Implementing CRC research: development of a tool for assessing post-fire hydrologic risk

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ABSTRACT

An output of the Bushfire CRC was the development of methods for assessing post-fire hydrologic risks to human life, infrastructure, and water quality. The work was delivered as part of the Fire in the Landscape research theme and built on many years of research conducted by the Forest Hydrology research group at the University of Melbourne in collaboration with the Bushfire CRC, Melbourne Water and DELWP.

The Bushfire CRC project was identified for research utilisation by CRC end-users and a face-to-face meeting between end-users, researchers and AFAC research utilisation staff was arranged. The meeting resulted in the development of a three phase research utilisation plan. The first phase was a nationwide assessment of hydrologic risk related to wildfire and the development of a set of national guidelines based on general principles. This work was resourced by AFAC and delivered in 2014. Phase two was managed by ACT Parks and Conservation Service and aimed at advancing the generalised risk guidelines developed for AFAC and applying them to ACT catchments. This was completed in 2016 with the delivery of a suite of GIS tools that built on the algorithms that were developed for the Bushfire Rapid Risk Assessment Teams in Victoria. Additional research - phase three - could parameterise models for specific catchments, with the aim of delivering quantitative information on the probability and magnitude of post-fire erosion.

The project has generated some lessons about the research utilisation process:

1. End-users must be clear about what they need and have a sound technical understanding of the research.
2. All parties need to have a common picture of what is to be developed and how it is to be used.
3. Researchers should be prepared to synthesise their work such that the complexity of processes does not impede the development of practical tools.

INTRODUCTION

Heavy rain in areas burnt by bushfire can mobilise enormous volumes of sediments and nutrients into rivers and water reservoirs, threatening the quality and supply of water to Australia's capital and regional cities and damaging freshwater ecosystems (Sheridan et al. 2009; Nyman et al. 2011). This is because burned headwater catchments contain large amounts of ash sediment and debris that is readily flushed into rivers and water supply reservoirs by surface runoff. High sediment loads from debris flows cause high turbidity and water contamination due to increased nutrient and metals from pollutants in the runoff (Nyman et al. 2015; Langhans et al. 2017).

This type of contamination occurred from post-fire debris flows after the Canberra fires in 2003, resulting in water restrictions in the ACT (White et al. 2006) until a new water treatment plant was constructed. Similar contamination occurred in the Ovens River after the Eastern Victorian alpine bushfires in 2003 and in Lake Glenmaggie after the 2007 bushfires in Victoria. Serious post-fire water quality issues have also been documented in the Nattai Catchments near Sydney and the Lofty Ranges near Adelaide. These scenarios from various landscapes across south eastern Australia highlight the importance of considering water quality issues when managing fire in high value water-supply catchments (Nyman and Sheridan, 2014).

FIGURE 1 - RASIED TURBIDITY IN A MOUNTAIN CREEK IN THE ACT FOLLOWING HIGH INTENSITY FIRE

RESEARCH

The problem that fires pose to water quality was recognised by fire and land management agencies represented on the former Bushfire CRC. In response, the CRC commissioned the Forest Hydrology research group of the University of Melbourne to investigate the effects of forest fire on catchment processes. The project was part of the Fire in the Environment theme which ran from 2010-2014. Research investigated how fire severity and rainfall intensity in steep hilly landscapes contributes to sedimentation and pollution in forested water supply catchments in south eastern Australia (Bell et al. 2014; Jones et al. 2014). The aim was to deliver findings that could help inform and guide development of tools and resources for land and fire managers to assess and address risks to critical water assets in forested catchments. The work built on many years of research conducted by the Forest Hydrology research group in collaboration with Melbourne Water and Victorian Department of Environment, Land, Water and Planning (DELWP; e.g. Sheridan et al. 2009; 2011).

RESEARCH METHODS

The research addressed two key questions. 1) What are the real risks to uninterrupted water supply if catchments are burnt by bushfires. 2) Can the risk be reduced with prescribed fire? The scientific methods included reviews of the international research literature, surveys of extreme erosion events and field experiments to quantify the relationships between fire severity, aridity and post-fire erosion (Nyman et al. 2011). The field studies encompassed a wide range of forest environments in Victoria burned during the 2009 Black Saturday bushfires.

RESEARCH OUTPUTS

The research showed that at the study site water quality risk was primarily associated with slope, fire severity and aridity. Risk increased on steeper slopes, at higher fire severities and in drier landscapes. The relationships between the factors were characterised in a series of models and published in international journals (Nyman et al. 2013a; 2013b; 2013c; 2015; Noske et al. 2016; Sheridan et al. 2016; Langhans et al. 2017).

Another key outcome from the research was that the results showed the risks to water quality are largely associated with large-magnitude events that are threshold driven. So during most erosion events the risks to water quality are relatively small. But in a few cases the combination of rainfall intensity, fire severity and slope result in extreme events such as debris flows and these are the ones most likely to have consequences for water supply and infrastructure. The focus of model development is therefore to represent the conditions when thresholds of extreme events are exceeded.

