Final report for EQC Project 12/U640

Developing volcanic hazard and risk models for the Auckland Volcanic Field as part of the DEVORA project

Dr. Natalia Irma Deligne, June 2016

Abstract (Technical & Non-technical)

Auckland, New Zealand, faces a unique volcanic challenge: the city is built on of the Auckland Volcanic Field (AVF), which will almost certainly erupt again. Unfortunately, the location, timing, or size of the next eruption are unknown. This project set up the framework for understanding and evaluating risk resulting from such a complex and challenging situation. RiskScape, a multi-hazard risk assessment tool, has been expanded to consider the proximal volcanic hazards expected in an AVF eruption. The Auckland building stock is now currently in a RiskScape compatible format, permitting direct evaluation of the consequences Auckland faces from a local eruption. Finally, a development of a detailed scenario of the hypothetical "Mt Ruaumoko" eruption provides insights on how Auckland's infrastructure will be compromised and levels of services impacted before, during, and after an Auckland eruption. Results indicate that critical services and infrastructure will operate at reduced or no service capacity for weeks to years following an eruption.

Motivation

The Determining Volcanic Risk in Auckland (DEVORA) research programme commenced in 2008 with three research themes: understanding the geology of the Auckland Volcanic Field (AVF; theme 1), understanding the eruption hazards of the AVF (theme 2), and understand the risk posed by the AVF to Auckland (theme 3). This post-doctoral fellowship was developed to determine how to approach theme 3, with RiskScape identified as the desired risk-calculation platform, and once determined, contributing to understanding the risk the AVF poses for Auckland (and New Zealand).

Methodology

Given the rather broad motivation, the post-doc comprised of several projects, each with its own methodology. I summarise each below.

RiskScape improvement

RiskScape is a multi-peril risk assessment software programme jointly developed by GNS Science and NIWA. RiskScape has a module structure (Figure 1): to run, one must have a hazard module, describing the severity of the peril across space, an asset module, describing exposed elements such as buildings or people, and a vulnerability module, which provides impact given the hazard severity and the asset attributes.

