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NATURAL HAZARD MITIGATION DECISION SUPPORT SYSTEM

Annual project report 2015-2016

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Cover: A flooded road in Victoria
Credit: Country Fire Authority

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Decision support systems (DSS) that contain integrate models for the assessment of natural hazard mitigation options are an important component of robust, transparent, and long-term mitigation planning. Integrated modelling of underlying social, environmental, and economic systems is required to take into account system dynamics, and to explore the implications of future changes, such as changes in demographics, land use, economics and climate. Consequently, a generic decision support system for the long-term planning for natural disaster risk reduction is being developed through the Bushfire and Natural Hazards Cooperative Research Centre.

The project consists of implementing an iterative development and use cycle across three different case studies. The development aspect of this cycle focuses on creating a generic framework for the integration of models to answer policy relevant questions, in this case for improved understanding and reduction of disaster risk. The use process tailors this framework to each of three case study regions, Greater Adelaide, Greater & Peri-Urban Melbourne and Tasmania.

The focus of 2015-2016 has been on the use cycle for Greater Adelaide, with a first prototype of the software application presented to end-users and five exploratory scenarios qualitatively and quantitatively developed that capture policy-relevant uncertainties in the development of Greater Adelaide. The DSS application in its first iteration provides annual expected losses from coastal inundation, riverine flooding, bushfire and earthquake. The entire use process has been driven by several stages of stakeholder engagement involving SA's State Mitigation Advisory Group.

Work has also begun on the Greater & Peri-urban Melbourne case study with the first stage of stakeholder engagement occurring on the 21st – 23rd October 2015. This involved questionnaires, semi-structured interviews and a workshop to collect information on spatial region, hazards, drivers for change, risk reduction options and indicators of interest. Model development followed focussing initially on the central land use model, and data have also been collected for hazard modelling. Further stakeholder work will occur in the second half of this year including presentation of a first iteration of the software, and its integrated use process of exploratory scenario development.

The first stage of stakeholder engagement for the Tasmania case study occurred on 4th – 6th November 2015. Similar information was collected regarding inputs to the system's development. The spatial region considered initially excluded the World Heritage and National Park sites on the South West of the island, but this has changed due to fire events over summer 2015/16. Due to this change in scope the DSS development has been delayed, with a first iteration of the software now planned to be completed in 2017.

Other work has also involved the development of specific hazard models by project team members to be integrated within the systems for each of the case studies. These include a riverine flood and coastal inundation model, and a bushfire risk assessment model co-developed with SA's Department of Environment, Water & Natural Resources (DEWNR).

END USER STATEMENT

Ed Pikusa,

Lead User Representative, Economics and Strategic Decision Making Cluster
Department of Environment, Water & Natural Resources, SA

I have been involved as an end user of this project since the creation of the CRC, and have been involved particularly with the development of the Greater Adelaide case study.

This project is not developing a 'black box' solution of disaster mitigation, but is a platform to integrate models and examine long-term trends of policy decisions. The process to undertake this is a conversation between end users, technical experts and the researchers.

It was an early decision to use case studies to illustrate the process. This resulted in the Adelaide, Melbourne and Tasmanian demonstrations, which have proven to be very successful in engaging end users. The use of scenarios presents end users with an opportunity to question not only the model results but also their assumptions in the future

There are opportunities for future model refinement as the case studies are finalised. The package is intentionally customisable so new models and planning scenarios can be added

Future use of the package is being anticipated for multi-hazard emergency management agencies, single hazard emergency service organisations, and central government planning agencies. Engagement from these end user agencies is encouraged to ensure the platform will receive the best chance to be used in future.

INTRODUCTION

The challenges facing policy makers grow increasingly complex and uncertain as more factors that impact on their ability to manage the environment and its risks need to be considered. Due to a large number of influencing environmental and anthropogenic factors, natural hazard risk is difficult to estimate accurately, and exaggerated by large uncertainty in future socio-economic consequences. Furthermore, resources are scarce, and the benefits of risk reduction strategies are often intangible. Consequently, a decision support system assisting managers to understand disaster risk has great advantage for strategic policy assessment and development, and the development and application of such a system is the focus of this project.

The developed decision support system allows for the dynamic understanding and assessment of all three components of risk; exposure, vulnerability and hazard, in line with recent recommendations from the World Bank's Global Facility for Disaster Reduction and Recovery (Fraser et al, 2016). The DSS thus allows policy makers to better understand the drivers of risk and the impact of their policies on the risk profile now and into the future. The hope of this is that it enables policy makers to account for climate change, urbanisation, population increases and future environmental conditions in risk assessments.

The overarching framework of the decision support system: (i) is able to deal with complex problems in a systematic and transparent manner; (ii) makes best use of available sources of data and information; (iii) is adaptable/flexible; (iv) deals with multiple, competing objectives: (v) identifies mitigation options that represent the best possible (optimal) trade-offs between objectives; (vi) deals with uncertainty; (vii) caters to a large number of potential solutions; (viii) enhances understanding of the side effects and impacts of different combinations of policy options; and (ix) adopts an interdisciplinary approach across various policy fields.

PROJECT BACKGROUND

DISASTER LOSSES ARE SIGNIFICANT, AND CAN BE REDUCED

The impacts from natural disasters are staggering in regard to human and economic losses. While the immediate and post-crisis response to disasters is extremely important, mitigation activities before a natural disaster occurs can be extremely effective in reducing potential losses — for every dollar spent on mitigation, a saving of one and a half to five dollars in recovery costs can be expected (Rose et al., 2007). However, developing and implementing mitigation can be extremely difficult in practice, because of the difficulty of convincing decision makers of the advantages of spending money on mitigation works compared with the short-term benefits offered by other potential projects and activities. In addition, because disasters are relatively infrequent, the people influencing mitigation activities may have little personal experience to guide their evaluation of risk, or the relative benefits of alternative mitigation options. Furthermore, mitigation budgets are generally limited, and given the difficulties mentioned above, the selection of an optimal set of mitigation options is very difficult when many alternative mitigation options are available.

