Potential opportunities and strategies for improved bushfire pine and hardwood plantation protection and management across Australia.

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Contents

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Limitations/ Disclaimer.
This document has been prepared and issued in good faith and has been prepared without payment, in order to aid progression of this important issue.

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It is up to each pine and hardwood plantation owner to meet State/ Federal/ Local government plantation protection and management fire requirements. It is up to each owner to consider potential opportunities and strategies to best protect plantations from bushfires inside and outside plantations and to best protect personnel involved in fighting bushfires within and adjacent to the plantations. Opportunities and strategies adopted would likely vary with each owner, taking into account a broad range of issues, fire risks, fire seasons and differing opportunities. The document focusses on potential opportunities and strategies, but doesn't get into detail in regards to area or width specifics such as firebreaks to any great degree, some of this is covered in some of the guideline documents listed in this document.

In addition, any limitations would be outlined in the final plantation owners bushfire protection documents, as agreed with the forest owners/ parties involved.

1. Introduction.

This draft document has been issued in good faith in order to aid progression of this important issue. As noted above, it is up to each pine and hardwood plantation owner to develop opportunities and strategies to best protect pine and hardwood plantations from bushfires inside and outside plantations and to best protect personnel involved in fighting bushfires within the pine plantations.

It is noted that there are many similarities in regards to bushfire protection of pine and hardwood plantations, this document focusses on pine plantation potential opportunities and strategies, but the document is designed so it can be used for hardwood plantations in many cases. It is noted that many plantation businesses have both pine and hardwood plantations, so having one document assists these businesses. It is also noted areas such as the Green Triangle have a mix of pine and hardwood plantations. It is important to note that most of the research information and guidelines are based on pine plantations.

After the large bushfires killing considerable areas of particularly pine plantations in recent years, it is opportune to review potential protection arrangements inside and outside plantations across Australia.

The document focusses on potential opportunities and strategies, but doesn't get into detail re specifics to any great degree, some of this is covered in some of the guideline documents listed in this document.

It is also opportune to pull together information in the guideline documents listed below, the majority over five years old, this has been completed, as noted, but doesn't get into detail re specifics to any great degree.

It is also opportune to review pine and hardwood plantation fire salvage, recovery and re-establishment, to explore opportunities to maximise salvage, maximise timber value associated with fire salvage and possibly integrate plantation bushfire protection and salvage strategies.

2. Background information.

Detailed background information is provided at the back of this document, under the headings laid out below.

- Impacts of bushfires on plantations. Appendix 1).
- Practices used to reduce bushfire risks in plantations. Appendix 2).
- Some plantation fuel issues to consider first. Appendix 3).
- Is there a need to review strategies and opportunities for improved bushfire plantation protection across Australia? Appendix 4).

3. Plantation bushfire protection guideline documents.

There is useful information in regards to pine and hardwood (mainly pine) plantation bushfire protection in the documents listed below:

- Bartlett, 2012. Fire management strategies for Pinus radiata plantations near urban areas, Australian Forestry 2012 Vol. 75 No. 1 pp. 43-53.
- Tony Bartlett, undated, Fire management in pine plantations, Director, ACT Forests.
- Forest Fire Management Group (FFMG), 2007, Softwood Plantation Fire Synopsis, a sub-Committee of the Forestry and Forest Products Committee which reports to the Primary Industry Ministerial Council, Endorsed by: Australasian Fire Authorities Council Ltd (AFAC), ISBN 0 643 06533 4 © Forest Fire Management Group November 2007. Includes considerable specific details and ideas.
- Forest Fire Management Group (FFMG), 2007, Softwood Plantation Fire Synopsis, three very simple burning guides, those guides are provided in Appendix 4 (FFMG, 2007).
- Forest Owners' Conference (FOC) 2017 Plantation Fire Protection Guidelines (Victoria/ SA). The Green Triangle Forest Owners Conference / Green Triangle Fire Alliance has been operational since 1979.
- Plantation Managers Fire Agreement, WA.
- Guidelines for Plantation Fire Protection (DFES 2011). The Forest Industry Federation of Western Australia, along with the Department of Fire and Emergency Services, developed Guidelines for Plantation Fire Protection. WA has a system where a Fire Management Plan addressing local authority requirements and applicable guidelines.
- Code-of-Practice-for-Timber-Plantations-in-Western-Australia 2014. Forest Industries Federation (WA) Inc.
- FESA (WA), 2007, Standards for Plantation Fire Protection Draft as of 12/2007, vs 2.
- Primary Industries and Resources South Australia, 2009, Guidelines for Plantation Forestry in South Australia.
- Useful information in MG Cruz, MP Plucinski, 2007, Billo Road Fire, Report on Fire Behaviour Phenomena and Suppression Activities, Bushfire CRC. November 2007.
- Woodman M, Rawson R, 1982, Fuel Reduction Burning in radiata pine plantations, Research Report Number 14, DCE (Victoria), August.
- Thomson DS, 1978, Low Intensity Prescribed Burning in Three Pinus radiata stand types, Research Report Number 2, DCE (Victoria), February.

It is recommended that forest owners have these documents and consider them in their fire protection documents/ plans.

4. Potential opportunities and strategies for improved bushfire pine and hardwood plantation protection and management across Australia.

Potential opportunity and strategy improved bushfire pine and hardwood plantation protection and management at plantation boundaries and inside plantations include:

Note 1. Legend.

- D = Design bushfire protection and management measure.
- HR = Hazard reduction bushfire protection and management measure.
- S = Safety bushfire protection and management measure.
- HV = Harvesting bushfire protection and management risk reduction measure.

- G = Growth promotion bushfire protection and management measure, increasing growth, log size and log recovery in the event of a bushfire.

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	**Protection measure. Note 1.**	**Boundary and/ or inside**	**Other detail.**
Fire protection is recognised in the early stages of plantation development for each rotation and that appropriate action is taken to reduce possible hazards. This can be refined in each rotation. As noted by Cheney & Richmond (1980) there are "Four principal aspects of plantation design affect fire protection. These are: • The shape and size of discrete planted units; • the intensity and standard of access; • the provision for firebreaks and/or fuel breaks; and • the distribution of age classes through the area". These can be refined in each rotation.	D, HR, S, HV	Boundary and inside	It is widely recognised that attention to fire protection early in the life of a plantation can dramatically reduce future risks and costly fire protection measures.
Consider having as wide as possible geographic spread of estate to reduce the potential for major losses	D, HR	Boundary and inside	May need to consider purchasing / establishing plantations in other regions
Consider potential plantation salvage opportunities if a bushfire damages a plantation area. Potential opportunities and strategies in regards to plantation salvage are outlined in Section 7 of this document.	HV		
Explore growing additional non allocated plantations for pulp, sawlog, veneer wood supply in the event of bushfire losses. Where required these plantations can be used to supply additional timber after bushfire losses, as parcel sales or for export if required	HV	Boundary and inside	Full commitment of projected production does not leave any room to move if there is a major loss of plantation area to fire
External fire breaks and maintenance of these. Options include slashing, ploughing, grading and spraying.	D, HR, S	Boundary	Width calculated taking into account the adjacent fire hazard, slope, land ownership etc
High standard access provided and maintained around all plantation boundaries (as possible), avoiding dead ends wherever possible.	D, HR, S	Boundary	Has other advantages in speed of fire attack, fire safety and in harvesting.
Major internal fire breaks and maintenance of these. These may not necessarily be cleared breaks but pruned branches with needle/ litter layer reduced. It would be useful to have these on both sides of all major roads.	D, HR, S	Inside	These breaks should be valuable to aid in fire control and also backburning if required as a last resort.
Increased and improved access tracks/ breaks between plantation compartments. Consideration given for two-way traffic at say 7-8 metres wide, removal of some trees to improve harvesting and fire safety.	D, HR, S, HV	Inside	Trees at these locations would be high pruned.
Signage of all roads, fire trails and water fill up points.	D, HR, S	Boundary and inside.	
Quality maps, with road names reflecting on-ground signposting to assist navigation within the estate.	D, HR, S	Boundary and inside	These maps should also be distributed to

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	Protection measure. Note 1.	Boundary and/ or inside	Other detail.
			neighbouring landholders and Fire Brigades
Graduated restrictions on all forest operations dependent on local FFDI levels, Fire harvesting and machine closures in nominated fire danger conditions as stipulated in each area. All equipment used needs to meets Australian/ state requirements for fire safety and be safely maintained. Vehicles, machinery and equipment to be used in the forest during the fire season should be routinely maintained and tested, and carry appropriate fire suppression equipment.	HR, S, HV	Boundary and inside	
Provision of fire suppression equipment and resources to reflect the risk of fire to the plantation and the scale of the business, including the appropriate reaction to predicted weather conditions. Vehicles include crew safety spray systems, minimum water reserves, heat curtains and firefighting blankets.	HR, S, HV	Boundary and inside	
Installing or setting up large firefighting dams in strategic, central and safe locations, for slip on, tanker and helicopter water supply. Where achievable, these can be integrated with water supply lines to fill dams up in quiet times	D, HR, S	Boundary and inside	If water supply pipes are available beside these dams, fill them up in times of need when water is available.
Setting up water supply pipes, hydrants and overhead stand pipes for tankers and slip on units in safe areas inside of plantations and at the plantation boundaries. This may seem expensive, but over the life of two to three plantation rotations, this would be relatively inexpensive. Another option is to integrate with town supply networks where they exist. Another option is to set up water supply dams that can be filled overnight or in quiet periods from water supply networks in fire danger periods.	D, HR, S	Boundary and inside	Seek approval to integrate with town supply networks where they exist, with the water used only for fire suppression. If not available, may need the setting up of a water supply network, likely more suitable for larger plantation areas only.
Hazard reduction undertaken in native vegetation retention areas within plantation estates, including at the boundaries.	HR, S	Boundary	This can also be used to assist in removal of pine seedlings. Cool burns are also important for native forest health.
In very large plantation estates, spread harvesting across all the forests to reduce risks from large loss of forests in one area.	HR, S, HV	Inside	
Continue to maximise second rotation (and following) organic matter retention post clearfall using techniques such as crusher rolling. This retains organic matter and nutrients, assisting early growth and also reduces regrowth of species such as wattles, a later fire risk. Noting this, fuel loads are higher for a few years till this organic matter breaks down.	HR (but has advantages in increased growth/ reduction wattles), G	Boundary and inside	Chopper rolled site: heavy and continuous mulched-down slash fuels which initially provide high surface fuel levels and act to reduce suppressing grass/shrub regeneration.