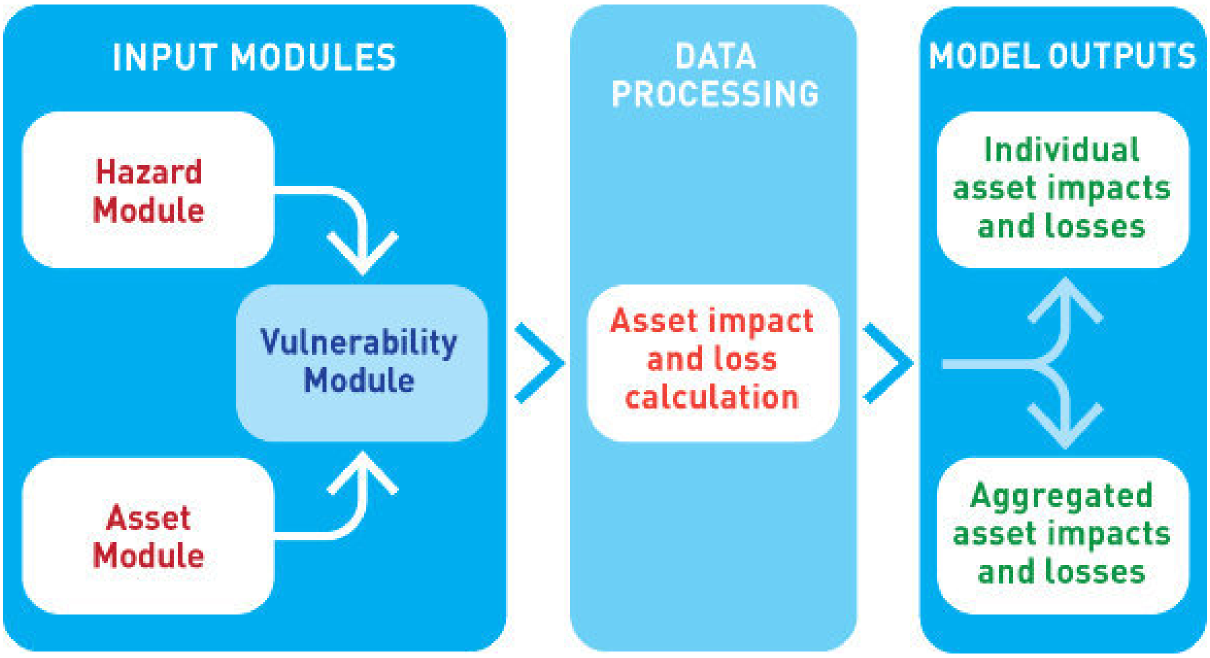

Figure 1. RiskScape's modular structure.

In 2012, volcanic ashfall was the sole volcanic peril within RiskScape, with limited, poorly documented associated fragility functions. There was also no Auckland building stock asset layer developed for RiskScape.

Hazard module

To ensure RiskScape would be relevant for DEVORA, I undertook a survey of AVF hazards, and evaluated which of them have sufficient information and are likely to cause sufficient damage to warrant inclusion within RiskScape. This was done primarily by evaluating the literature and applying expert judgement.

Once additional volcanic hazards were selected for inclusion in RiskScape, with University of Canterbury PhD student Grant Wilson I identified and evaluated units that describe the intensity of a hazard ("hazard intensity metric", or HIM; for ash, examples include thickness, mass, density, composition, grainsize) to determine which measure was best suit for RiskScape. Considerations included how easy it is to measure a given HIM, whether it is used in the output of a hazard model, and importantly, how correlated the HIM is to the impact and damage caused by the hazard.

Hazard module improvements are detailed in Deligne and Wilson (2015) (Appendix A).

Asset module

The Auckland building stock was put into a RiskScape-friendly format as part of an Auckland Council-commissioned report evaluating earthquake risk for Auckland (Cousins et al. 2014; Appendix B); the methodology is provided in the report. Input datasets included QV data, Auckland Council building footprint and rates shapefiles, and an earthquake prone building spreadsheet. Considerable data curation was required. Missing attributes were randomly assigned values from similar buildings in Auckland.

Vulnerability module

In collaboration with the University of Canterbury, I assisted development of fragility functions for RiskScape. This is detailed in Wilson et al. (2014) (Appendix C).

Addressing Auckland volcanic field spatial and temporal challenges

A major challenge with evaluating the consequences of an Auckland Volcanic Field (AVF; Figure 2) eruption is that the location, size, and timing of the next eruption are unknown. There are no useful patterns for forecasting purposes to say with any certainty where, when, or how big the next eruption(s) will be. This makes it challenging to evaluate risk for Auckland.