HOW DECISION SUPPORT SYSTEMS HELP SOLVE THE PROBLEM

Because of these difficulties, the use of decision support systems (DSS) is advantageous, as such systems (1) are transparent and can quantify the expected benefits of mitigation investiture across multiple criteria, enabling strong arguments for the selection of particular mitigation options to be made, (2) can be used to assess the likelihood and consequences of natural disasters across multiple criteria, enabling less bias when assessing the relative benefits of mitigation options, and (3) can make use of formal optimization techniques to find optimal or near-optimal portfolios of mitigation options. However, DSSs for natural disaster mitigation have tended to focus on disaster preparedness and the immediate and post-crisis response to emergencies. Of those DSSs that have focused on mitigation, none have considered, simultaneously, both (1) temporal non-stationarity in climate or land use, and (2) the use of optimization to identify suitable mitigation portfolios. These two aspects are important, as natural disasters are likely to become more frequent with climate change, and because consequences of natural disasters are strongly sensitive to the land uses at the location of the natural disaster.

OUR APPROACH TO BUILDING DECISION SUPPORT SYSTEMS

Consequently, this project is developing an integrated natural hazard mitigation DSS framework, which will be used to develop prototype DDSs for three case studies. Of these three case studies, the first being considered is the Greater Adelaide region, the second will consider Greater Melbourne and peri-urban fringes, and the third Tasmania. Through a workshop driven development cycle, this project will deliver prototype DSSs to end users that will optimize the choice of mitigation options, through assessing the performance of various options over the long term using simulation-optimisation approaches. The performance of mitigation options will be evaluated in an integrated way, across a number of natural hazards (bushfire, flooding, coastal surge, earthquake) whilst taking account of land use and climate change.

Consequently, the specific objectives of the project are:

1. To develop a systematic and transparent approach to sifting through, evaluating and ranking disaster and natural hazard mitigation options using analytical processes and tools.
2. To develop prototype decision support software tools that implement the above approach for three end-user defined case studies; Greater Adelaide, Greater & Peri-urban Melbourne and Tasmania.

PROJECT OUTCOMES

1) A systematic and transparent approach to evaluating natural hazard risk reduction options.
2) A framework for making more strategic and less responsive decisions.
3) Building strategic capacity across governments and agencies for considering the future challenges of natural hazard risk in dynamic and growing regions.
4) The ability to sift through, evaluate and rank a large number of risk reductions options.
5) Understanding the trade-offs between economic, environmental and/or social objections for risk reduction options.

RESEARCH QUESTIONS

Methodological questions the project will help answer, include:

1. What tools are helpful for elucidating case study specific information regarding policy options, drivers and uncertainties from domain knowledge experts in workshops?
2. How can we compare all mitigation options available, and identify the mitigation options that give the best possible trade-offs between objectives?
3. How might optimization routines and hazard models be designed to reduce the computational time of finding mitigation options that represent near optimal trade-offs between decision objectives?
4. How significant is the inclusion of land use change when assessing long term mitigation investment strategies?
5. How can uncertainty be better incorporated within natural hazard mitigation assessment?
6. How can metrics be improved for automated land use model calibration?

Questions, relating to the case studies, that the project will help answer, include (for each case study):

1. What are the optimal mitigation options across long-term planning horizons?
2. How will climate and land use change affect natural hazard risk, and what are the implications for this in regard to disaster mitigation budgets?
3. What trade-offs exist between economic, environmental and/or social objectives for different mitigation options?

WHAT THE PROJECT HAS BEEN UP TO

The following sections provide details on progress that has been made on several aspects of the project. Several models have been developed for their inclusion in the system as outlined below. Also covered are progress on the three case studies within the project, Greater Adelaide, Greater & Peri-urban Melbourne, and the whole of Tasmania.

GENERIC MODEL DEVELOPMENT

The project team has developed several hazard risk models to be included within the integrated system. Details are provided below on the flood inundation model developed for use in Greater Adelaide, and the coastal inundation model developed for application in all three study regions. Also provided are details on the bushfire risk assessment model developed external of the project in collaboration with DEWNR, to be incorporated within the applications for all three regions.

Flood Inundation

A flood hazard model has been developed for the rapid assessment of flooding extent and inundation depth. A simple model of inundation has been chosen to ensure fast computational times. This is critical: given the simulation-optimisation approach being taken by the project, computational expense within the simulation side of the DSS needs to be kept as low as possible due to the computational intensity of the optimisation process.

The flooding model operates by calculating the flow depth along a channel based on historical data. This flow depth is then assigned to raster pixels that correspond to the channel on the output raster. Subsequently, a digital elevation model (DEM) is used to generate the hydrological flow paths across the landscape. The flood depth at a channel raster cell is then propagated through the flow path connected to that cell, assuming a planar water surface, and the flood depth is calculated by subtracting the land surface elevation of a raster pixel (as given by the DEM) from the water surface elevation at that location.

This has been applied to the Greater Adelaide case study. It is however thought that for Greater & Peri-urban Melbourne and Tasmania, existing inundation modelling will be used to consider riverine flood hazard. The overall calculation of risk, through expected losses, however will use the approach outlined below for all three case study locations.

Expected losses are calculated based on Geoscience Australia's Flood Vulnerability Functions for Australian Buildings. These relate losses to inundation depth and construction type (through associated vulnerability curves). Losses are then calculated, using these vulnerability functions and the building stock model for multiple flood events of different return periods. This then allows the creation of a curve for likelihood and impact with risk being represented by the area under the curve (expected losses in any year).

Coastal Inundation

A coastal hazard model has been developed for the rapid assessment of flooding extent and inundation depth, given a coastal surge height as input. Conceptually, inundation depth and extent are calculated using a 'bathtub' model. In a similar way to how the flooding model works, the coastal inundation model assumes a planar water surface in determining extent, and calculates inundation depth as the difference between the coastal surge height and the land surface elevation as given from a DEM.

Losses and risk are calculated by the coastal inundation model in exactly the same way as for the flooding model. Based on water depth, construction type (and associated vulnerability curves), and economic value regarding values at risk in a region, expected losses can be determined for the particular coastal inundation event. This then allows the creation of a curve for likelihood and impact across multiple representative events, with risk being given by the area under the curve.

