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Delivering a New Australian Fire Danger Rating System – Building on decades of research to deliver public safety outcomes

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Abstract

The Australian Fire Danger Rating System (AFDRS) was launched on 1 September 2022, bringing a generational change to the way that Australia calculates and communicates fire danger. Its focus is improved public safety and reduced impacts of bushfires through:

- Improving the science behind fire danger predictions.
- Improving the way that fire danger is communicated.
- Providing government and industry with better decision-making tools.
- Reducing future costs associated with bushfire impacts.

The previous fire danger rating system was introduced in the 1960's by Australia's first full-time bushfire researcher, Alan McArthur, based on extensive experimental fires. While useful, the system included only two fire behaviour models (dry sclerophyll forest and grassland), was not easily updateable and fires were being experienced that increasingly exceeded its design parameters.

In July 2014, Senior Officers and Ministers agreed that the development of a new system was a national priority. The new system was developed by the New South Wales Rural Fire Service in collaboration with the Bureau of Meteorology, all Australian states and territories and the Commonwealth government. Program management and system implementation were coordinated by AFAC (Australia's National Council for Fire and Emergency Services).

The new AFDRS uses contemporary fire behaviour science, makes better use of available data and uses software infrastructure that can be continuously improved. The AFDRS starts with eight fire behaviour models representing a range of Australian vegetation types, it captures current fuel information, uses satellite data, integrates weather from the Bureau of Meteorology and calculates fire danger down to a 1.5km by 1.5-kilometer grid. These calculations are linked to tools that assist fire operational decision-making via a Fire Behaviour Index that is calibrated to operational implications for fire management.

A separate arm of the project developed a public-facing Fire Danger Rating framework, guided by one of Australia's largest social research projects. The research found that, while fire danger signage was well recognised, few acted on fire danger ratings to plan their activities. Focus groups and subsequent surveys found that the community preferred a simplified public-facing system where each fire danger rating had a distinct call to action.

The implementation of the new system required an enormous effort from all levels of government across all States and Territories as well as the Commonwealth. It required updates to legislation, policy, procedures, web pages and other IT infrastructure, as well as replacement of physical signage. However, as a result, Australia has a significantly new way of calculating and communicating fire danger, that is continuously improvable and which will bring benefits for decades to come.

1. Introduction

The 2009 Black Saturday fires that devastated the state of Victoria was a watershed moment for Australian bushfire management. It was Australia's highest-ever loss of life from bushfires and many people were left homeless (Parliament of Victoria, 2010). With at least 18 major bushfire inquiries in Australia since 1939, the

Black Saturday fires were by no means the only devastating fires (Parliament of Australia, 2022), nor were they the largest or most recent. The unprecedented fires of the 2019-2020 Black Summer saw over 24 million hectares burnt, 3000 homes destroyed, 33 lives lost, species populations devastated and accrued an estimated financial impact of $10 billion (Commonwealth of Australia, 2020).

But it was the Black Saturday fires of 2009 that galvanised contemporary efforts to improve bushfire management systems in Australia, including the first efforts to review Australia's aging fire danger rating system (Figure 1).

