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Key principles and approaches in geohazard communication for enhancing disaster resilience

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Abstract: Communication is an essential aspect of preparing for, avoiding or responding to the occurrence of natural geohazards. As such, it forms an integral part of any strategy to enhance resilience to geohazard events. Conversely, inadequate or lack of communication is a common factor in failing to minimise the risks involved. Communication about geohazards occurs at several different levels: between geoscientists and other professionals such as the engineers and planners; between professionals and other groups such as emergency services and insurance companies; and between all of these parties and the general public who are affected by events. Geoscientists need to be involved in all of these lines of communication. This paper examines the essential role of geoscientists in helping to reduce the risks associated with a wide range of geohazards. A series of key principles that links to a generic model of geohazard communication applicable to a wide range of scenarios is presented.

Keywords: geohazards, natural hazards, geoscience communication, disaster risk reduction, disaster resilience

Abstrak: Komunikasi merupakan aspek penting dalam siapsiaga, penghindaran dan tindak balas terhadap kejadian geobahaya tabii. Ia adalah teras utama kepada pembinaan daya tahan terhadap impak geobahaya. Sebaliknya, kegagalan dalam komunikasi seringkali mengakibatkan sesuatu risiko tidak dapat dinilai dengan baik atau dikurangkan. Komunikasi risiko tentang geobahaya dapat dibahagi kepada beberapa peringkat dan kumpulan pihak berkepentingan, iaitu profesion geosaintis dengan profesion lain seperti jurutera dan juru perancang bandar; kumpulan profesion dengan kumpulan perkhidmatan kecemasan dan syarikat insurans; serta kumpulan profesional dengan orang awam. Geosaintis mempunyai peranan tersendiri dalam setiap peringkat kerjanya dan komunikasi dengan kumpulan tersebut. Kajian ini mengkaji kepentingan keterlibatan geosaintis dalam pengurangan risiko untuk pelbagai jenis geobahaya. Berdasarkan senario kerja-kerja geosaintis, beberapa prinsip dan amalan telah dikemukakan untuk membolehkan komunikasi maklumat geobahaya dapat dilaksanakan.

Kata kunci: geobahaya, bahaya tabii, komunikasi geosains, pengurangan risiko bahaya, dayatahan bencana

INTRODUCTION

Resilience is defined by as "the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions" (UNISDR, 2009). Resilience helps to reduce the vulnerability of a community to a known hazard. It can be achieved, in part, by avoiding development in hazardous locations through spatial planning, and by providing and responding to effective early warning systems. Resilience also entails planning and designing effectively for the continued functioning of critical infrastructure in the event of a disaster, in order to provide essential support to communities during the event and to ensure that full services can be restored as quickly as possible thereafter, during the recovery phase (Auckland Council, 2014).

Through a combination of climate change, increasing population and expanding development pressures, the magnitude, frequency and consequential risks associated with natural hazards are all increasing. In order to build resilience and adaptation strategies against these events, and to respond effectively when they occur, geoscientists have a pivotal role to play in conveying information to other people on the hazards and risks within particular areas, and how to deal with them. Irrespective of the nature of the hazard, reliable information is needed in several different stages, prior to, during and after an event. This has been demonstrated in developing detailed planning guidance to address the risks posed by subsidence hazard in Ripon, in the United Kingdom (Thompson *et al.,* 1996; 1998). A similar liaison between geoscientists, engineers, planners, insurers and others has been illustrated in dealing with the aftershocks of the Canterbury Earthquakes in New Zealand (Becker *et al.,* 2015). In both cases, the geoscientists assessed what was needed, through dialogue, before developing the advice or guidance that was needed.

This paper draws on a generic model of geohazard communication, which was developed from the Ripon experience (Thompson *et al*., 2019). The focus is primarily on the initial stages, leading up to and during an event, with particular emphasis on improving resilience and preparedness. The purpose is to highlight key principles related to a generic model of geohazard communication that is capable of being applied to a wide range of scenarios. The importance of communication, particularly two-way communication and collaboration is emphasised.

LEVELS OF COMMUNICATION

Risk communication is grounded in an assumption that the public should have a generalised right to know about hazards and risks (Reynolds & Seeger, 2005). The availability of information allows the public to make informed choices regarding risk and, in this way, risk communication facilitates both decision-making and risk-sharing. While having a level of hazard awareness is an important initial step towards becoming better prepared, a high level of awareness does not necessarily mean that the public either have the correct knowledge or are able to act upon it, when needed, to reduce their risks (Amri *et al.,* 2017). Careful consideration needs to be given to the type of information communicated to different groups of people, taking account of what they need to do with that information within the overall scheme of risk reduction, and to the method of communication used.

