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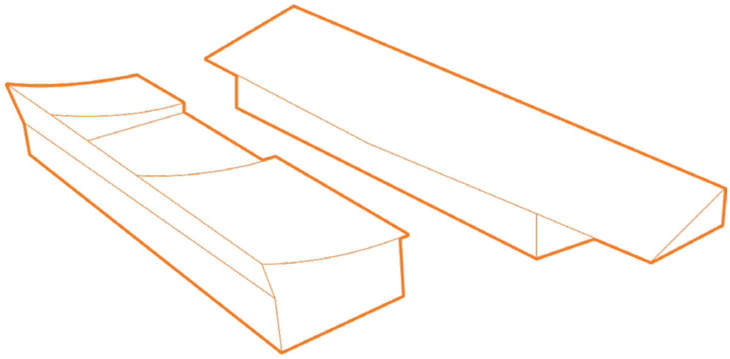

BUSHFIRE SPRINKLER SYSTEMS FOR INCREASED BUSHFIRE RESILIENCE OF NEW AND EXISTING RESIDENTIAL BUILDINGS

PHASE 1 FINAL REPORT

OCTOBER 2022

ABOUT THIS REPORT

Title: Bushfire Sprinkler Systems for Increasing Bushfire Resilience of New and Existing Residential Buildings – Phase 1 Final Report

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Executive Summary

This report outlines findings from Phase 1 of the project 'Bushfire Sprinkler Systems for Increasing Bushfire Resilience of New and Existing Residential Buildings'. It contains the following:

1. A detailed but concise review of scientific literature and technical guidance relevant to the design of bushfire sprinkler systems.
2. An illustrative case study that is used to explore the challenges facing homeowners who wish to install an effective bushfire sprinkler system.
3. A prioritised plan, or 'roadmap', for future research on this topic.

Key issues identified in the literature, which require further scientific investigation and/or development of technologies, include the following:

A. Quantitative comparison of the various mechanisms by which water sprays could afford protection against ember attack, radiant heat, and flame contact.
B. Further characterisation of wind effects on sprinkler sprays under bushfire conditions.
C. Assessment of post-impact water transport mechanisms (e.g. splashing, film flow, etc.) and their potential to disrupt or enhance bushfire protection.
D. Investigations into water-saving strategies, including the intermittent or staged/zoned operation of sprinklers, and the use of foam or gel-forming agents, or fire retardants, with bushfire sprinklers.
E. Further development and assessment of technologies for the autonomous or remote activation of bushfire sprinklers.

A prioritised list of potential future research packages has been developed to address these issues, as summarised below (and continued on the following page).

Summary of key research priorities for bushfire sprinklers.

Work Package	Proposed Activities	Knowledge gaps addressed
1. AS 5414 testing of common sprinkler arrangements	• Independent water distribution testing of a range of available sprinkler heads to AS5414 Appendix A, including irrigation sprinklers often used for bushfire protection, and purpose-built wall-wetting fire sprinklers • Testing in quiescent and windy conditions	• Apparent lack of AS 5414-compliant sprinkler arrangements • Limited information available on wind effects on bushfire sprinkler sprays • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)

Work Package	Proposed Activities	Knowledge gaps addressed
2. Testing and simulation of wind effects and post-impact transport	• Further development of CFD methods for bushfire sprinklers, including: - Post-impact transport (e.g. splashing, film flow, etc.) - Improved treatment of turbulence (e.g. using large-eddy simulation) • Validation of CFD models with practical field testing of sprinkler systems on real homes with actual and simulated wind conditions • CFD simulations of sprinklers for archetypal house, property and bushfire scenarios	• Limited information available on wind effects on bushfire sprinkler sprays • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)
3. Laboratory testing of bushfire protection by water sprays	• Carry out a campaign of furnace tests to validate direct cooling and radiation attenuation afforded by water sprays • Carry out a campaign of wind tunnel tests to investigate ember protection afforded by water sprays, including: - Extinguishment of accumulated embers - Potential prevention of ember entry through openings • Develop and validate physics-based theoretical models to complement testing • Further development of CFD methods for bushfire sprinklers, including: - Modelling of radiant heat - Modelling of cooling by sprays - Modelling ember attack	• Limited ability to accurately quantify protection afforded by bushfire sprinkler systems • Lack of evidence supporting feasibility of protection via various mechanisms (e.g. radiation attenuation, ember extinguishment, etc.) • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)
4. Assessment and development of autonomous activation technologies	• Develop a set of priority candidate activation technologies and systems • Undertake numerical modelling of their performance under bushfire scenarios • Laboratory and full-scale systems testing program	• Technologies for automatic and autonomous activation of bushfire sprinklers are not yet well developed or proven
5. Detailed design case studies	• Identify range of archetypal bushfire sprinkler design scenarios • Develop sprinkler system designs for each scenario, based on quantified assessment and optimisation of system effectiveness • Conduct cost-benefit analysis for each scenario, and compare sprinkler system with other (passive) measures	• Uncertainty surrounding the benefits of sprinkler systems, as compared to passive bushfire protection measures • Lack of detailed, evidence-based design guidance and application case studies available to building design professionals, or householders, on design of bushfire sprinkler systems
6. Develop detailed, evidence-based design guidance	• Develop appropriate resources that provide information to key stakeholders based on results from previous work packages	• Lack of detailed, evidence-based design guidance and application case studies available to building design professionals, or householders, on design of bushfire sprinkler systems

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List of abbreviations

APZ	Asset protection zone
BAL	Bushfire attack level
CFA	Victorian Country Fire Authority
CFD	Computational fluid dynamics
CFS	South Australian Country Fire Service
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FEMA	Federal Emergency Management Agency
FPAA	Fire Protection Association Australia
FWPA	Forest and Wood Products Australia Limited
NCC	National construction code
RFS	New South Wales Rural Fire Service
SBRC	Sustainable Buildings Research Centre
WEEDS	Wind-enabled ember dousing system

1 Introduction

This report outlines findings from Phase 1 of the project 'Bushfire Sprinkler Systems for Increasing Bushfire Resilience of New and Existing Residential Buildings', which was conducted by the Sustainable Buildings Research Centre (SBRC) at the University of Wollongong, supported by Forest and Wood Products Australia (FWPA). This phase of the project was designed to establish a foundation on which further scientific investigations into bushfire sprinkler systems can be based.

1.1 BACKGROUND

Bushfires (also known as wildfires) pose a significant hazard to human populations in many jurisdictions around the world, and the severity of this hazard is predicted to increase into the foreseeable future, primarily due to the impacts of global warming and urban expansion [1–6]. Risk management at the wildland-urban interface can involve various types of action, including:

- Wildland fuel management (e.g. clearing vegetation or prescribed burning);
- Separation of wildland fuels and houses via urban planning policies and/or the clearing of vegetation to establish 'asset protection zones' (APZs, also known as 'defensible space');
- 'Hardening' exposed buildings (i.e. designing and/or retrofitting houses and other buildings for improved resistance to bushfire attack);
- Support for residents to effectively prepare for, and respond to, bushfires.

Previous research has typically indicated that people and property are protected most effectively when a multi-faceted approach is adopted, involving action in all or most of the above-listed categories [6–10].

