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Reporting fire in Australia's forests and vegetation

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Executive summary

The Australian Government has a number of policies that require information on health and vitality or condition of forests and other vegetation. Because it is not practical to assess the health and condition of all forests and vegetation, indicators for which data can be practically collected are used. Indicators are used for this purpose in the Montreal Process, State of the Environment reporting and National Monitoring and Evaluation Framework. For example, Montreal Process indicator 3.1 is '*area and per cent of forest affected by processes or agents beyond the range of historic variation*'.

Fire is an integral part of the ecosystem processes that determine floristics, diversity and structure of Australian forests and other vegetation. Fire regimes and fire management practices can affect the health and condition of forest and vegetation types in beneficial or detrimental ways. Monitoring and reporting fire and its impacts is therefore an important part of monitoring vegetation.

Monitoring and reporting fire and its impacts on forests and vegetation requires regularly collecting data and information on fire extent, intensity and frequency and access to equivalent information on vegetation extent, type, use management and condition. Regular monitoring and reporting of the relationship between fire regimes and the relationship to forests and vegetation is essential to develop an understanding of the ecological sustainability of current fire regimes and fire management practices.

This report assesses whether the information reported on fire in Australia's forests and vegetation is sufficient in terms of quality, completeness and availability to enable reporting on Montreal Process indicator 3.1. The assessment shows that the Montreal Process indicator 3.1 cannot be practically reported at the national scale. A coordinated and standardised national approach is needed to gather accurate data to report fire data, including intensity and/or damage indices that allows for spatial comparison with vegetation mapping and identified community fire sensitivity. No State or Territory agency can currently report in a way that would provide an up to date, comprehensive and meaningful analysis.

The report discusses a number of cost-effective options to implement a coordinated and standardised national approach to future gathering of appropriate fire data that would enable meaningful national assessment of the impacts of current fire regimes. The merits of implementing a national approach to monitor and report on the impact of fire on vegetation condition and health indicators are discussed. The most practical approach is based firstly on using the coarse resolution satellite data for relatively open-crowned forest and vegetation and secondly using higher resolution satellite data where the vegetation has denser and closed crowns. In areas with high value vegetation, satellite data can also be combined with targeted aerial photographic interpretation for accurate fire history mapping at a sufficient scale and resolution to capture small low intensity fires. While remotely sensed datasets are available, these are no substitute for ground collection of data on vegetation use and management, structure, floristics, condition and health. Predicting the impacts of changed fire regimes requires modelling fire impacts for specific projects. There is sufficient empirical research and understanding of the ecology of many dominant tree species to begin developing these models for many of the major forest types.

1. Fire and Australia's forests and vegetation

1.1 Background

Fire regimes, that is, the frequency and intensity of fires, are an integral part of the ecosystem processes that determine floristics, diversity and structure of Australian forests and other vegetation (Walker and Singh 1981, Standing Committee on the Environment and Conservation 1984, Attiwill 1994, Bradstock et al 2002). Fire can be either beneficial or detrimental (Jurskis 2004, White and Jurskis 2004). The fire regime in many parts of Australia has altered due to land use changes and adoption of European land management practices (Jurskis et al 2003). This has resulted in regional and community level vegetation change (Gill 1981, Attiwill 1994, Florence 1994, Jurskis 2004).

The effects of wildfire on forest and vegetation vary depending on the time since fire. In the short term (months) these effects are quite different to those in the long term (decades). In the short term they include temporary loss of vegetation cover (eg shrubs and grasses), temporary loss of litter cover, some permanent loss of mature trees and vigorous regrowth of existing perennial trees and shrubs. In the longer term these effects can include thickening of the perennial woody vegetation of open grasslands and grassy woodlands/savannas. This can be attributed to a number of fire regime-related processes, such as where previously sparse shrub and tree layers have increased in cover due to a lack of regular fire (Rolls 1999). In other places dense forest communities have spread from community margins and woody weeds have colonised new areas (Rolls 1999, Gifford and Howden 2001).

In many areas vegetation change has become a major conservation issue. For example, in northern Queensland, rainforest and *Melaleuca* forests are encroaching into wet eucalypt forests. Aerial photographs show that in some areas over 50% of the wet sclerophyll forests and woodlands that had a grassy understorey in 1943 now have a rainforest understorey (Harrington and Sanderson 1994, Harrington 1995). In some areas of Cape York there has been a 20% decline in the area of open grasslands over the last 10 years **(**Peter Thompson, Cape York Development Council, pers comm).

The extent to which these processes of vegetation change have occurred nationally is not clear because the lack of measurable and reliable information about Aboriginal and early settlement fire regimes and distribution of many vegetation communities (Benson and Redpath 1997)**.**

Once the open grassy vegetation in these tropical and subtropical environments has changed to rainforest and scrub, prescribed burning to return to open grassy woodlands is no longer achievable, except under extreme drought conditions. With encroachment and eventual understorey dominance by rainforest species, the fire regime effectively changes from frequent low intensity burning to infrequent high intensity burns. These thickening processes can also be of major importance to forest health and vitality and fire management. As the forest overstorey matures, competition leads to a higher proportion of trees in poor condition more susceptible to pathogens and disease.

There are also consequences for conservation management and species diversity where the floristics and vegetation structures of large areas change and the habitats typical of grasslands and open forest communities may become increasingly restricted (Attiwill 1994, Rolls 1999).

The impacts of changes in fire regime should be considered in the context of the Australian Government's requirements to report on the health and condition of forests and vegetation. This requires a monitoring and reporting process.

1.2 Reporting fire in Australia's forests and vegetation

Reporting on the pattern and relationship between fire incidence and Australian forests and vegetation requires that data are collected on fire regime and vegetation type, extent and condition. Ideally, the survey design should enable comparable spatial and temporal data to be analysed. Unfortunately, data on fire regime and vegetation type, extent and condition, are usually collected at different spatial and temporal scales thus making comparisons somewhat tenuous.

Meaningful monitoring and reporting of fire and its impacts on vegetation requires data and information on fire regimes, that is, patterns of fire intensity and frequency, fuel type and seasonality, and on how these affect vegetation age classes, canopy cover, stratal segregation and species compositions. These data may be collected for planned and unplanned fires. This is essential for understanding ecological sustainability of current fire regimes and fire management practices. Reporting fires only by area burnt annually, without including intensity and frequency, is inappropriate for Australian forests for assessment of ecological sustainability and biodiversity impacts. This has been reviewed in detail for the Australian environment by Gill et al (1999).

Australia has 910 recognised vegetation communities of which 457 communities, encompassing 156 million hectares, are considered to be forest and woodland (NFI 1998). The nature and classification of Australia's forest communities at the national level is discussed in detail in Australia's First Approximation Report for the Montreal Process (MIG 1997). By applying a consistent definition of forest, the National Forest Inventory (NFI) aggregates Australia's forest and woodland communities into 17 broad forest types comprised of 64 classes. These classes are defined by the dominant genus, height and cover. State and Territory forest management agencies routinely use these classes to translate and compile national forest information from regional and state level forest and vegetation mapping.

Summary statistics for the NFI forest classes within each State and Territory are presented in Appendix 1. Reporting impacts and changes of fire regimes in these forest classes is expected to show patterns of fire regimes with changes in major species in the overstorey. However, due to a lack of information about floristic changes, they cannot be expected to show the effect of fire regimes in the overstorey or understorey.

To understand ecological impacts and changes in the floristics of forest and vegetation communities would require access to a more detailed vegetation classification than the 64 NFI forest classes. The National Vegetation Inventory System (NVIS), with its description of association and sub-association, levels 5 and 6 respectively (NLWRA

2001; ESCAVI 2003), would satisfy this requirement. The NVIS framework includes both structural and floristic information required to monitor and report on forest and vegetation health and vitality, and other ecological changes due to changes in fire regimes.

1.3 Project Aims:

The aims of this project were to:

1. document the status of fire incidence datasets including fire extent mapping at the national, State and Territory levels including both wildfires and planned fires

2. assess opportunities for establishing a national fire incidence dataset by compiling data collected by State and Territory land management agencies.

2. Australian fire incident reporting, data collection and datasets

The following information has been compiled from telephone interviews and electronic communications with relevant Australian Government and respective State and Territory agency natural resource and/or data managers. This information was compiled during June and July 2001 and revised in 2005 after sending sections back to State and Territory agencies for checking.

2.1 Australian Government

Reporting fire statistics and fire data collection in Australia is the responsibility of State and Territory government agencies. Data held by the Australian Government has usually been compiled from State and Territory agencies when needed for activities such as the Comprehensive Regional Assessment process undertaken to develop Regional Forest Agreements, the NFI, State of the Forest Reports and State of the Environment reporting. The data has not been maintained or updated after those activities. Much of this fire related data is in the form of summaries or overviews, not at the level of detail necessary to assess fire regimes changes on the health and vitality of forest and vegetation communities.

Currently there is no consistent national fire extent dataset covering all forest and vegetation types at a uniform scale that can be related to vegetation types. The only information that has a national coverage is that compiled for the State of the Environment reporting. This is the landscape fire extent data collected by the Western Australian Department of Land and Administration (DOLA) and provided to the Australian Government. While there are advantages with a national dataset which is regularly collected using a consistent method, there are inherent disadvantages with this type of remotely sensed satellite data that are symptomatic of problems in measuring, monitoring and reporting fire data at a scale that enables vegetation change to be assessed and monitored. These problems are discussed in further detail later.

