Haining Farm

Bushfire Risk Analysis

VICTORIA State Government
Environment, Land, Water and Planning

Acknowledgements

This report was made in consultation with:

Dr Kevin Tolhurst AM (The University of Melbourne)

Justin Leonard (CSIRO)

Author

Department of Environment, Land, Water and Planning, Victoria.

Photo credit

Department of Environment, Land, Water and Planning, Victoria.

Accessibility

If you would like to receive this publication in an alternative format, please telephone the DELWP Customer Service Centre on 136186, email customer.service@delwp.vic.gov.au "http://www.relayservice.com.au"www.relayservice.com.au. This document is also available on the internet at www.delwp.vic.gov.au.www.delwp.vic.gov.au.

Contents

1. Context

Haining Farm is a 59 hectare area of public land currently managed by Parks Victoria and leased as a working dairy farm. It is in Don Valley, at the confluence of the Yarra River and the Don River.

Haining Farm forms part of the Yellingbo Conservation Area and the intention for the site is to change the current use to provide other forms of land management and educational opportunities with a greater emphasis on sustainability.

A community-based working group known as the Haining Farm Redevelopment Working Group (Working Group) was established to develop a plan for the site that did not materially increase the bushfire risk to the broader community.

To assist in the process, the Working Group assisted in selecting the independent expertise of Dr Kevin Tolhurst (University of Melbourne) and Justin Leonard (CSIRO) to work with DELWP bushfire specialists. They assessed different revegetation and development options for Haining Farm, including those put forward by the Working Group, to evaluate the relative bushfire risk of each option to the broader landscape. This report has been endorsed by Dr Kevin Tolhurst and Justin Leonard.

The following case study outlines the bushfire risk modelling undertaken.

1.1 Determining the Investigation Area

Haining Farm itself is a small site, but there is a larger area within the landscape that could be impacted by changes on the site. An extent that included surrounding towns was deemed the Haining Farm Investigation Area and bushfire risk analyses were based on this footprint (Figure 1). The Investigation Area is large enough to include surrounding residences, but excludes areas that are unlikely to be impacted by fire behaviour influenced by revegetation at Haining Farm.

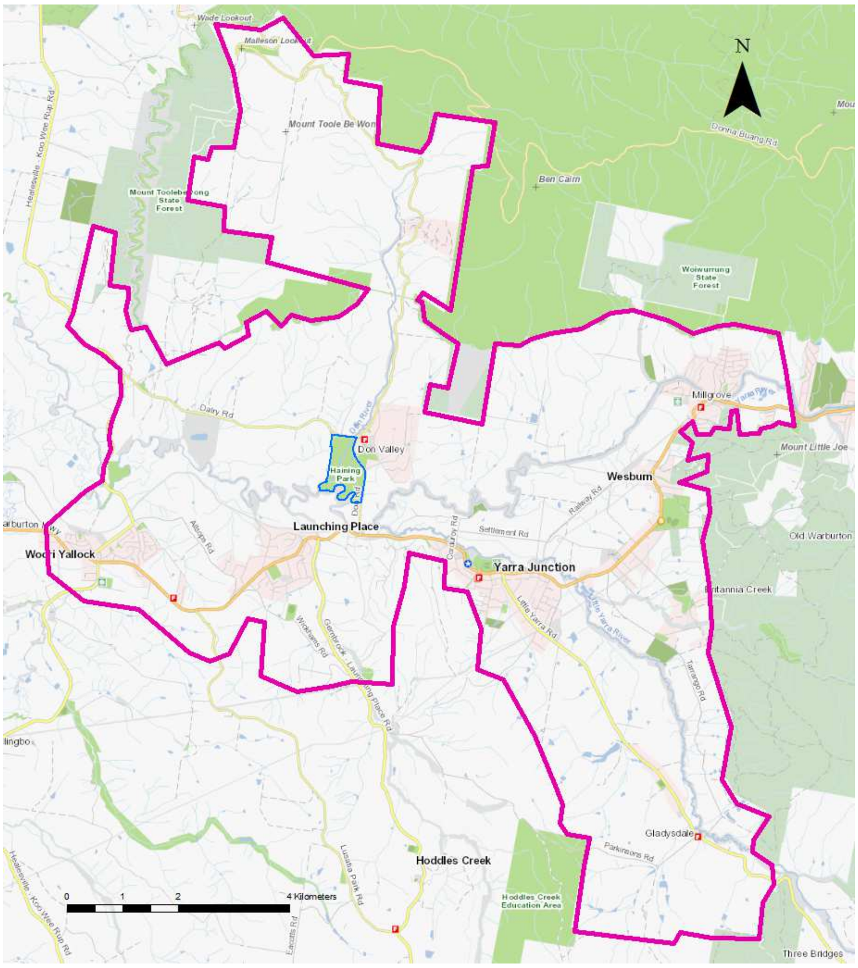


Figure 1. The Haining Farm Investigation Area (within purple outline). Haining Farm is outlined in blue.

1.2 Modelling parameters

PHOENIX RapidFire 5.0 (PHOENIX) bushfire simulation software was used to quantify the level of bushfire risk. This software requires specific parameters, as defined below (Weather, Simulated Ignitions, Fuel Modification, Fuel Types and House loss probability). For more information on PHOENIX, refer to The University of Melbourne: http://sustainable.unimelb.edu.au/tolhurst. More detail on modelling assumptions can be found in section *7. Assumptions* below.

Weather

Weather conditions are measured using the Forest Fire Danger Index (FFDI), which accounts for dryness (based on rainfall and evaporation), wind speed, temperature and humidity. The higher the FFDI, the more dangerous the bushfire weather. Fire Danger Ratings directly correlate with FFDI:

Fire Danger Rating	Forest Fire Danger Index
Low – Moderate	0 – 11
High	12 – 24
Very High	25 – 49
Severe	50 – 74
Extreme	75 – 99
Catastrophic	100 +

Historically, bushfires burning under conditions where the FFDI has been greater than 100 have caused the greatest losses of human life in Victoria. Australian Standards for the Construction of Buildings in Bushfire Prone Areas (AS3959-2009) sets FFDI 100 as the design weather threshold assumption for regulating house design. FFDI 100 also has an average return interval of approximately 30 years in the Investigation Area. FFDI 100 was therefore chosen by the Working Group to be the desired weather conditions for providing a relative risk assessment base on bushfire modelling.

