REPORT ON – "INVESTIGATION OF THE HOUSE LOSSES IN THE TOODYAY BUSH FIRE 29 DECEMBER 2009"

BUSH FIRE & ENVIRONMENTAL PROTECTION BRANCH

AUTHOR: **RALPH SMITH**

CONTRIBUTING BF & EPB STAFF: JADE LEASK, ANLE TIEU, ANN VALENTI

OTHER CONTRIBUTORS: FESA: ROBERT FRASER, SVEN ANDERSEN

BUREAU OF METEOROL0OGY: BRAD SANTOS, JOE COURTNEY

DATE: 5 AUGUST 2010

CONTENT

1. Executive summary

The bush fire that occurred near Toodyay on the 29th December 2009 was one of the most destructive, in terms of house loss, to ever occur in contemporary Western Australia. The fire commenced at around 1 pm in a harvested barley crop that retained around 20 to 30 centimetre tall stem residue that was 100 percent cured. There were 38 homes destroyed in the bush fire. Even though the fire was extremely fast moving, at times on very steep slopes and quite intense there was no loss of life associated with the fire event.

The bush fire fuels varied from the barley crop residue, through tall unmanaged annual grasses mixed with leaf litter and some scrub plants to intact mixed woodland scrub fuels. The overstorey fuels varied from *Eucalyptus loxophleba* (york gum), with *Eucalyptus wandoo* (wandoo) and *Eucalyptus accedens* (powder bark wandoo) through to a mixed banksia woodland. Many of the powder bark wandoo areas appear to have been subject to an extreme fire event around 30 years ago as there were a number of areas with trees of similar height and bole diameter, possibly indicating regeneration post a fire event.

The mixed banksia woodland areas appeared to have suffered the most intense fire behaviour with much of the overstorey defoliated and the ground was bare of surface vegetation post the fire. The remnants of the scrub layer indicate that this area was very heavily stocked with scrub.

Whilst it is difficult to estimate with certainty the fuel load within the fire affected area it is possible to get a comparative estimate. This is achieved by comparing the neighbouring vegetation and its homogeneity with the burnt area and if consistent it is possible to estimate the fuel load that was present prior to the fire by comparing the fuel load and structure in the neighbouring unburnt site. It was estimated that the fuel loads were approximately 3 t/ha for the cropped area[1] and 11 t/ha of leaf litter combined with approximately 2 - 4t/ha of grass fuels in the wandoo overstorey fuel loads, contributing a total fuel load of approximately 13 to 15t/ha[2]. It is estimated that there was around 15t/ha of fuel within the banksia woodland sites.

The land was very steep to the east of the ignition point (the fire was under a westerly influence) and in a number of locations the fire ran upslope on slopes that varied from slight through to approximately 14 degrees. In this region the fire was running at around three times the forward rate of spread, when compared with the fire running on the undulating topography. The remainder of the fire ran through undulating slopes of varying steepness and length of slope.

[1] This tonnage is based on field work conducted by FESA.
[2] The tonnage of 15t/ha was applied to the CSIRO Forest Fire Danger Meter Mk5

The methodology applied to ascertain the house destruction or loss contributing factors were to inspect all the homes destroyed in the fire, some that had suffered partial damage and some that had suffered no damage. All the homes inspected were within the fire boundary and had the potential to be affected by the fire. During the inspections two assessment forms were completed as far as possible, within the constraints of a post fire forensic assessment. In some instances the property owner was present during the inspection, but most inspections were undertaken without any specific local knowledge. There were 38 destroyed houses, four partially damaged and five undamaged houses for total of 47 houses inspected and assessed.

Following the analysis of the houses and their surrounds it remains very clear that the key elements to the house being destroyed, damaged or undamaged are:

- Constructing to the appropriate standard as identified in "Planning for Bush Fire Protection (PfBFP)" and "AS 3959 (2009) Construction of buildings in bush-fire prone areas". This analysis and interpretation of the data must be cognisant that whilst PfBFP (first published in 2001 and again in 2010) and AS 3959 are current publications virtually all of these homes were built prior to these guidelines being published and applicable. Even today "AS 3959 (2009) Construction of buildings in bush-fire prone areas" is not being formally applied to the homes being rebuilt in the fire affected area as the area has not been declared bush fire prone.

- Establishing and maintaining a building protection zone or 20 metre circle of safety adjacent to the house (for individual buildings/homes) which would have a fuel load of less than 2 t/ha and scattered shrubs. From the stems and other material remaining post fire it was possible to identify that 36 houses had tall vegetation within 20 metres of the house and of these 36 houses 26 were destroyed. In 34 locations there were tree crowns greater than 10 to 15 metres apart and 26 of these houses were destroyed. Establishing and maintaining a hazard separation zone so that the fuels between the house and up to 100 metres (for individual buildings/homes) which would have between 5 – 8 t/ha and spaced trees. The HSZ contained 45 mature classifications, two over mature and one unclassified scrub type.

The land use was assessed by either direct advice from the owner/occupier or by assessing the continuity of the scrub vegetation. Where there was no obvious grazing effect nor a sign advising that the site was a "Land for Wildlife" registered location the land was categorised as "lifestyle". There were 46 sites categorised as "lifestyle", one as "grazing" and one as "conservation." This implies that the site has some vegetation modifications, but essentially the site has a significant level of tree overstorey cover and intact scrub vegetation.

A further consideration during the field assessment was whether there was any land management practices that could have been used to mitigate against the rapid spread of the fire. There were 12 properties where it was possible to identify (either through owner/occupier advice or visual inspection) that they had developed a BPZ and HSZ or they had managed the fuel. There were a further 35 properties where it was not possible to make a determination and one property where it was possible to determine

that no action had been taken. Of the 12 properties where it was possible to identify that the fuel load had been managed, nine houses had been destroyed seven of which were made of non-flammable materials such as cellulose cement and two were made of timber. The level of fuel management was not able to be identified or quantified.

- Establishing and maintaining an extended hazard separation zone or community protection zone of up to 2 – 3 km which would have a fuel mosaic of less than 8 t/ha, but less intensive management of the zone than the hazard separation zone (HSZ), and an increased consideration of biodiversity protection requirements. From the indicators available and conversations with owner/occupiers post the fire, it appears that there was little extended community protection zone work regularly being undertaken in recent years.

- Another key component of whether a house was destroyed, or burnt, or not appears to be its position relative to the head fire. In a number of instances houses that were very close to one another suffered significantly different outcomes. This appears to have been as a consequence of whether the head fire directly attacked the home or not. Management of the BPZ, the HSZ and the community protection zone all have an impact on the head fire's performance. In some instances it appears that properties with similar vegetation structure and fuel load suffered significantly different outcomes because of the variation in the wind direction and therefore the bush fire behaviour.

