Tasmanian Wilderness World Heritage Area Bushfire and Climate Change Research Project

A research project to investigate the impact of climate change on bushfire risk to Tasmania's wilderness areas and appropriate management and firefighting responses

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This independent Final Report has been prepared for the Tasmanian Government.

As an independent Chair, I chaired a Steering Committee consisting of the head of agency of the Tasmanian Government Departments of Premier and Cabinet; Primary Industries, Parks, Water and Environment; and Police, Fire and Emergency Management, and the First Assistant Secretary of the Australian Government Department of the Environment and Energy. The Steering Committee was supported by a Technical Working Group with representatives from the Tasmanian Government Departments of Primary Industries, Parks, Water and Environment, and Police, Fire and Emergency Management.

The work of the Chair was supported the Department of Premier and Cabinet's Tasmanian Climate Change Office.

I would like to thank Dr Adrian Pyrke, consultant to the Research Project; and Ms Shona Prior, Ms Jane Colton and staff of the Tasmanian Climate Change Office, for their considerable efforts in compiling and drafting this Report.

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The Research Project has involved extensive engagement with, and input from, a multitude of key stakeholders including the Tasmanian Government and its fire management agencies, the Australian Government, the research community, TWWHA landowners, conservation groups and non-government organisations.

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Responsibility for the content of this Report and its recommendations rests with me.

AJ (Tony) Press

EXECUTIVE SUMMARY

Introduction

The Tasmanian Wilderness World Heritage Area (TWWHA) is one of Tasmania's iconic places. It contains globally significant examples of natural and cultural heritage and is an important natural, cultural, economic and social State asset.

Bushfire has been a natural and persistent phenomenon in the TWWHA for millennia. Prior to European colonisation, Aboriginal people actively used fire to manage vegetation in many parts of the region.

Large, landscape-scale bushfires have been reported as early as the 1850s for parts of the TWWHA. Since the 1930s there have been at least 12 fires in or near the TWWHA that were greater than 20,000 hectares in size.

In January and February 2016, Tasmania recorded thousands of lightning strikes, which started multiple fires in exceptionally dry climatic conditions. From 13 January to 15 March 2016, a total of 145 vegetation fires affected approximately 126,800 hectares across Tasmania, including an estimated 19,800 hectares (around 1.3 per cent) of the TWWHA.

The most significant impact to the natural values in the TWWHA from the 2016 bushfires occurred as a result of the fires in the Lake Mackenzie, February Plains and Lake Bill areas. These fires occurred within the fire-sensitive alpine and subalpine vegetation areas and affected 85 hectares of one of the TWWHA's most significant flora values, the pencil pine. This species is an iconic example of Gondwanic legacy in the TWWHA, which contributes to the property's Outstanding Universal Value. The proportion of pencil pines impacted by the 2016 fires comprised a very small percentage of the total extent of pencil pines in the TWWHA, while the majority of the areas affected were composed of vegetation types and fauna that are adapted or resilient to fire.

The scale of the 2016 bushfires, both in number and geographic extent, presented a particularly complex and resource-intensive fire-management challenge for the TWWHA. The 2016 firefighting response involved an unprecedented effort of more than 5,600 Tasmanian volunteer and career firefighters, 1,000 interstate or overseas firefighters, and as many as 40 aircraft assisting each day during the peak. The cost of the 2016 bushfires has been estimated at $52.6 million[1].

TWWHA Bushfire and Climate Change Research Project

The Tasmanian Government established the TWWHA Bushfire and Climate Change Research Project in March 2016. It committed $250,000 to investigate the impact of climate change on Tasmania's wilderness areas and to identify ways to improve how Tasmania prepares for and responds to bushfires in the TWWHA.

[I] Estimate provided by the Tasmania Fire Service in November 2016.

The objectives of the Research Project (as outlined in the Terms of Reference provided at Attachment 3) are to:

- examine how climate change will affect future fire danger and other variables that may lead to an increased risk of bushfire, and its impacts on the TWWHA;
- provide recommendations on the most appropriate methods for monitoring and recording vegetation dryness levels within the TWWHA; and
- examine firefighting techniques, interventions and resources that can be safely and effectively employed by the Tasmania Parks and Wildlife Service and the Tasmania Fire Service to prepare for, and respond to, bushfires in the TWWHA, including the most appropriate methods to extinguish fire within alpine areas.

The outcomes of the Research Project are to improve understanding of how climate change will impact bushfire risk in the TWWHA; and improve the ability to prepare for, and respond to, bushfires in the TWWHA.

Research undertaken through the Research Project

The Research Project has undertaken a comprehensive review and gap analysis of research and activities relating to bushfires in the TWWHA. This review and gap analysis considered the 'Prevention, Preparedness, Response and Recovery' (PPRR) risk management model. As a result, this Report identifies current operational practice, current work and research underway, and areas for further work or research relating to these broad areas.

High-priority research needs were identified through this review process. A number of these needs were addressed by commissioning new research through this Research Project. This new research examined:

- the history of lightning fires in the TWWHA and adjacent areas (findings of this research are presented in the 'Preparedness' section of the Executive Summary);
- the impact of climate change on weather-related fire risk factors in the TWWHA (findings of this research are presented in the 'Preparedness' section of the Executive Summary); and
- the impact and effectiveness of fire suppression chemicals in the TWWHA (this research continues to be undertaken at the time of publication of this Report).

In addition to these new research projects, two synthesis studies were commissioned to bring together current understanding of bushfire in the TWWHA. These examined the impact of climate change on:

- future fire behaviour in different vegetation types in the TWWHA (results of this research are presented in 'Values in the TWWHA' of the Executive Summary and
- future fire regimes for natural values (results of this research are presented in 'Values in the TWWHA' of the Executive Summary).

The Research Project has been underpinned by extensive engagement with, and input from, a multitude of key stakeholders, including the Tasmanian Government and its fire management agencies, the Australian Government, the research community, TWWHA managers, conservation groups and non-government organisations.

Initiatives undertaken in response to the 2016 bushfires

Following the 2016 bushfires, Tasmanian fire agencies (Tasmania Fire Service, Tasmania Parks and Wildlife Service, and Forestry Tasmania) have undertaken a number of initiatives. These initiatives include commissioning this Research Project, undertaking post-fire surveys of fire-affected areas, establishing monitoring sites, and consulting with the research community to inform responses in key fire-affected areas.

Post-fire data has been incorporated into Tasmania Parks and Wildlife Service's risk assessment models, and mapping of fire boundaries and natural values has been improved. Interested groups and organisations have been consulted in relation to fire preparedness and protection of assets. Scoping of options for increased volunteer support for firefighting efforts has been initiated, and the Tasmania Fire Service has expanded its skills training in remote area firefighting. Lessons from the 2016 bushfires have been incorporated into pre-season briefings for State and regional personnel involved in fire management.

Values in the TWWHA

Overview

The Tasmanian Wilderness is inscribed on the World Heritage List under four criteria for "natural heritage" and three criteria for "cultural heritage".

Identifying and understanding the natural and cultural values of significance in the TWWHA, particularly those that are fire-sensitive, is important because their protection has implications for fire management in the TWWHA. Bushfire presents one of the biggest challenges to managing and protecting the values that are recognised as significant to the TWWHA's World Heritage status. The knowledge and management of buttongrass vegetation is particularly important to the successful management of bushfire risk in the TWWHA. This is because buttongrass is extremely flammable and extensive, and is the main vegetation type targeted for planned burning, yet it has intrinsic natural values that also require protection.

Many of the values can be significantly harmed or lost following a single bushfire or by an unfavourable fire regime. Some species are fire-sensitive, while others may be lost or altered in the complete absence of fire. Maintaining and protecting TWWHA values requires the deliberate application of appropriate fire regimes to some areas, while excluding fire, as far as practical, from other areas.

Report findings

The major impacts projected to occur from climate change are related to increases in vegetation and soil dryness and flammability, as indicated by projections for the Mount Soil Dryness Index and increased dry periods. Increases in soil dryness are likely to be already occurring (ie within the 2010-2030 time period) and manifest as increased occurrence of lightning ignitions and areas

burnt, and increased fire occurrence in organic soils. The upward trend in dryness and flammability is expected to continue.

The values in the TWWHA that are most threatened by an increase in fire frequency are fire-sensitive palaeoendemic species; alpine ecosystems; rainforest ecosystems; and organic soils and landforms.

Fire management arrangements for the TWWHA

The Tasmania Parks and Wildlife Service is the management authority for the TWWHA and meets its responsibility for managing bushfire in the TWWHA through a combination of activities. These activities are guided by the TWWHA Management Plan 2016 and other well-developed policies and plans that cover bushfire prevention, preparedness, response and recovery.

The Australian Government provides the Tasmanian Government with $3.4 million per annum (baseline funding until 2018) to assist with management of the TWWHA under a World Heritage Grants Funding Agreement. The Tasmanian Government contributes a minimum $4.9 million per annum. In 2015, the Australian Government committed to supporting Tasmania to strengthen its management of the TWWHA by providing an additional $10.2 million, over four years from 2014-15, for its protection, conservation, presentation and rehabilitation. Fire management arrangements for the TWWHA sit within the broader context of Tasmania's fire management arrangements.

The Tasmania Fire Service supports and works closely with the Tasmania Parks and Wildlife Service in fire management in the TWWHA, but does not take a direct operational role for response in the TWWHA, except when very large fires occur, fire threatens human settlements or the fire operational capacity of the Tasmania Parks and Wildlife Service is exceeded. The Tasmania Fire Service has a collaborative role in terms of preparedness and may have a support role in recovery from some bushfires in the TWWHA. Forestry Tasmania also works closely and cooperatively with the Tasmania Parks and Wildlife Service in many aspects of fire management.

Report findings and recommendations

Current fire management arrangements for the TWWHA are well-developed and the Tasmanian fire agencies have sound protocols and practices for working together in bushfire prevention, preparedness, response and recovery. The scale of the 2016 bushfires was significant in terms of the number of ignitions and the extent of area impacted. The firefighting effort in response was extraordinary in terms of financial, physical and human resources applied from Tasmania and other jurisdictions.

This Report concludes that the risks of bushfire to the TWWHA will increase in coming years under the influence of climate change. It is likely that climatic conditions like those in 2016 will re-occur, and other aspects of fire risk will also increase. It is therefore important to take the lessons learned from the 2016 bushfires, and the climate projections referred to in this Report, to prepare for a future where fire management in the TWWHA is expected to be more challenging. The increase in bushfire risk has already started, and changes to management are needed now and well into the future.

Recommendation 1 – Comprehensive fire management planning

Clear, well-defined objectives for fire management should be incorporated into a Fire Management Plan for the TWWHA. These objectives should identify how fire management (fire suppression, 'let go' and management fires) will be used to protect and conserve the natural and cultural heritage values in the TWWHA.

The Fire Management Plan for the TWWHA should clearly set out the circumstances in which priority will be given to protecting the Outstanding Universal Value of the TWWHA over built assets within its boundaries.

Prevention

Current operational practice

The Tasmania Parks and Wildlife Service's Strategic Fire Management Plans present strategies for preventing and mitigating bushfires in the TWWHA.

Bushfire risk assessment and modelling is an important risk management tool. The risk assessment informs the management of risk by identifying and prioritising areas that may be suitable for risk mitigation activities such as fuel reduction burning. It also identifies areas that are not suitable for risk mitigation, but can be prioritised for suppression or other response activities when bushfires approach or threaten particular values.

In recent years, the development of the Bushfire Risk Assessment Model (BRAM) has been important for planning and fire response in the TWWHA. BRAM is a computer mapping system that models and maps the risk of bushfire at 100-metre grid resolution. Data used by BRAM comes from many sources and is combined and analysed to calculate risk scores for the State, including the TWWHA. The final product is a map of bushfire risk across Tasmania.

Planned burning is used as a management tool in the TWWHA, where it is appropriate to do so and where funding permits, to achieve a number of key objectives.

Bushfires spreading accidentally from campfires are a significant risk to the natural values of the TWWHA. The statutory regulation of campfires is covered under *the Fire Service Act 1979*, and for the TWWHA under the *National Parks and Reserved Land Regulations 2009*. Most of the TWWHA has been declared a Fuel Stove Only Area to protect natural values, and fires are totally banned in these areas. Additional restrictions on campfires are imposed by the Tasmania Parks and Wildlife Service at times of very high fire danger, triggered by criteria that are more stringent than those typically used for the declaration of Total Fire Bans by the Tasmania Fire Service.

Recent work and research

In the early 1990s, the Tasmania Parks and Wildlife Service started work to improve knowledge of fire behaviour in buttongrass moorland, in order to increase the effectiveness of fire operations; both suppression and planned burning. This has included collecting data from small, experimental fires, planned burns and bushfires. These studies were published in a series of scientific papers, and the operational findings informed the development of fire behaviour equations, the Moorland Fire Danger Index and prescriptions for planned burning. The buttongrass fire

behaviour model now underpins fire operational practice for all buttongrass vegetation in Tasmania.

A landscape fire-spread modelling tool, FIRESCAPE-SWTAS, has been developed for South-West Tasmania. It explores how much benefit, in terms of reduction of damage to natural values such as rainforest, is provided by differing amounts of planned burning.

An understanding of the fire ecology of ecosystems present in the TWWHA is necessary to develop sustainable planned burning programs, and to protect fire-sensitive and fire-dependent values. Fire ecology research and monitoring undertaken by the Department of Primary Industries, Parks, Water and Environment (DPIPWE) has prioritised the unique buttongrass moorland vegetation, where planned burning plays both a crucial ecological and fire protection role. Numerous studies have contributed to Tasmania's understanding of buttongrass vegetation ecology and therefore planned burning.

Fire appears to be important in the maintenance of at least some of Tasmania's grassy vegetation, particularly in highland areas (montane grasslands), where other environmental influences such as frost and poor drainage are insufficient to prevent invasion by shrubs and trees. A draft montane grassland fire management strategy and plan has been prepared with the following aims: (1) to maintain or increase the area of montane grassland in the public reserve estate, (2) to ensure a diversity of structure and floristics that will support all known rare or threatened species that occur within montane grassland, and (3) to maintain cultural traditions that achieve the above objectives.

The Warra Long Term Ecological Research site of 15,900 hectares was established in 1995 to encourage long-term ecological research and monitoring in wet eucalypt forests in Tasmania. Following the extensions to the TWWHA of 2013, 80 per cent of the Warra site is now in the TWWHA, while the remainder is on Permanent Timber Production Zone land managed by Forestry Tasmania. Warra is a scientific research site of national and international importance. The significant value of the investment in the infrastructure and already established data collection at Warra cannot be overstated. The site contributes to the understanding of many aspects of land management and climate change science.

The Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC) is currently investigating the changing opportunities for planned burning in Tasmania under climate change, with a focus on particular aspects that could affect the future viability of planned burning.

Report findings and recommendations

Recommendation 2 – The Bushfire Risk Assessment Model (BRAM)

The Tasmania Parks and Wildlife Service and DPIPWE should maintain an ongoing program of investment in and development of fire management tools, including the BRAM and the Bushfire Operational Hazard Model (BOHM). As the BRAM is used across all agencies and tenures in Tasmania, it is imperative that it is fully auditable, and that its structure, inputs and operability are regularly reviewed.

BRAM should be fully integrated as a whole-of-government decision-support system with appropriate governance structures established accordingly; and readily accessible by all Tasmanian fire agencies and incident management teams.

BRAM should be supported to a greater extent than it is at the present time. The current level of operation means that its full capacities are not being used and the incorporation of new information and programming is restricted. It should be noted that while BRAM is an excellent tool to consider the spatial arrangement of risk, other risk modelling tools are available that simulate the spread of fire and these are now routinely used in fire management. BRAM cannot be considered as the sole bushfire risk assessment tool available for the TWWHA.

The current design of BRAM, however, limits the practical availability and use of the system to a small group of fire management officers within the Tasmania Parks and Wildlife Service. There would be significant benefit in increasing the accessibility of BRAM by rebuilding it as a new computer system that is available to inform fire managers in the Parks and Wildlife Service, Forestry Tasmania and the Tasmania Fire Service, and from wherever they may be operating, to make critical decisions on priorities and dispatch in conjunction with other fire behaviour modelling tools. The provision of training on BRAM to a wider range of operational users is also required.

It is imperative that that BRAM continues to incorporate the best knowledge of fire behaviour models. Enhancement of the system should include use of appropriate fire-spread simulation tools for new vegetation types (such as moorland) when they are developed. Existing fire behaviour models and fire simulators should not be misused, that is, used beyond the vegetation types and fuels for which they have been validated.

Recommendation 3 – Objectives for planned burns

Clear objectives (at the strategic and program levels) should be set for management burning in the TWWHA.

The short, medium and long-term results of management fires should be monitored to evaluate the fires against specified objectives, and the findings used to retain, improve or modify approaches taken to management burning.

Burning programs should reflect the best available evidence. Fire simulation modelling tools should be used to guide the development of planned burning programs to meet objectives and new data incorporated into the models as they become available.

As with other management activities, the monitoring of management burns should be actively incorporated into the adaptive management framework for the TWWHA.

Similarly, the re-introduction of Indigenous burning practices should have clear objectives, and monitoring should be incorporated into the adaptive management framework for the TWWHA.

Recommendation 4 – Monitoring the consequences of fire

The short, medium and long-term impacts of planned and unplanned fires should be monitored in order to understand the consequences of fire for the natural and cultural values of the TWWHA.

The findings of this monitoring should be used to plan future response to bushfires and to inform decisions about the use of management burning.

As with other management activities, monitoring the impacts of bushfire management should be actively incorporated into the adaptive management framework for the TWWHA.

Preparedness

Current operational practice

The Tasmania Parks and Wildlife Service has, for 20 years, employed firefighters specifically trained in remote area firefighting and has developed techniques, specialised equipment and expertise to support this activity. In more recent years, the Tasmania Parks and Wildlife Service has increased the number of other specialist fire staff.

Remote area firefighting is a highly specialised field for both firefighting crews and pilots and requires a high level of fitness. Aircraft, primarily helicopters, are available for firefighting in the TWWHA through shared contracting arrangements coordinated by the Tasmania Fire Service. The Tasmania Parks and Wildlife Service operates a Fire Duty Officer system to manage daily fire preparedness and response.

Early fire detection and response time is critical for the successful delivery of any fire management program. The smaller the fire, and less vigorous the fire behaviour, the greater the probability that initial attack crews will be able to suppress or contain the fire. For example,

bushfires in buttongrass can grow within less than an hour to a size where suppression is no longer practical.

In Tasmania, bushfire detection is generally undertaken by ground-based staff or public reporting through the Tasmania Fire Service FireComm branch (000 emergency calls), or through operational detection systems including fire towers, aerial spotter flights, monitoring systems such as cameras, and websites that present satellite data, such as Sentinel, Weatherzone or Landgate Firewatch.

When advance notice is possible, the Bureau of Meteorology provides lightning warning forecasts to the Tasmania Parks and Wildlife Service. Lightning occurrence tracking is paramount to early detection and response to any remote fire or fires caused by lightning strike. Information available from monitoring systems, both pre- and post-lightning events, is used in association with information and advice from the Bureau of Meteorology forecasters to guide timing and location of fire-spotter flight paths.

Recent work and research

The Tasmania Parks and Wildlife Service is augmenting the operational capacity of the Bushfire Risk Assessment Model (BRAM) to support decision-making. This involves developing a Bushfire Operational Hazard Model (BOHM) that takes into account the daily and forecasted weather observations to calculate fire weather indices and fire behaviour values, based on vegetation types and fuel loads. This system will assist personnel making resource deployment decisions, based on risk and the availability of resources, to prepare for and dispatch in response to bushfires.

Research undertaken through the Research Project indicates that the occurrence of lightning fires in the TWWHA and adjacent areas has greatly increased over the past 45 years, and particularly in the past 15 years. All of the recorded lightning fires between 1980-81 and 2015-16 were ignited in long unburnt vegetation. It is probable that the risk of lightning ignition in buttongrass increases with time post-fire.

Research undertaken by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) through the Research Project indicates that climate change will impact on a number of weather-related climate risk factors. Specifically, the research indicated:

- an increase in fire danger ratings towards the end of the century for dry eucalypt and buttongrass moorlands;
- an increase in soil dryness that continues from now and throughout the rest of the century, as indicated by the Mount Soil Dryness Index (MSDI) and identified thresholds of flammability;
- a rapid transition between summer and winter (ie a longer summer and a shorter autumn), with more intense conditions in summer;
- a slight decline in lightning-conducive conditions, but no change to extreme dry-lightning conditions; and
- a likelihood that extreme dry-lightning conditions will peak in summer, coinciding with peak increases in dryness indicators.

Report findings and recommendations

The findings of this research have significant implications for future fire management in the TWWHA, as the conditions that led to the 2016 bushfires are expected to become more frequent as the century progresses. Increased spring and summer dryness, lower rainfall, higher temperatures and increased occurrence of lightning fires, combined, pose a major challenge to fire management in the TWWHA and the long-term protection of its natural and cultural values.

Recommendation 5 – Research on fire and natural and cultural heritage values

An ongoing program of scientific research and monitoring should be maintained in the TWWHA that supports understanding:

- *the interaction between climate change and the natural and cultural values of the TWWHA; and*
- *the evolving relationship between climate change and the projected impacts of fire on natural and cultural values in the TWWHA.*

This research should focus, in the first instance, on those values that are expected to be most vulnerable in the short term (for example relict Gondwanan flora).

This program of research should involve a broad spectrum of the research community, as well as personnel from DPIPWE and other Tasmanian Government agencies.

The program of research should be regularly reviewed and audited. The 'DPIPWE TWWHA Bushfire Research Group' should continue to be actively engaged in the process of developing objectives for this research program.

Attachment 9 sets out a prospective list of priority research to support fire management in, and the understanding of the impacts of fire on, the World Heritage values of the TWWHA.

Recommendation 6 – Research on fire vulnerability, fire behaviour and fire model inputs

In the short to medium-term, significant research effort should be directed to:

- *further understanding the consequential interactions of climate change with fire vulnerability, behaviour and impact;*
- *understanding fire behaviour and flammability thresholds, particularly in dry conditions, of organic soils and the interaction between climate change, fire and organic soils;*
- *developing a comprehensive understanding of soil and fuel moisture in the various vegetation communities in the TWWHA; efficient methods to monitor and model soil and fuel moisture across the vegetation types in the TWWHA; and the development of reliable soil moisture indices for the TWWHA that can then be incorporated into fire behaviour models and fire danger indices;*
- *developing techniques for more accurately assessing fuel loads and mapping fuel types in different vegetation communities in the TWWHA and incorporating these into fire behaviour models; and*
- *developing fire behaviour models and associated fire spread simulators for peatlands, grasslands, wet eucalypt forest, coniferous rainforest, rainforest without conifers, and other vegetation communities in the TWWHA.*

This research should take into account national initiatives that are currently underway in the development of bushfire indices, and modelling and fire behaviour tools. The research should concentrate on those areas, soils and vegetation communities in the TWWHA that are not currently well represented in fire behaviour models and fire danger indices.

Recommendation 7 – Lightning and ignition detection

The Tasmanian fire agencies, in consultation with the Australian Bureau of Meteorology, should keep abreast of emerging technologies for predicting and detecting lightning strikes and ignitions.

If and when new technologies become available, these should be incorporated into preparedness and response planning for bushfire in the TWWHA.

A detection strategy should be developed that details the bushfire detection arrangements for the TWWHA, based on contemporary ignition risks and detection methods.

Recommendation 8 – Capital investment

The Tasmanian fire agencies should develop a whole-of-government program of investment in facilities and equipment that enhance fire management capabilities in the TWWHA and more generally in Tasmania.

This program should include:

- *identification and evaluation of options for installing new automatic weather stations in the TWWHA and nearby areas to improve weather and data records for the region; remote area sensors for monitoring local rainfall and soil moisture; and early detection facilities such as fire-watch installations;*
- *firefighting equipment available to fire agencies in different regions of Tasmania;*
- *improved communication facilities (that is for the radio network), to enable better communication between agencies, and for remote firefighting teams; and*
- *investment in facilities and equipment to enhance aerial firefighting efforts.*

This investment program should be developed on a whole-of government basis to maximise the benefits to all fire agencies and the Tasmanian community. Organisations such as the Bureau of Meteorology should be involved in order to ensure the fire agencies obtain the highest benefits from Tasmanian weather and climate data.

In constructing this investment program, an audit of existing weather and climate sensors in the region should be conducted and protocols developed for incorporating these data into real-time forecasts of fire weather.

Response

Current operational practice

The main means of identifying fire-sensitive natural and cultural values, and relevant priorities and response in the TWWHA is through the Natural Values Atlas, the Bushfire Risk Assessment Model (BRAM), and specialist staff from the Department of Primary Industries, Parks, Water and Environment.

The basic principle for determining response strategies and priorities is that the highest rated values from BRAM will be protected in preference to lower rated values.

Human life is afforded the highest priority in BRAM, and areas where visitors to the TWWHA are likely to be present are given the highest ranking. Typically, the highest ranking for natural values is assigned to areas that are fire-sensitive because there would be permanent and significant losses if burnt.

Responding to fires in the TWWHA requires consideration of broader strategic fire suppression priorities after consideration of the values, operational limitations and available resources. In reality, not all values can be protected at all times, and therefore a triage process is involved in strategic decision-making. The suppression objectives, strategies and allocation of resources are ultimately based on what can realistically be achieved to protect identified and agreed priorities.

Bushfire risk assessment is a dynamic process that recognises and adjusts to circumstances as they change. It relies on information from a range of sources and the application of appropriate fire models.

During a large bushfire event, where there are a number of fires that require suppression response, assessment can occur at both the State and regional level, using a risk assessment approach consistent with the National Emergency Risk Assessment Guidelines (NERAG) to:

- enable the timely and relevant issuing of community warnings;
- prioritise operational activities on the fireground; and
- undertake options analyses in determining suppression and control strategies.

Fire risk to visitors is mitigated by developing emergency response plans or actions within the Fire Action Plan to enhance visitor safety. The Tasmania Parks and Wildlife Service has a draft emergency response plan for the Mt Field National Park, which includes responding to fire with appropriate trigger points.

During the 2016 bushfires, the Tasmania Parks and Wildlife Service set up a Visitor Management Team to coordinate warnings to walkers, detection and relocation of visitors at risk (those in the path of fires), closure of campgrounds, walking tracks and reserves, communication with the public, and liaison with incident management teams and the State Fire Duty Officer.

Report findings and recommendations

Recommendation 9 – Mapping of values

DPIPWE and the Tasmania Parks and Wildlife Service should continue to improve mapping, and incorporate the most up-to-date and available vegetation, soil and other natural and cultural values mapping into TASVEG and the Bushfire Risk Assessment Model (BRAM).

The availability of high-resolution aerial imagery has increased significantly in the past decade. Higher resolution mapping of natural values will significantly improve the inputs to the BRAM and enhance the fire risk assessments BRAM produces.

There is a role for the broader research community in providing both input to, and review of, natural and cultural values mapping for the TWWHA.

Recommendation 10 – Operational capability

The Tasmania Parks and Wildlife Service should review its immediate, medium and long-term fire suppression capabilities, including staffing.

This review should be done in consultation with other fire agencies in Tasmania as skills, demographic factors, and agency capabilities are expected to change significantly across all agencies.

This review should also take into account the spatial context of bushfire risk; emerging technological development; future fire suppression capabilities such as new fixed- and rotary-wing aircraft; and the future requirements for skilled, remote-area firefighting teams.

A review of resources and staffing arrangements should be undertaken to facilitate flexibility and responsiveness in capability to match annual variation in fire seasons (ie that impact workload).

The aim of this review is to understand what resources are required by the Tasmania Parks and Wildlife Service to manage current and future bushfire risk, and what actions need to be taken now to ensure that adequate levels of skill, staffing, equipment and decision-support tools are available for fire management in the future.

Recommendation 11 – Use of volunteers

The Tasmania Parks and Wildlife Service, in conjunction with other Tasmanian fire agencies, should review the future potential for the use of volunteers in supporting fire management activities, including the potential to use trained remote area volunteer fire crews.

This review should be conducted in conjunction with the review of the Tasmania Parks and Wildlife Service's fire suppression capabilities.

Recommendation 12 – Fire suppression techniques and methods

The Tasmanian fire agencies should regularly review operational practices, fire suppression technologies and techniques used in other jurisdictions and determine their efficacy for Tasmania, including in the TWWHA.

In the TWWHA, particular attention should be paid to:

- *early intervention techniques and technologies such as early detection and rapid attack; and*
- *continuing to investigate methods and equipment for extinguishing ground (organic soil) fires (eg spike and pump combinations).*

Recommendation 13 – Aerial fire suppression

The Tasmania Parks and Wildlife Service and the Tasmania Fire Service should review future capabilities in fixed- and rotary-wing aircraft for fire suppression in the TWWHA, and for the safe insertion of remote area firefighting teams, including where landing or hover exit is not possible.

This review of aircraft support should be carried out in conjunction with the review of staffing capabilities.

Recommendation 14 – Research on fire suppression chemicals

The current research on the efficacy and environmental impacts of the use of fire suppression chemicals in the TWWHA should be continued in the short term.

This research should inform the development of guidelines for future use of fire suppression chemicals in the TWWHA.

Recommendation 15 – Use of fire suppression chemicals

The Tasmania Fire Service and Parks and Wildlife Service should review the future use of fire suppression chemicals in the TWWHA following the conclusion of the research project currently being undertaken.

Research, monitoring and adaptive management should continue on the use of fire suppression chemicals from the perspective of both impacts on TWWHA values, and guidelines on the effective and efficient operational strategies and tactics of the various fire chemical classes.

If the research determines that the use of fire suppression chemicals is appropriate in the TWWHA, suitable procedures will need to be established, as well as training and equipment, to manage the use of these products in a safe and responsible manner.

Protocols for future decisions to use fire suppression chemicals in the TWWHA should be incorporated into the TWWHA Fire Management Plan and associated operational fire guidelines.

As an interim measure, the use of fire suppression chemicals should be undertaken using a precautionary approach, where application is assessed and approved on a case-by-case basis.

The use of fire suppression chemicals for firefighting in the TWWHA should balance potential environmental impacts (if any) with the protection of the natural and cultural heritage values of the TWWHA.

Recommendation 16 – Improved public information and communications

The Tasmania Parks and Wildlife Service should develop a specific communications plan on bushfires and fire management. This plan should include:

- *public information on the restrictions on lighting fires in the TWWHA and the impacts of bushfire on sensitive natural and cultural assets;*
- *the dissemination of public information on fire danger during the fire season;*
- *the dissemination of public information during fire events including bushfires and management fires, including suppression activities; and*
- *the dissemination to the public of information on the extent and impacts of bushfire in the TWWHA.*

The communications plan should also cover the provision of public information during extreme bushfire events, such as those that occurred during 2016.

Good quality public information can play an important role in building community support for fire management in the TWWHA, and for the efforts of fire agencies during extreme events.

Recovery

Current operational practice

Building on the Victorian approach, in 2011 New South Wales and the Australian Capital Territory developed Burned Area Assessment Teams and also invited the Tasmania Parks and Wildlife Service to participate in a cooperative arrangement across jurisdictions.

These teams draw together expertise in a range of scientific disciplines and conduct a rapid risk assessment immediately following an emergency event. These assessments are used to assist managers in identifying and minimising future impacts – both immediate and longer-term – caused by the emergency event. The goal is to reduce further threat to life, property, infrastructure and the environment. The outputs of the process, which include a written report, support the transition from emergency response to recovery.

The Department of Primary Industries, Parks, Water and Environment (DPIPWE)'s Natural and Cultural Heritage Division and the Tasmania Parks and Wildlife Service have supported this multi-jurisdiction approach, providing some input to the development of the process, and may provide personnel for teams in the future. This assessment approach has been used in Tasmania by the Parks and Wildlife Service, Forestry Tasmania and the Tasmania Fire Service in 2013 and 2016, drawing on the assistance of expertise from other states and territories.

Assessment of the impacts on natural values following major fire events is a function performed by DPIPWE's Natural and Cultural Heritage Division, where resources and time permit. The tasks are assigned to a small team of specialists, typically botanists, zoologists, geomorphologists, soil scientists and spatial data analysts. Brief reports are prepared that highlight:

- the area of different vegetation types burnt within the fire perimeter, based on TASVEG vegetation mapping;

- natural values that may have been affected, such as threatened species, threatened vegetation communities and fire-sensitive species or soils; and
- the context of the impacts within the broader management of fire regimes for species or ecosystems of concern.

When considered appropriate, longer-term monitoring and studies are established for targeted species or values.

Report findings and recommendations

Recommendation 17 – Role of Bushfire Rapid Risk Assessment

The Tasmania Parks and Wildlife Service and other fire agencies should establish protocols for 'rapid assessment' of the impacts of major bushfires in the TWWHA and resourcing of immediate priorities for recovery action.

Rapid assessment techniques are used in many jurisdictions in Australia and overseas to provide an initial assessment of fire impacts and priorities for recovery and rehabilitation. While these 'rapid assessments' cannot replace long-term investigation and monitoring of fire impacts, they can be useful in prioritising recovery efforts and rationalising commitment of resources to recovery.

The efficacy and usefulness of rapid assessment techniques should subsequently be evaluated, and their implementation modified if required.

Recommendation 18 – Ecosystem rehabilitation and restoration trials

The Tasmania Parks and Wildlife Service and DPIPWE should undertake trials of post-bushfire rehabilitation techniques (eg erosion control, tree planting, seed germination and seed banks), especially for vulnerable species, communities and other significant values in the TWWHA.

This work should be integrated into a broader research strategy for the TWWHA, and incorporated into the Adaptive Management framework contained in the TWWHA Management Plan.

Protecting the natural and cultural heritage values of the TWWHA will be challenged by the increased likelihood of bushfires under projected climate change. Some of these challenges are already apparent as increased soil dryness and increased occurrence of ignition from lightning strikes. Given the national and international significance of the TWWHA and its importance to the Tasmanian economy and Tasmania's image, it is imperative that steps be taken now to prepare and plan for these future challenges.

Tasmania has well-developed fire management arrangements and procedures for the TWWHA across the areas of bushfire prevention, preparedness, response and recovery. Tasmania also has

well-developed interagency cooperation mechanisms that underpin responses to large and complex bushfire events. It is likely that the capacity of all Tasmanian fire agencies will be under great pressure at times in the future. Tasmania's ability to call in additional resources from other jurisdictions may also be challenged by extreme climate events elsewhere.

This Report sets out recommendations that can be employed by Tasmania to prepare for, and respond to, future bushfire threat in the TWWHA. While some recommendations focus on the responsibilities of particular agencies, responding to and implementing these recommendations will require consideration across all areas of government so that the benefits that accrue are available and shared across the Tasmanian economy.

1. INTRODUCTION

1.1 History and role of fire in the Tasmanian Wilderness World Heritage Area (TWWHA)

1.1.1 History

Bushfire has been a natural and persistent phenomenon in the Tasmanian Wilderness World Heritage Area (TWWHA) for millennia. Prior to European colonisation, Aboriginal people actively used fire to manage vegetation in many parts of the region. The fire regimes subsequently changed following European colonisation.

Landscape-scale bushfires were reported as early as 1850 for parts of the TWWHA and there is good evidence of such fires occurring before European settlement (Dr Jon Marsden-Smedley pers. comm.; Dr Michael-Shawn Fletcher pers. comm.). Table 1 lists the large fires that have burnt in or near the TWWHA or in similar country in North-West Tasmania. Since the 1930s there have been at least 12 fires in or near the TWWHA that were greater than 20,000 hectares in size. Eight fires were greater than 40,000 hectares in size. One of these events, the Giblin River fire, occurred in 2013.

Table 1: Estimated area of large fire (more than 5,000 hectares) events in or near the TWWHA

Fire name	Year	Area (ha)
Tasmania*	1897-98	~ 2,000,000
Mostly in TWWHA*	1933-34	629,000
Pelion Range*	1930s	16,907
Frenchmans Cap*	1939	118,054
Eldon Range*	1950s	24,346
Central Plateau*	1961	85,197
Raglan Range*	1966	9,448
1967 Fire	1967	198,780
Adam Range*	1981	7,515
Zeehan	1981	13,527
Cape Sorell - Dunes Beach - Hibbs Lagoon	1982	11,253
Savage River	1982	53,721
Pine River 1*	1982	13,648
Tungatinah 1	1982	7,610
Birch Inlet - Low Rocky Point*	1986	36,724
Mulcahy Bay*	1987	23,561
Central Plateau*	1989	6,173
Pieman River	1995	10,791
Temma Road	1995	5,268
Ummarrah Creek*	2000	5,008
Cape Sorell	2001	6,235
Mt Frankland Donaldson	2003	78,168
Reynolds Creek*	2007	25,273
Cracroft River*	2007	13,085
Heemskirk Rd	2008	13,719
Wayatinah	2010	6,285

Fire name	Year	Area (ha)
Meadowbank Road	2012	5,234
Poatina*	2012	8,512
Giblin River*	2013	40,468
Lake Repulse	2013	10,238
Lake Mackenzie Complex*	2016	24,700

* These fires occurred in the TWWHA

(Source: database records of Tasmania Parks and Wildlife Service; Marsden-Smedley 1998)

1.1.2 Role of fire

Fire plays a fundamental role in maintaining and changing ecosystems in the TWWHA, and protection of the natural values of the TWWHA depends on both past and future fire regimes (DPIPWE 2015a). Fire is also an important component of cultural landscapes, past and present, and its management is important for protecting cultural heritage. It is also an important cultural tool for Tasmanian Aboriginal people, who have used fire to manage and connect to the landscape (DPIPWE 2015a), as described in section 4.3.1.

Since the arrival of Europeans in Tasmania, both the presence and absence of fire have resulted in major changes to vegetation, and there are many examples of this across Western Tasmania. Around half of the fire-sensitive vegetation types in the Central Plateau were deliberately burnt by a highland grazier, resulting in the 1960-61 fires (alpine and subalpine heath, subalpine rainforest, rainforest and native conifers) (Johnson and Marsden-Smedley 2002). This included about half of the pencil pine on the Central Plateau.

The Savage River fires in 1982 burnt approximately 15,000 hectares of rainforest (Barker 1991) and, over a period of 100 years, over one third of King Billy pine forest has been lost to fire across Tasmania (Brown 1988). In addition, fire has caused a major loss of subalpine coniferous vegetation and soils on the Central Plateau, with erosion still continuing over 50 years since the fires (Cullen 1995; Bridle et al. 2001; Storey and Comfort 2007). In contrast, inadequate fire frequency in Tasmanian montane grasslands is currently leading to loss in species diversity and has reduced the extent of this community (Kirkpatrick 1999; Bowman et al. 2013; DPIPWE unpublished data).

The effect of fire on biodiversity and geodiversity depends on the fire regime (ie intensity, season, frequency, distribution and the type – crown, surface or ground fires). Without management intervention, summer bushfires can burn with great intensity and on a landscape scale. These fires can extend into fire-sensitive areas and may cause damage that is effectively permanent, resulting in a landscape that contains large areas of uniform-aged vegetation and lacks fire-sensitive features.

1.2 Tasmanian fires of January – March 2016

1.2.1 The scale of the fires in the TWWHA

Leading into the 2015-16 bushfire season, Tasmania experienced drier than average winter, spring and summer seasons, due to the combination of an El Niño event and strong Indian Ocean Dipole (Tasmanian Government 2016a). The North-West region of Tasmania experienced the driest weather period on record. The lower levels of rain contributed to extremely dry fuel and soil conditions, which increased fire risk and exacerbated fire behaviour on days of increased fire danger (Tasmanian Government 2016a).

A map depicting the climatic conditions in Tasmania leading up to the 2016 bushfires is provided at Figure 1, including sustained negative values (below -7 degrees Celsius) of the Southern Oscillation Index (SOI), which indicates the El Niño episode. Figure 1 also depicts the record low rainfall experienced across much of Western Tasmania, including areas of the TWWHA.

Figure 2 shows that the potential for bushfire was assessed as above normal across North, North-West and East Tasmania, as well as in the Midlands and South-East Tasmania (Bushfire and Natural Hazards Cooperative Research Centre 2015). The bushfire potential in the remainder of the State, including much of the TWWHA, was considered to be normal, despite the record low rainfall that was experienced over the TWWHA, as depicted in Figure 1.

According to the Tasmanian Government (2016a), on 13 January 2016, mainland Tasmania recorded 889 ground strikes from lightning, which started over 80 fires. These were followed by 2,487 lightning strikes on 28 January 2016 and another series of lightning strikes in February 2016.

From 13 January to 15 March 2016 the Tasmania Fire service recorded a total of 229 vegetation fires (AFAC 2016a) that affected approximately 126,800 hectares across Tasmania including an estimated 19,800 hectares (around 1.3 per cent) of the total TWWHA area[2]. The areas of the TWWHA impacted are represented at Figure 3.