This model has been applied to the Greater Adelaide case study, and will likely be used for Greater & Peri-urban Melbourne, and Tasmania.

Bushfire Risk Assessment

A bushfire risk model has been developed by members of the project team in collaboration with DEWNR, as an aside to the main project, but that will be integrated into developed DSSs. The bushfire risk assessment model (BRAM) has been adapted from the TASBRAM application developed by David Taylor at Tasmania Parks & Wildlife and InsightGIS [see InsightGIS (2014)]. This model considers the likelihood of bushfire events in a particular cell based on three main components, including ignition potential, fire behaviour and suppression capability. Ignition potential is a combination of factors relating to lightning probability (based on historical data and can be influenced by climate change) and historical data regarding human fire sources. Fire behaviour consists of head fire intensity, a function of fuel groups and climate data (90^{th} temperature and relative humidity percentile) and the rate of spread (an existing model based on fuel groups and weather), along with vegetation type and slope. Suppression capabilities relate to how quickly a fire can be detected and suppressed and is determined by the number of fire stations, fire towers, roads and air support/attack that are available. These factors are combined spatially to determine the likelihood of occurrence of a bushfire and its intensity in each cell. Economic data are then overlaid to assess number of people and capital stock at risk for each cell considering the capital stock's vulnerability based on fire intensity, building age and standards.

The model has been developed for the Greater Adelaide case study, and will be integrated within the software application in the coming months. It is expected a similar system will be applied to the Greater & Peri-urban Melbourne and Tasmanian case studies. Discussions have occurred between project members and Victoria's DELWP as to how to improve certain dynamics of the model, including outputs from PHOENIX, and these discussions will continue.

DSS APPLICATION CASE STUDIES

Three case study DSS applications are included within the project. The following sections outline the advances in each of these over the previous 12 months.

Greater Adelaide

The Greater Adelaide case study has developed a DSS framed on the system diagram shown in Figure 1. The software application has been developed and submitted to the BNHCRC. This application includes hazard modelling of riverine flooding, coastal inundation, and earthquake, with bushfire and heatwave to be included in coming months. Screenshots of the modeler interface, and static risk outputs are shown for earthquake in Figures 2 and 3.