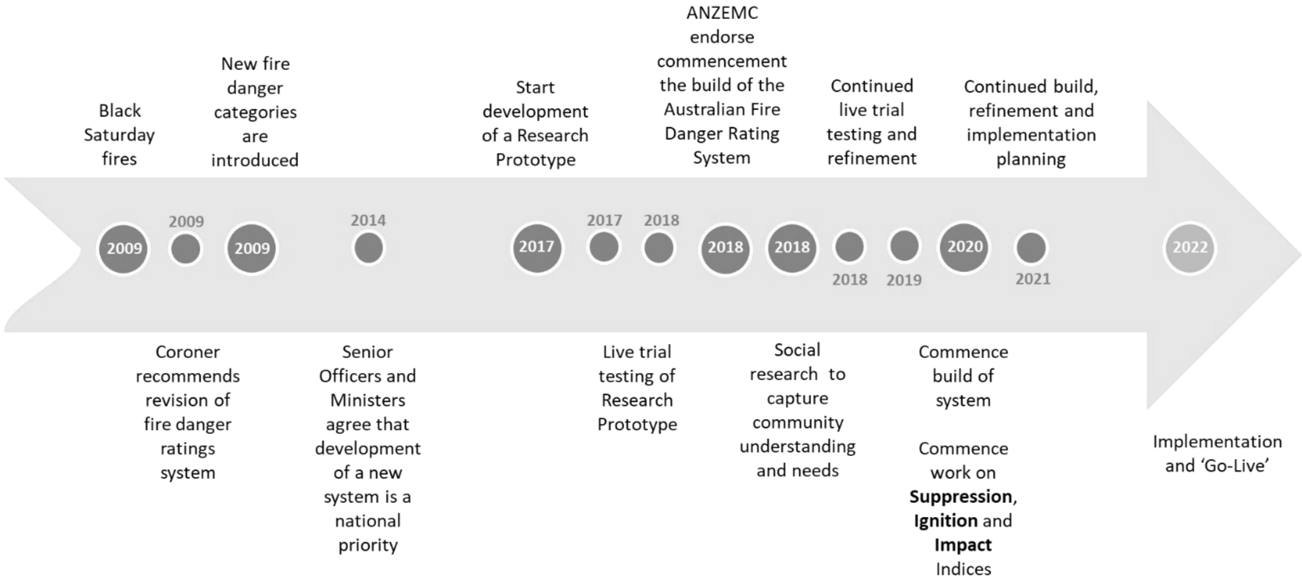

Figure 1- History of the development of the AFDRS

2. Fire Danger Ratings in Australia

Fire danger is a general term representing many factors culminating in a fire environment including ignition potential, fire hazard, risk, rate of spread, difficulty of control, fire impacts and safety. Fire danger rating is a valuable tool in communicating bushfire risk to the community, not only by increasing public awareness but also as a trigger for notification of potential threats. Importantly, because of its foundation in fire weather and behaviour, fire danger rating also provides a tool for decision-making in fire suppression operations and prescribed burning (Matthews *et al.*, 2018).

2.1. The McArthur System

Alan McArthur was the first full-time bushfire scientist in Australia, when he gained a job in 1953 working for the then Commonwealth Forest and Timber Bureau. He was tasked with developing a national fire danger rating system to suit Australian conditions. Alan and his team conducted more than 400 experimental fires that provided data to support fire behaviour models for dry sclerophyll forests, and later, for grassland. This work, together with data from high intensity bushfires, led to McArthur introducing two indices, The Forest Fire Danger Index (FFDI) and the Grassland Fire Danger Index (GFDI). These were aligned to fire danger ratings based on fire suppression difficulty (Cruz et el. 2015).

2.2. Attempts to modify the system

Although the McArthur system served Australia well for many decades, the Black Saturday Fires of 2009 underscored its various weaknesses. The 2009 Victorian Bushfires Royal Commission (Parliament of Victoria, 2010) made several recommendations that led to attempts to modify the system, including a review of the number of fire danger rating categories to provide more definition at higher danger levels, and the additional of a 'catastrophic' ('Code Red' in Victoria) category to capture fires that were increasingly being experienced beyond McArthur's original design parameters (Figure 2).

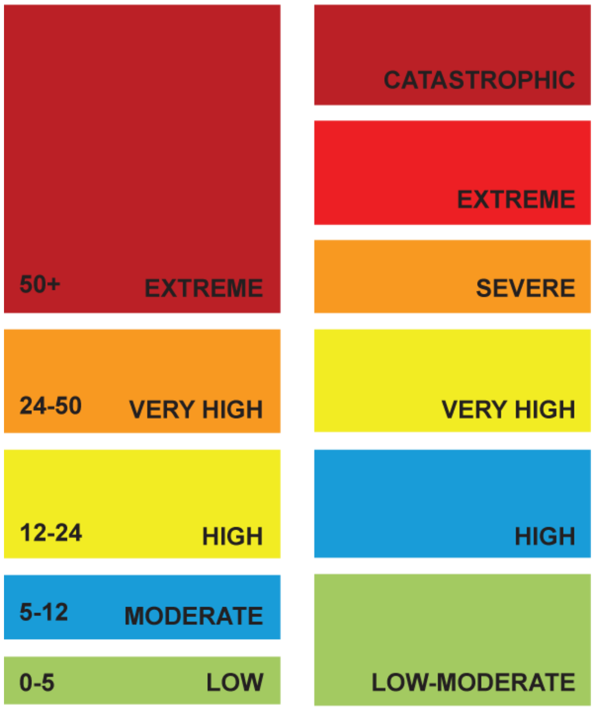

Figure 2- Changes to forest fire danger ratings after 2009

Later, there were also changes made to the ratings for grasslands, causing the GFDI and FFDI to no longer be aligned in terms of the ratings they represent.

