Improving Flood Warning Systems

IN LOWER HUTT

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Abstract

This project provided the Greater Wellington Regional Council with community-input based recommendations for improving their current flood warning system on the Waiwhetu stream to promote a more people-based warning system. We achieved this by researching their current warning system, developing preparedness materials, and investigating the community's perceptions of preparedness, awareness, and the current system. We recommended implementing tiered, redundant early warning media including Emergency Mobile Alerts and voice sirens, a flood preparedness campaign, and an all-stakeholder "one-stop shop" website.

Executive Summary

Introduction

Natural disasters have killed nearly three million people in the last 20 years, and the United Nations predicts disasters will become more lethal (United Nations International Strategy for Disaster Reduction [UN/ISDR], 2015). Warning systems decrease risk from these disasters by allowing robust community action before disasters occur. These systems tie together strategies for early detection, communication, and public preparedness as community preference and the expected severity of disasters require. In the Lower Hutt region of New Zealand, the implementation of these strategies for flooding do not meet the standards necessitated by the severity of flooding in the region or the preferences of the community, requiring the Greater Wellington Regional Council (GWRC) to revamp their systems in an effort called the 'Flood Warning Improvement Project.' Our role within this project is to collect feedback from the community on communication preferences and public preparedness as a pilot program for the wider project.

Background

In the last 20 years, 4.4 billion people have been affected by disasters at the cost of US$4.8 trillion, mainly affecting lower-income communities without resources to protect themselves. Given threats such as increased rainfall and rising sea level posed by climate change, disasters are expected to be more severe in the future. Due to this growing risk, protective measures, such as warning systems, must be implemented with an evolving understanding of the causes of floods, their effects on communities, and how to combat risks posed.

Warning systems mitigate damages like these via three primary avenues: early detection, public notification, and public awareness and preparedness. Early detection involves detecting disasters before they occur, allowing citizens to prepare for and respond in advance of disasters. While it is important to send warnings well in advance of a disaster, care must be taken to ensure accuracy to prevent the public from responding in inadvisable ways to events which ultimately do not occur. Public notification is the process of alerting the community at risk of a disaster before it occurs, without which early detection is useless to the public. Public awareness and preparedness require knowledge of risks and readiness for disasters within the community, allowing effective responses after detection and notification. All these components must be implemented effectively in order for any one of them to be effective in reducing damages from disasters.

Flooding is New Zealand's most costly natural disaster, in part due to the 18,000 kilometers of coastline and 350 estuaries, harbors, inlets, bays, and beaches on the islands. In the Hutt Valley, a flood along the Hutt River in 1976 caused over NZ$205 million in damages, and GWRC estimates that such a flood occurring today could incur damages in excess of NZ$1 billion. On the Waiwhetu stream in the Hutt Valley, which is prone to flooding due to its small size, surrounding land use, and its estuarial nature, another flood in 2004 caused nearly NZ$200 million in damages, making it an area of focus for GWRC.

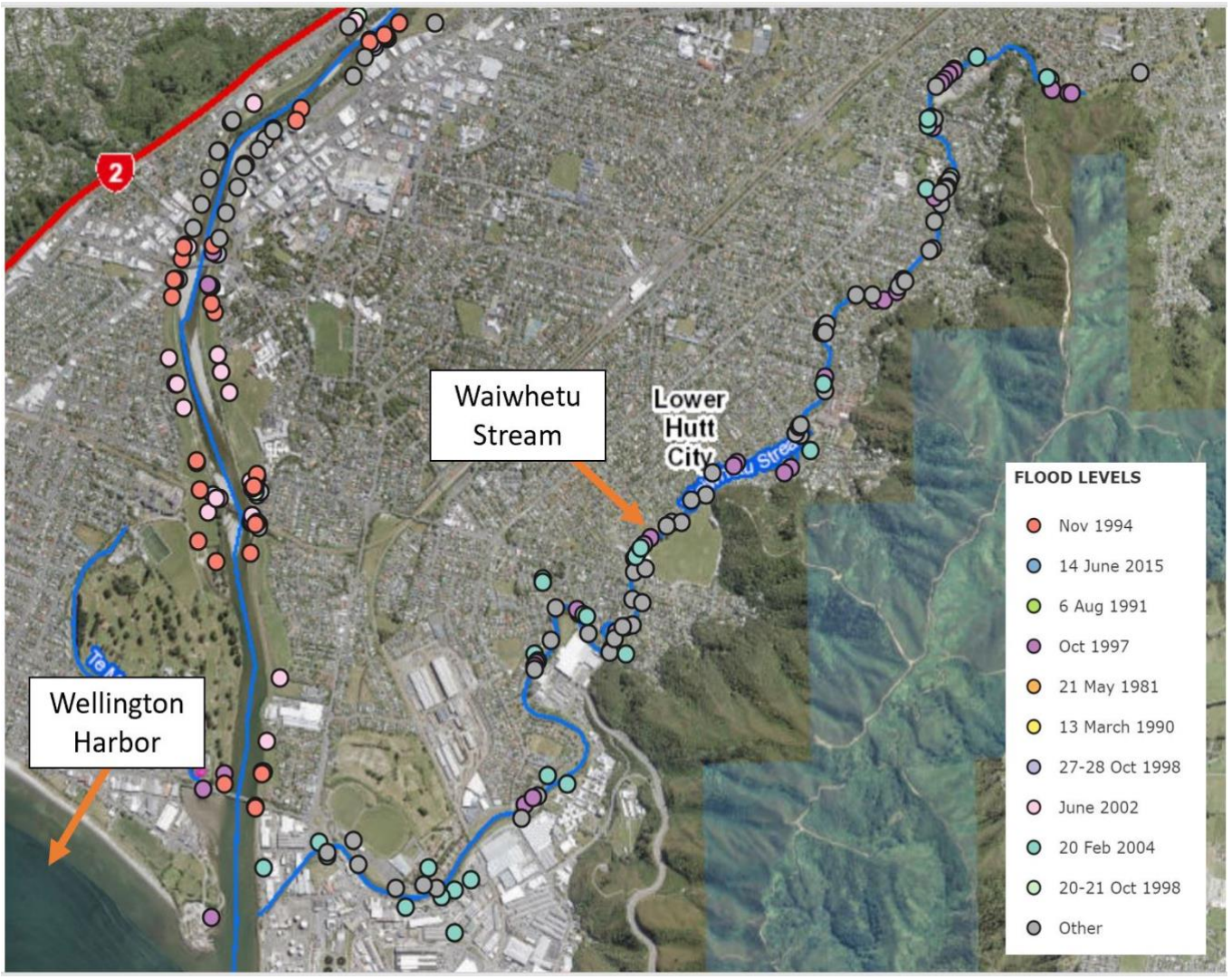

Figure I: Map displaying geographically significant features of the Waiwhetu stream. From Greater Wellington Regional Council.

Methods of communication used in Lower Hutt, such as texts, websites, door knocks, and social media, can reach much of the population, but not all, and studies on public preparedness for floods in the area indicate a lack of preparedness that could render warnings ineffective. Currently, organizations involved in providing warnings largely work separately and collaborate in cumbersome ways, with layers of officials sequentially interpreting the available data before issuing a warning. This creates a potential for delay and difficulties in communication. These organizations are exploring methods to decrease flood risk exposure in the region by revamping their warnings with defined plans, streamlining inter-agency collaboration, mitigating damages with infrastructure, and developing the "one-stop shop" information portal proposed by GNS Science for the community and all organizations. The Waiwhetu stream will serve as the location for the pilot of this project due to its flood history and active community. Our purpose within this pilot will be to gauge community notification preferences and their level of flood preparedness and awareness.

Methods

To create recommendations to GWRC for this pilot, we researched how organizations can best provide warnings to communities and the extent of and how to increase public preparedness and awareness. To understand the roles of government organizations within flood warning systems and the characteristics of the stream, we conducted open-ended meetings with experts from GWRC, Wellington Region Emergency Management Office (WREMO), Wellington Water, MetService, GNS Science, and Friends of Waiwhetu (FW). In meeting with these organizations, we aimed to understand the limitations of warning systems in the area, the roles of each organization within flood warning systems, and to refine our recommendations.

To understand communication preferences and levels of community preparedness and awareness, we conducted interviews and surveys (found in Appendix A) in-person and online. We issued surveys on platforms such as Facebook, Reddit, and Neighbourly in an effort to drive wide response and conducted in-person surveys to target local communities and control for access to technology. Interviews done in-person served as opportunities to broaden questions and themes from the survey and contextualize survey responses. To address public preparedness, an informational pamphlet covering various ways to be prepared for a flood, a strategy WREMO currently uses for earthquakes, was drafted and shown to community members in interviews to ensure it was properly informative. A draft of the public interface of a one-stop shop was also created based on survey results of what the community wanted. We asked community members how they felt about these in our surveys and interviews.

Interviews were subject to content analysis with the use of a codebook devised deductively to capture ideas deemed useful in contextualizing survey data. Data from surveys were directly tabulated and cross-tabulated, often against demographic groups to investigate differences across groups.

Findings

We based our findings on 220 community surveys, nearly 27% in-person, and 18 interviews, the full demographic details of which can be found in Appendix E. Our findings include a preference for expedited warnings via Emergency Mobile Alerts and voice sirens, methods of structuring educational materials for flood preparedness such as pamphlets and websites, and a lack of awareness of flood risks.

Through meetings with stakeholder agencies, we affirmed they could more effectively work together to predict floods and notify the public using a "one-stop shop" website. Through surveys, we found various perspectives on communication methods, such as a preference with 83% of respondents for Emergency Mobile Alerts (EMAs) among other options, though this varied by age and location. Along with EMAs, voice sirens, phone calls, and door knocks were also found to be preferable at night.

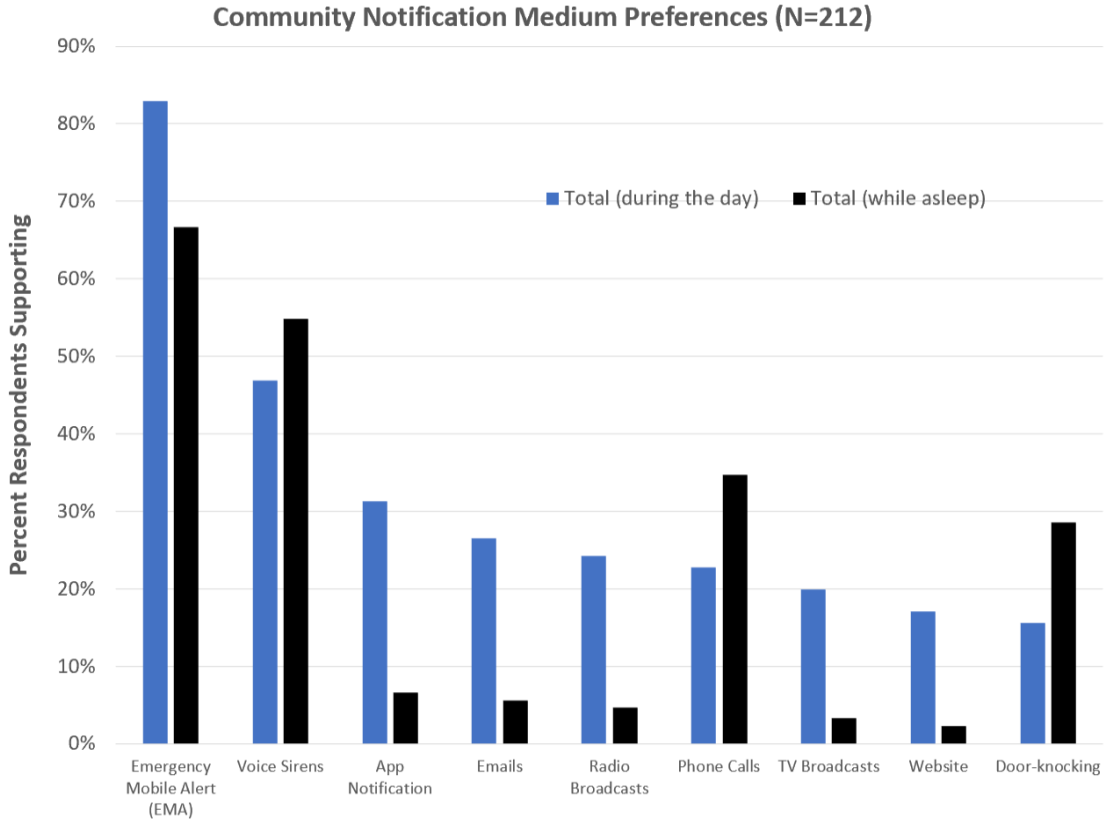

Figure II: Community notification preference

These data points showed the discrepancy between online and in-person surveys, with 87% of online and 66% of in-person respondents preferring Emergency Mobile Alerts. Other notification preference differences by survey method can be found in Appendix C, with few other distinct differences outside of notification preference. We also found a preference for lead time above certainty in warnings being issued, with over half of those surveyed indicating they would like to be notified of a "severe flood" occurring within 10 hours even if it was 10% certain to occur, the lowest certainty included on the survey. The surveys additionally showed that over a third of respondents were minimally or not concerned about sea level rise and a quarter felt significantly at risk of flooding, indicating alongside interviews that there is not uniform awareness in the community to the various forms of flood risk such as current and imminent floods.

In surveys, we found that only 13% of respondents felt fully prepared for flooding, and only 2 of the 18 interviewees indicated they were prepared. We also found that 42.9% of respondents, a plurality, were only willing to spend five to ten minutes preparing for a flood. To assist in remedying this lack of preparedness, we designed a pamphlet (Appendix F) and website (Appendix C) based on expert advice and community input on what would constitute useful information. The pamphlet and website provided information on what to do before, during, and after a flood as well as emergency contacts, a household emergency plan template, and other pertinent information regarding specific tasks to do during a severe flood. The website also would have information regarding other natural hazards along with current alerts and notifications.

Recommendations

We recommend the implementation of a tiered, redundant warning system, particularly stressing the use of Emergency Mobile Alerts, voice sirens if resources permit, and door-knocking and phone calls for reaching communities at night. We also recommend the implementation of GNS Science's proposed one-stop shop website with flood education materials, alerts, real-time graphics, and organization contacts for the public in addition to providing an inter-agency platform for the sharing and analysis of data and warning collaboration. We further recommend the distribution of an informational pamphlet by mail, the aforementioned one-stop shop website, and social media to promote preparedness within the community around the Waiwhetu.

Figure III: Public Preparedness Pamphlet.

Conclusion

Our project was part of a greater five-year Floodplain Management Plan managed by GWRC. Even though the results and recommendations are specific to the Waiwhetu stream, the methods that we used can be implemented for other waterways as well. Climate change will continue to increase the frequency and intensity of natural disasters, but with the development of more robust warning systems, we can reduce the risk associated with these disasters.

Authorship

In the making of this proposal, all members carried out writing, editing, researching, surveying, and interviewing.

Lindsey Stevens contributed skills of graphic design, ideas for social outreach, and drafted survey questions. She wrote and researched topics dealing with natural disasters, their risks, climate change, the causes of flooding, public preparedness, as well as other relevant topics. She completed the pamphlet and the mock one-stop shop website.

Brandon Weyant contributed organizational and planning skills, facilitated communication with GWRC and other organizations. He researched and wrote about the organization of flood warning systems and their implementation, and drafted interview questions. He also conducted research on and wrote about the current situation along Waiwhetu and wrote the conclusion.

Chester Barber contributed skills of rhetorical and visual planning, creation, and editing for all materials. He researched and wrote about the effectiveness and viability of warning systems and how to implement similar systems among other topics.

Joseph Esposito contributed skills of editing and writing. He worked as the main editor for the report and wrote about the history of Hutt Valley and the Waiwhetu stream. He also worked to edit, draft, and finalize public survey and performed the analysis of the survey data. He contributed ideas for public preparedness and researched content on various disaster preparedness websites.

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Introduction

1 - Introduction

In the last 20 years, nearly three million people were killed globally from natural disasters such as storms, floods, earthquakes, and landslides (Ritchie & Roser, 2018). Disaster risk is referred to as a disaster's likelihood of causing death, injury and destruction (UN/ISDR, 2015). Climate change is currently compounding disaster risk by increasing the potency of disasters and the vulnerability of communities (UN/ISDR, 2015). As disaster risk continues to increase globally, measures to protect communities must be implemented and continually updated to mitigate threats (Bradford et al., 2012).

Warning systems are known to be effective at decreasing disaster risk (Rogers & Tsirkunov, 2010). A warning system is a system designed to detect threats in advance and provide the community with an early warning to react to and mitigate damage from threats (UN/ISDR, 2015). One obstacle to implementing a warning system in a community is determining how best to do so for the given region, as the system's structure must reflect the expected severity of disasters as well as community preferences and resources (United Nations [UN], 2006).

