FROM SCIENCE TO PRACTICE: A NEW ZEALAND CASE STUDY OF IMPROVING NATURAL HAZARD RESILIENCE

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ABSTRACT

At a fundamental level the earthquake problem is one of risk reduction, but there are major challenges related to the transformation of scientific knowledge into sustainable community practices. The potential scope of shared responsibilities for delivery of social outcomes is also notoriously uncertain. In New Zealand, advances in understanding of seismic risk have occurred on several fronts since the 1930's, leading eventually to new and widely-emulated practices in seismic isolation and capacity design for reinforced concrete structures. Reconstruction policy was also an early consideration with the Earthquake and War Damage Commission created during the 1940's. It was recognised that economic recovery had been excessively slow in communities damaged by earthquake, due to lack of insurance and limited access to capital for reconstruction. The Earthquake Commission (EQC), as this government entity has been named since 1993, remains at the centre of arrangements for dealing with geological risks, through its insurance scheme for residential property and its duties to facilitate research and public education into natural disasters and methods of reducing or preventing the damage they cause. EQC fosters research and public education in relevant areas of natural hazards science and engineering and assists its transformation from "science to practice", offering a connection between scientific progress and improved resilience within the community. In this paper we argue that a key condition for successful knowledge transfer is an adaptive research culture, guided by simple principles rather than precise planning or direction. A core objective is to build alliances across organisations to enable collaborative decision-making and iterative learning. Through examples of research and community partnerships, the imperatives for EQC investment in research and public education are outlined.

KEYWORDS: Research, Public Education, Earthquake, EQC, New Zealand.

1. LIVING WITH EARTHQUAKES

At a fundamental level the earthquake problem is one of risk reduction, but there are major challenges related to the transformation of scientific knowledge into sustainable community practices. Earthquakes and volcanoes have shaped the mythology and history of New Zealand since these islands were first settled by Maori in the 13^{th} century. However, not since the 1930's and early 1940's – a period in which large shallow earthquakes struck repeatedly - has New Zealand suffered major social disruption or serious economic setback due to geological hazards, although there have been local impacts (ODESC, 2007). The damaging earthquakes of that earlier period prompted the introduction of principles for seismic design, developed largely in Japan and California, which formed the basis of the first national building code in 1935. Those experiences contributed to the emergence of a research culture at Government laboratories and universities and later to the development of widely emulated practices in seismic isolation (Skinner, et. al., 1993) and capacity design for reinforced concrete structures (Park and Paulay, 1975; Paulay and Priestley, 1992). Reconstruction policy was an early consideration with the Earthquake and War Damage Commission created during the 1940's as an instrument of social policy using the insurance model. It was recognised that economic recovery had been excessively slow in communities damaged by a large earthquake near Wellington in 1942, due to lack of insurance and limited access to capital for reconstruction. Later, cover for other geological perils was included and, later still, cover for war damage dropped and the insurance cover organised around residential property only. Decades of relative seismic and volcanic quiescence since the 1930's pose a challenge for the effective management of natural hazard risk. The number of urban dwellers has swelled and with it a dependency on networked services, while few residents or community leaders today have experienced personal loss to geological hazards. Competitive forces in commerce and public sector restructuring have added complexity to the sharing of knowledge and accountabilities for managing natural hazard risk. At the same time, legislative reforms have introduced new expectations of sustainable development and environmental resilience, with New Zealand's long-term resilience to natural hazards a significant and growing determinant of planning outcomes at community level. The latest changes are expected to facilitate assessment and reduction of risk at all levels in the community, while their effectiveness varies according to the human capacity and financial resources of local communities and their commitment to strategic, as opposed to short-term planning (CAENZ, 2004). Against this backdrop of culture and tectonics the modern EQC (www.eqc.govt.nz) has a mandate to facilitate research and education about matters relevant to natural disaster damage, methods of reducing or preventing such damage, and the insurance provided under governing legislation, the Earthquake Commission Act (1993). EQC invests in research capabilities including the skills and enabling technologies, and facilitates research and its application. The aim is to reduce the government's liabilities arising from natural hazard events and to make communities more resilient to geological hazards. In this paper, we illustrate the imperatives that guide EQC's research facilitation and public education and its application to community resilience using examples of research and community partnerships.