Geohazards, however, are usually complex phenomena which are best understood by technical experts, i.e. geoscientists. Moreover, the technical information possessed by the scientists is rarely in a form that can readily be understood or acted-upon by those who need to respond to the levels of risk associated with geohazard events – whether they be politicians, decision-makers, members of the emergency services or members of the public. Relevant information needs to be explained in terms that meet the requirements of each group (McKirdy *et al.,* 1998; Marker, 2008; Liverman, 2008), so that considered decisions and actions can be taken, without causing undue fear, panic or complacency. Communication of information about geohazards and associated risks is required at three levels:

- between the geoscientists who study, develop understanding of and monitor the natural processes involved, other specialists involved in risk assessment, and the engineers and planners who design or plan for appropriate solutions;
- between any of those groups and the emergency services and insurance companies who need to respond to events and/or support recovery thereafter; and
- (not least) between all of these and the general public who need to be aware of hazards and how to react to them.

Geoscientists therefore need to be involved in all of these lines of communication, so that they can help to ensure that reliable information is provided in a readily accessible way and is properly explained. A key feature is that the information given to each group needs to be different: customised to ensure that it can be understood – and acted upon – by the 'target audience' involved and integrated into their own procedures. It should be recognised that communication about hazard and risk is not just a one-way process. It requires frequent interaction, dialogue and collaboration, so that information is properly tailored to the requirements of those who need to use it. Feedback is vitally important. Risk communication is "an interactive process of exchange of information and opinion among individuals, groups, and institutions" (National Research Council (US) Committee on Risk Perception and Communication, 1989).

KEY PRINCIPLES OF COMMUNICATING GEOHAZARD AND RISK INFORMATION

There are four key principles critical for geohazard communication. The first is for geoscientists to have a thorough understanding of the hazards involved so that they can explain these to people with limited or no specialist knowledge. Being able to explain scientific concepts clearly to non-specialists is a skill in itself and an important pre-requisite to holding meaningful discussions with others. Three additional key principles include the need for information to be customised to the needs of each different target audience; for the communication to be a two-way process in each case; and for the information to be delivered, as appropriate, to each group. The four key principles for transmitting information on hazards form a logical sequence, within which there are eight stages of geohazard communication (Figure 1).

Key principle 1: Understand the hazards and associated risks

This is traditionally the main focus for most geoscientists involved in the study of geohazards and will