As a result of varying circumstances, different regions handle warning systems in different ways. Around Nepal's Karnali River, alongside community flood preparedness programs, some residents are trained to read gauges along the river, compare the data to forecasts, and communicate the risk of floods to individuals downstream (Smith, Brown & Dugar, 2017). Some communities in Nepal notify members of floods via house-to-house visits or drums to reach those with no other means of communication, an example of how proper utilization of local resources can contribute to a more effective system (Gautam & Dulal 2013). On Japan's Disaster Prevention Day, millions of people in Japan practice what they would do during the event of a natural disaster (Birmingham, 2011). An effective warning system ties together strategies of early detection, public notification, and public preparedness (UN, 2016).

In New Zealand, flooding is the most common and destructive form of natural disaster (McSaveny, 2006). Disaster risk mitigation in New Zealand tends to focus heavily on earthquakes and tsunamis. This trend holds for the Wellington region of New Zealand: in discussions with our sponsoring organization, Greater Wellington Regional Council (GWRC), their experts informed us that, warning systems for flooding in this area lack essential features, including accurate early detection, far-reaching notification, and public preparedness for floods. To mend issues with communication, public preparedness, and awareness, it is vital to establish communication between the local government and communities affected in New Zealand, such as those of the city of Lower Hutt.

The Waiwhetu stream in Lower Hutt has been selected to be the site of a pilot flood warning system by GWRC, a local government community services organization, as part of their Flood Warning Improvement Project due to the flood history of the stream and the active community surrounding it. This project plans to unify several organizations in the Lower Hutt region working in flood and natural disaster protection.

Our role within this project was to collect data from the community in order to create a set of feasible and sound recommendations regarding communication media, and tolerances of the community to frequent notifications as well

as improving community awareness and preparedness on the topic of flooding. We accomplished this by meeting with local agencies, councils, and organizations, surveying and interviewing communities, analyzing the data gathered, and drawing conclusions on how to best structure the warning system based on the information gained from analysis.

Meeting with US Ambassador Scott Brown

Background

2 - Background

It is important to know what causes floods and how floods affect communities in order to combat their risks and damages. The effects of floods are discussed in Section 2.1. To understand strategies to mitigate these risks and damages, warning systems are discussed in Section 2.2. It is also important to investigate the communities themselves with regards to their geography, history, awareness, and preparedness for natural disasters, as is discussed in Section 2.3.

2.1 Disasters and Risk

In the last 20 years, nearly three million people lost their lives to natural disasters; 4.4 billion were injured, rendered homeless, displaced, or in need of emergency assistance; and incurred US$4.8 trillion in damages Ritchie & Roser, 2018; Wallemacq et al., 2018). Studies show that as atmospheric temperatures rise, natural disasters become more frequent and severe: one report found that the number of weather-related natural disasters has increased 46% since the year 2000, currently averaging at 306 severe natural disasters occurring every year (Van Aalst, 2016 & Science and Technology Research News [STRN], 2017). A majority of these disaster-related deaths were in lower and lower-middle income communities, illustrating the global pattern of more deaths in natural disasters in areas with fewer resources (Wallemacq et al., 2018). As these risks grow and communities, particularly the already vulnerable, are further endangered, better ways of mitigating disaster risk are needed.

2.2 Disaster Risk Mitigation

Warning Systems

Warning systems are systems designed to ensure that the public is alerted of a disaster before it occurs in order to mitigate damages and impacts of the natural disaster. There are several components of warning systems which our group has adapted from various systems in place around the world and consolidated into three key areas: early detection of natural disasters, notification of the public, and public awareness of risks and preparedness for action (UN, 2006; World Meteorological Organization [WMO], 2013; University Corporation for Atmospheric Research [UCAR], 2010). An effective warning system is dependent on each of these components working together, and these components of a warning system are in turn dependent on public preference, the severity of risks, and resources available to the community at risk.

Early detection involves detecting potential natural disasters before they occur through forecasting systems and data monitoring technology. More lead time on a warning allows individuals the time to respond to a greater extent, moving more and larger pieces of property (Carsell, Pingel, & Ford, 2004). The quality of this detection and subsequent predictions is also important: uncertainties in predictions could lead to false warnings and inadvisable actions, incurring costs and community distrust which more accurate predictions could avoid (Grasso, Beck & Manfredi, 2007). On top of these considerations, for full utilization of early detection, it is important that there are effective forms of notification for the public.

Public notification is the process of alerting the public of a natural disaster before it occurs. Those issuing warnings can do so through a variety of methods depending on communities' resources and preferences. A study in Scotland found homeowners who had received flood warnings took measures to mitigate damages at a rate of about 87%, compared to less than 63% for those who had not received warnings (Werrity, Houston, Ball, Tavendale & Black, 2007). In the United States, cell phone notifications and emails are generally used to alert residents of a disaster in or near their community (National Oceanic and Atmospheric Association, n.d.). In Hawaii, however, sirens are utilized to alert the community of disasters (County of Maui, n.d.). This displays how notification may differ, though effective notification requires ensuring that community members understand the warning and take the correct course of action once the warning is disseminated (UCAR, 2010).

Public preparedness for a flooding event requires both community knowledge of risks and readiness in the community for a natural disaster. Like other elements of warning systems, public preparedness varies based on specifics of an area such as susceptibility to disaster. Research shows that, in the United Kingdom, for instance, the public often does not have the necessary understanding of flood protocols and risk to react properly to a flood, as the public is not concerned with flooding (Parker et al., 2009). An example of an action to increase public preparedness is Japan's Disaster Prevention Day: on this day, millions of people in Japan practice what they would do during the event of a natural disaster (Birmingham, 2011). Along the Karnali river in Nepal, the community members locate safe places and evacuation paths before a flood occurs (Smith et al., 2017). Education is a key element of public preparedness: proactively informing residents before flooding events helps ensure proper actions are taken (Parker et al., 2009). The United States has instituted the Ready Campaign to educate families on how to respond to disasters (Ready, 2003).

There is no perfect warning system, as each area has varying resources, public preferences, and severity of natural disasters. Therefore, the challenge of creating a warning system lies in assessing the location and implementing the ideal warning system for that area. In order to have an effective warning system, the three main aspects, early detection, public notification, and public preparedness, must be put in place with the specifics of the area in mind (UN, 2016).

2.3 Flooding in New Zealand

Flooding is New Zealand's most costly and frequently occurring natural disaster (Bell, Hume, Hicks, 2001). The Insurance Council of New Zealand reports costs related to flooding of NZ$442.3 million between 1996 and June 2014 (Cattoën, McMillan & Moore, 2016). New Zealand has about 18,000 kilometers of coastline with over 300 estuaries (National Institute of Water and Atmospheric Research [NIWA], 2001). Estuaries are the juncture between the ocean and freshwater and are thus vulnerable to increased flooding due to rising sea levels (Bell et al., 2001).

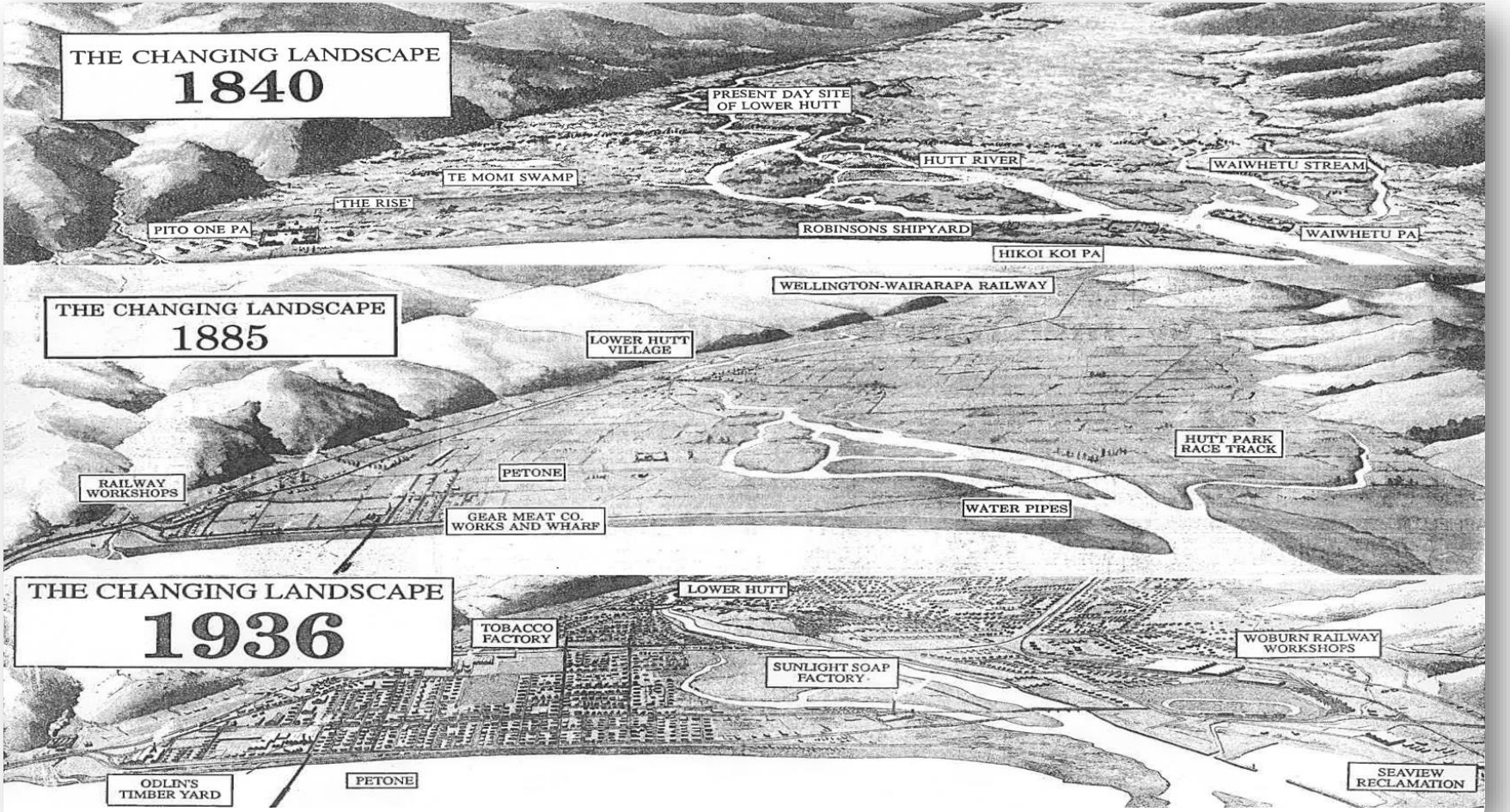

Figure 1: Land development in Lower Hutt between 1840 and 1936. Used with permission of the Dominion Post and the artist Bob Kerr.

Flooding in the Hutt Valley

The Hutt Valley is an area within the Wellington region of New Zealand and contains the estuarial Hutt River. The river and region have a history of alteration: by the 1880s, forests around the river had been removed by colonists, which changed the river's course (GWRC, 2014). In 1898, the entire valley floor was flooded, which led to some of the first stopbanks being used to help alter the Hutt River (GWRC, 2014). Land development between the 19th and 20th century can be seen in Figure 1 above. Documentation of flooding in the region has dates back to the early 20th century, with a flood on April 27th of 1920 covering "lower-lying parts of Lower Hutt… with water," and extensive flooding through 1920-1950 from "torrential rain" which outpaced drainage (Cowie, 1957). In 1976, on December 20th, torrential rain caused an infamous flood, with water levels not seen in 50 years, causing NZ$205 million in damages, destroying homes, and straining emergency crews (GWRC, 2014).

Picture of Lower Hutt

Due to these flooding incidents, physical structures such as stopbanks were implemented in order to further mitigate flooding from the Hutt River (Cowie, 1957).

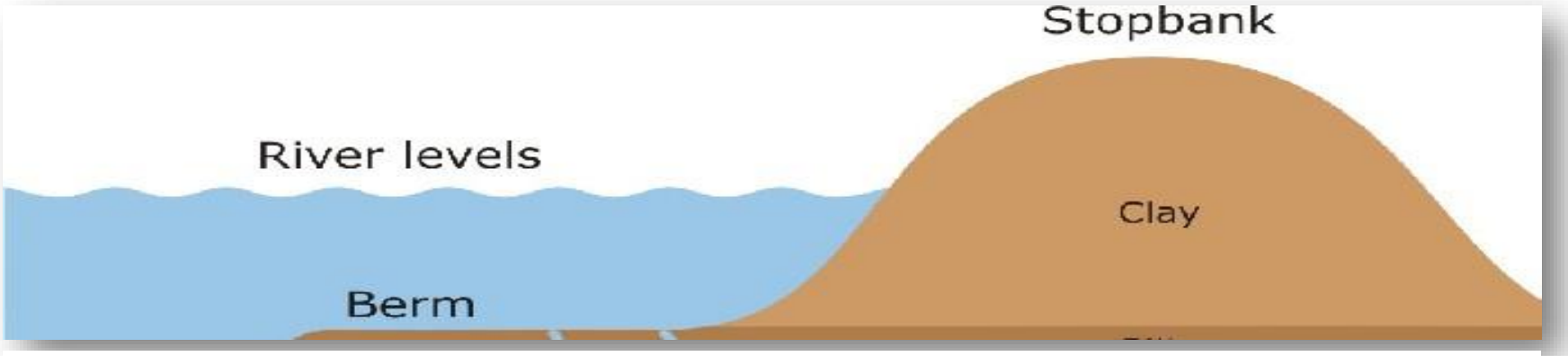

Figure 2: Cross section of a river with a stopbank. Adapted from Waikato Regional Council.

These measures, however, have not nearly eliminated risks posed to the Hutt Valley by floods. If the Hutt River floodplain experienced a large flood today, GWRC estimates that due to unpreparedness the community would experience a wide range of social and psychological impacts, including loss of life and property, separation from loved ones, and lasting psychological effects such as persistent fear of flooding and rainfall in general (Greater Wellington Regional Council [GWRC], 2016). In addition to the risk of injury or death, there would be physical damage and disruption to homes, schools, workplaces, community facilities, essential services, and emergency services (GWRC, 2016). The financial cost from a large flood could exceed one billion New Zealand dollars and these damages to infrastructure could take months to repair, debilitating the Hutt Valley community (GWRC, 2016).

Figure 3: Lower Hutt 2004 flood. From Ministry of Civil Defence & Emergency Management. (Left and bottom two)

Flooding along the Waiwhetu Stream

The Waiwhetu stream has an estuary, making the stream highly susceptible to flooding due to the possibility of the Hutt River (the river Waiwhetu branches off from) and coast flooding simultaneously (Mclay, 1976). The catchment, the area from which water drains into the stream, is approximately 18 square kilometers, with a majority

Figure 3: Lower Hutt 2004 Flood (left). From Ministry of Civil Defence & Emergency Management.

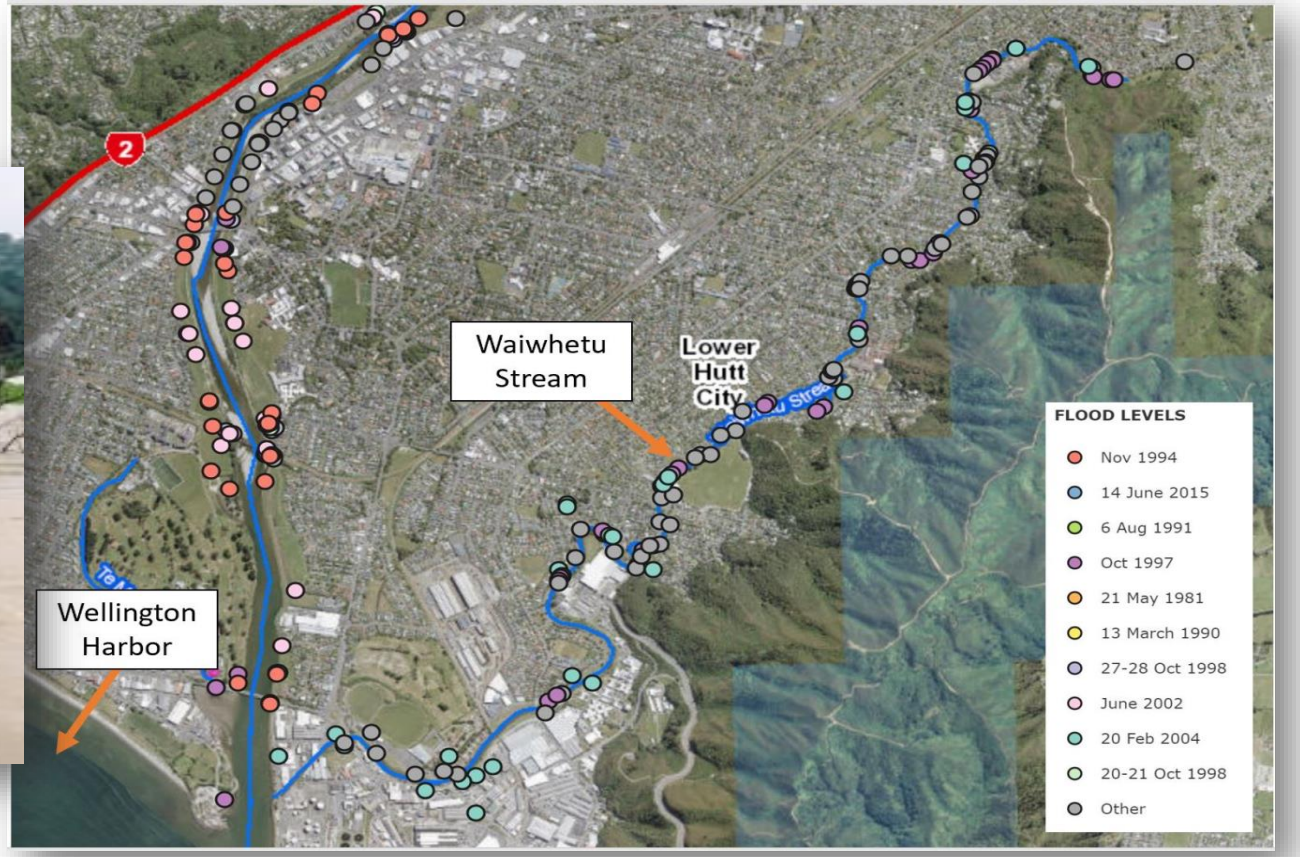

Figure 4: Map displaying geographically significant features of the Waiwhetu stream. From Greater Wellington Regional Council.

dedicated to residential and industrial-use land, making a large percentage of the catchment impermeable, inhibiting drainage and increasing susceptibility to floods (GWRC, 2016). Due to the sensitivity of the Waiwhetu catchment to flooding and the associated threat to urban areas, it is vital that the flood probability and risks are known. Figure 4 above shows regions affected by past flood events along the Waiwhetu stream.

