

Desktop review – Impact of bushfires on water quality

Summary for public dissemination

For the Australian Government Department of Sustainability, Environment, Water,
Population and Communities

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18th March 2011



THE UNIVERSITY OF
MELBOURNE



Australian Government

**Department of Sustainability, Environment,
Water, Population and Communities**

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Impacts of bushfires on water quality

Landscape scale fires in forested south-eastern Australia have critically impacted a range of catchment values, including water quality, and heightened community concern about fire and catchment management. Many Australian cities and rural communities source their water from forested catchments, areas particularly susceptible to bushfires.

This review considers the water quality impact of recent bushfires throughout Australia. Post-fire changes in water quality may result in water supplies that are unfit for use (White et al., 2006; Smith et al., 2011). The objective of this report is to review literature on the impact of bushfires on water quality, including recommendations for management actions immediately before, during and after a bushfire. A major focus of the report is on how various uses and values of water may be impacted by fire-related changes to water quality.

Recent impacts from around Australia

Several studies from around Australia report impacts on water quality as a result of bushfires. In some cases these impacts resulted in water supplies that were unfit for use. For example:

- following the 2003 fire in the Bendora reservoir (ACT), turbidity values were exceptionally high and reached levels of 3000 NTU (Nephelometric Turbidity Units) near the bottom. Apart from chlorination and fluoridation no treatment was available and, together with a limited supply from an alternative source, resulted in severe water restrictions in Canberra (White et al., 2006)
- following post-fire debris flows in the upper Buckland River in north-eastern Victoria, turbidity values reached 129,000 NTU, some 26000 times the guideline value¹ for drinking water. Maximum concentrations for iron, arsenic, chromium and lead exceeded guideline values for drinking water by factors of 2467, 40, 18 and 98 times, respectively. Rural towns dependent on this water were required to adopt water restrictions (Leak et al., 2003), and
- in tributary rivers of the Gippsland Lakes in eastern Victoria following the 2006/07 fires, flooding resulted in maximum turbidity and nutrient values exceeding guideline values¹ (Figure 1). This contributed to a prolonged bloom of cyanobacteria (blue-green algae) in the Gippsland Lakes (Cook et al., 2008).

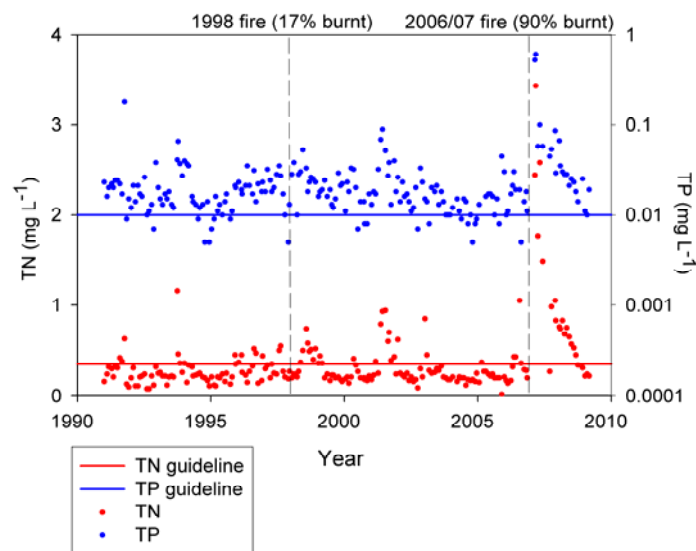


Figure 1: Monthly total nitrogen (TN) and total phosphorus (TP) concentrations measured at the Lake Glenmaggie outflow before and after bushfires in 1998 and 2006-07, Victoria. Note the difference in axis scales between TN and TP. Data accessed through the Victoria Water Resources Data Warehouse.

¹ Turbidity guideline values are from the Australian Drinking Water Guidelines (NHMRC, 2004), whereas guideline values for phosphorus and nitrogen are from the ANZECC (2000) water quality guidelines for aquatic ecosystems (lowland rivers, south eastern Australia).