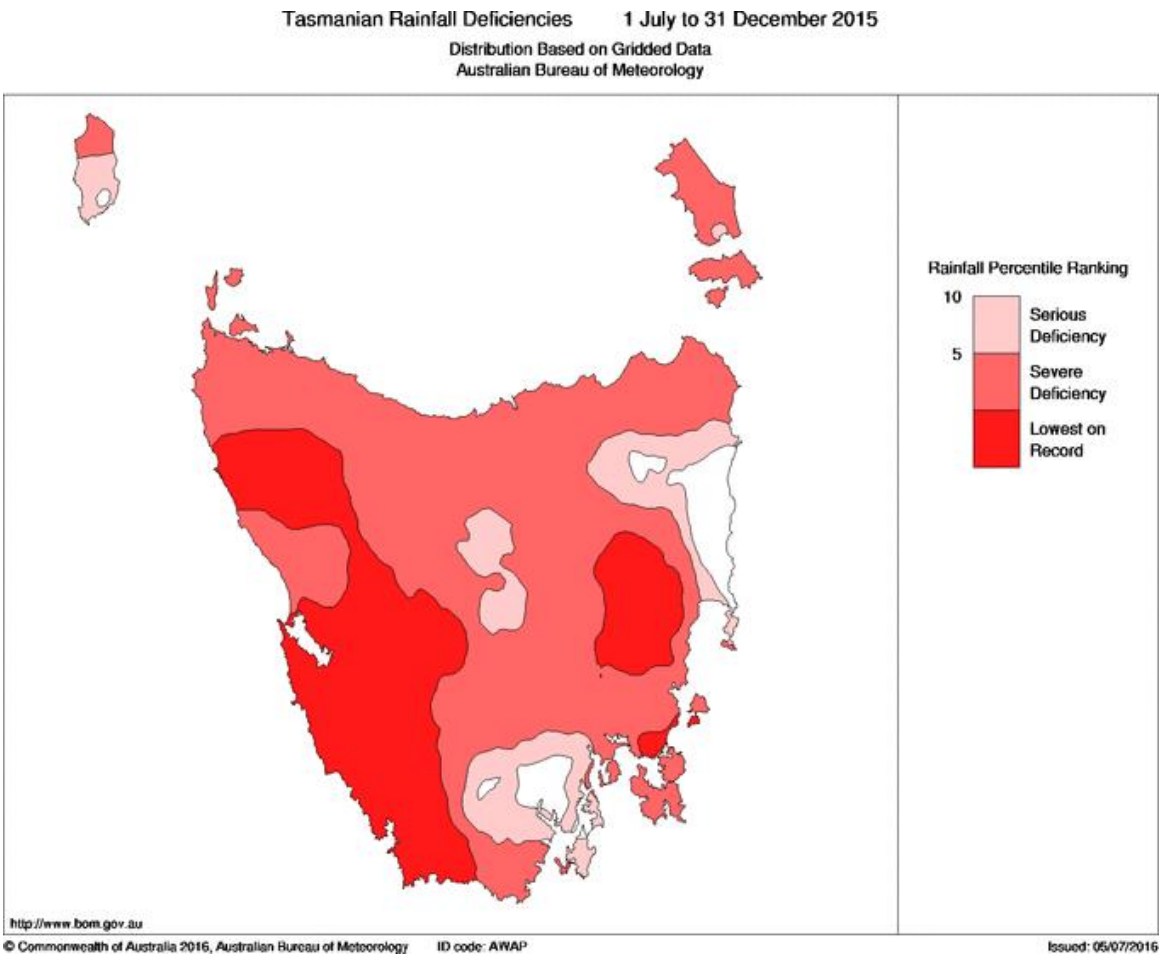
The firefighting effort involved more than 5,600 Tasmanian volunteer and career firefighters, 1,000 interstate or overseas firefighters, and as many as 40 aircraft assisting each day during the peak (Premier of Tasmania 2016a). The cost of the bushfires has been estimated at $52.6 million[3].

The following fires and fire complexes were the most significant in the TWWHA: the Lake Mackenzie Complex (including Patons Road, Mersey Forest Road, February Plains, Lake Mackenzie Road and Devils Gullet), Lake Bill, Dove River, Maxwell River South and Gordon River Road. Figure 4 indicates the location of these fires and the other major fires that were burning between January and March 2016. Attachment 1 (AFAC 2016a) provides a summary description of the major fires that were burning across Tasmania during this time.

Further details of the assessment of the impact of the 2016 bushfire on the TWWHA are provided in section 7.2.3.

[2] Based on information provided by the Department of Primary Industries, Parks, Water and Environment (DPIPWE).

[3] Estimate provided by the Tasmania Fire Service in November 2016.



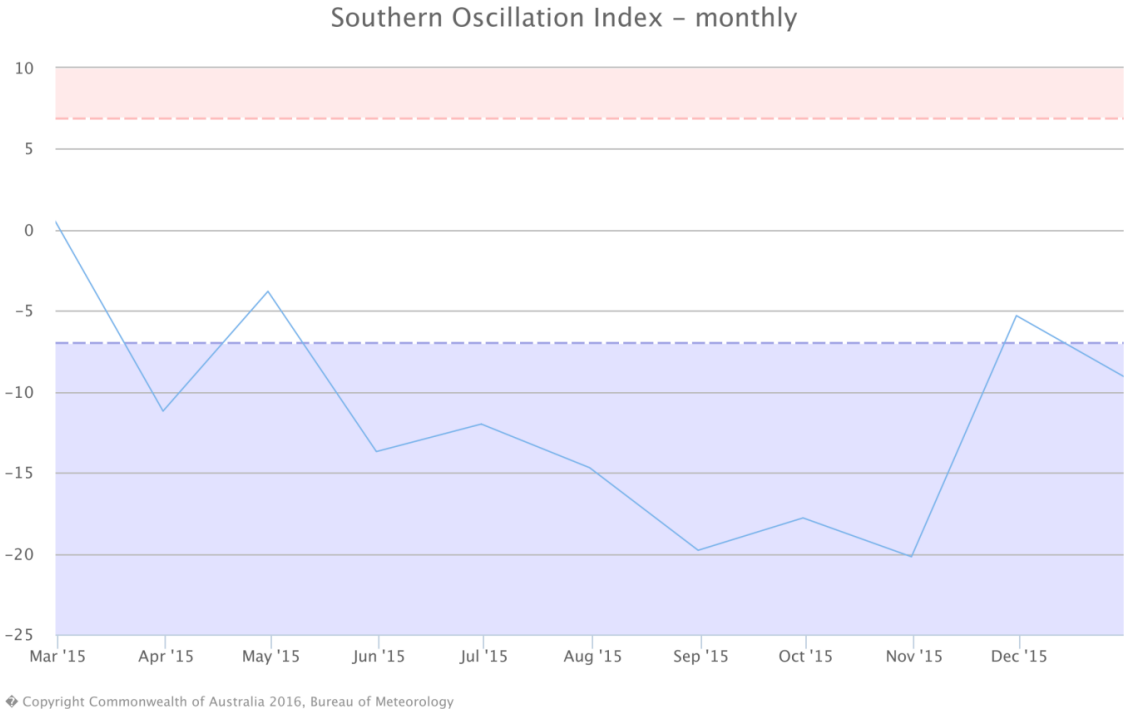


Figure 1: Climatic conditions in Tasmania leading up to the 2015-16 bushfire season
(Source: Bureau of Meteorology, 2016)

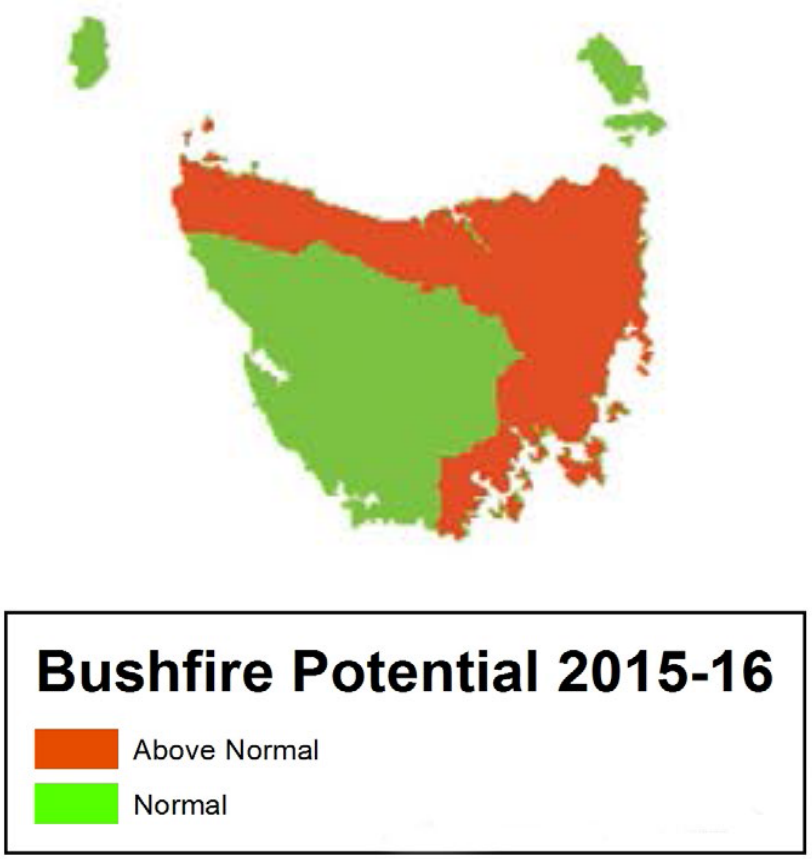


Figure 2: Southern Australia Seasonal Bushfire Outlook 2015-16 November update
(Bushfire and Natural Hazards Cooperative Research Centre 2015)

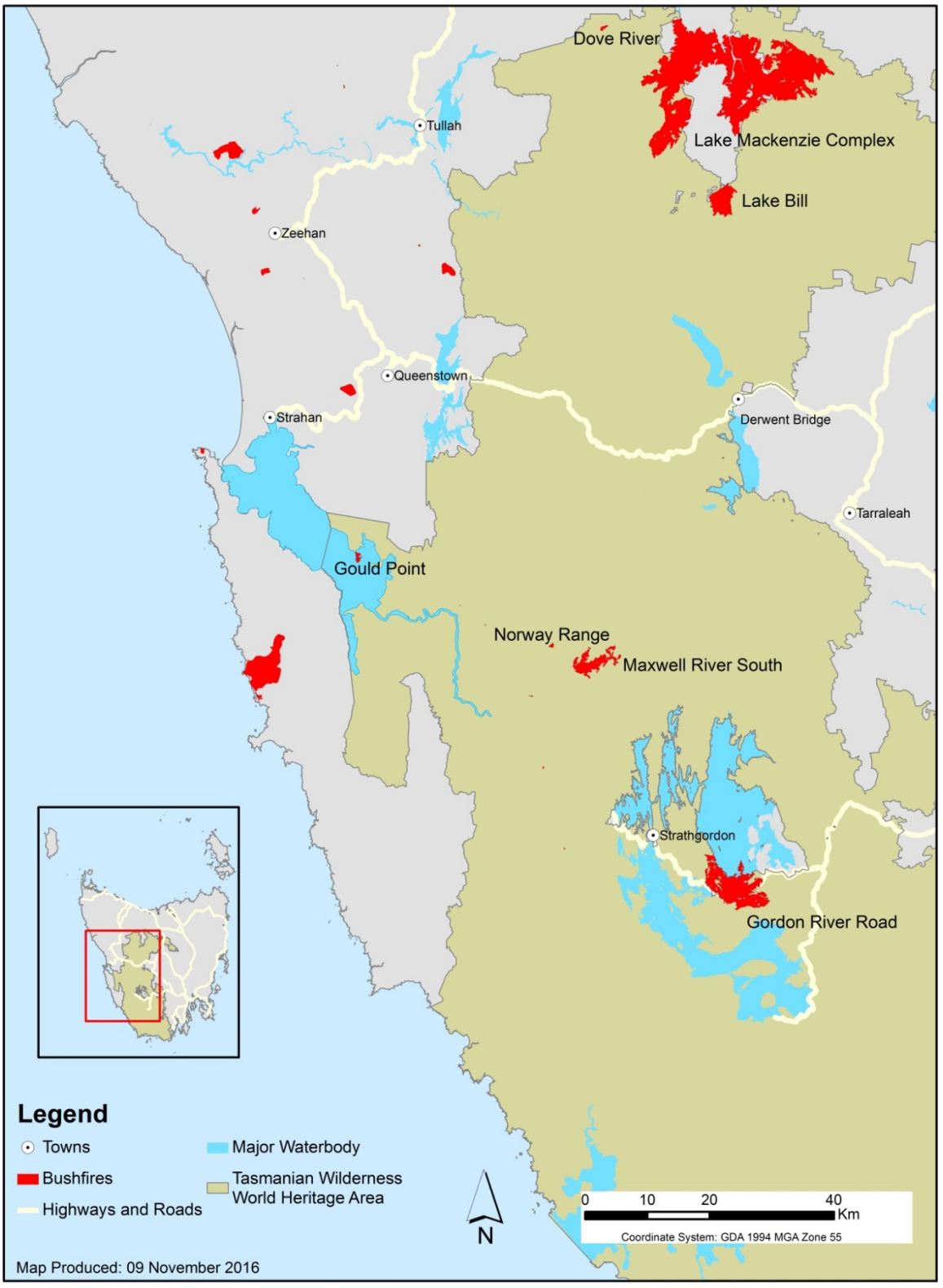


Figure 3: Location of fires that started from 13 January to 27 January 2016 inclusive in the TWWHA and areas further west. Fire names are shown for the major fires in the TWWHA (see Table 2)

(Source: information provided by the Department of Primary Industries, Parks, Water and Environment and map prepared by the Tasmania Parks and Wildlife Service)

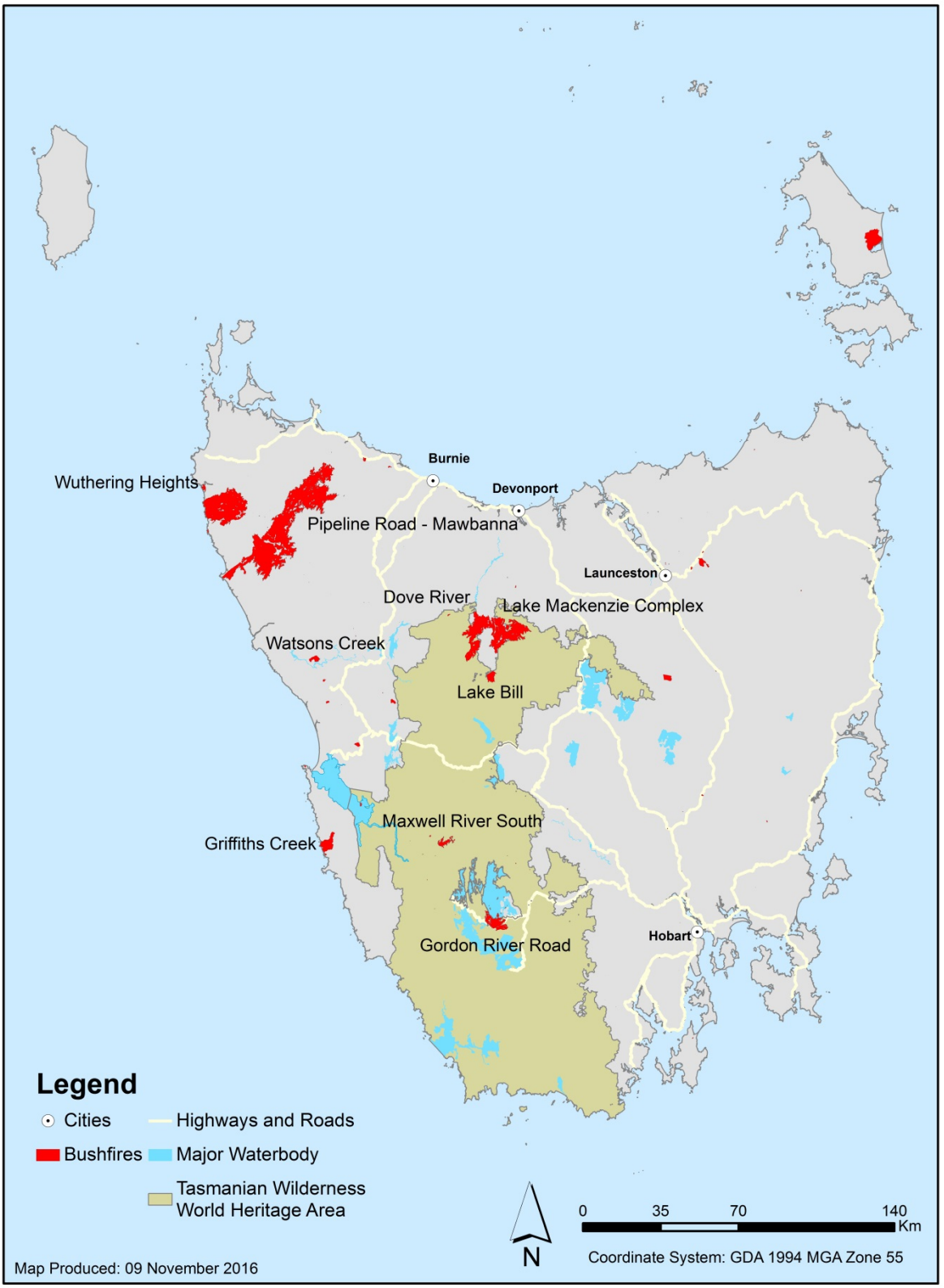


Figure 4: Location of active fires in Tasmania during the period 13 January to 15 March 2016
(Source: information provided by the Department of Primary Industries, Parks, Water and Environment and map prepared by the Tasmania Parks and Wildlife Service)

1.2.2 Early stages of response to TWWHA fires, January 2016

In the immediate aftermath of the lightning storm that crossed the State in the early evening (or late afternoon) of 13 January 2016, the Tasmania Parks and Wildlife Service Fire Duty Officer (see section 5.1.2) responded to fires as they were detected during the evening. At the outset, it was not known how many fires there were or where they were located, and with the low number of fires initially reported it was clear that the priorities were to suppress some fires and to warn or relocate visitors near others. A small visitor management team was established during the evening to coordinate the management of visitors in remote areas to ensure their safety.

The number of known fires grew overnight, and so prioritising fires as a separate and more formal task began. On the morning of 14 January 2016, all known fires were assessed in terms of their size, vegetation that they were burning in, soil and fuel moisture in the vicinity of the fire, potential to grow, which fires would grow fastest and values that would be affected if they grew. The values considered included human life, natural values, infrastructure and other assets. As new fires were detected, the process was repeated and the priorities were communicated to incident management teams.

The number of fires outside the reserve system continued to grow at the same time, and these also needed to be considered within the overall State priorities. A Strategic Planning Unit was established within the State Fire Operations Centre of the Tasmania Fire Service, which took over prioritisation of all fires irrespective of tenure.

The Tasmania Parks and Wildlife Service reviewed the overall strategy for the management of these incidents developed by the fire agencies. The revised strategy for management of these incidents included the following:

- ensuring safety of visitors to the reserve system by establishing a formal Visitor Management Team that liaised with the Incident Management Teams around the State to coordinate the warning and relocation of visitors at risk, and closure of tracks, campgrounds or reserves where required;
- reducing the likelihood of impact on reserve visitors by informing the public of track, campground and reserve closures and ways to keep safe through media, social media, internet and the Visitor Information Network;
- ensuring the most appropriate response to fires and protection of values by prioritising fires and communicating the priorities to Incident Management Teams. Initially the Tasmania Parks and Wildlife Service prioritised fires on reserved land, but subsequently participated in a multi-agency, coordinated statewide prioritisation of fires across all lands; and
- reducing the likelihood of further fires starting and distracting the current suppression effort and increasing the workload by conducting a risk assessment of campgrounds and implementing an indefinite ban on campfires in high risk reserves across the State. These areas were then patrolled at a higher level.

The lightning storm of 13 January 2016 ignited 29 fires that were recorded as affecting the TWWHA (see Table 2)[4]. Eleven of the fires affecting the TWWHA spread to a size more than 38 hectares, while the remaining 18 fires each remained less than seven hectares in size. All of the Tasmanian fire agencies, including the Tasmania Parks and Wildlife Service, were engaged in managing dozens of ignitions on all categories of public and private tenures.

The major TWWHA fires were detected from 15 January to 21 January 2016. Table 2 provides a summary of these detected fires. The information regarding detection dates, provided in Table 2, indicates how some lightning fires can remain hidden for many days from available methods of detection including spotter flights (see section 5.1.3). A multi-agency Incident Management Team at Launceston took over the management of the northern TWWHA fires on 19 January 2016, while the southern TWWHA fires were managed from an incident management team at Cambridge from 22 January 2016

The largest of the TWWHA fires, the Lake Mackenzie Complex fire, started as five separate lightning ignitions; two started outside the TWWHA in the Mersey Valley, but all five fires eventually joined up to create one fire. As indicated in Table 2, detection of three of these ignitions did not occur until 19 January 2016 when all five fires made their first significant spread under high fire weather conditions.

Table 2: Summary of the detection and suppression of fires affecting the TWWHA from the lightning storm of 13 January 2016

Date detected	Total number of fires detected	Names of significant fires and approx. final size	Comments on significant fires
13 January	5		No significant fires developed from these fires.
14 January	6	Gould Point (100 ha)	Gould Point fire was monitored until 19 January when back-burning was undertaken.
15 January	9	Patons Road*; Mersey Forest Road*; Lake Bill (1,400 ha)	Patons Road and Mersey Forest Road fires started on Forestry Tasmania managed land. Suppression on Patons Road and Lake Bill fires started on 15 January 2016; Mersey Forest Road fire on 16 January.
16 January	1	Dove River (56 ha)	Dove River fire was assessed as a risk to the Cradle Mountain area visitors, so crews were redeployed from Lake Bill fire to this fire on 16 January.
17 January	2	February Plains*; Gordon River Road (4,200 ha)	The location of the February Plains fire could not be determined following initial report until 19 January. Suppression action on Gordon River fire began 18 January.
18 January	3	Maxwell River South (1,400 ha)	Suppression action began 31 January.

[4] There are likely to have been more ignitions in the TWWHA from this lightning storm which were never detected.

Date detected	Total number of fires detected	Names of significant fires and approx. final size	Comments on significant fires
19 January	2	Lake Mackenzie Road*; Devils Gullet*	Devils Gullet was a spot fire from the Lake Mackenzie Road fire. Suppression started by TFS crews on 19 January (all PWS firefighters were committed to other fires).
21 January	1	Norway Range (40 ha)	Norway Range fire was monitored only.

* Fires that joined together to create the Lake Mackenzie Complex fire (24,700 ha).
(Source: information summarised from records of duty officers of Tasmania Parks and Wildlife Service and Forestry Tasmania; fire size from information provided by the Department of Primary Industries, Parks, Water and Environment)

1.3 TWWHA Bushfire and Climate Change Research Project

1.3.1 Research Project background

The 2016 fires highlighted the need to consider the impacts that climate change will have on the occurrence, frequency, and extent of bushfires in the TWWHA and the implications this will have for the management and protection of the values of this iconic region.

In March 2016, the Premier, Will Hodgman MP, announced the Tasmanian Government's commitment of $250,000 towards a new research initiative to investigate the impact of climate change on Tasmania's wilderness areas and strengthen firefighting techniques to prepare for and respond to bushfires in the wilderness, hereafter referred to as the TWWHA Bushfire and Climate Change Research Project (the Research Project) (Premier of Tasmania 2016b).

The Research Project focused on the TWWHA, the location of which is indicated in Attachment 2, and included on the World Heritage List (UNESCO 2016a). The results of the Research Project are also relevant to adjacent and other protected areas in Tasmania.

The Research Project has been led by an independent chairperson, Dr Tony Press, Adjunct Professor at the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC). The Research Project was overseen by a high-level Steering Committee with representatives from the Tasmanian Departments of Premier and Cabinet; Primary Industries, Parks, Water and Environment; Police, Fire and Emergency Management; and the Australian Government's Department of the Environment and Energy. A Technical Working Group with representatives from the aforementioned Tasmanian agencies was established to support the Research Project.

The Research Project has been undertaken in two stages:

- Stage One: Interim Report was provided to the Tasmanian Government in July 2016; gap analysis to identify research needs in relation to the project's objectives (see below); and commissioning of specific research to address high priority research needs.
- Stage Two: Final Report (this Report) to be provided to the Tasmanian Government by December 2016.

1.3.2 Research Project Terms of Reference, objectives and outcomes

The Terms of Reference for the Research Project are at Attachment 3. The objectives of the Research Project are to:

- examine how climate change will affect future fire danger and other variables that may lead to an increased risk of bushfire, and its impacts on the TWWHA;
- provide recommendations on the most appropriate methods for monitoring and recording vegetation dryness levels within the TWWHA; and
- examine firefighting techniques, interventions and resources that can be safely and effectively employed by the Tasmania Parks and Wildlife Service and the Tasmania Fire Service to prepare for, and respond to, bushfires in the TWWHA, including the most appropriate methods to extinguish fire within alpine areas.

The outcomes of the Research Project are:

- improved understanding of how climate change will impact on the TWWHA; and
- improved ability to prepare for, and respond to, bushfires in the TWWHA.

1.3.3 Related activities to the Research Project

Two activities related to the Research Project have recently been undertaken, and relevant elements of these activities have been considered in this Final Report.

Firstly, the Australasian Fire and Emergency Service Authorities Council (AFAC) undertook an independent operational review into the management of the Tasmanian fires of January 2016 (AFAC 2016a). The AFAC Review report was publicly released in April 2016 and provided Tasmania's fire agencies with 12 recommendations. These recommendations have been considered in this Report. The AFAC Review did not include a detailed discussion of the impacts of climate change on future bushfire risk in the TWWHA. It did, however, reference research by CSIRO and the Bureau of Meteorology relating to trends in climate variables out to 2100 (AFAC 2016a).

Secondly, on 17 March 2016, the Australian Senate called an inquiry into the 'Response to, and lessons learnt from, recent bushfires in remote Tasmanian wilderness'. Following the calling of the July 2016 federal election, the inquiry lapsed, delaying the report timeframe. On 13 September 2016, the Senate agreed that the inquiry would recommence, with a reporting date of 1 December 2016 (Parliament of Australia 2016). The Research Project has considered the submissions made to the Senate inquiry.

1.4 Final Report purpose and structure

1.4.1 Purpose

The purpose of the Final Report, as outlined in the Terms of Reference for the Research Project, is to:

- summarise the work undertaken in Stage One of the Research Project and provide practical information and tools for the Tasmania Parks and Wildlife Service and the Tasmania Fire Service to manage bushfires in the TWWHA; and
- provide recommendations to the Tasmanian and Australian governments regarding future management of bushfire threat in the TWWHA.

1.4.2 Structure

The structure of the Final Report follows the 'Prevention, Preparedness, Response and Recovery' (PPRR) risk management model and is presented in eight sections:

- **SECTION 1 (Introduction)** provides context regarding the history and role of fire in the TWWHA and an outline of the Research Project.
- **SECTION 2 (Values in the TWWHA)** provides an overview of the natural and cultural values of the TWWHA and the link between the protection of these values and fire management.
- **SECTION 3 (Fire management arrangements for the TWWHA)** provides an overview of fire management arrangements for the TWWHA including funding, and relevant Tasmania Parks and Wildlife Service plans, policies and procedures.
- **SECTION 4 (Prevention)** focuses on bushfire prevention and mitigation in the TWWHA in terms of current operational practices, recent work and research, and areas for further work or research.
- **SECTION 5 (Preparedness)** focuses on bushfire preparedness in the TWWHA in terms of current operational practice, recent work and research, and areas for further work or research.
- **SECTION 6 (Response)** focuses on bushfire response in the TWWHA in terms of current operational practice, recent work and research, and areas for further work or research.
- **SECTION 7 (Recovery)** focuses on bushfire recovery in the TWWHA in terms of current operational practice, recent work and research, and areas for further work or research.
- **SECTION 8 (Conclusions)** provides the Research Project's conclusions.

1.5 Research commissioned through the Research Project

As part of the Research Project, new research was commissioned to help inform the findings and recommendations of this Report. This research included:

- an examination of the history of lightning fires in the TWWHA and adjacent areas. This research was undertaken by Dr Jon Marsden-Smedley (Marsden-Smedley 2016) and is discussed in more detail in Section 5.2.2 – Future Bushfire Risk;
- an examination of the impact of climate change on weather-related fire risk factors in the TWWHA. This research was undertaken by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) (Love et al. 2016a, Love et al. 2016b) building on

the ACE CRC's Climate Futures for Tasmania research and is discussed in more detail in Section 5.2.2 – Future Bushfire Risk; and

- an examination of the impact and effectiveness of fire suppression chemicals in the TWWHA. This research was being undertaken by the Department of Primary Industries, Parks, Water and Environment at the time of publication of this report and the results of the research will be available towards the end of 2017.

In addition to these new research projects, two synthesis studies were commissioned to bring together current understanding of bushfire in the TWWHA:

- an examination of the impact of climate change on future fire behaviour in different vegetation types in the TWWHA. This report was written by Dr Jon Marsden-Smedley (Marsden-Smedley 2016) and is discussed in more detail in Section 2.5.1 – Future Fire Behaviour; and
- an examination of the impact of climate change on the future fire regimes for natural values. This report was written by Professor Jamie Kirkpatrick (Kirkpatrick 2016) and is discussed in more detail in Section 2.5.2 – Consequences of future fire regimes for natural values.

2. VALUES IN THE TWWHA

2.1 Roles and responsibilities

Identifying and understanding the natural and cultural values of significance in the TWWHA, particularly those that are fire-sensitive, is important because their protection has implications for fire management in the TWWHA.

The TWWHA was first inscribed on the United Nations Educational, Scientific and Cultural Organisation (UNESCO) World Heritage List in 1982. Since 1982, the TWWHA has been expanded several times, with a major extension in 1989 and minor boundary modifications in 2010, 2012 and 2013 (Australian Government 2016a). The 1,584,460 hectare TWWHA property comprises approximately 20 per cent of the area of the State of Tasmania. Attachment 2 (DPIPWE 2016a) depicts the location of the present TWWHA.

As a signatory to the Convention Concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention), the Australian Government has obligations to identify, protect, conserve and present its World Heritage properties, in this case the TWWHA (Australian Government 2016a).

An Australian World Heritage Intergovernmental Agreement (IGA) (Australian Government Intergovernmental Agreement 2009) was established in 2009, between the Australian Government and all Australian states and territories, to determine respective roles and responsibilities in meeting Australia's obligations under the World Heritage Convention.

The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act) is the principal instrument for implementing Australia's World Heritage Convention obligations. Under the EPBC Act, World Heritage places, among other things, are defined as matters of national environmental significance (Australian Government 2016b).

The TWWHA consists primarily of reserves proclaimed under the Tasmanian *Nature Conservation Act 2002* and managed by the Tasmania Parks and Wildlife Service. Since its inscription on the World Heritage List, there has been a partnership arrangement between the Australian Government and the Tasmanian Government to ensure the protection of the outstanding natural and cultural heritage of the TWWHA (DPIPWE 2016a).

Obligations imposed under the World Heritage Convention (that are delegated by the Australian Government to the Tasmanian Government) are implemented by the day-to-day management responsibilities of the Tasmania Parks and Wildlife Service under the Tasmanian *National Parks and Reserves Management Act 2002*. Further details regarding the Tasmania Parks and Wildlife Service's legislative responsibilities are provided at Attachment 4.

2.2 The TWWHA and the World Heritage List criteria

The Tasmanian Wilderness is inscribed on the World Heritage List under four criteria for "natural heritage" and three criteria for "cultural heritage". The criteria are:

Natural heritage:

- "(vii) to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance;
- (viii) to be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features;
- (ix) to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals;
- (x) to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation" (UNESCO 2016a); and

Cultural heritage:

- "(iii) to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared;
- (iv) to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history;
- (vi) to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance" (UNESCO 2016a).

The criteria for assessing whether cultural and natural heritage is of Outstanding Universal Value have evolved over time and the criteria against which the TWWHA was listed in 1982 and 1989 are not identical with the current criteria (UNESCO 2016b). However, the underlying concepts have remained constant.

Attachment 7 (Australian Government 2016a) provides a list of World Heritage values from the Department of the Environment and Energy. The list is based on the 1981 and 1989 nominations for the TWWHA, assessments by the advisory bodies to the World Heritage Committee (International Union for Conservation of Nature (IUCN) and International Council on Monuments and Sites (ICOMOS)) and reports to the World Heritage Expert Panel. The Department is updating this list to include the values in the areas added to the property in 2010, 2012 and 2013 that contribute to the property's Outstanding Universal Value under each criterion.

2.3 Statement of Outstanding Universal Value (SOUV)

Outstanding Universal Value is defined as "cultural and/or natural significance which is so exceptional as to transcend national boundaries and be of common importance for present and future generations of all humanity" (Australian Government 2016c).

When the Tasmanian Wilderness was first listed as World Heritage in 1982, a Statement of Outstanding Universal Value (SOUV) was not required. An SOUV is the official statement adopted by the World Heritage Committee identifying the criteria under which a property is inscribed on the World Heritage List (Australian Government 2016c).

The primary purpose of an SOUV is to be a key reference for the future effective protection and management of a World Heritage property.

At the request of UNESCO's World Heritage Centre, the Australian Government is working with the Tasmanian Government, and technical advisory bodies to the World Heritage Committee, to develop the SOUV for the TWWHA (Jaeger and Sand 2015). The retrospective SOUV will be submitted to the World Heritage Centre by 1 December 2017 in the State Party Report on the state of conservation of the TWWHA. The State Party Report will be considered by the World Heritage Committee at its meeting in 2018 (Australian Government 2016c).

The SOUV for the TWWHA will take into account the findings of a synthesis report which will compile all available information about cultural sites in the TWWHA, and it will provide more detailed information on the cultural values of the TWWHA and how these values relate to its Outstanding Universal Value (Australian Government 2016c).

Once endorsed by the World Heritage Committee, the SOUV will be a key reference point for future protection and management of the TWWHA. It will also be a key reference point for monitoring, periodic reporting and state of conservation reporting. It is proposed that the SOUV be updated in future years to reflect the results of a comprehensive cultural study (which will be conducted over several years).

More information on the process to finalise an SOUV for the TWWHA is included in the 2016 State Party Report on the state of conservation of the Tasmanian Wilderness World Heritage Area (Australian Government 2016d).

2.4 Fire and the TWWHA values

Bushfires present one of the biggest challenges to managing and protecting the values that are recognised as significant to the TWWHA's World Heritage status.

Many, but not all, values can be significantly harmed or completely lost following a single bushfire or by an unfavourable fire regime. Examples of some of the most fire-sensitive values in the TWWHA include (see section 2.5.2, Table 7 and Attachment 7):

- some categories of Aboriginal heritage sites;
- endemic conifers: King Billy pine (*Athrotaxis selaginoides*), pencil pine (*A.* cupressoides) and Huon pine (*Lagarostrobos franklinii, Diselma archeri*, *Microcachrys tetragona*, *Pherosphaera hookeri*);
- deciduous beech (*Nothofagus gunnii*);
- rainforest and alpine vegetation;
- some organic soils, including *Sphagnum* peatlands; and
- breeding habitat of orange-bellied parrots (*Neophema chrysogaster*).

Conversely, some values in the TWWHA may be lost or altered in the complete absence of fire. Examples include:

- the broad patterns of vegetation in the landscape, which were shaped by Aboriginal fire regimes over thousands of years and are still significant to Aboriginal people;
- habitat for some fauna, including the feeding habitat for orange-bellied parrots;
- some areas of montane grassland; and
- plant species that depend on fire for regeneration.

Therefore, maintaining and protecting TWWHA values requires the deliberate application of appropriate fire regimes to some areas, while excluding fire, as far as practical, from other areas.

2.5 Overview of expected climate change impacts and consequences for bushfires in the TWWHA

2.5.1 Future fire behaviour

The following is a summary of Dr Jon Marsden-Smedley's report titled 'Lightning fires in the Tasmanian Wilderness World Heritage Area and adjacent areas' (Marsden-Smedley 2016), as commissioned through this Research Project and provided on 9 November 2016.

Dr Marsden-Smedley's report is informed by the Antarctic Climate and Ecosystems Cooperative Research Centre's (ACE CRC)'s analysis of the impact of climate change on weather-related fire risk factors in the TWWHA, which was also commissioned through the Research Project (see section 5.2.2.2) (Love et al. 2016a and Love et al. 2016b), and considers the implications of this information for future fire events in the TWWHA.

2.5.1.1 Implications for fire from climate change in the TWWHA between 1980 and 2100

The climate change projections provided by ACE CRC's analysis (Love et al. 2016a and Love et al. 2016b) indicate that between 1980 and 2100, only minor changes are projected to occur for: wind speed, Moorland Fire Danger Index[5] and relative humidity. Moderate increases are projected in: Forest Fire Danger Index[6] and temperature, along with minor decreases in moorland fuel moisture.

[5] The Moorland Fire Danger Index (MFDI) was developed from the Buttongrass Moorland Behaviour Prediction System in recognition that other fire behaviour prediction systems were not appropriately reflecting fire behaviour in Buttongrass moorlands (see section 4.2.1.1).

[6] The McArthur Forest Fire Danger Index (FFDI) is a standard index used by weather forecasters and fire services in Australia to determine fire hazard and make operational decisions around fire management. The FFDI incorporates surface air temperature, relative humidity and wind speed, combined with an estimate of fuel dryness (Drought Factor, based on Soil Dryness Index and recent precipitation) to give an index of daily fire danger. It is based on dry forest fire behaviour measurements.

In contrast, major increases are projected to occur in Mount Soil Dryness Index[7] (MSDI) and two measures of dry periods: more than 30 days with less than 50 mm of rain; and MSDI greater than 50, particularly in summer and autumn. The lightning potential is expected to decrease.

The major impacts projected to occur from climate change are related to changes in vegetation and soil flammability resulting from increases in the MSDI and dry periods. These increases in soil dryness are likely to be already occurring and manifest as increased occurrence of lightning ignitions and areas burnt, and increased fire occurrence in organic soils.

The relationships between organic soil types in the TWWHA and their potential to burn during bushfires are very poorly understood. From the information that is available, the critical factors determining the potential for organic soil fires to occur are related to the soil organic content and moisture content. This means that the organic soils most at risk are probably those that have high levels of organic matter and are located in areas that were, in the past, too wet to sustain burning.

Under the current climate, the conditions suitable for conducting safe and effective buttongrass moorland planned burning occur more frequently in autumn than in spring. The projected increases in autumn of MSDI and dry periods will mean that planned burning in buttongrass moorland in autumn is highly likely to be adversely impacted, most notably because wet scrub that is adjacent to buttongrass moorlands will be dry enough to burn throughout autumn.

Based on post-fire recovery times, the area of coniferous alpine heath and coniferous rainforest will be reduced if fires burn, on average, more than about 0.1 to 0.2 per cent of the total area of the vegetation type per year. In the case of rainforest without conifers, the area of rainforest will be reduced if fires burn, on average, more than about 1 per cent of the total rainforest area per year. During the period 1980 to the present, fires burnt about 0.01 per cent of coniferous alpine heath, about 0.05 per cent of coniferous rainforest and about 0.6 per cent of rainforest without conifers per year. While significant, the rate of burning over this period is low enough to permit post-fire recovery without causing overall decline of these vegetation types. The burning of these fire-sensitive vegetation types did, however, cause very significant decline over the 100 years preceding 1980.

2.5.2 Consequences of future fire regimes for natural values

The following is a summary of Distinguished Professor Jamie Kirkpatrick's report titled 'Consequences of future fire regimes on world heritage values' (Kirkpatrick 2016), as commissioned through this Research Project and provided on 28 October 2016.

Professor Kirkpatrick's analysis is informed by ACE CRC's analysis of the impact of climate change on weather-related fire risk factors in the TWWHA, which was also commissioned through the

[7] The Mount Soil Dryness Index (MSDI) is a simple soil moisture model calculated from rainfall and temperature observations and has been used in Tasmania for over 40 years in bushfire management. The MSDI is used as an indicator of soil and surface fuel dryness and therefore vegetation flammability across a region, but it does not account for variation of soil or vegetation type.

Research Project (see section 5.2.2.2) (Love et al. 2016a and Love et al. 2016b) and considers the implications of this information for natural values in the TWWHA.

2.5.2.1 Introduction

Formally and informally recognised values of the TWWHA under the World Heritage criteria vary in their likely responses to possible changes in fire regimes. Responses range from: susceptible to extinction; to sublimely indifferent; to likely to increase. Changes in fire regimes that may threaten some of the TWWHA values may benefit others, as the ecosystems of the World Heritage Area vary from those that can be destroyed for long periods by a single fire to those that can be destroyed by the absence of fire for decades to centuries. Species and geoheritage features in the same ecosystem can respond very differently to fire. These variations in response require a diversity of fire regimes to match the functional diversity of the highly Tasmanian-endemic biota. A diversity in fire regimes is provided, with or without human intervention, by variability in the spatial and temporal incidence of ignition, the differing tendencies of different vegetation types to propagate fire, and the influence of lakes, rivers and topography on the patterns of fire spread (Jackson 1968; Wood et al. 2011a; di Folco and Kirkpatrick 2013).

(Note: The vegetation communities listed below are a subset of the communities in Kirkpatrick (2016). Kirkpatrick (2016) also provides detail on other values that may be threatened by decrease in fire frequency, and discussion of Indigenous burning.)

2.5.2.2 Values most threatened by an increase in fire frequency

Fire-sensitive palaeoendemics

The surviving plant clades from the Cretaceous are concentrated in the zone of intergradation between rainforest and alpine vegetation where fire has been long absent (Jordan et al. 2015). The most fire-sensitive of these clades, such as King Billy pine (*Athrotaxis selaginoides*) and pencil pine (*A. cupressoides*) have no capacity to vegetatively recover after all their foliage has been killed by fire. They do not store disseminules in their canopies or the soil, and do not have disseminules adapted to long-distance dispersal. They can be rendered locally extinct by just one fire (Kirkpatrick and Dickinson 1984). There are many invertebrate species that are concentrated on, or totally depend upon, the most fire-sensitive clades (Kirkpatrick et al. 1993).