In general the houses that were in the direct line of the head fire run suffered the greatest impact and therefore loss. This loss may have been from the ember attack, radiant heat or direct flame contact.

2. Objectives of the study (scope of work)

The objectives of the study were to:

1. Analyse the head fire to tail fire and flank fire rate of spread for the first four hours of the fire and if possible, extend this out to the first eight hours of the fire
2. Analyse the fire behavior, particularly the rate of spread, including the fire direction and intensity,
3. Analyse the impact or non-impact of the Toodyay fire on homes in the area affected by the fire

3. Environmental conditions

The Toodyay area had been subject to the normal summer drought conditions prior to the fire. The bush fire started in a harvested barley crop, which was 100% cured and had stubble of approximately 20 to 30 cm in height.

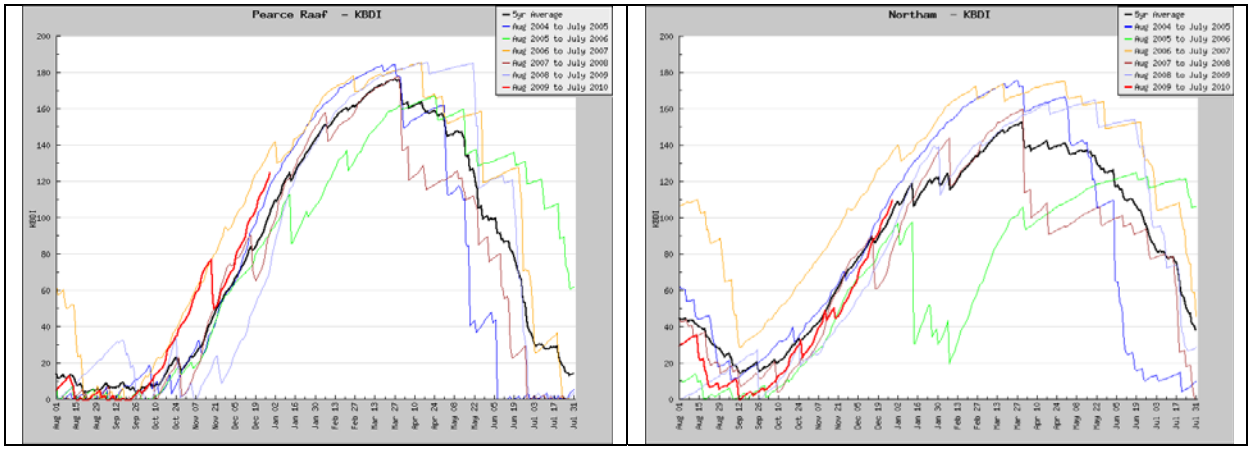


Figure 1: Keetch-Byram Drought Index for the closest recording sites

The fire ran within the harvested barley for a period and then travelled into the grass[3] with a tree overstorey. The slope and soil structure also changed when the fire moved from the barley field becoming more rugged with many areas containing rock outcrops, breaking through the soil surface and producing discontinuous fuel areas.

The overstorey varied from *Eucalyptus loxophleba* (york gum), with *Eucalyptus wandoo* (wandoo) and *Eucalyptus accedens* (powder bark wandoo) through to a banksia woodland. Many of the powder bark wandoo areas appear to have been subject to an extreme fire event around 30 years ago as there were a number of areas with trees of similar height and bole thickness, possibly indicating regeneration post a fire event.

The banksia woodland areas appeared to have suffered the most intense fire behaviour with much of the overstorey defoliated and the ground was bare of surface vegetation post the fire.

The tree density was generally variable and where basal areas were assessed, they ranged from 0 to 11 m²/ha. There was quite a range of basal area within the various overstorey species with york gum ranging from 3 – 9 m²/ha, powder bark wandoo and wandoo 8-11 m²/ha and banksia 3-6 m²/ha.

[3] Grass in this instance encompasses annual crops and weeds such as wild oats

Figure 2: Indicative vegetation in which the fire started and ran during the early stages of the fire

4. Fire behaviour

The fire occurred on the 29 December 2009 at approximately 1 pm. The fire travelled in harvested barley before travelling through a range of vegetation types, comprising crop, grass, weeds and leaf litter. The overstorey also changed from a sparse york gum thorough powder bark wandoo, wandoo and banksia woodland.

The topography changed dramatically as the fire progressed through undulating land to steep hills of around 14 degrees, back to undulating and again through steep hills.

The fire behaviour changed as a consequence of the changes in fuel load, fuel availability, fuel structure and the associated slope. Contributing to the fire rate of spread was the volume of embers generated by the running fire within the various fuel types.

The available fuel load varied significantly from a harvested barley fuel of around 3t/ha through to a combination of leaf litter and natural grass, estimated to range between 13 to 15 t/ha.[4]

Listed below are the weather conditions as determined by the Bureau of Meteorology.

[4] Natural grass is defined on the CSIRO Grassland Fire Spread Meter as "undisturbed and/or very lightly grazed natural grasses or improved pasture, generally more than 50 cm tall."

Table 1: Hourly observations at Muresk DAFWA, 29 December 2009. Wind speed values have been converted from the observed values at a height of 3m to 10m estimated values by an up-scaling factor of 1.16.[5]

Time (WST)	Temperature (°C)	Dew point Temperature (°C)	Relative Humidity (%)	Wind Speed (km/h)	FDI
1200	42.8	0.6	7	41	113
1300	42.9	0.9	7	41	114
1400	42.1	3.3	9	34	73
1500	39.4	4.8	12	32	54
1600	34.8	5.2	16	32	43
1700	34.1	4.6	15	28	33
1800	33.2	5.1	17	24	23
1900	30.8	6.3	21	28	26
2000	29.7	6.8	23	30	27
2100	25.4	11.8	42	32	19

Table 2: Head fire rate of spread modified for vegetation

Time (WST)	Temp (°C)	Relative Humidity (%)	Wind Speed (km/h)	FDI	HFRoS (kM/hr) for undulating topography	Fuel type
1200	42.8	7	41	113	13.1[6] / 1.95	Grass / forest[7]
1300	42.9	7	41	114	13.1 / 1.95	Grass / forest fuels
1400	42.1	9	34	73	1.5	forest fuels
1500	39.4	12	32	54	1.21	forest fuels
1600	34.8	16	32	43	0.9	forest fuels
1700	34.1	15	28	33	0.82	forest fuels
1800	33.2	17	24	23	0.67	forest fuels
1900	30.8	21	28	26	0.60	forest fuels
2000	29.7	23	30	27	0.57	forest fuels
2100	25.4	42	32	19	0.28	forest fuels

It was estimated that the fuel loads were approximately 3 t/ha for the cropped area[8] and 11 t/ha of leaf litter combined with approximately 2 - 4t/ha of grass fuels in the wandoo overstorey fuel loads, contributing a total fuel load of approximately 13 to 15t/ha[9].

