doi: https://doi.org/10.4995/WDSA-CCWI2022.2022.14830

WATER FOR FIREFIGHTING: A COMPARATIVE STUDY ACROSS SEVERAL CITIES

Adeshola Ilemobade[1]

[1]School of Civil and Environmental Engineering, University of the Witwatersrand, Johannesburg Johannesburg, Gauteng, South Africa

[1]*adesola.ilemobade@wits.ac.za*

Abstract

Studies into water for firefighting are sparse in global literature. Over the past three decades, 6 published studies have been undertaken in South Africa to quantify the extent of municipal water employed to fight fires. These studies have been necessary considering the need to conserve scarce and dwindling freshwater resources while providing adequate fire protection to many South African communities. While these studies have been driven by similar objectives, their analysis have not produced results that can easily be compared in order to extract generic highlights that can aid national firefighting efforts. In addition, the recent firefighting studies postulate that the minimum fire flows in the South African National Standard (the SANS 10090) and Guideline (The Red Book) are conservative and therefore do not promote the appropriate design of water networks. This may be attributed to the fact that the fire flows in the 1st edition of the SANS 10090 were likely over-estimated for South Africa since they were compiled with the assistance of organisations from the UK, USA, Canada, New Zealand and Germany, and have not notably changed since.

This paper therefore aims to address 2 objectives. The first objective will extract as much data as is possible from each of the 6 studies and will analyse the data with the aim of comparing consistent parameters (such as fire flows). The second objective will compare results obtained from the first objective with the SANS 10090, The Red Book and available international Standards and Guidelines for firefighting. Based on the results from the second objective, this study will conclude on the appropriateness of the minimum fire flows in the SANS 10090 and The Red Book to current firefighting efforts.

Keywords
Water for firefighting, Firefighting Standards and Guidelines.

1 BACKGROUND

Few studies in the global literature have addressed the topic of water for firefighting. A cursory search using the SCOPUS search domain for *article title, keywords and abstract* using the following keywords: "*water for firefighting*", produced 787 documents, a fraction of which address flows, volumes and temporal variation of fires within communities. Including "*standards* and *guidelines*" to the above keywords narrowed the search and produced only 8 documents. When compared with the results of other keyword searches (e.g. "*optimal water networks*" – 10 217 documents, "*water meter management*" – 4 772 documents, and "*water reuse*" – 27 552 documents), the limited research in water for firefighting becomes more evident.

Firefighting infrastructure, although rarely used when compared to infrastructure that provides basic services, protects residential and non-residential communities from the devastating impacts of fires. Sadly, fires have been shown to be devastating on many levels, including economic, environmental and fatalities. To extinguish fires, several agents may be employed, with water being the most popular due to several reasons including its relative ease of availability, its relatively affordable cost, and its ability to extinguish most types of fires. Unfortunately, increasing aridity in many communities is negatively impacting the availability of freshwater resources, not only for firefighting, but more importantly, for meeting basic needs, sustaining economic development and maintaining environmental flows.

South African municipalities are legally obligated to provide water for firefighting [1] and thus, water for firefighting is given equal importance as drinking water when designing water networks. Water distribution systems are therefore designed for both peak water demand plus fire demand, and as a result, water network capacity may increase by as much as 20 % [2].

Because of the above, it is imperative to minimize freshwater extraction while meeting increasing water demand for different requirements including firefighting. This study addresses water for firefighting.

2 LITERATURE

A few South African and international studies have addressed water for firefighting. Highlights from these studies are mentioned below:

van Zyl and Haarhoff (1997) [3] investigated fire incidents spanning 1980 to 1991within a section of the City of Johannesburg (CoJ) Central Business District (CBD) in the SA Province of Gauteng and a residential area in the SA Province of Mpumalanga. Highlights were: (i) extinguishing large fires in Johannesburg over the 11-year period typically took between 30 and 90 minutes with fire flows typically ranging between 5 and 35 ℓ/s. (ii) 90 % of the large fires investigated were extinguished using fire flows of 52 ℓ/s or less and 440 kℓ of water or less; (iii) peak consumer demands were observed only at small intervals during the year, and usually did not coincide with fire events that typically took place in mid-Winter.