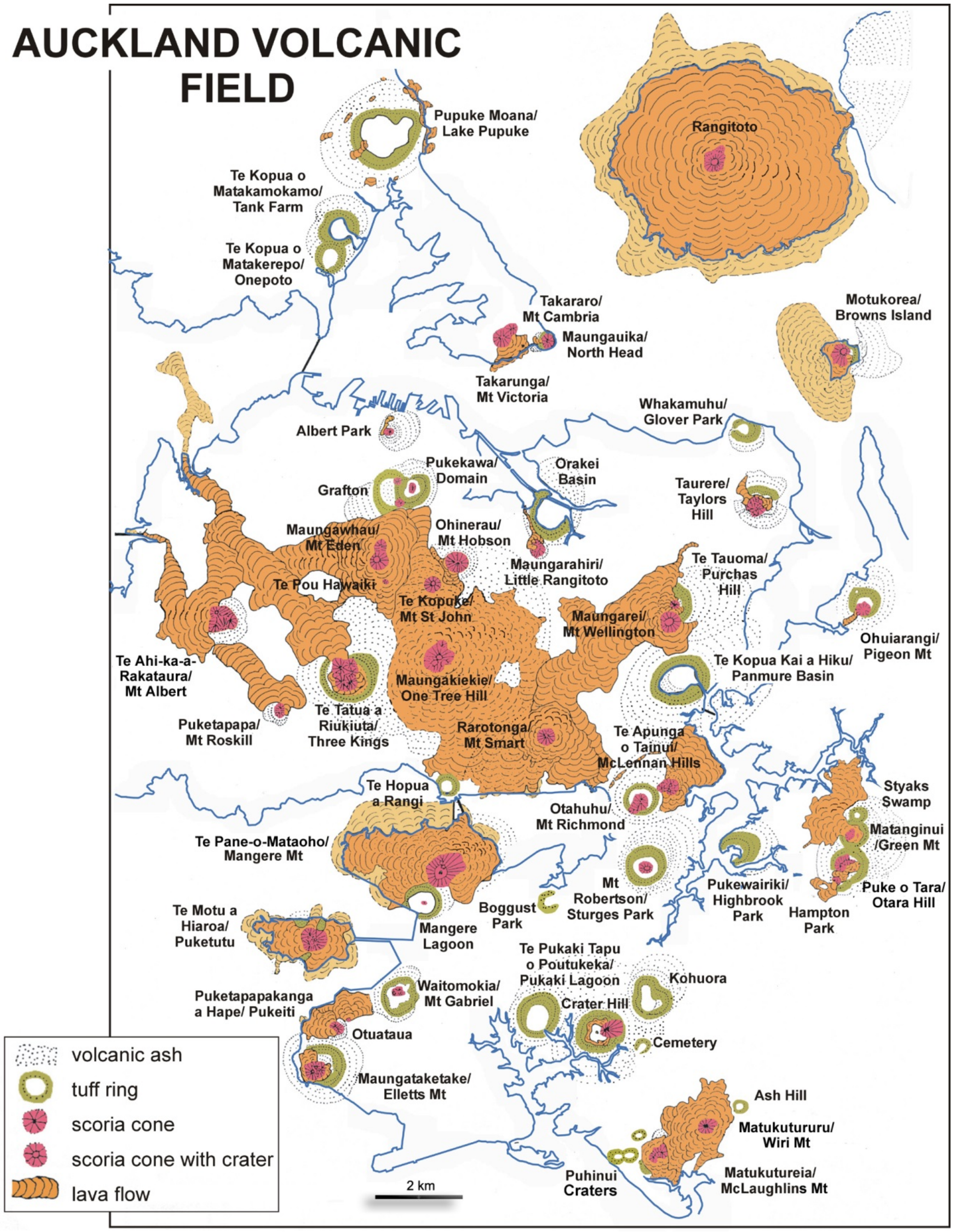

Figure 2. Auckland Volcanic Field (AVF), with known vents labelled. Mapped tephra blankets, tuff rings, scora cones, and lava flows are indicated per legend. Geology from Kermode (1992).

To understand what the community envisioned / expected, I organised two workshops, one with Masters and PhD students working directly on AVF hazards and volcanic impacts, and second broader one involving GNS staff, academics, Auckland Council CDEM staff, Auckland Lifeline Group members, and DEVORA steering committee members. Through these the concept of a 'DEVORA grid' emerged to be able to evaluate the impacts of an eruption at various parts across the city, along with the development of more detailed scenarios in various parts of the city. The first scenarios considered were those developed in Johnston et al (1997) for the then-Auckland Regional Council; the final list of scenarios evolved from this to reflect current needs and interests.

Mt Ruaumoko scenario

In collaboration with the Economics of Resilient Infrastructure Programme, I lead the development of a detailed AVF eruption scenario which based on the continuation of Exercise Ruaumoko. The methodology is detailed in Deligne et al. (2015) (Appendix D). The aim of the scenario was the production of a series of infrastructure outage maps for the major lifeline sectors.

Results

RiskScape improvement

Hazard module

In addition to volcanic ashfall, RiskScape now has hazard module capabilities for pyroclastic density currents, lava flows, edifice construction, and lahars. Lahars are unlikely to impact Auckland be were included so that RiskScape volcano is nationally relevant. Table 1 provides the Hazard Intensity Metrics selected for each hazard. Ballistics will be incorporated in the future once a HIM that works for RiskScape has been selected. More details are provided in Deligne and Wilson (2015) (Appendix A).