SCIENCE TO ACTION

Utilisation of the research commenced with a meeting between the lead end users, researchers and AFAC. A key issue going into the meeting was: to what extent can novel research outputs from a Victorian catchment be applied to the landscapes of AFAC members which span Australia and New Zealand? The challenge was to make practical sense of the science and translate it so that the value was maximised for all AFAC members (AFAC, 2017).

The solution was found in recognising that the validity of the detailed knowledge obtained from the study site decreased as the domain over which it was applied increased. This was represented in a matrix that aligned management objectives against the state of knowledge and data availability (Figure 2). Quantitative predictions about the amount of sediment that was likely to be produced following fire were valid for the study site. Qualitative predictions about hydrologic risk were valid for similar landforms with the same hydro-geomorphic properties. In light of this matrix it was also established that the broad assessment of risk associated with bushfire could be carried out at a landscape scale across Australia and New Zealand using existing data and models. The resulting research utilization plan had three phases reflecting the stages identified in the matrix.

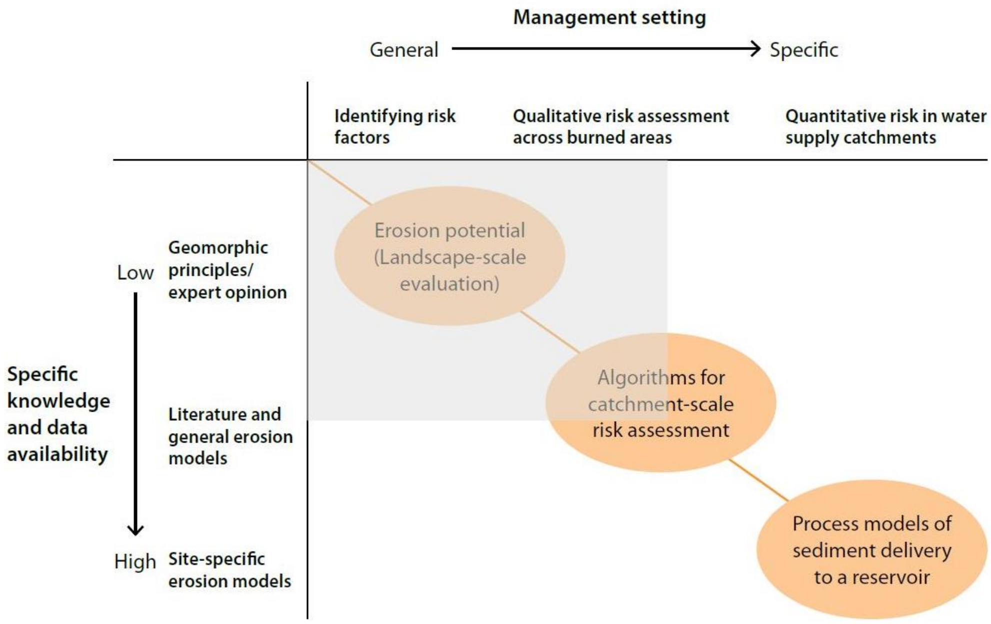

FIGURE 2 - THE TYPES OF MODELS FOR RISK ASSESSMENTS VARY DEPENDING ON THE MANAGEMENT SETTING (TOP AXIS) AND THE SCIENTIFIC KNOWLEDGE (LEFT AXIS) OF THE UNDERLYING HYDRO-GEOLOGICAL PROCESSES. THIS DIAGRAM ILLUSTRATES HOW SCIENCE GAINED FROM ONE SPECIFIC SITE COULD BE TRANSLATED GENERALLY FOR APPLICATION IN DIFFERENT CONTEXTS. THE SHADED AREA REPRESENTS THE REGION OF THE SCIENCE-MANAGEMENT SPACE THAT WAS TARGETED IN THE FIRST PHASE OF UTILISATION.

PHASE ONE: NATIONAL GUIDELINES

The first utilisation product, funded by AFAC, was an Australia and New Zealand wide assessment of erosion risk associated with wildfire (Nyman and Sheridan, 2014). The work assessed the post-fire erosion potential in water catchments in every Australian

State and Territory and New Zealand and was accompanied by generic guidelines for evaluating risk to water quality. Spatial data generated during the project were distributed to each jurisdiction and the report was made available to AFAC members from the AFAC website.

PHASE TWO: RISK ASSESSMENT TOOLS FOR THE ACT

The second utlilisation product, funded by ACT Parks and Conservation Service, was a suite of GIS tools that generate post-fire risk assessments of erosion, flooding and water quality for the ACT. The tools were developed by combining the results of the CRC research with other work funded by the Victorian Department of Environment, Land, Water and Planning for use by the Bushfire RRATS in Victoria. The tools were trialled successfully during the 2015-2016 bushfire season and are in use in the ACT.