[5] J Courtney, 2009, "Meteorological aspects of the Toodyay and Badgingara Fires, 29 December 2009," Western Australian Regional Office, Bureau of Meteorology, Perth, WA. 24 February 2009

[6] In the harvested cropped area the HFRoS was estimated at 5.4 km/hr

[7] Forest fuels in this context refer to a predominant scrub layer with some leaf litter under a tree overstorey.

[8] This tonnage is based on field work conducted by FESA.

[9] The tonnage of 15t/ha was applied to the CSIRO Forest Fire Danger Meter Mk5

The land was very steep to the east of the ignition point and in a number of locations the fire ran upslope on slopes that varied from slight through to approximately 14 degrees. The remainder of the fire ran through undulating slopes of varying steepness and length of slope.

Table 3: Slope to Rate of Spread (RoS) Relationship

Slope °	RoS multiplier
+ 5	1.4
+ 10	2
+ 15	3
+20	4
- 5	0.75
- 10	0.5
-15	0.33
-20	0.25

Source: Grassfires fuel, weather and fire behaviour by Cheney & Sullivan

As demonstrated in table 3 the influence of the slope resulted in the fire head fire rate of spread increasing by up to three times that of the undulating topography.

When the head fire behaviour was considered the slope influence resulted in the head fire rate of spread increasing dramatically, although this was for relatively short periods. The impact of the spotting must also be considered, but is very difficult to quantify as there has been very little research into spotting within this vegetation suite and GFDI.

Table 4: Head fire rate of spread modified for vegetation and slope

Time (WST)	FDI	HFRoS (kM/hr) for undulating topography	Fuel type	Slope	Slope corrected HFRoS
1200 -1300	113	13.1 / 1.95	Grass / forest	<5°	13.1 / 1.95
1300 - 1400	114	13.1 / 1.95	Grass / forest fuels	Up to 14°	5.85
1400 - 1500	73	1.5	forest fuels	undulating	1.5
1500 - 1600	54	1.21	forest fuels	undulating	1.21
1600 - 1700	43	0.9	forest fuels	undulating	0.9
1700 - 1800	33	0.82	forest fuels	undulating	0.82
1800 - 1900	23	0.67	forest fuels	undulating	0.67
1900 - 2000	26	0.60	forest fuels	undulating	0.6
2000 - 2100	27	0.57	forest fuels	undulating	0.57
2100 - 2200	19	0.28	forest fuels	undulating	0.28

The fire from the original ignition appears to have developed into two primary head fires as a consequence of the slope, continuous fine aerated fuels and the wind. The fire

appears to have become principally two head fires, with associated flank fires at around 13.45 hours and some 1100 metres from River Road.

The fire behaviour changed as the slope varied and the overstorey species varied between *Banksia spp*, *Eucalyptus wandoo* (wandoo) and *Eucalyptus accedens* (powder bark wandoo) with some *Eucalyptus loxophleba* (york gum). Anecdotal evidence during the field inspection revealed that the surface fuel, type, structure and availability varied loosely in line with the dominant overstorey species. The banksia suffered the most intense fire behaviour where it was crown defoliated and the scrub fuels totally consumed.

Figure 3 – The impact of the fire on the banksia dominant overstorey areas

Figure 4 – The indicative broken soil and therefore discontinuous fuel load associated with the wandoo and powder bark wandoo areas

Fire intensity

It is estimated that the fire intensity varied across the landscape as the fire behaviour, fuel and slope varied.

The fire intensity assessment is based on the following assumptions:

- Fuel was 100% cured and available
- The fine fuel moisture content was estimated at less than 3%
- The wind speeds determined by the BoM were accurate
- The fire basically ran through undulating slopes, but did also run up and down slopes estimated at 14°
- The spotting impact has not been determined, although it is known that certain areas did receive very large amounts of burning embers
- The fuel loads are estimations
- The fuel heat yield is estimated at a consistent 18,600 kJ/kg[10]

[10] The heat yield of 18,600kJ/kg was selected because of the variability of the fuel type.

Table 5: Estimated fire intensity

Time (WST)	FDI	HFRoS (km/hr)	Fuel type	Estimated fire intensity kW/m
1200	113	5.4	Barley	8,370
1300	113	13.1 / 1.95	Grass / forest	33,852 / 15, 066
1400	114	13.1 / 1.95	Grass / forest fuels	33,852 / 15, 066
1500	73	1.5	forest fuels	11,634
1600	54	1.21	forest fuels	9,374
1700	43	0.9	forest fuels	6,975
1800	33	0.82	forest fuels	6,417
1900	26	0.60	forest fuels	4,660
2000	27	0.57	forest fuels	4,408
2100	19	0.28	forest fuels	2,176

5. Investigation of the Toodyay area house loss and damage

The investigation of the houses destroyed and damaged in the Toodyay fire utilised two tools. These were the:

- "FESA House Loss Fire Assessment" form which covers basic building construction standards, building protection zone and hazard separation zone fuel loads, vegetation structure, type and health; and
- "CSIRO Bushfire Building Damage Survey" form which is centred on building construction materials and standards.

The methodology applied was to inspect all the homes destroyed in the fire, some that had suffered partial damage and some that had suffered no damage. All the homes inspected were within the fire boundary and had the potential to be affected by the fire. During the inspections the two forms were completed as far as possible, within the constraints of a post fire forensic assessment. In some instances the property owner was present during the inspection, but most inspections were undertaken without any specific local knowledge. There were 38 destroyed houses, four partially damaged and five undamaged houses for total of 47 houses inspected and assessed.

Following the analysis of the houses and their surrounds it remains very clear that the key elements to the house being destroyed, damaged or undamaged are:

- Constructing to the appropriate standard as identified in "Planning for Bush Fire Protection" and "AS 3959 Construction of buildings in bush-fire prone areas"
- Establishing and maintaining a building protection zone or 20 metre circle of safety adjacent to the house (for individual buildings/homes) which would have a fuel load of less than 2 t/ha and scattered shrubs.

- Establishing and maintaining a hazard separation zone so that the fuels between the house and up to 100 metres (for individual buildings/homes) which would have between 5 – 8 t/ha and spaced trees
- Establishing and maintaining an extended hazard separation zone or community protection zone of up to 2 – 3 km which would have less than 8 t/ha, but less intensive management of the zone than the HSZ, and an increased consideration of biodiversity protection requirements.