Three different FFDI 100 scenarios, with variations in weather patterns, were used for bushfire simulations and the results were averaged. The three different variations of FFDI 100 were selected based on relevant weather patterns and to reflect different weather drivers behind fire behaviour (e.g. temperature vs wind speed). This enabled the analysis to include a realistic range of potential variations in bushfire behaviour.

To estimate vegetation curing during summer conditions in the Yarra Valley, the Country Fire Authority's composite maximum curing data from one of the driest 11 year period on record (2003-2014) was used. The curing conditions used were taken to be a "worst-case" scenario. This is due to assumed drought conditions preceding an FFDI 100 day.

Simulated Ignitions

Landscape-scale risk analysis models examine the results from multiple simulated fires. This process attempts to account for potential ignitions across the landscape, rather than assuming where an ignition will occur. For Haining Farm, fires were simulated on a grid across the landscape with each grid point representing a single ignition (Figure 2). The extent of the ignition grid was determined by a pre-analysis of fire spread in the region with an FFDI of 100. The fires were simulated individually and do not interact. The results from all simulated fires were averaged in grid cells across the Investigation Area.

The scenarios described above resulted in 228 simulated fires for each of the three weather conditions (all FFDI 100), which equates to 684 bushfires simulated per revegetation scenario.

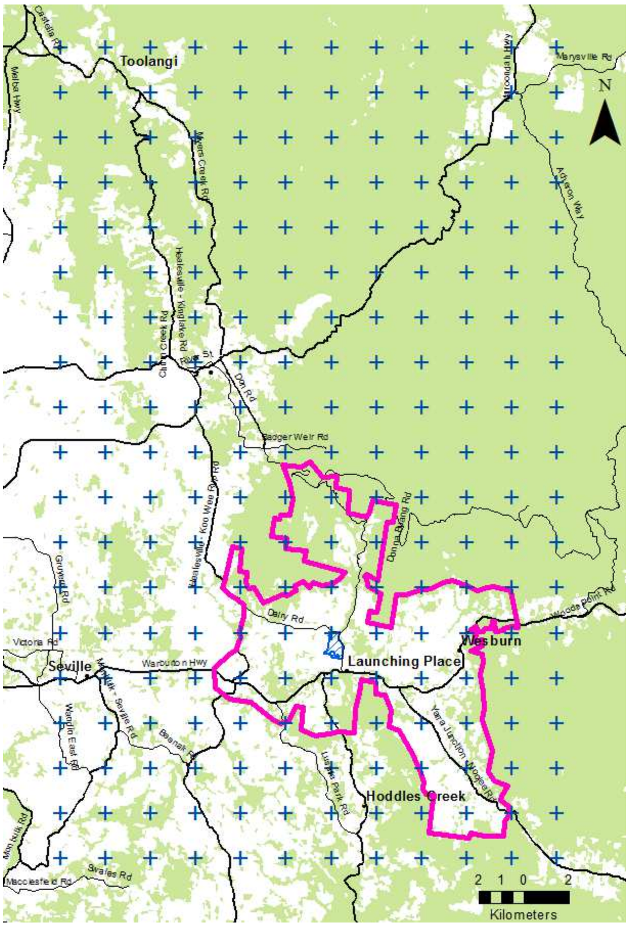


Figure 2. The ignition grid for the Haining Farm Investigation Area. Each '+' represents an ignition point. Each ignition point was modelled under 3 variations of FFDI 100. The Investigation Area is shown in purple outline.

Fuel Modification

In all simulations, no previous fire history (planned burning or bushfires) was assumed. This is a theoretical scenario used to estimate maximum fuel loads across the landscape. Doing so enabled us to benchmark current and historical risk levels against a meaningful maximum limit. We can also analyse geographic influence and fuel modification risk without bias from recent fire events. All results in this case study were given with the assumption that no fuel modification in the broader landscape had occurred. This is not the case in reality, however it is a useful method to examine the potential effects of revegetation at Haining Farm without the influence of other risk mitigation activities.

Fuel Types

PHOENIX uses a data input called "Fuel Types" to interpret vegetation in the landscape from a fire behaviour perspective. These Fuel Types are based on a grouping of Ecological Vegetation Classes (EVCs) on common characteristics including having a similar maximum Surface Fine Fuel Hazard level, a similar maximum Elevated Fine Fuel level, and a similar Bark Fine Fuel Hazard level. These fuel types will have similar growth patterns and primary productivity and so have similar accumulation rate patterns. Within Haining Farm, for example, there are temperate grassland, riparian forest shrub and areas that are not flammable (water).

For more information on fuel hazard, see *"Overall fuel hazard assessment guide, 4th edition"* at: http://www.cfa.vic.gov.au/fm_files/attachments/Publications/Overall_Fuel_Hazard_Assessment_Guide.pdf

House loss probability

House loss probability is calculated using an algorithm developed by The University of Melbourne's bushfire scientists using data from the 2009 Victorian bushfires[1]. Data from historical fires has been collected to understand the processes that relate to house destruction during fires. These data have been used to model relationships between ember density, flame intensity and magnitude of convection observed in bushfire behaviour that resulted in loss of houses. Research will continue to further improve understanding of these relationships and therefore the house loss function that is built into PHOENIX. The house loss probability function examines the fire behaviour simulated in a location and calculates if the house might survive or be destroyed. It cannot take into account local factors such as active defending of a house, the level of house and garden maintenance or if that house has been built with a Bushfire Attack Level (BAL) rating.

1.3 Other factors that reduce bushfire risk

The following are factors that aim to reduce bushfire risk, but have not been considered in the modelling undertaken.