Throughout the 20th century, sections of the Waiwhetu, a stream opposite the Hutt Valley from the Hutt River, have had physical infrastructure introduced (GWRC, 2014). Because the Waiwhetu drains into the Wellington harbour, its level depends on the tides. In 2004, the Waiwhetu exceeded stopbanks and flooded homes (O'Neil, 2015). The combined cost of flooding along the Waiwhetu and the other damages caused by the storm was an estimated NZ$200 million (Walton et al., 2004). Due to this severe flooding, the Waiwhetu stream became an area of focus for the Greater Wellington Regional Council Floodplain Management Plan, which will be discussed later on in this chapter (GWRC, 2017).

Current Flood Warning System in Lower Hutt

Lower Hutt uses relatively technologically advanced forms of notification, including SMS text messages, websites, social media, the Red Cross phone application, and phone calls (Leonard et al., 2016). This is problematic, as the last census in 2010 found that roughly 23% of households in Lower Hutt do not have internet access, 13% do not have access to a telephone, and some households do not have access to either, limiting access to warning notifications (Stats NZ, 2013). Additionally, a report conducted by the New Zealand Climate Change Research Institute in 2011 found that 54% of Hutt Valley households did not know their area's level of flood risk (Lawrence & Quade, 2011). A group from Worcester Polytechnic Institute reported four years later that data and results from this report had largely remained unchanged (Ammeson et al., 2015). A study by the European organization Natural Hazards and Earth System Sciences (NHESS) found that "public awareness does not ensure public preparedness:" while 80% of those surveyed knew they were prone to flood risk, only 34% of those surveyed felt prepared for a flood (Bradford et al., 2012). Based on these studies, it is very unlikely for people in Lower Hutt to be fully prepared for floods.

In the Lower Hutt, there are several organizations invested in flooding detection, notification, or response to varying degrees. GWRC, among other responsibilities, owns hydrology equipment and employs a team of hydrologists to interpret rain gauges and river levels around the Wellington region. These data are passed on from hydrologists to flood managers and staff within the Wellington Region Emergency Management Office (WREMO), who can mobilize during a flooding event and issue warnings. Wellington Water is a water management organization—handling drinking water, stormwater, and flooding related to burst pipes—partially owned by GWRC as well as Hutt City Council (HCC). MetService is a weather forecasting organization in New Zealand, based in Wellington, which monitors rainfall and forecasts storm events, with different tiers of alerts for larger storm systems. GNS Science is a government research organization currently playing a large role in earthquake detection and alerts, also issuing alerts for tsunamis as a

result of earthquakes. These organizations coordinate efforts to collect data and notify the public as shown below in Figure 5.

The current system starts with GWRC, MS, and NIWA telemetry collecting data on river levels as well as rain forecasts and analyzing them. This analysis, should it predict a flood, goes through a chain of 'duty officers' and operators employed by GWRC, WREMO, and Hutt City Council before finally reaching the public.

Floodplain Management Project

The aforementioned organizations are jointly on the second year of a five year plan to revise the existing flood warning system. As stated above, there is no central authority for communities to find warning information from; warnings contained varied information, and warnings took needlessly long to process. Through this five year plan,

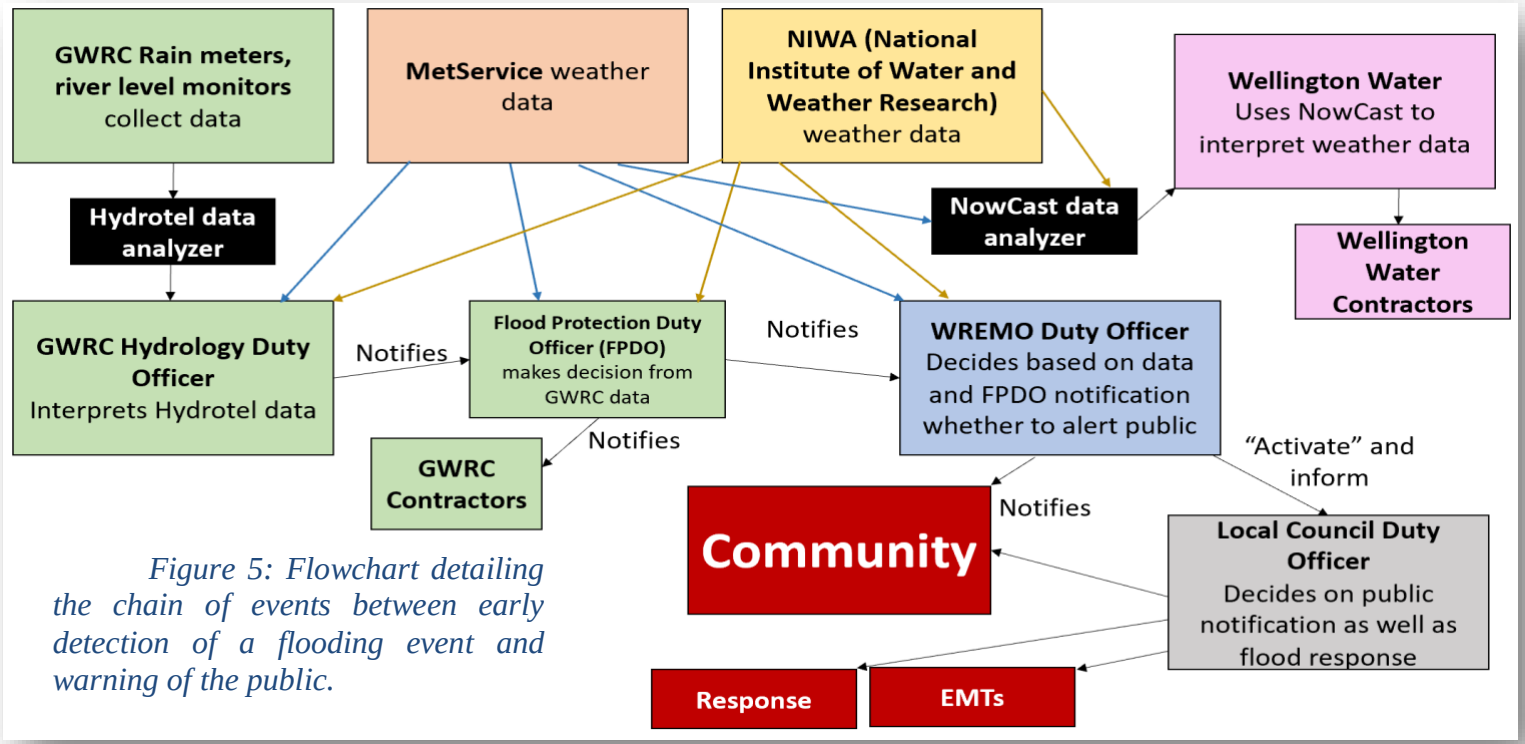

Figure 5: Flowchart detailing the chain of events between early detection of a flooding event and warning of the public.

these organizations intend to streamline and unify their action protocols. In 2016, GNS Science reviewed the current flood warning system in Lower Hutt and devised four areas to focus on when formulating the next system:

1. Mitigate damages through physical infrastructure, land planning, and warnings on the basis of risks faced
2. Reorganize alerts with clearly defined plans for all members of the community and area
3. Adopt a "one team-one warning" system to unify agencies in collaboration with a shared plan (Leonard, Becker, Woods, & Potter, 2016)
4. Develop a "one-stop shop" to provide free access to relevant information for members of the community (Leonard, Becker, Woods, & Potter, 2016)

To create and test a new flood warning system, these organizations are revising and implementing a pilot system along the Waiwhetu stream. In order to inform the restructuring of alerts and warning systems, our purpose in this pilot project is to do the initial work of gauging community preferences in how to be alerted during a flood, their level of preparedness for flooding, and their awareness of flooding.

Tour of Waiwhetu (top)
At the parliament building with our sponsor Ross (bottom)

Methodology

3 - Methodology

The goal of our project is to create recommendations to the Greater Wellington Regional Council (GWRC) for a flood warning system pilot which organizations can extend to other types of disasters and locations with limited additional research and development. We created the recommendations with these guiding objectives:

1. Research how local agencies can provide warnings best suited to the community.
2. Develop media to increase community preparedness for floods.
3. Investigate public awareness of flood risk.

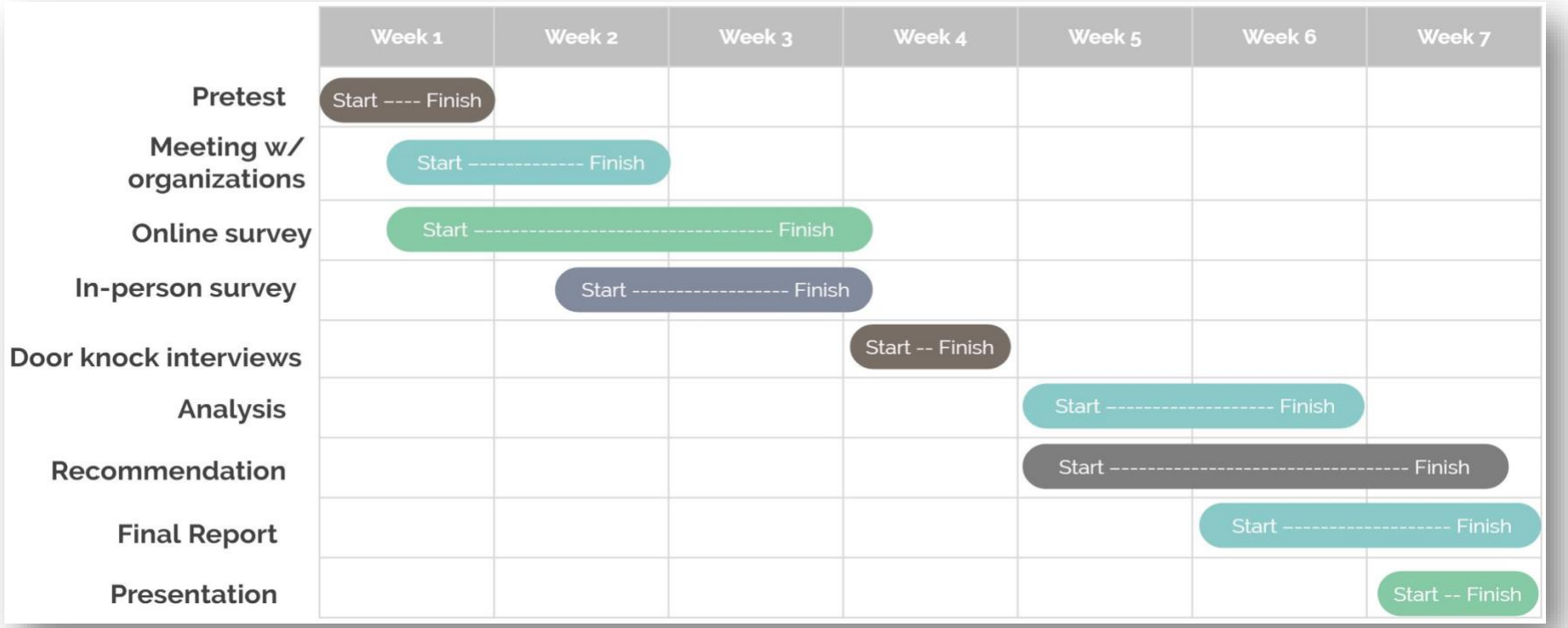

Figure 6:Gantt Chart detailing the project timeline

3.1 Understanding Government and Organization Roles

To understand the government's past work and their role in flood warning systems, we conducted meetings with experts from GWRC, Wellington Region Emergency Management Office (WREMO), Wellington Water, MetService, and Friends of Waiwhetu (FW). During these interviews, we asked a series of open-ended questions to promote discussion and generate new questions to lead to a more beneficial discussion (Keller, 2010).

Organization	Interviewees	Reason
WREMO	David Russell (Group Controller)	Understand the vision of the Waiwhetu pilot project from WREMO's perspective
	Ainslie Ryder (Community Resilience and Recovery)	
	Elizabeth Smith (Operational Readiness and Response)	
GWRC	Flood Department	Discuss the full goals of our project and how the current system is organized
FW	Merilyn Merrett (Chair)	Understand the stream and its flora.
Wellington Water	Ben Fountain (Chief Advisor: Stormwater)	Understand how flooding affects Lower Hutt's water systems
MetService	Peter Kreft (Manager, Operational Science & Policy)	Understand how information is first communicated.
	Chris Noble (Manager, Severe Weather Services)	
GNS	Graham Leonard (Senior Scientist)	Understand the role of GNS and recommendations

Table 1:Meetings

Meetings with Local Organizations

We met with members of GWRC, WREMO, Wellington Water, MetService, and FW. GWRC, our sponsoring organization, is responsible for mitigating flood risk in the Wellington region. WREMO works to prepare and implement solutions to mitigate risk during disasters. Wellington Water is concerned with managing drinking water, stormwater, and wastewater in the Wellington region. MetService is in charge of weather services and forecasting. FW is a committee that works toward a healthy ecosystem along the Waiwhetu stream. Our objectives in meeting with these organizations were the following:

- Fully understand the limitations to warning systems and communication along the Waiwhetu stream.
- Understand each organization's role in flood warning systems more fully.
- Develop and review a survey that addresses all the components of our research problem
- Connect with or learn of other community members who would have valuable information relating to our project's goals.

The questions we asked these organizations can be found in Appendix A, and a list of those we met with can be found above in Table 1.

3.2 Assessing Public Perception and Preparedness

To understand how the public wishes to be communicated with and to assess their levels of preparedness and awareness, we conducted surveys and interviews with residents in areas and establishments surrounding the Waiwhetu stream. Surveys included a mix of in-person and online anonymous surveys in order to capture as wide a socio-economic demographic as possible. Interviews were performed to learn of some of the more personal aspects of flooding among those who live by the stream.

