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Valuing hazard data:

Looking closely at GeoNet

Report to EQC

July 2009

Preface

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NZIER was established in 1958.

Authorship

This report has been prepared at NZIER by Peter Clough and John Yeabsley. We acknowledge the assistance of the staff of the EQC, particularly Priscilla Cheung who cheerfully worked her way through an extensive list of interviewees to set up a series of sessions despite the complex timing constraints we and others imposed, all of those who we interviewed, Rachael Trudgeon who plied us with coffee and tea to keep us going, and Hugh Cowan, whose enthusiasm and knowledge of the issues was always encouraging. We also must thank Rob Laking who, after having been on the review panel, helped set up the project and advise us as part of the process of carrying it through.

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Key points

GeoNet has provided a positive return on investment for EQC (through reduction in reinsurance costs), and also for other parties with interest in academic research (IGNS, universities, FRST/MRST), disaster preparedness (local authorities, McDEM, CAA, DOC) and the wider public through impacts on insurance costs and mapping technology (LINZ).

How much of this benefit is attributable to GeoNet is indeterminate, because it is difficult to separate out other factors' influence, but the full report examines this to the extent possible. Our conclusions are briefly pulled together below.

Improved information on hazards has led to recalibration of the risk models applied to NZ, with benefit to all insurance purchasers in NZ (not just EQC).

Also there are external benefits from the new understanding of the nature of the local hazards (based on better information) and reducing the uncertainty around the nature of the seismic and related risks. The volume and real time availability of the hazard monitoring data means better and more up to date information is available during or just after hazard events to assist in managing or responding to them.

The general international literature on the value of information has little to say about this type of information, but there is some specialised literature built on the expectation that improved seismic knowledge results in various types of avoided costs accruing to the community when adverse seismic events occur. Some of the benefits will come from direct reductions in expenditures, others by enabling redirection of expenditures for greater system resilience. The timing and scale of these effects is variable as they are subject to differing degrees of delay in implementation. The decision-making processes with implications for the effects on the building and infrastructure stock are complicated and benefits take time to be realised.

The expected value of avoided costs is usually small with low frequency high impact events in the presence of a positive discount rate, but reducing uncertainty and improving understanding is of real value for planning between such events. This benefits agencies involved in planning for and implementing disaster response, and to the extent it results in increased infrastructure resilience also has a positive feedback on EQC's potential liability.

Also there are benefits from skills development and the export of related services, and from pure academic interest in pushing boundaries of knowledge. The latter effect will inevitably increase the amount of work done in the NZ context and thus improve further our understanding of the local hazards.

Criteria built on new knowledge of the nature of risk, scale of potential impact and ability to act on that knowledge provide guidance on where new investment is most worthwhile.

Overall

Subject to a number of limits of the assessments we have been able to make due to lack of information, (as discussed in the rest of the paper) we conclude that:

- The past investment in GeoNet was worth it for the EQC's private benefit.
- Thus it was also worthwhile from a national perspective, as there are further benefits and no extra costs.
- Future investment to maintain the capability of GeoNet will be worthwhile for the EQC as the benefit return each year should exceed the costs.
- So the national benefit too will exceed the costs.
- Future benefits for the EQC and nationally from investment to enhance GeoNet capability may be worth it in some cases.

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1. Introduction

GeoNet is a New Zealand hazard related data collection and transmission system that is operated by GNS science, a CRI. After a small and dispersed monitoring structure was pulled together in the last decade of the twentieth century, plans were drawn up to build a larger, integrated set of measurement sites. This was to be nationally funded.

But this funding was not to be. Instead, after attempts to create a coordinated "beneficiaries club" did not work out, the broad proposal was sponsored by the research funding side of the Earthquake Commission (EQC). During the 8 years of operation they had the progress reviewed by two panels which included a strong dose of international expertise in seismic monitoring.. Both concluded there would be payoff to additional investment in the network. The second panel's view[1] was that the system was working well and that it had high national value.

1.1 The brief

To gain a more in depth picture of the scale and scope of the national benefit from the investment in the development of the GeoNet system EGC commissioned NZIER to carry out a study. Terms of reference are at Appendix A.

The focus was on the GeoNet hazards monitoring system but was also to cover development of the associated Minerva risk modelling tool, the flow on from new data and hazards research to risk modelling, and changes in EQC's strategy of engagement with reinsurers. The analysis was intended to assist EQC in quantifying the contribution its GeoNet and related investment has made to improved knowledge and modelling of geological hazards and risk, and towards the wider objectives of its overall research portfolio covering natural hazards in New Zealand.

The methods adopted and data gathered in the course of the work should assist EQC and the research community to make more informed decisions about investment in improving information about natural hazards.

The analysis covers:

- the return to EQC on its own investment in GeoNet and related research
- the wider net benefit to New Zealand from the resulting improved knowledge about natural hazards.

The method employed was straight forward. The team undertaking the study were provided with a range of relevant material produced by EQC over the years and also facilitated to interview a range of people[2] specially knowledgeable about the various benefits that might accrue from the improved information that became available from

[1] GeoNet Panel (2008)

[2] See the list of those who contributed at Appendix C.

the investment in the system. We were also asked to look in the literature for relevant material that could potentially assist in developing a picture of the benefits.

This study falls in the general class of analysis using economic cost benefit measurement. Economic cost benefit analysis (CBA) assesses the worth of GeoNet by identifying the differences between the world with GeoNet and what would have happened without it. It encompasses public value, which is interpreted broadly as any benefit that accrues to New Zealand or New Zealanders, based on the expectation that there will be externalities from the information gathered by GeoNet that will not be fully captured by EQC or those involved in creating and maintaining GeoNet.

1.2 GeoNet the basics

GeoNet is a measuring and reporting system. Its core is a string of monitoring stations spread around New Zealand, whose location is exactly known. They are of different types: some are seismic, others volcanic, and yet others are reporting on earth slips. Finally and most recently established, there are stations to look out for water movements associated with tsunami.

The latter are an instance of the gradually shifting nature of the heart of the GeoNet capability. The task of monitoring for tsunami was assigned to GeoNet because its communication setup was already in place and could be used at marginal cost to provide the information gathering and distribution services desired by those interested in tsunami.

The stations are all carefully located with individual mechanisms of various types to observe and measure the effects – via appropriate instrumentation – of the phenomena of concern and transmit the rich (continuous digital) data[3] via satellite back to a ground centre in Sydney from whence it is retransmitted to its various users.

Investment in GeoNet to June 2008 has been $50.5 million, comprising running costs of about $4.8 million per year, accumulating to about $29 million, and capital costs of about $6 million in the first year and $2-3 million per year thereafter, accumulating to $21.5 million. GeoNet has accounted for 9% of EQC gross premium income over the 2002-2008 period, ranging from a high of 12.9% in 2002 to a low of 6.8% in 2003.

As a share of EQC's investment in research activity since it began in year ending June 2002, GeoNet has accounted for 85% of research funding, compared to 11.6% for other research activity and 3.4% for development and operation of Minerva risk assessment tool.[4]

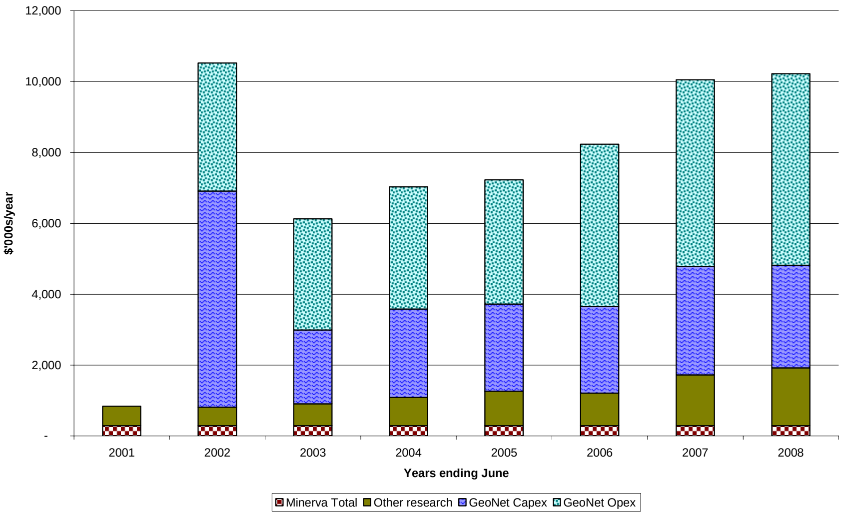
[3] The daily output of data from GeoNet is a DVD-load.

[4] This is based on an operating cost for Minerva of about $100,000 per year, and development costs of $1.5 million. Much of the development cost will have preceded the period being considered here, but it has been annualised over 15 years at 9.5% per annum (as per Treasury's

We understand that annual levels of investments currently proposed to develop the system over the next ten years are about the same levels as recent years.