PHASE THREE: QUANTITATIVE PREDICTIONS

Implementation of the third phase of utilisation in the ACT requires the calibration of models to deliver quantitative predictions. Data for this purpose are being collected in conjunction with the burning program. Rainfall gauges, turbidity monitors, streamflow monitors and sediment traps (Figure 3) are being installed in suitable locations as soon as possible after burns to gather these data.

FIGURE 3 - A SEDIMENT TRAP AND A V-NOTCH WEIR INSTALLED IN A BURNED GULLY

OPERATIONS

ACT Parks and Conservation Service uses the post-fire hydrologic risk tools for two purposes: 1) to plan prescribed burning operations; and 2) to target drainage and infrastructure works in identified risk-prone areas with significant water assets and important ecosystems.

CONDUCTING A FUEL REDUCTION BURN

The work flow for incorporating water quality risk into a prescribed burn has four stages illustrated using the Wombat Creek fuel reduction burn conducted by ACT Parks and Conservation Service in April 2017:

1. assessment of the proposed burn for erosion sources (Figure 4);
2. completion of the burn plan taking account of water quality risk (Figure 5);
3. assessment of fire severity (Key and Benson, 2006; Leavesley et al. 2015; Figure 6); and
4. assessment of the post-fire hydrologic risk using the tools (Figure 7).

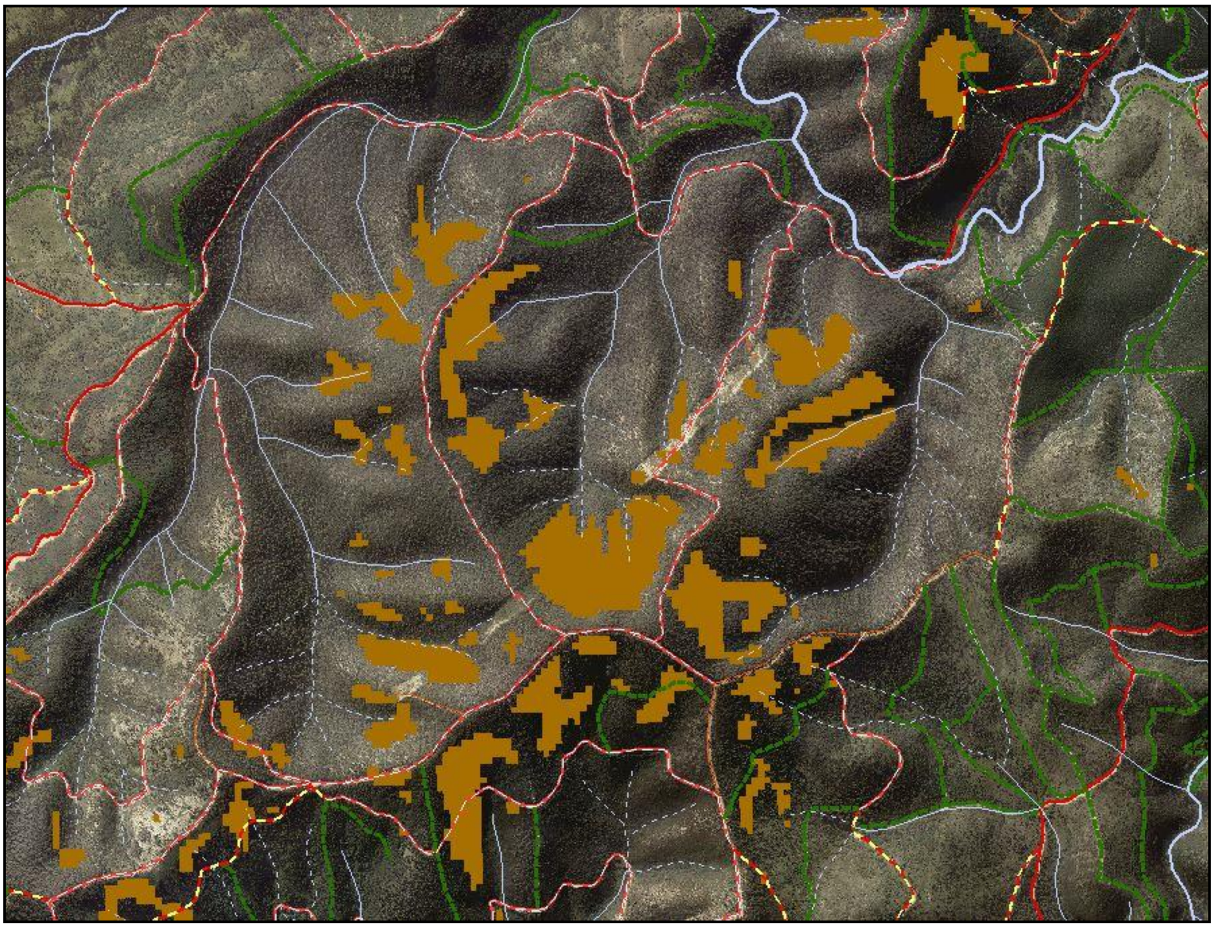

FIGURE 4 - POTENTIAL SOURCES OF DEBRIS FLOW WITHIN THE WOMBAT CREEK BURN; EROSION SOURCE AREAS ARE INDICATED BY BROWN SHADING

