of incidents occurring in each month over the course of a year. In blue, it shows the average fire flow volume per incident each month. An expected seasonal trend is observed with a notable rise in incidents per month from June to October which are typically low rainfall months in Johannesburg. While average fire flow volume ranges between 7 – 12 kl per incident, there is no observable trend over the course of the year. This implies that while the frequency of fire occurrence is strongly related to climatic conditions, the volume of water used to quench the fires, and by implication, the size of the fires, is not a function of climatic conditions.

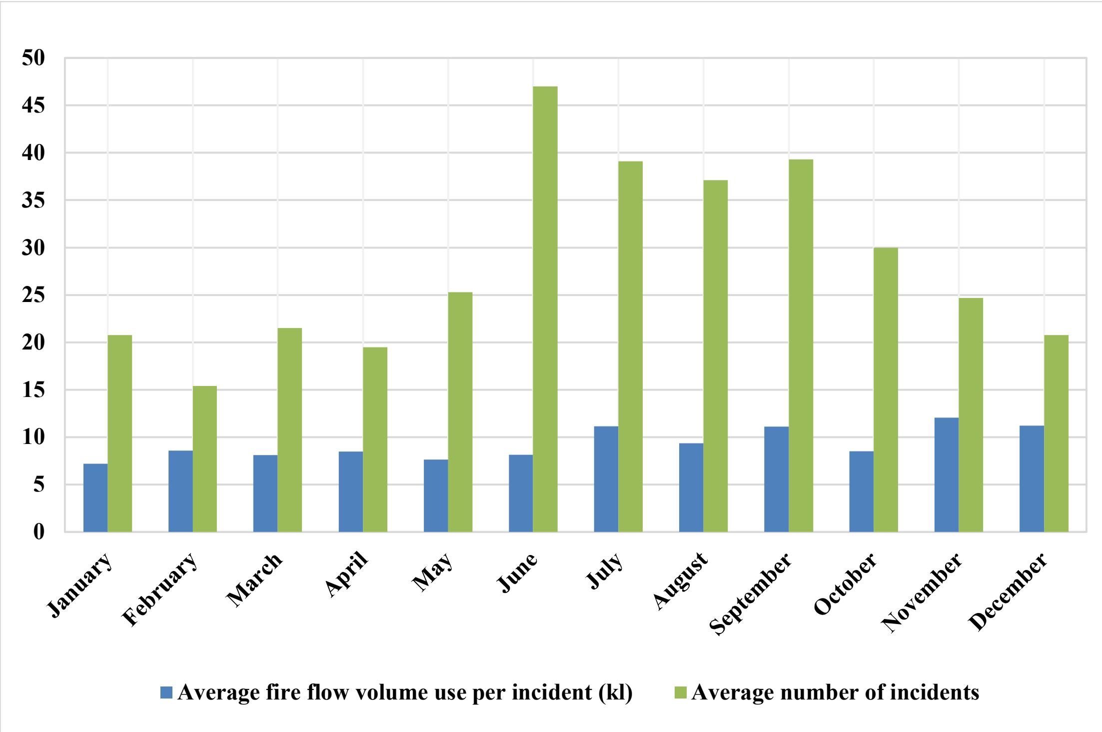


Figure 5-10 - Average fire flow volume and number of incidents per month from 2006 to 2016

Figure 5-11 displays the occurrence of incidents through the course of a day averaged over the period January 2006 to September 2017. In green, it shows the percentage distribution of incident start times. Three peaks, regarding the time of fire occurrence, are observed at 01h00, 15h00 and 20h00. The highest of the three being at 01h00 with 230 (5.9%) fire incidents being reported between the hours of 24h00 and 01h00. The blue line shows a residential water demand pattern published by van Zyl (1996), later adapted by Scheepers (2012). The peak factor line shows primary peak domestic usage at 6h00 and secondary at 16h00-17h00. When compared to the occurrence of fires it is observed that peak fire occurrence does not correspond with peak water demand in the city of Johannesburg. Importantly, the contrary is true, the lowest observed fire occurrence times are around 6h00 and 16h00. This is an beneficial relationship that results in less strain on the WDS.

Figure 5-12 displays the average fire flow volume and duration over the course of a day. The top line, which displays the average fire flow volume recorded per incident, shows that the largest water use period in the day is at 01h00 which is also when the largest numbers of fires are reported to occur (figure 5-10). The bottom line of figure 5-12 shows the average firefighting duration for an incident starting at any given time. Figure 5-12 suggests that the size and duration of a fire does not exhibit any significant trend over the course of the day.