The pattern of costs is illustrated in Figure 1. In the early years of GeoNet the bulk of the spending was on capital investment, but in recent years operational and maintenance spending have exceeded capital upgrade and renewal.

Figure 1 EQC research funding over the past 8 years



Source: NZIER, from data provided by IGNS and EQC

The data provided by GeoNet has become integral to the EQC's operations, being used to continuously update the Minerva model to assess risk before events and potential liabilities after they occur. It has also become embedded in processes external to EQC, such as connections to the Continuous Operating Reference System used by Land Information New Zealand (LINZ) in revising its mapping datum and use by various local and central government agencies with responsibilities for civil defence preparations.

1.3 Findings in brief

Overall

We have devoted the rest of this report to addressing the questions about the benefits of the investment in GeoNet. This section pulls together a series of crucial conclusions we have formed about the nature and results of that investment. The conclusions reported here draw on the discussion in the rest of the report and thus

guidelines on discounting research and development investment), to arrive at an annual cost of $192,000 per year on development, in addition to operating costs.

on our interactions with those we interviewed, the material they put in front of us and the reading we undertook.

It must be noted that these are our professional judgements and must be seen as carefully made opinions that are founded on the facts and our analysis of them.

We conclude that:

- The past investment in GeoNet was worth it for the EQC's private benefit.
- Thus it was also worth while from a national perspective, as there are further benefits and no extra costs.
- Future investment to maintain the capability of GeoNet will be worthwhile for the EQC as the benefit return each year should exceed the costs.
- So the national benefit too will exceed the costs.
- Future benefits for the EQC and nationally from investment to enhance GeoNet capability may be worth it in some cases.

2. Information and value

The value of GeoNet substantially revolves around the worth of the improvement in information it provides. Information is a product notoriously subject to market failure, because often it is difficult to control access to, and use of, information once it is provided, and hence difficult to fully recover costs of generating the information. Even where information can be appropriated and made subject to commercial transactions, keeping it confined to the transacting parties can be inefficient, because the marginal cost of extending information to new users, once it is generated, is virtually zero, so price rationing is likely to choke off beneficial activities that could create more social value from that information.

Hence information is surrounded by debate about positive externalities from wider access and the role of government in supporting information provision[5]. In recent years, with the lowering of transaction costs of moving electronic information around on the internet, there has been a tendency in OECD countries to increase the free availability of information generated by government agencies (e.g. topographical mapping information) in the expectation that free access will generate more net benefit in the community at large than can be recovered by pay for access. GeoNet sits within that pattern by gathering and widely disseminating information.

The international literature on the value of information is somewhat diffuse tending to be rather topic specific, reflecting a view that as an ill-defined or at least ethereal product, information can take many forms and thus play wildly different roles. This leads in turn to the logical result that the value of information can be very different according to the type of information and the setting.

Hirshleifer[6], defines information very generally as events tending to change the individual's subjective probability distributions over possible states of the world[7]. The key feature here is the way the information drives the process of change in the world view of the individual. Much of the literature is about economically relevant information in the context of inventions (a literature in its modern form stemming from Arrow[8]) or to the specifics relating to the process of bargaining about prices (Kennan and Wilson[9]).

[5] To cite but two relatively recent local controversies, there has been debate about the review of New Zealand's intellectual property laws (which are one way the government provides a legal structure to deal more consistently and cheaply with the issues raised in the first paragraph of this section) and also about the pricing of the Statistics NZ data which is, of course supplied free by citizens as part of their obligations to the state.

[6] Hirshleifer, J (1972)

[7] He calls this the economist's approach and distinguishes it from the usage employed in Communications or statistical theory where a dispersed probability distribution is called less "informative" than a more concentrated one.

[8] Arrow, KJ (1962)

[9] Kennan J & R Wilson (1991)

But the context of interest here for the effect of the information is rather removed from this simple idea, whereby the value of the information will be reflected in the difference in price. In the situation here, we have to look a little more deeply at the way the information works through from its source to some change in the views about the world held by agents, and thence to a "positive" change in the world[10]. It is this latter difference in welfare that is seen as the "value," or more generally "benefit," of interest in the CBA.

Information from GeoNet can improve the estimation of expected values of events from seismic hazards, lowering the average, as it were, of the potential liability. This is the sort of thing that happened as a result of the research that resulted in the discovery of long slow earthquakes and the likely increase in the recurrence interval between severe earthquakes along the Wellington fault. This result, however, was a happy chance outcome – as we hear it the investigators could not have known in advance that the improved understanding would not have gone the other way to increase risk and thus the expected value of losses. (The implications of this question are reviewed below.)

Another important effect of information is to reduce the uncertainty around potential outcomes, in effect reducing the variance around the estimates of expected value. This reduction has value to society regardless of which way (or if at all) the associated information shifts the means.[11] This effect appears to have happened in the case of GeoNet, in that the major models used by reinsurers have been recalibrated in light of the information available for New Zealand.

In broad terms the value of GeoNet's information is derived from its contributions to economic welfare enhancement, from:

- The reduction or avoidance of the costs of ignorance
- The comfort derived from feeling in control of the situation
- The transferrable knowledge & skills gained from gathering information
- The option value of developing information that may be useful in future
- The existence value of gaining information for its own sake.

2.1 Overview

The literature on the economics of information in its modern form starts with the classic Stigler paper[12]. His approach was relatively focused; it built around the way that improved information can pay off for those engaged in search-type activities, such as lower prices, or higher wages in an environment of uncertainty that can only be addressed by undertaking costly activities.

[10] In this context "positive" means "welfare enhancing" from a social viewpoint.

[11] This is the subject of the discussion in previous paragraph and below.

[12] Stigler (1961).

The advantage of this broad model as a method of examining the issue of the value of information is clear: there are direct effects with measurable prices associated with them. Thus the benefits can be seen straight forwardly.

Our investigation of the literature since then is that, for all of the general ideas encompassed say by Hirchleifer (cited above) and Lamberton[13] there is little by way of a general economics of information that creates an authoritative framework.

What there is rather, is a series of advances in areas related to the general topic. This is characterised in pieces such as the overview by Allen[14], which has a promising abstract approach where some structure is erected, but the rest of the piece turns into a series of interesting remarks about different aspects of the broad topic. So we can reasonably conclude that where progress can be said to have been made it seems narrow and specific rather than broad. Even the magisterial Joseph Stiglitz[15] normally quick to propose sensible advances, (though admittedly focused on a slightly different question here) says about the subject:

> *"Since results often seem to depend, so sensitively, on the particular information assumptions employed, how are we to know what is the correct model? But the standard models have themselves made a particular set of informational assumptions—that information is perfect, or at least fixed—a set of informational assumptions which is fundamentally indefensible. Equally importantly, information economics has shown that results using that particular assumption themselves are far from robust.*
>
> *The complexity of the subject has resulted in many of the models being highly parameterized—using assumptions (like quadratic or constant absolute risk aversion utility functions) that, while mathematically tractable, are known to have properties that are inconsistent with observed behavior."*

Valuing information in general, then, from this brief literature review, is still very much work in progress. The cases where actual values are attached to information are highly specific. They rely broadly on exploiting particular aspects of the situation to achieve a valuation – a form of 'indirect' analysis. It usually relies on looking at the way a new piece of information affects the outcome of a well specified decision that an agent is facing. The change in the outcome is then valued directly and the difference associated with the new information – along the lines of Stigler's early work.

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[13] See, for instance, Lamberton's section in Babe (1993) where he effectively suggests that the advances since Lamberton (1971) - which is said to be the first compilation on the topic – have not been particularly useful. And the patchy nature of the discipline is reinforced when it is realised that Lamberton's early compilation is just that: a series of papers linked by their common subject rather than their common approach.

[14] Allen (1990).

[15] Stiglitz (2000)

This whole process is in itself not unusual in cost benefit analysis; many of the effects that are being examined are not directly priced in markets and therefore have to be evaluated indirectly. A variety of techniques are used.

2.2 Hazards, value and information

In the more focused engineering and hazard literature the traditional approach seems to be via loss models. These are dependent on four crucial building blocks[16] and the way information changes that affect the quality of the results (and thus contribute final value) can be traced by examining the different components.

The elements are:

- Source model (hazard size and type);
- Earth model (transmission);
- Exposure (inventory of the assets at risk); and
- Vulnerability (how the hazard types affect the assets)

Tracing the effect of new and enhanced information through the chain of reasoning created by putting these blocks together gives a characterisation of the effect.

But to our reading it seems to be very specific to the particular situation, and thus similar to the state of the economic analysis. It all depends on the detail.

