The self defence alternative in the fight against severe bushfires
Part 2 Science and logic (Fire agency approach vs. self defence)

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Abstract
The aim of this paper is to examine the fire agency policy model and the self defence system for performance and quality of science. Their performance is assessed by whether or not their methodology will achieve their stated aims and the quality of their science and logic is assessed against credible scientific references.
The analysis found that the fire agency policy model was scientifically inadequate, and that their stated performance objectives for property protection cannot be delivered by their core components. It found that the self defence model / strategic flame dimension model was scientifically valid and that its core components are able to deliver its stated objectives, which require a higher standard of protection than the fire agency policy model.

Introduction
This is Part 2 of a two part study arising from the following question: Why is the damage toll still so high in severe bushfires in Australia in the 21st century? Part 1 (O'Bryan 2006b) found that the property protection component of the fire agency policy model was inadequate for severe bushfires and was incapable of reducing the damage toll. It found that the self defence system was capable of protecting individual properties in severe bushfires and therefore capable of reducing the damage toll.
In this paper, the fire agency policy model and the self defence system will be evaluated according to two criteria, their performance and their scientific basis. Their performance is assessed by whether or not their methodology will achieve their stated aims and the quality of their science and logic is assessed against credible scientific references. The fire agency approach is represented by the policies and advice currently promoted by fire agencies in two most fire prone States, Victoria and NSW. The self defence system will be analysed together with its scientific base, the strategic flame dimension model (described in O'Bryan, 2006a).

Evaluation methodology
The source data for each model is as follows.
Fire agency policy model
The main references for this section are recent publications from Victorian and NSW fire agencies that are still current. In regard to new development sites, they present the regulatory provisions that apply. In regard to existing properties and neighbourhoods, both States provide advice, which is basically a list of tips and suggestions, do's and don'ts, but with no strategic content (eg, CFA, 2004). Notable strategic omissions include reference to direction, dimension and location.
Self defence system
The self defence system has three elements, keep the moving flame away, retain adequate suppression resources on site and install strategic protection zones to protect assets from damage. Its scientific basis is provided by the strategic flame dimension model, which is a systematic methodology for protecting individual objects or strengthening a control line. It is based on managing flame dimension (moving or stationary) in strategic locations on a given site so that flame contact or incident radiation does not exceed the thermal load of the object. There are two types of flame protection zones - flame dimension zones and flame influence zones. The size of the flame dimension zones can be adjusted according to the heat tolerance of the surface of the object or the risk preference of owner. The size of the flame influence zone is commensurate with the flame's dimension. The object is deemed to be adequately protected on a severe fire day when the flame influence zones do not overlap the flame dimension zones (O'Bryan, 2006a).

The evaluation focuses on the quality and delivery potential of their core principles.
The method of performance assessment is as follows. For each property protection approach, their stated objectives will be identified, then their core components will be outlined and examined and finally, the ability of these components to deliver the objectives is assessed.
The method of evaluation of quality of the science is as follows. For each fire protection approach, identify the key underlying principles, and then assess their scientific credibility.

Results of evaluation

Performance assessment of fire agency policy model

- Case study - Victoria Major source: CFA (2002)

Stated objective: Provide dwelling with an area of defendable space against damage from radiant heat, direct flame contact and ember attack (see WMO Kit - Definitions, CFA, 2002).
Core components:
1 Defendable space: The concept of defendable space is intended to provide an area of protection from radiation, flame contact and ember attack.
Comment: For this concept to be realistic, these gaps must be free of flammable fuel so that the approaching flame can stop its run at the gap and embers cannot ignite within it. But, the WMO Kit does not specify a non-fuel zone.
2 Setback distances: Setback distances are based on severe fire weather (Fire Danger Index - FDI 120) and estimated flame lengths for each vegetation type. Setback ensures that incident radiation onto a vertical wall will not exceed 29 kW m^{-2}, which is regarded as wood ignition point without flame (Maughan and Bosomworth, 2004). WMO tables specify setback distances for a wall of flame in each vegetation type. The following examples apply to flat ground: in tall forest or heathland - 80m setback, in medium forest - 60m, in low forest or woodland - 30m. A wall of flame in grassland rates no mention, other than to say that grass simply needs to be short if it occurs within 30m of dwelling.
Comment: Butler and Cohen (1998) indicate that, at a given distance, flame height influences incident radiation and that the critical variables for damage are incident radiation and time of exposure. Neither the WMO Kit nor Maughan and Bosomworth (2004) describe the models used to calculate flame size, nor is the duration of exposure mentioned. It is a not scientifically sound to present distance as the trigger level for ignition when there has been no account of residence time of a flame (which equates to exposure time) in adjacent fuel beds.

