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Project Beagle: A Financial Risk Management Tool for Liquefaction Hazard in Christchurch, New Zealand

M. C. Hébert[1], M. Ryburn[2] and T. McMorran[3]

ABSTRACT

The 2010-2011 Canterbury earthquake sequence had a significant impact on the buildings and infrastructure of the greater Christchurch area. Sites that were significantly damaged were considered by financial institutions as having many uncertainties, making lending decisions difficult and slow. In this paper, the development of a geotechnical risk assessment tool, known as Project Beagle is discussed. The aim of the tool is to provide a user an understanding of the risks associated with lending money for property in Christchurch and the potential effect of liquefaction damage on the property value. The model was developed by gathering publically available geotechnical spatial data from the Canterbury Geotechnical Database and amalgamating it into one map by assigning weightings to each layer. The tool provides a single risk score for each residential site, to enable the user to compare the relative liquefaction risk associated with properties in greater Christchurch. To validate the model, risk scores and their corresponding likely foundation type were correlated against known foundation solutions for 100 selected sites in the Christchurch area. It was found that a simple model using quality data achieved a concise tool. The methodology applied in Project Beagle could be used to develop similar tools for hazards other than liquefaction damage.

Introduction

The 2010-2011 Canterbury earthquake sequence had a significant impact on the buildings and infrastructure of the greater Christchurch area. The Ministry of Building, Innovation and Education (MBIE) issued guidance for rebuilding houses following the Canterbury earthquakes in order to ensure rebuilt foundations are appropriately designed to accommodate liquefaction and any resulting ground settlement and/or lateral spread. As a result of this guidance, the cost of rebuilt foundations has a direct relationship to the extent of the liquefaction hazard at a particular site. MBIE also published the "Residential Foundation Technical Categories" map in October 2011, which expresses the level of liquefaction risk in Canterbury residential areas. The sites categorized as having significant land damage from liquefaction possible in future large earthquakes, referred to as TC3 sites, were considered by financial institutions as having many uncertainties, making lending decisions difficult and slow. As a result, following the publishing of technical categories by MBIE, Westpac and other financial institutions treated TC3 properties

[1] Ms. Marie-Claude Hébert, Engineering Geology, Golder Associates, Christchurch, New Zealand, mchebert@golder.co.nz
[2]Mr. Mike Ryburn, Risk Management, Westpac New Zealand Limited, Christchurch, New Zealand, mike_ryburn@westpac.co.nz
[3]Mr. Tim McMorran, Engineering Geology, Golder Associates, Christchurch, New Zealand, tmcmorran@golder.co.nz

with more caution than the rest of Christchurch properties. This was due to the uncertain outlook on the future of these properties including a lack of information available on remediation techniques and costs and the future insurability of these properties. At the time, insurers had imposed a blanket ban on the Christchurch area, as aftershocks were still common and insurers were quantifying the financial impacts of the earthquakes. After attending community meetings and having discussions with local businesses, Westpac had learned about a geotechnical risk tool used by an insurance company to rank properties against each other to compare for likelihood of damage. Considering the land issues raised by the 2010-2011 Canterbury earthquake sequence, their associated costs, and their applicable insurance cover, Westpac reached the conclusion that it needed a structured approach to its house lending in Christchurch and in February 2013 engaged Golder Associates (Golder) to develop a geotechnical risk assessment tool, referred to as "Project Beagle". Westpac's assessment of factors controlling property values showed that property values in the greater Christchurch area were strongly influenced by the likely cost of foundation repairs from damage caused by past or future earthquakes. The aim of Project Beagle is to provide a user (a Westpac loan officer) with a structured approach to understanding the risks associated with lending money secured by a property in Christchurch, particularly TC3 properties, and also the potential effect of liquefaction damage on the value of Westpac's property portfolio in Christchurch. Project Beagle would be used internally by Westpac staff to direct assessments of financial lending by providing a standard methodology that would focus on material risks, at a time when there was considerable uncertainty as government and private insurance responses were still in development.

Methodology: Developing Project Beagle

Golder was engaged in February 2013 by Westpac to develop Project Beagle using data made available following the earthquakes. Despite two years having passed since the major 22 February 2011 Earthquake and 17 months having passed since MBIE had categorised the land, the risk to lend to sites zoned TC3, considered to be the most likely to incur liquefaction damage in future earthquakes, was considered complex by Westpac and other financial institutions. Westpac wanted to better understand TC3 property risk through a more detailed assessment of the geotechnical vulnerability and commercial risk faced by any TC3 property. Golder's brief was to design a tool to be used in Westpac's normal assessment procedure for categorising lending risk that describes the geotechnical vulnerability range.