There are also other reports of fire impacts that were less severe. For example, in forest streams in Kakadu National Park (Northern Territory) low severity fires resulted in a negligible change between pre-burn and post-burn levels of phosphorus, nitrogen, iron and manganese in stream water (Townsend and Douglas, 2004).

How do fires affect water quality?

Fires often trigger increased amounts of runoff and erosion in response to the pattern of immediate post-fire rainfall (Shakesby and Doerr, 2006). Figure 2 illustrates how fire can lead to more runoff and erosion in a forest catchment. Loss of vegetative cover, including reduced leaf litter on the soil surface, means that:

- more water reaches the soil surface, resulting in more runoff eroding the soil and transporting sediment, and
- raindrops impact directly on exposed soil and ash, leading to more erosion.

Combustion of leaf litter and ground cover as well as heating of the soil means that:

- soils may become more water repellent (hydrophobic), leading to more runoff, and
- ash is produced, which is detached from the soil surface and washed into streams or may block soil pores, reducing infiltration and leading to more runoff.

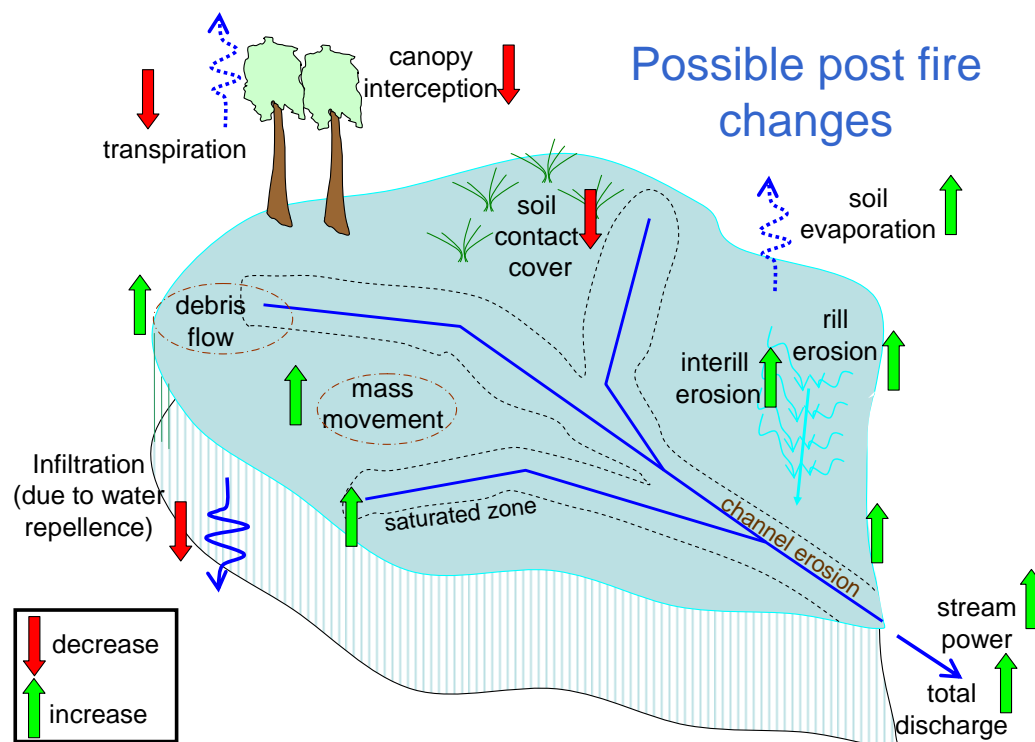


Figure 2: Changes following fire that may occur in a catchment leading to increased runoff and erosion.

As well as increasing runoff and erosion, fire can change soil chemical properties making nutrients, metals and toxins more available for transport into waterways. Fire suppression activities are also important, particularly the construction of control lines, since they may leave the soil exposed and more susceptible to erosion. The combined impact of fire and fire-fighting can lead to large increases in the amount of sediment, nutrients and other constituents (e.g. ash or metals) entering our streams and reservoirs during post-fire storms.



