# Long-term communication of volcanic risk for effective decision-making


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# Executive Summary

Communication of information about volcanic hazards and risk varies, depending on the status of the volcano (e.g. quiescence, unrest, eruption, post-eruption, recovery), and the population exposed. It is made challenging by factors such as uncertainty about the likelihood, timing, and location of an eruption, the variation of impacts across space and time, and personal circumstances. Communication of volcano information is necessary to help inform decision-making for volcanoes. While previous studies have investigated information and communication for specific hazards, eruptive events, locations, or formats, gaps exist in knowing what is required at each of the different stages of activity (i.e. from quiescence to recovery). Our research thus investigated volcano communication over such stages to understand decision-making needs (e.g. for preparedness, planning, response, recovery), and the information required. We focused on information provided by science agencies and how it might be used by other agencies, organisations, and the public of Aotearoa New Zealand.

We first undertook a review of volcano literature and data within NZ. We found that the literature about information and communication focussed more on quiescence and eruption, and less on unrest and post-eruption/recovery. The review also highlighted that there is increasing appetite for information as activity escalates from unrest onwards, and that the nature and purpose of information differs across stages (e.g. hazard and risk information required for planning purposes during quiescence was different to impact information needed during an eruption). The results of the review emphasise the need to both better document existing information and communication (as these are absent from recorded literature), as well as to undertake more work - particularly for unrest and post-eruption/recovery - to fill any information gaps

The review was followed by seven focus group discussions with agencies, organisations and public (e.g. emergency managers and responders, Public Information Managers, science communicators, infrastructure managers, health, insurance, conservation agencies/land managers, including those with formal roles that were also affiliated to iwi or hapū), and one interview (media). Discussions focused on a scenario for Ruapehu volcano covering several stages of activity. Like the literature review, we found that information and communication needs escalated with increasing activity alongside concern levels. Information was moderately and extremely important for almost all participants across all stages. Information overload was highlighted as an issue, particularly for the public across all stages, and for agencies at earlier stages.

In terms of information required, some information was considered critical across all stages from quiescence to post-eruption, including what the volcano is doing now (e.g. Volcanic Alert Levels), what actions people should be taking, and where to get more information. Looking specifically at the different stages - during quiescence, information about what a volcano is doing now, actions to take and where to get more information were considered critical. Sector-specific impact information was also important for planning purposes. As activity moved from quiescence into unrest, information related to forecasts, precursors and locations at risk became more important. During an eruption, alongside the information required for unrest, information about impacts and how to address these was critical. Impact information was also important for post-eruption and recovery, with recognition there could be long-term on-going impacts. Other aspects that were raised included the need for multiple sources and channels of information beyond science agencies; the need to manage information consistency, misinformation and overload; the importance of relationships for communication; and the need for continual evaluation, improvement and development of products.

Given the evolving nature of information and communication across stages of volcanic activity, we recommend that strategies, plans and templates be developed to ensure the right types of information are provided within appropriate timeframes, and in the most effective ways (e.g. via sources, channels, etc.). This would be an excellent next step from this project. We also advocate for on-going social science research to better inform our understanding of information needs and decision making for underrepresented stages (unrest, post-eruption/ recovery), and the development of evidence-based resources to help guide future volcano decision-making. More research could also help understand how to adequately inform people, while reducing people's perceptions of information overload.

**Keywords:**

Volcano, risk perception, hazards, communication, decision-making, social science, empowering people.

# Introduction

Communication of information about volcanic hazards and risk varies over time, depending on the status of the volcano (e.g. whether it is in quiescence, unrest, eruption, post-eruption), and the population exposed. It is made challenging by factors such as uncertainty about the likelihood, timing, and location of an eruption, the potential impacts which may vary across space and time, and personal circumstances. Communication about such aspects is essential to inform decision-making.

In contrast with earthquakes, volcano hazard and risk information, and communication research has been limited in Aotearoa New Zealand. There has been work on the communication of hazard, risk and preparedness actions related to the 1995-1996 Ruapehu eruption sequence (Johnston et al., 1999), for the 2007 Ruapehu Crater Lake lahar (Becker et al., 2017; Dittmer, 2008), and on responses to the 2012 Te Maari eruptions (Leonard et al., 2014). Research has also been conducted during periods of quiescence, including communication about lahars on the Whakapapa ski field (Leonard et al., 2008), on people's responses to hazard maps in Tongariro National Park (TNP) (Coomer and Leonard, 2005), on people's perceptions and preparedness about both weather and volcanic risks on Tongariro (Dhellemmes et al., 2016), and on Volcanic Alert Levels (Potter et al., 2014). Outside of TNP, several studies exist on risk communication for volcanoes without current activity, including Auckland Volcanic Field (Horrocks, 2008; Thompson et al., 2015; Paton, 2007), Tarawera (Thompson et al., 2015), and Taranaki (Clive et al., 2021; Finnis et al., 2010). Research has also been conducted on inter-organisational response communications for volcanic unrest (Doyle et al., 2015; Paton et al., 1999) and effective framing of eruption forecast statements (Doyle et al. 2014 a,b).

While such studies have provided excellent background on the communication of information for specific hazards, eruptive events, locations (e.g. Whakapapa ski field), or formats (e.g. maps, probability statements), gaps exist in understanding the range of information and communication strategies that might be required across different contexts, audiences, and timeframes. This has implications for understanding the effectiveness of information and communication for decision-making (e.g. from preparedness through to responding and recovering). Internationally, similar gaps also exist in understanding how to communicate volcanic hazard and risk (Donovan & Oppenheimer, 2016).

Given our gaps in understanding about volcano hazard and risk information communication in Aotearoa New Zealand (NZ), this research sought to investigate such aspects across time (i.e. from quiescence and unrest through eruption and post-eruption) to better understand people's needs for decision-making. For example, do certain agencies need different information communicated to them during unrest, versus during in an eruption, and what might that information look like? Our research included: 1. A review of existing volcano information and communication literature and data within NZ; and 2. Focus groups and an interview with those who use volcano hazard and risk information to understand their information needs, including for decision-making. We focused on the provision of information and communication by science agencies, but focus groups and interviewees tended to also discuss broader information provision. Limitations of the research included a focus on the NZ context, with a specific focus on Ruapehu volcano in TNP. Further research is needed to align our findings with other volcano contexts, nationally and internationally.

Results from this research can help science organisations and entities (e.g. GeoNet, emergency management, DoC, iwi) frame and provide advice to agencies and the public. Better framing and communication of information can assist in people's interpretation of that information, and help inform decisions about preparedness, planning, response and recovery, leading to a decrease in impacts for individuals and communities. This project is aligned with Toka Tū Ake EQC's 2021-23 strategic area for research investment, 'How people perceive and manage risk (empowering people)'.

**Research methods**

To understand the context of the research, and results and discussion, we include a short section on the methods used to collect our data. Further information on these methods can be found in Appendix 1.

1. Literature and data review: We undertook a systematic search and narrative review of published volcano research for NZ, alongside a review of unpublished data and documents, to identify the types and effectiveness of volcano information and communication in the past, as well as any existing evaluations and lessons learnt (Appendix 1.1). Our review was divided into communication for five stages of volcano activity: quiescence, unrest, response (e.g. for a short-lived eruption, or longer duration eruptions), post-eruption and recovery (Das et al., submitted). Findings are discussed in the context of those categories.

2. Focus groups and interview: To gather new data on information and communication needs for volcano risk information, we conducted seven focus groups between May - September 2023. These included a total of 74 participants, with 28 members of the public from Rotorua and Taupō, and 46 decision-makers. One additional person was interviewed online, via Zoom. The focus groups and interview were semi-structured, and focused on information and communication needs for an evolving volcanic activity scenario at Ruapehu volcano, similar to the 1995-96 event. The scenario used similar stages to the literature review, ranging from Ruapehu being at Volcanic Alert Level 1 (VAL 1) ('quiescence' or 'minor unrest', Stage 1) through heightened unrest (VAL 2, Stage 2), eruption (VAL 3-4, Stage 3), and post-eruption (VAL 2, Stage 4), across a timeframe of several months (Appendix 1.2).

Focus groups sessions were held at public spaces (e.g. libraries) in Taupō and Rotorua. Sessions in National Park, Hawke's Bay and New Plymouth were located in either council offices or alongside volcano advisory group meetings (i.e. Central Plateau Volcanic Advisory Group (CPVAG) and Taranaki Seismic and Volcanic Advisory Group (TS-VAG)). National Park was chosen due to its close proximity to the central North Island volcanoes. Taupō, Rotorua, New Plymouth and Hawke's Bay could be impacted by ashfall by Ruapehu volcano and many members of the communities visit TNP. In the focus groups, we first included an icebreaker question, asking participants about their experiences with volcanoes. This allowed us to gain important context. We then asked the participants three questions linked to each stage of activity for Ruapehu. The first two questions were: What was their level of concern about volcanic activity? And how important was information to them? Both questions were ranked by individuals in each group on a Likert scale.

