Environmental Modelling & Software 61 (2014) 65–77

Contents lists available at ScienceDirect

Environmental Modelling & Software

journal homepage: www.elsevier.com/locate/envsoft

The application of componentised modelling techniques to catastrophe model generation

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ARTICLE INFO

Article history:
Received 26 June 2013
Received in revised form
8 May 2014
Accepted 4 July 2014
Available online

Keywords:
Integrated environmental modelling
Catastrophe modelling
Groundwater flooding

ABSTRACT

In this paper we show that integrated environmental modelling (IEM) techniques can be used to generate a catastrophe model for groundwater flooding. Catastrophe models are probabilistic models based upon sets of events representing the hazard and weights their likelihood with the impact of such an event happening which is then used to estimate future financial losses. These probabilistic loss estimates often underpin re-insurance transactions. Modelled loss estimates can vary significantly, because of the assumptions used within the models. A rudimentary insurance-style catastrophe model for groundwater flooding has been created by linking seven individual components together. Each component is linked to the next using an open modelling framework (i.e. an implementation of OpenMI). Finally, we discuss how a flexible model integration methodology, such as described in this paper, facilitates a better understanding of the assumptions used within the catastrophe model by enabling the interchange of model components created using different, yet appropriate, assumptions.

1. Introduction

Global economic losses related to natural hazards are large and increasing. Total economic losses reached US$130 billion in 2010, US$380 billion 2011 and US$160 billion in 2012 (Munich Re, 2011a,b, 2012). Insurance is a method of managing these financial risks, the objective of purchasing insurance is to avoid a loss large enough to cause failure by spreading the cost. However, natural hazards or 'perils', can affect many insured properties across a wide area (e.g. 100s of km across) in a limited time window (e.g. <72 h). For example, Hurricane Andrew in 1992 caused an estimated $26.5bn in losses to property, leading to the failure of 13 insurance companies (AIR, 2002; Cummins, 2007). To protect against this, insurers buy reinsurance. The reinsurers have to cost this insurance by estimating the insured losses caused by extreme events, such as hurricanes and earthquakes and then predicting the probable likelihood of such an event occurring. The difficulty is that insurers previous claim experience is often of little use when trying to predict insured losses. This is because extreme events are rarely directly comparable, and insured property 'exposure' changes rapidly. For example inflation, real growth in property values, varied insurance penetration, and changes in properties' locations within a portfolio must be accounted for to create a figure for likely insured losses (Tower Perrin, 2005; Swiss Re, 2007). Catastrophe models, developed over the last ~25 years (Grossi et al., 2005), are one solution to this problem.

The aim of this paper is to demonstrate a proof-of-concept by showing how Integrated environmental modelling (IEM) methods and techniques can be used to construct a catastrophe model using the example of groundwater flooding risk of the Marlborough and Berkshire Downs in the UK. Although there is extra effort required to make models linkable once a linked modular catastrophe model has been constructed, several advantages can be gained, for example an increased flexibility by allowing for the interchange of compatible components. Linked modelling can facilitate both an improved understanding of and better insight into the interactions between model components, in part because of the need to fully document and define the models and datasets being exchanged between components.

This paper will firstly look at flooding in the UK and UK insurance policy; we will then discuss how the insurance industry use catastrophe models to improve loss calculations and how IEM modelling methods and techniques could be adopted to generate catastrophe models. The second part of the paper will work through a case study example of groundwater flooding in the Marlborough and Berkshire downs.

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http://dx.doi.org/10.1016/j.envsoft.2014.07.005
1364-8152/

2. Flooding and the UK insurance industry

Unlike many other countries, in the UK, the majority of domestic and business flood damage losses are covered by the insurance market rather than government funds. Under the 'Statement of Principles', an agreement setup in 2000 between the British Government and the Association of British Insurers (ABI), insurers committed to providing cover for almost all properties, other than where the risk is deemed significant and no plans are in place to manage the risk within a 5 year time period (DEFRA, 2011). In the last 10 years in the UK, there have been several major flood events. The biggest and most catastrophic were the 2007 floods which consisted of a mixture of surface and groundwater flooding events which affected large areas of Yorkshire, the Midlands and the West of England. This demonstrated without doubt that flooding in the UK can be devastating, from social impacts such as loss of life, dislocation of thousands of people and major economic impacts which cost insurers over £3 billion (Pitt, 2008). Two years later, the 2009 floods affecting a smaller area of Cumbria, West Wales, Dumfries and Galloway, still cost insurers over £1.5M (Munich RE, 2011a). The Association of British Insurers has put the average cost of flood damage (all types) in the UK to homes affected at between £20,000 and £40,000 each (Dailey et al., 2009).

