Institution: Plymouth University

Unit of Assessment: UoA C17 (Geography, Environmental Studies and Archaeology)

Title of case study: Wildfire threat to water resources: informing catchment management policy and practice

1. Summary of the impact (indicative maximum 100 words)

Under future climates, wildfire will exacerbate threats to water security. Our research demonstrates that burning of surface vegetation can invigorate hillslope hydrological response with marked increases in sediment and nutrient delivery to river networks and reservoirs. Negative water quality effects include high turbidity, toxic algal blooms and fish kills with implications for water supply at critical times in the water year. Through quantifying post-fire runoff and nutrient yield processes, the research has informed (i) catchment management decisions, policies and water resource risk assessment in Australia and (ii) water industry resource protection plans in the UK.

2. Underpinning research (indicative maximum 500 words)

The research detailed in this case study has been led by ***Dr Will Blake*** since his appointment as Lecturer at Plymouth University in 2003. The work had begun a year prior to this in his role as a co-Investigator on an NERC research programme with *Shakesby* and *Doerr* (Swansea University; (£95k). The research initially explored the impact of multiple wildfires in Sydney's water supply catchments on hydro-geomorphological processes. This involved collaboration with Australian partners *Wallbrink* (Commonwealth Scientific and Industrial Research Organisation (CSIRO) and *Humphries* (Macquarie University), along with funding from Sydney Catchment Authority (£72k). The research theme has been developed during the past decade with (i) further NERC funded research by *Blake* after major wildfires in Greece (2007; £55k); (ii) Royal Society funding to support *Blake's* position as visiting scientist at CSIRO (2007) and a knowledge exchange visit to University of Melbourne (2007), (iii) water industry support of postgraduate research at Plymouth on UK water supply catchments (2010 – present) and (iv) the appointment at Plymouth of *Dr Hugh Smith* (Marie Curie Fellow 2011-13) from University of Melbourne, with international expertise in wildfire and water quality (£144k).

The research focuses on environmental processes in burnt catchments and how these impact on downstream water quality. Distinctive insights into post-fire processes have been gained though measurement of soil hydrological properties, runoff generation, sediment sources and downstream sediment and nutrient transfer. Within the NERC-funded Sydney-based collaboration soil erosion research (e.g. Doerr et al. 2006) initially demonstrated dramatic changes in surface runoff generation processes under different intensities of fire. Extreme soil temperatures rendered a surface soil layer prone to mass movement after prolonged rainfall with hypothesised mobilisation of large quantities of nutrient rich material to downstream waterbodies. This hypothesis was tested by tracer studies (Blake et al., 2006, 2009; Wilkinson et al., 2009) which, for the first time, explored the use of fire-modified soil properties to elucidate sediment and phosphorus sources and yield. Results demonstrated a switch in dominant sediment generation processes from long-term gully and channel development inputs to mass wasting of burnt, nutrient-rich ash and topsoil. These processes led to significant quantities of nutrient rich material being transferred to river networks and, over a period of years, to the water column of a downstream reservoir where water quality was threatened by enhanced nutrient inputs. Research in burnt Mediterranean coniferous forest in Greece (Blake et al., 2010) took this research one step further and provided quantification of the potential bioavailability of particulate phosphorus in sediment transported downstream, hence making the connection between (1) transfer of burnt material from slopes to channels and (2) impacts of this material on water quality, especially the risk of toxic algal blooms downstream. These issues are now being explored in upland UK catchments. Here the potential for moorland and pine plantation fires to deliver sudden, discrete inputs of dissolved and particulate Phosphorus to warm reservoir waters are of increasing concern to the water industry.

3. References to the research (indicative maximum of six references)

Shakesby, R.A., Chafer, C., Doerr, S.H., Blake, W.H., Humphreys, G.S. and Wallbrink, P.J. (2003). Fire severity, water repellency characteristics and hydrogeomorphological changes following the Christmas 2001 Sydney forest fires. *Australian Geographer* 34, 147-175 .

Peer reviewed journal (impact factor 0.691). The article has been cited 50 times (WoS).

Doerr, S.H., Shakesby, R.A., Blake, W.H., Chafer, C.J., Humphreys, G.S., Wallbrink, P.J. (2006). Effects of differing wildfire severities on soil wettability and implications for hydrological response. *Journal of Hydrology* 319: 295-31.

Peer reviewed journal (impact factor 2.964). The article has been cited 93 times (WoS).