Performance assessment: Do defendable space and setbacks achieve their objective?

Protection against radiant heat?	No - there is no barrier to advancing surface flame
Protection against direct flame contact?	No - there is no barrier to advancing surface flame
Protection against ember attack?	No - many embers that fall into the protection zone will ignite and generate surface fires.
If suppression forces are present on these sites, will their efforts be facilitated?	Yes

- Case study - NSW Major source: RFS (2001).

Stated objective: The purpose of the Inner Protection Area (IPA) is to manage heat intensities at the building surface while the Outer Protection Area (OPA) aims to reduce the potential length of flames by slowing the rate of spread, filtering embers and suppressing the crown fire (see Appendix 2, RFS, 2001).

Core components:
1 Asset protection zones: The Asset Protection Zone (APZ) incorporates an OPA and an IPA. The APZ should include a perimeter track.
APZ width = OPA (10m for residences) + IPA (distance is fuel type dependent).
Lower fuel load within APZ is said to provide protection because of reduced rate of spread.
Comment: Based on the specifications, a surface fire will run freely within the APZ. It will have a low flame height, but there may not be a fuel-free area to stop it. The closest reference to a fuel free barrier is the track and the “discontinuous fuel” specification, but no

strategic location guidelines are given. The relationship between fuel load and rate of spread is a belief that has no scientific backing (see scientific section below).

2 Setback distances: Setback distance calculations are based on the worst possible fire behaviour (FDI 80) and maximum fuel load in each fuel type so that it generates maximum flame length. Emitted radiation from a flame face is 80 kW m^{-2} (from Table 5.1). Table A3.2 lists each vegetation type by fuel load, rate of spread, and intensity and flame length. The stated threshold incident radiation level is 31kW m^{-2}, when the unpiloted ignition of treated hardwood timber is said to occur. This criterion is used as the basis for determining minimal setbacks (see Appendix 2, RFS 2001). The following setbacks apply to flat terrain (from Table A in Section 3.2): forest (flame height 30m) - setback 40m; woodland, heaths (flame height 10 – 20m) - setback 35m; grassland, rainforest, mallee, small areas of forest (< 1ha) (flame height 3 – 10m) - setback 20m plus fire trail.

Comment: Refer to comments about defendable space and setback in the Victorian case study above. Inclusion of small forest areas (< 1ha) in the 20m setback category is curious.

Performance assessment: Do the APZ and setbacks achieve their objective?
(Strictly speaking, the stated objective is not as specific as these questions indicate. Instead it seems to require only a reduction in these elements.)

Protection against radiant heat?	Possibly, but only if the track provides a barrier to advancing low flame
Protection against direct flame contact?	Possibly, if the IPA provides a barrier to advancing low flame
Protection against ember attack?	Possibly, if the embers that ignite inside the APZ zone run into a fuel free barrier.
If suppression forces are present on these sites, will their efforts be facilitated?	Yes

Performance assessment of the self defence system / strategic flame dimension model

Stated aim: The self defence system as outlined in Part 1 (O'Bryan, 2006b) aims to provide protection to nominated objects against damage by flame contact or radiation from any flame (moving or stationary), of any cause (single front, multiple front, and embers).

Core components:

1 Flame influence zones: Flame influence zones manage the impact of the flames with flame contact zones and flame radiation zones. The width of the flame contact zone is defined as maximum flame rollover distance. The width of the flame radiation zone is determined by fuel bed type, flame height and residence time, but can be adjusted in accordance with the object's thermal tolerance. The sources of thermal tolerance and flame height models and residence time data are available (O'Bryan 2005).

Comment: Prevention of flame contact and incident radiation damage are accounted for in both moving and stationary flames. Models and data are transparent and documented (O'Bryan 2005).

2 Flame dimension zones: Flame dimension zones are specified by width and flame height and located in strategic areas. There are two types, no-flame and low flame zones. Specifications in each zone vary according to the object's thermal load tolerance and maximum allowable flame dimensions in the appropriate fuel bed layer.