Water spray systems have been used to protect houses from bushfires since at least 1984 [11]. The design of such bushfire sprinkler systems can vary from ad-hoc arrangements of garden irrigation sprinklers positioned to wet the at-risk building and/or its surroundings, through to engineered systems integrated with the building fabric [11,12]. The sprinkler heads are typically installed outdoors, although the potential that typical indoor fire sprinklers may also provide some protection against bushfires has been raised [11,13,14]. Activation of the sprinklers can be achieved manually on site (e.g. by the activation of a pump or valve), remotely (e.g. using radio or SMS technology), or autonomously (e.g. using heat sensors).

At the time of writing, the Australian National Construction Code (NCC) and relevant referenced standards [15–17] did not require designers of new buildings in bushfire-prone areas to include bushfire sprinklers, or permit them to use bushfire sprinklers to offset other bushfire safety design requirements. This treatment of bushfire sprinklers appears to be typical in other jurisdictions as well; while the International Wildland-Urban Interface Code [18] requires the most vulnerable category of buildings to be protected by an "approved automatic sprinkler system … in accordance with nationally recognised standards", many jurisdictions that have adopted the code have deleted this clause, and where the clause is adopted it is taken to refer to typical indoor fire sprinklers rather than bushfire-specific designs, to the best of our knowledge.

Sources of bushfire safety guidance typically take a similar approach, by either not mentioning sprinklers or presenting them as an optional measure that can be taken in addition to the necessary 'passive' measures (e.g. protection of windows using screens or shutters, closing of gaps that could allow embers to enter the building, removal or covering of exposed combustible building elements, etc.). Several potential issues apply to 'active' protection systems (i.e. sprinklers) but not 'passive' systems, and these issues are likely to have led to the different treatment of active and passive measures in building codes and bushfire safety guidance. Such issues include:

1. Potential poor reliability of sprinkler systems due to their relative complexity;
2. The potential for sprinkler systems requiring manual activation on site to motivate residents to 'stay and defend' their property, or to 'leave late', rather than evacuating safely; and
3. The limited evidence currently available that demonstrates the effectiveness of sprinklers in providing bushfire protection, or demonstrates how to design effective systems.

These three issues need to be addressed in the design and use of bushfire sprinkler systems, as discussed in the following paragraphs.

The issue of reliability can be addressed through engineering measures, in a similar fashion to other active safety systems (such as indoor fire sprinklers or safety devices in lifts/elevators). For bushfire sprinkler systems to be reliable, they must [12,13]:

- Include an independent water supply (since mains water pressure often drops to unusable levels during bushfire events);
- Rely only on independent power supplies (since mains electricity supplies are often interrupted during bushfires);

- Be capable of operation within the heat, smoke, and wind of a bushfire without malfunction or significant degradation in performance; and
- Be maintained over time to prevent malfunction.

The second potential issue listed on the previous page (i.e. the risk of motivating residents to remain at home to activate sprinklers as bushfires approach, rather than evacuating early) could be overcome by technologies for reliable autonomous or remote activation of sprinklers, and through clear communication of sprinkler system requirements and capabilities to system designers and residents.

Regarding the third potential issue, existing evidence demonstrating bushfire sprinkler effectiveness was reviewed and extended in a doctoral thesis by the first author [12], and is reviewed again in this report. The research road map proposed in this report is designed to address gaps in the existing evidence base.

Whether or not bushfire sprinklers are ever treated equally to passive measures in building codes and bushfire safety guidance remains to be seen. Even if sprinklers remain a secondary, optional protection measure, continued scientific investigation into their effectiveness, and development of technologies to improve their performance, will facilitate the provision of more detailed, evidence-based guidance to those residents who choose to install them. Such guidance would empower households to make better-informed bushfire risk-management decisions, to design effective sprinkler systems, and potentially to achieve improved life and property safety.

1.2 PROJECT AIMS AND REPORT CONTENTS

The aim of the current project is to establish a more comprehensive evidence base to support the design of effective and reliable bushfire sprinkler systems. Phase 1of the project, from which this report has been developed, has focused on reviewing existing knowledge and design guidance, and developing a plan for potential future phases of work.

This report provides the following:

- Section 2 presents a concise summary of existing design guidance and scientific literature relevant to bushfire sprinkler systems;
- Section 3 presents a case study that illustrates how existing guidance can be applied to the design of real systems; and
- Section 4 summarises future research needs and priorities.

2 Existing Guidance and Knowledge

Existing sources of guidance on the design of bushfire sprinkler systems, and the current scientific knowledge underpinning that guidance, have been reviewed below. Each sub-heading in this section corresponds to a primary task that the designer of a bushfire sprinkler system needs to undertake. Key issues and gaps in the current understanding of bushfire sprinklers have been emphasised in the text through the use of breakout boxes.

2.1 SELECTION AND POSITIONING OF SPRINKLERS

Designers of bushfire sprinkler systems face the critical task of selecting appropriate sprinkler heads (or other means of releasing water, such as slotted pipes), and deciding where they are to be installed relative to the building that requires protection. Existing guidance on these design decisions is not consistent, and lacks detail in many cases. A summary is provided in Table 1.

Table 1: Summary of existing guidance on the selection and positioning of sprinklers.

Source	Guidance

AS 5414:2012 [19]	The Australian standard for bushfire water spray systems specifies the following for a system designed to address ember attack and radiant heat fluxes up to 19 kW m^{-2}:
	- Sprinklers shall be metal.
	- Sprinklers shall have no moving parts and be fitted with blow-off caps, unless otherwise protected against insect blockage.
	- Sprinklers shall deliver water to target surfaces at rates not less than:
	  ○ 10 L m^{-2} min^{-1} on unscreened glazing;
	  ○ 5 L m^{-2} min^{-1} on roofs, decks, screened glazing and 'other surfaces'; and
	  ○ 1 L m^{-2} min^{-1} on perimeter ground surfaces.
	- Sprinklers shall be positioned to 'minimise the effect of wind'; Appendix A of the standard specifies a compulsory test method for the confirmation that sprays deliver water as required under quiescent conditions and under a simulated 45 km h^{-1} cross-wind.

AS 2118.2:2021 [20]	Whilst not intended for bushfire protection, the Australian standard for wall-wetting sprinkler systems (previously referred to as drenchers) is relevant, and specifies the following features for systems to address radiant heat fluxes of up to 40 kW m^{-2}: - Sprinklers shall be vertical sidewall or window type, which spray in an arc of approximately 180° towards the wall, with a discharge coefficient (i.e. K factor) of 8 L min^{-1} kPa$^{-0.5}$. - The minimum flow rate through sprinklers is 75 L min^{-1}, or 55 L min^{-1} where individual windows are 1.8 m wide or less and are separated by a wall section that is greater than 500 mm wide. - The maximum vertical spacing of sprinklers is 4.6 m for glazed and combustible building envelope/infill materials, or 6.0 m for continuous non-glazed non-combustible infills. - The horizontal spacing of sprinklers shall be between 1.8 and 2.5 m.