Another key component of whether a house was destroyed or burnt or not appears to be its position relative to the head fire.

The components of the assessment included:

- Construction standards
- Building protection zone
- Hazard separation zone
- Fuel or vegetation
- Land use
- Fire behaviour.

Construction standards

The construction standard analysis identified that of the 47 houses assessed only six houses were constructed of flammable materials such as wood and one house was constructed of hay bales and cement rendered. Of the remaining 40 houses, 21 of which were destroyed, 16 were constructed of cellulose cement.

An analysis of whether the home had boxed eaves or not indicated that there were 38 houses which did not have boxed eaves, or could not be identified, and of those 28 houses had been destroyed. There were a total of 46 metal roof houses and one that was not, and it was destroyed as were 37 metal roof houses.

Six of the homes destroyed had wooden window frames and there were nine houses in total with window wooden frames.

Of the 47 houses assessed 36 had gaps in which embers could enter the roof, walls or under the house. This assessment utilised indicative indicators such as the absence of sarking on metal roof houses.

There were a total of 11 houses with six destroyed that had tall plants within 2 metres of the windows. It is not possible to confirm that the loss of integrity by a window, if indeed there was a loss of integrity, was the cause of the fire entering the house.

There were tree crowns within 2 metres of the house in 20 instances and of those 13 houses were destroyed. There were also 12 houses with tree crowns overhanging the house and of those 7 were destroyed.

There were also six houses with evaporative air conditioners and of those 3 were destroyed. In one instance the cause of the fire within the house was entry via the evaporative air conditioner.

In regard to the residents having undertaken bush fire preparedness measures and have a bush fire plan 10 indicated that they did and of those two homes were destroyed.

Building protection zone (BPZ)

The building protection zone analysis indicated that there were 36 houses with tall vegetation (greater than 10cm high) within 20 metres of the house other than the odd not clumped shrub. Of these 26 houses were destroyed.

In 34 locations there were tree crowns closer together than 10-15 metres and 26 of these houses were destroyed.

It is also estimated that there was greater than 2t/ha of available fuel in the BPZ in 29 houses and of those 20 were destroyed.

Hazard separation zone (HSZ)

The following table is indicative of the estimated bush fire attack level on the houses and the subsequent impact on the house. This is based on the separation distance between the house and the predominant vegetation.

Bush Fire Attack Level (BAL)	Number of Houses Inspected	Number of Houses Destroyed
BAL – Low Or undetermined	2	2
BAL – 12.5	0	0
BAL - 19	15	12
BAL - 29	9	7
BAL – 40	10	8
BAL - FZ	11	9

It is estimated that 44 of the houses had fuel loads in excess of 5 – 8 t/ha in the HSZ (which is the zone between the edge of the BPZ and up to 80 metres out from the dwelling) and of those 28 houses had been destroyed. 30 houses were assessed as

being within a woodland overstorey with a scrub understorey and of those 23 were destroyed.

Within the HSZ the scrub structure was rated according to four categories of young, growing, mature and over mature.

The scrub categories were defined by:

Young

- Young & growing
- Green
- Foliage is sparse & generally low
- Easy to walk through

Growing

- Still growing, but may have flowered and set seed
- Basically green foliage but up to 20% may be dead
- Foliage is moderately fine in structure
- Mixed size classes of scrub vegetation
- Medium density
- Moderately easy to walk through

Mature

- Many plants starting to mature
- Foliage may be up to 50% dead
- Foliage is moderately fine with some coarse material
- Mixed size classes of scrub vegetation
- Dense and/r continuous vegetation layer
- Difficult to walk through

Over Mature

- Many plants mature and commencing senescence
- Foliage over 50% dead
- Foliage is moderately coarse with some fine material
- Mixed size classes of scrub vegetation
- Dense continuous vegetation
- Difficult to walk through

The HSZ contained 45 mature classifications, two over mature and one unclassified scrub type.

The land use was assessed by either direct advice from the owner/occupier or by assessing the continuity of the scrub vegetation. Where there was no obvious grazing effect nor a sign advising that the site was a “Land for Wildlife” registered location the land was categorised as “lifestyle”. There were 46 sites categorised as “lifestyle”, one as “grazing” and one as “conservation.” This implies that the site has some vegetation

modifications, but essentially the site has a significant level of tree overstorey cover and intact scrub vegetation.

A further consideration during the field assessment was whether there was any land management practices that could have been used to mitigate against the rapid spread of the fire. There were 12 properties where it was possible to identify (either through owner/occupier advice or visual inspection) that they had developed a BPZ and HSZ or they had managed the fuel. There were a further 35 properties where it was not possible to make a determination and one property where it was possible to determine that no action had been taken. Of the 12 properties where it was possible to identify that the fuel load had been managed, 9 houses had been destroyed 7 of which were made of non-flammable materials such as cellulose cement and 2 were made of timber. The level of fuel management was not able to be identified or quantified.

There was at least one example were a property owner left the decision to leave too late and found that he was effectively cut off. Potentially this could have been a catastrophic outcome, but instead possibly proved to be very opportune for a number of neighbours. The neighbour whose home caught alight advised me that this man undertook suppression action on his house that was in the early stages of catching alight and he suppressed the fire. It also believed that he looked after two other houses in the close vicinity. This action was undertaken in the Drummondi Drive area which is in the wandoo / powder bark wandoo overstorey area.

Figure 5 – Indicative level of damage prior to the suppression actions

6. Impact of the fire on the buildings and surrounds

The impact of the fire to the buildings, the surrounding vegetation and landscape vegetation varied quite significantly. Different vegetation types reacted very differently to the fire, such as the banksia woodland suffered overstorey defoliation and surface fuels being completely consumed. The wandoo woodland overstorey surface fuel types had a range of impacts within the vegetation suite. This may have been a factor of the different scrub structure and type associated with the various overstorey, and also the different soil structure where the wandoo fuels where more associated with broken, rocky ground and hence less continuous surface fuels. The banksia woodland was associated with the sandy soils which provided an aerated and continuous surface fuel.

The actual fuel load varied within the different vegetation types, but there is anecdotal evidence to indicate that for many locations the period between landscape scale burning was unknown at 31 properties, around 30 years for one property, between 22-28 years for 3 houses, around 15 years for two properties, greater than 8 years for 10 properties and one property it is greater than 6 years.

The heavy fuel loads and very steep slopes significantly influenced the fire behaviour the impact on the vegetation and the consequent impact on the houses. In parts, the fire ran up slopes of around 14°. The influence of the slope on the wind direction also influenced the fire run. The wind direction appears to have been variable and this appears to have been influenced by the slope and also the actual natural wind direction variations.