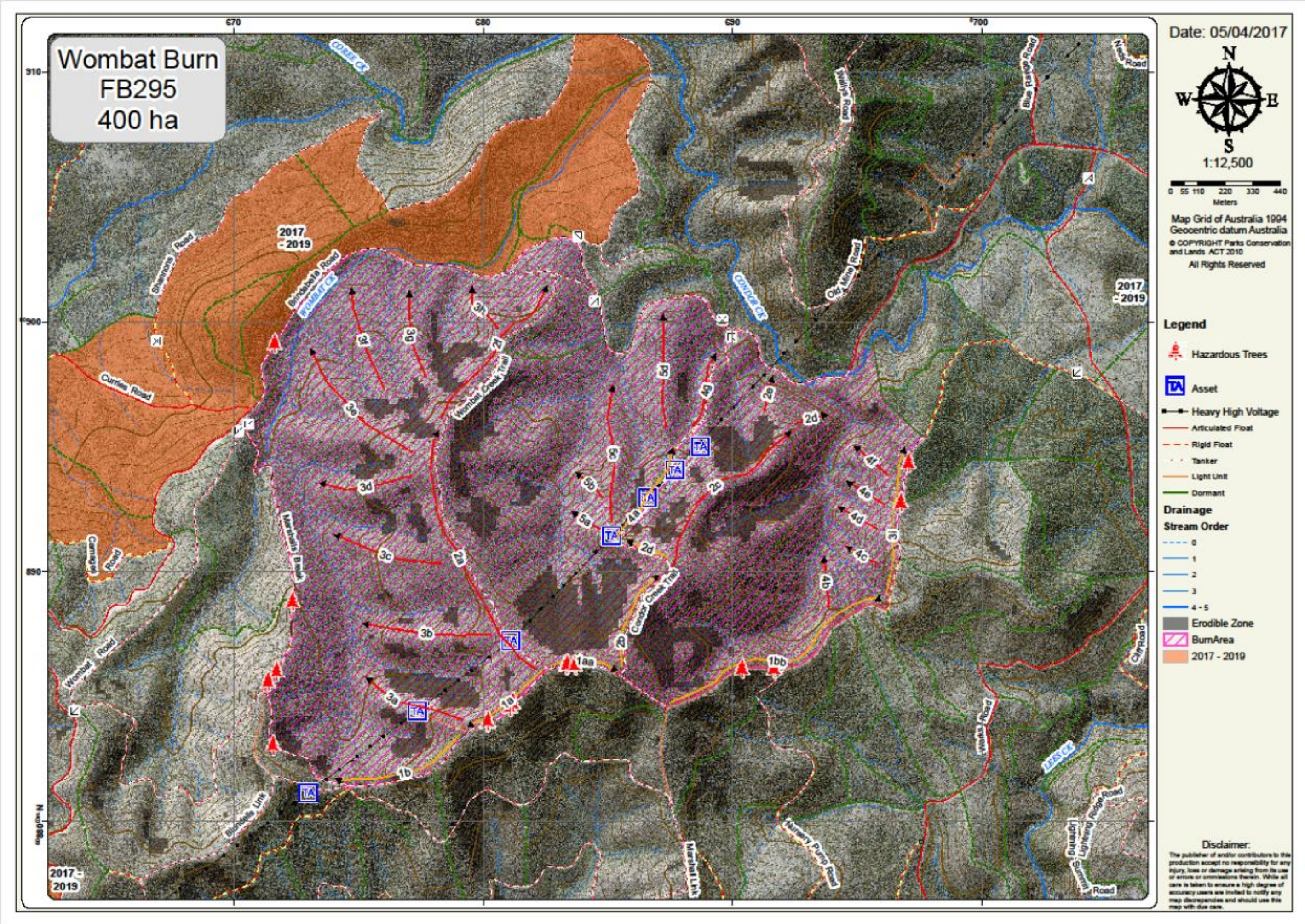

FIGURE 5 - BURN MAP FOR THE WOMBAT CREEK BURN. PINK CROSS-HATCHING INDICATES THE FIRSGROUND; BROWN SHADING INDICATES POTENTIAL SOURCES OF EROSION; RED ARROWS INDICATE THE IGNITION PLAN. THE IGNITION PATTERN WAS DESIGNED TO MINIMISE BURNING OVER THE POTENTIAL EROSION SOURCE AREAS ON SOUTH-EASTERN ASPECTS OF THE BURN