2. RESEARCH AND EDUCATION - THE EARTHQUAKE COMMISSION AND ITS ROLE

2.1 Research Investment

EQC invests in research capabilities as well as research itself. The largest of these is to support geophysical monitoring and research with the enabling technologies and underpinning expertise in data management. "GeoNet" as this major research equipment facility is known, also supports a wider operational context related to national Civil Defence readiness and response. Faculty positions at four New Zealand universities are supported to provide vision and leadership in relevant fields of scholarship and to address gaps in New Zealand's capacity to assess and mitigate geological risk. EQC grants for research are contestable and proposals are required to meet standards of open science review in keeping with international norms. One funding pool is offered to experienced researchers in alternate years, and a second pool supports post-graduate student and early career research. A grant to the Fulbright Foundation provides a promising student each year with PhD research opportunities in the USA. Other grants facilitate technical meetings for relevant professional societies and engineering lifelines groups, post-disaster investigations and wider dissemination of knowledge resulting from EQC funded research. Project funding for the national standards organisation, Standards New Zealand, contributes to the revision of building codes and guidelines. EQC periodically funds research to address specific operational needs, and such work is offered through a tender process or negotiated in those cases where natural monopolies or complexity of scope make a consortia approach preferable. The services of a small number of technical advisors are retained to support grant allocation processes, under the direction of a research manager who is a member of the EQC executive management team. EQC Board oversight of the research function is delegated to the Research Committee of the Board.

2.2 Principles and Objectives

A well known principle of system design is that all components and linkages need to be upgraded evenly if the entire system is to perform optimally, with an equivalent improvement of outcome (Elms, 1992). EQC aims to apply this principle to research facilitation, while accepting that the knowledge that drives innovation is augmented by experience and events, regardless of formal planning and direction (Figure 1). A basic premise of the research program recognizes the dynamic essence of knowledge and the interdependencies that link knowledge to innovation and its application to best practice. Over the years this approach has evolved into a strategy that consists of a few principles that guide action, not precise planning from the top. One is to build alliances across organizations, in order to encourage collaborative problem solving and decision-making. Another is to foster an adaptive research culture, which demands integration of the physical, social and engineering sciences to address the totality of the risk environment, and flexibility in the approach to funding. In this way, niche opportunities are less likely to be neglected and new ideas can emerge in spite of priority settings. As an agency that facilitates theme-specific rather than sector-specific research, EQC seeks to ensure a broad perspective is maintained through the following objectives:

- The imperative to address gaps in knowledge about New Zealand's exposure to geological hazards and methods applied to reduce the severity of future impacts
- The importance of mentoring arrangements that build intellectual capital and international linkages;
- The need for niche support for training and capability development in relevant disciplines, supplementary to baseline public investment in higher education and basic research
- The need for stewardship and renewal of enabling technologies to support modern science and engineering research