For the third question, we also asked participants what information was critical, nice to have, and not needed, and to indicate their answers via a group card sorting exercise (using pre-determined information categories as well as newly defined categories) (Figure 1).

Discussions were audio recorded and transcribed. Data for all three questions were statistically analysed using frequencies, and graphed in different ways. This was supplemented with quotes from the transcriptions to understand specific information needs and uses.


**Figure 1.** Group card sorting exercise in Taupō.

# Results and Discussion

**Literature and data review**

As highlighted in the methods section, our review of volcano literature was divided into five different stages of activity. These included quiescence, unrest, eruption, post-eruption (directly after) and recovery (Figure 2). A version of these stages was also used in the Ruapehu scenario for the focus groups and interview. The literature review results presented in this report are taken from our paper Das et al. (2024, submitted).

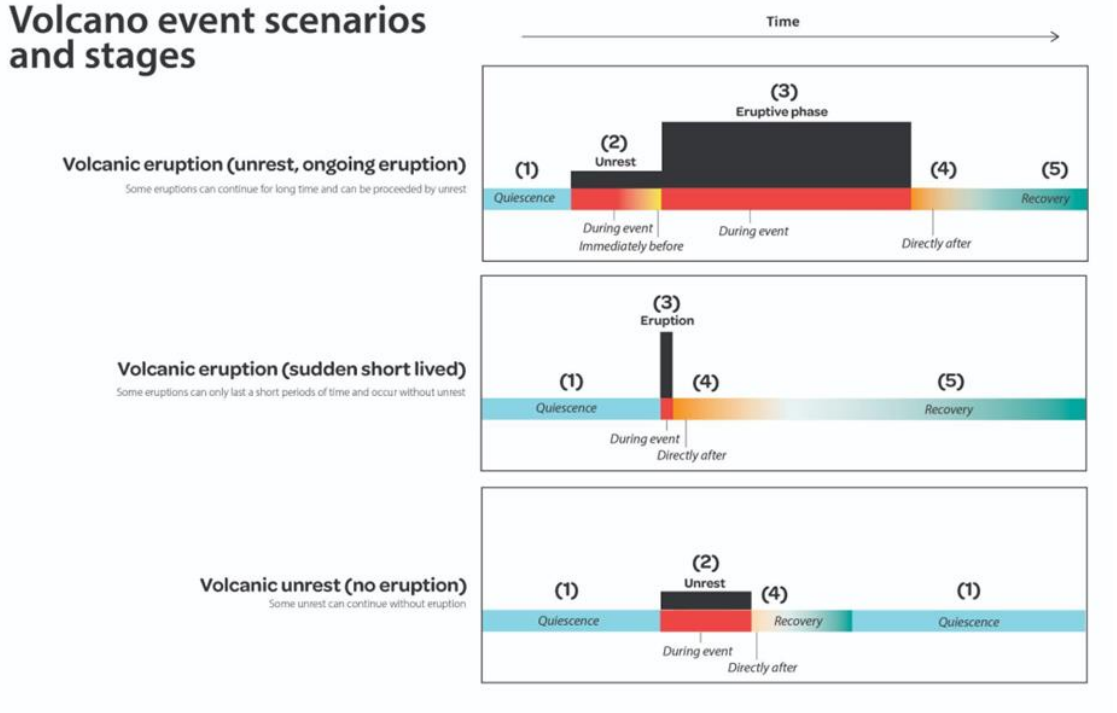



**Figure 2.** Stages of volcanic activity for different types (scenarios) of volcanic eruption

***Volcano information - available across all stages***

For context it is important to note that New Zealand's geological hazards are continually monitored across all stages by GeoNet, a programme run by GNS Science (Potter et al., 2018). GeoNet officially communicates the status of current activity as a Volcanic Alert Level (VAL) for each volcano via Volcano Activity Bulletins (VABs) (Gentle et al., 2016; Potter et al., 2018). VALs are moved up or down depending on the interpretation of observations (Potter et al., 2014). This living information is available on a website and app, but is usually only actively written about and broadcast when changes occur (i.e. when unrest increases, communicated by a change from VAL 1 to VAL 2, or VAL 0 to VAL 1) or to provide an update, via VABs, news stories, or YouTube videos, which often also go out via social media. GNS Science, through its website (www.gns.cri.nz) provides a wide range of information about volcanoes in NZ, the hazards they pose, and preparedness and mitigation actions (including links to international information), as does the National Emergency Management Agency and Emergency Management Groups with volcanoes.

***Volcano information specific to different stages***

In undertaking the literature and data review, a variety of aspects on information and communication were found across timeframes. These are summarised in Figure 3, which highlights differences in reported information types and communication across stages of activity.

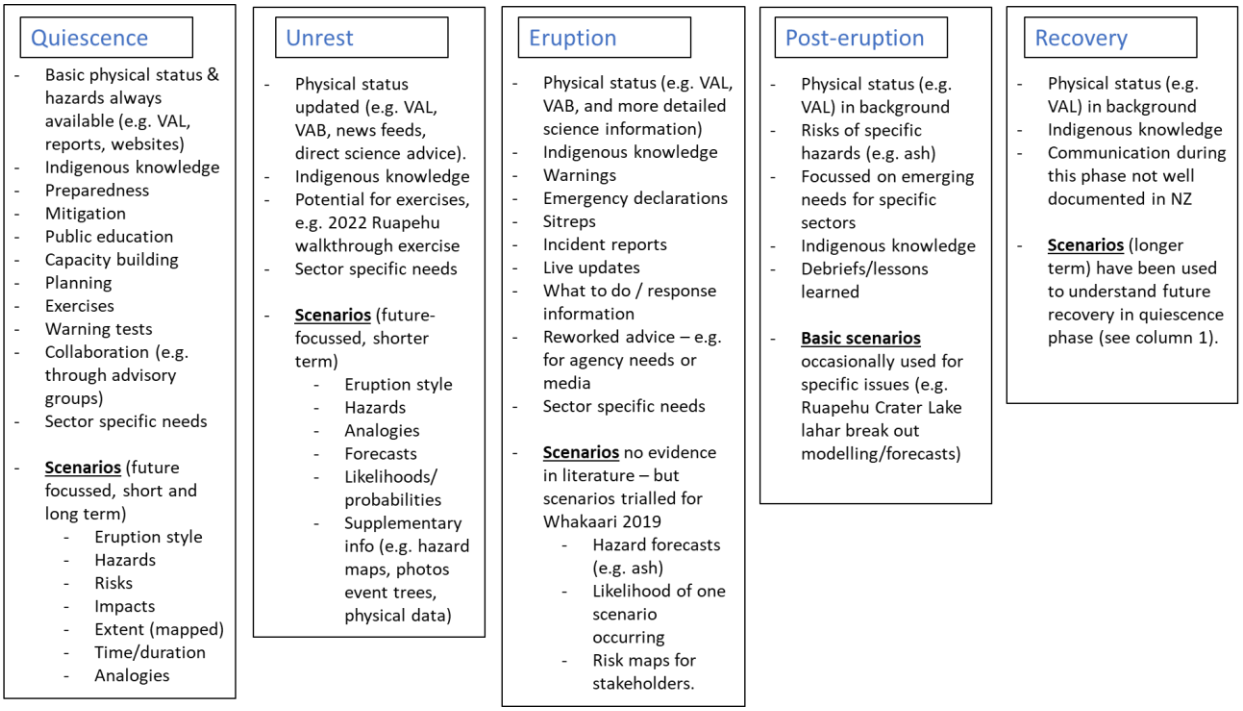



**Figure 3.** Information and communication activities across different stages of volcanic activity – summary of findings from review of New Zealand-specific literature and supplementary grey literature (Das et al., 2024 submitted).

First, most literature reports on information and communication during quiescence and eruption. Gaps exist in the peer-reviewed literature about volcano information and communication during unrest and the post-eruptive stages, including recovery. Given that information about communication during unrest does exist in supporting documents (e.g. Volcano Alert Bulletins) it is important that case studies be written up.

Second, the review highlighted the evolving nature of information and communication over different stages of volcanic activity. Information and communication differ across stages, in terms of topics, frequency, level of tailoring, and purpose. While scientific information about the current physical status of a volcano is always available (e.g. via the VAL table, VABs and news items on GeoNet), the need for more frequent and detailed information increases throughout unrest, eruption, and post-eruption stages (Leonard et al., 2014). During quiescence, information and communication focuses on sharing knowledge, planning for volcanic events, and building response capacity across agencies and the public. During unrest, communication focuses on information regarding physical science, what might happen in future (e.g. via scenarios), and response planning. In the eruptive phase, communication provides updates on the volcano's physical status, potential hazards, warnings, emergency declarations, situation and incident reports and advice for emergency management decisions. Advice may also be reworked by agencies to suit their needs. In the post-eruption and recovery stages, communication may be more tailored to the emerging needs of specific sectors; however, the NZ literature is limited on these topics.