Fuel management occurs in key areas such as Mount Toolebewong. This topographic feature can influence fire behaviour under Victoria's fire danger weather conditions through 'ramping' and producing embers. DELWP and Parks Victoria recognise the importance of this area for protection of life and property and so have managed fuel levels as a Bushfire Moderation Zone (BMZ). A BMZ is a Fire Management Zone that aims to reduce the speed and intensity of bushfires. It is designed to protect nearby assets, particularly from ember attack and spot fires. See the *'Code of Practice for Bushfire Management on Public Land 2012'*.

Rapid early fire suppression has not been included in this modelling, but is a critical method to minimise bushfire impacts. There are several CFA stations within and surrounding the Investigation Area, three DELWP/Parks Victoria work centres with fire fighting vehicles and machinery and helicopters. The Yellingbo Bushfire Risk Management Plan currently being created in consultation with CFA brigades is investigating how to increase the likelihood of successful early fire control.

Victoria is a high bushfire risk State and management of private property to reduce bushfire risk is also important. There are actions that residents can take around their homes to reduce ember and radiant heat impacts, as well as on larger properties. See *'Landscaping for Bushfire'*, produced by the CFA to assist residents to contribute to their bushfire risk reduction.

1. Thornton, R.P (Ed), 2011, '*Proceedings of Bushfire CRC & AFAC 2011 Conference Science Day'*. 1 September 2011, Sydney Australia, Bushfire CRC, pp74 – 86. Available from: http://www.bushfirecrc.com/sites/default/files/managed/resource/proceedings_of_bushfire_crc__afac_2011_conference_science_day.pdf

2. Identifying existing risk in the Investigation Area

2.1 Bushfire context

The Investigation Area is situated in the Yarra Valley, surrounded by hills. Mount Toolebewong is situated to the north west, Yarra Ranges National Park to the north, Mount Little Joe in the Yarra State Forest to the east and private forest running from Yarra Junction to Gladysdale (Figure 1).

Steep changes in terrain have a strong influence on fire behaviour. A fire moving uphill pre-heats and dries fuels more effectively and hence spreads more quickly. If a strong wind is also pushing the fire uphill, an effect known as ‘ramping’ can occur. This means the hill can act as a giant ramp resulting in fires being pushed quickly uphill and throwing embers that start spotfires long distances (up to 30km). In the Investigation Area, Mount Toolebewong is the most significant topographic feature in the study area that can act as a ramp under common bad fire conditions where wind travels from the north west. Vegetation on the north-western slopes is dry and can produce heavy ember loads. The remainder of the forest ranges from damp to wet vegetation types. These usually require hot and dry seasonal conditions to carry a bushfire. The base of the surrounding hills is a mix of lowland forest, heathy woodland and some damp forest.

The valley itself is largely agricultural landscapes with town centres. The valley is seasonally wet and dries in summer. The extent of drying varies year to year. CFA curing data during peak summer dryness in drought indicates that grassland curing can range from 50% - 80% and has been recorded higher. Fires can move from the hills and spread quickly through cured grasslands. The rate of spread depends on the strength of wind, amount of embers and the curing of grass.

Riparian vegetation exists along rivers and is more intact in some areas than others. Riparian areas have only a limited influence on bushfire at the landscape scale.

Currently Haining Farm itself is open, grassy farmland with scattered trees. Remnant vegetation exists mainly along riparian areas and is mapped as Treed Swampy Wetland and Riparian (higher rainfall) Ecological Vegetation Classes (Figure 3).

Figure 3. Current vegetation at Haining Farm. Predominantly farmland, there is a scattering of Treed Swampy Wetland and Riparian (higher rainfall) ecological vegetation classes.

2.2 Bushfire risk at the urban interface

At the urban interface, areas of vegetation may pose a threat to nearby houses and agriculture. The degree of this threat is largely dependent on the distance between the vegetation and the asset and the level of preparedness of the asset.

The chance of a specific house surviving a bushfire depends on many factors. How the fire arrives and the terrain, vegetation and weather conditions of the time of arrival was modelled using PHOENIX. However, other factors around urban design also influence house survival and cannot be modelled using PHOENIX. Building design, as well as human behaviour before, during and after bushfire impact can play a significant role in reducing the probability of individual house loss.

Research from historical bushfires has established the causes of loss from bushfires is usually embers, radiant heat and flame contact. Embers play a crucial role in house loss, as can be seen in the table below:

Table 3. Bushfire elements that cause house losses from two major south-east Australian bushfires[2].

	Canberra 2003	Victoria 2009
Embers and some radiant heat from surrounding objects	34%	33%
Embers only	49%	19%
Predominantly radiant heat	5%	5%
Flame contact from bush vegetation	2%	13%
Other	1%	2%
No direct bushfire attack	7%	7%
Unknown	2%	22%

Ember attacks result in the greatest number of house loss. Embers can enter a house at openings such as doors, windows, gutters and air vents. The positioning of garden beds against homes can also increase likelihood of damage if embers ignite the vegetation and flames create enough radiant heat to impact on the structure.

Fences and decking are also a source of radiant heat and can spread bushfires from house to house. Other sources of ignition include wood piles, gas and chemical containers and other items in the yard, including gardens and cars.

This research cannot be incorporated into PHOENIX modelling, but it has been acknowledged and accounted for in revegetation designs. The introduction of an open woodland buffer to manage ember loads and reduce wind impacts on fire behaviour is important to address local-level risk. Further, the 20m perimeter fuel break for urban interface has been included to reduce radiant heat impacts and the spread of a flaming front.