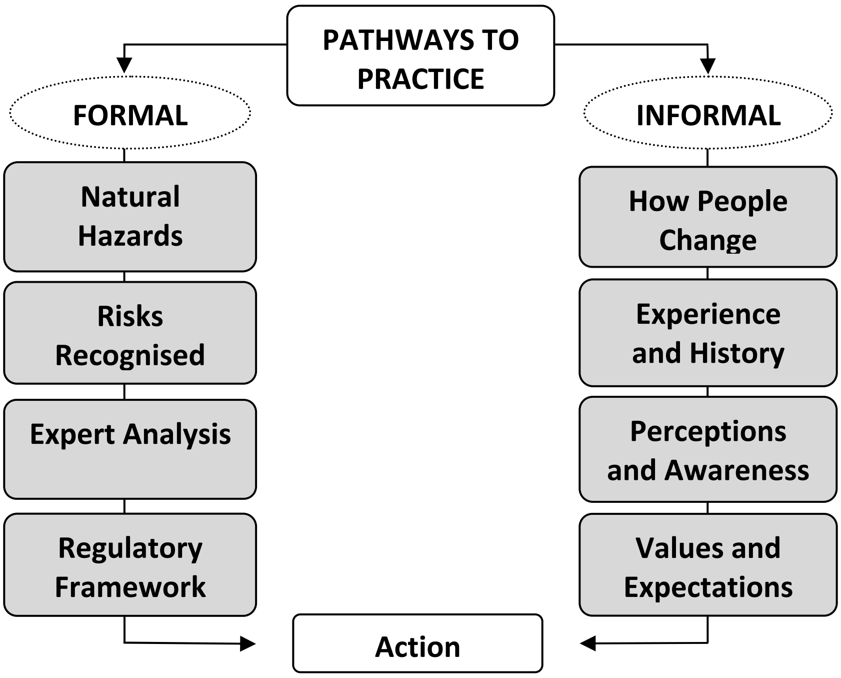

Figure 1. Formal and informal processes link the acquisition of knowledge and its uptake by people with a variety of backgrounds. A research culture responsive to the totality of the risk environment must demonstrate integration of physical, engineering and social sciences and understanding of these processes (adapted from CAENZ, 2004).

By parallel investment in public education EQC aims to see increased numbers of people taking actions to reduce and prevent damage caused by natural disasters. For more than a decade EQC has used various tools to promote this outcome and the results of regular consumer surveys have been seen as the way to determine the effectiveness of these measures, which included television commercials, internet and billboard advertising, schools information kits, museum and science-centre sponsorships, ethnic minority education and brochure translations, a mitigation website (www.eq-iq.org.nz) and display road-shows. Research has provided insight into the efficacy of EQC's education and outreach activities, identifying both the strengths and limitations. Surveys have shown that while reported awareness of mitigation methods and solutions has risen, mitigation activity has remained static. EQC's television and print media messages to encourage greater home safety have clearly raised awareness but other methods will be needed if people are to be motivated to more effectively mitigate risk in their own homes. Research conducted for EQC has provided insight into the barriers to mitigation actions (Paton et. al., 2003; McClure, et. al., 2007). Common factors include perceptions that the problem is insurmountable, the mitigation tasks too difficult to undertake, and the tendency to attribute responsibility for action to others. EQC is now adapting its public education strategy to tailor the timing and delivery of key messages to an increased number of specific audiences, through community-based partnerships, in order to maximise their effectiveness. This approach acknowledges that the media are increasingly diverse and that natural disaster education is a lifelong process.

3. THE TRANSFORMATION CHALLENGE - SCIENCE TO PRACTICE

The following sections illustrate how EQC's investment in research, although diverse in topic and scale, is unified by relationships between researchers, industry associations and public agencies for public policy and regulation.

3.1 Enabling Geophysical Research

Risk assessment is the fundamental basis for the process of risk management, requiring adequate knowledge of the hazard and the ability to evaluate trends. Without the resources to support and deliver such insight the risk management process has no adequate basis. "GeoNet" is a distributed network of geophysical instruments and software applications, supported by skilled personnel that facilitate data gathering and dissemination of information about New Zealand earthquakes, volcanic activity, large landslides and the slow deformation that precedes large earthquakes. Designed and operated by the national earth science research institute, GNS Science, the GeoNet facility represents an ~$80 million investment by EQC over 10 years, with additional contributions from other public agencies, including Land Information New Zealand and the Department of Conservation. Management of GeoNet, under an agreement with EQC in force since 2001, includes the public provision of data through a website (www.geonet.org.nz) at specified levels of accuracy and reliability. GeoNet not only gathers fundamental data necessary to continue high-quality research, but also provides coverage and resolution that allows the research to make gains in applicability and confidence limits, and opportunities for increased research collaboration — necessary for effective analysis of a large data resource. The high degree of system automation in near real-time also permits the delivery of rapid alerts and, in certain circumstances, warnings, for example to support aviation forecasting of ash plume dangers and to evaluate the likelihood of tsunami generated by earthquakes offshore.