Surveys

Our survey was designed to investigate how and when community members prefer to receive notifications for a flood warning, the level of preparedness of the community, and the awareness of flooding related topics by the community. To aid with our analysis, we also wished to detect trends in responses based on the level of education and understanding of relevant topics, age, and socioeconomic situation. In pursuit of this goal, our survey was split into the following categories:

- Flooding and Flood History
- Warning Systems
- Flood Preparedness
- Optional Demographics

We created two forms for our survey: an online form through Google Forms and a paper form. Anonymous online surveys are an effective method of surveying the public due to their accessibility and relative freedom from social pressures (Pflug & Schneider, 2016). The questions asked can be found in Appendix A. This survey was distributed digitally on Instagram, Facebook, Reddit, and Neighbourly. Emails containing the survey were also sent out to mailing lists by GWRC and our group placed fliers with a QR code in public areas. While our online survey provided many

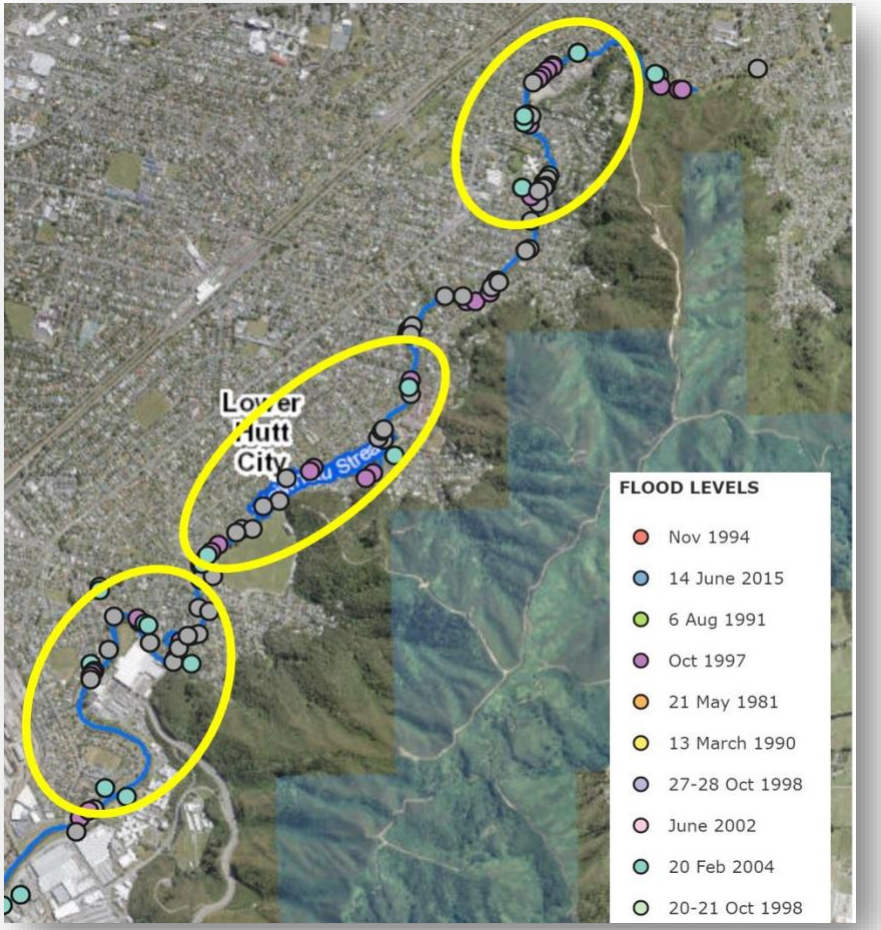

Figure 7: Communities interviewed along the stream.

Planning where to door knock

responses, it was important for us to capture the views of those in the community without access to the internet.

To capture a more random sample and gain perspectives of those without internet access, we conducted paper surveys in public areas, such as along the stream, in train stations, and at the mall. By conducting the survey in common areas, the responses yielded should be more representative of the population than the online survey. For consistency, this survey contains the same questions as the online survey (Found in Appendix A).

Community Interviews

To gather local, in-depth opinions on flooding and the warning systems in place, we scheduled interviews with members of the public, and we also conducted door-knock interviews with residents near the Waiwhetu stream over the course of three days. The interviews were similar to the survey but focused on a more specific and personal understanding of the survey topics. These interview questions can be found in Appendix A.

3.3 Storage and Analysis of Data

All data collected over the course of the project were stored on a shared Google Drive. Jottings and audio recordings that were taken in the field were transcribed to text documents and stored for analysis. The responses to our online surveys were automatically tracked by Google Forms, and paper survey responses were entered as Google Form entries in order to amalgamate survey data. Interview scripts were stored in Google Documents. All raw data were deleted at the end of the project to protect confidentiality.

Planning out our timeline

Interviews were subject to content analysis. A codebook was devised deductively to broadly capture the ideas deemed most useful in contextualizing survey data. Key quotes or sections which captured possible intents behind similar survey responses or went beyond the scope of the survey were coded in order to provide an understanding of community preferences which the survey could not fully. The codebook can be seen in Table 2 on the next page.

Meeting with Merilyn Merrett

Picture of Waiwhetu

CODES	WHEN TO CODE
How to Notify	Interviewee speaks about how they like to be communicated with, what forms of communication they can, cannot, prefer, or prefer not to use, whether for notifications or for everyday life
When to Notify	Interviewee speaks about when they would like to receive warnings based on likelihood of event, how far in advance they would like to receive the warning, and any opinions or reasoning behind their thoughts
Active Preparedness	Interviewee speaks about what they would do in the event of a flooding scenario such as installing sandbags, leaving home, and the like
Passive Preparedness	Interviewee speaks about preventative items or programs for flooding scenarios such as owning insurance, house being raised, emergency kit, food, and any other items which could improve floods response
Flooding Experience	Interviewee speaks about past flood experience that they have personally had or heard about from others
Concern	Interviewee speaks about or shows their relative concern for flooding in terms of their willingness to take risks in a flooding scenario, their concern that floods will happen, or their lack thereof
Available Information	Interviewee speaks about availability or lack of availability of information pertaining to what to do before, during, or after a flood, how to prepare for a flood, flood warnings, forecasts, risks, other information pertaining to floods, or offers opinions on how to provide information on these matters
Awareness	Interviewee speaks about flooding, what causes it, how many floods there have been in the past, or says anything displaying an awareness or lack thereof related to flooding incidents in their community, New Zealand, or in general
Feedback	Interviewee speaks about the project, the pamphlet, the one-stop shop, or any of the work by GWRC, WREMO, or any other organizations on the flood in an opinionated way displaying their thoughts on the work being done to the stream or warning systems

Table 2: Codebook

Depending on the nature of the data, surveys were tabulated in one, two, or more dimensions; variables were defined across responses and tabulated; graphs and charts were created; and data were subjected to cluster analysis.

As our online and in-person surveys most frequently utilized Google Forms, our group created several instances of the survey on Google Forms in order to separate specific survey groups.

3.4 Public Preparedness Campaign

One of our primary objectives was to work to increase community preparedness for flooding. Through meetings with relevant organizations, research, and community interviews, we decided to create a campaign called 'Ready NZ.' The purpose of 'Ready NZ' is to inform people about not only flooding but of all natural disasters.

One-stop shop website

One key component of our proposed 'Ready NZ' campaign was a website for people to learn about how to prepare for and react to floods. The idea of a 'one-stop shop' for the community to become prepared and stay up-to-date on flood risks was originally raised by GNS Science (Leonard, Becker, Woods, & Potter, 2016). After looking at various websites on disaster preparedness, notably the United States natural disaster preparedness website 'Ready.org,' our group designed a mock-website for a one-stop shop. To fit the website to community preferences, we asked the community on our surveys what information they would most like to see on a 'one-stop shop' website. The mock website design is included in Appendix B.

Pamphlet

In order to provide preparedness to community members who did not use the internet, our group also decided to create a flood preparedness pamphlet. This pamphlet was based on an educational pamphlet for earthquakes designed and distributed by WREMO but is part of our overall 'Ready NZ' campaign. The goal of this pamphlet is to inform the community of how to act in the event of a flood, so our group asked the community in interviews to review drafts of the pamphlet as it was designed and provide input on how clear it was.

Our final presentation

Results

4 - Results

4.1 Findings and Analysis

Our group's main objectives in this project were to research how local agencies could best warn the community of a flood, to develop media to increase public preparedness for floods and to understand public awareness of flooding. We based our findings on 220 community surveys and 18 interviews of stream-side residents. Our group found the age distribution of our survey respondents to be reflective of the census age distribution of Lower Hutt (Stats NZ, 2013). About 60% of survey responses were from suburbs around the Waiwhetu stream. Roughly 27% of survey responses were done in-person and sampled randomly, the other surveys being distributed online. Demographics were found to vary based on whether the survey was taken online or in person. The complete demographics of our surveys can be found in Appendix E.

Our surveys and interviews yielded numerous findings. The community wishes to be informed through as many communication channels as possible, with the most preferred channels being Emergency Mobile Alerts (EMAs) and voice sirens. The majority of members of the community are not concerned if alerts are false alarms or are given out for less likely flooding events. Some are concerned about the channels used for varying likelihoods, though. In terms of preparedness, we found that those surveyed did not feel entirely prepared for a flooding event, and we have designed a pamphlet and a mock-up website to address these issues based on community preferences. Finally, for awareness of the community, we found that the community is not entirely aware or concerned with risks facing them, such as sea level rise.

Communication

1. **There are opportunities for more efficiencies and collaboration between the local agencies involved in predicting floods and notifying the public**

As briefly discussed in the Background, the stakeholder organizations in flood detection and warning are not efficiently working together. Through meetings with Wellington Water, GNS Science, MetService, Greater Wellington Regional Council (GWRC), and Wellington Region Emergency Management Office (WREMO), our group determined that there are opportunities to use a one-stop shop website or server system to streamline flood detection as well as notification and education of the community. This system would allow for data collection to flow from various sources to one and could allow for the standardization and automation of several decision points in the flood warning process which are currently reliant on the experience of experts.

2. **The public generally prefers Emergency Mobile Alerts (EMAs) and Voice Sirens for warning notifications**

Members of the community seem to favor the Emergency Mobile Alerts (EMA) for warnings but, in specific instances such as at night, options such as phone calls, door-knocking,

and voice sirens were relatively favored, with an increase of respondent support from 15.6%, 21.8%, and 46.9% of respondents to 28.6%, 35.5%, and 54.9% respectively.

Our results found, however, that preferred communication mediums vary with age, and that those over 65 were much more likely than other age groups to select options such as

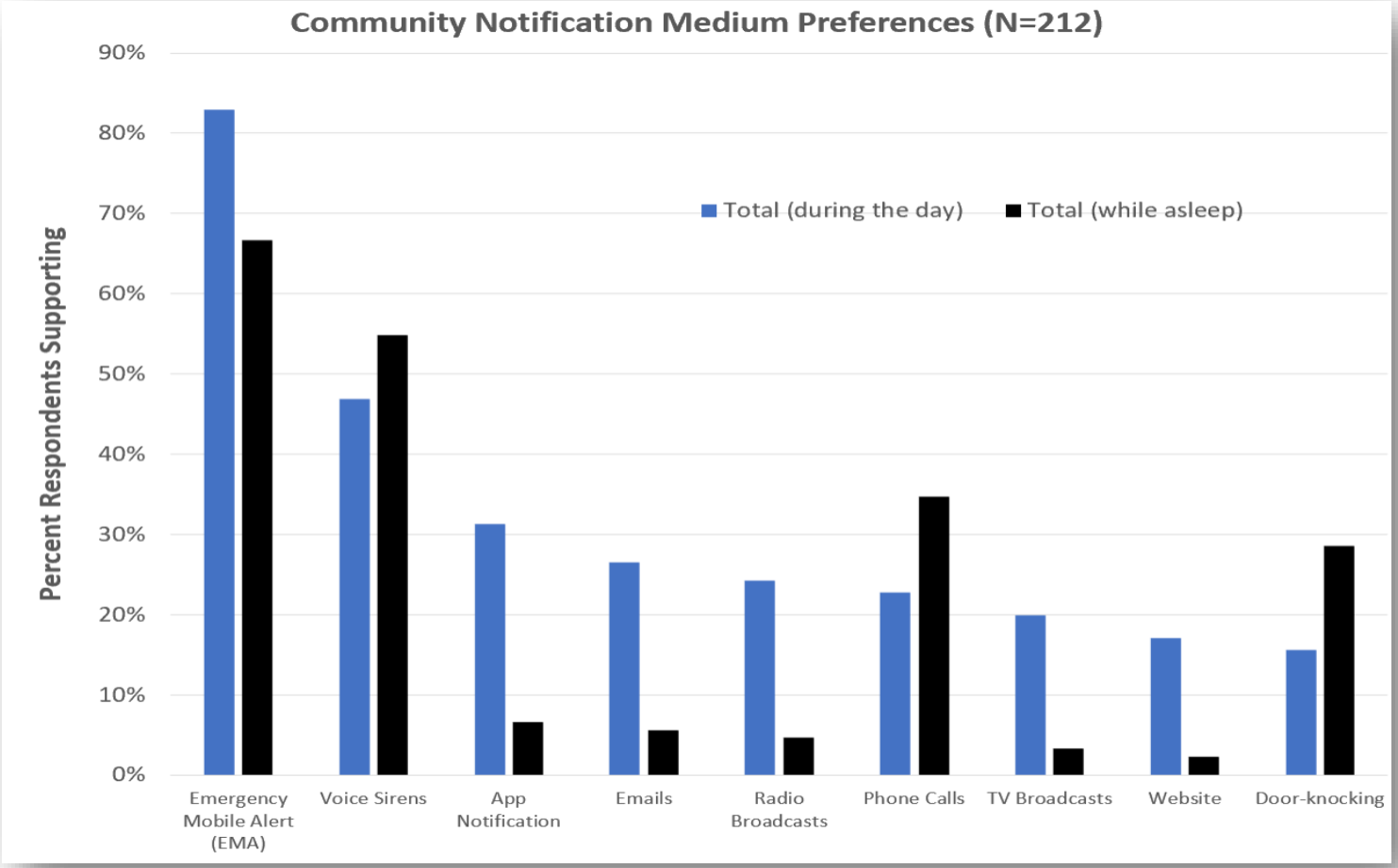

Figure 8: A chart displaying the difference in communication channels preferred depending on scenario.

phone calls (55.6% support compared to 22.7% overall community support) and emails (59.3% to 26.5%). This is likely due to the fact that these are standard forms of communication which they are used to. A chart of communication preference based on age can be found in Appendix C. There were also some differences in results based on whether the survey was taken in-person or online. Most notably, for communication preferences, while 87% of those surveyed online preferred EMAs, only 66% of those surveyed in-person preferred this. Other differences between online and in-person surveys can be found in charts in Appendix C. Results also seemed to vary slightly based on where the respondents lived; 62.1% of Waterloo residents chose door-knocking as a medium for flood warnings. This is interesting, as general demographics for the Waterloo responses do not strongly differ from the average. Waterloo residents also displayed more connectedness as a community through surveys: in a question asking the extent of help that the surveyee would provide to neighbors in the event of a flood, 62% of Waterloo respondents claimed they would do as much as they could to help their neighbors compared to 41% overall. In the Waiwhetu suburb, voice sirens had 87.5% support. It is important to note the sample sizes of these demographics; only eight surveyees identified as 'Waiwhetu' residents. This brings us to one of the limitations of our research. While there were many responses to our surveys, some suburbs around the stream received more traffic than others. Waterloo, Naenae, and Epuni produced the most responses of specific suburbs, with 29, 26, and 16 respondents respectively. Communities such as Gracefield, Waiwhetu, and Moera had 10 or fewer respondents each. Another limitation of our findings was our failure to ask about social media as a warning method in surveys.

3. **The community of Lower Hutt is accepting of more frequent warning notifications if these notifications allow for more lead time**

In terms of when to be notified, our results show that members of the community wanted to be warned of a flood when it becomes slightly more certain and were willing to receive less certain alarms in favor of increased lead time on a warning before a flooding event occurring. When given a scenario of a "severe flood" occurring within 10 hours, 53% of those surveyed desired a warning for a flood with a 10% chance of occurring, 79% desired a warning if it were a 30% likelihood, and 97% if there was a 50% likelihood. The trend of these data can be seen in Figure 9.

When asked whether it was favorable to have fewer overall notifications or more overall lead time before a flood, 55% of responses favored more lead time and only around 5% felt strongly about having fewer notifications.

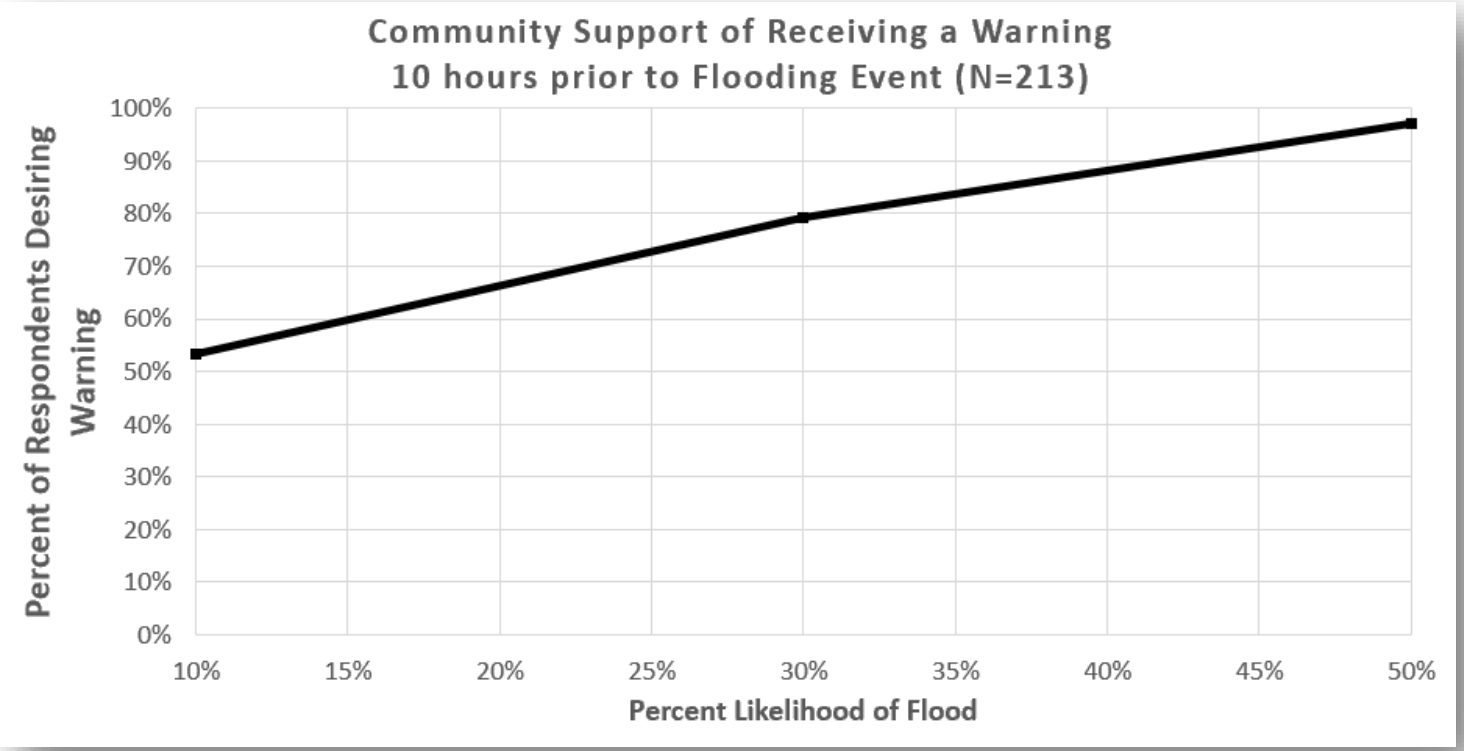

Figure 9: Community support of a warning at various flooding likelihoods.