Given that our review highlights that information and communication constantly evolve across stages of volcanic activity, more thought should be given to what should be provided at these different stages, and how, taking into account decision-makers' needs. A related issue regarding the evolution of information and communication, is that of transition between the different stages. Transition of information between volcanic stages has not been explored in the NZ literature, particularly as volcanic activity escalates or de-escalates. These transitional aspects would benefit from future research.

Third, while decision-making needs were highlighted in the review, particularly in relation to emergency management needs for the eruption stage, further research is needed to understand what decisions are relevant across the other stages. A better understanding of decision-makers' needs, including needs from a Mātauranga Māori perspective (Gabrielsen et al., 2017), can help guide information products and communication approaches. For example, during the 2022 Taupō Volcano unrest, questions arose from decision-makers regarding how deformation might impact infrastructure and how this should be communicated and acted upon, but the NZ and international literature gives no guidance on this. It is possible that impact-based forecasts might be useful in the volcano context to help decision-makers understand what the issues might be, and to guide their responses, as has been explored in a severe weather context (Potter et al., 2021).

Finally, given the increasing use of scenarios as a product for volcano communication in New Zealand, we also touch briefly on their utility across different eruption stages. Scenarios prepared during the quiescence stage are often used for planning purposes, may be short or long-term, and cover aspects such as the geographic extent of a particular possible volcanic event, the timeframe of an event, and the hazards and impacts that may occur. In the quiescence stage, a few recovery scenarios have also been constructed. During unrest, shorter-term scenarios have been useful to help understand the different pathways that may lead on from the unrest. For each scenario analogies of previous events are presented for context, along-side potential hazards, the likelihood of each scenario occurring, and other supplementary information (e.g. maps, photos, etc). Unrest scenarios can also inform exercising needs, as observed during the 2022 Ruapehu unrest period, when an informal 'walkthrough' exercise was conducted, or for exercise Ruaumoko in Auckland where unrest was injected as part of the exercise (Lindsay et al., 2010). In terms of the eruption phase, an eruption scenario was trialled immediately following the 2019 Whakaari eruption (e.g., GeoNet: Volcanic Activity Bulletin) where the likelihood of one scenario occurring was communicated to stakeholders and the public via GeoNet, and risk maps were developed for stakeholders to help responders with decision-making. In the post-eruption and recovery stages scenarios have been less utilised, and if they have been used, it has been only in an ad-hoc way (e.g. modelling for the Ruapehu Crater Lake break out lahar). Given scenarios are a well utilised form of information provision and communication, there are opportunities to consider what elements of scenarios could be consistent across the stages of volcanic activity (e.g. a consistent use of likelihood/probability), what might need to be adapted across stages and/or type of volcano, whether scenarios could be more usefully applied in a post-eruption context, and how scenarios can be more people- and decision-centred. This, again provides an opportunity for future research.

**Insights from focus groups and interview**

As mentioned previously, our literature review was followed by focus groups and an interview, which were based upon a Ruapehu scenario of activity, similar to 1995-1996, split into stages of activity (1-4).

***Experience of participants***

Focus group participants in Taupō and Rotorua, who were more general public, had experienced the 95-96 Ruapehu eruptions, studied science or geology, undertook recreation on volcanoes, and/or worked in a professional capacity related to volcanoes including park management, recreation, health, emergency management, defence, etc. Thus, participants had more capacity to understand and interpret volcano information, and assess the risk posed by volcanoes. In saying that though, there were still knowledge gaps

observed, particularly related to volcano types, locations, hazards, processes and impacts.

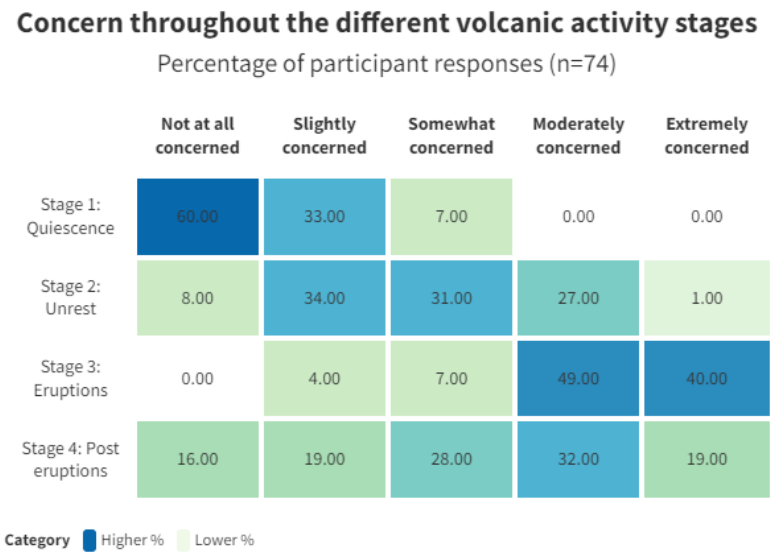
In terms of those with an advisory capacity, people came from a variety of 'agencies' or 'organisations' and had a variety of backgrounds. Common participants included local and national emergency managers, emergency responders (e.g. Police, FENZ), Public Information Managers, science communicators, educators and researchers, infrastructure managers, health workers, insurance agencies, media, conservation agencies/land managers, and those with formal roles that were also affiliated to iwi or hapū. Experience of agency participants varied – some had vast training in understanding volcanoes and how to respond to volcanoes, others had day-to-day roles which involved a component of volcano planning, others had lived through events like Ruapehu 95-96, while some people's experience (particularly if volcano was only one distant aspect of their role) was restricted mostly to recreation on volcanoes. There was an overall high level of experience in responding to past volcano events, with many involved in working on previous Ruapehu eruptions, lahar and unrest episodes (particularly from the National Park group) or Whakaari.

Experience did affect people's response to information. For example, many had been on the receiving end of information in the past, so their need for being fed, or for seeking, more basic information was not as essential over the different stages of activity. However, they did still seek to confirm basic information (even if they thought they knew it), to reassure themselves that they were giving out the correct message to others like the public. In general, then, agencies and organisations required more detailed information, and while some were interested in science information on hazards, processes and extent of a potential eruption across all stages, there was most emphasis placed on impacts and what to do regarding those impacts.

***Levels of concern at different stages of activity***

Overall concern levels were low during the quiescence phase, with 60% stating they were not concerned at all with volcanic activity from Ruapehu and 33% slightly concerned (Table 1). During unrest (Stage 2), concern levels rose, with the majority saying they were slightly and somewhat concerned (34% and 31% respectively). Overall, concern levels peaked at the eruption phase with 89% of participants stating they would be either moderately or extremely concerned about volcanic activity. Relatively soon after the eruptions had stopped, concern levels dropped, but stayed higher than they were during the unrest phase.

**Table 1.** Categorical heatmap of the level of concern across all participants counts and percentages of total by stage.



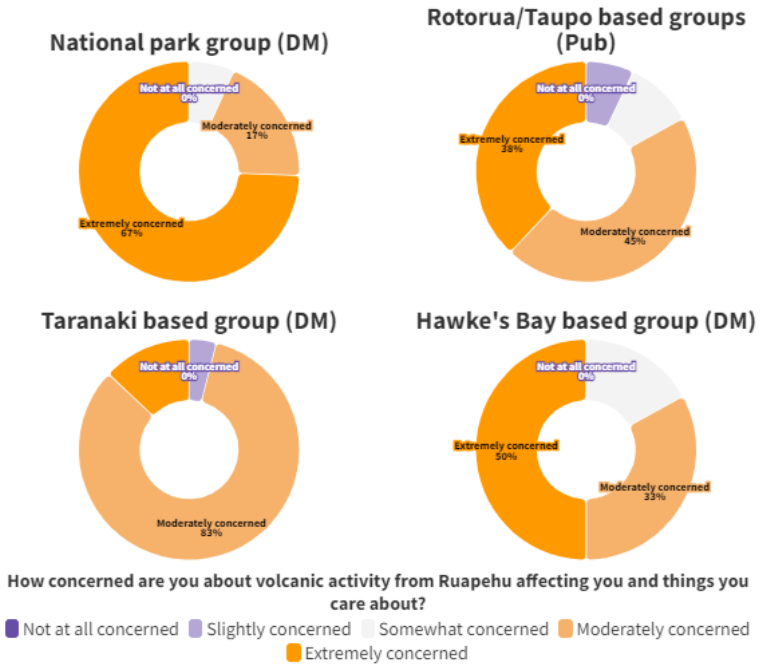
It was clear that concern was dependent on the context, like where someone was located, or what they may be doing (e.g. Are you near the mountain? Are you planning/doing a certain activity like travelling or skiing? Do you have a responsibility for others like children?). People expressed lower concern levels during the eruption phase based on the fact that they were located further away from Ruapehu (Figure 4).