This variation in wind direction and fire behaviour had a significant impact on the buildings and their survivability. The fuel load was considered to be high across the whole fire location.

Figure 6 – Indicative level of ember attack associated with the bush fire

As can be observed in figure 5 the tarpaulin (which was placed on the hill near to the communication towers prior to the fire) suffered significant ember attack. This is indicative of the type and quantity of embers likely to have been attacking the homes within the bush fire's path.

At least one property owner was very prepared with a well developed and maintained BPZ and HZS, but with an evaporative air conditioner. This house was destroyed as a consequence of ember attack onto the evaporative air conditioner and the fire spreading through the home. The owner was also mentally and physically well prepared and was planning to remain at the property. The owner left the property to assist a neighbour evacuate and when he returned the house was alight. The evaporative air conditioner did not have a protective cover.

Figure 7 – A destroyed home with a mature grass tree in close proximity

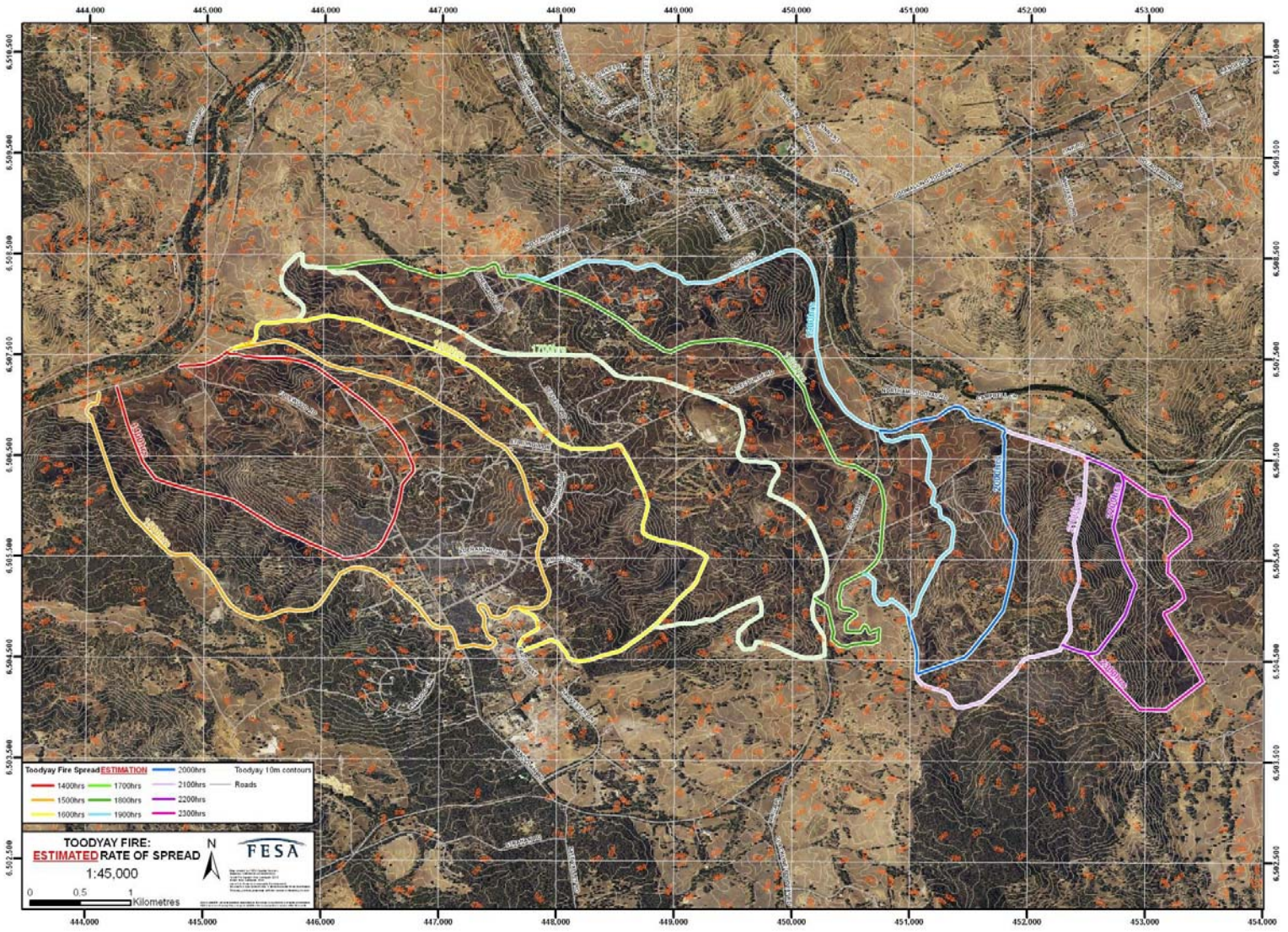
Figure 8 – A destroyed house

Figure 9 – A hay bale home that was cement rendered and destroyed

The head fire run direction was determined by analysing the fire scar impact on the combustible and non-combustible indicators by utilising the standard bush fire investigation approach. By analysing the head fire direction it was possible to determine whether the house had been attacked by the most intense and highest flame height/length areas.

In general the houses that were in the direct line of the head fire run suffered the greatest impact and therefore loss. This loss may have been from the ember attack or radiant heat or direct flame contact.

Appendix 1


Toodyay Fire Spread ESTIMATION
1400hrs
1500hrs
1600hrs
1700hrs
1800hrs
1900hrs
2000hrs
2100hrs
2200hrs
2300hrs
Toodyay 10m contours
Roads
TOODYAY FIRE:
ESTIMATED RATE OF SPREAD
1:45,000
N
FESA
0
0.5
1
Kilometres

Appendix 2

FESA

Fire & Emergency Services
Authority of Western Australia

BUSH FIRE & ENVIRONMENTAL PROTECTION BRANCH

To the householder

This questionnaire has been prepared to gather information about the effects of the fire on dwellings that have been lost or damaged as a result of as bush fire. The information will be used to enable FESA to gain a better understanding of the fire behaviour and its impact on houses built in the natural environment and ways in which life and property can be better protected.