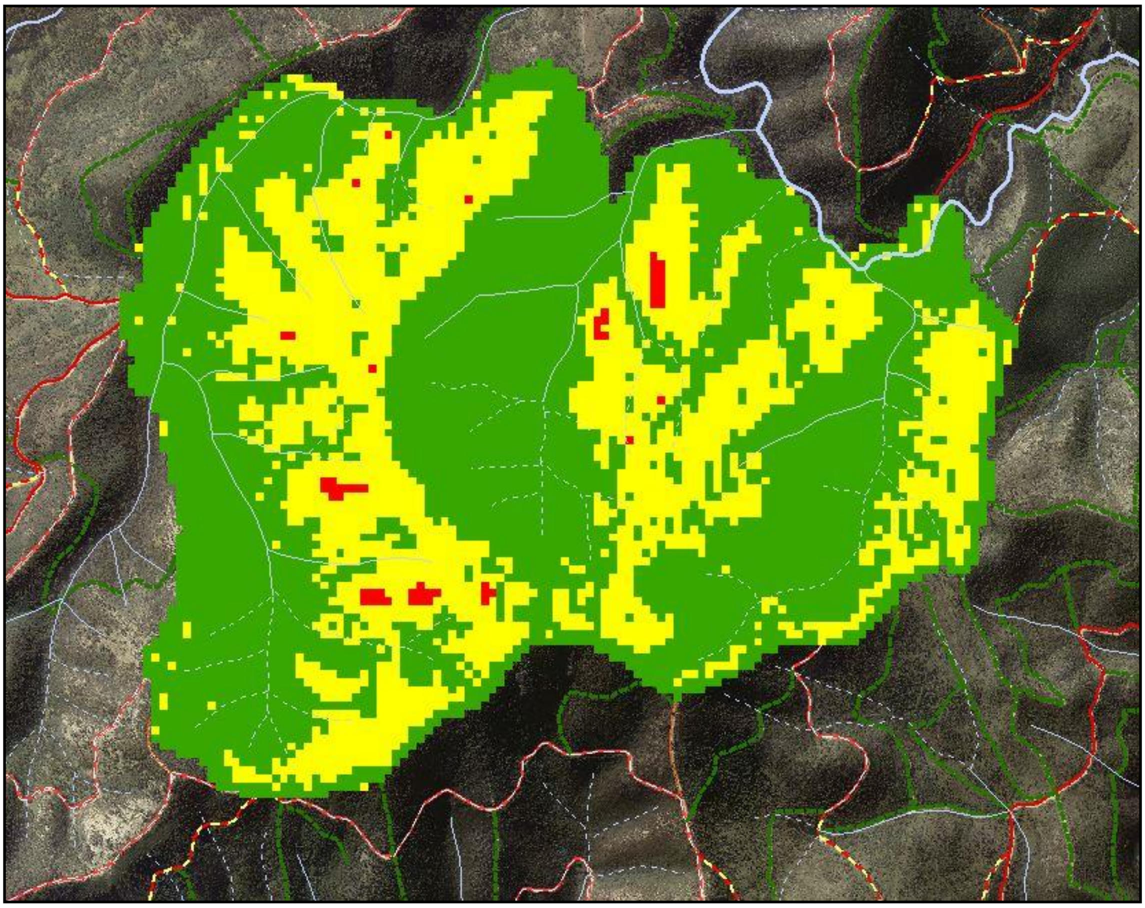

FIGURE 6 – FIRE SEVERITY ASSESSMENT OF THE WOMBAT CREEK BURN USING THE FIREMON METHOD DEVELOPED BY THE UNITED STATES FOREST SERVICE AND ADAPTED FOR THE ACT. GREEN INDICATES UNBURNT; YELLOW INDICATES MINIMAL BURN AFFECTS TO THE CANOPY; AND RED INDICATES CANOPY SCORCH OR CONSUMPTION. THE OBJECTIVE OF MINIMISING BURNING WITHIN POTENTIAL EROSION SOURCE AREAS WAS ACHIEVED.

