WATER SERVICES
ASSOCIATION OF AUSTRALIA

BUSHFIRE MANAGEMENT

NATIONAL GOOD PRACTICE OPERATIONAL GUIDELINES FOR THE AUSTRALIAN WATER INDUSTRY

Bushfire management

National good practice operational guidelines for the Australian Water Industry

May 2020

About WSAA

The Water Services Association of Australia (WSAA) is the peak industry body representing the urban water industry. Our members provide water and sewerage services to over 20 million customers in Australia and New Zealand and many of Australia's largest industrial and commercial enterprises.

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More information

Please contact info@wsaa.asn.au

Additional information

Report contact	Arran Canning T: +61 458 585 347 E: arran@waterfutures.net.au
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Project director	Greg Ryan
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Document co-authors and contributors

DOCUMENT AUTHOR AND CONTRIBUTOR	ORGANISATION
Michael Watson	Barwon Water
William Buchanan	Barwon Water
Prakash Rao	City West Water
Darren Masters	Coliban Water
David Sheehan	Coliban Water
Luke Haynes	Goulburn Valley Water
Guy Richardson	Icon Water
Muneeb Sunna	Lower Murray Water
Denise Fontana	Melbourne Water
John Day	North East Water
Brendan Guiney	NSW Water Directorate
Luke Sawtell	Queensland Urban Utilities
David Cameron	Queensland Water Directorate
Shane Pritchard	SA Water
Zoe Hines	South East Water
Rebecca Gonzalez	Sydney Water
Luc Richard	TasWater
Steve MacCarthy	Water Corporation
Arran Canning	Water Futures (engaged by WSAA)
Dan Deere	Water Futures (engaged by WSAA)
Greg Ryan	Water Services Association of Australia (WSAA)

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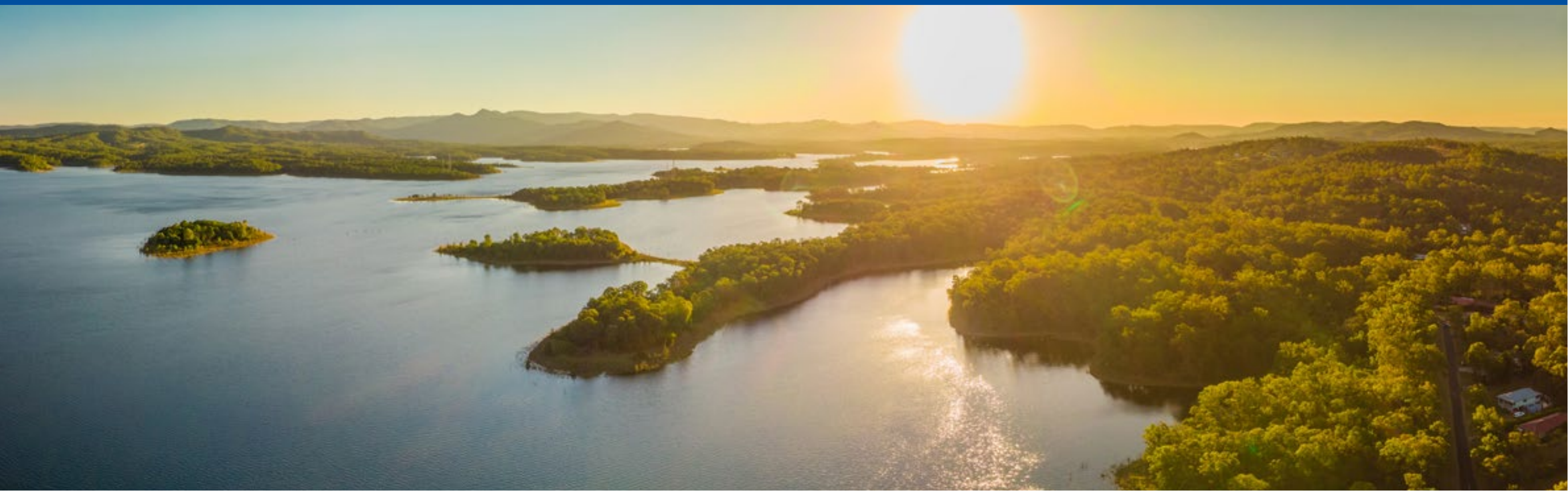
1 Introduction and background

The devastating fires in Australia over the 2019-2020 period highlighted the need for the water industry to have practical guidance ready at hand for the management of drinking water supplies during such events.

Over 12 million hectares of bush was burnt across the Australian landscape, and vast areas of drinking water catchments in NSW and Victoria were impacted. This was exacerbated by record-breaking temperatures, severe drought and high winds. The increase in bushfires is a trend that is expected to increase into the future as a result of climatic change and other factors. Through the experience of previous bushfires in drinking water catchments, some water utilities have a good understanding of the risks that they pose, including risks to water quality and impacts to infrastructure. In future these risks will become relevant to more water utilities.

The intent of this National Good Practice Operational Guideline for Bushfire Management for the Australian Water Industry ('the Guideline') is to utilise the current knowledge and experience in the industry to provide practical guidance across the water sector on bushfire and water quality management. The Guideline includes a number of case studies from water utilities around Australia.

The Guideline aims to provide support to planning and operational staff within a water utility so that they can plan, respond and recover from a bushfire emergency based on sound practical experience. The Guideline is not intended to be used in isolation and should be used to support existing Incident and Emergency Response Plans, through either the development of a Bushfire Management Manual, or by integrating the material relevant to bushfires into existing management plans, such as an Incident and Emergency Plan, Drinking Water Quality Management Plan, Environmental Management Plan or Asset Management Plan. Across the state and territory jurisdictions in Australia there are existing pieces of legislation, regulations, codes of practice and supporting documents for bushfire management. This Guideline represents good practice across the broader water utility industry, based on experience, but it does not take precedence over federal, state or local legislative requirements.



2 Bushfire and water quality overview

The impact of bushfires on drinking water catchments can compromise water quality both in the short term and in the long term, for months to years afterwards, by causing a change in the water balance and catchment landscape.

During active fires, forest litter is replaced by an ash and charcoal layer, with ash settling on lakes and reservoirs. Rainfall events post-fire can have a significant effect on water quality, from increased rates of erosion, increased sediments and turbidity, and the introduction of a range of chemicals and precursors into the water supply. The degree to which a bushfire has negative impacts on water quality depends on multiple factors, such as the intensity of the fire, post-fire precipitation, catchment topology and local ecology.

2.1 Fire intensity

The intensity of the bushfire determines the severity of the water quality consequences. Low-intensity fires that do not burn the crown of the forest lead to increased leaf litter, which during post-fire rainfall lead to increased dissolved organic carbon (DOC) concentrations in water storages. If the leaf litter ends up in streams this can result in an increase in microbial activity, reduced dissolved oxygen levels and the release of metals, such as manganese, from the sediments. On the other hand, high-intensity fires, which burn the above ground matter and soils, can result in a different range of issues.

Due to the extreme heat generated by these fires, most of the organic matter is volatilised, resulting in the inorganic nutrients in the leaves leaching out and passing into the soil. As a result, following rainfall, there will be an increase in phosphorus and nitrogen entering waterways and reservoirs. The increase in phosphorous can lead to future algal blooms. High-intensity fires can also lead to the leaching of trace elements, such as copper, lead and chromium, and in particular the volatilisation of mercury, which can reabsorb and be released as methylmercury. High-intensity fires can also result in the loss of riparian vegetation that supports the banks of rivers and streams. With the loss of these trees and their root systems, over time this can result in land disturbance and erosion, causing an influx of sediments, nutrients, ash and burnt organic material into raw water supplies. High intensity burns not only have a water quality impact, but can have a water quantity impact, leading to increased water yields from the catchment in the short term, by a combination of hydrologic processes, including dramatic decreases of evaporative losses (interception of precipitation and transpiration) from the forest canopy, and increases in soil moisture and runoff generation from hillslopes. These, in turn, can produce greater storm runoff, including large peak flows and an overall increase in water production from fire-affected landscapes.

2.2 Potential contaminants

Based on previous bushfire experiences in Australia, and across the globe, water quality issues have been divided into two main categories: Priority 1 and Priority 2.

Priority 1 covers the most commonly reported issues from bushfires that can cause significant water quality concerns and disruption to supply.

Priority 2 includes issues that have occurred at lesser frequencies or the consequences are considered less severe.

2.2.1 Priority 1

2.2.1.1 Suspended solids

Suspended solids input into waterways following fires and rain events leads to increases in the turbidity and colour of the water, while also transporting other particle-associated contaminants. The magnitude of impacts from suspended solids entering waterways is highly variable and dependent on the intensity, magnitude and frequency of rainfall events following bushfires, and a range of factors that influence post-fire erosion. It has been reported that up to 500 times the background sediment loads have been measured following fires and associated rainfall. Most of this was attributed to channel erosion and incision of unchannelised drainage lines, following short duration high-intensity summer storms. An example of this is after the Cotter fire in Canberra in 2003 where 482 km2 of catchment burned and the maximum turbidity increase was 30 times higher than the previous maximum. It can take up to two years for reservoirs to return to pre-fire conditions. However, in other cases, some reservoirs were not noticeably impacted following large fires and associated rainfall, and this can be due to the capacity of the reservoir to mitigate the impacts of the contaminated inflows.

2.2.1.2 Nutrients

The impacts from nutrients, particularly nitrogen and phosphorus, can be a major issue associated with bushfires in drinking water catchments. Some studies have shown more than one order magnitude increase in background concentrations after fires, while others show minimal impacts. Factors that affect the variability of impact are burn severity, erosion processes, the extent of delivery to streams, soil and forest vegetation types, and storage and retention of nutrients. The immediate major source of phosphorus comes from leaching of ash deposits, while atmospheric deposition is the dominant source of nitrogen. In the medium term, erosion through the loss of bank stabilisation can also lead to the transport of nutrients into waterways. It can take up to three years for nutrient levels in reservoirs to return to pre-fire levels following a large burn and subsequent major rainfall event. Although there may be some peripheral issues with nutrients entering waterways following bushfires, such as the presence of ammonia, nitrate and nitrite, the predominant issue and concern is indirect – the increase in phosphorus leading to the growth of cyanobacteria. With cyanobacterial blooms come risks from cyanotoxins, as well as taste and odour compounds, particularly 2-methylisoborneol (MIB) and geosmin.

2.2.1.3 Organic carbon

Fires can have a major impact on forest floor and surface soil organic matter levels. Through runoff and erosion, the carbon can be exported into waterways. Increases in carbon, as DOC, while in itself not a major concern, is a precursor to disinfection by-products (DBPs), such as trihalomethanes (THMs) and haloacetic acids (HAAs). Following fires nitrogenated DBPs can also form, such as haloacetonitriles (HAN) and halonitromethanes. Any impact is difficult to predict since the formation of DBPs are dependent on carbon speciation, background levels of DOC and water treatment processes. A change in the levels and speciation of DOC in raw water can have an impact on water treatment processes, requiring optimisation of coagulants to remove higher organic fractions from the water. This may prove challenging and could undermine water treatment processes.

2.2.1.4 Metals

The contamination of waterways from metals is mostly an aesthetic issue, relating to the presence of iron and manganese transported from burnt soil or released from rivers due to waterways becoming anoxic from a reduction of dissolved oxygen. However, there have been examples where other metals, such as chromium, arsenic, lead, mercury and copper have been released for soils at concentrations that have exceeded the health-based guideline values in the Australian Drinking Water Guidelines (ADWG) following post-fire inflows.

2.2.2 Priority 2

There are a number of other documented water quality issues that may arise from catchment fires. While these are important for water quality managers to be aware of, it is very difficult to predict whether or not they will be an issue so they have been given a second level priority. These include the following.

2.2.2.1 Cyanide

Cyanide can form from the combustion of organic material and present in ash or deposits from the atmosphere. Impacts are most likely short-lived and confined to the initial post fire rainfall events.