There is no doubt that the early European fire regimes resulted in a massive reduction of the fire-sensitive palaeoendemics, and that the fire prevention and fire management associated with reservation for conservation have dramatically slowed the process of loss in range of these species of outstanding universal value. Recent spatial modelling has suggested that attrition of fire-sensitive vegetation will continue, given business as usual in the context of climate change (Yospin et al. 2015).

Alpine ecosystems

The globally unusual dominance of alpine vegetation by highly Tasmanian-endemic scleromorphic shrubs and cushion plants (Kirkpatrick 1997) is sensitive to changes in fire regimes. Most alpine shrubs are obligate seed regenerators, with very few vegetatively recovering from fire, and most having limited dispersal ability. A frequency of fire of once in 20-40 years would prevent most alpine areas from becoming alpine heath (Kirkpatrick and Bridle 2013; Harrison-Day et al. 2016).

Despite the general undesirability of fire, some alpine daisy shrubs, which are wind-dispersed and short-lived, can become highly abundant after fire, dying out after approximately half a century (Kirkpatrick et al. 2002). In long unburned areas they persist because fluvial erosion provides a constant regeneration niche.

A second situation in which an increased incidence of fire may be construed to have positive conservation effects on shrubs and cushion plants in the alpine and subalpine parts of the World Heritage Area, is where rushes, sedges and shrubs overwhelm cushion plants in the eastern part of the World Heritage Area, where all the species in the cushion mosaic recover rapidly after a fire, in contrast to the invading shrubs. However, in the central and western mountains, the frequent presence of the fire-sensitive cushion plant *Dracophyllum minimum* (Kirkpatrick and Dickinson 1984) in the mosaics makes fire undesirable.

The balance between bare ground and vegetated patches in fjaeldmarks is affected by fire. Fjaeldmarks are rare in Tasmania and are the habitat of several rare species (Kirkpatrick 1997). However, a mildly higher fire incidence may have some positive effects.

Rainforest ecosystems

Several of the fire-sensitive palaeoendemic clades can dominate or co-dominate rainforest. Yet, there are many tree and shrub species in rainforest that can recover from fire vegetatively, by long-distance dispersal or through soil seed stores. Thus, rainforest as a formation will recover from a single fire while losing the most fire-sensitive of its species. However, repeated fire eliminates the formation, as indicated by the many areas where moorland occupies soils formed under rainforest (di Folco and Kirkpatrick 2013). Conversely, rainforest can replace moorland in the absence of fire, even kilometres away from rainforest boundaries (di Folco and Kirkpatrick 2013), as sassafras (*Atherosperma moschatum*) is wind-dispersed and celery top pine (*Phyllocladus aspleniifolius*) is bird-dispersed (Barker and Kirkpatrick 1994).

The projection of drier summers in western Tasmania with global warming (see section 5.2.2.2) is yet to be evident in the climatic data, but, if it does occur, and dry lightning strikes continue to be frequent, the probability of rainforest burning might be greater than in the past. However, if ignition occurs before the rainforest soils dry out, therefore burning only moorland, the burned moorland would provide a barrier to the movement of fire into rainforest, possibly lowering the probability of rainforest loss. Planned aerial ignition of large areas of moorland when the rainforest areas are too moist to burn might possibly achieve the same outcome (Marsden-Smedley and Kirkpatrick 2000; King 2004; King et al. 2006).

Organic soils and landforms

The organic soils of the World Heritage Area are globally unusual in that they are bioturbated by burrowing crayfish. The extensive moorland organic soils recover quickly from losses related to fire on valley flats, and very slowly on slopes (di Folco and Kirkpatrick 2011). The diverse alpine organic soils can be truncated by fire (Kirkpatrick and Dickinson 1984; Bridle and Kirkpatrick 1997).

The patterned mire formations of the alpine and subalpine zones of the World Heritage Area have been recognised to have outstanding universal value because they are formed from a different

process from those in the Northern Hemisphere. Wherever upright shrubs grow in the dams of mire ponds or along the ridges, fire can disrupt the features, as happened on Mt Wellington in 1967 (Whinam and Kirkpatrick 1994).

There can be catastrophic loss of the fibric layer of organic soils during and immediately after fire. Such loss has frequently been observed under scrub and rainforest. Organic soils slowly combust under the surface until the soil is soaked by rain. Losses appear to be rare under moorland.

3. FIRE MANAGEMENT ARRANGEMENTS FOR THE TWWHA

3.1 Funding

The Australian Government and the Tasmanian Government have jointly contributed to the costs of managing the property since 1983.

The Australian Government provides the Tasmanian Government with $3.4 million per annum (baseline funding until 2018) to assist with management of the TWWHA under a World Heritage Grants Funding Agreement (Australian Government 2016e). The Tasmanian Government contributes a minimum $4.9 million per annum.

This combined funding has contributed to a number of activities that increase Tasmania's capacity to manage and reduce the impacts of fires in the TWWHA (Australian Government 2016e).

In 2015, the Australian Government committed to supporting Tasmania to strengthen its management of the TWWHA by providing an additional $10.2 million, over four years from 2014-15, for its protection, conservation, presentation and rehabilitation (Australian Government 2016e). The funding, over four years from 2015, includes:

- "An annual payment of $1.5 million per year, indexed for inflation, to support the Tasmanian Government's management responsibilities in the area added to the TWWHA in 2013. This funding is matched by the Tasmanian Government.
- A one-off payment of $3.2 million in 2015-16 to address high priority road safety issues and biosecurity concerns relating to the spread of invasive species, pests and pathogens in the area added to the TWWHA in 2013.
- $575,000 to progress the work being undertaken by the Tasmanian Aboriginal Heritage Council with the Tasmanian Aboriginal community to provide more detailed information on the cultural heritage of the property and how this relates to its Outstanding Universal Value." (Australian Government 2016e).

The Australian Government also provided a one-off payment of $1.5 million in 2012-13 to the Tasmanian Government to support the development of a new management plan for the TWWHA (Australian Government 2016d).

In relation to the management of bushfires, Tasmania assists in meeting Australia's obligations under the World Heritage Convention through a combination of measures, predominantly managed by the Tasmania Parks and Wildlife Service under the Tasmanian *National Parks and Reserves Management Act 2002*. This includes the TWWHA Management Plan 1999 and policies and plans that govern fire management in the TWWHA. These are outlined in subsequent sections.

3.2 Legislation and statutory plans

Fire management arrangements for the TWWHA sit within the broader context of Tasmania's fire management arrangements. These arrangements are detailed in full at Attachment 4 (from AFAC 2016a and Tasmanian Government 2016a) and the legislation relevant to fire management in Tasmania is listed at Attachment 5.

The Tasmania Parks and Wildlife Service is responsible for managing bushfire in the TWWHA through a combination of activities. These include mitigation activities, such as fuel reduction burning and responding to bushfires in the TWWHA, which are carried out using a risk management approach.

Subsection 30(3)(ca) of the Tasmanian *National Parks and Reserves Management Act 2002* gives authority to the Tasmania Parks and Wildlife Service to "take any steps or undertake any activities that the managing authority considers necessary or expedient for the purposes of preventing, managing or controlling fire in reserved land".

As an occupier of land, the Tasmania Parks and Wildlife Service is also obligated under section 64 of the Tasmanian *Fire Service Act 1979* to take diligent steps to extinguish fire or prevent it from spreading to other land tenures and to report the fire. The Tasmania Parks and Wildlife Service must also consider fire management arrangements in the private land in the TWWHA (owned by the Tasmanian Land Conservancy, Bush Heritage Australia and Hydro Tasmania) as well as Aboriginal land vested in the Aboriginal Land Council of Tasmania, areas managed by TasNetworks, and Forestry Tasmania.

A map depicting the contiguous land tenure boundaries of the TWWHA is provided at Attachment 6.

3.2.1 TWWHA Management Plan

3.2.1.1 TWWHA Management Plan 2016

The formulation of the TWWHA Management Plan 2016 (DPIPWE 2016a) (the Plan) is a statutory process set out in the Tasmanian *National Parks and Reserves Management Act 2002* (the Act).

In respect to fire management, the Plan does not specifically set out the objectives for fire management in the TWWHA. Rather, it refers to the relevant policies and plans that govern fire management in the TWWHA. This enables the relevant policies and plans, particularly the regional strategic fire management plans, to be reviewed and updated, providing the Tasmania Parks and Wildlife Service with more flexibility than would be the case if prescribed in the TWWHA Management Plan (which is only required to be updated once every 10 years).

The Plan has a strong emphasis on ongoing research and provides numerous management actions in support of this. It also prescribes a fire plan for the TWWHA that will integrate all aspects of fire management. The fire plan is to include objectives to guide the use of fire management, provide guidance on protection of outstanding universal values over other values and built assets, integrate cultural and ecological burning, map strategic and priority areas for burning, identify areas for strategic protective burning and cultural landscape burning, and guide an increase in the level of planned burning to meet modelled risk management requirements. The Plan prescribes

management actions to increase understanding of the ecological role of fire, to protect values from inappropriate fire regimes through planned burns and for improved treatment of Aboriginal cultural values in the Bushfire Risk Assessment Model (BRAM) (DPIPWE 2016a).

3.3 Fire policies and procedures of the Tasmania Parks and Wildlife Service

3.3.1 Tasmania Parks and Wildlife Service Fire Management Policy 2014

The Fire Management Policy 2014 (DPIPWE 2014b) is the top level policy for the Tasmania Parks and Wildlife Service fire management, and all other Tasmania Parks and Wildlife Service fire management policies are subordinate to it. The Policy outlines the Tasmania Parks and Wildlife Service's management responsibility and obligations regarding the TWWHA and what it will do to deliver its responsibilities.

3.3.2 Fire Planning Policy 2014

The purpose of the Fire Planning Policy 2014 (DPIPWE 2014a) is to identify the framework (Figure 5) for fire management planning to be used by the Tasmania Parks and Wildlife Service for reserved land, and other Crown land, that it is responsible for managing. The policy aims to identify:

- the hierarchical relationships between legislation, codes of practice, various fire plans and other administrative documents;
- the names, primary purposes and content of the various categories of fire plans within the multi-tiered framework; and
- the responsibilities for preparation, delivery and approval of the fire plans (DPIPWE 2016a).

Some key plans and documents specified in this policy include:

- Regional Strategic Fire Management Plans (see section 3.3.6);
- Fire Management Strategies (for individual reserves or groups of reserves, although there are none current for the TWWHA);
- Fire Action Plan;
- Fire Works Plans;
- Annual Planned Burning Program; and
- Fire Emergency Response Plans (DPIPWE 2014a).

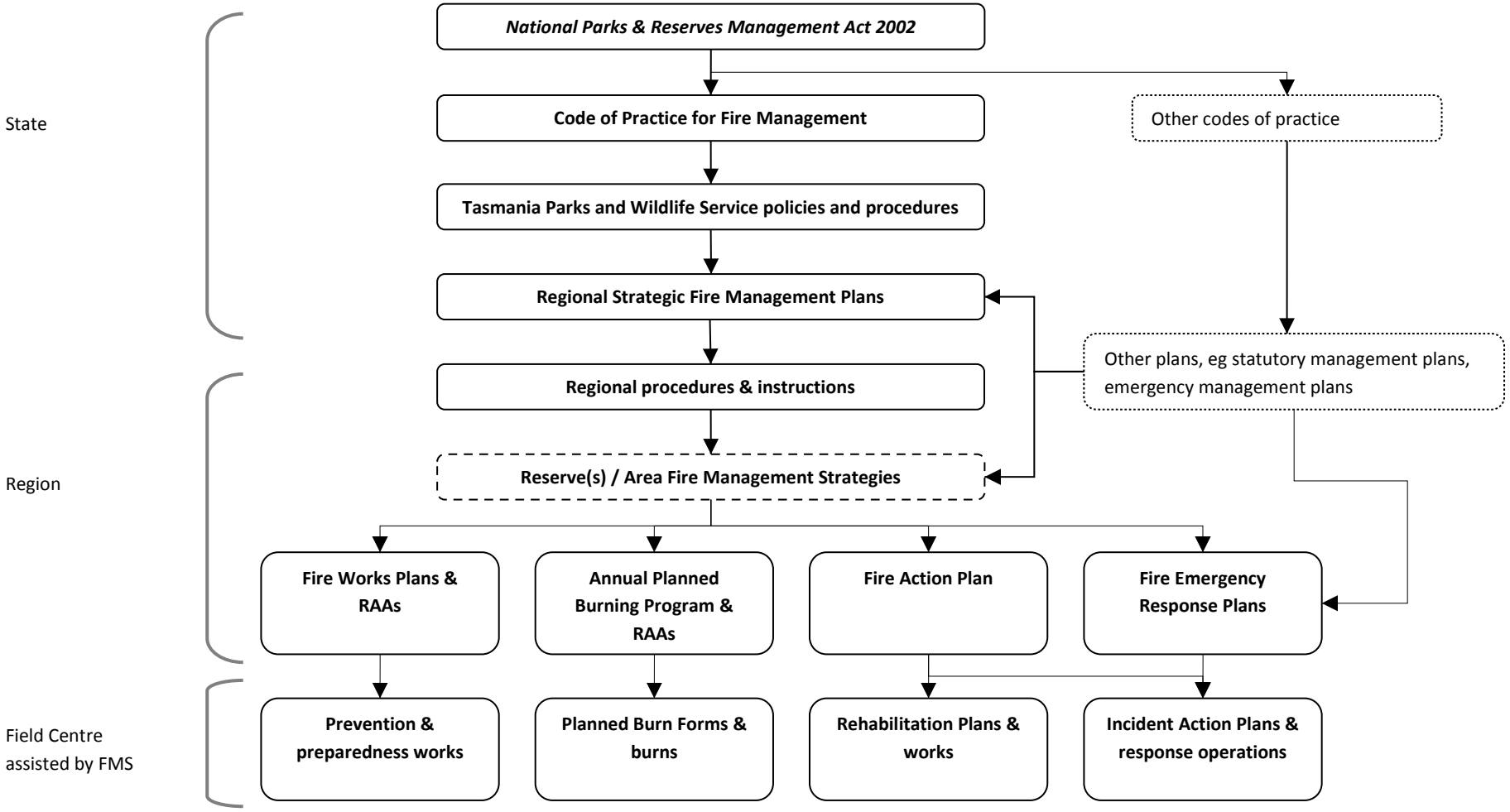


Figure 5: Fire Planning Framework of the Tasmania Parks and Wildlife Service, from the Fire Planning Policy

3.3.3 Wildfire Response Procedures

The purpose of the Wildfire Response Procedures is to ensure that:

- Tasmania Parks and Wildlife Service employees are aware of their responsibilities and the responsibilities of others, and how to proceed when notified of a bushfire; and
- the response to bushfires is timely, efficient, adequate and consistent, and to improve the allocation and distribution of firefighting resources, especially people, within the limits of overall staffing.

3.3.4 Fire Duty Officer procedures

This document specifies the procedures to be adopted in the establishment and operation of Duty Officers at the State level, with the aim to ensure that:

- Tasmania Parks and Wildlife Service responses to reported fires are initiated;
- an appropriate state of readiness for Tasmania Parks and Wildlife Service employees is maintained;
- Tasmania Parks and Wildlife Service employees are provided with points of contact to coordinate resource sharing between the regions, and facilitate the use of Hobart office employees and the fire crew; and
- other agencies, particularly the Tasmania Fire Service and Forestry Tasmania, are provided with a single, reliable and authoritative point of contact in the Tasmania Parks and Wildlife Service.

3.3.5 Other operational fire procedures

In addition to the aforementioned policies and procedures, the Tasmania Parks and Wildlife Service has a suite of policies and procedures that document preparedness and response arrangements. These cover a variety of matters such as:

- firefighter fitness assessment;
- Incident Management Team (IMT) guidelines;
- training framework;
- strategic pre-position of helicopter resources; and
- process for the use of foam and water enhancer products for fire management and suppression (see section 6.1.4).

3.3.6 Regional Strategic Fire Management Plans

Regional Strategic Fire Management Plans have been developed by the Tasmania Parks and Wildlife Service for each of its operational regions: Northern (DPIPWE 2009), Northwest (DPIPWE 2012) and Southern (DPIPWE 2011b). The boundaries of the operational regions are shown in Attachment 8. The principle of these plans is to ensure that the approach taken by the Tasmania Parks and Wildlife Service focuses resources on areas with the highest levels of identified bushfire risk.

The Regional Strategic Fire Management Plans, which were prepared much later than the 1999 TWWHA Management Plan (DPIPWE 1999), have informed the management of fire in the

TWWHA since their development, with bushfire risk assessment (Bushfire Risk Assessment Model – see section 4.1.2) as their basis. The plans cover fire prevention, preparedness, response, restoration, resource requirements, and standards monitoring and reporting.

Guided by the risk assessment, the TWWHA is mapped into a fire zoning overlay with four categories:

- **Asset Zone** – areas with assets of high importance requiring protection from fire (includes natural, cultural and built assets).
- **Asset Protection Zone** – areas of high strategic importance to protect values in Asset Zones.
- **Strategic Fuel Management Zone** – areas for fuel management that will increase the likelihood of controlling a bushfire in, or the forward spread through, the area.
- **Land Management Zone** – fire management in the zone aims to maintain appropriate fire regimes for the vegetation communities, species diversity and cultural heritage.

3.3.7 Fire Action Plan

The Tasmania Parks and Wildlife Service annually reviews and updates its Fire Action Plan (FAP), which guides daily preparedness during the bushfire season and provides information and guidance to staff to consider in the initial response to a fire. A key principle of the Fire Action Plan is that the activities of the Tasmania Parks and Wildlife Service staff depend on the forecast Forest Fire Danger Index (FFDI) and consequent bushfire risk. The Fire Action Plan specifies arrangements for:

- FFDI triggers for staff actions and availability;
- standby or prepositioning of resources including firefighters, equipment, machinery and aircraft;
- fire-spotter flights;
- walking track closures;
- reserve closures; and
- campfire restrictions (at FFDI 25 – a lower level than Total Fire Bans which are usually triggered at FFDI 38).

3.3.8 Bushfire preparedness and response

Collectively, the policies, procedures and plans summarised above guide the daily preparedness and response of the Parks and Wildlife Service to bushfires during the fire season.

Preparedness is provided by:

- preseason preparation activities and training (eg fire training; fire season preparedness days; firefighter fitness assessment);
- rostering of duty officers, firefighters and Incident Management Teams across the State (Fire Duty Officer Procedures; Incident Management Team Guidelines; Fire Action Plan);
- daily fire action plans prepared by the Fire Duty Officer, which detail the arrangements for the next day in accordance with the triggers specified in the Fire Action Plan; and

- the functioning of the Fire Operations Room in Hobart and continuous 24/7 monitoring of the State situation by the Fire Duty Officer.

Response is guided by the Wildfire Response Procedures, the Regional Strategic Fire Management Plan, the Fire Action Plan, the Bushfire Risk Assessment Model (BRAM) and Bushfire Operational Hazard Model (BOHM) and coordinated in the first instance by the Fire Duty Officer (see section 5.1.2). Further details on response strategies and tactics are provided in section 6.

3.4 Evaluation of the effectiveness of fire management in the TWWHA

In November 2015, the Tasmania Parks and Wildlife Service published a report on fire management as a component of its broader monitoring and evaluation program for Tasmania's parks and reserves (DPIPWE 2015b).

While the Tasmania Parks and Wildlife Service has noted that future editions of the Report will examine the impacts and implications of the 2016 bushfires, it concluded, at the time, that fire management in the TWWHA was being undertaken appropriately. The evaluation report also found that:

- The total area affected by fire has increased significantly in the decade ending in 2013 compared with the previous decade.
- The actual number of bushfires increased slightly in an inter-decade comparison, with 37 fires across 1993-2003 and 43 fires across 2003-2013.
- The number of planned fires had increased slightly in the most recent decade compared to the earlier one, but the total area affected by planned fires had trebled in the same decade in comparison, as the average size of planned burns had increased.
- In the decade from 1993-2003, ignitions caused by lightning accounted for only 15 per cent of the total fire-affected area. By contrast, in the recent decade 2003-2013, 99 per cent of the total area affected by unplanned fire was attributed to lightning ignitions.
- Relatively small areas of fire-sensitive vegetation have been affected in the last decade, and only a small percentage of the total TWWHA area. Most of the affected area is buttongrass, which is fire-adapted. For example, only one per cent of the total area affected by the Giblin River fire in January 2013 was subsequently assessed as fire-sensitive.

The Report identified elements being progressed of a strategy to manage the risks to fire-sensitive vegetation from dry lightning:

(i) improved dry lightning forecasting (some aspects of Antarctic Climate and Ecosystem's Climate Futures for Tasmania research, see section 5.2.2.2);

(ii) improved understanding of fire behaviour and flammability of fire-sensitive vegetation (eg rainforest flammability, see section 5.2.3);

(iii) early fire detection and faster initial response; and

(iv) development of a strategy for more fuel reduction burning.

3.5 Recommendations relating to fire management in the TWWHA

Recommendation 1 – Comprehensive fire management planning

Clear, well-defined objectives for fire management should be incorporated into a Fire Management Plan for the TWWHA. These objectives should identify how fire management (fire suppression, 'let go' and management fires) will be used to protect and conserve the natural and cultural heritage values in the TWWHA.

The Fire Management Plan for the TWWHA should clearly set out the circumstances in which priority will be given to protecting the Outstanding Universal Value of the TWWHA over built assets within its boundaries.

4. PREVENTION

4.1 Current operational practice

4.1.1 Prevention and mitigation strategies

The Strategic Fire Management Plans (see section 3.3.6) present strategies to be used for prevention and mitigation of bushfires in reserves managed by the Tasmania Parks and Wildlife Service. These are summarised in Table 3. Two of these strategies are discussed in more detail: fuel reduction burning (see section 4.1.3) and campfire restrictions (see section 4.1.4).

Table 3: Summary of the strategies used in the TWWHA for prevention and mitigation of bushfires

Strategy	Description	Level of use
Fire management zoning	Zoning of all areas of the Tasmanian Wilderness World Heritage Area (TWWHA) to guide priorities for mitigation and response strategies	Entire TWWHA is in the process of being mapped into four zone categories (see section 3.3.6)
Fuel reduction burning (planned burning)	The planned application of fire to reduce hazardous fuel quantities; undertaken in prescribed environmental conditions within defined boundaries	Used regularly, mainly in buttongrass (see section 4.1.3)
Campfire restrictions	Statutory restriction of campfires (eg Fuel Stove Only Areas)	Campfires prohibited in most of the TWWHA, except designated fireplaces and areas added recently to the TWWHA
Administration	Hazardous works shut down (eg welding, chainsaw use); reserve closures (partial or complete)	Routine practices specified in the Fire Action Plan
Education	Communication programs to increase understanding of bushfire safety and fire prevention	Interpretation (visitor centres, Discovery Ranger program) and publications widely used
Enforcement	Tasmania Parks and Wildlife Service Authorised Officers enforce statutory laws and regulations relating to bushfire prevention (eg illegal campfires)	Rangers, field officers and firefighters enforce laws throughout TWWHA including patrols of at-risk areas
Emergency response plans	A pre-incident plan that sets out the response required (actions and roles) to expedite decision-making to protect people from bushfires in specific areas	Several plans in draft form for specific visitor areas of the TWWHA
Fire breaks	Mechanical construction of fuel-reduced areas adjacent to assets	Rarely used in TWWHA at present; a possible future tactic to protect fire-sensitive natural values in small areas (eg stands of conifers)
Fire trails	Tracks created and managed specifically to provide access for fuel reduction burning and fire control	Very few fire trails in the TWWHA
Engineering	Design of structures that are resistant to bushfires or to minimise the risk of bushfire ignitions	Few buildings designed to contemporary building standards for bushfire-prone areas

4.1.2 Bushfire Risk Assessment Model (BRAM): Risk mapping in the TWWHA

Bushfire risk assessment and modelling is an important risk management tool. The risk assessment informs the management of risk by identifying and prioritising areas that may be suitable for risk mitigation activities such as fuel reduction burning, and identifying areas that are not suitable for risk mitigation but can be prioritised for suppression or other response activities when bushfires approach or threaten particular values.

There is a recognised need to understand fire behaviour specific to vegetation types, and to develop predictive modelling that identifies both level of risk and potential impact in the event of bushfire. This modelling is key to supporting effective management of the risk of fire in the TWWHA. Tasmania has made significant progress in the State's bushfire risk management capability, through developing and introducing the Bushfire Risk Assessment Model (BRAM) by the Tasmania Parks and Wildlife Service in the late 2000s.

BRAM is a computer mapping system that models and maps the risk of bushfire at 100-metre grid resolution. Data used by BRAM comes from many sources and is combined and analysed to calculate risk scores for the State, including all Tasmania Parks and Wildlife Service reserves. The final product is a map of bushfire risk across Tasmania.

BRAM identifies the likelihood and consequence of a fire at a particular point. The risk is determined through a qualitative risk matrix, incorporating likelihood of fire and values at risk (consequences). The process identifies relative risk at a particular point. The output is represented as spatial layers that show the likelihood, values at risk and actual risk (DPIPWE 2011a). The model uses four major elements to calculate risk (Figure 6):

- **fire behaviour potential**: the manner in which fuel ignites, flame develops, and fire spreads;
- **ignition potential**: the probability or chance of fire starting as determined by the presence of causative agents (likelihood);
- **suppression capability**: the factors and limitations that are related to the ability to contain a bushfire upon detection (likelihood); and
- **values at risk**: a specific or collective set of natural resources, cultural sites and man-made improvements and/or developments that have measurable or intrinsic worth, and which could potentially be destroyed or otherwise altered by fire in any given area (consequence) (DPIPWE 2011a).

BRAM is fully operational and updated annually to ensure that areas identified as being at higher risk are prioritised for treatment (planned burning, mechanical fuel reduction, emergency response plans). BRAM enabled the prioritisation for the development of Strategic Fire Management Plans for the Southern, Northern and Northwest regions of Tasmania, as described in section 3.3.6. BRAM and associated tools are also used by fire duty officers for daily preparedness throughout the bushfire season (see section 5.1.2) and for determining values at risk and suppression priorities once fires start (see section 6.1.1).

Bushfire Risk Assessment Model (BRAM)

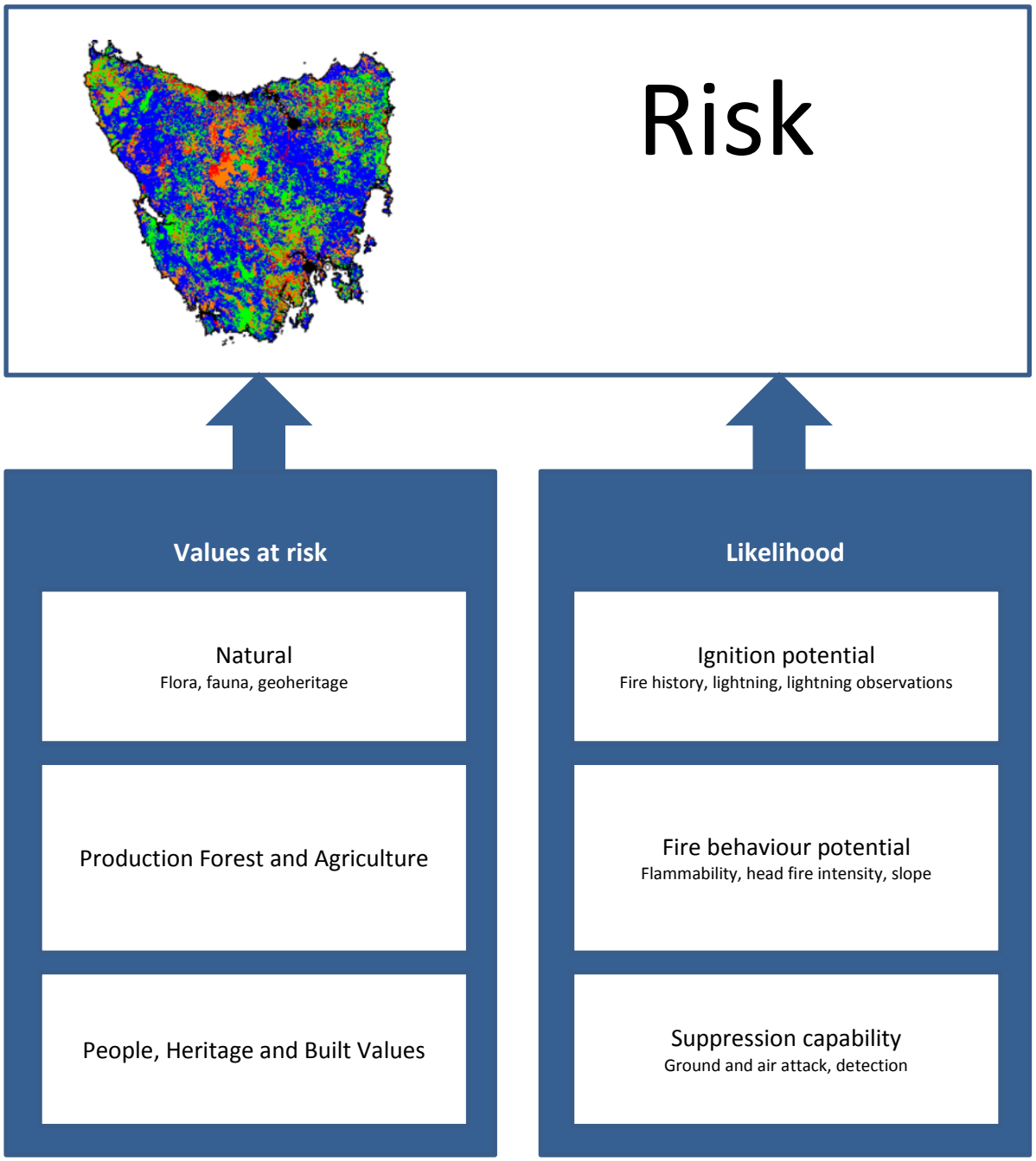


Figure 6: The Bushfire Risk Assessment Model (BRAM) developed and used by the Tasmania Parks and Wildlife Service

4.1.3 Planned burning

From a natural values conservation perspective, fire management in the TWWHA should ensure that ecosystem function, approximate distributions of the major biomes, and fire-dependent and fire-sensitive values in the TWWHA are maintained through appropriate fire regimes. The changes in burning post-European settlement have contributed to loss of both fire-sensitive and fire-dependent values (see Glossary for definitions of terms) in the TWWHA (Marsden-Smedley and Kirkpatrick 2000). Removing planned burning altogether from the TWWHA is considered an ecologically unacceptable fire management policy because of the deleterious consequences for natural and cultural values that would ensue (see section 4.2.1).

Planned burning is used as a management tool in the TWWHA, where it is appropriate to do so and where funding permits, to achieve the following objectives (see section 4.3.1):

1. To protect people and built assets (Asset Protection Burns).
2. To reduce the risk of damage to fire-sensitive values from bushfires (Asset Protection Burns and Strategic Fuel Reduction Burns); and
3. To provide the fire regime (eg frequency, season and intensity) required by fire-dependent species and vegetation communities (Ecological Burns).

The tourist infrastructure at Cradle Mountain, Lake St Clair and Mount Field are examples of where planned burning has been undertaken to achieve the first objective.

Planned burning to achieve the second objective is undertaken almost exclusively in the extensive buttongrass moorlands in lowland and montane areas. Where possible, this burning is planned to simultaneously address the third objective. Strategic Fuel Reduction Burns aim to reduce the likelihood and impact of landscape-scale bushfires, thus indirectly protecting natural values, while Asset Protection Burns are typically located close to specific fire-sensitive natural values.

The third objective is commonly referred to as ‘ecological burning’ while the first and second objectives are often called ‘fuel reduction burning’.

Examples of recent burning to achieve the third objective include montane grasslands at Lees Paddocks in the northern part of the TWWHA, where floristic diversity is believed to have declined due to lack of fire (Balmer et al. 2015); and buttongrass moorlands in the South-West aimed at maintaining the feeding habitat of the orange-bellied parrot (see section 4.3.3.4).

The priorities, patterns and methods of planned burning in the TWWHA have changed considerably over the past 30 years. Planned burning to maintain orange-bellied parrot habitat, and protect visitor areas, has occurred throughout this period, but burning along the Lyell Highway (second objective) has declined as malicious illegal fire-lighting in the TWWHA has virtually ceased. Through this period, there has been an increase in understanding of the benefits and techniques for the planned application of fire in buttongrass moorlands. Larger burns in remote areas are now routinely undertaken as part of the program of Strategic Fuel Reduction Burns guided by recent research (see section 4.2.1).

Large planned burns are undertaken in remote areas by helicopter ignition with minimal or no on-ground crews. More traditional styles of planned burns, using fire crews and tankers, are undertaken at visitor nodes.

Possible deleterious impacts of planned burning in the TWWHA are assessed via the Reserve Activity Assessment process undertaken by the Tasmania Parks and Wildlife Service (DPIPWE 2014a), which mandates an annual internal review of proposed planned burns.

4.1.4 Campfire restrictions

Bushfires spreading accidentally from campfires is a significant risk to the natural values of the TWWHA. This risk is increasing with growing visitation from interstate and international visitors who are not aware of the 'Fuel Stove Only Area' policy or do not receive adequate information due to ageing interpretation, limited availability of material (eg signs and publications), language and/or cultural barriers.

There is poor understanding among many TWWHA visitors about how to safely light and extinguish campfires. In the TWWHA, this risk is exacerbated by the significant extent of organic soils. Campfires lit on organic soils can smoulder underground (hidden from view) and few people are aware of how difficult it is to properly extinguish such fires. Accidental fires from fuel stoves (eg petrol and methylated spirits) do occur and user inexperience is often the cause.

The statutory regulation of campfires is covered for all of Tasmania under the Tasmanian *Fire Service Act 1979*, and for the TWWHA under the *National Parks and Reserved Land Regulations 2009* (made under the Tasmanian *National Parks and Reserves Management Act 2002)*. Most of the TWWHA has been declared a Fuel Stove Only Area to protect natural values, and fires are totally banned in these areas. There are some places where campfires in existing fireplaces are permitted, particularly in areas included in the TWWHA in 2013. Additional restrictions on campfires are imposed by the Tasmania Parks and Wildlife Service at times of very high fire danger, triggered by criteria that are more stringent than those typically used for the declaration of days of Total Fire Ban by the Tasmania Fire Service, and signs are erected at locations specified in the Fire Action Plan.

4.2 Recent work and research

4.2.1 Planned burning

4.2.1.1 Buttongrass fire behaviour

In the early 1990s, the Tasmania Parks and Wildlife Service recognised that the knowledge of fire behaviour in buttongrass moorland was very limited and therefore fire operations (both suppression and planned burning) were not as effectively managed as they could be.

Buttongrass moorland communities are the most extensive vegetation group in the TWWHA (see Table 6 and Attachment 7), the most flammable and the most frequently burnt by both planned and unplanned fires. A series of research projects were developed by the Tasmania Parks and Wildlife Service to better understand the weather and fuel parameters that influence the rate of spread and intensity of fires in buttongrass.

An area of small experimental fires was established at McPartlan Pass in the TWWHA in 1991 and fire-spread data was collected from this experiment, and also from planned burns and bushfires. More experimental fires were lit later in the 1990s, to better understand the conditions under which buttongrass fires self-extinguish. These studies were published in a series of scientific papers and the operational findings were summarised in Marsden-Smedley et al. (1999), including fire behaviour equations, the Moorland Fire Danger Index and prescriptions for planned burning. The buttongrass fire behaviour model now underpins fire operational practice for all buttongrass vegetation in Tasmania.

Buttongrass fires spread very quickly and intensely, even when the ground is completely saturated or has freestanding water. Fires can spread within 24 hours of rain, but wind speed is the overriding factor determining the rate of spread. Even on relatively calm days, buttongrass fires can be fast moving and very difficult to control.

4.2.1.2 Fire simulation modelling: FIRESCAPE-SWTAS

The computer simulation model called FIRESCAPE-SWTAS was developed for South-West Tasmania. It is used to explore how much benefit, in terms of reduction of damage to natural values such as rainforest, is provided by differing amounts of planned burning. FIRESCAPE has also been applied to other parts of Australia (King et al. 2011; Bradstock et al. 2012).

FIRESCAPE-SWTAS incorporates fire-spread equations from models (eg buttongrass as described above), as well as real landscape spatial data on topography and vegetation, and a 'weather generator' based on available historic data from weather stations. FIRESCAPE-SWTAS 'lights fires' and they spread through the landscape for as many simulated years as desired (typically 100 'computer years'). Testing of different patterns and annual percentage of area burnt by planned burning is what the FIRESCAPE model was designed to do. Recently burnt areas are assumed to either stop unplanned fires or at least slow their rate of spread in accordance with the fire behaviour models.

The published papers (King et al. 2006; King et al. 2008) indicate that if burning is applied at the broad scale, 10 per cent of the total buttongrass area in South-West Tasmania needs to be burnt every year to significantly reduce the extent of unplanned bushfires and consequently achieve a result with tangible benefit for protecting fire-sensitive natural values, although lower levels of burning (eg 5 per cent) can still provide some benefit. The model also shows that if planned burns are applied strategically (eg immediately adjacent to fire-sensitive assets such as rainforests) then a level of protection can be achieved by burning about 3 per cent of the total area of buttongrass moorland per year.

4.2.1.3 Buttongrass fire regime and natural values impacts

An understanding of the fire ecology of ecosystems present in the TWWHA is necessary to develop sustainable ecological or planned burning programs, and to protect fire-sensitive and fire-dependent values. Fire ecology research and monitoring undertaken by the Department of Primary Industries, Parks, Water and Environment (DPIPWE) has prioritised the unique buttongrass moorland vegetation, where planned burning plays both a crucial ecological and fire protection role. Studies to date have primarily focused on the stability of the moorland-forest

boundaries, the rate of community recovery following planned management burning in the different types of moorland present in the TWWHA, and community response to differing fire intervals. To date, there has not been any attempt to investigate the impacts of differing spatial patterns as a factor of fire regimes.

DPIPWE's role has focused on long-term monitoring which is less suited to research undertaken by other organisations or to address specific operational fire management questions. A significant amount of research that is relevant to fire regimes and planned fire is also undertaken by a range of other organisations including universities, CSIRO and non-government organisations.

In the 1990s, DPIPWE's Natural and Cultural Heritage Division (then a part of the Tasmanian Parks and Wildlife Service) initiated a series of research projects to investigate the response of natural values to fire in buttongrass moorlands. This was triggered by limited knowledge of fire regime requirements for natural values, plans to undertake landscape-scale planned burns in moorland, and guidelines at the time that recommended burning moorlands every five to seven years. Research monitoring sites were established in moorlands near Lake Pedder and Lake St Clair – representing low productivity and moderate productivity moorlands respectively. Collaborations were established with the University of Tasmania, with several PhD projects completed. A series of publications and reports were produced and these are mostly summarised in the proceedings of the Buttongrass Moorland Management Workshop held in 2007 (Balmer et al. 2010). Since then, research has continued and further publications and reports have been produced, both within and outside DPIPWE (eg di Folco and Kirkpatrick 2011; Driessen et al. 2013; Driessen 2016; Storey and Betts, 2011). The results of this work form the basis for advice on fire regimes for natural values conservation in the TWWHA (DPIPWE 2015a). The monitoring is ongoing and the January and February 2016 bushfires, which burnt long-term monitoring sites, provide an opportunity to compare differences in impact and recovery time from these bushfires to the previously measured response to planned fires.

The buttongrass moorland flora comprises at least 209 vascular plant species that are substantially dependent on buttongrass moorlands; of these about 69 are endemic to Tasmania, most largely restricted to Western Tasmania (Jarman et al. 1988; Lawrence et al. 2007). Buttongrass moorland ecological studies have found that most of these species recover quickly following fire (Brown et al. 2002; Storey and Balmer 2010). Nevertheless, successional patterns can be seen, for example the abundance of some is greater in the first few years post-fire, while others become an increasingly important component of older moorlands (Jones 2007; Kantvilas 2007; Storey and Balmer 2010). A small proportion of species (mainly shrubs and obligate seeders and some lichens) may be significantly reduced in abundance by short intervals between fires (less than years), but others (mainly grasses and herbs) are advantaged by such short intervals (Kantvilas 2007; Storey and Balmer 2010). Few species are known to be eliminated from the community by long fire-free intervals (more than 20 years) provided the structure of the vegetation remains as moorland. However, some species become more sparsely distributed (particularly grasses, herbs and some bryophyte species, Brown et al. 2002).

Transition to scrub does not typically begin to occur for at least 25 years in fertile habitats and takes much longer in infertile, poorly drained situations. However, given the risks associated with

fire intervals of short or long duration, an optimal fire regime for most moorland plants would vary fire intervals, avoiding the occurrence of either short intervals or long intervals across large areas (DPIPWE 2015a). Fire has occasionally been observed to cause losses of organic soil in some environments and may take many decades to be replaced by natural soil formation (di Folco and Kirkpatrick 2011). Given the importance of soil-stored seed and vegetative regeneration from surface rhizomes, it is desirable to avoid combustion of the organic soil surface.