2.3. The need for a contemporary system

Decades of research had been carried out since the McArthur system was introduced in the 1960's with countless field-studies leading to new fire behaviour models and a refined understanding of how fire behaves in a variety of fuel types. There had also been research into the impacts of bushfires, and an improved knowledge among practitioners about the implications of fires for prescribed burning, fire suppression and impacts. There had been numerous advances in weather forecasting and an improved understanding about how fire and the atmosphere interact. The quality of fuel data, satellite data and computational software and hardware had also improved (Cube, 2014).

The pressure was mounting on the McArthur system with its various design limitations highlighted (Cube, 2014):

- The design of the McArthur system did not allow for its components to be updated.
- The two fire behaviour models (one for grassland and one for dry sclerophyll forests) were not representative of Australian vegetation types and only accounted for about a third of the continent.
- Fires were being regularly experienced beyond its design considerations.
- It could not account for improved weather inputs from the Bureau of Meteorology.
- It could not account for the decades of improved fire behaviour research.
- It could not account for research into impacts of fire on assets and human lives.
- Decision-makers were forced to rely on a system with well understood flaws.
- The ratings and signage were not consistent from jurisdiction to jurisdiction.
- The system had become confusing for members of the public and did not inspire appropriate action to reduce risk.

The changes made after the 2009 fires only served to highlight the need for a new approach (Cube, 2014). In July 2014, Senior Officers and Ministers agreed that the development of a new National Fire Danger Rating System, based on new computational models, was a national priority (Matthews *et al.*, 2018).

3. The Australia Fire Danger Rating System (AFDRS)

In 2015 a roadmap was identified for the development and implementation of a new system. A national Program Board with jurisdictional and national representation was established in late 2016 to oversee development and implementation.

A key part of the development of the AFDRS was a collaborative approach involving all states and territories and the Commonwealth government. This was a considerable undertaking requiring the attention and commitment of the emergency services industry through the substantial challenges of the Black Summer fires of 2019-2020, the subsequent state and federal inquiries, various flooding events and the ravishes of the covid-19 pandemic.

Fortunately, Australia has a well-established National Council for Fire and Emergency Services (AFAC) with existing cooperative arrangements that proved useful to coordinate the program to develop and implement the AFDRS. Also, the New South Wales Rural Fire Service was well placed to take on the task of leading the science build, with help of the Bureau of Meteorology who built the fire danger calculation engine. Simultaneously, the South Australian Country Fire Service took on the task of leading one of the largest social research projects in Australia, to better understand the community's needs in relation to fire danger ratings.

3.1. The Fire Behaviour Models

Fire behaviour models in Australia are fuel specific, unlike the more unifying approach taken in the US. As fires spread and behave differently in different fuels, specific models have been built for major fuel types; e.g. grasslands, forests and shrublands (Cruz et al., 2015).

The AFDRS makes use of the best fire spread models that are available and ready for application. Table 1 provides an overview of the fire behaviour models used as guided through consultation with experts and by *A Guide to Rate of Fire Spread Models for Australian Vegetation* (Cruz *et el.*, 2015).

Table 1 Fire behaviour models used for the AFDRS

Fire behaviour model	Short name	Reference	Fuel type
CSIRO Grassland fire spread meter	Grassland	Cheney et al. (1998) and Cruz et al. (2015b)	Continuous grasslands
CSIRO Grassland for northern Australia	Savanna	Cheney et al. (1998) and Cruz et al. (2015b)	Grassy woodlands and open forests
Desert spinifex model	Spinifex	Burrows et al. (2018)	Hummock grasslands
Buttongrass moorlands model	Buttongrass	Marsden-Smedley and Catchpole (1995b)	Buttongrass moorlands
Dry Eucalypt Forest Fire Model (DEFFM or "Vesta")	Vesta	Cheney et al. (2012)	Shrubby dry eucalypt forests
Mallee heath model	Mallee heath	Cruz et al. (2013)	Semi-arid mallee heath
Heathland model	Shrubland	Anderson et al. (2015)	Temperate shrublands
Adjusted Pine model	Pine	Cruz (pers. comm.)	Pine plantations

3.2. The Fuel Types

A national fuel type layer (Figure 3) consisting of a 1.5 kilometer spatial grid, was developed based on available national, state and territory vegetation mapping. Considerable knowledge and effort was applied to convert vegetation mapping into a fuel type classification useful for application within the AFDRS (Matthews, 2022).