2.2.2.2 Organic combustion products

Polycyclic aromatic hydrocarbons (PAH), polychlorinated biphenyls (PCB) and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/F) may be produced during combustion in forest fires and released into the atmosphere or deposited in ash and soil. The concern around these chemicals is that they are potentially carcinogenic and can persist in the environment, and tend to bioaccumulate. However, in sampling studies undertaken, levels are generally low and within ADWG guideline values.

2.2.2.3 Anions and cations

Anions and cations released from soils during intense burns can enter waterways following rainfall events. These include sodium, magnesium, calcium, potassium, chloride and sulphate. While there may be small increases in TDS concentrations, the impact is likely to be minimal.

2.3 Summary

The severity of the fire has an effect on the water quality risks that are present. Table 2.1 summarises these issues for low and high-intensity fires, along with the water quality priority. There is a five-scale severity rating used in Australia to rate fires, which is explained in more detail in Section 7.3.1. In terms of water quality impacts, they are generally described only in terms of low and high severity fires. Therefore, some precaution should be taken when trying to assess the relationship between fire severity and water quality impacts. Recent research has shown there is not always a linear relationship between fire severity (i.e., temperature) and contaminants.

TABLE 2.1 WATER QUALITY RISK AND FIRE INTENSITY

PRIORITY	PARAMETER	LOW SEVERITY	HIGH SEVERITY
Priority 1	Suspended solids		●
	Nutrients		●
	Organic carbon	●	
	Metals	●	●
Priority 2	Cyanide		●
	PAHs, PCBs, PCDD/F		●
	Anion cations		●

3 Document structure

This document and the methodology to manage the bushfire risk to the water industry, is based on the well-established four-phase disaster management approach of prevention (planning), preparedness, response and recovery.

This approach aims to minimise losses in the event of an emergency, by helping water utilities anticipate potential impacts to their business and to be prepared during and after the emergency. The four phases are described as:

Prevention and planning

Take actions to reduce or eliminate the likelihood or effects of an incident

Preparedness

Take steps before an incident to ensure effective response and recovery

Recovery

Take steps to minimise disruption and recovery times

Response

Contain, control or minimise the impacts of an incident

4 Prevention and planning

4.1 Planning

The prevention and planning phase represents actions that should be taken well in advance of any future bushfire threat. These activities should be part of the normal planning and operational practices of a water utility. This phase focuses on creating a concrete plan for bushfire management, which includes risk assessment, development of response plans, implementing mitigations, training and exercises.

Table 4.1 describes a systematic approach to prevention and planning for bushfire threats. This chapter also provides additional supporting information to assist in undertaking the assessment and for the planning of mitigation actions.

Investment in risk reduction and resilience can deliver a triple dividend:[1]

- Avoid loss and suffering
- Reduce future disaster costs
- Unlock economic opportunities and broader economic and social benefits to be realised even in the absence of a natural hazard.

FIGURE 4.1 BUSHFIRE PLANNING PROCESS MAP

1 National Disaster Risk Reduction Framework (2018) homeaffairs.gov.au/emergency/files/national-disaster-risk-reduction-framework.pdf

TABLE 4.1 PREVENTION AND PLANNING APPROACH

OBJECTIVE	DESCRIPTION	ACTIONS	EXPLANATION AND EXAMPLES
MAPPING CRITICAL FUNCTIONS	The purpose of mapping critical functions is to ensure that the organisation has recognised which activities and services it must be able to maintain in the event of bushfire threats	Determine the critical functions that must be maintained during a bushfire threat	Prioritise drinking water supply over recycled water supply
		Determine the critical infrastructure that supports the critical functions	Identify critical drinking water reservoirs and understand drinking water network operations – how can water be re-routed in an emergency A Critical Infrastructure Rating (CIR) can be used to rate assets depending on the consequences of their lost functionality (Section 4.2)
		Determine key resources and staff that are required to maintain the critical functions	Identify skeleton staff that are essential during an emergency, e.g., water treatment plant operators, catchment rangers (firefighters) and develop emergency rosters
		Determine the key suppliers to support the critical functions	Treatment plant chemical suppliers Boom and silt curtain suppliers Fire suppressant suppliers Energy suppliers
		Document emergency management governance structures, and assign roles and responsibilities	Refer to existing Incident and Emergency Plans
		Develop a plan/document that summarises the list of critical functions, infrastructure, and other critical resources. To avoid an unnecessarily long list, ensure the selection is focused on what is truly critical, rather than what is merely important	Any summary document should be incorporated into existing incident and emergency management procedures
IDENTIFICATION AND MONITORING OF THREATS	The identification of bushfire related threats	Determine the character and causality of bushfire threats	Undertake an assessment of the potential threats from bushfires to infrastructure, water supply and to water quality Consider the proximity of infrastructure including buildings, dams, pipelines etc to bush/forest

OBJECTIVE	DESCRIPTION	ACTIONS	EXPLANATION AND EXAMPLES
IDENTIFICATION AND MONITORING OF THREATS RISK AND VULNERABILITY ANALYSIS	The identification of bushfire related threats Understand the risks that utilities face in the event of bushfires, and assess current mitigation and controls	Assess the current threat picture	Check if there is a current risk assessment or reference in Incident and Emergency Plans relating to bushfire risks
		What does the threat picture look like at different timeframes, e.g., next season, 5 years, 10 years	Consider different scenarios, such as the impact of climate change, new infrastructure, changes in land use, drought, development
		What has recent experience told us?	Has the water utility had recent bushfire experience? What has been learnt? What went right or wrong?
		Develop bushfire threat scenarios and incidents that the organisation wants to prepare itself for	Using the information from above, create bushfire threat scenarios based on what is probable under different current and future scenarios
		Undertake risk identification, based on scenarios above	Determine types of hazardous events from bushfires, e.g.:
			Catchment fires leading to poor water quality
			Catchment fires leading to untreatable raw water
			Fires leading to loss of critical infrastructure
			Fires leading to inaccessible infrastructure
			Fires leading to impact on resources and workforce
			Section 4.3 provides a list of additional
RISK AND VULNERABILITY ANALYSIS	Understand the risks that utilities face in the event of bushfire and assess current mitigation and controls	Risk assessment. Assess the likelihood and consequence of the identified risks, without controls	Undertake a qualitative risk assessment based on the organisation's risk framework, assessing likelihood and consequence. The risk assessment should be done in accordance with the organisation's risk framework and the Australian/New Zealand Standard for risk management, ISO 31000. This should be performed without current controls in place.
	The identification and documentation of identified improvement in a plan to reduce risks to acceptable levels	Capability assessment- assess current mitigations to manage the risks identified above and determine if there are gaps in capability, by:	Mitigations could include:
			Prescribed burn program
			Establishment of asset protection zones
		Determining the current mitigations for each risk	Alternative water supplies
			Powder Activated Carbon dosing at WTP
		Reassess risks with the current mitigation and controls in place	Protection of chemical lines in fire-prone areas by encasing in a double sheath
			Deployment of silt curtains
		Additional analysis may be required to assess capability	Agreements in place for chemical suppliers
			Rosters for critical staff
		Vulnerability analysis – vulnerability analysis will highlight the risks that do not have sufficient treatment for a water quality issue, or that critical infrastructure is in high-risk zones. This should drive the organisation's resource and planning on those specific issues	For example, the risk assessment might show that:
			There is no treatment for potential algal blooms in a reservoir
			There are no hazard reduction programs around vulnerable infrastructure
			There are no alternative water supplies if the water supply is contaminated
		Document the risk assessment and ensure that it is readily available and updated on a routine basis	It is recommended that an all hazards bushfire risk assessment is developed, but specific risks, such as water quality, are translated into the drinking water quality risk assessment. This would be applicable for other hazard areas, such as environment, assets etc.

OBJECTIVE	DESCRIPTION	ACTIONS	EXPLANATION AND EXAMPLES
DEVELOP PLANS	Update incident and emergency management plans	Engage with your State's fire management agency to discuss risks and mitigation activities	Determine which fire management agencies are responsible for managing bushfire in your catchments
		Establish clear processes for communication during all phases of fire management (planning, preparedness, response and recovery)	Understand if these agencies can offer any additional support (e.g. fire severity mapping or rapid risk assessments)
		Define roles and responsibilities within the organisation, the responsible external agencies and determine the lead agency for different scenarios	Request that your utilities critical assets are included in the fire agencies risk mitigation plans so that they can be monitored during active fires
		Agree with health and/or water regulatory on boil water protocols during and post bushfire, and document in incident management plans and drinking water quality management plans	Training of staff could include:
		Consider how the organisation's incident and emergency liaison officer is represented on external incident management teams	Incident and emergency training for incident management teams
		Document and include in the organisations Incident and Emergency Management Process	Liaison officer training for deployment into fire control centres
		Ensure staff are trained in incident and emergency management plans and procedures	Fire training for field staff (e.g., rangers)
			Fire awareness training for operational staff (e.g., maintenance staff entering fire zones post-fire)
	Develop improvement plans - the identification and documentation of identified improvement to reduce risks to acceptable levels	If the residual risk after current mitigations is still unacceptable explore additional controls.	Additional controls could include:
		Produce prioritised list of improvements based on residual risks	Installation of PAC dosing to manage algal bloom metabolites
		Assign responsibilities and timeframes for implementation	Prescribed burning or creating of fire breaks to protect critical infrastructure
			Development of incident management and contingency plans

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4.2 Critical functions and infrastructure

To support the decision making around critical functions and critical assets, a critical infrastructure rating (CIR) can be used to prioritise management and planning towards those consequences that affect core functionality. While the approach differs across different states, North East Water has developed a concise methodology that assesses critical infrastructure based on six consequence areas:

- Economic well being
- Social, environmental and public health
- Facility downtime
- Effects on service
- Rehabilitation and replacement costs
- External impacts, such as climate change.

Each of the consequence areas are assigned a score based on meeting specified standards. The scores are totalled and assigned a CIR based on overall operational importance. Appendix A shows the North East Water's procedure and serves and a best practice example for the water industry.

4.3 Bushfire risk and impacts

Water utilities can be faced with a range of challenges from the threat of bushfires, such as the initial debris flow that may affect lakes and water intakes. The first heavy rains following bushfires can bring significant changes in water quality, and longer-term water quality effects may last for several years. There can be a diverse range of outcomes resulting from bushfires which should be considered when undertaking the risk and vulnerability analysis. These include:

- Difficulty in reaching the water utility and critical infrastructure
- Loss of power
- Physical damage to pump stations, water treatment plants or networks
- Loss of telemetry/SCADA or electrical components
- Long term reduction in source water quality
- Short term contamination of drinking water sources
- Loss of source water
- Water demand in excess of production
- Loss of water pressure
- Disruption in service due to infrastructure damage
- Insufficient or inadequate staff access to facilities
- Problems relating to the de-pressurising of distribution systems
- Contamination of distribution systems.

Maintaining sufficient redundancy of drinking water infrastructure and source waters offers drinking water utilities with the best protection against the detrimental effects of bushfires.

4.4 Bushfire mitigations best practices

A Water Research Foundation report on the Effects of Wildfires on Drinking Water Utilities and Effective Practices for Wildfire Risk Reduction and Mitigation (WRF, 2013), produced several best practice mitigations that, based on industry experience, provided the greatest enhancement in the resilience to catchment and drinking water infrastructure, and they included:

- Conducting strategic fuel reduction activities (such as burning, mechanical removal, grazing, etc.) in the catchment and areas immediately surrounding reservoirs.
- Ensuring proper maintenance in and around wells, pumps, and storage tanks.
- Providing education in the form of staff training and awareness among rural residents.
- Encouraging state or local fire services to require fire safety activities around rural residences.
- Creating a network of shaded fuel breaks at key locations to provide firefighters access to remote areas.
- Developing partnerships and cooperation with other organisations to ensure that upstream reservoirs have sediment containment capacity.
- Being prepared in the event of a fire, including diversifying water intakes and establishing redundancy in treatment plants and raw water supplies.
- Planning for bushfire appropriately, such as having a formal plan, implementing fuel hazard reduction/ reducing bushfire severity, and developing pre-permitting sediment control structures downstream from high hazard areas.
- Managing forest areas in a way that will aid in delivering the highest water quality possible, taking into account factors such as the age and species composition of the forest.