2. Leonard, J., Blanchi, R., Leicester, R., Lipkin, F., Newnham, G., Siggins, A., Opie, K., Culvenor, B., Cechet, B., Corby, N., Thomas, C., Habili, N., Jakab, M., Coghlan, R., Lorenzin, G., Campbell, D. & Barwick, M, 2009,.'*Building and Land use planning research after the 7th February 2009 Victorian bushfires. Preliminary findings'*. [Online]. Melbourne: Interim report USP2008/018 - CAF122-2-12. Available from: http://www.bushfirecrc.com/managed/resource/bushfire-crc-victorian-fires-research-taskforce-final-report.pdf

2.3 Bushfire modelling – landscape scale

Modelling to determine existing bushfire risk within the Investigation Area (Figure 1) was done using the existing vegetation types as per DELWP's EVC mapping and PHOENIX fuel mapping. For modelling inputs, see *1.2 Modelling Parameters.*

Fires were simulated under FFDI 100 conditions and results provided a probability of house loss throughout the Investigation Area. The output of the modelling assumes an even distribution of houses as a measure of fire behaviour and intensity in a particular area and is not intended to predict whether any specific house will be destroyed in the event of a fire under the conditions modelled.

Current bushfire risk within the Haining Farm Investigation Area without revegetation:

The current probability of house loss on average, under FFDI 100 conditions, within the Haining Farm Investigation Area is 18%.

What does 18% mean?

This is the measure of the average probability of house loss (0 - 100%) anywhere in the Investigation Area from a potential bushfire experiencing FFDI 100 conditions.

The model does not account for actual houses that exist in this study area, as that can change in the future. Instead it presents results as a probability of house loss if a house were in that location.

It is important to remember that this probability has been derived under a set of assumptions (see *7. Assumptions*). One such assumption is that no planned burning or fuel treatments have been considered, so that the results are not influenced by changes in planned burning practices. In reality, planned burning and fuel management does occur in areas that reduce bushfire risk to the Haining Farm Investigation Area.

3. Initial revegetation scenarios – risk analysis

Several revegetation scenarios were modelled. When these were modelled in PHOENIX, the underlying Fuel Types were changed to suit the proposed re-vegetation plans. All models assumed the vegetation is in a mature state, i.e. at maximum fuel level.

3.1 Open woodland buffer

The effect of revegetation on neighbouring properties close to Haining Farm might not be evident in the landscape scale analysis. Discussions focused on how to manage any escalation in hazard resulting from revegetation of the farm to neighbours in close proximity.

Fire behaviour experts looked at the influence of an open woodland buffer on the overall bushfire risk in the landscape. An open woodland buffer incorporating a managed and manicured landscape that includes features to reduce the impact of embers, direct flame contact and wind driven fire behaviour can be used as a bushfire mitigation method. This would consist of a band of smooth barked trees with no mid-storey and some maintained grasses. The intention of the buffer is that these trees do not produce embers and reduce the influence of wind. An open woodland with a maintained grassy surface fuel layer and no significant mid-storey fuel would not sustain a crown fire. In comparison to dried grassy fuels that allow rapid movement of a fire, the open woodland buffer slows wind driven fire spread and catches embers from surrounding vegetation.

3.2 Perimeter fuel break

As a result of discussions within the Working Group and following advice from the CFA, a 20m fuel break was added around most of the perimeter of Haining Farm. The fuel break will be maintained to a very low fuel level and acts to further reduce potential heat radiation and fire impacts on existing roads and nearby residences.

3.3 Initial revegetation scenarios

Scenarios modelled as “Concept 1 – 3” were the concept designs against which public submissions were received via the Engage Vic website. The Working Group developed a recommendation in response to the community engagement and this concept has also been modelled. The Final Haining Farm Plan (see section 4. *Final Haining Farm Plan*) was developed in response to the recommendation of the Working Group and considers the results of the community engagement process and research into bushfire risk at the urban interface.

Table 1. Initial revegetation scenarios

Scenario Name	Description
Concept 1 **Working farm with conservation**	Similar native species revegetation along creek lines and Yarra River as per originally proposed concept. Much larger grassland breaks surrounding the farm, with open grassy woodland to the south east of the site.
Concept 2 **Commercial Agri-tourism operation**	Native species revegetation along creek lines and along the Yarra River only. Much larger grassland breaks surrounding the farm, particularly to the east and south east of the site.
Concept 3 **Education with conservation**	Almost the entire site revegetated except for an area of open grassy woodland in the south east of the site.
Working Group Recommendation	This scenario combined about 29.5 ha for conservation and 29.5 ha of farming / agricultural land, with community access, infrastructure and walking trails.

For more information on the Haining Farm Redevelopment Working Group, visit: https://engage.vic.gov.au/yellingboconservationarea