There still remains much to learn about fire ecology of moorland plants. For example the effect of patch size and spatial patterns of burning has not been investigated and may influence the community patterns due to effect of distance from unburnt vegetation on browsing and colonisation rates. The effect of fire age on reproductive behaviour in moorland plant species has not been studied, but observations of lack of seed production in many common sedges and Restionaceae may warrant further study to determine if seed production may be stimulated by fire, and whether seed productivity influences granivore population levels. Water permeability of soils and soil depth is associated with floristic composition, but it is not known how floristic composition impacts on vegetation flammability of moorland or how fire might impact on water permeability, soil depth or organic soil accumulation rates.

Over 35 species of vertebrate fauna have been recorded using buttongrass moorlands. However, few of these animals are known to spend their entire lifecycle within buttongrass moorland and the majority of them also occur in other habitats.

Buttongrass moorland is the primary habitat in Tasmania for four species of vertebrate: the broad-toothed mouse (*Mastacomys fuscus*), the ground parrot (*Pezoporus wallicus*), the striated fieldwren (*Calamanthus fuliginosus*) and the southern emu-wren (*Stipiturus malachurus*). Some research has been undertaken on the use of moorlands of different fire age by small mammals and birds (Arkel 1995; Driessen 1999; Chaudhry 2010). Some small mammals are absent from early successional stages (less than five years in moorlands on medium productivity soils, and 15 to 20 years in moorlands on low productivity soils). Mean densities of resident bird species are lowest in early successional stages after fire, and their presence is strongly influenced by the presence of adjacent unburnt vegetation (Chaudhry 2010). Unburnt riparian and other edge habitats are important for maintaining populations of birds and mammals.

Invertebrates comprise the greatest component of biodiversity in buttongrass moorlands. For example, in a study of the resilience to fire of ground- and foliage-active invertebrates in buttongrass moorlands, over 1,600 recognisable taxa were collected, yet only 16 per cent could be assigned a species name (Driessen 2016). Thus, it is difficult to determine what component of the invertebrate fauna is restricted to buttongrass moorlands. Ground-and foliage-active invertebrate fauna were found to be resilient to fire, with no medium/long-term loss of species following single fires. However, there are indications that other invertebrate assemblages such as soil-active invertebrates may be more vulnerable to fire; or at least take long periods of time (more than 30 years) to return to pre-fire levels of diversity and abundance (eg Green 2009).

4.2.1.4 Stability of fire boundaries

Several studies have been undertaken to investigate the stability of buttongrass moorland boundaries (Brown and Podger 1982; Balmer 1990; Brown et al. 2002; Marsden-Smedley et al. 2000; Wood et al. 2011a; Wood et al. 2011b).

This work demonstrated that while boundaries are normally stable, because of the feedback between vegetation flammability and environmental gradients related to drainage, topography and soil fertility, they can shift in response to changed fire regimes (Podger et al. 1988; Brown et al. 2002; Wood et al. 2011b).

Long-term monitoring plots have been established by DPIPWE's Natural and Cultural Heritage Division at sites originally surveyed in 1990 (Marsden-Smedley et al. 2000). Evidence for shifts in vegetation has also been observed from pollen analysis of peat cores (Fletcher et al. 2014; Fletcher et al. 2015) and changes in the physical properties in the soil profile (di Folco and Kirkpatrick 2013).

4.2.1.5 Impact of fire regimes on natural values in montane grassland

Fire appears to be important in the maintenance of at least some of Tasmania's grassy vegetation, particularly highland areas (montane grasslands), where other environmental influences such as frost and poor drainage are insufficient to prevent invasion by woody shrubs. Grasslands may also be lost through a conversion to sedgeland. There is strong evidence that many of the montane grasslands were maintained and extended through burning by Aboriginal people (Bowman et al. 2013), and since 1820, by clearing and burning by graziers (Kirkpatrick 1999). Substantial patches of montane grassland occur on reserved land, including the TWWHA.

A draft montane grassland fire management strategy and plan has been prepared (Kirkpatrick 2012) with the following aims: (1) to maintain or increase the area of montane grassland in the public reserve estate, (2) to ensure a diversity of structure and floristics that will support all known rare or threatened species that occur within montane grassland, and (3) to maintain cultural traditions that achieve the above objectives.

Burning of an area in Cradle Valley was unsuccessfully used to attempt to restore a grassland community that had become dominated by sedges. The cool wet conditions at the time of the ecological burn resulted in a low intensity patchy fire and resulted in very little bare ground. While a soil seed trial had proven the presence of *Poa* seeds in the soil, the fire failed to promote the recovery of grasses.

In October 2012 and 2013, as part of the montane grassland fire management strategy, the Tasmania Parks and Wildlife Service conducted low intensity ecological burns on land it manages at Lees Paddocks, and burning is planned for several other grassland areas in the TWWHA.

In order to determine whether the Tasmania Parks and Wildlife Service ecological management burning achieves the aims of the montane grassland fire management strategy, the Natural and Cultural Heritage Division has established basic monitoring of vegetation (Balmer et al. 2015) and invertebrates (Driessen in prep.) at Lees Paddocks.

Concurrent with burning on land managed by the Tasmania Parks and Wildlife Service, the Tasmanian Land Conservancy has developed a fire management plan for the Vale of Belvoir (Marsden-Smedley and Leonard 2014).

Further grassland monitoring sites in the TWWHA are planned, together with a more general vegetation survey of the current condition of grasslands in the TWWHA, to be undertaken in areas previously surveyed (Kirkpatrick and Duncan 1987). The areas where monitoring is likely to be established include grassland areas burnt in the Lake Mackenzie Complex, February Plains and Lake Bill fires of January 2016.

4.2.2 Warra Long Term Ecological Research site

The Warra Long Term Ecological Research site of 15,900 hectares was established in 1995 to encourage long-term ecological research and monitoring in wet eucalypt forests in Tasmania. Following the extensions to the TWWHA of 2013, 80 per cent of the Warra site is now in the TWWHA, while the remainder is on Permanent Timber Production Zone land managed by Forestry Tasmania.

In 2010, Warra became a member site of the Terrestrial Ecosystem Research Network, which was established under the Australian Government's National Collaborative Research Infrastructure Scheme (Terrestrial Ecosystem Research Network 2016). The management of Warra currently resides with the scientific staff of Forestry Tasmania, although a transition to joint management with Tasmania Parks and Wildlife Service is anticipated.

Warra is a scientific research site of national and international importance. The significant value of the investment in the infrastructure and already established data collection at Warra cannot be overstated. The site contributes to the understanding of many aspects of land management and climate change science. Some examples include (Forestry Tasmania 2016):

- Mt Weld Altitudinal Transects – a network of plots at 100-metre intervals along a 50 to 1300-metre altitudinal gradient to monitor long-term shifts in species' range;
- Log Decay Study – compares the succession of saproxylic species colonising large logs from mature *Eucalyptus obliqua* and smaller logs from regrowth *E. obliqua*;
- Warra Weirs Hydrology – continuous monitoring of stream flow and water quality in three small catchments;
- Warra Climate Station – an automatic climate station managed by the Bureau of Meteorology;
- Bushfire Chronosequence Plots – a series of 0.25-hectare plots in single-age, wet eucalypt forest stands established along a chronosequence of time-since-disturbance;
- Southern Forests Experimental Forest Landscape – a 33 x 32 km landscape dominated by lowland wet eucalypt forest that captures a gradient of disturbance intensity resulting from past bushfires and post-European land use;
- Warra Flux Tower (80 m tall) and Core 1-hectare plot (Supersite) – a member site of the Ozflux Network which aims to understand mechanisms controlling exchanges of carbon, water vapour and energy between terrestrial ecosystems and the atmosphere and to

provide data in carbon and water balances of key ecosystems for model testing (Ozflux 2016);
- Warra AusCover 5 x 5 km plot – a field site of the AusCover Network used for field validation and calibration of remote sensing products;
- Silvicultural Systems Trial – compares alternative methods of harvesting and regenerating tall, wet eucalypt forests; and
- AusPlots Forests plots – Warra hosts three plots in a continental network of 1-hectare plots in tall, wet eucalypt forests used to track forest growth and productivity along continental gradients.

DPIPWE's Natural and Cultural Heritage Division has been collaborating with Forestry Tasmania on the ongoing long-term monitoring at Warra. The studies of flora and fauna in wet forest communities aim to determine how these communities change over time, and when possible, changes in response to stochastic disturbance events such as bushfire. There is significant potential to expand the role of Warra for bushfire management, for example (Tim Wardlaw pers. comm.):

- including soil moisture recording for the Australian Soil Moisture Information System (see section 5.2.4);
- ongoing monitoring of fuel accumulation in wet eucalypt forest;
- relating forest structure to post-fire intensities; and
- improved understanding of rainfall intensity and fuel moisture in wet eucalypt forests, by relating canopy intercept and run-off to monitored catchment flow.

4.2.3 Modelling climate change impact on planned burning

The Antarctic Climate & Ecosystems Cooperative Research Centre (ACE CRC) has established a 'Prescribed Burning Project'. Through this project, ACE CRC is investigating the changing opportunities for planned burning in Tasmania under climate change, with a focus on three aspects that could affect the future viability of planned burning:

- Part I is an assessment of changes in the factors that determine when prescribed burning can be applied. These conditions include wind speed, atmospheric stability and fuel moisture, which directly influence fire behaviour, and relative humidity, temperature, Drought Factor and Mount Soil Dryness Index, which indirectly affect fire behaviour through their influences on fuel moisture. Changes in monthly values between current and future time periods in the Climate Futures for Tasmania projections have been assessed.
- Part II is a description of daily weather patterns related to extreme fire danger, and an overview of how these may change in the future. Changes in the frequency and distribution of daily weather patterns associated with atmospheric instability and extreme fire danger are investigated. This will focus on particular months and seasons when planned burning is applied in Tasmania.
- Part III describes changes to broad vegetation types caused by the interaction between climate change and frequency of burning (planned and unplanned). A vegetation model is

being developed to provide an indication of the future trajectory of vegetation, allowing gradual change to flammability across the landscape to be incorporated into longer-term planning and the consequences of prescribed burning to be considered.

The results of this work will help inform future planned burning regimes, both in the TWWHA and statewide, and will also improve knowledge of the interaction between climate change, burning and impacts on vegetation types.

4.3 Areas for further work or research

4.3.1 Aboriginal fire regimes

Planned burning is one of the strategies used in the TWWHA to mitigate the risk of damage caused by bushfires (Marsden-Smedley and Kirkpatrick 2000). While this is a contemporary use of fire as a management tool, planned burning is not only about bushfire prevention; Aboriginal people were also applying fire for cultural reasons in the TWWHA for thousands of years.

The detailed knowledge of the patterns of burning and fire regimes applied across the TWWHA by Aboriginal people is incomplete. However, it is apparent that the patterns of vegetation observed in the landscape today are strongly influenced by past Aboriginal burning. For example, the significant extent of buttongrass plains, created at the expense of rainforest, reflects, at least in part, Aboriginal burning patterns.

There is a need to develop as complete an understanding as possible of Aboriginal burning practices. This should draw on all lines of evidence, including cultural, historic and scientific sources. The knowledge gained will assist in developing planned fire regimes for the future.

The TWWHA Management Plan (DPIPWE 2016a) has the following management action:

> *Engage Aboriginal people to develop protocols that allow the use of fire as a traditional cultural practice.*

The contemporary use of planned burning in natural value management may reflect past anthropogenic fire regimes to some extent, where these are known. It will, however, need to respond to a new fire management paradigm, where land use, climate, landscape, management priorities and planning frameworks have all been fundamentally altered (Marsden-Smedley and Kirkpatrick 2000).

The reintroduction of Aboriginal involvement in planned burning will require the development of a partnership, and a new vision of planned burning that integrates objectives on cultural aspirations, biodiversity management and management of bushfire risk (including the risk to visitors, neighbours and staff during fire operations).

4.3.2 Bushfire risk modelling

Large summer bushfires ignited by lightning have occurred in the TWWHA in 2007, 2009, 2013 and 2016, and these have highlighted the threat to natural values from unplanned fires. As described in section 4.2.1.2, FIRESCAPE-SWTAS has provided significant insight into the role that planned burning in buttongrass can play in reducing this threat.

That said, the insight provided to date by FIRESCAPE-SWTAS is far from sufficient or complete evidence on which to design an expanded planned burning program. The cost/benefit ratio for both economic and nature conservation measures requires further analyses, as does the most beneficial and strategic patterns of burning. The results of published FIRESCAPE-SWTAS analyses are limited by the quality of data and models that were then available as inputs to the simulator.

Further analyses are required using a landscape fire-spread modelling tool (FIRESCAPE-SWTAS is one example of such a tool but others have since been developed) with improved input data and models to test specific hypotheses and planned burning scenarios, particularly under future climates. Questions that still require answering include:

1. On the basis of new input data and sub-models, what benefit is provided by planned burning for protecting natural values?
2. What are the spatial and temporal burning patterns that provide the most or optimum advantage?
3. What natural values are likely to be lost or severely impacted despite fuel reduction burning because of other factors?
4. What is the potential environmental cost (eg inter-fire interval for both planned and unplanned fires) for buttongrass vegetation of an expanded planned burning program?
5. What is the economic cost of a planned burning program for the buttongrass of the TWWHA and how much does that reduce bushfire suppression costs?
6. How will the costs and benefits be altered with climate change – is fire risk mitigation through fuel reduction burning a viable long-term strategy?

4.3.3 Impacts from planned burning

Based on the monitoring and research summarised in sections 4.2.1.2 and 4.2.1.3, there is now a clear understanding that planned burning can play an important ecological role in maintaining buttongrass moorland, as well as having a role in the protection of fire-sensitive values.

However, more knowledge is required to better understand the tolerance of species and landforms to fire frequency and intensity, and the other fire regime requirements of fauna, flora and landforms, such as fire size and patchiness. This knowledge is necessary in order to ascertain how we define and apply an appropriate fire mosaic at a landscape scale.

Furthermore, the impact of fire, including planned burning, on the formation and persistence of organic soils is poorly understood, as is the interaction of fire regimes with climate change.

Therefore, the monitoring and research of fire regimes and natural values of buttongrass ecosystems continue while implementing an adaptive management approach to the planned burning program.

4.3.3.1 Organic soils

Organic soils reflect an ongoing balance between plant production and the decomposition of plant remains. There is, however, more to learn about the interaction between fire and organic soils in Western Tasmania buttongrass, and opinions differ among scientists. For example, one

view is that burning under conditions when the soils are wet prevents soil loss and may actually increase levels of soil organic matter. However, there is wide consensus that burning when soils are dry has the potential to result in soil loss through combustion.

Soils may be vulnerable to ongoing losses for a significant period following fire, through the normal processes of mechanical soils erosion of bare ground and through increased rates of decomposition caused by changes to the hydrology and temperature regime of the soil (Bridle et al. 2003; di Folco and Kirkpatrick 2011). Effectively, the soil may be lost as gasses to the atmosphere and as dissolved organic carbon to the waterways. Soil formation following fire may be slower because of decreased inputs until the vegetation biomass returns to pre-fire levels. A sustainable fire regime may depend on sufficient time between fires for new organic accumulation to replace the material lost during and after fire.

The existing data (di Folco and Kirkpatrick 2011) suggests that the vulnerability of buttongrass soils to fire-associated losses varies with topography, with slopes being more vulnerable than valley flats. The work of di Folco and Kirkpatrick (2011) raises the possibility that the fire regimes required to reduce fire risk to sensitive values may result in net loss of soil at some sites. However, this research is based on data collection at three sites, over four years. Further work is required to more clearly identify thresholds in existing soil cover, topography and vegetation productivity that influence sustainable fire intervals. There is also a need to extend the work from buttongrass into other vegetation types with organic soil horizons that are vulnerable to losses during fire, to better understand the degree of protection needed in all environments.

The fauna of organic soils and their response to fire is poorly understood. A study of mites has found that both their diversity and density is greatest 30 years after fire, suggesting they may be vulnerable to more frequent fire regimes (Green 2009).

4.3.3.2 Fire regions

The TWWHA encompasses ecosystems with differing fire ecologies and fire regimes in a mosaic across the property. For example, even within a biome such as grasslands, altitudinal and floristic differences may mean differences in sustainable fire regimes. Similarly, fire is not uniform across the property; there are patterns in fire distribution and regular fire paths. Strategic fire planning would be aided by developing a fire regions map showing areas where the fire ecology and fire management environments are similar.

A fire regions map could be developed in an adaptive management approach where the regions are determined on current knowledge and updated over time as experience or targeted research indicate the need. To be most easily integrated into fire management planning, fire-related ecological research needs to consider the interaction of fire with environmental variation and operational constraints. The results of such research can then be used to update the fire region map.

4.3.3.3 Buttongrass fuels, organic soils and mapping

Buttongrass moorland fuels are highly variable across the landscape and overlay soils that spatially vary in depth and organic content. Current fuel accumulation models identify two fuel types in the TWWHA with moorlands associated with either low or medium-productivity

substrates (Marsden-Smedley and Catchpole 1995). However, an investigation has been proposed to determine if a third model of 'very low productivity' fuel accumulation is required for sparse buttongrass moorland, which indicates areas with a very shallow or incomplete organic soil cover (DPIPWE 2015a). Research has also been proposed to determine if burning to reduce the fuel loads in buttongrass may be contributing to unsustainable rates of organic soil loss (DPIPWE 2015a). This may be important because, according to present mapping, 'sparse buttongrass on slopes' is the most abundant sub-class of buttongrass vegetation in South-West Tasmania and where planned fire may result in substantial soil losses. It has been suggested, however, that the current map of 'sparse buttongrass on slopes' is an inaccurate and overrepresented artefact resulting from use of aerial photography taken soon after fires (Jon Marsden-Smedley pers. comm.). Accurate mapping of the three different moorland classes is required.

In the future, remote sensing tools will give the opportunity to look at fuel variation over time, over the landscape, to produce fuel maps for assessing fire risk and improving efficiency and prescriptions for sustainably burning moorland vegetation. Further data capture of fuel characteristics in sparse buttongrass moorland for calibration of remote sensing is required.

4.3.3.4 Orange-bellied parrot

Most known breeding activity of the critically endangered orange-bellied parrot occurs within 10 kilometres of Melaleuca Lagoon, South-West Tasmania. The birds nest in natural hollows or man-made nest-boxes in eucalypt forest and rainforest, and forage on the seeds and flowers of low vegetation in adjacent moorland and sedgeland plains. Inappropriate fire regimes have been identified as a high risk threat to the survival of the orange-bellied parrot (Department of Environment, Land, Water and Planning 2016). Inappropriate fire regimes affect the structure and productivity of moorlands and sedgeland plains in the breeding range. Orange-bellied parrots in the breeding range appear to prefer to forage in locations with a time-since-last-fire of between one and eight years (Brown and Wilson 1980). Limited fire in the breeding range between 2000 and 2010 may have reduced the amount of habitat in the preferred age-class and contributed to the observed decline in breeding participation by females (Department of Environment, Land, Water and Planning 2016). While available information supports the application of some fire in the breeding range, more work is required to determine appropriate ecological fire regimes for this species. The need for a better understanding of appropriate fire regimes for this species was identified as a priority by the Tasmania Parks and Wildlife Service in developing research and monitoring priorities for the TWWHA 2013–2018 (DPIPWE 2013). However, obtaining this information will be challenging, with fewer than 70 orange-bellied parrots known to exist in the wild.

4.3.3.5 Invertebrate fauna

Aspects of fire ecology relating to invertebrate fauna in buttongrass that require research include:

- Soil-active fauna, because previous work suggests that they may be more sensitive to fire than ground- and foliage-active fauna.
- The impact of fire on water-active fauna in moorlands, which has not been studied. Moorlands support a diversity of freshwater fauna in adjacent streams and rivers, as well as in pools and burrows within the moorland proper. In particular, moorlands support a

highly distinct assemblage of freshwater crayfish (*Ombrastacoides* spp. and *Spinasticoides* spp.) whose burrows provide habitat for a fauna known collectively as pholeteros.

- Assessing the extent to which invertebrate species are restricted to moorland – this will not only assist with understanding the potential impacts and recovery of moorland fauna from fire (for example, does adjacent vegetation provide a refuge for recolonisation), but also contribute to further understanding the significance of this ecosystem.

4.3.3.6 Montane grasslands

Research is needed to determine the extent of woody plant invasion (eg by scrub or rainforest species) or conversion to sedgeland (eg by buttongrass or other sedge species) of the montane grasslands of the TWWHA and to what extent this may be a response to changing fire regimes, browsing, or climate. Continuation of monitoring and research is also required to determine to what extent the invasion of woody plants into grasslands and grassy woodlands can be reversed through the implementation of ecological burning as specified in the draft montane grassland burning plan (Kirkpatrick 2012).

4.3.4 Planned burning strategy for the TWWHA

Although there is some guidance provided by the Regional Strategic Fire Plans, there is no overall direction for undertaking planned burns in the TWWHA in any single existing document. The TWWHA Management Plan (DPIPWE 2016a) calls for a fire management plan. A fire management plan is needed with clear program level objectives (AFAC 2016b) for planned burning and other fire strategies. The required components of a fire management plan are:

- objectives for managing cultural and natural values while mitigating bushfire risk to people and assets; and
- a program of mosaic burning for the TWWHA at a range of scales, from local to landscape, to achieve the stated objectives.

4.3.5 Organic soil dryness field testing method

Successful planned burning in Western Tasmania is very dependent on identifying the right conditions of fuel dryness that ensure target fuels will burn, while non-target fuels will not. Typically, this means that there should be a moisture differential between buttongrass, which is usually the target fuel, and other vegetation types such as scrub and forest, which are the non-target fuels (Marsden-Smedley 2009).

Furthermore, organic soils, in both the buttongrass and the surrounding vegetation, should be sufficiently wet to minimise the likelihood of smouldering fires in the ground. The suitable days for planned burning in buttongrass are understood in a general sense – two to three days following the end of significant rainfall are usually ideal – and buttongrass fuels can burn well even with saturated soils (Marsden-Smedley 2009). There is always a risk, however, that organic soils are drier than thought because of local scale inaccuracy of the Mount Soil Dryness Index (MSDI) and lack of local and recent rainfall records. There is anecdotal evidence that organic horizons in scrub can in some circumstances be significantly drier than the organic soil in buttongrass, creating the chance of smouldering soil fires should the planned burn cross the scrub boundary.

At the present time, there is no tested quantitative method for measuring organic soil dryness in the field, to verify the assumed soil moisture. Therefore, there is a need to develop a field method for checking organic soil dryness for use with planned burning with the following components:

- testing and choice of a suitable field measuring instrument;
- identification of appropriate threshold values for organic soil moisture in target vegetation (ie buttongrass) and non-target vegetation (eg scrub, forest, alpine communities) and links to modelled soil moisture mapping; and
- preparation of documentation, protocols and training for fire operational staff.

It is recognised that the second component listed above will involve considerable work.

4.3.6 Managing fire-sensitive values in flammable landscapes

There are areas in the TWWHA with fire-sensitive natural values that paradoxically occur in flammable parts of the landscape. One example is stands of pencil pines that occur in sedgy grasslands. There is a need to investigate techniques and strategies to manage fire in these areas, including testing whether planned low intensity fires can mitigate the risk of high intensity summer fires while maintaining natural processes and diversity.

4.3.7 Fire refugia prediction

Fires in the TWWHA, particularly in the South-West, can be predicted to occur more frequently in certain topographic positions than others. For example, north-facing slopes and lower altitudes are generally drier and therefore more likely to burn than southern-facing slopes and higher altitudes. There is, in turn, a positive feedback from this phenomenon that leads to less flammable vegetation in places where fire is less likely to occur (Wood et al. 2011b). There are other landscape features that can also reduce the likelihood of fire, such as where fire spread is restricted by boulder fields and water bodies. Fire-sensitive vegetation is often found in these areas, which can also be described as fire refugia.

It is assumed that fire refugia are where fire-sensitive vegetation is most likely to persist in the longer-term, particularly when confronted with increased fire frequencies. Modelling on how climate change will alter the distribution patterns of species even in the absence of fire, if available, should also be considered.

Therefore, areas that are both fire refugia, and direct climate change refugia, are important to identify, and may help determine the priorities for fire prevention, preparedness and response. DPIPWE has created a fire refugia spatial data layer, but there is potential for further work to ensure that the mapping is as robust and accurate as possible, based on the best available data and models, and to inform management systems such as the Bushfire Risk Assessment Model (BRAM).

4.3.8 Campfire and fuel stove risk

There is a need to develop a strategic document that reviews the prevention strategies and practices associated with campfires and fuel stoves to ensure that:

- the extent of the risk to TWWHA values is adequately analysed and understood; and

- the risk treatment strategies are updated commensurate with the level of risk, including designation of Fuel Stove Only Areas and other fire restrictions, development of education media and enforcement.

4.4 Recommendations relating to prevention of fire in the TWWHA

Recommendation 2 – The Bushfire Risk Assessment Model (BRAM)

The Tasmania Parks and Wildlife Service and DPIPWE should maintain an ongoing program of investment in and development of fire management tools including the BRAM and the Bushfire Operational Hazard Model (BOHM). As the BRAM is used across all agencies and tenures in Tasmania, it is imperative that it is fully auditable, and that its structure, inputs and operability are regularly reviewed.

BRAM should be fully integrated as a whole-of-government decision-support system with appropriate governance structures established accordingly; and readily accessible by all Tasmanian fire agencies and incident management teams.

BRAM should be supported to a greater extent than it is at the present time. The current level of operation means that its full capacities are not being used and the incorporation of new information and programming is restricted. It should be noted that while BRAM is an excellent tool to consider the spatial arrangement of risk, other risk modelling tools are available that simulate the spread of fire and these are now routinely used in fire management. BRAM cannot be considered as the sole bushfire risk assessment tool available for the TWWHA.

The current design of BRAM, however, limits the practical availability and use of the system to a small group of fire management officers within the Tasmania Parks and Wildlife Service. There would be significant benefit in increasing the accessibility of BRAM by rebuilding it as a new computer system that is available to inform fire managers in the Parks and Wildlife Service, Forestry Tasmania and the Tasmania Fire Service, and from wherever they may be operating, to make critical decisions on priorities and dispatch in conjunction with other fire behaviour modelling tools. The provision of training on BRAM to a wider range of operational users is also required.

It is imperative that that BRAM continues to incorporate the best knowledge of fire behaviour models. Enhancement of the system should include use of appropriate fire-spread simulation tools for new vegetation types (such as moorland) when they are developed. Existing fire behaviour models and fire simulators should not be misused, that is, used beyond the vegetation types and fuels for which they have been validated.

Recommendation 3 – Objectives for planned burns

Clear objectives (at the strategic and program levels) should be set for management burning in the TWWHA.

The short, medium and long-term results of management fires should be monitored to evaluate the fires against specified objectives, and the findings used to retain, improve or modify approaches taken to management burning.

Burning programs should reflect the best available evidence. Fire simulation modelling tools should be used to guide the development of planned burning programs to meet objectives and new data incorporated into the models as they become available.

As with other management activities, the monitoring of management burns should be actively incorporated into the adaptive management framework for the TWWHA.

Similarly, the re-introduction of Indigenous burning practices should have clear objectives, and monitoring should be incorporated into the adaptive management framework for the TWWHA.

Recommendation 4 – Monitoring the consequences of fire

The short, medium and long-term impacts of planned and unplanned fires should be monitored in order to understand the consequences of fire for the natural and cultural values of the TWWHA.

The findings of this monitoring should be used to plan future response to bushfires and to inform decisions about the use of management burning.

As with other management activities, the monitoring of the impacts of bushfire management should be actively incorporated into the adaptive management framework for the TWWHA.

5. PREPAREDNESS

5.1 Current operational practice

5.1.1 Capability

The Tasmania Parks and Wildlife Service has, for 20 years, employed firefighters specifically trained in remote area firefighting and has developed techniques, specialised equipment and expertise to support this activity. In more recent years, the Tasmania Parks and Wildlife Service has increased the number of other specialist fire staff. There is a Fire Management Section based in Hobart consisting of a State Fire Manager, two Fire Management officers, a Fire Equipment Officer, Fire Administration Staff, a Fire Crew Manager and permanent firefighters. In each region there is a Fire Management Officer and Fire Operations Officers. Seasonal firefighters are employed each season to bolster the number of firefighters. As well as specialist firefighters, field staff (including rangers and field officers) also contribute to this capability.

Remote area firefighting is a highly specialised field for both firefighting crews and pilots and requires a high level of fitness. In this context, all Tasmania Parks and Wildlife Service remote area firefighters are required to undertake a fitness assessment developed in the United States (Sharkey and Gaskill 2009). This assessment ensures they can cope with the demands of remote area firefighting and that the Tasmania Parks and Wildlife Service is not putting them or their colleagues at risk by tasking them with activities that they are not fit for. This assessment has been adopted by most Australian land management agencies and is considered current best practice.

There are many specialist roles that support firefighters on the ground including:

- Fire duty officers;
- Incident management teams (various specific skill sets – see section 5.3.1.2); and
- Fire observers (detection flights).

Staff from across the Tasmania Parks and Wildlife Service, including the Hobart Office and all field centres, are trained in these specialist fire functions as a secondary role to their regular work duties.

Aircraft, primarily helicopters, are available for firefighting in the TWWHA from shared contracting arrangements coordinated by the Tasmania Fire Service. More information on the Tasmania Fire Service, Forestry Tasmania, interagency arrangements and national support arrangements is provided in Attachment 4.

5.1.2 Fire Duty Officer

The Tasmania Parks and Wildlife Service operates a Fire Duty Officer system to manage daily fire preparedness and response. The Fire Duty Officer is on call 24 hours a day, seven days a week, from 1 October to 30 April and is the agency's first point of contact for fire reports or fire activity. The Fire Duty Officer operates from the Fire Operations Room in Hobart and uses the policies and procedures summarised in section 3.3 to maintain appropriate preparedness levels and response.

The position is a proactive one where the occupant actively seeks out likely fire situations, takes steps to prevent fire and responds rapidly to any fire reports.

Each day, the Fire Duty Officer sets out a daily fire action plan for the State based on forecast fire danger rating triggers set out in the Fire Action Plan (see section 3.3.7). This includes ensuring an appropriate level of staff resources, pre-positioning of staff, equipment, machinery and aircraft, deploying fire-spotter flights, monitoring fire weather and lightning detection websites, etc. This daily fire action plan is circulated to all relevant staff so that they are advised of the arrangements in their area and across the State.

The Fire Duty Officer initiates a response to any fire on reserved land or in areas where the Tasmania Parks and Wildlife Service has the nearest available firefighting resources. In most situations, the Fire Duty Officer manages the response as the Incident Controller but will delegate management of the fire to the on-call preformed Incident Management Team if the fire or fires exceed the Fire Duty Officer's span of control or ability to manage the fire with the resources allocated to the fire operations room. In the majority of cases, the Fire Duty Officer will dispatch a number of firefighters with a skilled sector commander to supervise the operations on the ground. In more complex cases, the Fire Duty Officer will dispatch an Incident Management Team and a large team of firefighters, and the Incident Management Team will assume responsibility for management of the fire.

The Fire Duty Officer role is tasked to the Tasmania Parks and Wildlife Service's specialist Fire Management Officers. The agency currently has five Fire Management Officers (two in Hobart and one in each of the three regions).

Where there are multiple fires going at any one time, the Fire Duty Officer may need to prioritise the response to fire. The process used to prioritise fire response will vary significantly depending upon the number, nature (values at risk) and scale of the fires. The process can be quite simple and based on the Fire Duty Officer's knowledge of the situation and likely outcomes, or it can be a more complex operation tasked to another team. Further detail on the prioritisation process is set out in section 6.1.1.

Effective emergency management relies on a comprehensive approach to preparedness and response.

5.1.3 Detection: flights, websites, public, fire towers

Early fire detection and rapid response is critical for the successful delivery of any fire management program. For example, bushfires in buttongrass can grow within less than an hour to a size where suppression is no longer practical. The smaller the fire, and less vigorous the fire behaviour, the greater the probability that initial attack crews will be able to suppress the fire.

In Tasmania, bushfire detection is generally undertaken by ground-based staff or public reporting through the Tasmania Fire Service FireComm branch (000 emergency calls), or through operational detection systems including fire towers, aerial spotter flights, monitoring systems such as cameras, and websites that present satellite data such as Sentinel, Weatherzone or Landgate Firewatch.

When advance notice is possible, the Bureau of Meteorology provides lightning warning forecasts to the Tasmania Parks and Wildlife Service. Lightning occurrence tracking is paramount to early detection and response to any remote fire or fires caused by lightning strike. Information available from monitoring systems, both pre- and post-lightning events, is used in association with information and advice from the Bureau of Meteorology forecasters to guide timing and location of fire-spotter flight paths.

A summary of the methods used to detect fires in the TWWHA is provided in Table 4. All of these methods, in combination, contribute to detecting bushfires; no single method is considered sufficient on its own. The Fire Duty Officer actively monitors all available information sources and instigates detection flights when considered necessary.

Table 4: Summary of the methods used in the TWWHA for detection of bushfires

Detection method	Level of use	Effectiveness	Risks – impact on TWWHA values	Research opportunities
Ignitions detection by aircraft	Used regularly – the most effective of available detection methods	Moderate – some fires not visible; weather can prevent flying	Ignitions not detected in time, resulting in large fires with significant environmental & cultural impact	
Ignitions detection by remote sensing	Publicly available websites are used regularly	Low – often too slow to facilitate rapid attack; cloud cover & satellite timing can prevent detection	As above	Research into best available technology is required. New products coming on stream.
Ignitions detection by public & fire towers	Used regularly – opportunistic reporting of fires by public	Low – often reports are too late to facilitate rapid attack; very limited coverage from existing fire towers	As above	
Remote lightning detection	Publicly available websites are used regularly	Low accuracy (± 1 km & high false negative rate)	Areas with potential ignitions not determined, resulting in large fires & significant environmental impact	Research of higher accuracy systems, and new systems.

5.2 Recent work and research

5.2.1 Bushfire Operational Hazard Model (BOHM)

The Tasmania Parks and Wildlife Service is augmenting the operational capacity of the Bushfire Risk Assessment Model (BRAM) to support decision-making. This involves developing a Bushfire Operational Hazard Model (BOHM) that takes into account the daily and forecasted weather

observations to calculate fire weather indices and fire behaviour values, based on vegetation types and fuel loads. This system will assist personnel making resource deployment decisions, based on risk and the availability of resources, to prepare for and dispatch in response to bushfires (Figure 7).

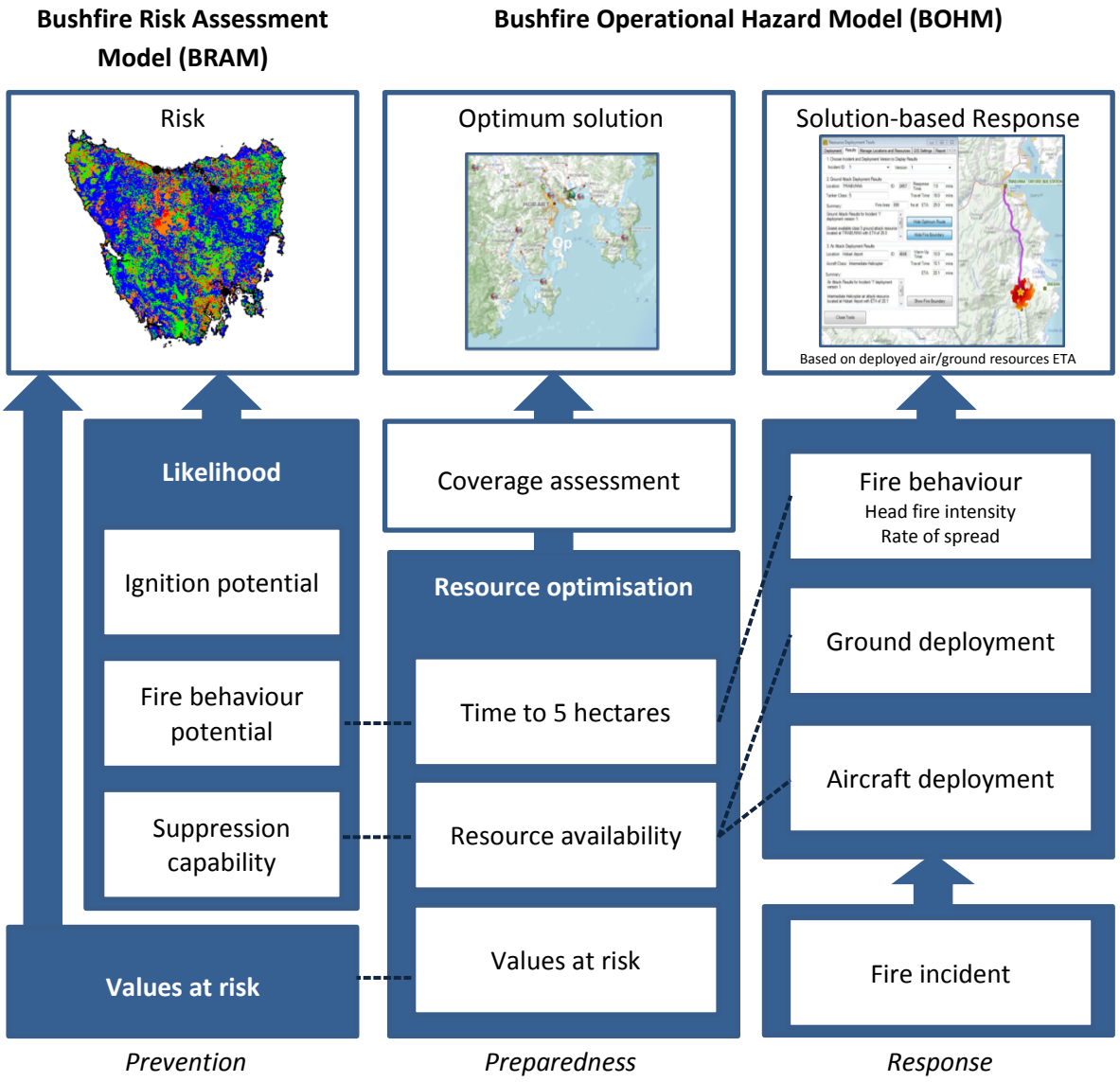


Figure 7: The Bushfire Operational Hazard Model (BOHM) developed and used by the Tasmania Parks and Wildlife Service

Once a fire occurs, the Tasmania Parks and Wildlife Service Fire Duty Officer is able to enter into the system an incident location and resource type (eg aircraft, fire tankers or remote crews) to dispatch to the location of the fire. The system will process the request, either using the road network (ground attack along with operating speed by vehicle class) or cruise speed (by aircraft type and straight line), to determine the most effective resource to dispatch (Figure 7). An

additional function has been added to the tool to display a rate of spread time to a five-hectare fire boundary (five hectares being a size identified as the threshold for successful initial attack) using topographic and vegetation type base maps. The Fire Action Plan of the Tasmania Parks and Wildlife Service also outlines minimum dispatch levels (for fires accessible by tankers), predicted fire behaviour according to vegetation types and Forest Fire Danger Index (FFDI) or Moorland Fire Danger Index (MFDI), and recommended firefighting strategies and tactics.

Deployment of remote area firefighters only occurs after a risk assessment has been undertaken, including consideration of the values at risk, likelihood of success, fire behaviour, current and forecast weather conditions, access and evacuation. The BOHM and BRAM tools contribute to this risk assessment.

5.2.2 Future bushfire risk

5.2.2.1 Changes in lightning fire incidence in the TWWHA

The following is a summary of Dr Jon Marsden-Smedley's report titled 'Lightning fires in the Tasmanian Wilderness World Heritage Area and adjacent areas' (Marsden-Smedley 2016) which was commissioned through this Research Project, and provided on 9 November 2016.

The occurrence of lightning fires in the TWWHA and adjacent areas has greatly increased over the past 45 years. During this time, lightning fires have gone from about 0.1 per cent of fires and 0.01 per cent of the area that was burnt, to about 28 per cent of fires and 78 per cent of the area that was burnt. Overall, nearly 60 per cent of the areas that were burnt during this period by lightning fires consisted of buttongrass moorland, about 12 per cent wet eucalypt forest, six per cent mixed forest and six per cent rainforest. This increase in the incidence of lightning fires in the TWWHA has been particularly marked in the past 15 years, with major lightning-caused fires occurring in 2001, 2007, 2013 and 2016. Most of the area burnt since 1980 is in the southern half of the TWWHA.

All of the recorded lightning fires between 1980-81 and 2015-16 were ignited in long unburnt vegetation. This indicates that it is highly probable that, in buttongrass moorland, there is a positive interaction between fire age and the potential for lightning to result in a sustaining fire. This is due to markedly smaller amounts of rain being required to extinguish lightning fires in low-density open moorlands than is the situation in closed high-density moorlands. This also indicates that planned burning in buttongrass moorlands, by creating more open fuel arrays, has the potential to significantly reduce the risk of lightning fires sustaining.

5.2.2.2 ACE CRC's Climate Futures for Tasmania research into impacts of climate change on future bushfire risk

Statewide Climate Futures for Tasmania Future Fire Danger Project

The high quality and fine-scale climate projections generated by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC's) Climate Futures for Tasmania project was applied through the Climate Futures for Tasmania Future Fire Danger Project, to increase understanding of bushfire meteorology and fire danger hazards and risks in a changing climate (ACE CRC 2016).

The project focused on six districts across the State, identified using the Bureau of Meteorology's weather forecast districts. These districts include a western region and a central plateau region, which cover some of the areas of the TWWHA. The results of the project were released in December 2015, with publication of the Climate Futures for Tasmania *Future Fire Danger: the Summary and Technical Report* (Fox-Hughes et al. 2015).