> ***"You've also got the context of geography as well. I mean Turangi obviously might be a little more worried about how [...] current volcanic [activity] might affect them, whereas at its low level in Taupo - it's a little lower in my concern…" Taupō public focus group participant***

Participants' past experience influenced concern levels for future events. For example, the past experience of Ruapehu 95-96 was described by one participant as "*terrifying*" which then caused them to be concerned for future events; or alternatively another person expressed lower levels of concern based on previous experience of Ruapehu, "*because I understand the scale of an eruption and I'm not too worried about Ruapehu in particular*". On the other side, concern could be caused by a lack of experience as described by one person whose daughter-in-law worried when she visited Taupō.

Several people stated that knowing the volcanoes are being monitored reduced their worry and concern. There was discussion that the monitoring system was trusted to pick up any changes that could then be relayed to the public and agencies through Volcanic Alert Levels and VABs. There was a notable regional aspect to levels of concern, with participants who lived or worked closer to Ruapehu showing more concern, in the eruption phase for example (Figure 4).

**Figure 4.** Concern levels by region for Stage 3, a small-moderate series of eruptions from a Ruapehu scenario. National Park n = 16, Rotorua/Taupō n= 29, Taranaki n = 23, Hawke's Bay n = 6.




**Importance of information at different stages of volcanic activity**

During Stage 1, importance levels varied across participants. Overall, in response to the scenario presented, participants' need for information increased from unrest through to eruption, and stayed high post eruptions (Table 2). In terms of regional results, the importance of information varied between regions (e.g. Figure 5), and public and agencies near Ruapehu rated information as generally more important.

**Table 2**. Heatmap of the level of importance of information across all participants counts and percentages of total by stage.

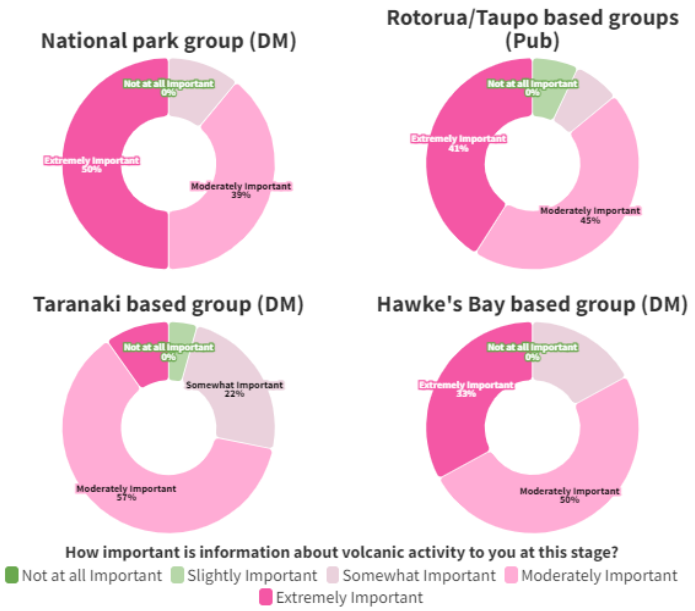
**Importance of information throughout the different volcanic activity stages**

Percentage of participant responses (n=74)

| | Not at all Important | Slightly Important | Somewhat important | Moderately Important | Extremely Important |
|---|---|---|---|---|---|
| Stage 1: Quiescence | 3.00 | 18.00 | 26.00 | 33.00 | 20.00 |
| Stage 2: Unrest | 0.00 | 4.00 | 13.00 | 49.00 | 33.00 |
| Stage 3: Eruptions | 0.00 | 0.00 | 1.00 | 7.00 | 92.00 |
| Stage 4: Post eruptions | 1.00 | 1.00 | 5.00 | 41.00 | 51.00 |

Category Higher % Lower %

**Figure 5.** Importance of information by region for Stage 2, moderate-heightened unrest. National Park n = 16, Rotorua/Taupō n = 29, Taranaki n = 23, Hawke's Bay n = 6.




Common reasons given for the importance of information included that access to information lessens worry or fear, and helps you feel in control, and that it was needed for planning purposes (e.g. Stage 1 or 2) or response and recovery-related decisions (Stages 3 and 4). Information overload was highlighted as an issue, particularly for the public across all stages, and for agencies at earlier stages (e.g. Stage 1). It was felt too much information could cause worry or anxiety. This has implications for developing strategies for information and communication. Certain types and amounts of information might need to be carefully managed at different stages to avoid overload, balanced with the need to retain trust and recognition of the agencies providing information, ready for when activity does increase.

***"I think when it's, like there's nothing happening, I'm just like I don't need any extra things stressing me out, I'll just I don't want to know about it right now." - Taupō public focus group participant***

***Sources and channels of Information***

The focus on the importance of information provoked a lot of discussion surrounding specific sources and channels of information. There was generally high awareness of GeoNet being a predominant source of information, across all focus groups and interviews, though many acknowledged multiple sources and channels were important to account for redundancy (e.g. DOC, CDEM, iwi/hapū, family or friends, Toka Tū Ake EQC, news, social media, Emergency Mobile Alerts, emails). There was a fair amount of discussion about the need for some agencies to rework information to send out via their own channels, across all stages. Credible and trusted sources were considered important, as seen in the literature (Mileti and Sorensen, 1990). Previous events were also used as sources of information for some, such as the HTHH eruption (2022), Ruapehu eruptions (1995-1996, 2007), Ruapehu 2022 and Taupō 2022-23 unrest phases, and Whakaari 2019. Participants used the Whakaari eruption as a most recent reference point for understanding VALs. However, participants also acknowledged the differences in context between Whakaari and Ruapehu volcanoes (e.g. location and access).

***Information needs at different stages of volcanic activity***

As part of the card sorting activity, we analysed both the public and agencies' information needs at different stages of activity. Figure 6 below shows one way of organising this data, where information identified as 'critical' was combined for the focus groups of National Park, Taupō and Rotorua (i.e. those closer to Ruapehu) across all four stages. It is evident from the data that some information is critical across all stages, such as what the volcano is doing now, what people need to do now, and where to get more information. As activity escalates into unrest; forecasts, precursors and areas at risk become more important. During eruption, information about impacts additionally becomes key, through into the post-eruption phase. Context is important to consider too though, as, for example, some agency participants reiterated that impact information for their sector was also key at Stages 1 and 2 where planning might take place. It is notable that information about volcano science and hazards was less mentioned, although it depended on the agency and context (e.g. those involved in recreational activities on Ruapehu were more likely to request such information to help them with understanding the risks and impacts to people and operations).

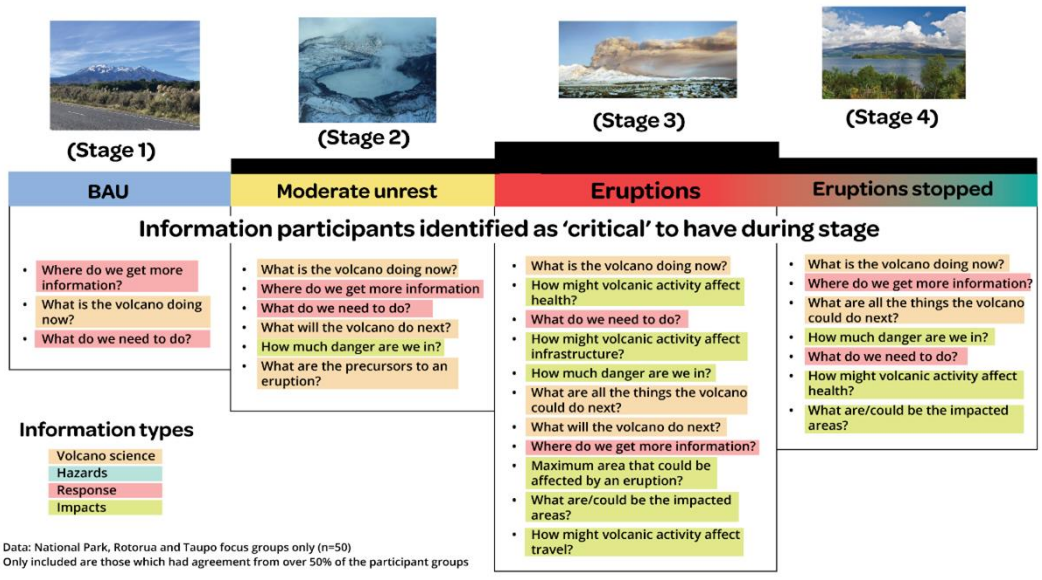



**Figure 6.** Critical information needs across various stages of volcanic activity for a Ruapehu scenario.

***Differences and similarities between public and agencies/organisations***

We identified some differences and similarities in information and communication considerations between the public and agencies (Figure 7). Key differences relate to differing levels of understanding about volcanoes, a limited range of sources used by the public compared with agencies, information overload as more of an issue for public, a request for more detailed impact information for agencies, and the importance of relationship-building between agencies as a communication mechanism. While a diversity of information was required by all participants, similarities between the public and agencies was also evident, particularly in terms of wanting to know information about what's happening with the volcano, a desire for information on forecasts, impacts, and actions to take, as well as knowing how to access more information if needed, and recognition of the role of Māori indigenous knowledge and practices.