Table 1. RiskScape Volcano hazards, associated hazard intensity measures (HIM), and input formats for hazard module.

Volcanic hazard	HIM	Input format
Volcanic ashfall	Thickness (mm)	Raster
Pyroclastic density current (PDC)	<u>Damage</u> Dynamic pressure (kPa) Presence/absence (default 50 kPa) <u>Clean-up</u> Deposit thickness (mm)	Raster (recommended) Presence/absence polygon
Lava flow	Height (m) Presence/absence (default 10 m)	Raster (recommended) Presence/absence polygon
Lahar	<u>Damage</u> Dynamic pressure (kPa) Inundation depth (m) Presence/absence (default 5 kPa and 2 m) <u>Clean-up</u> Deposit thickness (m) Presence/absence (default 2 m)	Raster (recommended) Presence/absence polygon
Edifice	Height (m), positive for built edifice, negative for depression Presence/absence – cone (default +10 m) Presence/absence – caldera or maar (default -10 m)	Raster (recommended) Presence/absence polygon

Asset module

The Auckland building stock is now available in RiskScape; people are assigned to buildings with different day and night time occupancy rates based on census data and building classification (e.g., commercial, single family home).

DEVORA grid

The DEVORA grid was developed to eventually provide a systematic way of evaluating volcanic impact and risk across Auckland. Following consultation, a 500 m grid was adopted across the city. The concept is that depending on the substrate and other parameters identified as influencing the type of volcanism likely at a given location, a grid point will have recommended eruption products for a small, medium, and large eruption. This would be uploaded into RiskScape and a user could explore the effects of an eruption in a location of their choice. University of Canterbury PhD students Daniel Blake and Josh Hayes are now working on developing rules for what hazards may feature where.

Figure 3 shows the DEVORA grid as it was initially conceived; the extent of the has changed since I completed my postdoc with the publication of Runge et al (2015) which provides a peer reviewed mathematically determined extent of the AVF.