Data collection is usually via fire incident reporting and statistics derived from such reporting methods. How data is collected, stored and analysed relevant to monitoring vegetation change is discussed for each of the major State and Territory agencies below.

As part of the National Carbon Accounting System, fire masks have been compiled to interpret and classify woody vegetation in Landsat satellite images for the period 1972–2000 (Australian Greenhouse Office 2001).

2.2 Tasmania

Three agencies in Tasmania are responsible for fire reporting. The Parks and Wildlife Service (PWS), which is a division of the Department of Tourism, Parks, Heritage and the Arts, is responsible for national parks and conservation reserves. Forestry Tasmania (FT) is responsible for fire management within State forests, including formal and informal reserves. These agencies use the same fire incident reporting systems and databases, although each maintains its own records and geographic information system (GIS) data. The third agency, the Tasmania Fire Service (TFS), is responsible for suppressing and reporting fires on private lands.

All three agencies use the TFS incident identification log that ensures a unique identification number is allocated to each fire incident. This allows tracking each incident and avoids double recording despite the differences in systems across the three agencies.

2.2.1 Parks and Wildlife Service and Forestry Tasmania

FT has developed an ORACLE wildfire database called FIRES (Fire Incident Reporting and Evaluation System). This is currently (mid 2005) being upgraded to assist in data collection, storage and integration with the GIS.

PWS stores its fire incident data in the FT system so that the system effectively covers all forested public lands in Tasmania. Data are collected through fire incident reports with the monitoring of wildfires and subsequent calculation of area burnt in final fire reports coming from ground staff, or from aircraft-borne global positioning system (GPS) units in the case of larger and/or remote fires.

In the case of larger fires, a GPS is used to map fire boundaries from the air at a nominal accuracy of 50 m. Helicopter mounted GPS is used sometimes. Where such methods are not required, boundary recording may be based on visual estimate, hand held GPS locations recorded on the ground and marked on 1:25 000 maps or by aerial photograph interpretation (API) accurate to about 10 m.

FT maps the boundaries of all wildfires in State forest using ground methods. This data is then digitised into the GIS for fire history mapping that can be used in strategic conservation management. The fire identification numbers can be used to refer back to the fire incident reports in FIRES. FT policy is to show the boundary of each fire larger than 1 ha in the GIS. Smaller fires are represented by a circle.

Vegetation type burned is recorded using the following categories:

1. Alpine heath
2. Blackwood forest
3. Bracken
4. Button grass moor land
5. Dry sclerophyll forest/*Callitris*
6. Dry sclerophyll scrub/heath
7. Grassland and herbs
8. Hardwood plantation
9. Wet sclerophyll forest
10. Mixed forest (eucalypt overstorey, rainforest understorey)
11. Mountain eucalypt forest
12. Mountain/montane moor
13. Native conifer forests (King Billy pine, *Athrotaxis*, *Podocarpus*)
14. Paddocks
15. Cool temperate rainforest
16. Rainforest scrub
17. Silvicultural regeneration (mostly wet sclerophyll forest types)
18. Softwood plantation
19. Sub-alpine eucalypt woodland
20. Unburnt

Due to the relatively small scale mosaic pattern of vegetation and topography, classifying wildfires using only one of the above categories will not accurately describe effects on particular vegetation types. Referring GIS wildfire overlays to detailed GIS vegetation overlays can overcome this to give accurate assessments of the areas burnt by vegetation type at more refined levels of classification of forest type. However, the GIS mapping of fires is not linked to the same database as that for vegetation and other API mapping work and for both agencies GIS mapping is not up to date. This has been identified as an area requiring greater work but it may not be a high priority and is limited by available resources.

Both agencies also have their own separate GIS systems. FT uses ArcInfo, whilst PWS stores much of its fire data in a Mapinfo system. FT can produce a full map for each wildfire, accurate to 10 m^2, back to 1978 and has identified the need to link the FIRES database and the GIS system so that spatial analyses of fire data can be done within one system.

Each fire incident report has space to record data on fire boundary, origin, vegetation type, tenure, season fire identifying number, and fire/man-hours data. With varying reliability, fires in forest environments may be categorised in terms of damage, ie: (1) unburnt – no scorch, (2) partial foliar scorch, (3) total foliar scorch, (4) foliar burn, (5) small branch burnt, and (6) large branches burnt.

PWS has no central database for planned burns. Individual districts and parks maintain their own records and areas are strategically identified as part of PWS management plans. FT maintains a separate information system – the coupe harvesting information system – for planned burns used for silvicultural regeneration on State forest. This is an Oracle derived system that details the area burnt, location of coupes and date of burn. Fuel reduction burns are recorded on the GIS and will soon be integrated into FIRES.

2.2.2 Tasmania Fire Service

Tasmania Fire Service (TFS) stores its data in the Australian incident reporting system (AIRS) database, which is constructed to the Australian Standard (AFAC 2002). AIRS is not currently supported by a GIS and has no information on fire damage indices or intensity other than fire weather data. For area calculation, wildfires are reported using GPS coordinates so that fire area can be accurately assessed for larger fires, although the majority of fires that the Tasmania Rural Fire Service responds to are under 5 ha and area reporting for these varies. Vegetation type burnt is reported using 23 categories, although only the category that typifies the majority of the vegetation is recorded. These are listed in Table 1.

As a result of the comprehensive regional assessment process, Forestry Tasmania has detailed GIS vegetation maps that cover most private land. PWS has access to much of the same data, which is held by the Department of Primary Industries, Water and Environment. These can be compared with collated spatial information within AIRS. However, it would require significant resources for spatial data for the larger fires to be digitised for fire history mapping on private land.

Table 1: Vegetation categories in the Australian incident reporting system for wildfire

Code	Vegetation type
1	**Plantation**
1.1	Exotic softwood
1.2	Native softwood
1.3	Native hardwood
1.4	Silvicultural regeneration
2	**Native forest**
2.1	Native forest – rainforest
2.2	Native forest – sclerophyll forest greater than 50 m height
2.3	Native forest – sclerophyll forest 35 – 50 m height
2.4	Native forest – sclerophyll forest 15 – 35 m height
2.5	Native forest – sclerophyll forest less than 15 m height
2.6	Native forest – all conifer forest
3	**Other vegetation types**
3.1	Mallee
3.2	Savanna
3.3	Hummock grasslands (spinifex and button grass)
4	**Alpine**
4.1	Alpine woodland and herb-field
4.2	Sub alpine woodland
5	**Low scrub/heaths**
5.1	Heath-lands/wallum
6	**Grasslands**
6.1	Improved grasslands and pasture
6.2	Native pastures
7.1	**Crops**
8.1	Orchards and vineyards
08	Vegetation type not known
09.9	Vegetation type not above
9.9	Insufficient information to classify
00	Vegetation not reported

2.3 Victoria

Victoria has three fire services: the Department of Sustainability and Environment (DSE), the Country Fire Authority (CFA) and the Melbourne Fire and Emergency Services Board. The latter is responsible for the Melbourne metropolitan area and is not considered further in this report.

The DSE is responsible for fire management, data collection and reporting and for conservation management on public land. The CFA is responsible for the prevention and suppression of fires and for the protection of life and property in case of fire in the rest of the State.

2.3.1 Department of Sustainability and Environment

The Department of Sustainability and Environment is responsible for all land management issues related to public land in Victoria. All fire data information is held within the integrated fires information system (IFIS) database that replaced the fire and incident reporting system (FIRS) database. IFIS is a meta-data driven system allowing an ease of reporting and analysis of data with regard to the attributes against which data is collected that was not achievable under the old FIRS system.

IFIS is based around a web interface with the format being defined by the use of a SQL Server 7 database. It has a GIS component with spatial fire data for planned and unplanned fires being linked to tabulated fire data collected through standardised fire reporting procedures across the five DSE fire management and reporting districts. Wildfires are reported by area and forest type. Forest type is divided into six groups:

1. ash forest and high elevation mixed species
2. mixed species forest
3. box, ironbark and red gum forests
4. softwood
5. mallee and native conifer forests
6. heathland and scrub

There is also a further breakdown into structural classifications. The area of individual tenures burnt is also recorded as well as whether or not a total fire ban was in force at the time of the fire. There are detailed reports on equipment and suppression techniques, as well as financial information and legal outcomes. The data go back to 1978. Being supported by GIS, analysis of fire frequency is possible. DSE provides mapped information on fire severity including the area and extent of wildfires that are generally over 5000 hectares in size. This dataset is derived primarily from Landsat 7 Thematic Mapper multispectral satellite data. Interpretation of aerial photographs supplements the dataset where Landsat data is unavailable. The combined fire severity classification is validated on a minimum number of field sites. The classification primarily differentiates crown burn (higher severity) and crown scorch (lower severity) classes of eucalypt forests, though the remote sensing method is also applied to treeless areas. In forested areas this dataset provides a reliable strategic management dataset to interpret fire effects. In treeless areas the datasets should be used as a guide only, as localised anomalies may occur. For instance, drought-affected grassland may not be reliably

differentiated from burnt grassland if the condition of each is bare soil. Used with care and with field checking, this dataset provides a reliable strategic overview of fire affected areas.