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	**Protection measure. Note 1.**	**Boundary and/ or inside**	**Other detail.**
			Consider access breaks in these fuels to reduce fire risk.
Optimising planting rates taking into account bushfire risks and possibly optimising log diameter size in salvage ie spacing to around 1,000 trees/ ha.			This can be done in locations where pulp/ chip sales are lower. Alternatively an early thinning around age 10 could be considered.
Use establishment practices that achieve rapid growth and early crown closure to suppress grasses and weeds. Fertilisers at Year 1 and maybe year 3 would assist	HR, HV, G	Boundary and inside	
Weed control to reduce fire fuels, including grazing.	HR, HV, G	Boundary and inside	Important within the plantation stands to reduce fuels as well as firebreaks and roads
Consider undertaking first thinning for pulp earlier, possibly at Year 10, second thinning at year 14 (mainly pulp, some small sawlog), 3rd thinning at age 19 (sawlog/ pulp). Early 1st thinning to start getting the stand set up for safer fuel distribution over the rotation. Consideration of fertiliser application post Year 10 thinning to maximise growth and canopy closure.	HR, S, HV, G	Boundary and possibly inside	This would increase log size earlier, not reduce pulp volumes that much and produce bigger timber if salvage is required. It would reduce needle load in canopies and may also reduce risk of crown fires.
Avoiding first thinning post age 13 wherever possible.	HR, S, HV, G	Boundary and inside	Fuel loads build up and if unpruned, these stands with blackberries are a huge fire risk.
Designated high priority bushfire protection to stands in the approximate age range 10-24 years, as there are reduced options for maximising sawlog and high quality log salvage in these age classes. Optimise growth/ thinning regimes/ fertilisation using foliar assessments in these age classes. Consider using growth simulations on different planting/ residual basal areas to factor in maximising growth, diameter growth, timber value, reducing ladder fuels and fire access.	HR, HV, G	Boundary and inside	Turning this argument around, if first thinning for pulp was undertaken at Year 10, second thinning at year 14 (mainly pulp, some small sawlog), 3rd thinning at age 19 (sawlog/ pulp), this would increase log size earlier, not reduce pulp volumes that much and produce bigger timber if fire salvage is required.
Spacing plantation rows to have no trees planted in every 15 th row (where 5 th row out row used), so this becomes an access point. No dead ends would be allowed. No thinning slash on tracks would be allowed for this out row or if allowed, slash must be removed after harvesting.	D, HR, S	Boundary	By the time the chopper rolled mulch has broken down, it would be easy to drive over this out row. Low and high pruning would be needed .
Low pruning adjacent to boundaries, breaks and important protection areas.	HR, S, HV	Boundary	

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	**Protection measure. Note 1.**	**Boundary and/ or inside**	**Other detail.**
Strategic high pruning adjacent to boundaries, breaks and important protection areas. A crown fire free Zone would likely require pruning to 8 m, thinning, and disposal of all slash by heaping and burning, practiced in conifer forests near south lake Tahoe Ca, and Flagstaff Az, and in South Australia. A crown fire free Zone around the Forestry Settlement of Mt Burr SA reduced the fire intensity from a crown fire to a surface fire and there were no losses in the township during a major run of the Ash Wednesday fires, 16 Feb 1983.	HR, S, HV	Boundary and inside at strategic locations	To be effective, fuel loads would also need to be reduced.
Thinning with mulch stacked away from trees.	HR, HV	Boundary and inside at strategic locations.	In strategic cases, mulch could be burnt.
Grazing in the boundary zone agreed with adjacent landholders, shared fencing arrangements.	HR, S	Boundary.	
Protection area hazard reduction at the boundary burnt every 2-4 years.	HR, S	Boundary.	
Conduct an annual meeting with local bushfire brigades to increase cooperation, outline available resources, ideas, concerns and planning upcoming hazard reduction burning.	HR, S	Boundary and inside.	It is important to give local brigades confidence to fight plantation fires. Sharing good maps, training them in plantation fire behaviour, well signed roads and field trips all help them feel more comfortable.
Establish neighbourly support arrangements.	HR, S	Boundary and inside	Note, if your organisation turns up to applicable fires, they are more likely to turn up to yours.
All employees or contractors with a fire management, detection or suppression role should be appropriately trained to national fire competency standards. Training days between brigades and forest owners, in the forest and outside the forest.	HR, S	Boundary and inside.	This training can also be completed with hazard reduction burning operations. Forest fire fighting can be very dangerous, so good training/ firefighting skills in forests is critical, this issue was raised in the Royal Commission submission.
Set up alliances for plantation coordinated firefighting efforts in bushfires and hazard reduction, as used in the Plantation Managers Fire Agreement, WA and FOC / Green Triangle Fire Alliance.	HR, S		Having optimum firefighting equipment, fire blankets and fire approved clothing is critical.
Mandated firefighting equipment (e.g. 400 litre fire unit capable of accessing all areas of coupe) for all forest operations working during the fire danger period. Encourage all plantation harvesting personnel to be trained in firefighting, have appropriate clothing/ PPE/	HR, S, HV		

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	Protection measure. Note 1.	Boundary and/ or inside	Other detail.
equipment and where possible have slip on water pumps in addition to fire extinguishers. Refuelling must be on hard stand surfaces.			
All business personnel have access to the app My Fire Watch is a good app that Brigade and others aren't aware of in the field. It identifies hot spots, giving a better indication of fire location and covers all over Australia, by Landgate. This app covers Hot spots at 0-12 hours old (great), 12-24 hours, 24-48 hours and 48-72 hours; Vegetation greenness; Lightning. Last 24 hours, 24-48 hours, 48-72 hour and also Burnt areas. It updates every 2-4 hours depending on satellite availability.	HR, S	All areas.	It would be good if plantation business could set up immediate fire notifications with My Fire watch. The same applies for Lightning tracker.
All business personnel have access to other fire/ lightning apps, including Fires Near Me, Wildfire Map, Firewatch Australia and Lightning (tracker),	HR, S	All areas.	
Use of satellite, drone, plane and other technology to provide early information to on the ground fire fighters. Longer manning times in higher fire danger periods, as well as high KBFI periods. Use of aircraft after lightning strikes.	HR, S	All areas.	
Increased and safe access for initial attack, safety of firefighters particularly those engaged in direct suppression is critical.	D, HR, S, HV	Boundary and inside.	This is important in setting up plantations and access.
Strategic areas raked at the boundary annually in December or just before the peak fire danger period.	HR, S	Boundary.	
Blackberry control at fire breaks and boundaries. Harvesting is designed to minimise large blackberry understories where possible.	HR, S, HV	Boundary.	Biological control of blackberries needs to be ramped up as an issue of national importance.
Safe retardant gel sprayed onto the ground and trees in extreme fire seasons.	HR, S	Boundary.	
Increase protection measures progressively in years likely to be extreme fire danger years using specialised climate services.	HR, S	Boundary and inside.	Could allocate machinery to improve breaks/ other options.
Innovations in fire tanker design. One option could be using 20,000 litre tankers (or water supply trucks) with 2-3 water cannons on top, manoeuvrable from the cabin.	HR, S	Boundary and inside.	
Annual assessment of fuel loads in plantations and opportunity areas.	HR, S	Boundary and inside.	
Plantation hazard reduction burning be practiced strategically throughout plantations when safe to do this. As emphasised in Thomson, 1978, there needs to continual monitoring of duff and surface moisture contents and wind speeds before and during HRB's. As also noted in Thomson, 1978, Low Intensity Prescribed Burning in Three Pinus radiata stand types was undertaken where there was a significant moisture differential between surface fuels and the duff layer. He notes that moisture contents great than 28 %, the duff layer should not ignite. Thompson notes the importance of avoiding burning the duff layer, targeting still conditions, avoiding lines of fire, planning the junction points of fires and taking into account slope.	HR, S	Boundary and inside.	One potential scenario is every 5 years possibly just before 1st thinning, post 1st thinning to allow slash on tracks to break down (well before 2nd thinning), after 2nd thinning and after 3 rd thinning. There is research and practice to show that this can be undertaken, but care is needed. I have