Golder put together a team including engineering geologists and a geographic information system (GIS) specialist. Project Beagle was developed by gathering and overlaying spatial data from the Canterbury Geotechnical Database and other public sources. 'Beagle Values' were assigned to each of the variables displayed on the map layers to amalgamate the data into one final risk map. Three models were initially put together with weighting given on the different categories and one model was chosen following the validation process. The output project was presented to Westpac as an excel spreadsheet with a user-friendly interface and an explanatory report. Westpac used the output from the project along with information acquired from insurance companies to create an Excel tool that allowed the Westpac lending officer to search a property by address. Understanding the insurance policy and geotechnical hazards for an individual property made it possible to identify sites that would require additional assessment prior to a lending decision being made.

Gathering data from the Canterbury geotechnical database

The Canterbury Geotechnical Database (CGD) was developed by the Canterbury Earthquake Recovery Authority (CERA) and district councils to gather and make available data related to the 2010-2011 Canterbury earthquake sequence. The CGD was developed for the use of geotechnical and structural engineers "to access geotechnical data shared by other engineers and their clients, and to share their own data in return". It is an online GIS-based database which provides a searchable source of geotechnical data obtained and uploaded by a range of people and organisations involved in geotechnical work in the Canterbury region. The data are categorised in 4 groups: Geotechnical Investigation Data, Geotechnical Investigation Analysis, Collated Investigation Data and Published Maps and Reports. The CGD includes information from over 36 000 ground investigations conducted in the greater Christchurch area, aerial photographs, field observations commissioned by Earthquake Commission engineers, LiDAR data and some analysis of that data.

The approach for Project Beagle was to create a concise model using the simplest data possible. Four maps from the CGD were used in Project Beagle:

1) MBIE Residential Foundation Technical Categories: This map expresses the level of liquefaction risk in Canterbury residential areas as three categories:
    a. TC1, where future land damage from liquefaction is unlikely.
    b. TC2, where minor to moderate land damage from liquefaction is possible in future large earthquakes.
    c. TC3, where moderate to significant land damage from liquefaction is possible in future large earthquakes.
2) Liquefaction and Lateral Spreading Observations: The EQC observed land damage map where some properties in greater Christchurch have been assigned one of six categories to display the level of land damage observed as a result of the various earthquakes during 2010-2011.
3) Vertical Ground Movements: This map shows the vertical elevation changes between LiDAR date sets that approximate vertical ground movements during significant earthquakes. Liquefaction-induced settlement measured during the earthquakes was found to reflect the complexity of foundation solution required to mitigate liquefaction induced settlement in future earthquakes. It is also likely that properties that have experienced significant overall ground settlement will require some reinstatement of land (by EQC) back to original levels, as EQC insures land within a certain distance of a dwelling.
4) Horizontal Ground Movements: Horizontal ground surface movements between LiDAR sets that approximate the movements during significant earthquakes. This layer indicates areas where lateral movement has occurred and has been split into two categories, according to the category of global lateral ground movement defined by MBIE 2012.

Amalgamating the data

Once the spatial data from the CGD was gathered, the layers were imported into GIS software, overlaid onto a cadastral boundary map. Every residential property in the greater Christchurch area was identified using their unique Title ID number. 'Beagle Values' were assigned to each of the variables displayed on the maps to amalgamate the data into one final risk map. Three models were initially put together with varying weighting given on the different variables of each layer. After a validation process, one model was chosen. The chosen model and the corresponding Beagle Values for each residential property are shown in Figure 1.