2.3.2 Country Fire Authority

The CFA is responsible for control of all fires on private land and interacts with the other agencies. For reporting purposes, the CFA uses a system called fire and incident reporting system (FIRS). This system was developed by the CFA in 1997 and is based on the Australian incident reporting standards. FIRS is also used by Tasmania's Fire Service, Western Australia's Fire and Emergency Services Authority, South Australia's Country Fire Service and the New South Wales Rural Fire Service.

A report is submitted for each fire that the CFA attends, including fires outside the CFA's area of responsibility. The information included mainly concerns property and personal damage, suppression resources and costs. Boundaries of larger fires may be mapped from aerial photos using infra-red side-looking radar imagery that is then transferred to computers for digitising, in some circumstances. Vegetation type and area burnt are not compulsory fields for reporting and are completed for an estimated 25% of cases. Vegetation type is identified by the local brigades and, when this item is completed, only the majority vegetation type is reported. The data for this attribute is therefore only indicative.

2.4 New South Wales

The Bushfires Act 1997 gives four agencies responsibility for fire management and data collection in New South Wales. Forests NSW is responsible for State Forests. The National Parks and Wildlife Service is responsible for National Parks and other conservation reserves. NSW Rural Fire Service, through 142 rural fire brigades, is responsible for private land. The fourth agency, the NSW Fire Brigades, is primarily focused on metropolitan areas and collects little information on vegetation affected by fire.

The *Bushfires Act 1997* also established a State Bushfire Coordinating Committee and Bushfire Management Committees (BMCs) across New South Wales. These committees must prepare Bushfire Risk Management Plans designed to coordinate fire risk management efforts of public and private land managers within individual BMC areas. Formulation of these plans involves three steps: nine classes of hazards are identified by a series of attributes including vegetation type, a threat map is prepared by overlaying community and environmental assets, the management prescriptions required to reduce risk and fire incident response procedures are detailed.

2.4.1 NSW Rural Fire Service

Although the NSW Rural Fire Service is not a land management agency, it maintains fire incident reports that contain data on the area burnt by fires which it attends. The information in these reports is not collated and centralised in one database and there is little or no mapping after fires other than that provided in situation reports. This was expected to change with the purchase and implementation of the Victorian CFA FIRS

database and reporting system – to be termed FIREZONE in New South Wales – across all the 142 Rural Fire Service districts.

Once this system is working, it will allow for centralisation of storage of fire data from notifiable incidents and coordinated mapping of fire histories, although vegetation classification is expected to continue at the same level, that is forest, scrub or grassland. This is the same as that used by Forests NSW and the Parks and Wildlife Service.

Area calculation for notifiable fires is based on burnt grid points marked on topographic maps using GPS methods and for larger fires, helicopter GPS methods as in Tasmania. The focus here is to provide situation reports rather than detailed post fire incident reports for land management analyses. These situation reports categorise fires by tenure and into three classes:

1. classes that involve only one agency
2. classes that require coordinated management
3. classes that require a declaration under Section 44 of the *Bushfire Control Act 1997* to release State funds.

Map scales and map names are also recorded as are the centroid point of origin of the fire, where known, and the equipment and personnel committed. Damage to property and injury information is also recorded but no information is provided on fire damage indices, such as scorch height, to the vegetation burnt.

2.4.2 Forests NSW

Forests NSW maintains a database – referred to as 'WILDFIRES' – of information on wildfires. This has verbal information and data but no maps. The database contains up to 30 years of fire information gleaned from written reports. Many recent larger fires have been mapped. The maps have been digitised and can be linked to the written fire reports by a unique identifier. However, this is only done when needed and that depends on particular project needs. There is no fire history mapping covering State Forest.

Each fire record within WILDFIRES is given a unique identity number and information on the size of the area burnt, date of fire, as well as personnel and equipment details. If the forest area suffers over 70% crown scorch this is also recorded. Unlike Bushfire Services, the area burnt calculated by Forests NSW is on the basis of the containment lines constructed rather than GPS and mapping of fire boundaries. Consequently there is potential to overstate the area burnt.

For planned fires there is no digital spatial dataset although maps are attached to many fire incident reports. These reports are kept in district archives. Area information is collated for annual reporting at the state level, with the number of fires and area burnt by planned and unplanned fires for each district being reported. The information on area burnt for planned fires is more reliable than that for unplanned fires because the post fire incident reporting system requires that the percentage of the area actually burnt is reported against the area that was planned to be burnt.

Vegetation types reported in fire reports are grass, scrub or forest. No attempt is made to classify further except when needed for particular research projects. Moreover, there is no attempt made to assess what proportion of the area of each vegetation category is burnt. Hence the forest area burnt annually relative to scrub and grasslands burnt may be overestimated, in addition to the inherent overestimation from the use of containment lines as a means of delineation.

2.4.3 Parks and Wildlife Service

The New South Wales Parks and Wildlife Service has a central fire incident management system that provides situation reports for fire events to an operations centre, as well as to local offices where fire locations are recorded. These situation reports contain information on area burning or burnt assessed by a number of methods depending on the terrain and the resources available. Where ground access is feasible, initial reporting may consist of GPS recording of fire boundary coordinates and assessment of suppression needs. Most fires that can be readily suppressed are, and often personnel from other districts can be rapidly brought in to assist. Fires that are left to burn are the exception rather than the rule, and this is only where weather conditions are such that the fire presents a minimal risk of continuing or where the terrain or remoteness of location dictates that suppression is not feasible.

Visual assessment of fire boundaries from helicopters is also used for recording onto topographic maps, although ArcPad and Map Master software packages may be used from the air to allow for transferring digitised boundaries into an ArcView GIS system. The accuracy of this fire boundary mapping is high, with boundaries being mapped to within tens of metres.

Vegetation information is not recorded, nor fire attributes other than likelihood of spread. Once reported, the status of the fire is monitored if immediate suppression activities are not called for. Monitoring can be via satellite imagery, where available, or periodic aircraft flights.

Reporting of fire incidents can be undertaken where required but this is a district responsibility unless part of a specific project and depends on need and special projects being undertaken. Reports are usually in the form of GIS analysis of vegetation types or assets affected with some aerial photo interpretation or ground verification, depending on the nature of the project.

All wildfires reported and/or attended by Parks and Wildlife Service personnel are recorded in the incident management system and situation reports are prepared. These reports do not contain information on fire damage or intensity. There is little information captured on the patchiness of the fire. Where specific projects have been undertaken, information on severity or degree of damage may be collected. That is not typical and is restricted to district level projects. Since 1995 data on pixels burnt, and from them the area burnt, are recorded and held centrally in spreadsheets. A similar procedure is undertaken for prescribed burning. Prescribed burns are not as consistently reported. Currently, situation reports for about two-thirds of all prescribed burns are included in central records.

All regions maintain their own management information and have GIS systems that contain vegetation cover and strategic fire management zones, where these have been determined. Fire history data held at district levels varies in terms of period for which data has been collected or mapped; this may go back several decades for some areas while in others data from recent fires is all that is available. It may also contain information on fuel loads. This is not assessed in a standardised manner and is collected when required at the district level and depends on local focuses and needs. Most fuel load data is collected as part of the process of determining the need for prescribed burning at a local level.

Despite the lack of information on fire attributes that would enable assessment of vegetation impacts, mapping of recent fire histories and comparison with detailed vegetation typing is possible for all land managed by the Parks and Wildlife Service. It requires a project to be initiated to collate all the vegetation information held as regional level GIS cover and comparison with annual fire history mapping which is also held as shape files. Some of the data goes back to the 1940s in some regions but generally most data originates from the mid 1960s. Comprehensive classification of fire events into intensity classes is not, however, achievable because details on patchiness and/or severity of burning are highly variable, although prescribed burning and wildfire are discernible. Analysis of whether or not current fire regimes are within or beyond the ecological tolerance of the community of the historic range of variation would require the development of modelled classification schemes using fire danger ratings and modelled fuel loads, rather than on empirical data.

2. 5 South Australia

Three agencies are involved in fire data collection and analysis in South Australia: the National Parks and Wildlife Service (NPWSSA), ForestrySA and the Country Fire Service.

2.5.1 National Parks and Wildlife Service

Records of most fire reports from 1975 to 2001 for the South Australian reserve system and adjacent lands are recorded in FIRESTATS, an oracle-based database. An Oracle database with a web interface accessible only within the agency has been in use since 2001. This database is still being developed and the earlier data will eventually be included.

Developing the new database was a cooperative effort between the NPWS and the Department of Transport, Urban Planning and Arts (DTUPA). These two departments work closely on fire history mapping in South Australia's reserve system. The Geographical Analysis and Research Unit of DTUPA is responsible for much of the data storage, integration and analysis for the NPWSSA, including fire history data.

This dataset provides fire scar mapping for most major fires that have occurred within South Australia's reserve system, providing aerial photographs are available. The areas burned are digitised from false colour infra-red aerial photographs at 1:40 000 scale, which is considered appropriate for medium to large fires. This mapping relies on distinguishing the burnt edge on the false colour infra-red aerial photograph. That often

involves subjective analysis and in some areas may be an estimate, such as where there has been low intensity burning. Positional accuracy is about 50 metres for the larger fires.