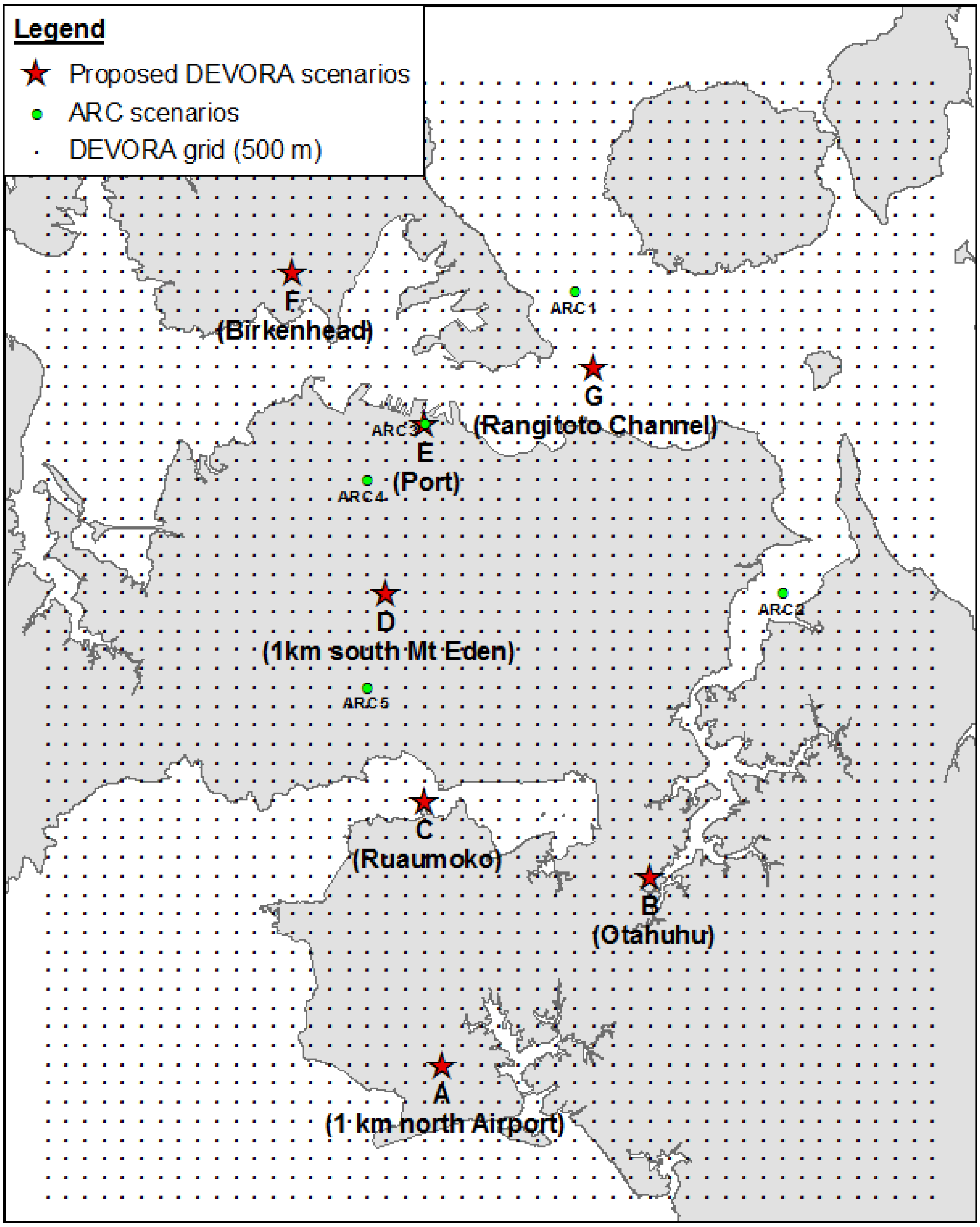

Figure 3. DEVORA grid and scenarios proposed in 2014; this has been revised since completion of the post-doc.

DEVORA case studies

Eight sites were selected for development of eruption scenarios. These were selected to collectively cover a range of likely eruption types (from Surtseyan through to predominately magmatic), land-use types in Auckland (industrial, commercial, residential), and include considering Rangitoto reawakening. University of Auckland honours student Caitlin Slabbert completed a first cut evaluation of the likely eruption styles at the case study sites, and University of Canterbury PhD students Daniel Blake and Josh Hayes are now working on developing the case studies. The Mt Ruaumoko scenario has already been developed (see next section).

Mt Ruaumoko

In conjunction with the Economics of Resilient Infrastructure programme, I lead the development of a detailed scenario exploring the potential consequences of an AVF eruption (Deligne et al. 2015; Appendix D). This involved adapting an existing scenario, creating hazard layers, and coordinating and meeting with many lifeline operators and Auckland civil defence personnel. This project had many contributors from the University of Canterbury and Massey University.

The final outputs included a series of hazard maps over the course of the hypothetical eruption, evacuation maps, a clean up model, and damage and outage maps for electricity, road network, rail (passenger and freight), Auckland Airport, water supply, wastewater, stormwater, and telecommunications. Table 2 summarises outage durations for the scenario.

Table 2. Hypothetical Mt Ruaumoko scenario sector outage durations (see Deligne et al. 2015; Appendix D).

Sector	**Overall outage**
CDEM – evacuation	7 weeks
CDEM – cleanup	> 6 months
Electricity	> 1 year
Fuel	4 months
Roads	> 7 weeks
Rail	> 7 weeks, permanent closure of some lines
Aviation	3 months
Port	Mostly negligible
Water supply	Wide scale restrictions for > 1 year
Wastewater	> 2 years of raw sewage discharge
Stormwater	Reduced capacity in some areas
Telecommunication	< 2 weeks

Student supervision

As part of my post-doc, I co-supervised three students at the University of Canterbury. PhD student Grant Wilson (graduated in 2015) focused on the impact of volcanic eruption on critical infrastructure, PhD student Daniel Blake is investigating the effects of volcanic eruptions on transportation networks, and Masters student Josh Hayes (graduated in 2015, now a PhD student) studied tephra clean up. These three students contributed considerably to consideration of risk in Auckland.