Any information collected will be kept confidential and no person will be specifically identified. At the completion of this project a report will be provided to all interested parties to enable them to better protect their property and assist FESA in helping us help you

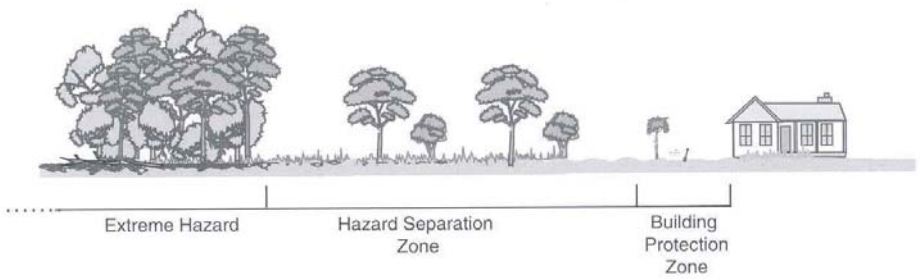
Your support with this project is very much appreciated.

House address / location: _____

Owned by: _____

Date: _____ GPS: _____

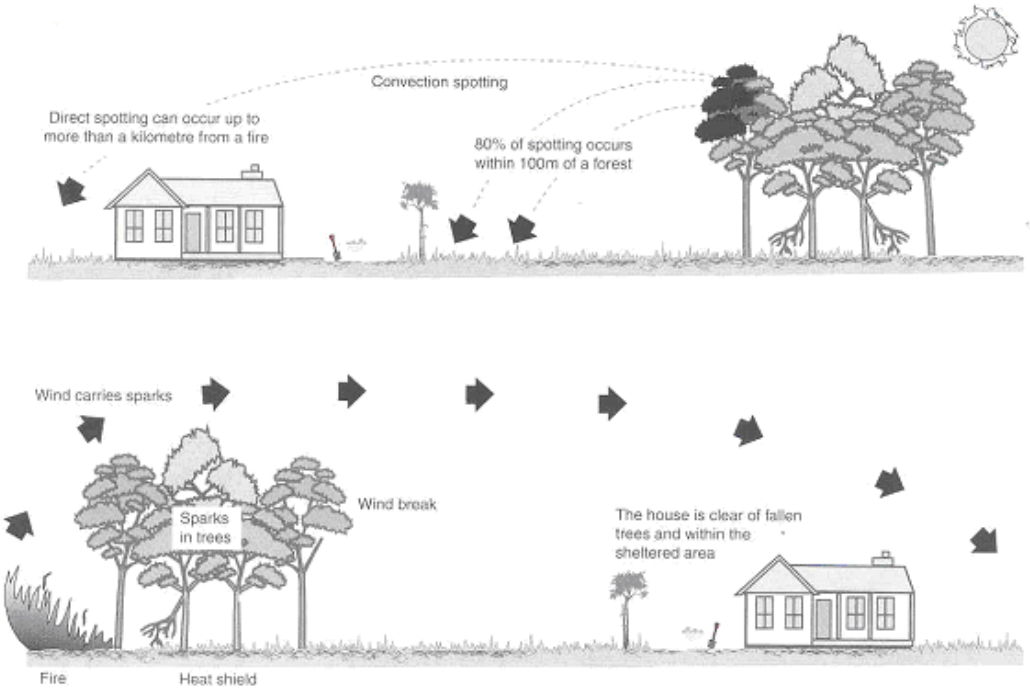
Construction standard		YES	NO	?
1	Was the property enhanced above the normal construction standards?			
2	Is/was the house constructed of brick or other non-flammable materials?			
3	Did the house have fly wire (not fibreglass) on doors and windows?			
4	Did the house have boxed eaves?			
5	Did the house have a metal roof?			
6	If Yes is/was it sarked?			
7	Did the house have gaps in which embers could enter the roof, walls or under the house?			
8	Were there (tall) plants adjacent (within 2 metres) to windows?			
9	Were the window frames wood or aluminium?	Wood	Alum	
10	Were there tree crowns within 2 metres of the house?			
	Were there tree crowns over hanging the house?			
11	Were there door mats adjacent to areas that may trap embers?			
12	Did/does the house have evaporative air conditioning?			
13	Did/does the evaporative air conditioning have a protective cover and was it applied?			
14	Is/was the house permanently occupied?			
15	Are the residents mentally and physically confident of staying and defending the house?			
16	Have the residents undertaken bush fire preparedness measures and have a bush fire plan?			
17	Were the gutters clear of leaves and litter?			



Hazard Separation Zone (HSZ)				
1	What is the distance between the house and the principal vegetation - <16m (BAL - FZ), 16 – <21m (BAL – 40), 21 - <31 (BAL - 29), 31 - <42m (BAL - 19), 42 – 100m (BAL – 12.5), >100m (BAL – Low) in the direction of the head fire travel?			
2	What was the principal vegetation type? F, W, S, MM, G			
		YES	**NO**	**?**
3	Is the site sloped?			
4	If Yes is the home upslope from the predominant vegetation?			
5	What is the slope (degrees)?			

Building Protection Zone : 20 metres 'Circle of Safety'		**YES**	**NO**	**?**
1	Was there tall (> 10 cm high) vegetation (grass) within 20 meters of the house, other than the odd shrub (not clumped)?			
2	How close were the shrubs to the building?			
3	Were the shrubs adjacent to the fire entry into the building?			
4	Was there dead material in the crown of the vegetation?			
5	Were the tree crowns less than 10 – 15 metres apart?			
6	Was the wood heap close to the house (within the BPZ)?			
7	Was there more that 2 t/ha of available fuel in the BPZ?			
8	Is/was there a fence close to the house (< 5m)?			
9	If Yes, was it of combustible material?			
10	Did it burn or lose rigidity and impact onto the integrity of the house?			
11	Was /are there flammable liquids stored in the house or surroundings?			
12	Was / are the gas cylinders appropriately placed and protected from radiant heat?			
13	Did the gas bottles vent?			
14	Was / is there anything obvious that exposes the house to an unreasonable level of threat? If yes describe: …… …… …… …… …… ……			
6	Was / is there more that 5t/ha of available fuel in the HSZ? If yes what was the estimated tonnage?			
7	Did the fire run up the slope or down the slope to the home?			

Vegetation code - F = Forest, W = Woodland, S = Shrubland,
MM = Mallee/mulga G = Grassland/pasture T = Tropical savanna woodland



Building protection zones must be maintained around all buildings.

Fuel (Vegetation)		
1	Do you know how long it had been prior to this fire since the native vegetation in the immediate vicinity of the home was burnt (within 1 km)?	…… ……
2	How much litter (depth) was present on the ground before the fire?	……
3	Describe the native vegetation of the area near the property (see guide below)	…… ……
4	Was the areas grazed in the vicinity of the house? If yes, was it heavily grazed?	…… ……

Fuel Load ~ scrub / leaf… ……/…… t/ha

Topography …… ……. .