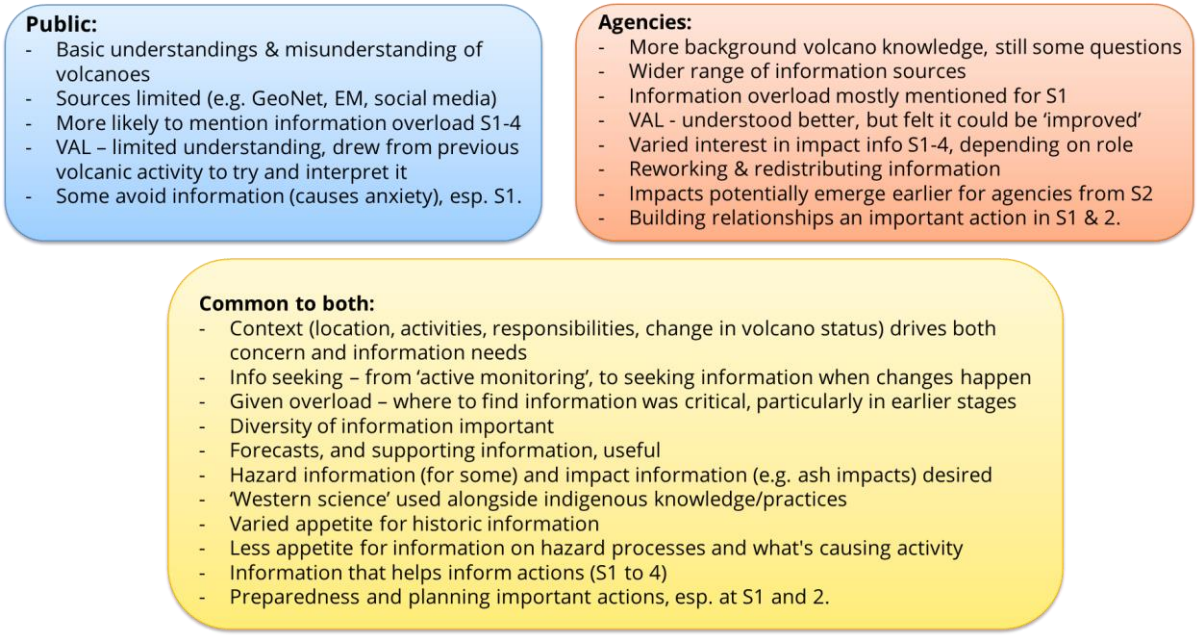



**Figure 7.** Differences and similarities between the public and agencies (S1 = Stage 1, etc). Differences are in the top two boxes and similarities in the bottom box.

# Conclusions

This research aimed to take a strategic overview of volcanic information and communication in NZ, to understand what is currently being provided over different stages of activity, and how it is used for decision-making. Our initial literature and data review found that there is more information being conveyed in both the quiescence and eruption stages, and less in the unrest and post-eruption stages, including for recovery. We could advance our understanding of information and communication for these stages by: 1. documenting examples of existing communication in NZ so that these can be shared (e.g. for the Taupo 2022-23 unrest, etc); 2. drawing from international examples of communication for these stages; and 3. undertaking further research in these areas – particularly for unrest and recovery.

The literature review also found that the nature of information and communication varies across stages of activity, with an increasing appetite for more information from the unrest stage onwards. This was confirmed by our public and agency/organisational focus groups and interview. They also suggested that information importance and needs vary across stages of activity depending on what is required for decision-making, with information required for planning and preparedness purposes earlier on, and a need for information that can inform responses as activity escalates.

In terms of content, both the literature review and data indicate that some information is critical across all stages from quiescent to post-eruption, including what the volcano is doing now (e.g. VALs, changes in activity), what people need to do now (i.e. what actions they should be taking), and where to get more information. Looking specifically to the different stages - during quiescence, information about what a volcano is doing now, actions to take, and where to get more information were considered most critical – as people kept an eye on the volcano from a far and undertook preparedness actions. Other types of information were also accessed by sectors in undertaking planning (e.g. sector-specific impact information). As activity moves from quiescence into unrest, information related to forecasts, precursors and locations at risk become more important, as people think about what they might need to do if an eruption occurs and how to plan for this. During an eruption, alongside the aforementioned information required for unrest, information about impacts and how to address these become elevated in importance, to support responses. Such information is also important moving into the post-eruption and recovery stages, with recognition that there could be long-term on-going impacts. Given that some information is important all the time, but as a situation evolves, information and communication needs also evolve, it is recommended that a strategy and plan for provision of this information is developed so the right types can be provided within the appropriate timeframes. This would be an excellent next step in terms of follow-up from this project.

Geonet was recognised as a trusted source of information in this study and remains a key contributor to the communication of volcano information. However, participants understood the need for provision of information from a diversity of sources and channels (e.g. DOC, CDEM, iwi/hapū, family or friends, Toka Tū Ake EQC, news, social media, Emergency Mobile Alerts, emails, etc), to ensure accessibility and redundancy. They acknowledged issues with multiple sources and channels though. In many cases information is re-interpreted and reworked, whether it be by an agency, or by the public posting in social media, leading to potential misinterpretation. Participants realised the importance of consistent and reliable information, which is a challenge in an evolving environment. As part of a strategy, important components should be considering how to best ensure consistency, especially when translating information and managing misinformation.

An additional issue that arose was that of information overload, particularly for the public, who felt this was an issue across all stages of activity. This should also be considered in any strategy, and planned for, by providing a balance of realistic information about volcanic hazards and risk, alongside actions that can be taken to mitigate that risk (Becker et al., 2015), to provide people with a sense of control that they can do something about volcanic hazards and risks, and reduce their worry. Another idea for addressing overload might include providing basic information (e.g. via GeoNet or on a website), but ensuring that people know how to find further information if needed, such as in the form of layers (Wood et al., 2017).

While this report does not discuss specific information 'products' in depth, we acknowledge that there are a number of information products already available and being used. These range from VALs and VABs, to hazard and risk maps, to scenarios, though to specific guidance on ash impacts. Some products could benefit from better visibility or accessibility (e.g. ash impact information was desired but people did not always know about where to find it), while others could be improved, or even developed from scratch. Both public and agency participants had many suggestions for improvements of existing products, or new information they might use, and these could be explored in future research and development. Scenarios are one such example, which are already well used, but could be enhanced. For example, it could be useful to consider what elements of scenarios could be made consistent across the stages of volcanic activity (e.g. a consistent use of likelihood/probability), what could be adapted across stages and/or type of volcano, and whether scenarios could be more usefully applied in a post-eruption context. Additionally given the importance of impact information, it could be useful to consider how impact forecasts might be added into the information mix. The evaluation, improvement and development of information products provides an opportunity for future research, as it is through such research that these can be tested to be fit-for purpose for decision-making.

A final mention relates to agencies' recognition that relationship building is an important aspect that needs to be undertaken particularly during quiescence and unrest, linking into the communication process. This was also reflected in the literature review via aspects such as exercising and planning during quiescence; and the importance of relationships when responding to an actual eruption. Therefore, it is important to include a relationship building aspect into an information and communication strategy for volcanoes. Attention should also be paid to relationships with Māori, including tangata whenua, such as iwi and hapū. Iwi and hapū are knowledge holders about volcanoes, knowledge generators, recipients and re-workers of information, and responders. In our focus groups we touched on important aspects of information by and for Māori, including for example, how volcanoes might be spoken about, or how iwi and hapū might make use of information such as VALs for response. More focussed discussions with Māori about volcano information and communication, or research using appropriate methods, would be beneficial in helping develop partnerships and working together on volcano communication.

We acknowledge that this project is limited in that it focussed on Aotearoa New Zealand, and specifically used Ruapehu as a case study. Discussions in the focus groups highlighted that results might vary depending on the volcano in question. For example, some information aspects might be considered more or less critical depending on whether you were talking about Taranaki or the caldera volcanoes, as opposed to cone volcanoes like Ruapehu or distributed volcanic fields such as Auckland. Consequently, these findings should be interpreted in the context of Ruapehu, and further research could expand this project to other volcano types. Additionally, comparisons with international examples could enhance our understanding about information and communication requirements for different stages of activity not seen recently in New Zealand. The local literature review, however, does show alignment with the focus group and interview data, lending credibility to the results.