Cumulative Forest Fire Danger Index (FFDI) is the sum of the daily maximum FFDI, in this case across one year, centred on a single fire season (ie July to June), and represents the level of potential incidence and/or severity of bushfire (Fox-Hughes et al. 2015). The results of the Future Fire Danger Project indicated an increase in the cumulative FFDI in all districts over the next century. The results also indicated a fire season that begins earlier and lasts longer across the State and a significant increase in the area of Tasmania experiencing very high and extreme levels of fire danger (ie 'high' fire danger days).

2016 analysis of the impact of climate change on weather-related fire risk factors in the TWWHA

Building on analysis undertaken for the statewide Future Fire Danger Project, ACE CRC was commissioned through this Research Project to undertake analysis of the impact of climate change on weather-related fire risk factors in the TWWHA (Love et al. 2016a and Love et al. 2016b).

Under a high emissions scenario in the Climate Futures for Tasmania downscaled climate models, the ACE CRC's preliminary research findings had the following broad characteristics (Love et al. 2016a and Love et al. 2016b):

- Widespread lightning outbreaks decrease in frequency and extent (but not necessarily intensity).
- Average conditions are projected to be less conducive to lightning. Love et al. (2016a) note that these findings relating to lightning are consistent with the work of Timbal et al. (2010), where instability is projected to decrease with time over Southern Australia during the current century (in the cooler months investigated in their study).
- Indicators of fire danger relevant to dry eucalypt forest increase significantly with respect to both average conditions and the intensity of extreme events.
- The mean fire danger increases in areas of buttongrass moorlands.
- Increases in fire danger indicators accelerate in the second half of the century.
- The most extreme values of buttongrass moorlands fire danger are projected to remain steady through to the end of the century.
- The number of days per fire season on which the Mount Soil Dryness Index (MSDI) exceeds 50, averaged over the TWWHA, increases by 16 per cent in the near future, 58 per cent by mid-century and 218 per cent by end-of-century.
- The area of the TWWHA over which MSDI exceeds 50 on a given day is projected to increase by similar percentages.
- The number of days per fire season on which 30-day antecedent rainfall is less than 50 mm increases by 8 per cent in the near future, 22 per cent by mid-century and 91 per cent by end-of-century.

- The tendency of dryness indicators is towards longer, more intense summers with more rapid transitions between summer and winter conditions.
- The areal extent of the TWWHA subject to dry lightning potential environment decreases across all seasons.
- The most extreme dry lightning potential environment events do not decrease in extent beyond the near future and peak in summer, coinciding with peak increases in dryness indicators.
- The frequency of occurrence of synoptic weather conditions, quantified using an operational classification scheme on an annual basis, does not change significantly.

ACE CRC is continuing to work on a full technical report of their research findings, which will be completed by March 2017.

5.2.3 Rainforest flammability

Unlike buttongrass, rainforests in the TWWHA do not burn often because they are too damp most of the time. The weather and fuel dryness conditions under which rainforests will burn is, however, of considerable interest to fire managers, because it is at these times that bushfires have the potential to cause them damage.

The Tasmanian fire agencies (Tasmania Fire Service, Tasmania Parks and Wildlife Service and Forestry Tasmania) provided support for a PhD project to investigate rainforest flammability in Western Tasmania (Styger 2014). A key finding of this work was that rainforests are unlikely to burn, unless there is less than 50 mm of rain in the previous 30 days. The research also found that the Mount Soil Dryness Index (MSDI) is also a predictor of rainforest fires but the Forest Fire Danger Index (FFDI) is not. Therefore it is clear that the fuel moisture is the factor limiting the occurrence of rainforest fires.

These findings provide fire managers with good insight to prepare for bushfires at the critical times when rainforests are vulnerable, ensuring adequate fire restrictions are in place and firefighting resources are ready.

5.2.4 Australian Soil Moisture Information System (JASMIN)

The Mount Soil Dryness Index (MSDI) is a simple soil moisture model calculated from rainfall and temperature observations and has been used in Tasmania for over 40 years in bushfire management. The MSDI is used as an indicator of soil and surface fuel dryness and therefore vegetation flammability across a region, but it does not account for variation of soil or vegetation type.

The Bureau of Meteorology has, for several decades, prepared a daily map of MSDI isolines for Tasmania, based on 9am rainfall observations throughout the State. The MSDI is known to have significant limitations; for example, it is not uncommon for field observers to report that the soil and surface fuels are much drier than current mapped value of MSDI should indicate, as happened in North-West Tasmania during the 2015-16 fire season. For the TWWHA, contributing factors to inaccuracies are believed to be (Styger 2014):

1. The very limited number of weather observation stations located in or near the area and therefore inaccurate interpolation between quite distant stations.
2. Accumulated errors in the value of the MSDI that follow many months, or in some areas years, without a return to saturated soils.
3. Variation in soil type and depth/slope/aspect and the variability in canopy capture and run-off from individual rain events.

The Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) is funding a national project to develop an Australian Soil Moisture Information (JASMIN) system (Dharssi and Kumar 2016). An output of this project will be a soil moisture model that will be of higher spatial resolution and accuracy than the current MSDI. Published data indicated that a physically-based land surface model, related to JASMIN, had greater skill at predicting soil moisture than MSDI (Dharssi and Kumar 2016). Further development of JASMIN is expected to incorporate inputs from satellite-derived measurements, surface weather and soil observations, and downscaling, which will improve the accuracy and resolution of the soil moisture model even further. An enhanced and adequate network of weather observation sites will be important to ensuring satisfactory ground verification of modelled values and confidence in the new system.

It is anticipated that JASMIN will eventually replace the current method of calculating MSDI, although it may be several years before it is fully operational. Trial outputs on a five kilometre grid are expected by the end of 2016. In the more distant future, empirical fire behaviour models may be developed with more direct inputs from newer soil moisture models and fuel moisture models; thereby making the MSDI completely redundant.

5.3 Areas for further work or research

5.3.1 Parks and Wildlife Service model of fire cover

5.3.1.1 Initial attack capability

Records of causes of bushfires in or near the TWWHA indicate that the overwhelming contemporary risk is from lightning fires (see section 5.2.2.1). Fires started by people, either accidentally (eg accidents with fuel stoves or campfire escapes) or maliciously (eg arsonists) have been recorded, but over the past 15 years such fires have had a relatively small impact on TWWHA values compared to fires caused by lightning.

Lightning ignitions can occur anywhere, including very remote parts of the TWWHA, and rapid suppression response to these fires is critical. In the right circumstances, fires in the TWWHA have the potential to spread very quickly; for example, a buttongrass fire event on an average summer day can grow from a single ignition point to 20 hectares in size in two hours. At this size, the fire

will have more than two kilometres of actively spreading fire edge to be extinguished. Therefore, the faster a fire can be attacked, the smaller the problem and greater probability of success of early extinguishment. Thus, the first few hours after fires start is the critical period when suppression will be most effective.

Multiple ignitions starting in the TWWHA from a single dry lightning event have become regular events over the past 15 years (although not every summer). For example, in 2010 and 2016, more than 10 fires in the TWWHA were started and spread on each occasion during single lightning events. When weather and fuel dryness conditions following a dry lightning event are favourable for firefighting, the Tasmania Parks and Wildlife Service has had success at extinguishing all fires with remote firefighters. Such was the case in early January 2010. However, dry lightning events have caused significant fires at other times.

The question of adequate preparedness to extinguish these fires comes down to having sufficient firefighters and aircraft of the right type in the right places at the time fires start. Ideally, firefighting resources would be deployed to a fire and be actively working on that fire within an hour, or even much quicker under severe fire weather conditions. Therefore, the strategic planning of an adequate level of firefighting resources depends on quantifying what the spatial and temporal level of bushfire risk is likely to be across the TWWHA over a summer and determining the multiples of firefighting resources required to cover that risk. The placement of these resources in or around the TWWHA on a daily basis becomes the operational task, but the resources must be available and ready in the first place. However, the Tasmania Parks and Wildlife Service has responsibility for bushfire response for a network of reserves in addition to the TWWHA, so the strategic planning must address the resourcing of bushfire risk at the statewide level, not just for the TWWHA.

The Tasmania Parks and Wildlife Service has never undertaken an analysis of its firefighting capability that can address the question at a strategic level of how many and what type of firefighting resources (eg remote firefighters, aircraft) are required on an annual basis for initial attack, specifically to address the protection of TWWHA values. Such an analysis is needed, although it cannot be done in isolation of the fire suppression arrangements of the broader Tasmanian community. In undertaking a strategic capability analysis, the aim would be to define levels of risk coverage based on the values to be protected, statement of unacceptable outcomes and the extremity of fire behaviour to be covered. It is worth recognising that it is unrealistic for the TWWHA to have 100 per cent fire suppression cover of all values on the most extreme fire weather days that may only occur on very rare occasions (eg once every 10 years).

5.3.1.2 Incident management capability

All firefighting operations, including remote fires, are supported by Fire Duty Officers and Incident Management Teams, to ensure that adequate forward planning and support for incidents is provided. The Tasmania Parks and Wildlife Service does not have a large fire operational workforce – there is good expertise, but resources quickly become stretched once major fires become established. Furthermore, major fire events commonly occur during the peak tourist and holiday season, when the Tasmania Parks and Wildlife Service also has responsibility for managing visitors to national parks, and other reserves and associated infrastructure. The majority of the

Tasmania Parks and Wildlife Service's permanent firefighter workforce, including remote firefighters, is primarily engaged in managing reserve visitation when not firefighting. Therefore, the tourist season contributes to stretching operational resources; and heavily booked tourist accommodation can also increase fatigue for individuals if fire personnel have to travel further each day.

There is a need to quantify the overhead resources needed to adequately support the Tasmania Parks and Wildlife Service's firefighting capability during normal and slightly above normal fire periods, and how these resources can be provided. Many of these resources are trained in specialist skills, including:

- Fire Duty Officers – to ensure appropriate preparedness arrangements are in place on a daily basis; trained to use systems such as the Bushfire Risk Assessment Model (BRAM) and the Bushfire Operational Hazard Model (BOHM); as well as having good fire experience to rapidly assess fires when they occur and make timely and critical decisions.
- Incident Management Teams – including Incident Controllers, Operations Officers, Air Operations Managers, Planning Officers, Situation Officers, Fire Behaviour Analysts, Public Information Officers and Logistics Officers.

There are a number of possibilities regarding how these skills could be provided across one or more organisations to ensure adequate fire cover for the TWWHA and other reserves. However, it must be recognised that an underpinning of knowledge regarding the management of natural and cultural values in reserves is essential across most of these skill sets. Interstate support is likely to be available for the most significant fire events, such as occurred in 2013 and 2016, but cannot be relied upon for the busy periods that can be expected in most years.

5.3.2 Fuel dryness and fire behaviour

Successful bushfire operations, including both the suppression of fires and the lighting of planned fires, depends on a good understanding of the fire behaviour in different vegetation and fuel types and how that is related to weather conditions. The fire behaviour is typically described in terms of fire rate of spread and fire intensity, and prediction of these parameters is undertaken using various empirical fire behaviour models that are specific to generalised vegetation or fuel types (Cruz et al. 2015). The models are in turn used to determine:

- operational preparedness on a daily basis throughout the fire season, including the location, type and number of firefighting resources; and
- what operational strategies and tactics can or should be employed, depending on the expected fire behaviour.

The rate of spread and intensity of bushfires in the TWWHA is strongly influenced by vegetation dryness, usually expressed as fuel moisture content. The flammability of surface fuels on the ground (eg dead leaf litter) is influenced by soil dryness, rainfall and humidity; while the flammability of vegetation fuels above the ground is controlled by rainfall and humidity. In some vegetation types the Mount Soil Dryness Index (MSDI) can be used to estimate coarse fuel moisture content (eg dead logs) and vegetation flammability. Most of the TWWHA is exposed to

high rainfall at all times of the year, although summer (December to February) tends to be drier and can include periods without significant rainfall. The daily bushfire risk is very dynamic, particularly in the summer months, rising and falling with rainfall events, as well as temperature, wind speed and humidity.

The flammability of organic soils is another factor that influences bushfire dynamics in the TWWHA. For example, bushfires that stop at the boundaries of less flammable vegetation may still be smouldering in the organic soils at the margins of rainforest, wet eucalypt forest and wet scrub. As well as causing damage to soil and vegetation in the area burnt, such soil fires form an ignition point for further above-ground fire when conditions change (eg increased wind speed and/or decreased humidity). Soil flammability is related to soil properties and soil dryness.

Comprehensive soil moisture and fuel moisture inputs determining whether or not fires will spread or smoulder in organic soils in the TWWHA are not available. Contributing factors include the paucity of weather stations throughout the TWWHA and the limited predictive power of the existing soil moisture model (MSDI). The flammability thresholds for organic soils are also poorly understood, both in terms of weather and physical soil properties (eg organic content, soil structure).

Fire behaviour models used widely in other parts of Australia have limited application in the TWWHA. For example, the McArthur Mk 5 Forest Fire Danger Meter (converted to equations by Noble et al. 1980) was developed for dry eucalypt forest, but is known to poorly predict fire spread in the wetter eucalypt forests of the TWWHA. No fire behaviour models have been developed for many widespread vegetation types of the TWWHA; for example: montane forests, wet eucalypt forests, eucalypt forests with a rainforest understorey, rainforests, wet scrub, and alpine vegetation. Some existing models developed elsewhere may be suitable for some vegetation types following validation and testing. A promising example is the New Zealand rainforest fire spread model which was developed for forests that are structurally very similar to Tasmania's rainforest. Fortunately, a reasonably robust fire behaviour model was developed for buttongrass vegetation in the 1990s (Marsden-Smedley et al. 1999).

Recent experience has shown that a single thunderstorm event can ignite 10 or more fires in the TWWHA; some of these will spread very little, if at all, while others will develop into major conflagrations. To be able to predict which fires are the biggest threat, and when, would be extremely useful. The controlling factors of vegetation type and fuel dryness are recognised in a general way. However, improving the predictive power of fire behaviour models that are applicable to TWWHA vegetation would provide fire managers with much better capacity to prioritise and plan for suppression operations.

Some research projects funded through the Bushfire and Natural Hazards Cooperative Research Centre (BNHCRC) and elsewhere (that are already underway) will contribute to better fire spread prediction in the TWWHA. An example is the development of a high resolution soil moisture system that will have application across Australia (Dharssi and Kumar 2016). There is still much to do for the TWWHA bushfire context, including:

- quantifying fuel and soil moisture thresholds of flammability for most vegetation types;

- quantifying soil moisture thresholds that control organic soil flammability;
- designing and installing an adequate network of weather data observation stations across the TWWHA;
- validating and customising systems (eg soil moisture models) for the Western Tasmanian environment; and
- developing new fire spread models for those vegetation types that need it and for organic soils.

5.3.3 Detection

5.3.3.1 Lightning forecasting

Lightning has become the most significant cause of bushfires in the TWWHA (see section 5.2.2.1). Therefore, prediction services for lightning events, and the probability of fires starting, are important tools for preparing for fire suppression. The Bureau of Meteorology provides forecasts of thunderstorms with reasonable accuracy at a regional scale 24 to 48 hours forward.

Any improvements in the accuracy and forecast capability would enable fire agencies to prepare better for response. Aspects of the forecasting that assist preparedness include:

- indication of the probable amount of rain associated with the thunderstorm, as well as the spatial patchiness and extent;
- the probable area where strikes will occur;
- the number of strikes that is likely; and
- atmospheric, fuel and landscape conditions that facilitate the spread of lightning fires.

Recent research (Dowdy and Mills 2012) has identified atmospheric and weather conditions that are good predictors of dry lightning fires spreading. Examples are: rainfall amount, atmospheric conditions (dew point depression and atmospheric instability) and fuel dryness. There is still a need to further develop these findings into forecast tools that assist fire managers; for example, a forecast map indicating the areas with high probability of ignitions from lightning fires. It may also be possible to explore, from historic fire records, if there are landscape predictors that could further help predict lightning fires, such as altitude, aspect, position on slope, vegetation type, fuel dryness and soil dryness.

In an ideal world, the accuracy of the forecast would be high enough to enable adequate numbers of firefighters and aircraft to be pre-positioned close to areas forecast to be at high risk.

5.3.3.2 Strike detection systems

Real-time detection systems are available for recording and mapping lightning strikes that hit the ground and including strikes as point data onto Geographic Information System (GIS) maps. These data have proven helpful in identifying where to look for lightning ignitions from detection flights over the TWWHA and other areas; typically such flights are only scheduled if little or no rainfall was associated with the lightning event. Examples of outputs from lightning detection systems are available in real time or near real time on free websites, but at much lower spatial resolution than commercially available.

The Tasmania Parks and Wildlife Service trialled a lightning detection service over the 2013-14 fire season. No analysis has yet been undertaken, but lightning ignitions that were recorded in the TWWHA, and elsewhere in Western Tasmania during that fire season, were certainly in the general area of detected and recorded ground strikes, with an indicative accuracy of approximately ± one kilometre. Issues limiting the usefulness of lightning detection services include:

- For every fire started by lightning, hundreds, if not thousands, of ground strikes can be detected.
- False negatives do occur, that is, ignitions with no indication from available lightning-detection services or forecasts.
- Smouldering fires starting from lightning can remain hidden for weeks and only become evident and spread when fuels become drier and or it becomes windier.
- With current system accuracy, it is not productive to invest in close aerial inspection of recorded strikes, searching for very small 'smokes'.

Thus, these lightning-detection services are of general value for searching areas for lightning fires, but with limitations. Any technological advancement in accuracy would assist in the early detection of lightning fires and early suppression. The Bureau of Meteorology is trialling new systems of lightning-detection and forecasting, and service enhancements are scheduled to start late in 2016 and continue over the coming years.

5.3.3.3 Detection strategy

The detection arrangements that have been used in the TWWHA over the last 25 years (see section 5.1.3) may no longer be adequate for the anticipated future bushfire risk for the TWWHA or even the apparent increase in lightning fires in recent times.

There is a need to ensure that the arrangements for detecting bushfires in the TWWHA use contemporary technology and methods and provide the best practical opportunity for rapid detection of new fires. The preparation of a detection strategy that includes the following components would assist:

- review of new and emerging technology, including remote sensing, drones and radar;
- review of the costs and benefits of using new technology and existing methods (eg spotter flights, fire towers) and designate an appropriate combination of detection methods; and
- specification of standards and procedures for operational implementation of the detection strategy.

5.3.4 Develop strategies to manage future bushfire risk

The implications of climate change for future bushfire risk are described in sections 2.5 and 5.2.2.2. It is important that these changing circumstances are carefully considered, and appropriate strategies developed to protect the natural and cultural values in the TWWHA as far as is practical. Some of these strategies will need implementing in the short term, while others may be anticipated for the longer term. Some strategies may be quite novel and outside

traditionally accepted views of managing wild and remote areas. In the process of changing operational practice, this stage of strategy development is a necessary link between research and the revision of guiding operational policies, plans, procedures and supporting information systems such as the Bushfire Risk Assessment Model (BRAM).

5.4 Recommendations relating to preparedness for fire in the TWWHA

Recommendation 5 – Research on fire and natural and cultural heritage values

An ongoing program of scientific research and monitoring should be maintained in the TWWHA that supports understanding:

- *the interaction between climate change and the natural and cultural values of the TWWHA; and*
- *the evolving relationship between climate change and the projected impacts of fire on natural and cultural values in the TWWHA.*

This research should focus, in the first instance, on those values that are expected to be most vulnerable in the short term (for example relict Gondwanan flora).

This program of research should involve a broad spectrum of the research community, as well as personnel from DPIPWE and other Tasmanian Government agencies.

The program of research should be regularly reviewed and audited. The 'DPIPWE TWWHA Bushfire Research Group' should continue to be actively engaged in the process of developing objectives for this research program.

Attachment 9 sets out a prospective list of priority research to support fire management in, and the understanding of the impacts of fire on, the World Heritage values of the TWWHA.

Recommendation 6 – Research on fire vulnerability, fire behaviour and fire model inputs

In the short to medium-term, significant research effort should be directed to:

- *further understanding the consequential interactions of climate change with fire vulnerability, behaviour and impact;*
- *understanding fire behaviour and flammability thresholds, particularly in dry conditions, of organic soils and the interaction between climate change, fire and organic soils;*
- *developing a comprehensive understanding of soil and fuel moisture in the various vegetation communities in the TWWHA; efficient methods to monitor and model soil and fuel moisture across the vegetation types in the TWWHA; and the development of reliable soil moisture indices for the TWWHA that can then be incorporated into fire behaviour models and fire danger indices;*
- *developing techniques for more accurately assessing fuel loads and mapping fuel types in different vegetation communities in the TWWHA and incorporating these into fire behaviour models; and*
- *developing fire behaviour models and associated fire spread simulators for peatlands, grasslands, wet eucalypt forest, coniferous rainforest, rainforest without conifers, and other vegetation communities in the TWWHA.*

This research should take into account national initiatives that are currently underway in the development of bushfire indices, and modelling and fire behaviour tools. The research should concentrate on those areas, soils and vegetation communities in the TWWHA that are not currently well represented in fire behaviour models and fire danger indices.

Recommendation 7 – Lightning detection

The Tasmanian fire agencies, in consultation with the Australian Bureau of Meteorology, should keep abreast of emerging technologies for predicting and detecting lightning strikes and ignitions.

If and when new technologies become available, these should be incorporated into preparedness and response planning for bushfire in the TWWHA.

A detection strategy should be developed that details the bushfire detection arrangements for the TWWHA, based on contemporary ignition risks and detection methods.

Recommendation 8 – Capital investment

The Tasmanian fire agencies should develop a whole-of-government program of investment in facilities and equipment that enhance fire management capabilities in the TWWHA and more generally in Tasmania.

This program should include:

- *identification and evaluation of options for installing new automatic weather stations in the TWWHA and nearby areas to improve weather and data records for the region; remote area sensors for monitoring local rainfall and soil moisture; and early detection facilities such as fire-watch installations;*
- *firefighting equipment available to fire agencies in different regions of Tasmania;*
- *improved communication facilities (that is for the radio network), to enable better communication between agencies, and for remote firefighting teams; and*
- *investment in facilities and equipment to enhance aerial firefighting efforts.*

This investment program should be developed on a whole-of government basis to maximise the benefits to all fire agencies and the Tasmanian community. Organisations such as the Bureau of Meteorology should be involved in order to ensure the fire agencies obtain the highest benefits from Tasmanian weather and climate data.

In constructing this investment program, an audit of existing weather and climate sensors in the region should be conducted and protocols developed for incorporating these data into real-time forecasts of fire weather.

6. RESPONSE

6.1 Current operational practice

6.1.1 Identifying and protecting fire-sensitive values in the TWWHA

Advice from the Tasmania Parks and Wildlife Service is that, for use in operational response, the main means of identifying fire-sensitive natural and cultural values and relevant priorities and response in the TWWHA is through the Natural Values Atlas[8], the Bushfire Risk Assessment Model (BRAM), the Common Operating Platform[9]; staff knowledge and contact with specialists in DPIPWE's Natural and Cultural Heritage Division.

As outlined in section 4.1.2, BRAM includes (the consequence) layers of natural values and is an input to determine different levels of bushfire risk in the TWWHA. In BRAM, relative importance rankings are assigned to a diverse range of values, including natural and built assets.

Human life is afforded the highest priority in BRAM, and areas where visitors to the TWWHA are likely to be present are given the highest ranking. Typically, the highest ranking for natural values is assigned to areas that are fire-sensitive because there would be permanent and significant losses if burnt. Examples include the Mt Anne and Walls of Jerusalem areas because of the presence of extensive, unique and very fire-sensitive vegetation such as King Billy pine and pencil pine forests.

The basic principle for determining response strategies and priorities is that the highest rated values from BRAM will be protected in preference to lower rated values. When there are many ignitions, as happened in January 2016, this principle is complicated by:

- the sheer number of fires and therefore potential impacts and competing values;
- fires outside the TWWHA, particularly to the west, that have the potential to impact on the TWWHA and may have even greater potential for damage to TWWHA values than those fires already inside the TWWHA;
- practical operational limitations on suppression imposed by the weather, access, terrain and fire behaviour (both current and predicted, including smouldering organic soil);
- unknown factors, such as undetected fires and fire behaviour that could not be accurately predicted with the tools and data available; and
- the limited availability of firefighting resources.

Responding to fires in the TWWHA requires consideration of broader strategic fire suppression priorities after consideration of the values, operational limitations and available resources. For example, in responding to fires in the TWWHA, the Tasmania Parks and Wildlife Service needs to consider the risk of fires that could cause significant damage to natural values within and outside the TWWHA, and also threaten people's lives, damage to infrastructure and property. Often fires

[8] A web interface allowing access to authoritative and comprehensive natural values information is available at https://www.naturalvaluesatlas.tas.gov.au/.

[9] The Common Operating Platform (COP) provides Tasmania's emergency service organisations a single mapped view of shared information for use in critical emergency incident planning and response activities.

that can have significant potential to impact on the TWWHA can be those that originate outside the TWWHA, particularly in the extensive buttongrass moorlands on the West Coast at the western edge of the TWWHA.

In reality, not all values can be protected at all times and therefore a triage process is involved in strategic decision-making. The suppression objectives, strategies and allocation of resources are ultimately based on what can realistically be achieved to protect identified and agreed priorities.

Bushfire risk assessment is a dynamic process that recognises and adjusts to circumstances as they change. It relies on information from a range of sources and the application of appropriate fire models.

During a large bushfire event, where there are a number of fires that require suppression response, assessment can occur at both the State and regional level, using a risk assessment approach consistent with the National Emergency Risk Assessment Guidelines (NERAG) to:

- enable the timely and relevant issuing of community warnings;
- prioritise operational activities on the fireground; and
- undertake options analyses in determining suppression and control strategies.

The risk assessment process considers both the consequence and likelihood of an event and relies on the application of a spatial proximity analysis that draws on existing data resources. In relation to likelihood, this considers the location of a bushfire, proximity to flammable vegetation types, expected fire behaviour and the size of the bushfire. Consequence is assessed considering impacts to life, critical infrastructure, the environment, major tourism/public administration and social setting. For most remote fires in the TWWHA, visitor safety and natural and cultural values are the major consequences of concern.

The information needed to inform the assessment comes from a wide range of sources. These include values (ie consequence) data stored in BRAM, data stored in the Natural Value Atlas, asset management systems, satellite imagery, observations from aircraft weather observations, field assessments, information on vegetation types and fire behaviour models. Finally, knowledge held by individual people such as rangers, biologists and fire managers is used whenever possible to inform assessment of fires in the TWWHA.

6.1.2 Visitor safety

Fire risk to visitors is mitigated by developing emergency response plans or actions in the Fire Action Plan to enhance visitor safety. The Tasmania Parks and Wildlife Service has a draft emergency response plan for the Mt Field National Park, which includes responding to fire with appropriate trigger points.

During the 2015-16 bushfire event, the Tasmania Parks and Wildlife Service set up a Visitor Management Team to coordinate warnings to walkers, detection and relocation of visitors at risk (those in the path of fires), closure of campgrounds, walking tracks and reserves, communication with the public, and liaison with incident management teams and the State Fire Duty Officer.

Protection of visitors is the first and highest priority of response to bushfires in the TWWHA. For example, walking tracks are searched by helicopter for at-risk bushwalkers, bushwalkers are

relocated by helicopter, campgrounds are closed and campers are evacuated. Once a fire is identified as a risk, roads, walking tracks and other facilities are closed to the public.

6.1.3 Comparison of firefighting techniques used in the TWWHA and other jurisdictions

The firefighting strategies, tactics and equipment used in the TWWHA are also used in other Australian jurisdictions. There are particularly strong operational similarities to parts of Victoria, New South Wales and the Australian Capital Territory, which also have mountainous, rugged forested terrain. The assistance that Tasmanian fire agencies have provided to Victoria and New South Wales, on many occasions, demonstrates the similarities in firefighting capability, particularly for firefighting in remote mountainous areas and in tall wet eucalypt forest. There are, however, some differences that are indicative of the unique physical environment of Tasmania and the smaller resource capacity of the agencies in Tasmania.

The similarities and differences between the firefighting techniques used for the TWWHA compared to Victoria and New South Wales are summarised below. These two states have been chosen because they are the most similar to Tasmania in terms of bushfire environments.

6.1.3.1 Response strategies

'Strategies' (as the term is used in bushfire firefighting) describes, at a general level, what is being done in the operational theatre at the whole incident level or on various parts of an individual fire. Key examples include:

- direct attack – extinguishing the perimeter of a fire, most typically with water (with or without additives);
- partial direct attack – extinguishing only certain parts of the perimeter of a fire;
- indirect attack – back-burning from existing control lines (eg roads) or from new control lines constructed for a specific fire;
- defensive firefighting – protecting people and assets but not attempting to control a fire; and
- monitoring – only monitoring the fire, but also predicting fire behaviour.

Defensive strategies used in the TWWHA, particularly for protecting people and built assets, are broadly similar to those employed in other states and territories. Notably, the public communication and warnings have tended towards standardisation across Australia since the 2009 bushfires in Victoria, and protecting people is universally the first priority. Relocation of people at risk from bushfires (eg bushwalkers) from remote areas by helicopter is regularly done in the TWWHA and also in national parks in Victoria and New South Wales.

Direct attack strategies used in the TWWHA are broadly similar to those used in the more remote areas of Victoria and New South Wales. Similarities in tactics and equipment include:

- tanker-based firefighting, that is, typically with four-wheel-drive small, medium and large water tankers;
- earthmoving equipment such as bulldozers (although used less in the TWWHA, see below); and

- water bombing with small and medium-sized helicopters.

A summary of the strategies and tactics used in firefighting in the TWWHA is provided in Table 5. In some circumstances, the firefighting response may involve only protection of people and monitoring of the fire, with no attempt to control or contain the fire.

Table 5: Summary of the strategies and tactics used in the TWWHA for response to bushfires

Fire strategies and tactics	Effectiveness	Level of use	Risks – impact on TWWHA values	Research opportunities
Rapid attack – helicopter inserted crews	High – if fire is <1 ha & accessible by helicopter landing; otherwise low	Used regularly by landing in open areas or hover entry-exit in low lying vegetation or rocky outcrops, but no Tasmanian crews trained in winch insertion techniques	Spread of pathogens on boots & tools	Investigation of most appropriate aircraft, techniques & coverage requirements
Aircraft (fixed-wing & rotary-wing) – water bombing	Low for well-established fires (unless guided by ground crews); high for initial attack	Used regularly throughout the TWWHA	Spread of water-borne pathogens causing contamination of water bodies; & toxicity of foam to aquatic fauna	Investigation of most appropriate aircraft, techniques & coverage requirements
Foam & gel added to water	High	Used regularly as additive to water by aircraft interstate, fire tankers & remote crews	Not well researched in Australia, but known toxicity to freshwater fauna	Research into impacts in Tasmanian environments
Retardant (long-term) added to water	High – under appropriate fire behaviour conditions and for some vegetation types	Limited use due to unknown environmental impact	Unknown	Research into impacts in Tasmanian environments
Back-burning	Moderate	Occasionally used in TWWHA	Increased size of fire; & potential for increased smouldering fire in organic soils	

Fire strategies and tactics	Effectiveness	Level of use	Risks – impact on TWWHA values	Research opportunities
Dozer & excavator control lines	High – fast containment of fires in accessible terrain; low effectiveness in rocky or boggy country	Limited use in TWWHA because of rugged terrain, boggy soils, lack of road access & potential impact on values	Damage to Aboriginal heritage; soil erosion; spread of disease (*Phytophthora*); damage to geoheritage (eg organic soils, glacial features); damage to biodiversity (eg loss of habitat trees); & recovery/ rehabilitation extremely slow & visible for many years	
Hose lays, sprinklers & soaker hoses	High – often the only tactic for smouldering fires, but long lead-time to establish	Used regularly throughout the TWWHA but restricted to small areas with practical water supply	Spread of pathogens	
Handline (dry firefighting)	High – in drier vegetation types; low if smouldering fire in organic soils	Infrequently used because smouldering fires are common	Spread of pathogens on boots & tools	
Closure of public access & relocation of visitors	High – visitor zones checked quickly by helicopter or vehicles	Used regularly to protect people.	None	
Partial suppression (typically partial direct attack)	High due to the restricted area attacked	Occasional use on large fires where suppression of fire in high priority areas of the fire is the only feasible option	None	

Fire strategies and tactics	Effectiveness	Level of use	Risks – impact on TWWHA values	Research opportunities
Monitoring & prediction of known fires (ie no suppression)	Moderate	Used regularly – for fires assessed as presenting no risk; or may be the only practical available tactic if fires are large or the smouldering fire perimeter is too long to enable effective suppression with available resources	Fire size escalates & impacts significant environmental & cultural values	Research to develop better fire spread models (eg rainforest, wet eucalypt forest, conifers) & soil dryness would facilitate better decision-making

Some key differences in tactics and equipment used in Tasmania compared to Victoria and New South Wales include:

- Remote firefighting crews are trained and equipped to be inserted into remote areas from helicopter by winching (New South Wales) or rappelling (Victoria). No Tasmanian fire agency currently has this capability. Tasmania does have personnel trained in remote firefighting, but they are inserted by helicopter landing or hover exit – this means that some fires cannot be accessed because firefighters cannot be inserted safely near enough to the fire to undertake suppression in a timely manner. Winch insertion was used by New South Wales firefighters in 2016 in the TWWHA, but this assistance is not available for initial attack at the critical times.
- Fixed-wing aircraft water bombing is used extensively in Victoria and New South Wales. In recent years, smaller fixed-wing water bombers have been trialled in Tasmania, but rarely used in the TWWHA. Water bombing from large helicopters (eg Erickson Air Crane) has never been done in Tasmania. Significant infrastructure is required to support larger aircraft and therefore the potential for benefit for the TWWHA, specifically for initial attack, requires investigation and costing.
- Air operations in New South Wales and Victoria are coordinated in more complex organisational systems, with personnel trained in specific aircraft and roles (eg Air Attack Supervisor) tasked with supervision roles. The typical air operations undertaken in Tasmania are smaller, with fewer aircraft, and therefore the scale of training and organisational complexity is smaller. During 2013 and 2016, attempts to utilise Air Attack Supervisors in Tasmania led to confusion and poor performance.
- Fire suppression chemicals have been used to a limited extent only in Tasmania, but they are used extensively in Victoria and New South Wales (see section 6.1.4). Foam and gel are water additives that are used in the TWWHA and other states and territories.
- Dry firefighting is a common tactic used by remote firefighters in Victoria and New South Wales, using hand tools (eg rakehoes, axes) to construct control lines in rugged country or earthmoving equipment in less rugged country. These techniques are used in Tasmania by

remote firefighters but less so in the wetter parts of the State, including most of the TWWHA, where dense vegetation and organic soils limit their effectiveness.

- Extinguishing smouldering fires in organic soils is a very big component of the fire suppression effort in the TWWHA; firefighters from other states and territories are typically not familiar with the techniques to do this. Use of long hose lays, pumps, water storage in large portable dams and water drops from helicopter buckets (targeted and directed from crews on the ground) are techniques which are used extensively in the TWWHA but rarely in other parts of Australia.
- Indirect attack is not often employed in the TWWHA because it has very few roads, tracks or suitable natural barriers (eg rivers) from which back-burning can be done. Building of new control lines with earthmoving equipment is rarely done for various reasons, including: the rugged and remote terrain; waterlogged soils; and the potential to harm environmental and cultural values. Indirect attack is more likely to be used in parts of Tasmania with more extensive road and track networks and is a common strategy in the heavily forested areas of other states and territories (where not too steep).
- Suppression on critical boundaries – in the remote areas of Tasmania, firefighters will often focus on 'key edges' for suppression, to reduce the risk of a fire burning into fire sensitive areas. This technique has been used extensively in remote areas of Tasmania where fires may have a very large boundary, but key edges are suppressed in order to restrict the run of a fire into a critical area, thus protecting the natural values. This is often done using hose lays and aerial support.

6.1.3.2 Organisation

As with all other agencies responsible for bushfire suppression in Australia, the Tasmanian fire agencies use the Australasian Inter-Service Incident Management System (AIIMS), including associated structural organisation and terminology (AFAC 2013). Typically AIIMS in Tasmania is used for individual bushfires or groups of bushfires which are managed by an incident management team. The system differences that exist between jurisdictions are evident to those involved when interstate assistance is provided for major events, but sufficient similarities exist for visitors providing assistance to 'hit the ground running'.

Dispatch, the act of ordering attack crews and/or support units to respond to a fire, is a critical system component to ensure that fires are contained quickly enough to prevent them becoming major events with consequential damage and high suppression expenditure. The system of dispatch for the TWWHA used by the Tasmania Parks and Wildlife Service (see section 5.1.2), is well organised, but does not have procedures mandating minimum response times, resource types (including aircraft) and numbers that are typical for bushfires in other states and territories. For example, aircraft pre-determined dispatch (PDD) is used in Victoria, where multiple aircraft are dispatched immediately to the first report of a fire when specific conditions are met.

6.1.3.3 Public information

Public communication about all bushfire incidents in Tasmania is coordinated through systems and processes established and managed by the Tasmania Fire Service. The Tasmania Parks and Wildlife Service is closely consulted in the development of these communication methods.

For smaller bushfire incidents, the main conduit for information to the public is the Tasmania Fire Service web pages: Alerts List and Alerts Maps. These web pages are updated regularly to show the current status of bushfires and public warnings; they are the primary source of information for the public for all bushfires managed by the Tasmania Parks and Wildlife Service, including those in the TWWHA.

For larger bushfires, which are under the control of an incident management team, the public communication is prepared by a unit in the incident management team. The Incident Controller approves all media releases and public warnings, and media interviews are delivered only by personnel delegated by the Incident Controller. The Public Information Unit also establishes communication with local community groups and stakeholders, preparing regular updates and advice. Given the cooperative and shared arrangements for incident management teams in Tasmania (see Attachment 4), both the Incident Controller and Public Information Officer, for bushfires in the TWWHA and neighbouring areas, could be persons from any one of the three Tasmanian fire agencies: Tasmania Fire Service, Tasmania Parks and Wildlife Service or Forestry Tasmania.

The provision of information to the public about bushfires has improved dramatically in the past 20 years with the development of the Tasmania Fire Service fire alerts web pages, national standard warnings and ABC commitment as an emergency broadcaster.

However, the public information section in the incident management team concentrates on providing information required to keep people safe. This has not, to date, typically included providing information to people who are planning recreational activity in reserves, or who are concerned about the impact of fires and want to know what fire suppression actions are being undertaken. The Tasmania Parks and Wildlife Service provides some information on its public website and social media on closure of reserves, walking tracks and camping areas.

6.1.4 Fire suppression chemicals

Tasmanian firefighting agencies use fire suppression chemicals added to water while combating bushfires. Certain chemicals were also used during the 2015-16 bushfires in the TWWHA.

Fire suppression chemicals generally fall into two types, short-term suppressants (foams and gels) and long-term retardants.

Long-term retardants are typically based on the fertiliser monoammonium phosphate and can provide a useful chemical firebreak that lasts days to weeks. These retardants are effective even when dried out until they are washed away through rainfall or firefighting activities. To date, the only long-term retardant used in Tasmania is Phos-Chek, which was used in the 2015-16 fires and may have been used to a limited extent in the TWWHA. While these retardants can be effective at fire suppression, there are concerns about their environmental impact.

Short-term suppressant chemicals are typically foams or gels that extend the efficiency of water as a fire suppression agent. Foams have been used in the TWWHA since the 1980s while gels have been developed more recently. The foams and gels have a short-term usefulness (four to six hours), but can provide an effective window for on-ground fire crews to extinguish fires, as well as protection for on-ground crews. The gel used in the 2016 TWWHA bushfires was Blazetamer 380. The foam used in Tasmania is Forexspan S, which was used in helicopter operations during the 2016 TWWHA bushfires.

The use of fire chemicals in Australia is governed by a longstanding position of the Australasian Fire and Emergency Service Authorities Council (AFAC), which provides that only products that have been approved by the United States Department of Agriculture are used. The effectiveness of these chemicals, in general, is well established. However, their effectiveness can be dependent on the state of the fire, type of vegetation, method of application, weather conditions and whether or not there is follow up by crews on the ground. Data relating to the effectiveness and impacts of the fire suppression chemicals used in the TWWHA has not yet been collected or analysed.

Firefighting foams at low concentrations are an effective tool to help extinguish fires in organic soils, as dry organic soils repel water (hydrophobic).

6.2 Areas for further work or research

6.2.1 Research to examine the impact and effectiveness of fire suppression chemicals in the TWWHA

The data relating to the effectiveness of the fire suppression chemicals used in the TWWHA have not yet been collated and analysed. Furthermore, the full potential impact of fire suppression chemicals on the flora and fauna of the TWWHA requires further investigation.

Research is currently being undertaken through this Research Project by the Department of Primary Industries, Parks, Water and the Environment to examine the impact and effectiveness of fire suppression chemicals in the TWWHA. The objectives of this research are to:

- collate data on the effectiveness of retardant use in the TWWHA during the January-March fires;
- review the literature on the impact of retardant use on biota, soils and ecosystems and identify potential risks to the TWWHA;
- design and establish a preliminary field trial using manual application of products to examine the potential impact of a range of available retardants, foams and gels on selected natural values of the TWWHA; and
- initiate the development of a decision support tool regarding fire suppression options in the TWWHA.