4. A tiered, context-based warning system would be effective at limiting excess notifications

In interviews with the community, interviewees preferred that warnings not be intrusive if the warning is not necessary. One interviewee expressed concerns of being "[woken] up at 2 in the morning" for a warning "midday tomorrow." The same interviewee summed up thoughts on the matter of early warnings by stating: "For a low chance [of a flood], [the warning] should be close to the event, and for a high chance [the warning] should be further away." In other interviews, interviewees made the point that a voice siren would not be necessary for a warning if it was of low

probability and long in advance. This led our group to the conclusion that a tiered warning system with increasingly intrusive alerts based on the likelihood, severity, and lead time before the flooding event would be the most effective way to avoid interrupting the daily lifestyle of residents along the stream without compromising the overall goal of alerting the community.

Awareness

1. **Sections of the community are unconcerned with the threat posed by sea level rise**

33.7% of respondents were unaware of the effects of sea level rise on flooding. Figure 10 shows a correlation between an increase in age and an increase in concern of rising sea level effects on flooding. This could be due to older residents having more experience with flooding throughout their lives. Appendix D contains the full set of data.

2. **The community is not uniformly concerned that they are at risk of flooding**

When asked about their concern for flooding impacting them, only 25.1% of people were greatly concerned, as seen in Figure 11. This shows that, given the scope of potential damages in the area from flooding, the community may not know the full extent of the flood risk they are exposed to.

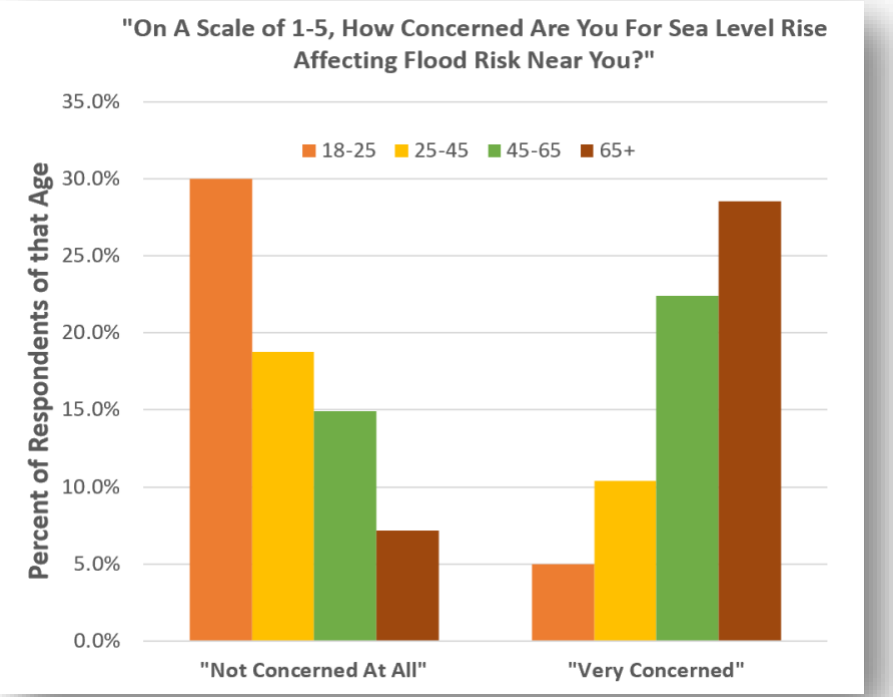

Figure 10: Chart of community fear of sea level rise worsening flooding based on age

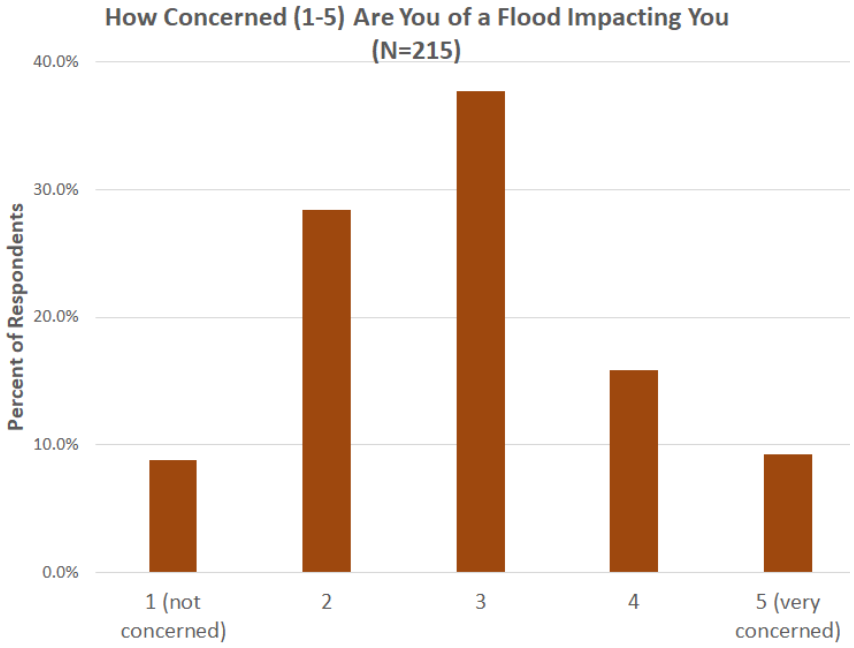

Figure 11: Graph of community concern of flooding

Preparedness

1. **The majority of people in Lower Hutt do not feel fully prepared for flooding**

Through our surveys and interviews, we have found a majority of people asked do not feel fully prepared for flooding. When asked how prepared they felt to respond to a flood, only 13% said they felt fully prepared, a small amount considering that 70.8% had experienced some level of flooding. When interviewed, 16 of 18 respondents indicated a lack of preparedness. Another common theme found was that interviewees felt more prepared for earthquakes, as this information is more widely distributed for earthquakes than for floods. One barrier for preparedness we have determined is that there is a lack of easily accessible information and urgency.

2. **Individuals in the community of Lower Hutt are generally unwilling to invest a large amount of time to increase their flood preparedness**

In our surveys, we asked the community of Lower Hutt how much time they would be willing to spend becoming prepared for floods. Results can be seen in Figure 12 below, and showed that only 17.5% of respondents were willing to spend over an hour preparing for a flood or other natural disaster. However, we found that the majority of people were willing to spend 5-10 minutes preparing for flooding. 94% of respondents chose 5-10 minutes or longer when asked how much time they would be willing to spend.

Meeting with the Mayor of Lower Hutt Ray Wallace

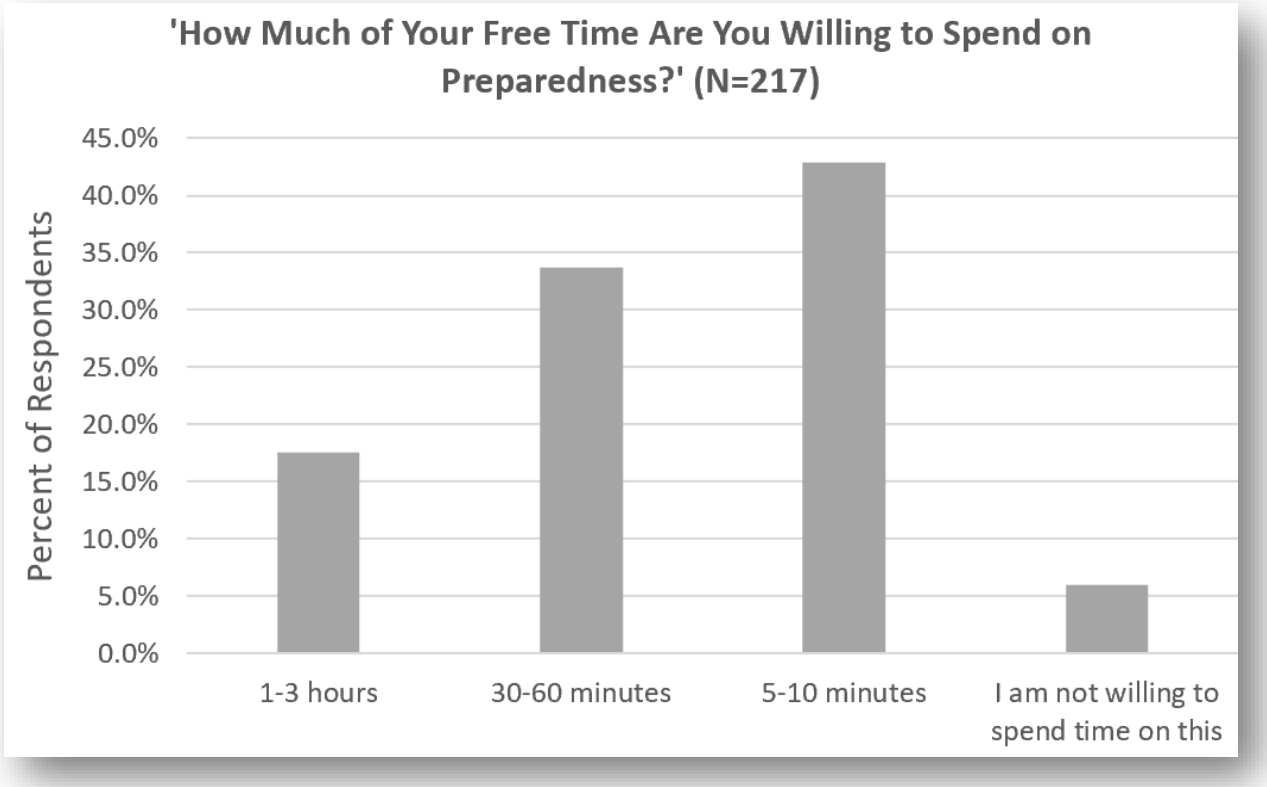

Figure 12: Community responses to a question asking how much time they are willing to spend on flood preparedness.

3. An informational pamphlet can be used to increase flood preparedness in the Lower Hutt community

When asked "do you feel prepared to handle a flood," one interviewee replied "No. The thing that would make me feel more prepared is a little pamphlet to arrive in the post that we can stick to your fridge that says 'here's an action plan in the event of a severe flood,' 'here's where you can go to get your sandbags,' 'here's where you go when you go when your house is underwater,' because they're pretty good at this kind of thing for earthquakes. I don't think it exists for flooding. That's the kind of thing that would make

me feel somewhat more prepared." This quote encapsulated the larger theme that time is a barrier to preparedness.

As a solution to this, we designed a preparedness pamphlet (Appendix F) using Photoshop and InDesign. The pages of the pamphlet reflect advice from experts on useful content and what the community would like to learn related to flooding preparedness as found in interviews. By having several people read the pamphlet, we estimated the average time for reading and comprehending the pamphlet to be about six minutes, which is ideal for the majority of the community that favors preparedness information in that amount of time.

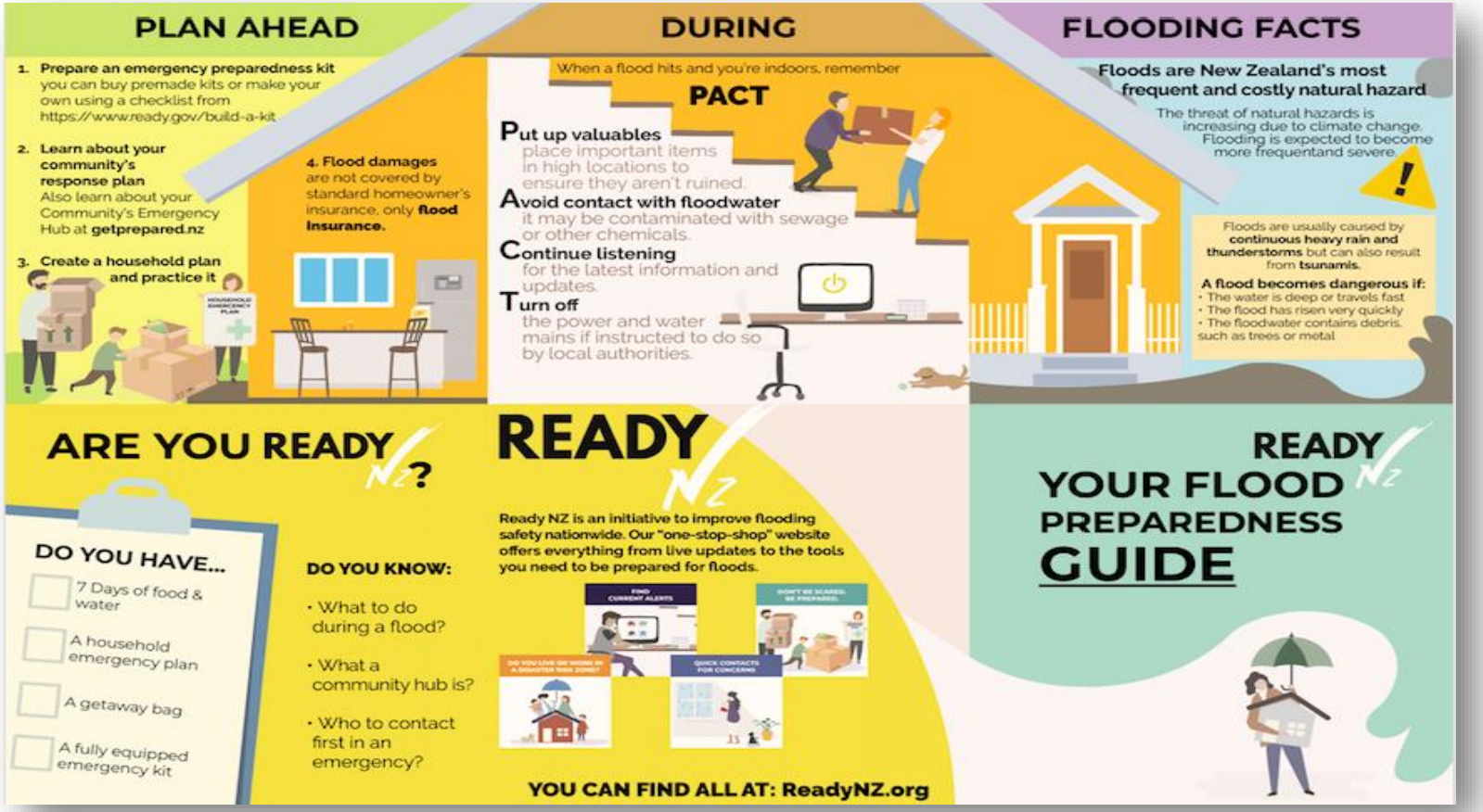

Figure 13: Public preparedness pamphlet.

4. There are opportunities to use a 'one-stop shop' to help communities to prepare for a flood

When we interviewed community members on how they would feel about a website that includes all the necessary information, every respondent indicated that it could be useful. When we asked the community what they would like to see on the website, one interviewee said "anything and everything that would be helpful." We also asked the community in surveys what they would like to see in a one-stop shop and the general trend seemed to be all of the options which we laid out for them, including flood warnings, levels of risk for specific areas, information on what to prepare for a flood, and organization contact information.

As a result of the community interest as well as recommendations from partnering organizations, our group designed a mock-up of an informational website as an example of the public end of the one-stop shop concept. Our draft website, which can be found in Appendix B, includes information on preparations for flooding, what to do in the event of a flood, and also calls for a feature to explain someone's flood risk when they enter an address. There is also a portion of the website dedicated to current flooding events, warnings, and real-time updates.