Source	Guidance
FM Global (2022) [21]	A datasheet on wildland fire produced by FM Global specifies the following type of sprinkler system for the protection of sections of walls and/or windows exposed to higher potential radiant heat fluxes than the construction is deemed to be able to withstand: - Vertical sidewall, quick response sprinklers, rated to 72 °C. - Positioning of the sprinklers to meet minimum flow rates per unit length of wall specified in Table 2.5.1 of the datasheet. Flow rates are specified for combustible and non-combustible building elements, and for three ranges of incident heat flux (≤ 30, > 30, and > 40 kW m^{-2}).
FPAA (2000) [11]	A survey of existing systems in 2000 led to three types of system being recommended: 1. Misting nozzles installed to project a fine spray into vulnerable locations, such as roof penetrations, gutters, door and window openings, decks, etc. The water from all sprays should travel a maximum of 1 m before impinging on the target surface, to minimise wind effects. 2. Install the same misting nozzles as in system 1, and also install: a. A ring main approximately 10 m from the building, with metal upstands supporting 'butterfly' irrigation sprinklers; and b. A second ring main approximately 30 m from the building that feeds 'impact' irrigation sprinklers positioned to wet the surrounding bush. 3. Install a typical indoor automatic fire sprinkler system, and extend it to provide coverage of verandahs, awnings, etc. Also install upright fire sprinklers above the ridge of the roof.
CSIRO (2021) [22]	The CSIRO's online Bushfire Best Practice Guide makes the following recommendations: - Sprinklers should "wet the building facade and any vegetation and fine debris in the immediate vicinity". - "Use the system to address specific weaknesses that can't be remedied through siting and design". - "If possible, 'compliment' the external system with internal sprinklers". - "Consider using additional sprinkler heads in the roof cavity, and underfloor spaces". - Use sprinklers made of non-combustible materials.
CFA (2021) [23]	The Victorian Country Fire Authority website currently suggests: - Sprinklers "fully cover the area of your house exposed to fire" including roofs, doors, windows and decks.
CFS (2021) [24]	The South Australian Country Fire Service website currently suggests: - Sprinklers direct water over the roof, windows, doors and underfloor areas; - Sprinklers should spray up towards roofing on verandahs; - Sprinklers placed near gutters so that "the spray is blown down over the walls and windows and back onto the roof"; and - Garden sprinklers on the windward side of the building.
RFS (2021) [25]	The New South Wales Rural Fire Service website currently suggests: - Sprinklers can be attached to gutters.
Webster (2020) [26]	Joan Webster's book 'Essential bushfire safety tips' suggests: - Sprinklers can be used in the protection of flammable walls, windows, decks, roof valleys, galvanised iron roofs, tiled roofs, cement-sheeting roofs, eaves, gutters, skylights, air conditioning unit intakes, roof 'whirligigs', refuge room or bunker, exit doors, gardens, and outbuildings. - Water should ideally run down the roof and walls '"like a waterfall". - Brass sprinklers must be used. - The second type of system recommended by FPAA [11] is also recommended by Webster.

Source	Guidance
NFPA (2021) [27]	The National Fire Protection Association in the USA has published a fact sheet that suggests: - Sprinklers can be mounted on the roof, under eaves, or on the property so that they spray back towards the building that needs protection; and - Water should "reach all vulnerable areas" on or near the building.
FEMA (2008) [14]	A 2008 fact sheet series published by the US Federal Emergency Management Agency suggested: - Typical indoor fire sprinklers can be effective in preventing damage from bushfires; - Exterior sprinklers can be installed under eaves or at the roof ridge; and - Garden sprinklers installed to wet the surrounding landscape.
GTVFD (2007) [28]	Guidance released by the Gunflint Trail Volunteer Fire Department (in the Minnesota, USA) recommends: - Irrigation sprinklers, such as impact or gear-driven sprinklers, positioned to 'ensure protection' of primary structures, surrounding vegetation, and pump and delivery lines. These systems appear to have been effective in protecting Gunflint Trail homes during the 2007 Ham Lake Fire [29].
Mitchell (2006) [30]	A 'wind-enabled ember dousing system' (WEEDS) has been proposed and subjected to some preliminary analysis. The system includes: - Hollow-cone spray nozzles installed pointing outwards from under the eaves, with an intention that wind will blow the spray back onto the building during bushfires, driving it to the same locations that embers tend to accumulate. Further analysis of this type of system using CFD was presented in the first author's thesis [12].
Blaze Control* [31]	One proprietary bushfire sprinkler system sold in Australia consists of brass nozzles designed to project a fine spray towards the roof and walls.
Bushfire Pro* [32]	Another proprietary system projects water outwards from near the gutters using dual-arm rotating sprinklers.
Ember Defender* [33]	Another proprietary system sold for ember protection in Australia consists of butterfly sprinklers mounted to the roof ridge and gutters. The sprinklers are supplied by plastic pipe.
Platypus* [34]	Another proprietary system sold for ember protection in Australia and Canada consists of a type of butterfly sprinkler installed to spray outwards from near the gutters and roof ridge.
Rainmaker* [35]	A range of three proprietary sprinklers sold for bushfire protection in Australia includes: - Dual-arm rotating sprinklers spraying outwards from near the gutters; and - Two types of impact sprinkler mounted at the gutters or roof ridge. All three sprinklers appear to be designed for connection to standard garden hoses.
Bunnings* [36]	Guidance published by the hardware chain Bunnings suggests: - Metal sprinklers installed on the ground to prevent flying embers from reaching the home; - Sprinklers (e.g. butterfly sprinklers) installed near gutters, spraying outwards, to "reduce the impact of radiant heat, ember attacks and direct contact with fire". The sprinklers being promoted appear to be designed for connection to standard garden hoses.

** Entries marked with an asterisk represent a selection of commercially available sprinkler products. Other products are also available. The authors do not endorse the products included here over other types of sprinkler.*

Table 1 demonstrates the limited level of detail that is provided in many readily accessible sources of design guidance, and the lack of consistency in suggested sprinkler types and sprinkler positioning. In our experience conducting fieldwork in bushfire-prone areas, the guidance currently available on bushfire sprinkler design leaves many households unsure of whether it is worth installing a system, and how to design an effective system should they choose to.

Moreover, the variety of types of sprinkler system being promoted and sold could include designs that are not effective, and can therefore give residents a dangerous false sense of security. For example, without proper analysis or testing, some types of rooftop or gutter-mounted sprinkler could fail to deliver water to vulnerable building elements due to wind effects, and systems with plastic hoses or fittings could malfunction when those components melt.

Underlying the decision of what sprinklers to install, and how to position them around the building, lie two fundamental questions:

1. How can water be used to effectively protect building elements from ember attack, radiant heat, and/or direct flame contact during a bushfire?
2. How are water sprays dispersed under the conditions of a bushfire?

Existing scientific evidence relevant to these questions, and the implications for existing design guidance, are explored in the following sub-sections.

2.1.1 Protection afforded by water sprays

The mechanisms by which water sprays can extinguish fires are relatively well understood [37]. However, the application of that knowledge to bushfire sprinkler systems has not been published in much detail previously.

Key issue: Mechanisms of protection

The most detailed sources of guidance currently available [19–21] focus on applying water directly to vulnerable building elements, such as windows and combustible walls, to mitigate radiant heat gains through direct cooling. Minimum flow rates for such wall-wetting sprinkler systems appear to have originated from physical tests in the context of structural fires (e.g. see [38–41]). This evidence is also valuable in the bushfire context, and represents one of the most appropriate foundations currently available for bushfire sprinkler system design. However, several bushfire-specific issues need to be taken into account:

- The previous testing has typically focused on the protection of tempered glass, so may not be directly applicable to plane or laminated glass windows, which are common in detached residential structures.