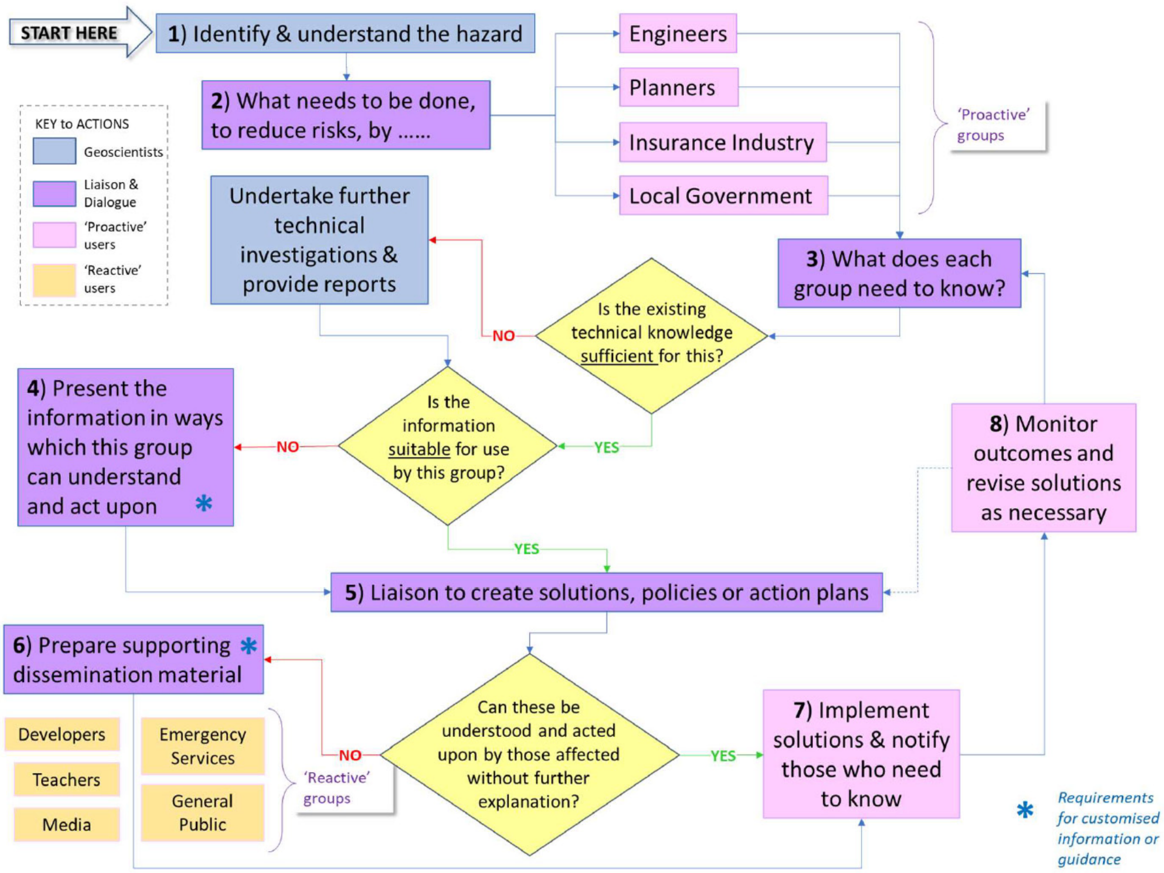

Figure 1: Generic model of geoscience communication in relation to geohazards (Source: Thompson *et al*., 2019).

generally be at a detailed, technical level. Information will routinely be exchanged between geoscientists on this level and will be published in scientific journals and conference proceedings. It is extremely important, however, for the level of understanding to go deeper than this, such that the scientist is able to explain things in 'plain language' without the use of technical 'jargon'. This is a skill in itself. It does not mean 'dumbing down' the information; it means explaining it properly. This involves: identifying all that you know about a particular subject; explaining this knowledge to a (real or imaginary) non-expert audience, such as an intelligent, enthusiastic child; using this to identify gaps in your knowledge; filling those gaps by learning more; and reassembling the information into a logical narrative, or story (Feynman, 2006).

Investigate and analyse the physical processes involved: The starting point, however, is for geoscientists to investigate and analyse the geohazard itself in as much detail as possible, using all available data. There is substantial scope - and necessity - for hazards to be investigated from a 'pure science' perspective, so that confidence can be built in our understanding of the processes and triggering mechanisms involved, and of the interaction between these processes and geological materials (rocks, sediments and soils). There is also a need to document and analyse historical hazard events so that empirical observations can be used to develop, refine and calibrate numerical models (e.g. of slope instability or fluvial flooding) or at least to develop conceptual models of more complex processes such as karstic dissolution and subsidence. The more data available (provided that it is accurate and verified), the more reliable will be any hazard assessments or forecasts that are made.

Additionally, there is considerable scope to undertake more explicitly 'applied' research, so that models and analytical programs are developed and tested for use in relation to real-world development scenarios. These may include highway engineering schemes, high-rise development on steep slopes, or urbanisation of river floodplains. Such schemes frequently present major challenges to geoscientists and engineers; testing the limits in terms of what can be achieved through engineering design in a battle against natural processes. In many countries, including Malaysia, immense pressures for economic development are increasingly in conflict with geohazards associated with land instability and flooding. The battle is relentless and the stakes – in terms of the risk of increasing societal costs associated with natural hazards – are ever increasing.

It is increasingly important, however, for geoscientists to learn – and step back from – the limitations of this approach. It will not always be possible to find a reliable or cost-effective engineering solution. Applied research should include learning more 'abstract' lessons about which areas are likely to be affected by certain types of hazard, so that future development can – as far as possible – be directed elsewhere. In cases where there are genuinely no alternatives, the same information can be used to quantify the levels of risk involved, the advisability (or otherwise) of the proposed development and the necessity for mitigation, monitoring and emergency response. Professional advice on such things needs to be taken on board by those responsible for sanctioning development within hazard-prone areas and needs to be reflected in the budgets made available – both for capital works and recurrent contingencies.