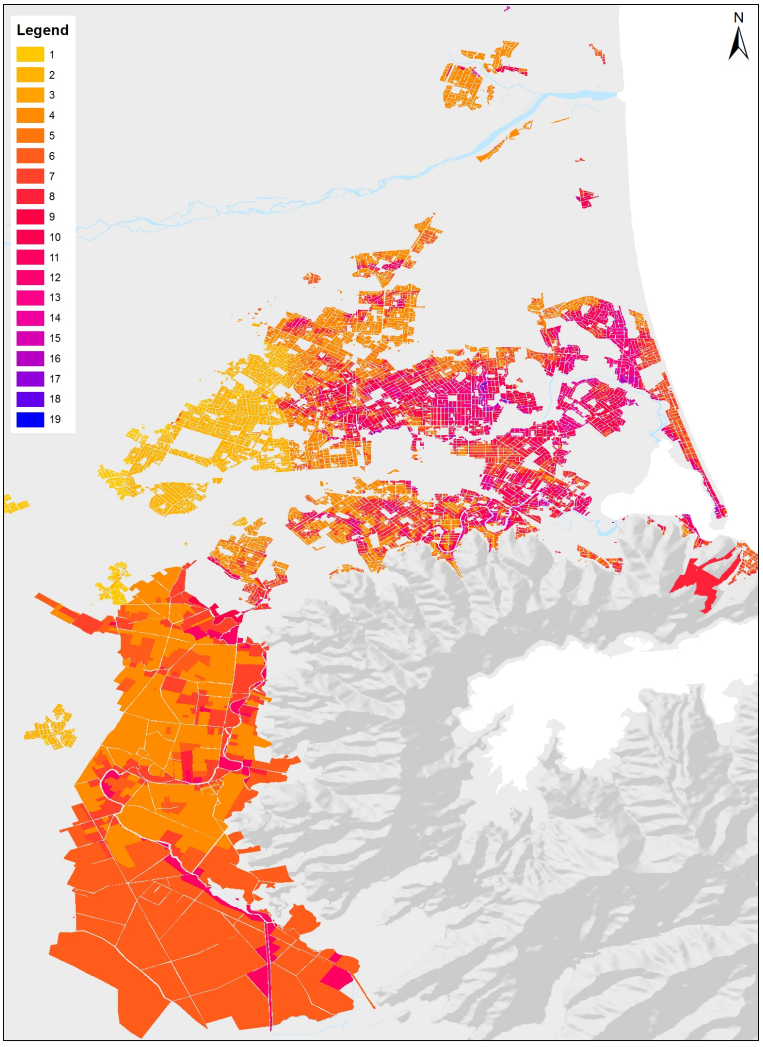

Figure 1: Beagle Scores for residential properties in greater Christchurch.

Project Beagle provides a single risk score for each residential site, to enable Westpac to compare the relative liquefaction risk associated with properties in greater Christchurch. Project Beagle assesses the likelihood that a particular foundation type will be required to develop a

given property based on various geotechnical parameters collected during the 2010-2011 Canterbury earthquake sequence. It is important to note that the methodology used has developed a qualitative risk ranking system, not a quantification of earthquake induced liquefaction risk. However, the consequence of a particular level of liquefaction hazard has been estimated by assigning likely suitable foundation types, with associated estimated costs, to the various Beagle Scores as a validation, as described below.

Validation

To validate the model, the Beagle Scores were correlated against appropriate foundation solutions for selected sites. Sample sites (98 TC3 sites, 2 TC2 sites) were chosen which have had geotechnical assessments carried out by Golder to determine appropriate foundation solutions as outlined in the MBIE guidance (MBIE 2012). The Beagle Scores for each site were compared to the proposed foundation solution.

The correlation between Beagle Score and MBIE Technical Category is shown in Figure 2 below. The MBIE Technical Categories were used as an input parameter for the Beagle Score, however the comparison in Figure 2 illustrates the importance of the additional parameters that were applied. Figure 2 shows the general trend of lower Beagle Scores correlating with TC1, while higher Beagle Scores correlate to TC2, and highest Beagle Scores with TC3. However, the overlap of Beagle Scores between MBIE Technical Categories can also be seen. Correlation of Beagle Scores to the MBIE Technical Category enabled the identification of sites that exhibited characteristics more like the Technical Category either above or below, e.g., TC2 sites that displayed land damage more expected of TC3, or TC3 sites displaying TC2 characteristics.