- While the films and puddles of water produced by wall-wetting sprinklers are likely to also provide some protection against embers that accumulate up against the exterior of the sprinklered building elements, this mechanism of protection does not appear to have been investigated directly. Embers that penetrate through openings in the building envelope are less likely to be addressed by wall-wetting sprinklers, but this does not appear to have been investigated either.
- Spray dispersion in the bushfire context could be substantially different to that in the previous tests, due to wind effects, and the potential for water-shedding building features (such as window sills and flashings) to disrupt water films flowing down the vulnerable surface; these issues are discussed in Section 2.1.2.

In addition to the direct cooling of vulnerable building elements, bushfire sprinkler systems could afford protection via several other mechanisms, as outlined below.

- Systems that spray water onto vegetation and other fuels near the building could provide protection by reducing the radiant heat and ember fluxes incident on the building. However, the effectiveness of this approach in comparison to other approaches (e.g. wall-wetting sprinklers) does not appear to have been assessed in a rigorous manner yet.
- The protection against ember attack afforded by sprays has not been studied in much detail yet. An undergraduate thesis by Alvarez and Pastizzo [42] documents some preliminary CFD modelling of sprays and embers interacting near a building in wind; their results appear promising, but further work is needed to strengthen the modelling assumptions, and to extend on the scope of their study. Existing test methods involving the lofting of artificial embers in wind tunnels [43–45] could also be applied to this problem.

  Attenuation of radiant heat by 'curtains' of airborne droplets is a well-understood phenomenon [46–49]. For a given mass of water, maximum attenuation is achieved by droplets with diameters approximately equal to the radiant heat wavelength, which is predominantly in the range 1–10 μm in the context of bushfires (as compared to the measured droplet diameters in typical bushfire sprinkler sprays of 150–2000 μm [12,50]). The trade-off between smaller droplets (for improved radiant heat attenuation) and larger droplets (for reduced wind effects) has not yet been comprehensively addressed. In the first author's doctoral thesis [12], nine sprinkler systems were simulated under various environmental conditions and the potential radiation attenuation was estimated from the simulated spray dispersion patterns. Systems that projected droplets into the air between the bushfire and the building attenuated 6–26 % of incident radiant heat, whereas airborne droplets emitted by systems that directed sprays onto the roof or onto the top of the building's façade (employing a 'rundown' method) did not attenuate a significant quantity of radiant heat.

- Our team has also conducted a preliminary analysis of the potential for droplets to intercept and extinguish embers while airborne [51]. Results indicated that for this mechanism to be significant, a system would need either: (i) to produce very small (~100 μm) droplets, or (ii) very high water flow rates (in the order of 1 L s^{-1} per metre of wall being protected).
- The suitability of indoor fire sprinklers for bushfire protection has not yet been investigated in detail.

Further work is needed to quantify and compare these mechanisms of protection within the bushfire context. Development of a sound scientific understanding of the processes involved will allow the industry to transition from its current reliance on anecdotal evidence [11,29,30,52,53] and engineering judgement [11,13], towards detailed, evidence-based design guidance.

2.1.2 Spray dispersion and water delivery

A critical challenge in the design of a bushfire sprinkler system is to anticipate how the sprays will be dispersed under the extreme conditions of a bushfire, which typically include strong, hot winds [54]. Many different physical processes are involved in the dispersion of water from bushfire sprinklers, some of which are illustrated schematically in Figure 1.

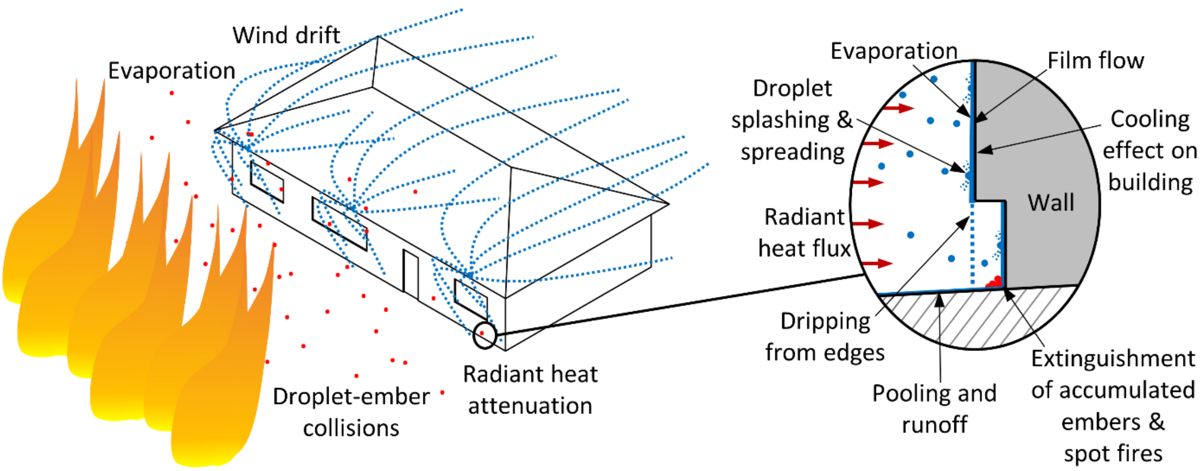

Figure 1: Schematic diagram of important physical processes that influence bushfire sprinkler performance. Red dots indicate embers, blue dots are indicative of water droplet trajectories and blue lines represent films of water on solid surfaces.

Key issue: Wind effects

Wind flow around buildings is complex and highly transient, and local air velocities (e.g. near the gutters of a building) can exceed the 'free stream' velocity by a significant margin [55]. The interaction of wind, bushfires, and structures is an active field of research [56,57]. The susceptibility of droplets to wind drift increases as droplet size decreases, and strong cross-flow (e.g. wind blowing through a sprinkler spray) can cause large droplets to become unstable and break up into groups of smaller droplets [58,59]. Droplet evaporation can also have a significant impact on water sprays emitted in wind [12,60].

General (qualitative) design guidelines, such as advice to use sprinklers that produce relatively large droplets, or to position sprinklers so they project water directly onto target surfaces over a short range, can help to minimise wind effects. However, a more detailed, quantitative understanding of spray dispersion under bushfire conditions would allow the provision of more detailed, evidence-based guidance regarding sprinkler selection and placement.

The test method in Appendix A of AS 5414 [19] provides a standard means to assess the susceptibility of specific sprinkler arrangements to wind effects, albeit through the simulation of a single simplified wind scenario. However, to the best of our knowledge, no evidence that any sprinkler systems have been tested using this method has been published.

The SBRC team has previously used computational fluid dynamics (CFD) simulations and experiments to investigate wind-building-spray interactions relevant to bushfire sprinklers [12,61]. Field tests of sprinklers in wind were used to validate CFD models, which were then used to analyse the performance of nine bushfire sprinkler systems in several sets of bushfire-like conditions. Within the cases investigated, wind was found to cause up to 40 % of the sprayed water to drift downwind of the building, and up to 20 % of water was evaporated. The susceptibility of different systems to wind effects appeared to be driven primarily by the positioning of the sprinklers. Systems that sprayed water outwards, away from the building, or above its roof, suffered relatively severe wind drift and evaporation, whereas systems that projected droplets towards the building over a relatively short range (e.g. from under its gutters towards its walls) were impacted less.

CFD simulation techniques can be applied to more comprehensive set of sprinkler systems and bushfire scenarios in the future, to build towards an understanding of sprinkler performance in bushfires that is more generally applicable.