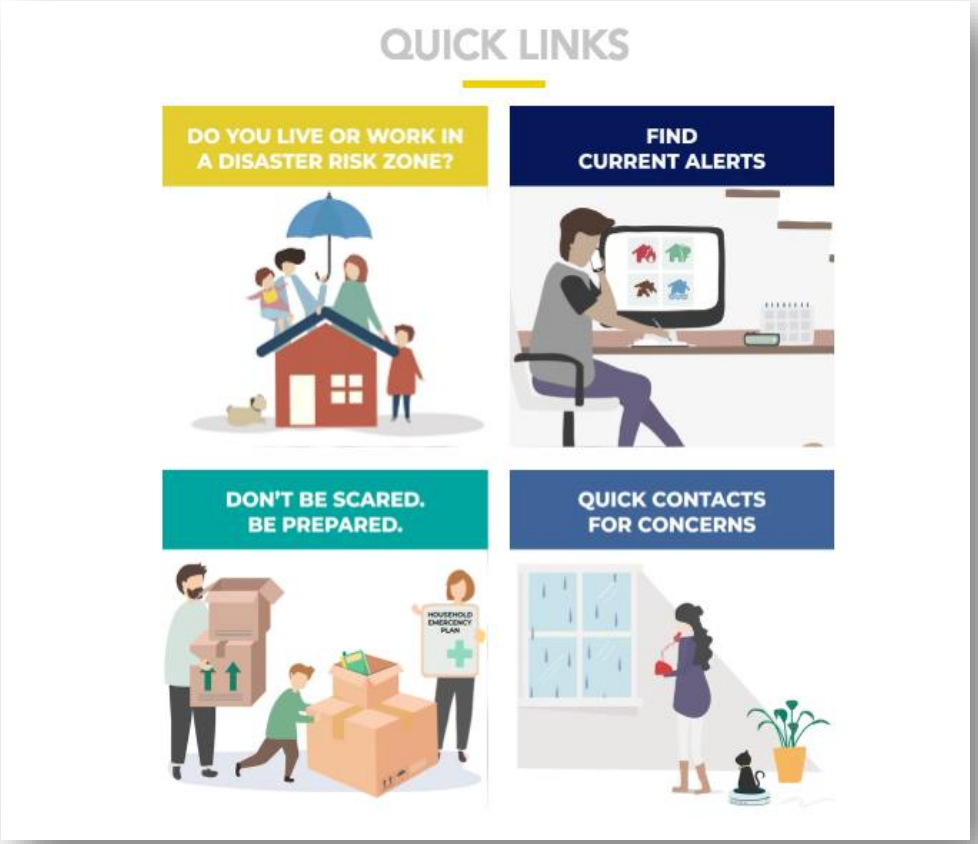

Figure 14: Quick links page of website

4.2 Discussion

Recommendations for Sponsors

Tiered, redundant warning system

We recommend warnings be issued primarily through Emergency Mobile Alerts, door knocks, and phone calls. Resources permitting, we recommend the installation and use of voice sirens such that they are capable of broadcasting specific messages about how to respond to the flood event and can be individually activated, much like the targeting of specific mobile towers for Emergency Mobile Alerts. We also recommend issuing warnings on apps such as the Red Cross app, social media—especially Facebook, and via email for redundancy. With the implementation of several means of warnings, we recommend they be implemented in a tiered fashion, utilizing certain media only when events are more certain or close, as detailed in the example below.

We recommend expediting warnings to the greatest extent realistically possible for the Waiwhetu, especially with a tiered system. While we would recommend mostly relying on broad forms of communication that can be activated and reach many people automatically such as Emergency Mobile Alerts, voice sirens, or app notifications, we recommend still having capabilities to activate more direct networks of communications, such as promoting the use of phone trees or door knocking within specific communities. In the interest of maximizing redundancy, we

CHANCES OF SEVERE FLOOD	< 1 hour	1-3 hours	3+ hours
<10%	No warning		
10-30%	EMA Voice sirens	EMA	Websites Social Media
>30%	EMA Voice sirens Door knock	Second EMA	EMA

Figure 15: Tiered redundant warning system example

recommend investigating the viability of or pursuing any possible further means of warning, such as radio or television alerts.

One-stop shop

We recommend implementing the one-stop shop concept proposed by GNS Science in order to inform the community and streamline the current flood warning system. To assist the community in getting informed, we recommend the website primarily promotes information on what to do before and after a flood, and for preparation, action plans, and safety information. We additionally recommend having flood warnings and alerts, real-time graphical representations of flood risks, and organization contacts available on the website and prioritized respectively in accordance with community perspectives. We recommend the tools and interface for the public on this website be able to be extended to other types of disasters, natural or otherwise, such as fires or terror attacks.

To address the potential over-reliance on expert experience in the system, we recommend that information on what particular pieces of data are and mean in relation to the stream and whether organizations take warning action

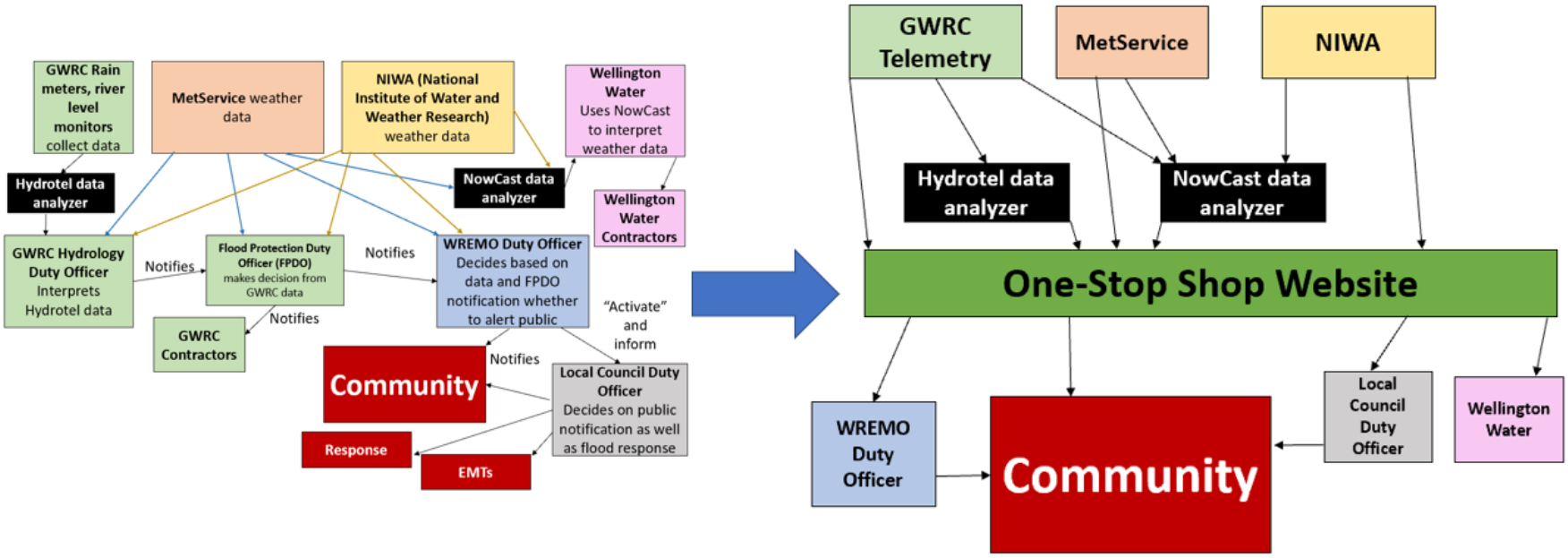

Figure 16: Current organizational structure compared to a structure utilizing a one-stop shop.

to be standardized by recording and analyzing data from the stream. This would shift the onus for determining whether current data are a sufficient cause for issuing the warning from the individual experience of an expert to objective comparisons between incoming data and a set standard. Involved organizations should automate this via the one-stop shop system, with any involved organization able to access the same data as before but in one place and, more importantly, with built-in analysis to interpret the data. Involved organizations should extend this framework to all other forms of disasters which collaborating organizations are capable of providing data for.

Our group recommends the implementation of a one-stop shop the same or similar in layout to the mockup we created, which can be found in Appendix B. We also recommend structuring the one-stop shop in such a way that data can be uploaded to the one-stop shop from telemetry, analyzed by the one-stop shop, and can be accessed by partner organizations such as Wellington Water.

Pamphlet

We recommend printing and distributing the pamphlet designed by our group or a similar pamphlet to the community of Lower Hutt. The design of our pamphlet can be found in Appendix F. The pamphlet should be distributed by mail to residents along the stream, making it available in certain public spaces, and by distributing it digitally via websites, email, and social media platforms.

Figure 17: Front of public preparedness pamphlet

Future Research

Throughout our project, we have identified the potential for future research. When we conducted our survey, we asked people if they would like to be notified of at 10%, 30%, and 50% chance of a severe flood happening in the next 10 hour. Future research should vary lead times, such as one hour, three hours and five hours, or the severity of the flood, such as mild, moderate, and severe. Due to interviewees expressing that they currently seek out warnings on social media, we would recommend also investigating warnings through social media as a notification option. In our surveys and interviews, we did not ask people their ethnic background, which might be

desirable information with regards to trends in data and would also ensure representation of the Māori community. One interesting finding from our project is that Waterloo prefers door knocking far more than any other community which would be good to investigate. With that data, it could be fruitful to find out how to conduct door knock warnings effectively and efficiently during a warning. While there was robust representation in suburbs such as Waterloo, Naenae, and Epuni, it might be beneficial to gain more information from residents in Waiwhetu, Moera, and Gracefield, as our sample sizes from these suburbs were not large enough to be conclusive. Finally, we would recommend researching how the front-end and the back-end of the one-stop would ideally operate.

Conclusion

5 - Conclusion

In this study, our objective was to find the best methods to notify the community along the Waiwhetu stream of a flood and determine the level of preparedness and awareness the community had. We were able to accomplish this through 220 surveys, 18 interviews, and multiple meetings with different organizations. We found that a one-stop shop website can be utilized to streamline the warning system and that the most preferred methods to warn the public are through Emergency Mobile Alerts and voice sirens. We additionally found the community at large is not uniformly aware of flooding threats and not concerned that sea level rise will affect flooding. Lastly, we found much of the community does not feel fully prepared and are not willing to invest much time to become prepared. From these findings, we recommend the following:

- Tiered, redundant warning system primarily using EMAs and voice sirens
- Implementing the proposed one-stop shop including public preference of content
- Production and distribution of an informational pamphlet

Our project along the Waiwhetu stream is intended to be a pilot project of a greater five-year flood protection revision plan managed by GWRC. Even though these recommendations are specific to the Waiwhetu stream, the methods that we used can be retrofitted to other disasters to form a warning system. Due to climate change, natural disasters are still increasing in frequency and intensity, but with the use of community-tailored warning systems, we can mitigate their risk.

5.1 IQP Learning Objective 1: Lessons learned about Technology and Society Projects

- **The public does not always share the same perceptions that the government organizations has.**

When we met with WREMO at the beginning of this project, they recommended that we not ask about the use of sirens due to past complications of using a flood siren system for tsunamis in the region among other various uses in New Zealand and failures in Japan. However, through more research, we decided it was important to include voice sirens in the survey. As a result, voice sirens became one of the most preferred methods of communication. This shows that criticism felt by organizations may be more prominent internally than in the public.

- **A community with a better understanding of floods and available resources work is better able to make inferences for themselves.**

While conducting interviews, we would probe the thought processes behind how the interviewees conducted themselves during the event of a flood. One engineer that we interviewed said that when he saw the signs of a flood, he would look at the rain gauge data on GWRC's web page and

MetService's forecast. Another less sophisticated approach many people employed was to look at the drains along the stream to see if they were overflowing or draining. These examples show that people are willing to make an effort to inform and secure themselves in a flood but may not know the best methods.

- **Learning how to communicate effectively is just as important as the early detection devices.**

A significant part of our project was figuring out how the community would like government organizations to communicate with them during a flood. This was because GWRC can predict when a flood is coming based on early detection, but if they cannot effectively warn the community, the early detection technology is useless.

5.2 Reflection

Joseph Esposito

Throughout the last fourteen weeks, I've learned more than I could even begin to write in this reflection. I've had the opportunity to not only learn about flooding and its impacts on a region, but also to see and speak with the very people that are impacted. This was eye-opening, as it made the threats associated with flooding so much more real and personal than I felt before starting work in New Zealand. I learned that talking and listening to people is a powerful tool for discovering answers to the many difficult questions, and that technology is most effective at solving problems when it is carefully considered by the public. I also learned to analyze large amounts of data through analyzing survey results. Lastly, I learned of how to start a project and follow it through to completion, and greatly appreciate the opportunity to work to help the very community which I've grown to feel a part of along the Waiwhetu.

Brandon Weyant

During this project, I have learned a great deal about floods and their effect on the community but also about working within a team, communicating effectively, and carrying out a research problem from beginning to end. These skills will carry with me well into my career and this project will provide a great story that I can tell people. Not only was the project great but living in another country for seven weeks gave me the opportunity to understand and appreciate another culture. The people we were able to meet through this experience were so nice and pleasant. This project also provided a great break from engineering; I met people who lived and thought completely differently than I do which was eye-opening. Overall this was an amazing experience which I will never forget.

Lindsey Stevens

I have grown incredibly in these last 14 weeks. This project experience has surpassed all expectations. I have learned more than I would ever have imagined and I am forever grateful for my ambitious group. We worked incredibly hard on this project and I feel that it really shows. The Greater Wellington Regional Council were incredible sponsors that enabled us to come up with creative

recommendations and they were very supportive throughout this process. I feel so fulfilled with the things we accomplished and the sights and culture I was still able to immerse myself in. I will never forget my time here in Wellington and I thank everyone that made this possible.

Chester Barber

This project afforded me the opportunity to learn first-hand about flood warning systems, something I never expected to be remotely involved in, and New Zealand, a place I've been looking to know more about for quite some time. Though New Zealand was just about everything I had expected, there was much more to flood warning systems than I had anticipated. In meetings with organizations, learning the sheer cost of systems like voice sirens or stopbanks and the potential for outlandish future methods like sirens attached to drones put into perspective the extent of public investment in protecting communities and the industries which arise from this. While I'm not sure I'll be involved in either New Zealand or flood warning systems going forward, I can say with some confidence that my experience with them will change my viewpoint in other fields.

Group

The 14 weeks spent working on this project have been among the most insightful in our lives. Entering this project, we had neither knowledge of the risks of flooding nor the challenges involved in protecting people from floods. The faces and stories we heard interviewing the community along the Waiwhetu stream put color to the threats and impacts of flooding which we learned about through research. The people we met throughout our time in New Zealand have been lovely to work with and helped us to ensure that our work would not only be meaningful and impactful for the community along the Waiwhetu, but also fulfilling for each of us in a way that we will remember for the rest of our lives. We'd like to say, once again, thank you to all of those who made this project possible, who helped us along the way, and the community of Lower Hutt. It's been a pleasure becoming part of the whānau at Te Pane Matua Taiao, and we will be sad to leave.

Kia ora. Tēnā rawa atu koutou. E noho rā.