4.5 Prescribed burns

Prescribed or planned burning is the controlled use of fire in the landscape with the intent of reducing fuel hazards, managing native vegetation and protecting biodiversity. Many water utilities use prescribed burns in drinking water catchments and around infrastructure to reduce the risk from bushfires. Prescribed burning is a mitigation tool that could be used to reduce potential risk.

The best conditions to undertake controlled burning is when the conditions suit safe fire lighting. The timing and intensity of burns are highly dependent on weather conditions, such as wind, and the times that are the best suited for native plants and animals. The use of techniques such as mosaic burning patterns can improve biodiversity and ecological values for native flora and fauna.

Catchments should be prioritised each year to ensure those with the highest bushfire risk are completed first. When planning the annual burn program water utilities should work closely with their state fire authority, local rural fire brigades and local councils.

4.6 Fire breaks

Fire breaks are strips of land that have been intentionally cleared of all trees, shrubs, grasses and other combustible material, thus providing a fuel-free area. Removal of combustible material includes the pruning of dead branches on plants, slashing dry/dead vegetation, removal of deadwood that is not ecologically important, removal of litter and weed control. The purpose of firebreaks is to allow access for firefighting and maintenance vehicles, and therefore they should be maintained in a state that allows for vehicles to move unhindered. Fire breaks can have the benefit of reducing the spread of low-intensity fires, but should not be relied upon to prevent the spread of all fires.

Fire breaks can be prepared using several techniques such as:

- Ploughed breaks
- Herbicide treated breaks
- Grazed breaks
- Burnt breaks.

The Western Australian Department of Fire and Emergency Services provides a detailed guide to constructing and maintaining fire breaks (DFES).

4.7 Asset protection zones

Asset protection zones (APZs) are areas around built assets where the fuel load has been reduced. An APZ provides.

- A buffer zone between a bushfire hazard and an asset
- An area of reduced bushfire fuel that allows suppression of fire
- An area from which back-burning may be conducted
- An area which allows emergency services access and provides a relatively safe area for firefighters to defend property.

Asset protection zones can be established as a method to reduce the impact of bushfire on critical infrastructure and therefore reduced the impact on critical services and functions.

APZs fall under a broader category of Fire Management Zones (FMZs), which are classifications used by fire authorities. Other sub-categories of FMZs include;

- Bushfire moderation zones: an area where fuel is managed to reduce the speed and intensity of fires, and for the protection of nearby assets, particularly from ember attack in the event of a bushfire.
- Landscape management zones: an area where fuel is managed to reduce the residual risk and improve ecosystem resilience for other purposes, such as tree species regeneration.
- Planed Burning Exclusion Zones: an area where planned burning is avoided, mainly because the vegetation cannot tolerate fire, or because it cannot be burnt safely. Examples include freshwater or saline wetlands, riverine rainforests and cultural heritage areas.

4.8 Asset standards

Critical infrastructure that is present in bushfire-prone locations should meet certain asset standards to limit fire-related damage and to ensure business continuity. When undertaking vulnerability analysis, it is worth considering an assessment against a set of standards. The bushfire risk assessment should be undertaken by a qualified bushfire risk assessor experienced in infrastructure assets.

The following provides an example of such a standard and is an extract from the Water Corporation asset standard for construction in bushfire prone zones.

The following building elements are generally required on Water Corporation Assets constructed in bushfire-prone areas, with the overarching principles and requirements of AS3959 leading the outcomes, noting that AS3959 is a residential bushfire standard and critical infrastructure design outcomes should exceed AS3959 objectives:

- **A** Buildings must be built on the ground, i.e. no raised floors with exposed sub-floor areas.
- **B** The exposed components of outer walls shall be of non-combustible material. All joints in the external surface material shall be covered, sealed, overlapped, backed or butt jointed.
- **C** Roofs are to be gabled, or of sufficient pitch to shed any leaf litter or debris easily. Rooflines to be clean with no valleys or un-protected vents.
- **D** Where required, eaves linings shall be a fibre-cement sheet, a minimum 4.5mm in thickness. All penetrations into the eaves shall be designed with non-combustible elements to prevent ingress of embers.
- **E** Where sarking is required, it shall have a flammability index of not more than 5 when tested to AS1530.2
- **F** No gutters or downpipes.
- **G** External personnel doors to be a solid core with a minimum thickness of 35mm with approved bushfire-rated weather strips or sealing to prevent ingress of embers all around.
- **H** External large access doors shall be either hinged solid core timber doors, or roller doors with suitable weather strips or draught excluders with a flammability index of not more than 5 when tested to AS1530.2, to ensure protection against ember ingress.
- **I** No windows, or where this is not possible, the windows must be protected with a rated Clearshield™ or approved equivalent, security and ember protection screen.
- **J** Weep holes, vents and louvres must be screened with a rated ember protection screen. Note that design allowance for restricted airflow through ember protection screens will need to be considered.
- **K** The trafficable surfaces of decking, stairs, ramps or landings shall be of non-combustible material.
- **L** Where practicable there shall be no above-ground water pipes, gas pipes and electrical conduits external to the building or structure. Where exposed pipes or conduits cannot be avoided, they shall be of metal construction and shielded to reduce the risk of radiant heat impact.
- **M** External Shielding (structures/fencing/panels) must only be considered where other protection elements are not available and must be approved by the Manager Corporate Security and/or Asset Management Services Security Consultant.

When undertaking an assessment, the structural elements are to be determined after the appropriate land clearances are achieved (30 metres as a minimum is always the target from an 'assessed fire fuel load").

4.9 Integrating bushfire management with existing systems and processes

4.9.1 Incident management

The guidance from this manual must be integrated into existing management systems, in particular into corporate incident and emergency management plans. Like most incident and emergency management plans this document is segregated into planning, preparedness, response and recovery and, therefore, should become a companion document and, if possible, integrated into existing systems.

4.9.2 Australian drinking water guidelines

The Australian Drinking Water Guidelines (ADWG) is the main point of reference for drinking water management in Australia, which State and Territory Acts and Regulations refer to, or are consistent with. As a result, potential water quality risks that arise from bushfires should be integrated into existing drinking water quality management. The risk identification and risk assessment approach described in Section 4.1 is consistent with the ADWG Framework for Management of Drinking Water Quality and, therefore, specific bushfire risks that are related to drinking water quality should be included in drinking water quality risk assessments. Similarly, where residual risks are not reduced to acceptable levels, the residual risks should be communicated to senior management and additional controls included in the drinking water quality management improvement plan.

Following a detailed risk assessment, preventive measures such as critical control points could be updated to include the management of risks from bushfires, particularly following subsequent rainfall events. These amendments could comprise of:

- Including critical limits on raw water supplies for turbidity or visual observations, to temporarily shut down water treatment plants following inflows of highly turbid water caused by ash and sediments.
- Modifying coagulation processes to enhance removal of increased turbidity or organics.
- Triggers to deploy silt curtains or booms in dams to contain ash.
- Triggers based on rainfall post-bushfire that would initiate a targeted water quality monitoring program
- Boil water advisory conditions for issuing and lifting. These should be agreed and documented, if possible, with health and/or water regulators.

4.10 Challenges in conducting bushfire mitigation

Drinking water utilities face a variety of challenges that affect their ability to implement effective bushfire mitigation activities. The following barriers should be considered when planning for bushfire mitigations:

- Being unable to access parts of a catchment area as a result of land ownership.
- Obtaining buy-in for bushfire mitigation activities from other organisations, government entities, and stakeholders with interest in bushfire mitigation activities.
- Acquiring permits to implement bushfire mitigation activities in catchments in a timely and low-cost manner.
- Gaining access to funding, or other types of resources, such as staff time and institutional understanding of the drinking water system's risk to bushfire.
- Availability of resources during national or state-wide bushfire events, such as silt curtains and coir logs.

It is therefore highly recommended that you establish a strong relationship with your State's fire management agencies in your area to seek support and advice.

4.11 Collaboration and partnerships

Collaboration among a variety of stakeholders can promote effective bushfire risk mitigation activities and also leverage funding for rehabilitation efforts by:

- Using partnerships with other organisations or drinking water utilities to evaluate bushfire risk and implement a comprehensive strategy for protecting critical catchments and infrastructure.
- Working with regulating entities to restrict land use activities or conduct other mitigation activities in critical catchments or critical infrastructure.
- Building collaborative forest management groups to educate communities about bushfire risk and employ mitigation techniques across several groups.
- Collaborating with regulating entities to gain approval to conduct mitigation activities.
- Partnering with landowners, and federal, state, local, and private stakeholders to implement bushfire mitigation activities in areas that are not owned by the water utility.
- Working in partnership with the community to leverage utility funds through grant programs.

4.11.1 Australian water sector mutual aid guidelines

Collaboration within the water industry in Australia is strongly encouraged and supported through the Australian Water Sector Mutual Aid Guidelines (WSSG, 2020). The guidelines are administered by the Water Services Sector Group (WSSG) and endorsed by WSAA, and they have been developed to ensure that in times of disasters and emergencies, water utilities are able to restore and sustain services more effectively by drawing on available resources from other unaffected areas of Australia. Support includes the provision of equipment, skills and the sharing of knowledge and experience.

To be eligible for assistance, the requesting water authority must be situated within, or have services within, or be providing services to a disaster/emergency area. Requests can be made by any officer authorised by the CEO/MD of the water utility. The guidelines provide a series of templates and guidance for water utilities on how to request assistance and how that will then be coordinated.

For all phases of bushfire management, water utilities should be aware that these arrangements exist and that they are included in incident and emergency planning plans.

4.11.2 The Water Service Sector Group

The Water Services Sector Group (WSSG) provides a forum for water utilities to share knowledge and develop capability in the areas of security, business continuity, incident and emergency management, and critical infrastructure resilience. The group comprises of the subject matter experts in these fields from across the national water sector. The WSSG is the representative group for the water industry under the Australian Government's Trusted Information Sharing Network (TISN) for Critical Infrastructure Resilience, coordinated by the Department of Home Affairs. The TISN is made up of similar groups from all critical infrastructure sectors which work collaboratively with government to improve critical infrastructure resilience and security. Contact WSAA for further information and or to request group membership.

A key role for the WSSG during bushfire emergencies is the coordination of mutual aid through the WSSG Executive, in accordance with the Australian Water Sector Mutual Aid Guidelines and in consultation with affected and supporting water utilities.

4.12 Expert panel

Not all experts will be held within a water utility, and with the infrequent nature of bushfires, over time knowledge and skills can be lost. Water utilities should consider establishing an expert panel to support bushfire management decisions. The role of the expert panel could include the following:

- Be established in the prevention and planning phase to review risks and vulnerability assessments and risk mitigations.
- Be involved in the preparedness phase to prepare and review incident and emergency scenario training exercises.
- Be available and on-call during the response phase to provide immediate advice to incident managers on bushfire related issues.
- Provide advice on mitigation strategies in the recovery phase.

While this panel may primarily be established within the relevant jurisdiction, water utilities can also utilise the Australian Water Sector Mutual Aid Guidelines to coordinate this type of sector-specific expertise, as required.

4.13 Planning checklist

The development of checklists are a useful way ensuring that planning checks are undertaken. The following example is a checklist adapted from the US EPA Incident Action List for Wildfires.

TABLE 4.1 PLANNING CHECKLIST FROM THE US EPA (ADAPTED FOR THIS GUIDELINE).