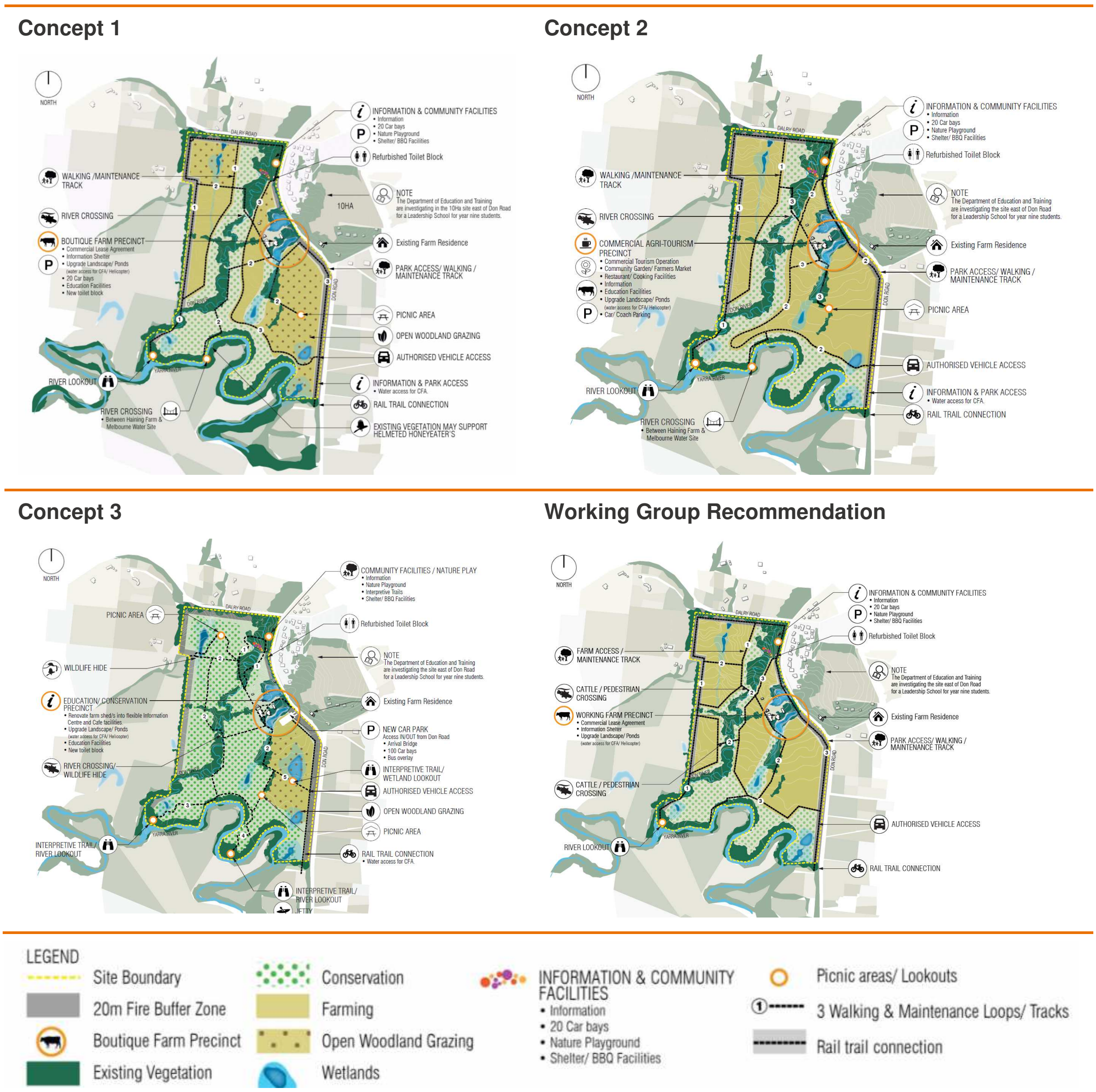


Figure 4. Revegetation concepts for Haining Farm

3.4 Results

PHOENIX modelling examined the probability of house loss on average across the Investigation Area, given the change in vegetation at Haining Farm in each of the concepts. The results below discuss the outcomes of the modelling on the final three concept scenarios and the Working Group final recommendation. Note that the final concept is outlined in chapter 4.

The options modelled and their respective average probability of house loss is as follows:

Table 2. Results for each revegetation scenario

Scenario	Area of revegetation	Average probability of house loss
Current vegetation (16 ha treed vegetation)		17.8%
Concept 1: boutique farm with conservation	28.6 ha	17.7%
Concept 2: commercial agri-tourism farming operation	25.6 ha	17.7%
Concept 3: habitat for threatened species with community access	48 ha	17.8%
Working Group Recommendation	29.5 ha	17.8%

The probability of house loss will vary across the Investigation Area, as indicated by the different colours in Figure 5. The results presented above are the average probability of house loss across the entire Investigation Area.

The results depend on factors within the landscape that influence bushfire behaviour, such as terrain and fuel, as well as the weather. Figures 5 shows the model outputs for house loss probability under current vegetation conditions (assuming no planned burning/fuel modification has taken place across the landscape). Each coloured dot represents the house loss probability averaged for the 3 weather scenarios of FFDI-100, and for every simulated bushfire that reached that location.

House loss probability is generally greater in heavily forested areas with large changes in terrain. In the figures below, the highest house loss probabilities are in areas of public land near Mount Toolebewong and Yarra Ranges National Park.

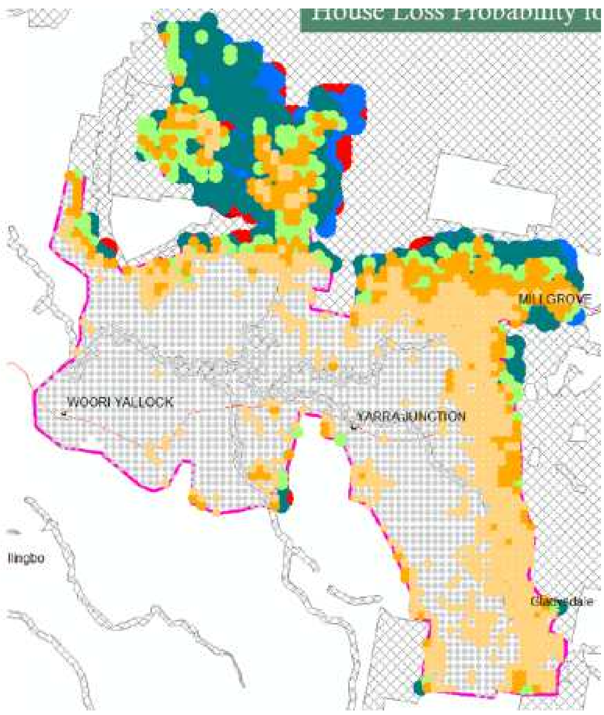


Figure 5. Current distribution of average house loss probability within the Investigation Area under Forest Fire Danger Index 100 weather conditions. This assumes fuels are long undisturbed and vegetation is as it currently exists.

Average House loss Probability

(1 being most likely)

The revegetation options in the concepts showed a slight change to landscape scale bushfire risk. Concepts 1 and 2 show a very slight decrease in average house loss probability from 17.8% to 17.7% (Figure 6). Concept 3 and the Working group recommendation showed no change in bushfire risk to what currently exists in the landscape.

Changes in bushfire risk in Concept 1 were mainly evident in the southern part of the Investigation Area near Gladysdale where there is a large amount of heavily forested area in steep terrain. The model indicates that revegetation of Haining Farm changes the rate at which fires move through the area. The open woodland buffer provides a low surface fuel region adjacent to Don Road and residential properties adjoining Don Road. It also acts as an ember buffer and has some influence on slowing winds. In the model this has been reflected by the change of rate of spread of some fires. However, over the length of the simulations and the entire Investigation Area, most fires were unaffected by the change.