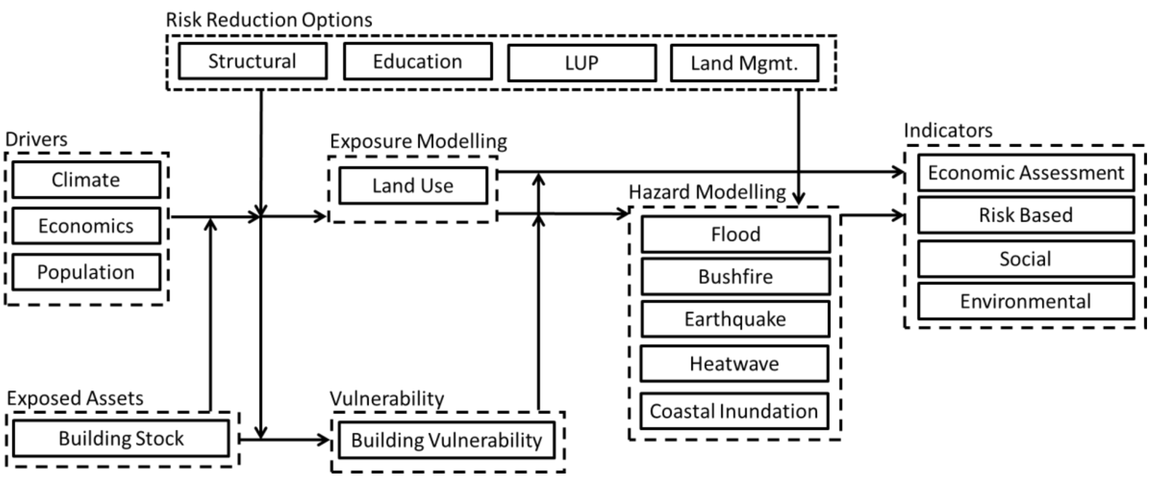

FIGURE 1: SYSTEM DIAGRAM FOR GREATER ADELAIDE

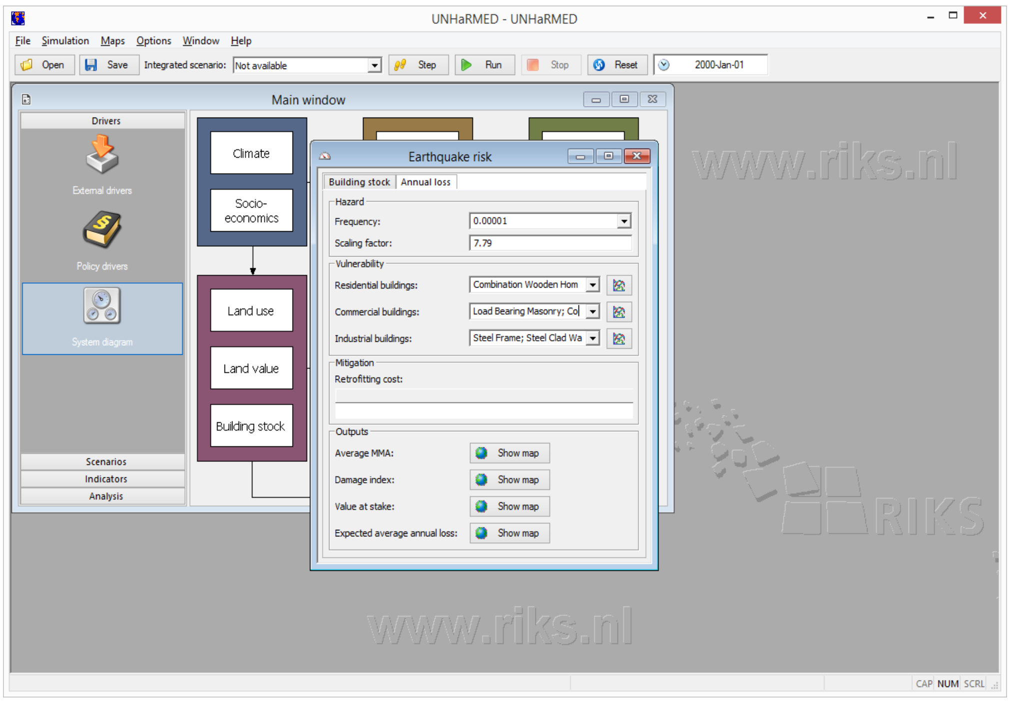

FIGURE 2: EARTHQUAKE RISK MODELER INTERFACE

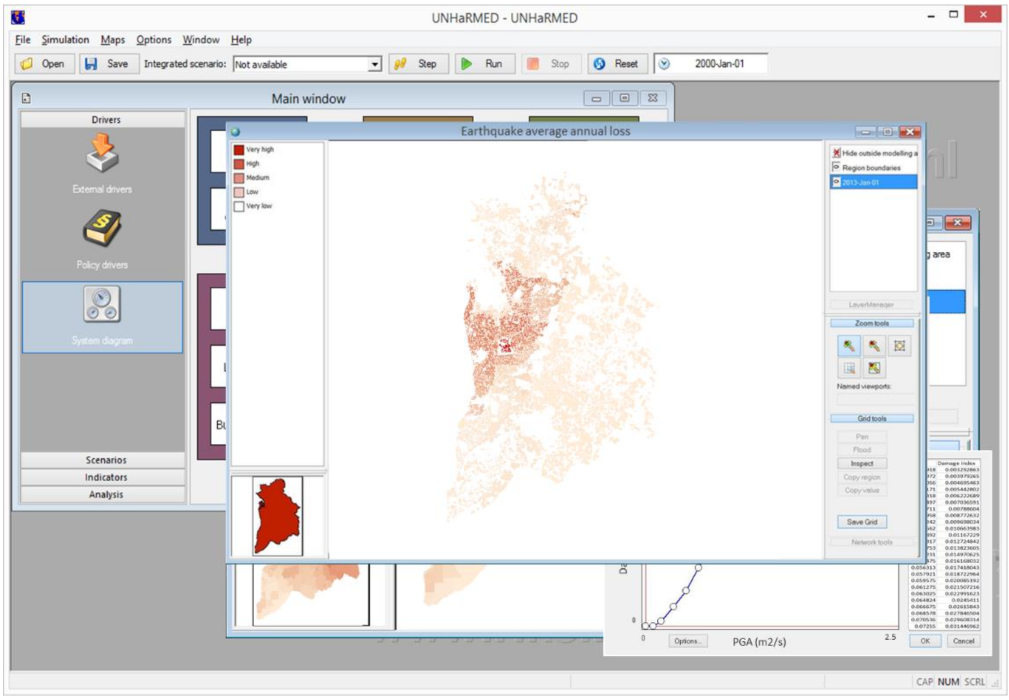

FIGURE 3: EARTHQUAKE RISK OUTPUT

Along with the development of the software application an extensive stakeholder interaction process has occurred providing end-users the ability to comment and offer feedback on the software, as well as consider the use of the system by exploring future scenarios for the development of Greater Adelaide. These future scenarios were developed with participatory inputs over two workshop sessions. Narratives were constructed by considering factors of resilience and the effectiveness of mitigation activities, and how these factors might change into the future making the region more or less at risk. Figure 4 shows the framing of the five scenarios. The report, *Visions Greater Adelaide 2050: An exploration of disaster risk and the future* (Riddell et. al., 2016), provides details on the narrative components of the scenarios, along with land use modelling outputs showing areas and activities of interest across the scenarios.

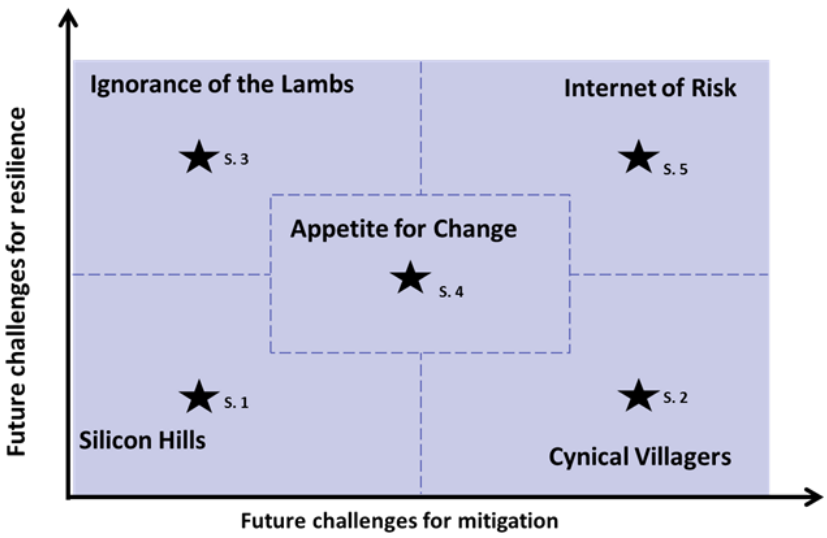

FIGURE 4: SCENARIO FRAMING FOR GREATER ADELAIDE

A workshop was held on the 17th November where these scenarios were presented, along with modelled outputs of the risk profiles for each. These outputs highlighted expected loss outputs for riverine flooding, coastal inundation, bushfire and earthquake in 2015, 2030 and 2050 for each of the five scenarios. Figure 5 highlights some of the outputs presented, including changes in rural residential living 2013 - 2050, and expected loss from riverine flooding for a 1in500 event in 2050.