Potential opportunity and strategy areas for improved bushfire plantation protection and management.	Protection measure. Note 1.	Boundary and/ or inside	Other detail.
There is some useful HRB guidance in Woodman M, Rawson R, 1982, Fuel Reduction Burning in radiata pine plantations, Research Report Number 14, DCE (Victoria), August and also Thomson DS, 1978, Low Intensity Prescribed Burning in Three Pinus radiata stand types, Research Report Number 2, DCE (Victoria), February. Night hazard reduction burning could be undertaken in riskier plantation areas/ higher fuel areas/ blackberry areas. Aero burn hazard reduction burning could be undertaken late in cool season evening, as obtain an even distribution of fire.			seen one case where fire burnt logged pine stumps and killed live trees with roots growing into these old stumps.
Use fire risk modelling and growth simulation to investigate which fuel management activities will have the greatest effect on reducing the risk to the plantation and prioritise these activities for implementation.	HR, S	Boundary and inside	This may indicate opportunities for better value by assisting a neighbour to implement a project rather than just working on your land.
Utilisation of needle mulch as a product. This would be difficult to extract and expensive.	HR, S	Boundary and inside.	Research undertaken in regards to this area. This also needs to be balanced against potential impact on soil nutrient status.
Use of drones to assist on ground performance in hazard reduction burning, checking boundaries/ tracks, dams, blackberries and at bushfires.	HR, S	Boundary and inside.	
Get involved in State, Regional and local bushfire planning to ensure due consideration is given to the economic and social value of the plantations	-	General.	Plantations make a significant contribution to regional employment opportunities
Enlist the support of the forest industry, your customers and contractors to promote the value of plantations (and the need to protect them)	-	General.	
Develop engagement and communication strategies to promote the importance of plantation protection to politicians, all levels of government and the general community.	-	General.	A set of key talking points can be very handy to promote a common message.

Considering bushfire risks, a good strategy would be to review plantation protection on boundaries, on all plantation edges. There is a need to consider local weather influences and recent experience has shown that the threat may not always come from the expected direction or under extreme conditions, eg the influence of sea breezes and downslope / valley channelled winds.

Specific widths of fire breaks and protection measures are not provided in this document, as a lot of factors feed into the break widths needed, including adjacent vegetation type and height, adjacent land ownership, willingness to undertake hazard reduction burning, land slope and other factors.

5. Potential bushfire opportunities and strategies outside plantations to protect plantations.

As also noted by Bartlett, 2012:

- *As most of the significant radiata pine plantation losses have resulted from bushfires entering the plantations from adjoining land, plantation protection strategies require a broader landscape approach to fire management. In particular, land on the northern and western sides of radiata pine plantations needs to be appropriately managed to minimise the prospect of fires entering the plantation. If these areas are native forest, then regular prescribed burning should be implemented to keep fine fuels at low levels. External boundary firebreaks 20-50 m wide will provide some fire protection, but they will not stop the progress of a bushfire once the Forest Fire Danger Index exceeds 32.*
- *The 2003 ACT bushfire originated from lightning-strikes in mountainous country located more than 25 km from the Canberra suburbs. A clear lesson from this bushfire is that greater effort must be applied to managing fuels and suppressing bushfires in areas of native forest within 30 km on the upwind side of substantial areas of radiata pine plantations and urban areas. Also, having plantation estates separated by a distance of 25 km will not necessarily preclude their loss in a large intense bushfire.*

As outlined by Jurskis, Bridges and de Mar, precautionary fire management should be undertaken across forested areas of NSW, developing guidelines and prescriptions for landscapes, not individual plants and animals; developing prescriptions to control the extent and spatial variability of fires by controlling fire behaviour, rather than prescribing artificial exclusion zones and fire intervals; recognising that low intensity burning protects edaphic controls and sensitive species, so that perceived conflicts between human and environmental protection are largely unreal; recognising increasingly extensive high intensity fire regimes and eucalypt decline as consequences of fire exclusion that must be considered in planning.

Potential opportunity and strategy areas outside pine and hardwood plantations include:

Potential opportunity and strategy areas outside plantations.	**Other detail.**
Set up alliances for plantation coordinated firefighting efforts in bushfires and hazard reduction, as used in the Plantation Managers Fire Agreement, WA and FOC / Green Triangle Fire Alliance.	
Forestry organisations, RFS, local government and landholders to undertake regular hazard reduction burning in nominated adjacent forested zones adjacent to plantations.	This cooperative approach would result in benefits to landholders and forestry organisations. It would also assist in developing and optimising relationships. A 5 year cycle would be optimal.
Cool season, autumn/ winter cooperative burning would be ideal. Adequate post fire season rains and then warmer/ dry days to reduce fire spread risks into plantations.	Night time operations could be considered in heavier fuel load areas and riskier locations.
Where possible, embed plantation fire specialists into the Incident Control Centre to ensure the economic and commercial value of the plantation resource is considered in incident management decisions.	
Map critical plantation risk zones where fires are a threat in the past and maybe the future.	These can be past fire risk areas, near highways, lightning strike areas and heavy fuel areas.
Map areas adjacent to important plantations as critical infrastructure to ensure focussed fire hazard reduction.	This would be a two-way street, only used where fire hazards within the plantation estate are managed and reduced. Outside the estate, hazard reduction would only be undertaken on a cooperative basis with adjacent landholders. There

	would be many win win situations.
Steep areas need to receive periodic cool hazard reduction burns.	In the 2019/ 2020 bushfires, fires on many areas of steep slopes were very hot, increasing fire spread and intensity into adjacent lands. The soils on the slopes can also erode after bushfires.
Set up improved access outside plantations, so fires can be attacked as quickly as possible.	
Set up pipes and overhead stand pipes for tankers and slip on units in areas outside of plantations.	These would only be available/ used for firefighting.
Risk assessment for areas outside of large plantations, considering lightning strike risk, highway fire risk, other plantation risks, initial attack failure risk and any other relevant issue.	

6. Potential opportunities and strategies for safe hazard reduction burning under plantations.

Potential opportunities and strategies for safe hazard reduction burning within plantations:

- Undertaken in autumn and winter. Timing of hazard reduction burns to consider reducing reignition risks.
- Grid pattern using drones, helicopters or planes to ensure a planned cool fire and fire junction points in cool times of the day or night.
- Burning after adequate end of fire season rainfall so the deeper litter is damp and fuel/ moisture testing is undertaken through needle litter dryness through depths and locations. Minimum moisture levels could be set for deep litter and litter near the surface.
- The same applies for optimising the moisture content of the inner bark. For hazard reduction burning after drought, ideally there should be greater rainfall after the drought break so the inner bark is as moist as possible. An inner bark moisture test could be developed at 20 cm tree height.
- Weather to allow for safe burning conditions and avoid smoke lingering too long.
- Possibly undertaken before thinning operations to avoid slash and higher fire intensities near trees.
- Consideration of night time burning to reduce fire intensity.
- Special care where blackberries are heavy and high.
- Use of hot spot technology to assess progression of burns.
- Monitoring of all burning operations and continuous refinement and learning.
- Always consider reignition risk from duff and stumps.

7. Potential opportunities and strategies in regards to plantation timber salvage, recovery and reestablishment.

The above identified potential opportunities and strategies in regards to pine and hardwood plantations are aimed at reducing risks to the plantations, in the plantations and from the plantations.

It is important to also consider potential opportunities and strategies if a bushfire damages a plantation area requiring timber salvage and reestablishment, outlined below. It is important that it is in the interests of all parties to maximise timber savage, other annual allocations could reduce more than without salvage.

Potential opportunities and strategies in regards to pine and hardwood plantation timber salvage and recovery include:

- Safety of personnel coming onto post-fire sites is critically important. Be aware of still hot / burning stump holes and hot spots; sharp sticks (burnt small saplings) protruding from the ground – these can penetrate the soles of boots and cause foot injuries; sharp burnt sticks at

eye level – wear safety glasses; post-fire intense storm events can lead to mass-flow and rapidly rising water levels in creeks and rivers – firefighters have died in flash floods; the ground can become slippery following rain; and dust and ash can aggravate eyes, lungs and skin.