van Zyl, Davy and Haihambo (2011) [4] report the results of a study of water used for firefighting in the Greater City of Cape Town (CoCT) area between 1 January 2005 and 21 April 2010. The data consisted of 72 589 records separated into 10 categories. Highlights from their study include: (i) vegetation fires predominated amongst the categories investigated and occurred mostly during the summer months when climatic conditions were conducive to vegetation fires; and (ii) 98 %, 95 % and 87 % of residential, commercial and industrial fires respectively were extinguished in 2 hours or less. Industrial fires had the longest durations and required the largest volumes of water to extinguish. Residential fires had the shortest durations and required the smallest volumes of water.

Myburgh and Jacobs (2014) [5], employing a database containing 554 records with water volumes and 546 records with computed fire flows from 1 Jan 2010 to 31 Dec 2010, analyzed fire incidents within 5 towns (i.e. 3 municipalities) in the SA Province of the Western Cape (WC). Highlights were: (i) average water volume used to extinguish 77 large Category 2 (Structural and Industry) fires was 8.60 kℓ; (ii) more than 90 % of fires were extinguished using less than 10 kℓ of water; (iii) 91.4 % of the 546 fires were extinguished with non-reticulated water supplies. This means that the municipal water supply was only directly used to extinguish 47 fires or 8.6 % of the total number of fires. This was achieved because fire fighters transported water from the fire station using pre-filled tanker vehicles as the first line of defence in all cases when attending to a fire call.

Mac Bean and Ilemobade (2019) [6] analyzed about 10 years (from 01 January 2006 to 30 September 2017) of fire incident reports (3 859 records) that occurred within the CoJ. Highlights from their study were: (i) the fire flows and fire risk categories in the South African National Standard, SANS 10090 (SABS, 2018) [7] and The South African National Guideline (The Red Book; [1]) are inconsistent; (ii) The Red Book recommends fire flows that are lower than the SANS 10090 and thus, violates the SANS 10090, which is a standard that stipulates minimum acceptable values; (iii) over the study's 10-year period, 75 % of fire incidents within the CoJ were extinguished using 6.60 kℓ of water or less, 87 % of fires were extinguished using 10 kℓ of water or less and 99 % of fires were extinguished using 100 kℓ of water or less; (iv) while the frequency of fire occurrence was strongly related to climatic conditions, the volume of water used to quench fires was not a function of climatic conditions; (v) over the study's 10-year period, 99.90 % and 99.60 % of fire incidents were extinguished using average fire flows that were less than the minimum fire flows for the lowest risk categories in the SANS 10090 and The Red Book respectively; (vi) The start times of peak fires did not coincide with typical peak residential water demand periods.

Essack and Ilemobade (2022) [8], using similar but better representative criteria, re-analyzed the initial database employed by [6], and in particular, addressed 89 large fires (fires requiring more than 5 kℓ to extinguish). Highlights from their study were: (i) in the initial dataset of 4 479 records (spanning 24 February 2003 to 26 September 2017), an average of 32 incidents occurred per 30-day month with an expected increase in the average number of fire incidents during SA's dry and cold (i.e. late autumn, winter and early spring) months (May to September). The higher average number of fires during the cold months were attributed to households using unsafe appliances for heating and cooking especially in informal settlements; (ii) 99 % of fire incidents were extinguished using 100 kℓ of water or less while 87 % were extinguished using 10 kℓ or less; (iii) fire flows for 99.90 % and 99.60 % of the fire incidents were less than the minimum fire flow of the lowest SANS 10090 fire risk category and The Red Book respectively; and (iv) fire flows ranged between 0 and 3 ℓ/s. Additional highlights by [8], with specific reference to large fires were: (v) the duration of 60 % of the large fires were between 30 and 120 minutes; (vi) the average volume of water employed to extinguish the large fires was 9.63 kℓ; (vii) the fire flows employed to extinguish the 89 large fires were less than the minimum fire flows for the lowest fire risk categories in the SANS 10090 and The Red Book; and (viii) municipal water was used to supplement water conveyed in the vehicles in ~99 % out of 84 large Category 2 fires.