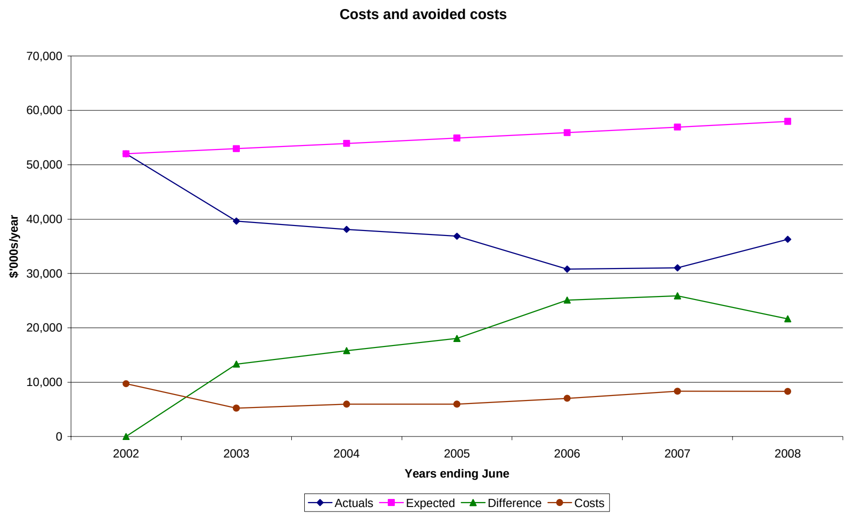
[16] Reasenberg (2005)

3. EQC benefits from GeoNet

3.1 Understanding and reinsurance

GeoNet is not just an expense, but an investment in improving the information base on which to assess the risks and potential liabilities faced by EQC. A return on that investment can arise if that improved investment reduces other costs faced by EQC. Figure 2 shows some of the financial results for EQC that have coincided with the investment in GeoNet and other research[17].

Figure 2 EQC financial effects around GeoNet



Source: NZIER, using data from EQC annual reports, IGNS

Reinsurance costs have reduced over the period since GeoNet began in 2002. Had reinsurance costs increased in line with the premiums received by EQC, reflecting the risk and potential liability for the number of properties covered, they would have risen over the period. So EQC has made a saving of the difference between the expected increase and actual decline in reinsurance costs Since the second year of GeoNet's existence this saving has exceeded EQC's costs for GeoNet and related research. The difference between expected and actual reinsurance averaged about $17million per year between 2002 and 2008, and the net saving over GeoNet costs averaged $8.6 million per year.

The portion of that net saving attributable to GeoNet is difficult to determine[18], but its size makes it quite likely that GeoNet-related spending has achieved a positive

[17] We would have liked to look back further at the series presented to capture the important initial years, but this was the limit of the data available.

[18] One structural effect is that the value of the GeoNet data could be seen as a stock and will possibly have more impact as it accumulates as time goes along, particularly once the new modeling and interpretation material appears.

private return for EQC. In addition there are likely to be benefits external to EQC that accrue to other New Zealanders and contribute to a positive social return and which would be consistent with EQC's legislated research remit.

In contrast to this aggregate analysis, EQC's actuaries examine the cost of obtaining cover for the risks faced for "layers" of the portfolio of properties at risk. This analysis indicates that the "Rate on Line" (a measure of the theoretical premium cost if risks were seen as unchanging) for a hypothetical $500m layer increased by ~21% over the years 2001 to 2009, whereas actual premiums for the same layer increased by ~13%.

As with the aggregate analysis above, this does not exactly pinpoint the effect of GeoNet and related research, as many factors contribute to the pricing of risk that are reflected in the premiums paid by EQC, such as exchange rates and the degree of correlation between different categories of risk underwritten by reinsurers. But the feedback EQC has received from underwriters during renewal negotiations suggests that the improving quality of EQC's information in recent years is setting it apart from other players (for instance in the amount of competition for its business) and contributing to the containment in the rise of premiums.

3.2 Operational efficiency

The data from GeoNet and the associated development of Minerva, are used by the EQC when grappling with the effects of an actual hazardous event, when they have to ready their response to the claims.

Clearly there is a benefit if the data enables the organisation to develop a better understanding of the event and its probable impact on the assets the EQC covers. The relevant EQC staffer (the insurance manager) rates the benefit (on a scale of slight to significant) in relation to his conduct of EQC's insurance function as "between moderate and significant". EQC told us that

> "The key thing is the higher confidence he now has in the data he is feeding into Minerva and the results it is giving him in terms of expected (model) numbers of claims. This improvement is allowing him to rely less on seeking out so-called expert judgments [..] and is giving him more confidence when dealing with the flurry of media enquiries about likely claims immediately after the event."

While compared with the main hazard exposure or even the reinsurance cost this is an effect that is much smaller, but it is a tangible benefit and fits into the category of reducing the costs of the ignorance of risk – near term benefits, as it looks toward the more focused and appropriately resourced restoration of normality. This comes about because by having an early, relatively accurate picture of the scale and spread of claims likely from an event allows the organisation of the EQC response to be a better match to the actual demand.

There is therefore a core of private benefit for EQC in reduced reinsurance costs and other operational gains that have been contributed by the investment in GeoNet and related research. While the exact magnitude of this benefit that can be attributed to GeoNet is indeterminate, as the total investment in GeoNet, Minerva and related research over 2001-2008 period is around 49% of the savings in premium, there is a strong likelihood that after allowing for other factors influencing those savings, the Geonet investment will have achieved a positive private return for EQC. In addition, further positive external benefits for other New Zealanders will add to the social return.

3.3 Our assessment

Overall we see the investment in GeoNet as having had a positive return for EQC. In the reinsurance area, where premiums are driven by a variety of forces from the state of competition to the interest rates on offer, it seems to have been one of the influences that has reduced premiums from what they otherwise would have been. Part of this has been the outcome of improved modelling which has reduced the risks of the EQC portfolio. But some has been the general improvement in the confidence with which the hazard modelling results are seen.

The general feed on into alternative risk modelling and the better understanding of the NZ seismic hazard system is likely to go on having an effect.

4. GeoNet: National cost-benefit

Benefits can be approached in many different ways. The broad approach here is in terms of a conventional cost benefit methodology. Benefits are any activities or outcomes that create or protect value for those operating in the economy. Costs are any activities that divert resource inputs from other uses, and hence forgo any value obtained from those other uses. A national cost benefit analysis encompasses effects on all members of the national community, among which EQC is just one entity, albeit an important one given its contribution to GeoNet. The basics of the general analytical device employed are drawn from the information discussion above. It also reflects the approach used in the CEBISM[19] report with appropriate modifications and amendments.

In broad terms the value of GeoNet's information is derived from its contributions to economic welfare enhancement, from:

- The reduction or avoidance of the costs of ignorance
  - Better preparedness for potential seismic hazard events
  - Better resilience of infrastructure and institutions during events
  - Better recovery and restoration of normality after an event
- The comfort derived from feeling in control of the situation
  - There is a pure value of security from feeling better informed about risks and consequences of infrequent events
  - This should also enable less "excessive precautions" around the consequences of events, due to better understanding and reduced uncertainty
- The transferrable knowledge & skills gained from gathering information
  - Opportunities for reusing such skills elsewhere, including export services
  - Options for information to filter into a better informed population
- The option value of developing information that may be useful in future
  - Opportunities for seemingly innocuous information to find more valuable uses at some future data
- The existence value of gaining information for its own sake.
  - The value of advancement of scientific knowledge for its own sake, irrespective of any current or foreseeable commercial value arising.

This approach is outlined in Figure 3. Many of the benefits of GeoNet and its associated research and information are in avoiding the costs when adverse events occur, or improving efficiencies in recovering from them. There is additional benefit in developing skills and products with marketable value elsewhere,

[19] The Committee on the economic benefits of improved seismic monitoring of the US National Research Council. The report is CEBISM (2009), and it discusses the sources of value from improved information related to seismic hazard monitoring.