Comment: The flame dimension zone model addresses all potential sources of damage, and allows flame height and zone width to be adjusted according to referenced data.

Performance assessment: Do flame protection zones achieve their aims?

Protection against radiant heat?	Yes. No-flame and low-flame zones ensure a safe separation and flame influence zones provide additional verification.

Protection against direct flame contact?	Yes. No-flame and low-flame zones ensure a safe separation and flame influence zones provide additional verification.
Protection against ember attack?	Yes. In low-flame zones, flame height is low, and in a no-flame zone, embers will either not ignite or the stationary flame can be extinguished.
If suppression forces are present on these sites, will their efforts be facilitated?	Yes

In summary, the evaluation study found that the core components of the fire agency policy models do not allow achievement of their stated objectives, but the core components of the self defence system do allow achievement of its objective. It can be readily seen that the self defence objective specifies a higher protection standard than the fire agency policy model.

Evaluation of quality of the science - fire agency policy model
The underlying principles include bushfire prone areas, setback zones, impact of radiation, use of fire behaviour models, and use of Byram's intensity.
1 Bushfire Prone Areas (BPA): The concept assumes that a vegetation mass is flammable and that its presence poses a prima facie threat during a bushfire if it falls within a defined radius of a dwelling.
Assessment: BPA is an artificial concept that has limited correlation to actual bushfire behaviour which means it has limited correlation to actual bushfire risk. Firstly, it omits reference to anything in the vegetation mass that relates to flame size or its flammability, eg, assessed fuel load, fuel structure, fuel age, aspect or direction from a dwelling. Secondly, it fails to consider potentially fire prone vegetation that falls outside the "standing vegetation" definition eg, the definition excludes a paddock of cured grass or a mass of old heath less than 2m tall or standing vegetation less than 1 ha.
2 Setback zones: (1) Fire agencies base setback distances on radiation from a given vegetation type with a predetermined fuel load. They propose that the only way to reduce danger is to apply spatial separation. (2) Agencies believe the benefit of reduced fuel load within zones is lower rate of spread.
Assessment: (1) lacks scientific credibility because it is based on artificial bushfire behaviour, it ignores residence time and it has no mechanism to determine actual fire behaviour. It therefore cannot claim to deal scientifically with on-site bushfire risk.
(2) This belief has been disproved (eg, Burrows (1999) in eucalypt litter fires). The real benefits of reduced fuel load can be shown to be reduced flame height and residence time (O'Bryan 2005).
3 Radiation impact:

- Emitted radiation levels: Both States assume a wall of flame emits 80+ kW m^{-2} horizontally, irrespective of vegetation type.

[Comment: Actual emissions (for a given flame height) vary according to vegetation type and location of the flame core, eg, 40 kW m^{-2} for heath fire (Thomas, 1971), approx 100 kW m^{-2} for flame core of litter fire (Packham and Pompe, 1971), approx 40 kW m^{-2} from a flame body above a ground based fuel source (from Sullivan et al., 2003).]

- Incident radiation levels: The trigger levels for damage for NSW and Victoria are 31 and 29 kW m^{-2} respectively.

[Comment: Fire agency figures do not account for exposure time. Credible references (eg, Babrauskas, 2001) suggest that auto ignition of a solid wood surface at 31 kW m^{-2} exposure with no flame requires 150 - 300 sec and with a pilot flame requires approx 70 sec.]

- Duration of exposure: No mention of residence times of adjacent vegetation.

[Comment: Radiation damage on a given surface has long been accepted as being a function of incident radiation and duration of exposure (Leonard et al., 2004). Leonard et al., (2004) quote relevant residence times between 15 and 33 sec.]

Assessment: The foregoing data suggests trigger levels used by both States do not appear to be based on scientific data. The relevant scientific question of ascertaining what incident radiation levels will cause damage after 10, 30 or 60 seconds exposure has been overlooked.

4 Usage of fire behaviour models: Maughan and Bosomworth (2004) note the limitations of current fire behaviour models, but do not specify the models used. RFS (2001) claims to use Byram's intensity to calculate flame lengths in grasslands and plantations and McArthur Meter (CSIRO, 1992) for forest fires, but no mention of models used for other fuel types. Table A3.2, however, lists flame length for each vegetation type with the suggestion that it is derived from a modified McArthur Meter.