### *Future Work*

In addition to the recommendations above for practically applying the results of this research into strategies, plans, product improvement/development and relationship building, there are many opportunities for future research work. This project revealed a number of gaps worthy of future exploration, which include:-

1. *Document examples of existing information and communication initiatives (e.g. development of new products; use of tools like forecasts), so these can be accessed and used in future, and align with international examples.*

2. *Undertake research to better understand information and communication requirements for understudied volcanic activity stages such as unrest, post-eruption and recovery.*
3. *Investigate how to best transition information and communication across stages, to recognise and account for evolving needs.*
4. *Evaluate and improve existing products (e.g. accessibility, content) and/or develop new products that reflect decision-making needs across different stages of activity for various audiences, and test these. Specific focus might be given to understanding the use of scenarios across different stages of activity, continuing to improve forecasts, exploring how impacts might be best represented and communicated (e.g. through impact forecasts or different types of impact information), and consideration of the best ways of presenting action-focussed advice (e.g. preparedness, response actions, etc).*
5. *Consider how indigenous Māori indigenous knowledge and practices can be better represented in information processes and products.*
6. *Continue to better understand specific sector needs and decision-making at different stages of activity (as our research was general, and did not do a deep dive into needs for each sector at different stages).*
7. *Better understand how information seeking might be facilitated (to reduce information overload), by investigating the best ways for people knowing "Where to find information".*

## Outputs and Dissemination

**Conferences**

*Geosciences Society of NZ Conference*

Das, M., Becker, J., Doyle, E.E.H., Charlton, D., Potter, S., Leonard, G., Johnston, D., Vinnell, L., Clive, M., Stewart, C., Tapuke, K., McBride, S., Krippner, J., Fournier, N., Miller, C., & Gabrielsen, H. (2022). *Understanding communication processes and decision making during different stages of volcanic activity in Aotearoa New Zealand*, Geosciences NZ Conference, 29 November 2022 (Oral presentation)

Becker, J.S., Charlton, D., Doyle, E.E.H., Johnston, D., Stewart, C., & Tapuke, K. et al., (2023). *Volcano Risk Communication in Aotearoa New Zealand*, Geosciences NZ Workshop, 13 November 2023. (Workshop)

*International Association of Volcanology and Earth's Interior (IAVCEI)*

Das, M., Doyle, EEH., Becker, J., Potter, S., Charlton, D., Vinnell, L., Leonard, G. (2023). Using risk comparisons to communicate natural hazard risks: lessons for volcanology. International Association of Volcanology and Earth's Interior General Meeting, Rotorua, 30 January-3 February 2023 (Oral Presentation)

Das, M., Becker, J., Doyle, E.E.H., Charlton, D., Potter, S., Leonard, G., Johnston, D., Vinnell, L., Clive, M., Stewart, C., Tapuke, K., McBride, S., Krippner, J., Fournier, N., Miller, C., & Gabrielsen, H. (2023). *Communication and decision making during different stages of volcanic activity in Aotearoa New Zealand*, International Association of Volcanology and Earth's Interior General Meeting, Rotorua, 30 January-3 February 2023 (Workshop presentation)

Das, M., Becker, J., Doyle, E.E.H, Charlton, D., Potter, S., Leonard, G., Johnston, D., Vinnell, L., Clive, M., Stewart, C., Tapuke K., McBride, S., Krippner, J., Fournier, N., Miller, C., & Gabrielsen, H., (2023). *Understanding risk communication during different stages of volcanic activity in Aotearoa New Zealand*, International Association of Volcanology and Earth's Interior General Meeting, Rotorua, 30 January-3 February 2023 (Poster presentation)

*Natural Hazards Workshop, Boulder, CO*

Becker, J.S., Doyle, E.E.H., Charlton, D., Potter, S.H., Vinnell, L., & Das, M. (2023). Understanding the Utility of Scenarios in Volcano Communication for Aotearoa New Zealand, Natural Hazards Workshop, Boulder, Colorado, 9-12 July 2023. (Poster presentation)

*Cities on Volcanoes 12 Conference, Guatemala*

Becker, J., Charlton, D., Potter, S., Scott, B., Doyle, E.E.H., Das, M., Krippner, J., Stewart, C., Leonard, G., Tapuke, K., Johnston, D., Clive, M., Vinnell, L., Gabrielsen, H., Miller, C., Fournier, N., & McBride, S. (2024). *Understanding volcano communication needs over time: A case study from Aotearoa New Zealand*, Social volcanology: Exploring the role of social science in support of volcano observatories and civil protection, Cities on Volcanoes 12, Antigua, Guatemala, 11-17 February 2024. (Oral presentation)

*Society for Risk Analysis (SRA) Australia-NZ conference*

Becker, J.S., Doyle, E.E.H., Charlton, D., Potter, S.H., Vinnell, L., & Das, M. (2023). *Understanding the Utility of Scenarios in Volcano Communication for Aotearoa New Zealand*, Society for Risk Analysis (SRA) Aus-NZ conference, Christchurch, 1-2 February 2024. (Poster presentation)

**Volcano Advisory Group meeting update presentations**

- *CPVAG, 27/4/2023, 4/7/2023*
- *TS-VAG, 25/5/2023*
- *Caldera Advisory Group (CAG), 6/11/2023.*

**Guidance updates**

Geonet Probability Translation Table (Doyle & Potter, 2015) reviewed and to be updated based on findings from Das et al., (2024, draft) and this wider study.

## Publications and Communications

Das M., Doyle, E. E. H., Potter, S.H, Charlton, D., Becker, J.S., Vinnell, L., Leonard, G. & Johnston, D. (2024, draft). Guidelines for communicating likelihood and probability of natural hazards. GNS Science Report.

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# Appendix 1: Research methods

## A1.1 Literature review method

To identify relevant articles related to the communication of volcano information, literature searches were conducted on Scopus and Web of Science databases using a combination of keywords related to volcano (volcano, caldera, lava, ashfall, tephra, pyroclastic, lahar), communication (communication, warning, messages, forecast, model, scenario, decision, alerts, information) and New Zealand (New Zealand, Ruapehu, Tongariro, Te Maari, Ngāuruhoe, Taupō, Whakaari/White Island, Rotorua, Tarawera, Ōkataina, Taranaki, Auckland, Northland, Raoul Island, Tuhua/Mayor Island, Maroa, Macauley Island, Brimstone Island and the Rumble). The search was limited to English language articles. No other limits were applied. The process used to identify the relevant articles is described by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart (Figure 8).

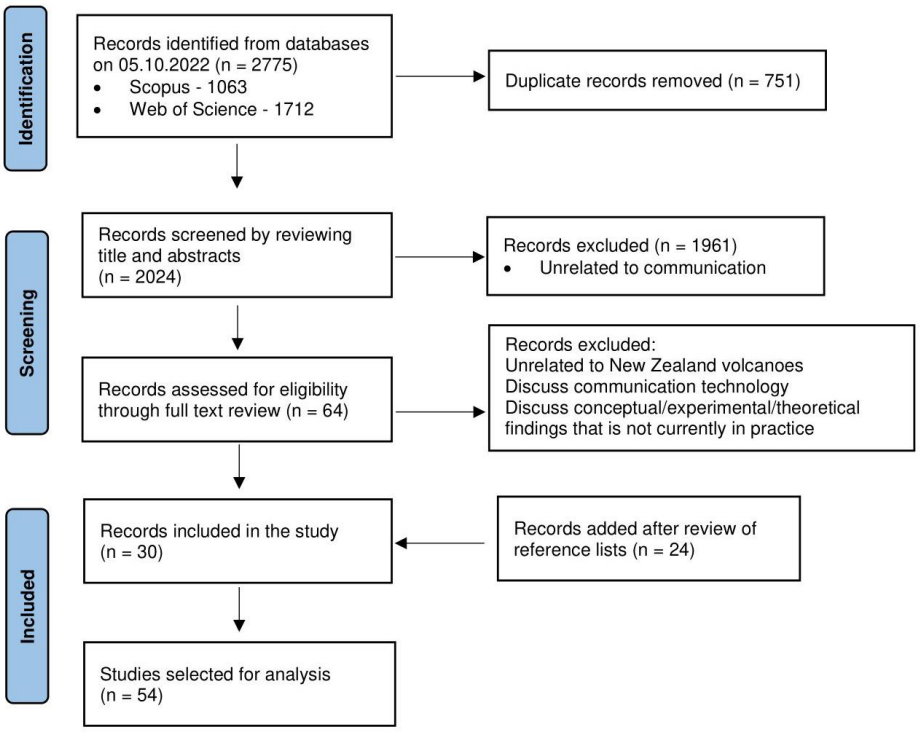



**Figure 8.** PRISMA for the literature review

A narrative review was undertaken where full text of the selected articles were read and information relevant to the research focus was analysed (Ferrari, 2015). During the review, we identified that academic literature found in formal databases missed many essential documents. Hence, we also draw on grey literature (e.g. news stories, Volcanic Activity Bulletins (VABs), science reports, grey literature, meeting documents) to fill the gaps in the narrative and identify directions for future research. This, however, does not imply an exhaustive review of grey literature, and is something that could provide added value in future.

We did not use coding or a specific structure for analysing the literature review data; it was exploratory, and results are based on what was identified as per the research focus. Therefore, the findings naturally report on a wide range of aspects related to information and communication. Results tend to naturally focus on two predominant aspects: (1) different types of information related to volcanoes (e.g. products, tools, plans, scenarios, etc.); and (2) communication processes (e.g. which stakeholders are involved, how messages are exchanged, etc.). We organised the data obtained from the review into different stages of volcanic activity from quiescence through to post-eruption.