Figure 3 Sources of value from improved knowledge of risk

	Event-contingent benefits		Accumulating benefits
	Immediate benefits	Near term benefits	Long term benefits
Reducing costs of ignorance			
Readiness before an event			
			Improved risk assessment
			Avoiding repeated risk exposure
	Real time warnings		Refining resilient engineering
	Evacuations of at risk sites		Resilient infrastructure design
	Infrastructure bracing/shut down		Emergency & recovery provision
	Rescue services to attention		EQC
	DOC Ruapehu		ACC
	CAA flight paths		Insurers/Re-insurers
	MCDEM		Damwatch, engineering standards
	Kestrel Group		
Resilience during an event			
		Reduced casualties	
		Reduced property damage	
		Direct & indirect (e.g. fires)	
		Reduced business disruption	
		Direct & indirect (e.g. network failures)	
		Reduced environmental spillovers	
		Reduced government administrative cost	
		Reduced emergency service cost	
Recovery after an event			
	Access to essential supplies		
	Closing down consequential risks		
	Orderly & appropriate coordination		
	MCDEM		
	DPMC		
Restoration of normality			
		Reduced structural repairs	Confidence in reduced disruption
		Reduced downtime	Lower provision for risk, insurance etc
Comfort in feeling in control			
Avoidance of excessive precaution			
			Defensive expenditures reduced
			Opportunities forgone reduced
			CAA flight paths, airport closures
Peace of mind			
			Pure value of security
Transferrable knowledge and skills development			
Refined skills & services of value elsewhere			
			International reputation
			Market opportunities enhanced
			GNS
			VUW
			FRST/MRST
			NZAID
			LINZ
Improved breadth and depth of knowledge			
			Public information base enhanced
Option value of knowledge that may be useful in future			
Existence value of increase in understanding			
			Public information base enhanced
			"Exhibition" value

Source: NZIER

Option value refers to the value of obtaining information that may be of use in future, although having little realisable value today. Its practical implication is to invest in more information gathering/protection than would be the case if basing decisions solely on clearly identifiable values, in effect hedging investment decisions about uncertainties of the future, which is particularly important when decisions today would have consequences that would be difficult to reverse. Aside from the use of options in financial markets, option value is a notion well established in the literature on environmental valuation, where protection of biological communities and their component species reduces the risk of irreversible loss of genetic information contained within them. In that context, there is a positive probability of finding species that contain a genetic gold mine, but the probability of any one species containing such genetic riches is very low and it is impossible to predict which species will prove valuable, so the approach is to sustain whole communities in the expectation that some of their component species will prove highly valuable. The recognition that some species/information may prove more valuable in future than it currently appears gives rise to increased investment protection, although such willingness to pay for future options is unlikely to be the largest component of value in such decisions.

Existence value refers to the value of knowledge for its own sake, and is particularly associated with the value of knowledge for academic understanding and advancement. Although there may be some realisable economic value in such advancement (such as the gate sales at exhibitions) such information is unlikely to recover the full costs of its generation, and tends to be funded to large degree as a public good. The benefit for the nation is in the improvement in understanding, the kudos of recognition in international scientific fora, and the opportunities created for participating in international collaborations. In principle such benefits should be primarily funded through research funding institutions in which the benefits of geological research are weighed alongside other claims on the public research dollar, and any additional benefit from investments such as GeoNet and related research are largely incidental.

4.1 Methodological stance

The basic idea that underpins a cost benefit analysis is simple; it consists in carrying out the kind of examination described above in one of Jan Wright's categories of information – the policy (in use) form[20].

The notion is to perform the mental experiment of comparing the values of two states of the world: one with the effect of interest and the other without it. The difference is the value of the effect.

Typically working out one or both of these states is non-trivial because it is not observed, or factual. So in the jargon of the cost-benefit literature it is the *counter-factual*. In this case the world actually contains the GeoNet system, so the

[20] Wright (2000)

counterfactual is the world as it would have been without the investment and development that has occurred in the last 8 years.

It turned out as we investigated GeoNet that there was not as "bright" a line between the halting and largely fragmented previous system and the new coordinated system as might have been envisaged. And it might have been that even without the EQC's significant decision and investment some sort of linked monitoring platform might have emerged.

But to avoid spending much of our available time and resources on the task of sorting out the details of less well-endowed "might-have-been" structure we have taken a decision to assign all the benefits of an integrated real-time continuously available monitoring network to GeoNet. If this is felt to be too generous, further work can be done with a modified counterfactual; one that assumes a degree of the benefit might have been available, even without the investment in GeoNet.

4.1.1 Progress of knowledge

Underpinning much of the discussion here is the nature and shape of the value of a stream of data as it improves our understanding of hazards. Our interviews and considerations have led us to believe that there are two sides to the way this understanding improves. We can call them "structural" and "factual", where the structural component is a theoretical (model) framework that provides the general logical context and the factual side is the data that applies this to particular cases.

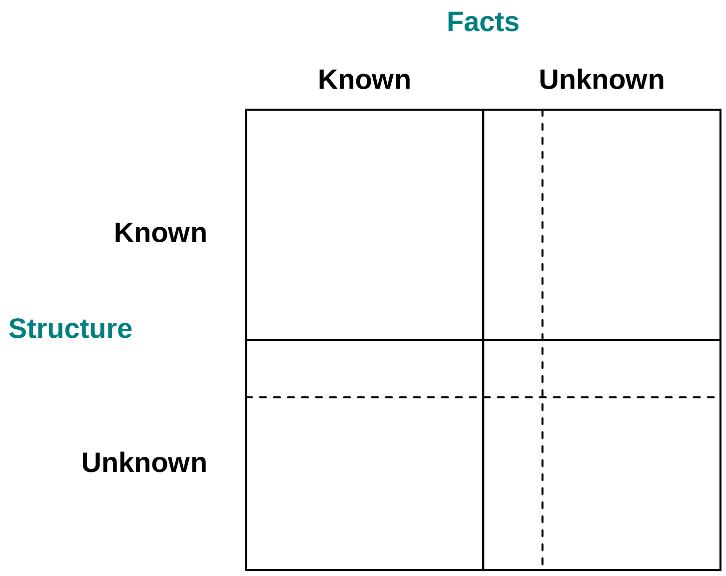
We see the GeoNet data having provided both: the factual material as a direct output, while the structural enhancements are the science and the improved models suggested and tested by the data. Our view as established here is that more, particularly rich data will attract more science resources to w2ork on it. Using the usual assumptions about production this will inevitably result in new hypotheses being developed and tested. In the picture being used, this translates into more structural knowledge coming on top of the factual material build up.

Turning to a general overview it is possible (though perhaps drawing a bit of a long bow) to use a version of this view of knowledge and understanding to chart the way value accrues. If we associate the structural element with one type of knowledge, and the factual with another we can construct a picture of the world of hazards in terms of Figure 4 below.

In this the four quadrants are the Rumsfeld set: including the infamous unknown unknowns, here able to be directly interpreted as hazards for which we have no structural models, nor much data. The other interesting sector is the unknown knowns – which are hazards where the model or framework with which to discuss the phenomenon is non-existent or believed to be weak, but there is a deal of available data.

In this picture of the world of hazards, we see a GeoNet-like influence on the dynamics of the quadrants able to be represented as moving the dividing boundaries so as to enlarge both sides of the known knowns box (and shifting the "mixed label boxes) while shrinking the unknown unknowns one.

Figure 4 Changing the point of reference



Source: NZIER

4.2 Individual components and the system

Note we have omitted many possible components of benefits from this list (such as reduced anxiety[21]) while others are subject to a discussion about their precise definition even without presuming their scale and quantification.

Note that underlying all of these specific elements is the way the whole information system has evolved, in terms of the potential use that can be made of the data streams. In particular, the manner that the data is made available, both actively and passively, matters.

The CEBISM report was right to stress the point that:

> "..successful risk management strategies for earthquake hazards requires that the benefits from reduced uncertainty provided by improved seismic monitoring are integrated with the factors that influence risk perception and choice. The extent to which information from seismic monitoring networks can be used to reduce loses from future

[21] Note this is partially because it is difficult to gain an estimate of the likely scale of value for this, but also because there is a high degree of individual belief involved in assessing the total quantum and impact of anxiety. This stems from our view that the extent to which hazards are discussed may influence the amount of anxiety felt in the community. And it is possible, as anxiety is a personal thing, that were increased information to provoke a greater degree of discussion (say because there were more news stories about hazards based on the new information) that, even though the absolute risks were decreasing, the community's anxiety level may be higher.

> earthquakes depends, to a large degree, on providing information to decision-makers and other end-users in an appropriate form and on the extent to which these individuals and groups understand and make use of this information."[22]

In other words, pure information is not much use on its own; it is the way it is employed that is important. This raises some potentially intriguing issues about responsibility for causing such things to happen.

Luckily, one of our observations bears on this question. We were struck by the effect that the data stream had had on the people and institutions most closely involved with the development of the monitoring network and the data distribution. They had moved to 'fill a vacuum' in the learning chain.

So we noted that the academic response (at least at Victoria and Massey Universities) has been flexible. They have moved to take advantage of the opportunities that the new data sources opened up.

We also were struck by the style adopted by GNS which seemed to have changed its style and indeed, output focus over the years of GeoNet's operation. During the 8 year period it had managed to develop methods to become, in effect, a scientific "middle man" providing services to supplement the free availability of the massive quantities of 'raw' data generated by the network. These are built around a variety of information 'products' (processed data taking forms more useful to the individual consumer).