Data collection began in January 1987 and is now part of a programme whereby false colour infra-red aerial photographs of each National Park are taken at the end of every fire season and the burned areas detected are then digitised. Prior to 1987, fire information was in the form of written fire reports. Data is stored as ArcInfo digital cover and paper maps. Digital data is only available for the Adelaide Hills, Flinders Ranges, Kangaroo Island, Ngarkat and Billiat National Parks. However, the programme is to be expanded and by storing it as ArcInfo shape files it can be overlain with state-wide vegetation cover.

Supporting this dataset is the Protected Area Management System (PAMS) database that contains information for individual reserves and text information about fires in particular reserves. This information does not currently include digitised maps for wildfires or planned fuel reduction or ecological burning activities.

2.5.2 Country Fire Service

The Country Fire Service SA (CFS) is responsible for all fires on private land. The CFS reports by two areas: the metropolitan area, encompassing Adelaide and other major metropolitan areas; the country area, which encompasses the rest of the state. There are different code numbers so that fires in these areas can be distinguished. Only country area fires are relevant to vegetation management.

The CFS uses the FIRS system purchased from the Victorian Country Fire Authority for reporting and data storage. The same reporting regime, methods, data fields and attributes are used. For assessing vegetation impacts, the same issues with this database apply as in Victoria.

There is no pre-incident reporting or data gathering and no data collected as to planned fire burns. However, post fire validation is practised and area estimates of fires collected by GPS and topographic map referral methods are made by brigade staff. The vegetation classification used is the same as that used by the Tasmania Rural Fire and the Victorian Country Fire Authority, as per the Australian standard (ASO 2577). However, there is no break down of the different types burnt by the fire but rather the vegetation burnt is largely described by dominant type**.** Also, there is no data collected as to vegetation damage indices. Currently the system is not GIS supported but non-digitised map information is held in archived hardcopy fire incident reports. There is also no follow up API work as per FIRESTATS.

2.5.3 ForestrySA

ForestrySA holds data on fires on state forests, which includes commercial plantations and native forest associated with the plantations. The native forest is managed by ForestrySA for conservation purposes. Most of the information for plantations is in spreadsheets with dates, logistic information and area burnt being given to the CFS. Except for burning plantation debris after harvesting, ForestrySA does not use

prescribed burning because the main plantation species, *Pinus radiata*, is killed by fire. The use of prescribed burning was expected to change with the introduction of native forest management plans (see below).

Most information on wildfire in plantations is held at the regional level, although centralisation of fire incident reports is in progress. These are mostly in the form of hardcopy reports with summary spreadsheets for individual fire seasons being prepared for annual reporting in the context of impacts on future yield calculations. These spreadsheets summarise the number of fires, the area burnt, and the fire danger rating on the day.

The area burnt by wildfires may in some instances be calculated by GPS and topographic methods. Aerial photography may be undertaken for larger fires, such as that for Ash Wednesday in 1983, and GIS cover constructed to assess the effects on future timber yields. Consequently, there is no information collected with regard to damage indices. The areas burnt by wildfire are estimated by field staff by ground checking, using compartment maps. This is practical because most of the plantation fires are small – less than 5 hectares. The other information held within the fire reports is mainly logistical, although date, fuel type in the area and the fire danger rating on the day is reported.

There is a research programme into fire management for native forests. This is for the purposes of formulating and implementing native forest management plans. Most of the native forest consists of remnant blocks or habitat buffers in or around plantations. Where vegetation typing from fire incident reporting has been included in GIS analysis for native vegetation, it is in accordance with the Australian Standard 2482 (Standards Australia 1989). The vegetation classification used in fire incident reporting for native forests in state forest is:

60010 Natural vegetation – general
60011 Shrubland
60030 Forest dense
60040 Forest medium
60050 Forest scattered
60051 Trees scattered
60060 Scrub dense
60070 Scrub medium
60080 Scrub scattered
60090 Mangrove
60100 Grassland
60160 Revegetated area
65010 Pine plantation
65011 Hardwood plantation

Datasets other than that from fire incident reports are also used for developing conservation management plans for remnant forest blocks. This includes data from the South Australian Biological Survey and local native vegetation mapping projects. Data on unplanned fire extent and intensity (eg crown fires), past fuel reduction burning and changes in vegetation attributes are being collected and collated from these sources, as well as from oblique aerial photography and remote sensing. Information will be used to construct GIS overlays for fire extent, intensity and more refined vegetation classifications.

2.6 Western Australia

Two main agencies in Western Australia are responsible for collecting fire information: the Department of Conservation and Land Management (CALM) and the Fire Emergency Service Authority of Western Australia (FESA). FESA incorporates the Fire Emergency Service and Rural Bushfire brigades. DOLA also collects fire information via its role in collecting satellite imagery data for mapping.

2.6.1 Department of Conservation and Land Management

CALM manages all public land in Western Australia. Information on planned and unplanned fires is collected from a variety of sources. This information is incorporated into the FIRE SYSTEM, an oracle database viewed through a web viewer interface. Reporting is centralised to encourage consistency. Planned and unplanned fires are reported against vegetation type. Vegetation types are at the formation level (that is, jarrah, karri, karri/tingle and mixed communities). Information on fire history with varying degrees of consistency can be provided back to 1937. Information on fire damage indices on native vegetation is not entered into the FIRE SYSTEM nor collected as part of routine fire reporting. However, particular research projects provide a solid understanding of typical fuel loads and the nature, behaviour and responses of fire to vegetation attributes in south west Australian forests (Gill et al 1997).

The FIRE SYSTEM is GIS supported, using ArcView and ArcInfo systems. Fire area is calculated manually by aerial photograph interpretation for medium to larger fires. The area of smaller fires is often estimated on the ground and/or from topographic maps. Data for larger fires provided by the Department of Land and Administration Remote Sensing Unit, as part of its Fire Scar mapping project, is used by CALM to give the area and daily rate of spread of unplanned and planned fires in non-forest and woodland environments. In the North Western and Goldfields regions of Western Australia the scale of planned fires is tens of thousands of hectares per year. That includes the traditional burning practices of communities as well as that of government agencies.

CALM considers that information from its planned and unplanned fire reporting systems is accurate compared with other states but recognises the inherent flaws related to DOLA satellite collection methods for larger fires and fire scar mapping (this is discussed below). However, new satellites technologies becoming available (eg the Terra satellite systems) are expected to give much finer resolutions than the current NOAA systems.

CALM also maintains datasets from particular projects with regard to fire management. These include data on prescribed burning in karri regrowth stands, fire history data for jarrah forests based on records of fire scars on Balga grasstrees and fire histories for particular national parks such as John Forrest and Yalgorup National Parks.

For prescribed burning of karri regrowth stands, the database contains information about fuel characteristics (ie fuel accumulation and fuel moisture contents), fire behaviour and fire impacts on tree growth, bark thickness and incidence of stem damage in young even-aged karri regrowth stands following prescribed burning. Data was collected from January 1983 to December 1995 and is stored in spreadsheets. Data has also been collected with regard to the effects of fire regimes on soil organic matter in jarrah and karri forests. These later two studies may be useful as case studies for future modelling work on the effects of fire.

2.6.2 Department of Land and Administration

A two year project was conducted to map fire scars throughout Australia from 1998 to 2000 using NOAA polar-orbiting satellites with thermal sensors at a 1 km^2 ground resolution. Although data has been collected for all of Australia, fire scar mapping and analysis has only been undertaken for Western Australia, the Northern Territory, and the tropical savanna region of northern Queensland (Munro et al 2005). The NOAA meta-data is held by the Commonwealth.

NOAA provides data on fire hotspots three times a day. However, mapping is on the basis of four pixels giving a unit size of 4 km^2. To collect data at lower resolutions is not considered practical due to the levels of noise in the system and the ability of the thermal sensors to detect heat signatures. This means that only large fires can be identified. There are also inherent problems in data capture under forest canopies and periods of high cloud cover. More effective satellite and thermal technologies, such as MODIS and Landsat high resolution imagery, have recently become available.

2.6.3 Fire and Emergency Services Authority of Western Australia

FESA includes the Bush Fire Service of Western Australia and uses the FIRS system from the Victorian Country Fire Authority for reporting and data storage. The same reporting regime, methods, data fields and attributes are used. For assessing vegetation impacts, the same issues with this database apply as in Victoria. There is no pre-incident reporting or data gathering and no data collected on planned fires. When FESA staff are notified of a fire and this turns out to be a planned fire, it is recorded as a false alarm.

Wildfires are reported by area and vegetation type. Fire area is often based on ground estimate, rather than mapping or GPS verification. The system is not supported by GIS. The vegetation classification system used is the same as that for AIRS and FIRS for the Tasmania Rural Fire Service and the Victorian Country Fire Authority, as per the Australian standard (ASO 2577). The data submitted are often estimates.

2.7 Queensland

Queensland has three main agencies with a major role in bushfire management or suppression and data collection. These are the Queensland Parks and Wildlife Service (QPWS), the Department of Primary Industries – Forestry (DPI Forestry) and the Department of Emergency Services (DES).

QPWS is responsible for the management of a large proportion of native forest in Queensland including national parks, state forests and timber reserves. The total area is over 12 million ha. This includes freehold and reserves held in trust by QPWS for administrative purposes and land (freehold and other) awaiting dedication as protected area under the *Nature Conservation Act 1992*.