- Planning and considering post bushfire timber salvage and recovery in advance, including funding of recovery, timber salvage optimisation (maximising volume by log and chip and also value), reestablishment works, seedling supply/ quick expansion, future log harvesting and additional supply considerations.
- Post Fire Harvesting needs to commence quickly, hence there is a need to assess and prioritising stands. Satellite and aerial imagery can be of great assistance.
- When salvage commences, consideration of additional fire management measures may be required:
    - May require on-site firefighting equipment to suppress fires that start in harvesting slash, where hot stumps may still occur.
    - Need to constantly clear charcoal from machines to prevent mechanical abrasion and machine fire.
    - Leave machines overnight in a safe place away from slash and hot spots.
- Developing a communication plan for community awareness and stakeholder engagement for log haulage operations with increased trucks, ensuring roads are opened to log haulage asap so operations can commence quickly, road weak spots identified, signage, possible geofencing of hazardous areas within the truck GPS tracking systems.
- Selling/ transport of salvaged logs to other areas of bushfire impacted states and also other states.
- Setting up interstate/ intrastate agreements where mills/industries in other states take fire resource following fires and in the following years the reverse occurs. This is a form of cheap insurance.
- Having clauses in sales contracts with customers to encourage / enable the use of salvage wood.
- Having clauses in harvesting and haulage contracts that allow for the rapid re-allocation of operation location
- Optimising timber size classes and timber value classes in salvage operations, a key point being earlier thinning/ regular thinning regimes and good fertiliser regimes where possible. Refer detail discussed above.
- Undertake environmental and roading recovery works, stabilising soils, repair wash-outs / blocking of culverts/ bridges and replacement of road signage
- Setting up strategic salvage log spray dumps at strategic locations where there is suitable access to water, pumps can be added when needed. These areas could be set up in suitable areas near water supply networks or larger waterways. These areas can be set up permanently or nominated in advance of any bushfires, and water supply dams, pollution runoff dams can be set up in advance to use for bushfire control and if need be timber salvage storage. Water approvals could be applied for in advance, on an as needed basis, subject to limits on different waterways.
- Where authorised, add safe and suitable additions to the sprays on salvage dumps to minimise log degrade. Using products such as titanium oxide applied to log surfaces absorb the least amount of water by creating the hydrophobic barrier, possibly increasing fungal resistance.
- Research dipping logs in an environmentally safe solution that delays blue stain and log degrade. It would be optimal to complete trials over five years and assess timber annually for strength, appearance and blue stain.
- research covering salvaged logs to increase life of salvaged material. This may involve plastic, geofabric, earth or other products. It would be optimal to complete trials over five years and assess timber annually for strength, appearance and blue stain.
- Research methods to reduce charcoal deposits on logs.
- Explore developing markets for blue stain timber.
- Explore burnt pine chip markets in advance of bushfires, to optimise timber salvage and reduce reestablishment costs.
- Consider early reestablishment of bushfire impacted plantations, as delayed re-establish will often result in woody weed, blackberry, wattle pine seedling

8. Importance of the potential opportunities and strategies outlined above in Sections 4-7.

Large bushfires can have large impacts on timber availability and supply arrangements and can be very costly. Impacts on timber availability, supply arrangements and costs can include:

- Loss of timber volumes and value from large bushfires.
- Reduced sales post bushfire.
- Lost production between the bushfires and replant.
- Reduced timber volume to industry and reduced employment.
- Reduced timber volume to harvesting contractors.
- Replanting costs can increase with woody plants and weeds.

This information emphasises the importance of broad consideration of the potential opportunities and strategies outlined above in Sections 4-7.

9. Annual plantation grower meetings.

It is beneficial for plantation growers in the major growing areas to meet and discuss important plantation industry issues, including in regards to plantation bushfire protection and savage. There are currently two good examples of these in Australia: the Plantation Managers Fire Agreement, WA and the Green Triangle Forest Owners' Conference / Green triangle Fire Alliance

Potential issues that could be discussed include:

- Setting up/ updating alliances for plantation coordinated firefighting efforts in bushfires and hazard reduction.
- mutual support including agreed response zones and automatic dispatch of resources;
- daily teleconferences (when FFDI>35) to discuss weather, equipment location and resourcing and forest operation restrictions and roster for plantation technical advice into IMT.
- Development of common standards and guidelines, eg FOC Fire Management Guidelines.
- Sharing equipment ideas and design and standardisation of fittings.
- Communication protocols.
- Learnings from other bushfire areas.
- Areas that didn't go well in recent bushfires.
- Consultation with adjacent landholders.
- Coordination of resources and planning for hazard reduction burning.
- Reducing smoke risks.
- High risk fire areas.
- Water supply arrangements.
- Plantation layout and design.
- Updated GIS information, access, dams, structures etc/ information to be updated.
- Firefighting mapping of plantations.
- Refinement of potential opportunities and strategies for pine and hardwood plantation protection.
- Refinement of potential opportunities and strategies for pine and hardwood plantation salvage/ salvage research.
- Areas where research is needed.

Interstate grower meetings could also be valuable to address important issues such as maximising bushfire salvage via agreements, log transport and other important issues.

10. Potential bushfire research and trial areas.

Potential bushfire research areas in relation to pine and hardwood plantation protection and salvage include:

- Early first thinning at age 10 years.

- Periodic fertilising post T1 to assist in maximising growth and value, crown closure and forest floor weed control.
- The effects of various plantation operations on fire behaviour, eg leaving unburnt heaps and windrows, thinning system types and the spatial arrangement of the harvesting debris / slash.
- Potential safe long term gel retardant products to set up improved fire breaks.
- Refined plantation layout.
- Blackberry control and blackberry rust initiatives.
- Breakdown products to reduce plantation floor mulch/ duff and fertilise trees, lowering the C:N ratio, potential breakdown products.
- Where authorised, add safe and suitable additions to the spray on salvage dumps to minimise log degrade. Using products such as titanium oxide applied to log surfaces absorb the least amount of water by creating the hydrophobic barrier, possibly increasing fungal resistance.
- Trial dipping logs in an environmentally safe solution that delays blue stain and log degrade.
- Trial covering salvaged logs to reduce water entry.
- Explore developing markets for blue stain timber.
- Other areas as nominated

11. Other related matters.

One potential idea is that important pine and hardwood plantations could be classified as critical protection zones requiring cooperative hazard reduction burning with land holders in the nominated adjacent forested zones, in cooperation with the forest owner personnel. If done right, this can be a win win.

Air quality impacts is an issue that needs to be considered in planning and also monitoring of cool season hazard reduction burns. Cool season burns would be much cooler than summer bushfires and only burn to top portion of the needle layer. However, timing of burns, inversions, residences and air quality need to be factored into burning programs.

12. Bushfire plantation protection plan, review and audit.

Considering the risk of bushfires, recent large bushfire losses, safety of bushfire personnel and opportunities with coordinated firefighting approaches, it is important that each pine and hardwood plantation business/ organisation have an applicable bushfire plantation protection plan in place, assessing potential opportunities and strategies. This would be refined for each business and ideally cover the following areas:

- Risk assessment/ high risk areas.
- Bushfire plantation protection strategies inside plantations at the boundary.
- Bushfire plantation protection strategies inside plantations.
- Bushfire plantation protection strategies outside plantations.
- Bushfire plantation protection strategies in regards to plantation salvage and salvage arrangements.
- Further protection opportunities.
- Auditing of the plan.
- Research opportunities.

It is suggested that annual review before and after each bushfire season that the plantation protection plan is reviewed, and if necessary, improvements made.

It is suggested that the plantation protection plan should be available publicly.

13. Contact details.

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References.

Geddes D, 2020, Database capture of individual significant-scale Australian forestry plantation fire losses. Prepared for Forest & Wood Products Australia by David Geddes Geddes Management Pty Ltd, March 2020.

Tony Bartlett, undated, Fire management in pine plantations, Director, ACT Forests.

A.G. Bartlett, 2012 Fire management strategies for Pinus radiata plantations near urban areas, Australian Forestry 2012 Vol. 75 No. 1 pp. 43-53.

CALM 1994, Fire Management on CALM Lands in The South--West of Western Australia, Submission to the Ministerial Review Panel enquiring into CALM's prescribed burning policy and practices and wildfire threat analysis February 1994.

MG Cruz, MP Plucinski, 2007, Billo Road Fire, Report on Fire Behaviour Phenomena and Suppression Activities, Bushfire CRC. November 2007.

MG Cruz, P De Mar and D Adshead, 2011, Radiata pine plantation fuel and fire behaviour guide. Technical Report.·June 2011. DOI: 10.13140/RG.2.2.26685.05608 Affiliation: CSIRO / GHD.

DFES 2011, Guidelines for Plantation Fire Protection. The Forest Industry Federation of Western Australia, along with the Department of Fire and Emergency Services, has developed Guidelines for Plantation Fire Protection.

FESA (WA), 2007, Standards for Plantation Fire Protection Draft as of 12/2007, vs 2.

Forest Industries Federation (WA) Inc 2014. Code-of-Practice-for-Timber-Plantations-in-Western-Australia 2014.

Forest Owners' Conference (FOC) 2017 Plantation Fire Protection Guidelines (Victoria/ SA).

Forest Fire Management Group (FFMG), 2007, Softwood Plantation Fire Synopsis, a sub-Committee of the Forestry and Forest Products Committee which reports to the Primary Industry Ministerial Council, Endorsed by: Australasian Fire Authorities Council Ltd (AFAC), ISBN 0 643 06533 4 © Forest Fire Management Group November 2007.

FPC, 2017, Plantation fire management and protection, Plantation Information Series, Forest Products Commission.

Geddes D, 2020, Database capture of individual significant-scale Australian forestry plantation fire losses. Prepared for Forest & Wood Products Australia by David Geddes, Geddes Management Pty Ltd, March 2020.