Figure 3: Channel scoured by debris flow (upper Buckland catchment, Victoria). Photo: G. Sheridan.



Figure 4: Flow downstream of post-fire debris flows (Wellington River, Victoria). Photo: A. Murphy, Melbourne Water.

Pollutants are eroded and washed into streams by overland flow, moving downslope in small channels (called rills) or as unconcentrated flow. The largest water quality impacts result from high magnitude events such as localised flash floods, large floods and debris flows (Smith et al., 2011). Debris flows are a type of erosion event involving a fast moving mass of unconsolidated, saturated debris (Figures 3 and 4; Nyman et al., 2011). In Victoria, post-fire debris flows have been observed in severely burnt, steep upland catchments in response to intense rainfall events (Nyman et al., 2011). They cause large amounts of channel scour and may deliver large quantities of sediment downstream.

What factors make post-fire water quality impacts more severe?

Studies show that the impact of bushfires on water quality can be highly variable. Perhaps the most significant factor influencing this variability is post-fire rainfall. The largest impacts on water quality following fire often occur in response to large and intense rainfall events (Smith et al., 2011). For example:

- two large storm events eroded most of the annual sediment output for two small headwater catchments of the East Kiewa River in the first year after fire in north-eastern Victoria (Lane et al., 2006)
- a very high intensity, short duration storm event in the burnt Upper Buckland River catchment in north-eastern Victoria generated debris flows resulting in very high sediment concentrations (59,000 mg L⁻¹ or 129,000 NTU) (Leak et al., 2003). Further downstream, dissolved oxygen concentrations fell to almost zero levels (EPA, 2003)
- a large rainfall event in the burnt catchment area of the Gippsland Lakes in eastern Victoria caused flooding that resulted in very high nutrient concentrations and contributed to a prolonged algal bloom in the Lakes (Cook et al., 2008), and
- an intense summer storm in the catchment area for the Ovens River in north-eastern Victoria resulted in concentrations of iron, copper, zinc, chromium, arsenic and lead that were 47, 32, >50, 40, 4 and 22 times the pre-event levels, respectively (North East Water, 2003).

In contrast, below average rainfall in the years following a fire can result in little impact on water quality. For example, much lower sediment yields were observed after fire in the Nattai catchment in the Blue Mountains in New South Wales during a period of well below average rainfall (Tomkins et al., 2007).

Aside from rainfall, studies have shown that a number of other landscape factors also contribute to the variability in water quality impacts, including:

- size and severity of the fire within the catchment
- type of erosion – e.g. debris flow, rill or interrill erosion
- size of catchment
- type of vegetation and soil
- topography, and
- time since fire.

For example, the absence of an effect on water quality following fire was attributed to the low severity of a burn in northern Australia and the low relief of the catchment (Townsend and Douglas, 2004).

In assessing post-fire water quality impacts in reservoirs, it is necessary to consider the attenuating capacity of the reservoir relative to the inflow of pollutants. This may depend on the size of the reservoir, storage levels at the time of the fire, and the extent of stratification within the reservoir. As a result, some reservoirs have shown little to no change in water quality despite high pollutant concentrations in their inflows. For example, unexpectedly low impacts were observed in Dartmouth Reservoir in Victoria (Alexander et al., 2004) and Mount Bold Reservoir in South Australia (Morris and Calliss, 2009) following fires in 2003 and 2007, respectively.

What are the main concerns for end-users of the water?

The ANZECC Guidelines (2000) provide guidance for acceptable levels of water quality constituents related to the intended uses of water. These guideline values can be applied to assess the importance of changed water quality conditions following fire.

Drinking water: The constituents of most concern following fire from a drinking water perspective are increased suspended sediment, nutrients and metals, while possible blooms of cyanobacteria (blue-green algae) after fire also present a threat to drinking water. Guideline values are frequently exceeded, especially following major rainfall events.