After water emitted from bushfire sprinklers travels through the air and reaches the surfaces of a building and/or its surroundings, it undergoes further transport through processes such as splashing, film flow, and evaporation (Figure 1). Such processes can be critical to the protective action of sprinklers, e.g. gravity-driven film flow is often relied on to spread water over building surfaces, and evaporation is the primary process that facilitates the cooling action of such films.

To design effective bushfire sprinkler systems, the detailed physics involved in these 'post-impact' transport processes does not necessarily need to be completely understood. For example, physical tests can be undertaken to measure the cooling effect of sprays on a heated surface, and the combined effects of splashing, film flow, evaporation, etc. will be included in the resulting data. These combined effects can then be characterised using a single spray efficiency factor, or coefficient of performance, without needing to understand or model each physical process separately. However, certain aspects of post-impact transport processes are important, and should be taken into account when designing bushfire sprinkler systems, as discussed below.

Key issue: Post-impact water transport

Many features of building envelopes are designed to shed rainwater away from the building (e.g. bargeboards, flashings, window and door headers, window sills, weatherboard cladding, etc.). The impact of such features on the effectiveness of bushfire sprinkler systems employing a 'rundown' method (i.e. relying on film flow to spread water over the vulnerable building elements) does not appear to have been studied in detail.

Where computer modelling (e.g. CFD) is used to support the design of bushfire sprinkler systems, it can be important that post-impact transport processes are modelled accurately. In these cases, a sound understanding of those processes is needed. Extensive literature exists covering droplet splashing, bouncing and spreading on impact with a solid surface [62], including many experimental studies (e.g. [63]), and this information can be used to model those processes. Several film flow models have also been developed for integration into CFD software [64,65]. To the best of our knowledge, this body of scientific knowledge has not yet been applied to assessments of bushfire sprinkler systems.

2.2 DESIGN OF WATER SUPPLY SYSTEMS

Much of the design guidance currently available for bushfire sprinkler systems focuses on the design of the water supply system, i.e. water storage, pumps, and pipework. The relative abundance of detailed guidance on this aspect of bushfire sprinkler design is made possible by knowledge from other engineering disciplines that deal with pipe networks, and from post-fire surveys, which provide insights into the resilience of pipes, pumps and tanks to bushfire.

Several design principles are well established [11,13,19]:

- Systems should include an independent water supply (e.g. dam, pond, river, or tank) that will reliably contain sufficient water during bushfire events, even during severe droughts.
- Systems should not rely on mains electricity, and therefore water should be either gravity-fed, or pumped using petrol/diesel/gas-driven, or battery powered, pumps.
- Pipe networks should be designed such that sufficient pressure is provided to every sprinkler.
- Tanks should be made of metal or concrete, or buried, to withstand bushfire attack [66].
- If pumps, generators, and/or batteries are used, they should be installed and shielded so as to avoid excessive radiant heat or flame contact during bushfires.
- All pipework and fittings should be metal, or be buried or otherwise protected.
- The water supply system needs to be frequently maintained and tested, to minimise the risk of malfunction during bushfires.

These guidelines, together with established engineering procedures for pipe network design, pump selection, etc., form a basis for the design of effective bushfire sprinkler water supply systems.

Establishing a water supply with sufficient capacity can be a critical challenge in the design of bushfire sprinkler systems. Several possible water-saving strategies have been proposed, but require further investigation to determine how they could be implemented without diminishing the effectiveness of the system, as discussed below.

Key issue: Water-saving strategies

To use limited water resources most effectively, previous publications have suggested: (i) intermittent sprinkler operation at times when full protection is not required (e.g. before the main fire front arrives) [13,19], or (ii) ‘zoning’ of systems so that groups of sprinklers can be operated when needed, without being forced to operate all sprinklers at once [19]. These strategies are likely to have merit, and should be included in future studies aiming to quantify bushfire sprinkler effectiveness.

This kind of active control of sprinkler systems (or zones thereof) can be achieved manually in situations where the property is actively defended by residents, and alternatively could be achieved automatically or remotely in appropriately designed systems. Future investigations into automatic and/or remote activation of bushfire sprinklers should consider options to provide staged or zoned control of the system in response to the passing bushfire. The reliability of such complex systems will also need to be considered.

The dosing of sprinkler water supplies with foam or gel-forming agents, or fire retardant, has also been suggested as a water-saving strategy [11,14,19]. Such agents can increase the 'dwell time' of water on vulnerable building elements and nearby fuels, or produce an insulating layer of char that inhibits combustion. The performance of foams, gels and retardants has been tested in scenarios where materials are pre-coated once, before the arrival of a bushfire [67–69]. Further investigation is needed to understand how these agents can best be used in a sprinkler system that operates continuously or intermittently during bushfire events.

2.3 SYSTEM ACTIVATION

As discussed in Section 1, sprinkler activation is a critical challenge in the design and operation of bushfire sprinkler systems. The simplest approach is to design systems for manual activation by people on site, e.g. requiring residents to start pumps and actuate various valves. However, this approach carries the risk that residents may not be present to activate the system, or may feel compelled to stay and activate it soon before the arrival of bushfire when they would otherwise choose to evacuate to safety much earlier. Technologies for remote or automatic activation of sprinklers could provide a solution to this problem, as discussed below.

Key issue: Technologies for reliable autonomous or remote activation

Several bushfire pump activation systems with autonomous and/or remote activation capabilities are already commercially available. Such technologies have not yet seen enough use to establish a substantial track record of reliable operation, and there could still be opportunity for significant innovation in this space.

Autonomous activation of bushfire sprinklers could be achieved using various methods, ranging from technologies similar to those used in 'sealed' or 'wet pipe' indoor sprinkler systems (i.e. temperature-sensitive bulbs in each sprinkler head), through to more technologically advanced electronic activation systems employing infrared detection of an impending bushfire impact, for example.

Conventional heat-sensitive fire sprinkler heads are typically installed high within compartments, and activated when hot combustion products accumulate near the ceiling. If they are to be applied to exterior bushfire sprinkler systems, new designs may need to be developed to ensure timely activation in response to radiant heat, or even ember attack. Regardless of the means of sprinkler activation, pressurised water supply to the system must be ensured, and this requires either manual, autonomous or remote activation of the water supply, which may not be trivial in a bushfire situation where the electrical grid and mains water pressure are unavailable.

Autonomous activation using an electronic control system and appropriate sensors is also possible. Potter and Leonard published a discussion of considerations relevant to such systems [13]. Appropriate sensors could include smoke, temperature, or infrared radiation sensors. As mentioned previously, the reliability of such complex electronic activation systems would need to be carefully addressed.

Remote activation of bushfire sprinkler systems can also be achieved by a number of means, such as electronic activation of valves and/or starting of pumps/generators via one or more telecommunication channels. The reliable implementation and timing of these operations is clearly very important and sensor systems to detect the arrival, or imminent arrival, of a bushfire at the property are necessary. The issues of provision of reliable communications with the sprinkler system are also challenging given that currently the most attractive channels of telephone/internet landlines, mobile phone data connectivity and satellite internet may all suffer outages in the event of bushfire.

There are clearly a wide range of issues that need to be addressed in the development of reliable and cost-effective autonomous or remote activation systems for bushfire sprinkler systems. However, such activation systems hold the key to allowing householders to 'leave early' before a bushfire immediately threatens their home, but with confidence that the sprinkler system will provide increase resistance of their home to the impact of the fire.