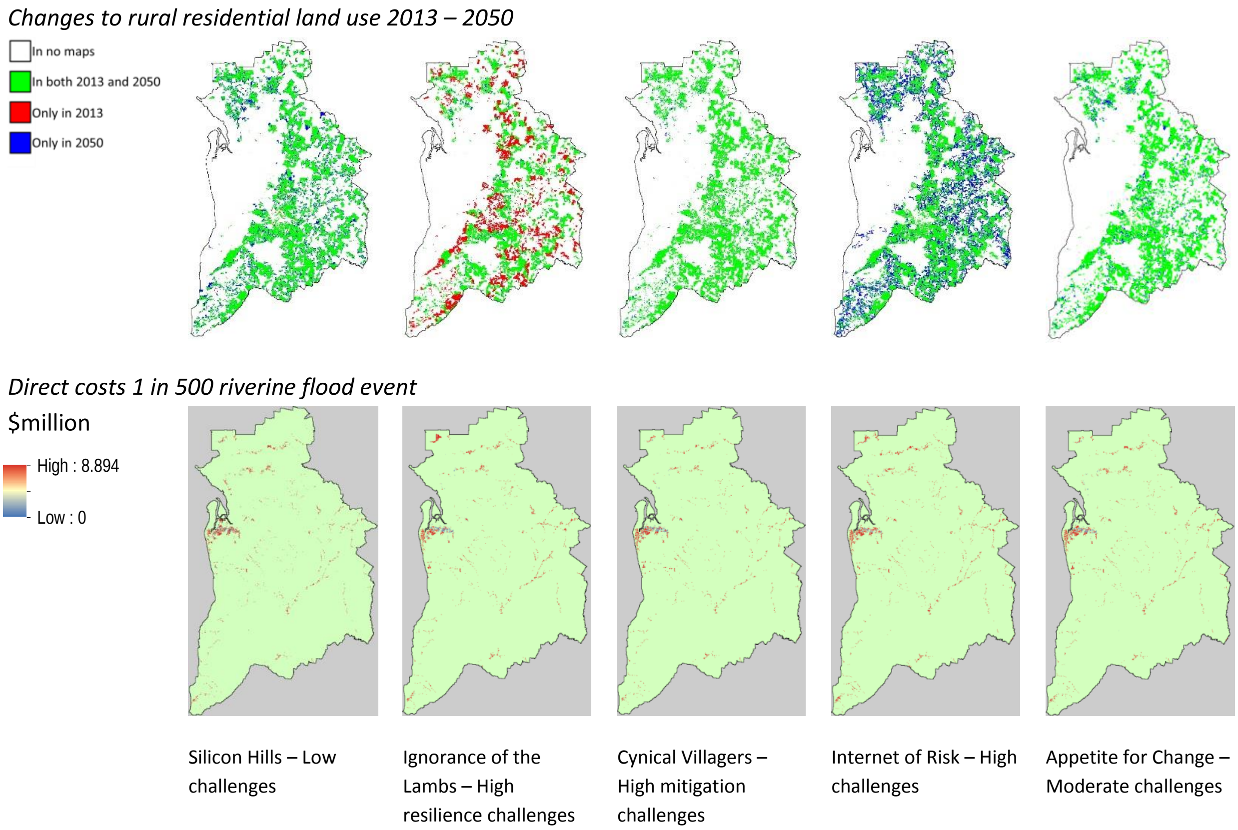

FIGURE 3: DSS SCENARIO OUTPUTS

The next steps for Greater Adelaide include the linking of a multi-objective optimization algorithm. This will allow for the testing of various risk reduction portfolios across the various scenarios to consider which portfolios provide the most effective trade-offs across different criteria. These policy support processes will again be delivered in an interactive workshop with end-users in November 2016.

Greater & Peri-urban Melbourne

The case-study on Greater & Peri-urban Melbourne began with the first stage of stakeholder engagement in October 2015. A report has been published with details of this process, see *Greater & Peri-urban Melbourne DSS Stakeholder Engagement Stage 1 Report* (Riddell et al, 2016). This provided input to the project team on the spatial extent considered relevant (see Figure 6 and Table 1 for the LGAs considered within the case study region), drivers and uncertainties in the development of the region, policy responses for risk reduction, and indicators of policy influence.