Leaf litter percent

age consumed ……% of total
Scrub fuel (≤1.5 m high) percentage consumed……% of total

Scrub structure rating – Young / Growing / Mature / Over mature

Within the HSZ what was the:
Height of scrub scorch (m) - ……..
Percentage of scrub crown scorch - ……%
Percentage of scrub crown defoliation - ……..%

Height of average tree crown scorch - …….. (m)
Percentage of tree crown scorch - ……..%
Percentage of tree crowns defoliated - …….%

Tree structure

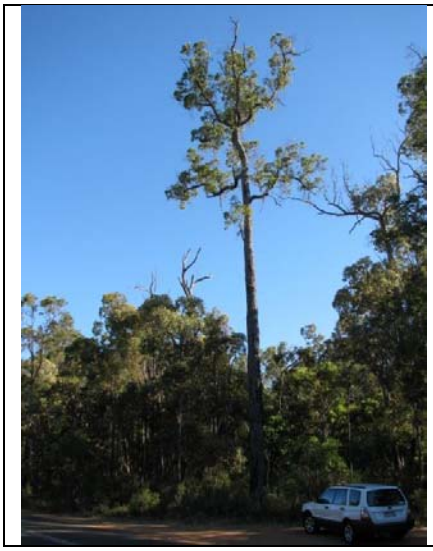
Total = 27, 12, 3

Vegetation Type

Forest Woodland with scrub Tropical savanna woodland Grassland (crop / pasture)

Tree structure

	1. Crown is around 1/3 the height of the tree 2. Crown is equal height and width 3. Crown is dense with many leaves covering all limbs Each component is rated up to 3 eg Crown is around 1/3 the height of the tree – Yes = 3 Crown is equal height and width - Yes = 3, No = 2 or 1 Crown is dense with many leaves covering all limb – Yes = 3, No = 2 or 1 **Total 3x3x3 = 27**
	1. Crown is less than 1/3 the height of the tree 2. Crown is less than the height and width ratio 3 Crown is dense with many leaves Each component is rated up to 3 eg Crown is less than 1/3 the height of the tree Yes = 3 Crown is less than the height and width ratio – Yes =2 Crown is dense with many leaves Yes = 3, No = 2 **Total 3x2x2 = 12**



1. Crown is significantly less than 1/3 the height of the tree
2. Crown is not equal height and width
3. Crown is sparse with many limbs exposed and few leaves

Each component is rated up to 3 eg
Crown is significantly less than 1/3 the height of the tree - Yes = 1
Crown is not equal height and width – Yes = 1
Crown is sparse with many limbs exposed and few leaves – Yes = 1

Total 1x1x1 = 3

Scrub structure

1. Young & growing
2. Green
3. Foliage is sparse & generally low
4. Easy to walk through

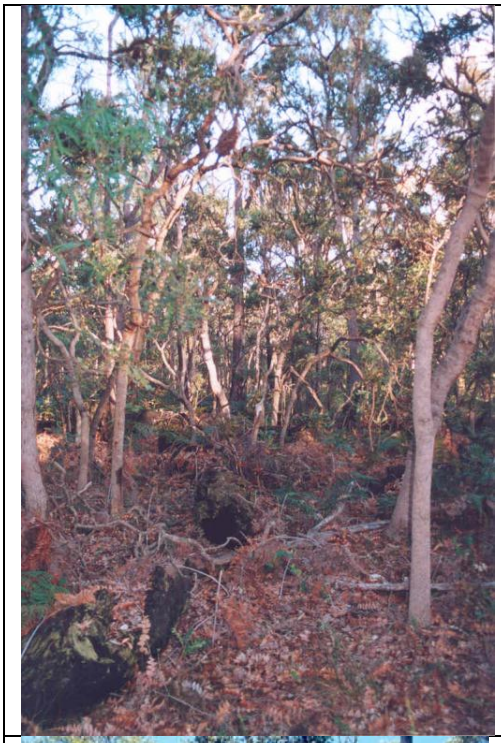
Rating = Young

1. Still growing, but may have flowered and set seed
2. Basically green foliage but up to 20% may be dead
3. Foliage is moderately fine in structure
4. Mixed size classes of scrub vegetation
5. Medium density
6. Moderately easy to walk through

Rating = Growing

1. Many plants starting to mature
2. Foliage may be up to 50% dead
3. Foliage is moderately fine with some coarse material
4. Mixed size classes of scrub vegetation
5. Dense and/r continuous vegetation layer
6. Difficult to walk through

Rating = Mature



1.Many plants mature and commencing senescence
2. Foliage over 50% dead
3. Foliage is moderately coarse with some fine material
4. Mixed size classes of scrub vegetation
5. Dense continuous vegetation
6. Difficult to walk through

Rating = Over mature

Land Use		
1	What is the main use of the land on the property, e.g grazing, lifestyle, conservation?	G / L / C
2	Other than perimeter firebreaks were there any fire breaks or tracks intersecting the property?	
3	Are there any land management practices that could have been used to mitigate against the rapid spread of the fire? Describe: …… ……... ……...	
4	Is the property rented or owned by yourself?	Rented / owned
5	Is the home permanently occupied?	Yes / No

Fire behaviour		
1	Was anyone present during the fire? If so are they able to provide any information regarding fire behaviour, e.g. direction of fire, speed (rate of spread) of the fire, spotting?	
	…… …… ……	

Further Comments

(if the property owner/renter has any further comments please provide them here)