Thage and Ilemobade (2022) [9] analysed 3 236 fire incident reports at the Sol Plaatje Municipality (SPM), South Africa, during the period 21 July 2017 to 21 August 2020. Highlights from their study were: (i) 99.9 % of fire incidents employed less than 1 900 ℓ/min (the minimum fire flow for the SANS10090 category D1 fires), 99.5 % of incidents employed less than 1 500 ℓ/min (the fire flow specified in The Red Book for Moderate Risk 2 i.e. cluster & low-income housing and high rise flats ≤ 3 storeys) and 93.9 % of fires were extinguished using 200 ℓ/min of water or less; (ii) about 93.3 % of fires were extinguished using 7 kℓ of water or less, about 96.9 % of fires were extinguished using 10 kℓ of water or less and about 99 % of fires were extinguished using 60 kℓ of water or less; (iii) the average number of fire incidents in SPM peaked during the months of July & August (winter) and September (spring). These months experience the least rain and the highest energy (electricity, wood, paraffin) consumption for heating and cooking use; (iv) while fires in the SPM typically occurred between 11h00 and 20h00, with more than 100 fires reported per hour, the highest peak during the course of a typical day was observed at 15h00 (161 fire incidents). In addition, while the peak occurrence of fires and the residential peak water demand do not coincide in the morning, this is not the case in the afternoon as the largest number of fires (161) occur at 15h00, just before peak demands are experienced.

Davies (2000) [10], in New Zealand, found that over a 3-year period, on average 96 % of Structural fires in the study area were either extinguished with non-reticulated water supplies or with less than 10 ℓ/s of reticulated water supply.

Benfer and Scheffey (2014) [11] presents 16 fire flow methods from the USA, UK, France, Germany, the Netherlands, New Zealand and Canada. Eleven (11) addressed pre-incident building planning and at least 5 addressed on-scene firefighting. The 16 fire flow methods were applied to 2 differently sized non-residential buildings and 2 differently sized single-family residential buildings. Their study included both sprinklered and non-sprinklered calculations. Highlights from their study were: (i) minimum fire flows varied greatly across many countries; (ii) the building planning methods recommended fire flows that were higher than the on-scene methods; (iii) for residential buildings fitted with sprinklers, 12 out of the 18 methodologies required the same fire flows as non-sprinkler fitted buildings; and (iv) as can be seen in Figure 1, the range of fire flows, applied to a sample site, in all the methods are large, with the minimum fire flows in the SANS 10090 and The Red Book located close to the minimum fire flows for most ranges.