### A1.2 Method for collecting data from focus groups and interview

Example shown from National Park focus group PowerPoint, held on 4 July 2023.

# Volcanic risk communication Central Plateau Advisory Group workshop

## Long-term communication of volcanic risk for effective decision-making

**EQC Biennial Research Programme: 2022 -2024**

Contact: **Julia Becker,** Massey University: j.becker@massey.ac.nz

Team: Manomita Das, Emma H. Doyle, **Danielle Charlton, Sally Potter, Graham Leonard, David Johnston**, Lauren Vinnell, Mary Anne Clive, **Carol Stewart, Kelvin Tapuke,** Sara McBride, Janine Krippner, Nico Fournier, Craig Miller and Hollei Gabrielsen, **Brad Scott**.

## Plan for this afternoon

- We want to understand how to **best communicate information about volcanoes** , using an example from Tongariro National Park (Ruapehu volcano).
- We are interested in understanding the **information communities/organisations need to know about volcanoes during different phases of activity** . We will carry out a few exercises with you all. No longer than 2 hours.
- Different project, but we are using outcomes from last workshop ( June 2021)
- Feedback will be used to help inform current research.
- This is not a formal GeoNet or government survey.

# Housekeeping and ethics

**Housekeeping:**

Toilets, fire, emergency exits and covid19

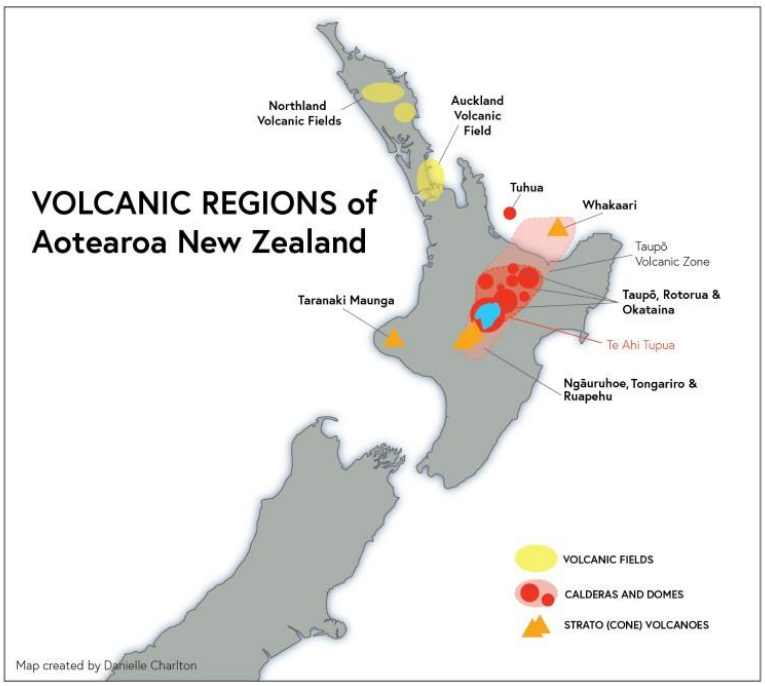
**Ethics:**

- Let us know if you have any comments or questions on the consent form.
- We are using recording equipment to capture discussion, but we will not link any comments to individuals.
- We may also take some photos to document the results.
- Please let us know if you would like us to stop the recording for any reason or not take any photos.
- Please be mindful of everyone's views and experiences. Some topics may be sensitive for some.
- Do not share what your fellow attendees tell us outside the group.

1. Volcanoes

## Icebreaker exercise:

# What are your experiences with volcanoes or volcanic activity?




# Ruapehu maunga

- Ruapehu is the highest mountain in the North Island and the **largest active stratovolcano** in New Zealand.
- It is located at the southern end of the Taupo Volcanic Zone.
- The active vent is filled by Crater Lake; water from this lake is frequently ejected onto the ice and snow during eruptions causing lahars.
- Ruapehu is a **stratovolcano** (composite cone volcano) made of successive layers of lava and ash deposits.
- The mountain is surrounded by a ring plain of volcanic material from lahars, landslides and ash falls.
- Eruption frequency: 10s – 100s years
- Last eruption: On 25 September 2007 there was an explosive eruption.

# Ruapehu scenario exercise

**What is a scenario?**

- Scenarios help us understandbehavior and needs during an event without having to be in one!
- Really useful for volcano eruption planning because eruptions are infrequent.

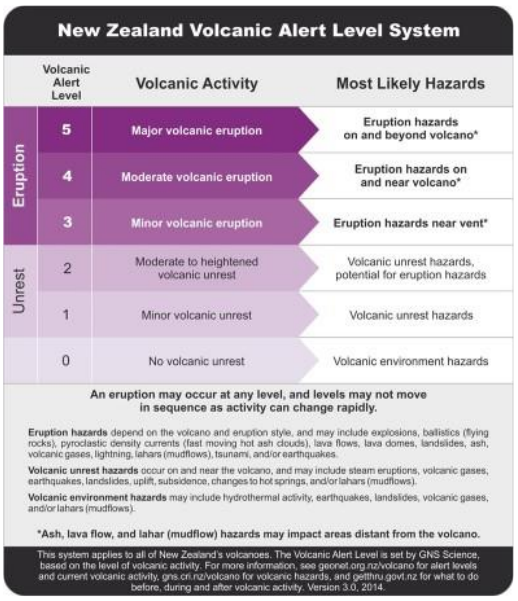
**What will happen?**

- A series of 'injects' will be delivered covering different stages
  - 1. Quiet time
  - 2. Unrest- volcano active but not erupting
  - 3. Eruption
  - 4. Post eruption
- For each 'inject' your group needs to discuss: your level of concern and what information you may need.

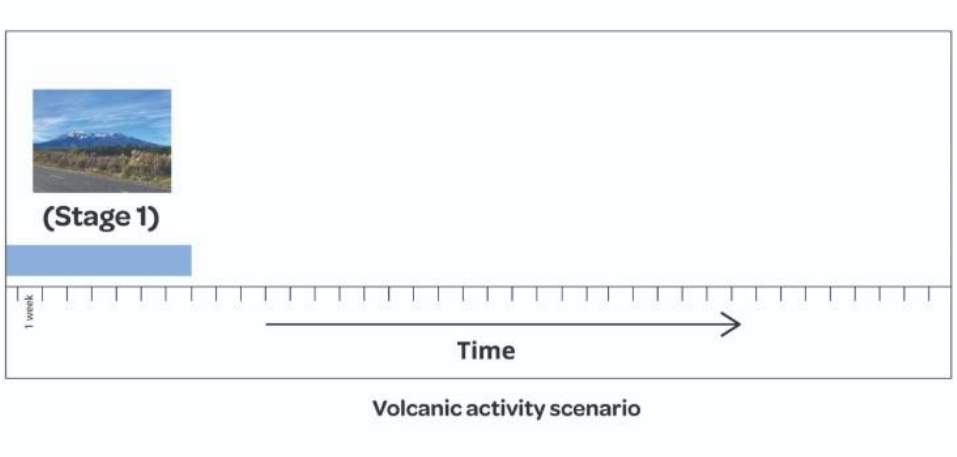
**Extra advice:**

- The volcano scenario is hypothetical, but could happen
- Just one of many scenarios
- Think about your current location and situation.
- Think about your needs and concerns

A reminder of the VAL system




## Stage 1: Quiet time/VAL1




Volcanic activity scenario

2. Scenario

# Stage 1: Quiet time/VAL1


***Monitoring information:***

- *No notable activity*
- *Lake temperature stable*
- ***Volcanic Alert Level 1 and Aviation colour code is green***

***Communications:***

- *Periodic Volcanic activity bulletin releases from GeoNet*
- *Basic news releases and social media posts*

***Timing:*** *around late october*

2. Scenario

# Stage 1: Quiet time/VAL1

**1) How concerned are you about volcanic activity from Ruapehu affecting you and your BAU activities?**

| Not at all concerned | Slightly concerned | Somewhat concerned | Moderately Concerned | Extremely concerned |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Scenario

# Stage 1: Quiet time/VAL1

**2) How important is information about volcanic activity to you and your organisation at this stage?**

| Not at all important | Slightly Important | Somewhat important | Moderately Important | Extremely Important |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Scenario