They include a range of information outreach products that were active rather than passive; and looking to connect with those entities who are potentially seriously affected by a hazardous event. GNS even offer services that review how owners of large asset bases might be affected by a hazard event and what might practically be done to mitigate or avoid the impacts.

The change is ongoing. Such changes are hard to evaluate individually, but are clearly of national benefit.

4.3 Logic of the identification of the benefits

The general structure of many of the types of benefits described below falls into the following logical shape.

Without the information flows from the enhanced monitoring, hazard precautions would take the form P with likely outcome in the event of a hazard scale H of loss L. But with enhanced information the precautions would shift to a different form P'. And the loss following P' with a hazard H is L', where L' is less than L. The benefit is the difference between L' and L (with allowance for any cost differences between P and P').

[22] Page 3, CEBISM (2009).

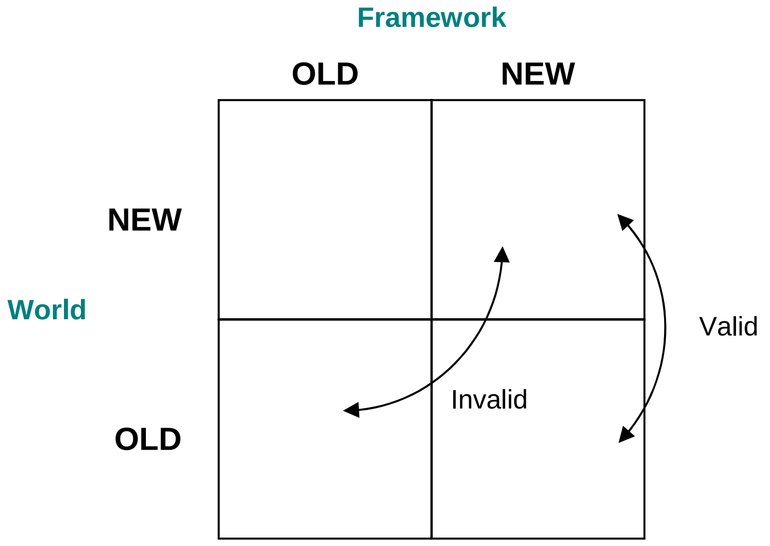
The net benefits can be seen in a vastly oversimplified way as having two fundamental elements. These can be thought of as corresponding to the mean and variance of the distribution of outcomes of a hazard event.

There are interesting technical questions in teasing out the effects, but a rough idea can be gained. We are specifically interested in the way that the mean might suggest a worse outcome while the variance shrinks (in other words the comparison seems to be producing a more certain world with a less attractive upshot).

But the "new" distribution mean must effectively be a preferred frame of reference. If it were not, there would be no reason to adopt it. So it is false to say that there has been a loss via the potential for a worse mean. This is a fallacy coming from failing to appreciate that the new distribution defines a (better) frame of reference as well as a description of the likely outcomes.

So the conclusion is that the better information (*even if it produces a worse mean*) is unambiguously better, because the previous way of looking at the world was flawed. The assessment must come from the known superior framework. This is illustrated in Figure 5 below.

Figure 5 Knowledge acquisition



Source: NZIER

This picture of the world of hazard knowledge can be used to answer the question: "if new information makes our position appear worse off than before, would we be better off not to have it". Ignorance may be bliss in the old adage, but clearly in terms of the diagram the answer is "No": once new information about a hazard reveals a new structure to the information, it is valid to compare old and new information in light of that structure, but not valid to compare old and new information in terms of an old structure now known to be superseded. If associated research had provided information that pointed to increased risk on the Wellington fault, for example, it would still have been valuable in leaving EQC better informed than would be the case if continuing to labour under the delusions of a less accurate assessment model.

Note one of the effects (the lower variance) reflects a commonplace among discussions that the value of improved information is to "reduce uncertainty" about the effects of hazards. From a valuation viewpoint, such an effect is "allocative" as it allows a more efficient (or 'Goldilocks') response; one that is not too much, and not too little – just right. It is as valuable to avoid overinvestment as it is to avoid underinvestment.

As we are using mainly avoided loss identification to look at the benefits the categories of loss are important.

These can be listed;

- Direct physical damage – buildings and infrastructure;
- Induced physical damage – fires, floods, hazardous material release, etc
- Human impacts – deaths and injuries;
- Response and recovery costs – emergency services, inspection repair etc; and
- Other losses – including business interruption, environmental and social.

The framework set out in Figure 3 can be used to ensure a comprehensive review of the various benefits.

This is done over the next sections.

4.4 Reviewing the sources of value:

4.4.1 Reducing the costs of ignorance of risk

a) Readiness before an event – immediate benefits

Benefits include:

Real time warnings

Evacuation of risk sites. Looking at the types of hazards covered locally there seems little likely benefit from earthquakes yet, as the predictive power is too uncertain. But in the case of landslides, volcanoes and tsunamis, there are practical possibilities of being able to save lives and reduce injuries by improving the resilience of infrastructure and institutions to deal with hazards.

Tsunamis are the result of undersea earthquakes or slips in the sea-floor and their impact warning time is dependent entirely on their location. In effect, the further away from NZ is their source, the more time we have to act if a warning is given. In concept, the advance information provides a warning, which can trigger a prepared response. The main focus of preparation is to ready individuals to move themselves and limited amounts of mobile property (in effect vehicles) to safety (high ground) within the available time.

The MCDEM interview suggested that a suitable degree of preparation had been undertaken based on careful identification of the heavily exposed sections of the population. In other words, the response to a threat might significantly diminish the numbers exposed to danger.

Thus the potential benefit from a nationally integrated information system that translates into a tsunami warning system could be very high. Saving lives is a clear national benefit.[23]

The value depends on the number of lives likely to be saved and the frequency with which an event occurs far enough away to render a warning effective. Recent events which have alerted us to tsunamis have been experienced elsewhere. It seems the likelihood of a serious tsunami event based on history is low, and their impacts will be confined to locations in the immediate vicinity of the coast.

Volcanic eruptions, on the other hand, are a feature of the New Zealand scene. The landscape of parts of both main islands are characterised by volcanoes that have displayed activity at times in the past. Auckland, for instance, is built on and around the cones of many volcanic outlets in a zone which is dormant rather than extinct, and it is possible there could be significant new activity there at some time.[24]. In the middle of the North Island Lake Taupo is a reminder of the scale of eruption that can happen from time to time. The destruction of the Pink and White Terraces was just one feature of the large eruption of Mt Tarawera in June 1886 when more than 150 lives were lost.

Perhaps more saliently Mt Ruapehu is still frequently active and has erupted relatively recently[25], to the detriment of the skifields and associated industries on its flanks. In the public mind the potential damage has recently concentrated on the possibility of a lahar and what it might do, spurred by the memory of the 1953 Tangiwai rail disaster when a crowded express went into the river as a lahar had taken out the bridge. The successful containment in the lahar that spilled down the Whangaehu River in 2007 after a breach of the crater rim demonstrated the value of well-informed preparedness in face of such events. But this is just one side of what an eruption could do.

[23] The national benefit from saving a single life on the road is taken as more than $3.6m for transport planning and cost benefit purposes. See Ministry of Transport (2008).

[24] An economic modelling exercise of a substantial volcanic outburst was undertaken by the RBNZ recently – Pepper (2008).

[25] See Johnston et al (2000), Paton et al (1998) and Ronan et al (2000) for useful discussion of this activity and its effects.

Our discussions, particularly with DoC showed that there were many positive benefits flowing from the improved sensor network monitoring. These ranged from understanding the evolution of the build up before an event to ordering warnings and clearing the affected area, and assessment of activity after the event when planning rescue operations, as occurred in the 2007 eruption that injured a climber sheltering in Dome Shelter in 2007. Improved understanding of the nature of the hazards and how events were likely to unfold had also changed the assessment of risks for positioning buildings and other infrastructure in particular locations.

An interesting demonstration of the value of enhanced understanding of the volcanology as well as real time monitoring came from discussion with the CAA. This improved information gives the CAA benefit of being able to accurately assess the risk to specific flight paths of the emissions during any particular hazard event. This allows a far more efficient response to the hazard as the geometry of its effects is known with more precision and thus the air movements can be programmed safely with less undue diversion of paths.

Indeed, we were told by CAA that the response to the dangers to flights from the volcanic eruptions is to divert or otherwise cancel the flights from airports and route sectors affected by fall out from ash plumes. The uncertainty that was inherent before the current GeoNet monitoring was in place led to many flights being cancelled during Ruapehu's last major emission (1996). With hindsight and the benefit of information from GeoNet and recent research, many of these flights would not now appear to have been at risk, and the improved accuracy of this information would enable less disruption of flight schedules in similar eruptions in future..