DPI Forestry is responsible for state forest managed for commercial uses. This forest is mainly plantations and associated native forest buffers.

The Department of Natural Resources and Mines, Department of Main Roads and Queensland Rail have fire management responsibility for almost 2 million ha, 204 000 ha and 33 663 ha respectively.

The Department of Emergency Services, through Queensland Fire and Rescue Service (QFRS), is responsible for fire prevention on all other lands and also takes the lead role, under the *Queensland Fire and Rescue Service Act 1990*, for wildfire suppression. Fire management focuses on prevention, resulting in widespread and extensive prescribed burning for fuel and hazard reduction. For suppression and strategic fire management across the state the DES, through QFRS and in particular the Rural Fire Brigades, is the lead agency. An inter-departmental committee has a coordinating role.

2.7.1 Queensland Parks and Wildlife Service

QPWS is responsible for the dedicated lands (parks and forests) under the *Nature Conservation Act 1992* and *Forestry Act 1959*. The basic fire management strategy is to reduce risk and maintain biodiversity by planned burning. Much of Queensland's public forested land managed under the *Forestry Act 1959* has been leased for grazing – approximately 4.2 million ha at March 2005. Leaseholders commonly use fire to encourage grass regeneration and to open woodlands for grazing. There has been some reporting or collection of data on impacts of this practise.

A NOAA satellite that senses infra-red radiation is used to find larger wildfires. It often provides the first indication of some fires in remote locations and helps to assess the scale and, over time, the movement of some of the larger fires.

Following particular fire events, the satellite imagery for the area in question can provide some fire scar mapping which helps identify the size and scale of the fire. To provide more refined data, the project under way in Cape York under the auspices of the Cape York Development Council has been expanded in collaboration with the Savanna CRC to cover larger areas of northern Queensland and has the potential to cover the rest of tropical Australia. The project combines NOAA satellite methods with Landsat 7 satellite imagery, which has a ground resolution of 25 metres. This higher resolution, satellite-data gathering technology, although more expensive, is used to collect fire data from areas identified as being of interest from NOAA imagery. The Landsat 7 return time is 16 days, compared with twice daily for the NOAA satellite. Dense cloud cover affects both methods. Landsat 7 high resolution imagery is used to provide monthly summaries rather than for daily fire monitoring for suppression purposes. It can also be used to identify potential improvements to fire management practices to reduce environmental impacts.

Landsat 7 may miss small, low-intensity fires that burn out or are suppressed quickly where an unburnt closed canopy remains. However, that is less likely than for the NOAA hot spot monitoring. Comparison between NOAA data and Landsat 7 data has shown that for Cape York NOAA hot spot monitoring only captures 30% of the fires seen from Landsat 7 imagery. This is due to the time of the pass and the scale of sensing. No comparison has been made with yearly or seasonal NOAA derived fire scar mapping undertaken for the Northern Territory and Western Australia.

QPWS Fire Information System collects and maintains data at the management centre level that does not depend on satellite imagery. This information is collected when needed in a reporting system and includes information about planned burning and unplanned fires. This reporting system provides location (textual/spatial), descriptor, burn type, severity, extent, status, detection/ignition date, values (natural and cultural resources, production values, etc) enhanced and threatened, wildfire control strategy, primary responsibility, resources, wildfire origin, wildfire cause, property damage, injuries, incident management team establishment, cross tenure movement, remedial actions identified, date fire out, etc.. Advice on each fire is entered initially from each management centre onto a web-based system (Fire Advice Web, which does not have spatial data) to keep all levels of management informed of current fire activity.

ParkInfo (based on ArcView), introduced in 2004, enables entry of the data for each planned and unplanned fire into a spatial database at each QPWS management centre. The information is collated for each district, region and state wide at least twice a year. The spatial information includes digitising the boundaries of new and past fires together with input from GPS and other methods such as satellite imagery that can provide a relevant shape file.

This mapping of fire boundaries for fire reports is done by a number of methods, including marking boundaries onto maps from the ground or the air, often with GPS recordings being taken. This system is well underway to providing comprehensive fire history data to cover all areas managed by QPWS.

Some fire history datasets covering national parks and state forests were compiled for the Fraser Island planning process, Regional Forest Agreement processes for south east Queensland and the southern brigalow bioregions (‘Western Hardwoods Region’) and individual datasets for particular park and forest areas. Four are of regional extent and are restricted to the southern brigalow and south east Queensland bioregions. These datasets, when combined, give comprehensive fire history mapping for public lands in the bioregions, and may include data and maps for some fires on private land. All other digital datasets held by the QPWS encompass information from individual aggregations of parks and forest managed by the agency.

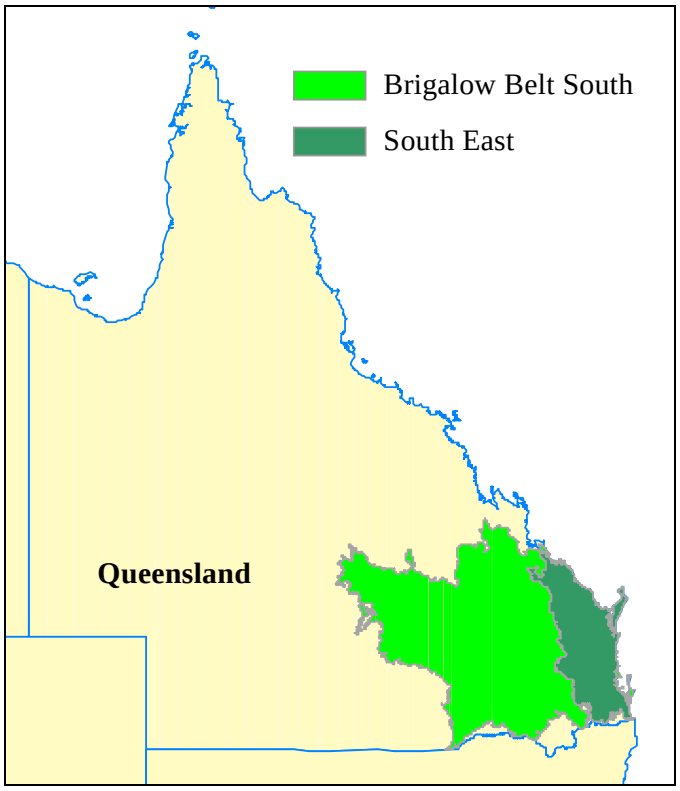

Figure 1: Southern brigalow belt bioregion and south east Queensland bioregion:

2.7.2 Department of Primary Industries

DPI Forestry is a commercial arm of government focused on operations in plantation areas. It uses fuel reduction burning in and around plantations. Although there is no centralised fire incident reporting system, DPI Forestry districts maintain written fire incident reports and there is a centralised register of all significant fire reports. Significance is assessed by suppression costs and resource losses as detailed on the wildfire data forms. This register is not supported by GIS.

The reporting method is specified in a manual that details what attributes are to be reported. The attributes recorded include data on fire and weather condition, such as temperature, wind direction and speed, and drought index and fire danger rating. Available fuel, average flame height, rate of fire spread and an estimate of spotting distance are collected if it is safe to do so.

Other information that may be collected includes a percentage estimate of scorch class (nil, moderate and severe). The ignition cause and area burnt are also recorded and divided into the forestry tenure and other areas burnt. For the forestry area, forest type and dominant species are noted on the Wild Fire Data Form. The codes and descriptions used are in Table 2.

Table 2: Queensland DPI Forestry, fire incident report vegetation codes and descriptions

Forest type	Species code	Description
NF	BP	Bunya pine – native forest
NP	BP	Bunya pine – native plantation
NF	HP	Hoop pine – native forest
NP	HP	Hoop pine – native plantation
NF	WSC	Wet sclerophyll – native forest
NF	DSC	Dry sclerophyll – native forest
NF	CP	Cypress pine – native forest
NF	RFT	Rainforest – native forest
NF	WLM	Wallum – native forest
NF	OTH	Other – native forest
NP	OTH	Other – native plantation
XP	OTH	Other – exotic plantation
NP	PHD	Hardwood – native plantation
XP	PCB	Caribbean pine (var. Bahamensis) – exotic plantation
XP	PCC	Caribbean pine (var. caribaea) – exotic plantation
XP	PCH	Caribbean pine (var. Hondurensis) – exotic plantation
XP	PEE	Slash pine – exotic plantation
XP	PTP	Patula pine – exotic plantation
XP	RDP	Monterey pine – exotic plantation
XP	LGP	Loblolly pine – exotic plantation

Fires are classified as:

1. very minor, where suppression cost is below $2000 and less than 20 m^3 is burnt
2. minor, where suppression cost is between $2000 and $20 000, and the resource loss is less than 250 m^3 or less than 0.2 ha of plantation
3. moderate, where suppression cost is between $20 000 and $75 000
4. major, where suppression cost is greater than $75 000 and resource loss is greater than 250 m^3.

Subsequent reporting depends on the class of fire. For very minor and minor fires, the wildfire data form and attached maps are submitted to the district manager for district records. For moderate fires the data forms, maps and reports with recommendations are submitted to regional managers for regional level records. Data, maps and reports on major fires are submitted to head office. It is not always practical to complete all fields on the report forms, especially for flame heights and rates of spread. A system ('Wildfire Database') for reporting regional fire summary statistics to a centralised register is in place.