TASKS	
☐ Conduct a hazard vulnerability analysis in which you review historical records to understand the past frequency and intensity of bushfires and how your utility may have been impacted. Consider taking actions to mitigate bushfire impacts on the utility.	☐ Understand how the local and utility emergency operations centre (EOC) will be activated and what your utility may be called on to do, as well as how local emergency responders and the local EOC can support your utility during a response. If your utility has assets outside of the local jurisdictions, consider coordination or preparedness efforts that should be done in those areas.
☐ Identify essential personnel and ensure they are trained to perform critical duties in an emergency (and possibly without communication), including the shutdown and start-up of the system.	☐ Develop outreach materials to provide your customers with information they will need during a bushfire (e.g., clarification about water advisories, instructions for private bore and septic system maintenance, and information about fire prevention and mitigation).
☐ Identify priority water customers (e.g., hospitals) obtain their contact information, map their locations and develop a plan to restore those customers first, in case of water service interruptions.	☐ Review public information protocols with local emergency management agency (EMA) and public health/water regulators. These protocols should include developing water advisory messages (e.g., boil water) and distributing them to customers using appropriate mechanisms.
☐ Establish communication procedures with essential and non-essential personnel. Ensure all personnel are familiar with emergency evacuation and shelter in place procedures.	☐ Develop a GIS map of all system components and prepare a list of coordinates for each facility.
☐ Develop an emergency drinking water supply plan and establish response partner contacts (potentially through your local or state emergency management agency or mutual aid network) to discuss procedures, which may include bulk water hauling, mobile treatment units or temporary supply lines, as well as storage and distribution.	☐ Practice mechanical thinning, weed control, selective harvesting, controlled burns and creation of fire breaks on utility managed property, and encourage these practices on property that may directly impact the utility, its water supply and/or water quality.
☐ Consider how evacuations or limited staffing due to transportation issues (potentially all utility personnel) will impact your response procedures.	☐ Create a zone of defensible space (APZ) for utility equipment and facilities (e.g., bore heads, structures, reservoirs, supports to wires and transformers). Consult with your local fire department for specific recommendations or requirements.
☐ Meet with the fire agency with authority in your utility's area. This could include a local fire department, state conservation and forestry offices. Review plans, discuss response activities (e.g., fire suppression chemical use) and identify hazards and vulnerabilities at your utility.	☐ Develop and maintain regular relationships with key agencies including telecommunications, energy providers, and Department of Health.
☐ Confirm and document generator connection type, capacity load and fuel consumption. Test regularly, exercise under load and service backup generators.	☐ Assess the possibility of, and procedures for, using reclaimed water for fire suppression (prepare public notice and talking points).
☐ Collaborate with your local power provider and EOC to ensure that your water utility is on the critical facilities list for priority electrical power restoration, generators and emergency fuel.	

5 Preparedness

As the bushfire season approaches water utilities should assess the risk of bushfires for the coming season to assess the likelihood of extreme bushfire risk. If the likelihood is high, then the utility should ensure that they are well prepared and contingency plans are up to date.

The following table provides guidance on some of the preparedness planning that should be undertaken prior to an impending fire season.

FIGURE 5.1 BUSHFIRE PREPAREDNESS PROCESS MAP

- ASSESS FIRE RISK
- HAZARD IDENTIFICATION
- OPERATIONAL CHECKS
- CRITICAL SUPPLY CHECKS
- TEST INCIDENT AND EMERGENCY PLANS

TABLE 5.1 PREPAREDNESS FOR EACH BUSHFIRE SEASON

ACTION	DESCRIPTION	DETAILS AND EXAMPLES	RESOURCES
ASSESS FIRE RISK	Reassess bushfire risk assessment using the latest information	Bureau of Meteorology forecasts Bushfire & Natural Hazards CRC seasonal bushfire outlook State Fire advice Climatic factors such as the Indian Ocean Dipole (IOD), Southern Annular Mode (SAM) and the El Niño Southern Oscillation (ENSO)	BOM, Fire Weather Knowledge Centre Bushfire & Natural Hazards CRC - Australian Seasonal Bushfire Outlook
HAZARD IDENTIFICATION	Immediately before fire danger period inspect the surrounds of infrastructure such as buildings, reservoirs and pump stations to assess the fuel hazards	If the facility and/or surrounding land and property are assessed as a high risk, a suitable hazard reduction program should be undertaken Hazard reduction could consist of slashing, the application of herbicides or controlled burning, depending on the extent of hazard Controlled burning should only be undertaken under suitable conditions and following consultation with the local fire service	CFA Victoria, Roadside Fire Management Guidelines
OPERATIONAL CHECKS	Check that assets are performing as expected and emergency and backup equipment is ready	Test critical equipment, such as generators, and UPS devices Investigate options that would allow water treatment plants to operate at reduced flow rates to better manage solid loads Pre-determine staging locations for the relocation of equipment, such as generators and spares from fire-prone areas Be aware of all critical control points and ensure that online monitoring is working effectively Where online monitoring is not available, plan to increase the frequency of grab sample testing Ensure on-call rosters and key contact numbers are up to date	Water quality management plans Asset condition assessments Incident and emergency management plans
CHECK CRITICAL SUPPLIES	Ensure that critical supplies are readily available	Check chemical supplies and supply contracts Determine if additional controls are required, such as booms, silt curtains, coir logs, and ensure that they are either in stock or readily available when required Ensure the water testing laboratory has all the correct sampling bottles	
TEST INCIDENT AND EMERGENCY PLANS	Run scenarios to practice and test incident and emergency response plans	Review and test existing emergency response plans Modify plans if required based on learnings Engage with your State's fire management agencies to review plan Ensure water utility liaison officers are trained to be deployed to the state or regional emergency operations centre (EOC) Undertake multiple agency incident and emergency scenario testing	

5.1 Preparedness checklist

The development of checklists are a useful way ensuring that preparedness checks are undertaken. The following example is a checklist adapted from the US EPA Incident Action List for Wildfires.

TABLE 5.2 PREPAREDNESS CHECKLIST FROM THE US EPA (ADAPTED FOR THIS GUIDELINE).

TASKS
☐ Actively monitor fire and weather conditions and be aware of regional bushfires.
☐ Check inventory and order extra equipment and supplies, as needed.
☐ Review and update your utility's emergency response plan (ERP) and ensure all emergency contacts are current
☐ Ensure communication equipment (e.g., radios, satellite phones) work and are fully charged.
☐ Conduct briefings, training and exercises to ensure utility staff are aware of all preparedness, response and recovery procedures.
☐ Address and, if possible, remove vegetation from around facilities located in medium to high fire danger zones. Consider replacing flammable vegetation with fire-resistant landscaping.
☐ Update priority water customers (e.g., hospitals) obtain their contact information, map their locations and develop a plan to restore those customers first, in case of water service interruptions.
☐ Evaluate the condition of electrical panels to accept generators; inspect connections and switches.
☐ Review and update fire management plans, including contingency plans for system operation if critical facilities are impacted by bushfire and access is limited or not possible.
☐ Fill fuel tanks to full capacity and ensure that you have the ability to manually pump the fuel in the event of a power outage. Ensure this equipment and other hazardous materials are located in a safe zone.
☐ Ensure proper safety gear is available for field employees.

6 Bushfire response

This section is not designed to replace the existing incident and emergency response plans of an organisation, but rather to provide supporting considerations in relation to bushfire risks. Generally, during bushfire emergencies, the response is coordinated through state agencies such as State Disaster Management Centres.

The scope of this guideline does not cover the management of active fires, but only the considerations relating to water supplies.

Considerations that need to be addressed during an active bushfire emergency include:

- Rapidly determining the scale and complexity of the disaster.
- Identifying the severity, root causes and interdependencies of impacts to basic critical life-saving and life-sustaining services within impacted areas.
- Develop operational priorities and objectives that focus response efforts on the delivery of the water services by the most effective means possible.
- Communicate disaster-related information across all levels of the public, private and non-profit sectors, using commonly understood and plain language.

If established, water utility incident and emergency managers should rely on advice from an expert advisory panel to support decision making. The figure below represents a generic incident response process; however, each water utility will have their own incident and emergency response plan, and that should be adopted, considering an all-hazards approach during the response phase of an active incident.

FIGURE 6.1 BUSHFIRE RESPONSE PROCESS MAP

6.1 Response checklist

The development of checklists are a useful way of ensuring that response checks are undertaken. The following example is a checklist adapted from the US EPA Incident Action List for Wildfires.

TABLE 6.1 RESPONSE CHECKLIST FROM THE US EPA (ADAPTED FOR THIS GUIDELINE).

TASKS
☐ Assign a representative of the utility to the incident command post or the local/state EOC.
☐ If needed, request or offer assistance (e.g., equipment, personnel) through mutual aid networks, such as the Australian Water Sector Mutual Aid Guidelines.
☐ Prepare and deploy equipment as needed to support firefighting operations, such as tanker trucks and related pumping equipment, as well as bulldozers for the construction of firebreaks.
☐ Account for all personnel and provide emergency care, if needed. If personnel are in the field, communicate with the Bureau of Meteorology (BOM) on local wind conditions in the fire area, so staff are aware of how quickly winds are shifting and if evacuation from facilities is required.
☐ If possible, refill treated water storage tanks each day to ensure maximum storage for demand, including fire suppression.
☐ Keep intakes and access hatches clear of debris.
☐ Work with the local emergency management authorities to identify passable access roads and to ensure that utility facilities in forested areas are clearly identified.
☐ Monitor raw water quality, develop a sampling plan and adjust treatment as necessary.
☐ Utilise pre-established emergency connections or setup temporary connections to nearby communities, as needed. Alternatively, implement plans to draw emergency water from predetermined tanks or hydrants. Notify employees of the activated sites.
☐ Notify regulatory/primacy agency if operations and/or water quality or quantity are affected.
☐ Notify customers of any water advisories and consider collaborating with local media (television, radio, newspaper, social media, etc.) to distribute the message. If emergency water is being supplied, provide information on the distribution locations.
☐ Use backup generators, as needed, to supply power to system components.
☐ Maintain contact with your electricity provider for power outage duration estimates.
☐ Monitor and plan for additional fuel needs in advance; coordinate fuel deliveries to generators.

7 Bushfire recovery

The purpose of this section is to describe and provide a systematic process for the recovery phase of a bushfire emergency for a water utility. The content of this section builds on learnings from water utilities and government agencies, as well as including practical case studies.

The recovery phase provides strategic level guidance, as well as detailed practical information and resources, to support water managers post bushfire emergencies.

This section has a primary focus on water quality impacts but also considers recovery aspects for other areas, such as environment and cultural heritage.