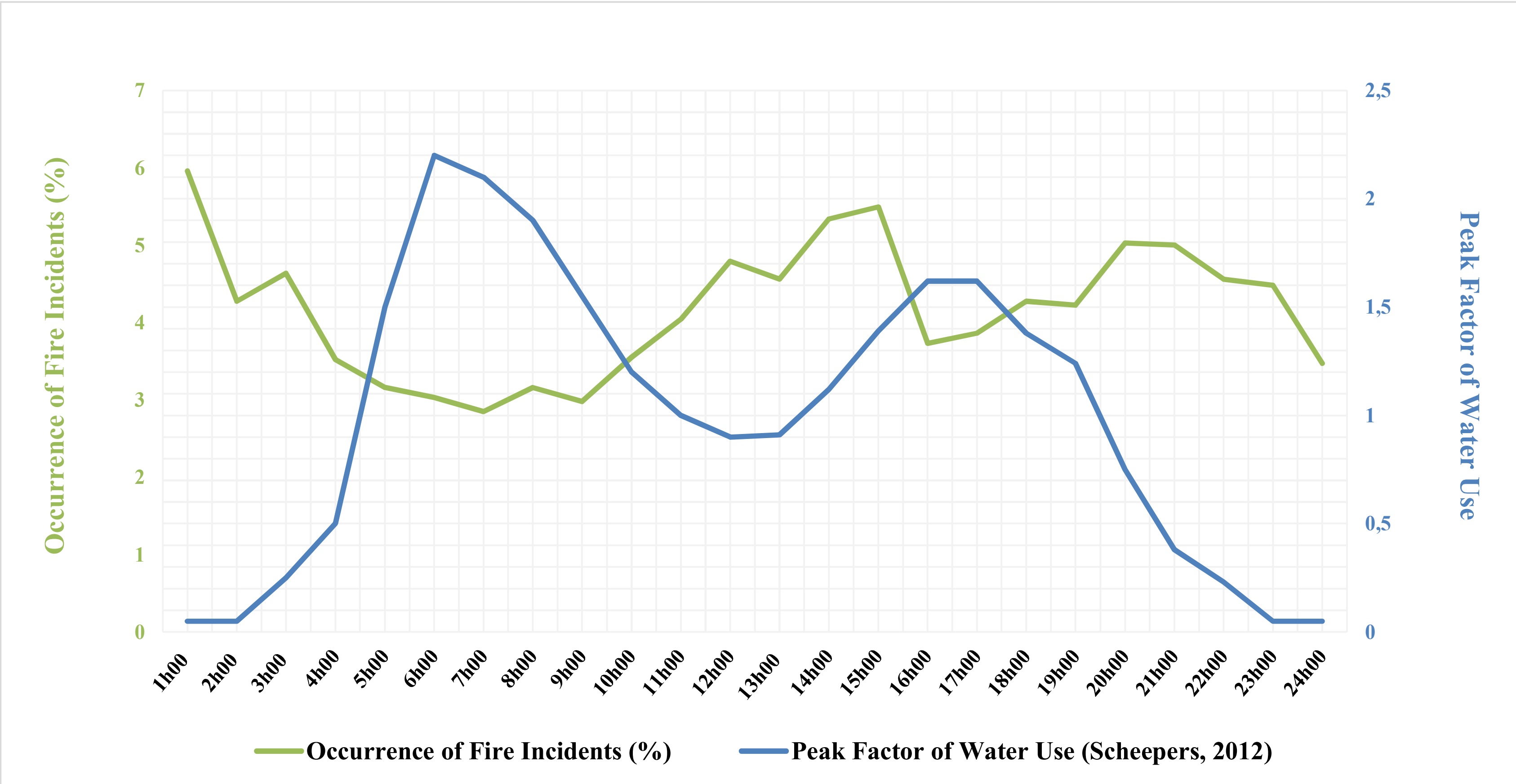


Figure 5-11 – Occurrence of fires vs residential peak water demand pattern

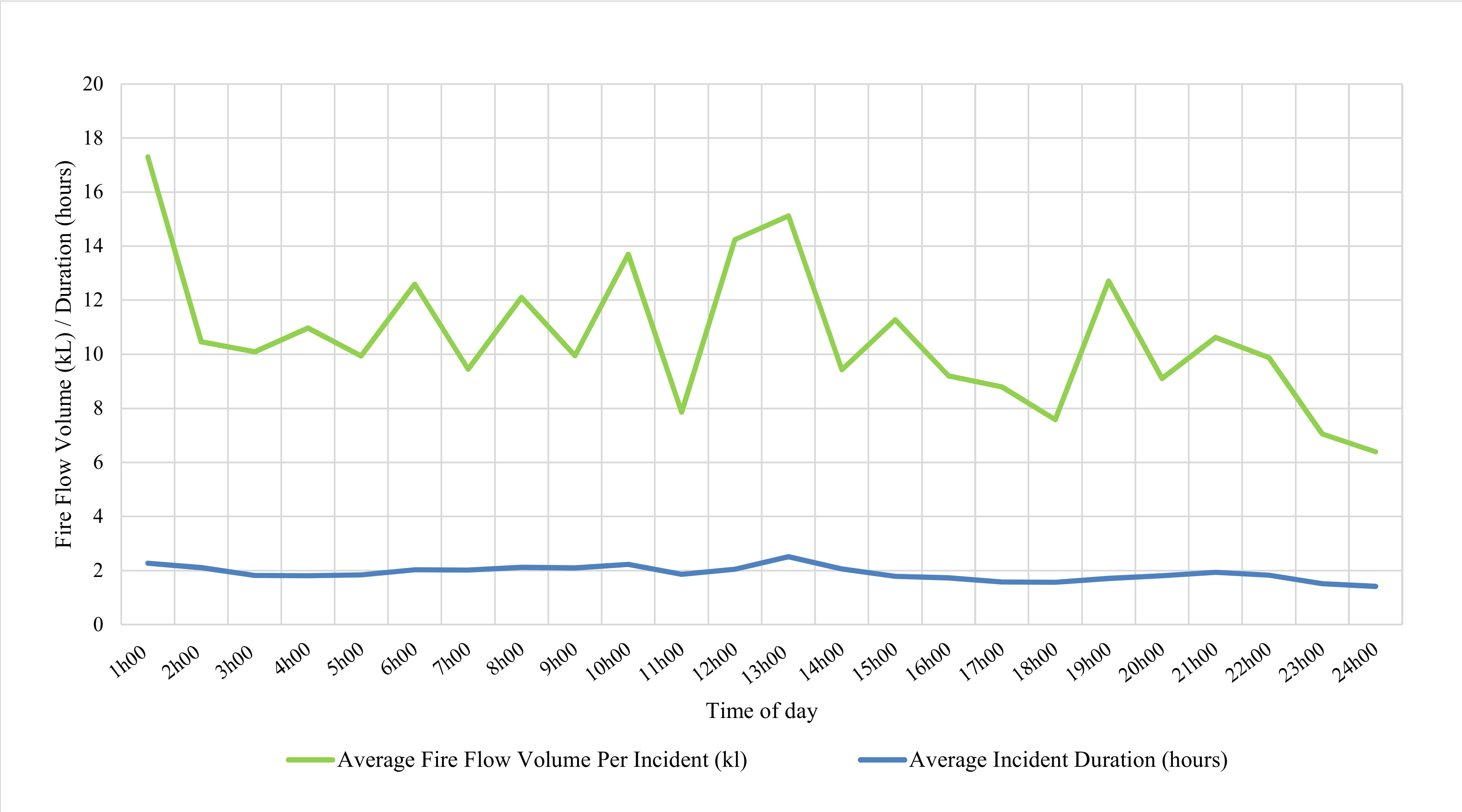


Figure 5-12 - Average fire flow volume and duration over a day

The American NFPA 1142 - 'Standard on Water Supplies for Suburban and Rural Firefighting' recommends the minimum capabilities of a fire department to deliver water (National Fire Protection Association, 2006). This recommendation is tabled in Figure 5-13 and enables an interesting comparison to be made between the study's data to the American National Standards. The data shown in figure 5-14 confirms the trend suggested in table 4.6.1 of the NFPA 1142 (Figure 5-12), that, greater fire flow volumes require greater fire flow rates.

4.6 Water Delivery Rate to the Fire Scene.

4.6.1 The fire department shall develop the capability to deliver the amount of water determined in accordance with Sections 4.2 through 4.5 to the incident scene at the rate shown in Table 4.6.1.

Table 4.6.1 Minimum Capability of Fire Department to Deliver Water

Total Water Supply Required		Rate Water Is Available at the Incident	
gal	L	gpm	L/min
<2,500	9,459	250	950
2,500–9,999	9,460–37,849	500	1,900
10,000–19,999	37,850–75,699	750	2,850
≥20,000	≥75,700	1,000	3,800

4.6.2 The water shall be available on a continuous basis at the rate shown in Table 4.6.1 within 5 minutes of the arrival of the first apparatus at the incident.

Figure 5-13 – NFPA 1124 Requirements for Water delivery rate to the fire scene (NFPA, 2007)

The horizontal lines superimposed on figure 5-14 indicate the minimum fire flow rates required by the NFPA 1142 for the corresponding fire flow volume range. The data points represent the fire incidents within the city if Johannesburg from January 2006 to September 2017. It is seen in figure 5-14 that the actual fire flow rates, except for a single incident (blue point above the blue line), plot significantly lower than the NFPA 1142 requirements.