2.7.3 Queensland Fire and Rescue Service

Queensland's Fire and Rescue Service (FRS) is responsible for fire prevention and suppression for freehold, leasehold, and crown land not managed by the other agencies. For many areas, it exercises this responsibility through the fire permit system and negotiation and cooperation with rural stakeholders. The service issues permits to conduct prescribed burns throughout 85% of Queensland and coordinates approximately 1600 volunteer rural brigades. The permits are issued by 2500 volunteer fire wardens who are responsible for specific areas.

FRS has a fire incident reporting and data gathering process for fire events. This is a scaled down version of the AIRS. The data gathered is not as comprehensive and, as with the other rural fire services, data collection and completion of forms is the responsibility of individual brigades. Planned and unplanned fires that a brigade attends are reported.

The information reported and submitted to the central AIRS database varies depending on the brigade. There is no checking on information that may be collected at the brigade level and not reported. Fire severity or intensity and fire weather attributes are not usually reported. The most consistently and commonly reported fields are location, type of fire (eg grass or scrub), area burned and date. The area burnt may be approximate and not based on mapped boundaries.

There is no reporting system for the widespread prescribed burning practiced by leaseholders and private landholders or unplanned fires that may be suppressed by leaseholders and private landholders. FRS does, however, receive satellite data collected by the Department of Natural Resources which it uses to alert individual brigades and uses for some specific GIS and/or fire history mapping projects. These do not enable assessment of vegetation impacts.

2.8 Northern Territory

2.8.1 Northern Territory Parks and Wildlife Commission

The Northern Territory Parks and Wildlife Commission (PWC), the lead agency for fire data collection in the Northern Territory, incorporates the Tropical Savanna Cooperative Research Centre and the Northern Territory Bushfire Council. The Northern Territory Fire Service is responsible for the greater Darwin metropolitan area. The rural fire brigades do not collect fire data.

PWC has limited resources and very large areas to manage and therefore relies primarily on NOAA data from DOLA, Western Australian for fire monitoring, research and management decision making and fire scar mapping. This information is based on the 'best pass' every nine days and monthly summaries, so that small and large fires may be missed or not reported. To minimise that and to provide more detailed and higher resolution data for specific projects and programmes, the PWC also obtains data from the ACRES Quicklook web site which displays available images from Landsat 7. PWC also purchases Landsat 7 high resolution images every three to four months for fire scar mapping.

Landsat 7 satellite high resolution images have a much higher level of resolution than NOAA satellite images. The former can be used to detect fire scars and fires less than 100 metres in size under good or better conditions. However, Landsat 7 passes over the Northern Territory every 16 days rather than daily for the NOAA satellite. Landsat 7 also has problems capturing data in the cloudy conditions that are typical for particular regions within the northern Australia, such as much of the Cape York area.

The satellite remote sensed data collected and collated by the PWC into one month fire map summaries is distributed to national park managers in the Northern Territory for local fire monitoring, particular research projects and/or management decision making. These fire maps can be at various scales depending on the satellite from which the data is obtained.

Another source of data relevant to the agreed indicators is the FirePlot long-term monitoring programme that can be used to model forest and woodland community responses to past, current and/or changed fire regimes. This programme, initially confined to Kakadu National Park, has been extended to the Litchfield, Nitmiluk and Gregory National Parks. It consists of 131 plots in Kakadu NP, 41 plots in Litchfield NP, 47 in Nitmiluk NP and 50 plots in Gregory NP. These are surveyed every five years for fauna and flora attributes as well as for soils, geology, slope and aspect, and fire history information. Plots are 40 m x 20 m in size and cover 37 land system classes.

Data from this long-term monitoring programme will be used to model ecosystem responses to varying fire regimes within national parks. It will be assessed against a range of spatial datasets, such as those from Landsat and NOAA fire scar mapping to indicate future biological trends as well as that from aerial transects in which the status of vegetation is recorded at specific locations. At each location, the vegetation is recorded as unburnt, fully burnt within a radius of 100 m, or partially burnt (< 20% burnt within 100 m).

The Northern Territory is well placed to provide information on fire impacts on vegetation with regard to fire histories if the fire scar mapping is maintained. From the fire plot dataset and location transects, the PWC will also be able to give an indication of the ecological tolerances of the communities captured by the fire plots. However, currently only data from the mid 1990s is available. Unlike the southern states, burning is widespread and tens thousands of hectares are burned over a period of weeks. Small isolated fires and closed canopy communities are only a small proportion of the total area burnt.

2.9 Australian Capital Territory

2.9.1 A.C.T. Emergency Services Authority

The A.C.T. Emergency Services Authority (ESA), through A.C.T. Bush Fire and Emergency Services, is responsible for the Strategic Bushfire Management Plan for the Australian Capital Territory. The plan includes a programme of fuel reduction burning and organisation or suppression activities. ESA is required to 'monitor the scope and effectiveness of the Strategic Bushfire Management Plan'. This requires an audit or review of process, outputs and outcomes defined by the plan and monitoring of the plan itself. The plan does not explain how that monitoring is to be undertaken or the nature of the data that would be collected to support that monitoring.

2.9.2 A.C.T. Rural Fire Service

The ACT Rural Fire Service (RFS) is responsible for fire prevention and suppression in rural areas of the Australian Capital Territory. RFS has 11 brigades including Parks Rural Fire Brigade, which is manned by the ACT Parks and Conservation Service and is responsible for fire prevention and suppression for nature conservation reserves, and Forests Rural Fire Brigade, which is manned by ACT Forests and is responsible for fire prevention and suppression for pine plantations.

The RFS records information on fires attended by RFS brigades. The information includes locality, approximate extent and, where submitted by the brigade, whether the vegetation burned was grass, native forest or pine plantation. With the exception of major fires such as in January 2003, the fires are not mapped.

3. Discussion and conclusions

3.1 Importance of fire monitoring and reporting

Many Australian native plant and indirectly, animal species, rely on particular fire regimes. That is, the periodicity, season and intensity of fire events, to maintain their relative positions of dominance or abundance within forest and vegetation communities. Across the continent fire regimes vary considerably in response to bio-climatic variables and in many instances have changed, with resultant changes in structure and floristics.

At the continental scale the impact of changes to fire regimes on the health and vitality of Australian forest and vegetation is often poorly understood. Although in-depth and long-term studies have been undertaken and have identified potential impacts from changes to fire regimes at the stratal and dominant species levels, these are few in number. These studies are also not comprehensive in terms of identifying the responses of all of the dominant species that may determine the classification of forest and vegetation communities.

Given this complexity, meaningful monitoring and reporting to meet policy requirements at the national level against the agreed indicators requires data not only as to the area burnt and the intensity of burning, but also requires the data to be in spatial context so that frequency of fire events or the interval between them can be determined.

Without such information meaningful assessment of whether or not current fire regimes, planned and unplanned, are within the range of historical variation and the ecological tolerance of forest communities at the landscape level cannot be undertaken.

3.2 Monitoring and reporting systems

Primary responsibility in Australia for monitoring and reporting of fire statistics lies with the of State and Territory government agencies. Currently there are 20 agencies around Australia responsible for fire management. These often have quite distinct and different management objectives depending on the land to be managed and the availability of resources. This affects the nature of the data that is collected in terms of quality and attributes measured. Generally, those agencies that have a fire management responsibility on private land are primarily focused on fire prevention for protection of life and property. Consequently the data recorded is focused on equipment used, area burnt and property damage. In many cases attributes such as the vegetation type burnt and severity of the fire are seldom recorded, and in most instances there is little accurate spatial data available for fire history mapping to determine past and current fire regimes. The detail at which data is recorded and the accuracy and reliability of area burnt estimates on private tenure are also highly variable, although all of the main private tenure agencies use similar reporting systems.

In contrast, agencies responsible for public land often have widely disparate, multiple objectives to manage. As a result, more detailed and extensive information with regard to the agreed indicators is often recorded. There are however, considerable differences in how the data is stored and collated. Although several of the public tenure land management agencies involved in fire management have detailed ongoing vegetation data collection and fire history mapping programmes in place, for others the data within fire incident reporting records have not been collated to a sufficient degree for Montreal Process reporting. There are also major differences between agencies in what is recorded. This is particularly so with regard to vegetation typing and severity of fire events.

Consequently, with the exception of forested areas on public tenure in Tasmania and southern Western Australia, there is little or no information comprehensively collected on fire intensity or damage to native vegetation, even though fire history mapping programmes may be in place. Importantly, most fire history mapping that has been undertaken is not up-to-date and/or only covers a period of a few years or specific target areas. For all agencies the vegetation type burnt by both planned and unplanned fires is not recorded within fire incident reports at the level of detail required for assessing impacts on forest and vegetation health/condition and vitality. Information on vegetation extent and type at the appropriate level can, however, be obtained from other datasets, for example, State and Territory NVIS datasets.