It is therefore of fundamental importance that geoscientists should understand the nature of each geohazard in as much detail as possible so that development decisions – whether by engineers, planners or other decision-makers - can be properly informed. Geoscientists also need to be sure about the limitations of their knowledge, so that models and predictions are kept within sensible bounds. Ideally, geoscientists need to be closely involved in the development, calibration and 'reality checking' of numerical models (rather than leaving this task wholly to the modelling experts) so that the information passed on to engineers, planners and others is reliable.

Explain the hazards, and their development implications, in 'plain language': The key to successful communication is to make sure that the appropriate information is given out and that everyone understands, and can act upon, what is being said. In order for geoscientists to be able to get their message across to those who need to act upon the information, it is essential that appropriate 'plain language' is used, avoiding the use of technical 'jargon' (Marker, 2008, Liverman, 2008). Geoscientists need to imagine that they are explaining the situation to someone with no prior knowledge or specialist expertise – for example, to an intelligent student at secondary school or one that is entering higher education. Similar guidance is often given to an expert witness when preparing and presenting proofs of evidence at a public inquiry, or to a jury in a trial.

Even if plain language is used, it is often difficult to avoid using at least some essential technical terms which the recipient will need to understand in order to follow the expert's reasoning. For example, terms such as 'landslide', 'subsidence', 'settlement', 'fluvial', 'karstic', 'regolith', 'weathering' and even 'geohazard' are generally understood by geoscientists but not by many others. All such terms should be explained when they are first mentioned, whether in a public presentation or in the text of a report. They should also be defined in an accompanying glossary or online resource. When talking about the risks associated with particular hazards, it becomes especially important to use clear and consistent definitions of the terms being used. Terms such as 'hazard' and 'risk' are often used interchangeably when, in fact, they have different meanings (Auckland Council, 2014).

Explain the levels of confidence involved: Although modelling is vital for all phases of natural hazard risk assessment and disaster management, communicating the uncertainty that is inherent in these models, and between different models which give a range of different outcomes or views, is a challenging task (Doyle *et al.,* 2019). Equally, they point out that not communicating these uncertainties, in an attempt to avoid overwhelming or confusing the receiver, can also be problematic. This is particularly so in the case of multi-model or cascading models where uncertainties can be compounded to give very large margins of error. Scientists must first understand decision-maker needs, and then concentrate efforts on evaluating and communicating the decision-relevant uncertainties, in a way that can be understood (Doyle *et al*., 2019). Once again, collaboration and two-way communication is seen to be the key.

There is always a concern that conveying a low degree of confidence in modelling predictions will fail to elicit any urgent response from decision-makers. However, by ensuring that the issues have been properly discussed, then at least it will be possible for informed decisions to be made. Failing to disclose the uncertainties could risk urgent warnings being issued without justification, leading to widespread mistrust in the modelling and warning systems, with potentially catastrophic consequences in future events. With regard to public warnings that are issued ahead of a forecast event, in order to be effective, it has been argued that the warning message needs to convey a high level of certainty about the event and what people should do (Mileti, 1995). Even if there is only limited confidence in the forecast, or an ambiguous situation, the message about it should be stated with certainty. That is not to say that the confidence of the prediction should be overstated; only that the message should provide confidence that the warning is real and should be heeded, even though it may be precautionary.

Key principle 2: Identify 'target audiences'

Geoscientists will sometimes know, intuitively, what needs to be done – e.g. whether the hazard itself can be reduced in some way; whether it can be avoided, through well-informed spatial planning; or whether it is likely to require emergency evacuations in response to warnings.

However, they will need to liaise with other professionals (those with the responsibility for carrying out these actions) in order to discuss the feasibility, or otherwise, of different approaches, and so that they can understand exactly what those groups of people need to do (Thompson *et al.*, 2019). In this way, geoscientists can tailor their inputs and advice accordingly. This serves to re-emphasise the importance of two-way communication. By engaging in early dialogue with the various different groups, an exchange of understanding, as well as information, can be developed, which can then lead to effective collaboration.

The need to differentiate between different target audiences in terms of the types of information required and the methods of communication to be used is nothing new (e.g. McKirdy *et al.*, 1998, Reynolds & Seeger, 2005; Marker, 2008; Becker *et al.*, 2015; Midtbust *et al.,* 2018; and Doyle *et al.,* 2019). In the geohazard context, it is useful to consider the potential range of different audiences in two main categories: those who need to be proactive in risk reduction such as engineers, planners and insurers; and those who would need to be reactive to any warnings that are given including developers, emergency services, the general public, and the media (Table 1). The two categories are somewhat flexible, since particular groups may behave either proactively or reactively in different circumstances.