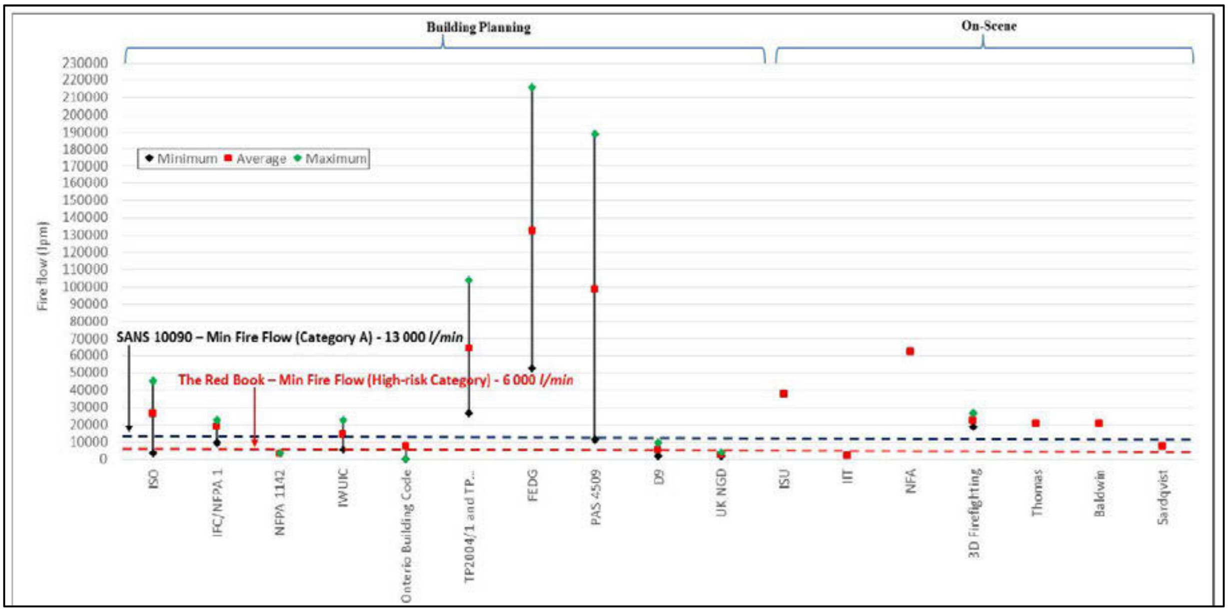

Figure 1. Benfer and Scheffey's (2014) 16 fire flows for a non-sprinklered, 4 645 m² non-residential building compared to the minimum flows in the South African Standard and Guideline

3 COMPARISON OF THE HIGHLIGHTS OF PREVIOUS STUDIES

While previous South African studies have been driven to address similar objectives, their analysis have not produced results that can easily be compared. This section therefore retrieves results published by previous studies and attempts to compare consistent parameters.

Figure 2 shows average fire flows employed to extinguish fires in each of the 3 studies plotted alongside the different minimum fire flows specified in the SANS 10090 and The Red Book. What is plainly obvious and which has been re-iterated several times in different publications ([5, 6, 8 and 9]) is that the minimum fire flows in both the SANS 10090 and The Red Book are conservative. Since these conservative flows must be included in the design of water networks, it is inevitable that larger water network component capacities will result.

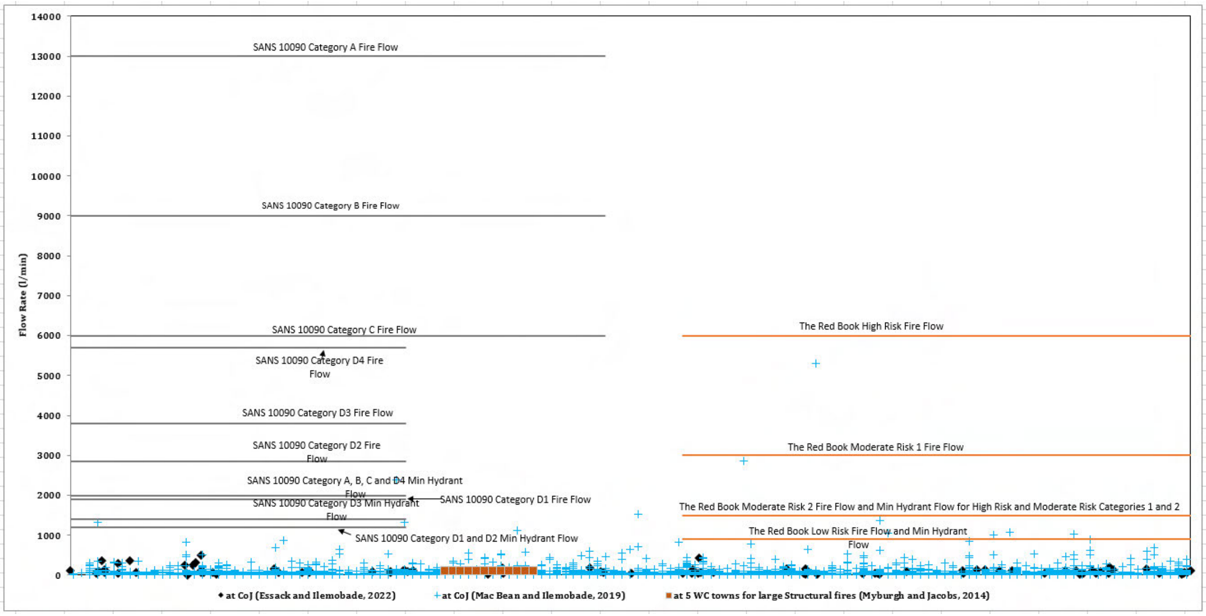

Figure 2. Fire flows from 3 studies with the SANS 10090 and The Red Book minimum fire flows superimposed

Specific highlights with regard to water volumes employed to extinguish fires were mentioned under each study's brief literature review above. Figure 3 presents the average volumes of water employed to extinguish fires for each representative month over the duration of each study. It is obvious that the average volume of water employed to extinguish fires are not correlated to the season of the year. In addition, in all studies, a significant percentage of fires (93.3% in the SPM [9], 75% in the CoJ [6], 91.4% in the 5 WC towns [5]) were (and could be solely) extinguished using certain fire engines - the Boom Pumper fire engine in the CoJ, for example, has a tank capacity of 9 kl.