Blake, W.H., Wallbrink, P.J., Doerr, S.H., Shakesby, R.A. & Humphreys, G.S. 2006. Magnetic enhancement in fire-affected soil and its potential for sediment-source ascription. *Earth Surface Processes and Landforms* 31, 249–264. ISSN: 0197-9337.

Peer reviewed journal (impact factor 2.49). The article has been cited 28 times (WoS).

Blake WH, Wallbrink PJ, Wilkinson S, Humphreys GS, Doerr SH, Shakesby RA, Tomkins K. (2009). Deriving hillslope sediment budgets in wildfire-affected forests using fallout radionuclide tracers. *Geomorphology* 104, 105-116.

Peer reviewed journal (impact factor 2.552). The article has been cited 25 times (WoS).

Wilkinson S.N., Wallbrink P.J., Hancock G.J., Blake W.H., Shakesby R.A., Doerr S.H. (2009) Fallout radionuclide tracers identify a switch in sediment sources and transport-limited sediment yield following wildfire in a eucalypt forest. *Geomorphology* 110 (3-4), 140-151.

Peer reviewed journal (impact factor 2.552). The article has been cited 22 times (WoS)..

Blake W.H., Theocharopoulos S.P., Skoulikidis N., Clark P., Tountas P., R. Hartley, Amaxidis Y. (2010). Wildfire impacts on hillslope sediment and phosphorus yields. *Journal of Soils and Sed*., 10(4), 671-682.

Peer reviewed journal (impact factor 1.965). The article has been cited 6 times (WoS).

4. Details of the impact (indicative maximum 750 words)

This research initiated changes in post-fire catchment management, bushfire management and forest protection strategies in Sydney's water supply areas. In April 2008, the Sydney Catchment Authority (SCA) produced a 'Guideline to the implementation of the SCA policy on fire management for water quality and quantity'. To quote the SCA's (Senior Spatial Analyst for Catchment Indicators), "the research [of Blake and colleagues] was fundamental in developing the policy" (statement from SCA, 2011) which relies on sound knowledge of runoff and sediment delivery processes. Three key policy principles most relevant are outlined below followed by details of the chain linking them to our research:

a) *Policy Principle 1: Minimise the area of bushland in important catchment areas burned by unplanned, high intensity bushfire.* Within this, the impacts of rainsplash and slope wash on hillslopes which "input organics and fine sediment into streams" and "fine sediment in the water column which can impact chemical and physical properties of the stored water, such as turbidity, dissolved oxygen and nutrient levels" are identified.

b) *Policy principle 2: Retain the integrity of riparian areas through protection from mechanical interference and the impact of fires.* Here the function of riparian (riverside) forest areas as

"inhibitors of sediment and nutrient to water storage in times of runoff" are flagged and the need to monitor fuel loads in these zones to protect them from wildfire are outlined.

c) *Policy principle 6: Implement response and recovery techniques to mitigate water quality impacts in areas severely disturbed by bushfire.* Here the need for rapid response to implement "remediation and pollution control strategies ... in critical areas to reduce erosion and sedimentation into major drainage features" are highlighted.

All three of these areas outlined within the 2008 Policy Document are linked directly to our research through citation of a key scientific summary document (Chafer, 2007) published by the eWater Cooperative Research centre (Australia's leading water resource management advisory group). The eWater Cooperative Research Centre website "*aims to bring together information about effects of bushfire on catchments and the water resources they collect ... to assist land and water managers with their impact assessment and rehabilitation planning*". Chafer (2007) distils the scientific evidence from our research articles (which are cited within it) and reports for assimilation by policy makers via the website gateway. It is cited in the 2008 SCA document detailing new policy principles and linked directly to our research by the statement of SCA Senior Spatial Adviser (quoted above). Policy principle 2 was further emphasised in the co-authored Technical Report by Wilkinson et al. (2007) which was linked to a workshop delivered by Wilkinson, Blake and Wallbrink at SCA headquarters during *Blake's* scientific visit to CSIRO. The workshop was attended by key SCA catchment managers at the time the 2008 policy document was being written and is linked by the 2011 testimonial of *Dr Chafer* quoted above. The influence of our research is evidenced through use of these and other research outputs in the 2010 Audit of the Sydney drinking water catchment which identifies areas to be targeted for additional action to protect water resources. Its continued relevance is highlighted by the October 2013 wildfires in the Sydney catchment area.