Gomes Da Cruz, Miguel; Alexander, Martin; Plucinski, Matt May 2017 Forest Ecology and Management Volume: 397 Pages: 27-38 The effect of silvicultural treatments on fire behaviour potential in radiata pine plantations of South Australia:

Government of Western Australia, 2016, "Reframing rural fire management", report of the special inquiry into the January 2016 Waroona fire. 29 April 2016.

Jesse K Kreye, J Morgan Varner, Leda N Kobziarn 2020. Long-Duration Soil Heating Resulting from Forest Floor Duff Smoldering in Longleaf Pine Ecosystems. Forest Science, 2020 DOI: 10.1093/forsci/fxz08

Jurskis V, Bridges B de Mar P (2003) Fire management in Australia: the lessons of 200 years. In 'Joint Australia and New Zealand Institute of Forestry Conference Proceedings 27 April – 1 May 2003' (eds EG Mason CJ Perley) pp. 353-368. (Ministry of Agriculture and Forestry: Wellington)

J. W. P. Nicholls and P. Cheney1972 Effect of Experimental and Wild Fires in Pine Plantations on Wood Characteristics & Pages 164-177. Australian Forestry Volume 36, 1972 - Issue 3 Published online: 15 Apr 2013 https://doi.org/10.1080/00049158.1972.10675582

Plantation Managers Fire Agreement, WA.

Primary Industries and Resources South Australia, 2009, Guidelines for Plantation Forestry in South Australia.

StéfanoArellano-Pérez[a]FernandoCastedo-Dorado[b]Juan GabrielÁlvarez-González[a]CeciliaAlonso-Rego[a]Jose AntonioVega[c]Ana DaríaRuiz-González[a] Forest Ecology and Management Volume 460, 15 March 2020. Mid-term effects of a thin-only treatment on fuel complex, potential fire behaviour and severity and post-fire soil erosion protection in fast-growing pine plantations. https://doi.org/10.1016/j.foreco.2020.117895.

Thomson DS, 1978, Low Intensity Prescribed Burning in Three Pinus radiata stand types, Research Report Number 2, DCE (Victoria), February.

Tumut and Adelong Times article 2020, 'Damaged, but not destroyed': Timber salvage underway dated January 24, 2020.

Woodman M, Rawson R, 1982, Fuel Reduction Burning in radiata pine plantations, Research Report Number 14, DCE (Victoria), August.

APPENDIX BACKGROUND INFORMATION.

1. Appendix 1. Impacts of bushfires on plantations.

The impacts of 2019/ 20 bushfires on plantations (mainly pine) and associated native ecosystems were large:

- Economic impact of lost timber and impacts on employment/ mills/ industries
- Impact on road infrastructure, including forest roads, fences, structures.
- Impact on water quality/ erosion/ sedimentation/ waterways.
- Impact on native fauna. There is a fair amount of native fauna residing in plantations/ adjacent corridors and large bushfires result in the loss of most of this fauna.
- Impact on air quality from native vegetation and plantations lasted for weeks at many bushfires, longer in some cases, but noting plantation fires extinguished fairly quickly. This is demonstrated in air quality data across the country between August 2019 and February 2020.
- Impact of bushfires on climate change is huge. In the main, pines are killed in extreme bushfires, stopping photosynthesis. Organic matter is lost, including most of the organic matter above the soil and in the foliage in many cases.

As outlined in the Tumut and Adelong Times article 'Damaged, but not destroyed': Timber salvage underway dated January 24, 2020, 10:47 am:

- *The forestry sector contributes to just under $2 billion of economic activity and supports nearly 5000 jobs in the Tumut and Tumbarumba regions.*

- *While the industry estimates about 1930 jobs and up to $800 million in economic activity is at risk following the fires, Softwoods Working Group chairman and timber industry veteran Peter Crowe is optimistic that won't be the case. "There may need to be a reconfiguration of the industry, but that doesn't necessarily mean there'll be job losses," he said. "Priority 1 is the salvage operation, then we need to get the nurseries cranked up and start replanting."*

- *The Softwoods Working Group says it's critical government commits to reestablishing the plantation, with a need to replace about 35,000 hectares of public forest and another 10,000 hectares of private forest. That could cost about $200m.*

- *It's likely the maximum amount of sawmilling capacity will be employed to mill the burn logs in the shortest possible time, meaning the sawmill at Oberon will likely come into play. That will increase truck movements, so too any moves to import fibre, should that be necessary.*

2. Appendix 2. Practices used to reduce bushfire risks in plantations.

Current practices used across different areas.

There are a range of current practices used to reduce bushfire risks in P radiata plantations across different areas:

- Fire towers, trained crews and suppression equipment.
- Access roads.
- Boundary roads.
- Firebreaks, external and internal.
- Pruning, low and high.
- Thinning.
- Dams for water supply.
- Strategic hazard reduction burning in plantations and adjacent areas, in some cases.
- Hazard reduction burning outside plantations, in some cases.

These practices are generally effective, but as expected, do have limits, as the Forest Fire Danger Index exceeds 35:

- Aren't that effective in extreme fires.
- Except for hazard reduction, don't reduce fuel levels.
- Provide protection over limited areas.
- If fire breaks and boundary roads aren't maintained, risks of non-containment of fires increases.
- Dams can be dry or low volume in summer months.

Address fire protection measures in design of the plantation.

As noted in FFMG, 2007, the Fire and Emergency Services Authority of Western Australia, (FESA 2001) "...promotes that potential fire protection should be recognised in the early stages of plantation development and that appropriate action is taken to reduce possible hazards. It is widely recognised that attention to fire protection early in the life of a plantation can dramatically reduce future risks and costly fire protection measures." This is fully supported.

As noted in FFMG, 2007, Cheney & Richmond (1980) recognise that "Four principal aspects of plantation design affect fire protection. These are: • The shape and size of discrete planted units. • The intensity and standard of access. • The provision for firebreaks and/or fuel breaks. • The distribution of age classes through the area". These design aspects are fully supported.

Fuel management zones, thinning and silvicultural treatments.

As noted in Gomes Da Cruz, Miguel; Alexander, Martin; Plucinski, Matt May 2017 Forest Ecology and Management Volume: 397 Pages: 27-38 The effect of silvicultural treatments on fire behaviour potential in radiata pine plantations of South Australia:

- They found the pruning and thinning fuel treatments significantly changed the plantation fuel complex, relocating ladder and canopy fuels to the surface layer, while breaking up fuel vertical continuity.
- Key beneficial effects such as the decrease in the vertical continuity of the fuel complex are long lasting, whereas disadvantageous effects such as increase in the surface fuel load are short lived. The fuel management zone prescriptions resulted in significantly lower fire line intensity and likelihood of crowning under the range of conditions where fire suppression activities are effective and safe to conduct. The effect of the silvicultural operations conducted in fuel management zones should not be viewed individually, but as a process that transforms a highly "flammable" fuel complex into a low flammability one early in the rotation.

Stéfano Arellano-Pérez 2020, considered thinning and fuel reduction in pine plantations. In NW Spain, plantation managers assume that thin-only reduces the potential fire behavior and effects by decreasing the quantity and continuity of canopy fuels. Nevertheless, thin-only can alter additional variables than control fire behavior and effects such as surface fuel availability and microclimate conditions. Moreover, the duration of thinning effects could vary and be species-specific. We present an approach linking field-measured fuel variables to well-established models for assessing the mid-term effects (six years) of thin-only on potential fire behaviour and severity and ability of burned stands to protect soil against erosion. Field variables were obtained from 41 thinning trials installed in stands of *P. pinaster* (22 locations) and *P. radiata* (19 locations). The results of the study reveal that, in the mid-term, it is unlikely that thin-only, without intervention in the surface fuels, may have a marked influence on the reduction of the severity of a subsequent fire.

Radiata pine plantation fuel and fire behaviour guide (Technical Report.·June 2011. DOI: 10.13140/RG.2.2.26685.05608 Affiliation: CSIRO / GHD (MG Cruz, P De Mar and D Adshead, 2011) is designed to assist pine plantation owners/managers and fire managers to make rapid assessments of fuels in radiata pine plantations at different growth stages, taking into account different silvicultural treatments, and estimate fire behaviour.

In regards to pers comm, P Cheney:

- Increased access for initial attack, safety of firefighters particularly those engaged in direct suppression is critical. Pruning to 3 m is essential if firefighting by direct attack is to be

contemplated. This used to be common practice but seems to be limited today. Higher pruning improves crew safety but may make suppression more difficult due to increased fuel loads.

- A crown fire free zone will require pruning to 8 m, thinning, and disposal of all slash by heaping and burning. I have seen this practiced in conifer forests near south lake Tahoe Ca, and Flagstaff Az, and in South Australia. A crown fire free Zone around the Forestry Settlement of Mt Burr SA reduced the fire intensity from a crown fire to a surface fire and there were no losses in the township. During a major run of the Ash Wednesday fires, 16 Feb 1983.

Use of prescribed fire.

Reviewing other information, prescribed burning in pine plantations has been undertaken in a number of cases, but I am unsure of the status at this time:

- ACT near Canberra, refer Bartlett, 2012.
- WA.
- South Australia.
- Queensland.
- Victoria.
- Spain.
- USA in native conifer forests such as Pinus ponderosa.