Although all fire management agencies can provide an estimate of the area of forest and vegetation burnt for particular years or periods, on the basis of current reporting methodologies and existing spatial datasets, meaningful reporting can only be achieved at the subregional level for specific areas and tenures. These include national parks and state forests in south west Western Australia and Tasmania, and public land in South Australia and Victoria and national parks. In New South Wales significant effort would

be required to collate fire datasets and conduct spatial comparisons with vegetation cover. There is also potentially enough collated information to carry out similar work in the southern brigalow and south east Queensland bioregions although fire history mapping is not up to date. For all of these areas, other than south west Western Australia and Tasmanian public land, identification of historical fire regimes and classification of recent fire events into intensity classes would require the development of models based on fire danger ratings or recorded fire weather and assumed fuel loads. Larger scale and accurate fire data is also available for most of Western Australia and the Northern Territory as a result of satellite fire monitoring and fire scar mapping programmes. This does not, however, capture data on small low intensity fire events that can make up a major component of the total area burnt in any one season and only covers the last few years.

Currently, no State or Territory agency can report immediately to provide an up-to-date, comprehensive and meaningful analysis of fire impacts on vegetation. This is primarily due to meaningful reporting requiring comparisons of current fire regimes, including classification of fires by intensity within major forest and vegetation types, to the historical range of variation and identified ecological tolerance of the community. The ecological tolerances of the vegetation communities is often not known in any detail, there is little intensity or damage data collected and identification of the historical range of variation is minimal at the national levels.

Several of the public land management agencies do have sufficient data and understanding of the fire ecology of many of the major forest and vegetation communities to conduct the analyses required to report for the majority of their forests and vegetation in the near future. These agencies are CALM in Western Australia for the southern forests, The Tasmanian Parks and Wildlife Service and Forestry Tasmania. With commitment of resources, other agencies can conduct programmes of data collation, digitising and analysis that will allow for meaningful reporting in the near future, although this will require the development of models to classify past fires by intensity or severity. These agencies are the South Australian National Parks and Wildlife Service, ForestrySA, the Victorian Department of Natural Resources and Environment, State Forests NSW, the NSW Parks and Wildlife Service and the Queensland Parks and Wildlife Service.

The resources needed to collate existing data and digitise it for the required spatial analysis will, however, vary and time frames for such work vary from months to years depending on the agency. Given that each of the major fire management agencies in all states and territories will require the dedication of specific project teams to carry out the work, expenditure to achieve the goal of providing up-to-date and meaningful data for reporting against the agreed indicators would nationally be in excess of several million dollars over a minimum period of two years. Development of modelled ecological tolerances for numerous major forest and vegetation communities will also be required if meaningful sustainability assessments are to be made. The latter can be achieved on the basis of the extensive body of research that has already been undertaken for many of the forest and vegetation types, but would also require extensive funding support.

For private tenures the amount of work to be undertaken required in terms of collation, and digitising is far greater, and estimates are likely to be indicative only rather than accurate representations of past fire extent and vegetation burnt. For northern western Australia, the Northern Territory and Queensland, there is sufficient satellite data collection and fire history mapping to report large-scale fires on both private and public tenures over the last couple of years.

The issue for the agencies responsible for fire reporting in Queensland and the Northern Territory is the remoteness of many of the fires, the limited resources available and the consequent reliance on satellite data collection with minimal API and/or ground verification or follow up fire incident report data collection. Although new and combined satellite data collection methodologies are being tried, the inability to include most small, low intensity fires under cloud or closed canopies into area estimates or for fire history mapping and determination of current fire regimes, is likely to continue. This is due to the major resource commitments required and the ability of the agencies to satisfy these independently.

On the basis of current datasets and in the absence of programmes to update, collate and develop models for fire intensity or severity, meaningful reporting can only be achieved for forests on Tasmanian and Western Australia public land. This is despite the fact that all agencies can provide an estimate of the area burnt each year for the last few years. The inherent accuracy problems in some of the data capture methods and inconsistencies in reporting between agencies, such estimates will vary widely in reliability. For estimation of area burnt, incorporation of current figures for private tenure into total state and national estimates would out-weigh the reliability of estimates from State and Territory agencies that do collect data in a consistent and accurate way as a result of the extent of private and leasehold forests. Therefore, meaningful reporting can only be achieved at either subregional levels in the near future and/or for specific land tenures in specific States.

3.3 Options to ensure national monitoring and reporting in future

A number of cost-effective options are currently available to implement a national coordinated and standardised approach for gathering appropriate fire incidence data, including fire footprint mapping, which would allow for meaningful assessments of the impacts of current fire regimes against the agreed indicators. The most practical of these would be based upon expansion of trial satellite-data gathering programmes to either cover the whole continent or cover those areas for which there is insufficient information and ongoing programmes of data collection. There are advantages and disadvantages with these methodologies, in heavily forested areas, to do with resolution and the ability of thermal sensors to collect information with regard to cool, small fires typical of prescribed burns under canopies and/or dense cloud cover.

Recent technological advances and combined tiered, remote sensing approaches to data collection have the potential to overcome these problems. For example, the newer MODIS satellite thermal remote sensors can potentially be used to identify hot spots more accurately and reliably than the NOAA satellite thermal sensors, given that it uses different and wider bands. This can then be combined with data collected from the Landsat 7 satellite to provide higher resolution spatial data in areas of special interest.

By utilising different satellites, special areas of interest can be identified – such as those areas where a high degree of burning is occurring or where little information is being provided by satellites on a regular basis because of dense cloud or canopy cover. In these areas, targeted API or Lidar data collection can be used to provide highly detailed and accurate data as to fire boundaries, damage indices and community responses.

However, any combination of methods must be undertaken in conjunction with the collation and digitising of existing datasets to provide comprehensive fire history mapping for current reporting needs and as benchmarks for future reporting. This information can then compared with standardised and detailed vegetation typing, such as NVIS, and modelled historical fire regimes for extant forest and vegetation communities to provide sustainability assessments of current fire regimes at the national and regional levels. There is sufficient empirical data and understanding of the ecology of many dominant tree species to begin developing modelled historical fire regimes and to identify the ecological tolerance of forest and vegetation communities to fire disturbance at the NVIS level 5/6. This approach would provide accurate and verifiable reporting for the agreed indicators, allow assessment of the ecological sustainability of current wild fire regimes and prescribed burning practices at the national level, and provide a practical means of ongoing monitoring. It would also provide essential data at a national level that can be used for development of fire related carbon release models and would also be of value to greenhouse gas inventory and abatement programmes.

Abbreviations and glossary

AIRS	Australian Incident Reporting System
API	Air photo interpretation - The examination of photographic images for the purpose of identifying objects and patterns and judging their significance. API may involve mapping the features of interest from a single photo or from two photos (known as a stereo pair), in which case the interpreter has the benefit of seeing the features in three dimensions. API is both an art and a science, and in general the more experienced the interpreter the better the result.
ArcInfo	A comprehensive GIS software package with advanced geoprocessing and data conversion capabilities produced by the Environmental Systems Research Institute, Inc.
ArcPad	A desktop GIS software package produced by the Environmental Systems Research Institute, Inc.
ArcView	A desktop GIS software package produced by the Environmental Systems Research Institute, Inc.
ERMS	Environmental Resource Management System - a desktop GIS software package produced by the NSW National Parks and Wildlife Service in the mid 1990s.
FirePlot	A long-term fire monitoring programme that can be used to model forest and woodland community responses to past, current and/or changed fire regimes.
FIRES	Fire Incident Reporting and Evaluation System
FIRS	Fire and Incident Reporting System
GIS	Geographic Information System
GPS	Global Positioning System
IFIS	Integrated Fires Information System
Lidar	A radar system that operates using visible, near infra-red or ultra-violet light. An acronym for “light detection and ranging. Lidar systems can measure surface material properties as well as deriving accurate DEMs.
Map Master	A desktop software package for mapping boundaries, points and linear features.

Mapinfo	A desktop GIS software package produced by the MapInfo Corporation, Inc.
MODIS	Moderate Resolution Imaging Spectroradiometer.
NOAA	National Oceanic and Atmospheric Administration
NVIS	National Vegetation Information System
ParkInfo	ParkInfo an information system that is based on ArcView developed and used by the Queensland parks and Wildlife service. ParkInfo enables entry of the data for each planned and unplanned fire into a spatial database.