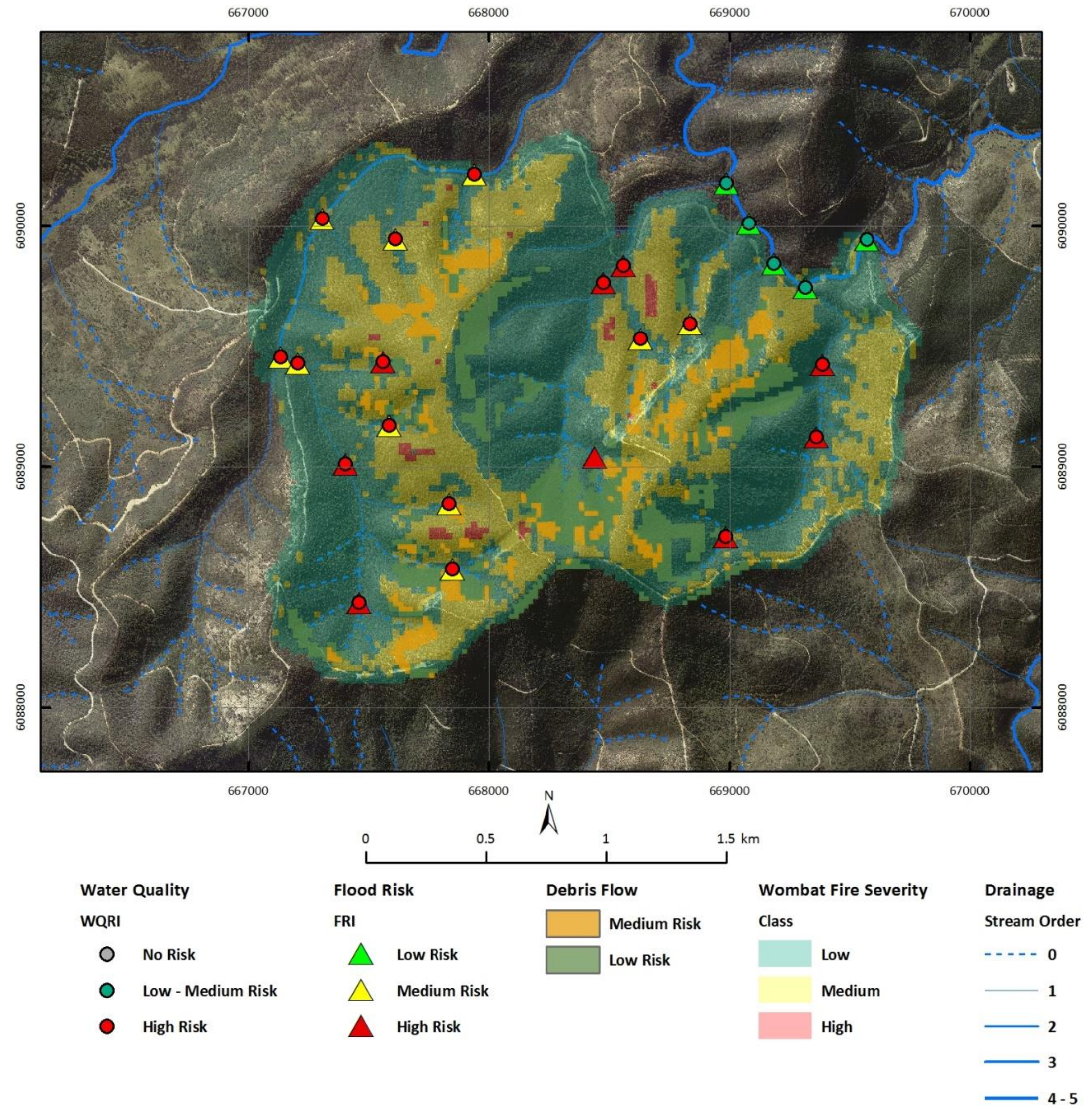

FIGURE 7 - POST-FIRE HYDROLOGIC ASSESSMENT OF THE WOMBAT CREEK BURN. THE BURN WAS CONDUCTED IN STEEP TERRAIN WITH RELATIVELY HIGH RISK OF POST-BURN HYDROLOGIC AFFECTS. THE BURN INCREASED THE RISKS BUT THE AFFECTS WERE LOCALISED TO THE BURN AREA SO THE AFFECT AT THE NEARES MAIN STREAM, CONDOR CREEK, WAS LOW.

IDENTIFYING RISK PRONE AREAS AFTER A WILDFIRE

The identification of hydrologic risk prone areas following a fire is a two stage process requiring an assessment of fire severity (Figure 8, 9) and an assessment of the post-fire hydrologic risk (Figure 10, 11, 12).

FIGURE 8 – THE BRANDY FLAT BURN ESCAPED CONTAINMENT ACROSS A CREEK AND BURNED AT HIGH INTENSITY CAUSING FULL CANOPY CONSUMPTION OR SCORCH OVER A WIDE AREA.