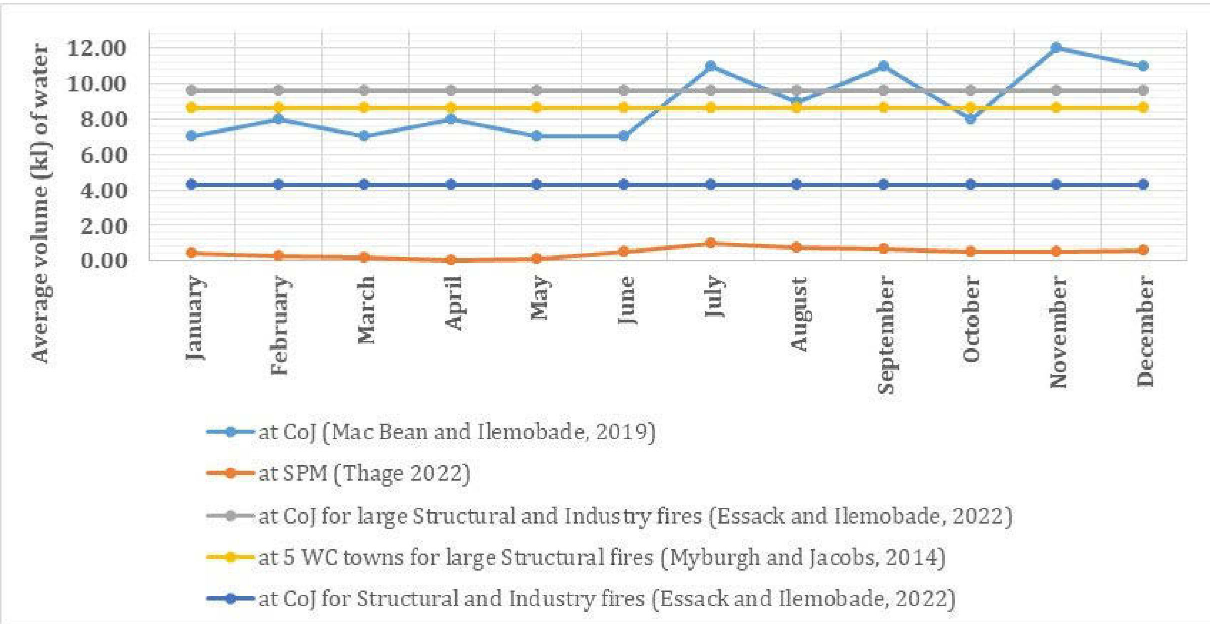

Figure 3. Average volume (kl) of water employed to extinguish fires for each representative month over the study periods

Figure 4 shows that in 3 (at the CoJ [6], [8] and SPM [9]) of the 4 studies, the frequency of fire incidents increases and peaks during the dry months (April/May to September) and is the lowest during the rainy periods (December to March). In the WC [4], the rainy months are between March and November and this explains why the chart for the WC displays marginally lower frequencies between March to October when compared with frequencies at other times of the year.