3 Illustrative Case Study

In this section of the report, we consider the design process facing a technically competent homeowner who wishes to install an effective bushfire sprinkler system. This case study is based on our experience interviewing such homeowners in other studies (e.g. [70,71]), and observations from our review of the technical guidance and scientific literature currently available (Section 2).

3.1 BUILDING ARCHETYPE

The archetypal building chosen for this exercise is shown in Figure 2, and details of the floorplan and window dimensions are provided in Figure 3. This archetype was developed by Isaacs [72] for energy efficiency analyses, and has been used as a detached housing archetype in multiple housing stock modelling studies, e.g. by Bannister et al. [73].

Figure 2: 3D sketch of the archetypal single-storey detached house, viewed from the north-west (reproduced from [72]*).*

In order to estimate the overall sprinkler water supply flow rate and storage requirements, we next consider the areas of each external surface of the case study house. The approximate total wall area (excluding windows) for an assumed ground-to-eaves height of 2.7 m is 117 m^2 with the area of windows being 44 m^2. If we assume a roof pitch of 22° and eave depth of 500 mm, the total roof surface area becomes 238 m^2, and the total area of the home's two gables becomes 37 m^2.

Figure 3: Dimensions of house and glazing for the detached house archetype (adapted from [72]*).*

3.2 LOCAL BUSHFIRE HAZARD

The severity of the local bushfire hazard can be characterised by a bushfire attack level (BAL), calculated according to AS 3959 [16]. The BAL accounts for the types of vegetation nearby, its proximity to the building, and the slope of the terrain under the vegetation, as well as the typical severity of bushfire weather conditions in the local jurisdiction. However, factors affecting the local bushfire hazard that are not captured by a BAL rating include the building's proximity to isolated gardens and trees, neighbouring buildings, and other items that can act as fuel sources in a bushfire, such as timber fences and wood piles.

In our case study, we will assume that the primary bushfire hazard is posed by forest fuels to the north-west of the building. We will consider a range of scenarios, where the BAL is 12.5, 19, or 40 (corresponding to predicted bushfire exposure involving ember attack, and either 12.5, 19 or 40 kW m^{-2} of radiant heat exposure, respectively), and where a neighbouring structure to the south of the house is either close (2 m from the south façade) or far away (greater than 10 m from the façade).

3.3 THE DESIGN PROCESS

The first challenge facing the homeowner is in locating detailed and evidence-based design guidance. As shown in Table 1, many existing sources of guidance are lacking in detail, and/or are inconsistent with other guidance. Our homeowner could be convinced to install sprinklers on their roof, near their gutters pointing outwards, under their eaves pointing inwards, at ground level aimed at the house, and/or in the landscape surrounding the house. Their ability to understand which approach is most appropriate, and how much protection will be afforded by the system, is severely limited by the state of the science and published technical guidance.

Supposing that the homeowner chooses to design their system according to AS 5414 [19] because it provides relatively detailed and quantified guidance, the following challenges will then be faced:

- The standard only specifies a system to address BAL 19, so in our scenarios involving BAL 12.5 the homeowner is not equipped to determine reduced water application rates appropriate for that level of hazard severity, and in scenarios involving BAL 40 the homeowner is left unsure of the level of protection that the AS 5414-compliant system will provide.
- The standard requires water to be discharged "over all points of vulnerability and possible ember ingress". However, the standard leaves the identification of 'points of vulnerability' up to the judgement of the user (albeit with some suggestions). Moreover, the efficacy of water sprays in preventing ember penetration through openings in the building envelope (e.g. under ridge capping) does not appear to be supported by existing evidence.
- No sprinklers appear to have yet been tested to AS 5414, so the homeowner is unable to design a system that complies with the standard without conducting their own water dispersion tests according to Appendix A. Without those tests, wind effects and other losses are ignored.
- The standard specifies requirements for systems intended to provide "a degree of building protection", but the degree of protection is not quantified (e.g. in terms of a reduction in effective radiant heat flux, or reduction in risk of ignition by embers).

In scenarios involving BAL 40, the homeowner may also refer to AS 2118.2 [20] or the FM Global datasheet [21] for guidance. Table 2 presents a comparison of the minimum water flow rates from these two documents with those from AS 5414. Notably, minimum flow rates from AS 5414 are similar to, and in some cases even higher than, the flow rates specified in the other two documents, despite the nominal level of protection being approximately half that specified in the other two documents. Moreover, the minimum flow rates specified in AS 5414 refer to the rate of water *deposition on the target surface*, whereas minimum flow rates in the other two documents refer to the rate of water *emission from the sprinklers*. Therefore, AS 5414-compliant systems need to emit water at even higher flow rates than indicated in Table 2, to allow for overspray, wind drift, splashing, evaporation, etc.

Table 2: Approximate comparison of minimum water flow rates across standards and guidelines.

Standard or guideline	Max kW m^{-2} applicable	Water flow rate per unit wall area (L min^{-1} m^{-2})		
		Unscreened glazing	Combustible wall	Non-combustible wall
AS 5414 [1] [19]	19	10	5	5
AS 2118.2 [2] [20]	40	6.5	6.5	5
FM Global [3] [21]	40	4.4–5.9	5.5–9.3	4.4–5.9

[1] *Flow rates stated explicitly in AS 5414. Note that these values represent the minimum rate of water deposition on target surfaces, whereas values from the other two documents represent the minimum water flow rate emitted by sprinklers.*
[2] *Note that AS 2118.2 was not developed for bushfire protection.*
[3] *Values taken from flow rates provided for 30–40 kW m^{-2} radiant heat exposure over the range of vertical sprinkler spacings listed in the FM Global datasheet.*

It is possible that the relatively high flow rates specified in AS 5414 resulted from the use of a larger factor of safety by the authors of that standard, potentially to address uncertainties around the efficacy of sprays in defending against ember attack, or in protecting plane glass windows from radiant heat. Nevertheless, for our homeowner designing a system in a BAL 40 scenario, these disparities in the available guidance are unhelpful.

Once the homeowner has selected appropriate sprinkler heads, tested them to AS 5414 (or decided to ensure appropriate water dispersion under strong winds by some other means), and determined where they need to be installed around the building, they can calculate the volume of stored water that is required.

Figure 4 provides a breakdown of the minimum water flow rates required to protect different sections of the case study building, and Figure 5 presents the required water storage capacity for the system. Values in these figures were calculated using the AS 5414 minimum water deposition rates and an assumed 'wetting efficiency' (i.e. fraction of water emitted from the sprinklers that is deposited on the target surface) of 80 %. The wetting efficiency has been assumed in this case study because, as noted previously, test data conforming to Appendix A of AS 5414 do not appear to be available for any sprinkler arrangements. Our previous CFD modelling [12] indicates that a value of 80 % may be achievable in a carefully-designed sprinkler system.