Key principle 3: Engage in dialogue

Having established which groups of people they need to liaise with, there is a need for geoscientists to understand

Table 1: Outline of information likely to be needed by various user groups in dealing with geohazards.

Types of Information / Guidance	"Proactive" User Groups				"Reactive" user groups			
	Engineers	Planners	Local Government	Insurers	Emergency Services	Developers	General Public	Media
Detailed technical information (including historical + monitoring data) on the nature, timing, causes, behaviour and spatial distribution of specific hazards *	✓			✓				
Simplified but clear and comprehensive advice on the nature, significance, magnitude, probability and spatial extent of the hazards **		✓	✓	✓				
Simplified summaries of key information on hazards, solutions and actions required**					✓	✓	✓	✓
Detailed technical input / comments on appropriate engineering solutions**	✓							
Clear, reasoned advice on appropriate planning approaches, including both forward planning policies and development control procedures**		✓	✓			✓		
Clear understanding of the need for rapid communication and the types of action required by emergency workers in response to warnings**			✓		✓			
Customised advice to provide an understanding of their full range of responsibilities**			✓		✓	✓		✓
Straightforward explanations on what to do in response to warnings**			✓				✓	
General guidance on responsible communication of hazard and risk information**	✓	✓	✓	✓	✓	✓	✓	✓

NOTES: * information or guidance produced by geoscientists. ** Information or guidance produced by geoscientists in collaboration with the relevant 'target audience' the type, and level, of information required, and what each group needs to do with that information in order to play its part in reducing the impact of hazardous events. This aspect includes additional steps for making sure that sufficient information is available, obtaining additional information, where necessary, and checking that the information is suitable for use by the intended audience (Figure 1). The objective, in all cases, is to ensure that each group can understand and act appropriately upon the information received. Once again, this requires close collaboration and two-way communication. Each of the groups listed in will have different requirements for information, based on the actions which they themselves need to take and the levels of interest and existing awareness or understanding which they are likely to have (Table 1). Precise details will vary from one situation to another and the following suggestions provide only a very general guide.

Proactive Groups: Civil engineers, including those responsible for the safe design of buildings, foundations, highways, railways, reservoirs, canals, flood defences, pipelines, coastal/sea defences etc., need detailed technical advice on the nature, scale and geographical location of the hazard, together with input from geoscientists to discussions on the range of engineering solutions and responses which may or may not be appropriate. Such advice may be needed both in the context of reducing or mitigating the hazards themselves, and/or in the context of remediating damaged areas following a hazard event. As previously noted, in some cases, the nature and scale of the hazard may be such that engineering responses or solutions might not be appropriate at all or may impose unaffordable costs. Geoscientists also have an important role to play in providing advice on these situations, based on their own specialist knowledge. Planners, regulators and inspectors (including those responsible for land zoning, policy development, building control, or the determination of planning permissions or licences, and the implementation and enforcement of conditions) need simplified explanations of the hazards and their spatial extent, together with clear explanations of what needs to be done by them in order to guide new development to the most appropriate (safe, sustainable and environmentally suitable) locations and to provide the necessary control. Local government officers generally need to understand their full range of responsibilities – particularly for communicating key messages about hazards, solutions and opportunities – but also for the coordination of planning, public warnings and emergency responses. Insurers need to understand the scale, probability and spatial patterns of risk, including access to the underlying technical datasets (e.g. on the magnitude, frequency, location and consequences of previous events), in order to be able to assess their own overall risks and thereby provide appropriate insurance cover at affordable premiums. Also, sound information gives a basis for re-insurers against large scale disasters to plan ahead.

Reactive Groups: Emergency services, including fire fighters, search and rescue teams, police, ambulance services, the army, civil defence and emergency rescue volunteers, need an awareness of the types of hazard involved and a clear understanding of the types of action required in response to specific warnings, in order to keep people safe. They need to be clear about relatively safe facilities and about planned evacuation and intervention routes. They also need to be aware of how best to communicate information to their workforces, the public and the media. Developers, including their architects and consultants, need to understand the planning and other regulatory requirements relating to hazard mitigation and the need for compliance because of environmental limitations on safe development, even if that reduces profits. They also need to understand their legal liabilities and moral responsibilities for safe development within hazard-prone areas. In the UK, developers are often also required, through planning conditions and/or legal agreements, to provide compensatory measures (such as natural wetland areas to alleviate flooding), in relation to development that would otherwise have an adverse effect. The general public, including community groups, lone individuals, teachers and children, need to have a general awareness of the hazards and an understanding of the importance of taking action to reduce their vulnerability. In particular, they need straightforward, clear and authoritative explanations on what to do in response to warnings.