FIGURE 7.1 BUSHFIRE RECOVERY PROCESS MAP

TABLE 7.1 BUSHFIRE RECOVERY RESPONSE PHASE GUIDANCE

TIMEFRAME	RESPONSE	DETAILS
IMMEDIATE ASSESSMENT TO DETERMINE RISK PROFILE IMMEDIATELY DAYS-WEEKS	Inspection of catchment and infrastructure	The earlier that an inspection can occur of the affected catchment or infrastructure, the higher the likelihood that additional measures can be implemented to manage threats or prevent further damage.
		The assessment of catchments is crucial so that the extent of the damage can be determined and, therefore, the likely outcomes can be predicted. Fire severity is an important factor to determine so that the risk to water quality with post-bushfire rains can be estimated. It is important to work closely with other agencies such as National Parks in your state to assist in fire intensity mapping.
		Assessment of infrastructure, such as reservoirs (roofing, linings, vermin proofing), network piping and telemetry should be undertaken.
	Implement water quality monitoring program	Implement a baseline water quality monitoring program to be ready to deploy immediately after post-rain events (Section 7.4).
	Undertake a risk assessment to determine management options	Based on the inspection of the catchment and infrastructure a rapid risk assessment should be undertaken of the affected catchment, (Sections 7.1 and 7.2).
		This should include an assessment of fire severity, infrastructure risks, water quality, environmental and cultural heritage risks.
MANAGE ADDITIONAL THREATS TO PREVENT FURTHER DAMAGE OR RISKS SHORT TERM 1-6 MONTHS	Flood erosion and mitigation works	Fires result in loss of groundcover and water-repellent soils that can lead to increased runoff, erosion and discharge into waterways from subsequent rainfall. Measures include increasing interception and infiltration through mulching, erosion netting, re-vegetation and emergency bank stabilisation works (Section 7.5.1).
	Sediment control measures	Increased sediment and nutrient mobilisation from burnt vegetation can be carried into rivers by runoff following rain, particularly in riparian zones. Measures include straw bales, silt fences and traps, rock walls, log barriers, de-silting of weirs, sediment curtains and booms, and coir logs in drainage lines (Section 7.5.2).
	Emergency repairs to existing flood mitigation infrastructure	Existing flood mitigation infrastructure may be impacted or damaged by fire and be compromised in its effectiveness in managing impacts of subsequent floods.
	Establish a longer-term water quality monitoring program	Bushfires can result in increased nutrient loads, increased water temperatures, decreased dissolved oxygen concentrations, cyanobacteria proliferation (algal blooms) and chemical contamination. Water quality monitoring will help to understand changes to water quality and how these changes impact its use and treatability (Section 7.4).
	Debris removal	Remove debris that is obstructing the passage of water or is posing a threat to infrastructure from subsequent flooding. Some post-fire debris is beneficial for providing habitat and refuge.
	Weed and pest control	Many weeds and pests respond positively to fires and can recover faster than native species. Control measures are needed to ensure that they do not out-compete native species.
	Remove dead stock	Stock that have died close to waterways can be a significant threat to water quality and present a disease vector if not removed quickly after a fire.
		Installation of temporary stock exclusion fencing. Riparian fencing can easily be damaged by fire allowing unrestricted access by stock to possibly sensitive riparian environments. Temporary fencing will help to preserve these areas until long-term repairs take place.
		Re-instate off-stream watering points: Any damaged off-stream watering points need to be reinstated with stock exclusion to provide livestock with access to water without damaging waterways.
		Education and engagement with farmers about the increased risk of water quality impacts.
	Reducing the load on wastewater treatment facilities	Remove debris that is obstructing the passage of water or is posing a threat to infrastructure from subsequent flooding. Some post-fire debris is beneficial for providing habitat and refuge.

TIMEFRAME	RESPONSE	DETAILS
RECOVER AND PRESERVE MEDIUM TERM 6-18 MONTHS	Recovery and relocation of threatened species	Many weeds and pests respond positively to fires and can recover faster than native species. Control measures are needed to ensure that they do not out-compete native species.
	Recovery and relocation of cultural heritage artefacts	Permanently or temporarily relocate artefacts at risk of further damage.
REHABILITATION AND RECOVERY LONG TERM	Re-establish and re-vegetate riparian vegetation buffer zone	Reinstate any damaged riparian areas through re-vegetation and structural works.
	Post-fire recovery monitoring	Undertake a specific water quality sampling program targeted at parameters of concern that could cause long term issues, such as nutrients and cyanobacteria. Adapt the monitoring program based on results to date.
	Re-vegetation	Some plant species cannot regenerate after a fire, so targeted re-vegetation is required to restore vegetation communities. Additional actions, such as contour scarification, can be used to enhance seeding and promote infiltration of rainfall.
	Recovery of habitats	Restore habitat conditions for fauna species where natural recovery may be slow or inhibited.
	Repair and replace damaged fencing	Including replacing temporary fencing with permanent fencing.
RESTORE, IMPROVING RESILIENCE AND ADAPTABILITY	Identify opportunities to use changes in channel capacity to re-engage floodplain	Increased sediment supply from burnt areas provides an opportunity to infill incised gullies and re-engage floodplains. Measures include the installation of pile fields.
	Fuel reduction regimes	Employ systematic fuel reduction activities to reduce the risk and intensity of subsequent fires. This should be carried out in accordance with specific strategies and plans. Establishing well-designed fuel reduction regimes is particularly important because of the changing climate. Increased temperature and dry periods are causing an increase in the duration of fire seasons within south-east Australia and a decrease in the opportunity to reduce fuel through control burning. Opportune conditions for control burning are decreasing and increased dry periods are likely to increase available fuel (Climate Council Australia, 2013).
	Asset standards	Review and apply appropriate asset standards for buildings and infrastructure (Section 16)

The above table was adapted from the ACT and Regional Catchment Post-Emergency Recovery Plan (ACT, 2018).

7.1 A framework for predicting post-fire water contamination risks

Post-fire water quality contamination risks, as described in Section 2, are driven by several factors which include:

- Fire intensity
- Fuel characteristics
- Mobilisation governed by hydrological processes such as:
  - Precipitation
  - Infiltration
  - Runoff
  - Erosion

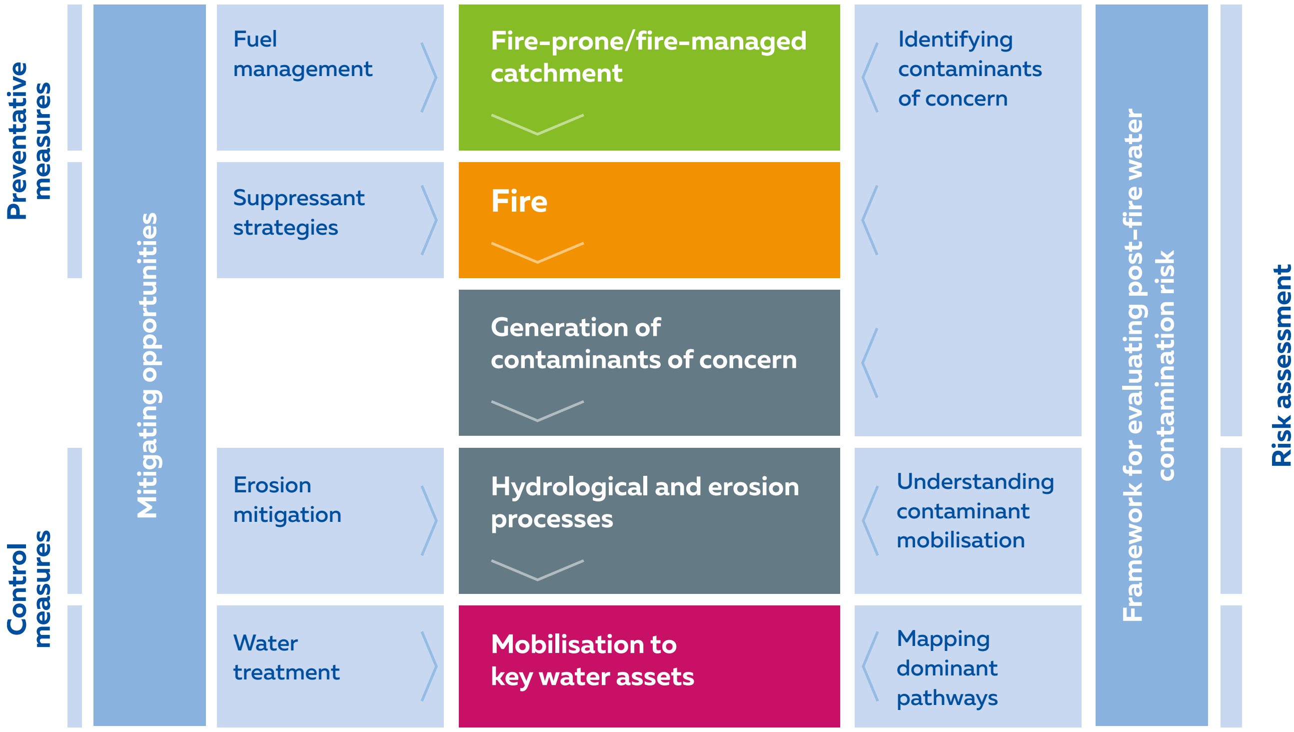
Mitigations and interventions exist at multiple opportunities in the management of bushfires. Figure 7.2 shows a model that can be used for predicting post-fire contamination risks. The framework can be used to support post-fire risk assessments to evaluate the sensitivity of a water asset, such as a dam or a water treatment plant, to a contamination event resulting from specific events, such as storms. The risk of contamination events occurring is dependent on the occurrence of fires with the relevant severity to produce sufficient contaminant loads, combined with the likelihood of different rain events, with the potential consequence being dependent on transport pathways, resident times of contaminants and the dilution capacity of water bodies, such as lakes and reservoirs.

This framework provides a structured approach to identifying mitigating strategies and undertaking risk assessments and is consistent with the ADWG risk management Framework. The framework has been adapted to incorporate the key ADWG Framework elements. It is recommended that any new process for managing water quality risks from bushfires should be consistent with existing drinking water management plans, as discussed in Section 4.9.2.

Throughout this guideline mitigating strategies can be implemented at the various phases to manage risk.

PHASE	MITIGATING STRATEGIES
Prevention/Planning	Effective fuel management that helps reduce the likelihood of severe bushfires
Preparedness	
Response	Fire suppression, limiting the spread of fires, particularly to sensitive areas
Recovery	Post-fire emergency measures can mitigate the mobilisation and transport of contaminants to water assets
	Treatment plants can be modified to meet specific decontamination needs

FIGURE 7.2 AN ADAPTATION FROM THE WORK OF NUNES, (2018), WHO PROPOSED THE FRAMEWORK FOR PREDICTING CONTAMINATION RISKS.



7.1.1 Identifying contaminants and water asset of concern

The contaminants of concern are discussed in Section 2 and should be identified well before any fire, through the planning phase risk assessment and vulnerability analysis. As highlighted previously, these contaminants can include a wide range chemicals and physical characteristics such as suspended solids, ash, nutrients, organic carbon, pyrolytic products and metals.

7.1.2 Understanding contaminant mobilisation

Contaminants can be mobilised by wind and water erosion, debris flow, mass failure and dissolution in water. Specific processes can be responsible for the majority of a particular contaminant. It is important to try and understand which rainfall and associated rainfall events could trigger fire-induced water contamination so that the probability of a contaminant adversely affecting a water supply system can be estimated given the magnitude of a rain event and its duration.

TABLE 7.2 EFFECT OF RAINFALL EVENTS ON CONTAMINANT MOBILISATION

RAINFALL EVENT	EFFECT	CONTAMINANT EXAMPLES
High intensity, short duration	Runoff related processes such as erosion, debris flow	Suspended solids Debris
Saturating rainfall	Mass failure of steep banks and slopes decreasing the soils bulk strength	Turbidity DOC
Saturating rainfall	Non-erosional processes such as subsurface mobilisation of contaminants	DOC Nutrients

Other factors that need to be considered when assessing the mobilisation of contaminants include:

- Topography
- The severity of fire and presence of on-ground material, such as ash
- Existence of, or loss of, buffers between fires and waterways.

7.1.3 Mapping dominant pathways

Water managers require support from a multidisciplinary team to accurately quantify the post-fire contamination risk, with the team having skills in hydrology, soils and chemistry. However, in the context of responding to a disaster and informing immediate mitigation options, mapping dominant pathways can also be qualitative. This includes assessing the potential direction of water runoff from the affected areas into rivers and streams, and ultimately lakes and reservoirs, to determine the potential for contamination, so that mitigation measures can be placed in the appropriate locations. If possible, an estimation of the time taken for contaminants to reach water bodies and intakes should be undertaken, so that mitigation measures can be applied in a timely manner. Factors that can influence the dominant pathways for contaminant transport include:

- The existence of trails and internal roads in the catchment that can direct the flow
- Major burnt gullies that direct contaminants to water supplies
- Movement of contamination across lakes or reservoirs during inflow events, based on experience.

Best practise in this area includes modelling approaches to estimate the impact of potential contamination following post-bushfire rainfall events. An example of this is provided in Appendix B: Hydrodynamic modelling for bushfire management and recovery in the catchment from Melbourne Water.