For any individual eruption this can be a significant benefit via cost saving as existing flight paths are determined to minimise the fuel use and thus the cost of operation. This benefit flows from permitting the response to be tailored to fit the hazard event because of the enhanced information about the hazard and its effects.

Landslides are often made up of a series of events. This means that not only are they more limited events with a slower build up and different consequences than the dangerous earthquakes (where it is typically the speed of the frantic movement that does much of the damage), but that their progress can be monitored and responded to in real time. New Zealand, as a geologically relatively 'young' country has areas where landslides are continually occurring. The recent temporary evacuation of Waihi village on the shores of Lake Taupo is an example of how information is used to assess risks, and of how improved understanding of landslip movements could reduce the extent and disruptiveness of emergency responses.

Another example we were given was at Taihape where a section of the town (including a school) was built on an area which seems to be moving. The obvious initial response was to change the allowable use (an effect that is a short term version of the hazard zoning discussed below.) Looking toward further more threatening movement, sensors have been installed to monitor movement and better assess the risks involved.

This creates a primed warning system.

Our assessment is that: there is a hierarchy of benefits here. In monitoring volcanoes there are relatively high people numbers and infrastructural exposure in Auckland and Bay of Plenty regions, and although there are difficulties associated with turning the data into warnings, the incidence rate is reasonably high. Overall this is a significant benefit from improving warning capability.

For tsunamis the possible exposure of many thousands of people within inundation range means there is potentially a substantial benefit from the combination of the GeoNet capacity and the associated eastblsihed warning system, through saving many lives. The likelihood of an event, though, is very low. The overall benefit level seems low.

Earthquakes have the potential to create serious impacts, but the realistic ability to warn is limited and thus the overall benefit seems low.

The landslide monitoring has probably shown its benefits already.

Infrastructure bracing or shut down

The potential for benefit here is largely dependent on the preparatory work that has been done outside of the GeoNet/ EQC grouping. Various exercises and studies have been carried out. For instance, we are aware of the *Lifelines* work which seems to be moving preparations along so as to be able to make appropriate use of any warnings that became available.

The ordering of hazard responsiveness is potentially the same as in the discussion above. The better warning potential and incidence rate of the volcano risks suggests that the ability of responsible authorities to, for instance, reroute rail and road traffic around the at risk sections of the network is already high.

Similarly tsunami warnings could be effectively acted on[26]. But there might not be a lot of incidence to respond to.

Earthquakes have potentially a high degree of response available, but the predictions are rare.

Rescue services to attention

This similarly would reflect the hazard hierarchy discussed above. And would be a result of being able to use the information to despatch the emergency teams sooner and more accurately as well as having background information about the safest and most accessible routes in and out of the site.

[26] This is on the assumption that the effect we heard about from several informants of a flood of spectators reacting to the warning by rushing to the shore to try and observe an approaching tsunami is not repeated when it is the real thing.

Our assessment of both of these categories of benefits is that the better data and lower uncertainty created by the GeoNet system has significantly improved the way that the warnings can be effective in being beneficial.

b) Readiness before an event – long term benefits

Benefits include:

Improved risk assessment

Improved earthquake recurrence models.

The data and its effect on the underlying science and understanding have already changed the way both the Wellington hazard is viewed and the parameters of recurrence modelling. In brief the two effects are:

1. to identify and interpret a range of slow events as releasing stress that was otherwise thought to be building up in the area around Wellington. This changes the likelihood of specific events to release pressure. In particular it reduces the risk of it being a large shake; and

2. to populate the historical record of the Wellington area's previous quakes. This has produced a distribution of events with a longer return time for serious threats (larger events) than was previously held.

The upshot has been a significant change in the estimates of the frequency and size of likely earthquakes. The benefits from this are that estimated event frequencies are lower: the new modelling produces significantly lower incidences of events with large destructive power in Wellington (the most exposed area).

Our assessment is that this is a significant benefit. Knowing the likely parameters of one of the most potent hazards in NZ is valuable not only for the EQC and not only for the present. The rational and discussion of this effect is in section above.

Note too that the way the data feeds through to enhanced "structural" understanding is an instance of the knowledge dynamics discussed in section above.

Avoiding repeated risk exposure

Improved hazard zoning is facilitated by better modelling of the hazard and the effects. Smaller confidence intervals around the effects of likely hazard activity mean that the zones are more accurate and can thus concentrate more appropriate regulatory impact on investments in buildings and infrastructure. .

We were informed about how the work on Mt Ruapehu had produced a clearer understanding of the way that a lahar would sweep down the mountain so as to occasion the relocation of significant buildings, that were in the line of descent.

On another scale there is the issue of retrofitting existing structures for earthquake resistance to reflect the better understanding. This is a long chain of causality. It includes many links that are drawn out or dampening in their effect on the adoption process.

The data and science results can be reflected on the probable impact on various types of structures. But drawing up minimum standards for existing assets and particularly deciding what the pathway should be for compliance is a decision that has economic and commercial consequences of a widespread nature.

As it was described to us the way the GeoNet system's results were feeding into retrofitting was a sensible and measured process. But it inevitably reflected the various forces that were at work.

Our assessment is that including the GeoNet results in the retrofitting standards for buildings and other structures in Wellington is a benefit. It will mean that the prescriptions used are more appropriate to the risks faced.

Refining resilient engineering

Better information about the way hazards function feeds through a complex chain of modelling effects based on the data and then is taken into engineering via practical and theoretical analyses. These will use these postulated forces to test structures for their robustness.

The upshot of this process is to change the way that engineers see structural engineering working under different conditions.

Resilient infrastructure design

Improved ground motion prediction models. Enhanced science and general event understanding also results in better prediction models for ground motion. As these are the basis for setting building standards any improved understanding here will generate a significant 'allocative' effect as the better targeting of the regulations matches buildings better with the known risks. This will encourage both lower risk buildings at lower costs and all the other appropriate combinations of construction and repair costs (such as cheap to build cheap to fix..

Given the scale of the relevant building investment, even an improvement of as little as 1% annually on the cost side would be a substantial national benefit. In terms of the recovery costs the greater the resilience of buildings to events of a stated type, the smaller the recovery costs. This is in part because less of the stock has to be replaced, and in part because there will be a greater amount of accommodation able to be used in the immediate aftermath of the event and thus reduce the disruption.[27] Some of this effect will accrue as benefits to the EQC too, as the ultimate insurer of such building losses.

[27] This analysis assumes that the devastation is not so great as to demand that the city be evacuated because there may be no adequate way of bringing water or food to the survivors.

Emergency and recovery provision

The question of the level of social investment in emergency and recovery services is never easy. The structure of the information tends to be low certainty in advance and complete certainty once an event has occurred.

The increased data and understanding, and the accompanying lowered uncertainty about the events stemming from GeoNet should have improved the way the problem can be approached. The discussion we had with all of those charged with thinking about such provision was that their confidence had been enhanced by the data and the underlying understanding that the system produced.

c) Resilience during an event – Near term benefits

Benefits include:

Reduced casualties

Our discussion with the hazard expert from the ACC revealed that better understanding of the type of hazard events could contribute to the reduction of casualties, even after the immediate calamity. This could happen via the way the recovery and rescue operation was managed, because the type of failure that buildings and other structures undergo depends on the details of the event.

So the deployment and the behaviour of the rescue teams could be calibrated more aptly by the enhanced ability of the coordinators to assess the precise nature of the event and thus its likely “on the ground” risk pattern.

Reduced property damage

Better understanding of the types of hazard events and the way their effects worked in terms of damaging structures could inform decisions about which buildings and other real property were still at risk.

Reduced business disruption

In the case of volcanology real time monitoring was pointed to during a discussion with the CAA as likely to reduce business disruption. The improved information gives the CAA benefit of being able to accurately assess the risk to specific flight paths of the emissions during any particular hazard event. This allows a far more efficient response to the hazard as the geometry of its effects are known with more precision and thus the air movements can be programmed safely with less diversion of paths.

Indeed, we were told by CAA that the standard response to the dangers to flights from the emissions was to divert or otherwise cancel flights when safety is at risk. The uncertainty that was inherent before the current GeoNet monitoring was in place led to many flights being cancelled during the last major eruption (1996). An examination of the type of information the network would produce would have allowed most of these flights to go ahead, because the information was so much more accurate.

For any individual eruption this can be a significant benefit via cost saving as existing flight paths are determined to minimise the fuel use and thus the cost of operation.

Our assessment is that this is a significant benefit. The enhanced ability to assess the risks more tightly and thus provide businesses affected by a hazard event with far better information will change the impacts on businesses substantially.