Conclusions

As a result of my postdoc, RiskScape now supports 5 volcanic hazards, up from 1 before. RiskScape now has current fragility and vulnerability functions, and can shortly be used to evaluate risk in

Auckland resulting from a local or distant volcanic eruption. The Auckland building stock is also now RiskScape compatible, and basic fragility functions are in place.

DEVORA also have a vision now of how to address volcanic risk in Auckland given the unique challenges posed by the AVF. Detailed scenarios will examine the consequences different eruption styles in various locations across the AVF. These scenarios will assist in the development of rules for eruption styles one may expect in different parts of the AVF, which will then be put into RiskScape so that users can explore the consequences of an eruption in the location of their choice.

A fully developed scenario at the site of the Exercise Ruaumoko vent, the hypothetical Mt Ruaumoko, has provided insight into the level of disruption Auckland may face before, during, and after an AVF eruption. Levels of service for most lifeline sectors will be compromised for 2 weeks to several years. The Mt Ruaumoko scenario is the first robust assessment of its kind to explore the consequences of an AVF eruption on the Auckland region.

Acknowledgements

We thank EQC for their support of this project (EQC Project 12/U640). We also acknowledge support from the RiskScape and Economics of Resilient Infrastructure programmes; both programmes are funded by the Ministry of Business, Innovation and Employment. Auckland Council funded the project resulting in Appendix B.

References

Cousins WJ, Nayyerloo M, **Deligne NI** (2014) Estimated damage and casualties from earthquakes affecting Auckland. GNS Science Consultancy Report 2013/324, 53 pp.

Deligne NI, Blake DM, Davies AJ, Grace ES, Hayes J, Potter S, Stewart C, Wilson G, Wilson TM (2015) Economics of Resilient Infrastructure Auckland Volcanic Field scenario. ERI Research Report 2015/03, 151 pp.

Deligne NI, Wilson G (2015) Architecture and hazard intensity metrics for RiskScape volcano. GNS Science Report 2015/019, 28 pp.

Kermode LO (1992) Geology of the Auckland urban area: sheet R11. Scale 1:50,000. Institute of Geological and Nuclear Sciences geological map 2. 63 pp. and 1 map.

Runge MG, Bebbington MS, Cronin SJ, Lindsay JM, Moufti MR (2015) Sensitivity to volcanic field boundary. Journal of Applied Volcanology, 4:22, doi: 10.1186/s13617-015-0040-z

Wilson G, Wilson TM, **Deligne NI**, Cole JW (2014) Volcanic hazard impacts to critical infrastructure : a review. Journal of Volcanology and Geothermal Research, 286: 148-182, doi: 10.1016/j.jvolgeores.2014.08.030.

Appendices

A. **Deligne NI**, Wilson G (2015) Architecture and hazard intensity metrics for RiskScape volcano. GNS Science Report 2015/019, 28 pp.

B. Cousins WJ, Nayyerloo M, **Deligne NI** (2014) Estimated damage and casualties from earthquakes affecting Auckland. GNS Science Consultancy Report 2013/324, 53 pp.

C. Wilson G, Wilson TM, **Deligne NI**, Cole JW (2014) Volcanic hazard impacts to critical infrastructure : a review. Journal of Volcanology and Geothermal Research, 286: 148-182, doi: 10.1016/j.jvolgeores.2014.08.030.

D. **Deligne NI**, Blake DM, Davies AJ, Grace ES, Hayes J, Potter S, Stewart C, Wilson G, Wilson TM (2015) Economics of Resilient Infrastructure Auckland Volcanic Field scenario. ERI Research Report 2015/03, 151 pp.