Concept 2, which includes 25.6 hectares of revegetation, resulted in a slight decrease (0.1%) in landscape scale bushfire risk. The addition of water bodies assisted to break up continuous fuels, as in Concept 1. The open woodland buffer was not included in this concept as it was not required to mitigate potential fire behaviour from revegetation as in other scenarios. The results of the modelling indicate that the small amount of revegetation has little impact on bushfire risk at the landscape scale.

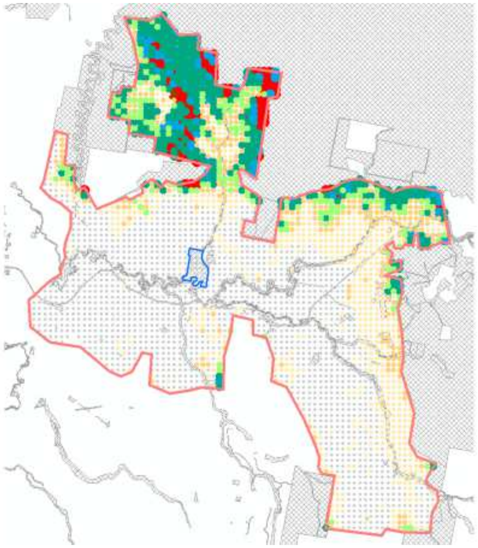
Concept 3 had the greatest extent of revegetation at 48 hectares. The open woodland buffer was positioned to manage local exposure in the south-eastern side of the site. Water bodies also assisted to break up fuels. The model indicates that, as per Concept 1, the open woodland buffer has an impact in mitigating the bushfire risk of revegetation on the site. There was a negligible difference detected at the landscape scale between the bushfire risk of the current farm and Concept 3.

The Working Group Recommendation includes 29.5 hectares of revegetation along the existing waterways. The use of water bodies was beneficial to mitigating the overall bushfire risk in this concept. The addition of water bodies assisted to break up continuous fuels, as in Concepts 1 and 2. Overall, the revegetation had a negligible influence on bushfire risk at the landscape scale.

Concept 1 -
Working Farm with
Conservation

Average house loss probability for target area is **17.7%**

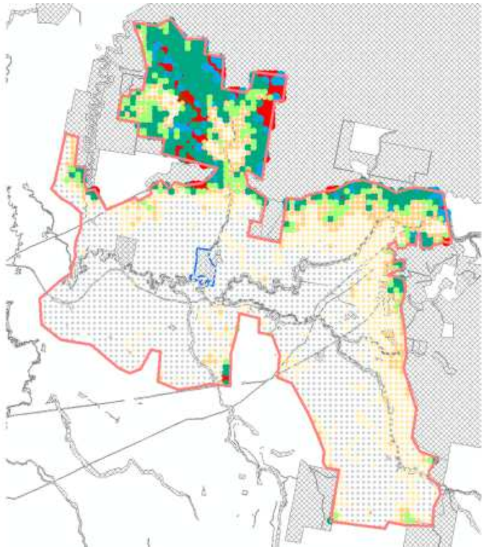
Avg_HouseLoss_Prob
0.000000 - 0.100000
0.100001 - 0.200000
0.200001 - 0.300000
0.300001 - 0.400000
0.400001 - 0.500000
0.500001 - 0.600000
0.600001 - 0.700000
0.700001 - 0.800000
0.800001 - 0.900000
0.900001 - 1.000000



Concept 2 -
Commercial Agri-tourism
Operation

Average house loss probability for target area is **17.7%**

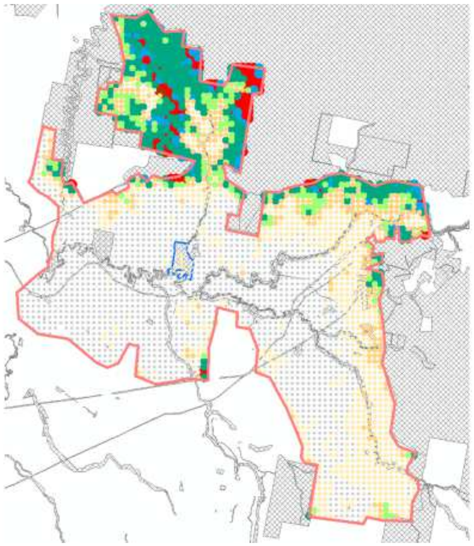
Avg_HouseLoss_Prob
0.000000 - 0.100000
0.100001 - 0.200000
0.200001 - 0.300000
0.300001 - 0.400000
0.400001 - 0.500000
0.500001 - 0.600000
0.600001 - 0.700000
0.700001 - 0.800000
0.800001 - 0.900000
0.900001 - 1.000000



Concept 3 -
Education with
Conservation

Average house loss probability for target area is **17.8%**

Avg_HouseLoss_Prob
0.000000 - 0.100000
0.100001 - 0.200000
0.200001 - 0.300000
0.300001 - 0.400000
0.400001 - 0.500000
0.500001 - 0.600000
0.600001 - 0.700000
0.700001 - 0.800000
0.800001 - 0.900000
0.900001 - 1.000000



Working Group Final
Recommendation

Average House Loss Probability
17.8%

Average house loss probability for target area is **17.8%**

Avg_HouseLoss_Prob
0.000000 - 0.100000
0.100001 - 0.200000
0.200001 - 0.300000
0.300001 - 0.400000
0.400001 - 0.500000
0.500001 - 0.600000
0.600001 - 0.700000
0.700001 - 0.800000
0.800001 - 0.900000
0.900001 - 1.000000

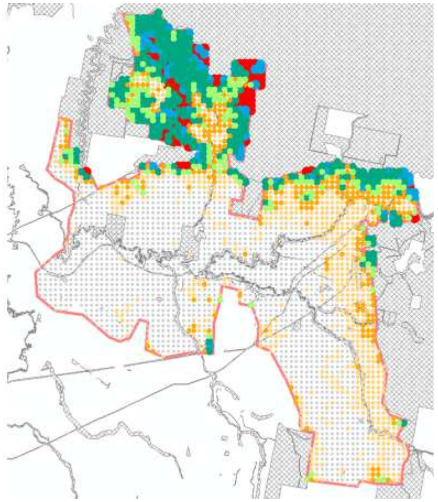


Figure 6. Modelled Average House Loss Probability for the Haining Farm Investigation Area under different revegetation scenarios

4. Final Haining Farm Plan

Based on the findings above, the final revegetation concept plan incorporates an open woodland buffer along the northern and eastern perimeters near existing roads. This, along with a 20m fuel break will act as a wind break and ember buffer to manage local risk and mitigate landscape scale risk (Figure 7). The fuel break may also assist in providing access to fire response vehicles such as slip-ons and tankers.