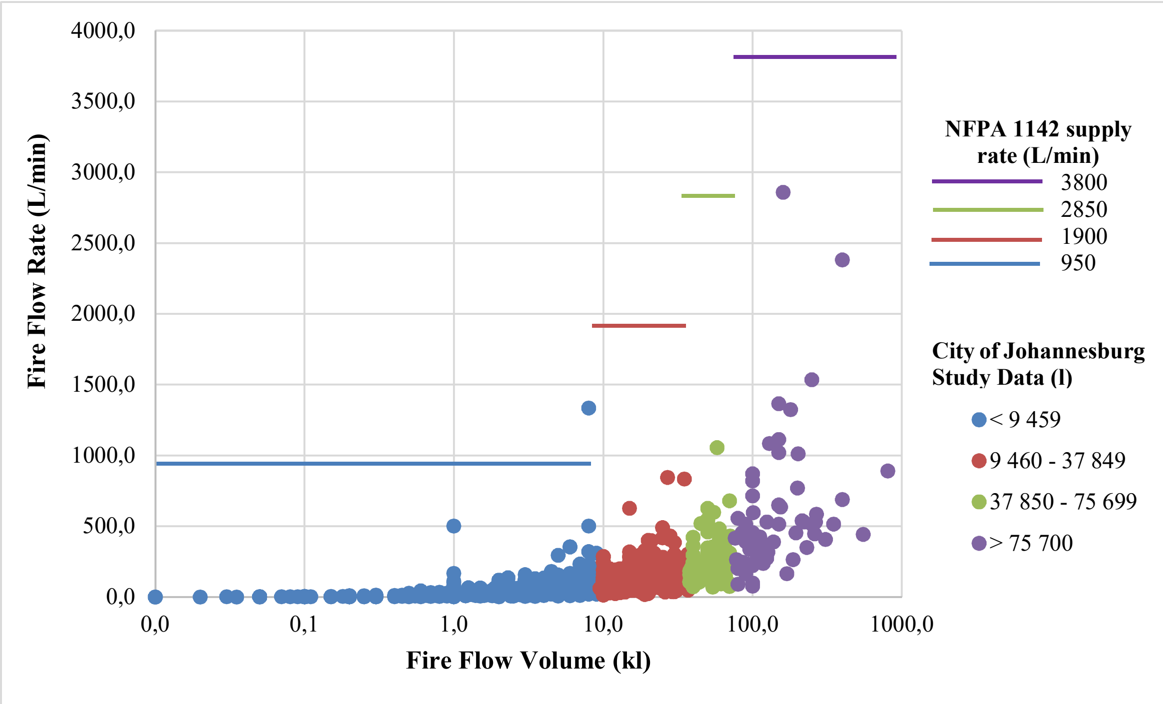


Figure 5-14 - Comparison of NFPA requirements to study data

Chapter 6

6 RECOMMENDATIONS & CONCLUSIONS

This chapter responds to the aim of objective IV (i.e. To recommend practical adjustments to the South African design guidelines and municipal by-laws (based on the already well-established national fire risk categories) formed from the observations and conclusions made from objectives I, II and III)

This study investigates the following question*: Are the current South African standards and design guidelines pertaining to fire flow provision appropriate for modern firefighting techniques and do they ensure the most efficient balance between providing sufficient fire protection and promoting sustainable water use?* This study has found that there is sufficient evidence for a formal review and update of SANS10090 with regard to the recommended fire flow requirements. Furthermore, the study has identified inconsistences and gaps in municipal by-laws which do not adequately specify minimum fire flow supply quantities or reference the relevant guidelines. Thus, recommendations are put forward in this final chapter to summarise and conclude the findings and observations made throughout this study.

6.1 RECOMMENDATIONS & CONCLUSIONS

6.1.1 Legislation

There is little understanding as to where the current fire flow values presented in the Johannesburg 'Emergency Services' by-laws were derived from. It has been expressed by survey participants that they have been continued as a result of their legacy and the lack of local studies to demonstrate a need for change. It is thus a recommendation that these and other legacy guidelines be re-evaluated in light of modern firefighting statistics and practice. Furthermore, national design codes and standards are only lawfully enforceable when clearly stipulated in the governing authority's by-laws.

Currently, specific water supply quantities cannot be enforced due to noncommitment disclaimers present in by-laws. These disclaimers, which protect water services providers from legal action, undermine the important influence of design standards. It is thus a recommendation that a firmer stance be taken in by-laws to hold water providers accountable to their supply volumes and reliability.

6.1.2 Fire Risk Category

As is done in South African guidelines, it is efficient for fire protection purposes to categorise land use areas and building types into different risk profiles. For each risk profile or category, the appropriate level of firefighting infrastructure and services needs to be carefully determined and quantified. The Red Book presents a single set of fire-risk categories to which all its various recommendations are determined by. On the other hand, SANS10090 presents two category sets: the primary set is titled, 'Fire Risk Categories', and the secondary set is titled, 'Possible Fire Sizes'. To prevent the minimum fire flow and the minimum hydrant flow being determined off differing risk categories which is currently possible with the existing SANS10090 risk structures, it is recommend that SANS10090 be accordingly adjusted so both minimum fire flow and the minimum hydrant flow be determined off the 'Possible Fire Sizes' risk categories. This recommendation has been adopted and is shown in table 6-2.

6.1.3 Hydrant reliability and spacing

Recurring hydrant problems that were identified in chapter 4 (the Status Quo Report) include: hydrant usability; hydrant visibility and accessibility; hydrant serviceability; and hydrant spacing. It is recommended that the enforcement of SANS 10090, clause 11.5.2 and 11.5.3, be improved and added to municipal by-laws. The firefighters interviewed expressed the difficulty and consequences of laying the 100mm hydrant supply lines further than 90 m. Furthermore, it is noted that the spacing of hydrants in residential areas in South Africa is notably higher than the other countries. It is recommended that hydrant spacing be limited to a maximum of 180 m for medium to low risk areas in South Africa (see table 6-1). This recommendation is in line with clause 4.35.4 of SANS 10400-T:2011 (SANS, 2011).

Table 6-1 – Hydrant Spacing Recommendation

Fire-Risk Category	Max Distance between hydrants (m)
A	90
B	120
C	180
D1	270
D2	
D3	
D4	
E	* As determined by individual risk assessment

6.1.4 **Design fire flow in and hydrant flow rate**

SANS 10090 requires multiply hydrants to be connected to discharge at the emergency site for the design fire flow to be achieved. However, due to the difficulty and rarity of connecting multiple hydrants during a single incident, it is recommended to reconcile the SANS 10090 'Flow In' to match the 'Minimum Hydrant Flow' in the lower risk (residential) categories as seen in table 6-1. However, the non-residential fire flow values presented in table 6-2 still enable three hydrants to be discharging simultaneously at their minimum flow rate. The fire incident reports presented in chapter 5 show the lowest fire flow rate of 350 L/min being recommended in table 6-2, these values ensure that at least 98% of all incidents in the City of Johannesburg over the past 10 years would be provided for.