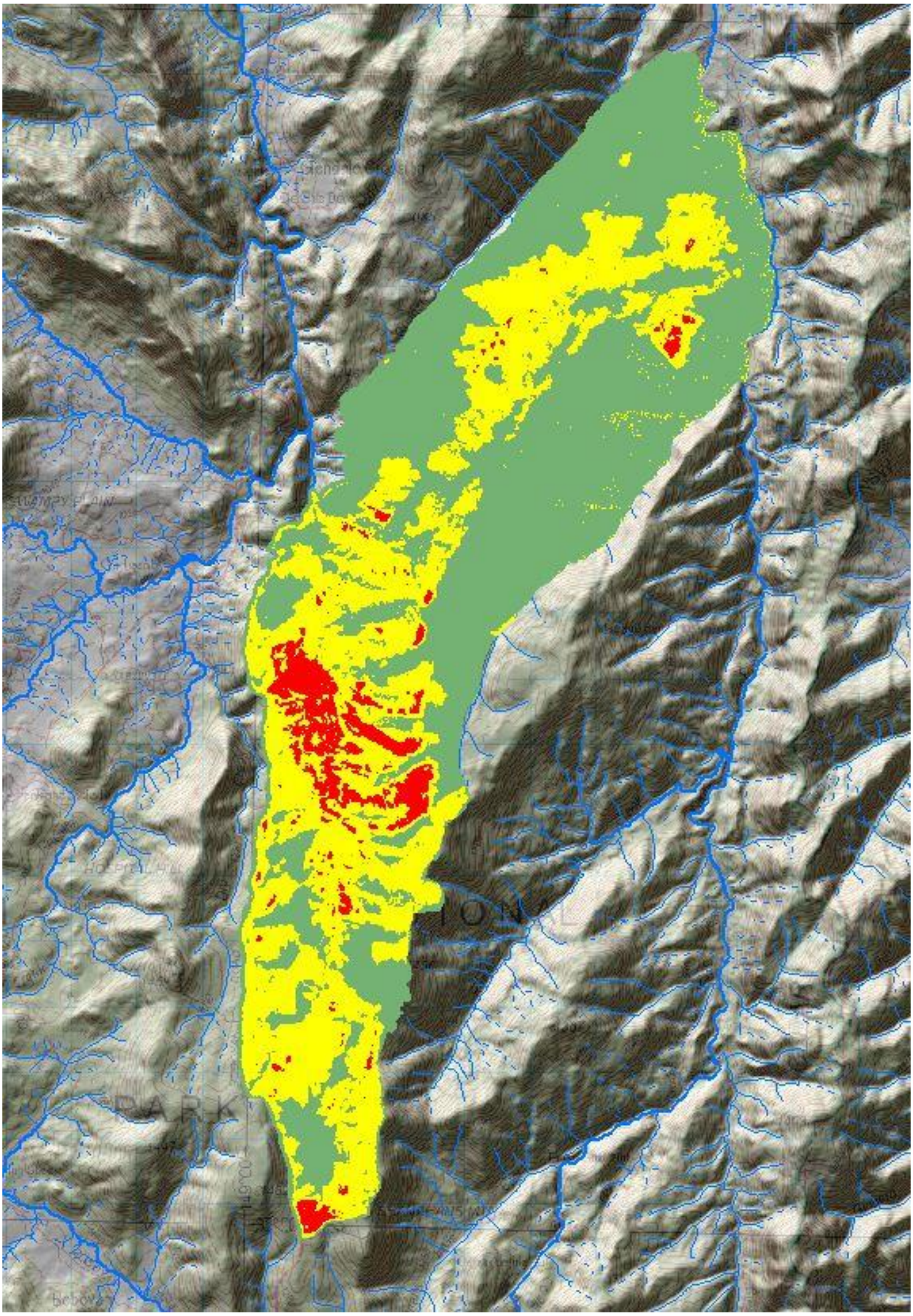

FIGURE 9 –FIRE SEVERITY ASSESSMENT OF THE BRANDY FLAT BURN USING THE FIREMON METHOD ADAPTED FOR THE ACT. THE BURN WAS CONDUCTED IN APRIL 2016 AND ESCAPED CONTAINMENT ACROSS A CREEK. THE FIRE THEN BURNED AT HIGH INTENSITY CAUSING FULL CANOPY CONSUMPTION OR SCORCH OVER A WIDE AREA. GREEN INDICATES UNBURNT; YELLOW INDICATES MINIMAL BURN AFFECTS TO THE CANOPY; AND RED INDICATES SUBSTANTIAL CANOPY SCORCH OR CONSUMPTION.