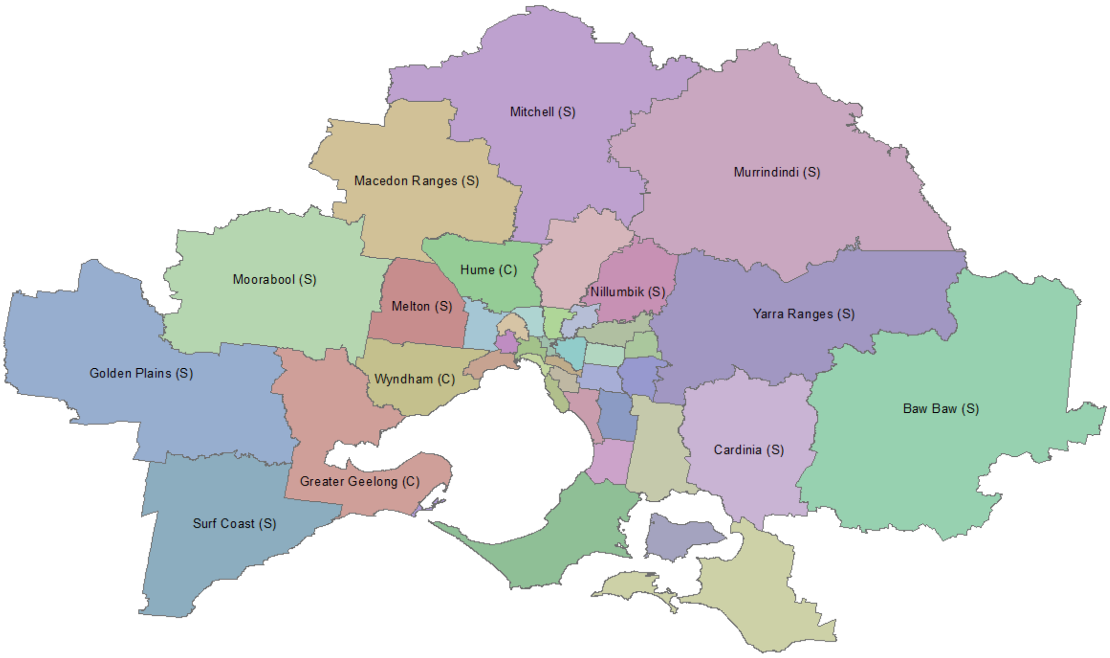

FIGURE 4: GREATER & PERI-URBAN MELBOURNE MODEL EXTENT

Greater & Peri-urban Melbourne Local Government Areas			
Banyule (C)	Golden Plains (S)	Melbourne (C)	Queenscliffe (B)
Bass Coast (S)	Greater Dandenong (C)	Melton (S)	Stonnington (C)
Baw Baw (S)	Greater Geelong (C)	Mitchell (S)	Surf Coast (S)
Bayside (C)	Hobsons Bay (C)	Monash (C)	Whitehorse (C)
Boroondara (C)	Hume (C)	Moonee Valley (C)	Whittlesea (C)
Brimbank (C)	Kingston (C)	Moorabool (S)	Wyndham (C)
Cardinia (S)	Knox (C)	Moreland (C)	Yarra (C)
Casey (C)	Macedon Ranges (S)	Mornington Peninsula (S)	Yarra Ranges (S)
Darebin (C)	Manningham (C)	Murrindindi (S)	
Frankston (C)	Maribyrnong (C)	Nillumbik (S)	
Glen Eira (C)	Maroondah (C)	Port Phillip (C)	

TABLE 1: LOCAL GOVERNMENT AREAS INCLUDED IN GREATER & PERI-URBAN MELBOURNE MODEL EXTENT

Following this engagement process work has proceeded on model development. The focus has been on data collection, and engaging with contacts throughout Victorian State Government ensuring that the data collected are appropriate, and the proposed methodologies align with current practices. These data have included relevant information for the land use model (historic land use maps, zoning policies, transport networks etc.), bushfire model, and factors regarding social vulnerability to natural hazards (spatial demographic data). In the coming months the land use model will be calibrated, and several hazard models will also be developed.

Table 2 outlines the next steps in stakeholder engagement. In early October 2016 the system will be presented to end-users in its first iteration for comment on interface design, risk reduction options and indicators. This will be accompanied by the exploration of the future of the region, creating narratives, as previously presented for Greater Adelaide.

Stage	Purpose	Description	Indicative Date
2	Land Use & Hazard Model Development [1]	End user input on land use model components, principally classification, suitability, accessibility and historic trends. End user input on hazard model specifications. (Individual meetings)	Jun 2016
3	DSS Feedback & Qualitative Scenarios	Presentation of first iteration of DSS with opportunity for feedback. Development of qualitative scenarios for the future of Tasmania. (1 day)	Early Oct 2016
4	Quantification of Scenarios	Participatory quantification of exploratory scenarios using simple models and historical trends. (½ day)	Late Oct 2016
5	Socio-economic & Risk Scenarios	Presentation of modelled scenarios highlight plausible socio-economic developments and risk profiles. Critical feedback on their development, extremity, plausibility, consistency and representativeness. (½ day)	Nov 2016
6	Policy Support	Presentation and discussion on policy support mechanisms and results from optimization of risk reduction portfolios and consideration of robust and adaptive approaches for future uncertainty. (½ day)	2017

TABLE 2: NEXT PHASES OF STAKEHOLDER ENGAGEMENT FOR GREATER & PERI-URBAN MELBOURNE CASE STUDY

1. A MEETING WAS HELD ON 17/6/2016 WITH PROJECT TEAM MEMBERS AND REPRESENTATIVES OF PLANNING WITHIN DELWP AND DEDJTR INFORMING THE DEVELOPMENT OF LAND USE MODEL, PARTICULARLY AROUND LAND USE CLASSIFICATION, ZONING POLICY AND PHYSICAL SUITABILITY CHARACTERISTICS OF THE LAND TO SUPPORT PARTICULAR ACTIVITIES

Tasmania

The case-study on Tasmania similarly began with the first stage of stakeholder engagement in November 2015. A report has been published with details of this process, see *Tasmania DSS Stakeholder Engagement Stage 1 Report* (Riddell et al, 2016). This provided input to the project team on drivers and uncertainties in the development of the state, policy responses for risk reduction, and indicators of policy influence. In the initial stages of engagement the spatial region to be considered was the whole of the main island Tasmania, excluding the World Heritage and National Parks area in the South West of the island, however based on the fire events of summer 2015/2016 the model extent was increased to the include these regions. Figure 7 shows the spatial extent.