Table 6-2 – Recommended Minimum Fire Flow and Hydrant Flow Values

Possible Fire Sizes	Min. Flow In (L/min)	Min. Hydrant Flow (L/min)
Non-residential buildings with divisions not greater than 5000 m².	9 000	2 000
Non-residential buildings having divisions not greater than 2 500 m².	6 000	2 000
Non- residential premises not greater than 1 250 m².	3 600	1 200
Houses > 30 m apart.	350	350
Houses 10,1 m to 30 m apart.	500	500
Houses 3 m – 10 m apart	900	900
Houses < 3 m apart	1 200	1 200

6.1.5 Pumping appliances

From the City of Johannesburg's daily fleet report, it was observed that within the 28 stations recorded, only 13 'first turn out' (pumping units) vehicles are in operation. Of the 104 registered vehicles in the city, only 32 are currently operational. SANS 10090 requires a minimum of 34 active and 8 reserve pumping appliances within the City of Johannesburg. As of the 9th of January 2018, the City of Johannesburg has a 31% realisation of the required number of pumping appliances. In 2003, the City of Johannesburg acquired a fleet of 15 brand new pumping units. This fleet of pumping appliances exceeds the NFPA 1901 and SANS 10090 performance requirements. However, according to clause 5.3.2.2 of SANS 10090, it is recommended that pumping appliances serve a maximum of 15 years in service, thus making this entire fleet due for replacement in 2018. The pumping appliances shortage crisis which will continue to worsen until resolved through the purchase of an estimated 29 additional trucks.

6.2 FUTURE RESEARCH OPPORTUNITY

An investigation into the large differences in international guideline values discussed in chapter three would provide much needed clarity as to why the values are so different. Additionally, a significant assumption made regarding the results presented in chapter 5: Fire Incident Reports, is that fire flow rates were assumed to be constant over the on-scene duration. Further investigation can be carried out to better understand the change in rate of water use during a fire emergency.

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APPENDIX A

Wits non-medical ethics clearance

Assessment of Ethics of Research Protocols in which humans are involved

Civil and Environmental Engineering Ethics Clearance Certificate No: CEECC- (543310-17)

Researcher: Cameron-Scott MacBean **Student No.** 543310

All research in which humans are involved either as informants or subjects (carried out in the University by undergraduates, postgraduates, staff or affiliated staff in the name of the University) need to respect the rights of individuals by ensuring that:

- the informant or subject has consented to the research without coercion;
- the questions posed are not insulting or embarrassing;
- confidential matters that could place the informant in an embarrassing, false or compromising position vis-à-vis authorities, are handled circumspectly;
- the privacy and wishes of informants are respected, i.e. anonymity of the informant is maintained if required;
- the informant is informed as fully as possible as to the aims and possible implications of the research.

For MSc researchers on a half coursework half research (MSc 50/50) or the Master of Engineering (MEng) program, the assessment is carried out by the School Ethics Committee within the respective Schools.

The research proposal by C Mac Bean includes the acquisition of information by the use of questionnaires and a School Committee composed of Prof Ndiritu, Prof Ilemobade and Dr Li assessed the proposed research protocols on August 28 2017.

The committee found the research proposal to meet all the requirements set by the HREC (Non-Medical) of the University of the Witwatersrand.

John Ndiritu
Post Graduate Coordinator
School of Civil and Environmental Engineering

APPENDIX B

EMS permission to conduct research

Jo'burg

a world class African city

City of Johannesburg
Emergency Management Services

Public Safety Headquarters
195 Main Road
Martindale
2000

PO Box 1496
Johannesburg
South Africa
2000

Tel +27(0) 11 758 9100
Fax +27(0) 11 758 9189

To: Mr. Cameron-Scott Mac Bean
Principal Investigator
University of Witwatersrand

From: Mr. M. Makhubalo
Acting Executive Head
EMS

05 October 2017

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH ON EVALUATION OF THE SOUTH AFRICAN GUIDELINES FOR THE PROVISION OF WATER FOR FIRE FIGHTING

Dear Mr Mac Bean

After considering all documents submitted to City of Johannes~~burg:~~ Emergency Management Services, I hereby confirm that, **MR MAC BEAN MAY / ~~MAY NOT~~** conduct his research study in the City Of Johannesburg: Emergency Management Services.

Yours Sincerely

MR M. MAKHUBALO
ACTING EXECUTIVE HEAD
PUBLIC SAFETY
EMS

ONCE PERMISSION IS GRANTED-

THE FOLLOWING CONDITIONS SHOULD BE ADHERED TO:

- **Findings / results to be made available to CoJEMS Executive Management.**
- **Recommendations to be suggested based on the outcome of the study.**
- **Implications to be suggested.**

I acknowledge and will abide to the conditions listed above.

MR MAC BEAN
PRINCIPAL INVESTIGATOR
UNIVERSITY OF WITWATERSRAND

APPENDIX C

Interview Documentation

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

Participant Information Sheet

Dear participant

Please take some time to read through the following information. If at any point you have any questions, please do not hesitate to ask myself, Cameron, or email me at a later date at 543310@students.wits.ac.za

OVERVIEW

You have been invited to take part in my MSc research study investigating the the question: Are the current national standards and design guidelines pertaining to fire flow provision appropriate for modern firefighting techniques and do they ensure the most efficient balance between providing sufficient fire protection and promoting sustainable water use? The investigation seeks to answer this question by comparing and evaluating the performance of various fire flow guidelines to identify opportunities for their improvement.

WHAT YOU HAVE BEEN ASKED TO DO

Thanks to your experience as a firefighter in Johannesburg you have been asked to participate in a confidential and anonymous face-to-face interview session, lasting around 30-45 minutes. This will be arranged for a time, date, and location of your convenience, prior to the end of October 2017.

You will be asked questions about your current role and experience of performing your firefighting duties in Johannesburg. You will also be asked to detail the processes and techniques that are implemented during a fire emergency in order for me to document the full process from emergency call to declaring the emergency site safe. Lastly, the interview will aim to help me understand and document your experiences regarding the supply and reliability of municipally suppled water for firefighting.

Your Data

Your participation in this study is completely voluntary. You may choose not to answer any of the questions asked of you. You may withdraw your participation at any time during or after the interview session up until any potential publication of the findings. Your interview responses and experiences will be confidential. Notes and recordings will be anonymised and stored with an encrypted folder, accessible only to myself, Cameron-Scott Mac Bean. Your personal responses will not be discussed with any fellow interviewees in the study.

For the purpose of enhancing the accuracy of the information obtained for our interview, with your consent, I will record the audio only of the interview. Also with your permission, I may include selective quotes from the transcription to illustrate points in my thesis and any resulting publications. These will be anonymised and great care taken to ensure that any quotes cannot be attributed to you.
Access to the published research will be available on the world-wide web and a link to the completed thesis can be emailed to you should you request.

Compensation

Please be aware that this research does not involve any payment or compensation for your participation. While this study will afford no individual benefits, it will benefit the field of civil engineering and community protection against firefighting.

Thank you for reading this information sheet and I hope to speak with you soon.

____

Cameron-Scott MacBean
MSc Researcher (Student No. 543310)
University of the Witwatersrand

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

PARTICIPANT CONSENT FORM

RESEARCH OVERVIEW

This MSc research study is investigating the the question: Are the current national standards and design guidelines pertaining to fire flow provision appropriate for modern firefighting techniques and do they ensure the most efficient balance between providing sufficient fire protection and promoting sustainable water use? The investigation seeks to answer this question by comparing and evaluating the performance of various fire flow guidelines to identify opportunities for their improvement.

DECLARATION OF CONSENT

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	
3. I agree to take part in this study and interview;	
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	
5. I agree to being audio recorded;	
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	
7. I understand that my participation in this interview does not involve any payment or compensation.	

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant:	Date:	Signature:
Name of Interviewer:	Date:	Signature:

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

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INTERVIEW QUESTIONS*

*Responses to be audio recorded should the participant allow, alternatively responses will be hand written by interviewer.