It is expected the results of the research will be available towards the end of 2017.

6.2.2 Bushfire Risk Assessment Model (BRAM) enhancement

The Bushfire Risk Assessment Model (BRAM) and the Bushfire Operational Hazard Model (BOHM) are powerful tools for bushfire response, as well as prevention and preparedness (see sections 4.1.2 and 5.2.1). Once a fire is detected, or indeed in the case of lightning events, multiple fires are detected, BRAM provides information on the following:

- What values are at risk from a particular ignition and the relative priority of those values in terms of fire-sensitivity. In the context of TWWHA natural values, BRAM contains the best available mapped information and this is updated annually.
- Which fires are likely to spread and how fast.
- Where the most useful firefighting resources to respond to a fire are located.

BRAM is a computer software system that was developed in-house by the Tasmania Parks and Wildlife Service, underpinned by a large amount of data.

An enhanced and new BRAM system is needed and should include the following specifications:

- provides service to fire operations being managed in areas where internet access is patchy or unavailable;
- provides access to all Tasmanian fire agencies;
- ensures that the best available knowledge of fire behaviour models and the most appropriate fire-spread prediction tools are used;
- ensures the best available mapping data is incorporated and updated regularly on all natural, cultural and built values; and
- has adequate oversight and management to ensure that information is not used inappropriately or as a 'black box' by unskilled persons.

6.2.3 Aboriginal heritage sites

Bushfires, particularly intense summer ones, have the potential to damage Aboriginal heritage sites directly or by consequent exposure of sites by removing the protective cover of vegetation and organic substrates. Aboriginal heritage sites, including Aboriginal cultural landscapes, can also be damaged by the actions taken by firefighters to control fires. For example, the mechanical disturbance of the ground surface by earthmoving machinery or vehicles can be particularly destructive. To ensure the best protection and management of these important cultural values during bushfire suppression operations, the fire managers need to know:

- where Aboriginal heritage sites of significance are located, ideally with a high level of spatial accuracy;
- the likely impact of the bushfire or suppression operations on that value; and
- appropriate strategies for minimising or preventing the impacts.

Two ways of identifying Aboriginal heritage sites during fire suppression operations can be used. Firstly, a desktop assessment can be undertaken using the Aboriginal Heritage Register, a database managed by Aboriginal Heritage Tasmania that contains information on more than 13,000 sites. Secondly, an archaeologist or appropriately trained and skilled Aboriginal Heritage Officer can undertake a field inspection of an area; for example a planned route for a control line

to be constructed by a bulldozer. In order to be effective, the utilisation of trained cultural heritage practitioners during the firefighting efforts requires access to information in the Aboriginal Heritage Register. There are practical limitations at the present time for utilising either of these methods, particularly given that decisions during suppression operations may need to be made quickly. The Aboriginal Heritage Register is not publicly available and as administrator, Aboriginal Heritage Tasmania has an obligation to ensure that the data are managed sensitively, in line with Aboriginal community expectations. For field assessments, the time required to ensure that an area is inspected may be prohibitive or it may be unsafe to do so given the fire situation.

There is a need for the Tasmania Parks and Wildlife Service to work with the Aboriginal community to develop protocols for accessing data from the Aboriginal Heritage Register, in ways that facilitate the making of strategic and tactical decisions to protect known sites during fire suppression operations, while also respecting the cultural sensitivities of the information on sites. These protocols should also cover how Aboriginal Heritage Register records could be included in BRAM so that the fire risk to Aboriginal heritage can be assessed.

There is also much work to do to gain a better understanding of the potential impacts of bushfires and suppression techniques on the different kinds of Aboriginal heritage sites in the TWWHA.

6.2.4 Better mapping of fire-sensitive TWWHA values

While the Bushfire and Risk Assessment Model (BRAM) is updated annually with the best available data, a review of the 2016 fires identified that many fire-sensitive values are not mapped with a particularly high level of accuracy. Examples include stands of pencil pine, deciduous beech and sphagnum bogs on the Central Plateau. More accurate mapping would help prioritise bushfire response. Geoconservation values and vulnerable soils are also poorly mapped. The availability of high resolution aerial imagery has increased significantly in the past decade and therefore it is now more feasible to prepare higher resolution maps of natural values than it was when the earlier vegetation maps of the TWWHA were prepared.

Improved scale of resolution and accuracy of mapping of natural values are required to ensure that supporting systems such as BRAM provide as strong a basis as possible for determining priorities for prevention, preparedness, response and for monitoring and reporting on fire impacts. The natural values include threatened flora and fauna, vegetation communities, geomorphological values and fire-sensitive values. Additional high resolution photography is required to extend improved mapping of values beyond the Central Plateau. In some cases, a better understanding of fire impacts and responses are required to improve the identification of the natural values that are at risk from bushfires.

6.2.5 Operational systems and techniques

There is potential for operational systems and techniques to be introduced for the TWWHA that are used in other parts of Australia and countries such as Canada. The work required is the evaluation of the suitability of various systems, techniques and equipment, and identifying the costs and benefits for their application in the TWWHA. Important themes to consider, some of which have already been identified by AFAC (2016a), include:

- Investigate organisational options for providing additional remote firefighting capability for the TWWHA. The options to consider could be one or more of the following: permanent or seasonally employed remote firefighters in the Tasmania Parks and Wildlife Service and the Tasmania Fire Service; volunteer firefighters in the Parks and Wildlife Service or Tasmania Fire Service; or private contract firefighters. An important aspect of developing this capability will be ensuring that organisational and industrial arrangements are made to enable remote firefighters to be pre-positioned in or near the TWWHA; for example, camping in remote areas that are at risk prior to forecast electrical storm events or days of very high bushfire danger, to ensure short response times. Furthermore, remote firefighters need to be very fit and therefore the average age would be expected to reflect this, so whatever model is adopted must recognise the challenge of sourcing an agile, fit group on a continual basis. Some other workforce considerations for an enhanced remote firefighting capability include:
    - good retention of seasonal and permanent crews has distinct benefits – a high degree of turnover is costly, difficult to manage and leads to loss of skill and knowledge;
    - volunteers are not available every day, so a much larger pool size would be required to provide a resource equivalent to a paid workforce; and
    - the cost and benefit of training and equipping volunteers needs to be evaluated compared to a paid workforce.
- The training and equipping of remote firefighters to be inserted by winching or rappelling from helicopters is required to provide an improved initial attack capability based in Tasmania for remote fires in the TWWHA and other areas. This is required regardless of what mix of firefighter engagement options is determined most appropriate. The development of policy and procedures appropriate for safe operations under Tasmanian forest conditions will be required; doctrine from other states or territories may not be directly transferable. It would be necessary to manage public and other stakeholder expectations because in some areas and circumstances winching operations may not be possible because of safety considerations.
- Investigate the type and size of water bombing aircraft that would be most effective for initial attack of fires in the TWWHA. This should consider both fixed-wing and rotary-wing aircraft. Airstrips that are potentially of benefit to the TWWHA (possibly with some upgrading) for dispatching rapid air attack are already present at Queenstown, Zeehan, Launceston and Maydena.
- Develop and train staff from Tasmanian fire agencies for designated air operations roles from the Australasian Inter-Service Incident Management System (AIIMS) to manage larger-scale air operations for firefighting, ensuring compatibility with systems used in either Victoria or New South Wales and alignment of training with national competencies.
- Develop appropriate dispatch protocols that provide specified response requirements for initial attack to meet key performance indicators; examples are maximum acceptable response times, minimum number and type of aircraft and remote crews. It is worth noting here that successful initial attack requires both rapid water bombing from the air and insertion of firefighters on the ground – neither alone is sufficient. The dispatch

protocol depends on the resources that are pre-determined as providing the required capability. Significantly increased investment in firefighting resources would be required before dispatch protocols could be practically developed, implemented and audited.

- Use of fire suppression chemicals (see section 6.2.1).

6.2.6 Improved public information

There is a need to improve information provided to the Tasmanian community on bushfires, so that it extends beyond the delivery of warnings and safety messages, while recognising that public safety is the highest priority. Systems that can provide regular updates to the public on bushfires could include coverage of:

- descriptions of the impacts of fires, such as estimates of the extent of fire-sensitive vegetation that has been burnt;
- impact on recreational facilities and closure of areas to the public; and
- summary of the firefighting resources (numbers and types) currently engaged in suppression and their tactics.

6.3 Recommendations relating to response to fire in the TWWHA

Recommendation 9 – Mapping of values

DPIPWE and the Tasmania Parks and Wildlife Service should continue to improve mapping, and incorporate the most up-to-date and available vegetation, soil and other natural and cultural values mapping into TASVEG and the Bushfire Risk Assessment Model (BRAM).

The availability of high-resolution aerial imagery has increased significantly in the past decade. Higher resolution mapping of natural values will significantly improve the inputs to the BRAM and enhance the fire risk assessments BRAM produces.

There is a role for the broader research community in providing both input to, and review of, natural and cultural values mapping for the TWWHA.

Recommendation 10 – Operational capability

The Tasmania Parks and Wildlife Service should review its immediate, medium and long-term fire suppression capabilities, including staffing.

This review should be done in consultation with other fire agencies in Tasmania as skills, demographic factors, and agency capabilities are expected to change significantly across all agencies.

This review should also take into account the spatial context of bushfire risk; emerging technological development; future fire suppression capabilities such as new fixed- and rotary-wing aircraft; and the future requirements for skilled, remote-area firefighting teams.

A review of resources and staffing arrangements should be undertaken to facilitate flexibility and responsiveness in capability to match annual variation in fire seasons (ie that impact workload).

The aim of this review is to understand what resources are required by the Tasmania Parks and Wildlife Service to manage current and future bushfire risk, and what actions need to be taken now to ensure that adequate levels of skill, staffing, equipment and decision-support tools are available for fire management in the future.

Recommendation 11 – Use of volunteers

The Tasmania Parks and Wildlife Service, in conjunction with other Tasmanian fire agencies, should review the future potential for the use of volunteers in supporting fire management activities, including the potential to use trained remote area volunteer fire crews.

This review should be conducted in conjunction with the review of the Tasmanian Parks and Wildlife Service's fire suppression capabilities.

Recommendation 12 – Fire suppression techniques and methods

The Tasmanian fire agencies should regularly review operational practices, fire suppression technologies and techniques used in other jurisdictions and determine their efficacy for Tasmania, including in the TWWHA.

In the TWWHA, particular attention should be paid to:

- *early intervention techniques and technologies such as early detection and rapid attack; and*
- *continuing to investigate methods and equipment for extinguishing ground (organic soil) fires (eg spike and pump combinations).*

Recommendation 13 - Aerial fire suppression

The Tasmania Parks and Wildlife Service and the Tasmania Fire Service should review future capabilities in fixed- and rotary-wing aircraft for fire suppression in the TWWHA, and for the safe insertion of remote area firefighting teams, including where landing or hover exit is not possible.

This review of aircraft support should be carried out in conjunction with the review of staffing capabilities.

Recommendation 14 – Research on fire suppression chemicals

The current research on the efficacy and environmental impacts of the use of fire suppression chemicals in the TWWHA should be continued in the short term.

This research should inform the development of guidelines for future use of fire suppression chemicals in the TWWHA.

Recommendation 15 – Use of fire suppression chemicals

The Tasmania Fire Service and Parks and Wildlife Service should review the future use of fire suppression chemicals in the TWWHA following the conclusion of the research project currently being undertaken.

Research, monitoring and adaptive management should continue on the use of fire suppression chemicals from the perspective of both impacts on TWWHA values, and guidelines on the effective and efficient operational strategies and tactics of the various fire chemical classes.

If the research determines that the use of fire suppression chemicals is appropriate in the TWWHA, suitable procedures will need to be established, as well as training and equipment, to manage the use of these products in a safe and responsible manner.

Protocols for future decisions to use fire suppression chemicals in the TWWHA should be incorporated into the TWWHA Fire Management Plan and associated operational fire guidelines.

As an interim measure, the use of fire suppression chemicals should be undertaken using a precautionary approach, where application is assessed and approved on a case-by-case basis.

The use of fire suppression chemicals for firefighting in the TWWHA should balance potential environmental impacts (if any) with the protection of the natural and cultural heritage values of the TWWHA.

Recommendation 16 – Improved public information and communications

The Tasmania Parks and Wildlife Service should develop a specific communications plan on bushfires and fire management. This plan should include:

- *public information on the restrictions on lighting fires in the TWWHA and the impacts of bushfire on sensitive natural and cultural assets;*
- *the dissemination of public information on fire danger during the fire season;*
- *the dissemination of public information during fire events including bushfires and management fires, including suppression activities; and*
- *the dissemination to the public of information on the extent and impacts of bushfire in the TWWHA.*

The communications plan should also cover the provision of public information during extreme bushfire events, such as those that occurred during 2016.

Good quality public information can play an important role in building community support for fire management in the TWWHA, and for the efforts of fire agencies during extreme events.

7. RECOVERY

7.1 Current operational practice

7.1.1 Bushfire Rapid Risk Assessment

Bushfire Rapid Risk Assessment was developed from the United States Burned Area Emergency Response (BAER) teams that were deployed to the Victorian bushfires in 2009 and introduced the concept of post-emergency rapid risk assessment.

Building on the Victorian approach, in 2011, New South Wales and the Australian Capital Territory developed Burned Area Assessment Teams and also invited the Tasmania Parks and Wildlife Service to participate in a cooperative arrangement across jurisdictions. These teams draw together expertise in a range of scientific disciplines and conduct a rapid risk assessment immediately following an emergency event. These assessments are used to assist managers in identifying and minimising future impacts – both immediate and longer-term – caused by the emergency event. The goal is to reduce further threat to life, property, infrastructure and the environment. The outputs of the process, which include a written report, support the transition from emergency response to recovery.

Reports are not intended to replace more detailed recovery assessments that are usually required. The reports do, however, alert government agencies to: the magnitude of potential post-fire risks (eg flooding); areas which may require further, more detailed rehabilitation or recovery planning; and the relative costs of mitigating post-fire risks compared to response operations.

The Department of Primary Industries, Parks, Water and Environment's (DPIPWE)'s Natural and Cultural Heritage Division and Tasmania Parks and Wildlife Service have supported this multi-jurisdiction approach, providing some input to the development of the process and may provide personnel for teams in the future. This assessment approach has been used in Tasmania by the Parks and Wildlife Service, Forestry Tasmania and the Tasmania Fire Service in 2013 and 2016, drawing on the assistance of expertise from other states.

7.1.2 Fire effects monitoring

Assessment of the impacts on natural values following major fire events is a function performed by Natural and Cultural Heritage staff where resources and time permit. The tasks are assigned to a small team of specialists, typically botanists, zoologists, geomorphologists, soil scientists and spatial data analysts. Brief reports are prepared that highlight:

- the area burnt of different vegetation types within the fire perimeter, based on TASVEG vegetation mapping;
- natural values that may have been affected, such as threatened species, threatened vegetation communities and fire-sensitive species or soils; and
- the context of the impacts within the broader management of fire regimes for species or ecosystems of concern.

When considered appropriate, longer-term monitoring and studies are established for targeted species or values.

7.2 Recent work and research

7.2.1 Assessment of the impacts of the 2013 Giblin River fire

As Tasmania battled fires in the South-East in January 2013, an even larger fire, started by lightning, spread to a final size of approximately 40,500 hectares in the South-West region of the TWWHA.

Very little suppression effort was undertaken on this fire – mostly the strategy consisted of monitoring, mapping and visitor safety management. An internal report was prepared by DPIPWE's Natural and Cultural Heritage Division staff that summarised the impacts of this fire on different vegetation types (Rudman et al. 2013). This report provided fire regime context for this significant fire, identified that most of the vegetation burnt was buttongrass and scrub, and described the likely impacts on fauna. The report underlined the difficulty in determining how much rainforest was burnt; current available methods cannot discern burnt areas beneath closed canopy, and vegetation mapping has limited accuracy.

Another study examined the impact of the Giblin River fire on the regeneration of shrub species in buttongrass moorland. This study highlights the impact that such high-intensity fires can have, even in the more fire-adapted buttongrass vegetation, and concludes that management burning can mitigate these impacts (French et al. 2016).

The Giblin River fire provided a rare opportunity to investigate the impacts of a major fire on river biota (fish and macroinvertebrates) and habitat structure. A number of river-monitoring sites had already been surveyed several years before the fire. The existence of a long-term river gauging station (recording flow and weather) on the lower Davey also gave an opportunity to develop a rainfall run-off model and to assess the immediate post-fire changes in hydrology of the Davey River in the late summer-autumn and winter of 2013. DPIPWE, in collaboration with the University of Tasmania and Freshwater Systems, undertook a survey of the river biota 12 months after the Giblin River fire (Davies et al. 2013). Macroinvertebrates declined in taxonomic richness; both the number of families and of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (Caddisfly) species, as the percentage of catchment burnt increased. This response was strongly influenced by stream gradient, with differential sensitivities in low-slope and high-slope streams. The macroinvertebrate response was accompanied by a number of responses in instream habitat, especially the proportion of area of fine sediments (especially sands) on the stream bottom. There were no significant relationships between the abundance or species richness of native fish and the area of catchment burnt across all sites surveyed for fish. In addition, no overall decline in fish abundance was observed between pre-fire and post-fire samples taken at six burnt main stem[10] sites. The hydrology component of the study revealed substantial post-fire changes in hydrology, with immediate summer-autumn increases in minimum and mean flows and increases in the magnitude and duration of high-flow events. Post-

[10] In hydrology, a main stem is the primary downstream segment of a river, as contrasted to its tributaries.

fire winter minimum flows, by contrast, decreased in magnitude, while the duration of low-flow and high-flow events were both elevated.

Surveys of moorland soils (Storey 2013) and fluvial systems (Storey 2014) in the Giblin River fire area found no direct damage to soils from smouldering fire. This was in part attributed to the relatively low flammability of moorland organic soils, and partly to the relatively wet condition preceding the fire. However, areas of burnt soil tens of centimetres deep over areas of several square metres were common in areas of wet scrub. Within the fluvial systems, which were surveyed almost 12 months after the fire, there was little sign of a geomorphic response that could be clearly attributed to the fire. In part this reflected the lack of pre-fire data on stream form and process in these areas.

7.2.2 Bushfire Rapid Risk Assessment for the Mersey Forest Fire Complex

A Bushfire Rapid Risk Assessment was undertaken for the Mersey Forest Fire Complex (Lake Mackenzie Complex plus Lake Bill fires) by the Bushfire Rapid Risk Assessment Teams (BRRAT). The BRRAT report was prepared for the Tasmanian Government by the Victorian Department of Environment, Land, Water and Planning and Parks Victoria, in conjunction with the Tasmania Fire Service, DPIPWE and Forestry Tasmania. The risk identification, assessment, prioritisation and evaluation process was completed in February 2016, in six days; hence the document was not intended to be a comprehensive report.

The report provides a brief summary and categorisation of the level of potential risks identified to natural, social and economic values such as:

- fire-sensitive vegetation and erosion of organic soils;
- perception of lack of protection and restoration of TWWHA values;
- disruption of access for maintenance, tourism and businesses;
- risk to public safety from untreated hazards along roads and tracks;
- infrastructure for power supply;
- Aboriginal heritage information and values of world significance;
- loss of catchment function; and
- reduction in hydro-storage capacity due to build-up of sediment and subsequent increased fire susceptibility.

The report also recommended immediate actions including:

- Assess and map the scale and degree of impact on organic soils, fire-sensitive highland vegetation communities and species; prioritise sites requiring emergency stabilisation.
- Assess roads and infrastructure for hazards, prioritise treatments and implement stabilisation works.
- Assess damage to power infrastructure; prioritise and replace or repair; monitor and review.
- Engage with Aboriginal community and key stakeholders.
- Inspect registered Aboriginal heritage places; assess condition and prioritise mitigation.

7.2.3 Assessment of the impacts of the 2016 bushfires on the values of the TWWHA

Since February of this year, the Department of Primary Industries, Parks, Water and Environment's (DPIPWE) Natural and Cultural and Heritage Division has been undertaking assessments of the impacts of the 2016 bushfires on the values of the TWWHA and other reserves.

The purpose of this assessment is to report on the impact of the 2015-16 bushfires on natural, Aboriginal and historic heritage values across all tenures, but primarily reserved land, and identify potential areas for post-fire remediation works, primarily in the TWWHA and the Western Tasmanian Aboriginal Cultural Landscape. The aim of the assessment is to:

- assess the impact of the 2016 fires on the natural, Aboriginal and historic heritage values of Tasmania, with special consideration to the TWWHA and the Western Tasmanian Aboriginal Cultural Landscape[11];
- identify situations where fire has initiated a threatening process, where a timely intervention has the potential to significantly reduce long-term damage to values;
- identify situations where monitoring is needed to understand fire impacts and recovery with and without rehabilitation interventions;
- provide advice to relevant land managers/owners regarding post-fire management of Aboriginal cultural values that are subject to natural or human impacts ie erosion, new vehicle tracks or recreational vehicle use, etc; and
- identify where the fire has created an opportunity for effective research to better understand the natural, Aboriginal and historic cultural values, including more effective site extent determinations and to improve their long-term management.

7.2.3.1 Natural Values

The surveys by the Natural and Cultural Heritage Division have involved site visits to Gordon Road, Lake Bill and areas of alpine and subalpine vegetation accessible from the Lake Mackenzie Road. Data and photographs from the areas impacted by the Lake Mackenzie Complex fire were presented to the 2016 TWWHA Bushfire Research Group workshop held on 8 June 2016 at the University of Tasmania in Hobart, where the potential and priority for rehabilitation works in the post-fire period were considered. The workshop assisted in the refinement of a qualitative decision tool for assessing post-fire rehabilitation priorities. The conclusions reached by the workshop group (DPIPWE 2016b) included agreement that:

- damage to some values was severe enough that recovery without intervention was unlikely;
- in cases where impacts were severe, the proportion of the value impacted by fire comprised a very small proportion of the total extent of the value in the TWWHA, reducing the priority/need for rehabilitation;

[11] The Western Tasmania Aboriginal Cultural Landscape is located on the North-West Coast of Tasmania and was added to the National Heritage List on 8 February 2013.

- the fire impacts provide an opportunity to undertake targeted trials to investigate methods of rehabilitation that are cheap and effective in restoring ecosystem function; these trials are warranted given the lack of rehabilitation experience in Tasmania; they would facilitate the acquisition of data on suitable rehabilitation methods for use for in response to future bushfires; and
- there are a number of outstanding tasks and research priorities that may improve bushfire prevention in fire-sensitive areas and which may improve the effectiveness of fire suppression.

The impacts to natural values of the TWWHA have so far been the subject of one Natural and Cultural Heritage Division report, which documented the outcomes of the 2016 TWWHA fire research workshop (DPIPWE 2016b). More detailed reports documenting field survey results are scheduled for completion later in 2016 (DPIPWE unpublished data).

The majority of the areas impacted by the 2016 fires in the TWWHA were composed of vegetation types and fauna that are adapted or resilient to fire. As a result, these areas are likely to recover to something similar to their original state within a relatively short time (less than 30 years or so).

A small subset of the vegetation types impacted were composed of fire-killed (ie very fire-sensitive), long-lived and poorly dispersed species.

On the Central Plateau, the affected area includes vegetation and soils that are not fire-adapted. This includes wetland peats, cushion moors, organic humus soils and sphagnum bogs. In areas of fire-adapted vegetation, there is evidence of damage to organic soils, including the blanket bogs of the buttongrass moorlands (DPIPWE 2016b).

The most significant impact to natural values in the TWWHA relates to the alpine and subalpine vegetation affected by fire in the Lake Mackenzie, February Plains and Lake Bill areas (Tasmanian Government 2016a). The most significant flora value fire-affected is pencil pine (*Athrotaxis cupressoides*). This species is an iconic example of Gondwanic legacy in the TWWHA, which contributes to the property's Outstanding Universal Value. It also contributes to the aesthetic importance of the alpine landscapes of the TWWHA, which is also part of the property's Outstanding Universal Value. The recovery of cushion moorlands, various alpine heathlands and sedgelands, and alpine sphagnum peatlands will be dependent on the fire intensity and degree of organic soil loss (DPIPWE 2016b).

The accuracy of vegetation and fire scar mapping is limited and therefore area assessments of fire impacts on vegetation can only be approximate. Higher resolution imagery captured for the Mersey Valley and Walls of Jerusalem just before the summer fires enabled a vegetation revision mapping to better assess impacts of the 2016 fires (TASVEG LIVE, unpublished DPIPWE data as at 31 October 2016).

Of the areas in the TWWHA which were within the fire boundary of the Lake Mackenzie Complex fire identified in Figure 3, 1,547 ha[12] were listed as Threatened Native Vegetation Communities including[13]:

- highland *Poa* grassland (218 ha);
- highland grassy sedgeland (868 ha);
- pencil pine (*Athrotaxis cupressoides*) forest and woodlands (85 ha);
- sphagnum peatland (63 ha); and
- cushion moorlands (none mapped but distributed in small patches (111 ha))[14].

Highland *Poa* grassland and highland grassy sedgeland are classed as moderately fire-tolerant, and the grass and sedge component usual recovers by re-sprouting. However, preliminary ground surveys by DPIPWE found localised areas (<0.1 hectare patches) of grassland in which the organic component of soils, including roots and seed banks, had been completely combusted.

Remaining organic and mineral soils will be exposed to erosional forces such as wind, water and frost heave until plant regrowth can occur. Where the soil has burnt, root systems and soil-stored seed are killed, so these areas will depend on seed dispersal from surrounding areas for their re-colonisation, which may be slow. Evidence of damage from an earlier fire to this vegetation type, at Lake Bill, demonstrated increased levels of bare ground and rock pavement after more than 30 years. It is likely that some areas affected in this fire will be visible as areas of active erosion for many decades (Tasmanian Government 2016a).

The 85 hectares of pencil pine woodland and forests within the fire boundary represents less than 0.5 per cent of the presently mapped extent of these communities. Preliminary field surveys undertaken by DPIPWE revealed fire impacts on some patches of this vegetation were severe, with only a small proportion of the pencil pine trees expected to survive the fire. Recovery of fire-killed stands is unlikely without active intervention. However, other topographically protected patches inside the fire boundary escaped with comparatively minor damage.

DPIPWE field surveys found that sphagnum peatlands, which are usually too wet to burn, had burnt with variable intensity, including broad areas of severe damage where moss was killed and underlying peat burnt to a significant depth. The potential for recovery without intervention is not yet clear but is likely to be small in severely damaged areas. Initial surveys found little evidence of live moss remaining in severely burnt areas. Also, sphagnum is sensitive to exposure to wind and ultraviolet radiation, and the peatland landform is susceptible to stream incision once moss is damaged. Surviving areas of moss are therefore at risk of further degradation.

DPIPWE field surveys also observed widespread occurrence of small areas of cushion moorland, not indicated in the TASVEG 3.0 mapping. These had often been severely impacted by fire. Re-sprouting had begun on some scorched cushions, but many have lost substantial amounts of organic soil from within the cushion heart and around the basal edge. The capacity of severely

[12] Estimate provided by DPIPWE's Parks and Wildlife Service.

[13] Note that some pockets of vegetation within the fire boundary escaped burning due to topographic protection etc.

[14] Estimates provided by DPIPWE's Natural and Cultural Heritage Division on 31 October 2016.

damaged cushions to survive post-fire exposure to frost, wind erosion and dehydration is not known.

The fires, and subsequent high rainfall events, have also impacted soil and geomorphology in the area, including significant impacts to geoconservation values including both organic and mineral soils, karst systems, fluvial systems and slopes. The organic soils and karst systems are recognised as part of the TWWHA's Outstanding Universal Value. Preliminary post-fire surveys observed that the surface organic matter had been combusted across most of the fire-affected region, exposing surface rhizomes and roots in some instances. More serious combustion of organic soils was much more locally restricted, with the most serious losses of organic soils observed from sphagnum peatlands and in some areas of alpine sedgeland. Although not investigated in the preliminary post-fire surveys, fires in organic soils in rainforest areas were an issue during fire suppression (Tasmanian Government 2016a).

A six-week camera-trap fauna survey of burnt and unburnt vegetation near Lake Mackenzie in May-June 2016 recorded 13 species of mammal including spotted-tailed quolls, eastern quolls, Tasmanian devils and platypus. More mammal species (six) were recorded more frequently in unburnt vegetation than in burnt vegetation. Only eastern quolls were recorded more frequently in burnt vegetation. As expected, small mammals such as native rodents and antechinuses were virtually absent in burnt vegetation; these species are expected to re-colonise as vegetation recovers.

7.2.3.2 Aboriginal Heritage Values

The Natural and Cultural Heritage Division's Aboriginal Heritage Tasmania branch have undertaken desktop assessments and field surveys of the impacts on Aboriginal heritage values of the 2016 bushfires. Fieldwork in the TWWHA has, up until November 2016, involved approximately two on-ground person days during a site visit to remote rockshelters located in intense burn regions within the Forth River Valley15 .

The assessments of the impacts of the 2016 bushfires have indicated that threats to Aboriginal cultural heritage include exposure and increased accessibility as a result of loss of vegetation which increases the threat of destruction (unwitting or deliberate), vandalism or artefact collection. While Aboriginal Heritage Tasmania has provided timely desktop risk assessment advice for the intersect of Aboriginal heritage and burn areas within the TWWHA, potential impact from soil disturbance and destabilisation through vehicle access or heavy machinery involved in rehabilitation and recovery works has not been confirmed on the ground.

The assessments have provided a rare opportunity to reassess two existing Aboriginal Heritage Register (AHR) rockshelter sites within the TWWHA, update site records using current technology, and address immediate Aboriginal cultural protection and management issues in consultation with the Tasmania Parks and Wildlife Service and the Aboriginal community.

[15] Natural and Cultural Heritage's Aboriginal Heritage Tasmania has advised that the 2016 bushfires also impacted on aboriginal cultural values outside the TWWHA, including values in the Arthur Pieman Conservation Area, the Sundown Point State Reserve and the Western Tasmania Aboriginal Cultural Landscape.

Aboriginal Heritage Tasmania is continuing to work with the Tasmania Parks and Wildlife Service and the Aboriginal community to undertake post-fire assessments of the impacts of the 2016 bushfires on Aboriginal heritage values.

7.2.4 Rehabilitation actions

No rehabilitation works have been undertaken other than standard post-fire work relating to restoration of areas impacted by firefighting activities. Much of the area burned in the TWWHA falls within biomes that naturally burn and have a natural capacity to recover from a single fire. The exception to this is the alpine and subalpine areas burnt by the Lake Mackenzie Complex and Lake Bill fires, where a range of conservation values have suffered damage that is likely to be permanent. However, given the relatively small proportion of the State's alpine zone that was burnt, the fire did not significantly reduce the security of any of the damaged conservation values. In this context, rehabilitation is not necessarily a high priority. Also, the June 2016 floods fully absorbed DPIPWE's capacity to respond to environmental events. For these reasons, no rehabilitation of natural values was planned.

7.3 Areas for further work or research

7.3.1 Role of Bushfire Rapid Risk Assessment

The Bushfire Rapid Risk Assessment report commissioned for the Mersey Forest Fire Complex (Lake Mackenzie Complex and Lake Bill fires) seems to have been under-utilised for recovery planning. The concept of rapid assessment is recognised in the Tasmanian Emergency Management Plan and the subordinate State Special Emergency Management Plan Rapid Impact Assessment, where responsibility for bushfires is allocated to the fire agencies. Such assessments are now routine in other Australian jurisdictions.

There is a need to resolve for future fires in the TWWHA and other reserved areas, whether or not a rapid risk assessment will be commissioned. If so, there needs to be policy and protocols around implementation, actions, reporting and auditing. Amendments to the Tasmanian Emergency Management Plan and the State Special Emergency Management Plan Rapid Impact Assessment would ensure consistency and a supporting mandate. Examples of other doctrine that would be useful in revised State plans are: criteria for instigating a bushfire rapid risk assessment; the scale of the assessment required; the process for initiating an assessment; and how reports are delivered and used by Government.

7.3.2 Ecosystem recoverability

Historically, alpine areas and rainforests of the TWWHA have rarely been dry enough to burn, and fires in these fire-sensitive ecosystems have been relatively infrequent, compared with more flammable habitats. As the climate warms and summers become drier in the TWWHA, fire frequency in these habitats may increase. Some communities have demonstrated a relatively high resilience to bushfires but, as the climate changes, this may change. Vegetation that currently recovers quickly from the impacts of fire may not recover as quickly as the climate changes.

To help prioritise fire suppression efforts in these fire-sensitive habitats, it is now important to understand the recoverability of these communities post-fire (Gilfedder et al. 2012). Given the

importance of natural values in these ecosystems, it is also important to understand in what situations rehabilitation actions can be used to mitigate against the impacts of bushfire when suppression efforts are unsuccessful (see section 7.3.3).

7.3.3 Trials of rehabilitation techniques

Rehabilitation of natural areas after fire takes two forms: the rehabilitation of areas impacted by firefighting activities; and the rehabilitation of natural values. This section considers the latter. Such rehabilitation is most likely to be needed in areas where a given fire is outside the desirable range of fire frequency or intensity. In such situations, fire can cause significant changes and the natural fire response will not result in recovery of the damaged conservation values.

A rehabilitation response would be justified where some or all of the following criteria are met:

- The fire has impacted the conservation status of a significant feature.
- There is potential for successful and cost-effective rehabilitation that will significantly improve outcomes for the feature.
- There are fire-initiated degradation processes operating that will cause further damage without intervention.
- There are important conservation values associated with the damaged feature that are now vulnerable.
- There are good social, political, or economic reasons to intervene.

Areas where active rehabilitation may be justified include: alpine areas where many conservation values are highly sensitive to fire, and recovery rates are slow; organic soil horizons burnt over large areas; and aeolian (wind-deposited) landforms that may be prone to erosion when vegetation is absent. Rehabilitation may also be justified where a highly vulnerable conservation value has been damaged, such as a threatened species or vegetation community. Rehabilitation in wet eucalypt forest or dry eucalypt forest is less likely to be justified from a conservation perspective, although it may have an economic benefit.

The Lake Mackenzie Complex fire highlighted that there is relatively little Tasmanian experience with rehabilitation of natural values after fire. At the Lake Mackenzie Alpine Fire Impacts Workshop (DPIPWE 2016b), it was clear that, although there is extensive experience with alpine rehabilitation following fire in Victoria, New South Wales and the Australian Capital Territory, these techniques have largely not been applied in Tasmania. One exception is the largely unsuccessful attempts that have been made to halt soil erosion on the eastern Central Plateau initiated by the 1960-1961 fire (Storey and Comfort 2007). The recommendation of the workshop was to undertake targeted research trials aimed to determine the effectiveness of post-fire rehabilitation methods (DPIPWE 2016b). There is a need to trial techniques in Tasmania that have been successful on the mainland, and to develop and trial techniques that could be used on values such as pencil pine (*Athrotaxis cupressoides*) that are peculiar to Tasmania.

In the alpine and subalpine zones, potential targets for rehabilitation trials include:

- burnt soils (to prevent ongoing sheet erosion);
- pencil pines (to facilitate regeneration of damaged stands);
- sphagnum (to facilitate rate and areal extent of recovery); and

- water flow control (to prevent incision in damaged wetlands).

Examples of rehabilitation techniques to be trialled include: constructing barriers to surface water movement; planting of seedlings and/or spreading seeds; feral animal control (eg rabbits (*Oryctolagus cuniculus*)); and fencing exclosures to prevent grazing from marsupials and introduced mammals.

It is likely that a more thorough review of post-fire rehabilitation needs beyond the alpine zone would identify additional targets for trials.

7.3.4 Fire, climate change and introduced animals

Climate change and fire interactions could possibly facilitate increased spread of introduced species. Fire has the potential to facilitate the movement of the following three species because the post-fire environment provides both food and ease of movement:

- Rabbits occur widely in the Central Plateau area of the TWWHA where they can impact on native vegetation and cause soil erosion, and this risk may be exacerbated under the warmer and drier conditions projected for this area. Rabbits have been observed at higher altitudes in the Victorian Alps under warmer and drier conditions.
- The risk posed by common starlings (*Sturnus vulgaris*) may increase under climate change, as this highly invasive species has the potential to spread into disturbed areas such as alpine and coastal habitats.
- Fallow deer (*Dama dama*) are currently thought to be constrained to the eastern edge of Central Plateau Conservation Area by climatic (altitudinal) factors, but there is the potential for expansion into the TWWHA under the projected warmer and drier climate of the Central Plateau.

There is a need to monitor the spread of introduced species such as rabbits, starlings and fallow deer in the TWWHA and determine causal factors, such as the interaction between climate change and fire.

7.3.5 Improved techniques to attain higher resolution of fire scar mapping

Accurate mapping of fire scars is a fundamental part of fire management that informs the following:

- determination of fuel characteristics (related to time since fire) that in turn contribute to calculating the rate of spread and intensity of future bushfires (for example in the BOHM);
- selection and scheduling of future planned burns;
- monitoring of fire regimes and ecosystem responses;
- reporting on bushfire impacts on natural and cultural values (eg extent of burnt vegetation communities and losses of fire-sensitive values);
- reporting on carbon emissions; and
- future fire research projects undertaken by various organisations including universities.

The mapping of fires is becoming increasingly sophisticated and accurate as technology develops. Fires are routinely mapped in the TWWHA by GPS from aircraft, while some larger fires are mapped from aerial images and remote sensing. Research is needed, however, to improve our capacity to use remote-sensing methods to identify and map fire boundaries. A particular problem in the TWWHA is the mapping of fire scars underneath the closed canopies of forest vegetation, particularly rainforest, because the burnt ground is difficult to detect using remote sensing.

7.4 Recommendations relating to recovery from fire in the TWWHA

Recommendation 17 – Role of Bushfire Rapid Risk Assessment

The Tasmania Parks and Wildlife Service and other fire agencies should establish protocols for 'rapid assessment' of the impacts of major bushfires in the TWWHA and resourcing of immediate priorities for recovery action.

Rapid assessment techniques are used in many jurisdictions in Australia and overseas to provide an initial assessment of fire impacts and priorities for recovery and rehabilitation. While these 'rapid assessments' cannot replace long-term investigation and monitoring of fire impacts, they can be useful in prioritising recovery efforts and rationalising commitment of resources to recovery.

The efficacy and usefulness of rapid assessment techniques should subsequently be evaluated, and their implementation modified if required.

Recommendation 18 – Ecosystem rehabilitation and restoration trials

The Tasmania Parks and Wildlife Service and DPIPWE should undertake trials of post-bushfire rehabilitation techniques (eg erosion control, tree planting, seed germination and seed banks), especially for vulnerable species, communities and other significant values in the TWWHA.

This work should be integrated into a broader research strategy for the TWWHA, and incorporated into the Adaptive Management framework contained in the TWWHA Management Plan.

8. CONCLUSIONS

Tasmania has well-developed fire management arrangements and procedures across the areas of bushfire prevention, preparedness, response and recovery for the Tasmanian Wilderness World Heritage Area (TWWHA).

Research undertaken through this Project has shown that the TWWHA is likely to experience increasing bushfire risk in the future as a result of a changing climate. This will have significant implications for managing and protecting the globally significant natural and cultural values of this iconic region.

Increased bushfire risk will place pressure on Tasmania's firefighting capability in coming years. Protecting the natural and cultural heritage values of the TWWHA will require actions that are beyond 'business as usual' and will require decisions and investments to be made on a whole-of-government basis, including in human resources.

Specialised firefighting capabilities are an important asset in protecting the TWWHA's natural and cultural heritage. This specialised capability is key to effective initial attack, containment and suppression for fires in wilderness areas. Adequate capability, including remote firefighters and aircraft, needs to be based and available in Tasmania to ensure preparedness at short notice and rapid initial attack.

Maintaining a cooperative network of national firefighting resources and capabilities will become more critical in the future to ensure Tasmania can respond to significant bushfire seasons like that seen in 2016. However, interstate firefighting resources are also likely to be stretched due to longer fire seasons and the potential for future coincident extreme natural events as the climate changes.

It is important that the lessons learned from the 2016 bushfires, and the climate projections contained in this Report, are taken into consideration in preparing for a future where fire management in the TWWHA is more challenging.

This Report sets out recommendations that can be employed by Tasmania to prepare for, and respond to, the future bushfire threat in the TWWHA. The implementation of these recommendations is required to ensure that the outstanding universal values of the TWWHA are afforded, as far as practical, protection for the future.

Tasmanian firefighting agencies have shown a clear determination to learn from the 2016 bushfires and have already implemented a number of changes ahead of the 2016-17 bushfire season.

An ongoing program of scientific research and monitoring is vital to understanding the evolving relationship between climate change and the vulnerability to fire of natural and cultural values in the TWWHA.