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Appendix 1: National Forest Inventory forest classes and areas (hectares) by State

Forest type	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
1. *Acacia* low woodland forest			2,001,370	2,891,234	1,078,636		37,500	3,985,493
2. *Acacia* medium woodland forest			129,032	1,308,342	276,688	50,734		
3. *Acacia* tall woodland forest				242,593				
4. *Acacia* low open forest			525,494	275,023	470,966		200	100
5. *Acacia* medium open forest		12,403	856,905	2,409,843	7	22,026	25,500	
6. *Acacia* tall open forest								
7. *Banksia* low woodland forest				90,714		158		
8. *Callitris* low woodland forest				6,403	109,181	789	7,100	
9. *Callitris* medium woodland forest	461			69,844	137,998		35,600	
10. *Callitris* tall woodland forest								
11. *Callitris* low open forest					1,270			
12. *Callitris* medium open forest	24	261,199		310,333			7,600	
13. *Callitris* tall open forest								16,000
14. *Casuarina* low woodland forest					1,863	1,387	3,800	24,400
15. *Casuarina* medium woodland forest	18			2,289	25			
16. *Casuarina* tall woodland forest				173				
17. *Casuarina* low open forest		7		188	726,234			
18. *Casuarina* medium open forest	308	45,678		137,520				
19. *Casuarina* tall open forest								
20. Eucalypt mallee low woodland forest		9,211			4,430,258		1,040,300	3,918,305
21. Eucalypt mallee medium woodland forest				126,923	410,442		4,200	
22. Eucalypt mallee tall woodland forest								
23. Eucalypt mallee low open forest		8,058			1,268,068			1,055,086
24. Eucalypt mallee medium open forest		3,085,131			974			

Forest type	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
25. Eucalypt mallee tall open forest								
26. Eucalypt low woodland forest	3,171	114,009	6,715,490	1,676,253	1,206,077	61,934	209,400	3,431,072
27. Eucalypt medium woodland forest	18,304	10,266,955	16,432,307	25,528,832	582,063	1,258,672	721,200	19,038,176
28. Eucalypt tall woodland forest		91,474		1,012,239		2,75,185	114,300	
29. Eucalypt low open forest	4,905	72,039	8,286	112,362			225,100	
30. Eucalypt medium open forest	65,437	8,021,344	5,684,513	3,260,798	43,179	6,890	2,761,600	1,776,913
31. Eucalypt tall open forest	28,787	3,854,838		60,787	909	840,014	2,281,900	170,921
32. *Leptospermum* low open forest	82					18,827	9,100	
33. *Leptospermum* medium open forest								
34. *Leptospermum* tall open forest								
35. Mangroves low open forest/woodland					314			
36. Mangroves medium open forest								
37. Mangroves low closed forest								
38. Mangroves medium closed forest		3,121	445,489	153,502	19,711		2,600	172,880
39. *Melaleuca* low woodland forest			977,501	1,805,485	825		80,600	155,056
40. *Melaleuca* medium woodland forest			301,668	34,130				
41. *Melaleuca* tall woodland forest				4,549				
42. *Melaleuca* low open forest			756	12,494	181	579	9,400	
43. *Melaleuca* medium open forest		44,411	427,607	236,979				
44. *Melaleuca* tall open forest								
45. Mixed species low woodland forest				606,921	16.606			
46. Mixed species medium woodland forest			55,177	389,947	891			
47. Mixed species tall woodland forest				33				
48. Mixed species low open forest				91,634	902			
49. Mixed species medium open forest				280,029				
50. Mixed species tall open forest				163,014				

Forest type	ACT	NSW	NT	Qld	SA	Tas	Vic	WA
51. Other low woodland forest					4,435		2,600	397,561
52. Other medium woodland forest		10,380					400	650,783
53. Other tall woodland forest								
54. Other low open forest		20,238				286	119,000	
55. Other medium open forest		316,446					800	
56. Other tall open forest		16,038						
57. Rainforest low closed forest				308,635		539		
58. Rainforest medium closed forest		467,236	317,835	1,084,782		406,748	15,900	6,798
59. Rainforest tall closed forest				1,532,888		190,018		
60. Plantation hardwood	33	44,451			527	84,979	10,600	152,800
61. Plantation softwood	19,536	246,934	4,298		51,424	70,994	234,600	94,500
62. Plantation unknown								
63. Non-forest	94,856	347,305	99,514,812	34,232,296	71,009,896	3,499,286	14,724,600	217,503,155
64. No data — spatial		5,981,744	419,423		1,608,558	19,756	55,900	
No data	4,078	46,797,684		92,259,989	14,940,892		18,600	
Total forest	121,497	26,741,882	34,879,431	46,227,715	10,788,704	3,134,787	7,715,700	34,799,545
Total area of State or Territory	235,922	33,362,316	134,817,963	172,720,000	98,400,000	6,808,000	22,760,00	252,550,000

Source: NFI (2001)

Appendix 2: Queensland Parks and Wildlife fire history datasets

Control burn history database of southern brigalow bioregion (SSB) forest reservations – FER — Department of Natural Resources and Mines

The control burn database represents boundaries of control burns in native forest reservations of the Southern Brigalow Bioregion under the administration of the Department of Primary Industries – Forestry (DPIF). The control burn boundaries recorded by DPIF show where the control burn was attempted; not all of this area may have been successfully burnt. An estimate of the percentage burnt is included in the attributes as are start dates, spread rate, cost and drought index. The database consists of one ArcView shapefile or several Arcinfo coverages for each year of the fire. Boundaries are primarily from DPIF paper maps for data collected from 1982 to 1998 with additional management unit identification (MUID) boundaries from the Queensland Forestry MUID digital database overlaid. ArcInfo coverages were used from 1992 for some parts of the fire boundaries. The source data was mapped at various scales, but most commonly at 1:25 000 and 1:50 000. Positioning of the fires was initially done manually over a light table using transparent satellite imagery plots with overlaid MUID boundaries. Data was then entered into ArcInfo.

Another capture method was later developed which was applied in the majority of the data capture process. Scanned images of the fire maps were rectified to the Queensland DPIF MUID digital database using Arcinfo. The data were then digitised on screen with the rectified image displayed behind the fire coverage. Attributes are from DPIF records of fire information.

Wildfire history database of southern brigalow bioregion forest reservations — Department of Natural Resources and Mines

The Wildfire database represents boundaries of unplanned fires in forest reservations of the southern brigalow bioregion managed by DPIF. It consists of polygons and attributes. Attributes include start dates, area burnt, cause, cost and various environmental measurements. The period covered is from December 1964 to February 1998.

Fire boundaries are sourced from DPIF wildfire paper maps. The source data was mapped at various scales from 1:24 000 to 1:100 000, but most commonly at 1:25 000 and 1:50 000 scales. The scale of source wildfire maps are identified within the polygons. Data are entered from maps in the same way as described above. Coverage for each year was entered separately and later merged in ArcView to produce shape files of all fires.

All available paper maps have been captured. It was found at the time of data collection that paper records of unplanned fires prior to 1981 no longer existed for most reservations of the southern brigalow bioregion. Burnt areas less than 10 ha in total area were not intentionally captured, although some may have been digitised coincidentally. Preliminary checking with field-site data indicated that a large proportion of unplanned fires were not being recorded in the wildfire database.

Thus the database does not give a complete picture of wildfire histories of the forestry reservations. This may be largely due to the remoteness of the Southern Brigalow Bioregion forestry reserves, as unplanned fires occur without being recorded or observed. The checking undertaken at this time is only preliminary; further verification was planned.

Forest fire history of south east Queensland — Department of Natural Resources and Mines

This dataset consists of controlled or prescribed burning and wildfire histories delineated as spatial ArcInfo polygon coverages. These were generated from forestry district office records such as reproductions of paper wildfire and prescribed burn forestry maps with line work digitised from existing geo-rectified overlays of tenure boundaries, roads, rivers and other features.

The positional accuracy of these fire history coverages varies, because it depends on data that varies in scale and quality. An accuracy rating has been allocated to each fire where possible, although this too depends on the quality of the data the line work may have captured from roads and rivers and other features.

Most fire records are for state forest areas, although some records have been captured for private land and national estates.

Draft fire history of QPWS protected areas in South East Management Region. (EPA - QNPWS)

An ongoing programme to map the fire histories of prescribed burning and wildfires in QNPWS national parks, conservation parks and other protected areas in south east Queensland is in place. Data from January 1961 was integrated into an ArcInfo database. Data was obtained from QNPWS fire reports for fires since 1984 and from clear overlays onto which fires have been drawn each year, and where these are insufficient, through internal departmental memoranda and local knowledge. Data for fires prior to 1984 are from reports of fire threatening national park reservations.

Typically the boundaries of each fire are marked on clear overlays by local staff after each fire using their knowledge of the fire. Relevant topographic maps and aerial photographs may also be used and boundaries may driven and GPS recordings undertaken to verify the fire boundary. This is not, however, universal and depends upon the circumstances at the time and within the district. The data was then digitised using ArcInfo software.

Lumholtz National Park database

This consists of a GIS mapping database containing a vegetation map as per NVIS and fire history coverages from 1994 to 1997. Data was from departmental vegetation surveys and fire reports. These were digitised onto Environmental Resource Management System (ERMS) and transferred to vector ArcInfo format.

Magnetic Island National Park Database

This consists of a GIS mapping database containing a vegetation map as per NVIS and fire history coverages from 1970 to 1996. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to vector ArcInfo format.

Hinchinbrook Island National Park GIS

This ArcInfo GIS consists of data on vegetation communities as per the NVIS, road and park infrastructure, topography, creeks, fire history and tenure boundaries. The data date from 1991.

Mt Elliot (Bowling Green Bay National Park) database

This consists of a GIS mapping database containing a vegetation map as per NVIS and fire history coverages from 1985 to 1997. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to vector ArcInfo format.

Cape Cleveland (Bowling Green Bay National Park) database

This consists of a GIS mapping database containing a vegetation map as per NVIS and fire history coverages from 1985 to 1996. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to vector ArcInfo format.

Paluma Range National Park database

This consists of a GIS mapping database containing a vegetation map as per NVIS and fire history coverages from 1988 to 1996. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to vector ArcInfo format.

White Mountains National Park database

This consists of a GIS mapping database containing a vegetation map as per the NVIS and fire history coverages from 1990 to 1997. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to vector ArcInfo format.

Edmund Kennedy National Park database

This consists of a GIS mapping database containing a vegetation map as per the NVIS and fire history coverages from 1988 to 1996. Data was from departmental vegetation surveys and fire reports. These were digitised onto ERMS and transferred to ArcInfo.