- PROCEDURE AFTER AN EMERGENCY CALL IS RECEIVED
  - What are the main steps from call received to site declared safe?
  - When is the tanker filled, to what extent and why?
- THE SIZING OF A FIRE AND THE RESULTING DECISIONS ON FIREFIGHTING STRATEGY AND EQUIPMENT
  - How is the required water demand determined? By..
  - Calculation
  - Experience estimate
  - Other
  - Not done – Maximum draw off taken
  - What are the various attack options and what essential equipment is required for each?
  - What modern technologies/equipment (e.g. high-pressure hoses, airators, nozzle types, etc) have become available in the past decade and what value do they add?

- CONNECTION TO FIRE HYDRANTS AND THE WDS
    - What are the different types of hydrants/WDS connections in Johannesburg?
    - How often are fire hydrants used.
    - 0-100% of the time?
    - What is the reason for this?
    - How often are multiple hydrants used during a single emergency?
    - 0-100% of the time?
    - What is the reason for this?
    - How are they configured?
    - What limitations (e.g. spacing, condition, locatability, etc.) are commonly experienced with hydrants?
    - What is the ideal hydrant spacing and why?
    - What is done when hydrants are not available?
    - What performance changes (e.g. negative pressures, low water supply, etc.) to the WDS have been observed when hydrants are connected?
    - How many hydrants can be connected to a tanker?
    - What equipment is used to connect to fire hydrants?
    - What are typically experienced hydrant flow rates and pressures?
    - What would be the acceptable lower and upper bounds?
- FIRE TRUCKS AND WATER TANKERS
    - How long does it take to refill a tanker (what size of tanker)?
    - How quickly can a tanker be emptied?
    - What is the maximum discharge rate and pressure it can generate?
    - Would provision over and above this be unusable?
    - Can a tanker be refilled whilst used to charge hoses?
- THE RELATIONSHIP BETWEEN WATER SUPPLY AND TIME ELAPSED TO CONTROL FIRE.
    - Does double the water supply half the time taken to control a fire?
    - What can be elaborated on this point?

- Is there a minimum fire flow at which point water it has zero effect on controlling a blaze?

- EXTERNAL FACTORS AFFECTING FIREFIGHTING PROCESSES AND EFFICIENCY
    - What are the different levels of skill, training, and qualification for firefighting?
    - What effects do the following factors have on the firefighting process and efficiency? Rank factors in order of significance and magnitude (proportion of 100%), and discuss why?
    - Size of tanker
    - Size of hoses
    - Number of firemen
    - Type of building
    - Location of fire
    - Water provision
    - Other?
        - National Guidelines and municipal by-laws
        - Present SANS 10090 &10252-1 documents
        - Are you familiar with these documents and their content?
        - Do you agree with their recommendations, why or why not?
        - What changes would you consider making?
        - Present Red Book guidelines
        - Are you familiar with these documents and their content?
        - Do you agree with their recommendations, why or why not?
        - What changes would you consider making?
        - Present Johannesburg municipal by-laws
        - Are you familiar with these documents and their content?
        - Do you agree with their recommendations, why or why not?
        - What changes would you consider making?

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

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Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

2 Participant Consent Form

Research Overview

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Declaration of Consent

Please Initial Box

1. I (*Participant*) have read and understood the Participant Information Sheet; ∝
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction; ∝
3. I agree to take part in this study and interview; ∝
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason; ∝
5. I agree to being audio recorded; ∝
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study; ∝
7. I understand that my participation in this interview does not involve any payment or compensation. ∝

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant: **Anonymous 1**	Date: 10/1/2018	Signature: **Anonymous 1**
Name of Interviewer: C.MacBean	Date: 10/1/2018	Signature:

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

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Declaration of Consent

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	✓
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	✓
3. I agree to take part in this study and interview;	✓
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	✓
5. I agree to being audio recorded;	✓
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	✓
7. I understand that my participation in this interview does not involve any payment or compensation.	✓

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant:	Anonvmous 2	Date:	20/10/2017	Signature:	Anonymous 2
Name of Interviewer:	Cameron-Scott MacBean	Date:	20/10/2017	Signature:	

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

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Declaration of Consent

Please Initial Box

1. I (*Participant*) have read and understood the Participant Information Sheet; ✓
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction; ✓
3. I agree to take part in this study and interview; ✓
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason; ✓
5. I agree to being audio recorded; ✓
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study; ✓
7. I understand that my participation in this interview does not involve any payment or compensation. ✓

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant: Anonymous 3	Date: 18/10/17	Signature: Anonymous 3
Name of Interviewer: Cameron MacBean	Date: 18/10/17	Signature:

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

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Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

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DECLARATION OF CONSENT

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	X
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	X
3. I agree to take part in this study and interview;	X
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	X
5. I agree to being audio recorded;	X
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	X
7. I understand that my participation in this interview does not involve any payment or compensation.	X

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant	Anonymous 4	Date:	17/10/17	Signature:	Anonymous 4
Name of Interviewer:	C. MacBean	Date:	17/10/17	Signature:	

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

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Declaration of Consent

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	A 5
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	A 5
3. I agree to take part in this study and interview;	A 5
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	A 5
5. I agree to being audio recorded;	A 5
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	A 5
7. I understand that my participation in this interview does not involve any payment or compensation.	A 5

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant:	Anonymous 5	Date:	17/10/2017	Signature:	Anonymous 5
Name of Interviewer:	C. MacBean	Date:	12/10/2017	Signature:	

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

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Declaration of Consent

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	X
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	X
3. I agree to take part in this study and interview;	X
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	X
5. I agree to being audio recorded;	X
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	X
7. I understand that my participation in this interview does not involve any payment or compensation.	X

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant: Anonymous 6	Date: 30-10-2017	Signature: Anonymous 6
Name of Interviewer: C. MacBean	Date: 30/10/2017	Signature:

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

2 PARTICIPANT CONSENT FORM

RESEARCH OVERVIEW

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DECLARATION OF CONSENT

	Please Initial Box
1. I (*Participant*) have read and understood the Participant Information Sheet;	✓
2. I have been given the opportunity to ask questions and have had them answered to my satisfaction;	✓
3. I agree to take part in this study and interview;	✓
4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	✓
5. I agree to being audio recorded;	✓
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	✓
7. I understand that my participation in this interview does not involve any payment or compensation.	✓

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant: Anonvmous 7	Date: 26/10/2017	Signature:	Anonymous 7
Name of Interviewer: CameronMacBean	Date: 26/10/2017	Signature:	[illegible]

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

Supervisor: Prof. Adesola Ilemobade

Investigating: The Provision of Water for Fire Fighting

Research Title: A Re-evaluation of the South African Guidelines for the Provision of Water for Fire Fighting

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Research Overview

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Declaration of Consent

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6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;
7. I understand that my participation in this interview does not involve any payment or compensation.

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant: C.MacBean	Date: 21/10/17	Signature:
Name of Interviewer: Anonymous 8	Date: 21/10/17	Signature: Anonymous 8

Investigator: Cameron-Scott Mac Bean, Masters Research Student, School of Civil and Environmental Engineering, University of the Witwatersrand.