Local communities can also play an important role in understanding local hazards themselves and two-way communication with these groups can be essential in carrying out vulnerability assessments (Catto & Parewick, 2008). Unlike the various other categories, communication with the public will often require (or at least, will benefit greatly from) an understanding of social psychology and will therefore usually require geoscientists to work in close liaison on this with appropriate experts within national, regional or local government or involved institutes. People who receive warnings first typically go through a social psychological process to form personal definitions about the risk they face and ideas about what to do before they take a protective action (Mileti, 1995). Public warning systems that take this process into account can be very effective in helping at-risk publics find safety before disasters strike. It may be difficult for people to understand a hazard warning when they do not understand much about the hazard itself – hence the need for carefully explained general information as well as (and in advance of) specific emergency warnings. Such information may also be beneficial in overcoming 'fatalistic' attitudes among some groups, including those which may be linked to long-held beliefs or ideologies, so that they are more likely to take heed of warnings when they are issued. It may also be beneficial for open explanations to be given immediately after disaster events, so that people can make sense of the situation and have confidence in future warnings. Effective public warnings must also provide for public interaction and foster the search for further information in addition to received warnings.

The media including television, radio and internet broadcasts, social media platforms and newspapers, are a special category in publicising information relating to geohazards. Media communications can be beneficial both in advance of any specific events, as part of the general public education and awareness, and as an integral part of any public warnings and rescue or recovery advice that is given immediately before, during and after a particular hazard event. But the media can also have very negative effects if not properly controlled. Hazard and risk information and warnings that are issued to the media by geoscientists or others therefore need to include clear but measured advice on the nature of specific hazards; the actions which are being or will be taken by planners, emergency services and other groups in response; and the importance of responsible communication.

Information Quality: As well as considering the various types of information required, consideration also needs to be given to the relative importance of different characteristics or qualities of information, in each case. Not all information needs to possess the high standards of technical accuracy and precision as that which is exchanged between geoscientists, or between those scientists and engineers. For other audiences, the emphasis should be on providing an appropriate level of simplification – without compromising essential accuracy – and on being as concise as possible. In all cases, there will be a need for clarity, and the avoidance (or clarification) of doubt.

Key principle 4: Deliver the required information

The generic model envisages that delivering the information is expanded into a number of separate stages: modifying the information (where necessary) to suit the user's requirements; liaison with the users to produce appropriate solutions, policies or action plans, and any supporting dissemination material that is likely to be required; then implementing those solutions and finally monitoring the outcomes to ensure that they remain 'fit for purpose' (Figure 1). The most effective method of communication for delivering information to the various user-groups will clearly vary from one group to another and with the nature of the specific task (with an obvious distinction, for example, between general information that is used to improve background awareness and preparedness, and that used for urgent warnings). The selection of appropriate media depends on suitability for the intended audience, penetration to the intended user group, cost and the possible need for future revisions of materials.

Detailed technical reports supported by database information, numerical modelling and other forms of computational analysis will be essential for communication between technical specialists within and between the geoscience and engineering sectors. Such reports, however, would be wholly inappropriate for passing information on to planners, politicians and other decision-makers. Instead, there is a need for such information to comprise simplified but accurate 'plain language' documents, maps (whether in printed or electronic form) and other graphics, each of which are tailored to the requirements of individual user-groups.

For the general public, including teachers, school children and students, similar information and guidance can best be provided by simplified but accurate educational programmes, broadcast from responsible sources via television, radio and/or the internet. For more detailed or site-specific information, which encourages the public to become more engaged with the issues, it may be possible to make use of mobile apps such as those used in connection with Singapore's citizen science engagement around flooding (https://www.mewr.gov.sg/topic/flash-floods) or flood risk mapping in the UK (http://www.knowyourfloodrisk.co.uk/). Alternatively, a good example of an online booklet written in plain language is that provided by Hong Kong's Civil Engineering and Development Department regarding landslide hazard and risk (https://www.cedd.gov.hk/eng/publications/geo/natural-terrain-landslide-hazards-in-hong-kong/index.html).