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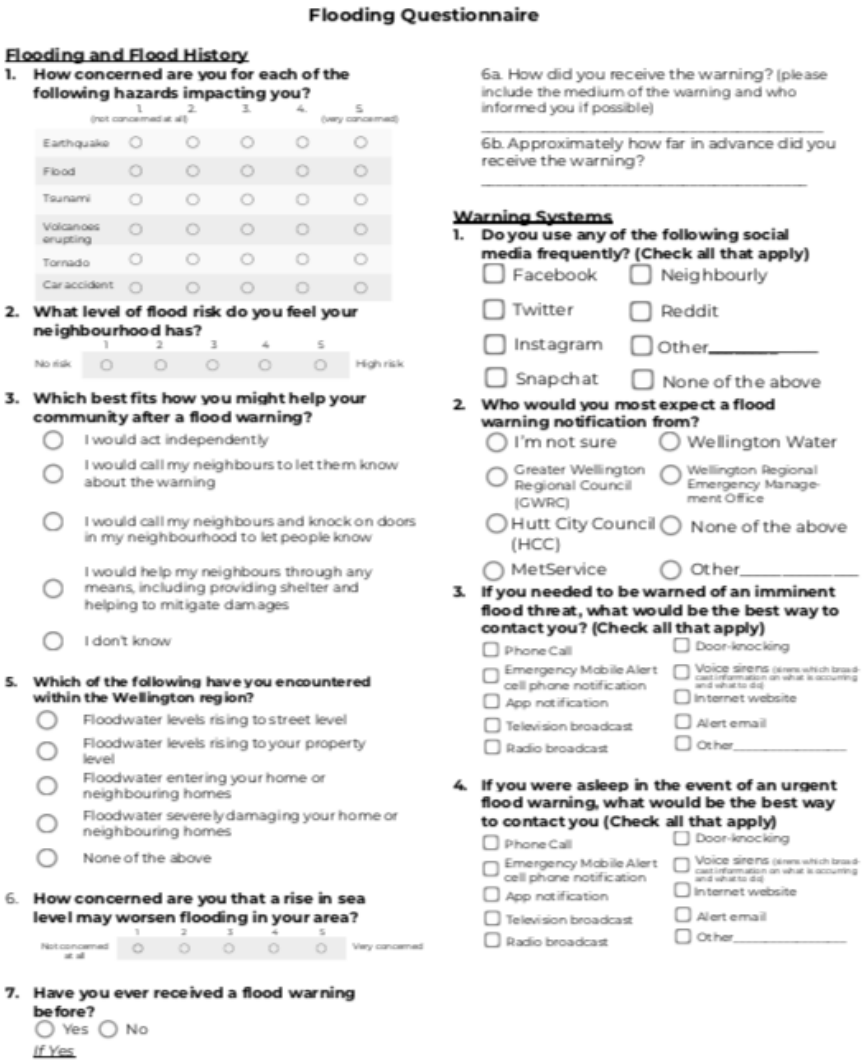
Appendix A - Surveys and Interviews



Flooding Questionnaire

Flooding and Flood History

1. **How concerned are you for each of the following hazards impacting you?**

	1 (not concerned at all)	2	3	4	5 (very concerned)
Earthquake	○	○	○	○	○
Flood	○	○	○	○	○
Tsunami	○	○	○	○	○
Volcanoes erupting	○	○	○	○	○
Tornado	○	○	○	○	○
Car accident	○	○	○	○	○

2. **What level of flood risk do you feel your neighbourhood has?**

	1	2	3	4	5	
No risk	○	○	○	○	○	High risk

3. **Which best fits how you might help your community after a flood warning?**
   - ○ I would act independently
   - ○ I would call my neighbours to let them know about the warning
   - ○ I would call my neighbours and knock on doors in my neighbourhood to let people know
   - ○ I would help my neighbours through any means, including providing shelter and helping to mitigate damages
   - ○ I don't know

5. **Which of the following have you encountered within the Wellington region?**
   - ○ Floodwater levels rising to street level
   - ○ Floodwater levels rising to your property level
   - ○ Floodwater entering your home or neighbouring homes
   - ○ Floodwater severely damaging your home or neighbouring homes
   - ○ None of the above

6. **How concerned are you that a rise in sea level may worsen flooding in your area?**

	1	2	3	4	5	
Not concerned at all	○	○	○	○	○	Very concerned

7. **Have you ever received a flood warning before?**
   ○ Yes ○ No

If Yes

6a. How did you receive the warning? (please include the medium of the warning and who informed you if possible)

_____

6b. Approximately how far in advance did you receive the warning?

_____

Warning Systems

1. **Do you use any of the following social media frequently? (Check all that apply)**
   - ☐ Facebook ☐ Neighbourly
   - ☐ Twitter ☐ Reddit
   - ☐ Instagram ☐ Other_____
   - ☐ Snapchat ☐ None of the above

2. **Who would you most expect a flood warning notification from?**
   - ○ I'm not sure ○ Wellington Water
   - ○ Greater Wellington Regional Council (GWRC) ○ Wellington Regional Emergency Management Office
   - ○ Hutt City Council (HCC) ○ None of the above
   - ○ MetService ○ Other_____

3. **If you needed to be warned of an imminent flood threat, what would be the best way to contact you? (Check all that apply)**
   - ☐ Phone Call ☐ Door-knocking
   - ☐ Emergency Mobile Alert cell phone notification ☐ Voice sirens (sirens which broadcast information on what is occurring and what to do)
   - ☐ App notification ☐ Internet website
   - ☐ Television broadcast ☐ Alert email
   - ☐ Radio broadcast ☐ Other_____

4. **If you were asleep in the event of an urgent flood warning, what would be the best way to contact you (Check all that apply)**
   - ☐ Phone Call ☐ Door-knocking
   - ☐ Emergency Mobile Alert cell phone notification ☐ Voice sirens (sirens which broadcast information on what is occurring and what to do)
   - ☐ App notification ☐ Internet website
   - ☐ Television broadcast ☐ Alert email
   - ☐ Radio broadcast ☐ Other_____

5. **How much lead time do you expect to have from a flood warning notification?**
Lead time refers to the time between the issued warning and the flooding event at your property

- ○ Less than 30 minutes
- ○ 30-60 minutes
- ○ 1-2 hours
- ○ 2-5 hours
- ○ 5-10 hours
- ○ More than 10 hours

6. **If there were a 10% chance of a severe flood occurring within the next 10 hours, would you want to receive a warning?**
○ Yes ○ No
7. **If there were a 30% chance of a severe flood occurring within the next 10 hours, would you want to receive a warning?**
○ Yes ○ No
8. **If there were a 50% chance of a severe flood occurring within the next 10 hours, would you want to receive a warning?**
○ Yes ○ No
9. **In general, would you rather have more lead time (with more frequent flood notifications) or less lead time (with less frequent flood notifications) Lead time refers to the time between the warning and the flooding event**

Less notifications | 1 ○ | 2 ○ | 3 ○ | 4 ○ | 5 ○ | More lead time

Flood Preparedness

1. **Which of the following do you have? (Check all that apply)**
- ☐ 1 - 3 days of food and water
- ☐ 4 - 7 days of food and water
- ☐ First aid kits
- ☐ Flashlight
- ☐ Wind-up radio
- ☐ None of the above

2. **How prepared do you feel to respond to a flood?**

Not Prepared | 1 ○ | 2 ○ | 3 ○ | 4 ○ | 5 ○ | Well prepared

3. **How much of your free time are you willing to spend to become prepared for a flood or other natural disaster?**
- ○ I am not interested in spending time on this
- ○ 5 – 10 minutes (ex. Instructional video or pamphlet)
- ○ 30 – 60 minutes (ex. Basic local class taught by officials)
- ○ 1 – 3 hours (ex. In-depth local class taught by officials)

4. **What would you expect to find in a 'one-stop-shop' flood warning website?**
Please select TWO
- ☐ Information on what to do before, during, and after a flood (preparations, action plans, safety information)
- ☐ Real-time graphical representations of flood risks in my area
- ☐ Organizations/contacts for reporting flooding events, damages, or concerns
- ☐ Flood warnings/alerts (notifications)

Optional

Which range best describes your age?
- ○ Prefer not to answer
- ○ 18-25
- ○ 25-45
- ○ 45-65
- ○ 65+

What annual income range best describes your household?
- ○ Prefer not to answer
- ○ Less than $20,000
- ○ $20,000 - $30,000
- ○ $30,000 - $50,000
- ○ $50,000 - $70,000
- ○ $70,000 - $100,000
- ○ $100,000 - $150,000
- ○ $150,000+

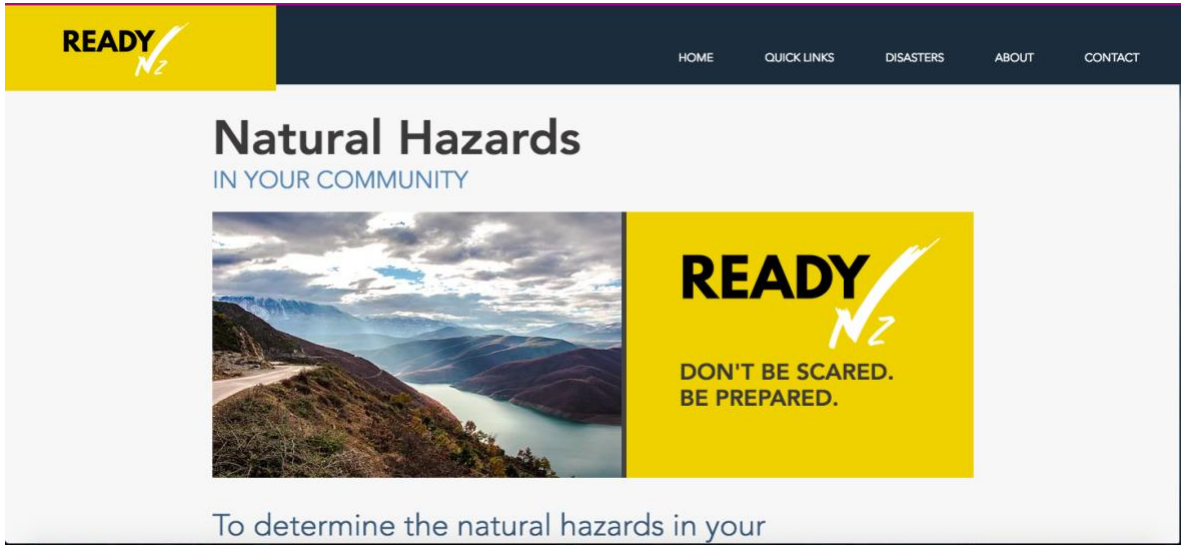
Which best describes where you live?
- ○ Prefer not to answer
- ○ Petone
- ○ Seaview
- ○ Naenae
- ○ Epuni
- ○ Waterloo
- ○ Gracefield
- ○ Lower Hutt
- ○ Wellington
- ○ Upper Hutt
- ○ Porirua
- ○ Other

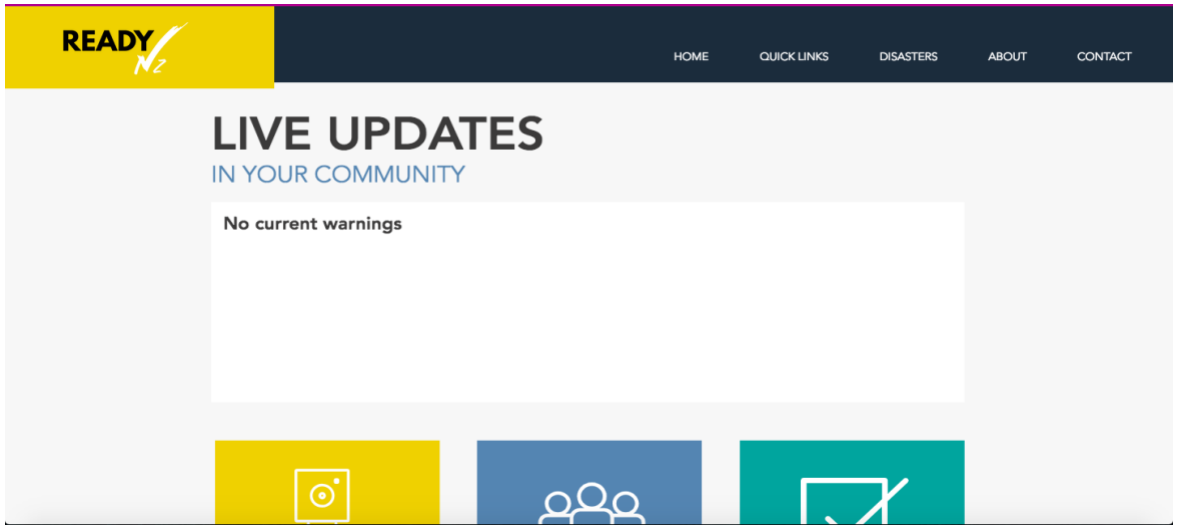
How long have you lived in this region?
- ○ Less than one year
- ○ 1-3 years
- ○ 3-7 years
- ○ 7-14 years
- ○ 14+ years
- ○ Prefer not to answer

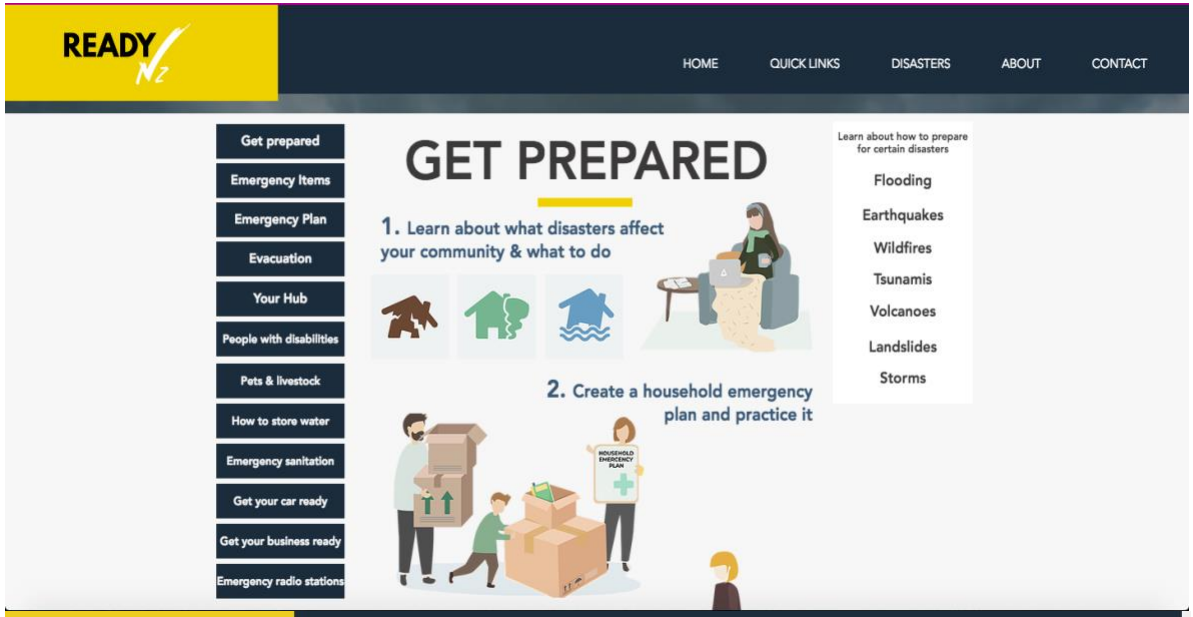
Which best describes your home ownership?
- ○ Prefer not to answer
- ○ I own or partly own my home
- ○ I do not own my home (ex. rent)
- ○ Other

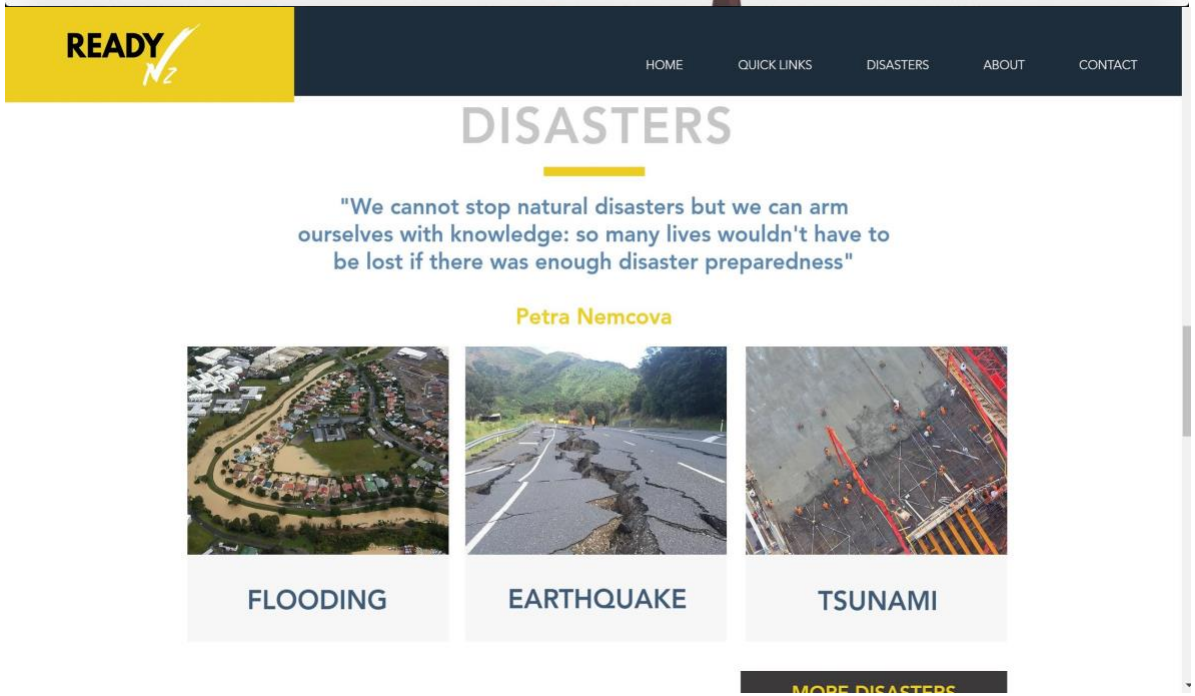
Thank you for taking our survey! If you'd like to learn more about flooding, and our project email
GrWPIwhetu@wpi.edu