Email: 543310@students.wits.ac.za

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DECLARATION OF CONSENT

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1. I (*Participant*) have read and understood the Participant Information Sheet;	A 9
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4. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason;	A 9
5. I agree to being audio recorded;	A 9
6. I understand that my participation will be kept anonymous and that I will not be named in any written work arising from this study;	A 9
7. I understand that my participation in this interview does not involve any payment or compensation.	A 9

I freely give my consent to participate in this research study and have been given a copy of this form for my own information:

Name of Participant:	Anonymous 9	Date:	27/10/17	Signature:	Anonymous 9
Name of Interviewer:	C. MacBean	Date:	27/10/17	Signature:	

APPENDIX D

9 January 2018 Fire Engine Strength Report

JOHANNESBURG EMERGENCY MANAGEMENT SERVICES

DAILY VEHICLE DOWNTIME REPORT

2018/09/01

	FLEET NUMBER	ALTERNATIVE ALLOCATION	VEHICLE REGISTRATION	PRODUCT CODE	VEHICLE CLASS	O	R	P	S	LICENSE EXPIRY	PROBLEM/DISCREPTION	SERVICE PROVIDER	DATE IN	COMMENTS
STATION	DISTRICT 1													
Ivory Park	WT4		NRH991GP	FML	Water Tanker	O				30/6/2018				
	BP6		NHH293GP	FML	Boom Pumper			O		28/2/2018	Accident damage	Boksburg	31/01/2017	Work in progress
Midrand	RP6		XNT018GP	FML	Rescue Pumper		O			28/2/2018	Engine overhaul	Hamberg	14/6/2016	Work in progress
	GU5		WJG908GP	FML	Skid Unit			O		31/3/2018	Accident repairs	Boksburg	2016/03/10	Work in progress
	WT2		DWR729GP	SFML	Water Tanker		O			31/3/2018	Repair water pump	Boksburg	2014/10/03	Work in progress
Lonehill	GU1	Diesloot	WJG897GP	FML	Skid Unit	O				31/3/2018				
	BP8		NRD401GP	FML	Boom Pumper			O		31/3/2018	Refurbishment	Boksburg	15/8/2016	Work in progress
	L2		NHH299GP	FML	Ladder		O			31/3/2018	Ready for collection			
	SW2	Florida Park	XKV305GP	FML	Swift water	O				28/2/2018				
Diepsloot	RP1		WMY095GP	FML	Rescue Pumper		O			28/2/2018	Oil leak	Hamberg	2017/09/10	Awaiting parts
			MZZ920GP	FML	Skid Unit		O			30/11/2015	Piston collapse	Hamberg	31/04/2017	Work in progress

					11	3	5	3						
STATION	DISTRICT 2													
Alexandra	TP2		NHG836GP	FML	Tanker Pumper		O			31/3/2018	Service	Hamberg	29/3/2017	Work in progress
	WT5	Rosebank	NRH995GP	FML	Water Tanker	O				31/3/2018				
	RP3		WMY155GP	FML	Rescue Pumper	O				28/2/2018				
Modderfontein	IP1		NHG854GP	FML	Industrial Pumper	O				28/2/2018	Leaking foam useable			
	HR1		NHH331GP	FML	Heavy Rescue	O				28/2/2018				
	HZ3		NHG845GP	FML	Hazmat			O		31/3/2018	Accident damage	Station	2017/06/11	
	TP5	Sandton	NHG843GP	FML	Tanker Pumper	O				28/2/2018				
Sandton	RP7		XNT026 GP	FML	Rescue Pumper		O			31/3/2018	Overheating	Hamberg	2015/09/12	Engine at agent
	BP7	Florida Park	NHH 296 GP	FML	Boom Pumper	O				28/2/2018				
	L5	Northview	NHH310 GP	FML	Ladder		O			31/3/2018	None start	Hamberg	18/5/2016	Work in progress
	GU3	Modderfontein	WJG 901 GP	FML	Skid Unit	O				31/10/2018				
	HP3		NHH328GP	FML	Bronto		O			31/3/2018	Broken prop shaft	Hamberg	2017/05/06	Work in progress
			DC27XJGP	FML	Command unit	O				31/5/2018				
		Modderfontein	CZ06ZFGP	FML	Hazmat	O				28/2/2018				
		Northview	CZ06YZGP	FML	Toolmover	O				28/2/2018				
Northview	AT2	Sandton	NHG852 GP	FML	Air Truck	O				28/2/2018				
	BP4	Eldorado Park	NHH289GP	FML	Boom Pumper			O		31/3/2018	Refufrbishment	Boksburg	15/8/2016	Work in progress

					17	11	4	2						
STATION	DISTRICT 3													
Berea	BP3		NHH286GP	FML	Boom Pumper		O			31/3/2018	Oil & water mixing	Hamberg	26/5/2017	Work in progress
	L4		NHH308GP	FML	Ladder		O			28/2/2018	Overheating	Hamberg	31/07/2017	Awaiting stripping
Central	AT1		NHG849GP	FML	Air Truck	O				28/2/2018				
	RP9		XNT046GP	FML	Rescue Pumper		O			31/10/2018	Overheating	Hamberg	13/07/2017	Work in progress
	CU2		MZT443GP	FML	Command Unit		O			31/3/2018	COF	Florida	30/06/2017	Work in progress
Fairview	TP7		NPX720GP	FML	Tanker Pumper		O			28/2/2018	Smoke in cab	Hamberg	27/3/2017	Work in progress
	HP2		NHH327GP	FML	Bronto	O				31/3/2018				Work in progress
	L1		FVR391GP	SLB	Ladder		O			31/3/2018	Overheating	Hamberg	22/10/2015	Work in progress
Malvern	BP10		NRD404GP	FML	Boom Pumper			O		31/3/2018	Refufrbishment	Boksburg	15/8/2016	Work in progress
Brixton	BP9		NRD402 GP	FML	Boom Pumper		O			31/5/2018	Overheating	Hamberg	31/07/2017	Work in progress
	WT6		NRJ003 GP	FML	Water Tanker		O			30/11/2015	COF & transfer case	Hamberg	2015/03/12	Awaiting parts
	IP2		NHG856 GP	FML	Industrial Pumper	O				28/2/2018				
					12	3	8	1						
STATION	DISTRICT 4													
Turffontein	L3		NHH305GP	FML	Ladder		O			31/3/2018	Diff noise silencer	Hamberg	27/9/2016	Work in progress
	TP6		NHG844GP	FML	Tanker Pumper		O			28/2/2018	Cutting out	Hamberg	2016/08/11	Work in progress