As noted in FFMG 2007, "Hazard reduction burning reduces fire behaviour by reducing the speed of growth of the fire from its ignition point; • Reducing the height of flames and rate of spread; • Reducing the spotting potential by reducing the number of firebrands and the distance they are carried downwind; and, • Reducing the total heat output or intensity of the fire. Prescribed burning is not intended to stop forest fires, but it does reduce their intensity and this makes fire suppression safer and more efficient. Prescribed burning is not a panacea nor does it work in isolation. It must be used in conjunction with an efficient fire fighting force." (Cheney 2004, referenced in FFMG 2007)

As noted in Bartlett, 2012, Radiata pine is a fire-sensitive species and trees may be killed by even moderate-intensity fire, which makes it difficult, although not impossible, to use prescribed fire to reduce fuels within pine plantations. Low-intensity fires (<500 kW m-1) in pine litter and pruning slash cause little damage in trees more than 16 y old. However, heavier slash from thinning operations close to trees, or smouldering logs against trees, will cause quite severe damage to the trees.

Bartlett, 2012, notes that while prescribed burning is technically feasible within radiata plantations, it is not routinely practiced. This study demonstrates that a 1-y-old prescribed burn under mature radiata pine moderated the intensity of an intense bushfire in the ACT.

As outlined in Forest Fire Management Group (FFMG), 2007, Nicholls and Cheney (1974) "Prescribed burning may therefore be used for these two important species (P. radiata and P. pinaster) without prejudice to growth rate or density characteristics." Also, the importance of moisture levels in the duff layer on determining fire intensity, and therefore the potential for significant damage to the plantation is also emphasised by Woodman and Rawson (1982).

The FFMG 2007 summarised:

- Fire intensity alone does not determine the damage to a stand or an individual tree. Increased residence time as a fire burns in relatively dry heavy fuels or duff layers will increase the likelihood of significant stem damage.
- At fire intensities typically used for fuel reduction burning in softwood plantations (200-300 kW/m) there should be no significant impacts on growth or stem damage (and subsequent sawn timber quality), provided also that the heavy fuels and duff layer do not ignite.
- Crown scorch will typically reduce stand growth in all species, with the extent of crown scorch determining the magnitude of the impact.

But there is a need for caution. As outlined in FFMG 2007, Woodman and Rawson (1982) mention work described by Billing (1980a) that supports the view that fire intensity alone is an unsuitable descriptor of the likely extent of damage to a softwood plantation. “The importance of factors other than bark thickness and the intensity of the flame front in minimising damage is shown by the results of clear felling during 1980 of a section of the Mt Franklin plantation. The stand (of P radiata) was 18 years old when burnt by low intensity bushfire, with flame heights generally less than one metre, in January 1969. During felling extensive damage became apparent, including fire scars to heights of 5-7m and extending on average, depending on tree size, around 22% to 46% of the circumference at stump height. It is probable that increased fire residence time, caused by dry heavy fuels, and the lower moisture content of the inner bark likely during summer were contributing factors.”

Bartlett, 2012, notes fine fuels can be reduced by either low-intensity prescribed burning or physical removal. Woodman and Rawson (1982) summarised a decade of research on prescribed burning of radiata plantations indicating that, under carefully prescribed conditions, prescribed burning can be used to reduce ground and elevated fine fuels in plantations of 11 y or older without damaging the trees. Some plantation managers establish Fuel Modified Protection Areas, previously known as Crown Fire Free Zones, over large strategic areas of the plantation. These areas need to be at least 200 m wide and the trees should be high pruned in stages as the plantation develops. Because of the intermittent nature of severe bushfires in radiata plantations there is only anecdotal evidence of the effectiveness of this fire management strategy.

As outlined in FFMG 2007,

- Woodman and Rawson (1982) summarise much of the Victorian work. “During spring, and under carefully prescribed conditions of fuel moisture and wind speed in particular, fuel reduction burning in both the needle litter layer and elevated fuel from thinning can be conducted with safety. Operations confined to stands aged 11 years or older should cause little or no stem damage and no reduction in stand growth. After first thinning operations fire can also be used, as an alternative to pruning, to remove much of the dead needle fuel from the lower crown.”
- Trial work in Victoria and WA produced three very simple burning guides, all based on burning being conducted during winter or spring when moisture levels in the duff layer are high enough to prevent that layer being ignited. The guides generally involve wind speeds, measured inside the plantation, of less than 5 km/h, surface fine fuel moisture contents of 12%-20% and elevated fine fuel (from pruning or thinning) moisture contents of 15%-22%. Burning of dead needles held in the lower branches of trees retained after first thinning generally requires fine fuel moisture contents of 25%-35% although, under some circumstances, “because they are extremely well aerated the aerial fuels can sustain burning at moisture contents up to 45%.” Those guides are provided in Appendix 4 (FFMG, 2007).
- However, while under conventional thinning regimes these burning guides proved to be acceptable, Norman (1985) examine how the burning guide can be applied in stands that had been very heavily first thinned in north-eastern Victoria. He conducted experimental fires in stands where fuels (fine and heavy) after thinning totalled approximately 83 t/ha, or about twice the load found after thinning operations where earlier experimental burning was conducted. In addition, the fuel was concentrated in just 30% of the stand area. Under these conditions, unacceptable levels of scorch and stem damage occurred using the burning prescriptions described earlier.
- The importance of ensuring the duff layer is too moist to ignite and continue to burn is also emphasised by Woodman and Rawson (1982). The important influence lighting technique can have on fire intensity is also highlighted.
- The reduction in fuel loads achieved appears to last for about 18 months to two years in young stands, while the fuel loads appear to remain lower for longer periods in older stands. There was also some evidence that successive burning resulted in reduced fuel loads for longer periods in young stands.

Pine hazard reduction burning trials.

The FFMG 2007 summarised hazard reduction burning trials in Queensland:

- Byrne (1980) describes a Prescribed Burning Guide for P elliottii plantations in Queensland based upon experimental fire data collected in Queensland and elsewhere. The Guide is based upon recognition of five fuel types; recognition of acceptable maximum flame heights (and therefore scorch levels) for the stands concerned; calculation of the amount of fuel available for burning based on to the number of days since at least 7 mm of rainfall; prediction of rates of fire spread and flame heights based on wind speed and relative humidity; the implementation of an appropriate lighting pattern and burning in the months of March to June when the BKDI is less than 200 points.
- Initial trials began in 1967, and in 1974 the technique was first used on a large scale. "Approximately 3,500ha of slash and caribaean pine were burnt at Tuan, Toolara, Beerburrum and Byfield during the winter of 1975" (Department of Forestry, Queensland 1976). Byrne and Just (1982) also describes the first trials of aerial methods to conduct fuel reduction burning operations in Queensland plantations.
- The importance of controlling the lighting pattern and the rate of lighting in such operations was highlighted during the 1975 operations mentioned above. Although the results obtained were considered to be generally excellent, "In almost every instance where scorch occurred, inexperience on the part of the lighting crew was responsible rather than selection of inappropriate burning conditions by the officer supervising the operations." (Department of Forestry, Queensland 1976).
- The impact on fuel levels of these operations is also described by Byrne (1980), as "... for practical purposes, it can be assumed that fuel quantities over most plantation areas almost fully recover (to) pre-fire levels three years after a low intensity fire."

As outlined in FFMG, 2007, de Mar (pers comm.) indicates why fuel reduction burning in P radiata in NSW it is not part of routine practice. "One of the major reasons that prescribed burning trials under radiata pine in NSW didn't proceed to more routine practice, is that in many places where it was tried, there were significant issues around re-ignition. Due to fuel moisture variability within burning sites, particularly sites with variation in topography and aspect, prescribed burns did holdover in the duff layer and old stumps etc in dryer areas, introducing significant ignition risk later in adverse weather and generating significant patrol costs. Accordingly, prescribed burning under radiata pine is somewhat of a resource intensive practice requiring frequent application for best results, and limited to relatively small and strategic areas such as in high community risk areas." I personally understand this reasoning, the practice has risks in pine plantations.

Hazard reduction burning and pine wood quality.

The impact of hazard reduction burning measures on pine wood quality would need to be further considered and researched. J. W. P. Nicholls and P. Cheney1972 assessed this issue. Sawn timber losses due to degrade were investigated in a 28-year-old stand of radiata pine subjected to a series of experimental fires covering a wide range of intensities. The effect of the burning treatment on radial growth rate and density characteristics was also studied. The experimental fires caused a reduction of 0.4 per cent of the total possible sawn volume. There was no effect on growth rate and only a slight reduction in density in the immediate post-fire year.

Firebreaks.

Bartlett, 2012, notes that internal firebreaks are generally recommended to be 6-10 m wide and aligned on a grid pattern 600-800 m apart, preferably with one dimension aligned to the prevailing direction of the worst fire weather. Plantation managers understand that firebreaks will not stop the forward rate of spread of high-intensity wildfires and that fire intensity often increases near firebreaks because the firebreak can act as a channel for wind flow in the plantation. Well-aligned firebreaks do, however, give firefighters greater capacity to control the flanks of wildfires. External firebreaks are generally recommended to be 20 m wide and maintained in a low fuel condition with no overhanging branches for a vertical height of 10 m. In NSW, these external firebreaks or buffers range from 20 to 50 min width depending on slope and whether they form part of an asset protection zone.