# Stage 1: Quiet time/VAL1

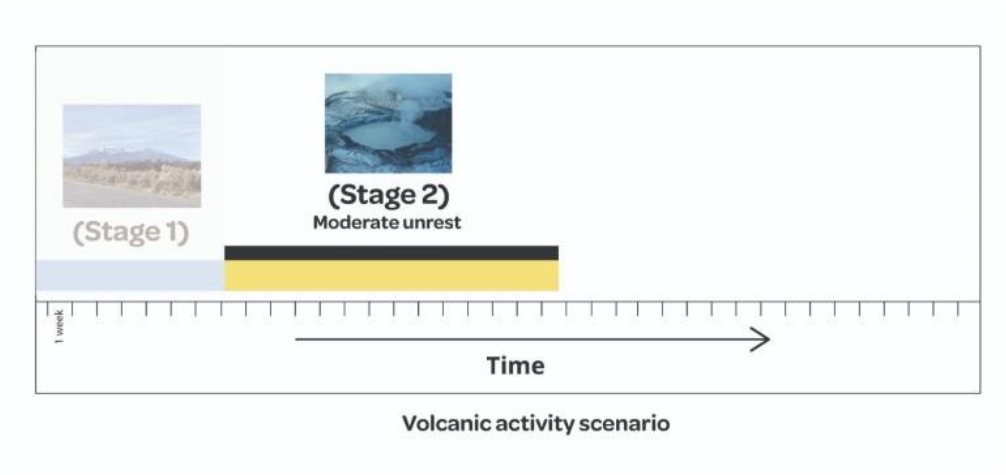

**3) What type of information is important to you/your organisation at this stage?**

**Group the topics in terms of importance**

Critical - nice to have - not needed

**Think about why**

# Stage 2: Moderate unrest/VAL2






# Stage 2: Moderate unrest/VAL2


***Monitoring information:***

- ***Moderate to strong volcanic tremor***
- ***Lake temp increases slightly***
- ***VAL increases to VAL 2- ACC to yellow***
- ***https://www.youtube.com/watch?v=d9KV-mnS2oE***

***Communications:***

- *More frequent Volcanic Activity Bulletin releases from GeoNet*
- *Media interviews*
- *News updates and social media posts*

***Timing:*** *early November through December.*

2. Scenario

# Stage 2: Moderate unrest/VAL2

**1) How concerned are you about volcanic activity from Ruapehu affecting you and your BAU activities?**


2. Scenario

# Stage 2: Moderate unrest/VAL2

**2) How important is information about volcanic activity to you and your organisation at this stage?**

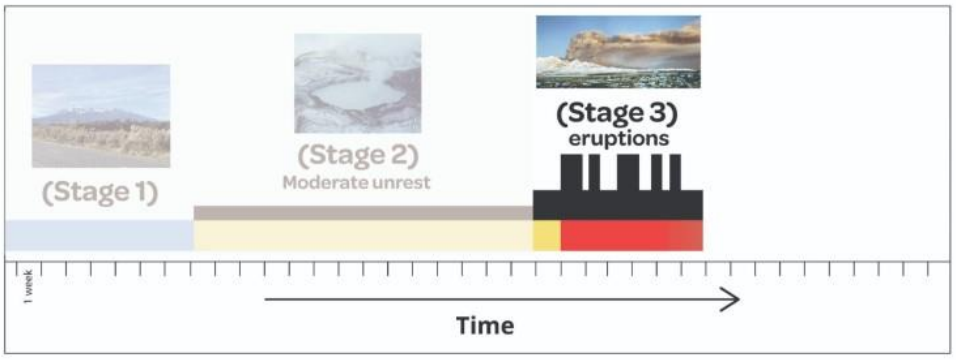
# Stage 2: Moderate unrest/VAL2


**3) What type of information is important to you/your organisation at this stage?**

**Group the topics in terms of importance**

**Think about why**

# Stage 3: small-moderate eruptions




Volcanic activity scenario

2. Scenario

# Stage 3: small-moderate eruptions


***Monitoring information:***

- ***An initial explosive eruption (06:30 am friday) with lahars***
- ***Eruption impacting the summit and flanks, with lahars in catchments***
- ***The same size or smaller eruptions continue on and off for 6 weeks***
- ***VAL raised to 3/4 and back to 2. ACC to red***

***Communications:***

- *More frequent Volcanic Activity Bulletin releases from GeoNet*
- *Media interviews*
- *Ash forecast maps issued*

***Timing:*** *late December - early February*

2. Video


Gallery: News coverage of Ruapehu eruption in 1996

https://www.youtube.com/watch?v=qDu35ObfFUM start at 3:00 mins in for 1 min or so

2. Scenario

# Stage 3: small-moderate eruptions

**1) How concerned are you about volcanic activity from Ruapehu affecting you and your BAU activities?**


2. Scenario

# Stage 3: small-moderate eruptions

**2) How important is information about volcanic activity to you and your organisation at this stage?**

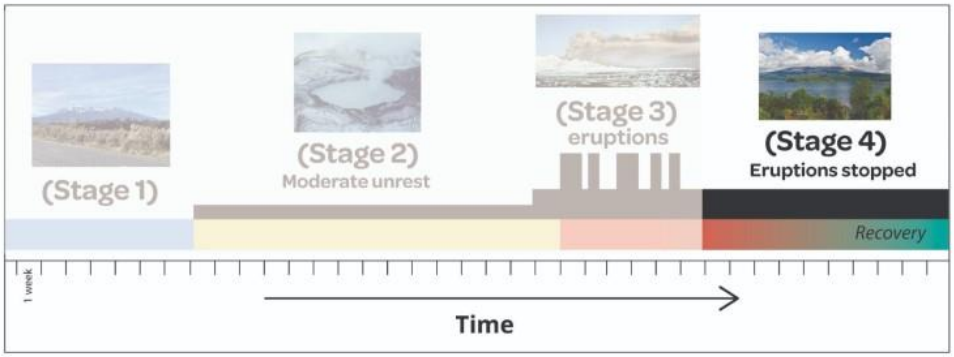
# Stage 3: small-moderate eruptions


**3) What type of information is important to you/your organisation at this stage?**

**Group the topics in terms of importance**

**Think about why**

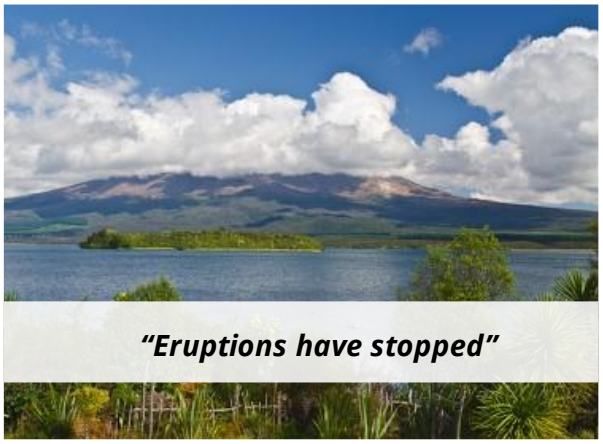
# Stage 4: Eruptions have stopped




Volcanic activity scenario

2. Scenario

# Stage 4: Eruptions have stopped




***Monitoring information:***

- *After a week of no eruptions, eruptions have ceased. Ash stopped.*
- ***Earthquakes are still occuring, but reducing in number***
- ***VAL decreases to VAL 2- ACC at yellow***

***Communications:***

- *Periodic Volcanic Activity Bulletin releases from GeoNet*
- *News updates and social media posts*

2. Scenario

# Stage 4: Eruptions have stopped

**1) How concerned are you about volcanic activity from Ruapehu affecting you and your BAU activities?**

| Not at all concerned | Slightly concerned | Somewhat concerned | Moderately Concerned | Extremely concerned |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Scenario

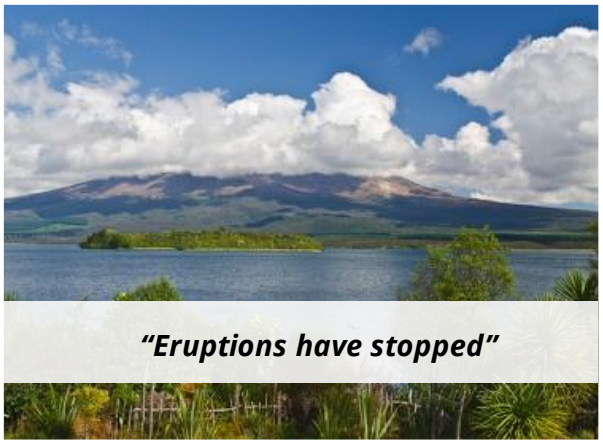
# Stage 4: Eruptions have stopped

**2) How important is information about volcanic activity to you and your organisation at this stage?**

| Not at all important | Slightly Important | Somewhat important | Moderately Important | Extremely Important |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Scenario

Stage 4: Eruptions have stopped




**3) What type of information is important to you/your organisation at this stage?**

**Group the topics in terms of importance**

**Think about why.....**

## Key messages about volcanic activity and communication

- **GeoNet** collects and monitors 24/7 data and responds to geohazards in New Zealand.
- Their website and app provides access to hazards information, including earthquake reports and Volcanic Activity Bulletins.
- Your **Local Civil Defence Emergency Management Group** will provide more information about volcanic risk and what you need to do in the event of volcanic activity.

Follow official advice provided by your **local Civil Defence Emergency Management Group**, the **Department of Conservation** (for visitors to the Tongariro and Taranaki National Parks), **local authorities** and **emergency services** both during and following volcanic activity.

**THANK YOU**