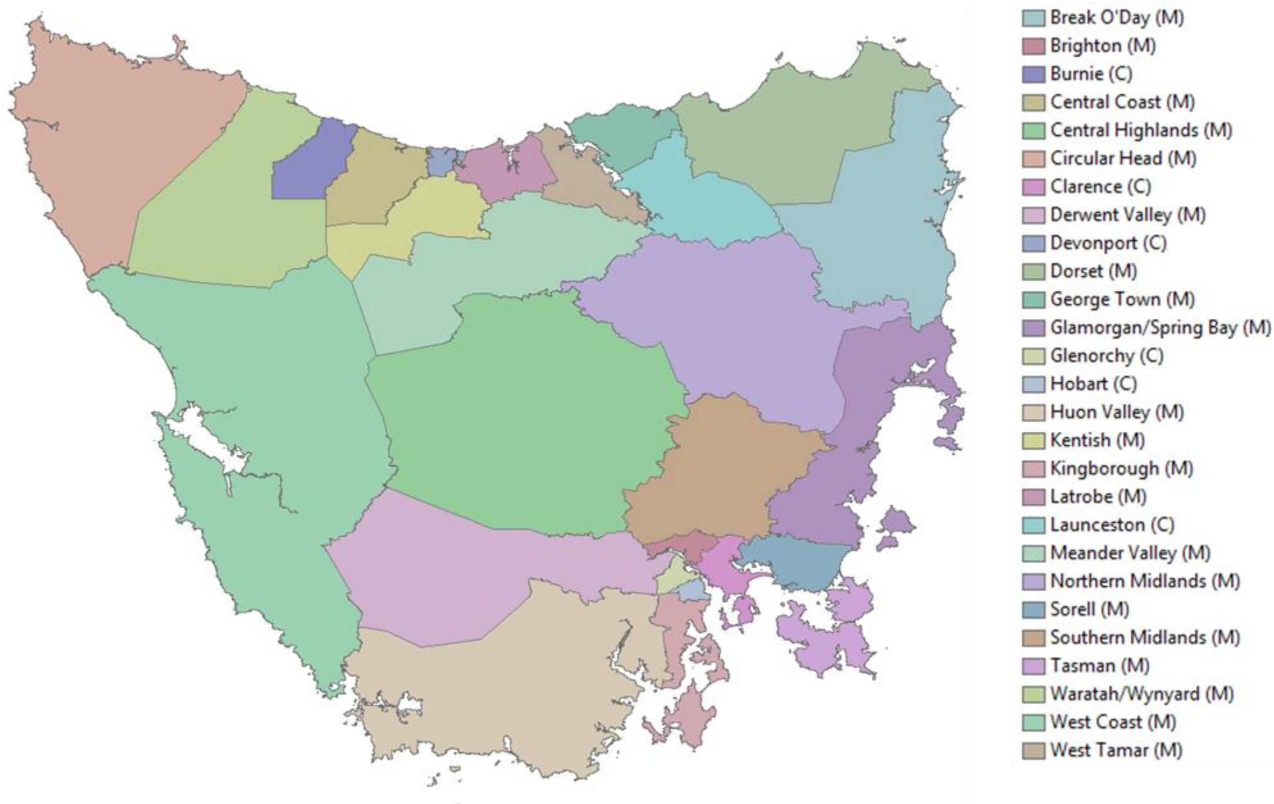

FIGURE 5: TASMANIA MODEL EXTENT

The recent changes to model extent (and consequent scope of project) have delayed overall progress of the system. Currently land use information has been sourced to begin model development. Table 3 below outlines the next stages in the case study planned for 2017.

Stage	Purpose	Description	Indicative Date
2	Land Use & Hazard Model Development	End user input on land use model components, principally classification, suitability, accessibility and historic trends. End user input on hazard model specifications. (Individual meetings)	Nov 2016
3	DSS Feedback & Qualitative Scenarios	Presentation of first iteration of DSS with opportunity for feedback. Development of qualitative scenarios for the future of Tasmania. (1 day)	2017
4	Quantification of Scenarios	Participatory quantification of exploratory scenarios using simple models and historical trends. (½ day)	2017

Stage	Purpose	Description	Indicative Date
5	Socio-economic & Risk Scenarios	Presentation of modelled scenarios highlight plausible socio-economic developments and risk profiles. Critical feedback on their development, extremity, plausibility, consistency and representativeness. (½ day)	2017
6	Policy Support	Presentation and discussion on policy support mechanisms and results from optimization of risk reduction portfolios and consideration of robust and adaptive approaches for future uncertainty. (½ day)	2017

TABLE 3: NEXT PHASES OF STAKEHOLDER ENGAGEMENT FOR TASMANIA CASE STUDY

PROJECT HIGHLIGHTS & OTHER ACTIVITIES

Following the third workshop for Greater Adelaide where risk modelling was presented for a variety of natural hazards, Andrij Slobodian from SA's Department of Planning, Transport and Infrastructure (DPTI) requested a copy of the earthquake modelling results in DPTI's capacity as earthquake hazard leader. These results were provided and subsequently presented by Andrij to the State Emergency Management Council including the premier and several ministers.

A journal paper has been published in Environmental Modelling and Software by several project members. The article covers topics related to future uncertainty, decision making, robustness and adaptation. Details of the paper can be seen in following section on publications.

A number of collaborations have also been developed between project members and top research groups around the world. Academics at the Karlsruhe institute of Technology's Center for Disaster Management and Risk Reduction Technology (CEDIM) particularly Dr James Daniell and Andreas Schaeffer have contributed earthquake hazard modelling for the Greater Adelaide case study, and publications regarding this will follow. Links have also been made with Amsterdam University's Institute for Environmental Studies – Global Water and Climate Risk with the inclusion of their macro-economic impact modelling to be considered, along with a review publication on the integration of risk in complex decision making.

A review paper is also in the final stages of drafting prior to submission on the status and future directions of decision support systems for natural hazard risk reduction. The paper has been co-authored by members of the project team along with academics from KIT. The paper will be submitted to Environmental Modelling and Software in the coming months.

PUBLICATIONS LIST

JOURNAL PUBLICATIONS

Maier, H.R., Guillaume, J.H.A., Van Delden, H., Riddell, G.A., Haasnoot, M., Kwakkel, J.H., 2016. An uncertain future, deep uncertainty, scenarios, robustness and adaptation: How do they fit together? Environmental Modelling and Software, 81: 154-164 (doi:10.1016/j.envsoft.2016.03.014).

REPORTS

Riddell, G.A., Van Delden, H., Dandy, G.C., Maier, H.R., Zecchin, A.C., Newman, J.P., Newland, C.P., (June 2016) "Visions Greater Adelaide 2050: An exploration of disaster risk and the future" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Riddell, G.A., Van Delden, H., Dandy, G.C., Maier, H.R., Zecchin, A.C., Newman, J.P., (June 2016) "Tasmania DSS Stakeholder Engagement Stage 1 Report" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

Riddell, G.A., Van Delden, H., Dandy, G.C., Maier, H.R., Zecchin, A.C., Newman, J.P., (June 2016) "Greater & Peri-Urban Melbourne DSS Stakeholder Engagement Stage 1 Report" The University of Adelaide, The Bushfire & Natural Hazard Cooperative Research Centre.

CONFERENCES

Van Delden, H., Riddell, G.A., Vanhout, R., Maier, H.R., Zecchin, A.C., Newman, J.P., Daniell, J.E., Dandy, G.C., 2016. A Spatial Decision Support System (SDSS) for understanding and reducing long-term disaster risk, 6th International Disaster and Risk Conference IDRC Davos 2016, Davos, Switzerland. 6th International Disaster and Risk Conference IDRC Davos 2016, Davos, Switzerland, Accepted.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., Newman, J.P., Dandy, G.C., 2016. Exploring the future of resilience and mitigation to better plan for disaster risk reduction. 6th International Disaster and Risk Conference IDRC Davos 2016, Accepted.

Van Delden, H., Riddell, G.A., Vanhout, R., Newman, J.P., Zecchin, A.C., Maier, H.R., Dandy, G.C., 2016. Integrating participation and modelling to support natural hazard mitigation planning, iEMSs 2016, Toulouse, France, Accepted.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., Dandy, G.C., 2016. Futures of resilience and mitigation: Combining stakeholder knowledge, statistical analysis and integrated modelling to better understand and reduce disaster risk, iEMSs 2016, Toulouse, France, Accepted.