3.2 Learning from Earthquakes

Earthquake disasters trigger the review of design and construction practices, with each major event revealing or highlighting specific issues. The 1994 Northridge, California, earthquake revealed deficiencies in pre-cast concrete construction and were reported by New Zealand engineers during post-event investigations (Norton et. al., 1994). Concerns were raised about the seismic performance of precast floors in particular. Precast hollow-core floor units had become popular during the 1980's because their reduced weight and speed of emplacement offered significant commercial benefits relative to traditional cast in-situ methods. Subsequent full-scale testing by the University of Canterbury of one of the prevalent floor assemblies of that period indicated serious deficiencies in seating and detailing at lower than expected seismic displacements (Matthews, 2004). A multi-agency technical advisory group set up to review the work went on to recommend changes in design approaches. An amendment to the Concrete Design Standard, NZS 3101 was adopted in 2004 and later cited by the Government agency responsible for national building controls (formerly the Building Industry Authority, now the Department of Building and Housing) as a means of compliance with the national Building Code. At that time, public disquiet about the effect of reforms to the regulatory environment of the building industry more than a decade earlier spawned reviews by Government of engineering design and construction practices, including the use of hollow-core floors. The objective was to determine the extent and nature of the use of these systems nationally, to relate that use to the concerns raised by the University of Canterbury tests and to advise the industry of any corrective actions that might be required. A number of existing buildings were identified with potential vulnerabilities in cities exposed to higher levels of earthquake hazard. Local government officials responsible for building controls in those areas were notified and advised to inform the respective building owners to make more detailed checks. Further testing at the University of Canterbury in accordance with details recommended in the revisions to NZS 3101 showed markedly improved performance from the original detail

(Lindsay, 2004; MacPherson, 2005). A practice advisory and more general policy have since been published to communicate publicly the government's position on the hollow core issue (DBH, 2007) and further refinements to the Concrete Standard may be anticipated.

3.3 Improving the Management of Landslip Risk

Many New Zealand communities are vulnerable to landslips, with EQC receiving an average of 770 claims each year over the last five years. Determining the balance between allowing people to develop or use land, and restricting their exposure to natural hazards is complex. Understanding how a variety of professionals across the planning spectrum evaluate natural hazard risks, what influences their decisions and how well planning assumptions carry through to performance are not well documented. Important work already undertaken through wider government research has identified best practice in land use planning for landslip prone areas (Saunders and Glassey, 2007). EQC is now facilitating a follow-up study involving different organisations and local communities to gauge the difference between current practice and best practice, specifically seeking insight into factors that may affect the quality of decisions for the use of landslip prone land. These factors include the perception of acceptable risk, the influence of legal liability, access to existing technical information, local government resources and internal processes that support decisions on land use, and compliance with, legislation and policies. The findings will be used to map relationships and influences on decision making, with the goal to identify practical ways to improve planning for the management and use of landslip vulnerable land. Investigation of the capacity and willingness of engineering and planning practitioners to apply the new guidelines also forms part of this assessment.

3.4 Adaptation of Standards

Engineering practice in New Zealand follows worldwide trends including principles, guidelines and recommendations, but in some cases may require the extension of design rules to local conditions, leading to uncertainties about the appropriateness of product or practice refinements. Shallow embedded plate anchors have a wide range of applications in the construction industry. They are commonly used to connect precast concrete panels and for the fixing of structural steel members to concrete panels. Until recently there were no practice guidelines or experimental results to determine the load deformation response of shallow plate anchors, despite their widespread use in New Zealand for many years. The work of Allington (2005) was specifically tailored to address this gap in knowledge and verify through testing the applicability of European and American standards. The study identified and recommended several modifications to account for the characteristics of plate anchors, which have now been incorporated into the Concrete Standard NZS 3101.