[Comment: The scientific credibility of the States' regulatory documents relies on the method of calculating flame size. Fire agencies have access to two models for prediction of flame height one for grass fires (CSIRO, 1997) and one for forest fires (McArthur Meter, CSIRO, 1992), but have nothing for other vegetation types. The grassfire meter (CSIRO, 1997) has reasonable accuracy (O'Bryan, 2005), but neither agency has referred to it.]

Assessment: Because flame size calculations derive from unspecified models, their scientific credibility is questionable.

5 Application of Byram's intensity: Both agencies rely on Byram's intensity for either describing fire behaviour or assigning a bushfire risk level.

- Byram's intensity is proportional to the square of fuel load.

[Comment: This belief derives from McArthur's (1967) unsupported claim that rate of spread is proportional to fuel load and this makes intensity proportional to fuel load squared. Recent trials by Burrows (1999) confirmed that when wind occurs, litter fuel load has no influence on rate of spread.]

- Radiant heat and flame length are related to Byram's intensity (RFS 2001, Appendix 2)

[Comment: Incident radiation at given distance from a given fire front increases as flame height increases up to around 12m tall, and thereafter remains constant (Tassios and Packham 1984). This is because Byram's fireline intensity describes rate of fuel consumption over the fire front's depth and as such has no relationship to emitted radiation, which is a function of flame temperature to the power 4.]

- Byram's intensities are presented as quantitative indicators of potential fire danger (eg, RFS 2001).

[Comment: Firstly, the figures may be scientifically meaningless for a given site because they estimate rate of spread by an undisclosed method and use a pre-determined fuel load. Secondly, Byram's intensity cannot account for stationary flames because at zero rate of spread, intensity is by definition zero, yet they inflict a substantial proportion of damage in rural interface fires.]

Assessment: Fire agency documents have used Byram's intensity in ways that are scientifically invalid. Use of Byram's intensity excludes consideration of stationary flames.

Evaluation of quality of the science – self defence system / strategic flame dimension model

The underlying principle of the system / model is that an object cannot suffer ignition, damage or injury from a flame if it is beyond reach of flame contact or if incident heat is below its thermal load tolerance. Because the flame size (moving or stationary) determines flame reach and incident radiation, an object can therefore be protected by managing flame size in strategic areas. Other key principles are now listed.

- This model is site specific and deals with severe weather conditions.
- It specifies that each fuel bed on site that may ignite is to be assessed for flame height, residence time and emitted radiation.
- It requires an estimate of the thermal load tolerance for each surface to be protected
- It requires that incident radiation on a surface does not exceed this tolerance and is also beyond flame contact distance.

[Comment: Working data based on published research for each of these variables has been summarised in O'Bryan 2005.]

Assessment: The principles seem scientifically valid and its site specificity enables it to be applied to any site. Estimation of the variables requires access to good data and a minimum knowledge base by the implementer. Improvement of these two factors will led to improvement in protection standards.

Discussion

This paper presents an analysis of the performance and the scientific credibility of two property protection approaches. The evaluations are done at the principle level rather than the implementation level because quality of principles foreshadows quality of outcomes.
In the performance evaluation, the assessment found that the core components of the fire agency policy model are incapable of delivering the stated objectives, but the core components of the self defence system were capable of achieving its objectives. Are the objectives of each approach reasonable? All objectives seem reasonable, but fire agency objectives aim for significantly lower standards of protection than the self defence system.
In the case of the science evaluation, the underlying principles behind the fire agency policy model were found to consistently lack scientific credibility. This implies that when these models are implemented, they have no scientific basis. The underlying principle of the strategic flame dimension model / self defence system was assessed as scientifically valid to the limit of current knowledge. When implemented, its effectiveness depends on the quality of data and modelling available and knowledge of the implementer. This suggests that as new data becomes available and more people are trained, protection results will also improve.

Conclusion

Part 1 of this study described the components of the fire agency policy model as suppression and property protection. It found the protection component was not capable of reducing the damage toll in severe bushfires, therefore leaving suppression as the only alternative for reducing the toll. This paper has found that the core components of the model cannot deliver its objectives and that it has no scientific credibility. Part I found that the self defence system was capable of reducing the damage toll and this paper found that it can achieve objectives and has scientific credibility.

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