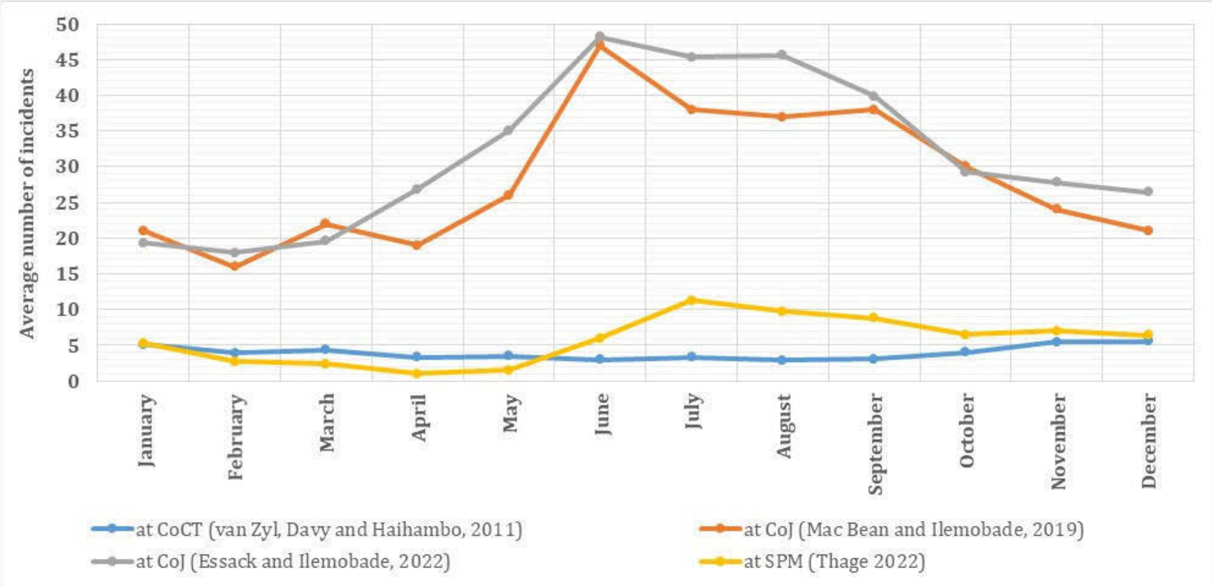

Figure 4. Average number of fire incidents for each representative month of the year over the study periods

Figure 5 shows that while the occurrence of fires and the typical residential peak water usage [12] do not coincide in the morning, this is not the case in the afternoon as the occurrence of fires in the 2 studies peak within an hour that the afternoon peak demand occurs. This may be because heating (during the dry and cold months) and cooking facilities are mostly employed in the afternoons when families are at typically at home.