Kibler Park	TP9		NPX724GP	FML	Tanker Pumper			O		31/3/2018	Accident damaged	Boksburg	30/4/2014	Possible write off
	RR7		NHH821GP	FML	Rural Response		O			31/5/2018	Gear selection	Hamberg	2017/09/07	Work in progress
	GU2	Turffontein	WJG898GP	FML	Skid Unit	O				31/10/2018				
Eldorado Park	BP1		NHH281GP	FML	Boom Pumper			O		31/3/2018	Refurbishment	Boksburg	15/8/2016	Work in progress
Orange Farm	RR10		NYR163GP	FML	Rural Response		O			31/3/2018	Refurbishment	Boksburg	31/07/2016	Work in progress
	RP4		WMY172GP	FML	Rescue Pumper	O				28/2/2018				
Lawley	RP2		WMY135GP	FML	Rescue Pumper		O			28/2/2018	Overheating	Hamberg	2017/01/08	Work in progress
	RR8		NYF027GP	FML	Rural Response		O			31/5/2018	No power	Hamberg	27/08/2017	Work in progress
	RR7		NYF035GP	FML	Rural Response		O				No power	Hamberg	27/08/2017	Work in progress
					11	2	7	2						
STATION	DISTRICT 5													
Diepkloof	EC13	Lawley	FHG901GP	SLB	Engine Company		O			31/10/2018	None start	Station	29/11/2017	Work in progress
	HP4	Florida Park	NHH329GP	FML	Bronto			O		31/3/2018	Accident damage	Boksburg	2017/07/02	Work in progress
	TP10		NPX727GP	FML	Tanker Pumper		O			31/3/2018	Engine overhaul	Advance	18/3/2015	Awaiting parts
Dobsonville	EC20	Ivory Park	NRD403GP	FML	Engine Company	O				31/3/2018				
Jabulani	TP1	Kibler Park	NHG832GP	FML	Tanker Pumper		O			31/3/2018	Overheating	Hamberg	2016/05/01	Engine at agent
			DC98ZNGP	FML	Engine Company	O				28/2/2018				
	WT7		NSZ097GP	FML	Water Tanker		O			31/7/2017	No pump pressure	Hamberg	29/4/2017	Work in progress
Hodgeson Str	RP5		WMY188GP	FML	Rescue Pumper		O			31/3/2018	Broken propshaft	Hamberg	2016/04/10	Work in progress

Rietfontein			DB29PNGP	FML	Engine Company		O			28/2/2018	Steering	Hamberg	23/5/2017	Work in progress
					9	2	6	1						
STATION	DISTRICT 6													
Florida Park	L6		NHH315 GP	FML	Ladder		O			29/2/2016	Overheating	Hamberg	18/3/2017	Work in progress
	GU4		WJG907 GP	FML	Skid Unit		O			31/3/2018	Steering	Hamberg	24/5/2017	Work in progress
	CU1		MZT351 GP	FML	Command unit		O			31/12/2015	Battery/l/disc	Station	2017/11/02	Work in progress
	BP11		NRD406 GP	FML	Boom Pumper			O		31/3/2018	Refufrbishment	Boksburg	15/8/2016	Work in progress
	SW1		XKV248GP	FML	Swift water	O				28/2/2018				
Randburg	TP8		NHG838 GP	FML	Tanker Pumper	O				28/2/2018				
	HP1	Randburg	NHH321 GP	FML	Bronto	O				31/3/2018				
Rosebank	BP2		NHH289GP	FML	Boom Pumper		O			31/12/2015	Engine overhaul	Hamberg	2015/07/07	Work in progress
Roosevelt Park	RP8		XNT040GP	FML	Rescue Pumper	O				31/3/2018				
	RR3		NHG824GP	FML	Rural Response	O				31/5/2018				
Hunters Hill	WT3		NRH990 GP	FML	Water Tanker		O			31/3/2018	Losing air, diff noisy	Hamberg	23/5/2017	Work in progress
	EC3		BZP234 GP	SLB	Engine Company		O			30/11/2018	Spring blade broken	Hamberg	2018/01/01	Work in progress
	GU6		WJH196 GP	FML	Skid Unit		O			28/2/2018	Gear box	Hamberg	19/1/2017	Work in progress
					13	5	7	1						
	STANDBY													
	EC1		BKD875GP	STANDBY	Engine Company		O			31/3/2018	Pump pressure	Hamberg	18/9/2013	Obsolete

	EC2		BKD877GP	STANDBY	Engine Company		O			31/3/2018	No power, steering box	Hamberg	21/7/2014	Obsolete
	HZ1	Northview	BKD885GP	SLB	Engine Company		O			31/3/2018	Gearbox faulty	Station	2016/01/02	Obsolete
	EC4		CVT384GP	SFML	Engine Company		O			31/3/2018	To be stripped for spares	Hamberg	2013/11/03	Obsolete
	EC5		CVT385GP	STANDBY	Engine Company		O			31/3/2018	Replace timing gear	Hamberg	15/4/2015	Obsolete
	EC6		CVT387GP	SFML	Engine Company		O			31/3/2018	No pump pressure	Hamberg	18/3/2015	Obsolete
	EC7		CVT388GP	SFML	Engine Company		O			31/3/2018	To be stripped for spares	Hamberg	26/10/2012	Obsolete
	EC8	Central	CVT389GP	SFML	Engine Company	O				28/2/2018				
	EC9		DLS124GP	STANDBY	Engine Company		O				Not in use	Hamberg		Obsolete
	EC10	Kibler Park	DWW367GP	SLB	Engine Company	O				31/3/2018				
	EC11	Brixton	FDK521GP	SLB	Engine Company	O				31/3/2018				
	EC12		FFJ147GP	SLB	Engine Company		O			30/4/2016	Engine overhaul	Hamberg	18/3/2014	Obsolete
	EC14		FHG906GP	SLB	Engine Company		O			31/7/2016	Accident repairs	Boksburg	13/11/2015	Work in progress
	EC16		FRV838GP	STANDBY	Engine Company		O			31/3/2018	Burnt wiring	Hamberg	2017/06/03	Work in progress
	EC17		JHY918GP	STANDBY	Engine Company		O			31/3/2018	Not in use	Hamberg		Obsolete
	EC18		JHY926GP	STANDBY	Engine Company		O			31/3/2018	Burnt out	Advance	29/4/2017	Possible write off
	HZ2	Northview	JWY059GP	SLB	Hazmat		O			31/7/2016	Not in use	Hamberg		Obsolete
	RR5	Lawley	NHG827GP	FML	Rural Response	O				31/5/2018				

	RR6	Rietfontein	NHG830GP	FML	Rural Response		O			31/5/2018	Power failure	Hamberg	25/11/2016	Work in progress
	TP3		NHG837GP	FML	Tanker Pumper		O			31/3/2018	Engine oil leak	Hamberg	31/3/2017	Engine at agent
	TP4	Eldorado Park	NPX723 GP	FML	Tanker Pumper	O				31/3/2018				
	BP5	Midrand	NHH291GP	FML	Boom Pumper	O				31/3/2018				
	RR4		NHG826GP	FML	Rural Response		O			31/5/2018	Sideshaft	Hamberg	31/04/2017	Work in progress
	RR11	Eldorado Park	NYR165GP	FML	Rural Response		O			31/05/2018	None start	Hamberg	28/11/2016	Work in progress
			DFJ044GP	STANDBY	Water Tanker		O			31/3/2018	Not in use	Hamberg		Obsolete
			DWW369GP	STANDBY	Engine Company		O			31/3/2018	Not in use	Hamberg		Obsolete
			DWW718GP	STANDBY	Skid Unit			O		30/9/2016	Accident repairs	Boksburg	23/9/2016	Work in progress
			DYG736GP	STANDBY	Engine Company		O			31/3/2018	Not in use	Hamberg		Obsolete
			DYG744GP	STANDBY	Engine Company		O			30/11/2014	Not in use	Hamberg		Obsolete
			FFK468GP	STANDBY	Skid Unit		O			30/4/2016	Engine overhaul	Hamberg	29/6/2012	Obsolete
			JHY927GP	STANDBY	Hydraulic Platform		O			31/3/2018	Not in use	Hamberg		Obsolete
					31	6	24	1						
					TOTALS	32	61	11						
		STANDBY	13		1ST TURN OUT	13								
		FML	75											
		SFML	5											
		SLB	11											
		TOTAL	104											
					Operational	O								
					Scheduled Maintenan	W								
			.		Breakdown/Repairs	R								
					Panelbeaters	P								
					Spare/Standby Vehic	S								
					Outstanding claim for	C								
					Licence expiry date	L								
					Fault	F								
					Location	LO								
					Vehicle assessmen	A								
					Expected date Out	EDO								