Classification of fuel types was led by the practical need to select an appropriate fire behaviour model, and to capture the range of variation in the fuel parameters that feed the inputs to the models. Fuel types that don't have a specific fire behaviour model (e.g. rainforests, arid shrublands, wetlands, rural and urban areas) have been allocated to the model with the most similar fuel structure (as per Cruz, 2015).

There are often factors limiting the flammability, fuel availability or fuel connectivity in these fuel types. So various modifications to fire behaviour models were made to account for these variations, such as a drying factor or a wind reduction factor. This allowed for calculations of fire danger to be applied across 23 fuel types, allowing more precise results (Matthews, 2022).

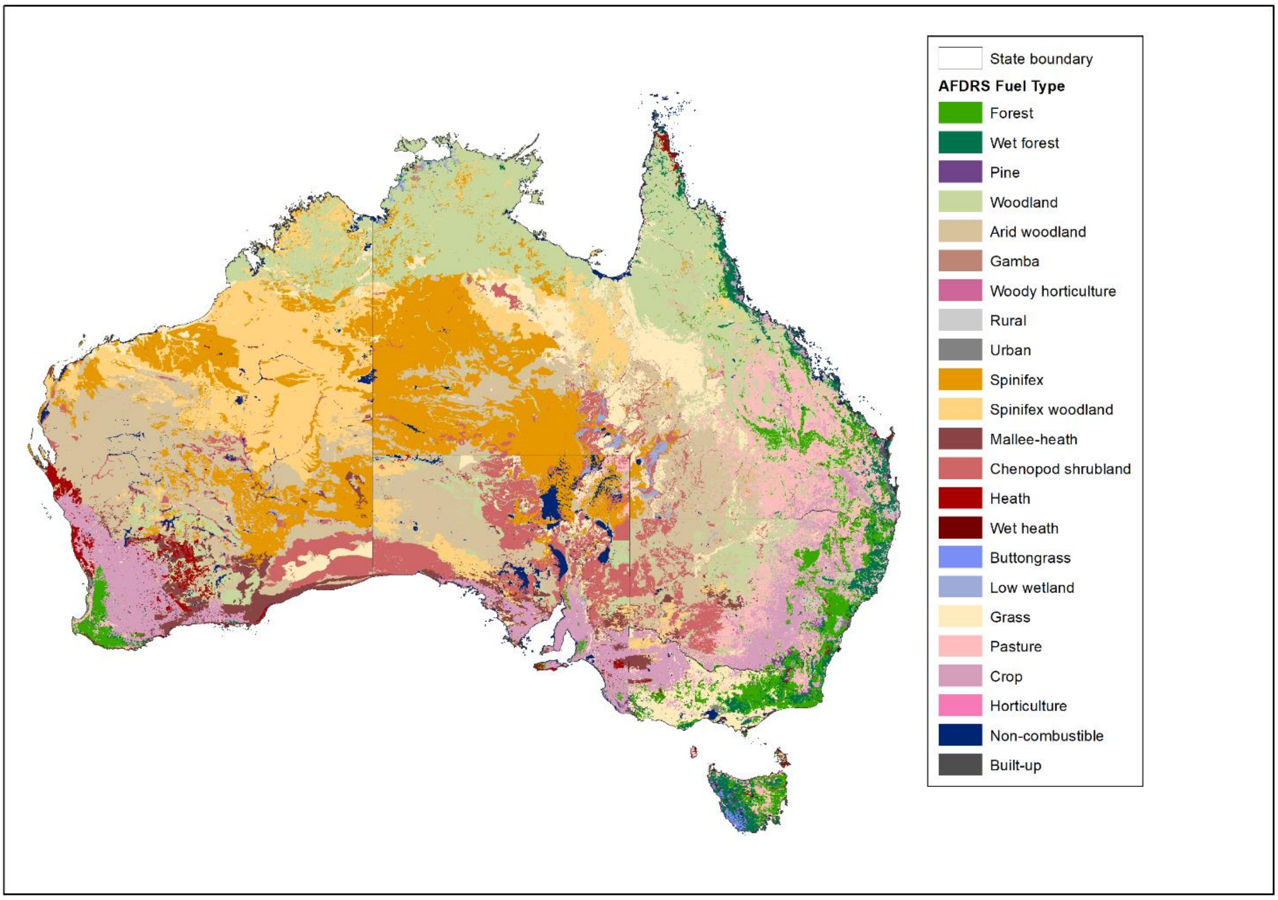

Figure 3 - Map of AFDRS fuel types across Australia

3.3. The Fire Behaviour Index

The Fire Behaviour Index (FBI) is expressed in whole numbers from 0 to 100+. It represents the severity of a fire should one occur under the forecast conditions. The FBI is divided into step-up categories controlled by table definitions (Figure 4 is an example) that represent contemporary understandings of how the underlying fire behaviour transitions create implications for prescribed burning, fire suppression and life and property loss. A step-up in FBI category is triggered by a change in (Matthews, 2022):

- Indicative fire behaviour and fire weather
- Implications for prescribed burning and fire spread
- Implications for suppression and containment
- Implications for potential impacts to life and property.

This, together with various guides produced as part of the FBI, ensures its usefulness as a decision-making tool for operational fire management.