Newman, J.P., Dandy, G.C., Maier, H.R., Zecchin, A.C., Van Delden, H., Riddell, G.A. 2016. Decision support framework to optimize flood mitigation measures, 7th International Conference on Water Resources and Environment Research (ICWRER), Kyoto, Japan.

Riddell, G.A., Van Delden, H., Newman, J.P., Vanhout, R., Maier, H.R., Dandy, G.C., Zecchin, A.C. 2016. A spatial decision support system for natural hazard risk reduction policy assessment and planning, SA Natural Resource Management Conference 2016, Adelaide, Australia.

Riddell, G.A., Van Delden, H., Telfer, S., Wouters, M., Vanhout, R., Maier, H.R., Zecchin, A.C., 2016. A Spatial DSS for the Understanding and Reduction of Long-Term Wildfire Risk 2016. A spatial DSS for the Understanding and Reduction of Long-Term Wildfire Risk, IAWF Fire & Fuels Conference 2016, Melbourne, Australia.

Maier, H.R., Van Delden, H., Newman, J.P., Riddell, G.A., Zecchin, A.C., Dandy, G., Newland, C., 2015. Decision-support system for mitigating long-term flood risk, paper presented at AGU, 12-16 December 2015, San Francisco, U.S.A.

Van Delden, H., Riddell, G.A., Newman, J.P., Maier, H.R., Vanhout, R., Zecchin, A.C., Dandy, G.C., 2015.
A framework for the development and use of Decision Support Systems for multi-hazard mitigation, MODSIM, November 29 - December 4, 2015, Gold Coast, Australia.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., 2015. Applying an 'outcomes of interest' scenario framework to consider uncertainties impacting risk reduction policies, MODSIM, November 29 - December 4, 2015, Gold Coast, Australia.

Guillaume, J., Maier, H.R., Van Delden, H., Riddell, G.A., Haasnoot, M. 2015. Deep Uncertainty, Non-stationarity, Scenarios, Robustness and Adaptation: How do they fit together in environmental modelling? Third Annual Workshop on Decision Making Under Deep Uncertainty, November 3-5, 2015, Delft, the Netherlands.

Newland, C.P., Van Delden, H., Maier, H.R., Newman, J.P., Zecchin, A.C. 2015. Using dynamic exposure modelling to evaluate evolving hazard risk, Poster presented at AFAC Conference, September 2015, Adelaide, Australia.

Newman, J.P., Van Delden, H., Riddell, G.A., Maier, H.R., Zecchin, A.C., Dandy, G.C., Vanhout, R. 2015. A framework for an integrated model that supports multi-hazard mitigation planning. Paper presented at AFAC Conference, September 2015, Adelaide, Australia.

Newman, J.P., Van Delden, H., Riddell, G.A., Maier, H.R., Zecchin, A.C., Dandy, G.C., Vanhout, R. 2015. Developing and using a decision support system for mitigation planning. Poster presented at AFAC Conference, September 2015, Adelaide, Australia.

Riddell, G.A., Van Delden, H., Maier, H.R., Zecchin, A.C., 2015. Including land value in hazard mitigation planning, Poster presented at AFAC Conference, September 2015, Adelaide, Australia.

Newland, C.P., Maier, H.R., Newman, J.P., Van Delden, H., Zecchin, A.C., 2015. Relationships between Cellular Automata based land use model parameters and spatial metrics: Enhancing understanding in a calibration context, Computers in Urban Planning and Urban Management (CUPUM), July 7-10, 2015, Cambridge, MA, USA.

CURRENT TEAM MEMBERS

	Prof. Holger Maier (University of Adelaide) Project Lead Researcher, responsible for ensuring that the project delivers to contractually agreed scope and budget, and also responsible for the project communication between end-users and the project team, and communication with the cluster Lead User Representative and Lead Researcher. Also responsible for supervision of post-doctoral fellow and PhD students.
	Dr Aaron Zecchin (University of Adelaide) Deputy project leader, co-supervision of post-doctoral fellow and PhD students, oversight of optimisation and development of overall process and decision support system.
	A/Prof Hedwig van Delden (Research Institute for Knowledge Systems (RIKS) / University of Adelaide) Key researcher, responsible for running participatory workshops with end-users, data/information/model integration, application and calibration of the Metronamica land use modelling framework for those cases it will be applied to, and development of DSS software. Also responsible for supervision of post-doctoral fellow and PhD students. Accountable to the Project Lead Researcher for delivery of the prototype DSSs.
	Emeritus Prof Graeme Dandy (University of Adelaide) High level oversight on optimization and development of overall process. Workshop facilitator.
	Jeffrey Newman (University of Adelaide) Responsible for literature review, collection of available data, information and models, development of overall framework, development and implementation of optimisation component of the project, day-to-day running of the project.

	Graeme Riddell (University of Adelaide) Responsible for day-to-day running of the project, data and model collection and conceptualization, and stakeholder engagement processes. PhD project looks to develop a framework to handle *knowledge uncertainty* (an uncertain future state of the world) for decision making with a focus on natural risk reduction planning.
	Charles Newland (University of Adelaide) Spatially distributed models are an effective means for the assessment of policy and planning investment options for optimal natural hazard mitigation. To broaden the applicability of spatially distributed models and allow more effective and efficient usage by decision makers, Charles' research aims to improve their calibration procedure.

REFERENCES

1. Fraser, S., Jongman, B., Balog, S., Simpson, A., Saito, K., Himmelfarb, A., *The making of a riskier future: How our decisions are shaping future disaster risk.* Global Facility for Disaster Reduction and Recovery, The World Bank, Washington DC, USA, 2016.
2. Rose, A., et al., *Benefit-cost analysis of FEMA hazard mitigation grants.* Natural Hazards Review, 2007. 8(4): p. 97-111.
3. INSIGHTGIS, *Tasmanian Bushfire Risk Assessment Model V3.1 - Technical Report V1.6*. 2014.