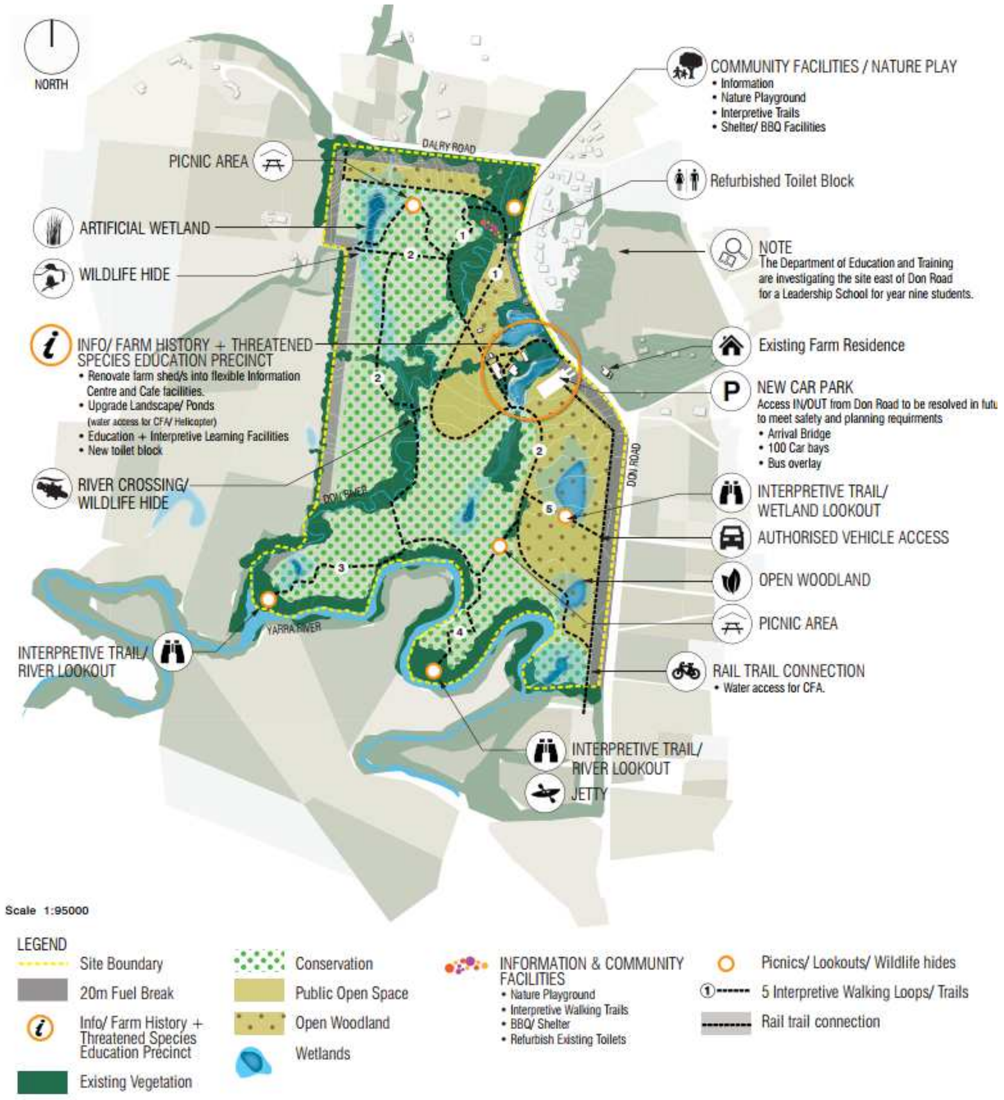


Figure 7. Final Haining Farm plan

Bushfire impact risk within the Haining Farm Investigation Area with proposed revegetation:

The probability of house loss on average, experiencing FFDI 100 conditions, within the Haining Farm Investigation Area with the proposed revegetation scenario above is 17.7%.

*see *7. Assumptions*

5. Conclusion

Of the five concepts that were modelled, all resulted in less than a 1% variation to the current landscape scale bushfire risk. The results indicate that revegetation of Haining Farm can be undertaken without impacting the landscape scale bushfire risk to the surrounding communities. This is due to mitigating features such as water bodies, the 20m fuel break at the perimeter of the site and the open woodland buffer.

The modelling, as well as current research, indicates that the introduction of a smooth barked open woodland could be a successful method of mitigating house loss risk in the broader landscape following revegetation of the site. The combination of the revegetation areas and the open woodland provided low local exposure potential as well as slowing the fire propagation rate through the farm compared to surrounding grasslands. The slower fire propagation rate reduced the overall bushfire risk in the broader landscape. More importantly, the open woodland buffer would be most beneficial to properties neighbouring Haining Farm.