GLOSSARY AND ACRONYMS

ACE CRC	Antarctic Climate and Ecosystems Cooperative Research Centre
AIIMS	Australasian Inter-Service Incident Management System
AFAC	Australasian Fire and Emergency Service Authorities Council
BOHM	Bushfire Operational Hazard Model – a computer-based mapping system developed by Tasmania Parks and Wildlife Service that assists in the preparedness and response to bushfires
BOM	Bureau of Meteorology
BRAM	Bushfire Risk Assessment Model
Bushfire	Unplanned vegetation fire. A generic term which includes grass fires, forest fires and scrub fires both with and without a suppression objective.
CFFDRS	Canadian Forest Fire Danger Rating System
Clade	A clade is a group of plants or animals that includes a common ancestor and all the descendants (living and extinct) of that ancestor
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Disseminule	A reproductive plant part, such as a seed, fruit, or spore, that is modified for dispersal
DPIPWE	Department of Primary Industries, Parks, Water and Environment
EPBC	*Environment Protection and Biodiversity Conservation Act 1999*
FAP	Fire Action Plan
FBP	Fire Behaviour Prediction
FEDOG	Fire Equipment Development Officers Group
Fire-dependent	Natural values that persist only in the presence of fire
Fire regime	The history of fire in a particular vegetation type or area including the frequency, intensity and season of burning. It may also include proposals for the use of fire in a given area.
Fire tolerant	Natural values that are likely to persist in the presence of fire, but may be eliminated if the bounds of tolerance are exceeded
Fire-sensitive	Natural values that will be significantly damaged by any fire. In some cases, the value may survive a single fire in damaged form, but is unlikely to persist after repeated fires.
Fire suppression	The activities connected with restricting the spread of a fire following its detection and before making it safe
Fjaeldmark	A plant community characteristic of sites where plant growth is severely restricted by extremes of cold and by exposure to wind, typical of alpine tundra and subantarctic environments. Found on mountains in Tasmania.
FWI	Fire Weather Index
ha	Hectares
FFDI	Forest Fire Danger Index

Geoheritage	Globally, nationally, statewide, to local features of geology such as its igneous, metamorphic, sedimentary, stratigraphic, structural, geochemical, mineralogic, palaentologic, geomorphic, pedalogic, and hydrologic attributes at all scales, that are intrinsically important sites or culturally important sites, that offer information or insights into the formation and evolution of the Earth, or into the history of science, or that can be used for research, teaching or reference
Ground fire	Fire that consumes the organic material beneath the surface litter ground, such as a peat fire
ICOMOS	International Council on Monuments and Sites
IMT	Incident Management Team
Initial attack	The first suppression work on a fire
IUCN	International Union for Conservation of Nature
MAC	Multi-Agency Coordination Group
Mire	An area of swampy, soggy or boggy ground
MSDI	Mount Soil Dryness Index
NAFC	National Aerial Firefighting Centre
NCH	Natural and Cultural Heritage Division (Department of Primary Industries, Parks, Water and Environment)
NERAG	National Emergency Risk Assessment Guidelines
Organic soil	Soils that contain significant organic material. In the context of the TWWHA, they have potential to burn if dry enough.
Palaeoendemic	A species that has been native to a region for a very long time (ie many millions of years)
PPRR	Prevention, Preparedness, Response and Recovery
PWS	Tasmania Parks and Wildlife Service
Scleromorphic	Firm and stiff leaves
SFMC	State Fire Management Council
SFOC	State Fire Operations Centre
SFPP	State Fire Protection Plan
SOI	Southern Oscillation Index
SOUV	Statement of Outstanding Universal Value
Surface fire	Fire that burns loose debris on the surface, which includes dead branches, leaves, and low vegetation
TASVEG	The Digital Vegetation Map of Tasmania
TFRF	Tasmanian Fire Research Fund
TFS	Tasmania Fire Service
TWWHA	Tasmanian Wilderness World Heritage Area
UNESCO	United Nations Educational, Scientific and Cultural Organisation

Attachment 1 – Summary of the major fires 13 January to 24 March 2016 in Tasmania

This summary is based on AFAC (2016a). The final fire sizes provided below have been updated with information provided by the Department of Primary Industries, Parks, Water and Environment and the Tasmania Fire Service.

The Wuthering Heights Fire Complex

The Wuthering Heights complex impacted approximately 21,400 ha. It includes the Stephens Rivulet fire first recorded on 20 January; the Julius River fire first recorded 20 January; the Rebecca Road/Rachael Creek fire first recorded on 14 January, together with the Temma back-burn on 28 January and the Arthur River back-burn on 30 January.

The Pipeline Road - Mawbanna Fire

The Mawbanna Fire included the Pipeline Road, Rulla Road, Sumac Road and Gahnia Road Fires and eventually burnt around 61,990 ha. It was first recorded 14 January at 1024 hours and marked as under control on 16 March. On 17 March a 'Watch and Act' message was issued for this fire, as the southern western edge of the fire had run further to the west coast since 7 March.

Griffiths Creek Fire

The Griffiths Creek Fire (2,933 ha) was first recorded on 14 January at 1601 hours. No control action other than monitoring was undertaken on this fire due to the low risk attached to this fire.

Maxwell River South Fire

The Maxwell River South Fire (1,400 ha) first recorded 18 January at 2101 hours and marked as patrol at 14 March 2016.

The Mersey Forest Fire Complex

This complex includes the Lake Mackenzie complex fire which was first reported on 15 January and burnt approximately 24,700 ha, the Lake Bill fire (1,400 ha) which was first recorded on 16 January and the Dove River fire (56 ha) which was also first recorded on 16 January. The Lake Mackenzie complex fire incorporated five fires that joined to become one fire: the Patons Road fire (15 January), the Mersey Forest Road fire (15 January), Lake Mackenzie Road fire (19 January), Devils Gullet fire (19 January) and the February Plains fire (17 January).

Gordon River Road

The Gordon River Road Fire (4,200 ha) was first recorded on 17 January at 1809 hours and marked as patrol on 14 March 2016.

Attachment 2 – Location of the TWWHA

Figure 8: Location of the TWWHA
(DPIPWE 2014)

Attachment 3 – Terms of Reference for the TWWHA Bushfire and Climate Change Research Project

Objectives and Outcomes

Objectives

- To examine how climate change will affect future fire danger and other variables that may lead to an increased risk of bushfire, and its impacts on the TWWHA.
- To provide recommendations on the most appropriate methods for monitoring and recording vegetation dryness levels within the TWWHA.
- To examine firefighting techniques, interventions and resources that can be safely and effectively employed by the Tasmania Parks and Wildlife Service and the Tasmania Fire Service to prepare for, and respond to, bushfires in the TWWHA, including the most appropriate methods to extinguish fire within the alpine areas.

Outcomes

- Improved understanding of how climate change will impact on bushfire risk in the TWWHA.
- Improved ability to prepare for, and respond to, bushfires in the TWWHA.

Outputs

Stage 1

Stage 1a – Interim report

The interim report will consider and review information that is currently available. It will include:

- a summary of research examining how future fire danger and other variables will impact on Tasmania's future bushfire risk in a changing climate;
- a summary of what is known of the impacts of climate change, particularly future fire danger and other variables, that may lead to an increased bushfire risk, in the TWWHA;
- a summary of the current approaches taken by the Tasmania Parks and Wildlife Service and the Tasmania Fire Service to respond to fires in the TWWHA, including identification of firefighting techniques, interventions and resources that are being utilised;
- based on currently available information, identification of fire-sensitive natural and cultural assets of significance in the TWWHA so that priorities for bushfire protection can be established for them; and
- a summary of relevant research and inquiries regarding the Tasmanian Government's response to the bushfires in the TWWHA that are currently underway.

The interim report is to be completed and made available to relevant agencies by the end of July 2016.

Stage 1b – Gap analysis and sub-projects to be undertaken to address identified gaps

A gap analysis will identify areas for additional research, gaps in current approaches and additional resources and tools that are required. The gap analysis will be undertaken in parallel with the interim report so that sub-projects can commence to address the identified gaps as soon as possible.

Sub-projects to address the identified gaps will be contracted out to appropriate organisations.

Stage 2 – Final report

The final report will:

- summarise the work undertaken in Stage 1 and provide practical information and tools for the Tasmania Parks and Wildlife Service and the Tasmania Fire Service for the management of bushfires in the TWWHA; and
- provide recommendations to the Tasmanian and Australian governments regarding future management of bushfire threat in the TWWHA.

The final report is to be provided to the Tasmanian Government by the first week in December 2016 with the intention that it could be publicly released by the end of the year.

Governance

Steering Committee

The Steering Committee will comprise:

- Dr Tony Press, Adjunct Professor Antarctic Climate and Ecosystems Cooperative Research Centre and Institute for Marine and Antarctic Studies (Chair).
- Mr Greg Johannes, Secretary of Department of Premier and Cabinet (DPAC).
- Dr John Whittington, Secretary of DPIPWE.
- Commissioner Darren Hine, Secretary of Department of Police, Fire and Emergency Management (DPFEM).

Should the Australian Government choose to contribute to the project, a representative will be invited to join the Steering Committee.

Roles and functions

- Provide direction and general guidance to the Secretariat.
- Facilitate access to Agency resources.
- Consider input from the Technical Working Group.
- Ensure that the project achieves its objectives and that the project's outputs are delivered.

Frequency of meetings

- The Committee will meet as frequently as required but not less than four times during the contract period. Matters may also be addressed out-of-session by email or telephone.
- Minutes will be kept and maintained by the Secretariat and will be distributed to Committee members.

Secretariat

The DPAC Tasmanian Climate Change Office (TCCO) will provide the Secretariat for the project.

The Secretariat will be responsible for:

- establishing and managing contracts with Dr Tony Press and contracts with other organisations that may be established as part of the project;
- providing assistance as required to the Steering Committee; and
- coordinating meetings with, and input from, the Technical Working Group.

Technical Working Group

A Technical Working Group will be established with representation from DPIPWE, DPFEM and DPAC.

The Technical Working Group will provide advice and input to assist with achieving the project's objectives and outputs.

The Secretariat will chair meetings of the Technical Working Group.

Budget

The total project funding is $250,000 (exclusive of GST). Agencies will provide in-kind support to the project. The Tasmanian Government has invited the Australian Government to contribute to the project. The TCCO will manage these funds and monitor and report additional in-kind support. Project funds will be used to engage Dr Press and to establish sub-projects to address gaps identified in Stage 1 of the project.

Attachment 4 – Tasmania's fire management arrangements

Tasmania's bushfire management is governed primarily by the Tasmanian *Emergency Management Act 2006* and the *Fire Service Act 1979*. The relevant elements of the framework are described in the subsequent sections of this attachment.

The Tasmania Parks and Wildlife Service is a member of the State Fire Management Council and is therefore a signatory to the State Vegetation Fire Management Policy 2012 (currently under review). It also has representation on all Fire Management Area Committees.

The Tasmania Parks and Wildlife Service has representation on the Multi-Agency Coordination Group (MAC) and it appoints Incident Management Teams for Level 1 and Level 2 fires on reserved land. Level 3 Incident Management Team positions are appointed by the Tasmania Fire Service Chief Officer based on recommendations from the MAC. The Tasmania Parks and Wildlife Service is usually represented at the State Fire Operations Centre (SFOC) and Level 3 IMTs.

Emergency Management

Emergency Management Act 2006

The Tasmanian *Emergency Management Act 2006* is the primary piece of legislation underpinning emergency management in Tasmania, including bushfire emergency events.

This legislation provides for a three-tiered approach under which emergency management committees are established at State, regional and municipal levels. The primary functions of committees at each level are essentially the same, namely to institute, coordinate, and support emergency management in Tasmania, including the preparation and review of the Tasmanian Emergency Management Plan (TEMP) and Special Emergency Management Plans. These policy and planning committees are not operational.

State Emergency Management Committee (SEMC)

Tasmania's State Emergency Management Committee (SEMC) is a policy and planning committee. SEMC membership includes:

- State Controller (either appointed by the Minister or a default position to the Police Commissioner – the current arrangement)
- Secretary, DPAC
- Secretary, Department of Health and Human Services (DHHS)
- Co-Chairs, State Emergency Management Advisory Group (SEMAG)
- Chief Officer, Tasmania Fire Service
- Chief Executive Officer, Ambulance Tasmania
- SEMC Executive Officer

SEMC is convened by the State Controller when the scope and resourcing of Tasmanian Government activity requires high level, interdepartmental coordination to provide whole-of-government advice to the Tasmanian Government. The role is one of coordination; it does not extend to managing the deployment of resources or other activities carried out by operational agencies. Operational command responsibilities remain with the relevant management authority.

Tasmanian Emergency Management Plan

The Tasmanian Emergency Management Plan (TEMP), established under the *Emergency Management Act 2006*, is the overarching framework to assist emergency services and emergency management partners to prepare for, respond to, and recover from emergency events.

The TEMP specifies the hazards (including fire) that the Tasmania Fire Service and other agencies are responsible for and outlines the arrangements for prevention and mitigation, preparedness, response and recovery. The TEMP recognises that the Tasmania Parks and Wildlife Service and Forestry Tasmania have responsibility for the administration and management of fire and fire control measures within the land tenures for which those agencies have management responsibility.

The TEMP also articulates how the components of Tasmanian emergency management work together under a single, comprehensive and flexible framework.

The TEMP sits in the background and is not actively used for most fire preparedness, response and recovery activities undertaken in the TWWHA.

Fire management

Fire Service Act 1979

For the purposes of the *Fire Service Act 1979,* the Tasmania Parks and Wildlife Service is a landowner and is therefore required to take reasonable measures to prevent fires leaving those lands that are managed by the Tasmania Parks and Wildlife Service.

State Fire Management Council

The State Fire Management Council (SFMC) is established under the *Fire Service Act 1979* to:

- develop a State vegetation fire management policy to be used as the basis for all fire management planning;
- advise and report regularly to the Minister (responsible for police and emergency management) on matters relating to the administration of the Act, as it applies to vegetation fire management;
- provide advice to the State Fire Commission regarding the prevention and mitigation of vegetation fires;
- perform such other functions relating to the prevention or mitigation of vegetation fires as the Minister may direct;
- establish a Fire Management Area Committee for each fire management area of Tasmania, to coordinate fire management activities within the defined fire management area; and
- consider and approve (with or without modifications) annual Regional Fire Protection Plans for each fire management area.

The SFMC is made up of the major land managers within the State along with government agencies responsible for the management of bushfires in Tasmania.

Fire Management Area Committees

There are 10 Fire Management Area Committees established for the State. The principal aim of the Committees is to bring together the various stakeholders that manage land use across the State, to work together to effectively manage vegetation fuels for the mitigation of bushfires.

Each Committee is required to prepare a Fire Protection Plan for their Fire Management Area in accordance with the *Fire Service Act 1979*. The Plans describe the prevention and preparation arrangements to mitigate bushfire risks within the fire management area.

State Fire Protection Plan

The purpose of the State Fire Protection Plan (SFPP), which is made under the *Fire Service Act 1979*, is to ensure that effective fire and emergency prevention and protection measures are provided throughout Tasmania. This SFPP sets the framework for these measures to be implemented by the Tasmania Fire Service, and other relevant agencies identified.

The SFPP is maintained by the Tasmania Fire Service on behalf of the State Emergency Management Committee (SEMC).

In implementing the SFPP, agencies focus on the protection of life, property and the environment from fire and other emergencies by developing appropriate prevention, preparedness, response and recovery strategies.

The Tasmania Parks and Wildlife Service provide input to the development of the SFPP but it is not influential in the day-to-day fire management of the TWWHA and sits very much in the background.

State Bushfire Safety Policy

The State Bushfire Safety Policy is a high-level management policy providing guidance to Government, agencies and other stakeholders in the development of strategic policies and plans to:

- recognise the shared responsibility for bushfire safety between the State Government, local governments, emergency and land management agencies, communities and individuals;
- increase community knowledge of and preparedness for bushfire risk, thereby informing the development of action plans to address such risk;
- support and improve local bushfire safety planning that tailors management of risk to the needs of the individual community; and
- ensure a safe response to bushfires by households and individuals in identifying bushfire safety options to maximise the likelihood of survival.

The Policy is developed, implemented and reviewed by the Chief Officer of the Tasmania Fire Service, in consultation with others. The Chief Officer is required to review and evaluate the Policy after each bushfire season.

Responsible agencies

Tasmania Parks and Wildlife Service

The Tasmania Parks and Wildlife Service is the land manager of the TWWHA. It is responsible for managing [the impacts of] bushfire through a combination of activities and is the lead fire agency for the TWWHA. These include mitigation activities, such as fuel reduction burning, and responding to bushfires in the TWWHA.

Subsection 30(3)(ca) of the Tasmanian *National Parks and Reserves Management Act 2002* gives authority to the Tasmania Parks and Wildlife Service to 'take any steps or undertake any activities that the managing authority considers necessary or expedient for the purposes of preventing, managing or controlling fire in reserved land'.

As an occupier of land, the Tasmania Parks and Wildlife Service is also obligated under section 64 of the *Fire Service Act 1979* to take diligent steps to extinguish fire or prevent it from spreading and to report the fire.

In addition to this obligation, the Tasmania Parks and Wildlife Service has numerous legislative responsibilities influencing its activities and fire management priorities:

- Tasmanian *National Parks and Reserves Management Act 2002*
- *Environmental Management and Pollution Control Act 1994*
- *Commonwealth Environmental Protection and Biodiversity Conservation Act 1999*
- *Forest Practices Act 1985*
- *Aboriginal Relics Act 1975*
- *Nature Conservation Act 2002*
- *Threatened Species Protection Act 1995*

The Tasmania Parks and Wildlife Service develops and maintains Regional Strategic Fire Management Plans for Northern, North Western and Southern Tasmania. A key objective of these plans is to develop a strategic and consistent approach to fire management planning that addresses the bushfire risk to land managed by the Tasmania Parks and Wildlife Service.

Tasmania Fire Service

The Tasmania Fire Service and the State Fire Commission (the Commission) are established under sections 6 and 7 of the *Fire Service Act 1979*.

The Commission is responsible for the formulation of fire service policy, the coordination and development of all fire services throughout the State, the development of effective fire prevention and protection measures and the development and promulgation of the SFPP.

The Tasmania Fire Service is the operational arm of the Commission and plays a central role in emergency management arrangements, particularly when and if a bushfire poses an imminent threat to human settlements or infrastructure primarily on private property. This arrangement is supported by formal documentation and procedures that provide the basis for response arrangements.

The Tasmania Fire Service supports and works closely with the Tasmania Parks and Wildlife Service in fire management in the TWWHA but does not take a direct operational role for

response in the TWWHA, except when very large fires occur, fire threatens human settlements, or the fire operational capacity of the Tasmania Parks and Wildlife Service is exceeded. The Tasmania Fire Service has a collaborative role in terms of preparedness and may have a support role in recovery for some bushfires in the TWWHA.

Forestry Tasmania

Forestry Tasmania is a Tasmanian Government business enterprise responsible for sustainably managing approximately 800,000 hectares of public production forest (Permanent Timber Production Zone land).

Forestry Tasmania manages its land consistent with its obligations under the *Forest Management Act 2013,* with fire management being one of its core activities.

As an occupier of land, Forestry Tasmania is obligated under the *Fire Service Act 1979* to take such diligent steps as necessary, during the fire permit period, to extinguish or prevent any fires burning on that land from spreading and to report the fire. Forestry Tasmania has fire management responsibility for significant tracts of public land neighbouring the TWWHA and therefore has considerable interest in preventing bushfires entering the TWWHA, and in turn expects the Tasmania Parks and Wildlife Service to (where possible) prevent fires from leaving the TWWHA. Forestry Tasmania and the Tasmania Parks and Wildlife Service work closely together on fire operations, providing mutual support.

Tasmania's multi-agency firefighting arrangements

A significant feature of managing bushfires in Tasmania is the Interagency Fire Management Protocol (the Protocol) between the Tasmania Fire Service, the Tasmania Parks and Wildlife Service and Forestry Tasmania. A strong spirit of cooperation exists between the three fire agencies, underpinned by the Protocol, and the agencies work closely together. The agencies recognise that this close relationship and mutual support is essential for a small state with limited firefighting resources.

The Protocol does, however, set out the responsibility for responding to any fire and arrangements for jointly dealing with fires, regardless of land tenure. Under the Protocol, the agencies are responsible as follows:

- Tasmania Fire Service: is responsible for all structural fire suppression statewide, and for fire suppression on all private lands, unallocated Crown land and in Wellington Park. Where bushfires occur under conditions and in situations where there is an imminent risk to, or actual impact upon structures and communities, the Tasmania Fire Service shall direct the response to those fires where practical.
- Tasmania Parks and Wildlife Service: for management and suppression of fire on land reserved under the *Crown Lands Act 1976* and the *Nature Conservation Act 2002.*
- Forestry Tasmania: for management and suppression of fire in State forest, or since 2013, known as Permanent Timber Production Zone land.

That said, the guiding principle is that the most able firefighting crew of any agency will respond immediately to any fire as a priority, regardless of the land tenure involved. This is consistent with

the approach taken during the 2015-2016 bushfires in the TWWHA, with the Tasmania Fire Service responding due to the large number of fires and associated threat to key infrastructure.

Under the Protocol, the Tasmania Fire Service has responsibility for the issuing of all declarations and warnings. All Incident Controllers, regardless of agency, incident tenure or complexity, are responsible for the authorisation of, and the request to release, warnings.

The Protocol also includes an agreement between the Tasmania Fire Service, the Tasmania Parks and Wildlife Service and Forestry Tasmania to coordinate the management of responses to level 3 incidents (a large bushfire carrying high risk that involves many resources and interagency operations).

When a level 3 incident occurs, a Multi-Agency Coordinating group (MAC) recommends to the Chief Officer of the Tasmania Fire Service that an Incident Management Team is established. These teams often consist of personnel from all three agencies.

The Protocol arrangements described above are not directly underpinned by legislation but have been consistently implemented for many years.

Multi-agency arrangements are also supported by a range of MAC-agreed Statements of Procedures. These include an agreement that there will be interoperability between agencies in terms of systems, terminology, training, skills, roles and functions.

Under the *Emergency Management Act 2006*, the State Fire Controller assumed overall responsibility for the management of the 2015-2016 bushfires, including those that impacted on the TWWHA. The State Fire Controller is the Chief Officer of the Tasmania Fire Service, and from time to time the Chief Officer delegated the responsibility to the Deputy Chief Officer. The decision was made to appoint the Deputy Chief Officer to the position of State Fire Controller in the days leading up to the first lightning strike events, and to stand up the State Fire Control Centre as per established trigger points for fire preparedness and response, due to the forecast weather conditions and dryness of fuels statewide.

Given the extensive resources required to manage the number of fires in the landscape, the State Fire Operations Centre and Incident Management Teams all consisted of a variety of agency representatives from within Tasmania, interstate and overseas. Tasmania Parks and Wildlife Service staff were actively engaged in key management roles and as liaison officers throughout the emergency, and in particular to coordinate the response on reserved land and in the TWWHA.

Interjurisdictional support arrangements

The Tasmania Parks and Wildlife Service is signatory to an Arrangement between member agencies of the Forest Fire Management Group, which includes similar fire and land management agencies across Australia and New Zealand. The purposes of this Arrangement are to:

- provide continuous improvement in the management of fire within forests and on rangelands in Australia and New Zealand;
- recognise that strong working relationships, goodwill and cooperation across organisational and interstate boundaries are critical to this process;

- promote and facilitate the exchange of bushfire management resources between the agencies; and
- provide for mutual support and aid during the fire management activities and emergency management activities.

Separately, the Tasmania Fire Service has interjurisdictional arrangements that can be called upon in times of need. The Arrangements for Interstate Assistance (AIA) provide for the timely and meaningful exchange of capability between states and territories during significant incidents.

Using these cooperative arrangements, Tasmania was able to deploy over 1,000 firefighters from other states and territories and New Zealand in response to the 2015-2016 bushfires.

Assistance from other jurisdictions is likely to be used again in the future to assist with managing significant bushfire events in the TWWHA. However, this assistance will never be on hand in time to provide adequate initial attack for the rapid containment of lightning ignitions – a strategy that is so important for protecting the fire-sensitive natural values of the TWWHA.

Other national arrangements

The National Aerial Firefighting Centre (NAFC) provides a cooperative national arrangement for combatting bushfires by facilitating and coordinating the procurement of specialised firefighting aircraft to complement local aerial and ground based firefighting resources. Tasmania used this service during the 2015-16 bushfire season; it includes Federal funds that partially support aircraft contract costs.

The Natural Disaster Relief and Recovery Arrangements provide a safety net for jurisdictions affected by natural disasters that require a coordinated and multi-agency and community response. It is expected that Tasmania will submit a claim for the 2015-16 bushfires.

The Australian Government Disaster Response Plan outlines coordination arrangements for the provision of non-financial assistance from the Australian Government. Tasmania received assistance from the Australian Defence Force during the 2015-16 bushfires through this arrangement for the overall bushfire response. The assistance received was the use of a Royal Australian Air Force Boeing C17 to transport a mobile base camp from New South Wales to Tasmania for use at Stanley in North-West Tasmania.

Attachment 5 – Legislation

- Tasmanian *Aboriginal Relics Act 1975*
- Tasmanian *Crown Lands Act 1976*
- Tasmanian *Emergency Management Act 2006*
- Tasmanian *Environmental Management and Pollution Control Act 1994*
- Tasmanian *Fire Service Act 1979*
- Tasmanian *Forest Management Act 2013*
- Tasmanian *Forest Practices Act 1985*
- Tasmanian *National Parks and Reserves Management Act 2002*
- Tasmanian *Nature Conservation Act 2002*
- Tasmanian *Threatened Species Protection Act 1995*
- Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*

Attachment 6 – Summarised land tenure for the TWWHA and surrounding areas

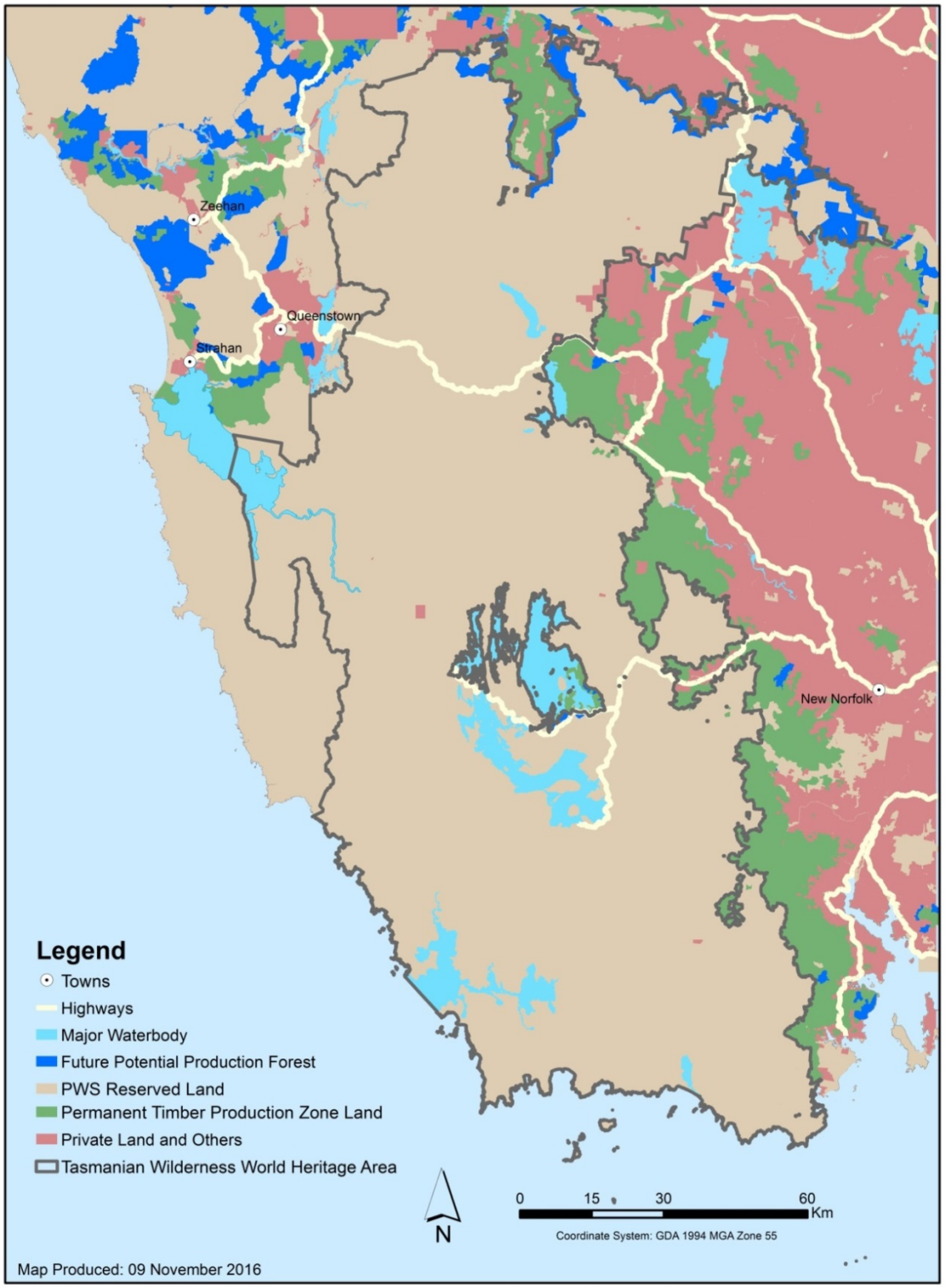


Figure 9: Summarised land tenure for the TWWHA and surrounding areas
(Source: information provided by the Department of Primary Industries, Parks, Water and Environment and map prepared by the Tasmania Parks and Wildlife Service)

Attachment 7 – Natural and cultural values of the TWWHA

Description of the values in the TWWHA

The following information has been drawn from the TWWHA Management Plan 2016 (DPIPWE 2016a), with additional commentary provided by the Department of Primary Industries, Parks, Water and Environment's Natural and Cultural Heritage Division. It is a not an assessment of values against World Heritage criteria, or intended to be a statement of local, State, national or Commonwealth heritage values in the TWWHA.

Fire-sensitive natural and cultural assets of significance in the TWWHA are a sub-set of these values (see sections 2.4 and 2.5.2).

Geodiversity

The TWWHA's complex and unusually complete geological history stretches back 1,300 million years, but also includes 3,000 million-year-old fragments of re-deposited rock, and is a valuable record of the earth's evolutionary history.

Geological features include two kilometre thick sequences of limestone that have extensive karst and glacio-karst landforms. Caves in karst areas contain fossil and sub-fossil deposits of extinct species including marsupial mega fauna and the thylacine.

The TWWHA contains both fossil and living evidence of the previous existence of the supercontinent Gondwana and the breakup that began about 180 million years ago. The TWWHA is also known for large intrusions of Jurassic dolerite that are not found elsewhere in Australia. These date from the breakup of Gondwana.

The TWWHA contains glacial legacies from three major periods that stretch, in total, over 850 million years. The most recent of these created the nation's most extensive glacial landscapes and include Cradle Mountain, Frenchmans Cap and the Arthur Ranges. Frenchmans Cap and a few other alpine areas in the TWWHA are now some of only a handful of areas in Australia where periglacial processes are still active.

The TWWHA has the longest undisturbed stretches of temperate, high-energy rocky and sandy coastline in South-Eastern Australia. There is a significant diversity of beach barrier (dune) systems, including bay head and river mouth, cliff-top, parallel and transgressive dunes. The oldest inter-glacial Pleistocene dunes and sand sheets in the TWWHA date back 125,000 years.

The TWWHA includes broad areas of organic soils in the blanket bogs associated with the buttongrass plains. The ongoing formation of these soils has created one of the largest organic terrains in the Southern Hemisphere. This is an important part of the characteristic TWWHA landscape of vast open plains.

Many of Australia's wild and natural rivers are located in the TWWHA, including entire catchments of the Franklin, Jane, Denison, Giblin, New, Davey and Old Rivers, where important natural processes continue to occur. These are seven of a limited number of Australian examples

where the whole basin is protected. The TWWHA also contains Australia's deepest lake, Lake St Clair, which was formed by various glaciations over the past two million years.

Flora

There are globally outstanding examples of natural ecological processes that are relatively undisturbed. There is an important array of Tasmanian endemic species, including many plants and animals descended from the biota of Gondwana and some of the longest-lived trees and shrubs in the world, such as the stands of King's lomatia estimated to be at least 43,000 years old.

The TWWHA comprises a large percentage of the remaining extensive, high quality, temperate wilderness in Australia, and is one of only a few such regions in the world. This feature provides a context of integrity within which the other recognised values are presented, maintained and protected. Overall management of the integrity and quality of wilderness values is recognised as an important aspect of contemporary fire management within the TWWHA.

The TWWHA is home to a profusion of threatened, rare, primitive and endemic plants. Among the most iconic of these are the palaeo-endemic conifers, which include Huon pine (*Lagarostrobos franklinii),* King Billy pine (*Athrotaxis selaginoides*) and pencil pine (*Athrotaxis cupressoides*). These three species are extraordinarily long-lived and slow-growing species, with Huon pine reported to reach ages of 3,462 years (Carder 1994).

Within the property are extensive undisturbed stands of the world's tallest flowering plant and other giant hardwood tree species. The Styx River Valley area has the highest concentration of registered 'giant trees' in Tasmania, with many trees over 90 metres tall and some close to 100 metres. Other important areas for giant trees include the *Eucalyptus delegatensis* forests of the Beech Creek and Council Creek areas near Wayatinah and the *E. obliqua* forests of the lower Weld and lower Huon River catchments.

The TWWHA also includes a complex mosaic of vegetation, including buttongrass moorland, temperate rainforest, alpine communities, eucalypt forest and riparian communities. The buttongrass moorlands and sphagnum peatland are among the vegetation communities developed over bogs that are key parts of one of the most extensive organic soil terrains in the Southern Hemisphere. A table outlining the vegetation groups by area in the TWWHA is provided in Table 6.

Table 6: Vegetation groups by area in the TWWHA

Vegetation group	Area in TWWHA (ha)	Percentage of TWWHA	Percentage of total vegetation type
Moorland, sedgeland, rushland and peatland	365,900	23	61
Wet eucalypt forest and woodland	362,900	23	33
Rainforest and related scrub	326,390	21	46
Dry eucalypt forest woodland	162,540	10	10
Scrub, heathland and coastal complexes	140,050	9	27
Highland treeless vegetation	76,410	5	71
Other natural environments	67,360	4	27

Vegetation group	Area in TWWHA (ha)	Percentage of TWWHA	Percentage of total vegetation type
Non-eucalypt forest and woodland	53,840	3	25
Native grassland	15,550	1	11
Agricultural, urban and exotic vegetation	1,610	0	0
Saltmarsh and wetland	230	0	1
		100	

(DPIPWE 2013) Data source: TASVEG 3.0, TVMMP 2013

The TWWHA's temperate alpine ecosystem is among the most diverse in the world, with about 70 per cent of the flora endemic to Tasmania (Balmer et al. 2004). Most of Tasmania's alpine area is contained within the TWWHA. The TWWHA also contains about 20 per cent of Tasmania's rainforest and about 240 of the 320 Tasmanian endemic higher plant species, of which about half have most of their distribution within the TWWHA (Balmer et al. 2004). The TWWHA rainforests and alpine areas are a stronghold for many of Tasmania's palaeo-endemic taxa, plants which have phylogenies dating back more than 19 million years; the genus *Athrotaxis* is estimated to date back the furthest (150 million years) (Jordan et al. 2015). These species are typically highly sensitive to fire.

Twenty-three vegetation communities occurring in the TWWHA are listed as threatened under Schedule 3A of the *Nature Conservation Act 2002*. This includes several coniferous communities, alkaline pans, wetlands, seabird rookery complex, highland grasslands and cushion moorlands (Table 7). The TWWHA also contains two nationally listed threatened communities, the alpine sphagnum bogs (and their associated ferns) and lowland grasslands.

Table 7: List of threatened vegetation communities occurring in the TWWHA

Schedule name	Area in TWWHA[16]	Percentage of TWWHA	Percentage of threatened community extent	Fire sensitivity[17]
Alkaline pans	513	0.03	98	Low
Athrotaxis cupressoides open woodland	16,269	1.03	100	Extreme
Athrotaxis cupressoides rainforest	3,514	0.22	98	Extreme
Athrotaxis cupressoides/*Nothofagus gunnii* short rainforest	4,257	0.27	95	Extreme
Athrotaxis selaginoides rainforest	10,565	0.67	55	Extreme
Athrotaxis selaginoides subalpine scrub	5,768	0.36	92	Extreme
Athrotaxis selaginoides/*Nothofagus gunnii* short rainforest	855	0.05	26	Extreme
Banksia marginata wet scrub	2,601	0.16	99	Moderate

[16] On advice from the Tasmania Parks and Wildlife Service, these are estimates only. The recent assessment of the impact of the Lake Mackenzie fire has indicated that statistics of vegetation communities are at best estimates.

[17] Fire sensitivity categories based on Pyrke and Marsden-Smedley (2005).

Schedule name	Area in TWWHA[16]	Percentage of TWWHA	Percentage of threatened community extent	Fire sensitivity[17]
Cushion moorland	3,020	0.19	95	Very High
Eucalyptus amygdalina forest and woodland on sandstone	319	0.02	1	Low
Eucalyptus brookeriana wet forest	724	0.05	10	High
Eucalyptus ovata forest and woodland	304	0.02	2	Low
Eucalyptus tenuiramis forest and woodland on sediments	75	0.00	0	Low
Eucalyptus viminalis wet forest	70	0.00	1	Low
Highland grassy sedgeland	8,214	0.52	44	Moderate
Highland *Poa* grassland	15,200	0.96	58	Moderate
Rainforest fernland	328	0.02	19	High
Seabird rookery complex	58	0.00	8	Very High
Sphagnum peatland	2,740	0.17	79	High
Spray zone coastal complex	0	0.00	0	Low
Subalpine *Diplarrena latifolia* rushland	164	0.01	13	Moderate
Subalpine *Leptospermum nitidum* woodland	3,606	0.23	96	Moderate
Wetlands	232	0.01	1	Low

(Data source: Threatened Native Vegetation Community Layer (TVMMP 2014).)

Fauna

The TWWHA is of immense importance to native species as an undisturbed natural ecosystem where biological, ecological and evolutionary processes can occur largely free from interference by humans.

Many types of fauna in the TWWHA are closely related to species found in other land masses that were once part of Gondwana. This includes the mountain shrimp, the Tasmanian cave spider and a number of other unique species of invertebrates within the following invertebrate groups: caddisflies, dragonflies, stoneflies and isopods.

The TWWHA is a refuge, and a stronghold, for a wide range of rare and threatened species, including carnivorous marsupials such as the Tasmanian devil, the spotted-tailed quoll and the eastern quoll. Other rare and threatened species found in the TWWHA include the Lake Pedder galaxias, Pedra Branca skink and the orange-bellied parrot. The TWWHA is a stronghold for species that are threatened or now extinct on the Australian mainland, such as the ground parrot and swamp antechinus.

The TWWHA is home to two surviving species of monotreme, the most primitive mammal group in the world, the platypus and the short-beaked echidna.

There are significant breeding populations of seabirds on remote islands off the South-West Coast. They include two of only three breeding colonies of the threatened and endemic shy albatross. There are approximately five million other seabirds, dominated in number by short-

tailed shearwaters and fairy prions (DPIPWE 2016a). The islands are also important breeding sites for little penguins and two threatened species of seal.

Approximately 25 per cent of Tasmania's lakes, tarns, lagoons and wetlands are in the TWWHA. Such areas have a high degree of invertebrate endemism and several endemic, rare and threatened freshwater fish. The waters of Port Davey and Bathurst Harbour contain a globally unusual assemblage of marine invertebrates.

Aboriginal people in the TWWHA

Aboriginal people consider the entire TWWHA landscape to be an expression of Aboriginal culture. The TWWHA is an Aboriginal landscape within which are stories, plants, animal and mineral resources, and heritage sites that connect the people with their ancestors, the Old people and the land. The cultural value of the TWWHA is therefore not limited to tangible Aboriginal cultural sites that have been identified. It is also important to recognise that the Aboriginal perception of values, in many situations, does not divide natural from cultural values; for example plants and animals are of cultural value to the Aboriginal community.

List of World Heritage values for the TWWHA

This list is based on the 1981 and 1989 nominations for the Tasmanian Wilderness World Heritage Area, assessments by the advisory bodies to the World Heritage Committee (IUCN and ICOMOS) and reports to the World Heritage Expert Panel. The Australian Government's Department of the Environment and Energy is updating this list to include the values in the areas added to the property in 2010, 2012 and 2013 that contribute to the property's Outstanding Universal Value under each criterion.

Natural values

World Heritage Criterion (viii) – Outstanding examples representing the major stages of the earth's evolutionary history

The Tasmanian Wilderness is an outstanding example representing major stages of the earth's evolutionary history. The World Heritage values include:

- geological, geomorphological and physiographic features, including:
    - rock formations including Precambrian rocks and Cambrian rocks;
    - Late Cambrian to Early Ordovician sequences of the Denison Range;
    - fossiliferous Ordovician limestone;
    - Permian-Triassic sediments and associated Jurassic dolerite intrusions;
    - Darwin Crater and Lake Edgar fault;
    - karst systems including glacio-karstic features;
    - karst geomorphology and karst hydrology;
    - glaciation, including glacial deposits of the Late Cainozoic, Permo-Carboniferous and Precambrian;
    - extraglacial areas (eg solifluction sheets, block streams, rock glaciers, landslip deposits);
    - periglaciation (eg Mt Rufus, Frenchmans Cap);

  - soils (eg peatlands); and
  - undisturbed river systems which show particular geomorphological processes;
- relict biota which show links to ancient Gondwanan biota including:
  - endemic conifers (including the King Billy pine *Athrotaxis selaginoides*, the Huon pine *Lagarostrobos franklinii* and the genera *Diselma*, *Microcachrys*, *Microstrobos*);
  - plant species in the families Cunoniaceae, Escalloniaceae and Winteraceae;
  - the plant genera *Bellendena*, *Agastachys* and *Cenarrhenes* in the Proteaceae*;*
  - other plant genera with Gondwanan links (eg *Eucryphia*, *Orites*, *Lomatia* and *Nothofagus*);
  - monotremes (eg platypus *Ornithorhynchus anatinus*, short beaked echidna *Tachyglossus aculeatus*);
  - dasyurid species;
  - parrots (eg orange-bellied parrot and the ground parrot);
  - indigenous families of frogs with Gondwanan origins (eg Tasmanian froglet *Ranidella tasmaniensis*, brown froglet *Ranidella signifera*, Tasmanian tree frog *Litoria burrowsi*, brown tree frog *Litoria ewingi*);
  - invertebrate species in the genera *Euperipatoides* and *Ooperipatellus;*
  - the Tasmanian cave spider (*Hickmania troglodytes*);
  - aquatic insect groups with close affinities to groups found in South America, New Zealand and Southern Africa (eg dragonflies, chironomid midges, stoneflies, mayflies and caddisflies);
  - crustaceans (eg *Anaspidacea, Parastacidae, Phreatoicidae*);
  - primitive taxa showing links to fauna more ancient than Gondwana (eg Anaspids, *Trogloneta* (a mysmenid spider), species of alpine moths in the subfamily Archiearinae, species in the genus *Sabatinca* of the primitive lepidopteran sub-order Zeugloptera (Australian Government 2016c)).