The reach of the research impact goes beyond the Sydney water supply area and helps underpin policy and changes to management operations elsewhere in Australia; e.g. in the state of Victoria. Our wildfire and water quality research contributes scientific underpinnings of key policy guideline documents developed by Assoc. Prof. *Patrick Lane's* group at Melbourne. This was developed during a knowledge transfer visit by Blake to Melbourne in 2007. *Patrick Lane* is a key policy advisor to Melbourne Water on post-fire catchment management who has been commissioned to develop hydrological knowledge and models to support management policy. Key links to the Sydney work are Smith et al. (2010, 2011) which use our research to inform policy and best management practice guidelines for protection of water supplies after wildfire. As outlined by in a letter from this policy advisor (University of Melbourne, 2013), "The Sydney-based research has helped inform models for assessment of wildfire risks to water supply, through the process understanding gained during the SCA project and collaborative discussion/workshops between the Sydney and Victorian researchers. These models are directly influencing pre and post fire catchment management activities of Melbourne Water wherein rapid response teams are mobilised to put erosion and sediment delivery mitigation measures in place in the areas predicted to be at greatest risk". Coherence with SCA policy principle 6 exemplifies the clarity of the messages to stakeholders from our process research.

The international reach of the research is further exemplified by the influence of the research on water resource management in upland UK where there is concern about coniferous plantation and moorland fires in upland reservoir catchments, as recognised by Southwest Water. As *Martin Ross*, Environmental Manager of Southwest Water says "research studies undertaken in Australia and Greece to quantify sediment and phosphorus yield from burnt forested slopes have been instrumental in raising our awareness of the risk posed by wildfire" (Statement from Environmental Manager, South West Water, 2012). Furthermore, "South West Water is explaining its concerns in public meetings and in discussions with Defra, Ofwat and environmental regulators in relation to global warming. The company is also taking [the research] into account in the development of its water resource protection plans for 2015 to 2020 and beyond. The research undertaken by Plymouth University has helped with the company's initial design work on the establishment of Paid Ecosystem rewards for upland farmers whose stock help to control scrub growth and wildfire risks" (Statement from Environmental Manager, South West Water, 2012).

5. Sources to corroborate the impact (indicative maximum of 10 references)

Australian catchment management policy

Chafer CJ 2007. *Wildfire, Catchment Health and Water Quality: a review of knowledge derived from research undertaken in Sydney's Water Supply Catchments 2002-2007*. eWater, Australia. Documents the chain linking the research to policy and is cited by Sydney Catchment Authority 2008. *Guideline to Implementation of the SCA Policy on Fire Management for Water Quality and Quantity*. TRIM Ref: D2008/01167.

Statement from Senior Spatial Analyst for Catchment Indicators, Sydney Catchment Authority, 2011. Details impact of Sydney water supply catchments wildfire research on SCA catchment management policy.

Impacts on water quality by sediments and nutrients released during extreme bushfires: Report 4: Impacts on Lake Burragorang. Report for the Sydney Catchment Authority, 2007. CSIRO Land and Water Science Report 6/07. February 2007 CSIRO Land and Water. Underpins claims made in statement from SCA analyst.

State of New South Wales and Department of Environment, Climate Change and Water NSW, 2010. *2010 Audit of the Sydney Drinking Water Catchment*. Report to the Minister for Water.

Wilkinson, S., Wallbrink, P., Blake, W., Shakesby, R. and Doerr, S. (2007). Impacts on water quality by sediments and nutrients released during extreme bushfires: Summary of findings. CSIRO Land and Water Science Report 38/07, Canberra.

Australian best practice guidance to industry

Statement of Professor of Forest Hydrology, University of Melbourne regarding impact of Sydney catchment wildfire and water quality research. 26/06/2013

Smith, H.G. Sheridan, G.J., Lane, P.N.J., Bren, L. 2010. Best Management Practice guidelines for mitigating impacts on erosion and water quality from post-fire salvage harvesting of plantation forests. Cooperative Research Centre for Forestry Technical Report 207. CRC Forestry, Sandy Bay, Tasmania, Australia. http://www.crcforestry.com.au/publications/downloads/TR207-revised.pdf (last accessed 19/06/13)

Smith, H.G, Cawson, J., Sheridan, G.J., Lane, P.N.J. 2011. Desktop review- impact of bushfires on water quality. Report to the Commonwealth Department of the Environment, Water, Heritage, and the Arts (DEWHA). Department of Forest and Ecosystem Science, The University of Melbourne, Australia available online at http://www.environment.gov.au/water/publications/quality/impact-of-bushfires.html (last accessed 16/06/2012)

UK Catchment management policy

Statement from Environmental manager, Southwest Water, Exeter, UK. 25/07/2012