Dams and water supply measures.

These can be developed and implemented with common sense, taking into account water availability throughout the fire season. There is some information in the guidelines quoted in this document.

3. Appendix 3. Some plantation fuel issues to consider first.

Fuel distribution in pine plantations.

Fuel distribution (pers comm P Cheney, 2020):

- Conifers are not self-pruning and retain dead material below and in the green crown from the base near the tip.
- The amount of dead material in the lower dead branches varies with species and the branch habit - in many southern pine it is sparse.
- Radiata pine of poor form may retain substantial litter with in the branch structure
- Mature conifer stands may retain a partial fuel gap between the surface litter and crown fuels- results in stop-start fire behaviour.
- Pine bark is a significant component and responsible for short-distance spotting.

As noted in Bartlett, 2012:

- Williams (1976) measured fuels in unthinned 12-yr-old radiata pine plantations stocked with 1400 trees ha-1. He found that only 5.6 t ha-1 (tonne/ hectare) of the fine fuel was on the ground and that there was 12.0tha-1 of living fine fuel and 5.0 tha-1 of dead fine fuel in the canopy. Of the living fine fuel, 7.7 t ha-1 was green needles and he estimated that the annual shedding and replacement of needles was 2.6 t ha-1.
- Woodman and Rawson (1982) found ground fuels in radiata plantations from 10 to 30+ y reach an equilibrium value of about 10 t ha-1 from an age of 15 y. Woodman and Rawson (1982) also found that following canopy closure (7-10 y), most of the additional biomass as the plantation grows is added in the stems of the trees, increasing from about 100 t ha-1 to 400 t ha-1. The foliage biomass remains relatively constant, only reducing in times of drought when accelerated needle shed occurs.

As noted in CALM, 1994, flammable fuels accumulate through needle cast and as a result of silvicultural operations such as thinning and pruning. Research has concentrated on quantifying and describing the fuel hazard in plantations, on defining fuel and weather conditions for executing very low intensity needle bed fuel reduction burns, on developing prescriptions for slash disposal burns and on determining the effects of fire on tree health and wood properties (Peet et al., 1971, McCormick 1973, McCormick 1976 and Burrows 1980, 1982, 1984). As a result of this research, guides have been produced to enable the planning and implementation of low intensity fuel reduction burns. There is a narrow window of opportunity for successfully executing prescribed burns (the window is somewhat wider for P. pinaster) so the amount of this type of burning done in WA varies each year, but is generally less than a thousand hectares for P. radiata and about 500 hectares for P. pinaster.

An important issue noted by Kreye et al, 2020, accumulation of organic debris can complicate efforts to use prescribed fire as a forest management tool, he explained, and this build-up of duff, particularly pronounced at the base of pines, is problematic if there is a wildfire. "When these forests do burn under dry conditions, the long-duration smouldering that occurs in this dense duff -- long after the 'flames' have gone out -- results in significant heat transfer to the tree as well as the soil," Kreye said. "That can result in mortality of large, older pines and potential ecological consequences below ground."

Fuel moisture.

As noted in FFMG 2007, fuel moisture content has a major influence on fire behaviour, and fires in pine fuels will ignite and be sustained at considerably higher moisture contents than in eucalypt fuels. “Because of the resin in dead pine needles they can be burnt at higher moisture contents (about 30%) than eucalypt litter (18-20%).

As also noted in FFMG 2007:

- Fuel moisture content has a major influence on fire behaviour, and fires in pine fuels will ignite and be sustained at considerably higher moisture contents than in eucalypt fuels. “Because

of the resin in dead pine needles they can be burnt at higher moisture contents (about 30%) than eucalypt litter (18-20%). This means that light surface fires to remove needles can be carried out under very mild conditions. Also suspended needles can be burnt when surface fuels cannot.

- Woodman and Rawson (1982) include work by Williams (1977) in P radiata stands in north-eastern Victoria to indicate the impact of various fuel moisture contents on potential fire behaviour in P radiata plantations.
- Fire Behaviour 25-30 Moisture Content (%ODW) Surface needles will not ignite; 20-25. Surface needles will just ignite and only carry fire with the assistance of wind. 15-20 Surface needles ignite and carry slow moving fire (e.g. ROS <0.5 m/min); 10-15 Surface needles easily ignited and carry fire of moderate intensity; 7-10 Surface needles carry fire of moderate to high intensity; <7 Very intense wildfire possible. Source: Woodman and Rawson (1982) after Williams (1977) * ** Surface needles refer to the top layer of dead pine needles on the plantation floor. They are more compacted than elevated dead needles but better aerated than the duff layer. ROS = Rate of spread
- Woodman (1982) studied fuel moisture changes in P radiata in an unthinned 17 year old stand, as well as a 28 year old stand thinned to 204 stems/ha, throughout one 24 hour sampling period to show that variations in moisture content are likely to be more pronounced in thinned stands, i.e. those exposed to greater fluctuations in temperature, relative humidity and air movement. Significant moisture loss from the duff layer can occur in a few hours if the initial moisture content is high. • The moisture content of the needle fuels can change rapidly from levels where burning is difficult to sustain to levels where moderate to severe fire intensities can occur."
- It is important, however, to recognise also that as relative humidity falls cured grass fuels will dry out more rapidly than coarser eucalypt and pine fuels, and therefore become available for burning earlier in the day than forest fuels.

As also noted in Thomson, 1978, Low Intensity Prescribed Burning in Three Pinus radiata stand types was undertaken where there was a significant moisture differential between surface fuels and the duff layer. He notes that moisture contents great than 28 %, the duff layer should not ignite.

Heat Transfer (pers comm P Cheney, 2020):

- Fire intensity relates only to radiant and convective heat transfer and scorch to the crown.
- Damage to the cambium depends on the amount of fuel consumed, the duration of combustion and the thickness of bark.
- Southern pines have thick bark.
- Radiata has moderately thick bark at the base but is susceptible to damage by any fire burning a component of slash in the Fuel bed.
- Pines grown from clones have very thin bark and are susceptible to any fires, sufficient to downgrade peeler logs to saw logs.

Pine firebrands.

- As noted by Bartlett, 2012, there is very little scientific evidence about firebrand movement during bushfires in radiata plantations under varying fire weather conditions. Under high Forest Fire Danger Indices, a bushfire burning in radiata pine will deposit significant ember loads downwind of the fire front. The issue of firebrand attack needs to be soundly considered in all strategies and opportunities. Also important is consideration of measures for containment of bushfires over the range of bush fire danger indices.
- At low humidity Radiata pine bark is quite flammable and can carry fire up a pruned stem into dead fuel suspended in the canopy. Small platelets of bark can produce A large number of firebrands. These may carry several meters starting spot fires under windless conditions but at higher intensities are burnt out in the convection column before ejection. With the collapse of the convection column, say at a fuel break, firebrands of bark platelets are blown directly out of the forest and cause a heavy ignition load on adjacent houses as described by Bartlett. Long-distance spotting is rarely observed in plantation fire – some reports have attributed LD spotting to cones which is unlikely. Firebrands that can travel > 5km are most likely from the

bark of eucalypts imbedded in the plantations or immediate surrounds (P Cheney, pers comm 2020).

4. Appendix 4. Is there a need to review strategies and opportunities for improved bushfire plantation protection across Australia?

There is never going to be a perfect solution for pine and hardwood plantation protection from bushfires, nor indeed any form of vegetated land use. However, at this time, it appears to be a good time to review all the potential opportunities and strategies in relation to pine and hardwood plantation protection.

As noted by Bartlett, 2012 in relation to the risk of loss of radiata pine plantations from fire:

- *The history of fires in Australian radiata pine plantations is that most fires are contained without significant loss of plantation assets. For example, from 1974 to 1994, Victoria recorded 308 fires affecting plantations. These fires burnt about 5% of the 106,000 ha of the then state-owned pine plantations, with an average fire size of 18 ha (CFA/DCNRNPC 1994).*
- *Most of the significant radiata pine plantation fires around Australia have destroyed less than 2000 ha of plantation each. In the ACT, prior to 2003, about 2,500 ha of plantation had been destroyed over an 80-y period, which is an average loss of about 30 ha a year. Around Australia, most losses have resulted from fires that have burnt into pine plantations from adjoining native forest or grassland under severe fire weather conditions, rather than from fires that commenced in pine plantations. In Victoria, statistics indicate that only 25% of plantation fires originate outside plantations, but account for 90% of the area burnt (CFA/ DCNRNPC 1994).*
- *The biggest losses of radiata pine plantations from fire occurred in 1983, including 21,000 ha in South Australia, 6,457 ha in New South Wales and 2,339 ha in Victoria.*
- *In recent years, however, the risk and impact of plantation fires appears to be increasing. The January 2003 ACT bushfire destroyed 10,500 ha of radiata pine plantation with a standing timber value of $56.142 million in a few hours. This included three plantation estates, located at Pierces Creek, Uriarra and Stromlo, separated by a north-south distance of 25 km.*
- *Over four days in December 2006, fire destroyed 10,866 ha of Forests NSW's radiata pine plantation estate east of Tumut, including 8,270 ha of radiata pine trees and 1256 ha of pine logging slash.*
- *In the disastrous February 2009 Victorian bushfires, Hancock Victorian Plantations lost 11,600 ha of radiata pine plantation, in four separate fires, with the largest single loss being 4,000 ha in the Mudgegonga fire.* Note: On information provided from HVP, Bartlett 2012 was incorrect, HVP's single biggest loss in that year was 8,126 ha in the Churchill – Jeeralang Complex and a total loss was 16,569 ha.