While there have been attempts made in NZ to consider the scale of the effects on business and general economic activity as a result of a hazard event[28] the way the data from the GeoNet system mitigates these effects is a topic that awaits serious attention. International literature estimating such potential benefits as the value of volcanic ash avoidance for aviation are suggestive of positive value (Kite-Powell 2001), but they have severe data limitations and provide no tangible values that can be reliably applied to the benefits of GeoNet in New Zealand.

Reduced environmental spillovers

Better understanding of an event can greatly enhance the operational ability of authorities to devote resources to act on potential environmental problems. Thus once a hazard comes into play, using the better real-time data flows means the type of event can be quickly summed up and the probable set of environmental hazards assessed and acted on.

Reduced government administration cost and Reduced emergency service cost

Reduction in government administration costs and in emergency service costs comes from better understanding of the nature of the risk being faced, and improvements in the level of preparedness. In our discussions with MCDEM, DOC and some of the academic researchers it was emphasised that improved information on the nature of hazards faced enabled them to more precisely tailor their preparations, avoid excessive precaution and improve the allocative efficiency of their responses.

It could be argued that these benefits are contingent on hazardous events materialising, and that with long return periods the expected value of these benefits dwindles to zero in discounted present value terms. However, this would be to hang too much on the shoulders of GeoNet and related research. Government policy has already decided that some level of disaster preparedness is required, and indeed has allocated resources to achieve that. If the data from GeoNet and related research enables those preparations to be done more efficiently, it is creating a value gain which is irrespective of whether the hazard materialises or not. Even if the research indicates the risk is lower than previously thought (as appears to be the case with earthquakes on the Wellington fault) reducing uncertainty around the risk should enable administrative efficiencies to be realised.

[28] White (1997), Savage (1998) as well as Pepper (2008)

Lower provision for risk insurance etc

Improved data has allowed more accurate modelling of the events and also better modelling of the impacts on the buildings and infrastructure, as the type of events that are likely to occur is more established. . This has meant that the loss models are subject to a lower degree of epistemic uncertainty.

Thus the regular negotiations that go on between the EQC and its reinsurers[29] are based on a different set of models than was previously being used. And that the new one produces plausible loss figures that are lower than the others.

As the reinsurance costs are in the tens of millions of NZ dollars annually this has resulted in significant EQC benefits.

4.4.2 Comfort in feeling in control

Improved information also increases confidence in the decisions being made and confers comfort in the sense of being more in control of the risk. That individuals are willing to pay for such "comfort" is well established: they pay for insurance that they hope never to make a claim on, pay for forecasts to reduce uncertainty about their decisions on the future, and pay for palliatives or alternative remedies for ailments whose effect is more psychological than physical. The same tendencies can be seen in the community at large, expressed through government's willingness to pay for improved information that gives comfort in their decisions.

It has not been possible to quantify this comfort factor, but it is likely to comprise a number of distinct components:

- Avoidance of excessive precaution – long term benefits
  - Defensive expenditures reduced
  - Opportunities foregone reduced
- Peace of mind – long term benefit
  - Pure value of security

4.4.3 Transferrable knowledge and skills development

a) Refined skills and services of value elsewhere – long term benefit

Benefits include:

International reputation and market opportunities enhanced

The academics were clear that the additional data had changed the way NZ research was seen in the rest of the academic community. The hazards here have unique

[29] These organizations undertake for a fee - related to the perceived amount at stake and the likelihood they will have to pay out – to cover EQC claims over a certain amount that would arise in relation to high priced low probability events.

features from a theoretical standpoint and thus once a rich data stream is available there are opportunities for path-breaking research.

In turn, this has already increased the application of research effort to NZ hazards. With more applied resource comes greater probability of likely improvements in understanding about the local risk profile. The views of the academics we talked to were that the flow of data has not been mined thoroughly yet. It was suggested that only the conventional work had been done. The implication was that there is a significant chance of more advances once the data is really trawled over.

It has also given an international profile to the quality of modelling and other local research outputs. This creates the possibility of new markets for NZ experts and practitioners. Commercially Dr Spurr was heavily involved in providing an alternative view to the conventional models of the risk structure of certain Japanese hazards. NZAid has organised the engagement of GNS in advising the government of Vietnam about the establishment of a hazard monitoring system.

We note too, that alongside and a partner in the GeoNet system is LINZ. They have their own Precision Reference system and have been considering moving to a real-time continuous reference data. They envisage a range of commercial opportunities opening up as a result of the flow on information is enhanced as local businesses change their production methods to make use of the better information.[30]

b) Improved breadth and depth of knowledge - long term benefit

These benefits are derived from the option value of knowledge that may have as yet unknown future uses, and existence value of knowledge for its own sake. We have not been able to quantify these benefits in this analysis.

[30] McKenzie Podmore (2009)

5. GeoNet: where to go?

5.1 Further research on the benefits?

As can be seen from the content of this report, despite the enthusiastic cooperation of many well informed people and looking at relevant literature, this activity is a branch of the economics of research and development – a topic still under development. Very little hard, quantitative data has been provided in the course of the interviews, and although some sense of the relative magnitude of different effects has been conveyed, the precise scale of these effects is indeterminate.

We think that a small element of further careful investigation and documentation of the key benefits identified above would be a useful activity. It would, at the least, contribute to the feeling of confidence needed by those charged with being accountable for the investment.

5.1.1 Our assessment

From our work above we would see the priority areas to consider as being:

- Tying down further the “private” value to the EQC directly from the investment; (as this seems to be an obvious gap that would help structure the next round of decision-making)
- Assessing the value of avoiding business (economic) interruption as part of trying to grapple with the underdeveloped benefits. (This aspect is seen as very important in the USA - to the point of justifying Federal intervention - but so far has been less well investigated here, perhaps because the insurance market for this is underdone compared with the USA. We can see forces implying the effects might be low – as seemed to be the case in the Auckland ‘blackout’ - or high as when the scenarios about a hazard event in Wellington are developed.)
- Using experts in instrumentation and measurement who are familiar with the way data has developed and used in other hazard monitoring systems to develop a view about the investments with the highest return in understanding.
- Value of several of the ‘wider’ effects that are difficult to assess (as having a better idea about their scale might affect the strategic value of recommendations about further investment) such as:
  - the feelings of being in control and
  - the potential to use the findings in the future.

5.2 Future investment?

What should be the focus of the next steps of the system? In discussion with interviewees, various suggestions were made as to where the priorities for further investment lay. In principle further investment should be guided by identifying opportunities where the economic return is likely to be greatest, but there are some characteristics of the investment in GeoNet and associated research that will affect the consideration of such opportunities:

- The bulk of the cost of GeoNet and associated research has fallen on EQC, although on some of the spin-offs of that research there has been some joint funding by LINZ and research institutions.
- EQC could reasonably expect some private benefit for its operations from further research and development, otherwise the question arises as to why it and not some other party is funding the work - notwithstanding the EQC mandate for general research
- There is a broad "halo" of other potentially benefiting parties from further research who may each expect to seek more work of relevance to their interest, and each of which might be expected to demonstrate the value to them of this work by contributing some co-funding to the process.

A broad choice has to be made between doing more of the same but better, and branching into new areas that have hitherto received less attention. Considerations of economies of scale and scope would suggest adding more depth to the existing coverage, as occurred when LINZ funded tsunami monitoring stations for connecting to the GeoNet. But offsetting this there are also likely to be diminishing returns setting in at some point, though we expect this is some distance away yet[31].

Another consideration is the orientation of much seismic research towards reducing the impacts of hazardous events which are extremely infrequent but potentially catastrophic when they occur. Reducing the damage to property suffered in such events is directly relevant to EQC's core business, and it also has a more indirect interest in disseminating information through the community that will lead to improved infrastructure and institutional resilience across New Zealand and reduce the potential for EQC's future liabilities. So the direction of further investment will also depend on the relative risks of different hazards and the ability to act on new information that may be found about them. However, in a standard economic cost benefit analysis with discounting of future effects, the expected value of benefit from events that happen infrequently and with long intervals will be rather small, and any change in those expected values from improved information will be smaller still.

Assessment of hazard types for future prioritising can be based on the value at risk, their probability and their "tractability" – the ability to respond to new information about them. Our assessment is outlined in Figure 6. This is presented as an illustration of the approach, not as the definitive answer, as it needs to be refined with empirical evidence drawn from multiple disciplines. However, it seems to us that recent discoveries about the low slow earthquakes and frequency have shifted the mix of attention for seismic research, with less urgency attached to earthquake risk and more to volcano risk, given the potential for greater warning of and containment of volcanic events should they occur.

[31] The existence of a eventual drop in the returns from additional investment in sensors - though at a density far greater than anything contemplated for GeoNet - was discussed with Dr Spurr based on Japan.