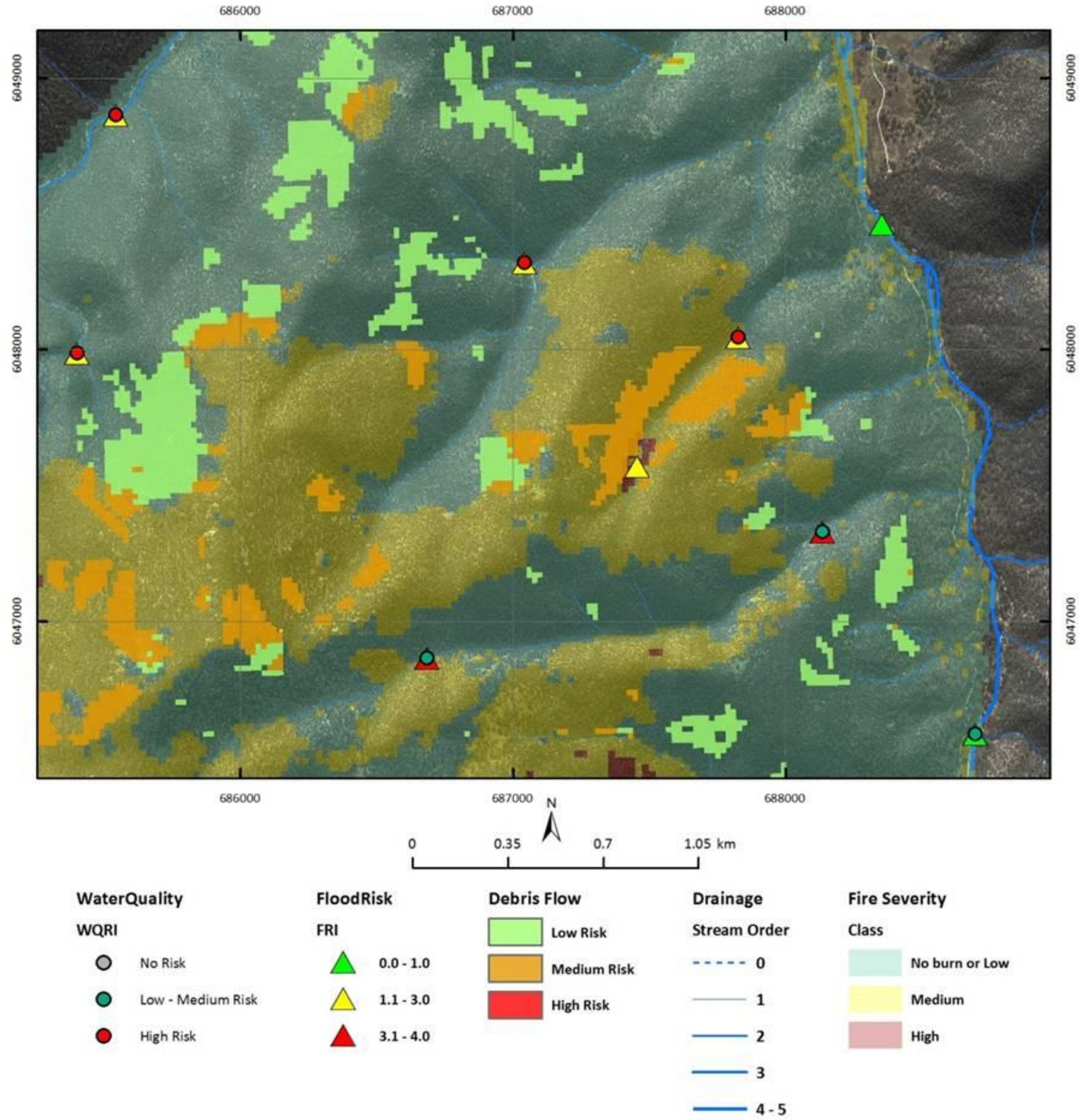

FIGURE 10 - POST-FIRE HYDROLOGIC ASSESSMENT OF THE NORTHERN END OF THE BRANDY FLAT BURN. THE BURNED GULLY IN THE CENTRE OF THE PICTURE WAS SUBJECT TO EROSION DURING AN INTENSE STORM EVENT TWO WEEKS AFTER THE BURN. THE ASSESSMENT SHOWS INCREASED HYDROLOGIC RISK IN THE GULLY BUT ONLY LOW RISK IN THE NAAS RIVER WHICH IT FLOWS INTO.

FIGURE 11 - A BURNT HILLSIDE THAT WAS THE SOURCE OF EROSION FOLLOWING THE BRANDY FLATE BURN IN THE ACT 2016

FIGURE 12 – SEDIMENTATION IN THE NAAS RIVER ACT 2016 AFTER THE BRANDY FLAT BURN. THE BOULDERS IN THE BACKGROUND ARE FROM A PREVIOUS AND MUCH LARGER EVENT POSSIBLY ASSOCIATED WITH BUSHFIRES IN 2003. ERODED MATERIAL CONSISTS OF ASH, ORGANICS (RIGHT TOP) AND MINERAL SOIL (RIGHT BOTTOM).

CRITICAL SUCCESS FACTORS

The critical factors in improving the management of post-fire hydrologic risk were the creation of a strong researcher-end user partnership, appreciation of the science and research methods and a shared commitment to collaborative discovery in the utilisation phase (AFAC, 2017).

There are three key lessons from this research utilisation process.

1. ACT Parks and Conservation Service staff undertook the lead end-user role during the BCRC research phase of the project and were motivated to do this because a high proportion of the ACT is water catchment. This meant there was end user involvement early in the project ensuring that researchers were aware at the outset of the context in which the bushfire sector would need to use the information.
2. Continuous engagement in the partnership made end users comfortable supporting the project as it travelled the path of investigative discovery. This was important because the results of research are by definition uncertain, so it is not usually clear where a project will lead or what might be delivered at the end.
3. The shared commitment to collaborative discovery in the utilisation phase allowed the complexity of the research models to be simplified for operational use in a way that maintained the quality of the information. This type of work can be particularly challenging for researchers whose research work typically involves a focus on details and a concomitant expansion of complexity.

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A SEDIMENT DEPOSIT ADJACENT TO A MOUNTAIN CREEK FOLLOWING A BURN IN THE ACT

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