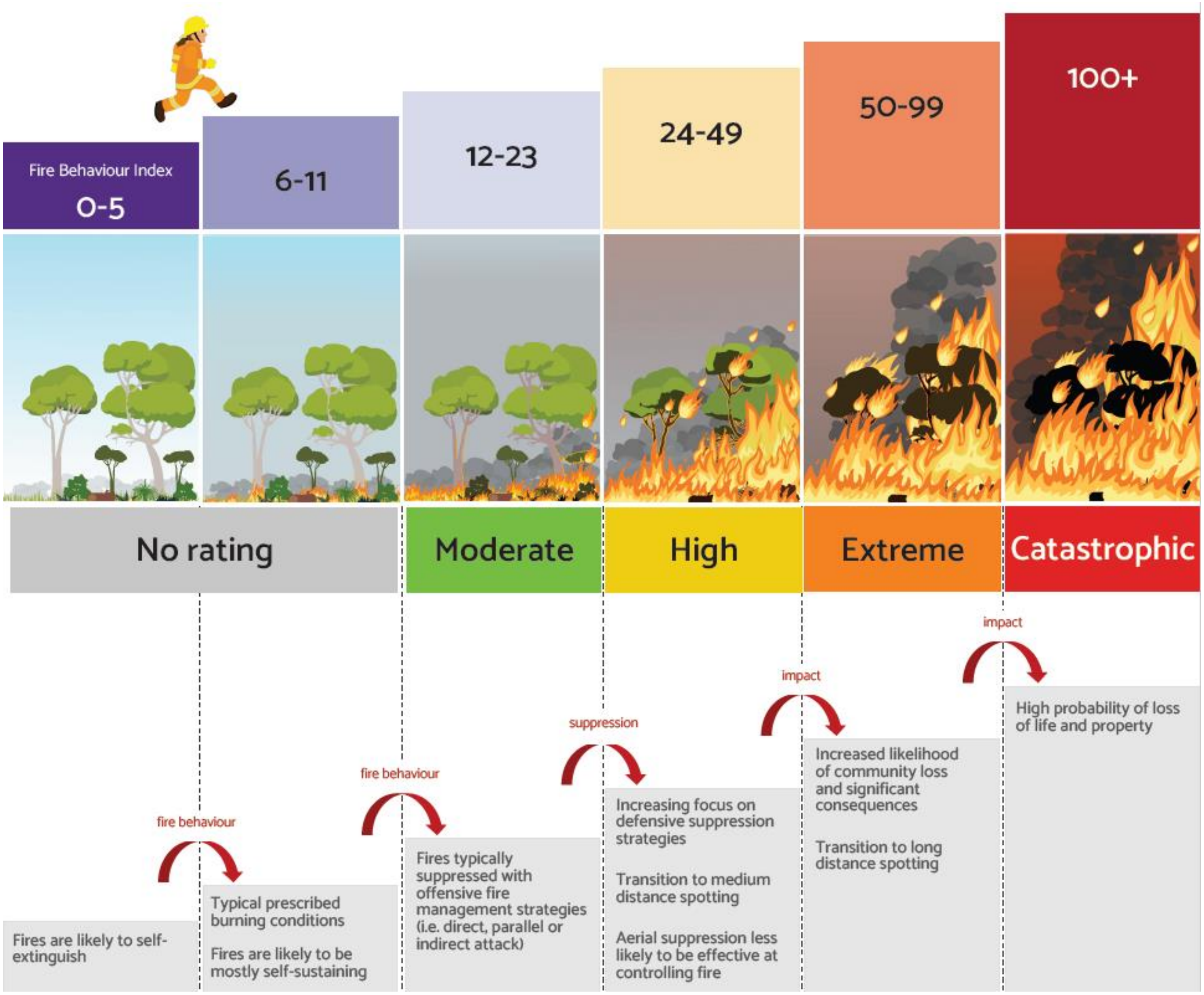

Figure 4 The Fire Behaviour Index for Forest Fuels, broken into steps that are relevant to fire operations

3.4. The Fire Danger Ratings

By contrast, the AFDRS Fire Danger Ratings are purpose built for ease of communication and comprehension for members of the community, so that members of the community are forewarned about fire danger conditions and can take appropriate action to reduce their risk exposure.

The social research conducted on the previous McArthur-based system was influential in the design of the new Fire Danger Ratings. The initial survey was the third largest ever conducted in Australia with 5,430 participants. The key outcomes were (Metrix, 2019):

- Most recognise the Fire Danger Rating system, but many didn't understand it. It was found that 93% had prompted awareness of the system but most thought it predicts how likely a fire is to occur, rather than predicting how dangerous a fire could be if one did occur.
- There is confusion over what action to take when, and it was found that few people would take action below the 'Severe' rating (refer to Figure 2 for the McArthur-based ratings post 2009).