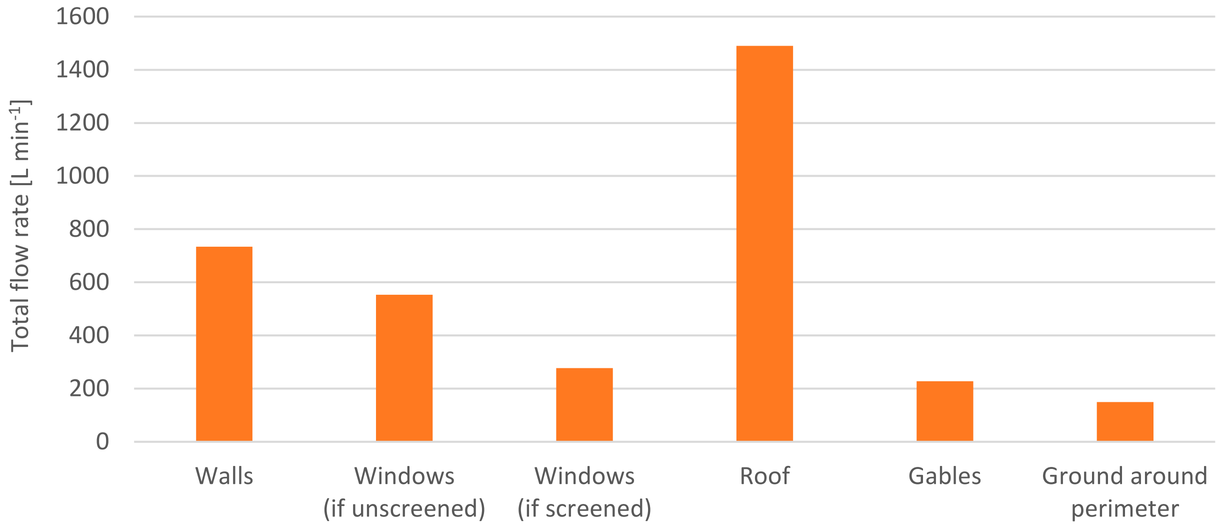

Figure 4: Total flow rates calculated for the case study building, based on AS 5414 water density supply requirements and an assumed wetting efficiency of 80 %.

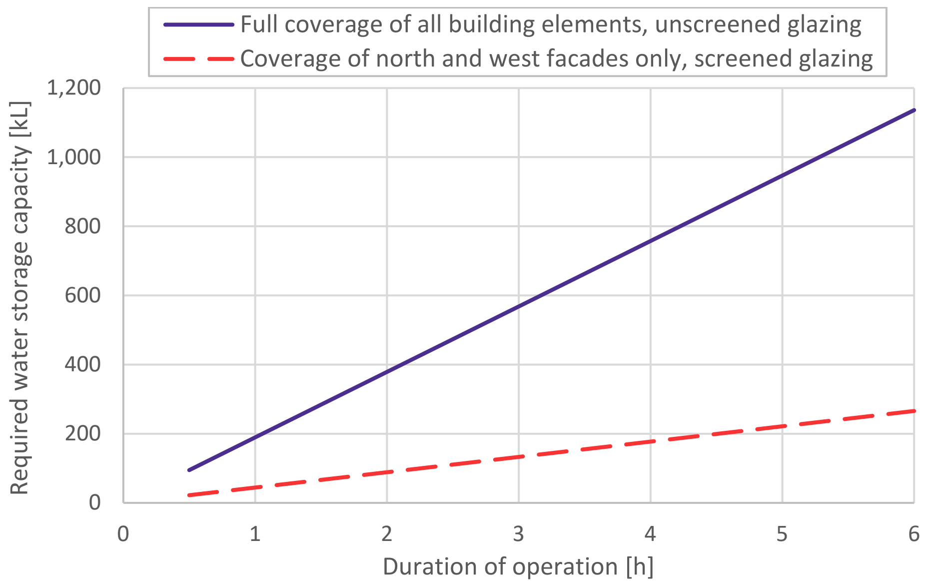

Figure 5: Required water storage capacity for the case study building, based on AS 5414 water density supply requirements and an assumed wetting efficiency of 80 %.

Two sets of data are included in Figure 5:

1. Full coverage of all building elements, assuming that the windows are unscreened.
2. Selective coverage of certain elements, including the hazard-facing (i.e. north and west) walls and windows, with no coverage of the roof or other facades; glazing is assumed to be screened in this case.

The duration of operation that the system is designed for (i.e. horizontal axis in Figure 5) is clearly an important design parameter. Recommendations in design guidance vary widely, from 30 min [19] through to 4 h [22], 6 h [13], or even 18 h [28]. If our homeowner adheres strictly to the AS 5414 recommendation (30 min), their system will require approximately 22–95 kL of water storage, depending on how many building features are assessed to be 'vulnerable' and provided with sprinkler coverage. Such quantities are likely to be well within the expectations of residents in rural and peri-urban areas, where dams and large water tanks are commonplace. However, if the system needs to operate for longer than 30 min, e.g. to address the hazard posed by a neighbouring structure in scenarios where one is close to the house, several hundred kilolitres of storage could be needed, and such large water storage requirements could be challenging and/or expensive to establish.

The homeowner could consider several water-saving strategies, such as intermittent or zoned sprinkler operation, or the use of foam or gel-forming agents, but no detailed information appears to be available to guide their effective implementation. The required capacity of the system could be reduced substantially by deciding not to spray the roof (see Figure 4), and this decision could be justified for non-combustible (e.g. steel or tiled) roofs given the apparent lack of evidence supporting the efficacy of rooftop sprinklers at preventing ember ingress. However, the effectiveness of rooftop sprinklers remains an open question, so our homeowner is left to make this judgement themselves.

When the homeowner comes to the design of a pipe network, selection of pumps, etc., there are relatively detailed and consistent resources available to guide these processes (see Section 2.2). For example, a useful example hydraulic calculation is provided in Appendix E of AS 5414.

The final challenge facing the homeowner is to integrate their new bushfire sprinkler system appropriately into their bushfire survival plan. In many cases, this is likely to require a system for autonomous or remote activation of the sprinklers. Existing technologies can provide this functionality; however their performance under bushfire conditions (including potential disruptions to telecommunications channels) is not yet completely proven (see Section 2.3).

4 Future Research Needs and Priorities

During the course of the present project we have investigated many of the key issues that need to be addressed to facilitate development of effective and economic bushfire sprinkler systems, which will in turn lead more widespread adoption of such systems by households in bushfire prone areas. A summary of highest priority knowledge and information gaps and our suggested programs of work to address these is provided in Table 3 with further details of some of the points outlined below.

Table 3: Summary of key research priorities for bushfire sprinklers.