For other constituents (e.g. inorganic salts, organic carbon, cyanide, polycyclic aromatic hydrocarbons) post-fire maximums generally do not exceed guideline values. However, with the limited number of records available, it is difficult to draw definitive conclusions about their impacts on drinking water quality following fire.

Aquatic ecosystems: Extremely high levels of turbidity and very low dissolved oxygen concentrations resulting from post-fire erosion are possibly the greatest threat to aquatic ecosystems following fire. Other threats include increased water temperatures, increased inputs of nutrients and altered flow regimes.

Despite the immediate impacts, aquatic ecosystems in Australia are remarkably resilient to major disturbance events such as fire and often populations of aquatic flora and fauna recover quickly provided there is connectivity between affected and unaffected habitats (Lyon and O'Connor, 2008). Those species that are more vulnerable tend to have smaller, more isolated populations or are not as well-adapted to survive periods with elevated suspended sediment concentrations.

Agriculture: The major water quality concerns for agriculture following fire relate to high loads of suspended sediment and, to a lesser extent, nutrients, metals, cyanobacteria, and salts. The primary concern with suspended sediment is the increased potential for sedimentation of dams. Guideline values for agriculture in relation to phosphorus, nitrogen and various metals are generally not exceeded except during very large post-fire erosion events. Similarly, in the few studies available on the effects of fire on salt levels, for example chloride and sulfate, concentrations were well within the guideline limits. The potential for increased flooding may be of greater concern than changes to water quality.

Recreation and aesthetics: Key concerns for recreation and aesthetic values of water after fire relate to suspended sediment and cyanobacteria. Fine suspended sediment affects the visual clarity of the water. While there is no guideline value for acceptability thresholds, the poor water quality events cited in this review compromised recreational use of water and visual amenity. Cyanobacteria pose a health risk and if a bloom is triggered by fire then recreational use of water may be compromised.

What management actions can be taken to minimise post-fire water quality impacts?

There are numerous management actions that can be taken before, during and after a fire to minimise the impacts on water quality.

- **Before the fire** there can be preparations to reduce the risk of fire in water supply catchments (such as fuel reduction burning and the construction of fuel breaks), as well as risk assessments based on catchment attributes and erosion potential to identify townships whose water supply is most vulnerable were a wildfire to occur. Development of integrated fire and water quality risk management plans would enable better coordination of all management actions designed to mitigate post-fire water quality impacts.
- **During the fire** it is important that fire-fighting operations adhere to the best practices and local standards in relation to the construction of mineral earth breaks (areas cleared of ground vegetation and litter) and the application of fire retardants.
- **Following the fire** managers need to act quickly to prepare an area before it rains and particularly before intense rain. The first task is to undertake a rapid assessment of the burnt area to facilitate rapid rehabilitation of control lines, implementation of sediment control measures, commencement of erosion mitigation works and initiation of water quality monitoring programs.

What are the key knowledge gaps?

Substantial knowledge gaps exist in our understanding of water quality impacts following bushfires. Greater understanding of these impacts from regions outside south-eastern Australia is required, while further research in south-eastern Australia is also needed, given that the steep, forested highland areas in central Victoria and New South Wales are particularly prone to large, severe bushfires. Expanded stream and reservoir monitoring before, as well as after fires, would provide important information on concentrations of constituents (particularly metals, organic carbon and nutrients) less frequently measured. Furthermore, greater knowledge of post-fire erosion processes and catchment sources of key constituents would contribute to the development of models to quantify post-fire risks to water quality, as well as guiding post-fire management actions aimed at reducing water quality impacts.