In the case of more urgent information, such as warnings issued in advance of forecast events and during actual events, other lines of communication will become increasingly important. Confidential daily bulletins may need to be issued routinely by those responsible for monitoring potential geohazards, in order to maintain an appropriate state of readiness amongst the various 'proactive' user groups (e.g. between local government and emergency services). Public warnings, when required, will also need to be issued by a respected, central, coordinating authority. People generally prefer to trust experts rather than media reports (Ahmad *et al*., 2014). While this is understandable, the importance of the formal media (newspapers, television, radio and internet broadcasting) in being able to disseminate information cannot be underestimated. It is important, therefore, that these outlets are provided with appropriate – suitably balanced and accurate – messages which are clearly linked to the advice from geoscientists and other trusted experts.

In Malaysia, the short message system (SMS / text messaging) is used to issue alerts to relevant officers in-charge of government agencies (Noorhashirin *et al*., 2016). It has been suggested that such alerts be extended to the general public community because of its speed, effectiveness, and functional resilience to disaster. To be effective however, such messages must always be carefully worded to avoid confusion and panic, and they must be credible, reliable and capable of being understood by the target audience, especially in rural areas (Sahu, 2006). For maximum effectiveness, SMS messages need to be backed-up by confirmatory and more detailed information issued via other means, such as television, radio, websites and social media (Niles *et al.,* 2019). While social media provide a corroborative source of information during hazard events, it can just as easily be the cause of disseminating misinformation (or 'fake news'), whether through a lack of understanding or mischievousness. This highlights the absolute necessity of being able to issue clear, accurate and authoritative information, as rapidly as possible, through reliable broadcast or electronic media or directly from respected (often government) sources. Frequently repeated warning messages can help to reduce the effect of misinformation and misperceptions (Mileti, 1995). They can focus people's attention on official messages, reduce rumours, and increase public confidence in the validity of the warnings.

KEY PRINCIPLES IN ACTION

The generic model was based on the case of Ripon, in England, where a comprehensive study of subsidence hazard was funded largely by the UK Government and partly by the local planning authority (Figure 1). There was a need for the local planning authority to guide new development towards relatively safe areas, unaffected by subsidence (Thompson *et al.,* 1996; 1998). The solution was found through dialogue and close liaison between planners and geoscientists with expertise in engineering geology, geomorphology, hydrogeology and hydrochemistry (Thompson *et al*., 2019). The solution was implemented primarily through policies within the Development Plan for the area and has subsequently been monitored and improved, where necessary (primarily to ensure continued compliance with changes in professional standards for geotechnical expertise). The policies were accompanied by information and guidance issued to all prospective developers and by summary information issued through local newspapers to the general public. This was primarily to reassure the public that, although the risk of subsidence needed to be taken seriously, the likelihood of this occurring at any given location was generally quite low.

Additional case studies, based on this generic model, were developed for the project on "Disaster Resilient Cities: Forecasting Local Level Climate Extremes and Physical Hazards for Kuala Lumpur", funded by the Newton-Ungku Omar Fund. These encompassed landslides in Columbia; flood risk mapping in the Asia-Pacific region; and rockfall hazard and risk assessment in Malaysia and elsewhere (http://ancst.org/nuof/publications-reports/). All these case studies involve the communication of geoscience information. They were compatible with the generalised model described above and, together, illustrate how various approaches can be developed within the overall framework. Several training sessions were held under the aegis of the Geological Society of Malaysia, a consortium member of the Newton-Ungku Omar Fund project. The training involved participants from the region, who had developed case studies on hazards in their respective countries, a few of which were published (Manh, 2018; Naing *et al*., 2018; Seng, 2018; Khan & Shah, 2019). During the hand-on-training, the generic model was found to be applicable to their respective work. The geohazard communication model is now being disseminated to be used in training modules for geology practitioners.

CONCLUSION

Effective communication of geoscience information is important for developing suitable responses to a wide range of geohazards. The role of the geoscientist is essential – not just in recognising and investigating the hazards – but also in liaising and collaborating with a variety of other practitioners, so that accurate and reliable information is communicated to those who need to use it, in a form that they will understand. Four key principles of geohazard communication have been identified to provide a framework to guide geoscience communication which can be adapted, as necessary, and applied to many different circumstances and geographical areas. The principles are linked to eight stages of a generic model for geohazard communication that has been tested in the field and found applicable to the region.

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