Work Package	Proposed Activities	Knowledge gaps addressed
1. AS 5414 testing of common sprinkler arrangements	• Independent water distribution testing of a range of available sprinkler heads to AS5414 Appendix A, including irrigation sprinklers often used for bushfire protection, and purpose-built wall-wetting fire sprinklers • Testing in quiescent and windy conditions	• Apparent lack of AS 5414-compliant sprinkler arrangements • Limited information available on wind effects on bushfire sprinkler sprays • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)
2. Testing and simulation of wind effects and post-impact transport	• Further development of CFD methods for bushfire sprinklers, including: - Post-impact transport (e.g. splashing, film flow, etc.) - Improved treatment of turbulence (e.g. using large-eddy simulation) • Validation of CFD models with practical field testing of sprinkler systems on real homes with actual and simulated wind conditions • CFD simulations of sprinklers for archetypal house, property and bushfire scenarios	• Limited information available on wind effects on bushfire sprinkler sprays • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)
3. Laboratory testing of bushfire protection by water sprays	• Carry out a campaign of furnace tests to validate direct cooling and radiation attenuation afforded by water sprays • Carry out a campaign of wind tunnel tests to investigate ember protection afforded by water sprays, including: - Extinguishment of accumulated embers - Potential prevention of ember entry through openings • Develop and validate physics-based theoretical models to complement testing • Further development of CFD methods for bushfire sprinklers, including: - Modelling of radiant heat - Modelling of cooling by sprays - Modelling ember attack	• Limited ability to accurately quantify protection afforded by bushfire sprinkler systems • Lack of evidence supporting feasibility of protection via various mechanisms (e.g. radiation attenuation, ember extinguishment, etc.) • Assessment needed of post-impact transport processes (e.g. impact of water-shedding building features and uneven film flow on water dispersion)

Work Package	Proposed Activities	Knowledge gaps addressed
4. Assessment and development of automatic and autonomous activation technologies	• Develop a set of priority candidate activation technologies and systems • Undertake numerical modelling of their performance under bushfire scenarios • Laboratory and full-scale systems testing program	• Technologies for automatic and autonomous activation of bushfire sprinklers are not yet well developed or proven
5. Detailed design case studies	• Identify range of archetypal bushfire sprinkler design scenarios • Develop sprinkler system designs for each scenario, based on quantified assessment and optimisation of system effectiveness • Conduct cost-benefit analysis for each scenario, and compare sprinkler system with other (passive) measures	• Uncertainty surrounding the benefits of sprinkler systems, as compared to passive bushfire protection measures • Lack of detailed, evidence-based design guidance and application case studies available to building design professionals, or householders, on design of bushfire sprinkler systems
6. Develop detailed, evidence-based design guidance	• Develop appropriate resources that provide information to key stakeholders based on results from previous work packages	• Lack of detailed, evidence-based design guidance and application case studies available to building design professionals, or householders, on design of bushfire sprinkler systems

4.1 AS 5414 TESTING OF COMMON SPRINKLER ARRANGEMENTS

Although AS 5414 has been in operation for a decade, there appears to be no readily available information as to whether any commercially available sprinklers/nozzles would comply with AS 5414. A high priority research and development activity to be undertaken as soon as possible is to test a range of candidate sprinklers according to the AS 5414 test methods under both calm and applied wind conditions. Three main sprinkler applications that would be targeted (in priority order) would be:

1. Wall-wetting sprinklers
2. Sprinklers for decks and other horizontal surfaces
3. Roof sprinklers

The immediate objective would be to assemble a water density/delivery performance database for a range of typical bushfire sprinkler configurations. Data would also be collected on post-impact water transport, e.g. through splashing and film flow. In subsequent phases of work, the data from this work package can be the used to assess the suitability of the AS 5414 test method, through a comparison with CFD simulations and field testing of sprays operating in more realistic wind flow.

4.2 TESTING AND SIMULATION OF WIND EFFECTS AND POST-IMPACT TRANSPORT

This work package focuses on the development of a rigorous evidence base to support the design of bushfire sprinkler systems that are resilient to the strong, hot, dry winds that typically accompany bushfires. Without detailed data on the wind drift, evaporation, and post-impact transport of water emitted by bushfire sprinklers, the selection and positioning of sprinklers is largely left to the judgement of system designers. This has led to a wide variety of systems being promoted, some of which would not operate as intended in realistic bushfire conditions. We propose that a range of further research needs to be undertaken including the following elements.

1. Further development of CFD methods for bushfire sprinkler assessment, including:
    a. Testing of improved turbulence treatment, such as large-eddy simulation and detached-eddy simulation.
    b. Simulation of post-impact water transport, through processes including splashing and film flow.
2. Field testing of several bushfire sprinkler arrangements in calm and windy conditions, collection of detailed data on the water dispersion patterns and post-impact transport, and use of that data to validate CFD models.
3. A parametric CFD simulation study to investigate a much broader range of sprinkler systems, building archetypes, and bushfire scenarios, than previously investigated [12].
4. Assessment of the suitability of the AS 5414 wind dispersion test method, through comparison with CFD simulations and field tests involving more realistic wind conditions.

4.3 LAB TESTING OF BUSHFIRE PROTECTION BY WATER SPRAYS

The limited ability to quantify the protection afforded by water sprays to buildings against ember attack, radiant heat and flame contact is a critical barrier preventing the design of more effective bushfire sprinkler systems. This work package focuses on developing experimental data and physics-based models to allow such quantification of sprinkler protection.

Specific tasks would include:

1. Furnace testing of non-combustible mock building elements in a test similar to AS 1530.8.1 [74], except with sprays wetting the specimen and/or spraying into the space between the

specimen and radiant heat source. This testing could be complemented by additional testing with combustible specimens (e.g. timber-clad walls and/or timber decks).

2. Wind-tunnel testing of sprays operating near mock building elements that are under direct ember attack, to investigate the effectiveness of sprays in:
    a. Extinguishing accumulated embers; and
    b. Preventing entry of embers through openings in the building envelope (e.g. under ridge capping)
3. Comparison of both sets of test data with existing theory, and development of new physics-based models where appropriate.
4. Use of test data to validate enhanced functionality in CFD simulations, including models for:
    a. Direct cooling of surfaces exposed to radiant heat;
    b. Attenuation of radiant heat by airborne droplets; and
    c. Extinguishment of embers.

4.4 ASSESSMENT AND DEVELOPMENT OF AUTONOMOUS ACTIVATION TECHNOLOGIES

The question of how bushfire sprinkler systems could and should be activated is critically important, as discussed in Section 2.3. This is a high-priority research requirement given that i) significant scientific and engineering knowledge gaps exists, and ii) the safety of householders will be greatly improved if systems can be automatically and/or remotely activated. We therefore suggest that a comprehensive program of work be undertaken that addresses this issue through activities such as the following:

1. Development of a short-list of candidate technologies and an assessment of their advantages and disadvantages, costs, etc.
2. Undertake a rigorous program of thermal modelling to determine the necessary sensitivity and temporal response to an impacting bushfire on sensors and detection systems.
3. Undertake a review of remote activation technologies and design of prototype systems.

4.5 DETAILED DESIGN CASE STUDIES

Once the effectiveness of bushfire sprinkler systems can be rigorously quantified (i.e. following the packages of work outlined above), a high-priority task will be to demonstrate how this new knowledge can be applied in the design of effective systems, and how effective the systems can be.

In this work package, archetypal design scenarios will be developed, covering situations from high-budget comprehensive sprinkler systems through to 'DIY' and last-minute/ad-hoc systems. Effective sprinkler systems will be designed and analysed for each scenario, and a cost-benefit analysis will be undertaken to allow comparison of different design options, as well as comparison of sprinkler systems to passive bushfire protection measures (e.g. substitution of materials).

4.6 DEVELOP DETAILED, EVIDENCE-BASED DESIGN GUIDANCE

The lack of consistent, detailed and evidence-based guidance to support the design of effective bushfire sprinkler systems has been a key finding of this report (see Section 2). Once the work packages described above have been undertaken, it will be possible to develop new guidance to overcome this problem.

Sprinkler system design resources will be developed in this work package. The aim will be to empower residents and professionals to design effective systems, to tailor those designs to their specific needs, and to understand the level of protection that each system is likely to provide. Target audiences for the guidance will include engineers, architects, and householders.

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