7.2 Catchment rapid risk assessment

Recovery is an integral component of fire management. Fires cause both immediate impacts and delayed impacts. Immediate impacts, driven by fire severity, location and topography can generate a range of future risks such as erosion, landslips and soil movement. These can be intensified by storms and flooding. Built infrastructure, such as roads and buildings, can also be affected by the secondary impacts, as well as endangered species, sensitive ecological communities and habitats. The deployment of a suitably qualified bushfire rapid risk assessment team (RRAT) should occur as soon as it is safe to do so. In some cases, where access is not possible, a desktop RRAP can be undertaken. The makeup of the RRAT will be dependent on the water utility's priorities and responsibilities. It may be required to deploy a multidisciplinary team to assess the range of water quality, environmental, cultural heritage and engineering risks.

The RRAT could include members that have expertise in the following areas:

Water quality

Identify water quality impacts as a result of the bushfires

Flooding and erosion

Identify flooding and erosion risks that have emerged as a result of the bushfire

Biodiversity

Identify the positive and negative effects of the bushfire and suppression activities on flora and fauna. Determine risks that have emerged, as well as future risks

Assets/engineering

Identify built assets that have been burnt by the bushfire or affected by suppression activities

Catchment management and operation

Identify forest and catchment management risks

GIS

Develop, maintain and analyse maps and spatial data for the BRRAT fieldwork, risk assessment and reporting.

The objective of the team is to assess impact so that recovery options can be planned and implemented to avoid future risks. Data sources that would be beneficial for the assessment would include:

- Satellite-derived remotely sensed imagery of before and after the fire
- Fire intensity rating based on satellite imagery or aircraft footage
- Previously modelled erosion risk potential
- Asset information databases
- Threatened species mapping
- GIS layers
- Vegetation communities.

A conventional risk assessment approach should be adopted to record hazards and hazardous events, and the likelihood and consequence of those events being realised. The existence of current mitigating strategies and controls should also be assessed. This process will highlight the highest risks and, therefore, allow for the prioritisation of mitigating actions.

7.2.1 Water quality risks

To support the assessment of water quality risks the framework described in Section 7.1 should be utilised. By using the framework for predicting post-fire contamination risks the assessment will identify contaminants of concern and assist with understanding contaminant mobilisation and map dominant pathways. Once the risk to potential contamination has been established, then the appropriate mitigation measures (Section 7.5) can be applied with the aim of reducing risks to acceptable levels.

7.2.2 Support and further information

Some jurisdictions across the country have State and Territory agencies that provide support for the rapid risk assessment process.

- The ASCT/NSW Inter-agency Rapid Risk Assessment Team (RRAT)
- The Victorian Bushfire Rapid Risk Assessment Team (RRAT)

In Victoria, DELWP coordinates the RRAT process, by forming multi-agency, multi-disciplinary, specialist teams that are deployed to rapidly evaluate post-emergency risk to the environment and recommend prioritised, and costed mitigation strategies. This model is scalable and adaptable to any large-scale emergency event, and draws team members from across government, including professional land managers, policy experts, and scientific and technical experts. DELWP's RRAT program has a national profile and has been deployed interstate on several occasions to support emergency management and recovery functions. Not all States and Territories have government lead RRATs, however, the process to undertake a rapid risk assessment is based on conventional risk assessment principles and the following examples represents good practice that can be utilised for other jurisdictions.

- Victorian approach is the North East Victoria & Gippsland Bushfire Rapid Risk Assessment Team report from the 2013 Alpine fires. (Appendix C).
- All hazards rapid risk assessment from an ACT perspective is the Orroral Valley Fire Rapid Risk Assessment Namadgi National Park.

  https://www.environment.act.gov.au/__data/assets/pdf_file/0003/1495236/orroral-valley-fire-rapid-risk-assessment-namadgi-national-park.pdf

7.3 Tools for assessment

7.3.1 Fire intensity/severity mapping

The mapping of the severity of bushfires in drinking water catchments is one of the most important assessment tools as it can provide the basis for current and future risk profiles.

It is recommended that water utilities work closely with their State public land management agencies that have this capability. Table 7.1 provides some guidance from the Bushfire CRC and NSW Parks and Wildlife Services on the bushfire severity rating scales used in Australia, while Table 7.2 shows examples photos and simple illustration of the severity classes.

Table 7.3 is a list of the current State agencies that provide this Fire Severity Mapping service as well as additional resources that will assist in the assessment.

TABLE 7.1 FIRE SEVERITY CLASSES AND DESCRIPTIONS

SEVERITY CLASS	DESCRIPTION	FEATURES	% FOLIAGE AFFECTED
Unburnt to patchy	Scorch height ≤ 2 m	**The ground material is not affected by fire** The height of the scorched leaves are no higher than 2 m	0% canopy and understory burnt
Low	Scorch height ≤ 2 m	**Burnt understory with unburnt canopy** All of the ground cover material is affected by fire The height of the scorched leaves is no higher than 2 m.	>10% burnt understory >90% green canopy
Moderate	Scorched height 2-5m	**Partial canopy scorch** All ground material affected by fire Leaf scorch height is >2m but ≤ 5 m. All or most mid-story canopy leave are scorched Upper canopy leaves may be partially scorched	20-90% canopy scorched
High	Complete canopy scorch	**Full canopy scorch/partial consumption** All ground material affected by fire All mid-story leaves scotched All upper canopy leaves	>90% canopy scorched <50% biomass consumed
Extreme	Completely charred	**Full canopy consumption** Ground, mid-story and upper canopy are completely affected by fire, most leaf material is removed or charred	>50% canopy biomass consumed

TABLE 7.2 IMAGES REPRESENTING FIRE SEVERITY SCALE, BFCRC (2015)

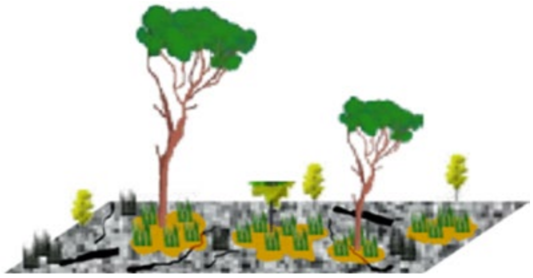
FIRE SEVERITY	EXAMPLE	SIMPLIFIED ILLUSTRATION
Patchy		
Low		
Moderate		
High		
Extreme		

TABLE 7.3 ADDITIONAL FIRE SEVERITY MAPPING RESOURCES

STATE	DESCRIPTION	WEBLINK
NSW	NSW Government Fire Extent and Severity Mapping (FESM)	datasets.seed.nsw.gov.au/dataset/fire-extent-and-severity-mapping-fesm
Victoria	DELWP Bushfire Response and Recovery – Spatial Data Coordination	www2.delwp.vic.gov.au/maps/news/bushfire-response-and-recovery-useful-spatial-data-resources
Bushfire CRC	Case study of bushfire severity mapping	library.dbca.wa.gov.au/static/Journals/917929/917929-92.pdf

7.4 Water quality monitoring

Depending on the scale of the fires in the drinking water catchment sampling programs may be required to understand the change in the risk profile of the raw water. In terms of priority, ease and value for money a preliminary sampling program would include:

- Turbidity/total suspended solids
- Dissolved organic carbon (DOC)
- Nutrient suite
- Total metal scan (including mercury).

Based on the risk assessment or if a water utility was concerned with other parameters, the sampling program could be extended to include:

- PAH, PCB, and PCDD/F
- Cyanide.

While a baseline monitoring program may be useful before initial post-fire rainfall, the priority should be to undertake sampling following significant rainfall events, such as > 50 mm in 24 hours.

For the sampling of rivers and streams, sampling should be undertaken during the 'first flush' or by the use of an automated event peak sampler, or composite sampler over the duration of the event. For lakes or reservoirs, samples should be taken at several depths as during inflow events the incoming water may travel beneath the surface at the same temperature as the incoming water.

Note that when interpreting results, consideration should be given to the duration of potential customer exposure as discussed in Khan et al., 2016.

If water quality issues are observed post rainfall, then it may be useful to consider a longer-term monitoring program. When water catchments and storages are adversely affected by contaminants, it can take up to five years for water bodies to return to pre-fire conditions. In some cases, adverse effects are not seen for months following bushfires, and this is particularly relevant for cyanobacterial blooms that can arise from an increase in nutrients in source waters.

The Water Corporation case study discusses their experience with water quality monitoring and the management of turbidity, resulting from the Perth Hills bushfire in 2005 (Appendix D – Water Corporation experience with water quality monitoring and turbidity management post-bushfire).

7.5 Mitigation options

7.5.1 Erosion mitigation

Whatever can be done to slow the movement of surface water on the fire ground will lead to an improved outcome. There are several mitigation options shown in Table 7.4, that if installed strategically on drainage lines and hillsides, will be beneficial.

Erosion mitigation is the process of minimising sediment loss from hillslope erosion. Possible treatments include mulching, re-vegetation and bank stabilisation. There are a number of considerations that need to be assessed during the rapid risk assessment so that the appropriate treatment areas and methods are identified, such as burn extent and severity, and the likelihood of erosion. Practical considerations should also be considered such as accessibility and the coordination of works with local landholders.

A better outcome will be achieved by landowners on the same slope or within the same sub-catchment coordinating works, rather than working in isolation or not at all. Targeted slopes with good access may be suitable for hydro-mulching or hand application of straw. Upper catchment slopes are generally more important and more effective to treat than lower slopes. Treating upper catchment slopes can reduce flow distances and interrupt overland flow before it hits lower slopes and washes away mulch cover.

7.5.2 Sediment control measures

Post bushfire rainfall can lead to the mobilisation of debris, sediments, ash and contaminants into waterways in both the short term and the long term. Several mitigation options can be used to reduce the impact of these issues and they are discussed in more detail in this section.

With the loss of ground cover and the natural attenuation that it provides, in combination with steep slopes and gullies, this will lead to increased mobilisation of sediments. Bush tracks can be the biggest source of sediment and erosive water flow paths. Track surfaces are mostly impermeable and tend to concentrate flows into drains that de-water into the adjoining bushland, where the vegetation normally reduces the energy of flows and entrains sediment. Post-bushfires, with the loss of ground cover, even in moderately severe fires, the lack of vegetation results in further mobilisation of sediments.

The use of physical barriers such as tree logs, coir logs, hay bales and silt fences can be used to control the mobilisation of sediments and debris. Table 7.4 discusses the methodologies and advantage of each method.

A South Australian study had the following practical recommendations to assist managers in locating and designing sediment traps for bushfire events (Morris, 2008).

- Planning prior to any fire event can alleviate rushed decisions. Review both location and sediment structure designs for a variety of fire scenarios.
- Before a fire occurring, prepare models of catchment processes including both flow velocity and potential erosion.
- Site location details that need consideration following a bushfire include fire severity, erosion potential, vegetation cover, slope length, slope gradient, drainage patterns, road drainage, site access and proximity to a reservoir.
- Source and determine expected delivery times for trap material. Also, have contingency plans in the event the material cannot be obtained.
- Build traps of an appropriate size for the volume of sediment and water likely to reach the trap.
- Determine the period of time traps will be required. Hay bales are a short term (6 months) solution. Silt trap or coir logs should be used for longer time frames.
- Develop clear guides, with both written and illustrated examples of trap designs and effectiveness. These guides need to be tailored to local conditions.
- Silt fence traps need sufficient support to prevent the trap from failing or, alternatively more traps need to be built in the area to reduce water velocity.
- Use geotextile bags to minimise weed spread, prevent fauna damage and prevent bale breakage. These bags add to cost, construction time and future clean up.
- Use minimal star pickets due to the problem of removal and the potential for boats to hit submerged pickets.
- Allocate resources to monitor and maintain any sediment traps that are constructed.

Two case studies that describe the practical experience in using sediment control technology are:

Appendix E	SA Water experience with the application for coir logs
Appendix F	Melbourne Waters experience with the application of debris racks and sediment dams

7.5.2.1 In stream control – silt curtains and booms

Silt curtains and booms can be installed to reduce and slow contaminants such as ash and turbidity and encourage them to be deposited as sediment. These should ideally be installed on the incoming rivers and streams into a lake, dam or reservoir.