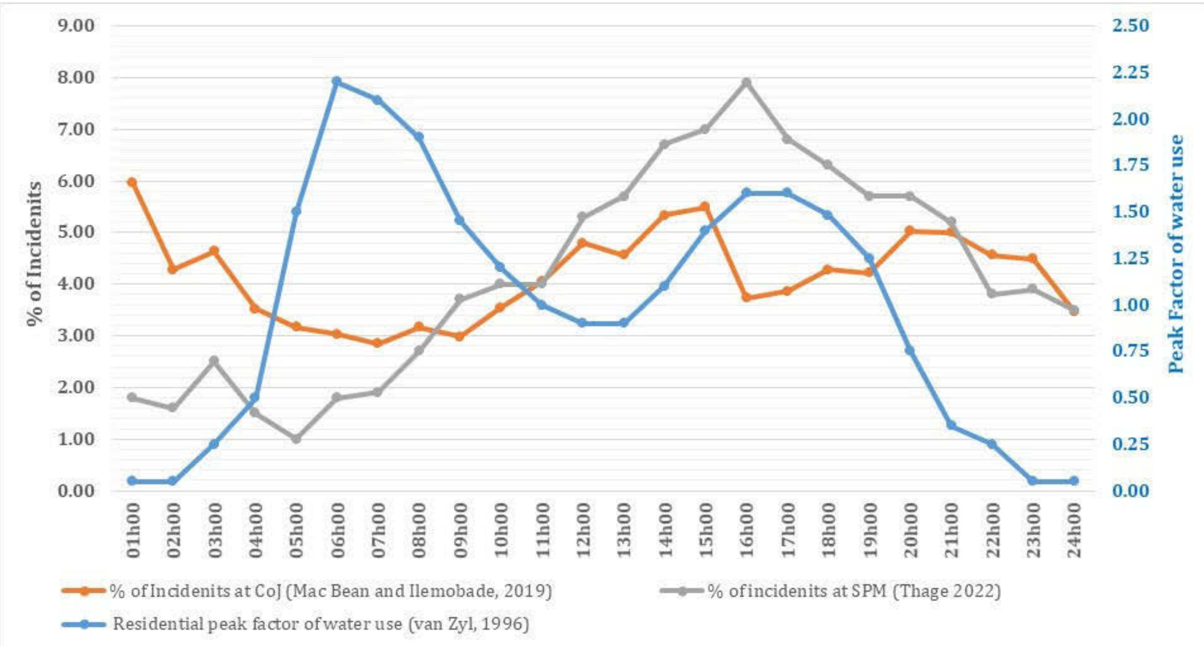

Figure 5. Daily variation of fire start times versus a typical residential peak water demand pattern

4 CONCLUSION

This paper addressed 2 objectives. The first extracted data from previous studies undertaken in South Africa and internationally, and analysed the data using consistent parameters, while the second compared the results obtained with the SANS 10090, The Red Book and available international Standards and Guidelines for firefighting. It is glaring that the fire flows in the SANS 10090 and The Red Book are conservative and while adequate fire protection must be provided to communities, the current fire flows need to be revised (reduced) in light of dire water scarcity and the need to design optimal (the least cost) water networks. The above results also provide hope to communities and local councils who cannot depend on erratic water supply to fight fires as well-equipped firefighting services (with fire engines that can convey 9 kℓ of water) may be able to extinguish at least 75 % or fires in communities.

5 REFERENCES

[1] DHS and CSIR (Department of Human Settlements, South Africa and Centre for Scientific and Industrial Research). The Neighbourhood Planning and Design Guide (The Red Book): Creating Sustainable Human Settlement. Pretoria. 2019. ISBN 978-0-6399283-2-6.

[2] Council for Scientific and Industrial Research (CSIR), Guidelines for Human Settlement Planning and Design (The Red Book). CSIR Building and Construction Technology, Pretoria, 2005.

[3] J. E. van Zyl and J. Haarhoff. "South African fire water guidelines and their impact on water supply system cost", Journal of the South African Institution of Civil Engineering, vol. 39, no. 1, 1997, pp 16–22.

[4] J. van Zyl, M. Davy and F. Haihambo, "Water used for fire fighting in Cape Town", Proceedings of the Computing and Control for the Water Industry (CCWI) conference, Centre for Water Systems, University of Exeter, 2011, pp 107-112.

[5] H. M. Myburgh and H. E. Jacobs. "Water for firefighting in five South African towns", Water SA, vol. 40, no. 1, 2014, pp. 11–17. https://doi.org/10.4314/wsa.v40i1.2

[6] C. B. Mac Bean and A. A. Ilemobade. "An evaluation of the primary South African Standard and Guideline for the provision of water for firefighting". Water SA, vol. 45, no. 4, 2019, pp. 691–699. https://doi.org/10.17159/wsa/2019.v45.i4.7551

[7] SABS (South African Bureau of Standards), SANS 10090:2018 South African National Standard. Community protection against fire. Standards South Africa (a division of SABS). Edition 3.1, 2018, Pretoria. ISBN 978-0-626-36193-8.

[8] F. Essack and A. Ilemobade, "Water for fighting large structural fires: a South African study", Urban Water Journal, 2022. https://doi.org/10.1080/1573062X.2022.2050928

[9] Thage and Ilemobade, "Water for firefighting in Sol Plaatje municipality, Northern Cape, South Africa", unpublished draft M.Sc. Research Report. University of the Witwatersrand, Johannesburg, 2022.

[10] S. Davies, Fire fighting water: a review of fire fighting water requirements. A New Zealand perspective. Fire Engineering Research Report 00/3, M.E. (Fire) degree at the University of Canterbury, March, 2000.

[11] M. Benfer and J. Scheffey, Evaluation of Fire Flow Methodologies. The Fire Protection Research Foundation, Quincy, Massachusetts, 2014. https://doi.org/10.1007/978-1-4939-2889-7

[12] J. E. van Zyl, "Peak factors in municipal water reticulation networks". Proceedings of the Water Institution of South Africa Biennial Conference and Exhibition, Port Elizabeth, South Africa, 20–23 May 1996.