<u>World Heritage Criterion (ix) – Outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment</u>

The Tasmanian Wilderness has outstanding examples representing significant ongoing geological processes and ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water and coastal ecosystems and communities, including:

- sites where processes of geomorphological and hydrological evolution are continuing in an uninterrupted natural condition (including karst formation, periglaciation which is continuing on some higher summits (eg on the Boomerang, Mount La Perouse, Mount Rufus, Frenchmans Cap), fluvial deposition, evolution of spectacular gorges, marine and aeolian deposition and erosion, and development of peat soils and blanket bogs);
- ecosystems which are relatively free of introduced plant and animal species;
- coastal plant communities free of exotic sand binding grasses which show natural processes of dune formation and erosion;
- undisturbed catchments, lakes and streams;
- alpine ecosystems with high levels of endemism;

- the unusual 'cushion plants' (bolster heaths) of the alpine ecosystems;
- ecological transitions from moorland to rainforest;
- pristine tall eucalypt forests;
- examples of active speciation in the genus *Eucalyptus*, including sites of:
    - hybridisation and introgression;
    - clinal variation (eg *E. subcrenulata*);
    - habitat selection (eg *E. gunnii*); and
    - transition zones which include genetic exchanges between eucalyptus species;
- plant groups in which speciation is active (eg *Gonocarpus*, *Ranunculus* and *Plantago*);
- conifers of extreme longevity (including Huon pine, pencil pine and King Billy pine);
- endemic members of large Australian plant families (eg heaths such *as Richea pandanifolia, Richea scoparia, Dracophyllum minimum* and *prionotes cerinthoides*);
- endemic members of invertebrate groups;
- invertebrate species in isolated environments, especially mountain peaks, offshore islands and caves with high levels of genetic and phenotypic variation;
- invertebrates of unusually large size (eg the giant pandini moth *Proditrix sp*, several species of *Neanuridae*, the brightly coloured stonefly *Eusthenia spectabilis*);
- invertebrate groups which show extraordinary diversity (eg land flatworms, large amphipods, peripatus, stag beetles, stoneflies);
- skinks in the genus *Leiolopisma* which demonstrate adaptive radiation in alpine heaths and boulder fields on mountain ranges;
- examples of evolution in mainland mammals (eg sub-species of Bennett's wallaby *Macropus rufogriseus*, swamp antechinus *Antechinus minimus*, southern brown bandicoot *Isodon obesulus*, common wombat *Vombatus ursinus*, common ringtail possum *Pseudocheirus peregrinus*, common brushtail possum *Trichosurus vulpecula*, eastern pygmy possum *Cercartetus nanus*, the swamp rat *Rattus lutreolus*), in many birds (eg the azure kingfisher *Alcedo azurea*) and in island faunas;
- animal and bird species whose habitat elsewhere is under threat (eg the spotted-tail quoll *Dasyurus maculatus*, swamp antechinus *Antechinus minimus*, broad-toothed rat *Mastacomys fuscus* and the ground parrot *Pezoporus wallicus*); and
- the diversity of plant and animal species (Australian Government, 2016c).

<u>World Heritage Criterion (vii) – Superlative natural phenomena, formations or features</u>

The landscape of the Tasmanian Wilderness has exceptional natural beauty and aesthetic importance and contains superlative natural phenomena including:

- viewfields and sites of exceptional natural beauty associated with:
    - flowering heaths of the coastline;
    - the South and South-West Coasts comprising steep headlands interspersed with sweeping beaches, rocky coves and secluded inlets;
    - eucalypt tall open forests including *Eucalyptus regnans*, the tallest flowering plant species in the world;
    - rainforests framing undisturbed rivers;
    - buttongrass, heath and moorland extending over vast plains;

- wind-pruned alpine vegetation;
- sheer quartzite or dolerite capped mountains (including Cradle Mountain, Frenchmans Cap, Federation Peak and Precipitous Bluff);
- deep, glacial lakes, tarns, cirques and pools throughout the ranges;
- the relatively undisturbed nature of the property;
- the scale of the undisturbed landscapes;
- the juxtaposition of different landscapes;
- the presence of unusual natural formations (eg particular types of karst features) and superlative examples of glacial landforms and other types of geomorphic features; and
- rare or unusual flora and fauna (Australian Government 2016c).

<u>World Heritage Criterion (x) – Important and significant habitats where threatened species of plants and animals of outstanding universal value still survive</u>

The ecosystems of the TWWHA contain important and significant natural habitats where threatened species of animals and plants of outstanding universal value from the point of view of science and conservation still survive, including:

- habitats important for endemic plant and animal taxa and taxa of conservation significance, including:
  - rainforest communities;
  - alpine communities;
  - moorlands (eg in the far South-West);
  - riparian and lacustrine communities (including meromictic lakes);
  - habitats which are relatively undisturbed and of sufficient size to enable survival of taxa of conservation significance including endemic taxa;
  - plant species of conservation significance; and
  - animal species of conservation significance, such as:
    - spotted-tail quoll *Dasyurus maculatus*;
    - swamp antechinus *Antechinus minimus*
    - broad-toothed rat *Mastacomys fuscus*
    - ground parrot *Pezoporus wallicus*
    - orange-bellied parrot *Neophema chrysogaster*
    - Lake Pedder galaxias *Galaxias pedderensis*
    - Pedra Branka skink *Niveoscincus palfreymani* (Australian Government 2016c).

Cultural values

World Heritage Criterion (iii) – Bear a unique or at least exceptional testimony to a civilisation which has disappeared

The Tasmanian Wilderness bears a unique and exceptional testimony to an ancient, ice age society, represented by:

- Pleistocene archaeological sites that are unique, of great antiquity and exceptional in nature, demonstrating the sequence of human occupation at high southern latitudes during the last ice age (Australian Government 2016c).

World Heritage Criterion (v) – To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change[18]

The Tasmanian Wilderness provides outstanding examples of a significant, traditional human settlement that has become vulnerable under the impact of irreversible socio-cultural or economic change. The World Heritage values include:

- archaeological sites which provide important examples of the hunting and gathering way of life, showing how people practised this way of life over long time periods, during often extreme climatic conditions and in contexts where it came under the impact of irreversible socio-cultural and economic change (Australian Government 2016c).

World Heritage Criterion (vi) – Directly or tangibly associated with events or with ideas or beliefs of outstanding universal significance

The Tasmanian Wilderness is directly associated with events of outstanding universal significance linked to the adaptation and survival of human societies to glacial climatic cycles. The World Heritage values include:

- archaeological sites including Pleistocene sites, which demonstrate the adaptation and survival of human societies to glacial climatic cycles and periods of long isolation from other communities (eg the human societies in this region were the most southerly known peoples on earth during the last ice age) (Australian Government 2016c).

[18] Based on the 1981/1989 nominations for the TWWHA, assessments by World Heritage Committee advisory bodies and reports to the World Heritage Expert Panel. The TWWHA was listed under cultural criteria (iv) in 1982. The 1989 nomination to extend the property referred to criterion (v). The 2015 UNESCO Reactive Monitoring Mission clarified that criterion (iv) is acceptable and will be reflected in the final SOUV. The Department of the Environment and Energy is updating this list accordingly.

Attachment 8 – Regional boundaries of the Tasmania Parks and Wildlife Service

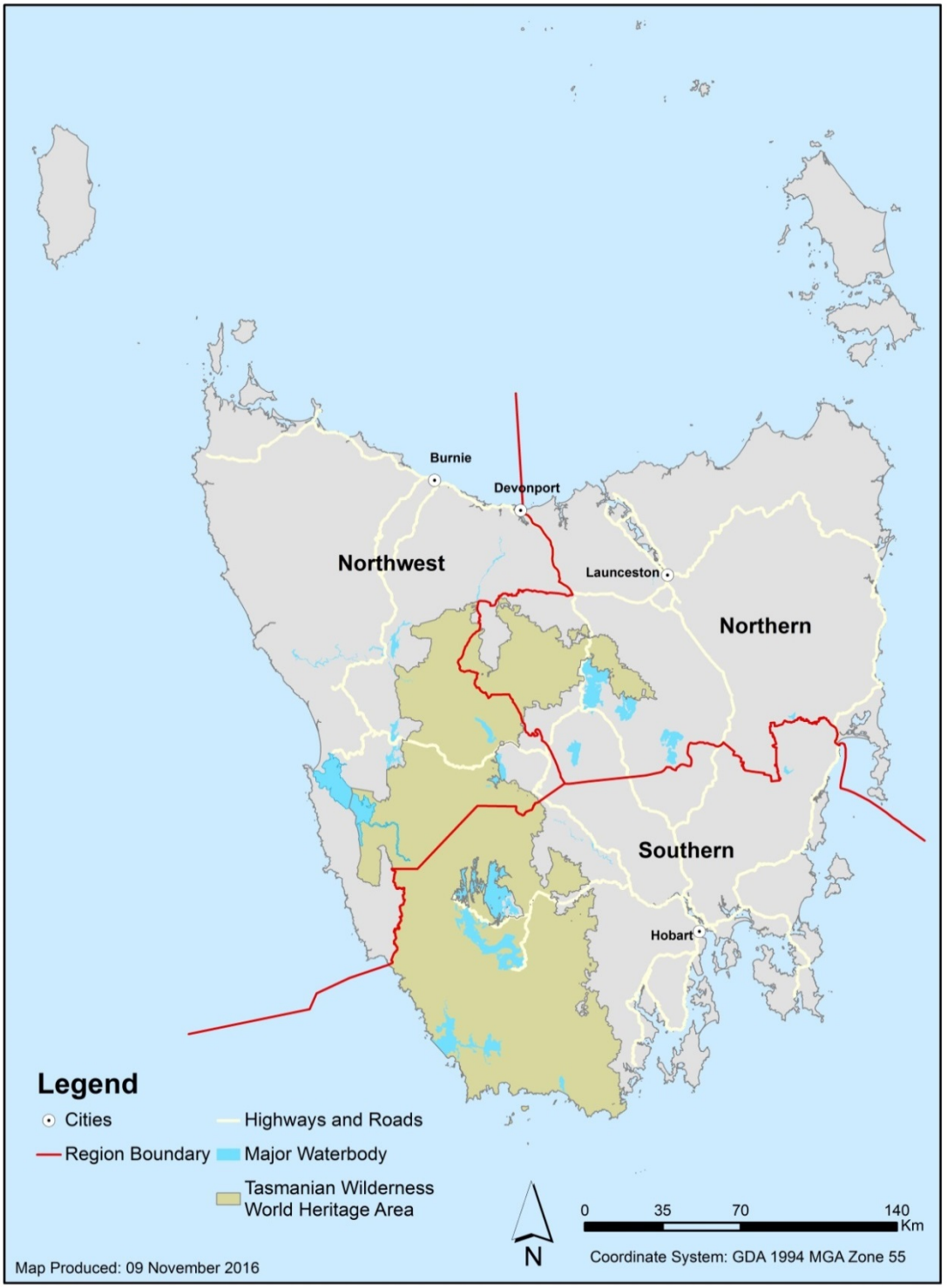


Figure 10: Regional boundaries of the Tasmania Parks and Wildlife Service
(Source: information provided by the Department of Primary Industries, Parks, Water and Environment and map prepared by the Tasmania Parks and Wildlife Service)

Attachment 9 – Prospective list of priority research to support fire management in, and the understanding of the impacts of fire on, the World Heritage values of the TWWHA

Table 8: Prospective list of priority research to support fire management in, and the understanding of the impacts of fire on, the World Heritage values of the TWWHA

Prevention
Aboriginal fire regimes Develop as complete an understanding as possible of Aboriginal burning practices, drawing on all lines of evidence including cultural, historical and scientific sources.
Improved bushfire risk modelling Undertake further analysis using a landscape fire-spread modelling tool with improved input data and models to test specific hypotheses and planned burning scenarios, particularly under future climates.
Impacts from planned burning Undertake research to better understand the tolerance of species and landforms to fire frequency and intensity and the other fire regime requirements of fauna, flora and landforms, such as fire size and patchiness. Specific areas for further research should include: Organic soils, Fire regions, mapping of buttongrass fuels and organic soils, orange-bellied parrot, Invertebrate fauna and Montane grasslands.
Organic soil dryness field testing method Develop a quantitative method for measuring organic soil dryness in the field, to verify the assumed soil moisture.
Managing fire-sensitive values in flammable landscapes Investigate techniques and strategies to manage fire in areas in the TWWHA with fire-sensitive natural values that paradoxically occur in flammable parts of the landscape.
Fire refugia prediction Identify areas that are both fire refugia, and direct climate change refugia, to help to determine priorities for fire prevention, preparedness and response.
Preparedness
Fuel dryness and fire behaviour Undertake the following activities to improve understanding of fuel dryness and fire behaviour: • quantifying fuel and soil moisture thresholds of flammability for most vegetation types; • quantifying soil moisture thresholds that control organic soil flammability; • designing and installing an adequate network of weather data observation stations across the TWWHA; • validating and customizing systems (eg soil moisture models) for the Western Tasmanian environment; and • developing new fire spread models for those vegetation types that need it (ie peat, wet forest, rainforest, alpine communities and other vegetation unique communities in the TWWHA) and for organic soils.
Strategies to manage future bushfire risk Taking into account the research undertaken through the Research Project on the impacts of climate change on future bushfire risk in the TWWHA (and associated impacts on fire behaviour and natural and cultural values), strategies should be developed to protect the natural and cultural values in the TWWHA as far as is practical.

Response
Aboriginal heritage sites Undertake work with the Aboriginal community to: • develop protocols for accessing data from the Aboriginal Heritage Register to facilitate the making of strategic and tactical decisions to protect known sites during fire suppression operations, while also respecting the cultural sensitivities of the information on sites. These protocols should also cover how Aboriginal Heritage Register records could be included in BRAM so that the fire risk to Aboriginal heritage can be assessed; and • gain a better understanding of the potential impacts of bushfires and suppression techniques on the different kinds of Aboriginal heritage sites in the TWWHA.
Better mapping of fire-sensitive TWWHA values Undertake the following work to improve mapping of fire-sensitive TWWHA values: • Improve the scale of resolution and accuracy of mapping of natural values to ensure that supporting systems such as BRAM provide as strong a basis as possible for determining priorities for prevention, preparedness, response, and for monitoring and reporting on fire impacts. The natural values include threatened flora and fauna, vegetation communities, geomorphological values and fire-sensitive values. • Invest in additional high resolution photography to extend improved mapping of values beyond the Central Plateau. In some cases, a better understanding of fire impacts and responses are required to improve the identification of the natural values that are at risk from bushfires.
Recovery
Ecosystem Recoverability Undertake research to understand the recoverability post-fire of communities such as alpine areas and rainforests of the TWWHA that have historically rarely been dry enough to burn.
Trials of rehabilitation techniques Undertake trials of rehabilitation techniques of natural values, particularly in alpine and subalpine zones. Such techniques to be considered include**:** constructing barriers to surface water movement; planting of seedlings and/or spreading seeds; feral animal control (eg rabbits); and fencing exclosures to prevent grazing from marsupials and introduced mammals.
Fire, climate change and introduced animals Monitor the spread of introduced species such as rabbits, starlings and fallow deer in the TWWHA and determine causal factors, such as the interaction between climate change and fire.
Improved techniques to attain higher resolution of fire scar mapping Undertake research to improve capacity to use remote-sensing methods to identify and map fire boundaries in the TWWHA.

NOTE: Some of the areas referred to in this table are addressed as separate recommendations in relevant sections of this Report.

REFERENCES

ACE CRC (2016) Climate Futures for Tasmania. Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) Available at http://acecrc.org.au/climate-futures-for-tasmania/ [Verified 18 November 2016]

AFAC (2013) Australasian Inter-service Incident Management System (AIIMS). 4th Edition. Australasian Fire and Emergency Service Authorities Council, Melbourne, Victoria.

AFAC (2016a) AFAC Independent Operational Review – A review of the management of the Tasmanian fires of January 2016. Australasian Fire and Emergency Services Authorities Council, Melbourne, Victoria. Available at http://www.fire.tas.gov.au/userfiles/tym/file/misc/1604_tasfirereport_final1.pdf [verified 18 November 2016]

AFAC (2016b) A Risk Framework for Ecological Risks Associated with Prescribed Burning – National Burning. Project: sub-project 3. Australasian Fire and Emergency Service Authorities Council Limited, Melbourne, Victoria.

Arkel B (1995) Small mammal secondary succession in buttongrass moorlands. MSc Thesis Unpublished (University of Tasmania: Hobart).

Australian Government (2016a) 'The World Heritage Convention'. Available at https://www.environment.gov.au/heritage/about/world/world-heritage-convention [Verified 18 November 2016].

Australian Government (2016b) 'Department of the Environment and Energy: About the EPBC Act'. Available at https://www.environment.gov.au/epbc/about [Verified 28 November 2016].

Australian Government (2016c) 'Department of the Environment and Energy: World Heritage Places - Tasmanian Wilderness - Outstanding Universal Value'. Available at http://www.environment.gov.au/heritage/places/world/tasmanian-wilderness/values [Verified 18 November 2016].

Australian Government (2016d) 'State Party Report on the state of conservation of the Tasmanian Wilderness World Heritage Area (Australia) – 2016' Available at http://www.environment.gov.au/heritage/publications/state-party-report-tasmanian-wilderness-2016 [Verified 18 November 2016]

Australian Government (2016e) Department of the Environment and Energy: 'World Heritage Places - Tasmanian Wilderness - 2015 World Heritage Committee Decision'. Available at https://www.environment.gov.au/heritage/places/world/tasmanian-wilderness/2015-whc-decision [Verified 18 November 2016]

Balmer J (1990) Two buttongrass moorland boundaries. *Tasforests* **2**, 134-141.

Balmer J, Whinam J, Kelman J, Kirkpatrick JB and Lazarus E (2004) A review of the floristic values of the Tasmanian Wilderness World Heritage Area. Nature Conservation Report 2004/3, Department of Primary Industries Water and Environment, Hobart, Tasmania.

Balmer J, Driessen MM and Whight S (2010) A review of fire history in south-west Tasmania. In J. Balmer (Editor), Proceedings of the 2007 buttongrass moorland management workshop, pp 3-9. Nature Conservation Report 2010/04. Department of Primary Industries, Parks, Water and Environment, Hobart.

Balmer J, Visoiu M and Whinam J (2015) DPIPWE Montane Grassland Management Program Lees Paddock and Vale of Belvoir 2012-15 Report. Unpublished report. Natural and Cultural Values Division, Department of Primary Industries, Parks, Water and Environment. Tasmania.

Barker MJ (1991) The Effect of Fire on West Coast Lowland Rainforest. Tasmanian NRCP Technical Report No 7, Forestry Tasmania, and Department of the Arts, Sport, and the Environment, Tourism and Territories, Australian Capital Territory, Canberra.

Barker P and Kirkpatrick JB (1994) Phyllocladus aspleniifolius: variability in the population structure, the regeneration niche and dispersion patterns in Tasmanian forests. *Australian Journal of Botany* **42**, 163-190.

Bowman DMJS, Wood SW, Neyland D, Sanders GJ and Prior LD (2013) Contracting Tasmanian montane grasslands within a forest matrix is consistent with cessation of Aboriginal fire management. *Austral Ecology* **38**, 627-638.

Bradstock RA, Cary GJ, Davies I, Lindenmayer DB, Price OF and Williams RJ (2012) Wildfires, fuel treatment and risk mitigation in Australian eucalypt forests: Insights from landscape-scale simulation. *Journal of Environmental Management* **105**, 66-75.

Bridle K and Kirkpatrick JB (1997) Local environmental correlates of variability in the organic soils of moorland and alpine vegetation, Mt Sprent, Tasmania. *Australian Journal of Ecology*, **22** 196-205.

Bridle KL, Kirkpatrick JB, Cullen P and Shepherd RR (2001) Recovery in alpine heath and grassland following burning and grazing, eastern Central Plateau, Tasmania, Australia. *Arctic, Antarctic, and Alpine Research* **33(3)**, 348-356.

Bridle K, Cullen P and Russell M (2003) Peatland hydrology, fire management and Holocene fire regimes in southwest Tasmanian Blanket Bogs. 03/07, Department of Primary Industries, Parks, Water and Environment, Hobart.

Brown MJ, Balmer J and Podger F (2002) Vegetation change over twenty years at Bathurst Harbour, Tasmania. Measuring and imaging: exploring centuries of Australian landscape change. Special Addition of *Australian Journal of Botany* **50(4)**, 499-510.

Brown PB and Wilson RI (1980) A survey of the Orange-bellied Parrot *Neophema chrysogaster* in Tasmania, Victoria and South Australia. A report for World Wildlife Fund (Australia), 65. National Parks and Wildlife Service, Hobart, Tasmania.

Brown MJ and Podger FD (1982) Floristics and fire regimes of a vegetation sequence from sedgeland-heath to rainforest at Bathurst Harbour, Tasmania. *Australian Journal of Botany* **30(6)**, 659-676.

Brown PB (1988) Distribution and conservation of King Billy pine. Forestry Commission, Hobart, Tasmania.

Bushfire and Natural Hazards Cooperative Research Centre (2015) Hazard Note: Southern Australia Seasonal Bushfire Outlook 2015-16: November update. Available at http://www.bnhcrc.com.au/hazardnotes/12 [Verified 18 November 2016]

Carder A (1994) 'Forest Giants of the World: Past and Present'. Fitzhenry and Whiteside, Ontario.

Chaudhry TA (2010) Avifaunal ecology and responses to post-fire succession of buttongrass moorlands in the Tasmanian Wilderness World Heritage Area. PhD Thesis (University of Tasmania: Hobart).

Cruz MG, Gould JS, Alexander ME, Sullivan AL, McCaw WL and Matthews S (2015) A Guide to Rate of Fire Spread Models for Australian Vegetation. CSIRO Land and Water Flagship, Canberra, ACT, and AFAC, Melbourne, Vic.

Cullen P (1995) Land degradation on the Central Plateau, Tasmania. The legacy of 170 years of exploitation. Parks and Wildlife Service, Hobart, Tasmania.

Davies PE, Cook LSL and Driessen MM (2013) Impact of the 2013 Giblin-Davey catchment Fire on River Biota, Habitats and Flow. Department of Primary Industries, Parks, Water and Environment, Tasmania.

Department of Environment, Land, Water and Planning (2016) National Recovery Plan for the Orange-bellied Parrot *Neophema chrysogaster*. Australian Government, Canberra.

Dharssi I and Kumar V (2016) Mitigating the effects of severe fires, floods and heatwaves through the improvements of land dryness measures and forecasts: Annual project report 2015-2016. Bushfire and Natural Hazards CRC.

di Folco MBF and Kirkpatrick JB (2011) Topographic variation in burning-induced loss of carbon from organic soils in Tasmanian moorlands. *Catena* **87**, 216-225.

di Folco MBF and Kirkpatrick JB (2013) Organic soils provide evidence of spatial variation in human-induced vegetation change following European occupation of Tasmania. *Journal of Biogeography* **40**, 197-205.

Dowdy AJ and Mills GA (2012) Atmospheric and Fuel Moisture Characteristics Associated with Lightning-Attributed Fires. *Journal of Applied Meteorology and Climatology* **51**, 2025-2037. doi: 10.1175/JAMC-D-11-0219.1.

DPIPWE (1999) Tasmanian Wilderness World Heritage Area Management Plan 1999. Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

DPIPWE (2009) Northern Region Strategic Fire Management Plan. Department of Primary Industries, Parks, Water and Environment, Tasmania. Available at http://dpipwe.tas.gov.au/Documents/PWS%20Northern%20Region%20Strategic%20Fire%20Managment%20Plan.pdf [Verified 18 November 2016]

DPIPWE (2011a) Bushfire Risk Assessment – Management Project Business Process Model V.4. Parks and Wildlife Service, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

DPIPWE (2011b) Southern Region Strategic Fire Management Plan. Department of Primary Industries, Parks, Water and Environment, Tasmania. Available at http://dpipwe.tas.gov.au/Documents/PWS%20Southern%20Region%20Strategic%20Fire%20Management%20Plan.pdf [Verified 18 November 2016]

DPIPWE (2012) Northwest Region Strategic Fire Management Plan. Department of Primary Industries, Parks, Water and Environment, Tasmania. Available at http://dpipwe.tas.gov.au/Documents/PWS%20North%20West%20Region%20Strategic%20Fire%20Management%20Plan.pdf [Verified 18 November 2016]

DPIPWE (2013) Tasmanian Wilderness World Heritage Area Research and Monitoring Priorities 2013-2018. Resource Management and Conservation Division, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

DPIPWE (2014a) Fire Planning Policy PWS P-055. (Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania) Available at http://dpipwe.tas.gov.au/Documents/PWS%20Fire%20Planning%20Policy%202014.pdf [Verified 18 November 2016]

DPIPWE (2014b) Parks and Wildlife Service Policy - Fire Management P-050. (Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania) Available at http://dpipwe.tas.gov.au/Documents/PWS%20Fire%20Management%20Policy%202014.pdf [Verified 18 November 2016]

DPIPWE (2015a) Fire regimes for nature conservation in the Tasmanian Wilderness World Heritage Area. Nature Conservation Report Series. Report no. 15/2, Natural and Cultural Heritage Division, Department of Primary Industries Parks Water and Environment, Hobart, Tasmania.

DPIPWE (2015b) Evaluation Report: Fire management in the Tasmanian Wilderness World Heritage Area November 2015, Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania. Available at http://www.parks.tas.gov.au/file.aspx?id=41886 [Verified 9 November 2016]

DPIPWE (2016a) Tasmanian Wilderness World Heritage Area Management Plan 2016, Department of Primary Industries, Parks, Water and Environment, Hobart.

DPIPWE (2016b) Lake Mackenzie Alpine Fire Impacts Workshop, 8 June 2016. Natural and Cultural Heritage Division, Department of Primary Industries Parks Water and Environment, Hobart, unpublished report.

Driessen MM (1999) Effects of fire on the broad-toothed mouse, *Mastacomys fuscus*, and other small mammals in buttongrass moorlands of western Tasmania - preliminary findings. Pp 119-126 in The Proceedings of the Australian Bushfire Conference, Albury Australia 7-9 July 1999.

Driessen MM (2016) Are moorland invertebrates resilient to fire? PhD Thesis (University of Tasmania: Hobart).

Driessen MM, Kirkpatrick JB and McQuillan PB (2013) Shifts in Composition of Monthly Invertebrate Assemblages in Moorland Differed Between Lowland and Montane Locations but not Fire-Ages. *Environmental Entomology* **42**, 58-73.

Fletcher MS, Wood SW and Haberle SG (2014) A fire-driven shift from forest to non-forest: Evidence for alternative stable states? *Ecology* **95**, 2504-2513.

Fletcher MS, Cadd HR and Haberle SG (2015) Can we infer vegetation change from peat carbon and nitrogen content? A palaeoecological test from Tasmania, Australia. *Holocene* **25**, 1802-1810.

Forestry Tasmania (2016) 'Warra Long-Term Ecological Research'. Available at http://www.forestrytas.com.au/understanding-our-forests/our-research/warra-long-term-ecological-research [Verified 18 November 2016].

Fox-Hughes P, Harris RMB, Lee G, Jabour J, Grose MR, Remenyi TA and Bindoff NL (2015) Climate Futures for Tasmania future fire danger: the summary and the technical report. Antarctic Climate and Ecosystems Cooperative Research Centre, Hobart, Tasmania.

French BJ, Prior LD, Williamson GJ and Bowman DMJS (2016) Cause and effects of a megafire in sedge-heathland in the Tasmanian temperate wilderness. *Australian Journal of Botany* **64**, 513-525.

Gilfedder L, Macgregor N, Bridle K and Carter O (2012) Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania. Report on an expert workshop held in Hobart, Tasmania on 29-29 November 2011. Report to the Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania.

Green D (2009) The soil mites of buttongrass moorland (Tasmania) and their responses to fire as a management tool. Pages 179-183 in M.W. Sabelis and J. Bruin (Editors) *Trends in Acarology*. Springer, Amsterdam.

Harrison-Day V, Annandale B, Balmer J and Kirkpatrick JB (2016) Decadal scale vegetation dynamics above the alpine treeline, Mount Rufus, Tasmania. Papers and Proceedings of the Royal Society of Tasmania, 150, in press.

Jackson WD (1968) Fire, air, water and earth – an elemental ecology of Tasmania. *Proceedings of the Ecological Society of Australia* **3**, 9-16.

Jaeger T and Sand C (2015) 'Reactive Monitoring Mission to the Tasmanian Wilderness, Australia 23-29 November 2015'. (International Council on Monuments and Sites – ICOMOS, International Union for Conservation of Nature – IUCN) Available at whc.unesco.org/document/140379 [Verified 18 November 2016]

Jarman SJ, Kantvilas G and Brown MJ (1988). Buttongrass moorland in Tasmania: Research Report No. 2. Tasmanian Forest Research Council Inc. Hobart.

Johnson KA and Marsden-Smedley JB (2002) Fire history of the northern part of the Tasmanian Wilderness World Heritage Area and its associated regions. *Papers and Proceedings of the Royal Society of Tasmania* **136**, 145-152.

Jones M (2007) How do bryophytes respond to fire in buttongrass moorland? *Australasian Plant Conservation* **16**, 16-17.

Jordan JJ, Harrison PA, Worth JRP, Williamson GJ and Kirkpatrick JB (2015) Palaeoendemic plants provide evidence for persistence of open, well-watered vegetation since the Cretaceous. *Global Ecology and Biogeography* **25 (2)**, 127-140.

Kantvilas G (2007) Lichens: an overlooked Lilliput in Tasmania's buttongrass moorlands, *Australasian Plant Conservation* **16**, 18-19.

King KJ (2004) Four analyses of computer simulations investigating fire–vegetation interactions and fire management options in southwest Tasmania. Australian National University: Canberra.

King KJ, Cary GJ, Bradstock RA, Chapman J, Pyrke AF and Marsden-Smedley JB (2006) Simulation of prescribed burning strategies in south-west Tasmania, Australia: effects on unplanned fires, fire regimes, and ecological management values. *International Journal of Wildland Fire* **15**, 527-540.

King KJ, Bradstock RA, Cary G, Chapman J and Marsden-Smedley J (2008) An investigation into the relative importance of fine scale fuel mosaics on reducing fire risk in south west Tasmania, Australia. *International Journal of Wildland Fire* **17** 421-430.

King KJ, de Ligt RM and Cary GJ (2011) Fire and carbon dynamics under climate change in south-eastern Australia: insights from FullCAM and FIRESCAPE modelling. *International Journal of Wildland Fire* **20** 563–577.

Kirkpatrick JB (1997) Alpine Tasmania: an illustrated guide to the flora and vegetation, Oxford University Press: Melbourne.

Kirkpatrick JB (1999) Grassy Vegetation and Subalpine Eucalypt Communities. In 'Vegetation of Tasmania'. (Eds JB Reid, RS Hill, MJ Brown, MJ Hovenden) pp. 265-285. (Australian Biological Resources Study, a program of Environment Australia: Canberra).

Kirkpatrick J (2012) Draft Montane Grassland Fire Management Strategy 2012-2016, Unpublished report to Department of Primary Industries, Parks, Water and Environment, Hobart, 8 pp.

Kirkpatrick JB (2016) Consequence of future fire regimes on world heritage values, unpublished report provided to the TWWHA Bushfire and Climate Change Research Project.

Kirkpatrick JB and Bridle KL (2013) Natural and cultural histories of fire differ between Tasmanian and mainland alpine vegetation. *Australian Journal of Botany* **65**, 465-474.

Kirkpatrick JB and Dickinson KJM (1984) The impact of fire on Tasmanian alpine vegetation and soils. *Australian Journal of Botany* **32**, 613-629.

Kirkpatrick JB and Duncan F (1987) Tasmanian high altitude grassy vegetation: its distribution community composition and conservation status. *Australian Journal of Ecology* **12**, 73-86.

Kirkpatrick JB, Hutchinson MN and McQuillan PB (1993) Alpine ecosystems. In S. Smith and M.R. Banks (Editors) Tasmanian Wilderness – World Heritage Values. Royal Society of Tasmania, Hobart.

Kirkpatrick JB, Bridle K and Wild A (2002) Succession after fire in alpine vegetation on Mount Wellington, Tasmania. *Australian Journal of Botany* **50**, 145-154.

Lawrence N, Balmer J, Storey, D and Whinham J (2007) The conservation value and reservation status of the Tasmanian Buttongrass moorland vascular plant flora. *Australasian Plant Conservation* **16**, 12-13.

Love PT, Fox-Hughes P, Harris R, Remenyi T and Bindoff N (2016a) Impact of climate change on weather-related risk factors in the TWWHA Interim Report, unpublished report provided by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) in August 2016 for the TWWHA Bushfire and Climate Change Research Project.

Love PT, Fox-Hughes P, Harris R, Remenyi T and Bindoff N (2016b) Impact of climate change on weather-related risk factors in the TWWHA Part II Report, unpublished report provided by the Antarctic Climate and Ecosystems Cooperative Research Centre (ACE CRC) in November 2016 for the TWWHA Bushfire and Climate Change Research Project.

Marsden-Smedley JB (1998) Changes in the fire regime of southwest Tasmania over the last 200 years. *Papers and Proceedings of the Royal Society of Tasmania **132**, 15-29.*

Marsden-Smedley JB (2009) Planned burning in Tasmania: operational guidelines and review of current knowledge. Fire Management Section, Parks and Wildlife Service, Department of Primary Industries, Parks, Water and the Environment, Hobart, Tasmania.

Marsden-Smedley JB (2016) Lightning fires and climate change in the Tasmanian Wilderness World Heritage Area and adjacent areas, unpublished report provided to the TWWHA Bushfire and Climate Change Research Project.

Marsden-Smedley JB and Catchpole WR (1995) Fire behaviour modelling in Tasmanian buttongrass moorlands .I. Fuel modelling. *International Journal of Wildland Fire* **5** 203-214.

Marsden-Smedley JB and Kirkpatrick JB (2000) Fire management in Tasmania's Wilderness World Heritage Area: ecosystem restoration using Indigenous-style fire regimes? *Ecological Management and Restoration* **1**, 195-203.

Marsden-Smedley JB and Leonard S (2014) Vale of Belvoir Reserve Fire Management Strategy and Fire Management Plan: 2014-2029. Tasmanian Land Conservancy, Hobart, Tasmania.

Marsden-Smedley JB, Rudman T, Pyrke A and Catchpole WR (1999) Buttongrass moorland fire-behaviour prediction and management. *TasForests* **11**, 87-99.

Noble JR, Gill AM and Bary GAV (1980) McArthur's fire-danger meters expressed as equations. *Austral ecology* **5**, 201-203.

OzFlux (2016) 'OzFlux: Australian and New Zealand Flux Research and Monitoring'. Available at http://www.ozflux.org.au/index.html [Verified 18 November 2016]

Parliament of Australia (2016) 'Response to, and lessons learnt from, recent bushfires in remote Tasmanian wilderness'. Available at http://www.aph.gov.au/Parliamentary_Business/Committees/Senate/Environment_and_Communications/TasmanianBushfires45 [Verified 23 November 2016]

Podger FD, Bird T and Brown MJ (1988) Human activity, fire and change in the forest at Hogsback Plain, Southern Tasmania. In: Semple KJFaNM (ed) Australia's Everchanging Forests, Proceedings of the first National Conference on Australian Forest History, Canberra 9-11 May 1988, 1988. Dept. Geography and Oceanography, Australian Defence Force Academy, ACT, pg 119-140

Premier of Tasmania (2016a) 'State of the State 2016'. Available at http://www.premier.tas.gov.au/speeches/state_of_the_state_2016 [Verified 18 November 2016]

Premier of Tasmania (2016b) 'Research project to protect wilderness areas'. Available at http://www.premier.tas.gov.au/releases/research_project_to_protect_wilderness_areas [Verified 18 November 2016]

Pyrke AF and Marsden-Smedley JB (2005). Fire attributes categories, fire sensitivity, and flammability of Tasmanian vegetation communities. *Tasforests* **16**, 35-46.

Rudman T, Mitchell L and Driessen M (2013) Giblin fire biodiversity assessment report. Internal report, Biodiversity Conservation Branch, Department of Primary Industries, Parks, Water and Environment, Tasmania.

Sharkey B and Gaskill SE (2009) Fitness and work capacity: 2009 edition. NWCG PMS 304-2. Boise, ID: National Wildfire Coordinating Group, Safety and Health Working Team, National Interagency Fire Center. Available at http://www.fs.fed.us/fire/safety/wct/wct_index.html [Verified 18 November 2016]

Storey K (2013) The impact of the 2013 Giblin River fire on moorland organosols of the Tasmanian Wilderness World Heritage Area. Unpublished report.

Storey K (2014) Rivers of the southwestern TWWHA: A reconnaissance survey of geomorphic character. Unpublished report.

Storey K and Balmer J (2010) Buttongrass moorland vegetation recovery following fire. In: J. Balmer (Editor), Proceedings of the 2007 Buttongrass Moorland Management Workshop. Department of Primary Industries, Parks, Water and Environment, Hobart, Tasmania, pp 65-69.

Storey K and Betts E (2011) Fluvial Geomorphology and Hydrology of Small Buttongrass Moorland Streams: the Gelignite Creek case study. Nature Conservation Report Series 11/05.

Department of Primary Industries, Parks, Water and Environment, Resource Management and Conservation Division, Hobart.

Storey K and Comfort M (2007) A progress report on the development of rehabilitation priorities for broad scale erosion within the World Heritage Area on the Central Plateau of Tasmania, 2005-06, Nature Conservation Report 07/01, Department of Primary Industries, Parks, Water and Environment, Hobart.

Styger J (2010) Rainforest flammability: Determining the conditions for fire ignition and spread within fire-sensitive vegetation. In 'School of Geography & Environmental Studies Conference Abstracts 2010'. (Sandy Bay Campus, University of Tasmania) (Unpublished).

Styger JK (2014) Predicting fire in rainforest, Unpublished PhD Thesis (University of Tasmania: Hobart).

Tasmanian Government (2016a) Tasmania's submission to the Senate Inquiry into the response to, and lessons learnt from, bushfires in remote Tasmanian wilderness. Tasmanian Government, Hobart.

Tasmanian Government (2016b) 'Plan for a Brighter Future: AGENDA 2016'. Available at http://www.premier.tas.gov.au/__data/assets/pdf_file/0006/280914/Agenda2016.pdf [Verified 18 November 2016]

Tasmanian Planning Commission (2016) 'Review of the '*DRAFT* Tasmanian Wilderness World Heritage Area Management Plan 2014': Director's report and representations'. Available at http://iplan.tas.gov.au/Temp/TrimDownload_811538.PDF [Verified 18 November 2016]

Terrestrial Ecosystem Research Network (2016) 'Warra Tall Eucalypt SuperSite'. Available at http://www.supersites.net.au/supersites/wrra [Verified 18 November 2016]

Timbal B, Kounkou R and Mills GA (2010) Changes in the risk of cool-season tornadoes over southern Australia due to model projections of anthropogenic warming. Journal of Climate **23(9)**, 2440-2449

UNESCO (2016a) 'Tasmanian Wilderness'. Available at http://whc.unesco.org/en/list/181 [Verified 18 November 2016]

UNESCO (2016b) 'The Criteria for Selection'. Available at http://whc.unesco.org/en/criteria/ [Verified 18 November 2016]

Whinam J and Kirkpatrick JB (1994) The Mt. Wellington string bogs, Tasmania. *Papers and Proceedings of the Royal Society of Tasmania* **128**, 63-68.

Wood SW, Hua Q and Bowman DMJS (2011a) Fire-patterned vegetation and the development of organic soils in the lowland vegetation mosaics of south-west Tasmania. *Australian Journal of Botany* **59**, 126-136.

Wood SW, Murphy BP and Bowman DMJS (2011b) Firescape ecology: how topography determines the contrasting distribution of fire and rain forest in the south-west of the Tasmanian Wilderness World Heritage Area. *Journal of Biogeography* **38.9**, 1807-1820.

Yospin GI, Wood SW, Holz A, Bowman DMJS, Keane RW and Whitlock C (2015) Modelling vegetation mosaics in sub-alpine Tasmania under various fire regimes. *Modelling Earth Systems and Environment* **1**, 1-10.