Floating silt curtains consist of a curtain of geotextile that is supported in a water body by floats and weights. They are only suitable in areas of low-velocity flows. When installing floating silt curtains in a channel, ensure that the float width equals the channel width. The geotextile curtain sides should be graduated downwards to match the channel sides. This will inhibit erosion of the sides of the channel.

7.5.3 Re-establish and re-vegetate riparian vegetation buffer zone

Fire is a serious threat to the integrity of most riparian vegetation. Most riparian vegetation is mesic, that is, it prefers moist environments and is highly susceptible to fires. Fire impacts the riparian areas by increasing sediment runoff into streams in the short term – due to the loss of its buffering capacity, and in the long term – due to an increase in localised erosion of the stream banks. In some cases, prior to re-vegetation, stream banks may become destabilised due to the loss of tree root systems. This may require bank stabilisation techniques. There are several useful references that detail bank stability and riparian re-vegetation, such as:

- CRC for Catchment Hydrology Guidelines for Stabilising Streambanks with Riparian Vegetation in 1999 (CRC Hydrology, 1999).
- Soil Conservation guidelines for Queensland – Chapter 11 Stream stability (DSITI, 2015).

TABLE 7.4 DESCRIPTION OF SEDIMENT AND EROSION CONTROL MEASURES (TAKEN DIRECTLY FROM EDEN PARK BUSHFIRE EROSION MITIGATION PLAN, WHITTLESEA, (2017))

MITIGATION	PURPOSE OF TREATMENT	DESCRIPTION	SUITABLE SITES	LIMITATIONS	OTHER CONSIDERATIONS
Hydro-mulching	Hydro-mulch is used in high-burn severity areas with increased erosion potential and slopes greater than 15 degrees. The primary purpose of hydro-mulching is to stabilise soils however native understory seed can also be applied to enhance vegetation regeneration. This has the added benefit of stabilising hillslope soils long-term after hydro-mulching material has broken down.	Hydro-mulching involves the spraying of a slurry mix consisting of seed +/- fertiliser, paper pulp or wood pulp and acrylic polymer or other tackifier. Hydro-mulch can be sprayed directly from a truck up to 30 metres away, or via hose extensions up to 100 metres away. Seed within the hydro-mulch mix generally sticks to the pulp which improves conditions for seed germination so long as moisture is maintained. The rate of application should be between 2.2 to 3.4t/ha with a desirable minimum of 80 to 100% cover. Different organic-based soil binders and tackifiers can be used to achieve short term or long-term stabilisation results. Similarly, various application rates can be used for different slope grades. Experienced local contractors should be used to undertaken hydro-mulching.	Soils with high-burn severity and high-erosion likelihood Slopes greater than 15 degrees without effective soil cover	Dry hydro-mulch is easily damaged by vehicular or pedestrian traffic (which allows water to enter under and detach the matrix) Runoff causing rilling erosion above or within hydro-mulched areas may break up the hydro-mulch blanket Long and steep slopes may lead to rilling as run-off concentrates Vehicular access may limit where hydro-mulching can be applied Cost and time of application Availability of indigenous seed to add to hydro-mulching mix	Coir-logs may be required in areas of potential rilling to slow and disperse water flow to prevent the hydro mulching blanket breaking up
Straw-mulching	Straw mulch provides immediate ground cover and protects the soil from erosion and loss of nutrients. Straw has typically been the most commonly used mulch, particularly in association with seeding. Mulch can reduce downstream peak flows by absorbing rainfall and allows pre-wetting of water repellent soil. Straw helps to secure the soil seed bank or manually broadcast seed. Straw mulch on burned areas helps maintain favourable moisture for seed germination and growth. Straw can be applied by hand, via truck-mounted straw blowers or aerially by helicopter in broad-scale agricultural settings. When straw is applied with truck-mounted straw blowers, indigenous seed may be applied initially followed by straw and then a tackifier to hold straw in place (three-stage process). Approximately 1 ha can be applied per truck each day. Straw mulching may be a suitable treatment in areas of Eden Park with smaller allotments as straw can be hand spread by individual landowners.	Straw mulch with weed-free straw helps provide temporary cover to erosion-vulnerable areas as a result of the fire. Straw is not hay and the two should not be confused. Straw is a stalk which is usually a waste product of wheat, while hay is typically a grass and can be a source of weeds. Straw can be applied by hand or straw blowers from a light truck. Past studies have shown that straw mulch is an effective treatment when applied to suitable sites and appropriate groundcover is achieved. Various sources suggest that at least 2.5 t/ha with at least 70% cover should be applied for best results. Straw has been suggested as providing greater reductions in erosion than hydro-mulching due to straw having longer fibres that require greater shear force to displace. Although straw can be moved by runoff, straw can interlock along the contour allowing it to store sediment and slow velocities.	Soils with high and moderate burn severity and high erosion likelihood Slopes up to 30 degrees without effective soil cover Upper slopes of catchment with high and moderate burn severity Areas that have been identified for seeding Areas that do not receive high wind	Availability of certified weed free straw Potential germination of high risk weeds Water runoff moving straw offsite Wind blowing straw offsite Logistics of moving straw around fire effected area Inadequate application resulting in limited erosion control or suppressing vegetation growth Vehicular access may limit where hydro-mulching can be applied Availability of indigenous seed	The use of fibrous mediums for erosion control (including mediums such as straw, paper and organic matter) is a growing area of research and new products are becoming available regularly. It is recommended that the most suitable fibre application method is used.
Fibre blanket	Fibre blankets are used on sites small sites around critical assets such as waterways that require immediate soil cover. When properly implemented fibre blankets are effective in reducing soil loss and sedimentation. They tend to be a temporary erosion control technique for exposed soils that are not subject to concentrated flow. Critical to the performance of the fibre blanket is the ability to control raindrop impact and sheet erosion within the underlying soil. Intimate contact between the blanket and soil is fundamental to successful re-vegetation.	Fibre blankets come in a variety of materials including wood fibre, wool, recycled fibre, coir (coconut fibre), straw and jute (plant product) and are generally used in conjunction with seeding or re-vegetation. Fibre blankets are used on sites that require immediate soil cover and can be used on moderate sloping batters, embankments and other sheet-flow environments. The thinner blanket type allows vegetation growth up through the blanket (ideal for placing over seeded soil). Thicker varieties of blankets are more desirable for weed control purposes. Wind damage resistance is related to the spacing of anchor pins and the strength of the root reinforcing and/or mulch.	High-burn severity areas Presence of water-repellent soils Bedrock areas with low infiltration and high runoff Ground surface areas free of grass and objects Low to medium velocity sheet flow with suitable anchoring	Temporary erosion control technique Synthetic blanket reinforcing can entrap wildlife such as snakes, birds and lizard Unless plant establishment is quickly achieved, most 100% organic-based blankets can experience slips (distortion) when placed on steep slopes	Synthetic reinforced fibre blankets should ideally be avoided within bushland and other areas where they could endanger wildlife such as ground-dwelling animals 'Jute' blankets have a service life of around three months, whereas 'Coir' blankets (made from coconut fibres) last around the same time as a domestic door mat when placed in direct contact with soil Ideally not placed over dispersive soils as this can lead to displacement of the blanket or severe rilling under the blanket
Fibre rolls	Fibre rolls form part of erosion control and stabilisation treatment strategy by trapping sediment and displaced soil. They are suited to high burn severity areas where there is a risk of soil loss and/or water quality deterioration. Fibre rolls are used where log erosion barriers are not practical.	Fibre rolls are designed to slow overland runoff, reduce the length of a slope (to slow overland flow velocity) and improve infiltration. They are prefabricated rolls manufactured from rice straw and wrapped in jute netting or ultraviolet degradable plastic. Approximately 23cm in diameter and up to 7.5m long, fibre rolls are designed for low-surface flows (i.e. not stream channels or gullies). Fibre rolls trap sediment, provide a seedbed for vegetative recovery and if water repellent soils are present can improve infiltration. Fibre rolls can function for up to two years but remain for several years after placement.	Heritage sites or other high-value areas at risk High and moderate burn severity areas Slopes with less than 20% of the original ground cover remaining Slopes between 10 and 20 degrees Soils not less than approximately 20cm deep Work best when recessed into a slope with complete ground contact and firm anchoring Coarse-grain soils	Can attract small rodents, which in turn attract snakes that may be trapped in the netting Availability of certified weed-free fibre rolls Difficult to install and awkward to transport Do not reduce erosion but trap sediment on a slope	Fibre rolls may be used around existing tunnel erosion areas to divert sheet-flow runoff around tunnels Inspect after each storm event Fibre rolls should be installed in a U-shape to trap sediment and disperse runoff velocities
Silt fences	Silt fences form part of an erosion control and stabilisation treatment strategy by trapping sediment and displaced soil. They are placed in areas of high value including water quality, aquatic and heritage assets. Silt fences can be used as part of a monitoring programme to monitor sediment movement. Erosion reduction from the use of silt fences can be highly effective when installed properly and maintained appropriately, however they have a poor capture rate for the finer silt particles (<0.02mm).	Silt fences are a geotextile fabric installed with wooden posts or metal star pickets. The typical height of a silt fence is 600 to 700mm and at least 300mm of fabric must be buried either in a 200mm trench or under a continuous 100mm high layer of aggregate or sand (not earth).	Areas accessible for inspection and maintenance In areas with high value where other forms of sediment traps may not be ineffective Ideally installed along the contour (i.e.: on a level surface across a slope)	Require significant installation effort Require on-going maintenance and monitoring Proximity to vehicle access Most fabrics have an effective service life of around six months Time consuming to install Can cause concentration of runoff if poorly located (or installed)	Once the site is stabilised remove the fences If the fence is located across contour ensure regular 'returns' to avoid water concentrating along the fence Inspect the fence at least weekly and after any significant rain

MITIGATION	PURPOSE OF TREATMENT	DESCRIPTION	SUITABLE SITES	LIMITATIONS	OTHER CONSIDERATIONS
Log erosion barrier	Log erosion barriers (LEBs) are used in moderate and high burn severity forested areas where hillslope erosion rates are increased significantly from fire. They reduce erosion by shortening slope length, improving infiltration, trapping sediment and increasing surface roughness. LEBs can be installed using fallen timber and can provide important ground-dwelling habitat after a fire event.	LEBs are logs that are placed in a shallow trench or on the contour of a slope (see Plate 17) and trap sediment if laid in a bricklayer pattern. The volume of retained sediment is dependent upon the slope, the size and length of the trees and upon correct implementation. Those LEBs with soil end berms trap more sediment. End berms can be earthen or made out of coir logs and are placed at the end of logs and run up-slope to trap sediment and prevent terminal scouring.	Slopes between 15 and 30 degrees Slopes with moderate and high burn severity Catchments with high values at risk Water repellent soils are present	Soil depths, rainfall intensity and soil water holding capacity can dictate LEB effectiveness Areas with rocks can hinder correct installation of LEB and result in erosion	Ensure correct implementation as trees improperly bedded can cause runoff and erosion under or (for those not placed on the contour) at the ends of the log Untrimmed limbs can prevent ground contact and result in erosion
Catch drains	Catch drains can be used to direct stormwater runoff around disturbed soil or an unstable slope. They are designed to collect sheet flow runoff from an unstable slope before it causes rill erosion. Catch drains can collect sediment laden runoff downslope of a disturbance and direct it to a sediment trap.	Catch drains are small open channels formed at regular intervals down a slope, or immediately down-slope or upslope of sensitive areas. These channels are usually excavated with U-shaped excavation tools or a grader blade. They typically have standardised cross-sectional dimensions. 'Push-down' (channel-bank) catch drains are formed by pushing the excavated material downslope of the drain. Catch drains are relatively quick and inexpensive to establish (or re-establish if disturbed).	Low gradient Upslope of batters Intermittently down long, exposed slopes Upslope of sensitive areas located within an overland flow path	Only suitable for relatively small flow rates Can cause flow concentration and significant erosion problems if overtopped during heavy storms Short to medium term solution Heavy earth moving equipment required Not suitable for dispersive soils	Catch drains must be designed for local hydrological and soil conditions If earth-lined catch drains discharge to an unstable outlet then erosion can occur downstream of the outlet (commonly experienced when cut into dispersive soils) Subsoil erosion-resistance should be investigated before planning or designing A suitable sediment trap should be included in plans if the diverted water is expected to contain sediment Maintenance schedules should include regular inspection of all catch drains and in particular, after storm events
Floating silt curtains	Silt curtains are designed to control the settling of silt suspended in water by providing a controlled area of containment. The boom allows water to flow freely, while acting as a barrier against sediments and other materials.	Silt curtains are floating containment barriers with a foam or air buoyancy chamber supporting a deep, permeable skirt. The skirt acts as a barrier to prevent the spread of silt, sediment and fine suspended solids whilst allowing water to still pass through. The air-filled floatation chambers are best for short-term deployment, ease of storage and low-cost freight options. Foam-filled chambers are most suitable when long-term deployment is required. The silt booms are available in a variety of sizes and materials.	Streams and rivers Water depth of at least 0.8m	Specialist advice is required if placing in waters with a velocity great than 0.15 m/s Can be limited to a wave height less than 150mm In all but exceptional circumstance (e.g. post bushfire) silt curtains should not be placed across the full width of a flowing channel or waterway	Wherever practicable, the bottom of the silt curtain must be anchored to the bed of the water body to prevent sediment-laden water passing under the fabric Inspections should be undertaken to inspect turbid blooms outside the silt curtain Periodic checks of the anchoring system should be undertaken