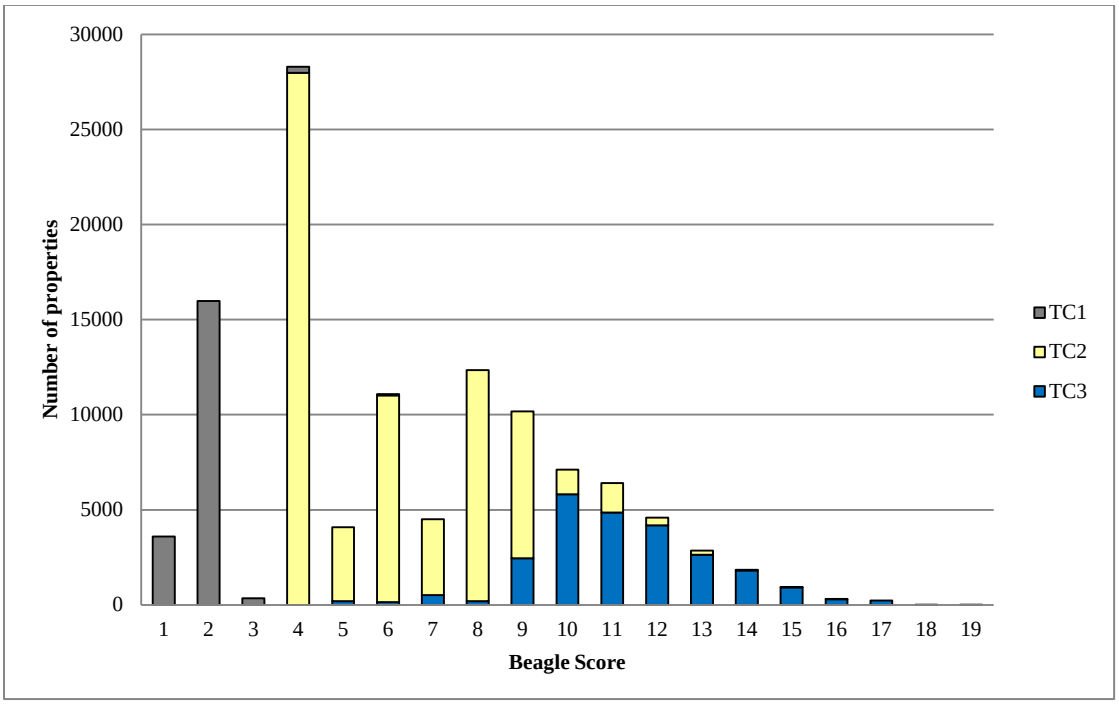

Figure 2: Distribution of Beagle Scores relative to their MBIE Technical Category.

Results: Using Project Beagle

For ease of use, the range of Beagle Scores have been subdivided into four risk categories, known as 'Beagle Categories' outlined in Table 1. The Beagle Scores are considered in conjunction with their MBIE Technical Category, and a description provided for each category.

Table 1: Beagle Categories relative to Beagle Scores.

MBIE Technical Category	Range of Beagle Scores	Beagle Category	Description
TC1	Any	Very low	Property unlikely to be affected by liquefaction
TC2	0 – 9		
	10 – 19	Low	Potentially difficult TC2 sites or lesser damaged TC3 sites. Standard NZ3604 or MBIE 2014 foundation solution is likely suitable
TC3	0 – 9		
	10 – 14	Moderate	Average TC3 sites, site specific foundation design is required but standard TC3 foundation solution from MBIE 2012 is likely suitable
	15 – 19	High	Site specific foundation design required, likely to be more expensive foundation solutions.

The tool provides a user who has no training in geotechnical engineering a better understanding of the severity of liquefaction hazards for a particular site and the likely complexity of foundation measures required to rebuild, should that be required. Additionally, the tool provides a better understanding of the likely costs associated with rebuilding the foundations, and so the effect on the property's value. An important requirement for Westpac was that Golder design a tool that is user friendly without needing onerous training. The end-user simplicity of the tool meant only a 2-hour training session for Westpac's Christchurch staff was necessary. Westpac noted that staff living in Christchurch had a better understanding of issues (geotechnical, financial and social) following the 2010-2011 Canterbury earthquake sequence than those living in other areas of New Zealand. Local knowledge of the Christchurch area has been a valuable advantage to the success of Project Beagle.

This tool is used internally by Westpac staff to enable a structured and consistent approach to assessments of financial lending for TC3 properties.

Discussion

The recovery following the 2010-2011 Canterbury Earthquake sequence has brought challenges in many fields of work from engineering to the financial sector. One challenge faced in the greater Christchurch area has been to adapt to new government issued residential zones, and understanding the financial impacts this zoning may have. For the recovery after natural disasters to run smoothly, unconventional methods and innovative solutions are often successful. The Canterbury Geotechnical Database and Project Beagle are examples of unique tools set up as a response to the 2010-2011 Canterbury earthquake sequence. Westpac had never worked with a geotechnical engineering firm, and in New Zealand, Golder had never been engaged to provide a geotechnical tool to a financial institution. This work may have been unlikely before the earthquakes but has proved to be beneficial to both parties involved and has shown that collaboration is an important part of hazard management.

The environment in Christchurch following the Earthquakes was unprecedented in New Zealand with a large number of damaged homes, the added complexity of varying land damage and the changes in building methods required to address these issues. Factors were also changing and evolving over time as the Canterbury Earthquake Recovery Authority (CERA) and local government authorities were formulating response measures. Standard bank risk assessment methodologies were not set to accommodate factors such as these. Project Beagle allowed Westpac to provide a standardised model to identify situations that had material risk associated with them, and put in place systematic responses to these. This allowed staff to confidently deal with TC3 lending proposals and provide quick responses and useful information to their customers.

Earthquake geotechnical engineering can have a wide range of applications. A central public database of earthquake geotechnical engineering data, such as the CGD, enabled the relatively straightforward development of Project Beagle. The data available in the CGD and the methodology applied in Project Beagle could be used to develop similar tools for hazards other than liquefaction damage such as volcanic hazard, flooding hazard, and rockfall hazard.

As more data became available on the CGD, consideration was given to updating Project Beagle. The validation process used when developing Project Beagle showed good correlation between Beagle Scores and damage at assessed sites, so the model was kept as described in this paper.

Conclusions

Using unconventional methods to solve a unique problem has benefits for both the client and engineers involved. Project Beagle is a success and continues to be used by Westpac. When developing the tool, it was found that a simple model using quality data achieved a concise tool.

Acknowledgments

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