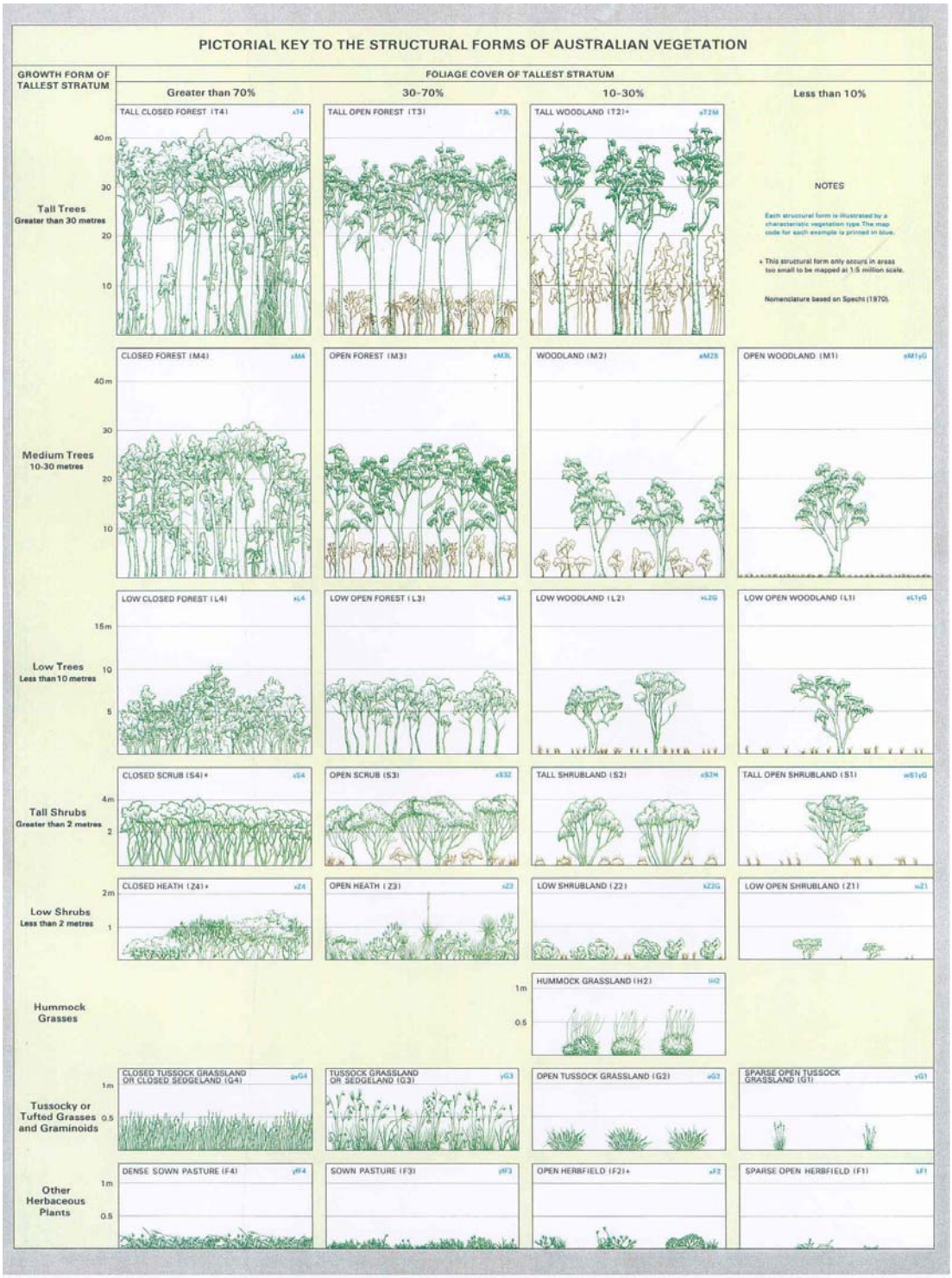
……
……
……
……
……
……
……
……

Thank them for assisting with this questionnaire

Vegetation of Western Australia

Name	Description	Height	Foliage cover	Comment
Tall Closed forest	Trees	>30 m	>70%	Rainforest
Tall Open forest	Trees	>30 m	30-70%	Karri forest
Medium Closed forest	Trees	10-30 m	>70%	Rainforest
Medium Open forest	Trees	10-30 m	30-70%	Eucalypts predominant
Woodland	Trees	10-30 m	10-30%	Transitional zone between higher rainfall forest margins and arid interior
Woodland Open	Trees	10-30 m	<10%	Euc studded grasslands
Low Trees Closed forest	Trees	<10 m	>70%	Widespread but patchy across nth Australia
Low Trees Open forest	Trees	<10 m	30-70%	Acacia forest of NT & Qld
Low woodland	Trees	<10 m	10-30%	Floristically very diverse
Open woodland	Trees	<10 m	<10%	Throughout much of inland Aust. Scarce water & poor soils
Tall Shrubs Open scrub	Shrubs	>2 m	30-70%	
Tall shrubland	Shrubs	>2 m	10-30%	Mallee & Mulga
Open shrubland	Shrubs	>2 m	<10%	Most widespread structural form of vegetation
Low Shrubs Open heath	Shrubs	<2 m	30-70%	
Low shrubland	Shrubs	<2 m	10-30%	Saltbush & bluebush
Low open shrubland	Shrubs	<2 m	<10%	Extreme environment – rocky ranges or skeleton soils
Hummock grasses			10-30%	Grass steppe
Tussocky or tufted grasses	Closed tussock grassland or sedgeland		>70%	
Tussock grasses				
	Open tussock grassland		10-30%	Mitchell grass
	Sparse open tussock grassland		<10%	Mainly on clay plains

Source: “Atlas of Australian Resources Vegetation”, 1990, AUSLIG, Australian Government Publishing Service, Canberra


PICTORIAL KEY TO THE STRUCTURAL FORMS OF AUSTRALIAN VEGETATION
GROWTH FORM OF TALLEST STRATUM
FOLIAGE COVER OF TALLEST STRATUM
Greater than 70%
30-70%
10-30%
Less than 10%
Tall Trees
Greater than 30 metres
TALL CLOSED FOREST (T4)
TALL OPEN FOREST (T3)
TALL WOODLAND (T2)*
Medium Trees
10-30 metres
CLOSED FOREST (M4)
OPEN FOREST (M3)
WOODLAND (M2)
OPEN WOODLAND (M1)
Low Trees
Less than 10 metres
LOW CLOSED FOREST (L4)
LOW OPEN FOREST (L3)
LOW WOODLAND (L2)
LOW OPEN WOODLAND (L1)
Tall Shrubs
Greater than 2 metres
CLOSED SCRUB (S4)*
OPEN SCRUB (S3)
TALL SHRUBLAND (S2)
TALL OPEN SHRUBLAND (S1)
Low Shrubs
Less than 2 metres
CLOSED HEATH (Z4)*
OPEN HEATH (Z3)
LOW SHRUBLAND (Z2)
LOW OPEN SHRUBLAND (Z1)
Hummock Grasses
HUMMOCK GRASSLAND (H2)
Tussocky or Tufted Grasses and Graminoids
CLOSED TUSSOCK GRASSLAND OR CLOSED SEDGELAND (G4)
TUSSOCK GRASSLAND OR SEDGELAND (G3)
OPEN TUSSOCK GRASSLAND (G2)
SPARSE OPEN TUSSOCK GRASSLAND (G1)
Other Herbaceous Plants
DENSE SOWN PASTURE (F4)
SOWN PASTURE (F3)
OPEN HERBFIELD (F2)*
SPARSE OPEN HERBFIELD (F1)
NOTES
Each structural form is illustrated by a characteristic vegetation type. The map code for each example is printed in blue.
* This structural form only occurs in areas too small to be mapped at 1:5 million scale.
Nomenclature based on Specht (1970).