APPENDIX E

2003 Pumping Units Fleet Specification

CITY OF JOHANNESBURG NEW FLEET FACT SHEET

TWO BRAND NEW
INDUSTRIAL PUMPERS

These highly specialised vehicles are used for industrial fires as they offer the unique Williams Hydro-Chem systems that allows the monitor to flow water / foam / and DCP simultaneously.

Chassis cab	: International 4900 with a 4 door cab.
Engine	: 530E 6 cylinder, developing 223 kw @ 2200 rpm
Transmission	: Allison HD 3060.
Superstructure	: Aluminum.
Foam tank	: 3800 litre Polypropylene tank
Pump	: Hale QSMG 5700 L/min midship mounted pump.
Discharges	: 2x65mm left/right panel.
Monitor	: Williams Hydro Chem 7570 l/min.
DCP System	: 158 kg system.
Foam system	: williams Hot-Shot 150 system.

CITY OF JOHANNESBURG
NEW FLEET FACT SHEET

SIX BRAND NEW
TANKER PUMPERS

These vehicles are used in areas where there is a limited or non-existent water supply system. These units operate as engine companies but have the added advantage of larger water tanks and the ability to dump or relay water.
Deploys hoselines for fire attack exposure protection

Chassis cab	: International Model 4900 with 4 door cab
Engine	: 530E 6 cylinder, developing 223kw @ 2200rpm.
Transmission	: Allison MD3060.
Superstructure	: Aluminum.
Foam tank	: 190 litre Polypropylene tank.
Water tank	: 6900 litre Polypropylene tank.
Monitor	: TFT deck gun. 76mm waterway.
Pump	: Hale QSG 4700l/min midship mounted pump
Discharges	: 1x38mm crosslay; 2x65mm left/right panel/rear.
Foam	: 2001 Foam Pro system
Dump valve	: Rear mount Newton Jet Dump.
Control Panel	: Top mount.
Portable tank	: Zico Electric dam holder @ 9000 litre portable dam.

CITY OF JOHANNESBURG NEW FLEET FACT SHEET

SEVEN BRAND NEW
TELE-SQUIRT BOOM PUMPERS

These vehicles are fully fledged engine companies with the added advantage of having a 15m hydraulic ladder capability. These vehicles are ideal for informal settlements. The 15m ladder allows monitor operation at a 15m height or outreach from the vehicle and is also ideal for adjacent structure protection.

Deploys hoselines for fire attack exposure protection

Chassis cab	: International Model 4900 with 4 door cab
Engine	: 530E 6 cylinder, developing 223kw @ 2200rpm.
Transmission	: Allison MD3060.
Superstructure	: Aluminum.
Foam tank	: 190 litre Polypropylene tank.
Water tank	: 1900 litre Polypropylene tank.
Monitor	: 3800 l/min tip mounted.
Foam system	: model 2002 Foam Pro system
Aerial	: Midmount 15m aluminum ladder.
Pump	: Hale QSG 4700 l/min midship mounted pump.
Discharges	: 1x38mm crosslay, 2x65mm left/right/rear panel discharges/ inlets. 100 mm waterway for monitor

APPENDIX F

Fire Incident Report Example

City of Johannesburg
Emergency Management Services

INCIDENT REPORT

STATION: Diepsloot Fire Station (5)

DATE:	11 JUNE 2019	Caller's Name:	CONTROL
STREET:	WILLIAM NICOL	Contact No:	011 375 5911
CROSS STREET:	FOUNTAIN RD	Time Received:	22:10
SUBURB:	LONEHILL	Method of Call	Phone: X / Verbal / Radio
BUILDING:	MONTEPOLLINO COMPLEX		
TYPE OF CALL	STRUCTURAL FIRE	Incident No:	040

Station	Officer	Appliance	Crew	Mobile	At Scene	F/STOP	D/D Stop	Left Scene	At Stn	KM Start	KM Stop
Stn 5	MBOVANE	ENGINE 5	6	22:11	22:30	22:50	00:05	01:08	01:20	16[illegible]993	16[illegible]011
SHIFT	RAMUBZULI	T-PUMPER	6		22:35			00:30			
R[illegible]on for delayed response (over 9 min):											
STN 15	SOSHA	T-PUMPER 15	3		22:54			00:30			
STN 20	KADWELL	T-PUMPER 20	2		23:05			00:30			

Address/Company

HOUSE NO 25 FOUNTAIN RD
& WILLIAM NICOL
BEVERLEY AREA
LONEHILL
2191

Type of Call: STRUCTURAL FIRE

Intervention

WE EXTINGUISH FIRE
USE 38MM HOSE X 3
LINES

W[illegible] Used: ± 6000L

C[illegible]: UKNOWN

Remarks:

ON ARRIVAL FOUND
DOUBLE STOREY HOUSE
WELL ALIGHT ON
THE ROOMS
UPSTAIRS. FIRE
SAFETY OFFICER
MOTSHWENI WAS ON SCENE
AND STANDBY OFFICER STN
19 LEBETLA WAS ON
SCENE ROOF WAS
ALREADY COLLAPSE WHEN
WE ARRIVED ON SCENE

Account Details

Owners Name:	P. B. MASHAMBA
Postal Address:	NO 20 MONTEPOLLINO COMPLEX
	NO 25 FOUNTAIN RD & WILLIAM
	NICOL BEVERLEY AREA
	LONEHILL — Code: 2191
Stand No:	
Home Tel No:	CellNo: 060 560 3031

Estimated Risk

	Building	Contents
Risk	3.5 MILLION	± 2 MILLION
Insurance		
Damage	± 2 MILLION	± 1 MILLION,
Total Risk	3.5 MILLION	± 2 MILLION
Total Damage	± 2 MILLION	± 1 MILLION

Vehicle Details

Make:		Reg No:		Owner:	
Make:		Reg No:		Owner:	
Make:		Reg No:		Owner:	
Make:		Reg No:		Owner:	
Make:		Reg No:		Owner:	

Assistance from Other Services:

JMPD	Name:	Man No:
SAPS	Name: ND RAMATLIMA	Force No:

Pt Transportation

Total Pt's Transported		P1	Hosp	P2	Hosp	P3	Hosp	P4	N/S
JHB	Amb No:								
	Amb No:								
NETCARE	Amb No:								
	Amb No:								
ER24	Amb No:								
	Amb No:								
Other	Amb No:								

Fire Safety Officer

N- MOTSHWENI

Watchroom Attendant

HLUNGWANI, MASILELA

Duty Officer

MBOVANE