In this paper we concentrate on groundwater flooding, because it is both poorly understood (e.g. Finch et al., 2004; Hughes et al., 2011), and often confused by non-specialists with surface water flooding. Groundwater flooding presents a substantial problem, but is not widely recognised either in the UK or internationally (Kreibich and Thieken, 2008). Hughes et al. (2011) suggest four types of groundwater flooding based on their origin:

a) A high water table in regional aquifers
b) Short-circuiting of flood defences
c) A rise of the water table due to cessation of mine dewatering
d) Barriers to subsurface flow caused by underground structures.

In the example used in this case study; the risk is primarily of Type 1 resulting from extremely high intensity and/or long duration rainfall.

The costs and impacts of just groundwater flooding events in the UK are significant and almost certainly underestimated (Green et al., 2006; Royse, 2011) because unlike surface water flooding, groundwater floods tend to be longer-lasting, typically remaining for the order of weeks or months. Groundwater flooding can be defined as flooding caused by the emergence of water originating from subsurface permeable strata (Cobby et al., 2009). The latest estimates suggest 1.6 million properties may be at risk in the UK (Jacobs, 2004), the most vulnerable being those located on the exposed Chalk aquifers of southern England e.g. south Oxford in 1997 (Macdonald et al., 2007, 2008a,b), but events also occur elsewhere, such as in Pilmuir in Scotland (Macdonald et al., 2008a,b). Typically, groundwater flooding occurs during winters where recharge is high during the early part of the recharge season and stays above average. The case study that has been used is in the Pang and Lambourn catchments within the Berkshire and Marlborough downs (Fig. 3A). The catchments experienced severe flooding during the winter of 2000/1 following unusual meteorological events in the previous 18 months (Adams et al., 2008), and again in the winter of 2002/3 (Hughes et al., 2011).

The actual cost of groundwater flood events, while less nationally than fluvial or marine flooding, can be significant e.g. the estimated cost of a relatively localised groundwater flooding event in 2000 in Brighton was £800,000, excluding the cost of the railway closure (Binnie and Veatch, 2001). Furthermore, groundwater flooding in Hambledon in 2000/01 was estimated by the local council to have resulted in financial losses of some £1.1 million (Green et al., 2006).

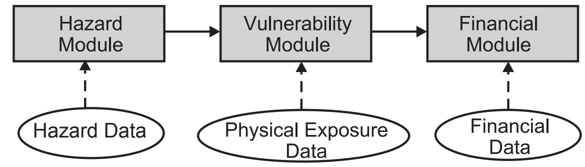

Fig. 1. One possible proposed conceptual framework of a traditional component based catastrophe model. Rectangles are modules, ovals are inputs and arrows indicate the flow of information.

After the 2007 flood events in the UK, a review was carried out looking at how the events were managed and what lessons could be learnt (Pitt, 2008). The review was extremely far-reaching, covering building regulations, emergency response, prediction and modelling. A key recommendation was the need to develop a whole system approach to understanding flood risk in the UK. This required that groundwater flood risk should be included within any flood risk management system.

Groundwater flood events often take decision-makers by surprise, as they are not included in conventional flood risk mapping. In recognition of this problem, the EU's Floods Directive (2007/60/EC) dictates that groundwater flood risk now has to be taken into account in any flood risk study. Damage to properties caused by rising groundwater levels is a worldwide issue (Hagerty and Lippert, 1982; Hamdan and Mukhopadhyay, 1991). Kreibich and Thieken (2008) have noted that loss assessment studies have in general neglected damage caused by groundwater. In order to evaluate the cost effectiveness of, for example, groundwater drawdown measures, the construction of rain surface and floodwater collection networks, there is a growing need to generate reliable loss assessments (Al-Sefy and Sen, 2006).

3. Catastrophe models

Catastrophe models have been used for the last 25 years by the insurance industry to assess risk by estimating likely losses from extreme events, whether natural or man-made. Catastrophe models are stochastic, event-set based computer models, which allow the potential for large losses from an insurer's current exposure (usually property assets) to be tested by subjecting them to many (e.g. 10,000) events representing scenarios for a hazard within a peril-region (e.g. 'UK flood') and are used to estimate the location, impact and frequency of possible future natural disasters (Grossi and Kunreuther, 2005). The purpose of a catastrophe model is to provide insurers with a better understanding of their liability to events in the year ahead. The models are then used: to "price" catastrophic risk; to control an insurer's risk accumulation; to diversify their risk; to estimate the insurer's reserves in case of loss; to minimise the amount of capital required to cover risks in the insurer's portfolio and finally to estimate the correct price to reinsure or transfer their risk (Chavez-Lopez and Zolfaghari, 2010). Most catastrophe models are based on an arrival process and provide tradeoffs between economic losses i.e. an evaluation of the severity and the probability that a certain level of loss will be exceeded on an annual basis (Haimes, 2004; Grossi and Kunreyther, 2005; Banks, 2006).

Fig. 1 provides an illustration of a typical framework for a catastrophe model. The contents, definitions, and names of each of the modules are not standardised and therefore do vary (e.g. Grossi et al., 2005; Qu et al., 2010). However, the broad work-flow as illustrated remains similar. Fig. 1 identifies three major 'modules',