Figure 4 Tractability of hazard types

	Value at risk	Probability	Responsivity
Earthquake	Large - wide area damage in cities like Wellington, Palmerston North, Napier, Christchurch etc	Moderate - frequent small movements, large quakes rare	Very low ability to predict or act on warnings
Volcano	Large - localised damage but widely spread possibilities in Auckland, Tauranga, Rotorua, and in energy-rich Taranaki	Moderate - low: infrequent events and localised impacts	High ability to respond to warnings, depending on type of eruption; some ability to contain impacts
Tsunami	Moderate - most settled coastal areas at risk, but localised impacts	Very low - very infrequent events, most not severe	High with sufficient warning from distant sources; low from local events
Landslip	Low - widespread occurrence but localised impacts	Moderate - usually triggered by rain or earthquakes	Moderate - avoidance and pre-emptive evacuation (e.g. Waihi)

Source: NZIER

The Taupo eruption of around 180 AD dwarfed more recent and better remembered catastrophic eruptions like Krakatoa; the eruption around 26,000 years ago was large enough to be classed as a super-eruption which ejected sufficient material into the atmosphere to change global climate for a period of years. In that sense New Zealand has a world class volcanic resource of importance for the study and understanding of volcanoes.

While there may be little practically that can be done to protect against such cataclysmic events, there is also evidence from around the world, particularly from Hawaii, Iceland and parts of Europe, that it is possible to manage and live with the risks of certain types of volcanic eruption. Understanding and predicting the characteristics of eruptions and their consequences would be of value to that risk management, particularly when large urban areas and infrastructure are located in dormant and potentially active volcanic fields.

5.2.1 Our assessment

From a strategic perspective we suspect that just adding "more of the same" may be reaching the point of diminishing returns in some areas. Hence, as the North Island is relatively well endowed with earthquake sensors relative to the South Island, it may be timely to place more emphasis on South Island coverage than deepening the coverage in the North Island. This may include drilling into the Alpine fault to understand more of its movement, as this appears to be one of the drivers of seismic activity with correlations to other parts of the fault system, and hence providing information wider than its immediate (and sparsely populated) vicinity. If more earthquake sensors are sought in the North Island, the emphasis would shift to different sorts of sensors, such as deep motion sensors rather than the existing mix of surface sensors.

This can be compared with the first four recommendation of the 2008 panel (which included instrumentation experts) which were:

1. Increase investment in the area of urban strong motion instrumentation, including representative structures.

2. Improve strong motion coverage along selected, major fault lines in the South Island.

3. Extend regular surveying of volcanic centres using InSAR and diffuse CO_2 monitoring.

4. Install a small network of tiltmeters high on Ruapehu.

We can see how each of these proposals might augment the existing capacity of the system and provide a degree of new information that would potentially have higher returns than the “greater density” more of the same approach..

This can be seen as building a “portfolio” of information sources bearing on hazards that have limited correlation. It means in general that the overall results will be of greater value than those coming from plunging heavily into any specific monitoring strategy.

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Appendix A Original terms of reference

COST/BENEFIT ANALYSIS OF GEONET AND RELATED EARTHQUAKE COMMISSION RESEARCH INVESTMENT

TERMS OF REFERENCE

Background

EQC wishes to commission an independent cost/benefit analysis of its investment in hazards research with particular focus on the GeoNet hazards monitoring system. It is intended that the analysis will assist EQC in quantifying the contribution its GeoNet investment has made to improved knowledge and modelling of geological hazards and risk, and towards the wider objectives of its overall research portfolio covering natural hazards in New Zealand. Also, it is expected that the methods adopted and data gathering in the course of the work will assist EQC and the research community to make more informed decisions about investment in improving information about natural hazards.

Scope

The consultant shall complete a national cost benefit analysis of GeoNet, in order to assess:

- the return to EQC on its own investment in GeoNet.
- the net benefit to New Zealand of GeoNet through improved information about natural hazards.

In bringing this analysis together, the selected consultant will be expected to take account of the criteria that EQC applied in its initial decision making regarding the investment, the scope and breadth of its other investments in research and education, and the interrelationships and co dependency that characterise these investments and its reinsurance programme. In particular, the consultant should take account of the various inter-related factors that have reduced uncertainty about New Zealand's geophysical risk and thus lowered EQC's re insurance costs:

- EQC's strategy of engagement with reinsurers;
- EQC's development of the "Minerva" risk modelling tool;
- The flow from new data (including GeoNet) and hazards research to risk modelling.

As a first step that consultant will, in discussion with EQC management, establish an appropriate method that not only delivers to EQC its objectives but also can be demonstrated to meet criteria that might be applied by other government agencies in establishing the costs and benefits of Crown investment in research and science. This method will be supported by a literature search of similar national and international evaluations as a basis for providing supporting evidence on the selection of the attributes that will make up this analysis. Measures will need to be established adequately to describe the effective levels of risk reduction that have resulted either directly or indirectly from GeoNet and hazards research over the previous decade. Consideration should be given to likely benefits that might arise from GeoNet's planned future configuration, the testing of key assumptions and general criteria or a decision model with which to assess the value of reduced uncertainty accruing from future investments.

A final report is to be prepared by 31 May 2009, in a form suitable for distribution to other Crown agencies and with the recommendations in a form suitable for management to take to the EQC Board.

Appendix B NZIER proposal (extract)

What you want

We understand you want to both value the current GeoNet and its accompanying developments, and look toward developing a logical method to assist in making the next round of decisions about further investment.

What we will provide

We see the task of fully valuing the results so far as a challenging one. We can see that a careful examination of the work together with a strong framework will allow a comprehensive listing of the types of benefits that are accruing. What we see as problematic is attaching numbers that are respectable social valuations to all these effects. For some classes of benefits we would be able provide numerical values that are either indicative or under estimates – such as "avoided cost" values. But for others we suspect there will be little relevant empirical material to draw on.

What we, therefore, suggest we provide will include the following:

- a complete overview of the various benefits flowing from the project, with a discussion of the underlying framework on which this is based;
- a series of valuations of selected elements, drawing on different methodologies. Thus some may be looked at in terms of "avoided cost" while others may be valued directly; and
- a discussion that considers the elements for which valuations are not readily to hand, and suggests lines of enquiry that would cast light on their size.

We will also address the questions posed in the Terms of Reference document attached at Annex. In particular we will carry out an appropriate literature review to set the scene for a national cost-benefit analysis of GeoNet, in order to assess:

- • the return to EQC on its own investment in GeoNet.
- • the net benefit to New Zealand of GeoNet through improved information about natural hazards.

How we will go about it

Our approach will be to work closely with you in designing and carrying out the assignment. We are looking to build on the work done in the panel report by gathering additional insights to try and populate the framework. This process is seen as gathering primary data in the form of information gleaned at interview from experts that you recommend. The range and content of the final report will draw directly on the experience of the people we talk to, but will be shaped by the analytical approach we are adopting in the light of the literature.

Who will do it and what it will cost

The lead team for this work will be: Dr John Yeabsley and Mr Peter Clough. They have both carried out many complex economic investigations and CBAs which have addressed the valuation of non-market goods and services. Where appropriate they will draw on support from other NZIER staff, including their in-house information specialists.

As discussed, they will look to engage with relevant outside specialists as a means to improve the robust quality of the final report.

Appendix C Informants

Those we talked to:

Building Codes and Loading Standards	
Andrew King	GNS Science
David Hopkins	Consultant to Department of Building and Housing
Civil Aviation	
Peter Lechner	CAA
Keith Makersey	Consultant
Civil Defence and Emergency Management	
David Coetzee	MCDEM
Richard Smith	MCDEM
Department PM&C	
Pat Helm	Advisor
Earthquake Commission	
David Middleton	Chief Executive
Michael Wintringham	Chairman
George Hooper	Research Committee Chair
Hugh Cowan	Research Manager
Energy Sector – Safety of Large Dams	
Murray Gillon	Dam Watch Services
Engineering Lifelines	
David Brunsdon	Kestrel Group
Michele Daly	Kestrel Group
Geodetic and Cadastral Survey	
Graeme Blick	Land Information NZ
Stephen Craig	McKenzie-Podmore Consultants
GeoNet	
Ken Gledhill	GNS Science
International Leverage: Development Cooperation	
John Egan	NZAID
International Leverage: Science Research	
Terry Webb	GNS Science
Loss Modelling for Casualty Estimation	
Rick Geisler	ACC
Loss Modelling for ReInsurance	
David Spurr	David Spurr Consulting
Michael Barckhausen	Aon Benfield
Martin Kreft	Munich Re
Probabilistic Hazard Assessment	
Terry Webb	GNS Science
Public Safety in Active Volcanic Areas	
Paul Green	Department of Conservation
Social Impacts of Natural Disasters	
David Johnston	Joint GNS-Massey Centre for Disaster Research
Universities – Teaching and Research	
John Townend	VUW
Euan Smith	VUW