References

- Alexander, S.J., Grace, M. and McKelvie, I., 2004. Effect of bushfires on receiving waters, eastern Victoria. First Interim Report to the Department of Sustainability and Environment, May 2004, Water Studies Centre, School of Chemistry, Monash University, Australia. [http://pandora.nla.gov.au/pan/47676/20050215-0000/www.dse.vic.gov.au/dse/nrence.nsf/fid/-50C870447326E485CA256ED10025C551/\\$file/Monash.pdf](http://pandora.nla.gov.au/pan/47676/20050215-0000/www.dse.vic.gov.au/dse/nrence.nsf/fid/-50C870447326E485CA256ED10025C551/$file/Monash.pdf)
- Australian and New Zealand Environment Conservation Council (ANZECC), 2000. Australian and New Zealand guidelines for fresh and marine water quality, volumes 1 and 2. Australia and New Zealand Environmental Conservation Council, Canberra.
- Cook, P., Holland, D. and Longmore, A. 2008. Interactions between phytoplankton dynamics, nutrient loads and the biogeochemistry of the Gippsland Lakes, Water Studies Centre, Monash University, Melbourne.
- EPA Victoria, 2004. River health: a snapshot of the effects of the 2003 bushfires, Melbourne. <http://www.epa.vic.gov.au/water/rivers/docs/bushfire.pdf>
- Lane, P.N.J., Sheridan, G.J. and Noske, P.J., 2006. Changes in sediment loads and discharge from small mountain catchments following wildfire in south eastern Australia. *Journal of Hydrology*, 331: 495-510.
- Leak, M., Passuello, R. and Tyler, B., 2003. I've seen fire. I've seen rain. I've seen muddy waters that I thought would never clear again. *Waterworks*, 6: 38-44.
- Lyon, J.P. and O'Connor, J.P., 2008. Smoke on the water: Can riverine fish populations recover following a catastrophic fire-related sediment slug? *Austral Ecology*, 33(6): 794-806.
- Morris, R. H. and Calliss, S., 2009. Does an emergency response protect our water reservoirs? Poster presentation, Bushfire CRC.
- National Health and Medical Research Council and the Agriculture and Resource Management Council of Australia and New Zealand (NHMRC/ARMCANZ), 2004. Australian Drinking Water Guidelines 6. National Health and Medical Research Council, Australian Government.
- North East Water, 2003. Laboratory analysis by Water ECOscience. Data report for North East Water, Wodonga, Victoria, Australia.
- Nyman, P., Sheridan, G.J., Smith, H.G. and Lane, P.N.J. 2011. Evidence of debris flow occurrence after wildfire in upland catchments of south-east Australia. *Geomorphology*, 125: 383-401.
- Shakesby, R.A. and Doerr, S.H., 2006. Wildfire as a hydrological and geomorphological agent. *Earth-Science Reviews*, 74(3-4): 269-307.
- Smith, H.G., Sheridan, G.J., Lane, P.N.J., Nyman, P., Haydon, S. 2011. Wildfires effects on water quality in forest catchments: a review with implications for water supply. *Journal of Hydrology*, 396: 170-192.
- Tomkins, K.M., Humphreys, G.S., Wilkinson, S.N., Fink, D., Hesse, P.P., Doerr, S.H., Shakesby, R.A., Wallbrink, P.J. and Blake, W.H., 2007. Contemporary versus long-term denudation along a passive plate margin: The role of extreme events. *Earth Surface Processes and Landforms*, 32(7): 1013-1031.
- Townsend, S.A. and Douglas, M.M., 2004. The effect of a wildfire on stream water quality and catchment water yield in a tropical savannah excluded from fire for 10 years (Kakadu National Park, North Australia). *Water Research*, 38(13): 3051-3058.
- Victorian Water Resources Data Warehouse, 2008. <http://www.vicwaterdata.net/vicwaterdata/home.aspx>
- White, I., Wade, A., Worthy, M., Mueller, N., Daniell, T. and Wasson, R., 2006. The vulnerability of water supply catchments to bushfires: Impacts of the January 2003 wildfires on the Australian Capital Territory. *Australian Journal of Water Resources*, 10(2): 1-16.