6. Glossary

Bushfire risk	The likelihood of damage to or disruption of a value, asset or function as a result of the impact of a bushfire hazard such as smoke, embers, radiation, convective heat, or fire-induced winds. Values, assets or function may be of a social, economic, environmental, or political nature. The level of bushfire risk may change depending of the time since last impact, the season, the intensity, the frequency, the scale and severity of the bushfire.
Ecological Vegetation Class	Ecological Vegetation Classes (EVC) is a way of classifying vegetation communities. An EVC consists of one or several floristic communities that appear to be associated with a recognisable environmental niche. Each EVC is described by a combination of its structure, floristic, life-form and reproductive strategy features, and through an inferred fidelity to particular environmental attributes. EVCs have been mapped across Victoria however this mapping is limited in its scale and does not completely cover existing vegetation. Despite this it is a good indicator of existing vegetation at a large scale and is useful as a reference for making more detailed PHOENIX RapidFire fuel maps.
Ignition grid	Fires are simulated at ignition points that are spread across the landscape in a grid pattern. The grid aims to incorporate as many potential ignitions that could impact on an asset as possible.
Fuel Hazard	The ‘fuel hazard’ or ‘overall fuel hazard’ is made up of a combination of identifying the fuel levels in the bark fuels, elevated fuels, near-surface fuels, and the surface (litter) fuels of an area.
Fire History	The occurrence of fire across the landscape over recorded history. Data reflects planned burn and bushfire footprints dating back to 1930s. More recent fires have more accurate mapping due to technology advances. These data are used to determine potential fuel loads in PHOENIX fuel types as fuels accumulate after a fire.
Fuel Load	The amount of fuel predicted to be in a fuel type in a time period after a fire. Fuel loads are measured in tonnes per hectare and are examined in different fuel strata (surface, elevated, bark).
Fuel Types	PHOENIX uses a data input called Fuel Types to interpret vegetation in the landscape from a fire behaviour perspective. These Fuel Types (about 40) are based on a grouping of about 900 Ecological Vegetation Classes (EVCs) on common characteristics including having a similar maximum Surface Fine Fuel Hazard level, a similar maximum Elevated Fine Fuel level, and a similar Bark Fine Fuel Hazard level. These fuel types will have similar growth patterns and primary productivity and so have similar accumulation rate patterns.
Forest Fire Danger Index	Weather conditions are measured using the Forest Fire Danger Index (FFDI) which accounts for seasonal dryness (based on rainfall and evaporation), wind speed, temperature and humidity. The higher the FFDI, the more extreme the bushfire weather.
PHOENIX RapidFire (PHOENIX)	PHOENIX RapidFire is a computer based bushfire characterisation tool that characterizes fire including flame height, ember density, spotting distance, convection column strength and fire intensity and provide a visualisation of fire dynamics for community warning, education and fire planning.

7. Assumptions

Address Points	Address points have been used as a proxy for dwellings. These are based on Victorian Government data from 2011 and do not reflect additional subdivisions and construction since that time. This data is currently being updated but was not ready at the time of production of this document.
Forest Fire Danger Index 100	A FFDI of 100 can be achieved from a range of combinations of wind speed, temperatures, relative humidity and drought factors. In this analysis, 3 historic sets of weather records were used for the simulations. The balance between fuel dryness and wind speed affects the nature of the fire behaviour so an average of 3 different historical events was used. Research has shown that 70% of all bushfire-related house and human life losses have occurred at FFDI level of 100 or more. Modelling assumed the grassy fuels were cured according to CFA's composite maximum curing data and available to burn due to assumed drought conditions preceding the FFDI 100 day. This means that it is assumed that these grassy areas were not irrigated in the lead up to the fire events.
Likelihood	The likelihood of all ignitions in this study is considered to be equal, whereas in reality the likelihood of fires occurring in any given location varies. To measure true 'likelihood' of a fire occurring, we need to predict: – The probability of a weather scenario – The probability of ignition in the weather scenario – The probability of impact PHOENIX RapidFire simulations assist with predicting the probability of impact. However, current science limits us to determining a weather scenario and assuming ignition. DELWP is currently researching how best to incorporate these other two probability types.
Maximum fuel load	Maximum fuel load refers to amount of fuel that would be in the environment should no disturbance (logging or fire) ever take place or over a very long period of being undisturbed. The Maximum Fuel Load is a modelled value that varies by vegetation type throughout the environment. This is used to provide a theoretical maximum risk scenario using estimated fuel load across the landscape. This enables us to benchmark current and historical risk levels against a meaningful upper limit, and to analyse geographic risk without bias from recent fire events.
PHOENIX RapidFire (PHOENIX)	The key model underpinning this report is PHOENIX RapidFire (PHOENIX). PHOENIX is a research tool developed by the University of Melbourne (Kevin Tolhurst and Derek Chong). It has been used by DELWP and other fire agencies for both incident prediction (State Control Centre PHOENIX RapidFire system) and as the key tool for bushfire risk assessment in a new strategic approach to fire management planning. All modelling has limitations (as set out below); however, PHOENIX is a useful tool in analysing landscape scale bushfire risk. Use of PHOENIX is coordinated through an agreement between DELWP, the University of Melbourne, and the Bushfire and Natural Hazards Cooperative Research Centre. DELWP acknowledges that a model designed for research is being applied operationally. PHOENIX is generally acknowledged by many stakeholders in the field, including DELWP, as a state-of-the-art, world-leading planning tool, critical for helping us understand how to reduce risk to life and property from major bushfires. PHOENIX simulation outputs may not reflect actual fire spread. There are several input layers and submodels within PHOENIX, each of which needs to be validated. The model is sensitive to minor differences in inputs. Small shifts in the weather, fuel accumulation functions, or time of ignition, can cause large differences in results. PHOENIX RapidFire version 5.0 was used for the creation of this report.

Suppression	PHOENIX is limited in how it can measure risk when it comes to response and suppression. It can measure the benefits of first attack, such as calculating the effectiveness of the immediate response of a certain number of vehicles and aircraft. However, it cannot measure variables that may hinder first attack, such as the condition of roads or the location of water points relative to the location of the fire. It also cannot account for decisions made during suppression efforts. ‘First attack’ suppression modelling was included to minimise emphasis of small fires.
Vegetation mapping	Current vegetation mapping for PHOENIX was checked with aerial imagery and DELWP’s Ecological Vegetation Class (EVC) mapping. Re-vegetation was determined by using the checked ‘current vegetation’ mapping and modifying the PHOENIX fuel layer to suit concept designs as per existing EVCs and suitable Fuel Types.