3.5 Guidance Information for Practitioners

The uplift of a structure from its foundation and rocking during a strong earthquake is a commonly observed phenomenon which has to be accommodated by design, and may also offer the potential to dissipate seismic energy. Special studies are recommended where dissipation of energy is to be accommodated by rocking of foundations, because dynamic interactions between foundations and the soil are non-linear and both the structural deformations and the associated redistribution of forces cannot be modelled using conventional linear elastic analysis. Although pioneering work on this topic has been published in New Zealand (Priestley et. al., 1978), and recent work at the University of Auckland is aimed at wider implementation of rocking protection as a retrofitting solution (Ma et. al., 2006), the revision of the NZ Loadings Standard (NZS 4203: 1992) has created an immediate need for guidance information for practitioners. In its previous form the Standard allowed simplified design procedures if the assumed ductility of a structure indicated uplift would occur at no less than 50% of the full elastic load – a restriction met by many low-rise, shear wall buildings. However, the revised Standard (NZS 1170.5: 2004) requires special studies wherever rocking structures are contemplated, reflecting concerns that the previous rules were not adequately supported by science. The absence of published guidelines to accompany this change posed difficulties for design offices which lack specialized modelling software and expertise. The change affects low-to-medium rise structures in particular, for which alternative design methods to prevent rocking would be uneconomic. This gap in guidance information which lay squarely between science and practice has now been addressed with guidelines completed and presently in review (Kelly, 2008). The aim of the new guidelines is to provide a sufficiently robust alternative to the special study currently required by NZS 1170.5, suitable for implementation in a spreadsheet format. The guidelines do not fully quantify non-linear soil properties, radiation damping and other complexities, but should provide guidance information at a level of detail applicable to design office assessment of moderate rocking and relatively simple and regular structures.

3.6 Fostering Collaboration - Engineering Lifelines

An example of successful community engagement fostered by EQC since the early 1990's, which has seen the challenge taken up by asset owners, local authorities and professional societies, is the New Zealand Engineering Lifelines process, through which a number of studies of vulnerability and mitigation options have now been completed in the metropolitan and provincial centres (Brunsdon, 2000). There are now lifelines projects and groups established or being planned in most regions of New Zealand, and the process represents an effective regional scale collaborative model for integrating technical processes with other community considerations. The process is based on the international risk management standard AS/NZS 4360:1999 (SA and SNZ, 1999), and is applied on a regional, rather than on an organisation-by-organisation, basis; responsibility for mitigation and preparedness remains with each participant organisation. The relationships and practices fostered through these activities over two decades are now being extended to mainstream, civil defence and emergency management planning (Brunsdon and Evans, 2003).

4. DISCUSSION

New Zealand is a country subject to a high risk from natural hazards, but with only two severely damaging earthquakes during the past 40 years (1968 and 1987). International experience has provided the exposure needed for benchmarking of local practice as it evolves. For younger professionals involved such experiences provide an enduring context for their careers in engineering and earthquake science. The gains from such learning, combined with advanced education and research are accrued over time and applied across three levels of civil administration (central, regional and local government) which play a vital role transforming hazards data and information into processes that improve disaster risk management. Territorial Local Authorities (73 city and district councils) are responsible for daily planning and consenting processes; Regional Councils (12) are responsible for environmental policy direction; Unitary Authorities (4) perform the combined functions of regional and local councils; and Central Government. Local government both administers and operates within key provisions of legislation that regulate community exposure to natural hazard risk. For the Earthquake Commission, a government entity now approaching 65 years of operation, there are opportunities to improve the sharing and application of knowledge related to natural disaster risk across these administration boundaries as well as those of technical disciplines and business models.

The examples presented in this paper are selected from a diverse pool of research to which EQC has contributed sponsorship often in tandem with industry partners, professional associations and other public sector agencies. The aim is to illustrate the principle that some research can only be, or is best, undertaken locally, because the knowledge needs are unique - no one else will do it - and it provides essential support to important sectors of the economy and society. Parallel needs exist to nourish the intellectual capabilities that are required to utilise, adopt or adapt science-related knowledge, products and technologies which have been developed elsewhere. To be able to appreciate the significance of trends and technologies that arise elsewhere, and to evaluate their relevance and priority for potential use and further local involvement, are attributes to which any small country might aspire and EQC seeks to maintain. Improving these outcomes is central to the EQC research strategy and complementary to its investment in skills, research capacity and knowledge. Both elements are a growing determinant of planning outcomes for commerce and government and critical to New Zealand's long-term resilience to natural hazards.

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