- It was found that while the signage is recognised, most people do not use the system to plan activities and the majority have never taken action relating to fire danger ratings.

Focus groups were conducted with a broad range of communities. Locations encompassed metropolitan and rural areas as well as a variety of low, medium and high-risk bushfire areas (Metrix, 2019): It was found:

- Participants felt that each fire danger rating should be associated with a unique and distinct action-orientated message.

- Participants strongly preferred a three or four-level rating system, with more levels than this seen as confusing and counterproductive.
- Most favoured a four-stage semicircle design with intuitive names and colours.
- A green, yellow, orange and red colour set was preferred.

The finalised public-facing fire danger rating system framework is shown below:

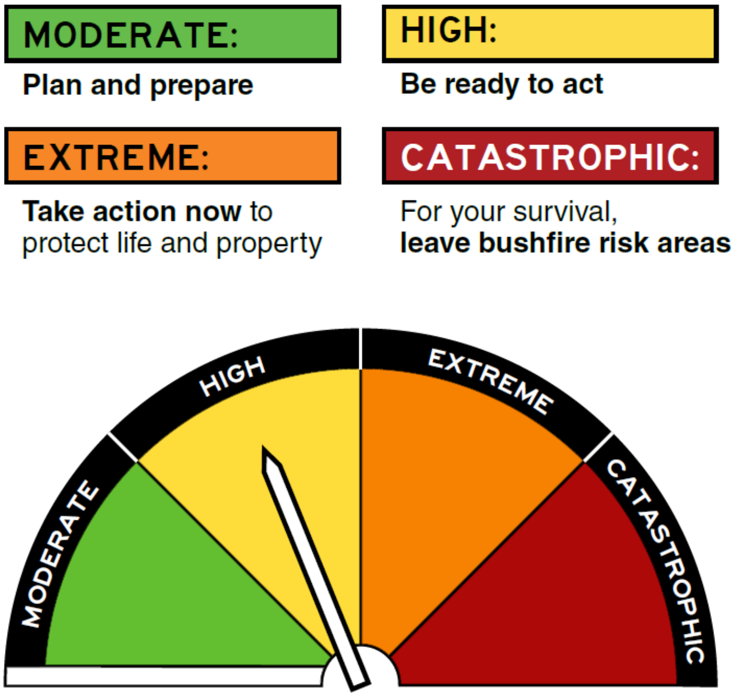

Figure 5 The AFDRS Fire Danger Ratings

The four action-orientated messages are related to underlying transitions in fire behaviour requiring different kinds of actions from members of the community. The fire danger ratings are therefore derived from thresholds in the FBI that encapsulate these transitions. This relationship was shown in Figure 4.

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