7.5.4 Treatment mitigations

Once contaminants have reached raw water intakes, then the last barrier for their management is the water treatment plant. This section describes some of the main contaminants that if increased can result in treatment challenges.

7.5.4.1 Turbidity

Following a bushfire, source water turbidity can vary significantly from pre-fire levels. Turbidity levels can increase up to 500-fold and concentrations post-fire have been seen above 4000 NTU. Under these extreme conditions, it may be infeasible to treat the raw water and the best option is to shut off the raw water supply and rely on network storages or alternative sources.

Under these circumstances, water utilities should immediately discuss options with their regulators and health departments, and if they are a bulk service provider, with their customers.

Treatability will be dependent on the design and capability of the water treatment plant. Less extreme turbidity levels in the raw water can be removed through the normal conventional treatment processes of flocculation, sedimentation and filtration.

However, increased turbidity may result in reduced flow through the treatment process, increased coagulant use and increased sludge production. Several recommendations should be considered:

- Jar testing should be used regularly to support decision making during extreme weather events. Water utilities that use and practice jar testing regularly on-site during normal conditions will be better able to respond to extreme events, avoiding consequences such as turbidity breakthroughs of filters and potential boil water advisories.
- It is important to closely monitor changes in coagulant demand and coagulation pH, as large water quality variations will increase the coagulant dose in most cases. It is important to monitor the usages and available stock of coagulant and pH adjustment chemicals, such as lime or sodium hydroxide during extreme events.
- Due to increased coagulant usage, it may be necessary to install or have on stand-by, additional chemical dosing pumps to increase the dosing capacity for coagulant chemicals.
- With increased residuals production, there may be a risk of bottlenecks in the solids handling processes. Increases in solids disposal should be considered, as well as the need for notification to environmental regulators.
- For unfiltered supplies, once turbidity increases above 1 NTU, then there is an increased risk to the efficacy of disinfection processes and therefore a risk of pathogen contamination. It is possible that boil water advisories may be triggered. Health agencies should be alerted to this possibility.
- At all times, critical control points should be monitored closely, and the existing critical limits and corrective actions diligently applied.

7.5.4.2 Nutrients

There is little to be done practically to manage nutrients once they have entered waterways. The increase in nutrients, especially phosphorus, leads to the risk of cyanobacterial blooms and their metabolites: cyanotoxins, and taste and odour compounds. In the absence of ozone/GAC/BAC the most effective way to manage the risks from these metabolites in the short-term is through the addition of powdered activated carbon (PAC) to adsorb the compounds upstream of filtration. However other options are available in the shorter term and the longer term. Table 7.5 summaries some of these options along with the advantages and disadvantages of each option.

TABLE 7.5 TREATMENT OPTIONS FOR CYANOBACTERIAL METABOLITES

CONTROL		PROS	CONS
Phosphorus binding	There are several products capable of binding and precipitating phosphorus, these include, aluminium sulphate, ferric chloride, ferric sulphate, modified clays and lime. Performance is highly dependent on hydrodynamics, water quality and the chemistry of the system. Phoslock, a lanthanum modified bentonite clay, has been promoted as a potential material to bind phosphorus.	Immediately effective in stripping phosphorus from the water column Effective at suppressing the release of phosphorus from sediments even under low dissolved oxygen concentrations	Agents are buried by additional sediment inputs and regular reapplication may be required Phoslock and similar lanthanum containing products are limited in use due to ADWG health-based guideline value for lanthanum of 0.002 mg/L
Mixing	There are generally two main types of devices used for mixing: bubble-plume aerators and mechanical mixers. Both have been shown to be effective in assisting in the management of stratification. Their success is highly dependent on the size of the reservoir, its water quality, and the prevailing conditions. They work by limiting access of phytoplankton to light and nutrients, thus limiting cyanobacterial growth.	Moderate CAPEX costs	Evidence is not strong of the ability to reduce cyanobacteria numbers Not effective in shallow or very large storages Potentially high energy solution Design is critical to success
Algicides	Algicides cause the death (lysis) of algal cells. The most common algicide used has been copper sulphate and its use dates back to 1890. Other complexes of copper have also been used, such as forms of copper-ethanolamine. Copper compounds work by a range of physiological and biochemical effects within cells after the copper (II) ion is taken up, leading to cell death and rupture.	Shown to be effective to control algal populations in the short term	Strict environmental regulations on its use (prohibited in some states) Unwanted environmental impacts on other species, such as zooplankton and fish Risk of increased organic carbon due to die-off of algae Release of intracellular toxins and odour compounds Accumulation of algicides in sediments with long-term ecological implications Implications for the removal of residual algicide through the water treatment process
Shut down supply	Shut down of water treatment on triggers, such as cyanobacterial cell count, biovolume concentration or toxins concentration.	Highly effective, eliminating the risk to consumers	Ceasing water supply has direct impacts on water availability. This is only an effective strategy if there is alternative raw water and/or treated water source.
Powdered Activated Carbon (PAC)	Powder activated carbon has been successfully used in the water industry to remove most cyanotoxins and reduce the taste and odour compounds, MIB and geosmin. The PAC dose concentration is dependent on toxin type and toxin concentration. Similarly, the dose concertation of PAC for MIB and geosmin is dependent on metabolite concentration. In addition, different PAC types, such as wood-based, coal-based, coconut-based, chemically activated or steam activated, have different performance characteristics for each metabolite (toxin type, MIB/geosmin). Recommended dose rates can range from 5-50 mg/L.	Well established treatment process Effective for most toxins and taste and odour compounds Moderate CAPEX	High contact time to be effective High OPEX if used often Can be operator intensive and hazardous to apply in the plant

CONTROL		PROS	CONS
Chlorination	Chlorine is an effective oxidant for microcystin and cylindrospermopsin, however, has limited efficacy against saxitoxins and MIB/geosmin under normal operating ranges, i.e. CT value of 15 mg.min/L.	Evidence shows chlorine is an effective treatment for microcystin and cylindrospermopsin	Not as effective for saxitoxins, requiring higher CT values of >20 mg.min/L
		Available as an existing treatment process at most WTPs	Not effective for MIB/geosmin
		No additional OPEX or CAPEX required	
Ozone/ GAC/ BAC	Ozonation is very effective for the destruction of microcystin and cylindrospermopsin, but less effective against saxitoxins and MIB/ geosmin. However, when combined with biologically activated carbon (BAC), reduction in concentrations of all metabolites has been observed.	Moderate ongoing OPEX	High up-front CAPEX required

7.5.4.3 Organic carbon and DBPs

The concentration of organic carbon (DBP precursors) can be effectively reduced through advanced processes such as ozone/GAC/BAC, but where absent, conventional coagulation and sedimentation processes can also be quite effective. Removal of organic carbon by conventional treatment can be increased through enhanced coagulation whereby the pH of the coagulation process is reduced to preferentially reduce colour (DOC) over turbidity. However, once DBPs are formed there is no simple way to reduce concentrations other than by using advanced technologies.

7.5.5 Impact to water treatment

With the increase in contaminants in raw water sources following post-bushfire rainfall, there will be direct impacts at the water treatment plant, in terms of additional chemical usage and operational costs. Table 7.6 summarises these increased impacts in relation to some of the main contaminants.

TABLE 7.6 IMPACT ON WATER TREATMENT BASED ON CONTAMINANT

IMPACT	TURBIDITY	TOTAL PHOSPHORUS	TOTAL NITROGEN	MANGANESE AND IRON	DISSOLVED ORGANIC CARBON
Increased coagulant use	●				●
Increased sludge production	●				●
Increased oxidant demand	●				●
Increase DBPs	●		●	●	●
Increase in cyanotoxins		●			
Increased T&O		●	●		●
Increased operating costs	●	●	●	●	●

7.6 Recovery checklist

The development of checklists are a useful way ensuring that recovery checks are undertaken. The following example is a checklist adapted from the US EPA Incident Action List for Wildfires.

TASKS
☐ Undertake a rapid risk assessment of the affected areas (Complete damage assessments).
☐ Assign a utility representative to continue to communicate with customers concerning a timeline for recovery and other pertinent information.
☐ Continue work with response partners to obtain funding, equipment, etc.
☐ Complete permanent repairs, replace depleted supplies and return to service.
☐ Coordinate with landowners and other partners to restore and treat burned areas.
☐ Compile damage assessment forms and cost documentation into a single report to facilitate the sharing of information and the completion of state and federal funding applications.
☐ Identify mitigation and long-term adaptation measures that can prevent damage and increase utility resilience. Consider impacts related to future climate conditions and the increased frequency of bushfires when planning for system upgrades (e.g., installing buffer strips, removing hazardous fuels).
☐ Develop a lessons learned document and/ or an after-action report (AAR) to keep a record of your response activities. Update your vulnerability assessment, ERP, fire models and fire management plans.
☐ Consider implementing the following mitigation measures to prepare for possible flash flooding events following a bushfire:
Obtain and use burn severity mapping to help determine catchment risk and mitigation strategies.
Monitor the catchment, as conditions may be different post-fire. Identify potential failure points within your service area: ensure culverts can handle increased flow, and determine runoff points and areas where water will now collect
Install a rain gauge upstream of intake for early warning of heavy precipitation that could lead to high turbidity water and sensors to monitor the amount of debris and sediment coming downstream.
Consider instituting erosion control measures to protect against runoff and sediment concerns that occur during suppression and precipitation.

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Appendices

All case studies available at WSAA website
wsaa.asn.au/publication/national-good-practice-operational-guidelines-bushfire-management-australian-water

Appendix A	North East Water critical infrastructure rating (CIR)
Appendix B	Hydrodynamic modelling for bushfire management and recovery in the catchment from Melbourne Water
Appendix C	North East Victoria & Gippsland Bushfire Rapid Risk Assessment Team report from the 2013 Alpine fires
Appendix D	SA Water experience with the application for coir logs
Appendix E	Melbourne Water's experience with the application of debris racks and sediment dams
Appendix F	Managing water quality in the Huon River catchment
Appendix G	Drought, fires, floods and water quality
Appendix H	Monitoring water quality and managing turbidity after the Perth Hills bushfire
Appendix I	Lindfield Park Road rehydration project
Appendix J	Getting started on bushfire recovery