Other earlier plantation losses across eastern Australia have been extracted from Forest Fire Management Group (FFMG), 2007, not perfect by years, but give an idea:

- Data collected by State Forests NSW shows that for the seven-year period 1996/97 to 2002/03, during the period concerned, approximately 2,000 ha of softwood plantation (both publicly and privately owned) were burnt.
- For the 27 year period from 1973 to 1999, Tolhurst (2001) indicates the loss of State-owned softwood plantation averaged 0.15% pa of the total softwood plantation area (Victoria).
- Statistics available from Forestry South Australia from 1974/75 to 2003/04 indicate that the average area of softwood plantation burnt was 97.6 ha/yr or approximately 0.1% of the total plantation area each year. FFMG, 2007.
- In Queensland, fires that affected softwood plantations burnt an average area of 635 ha/yr of softwood plantation although not all of the plantation areas burnt would have been totally lost. Although accurate figures on total losses are not available, the loss due to wildfire is estimated to be less than 0.5% per annum.
- In Tasmania, statistics for the ten-year period from 1994/95 to 2003/04 show that the average area of softwood plantations burnt was 68 ha/yr which is 0.1% per annum of the total estate.

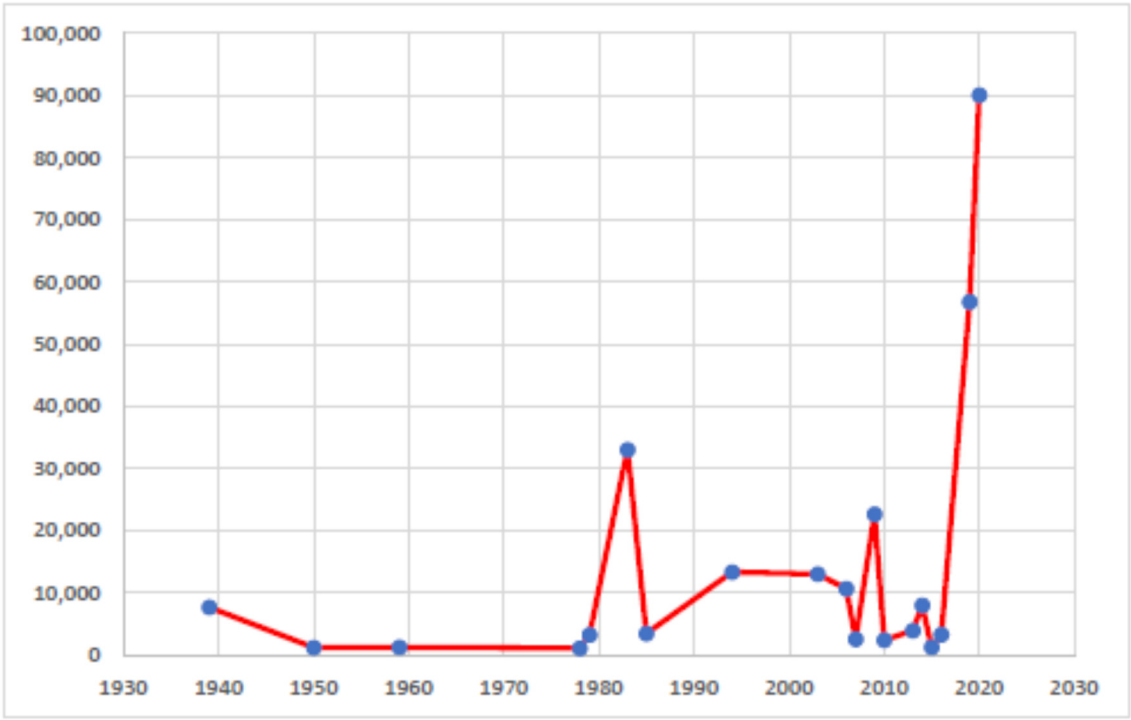
Other more recent plantation losses across eastern Australia have been extracted below from different sources, not perfect by years, but give an idea of losses:

- There was a fire in the Carabost-Murraguldrie area of southern NSW which killed 2,000 hectares of pine plantation in 2014 at a replacement value of around $3M.

- Another more recent example of a bushfire, the recent fires in the Batlow Tumbarumba area of NSW were large and intense. And also very large, around 48,000 hectares of pine plantation has been killed/ damaged by intense bushfires in January 2020. Most of the plantation estate is owned by Forestry Corporation, I understand that includes 10,000 hectares of private plantation lost.
- Bombala (NSW) has also lost about 6,300 hectares of state forests in that area in 2020 (20 per cent of its estate).
- About 35 % of the 27,000 hectares of southern pine and radiata pine plantations in the Walcha and Grafton management areas have been impacted by fires in 2019/20.
- About 6,000 hectares of private pine lost in north-east Victoria in 2020.
- The Western Australia Waroona bushfire destroyed 3,330 hectares of pine planation in the McLarty and Myalup pine plantations west of Waroona. Further detail on this is outlined below. Government of Western Australia, 2016.
- During the decade before January 2016 in WA, major bushfires have resulted in very significant damage to pine plantations in the Blackwood Valley, at Gnangara and Yanchep. Government of Western Australia, 2016.

As outlined in Geddes D, 2020, Database capture of individual significant-scale Australian forestry plantation fire losses, there have been some large losses in the last 40 years, as outlined in Figure 3 of that report, attached here.

Figure 3: Australian plantation area losses (ha) from individual fires exceeding 1,000 ha in size



Also outlined in Geddes D, 2020, Database capture of individual significant-scale Australian forestry plantation fire losses, there have been a number of fire losses greater than 100 ha in the states/ territory, as outlined in Table 1 of that report, attached here.

Table 1: Number of >100 ha individual fire losses by Australian state

State or Territory	No. >100 fires	Period	No. >100 fires	Period
ACT	6	1939-2020	0	2005-2020
NSW	27	1968-2020	13	2005-2020
NT	1	2005-2020	1	2005-2020
QLD	30	1977-2020	16	2005-2020
SA	44	1029-2020	12	2005-2020
TAS	22	2000-2020	16	2005-2020
VIC	65	1962-2020	37	2005-2020
WA	31	2005-2020	22	2005-2020

As outlined in Government of Western Australia, 2016, in relation to the Western Australia Waroona bushfire, the Special Inquiry received evidence that fuel management activities undertaken including:

- establishing fire breaks in excess of the size required by the Code of Practice for Timber Plantations in Western Australia;
- fire break maintenance was undertaken from August to November 2015 in preparation for the heat of summer;
- pruning across access roads was undertaken in August September 2015; and
- needle bed burning in the plantation is undertaken in the winter/spring of each year.

The mitigation activities outlined above provide adequate plantation protection for small to medium fires (Government of Western Australia, 2016). However, the fire conditions on 7 January 2016 were of such intensity that firebreaks and reduced fuel areas within the plantation were not adequate to prevent spread of the fire. The Special Inquiry has observed that, within the plantations, areas that were needle bed burnt in 2015 had less fire impact and damage. Furthermore, the land adjacent to the planation was only subject to irregular small scale hazard reduction burning. Previously vegetation around McLarty Pine Plantation had been burnt every 3 to 4 years as protection for the plantation. This lack of fuel management may have contributed to the destruction of the pine plantation.

As outlined in FOC Plantation Fire Protection Guidelines , 2017, the Forest Owners Conference (FOC) is made up of fifteen Plantation Managers and three Fire Authorities in the Green Triangle Region on the border of South Australia and Victoria. In 2017 this area comprised some 350,000 ha of land managed primarily for the production of hardwood and softwood products. These guidelines have stood the test of time. Since their adoption by FOC members in 1986, these guidelines, along with other fire prevention measures have contributed to the reduction of plantation area lost in fires to less than 0.1% per annum.

In summary, a fair summation is that Bartlett is correct, the risk and impact of plantation bush fires does appear to be increasing. This is not necessarily all due to one factor, it is likely related to many factors, including fuel load, adequacy of protection measures in place, maintenance of protection measures, resource availability, climate factors and weather.

In relation to the bushfire impacts outlined above, increasing protection measures and reducing hazards should considerably reduce bushfire impacts, reduce loss and improve fire fighter safety.

As also noted by Bartlett, 2012, experience from both the 2001 and 2003 ACT bushfires indicates that once a bushfire enters a radiata plantation, it is impossible to stop the forward spread within the plantation if the Forest Fire Danger Index exceeds 35, even if firebreaks in excess of 100 m width exist. This is noted and a section on fire salvage arrangements to optimise potential strategies and opportunities in regards to pine and hardwood plantation salvage has been added in this document.

Taking into account the above information, it is opportune to review and explore all potential strategies and opportunities to reduce bushfire hazard levels and fuel distributions/ loads inside and outside plantations.