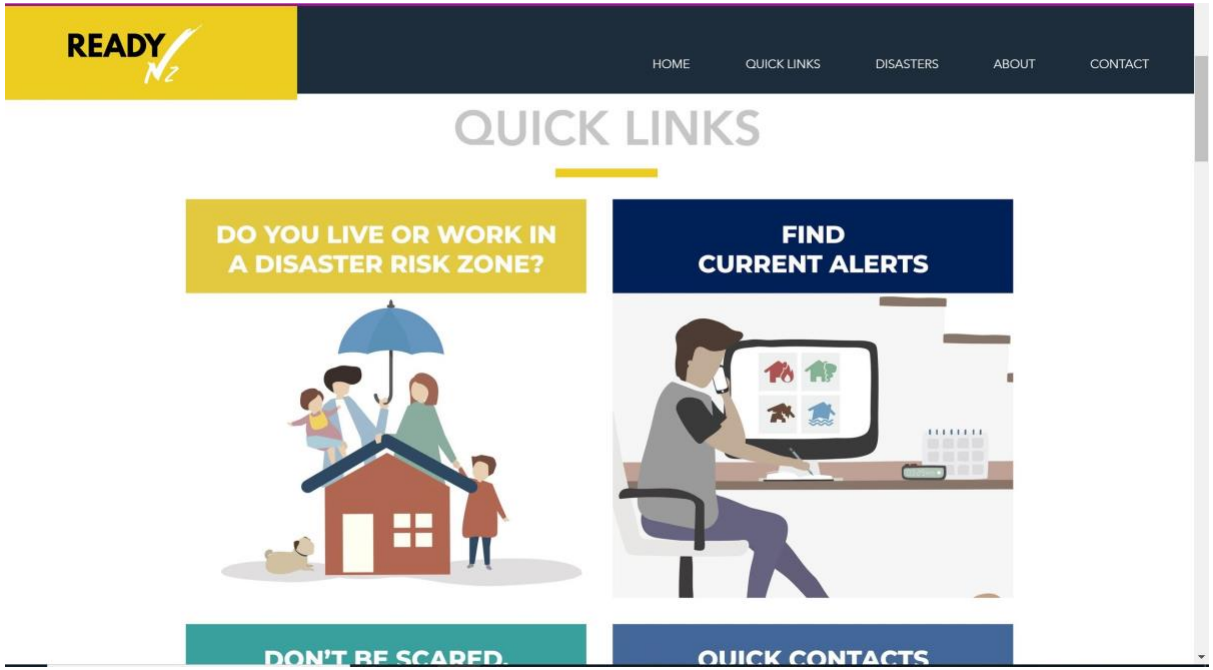
Appendix B - One-Stop Shop Mock-up






READY NZ
HOME
QUICK LINKS
DISASTERS
ABOUT
CONTACT
Get prepared
Emergency Items
Emergency Plan
Evacuation
Your Hub
People with disabilities
Pets & livestock
How to store water
Emergency sanitation
Get your car ready
Get your business ready
Emergency radio stations
GET PREPARED
1. Learn about what disasters affect your community & what to do
2. Create a household emergency plan and practice it
Learn about how to prepare for certain disasters
Flooding
Earthquakes
Wildfires
Tsunamis
Volcanoes
Landslides
Storms


READY NZ
HOME
QUICK LINKS
DISASTERS
ABOUT
CONTACT
DISASTERS
"We cannot stop natural disasters but we can arm ourselves with knowledge: so many lives wouldn't have to be lost if there was enough disaster preparedness"
Petra Nemcova
FLOODING
EARTHQUAKE
TSUNAMI


READY NZ
HOME
QUICK LINKS
DISASTERS
ABOUT
CONTACT
QUICK LINKS
DO YOU LIVE OR WORK IN A DISASTER RISK ZONE?
FIND CURRENT ALERTS
DON'T BE SCARED.
QUICK CONTACTS

QUICK LINKS

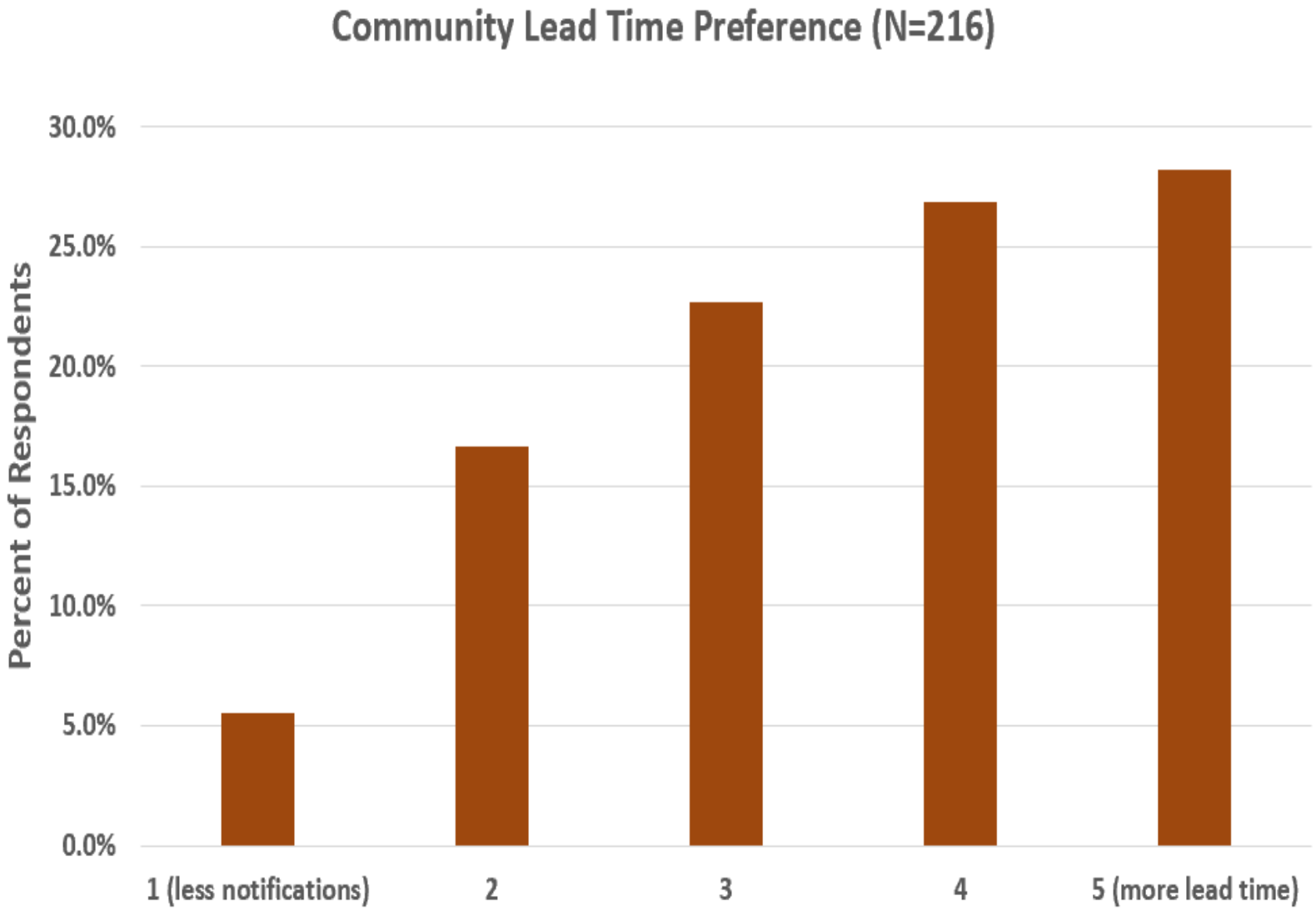
DO YOU LIVE OR WORK IN A DISASTER RISK ZONE?

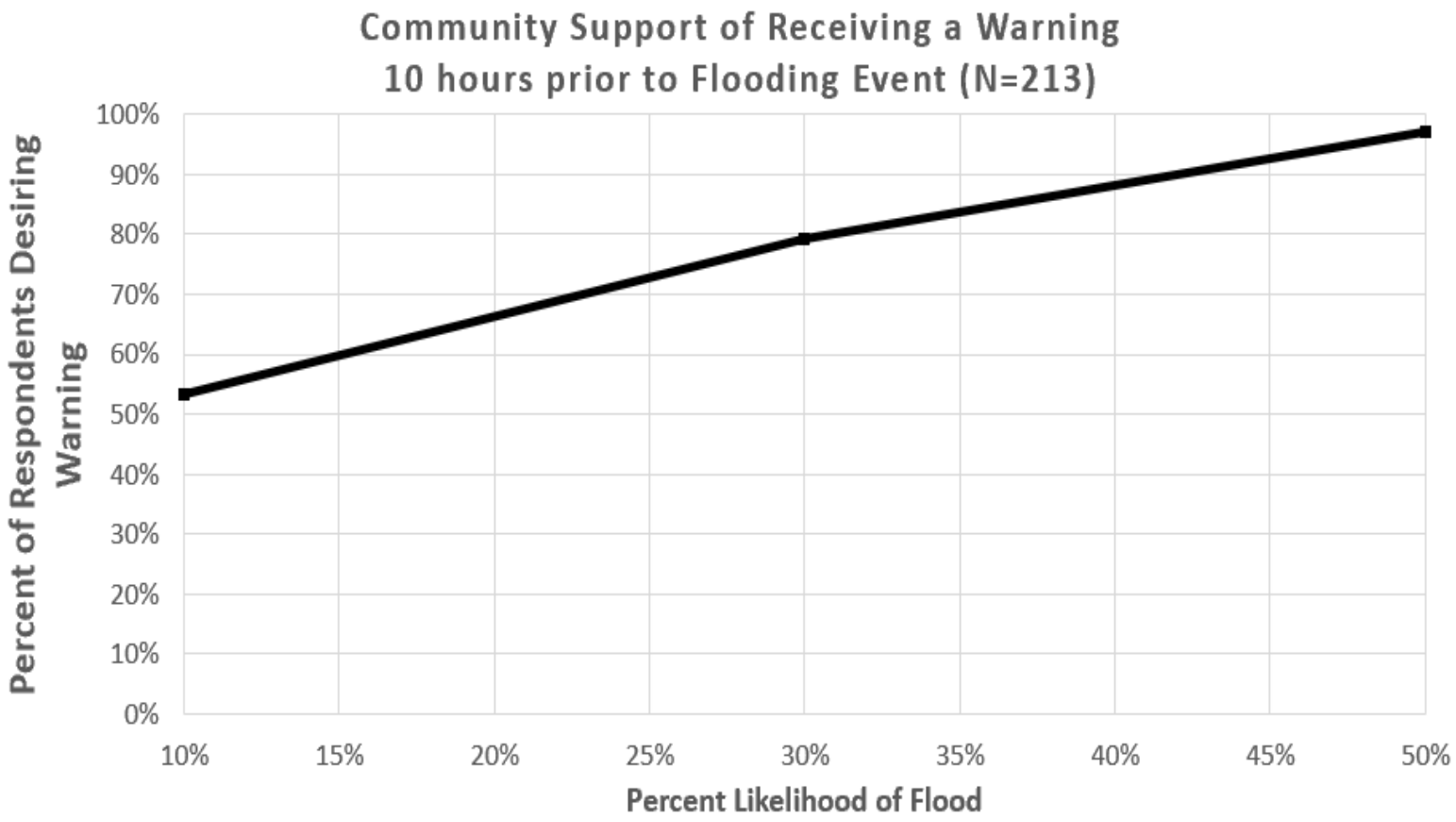
FIND CURRENT ALERTS

DON'T BE SCARED. BE PREPARED.

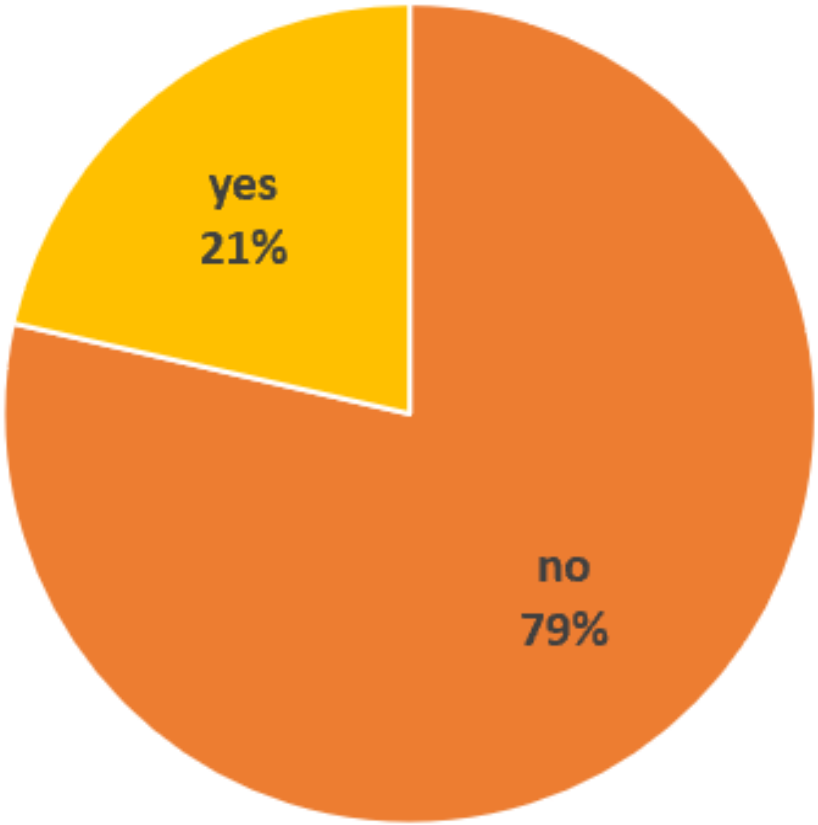
QUICK CONTACTS FOR CONCERNS

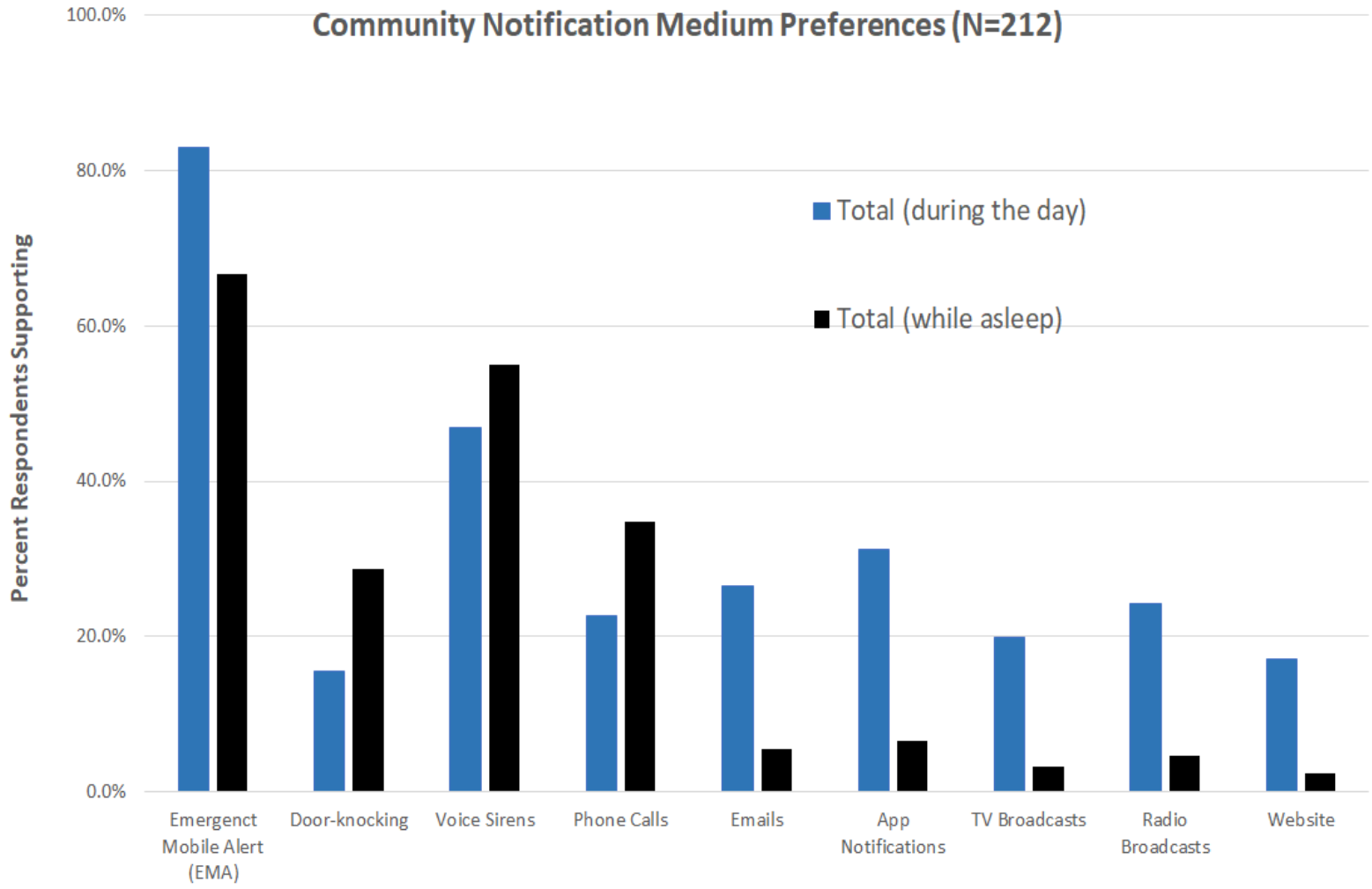
Appendix C - Communication Data

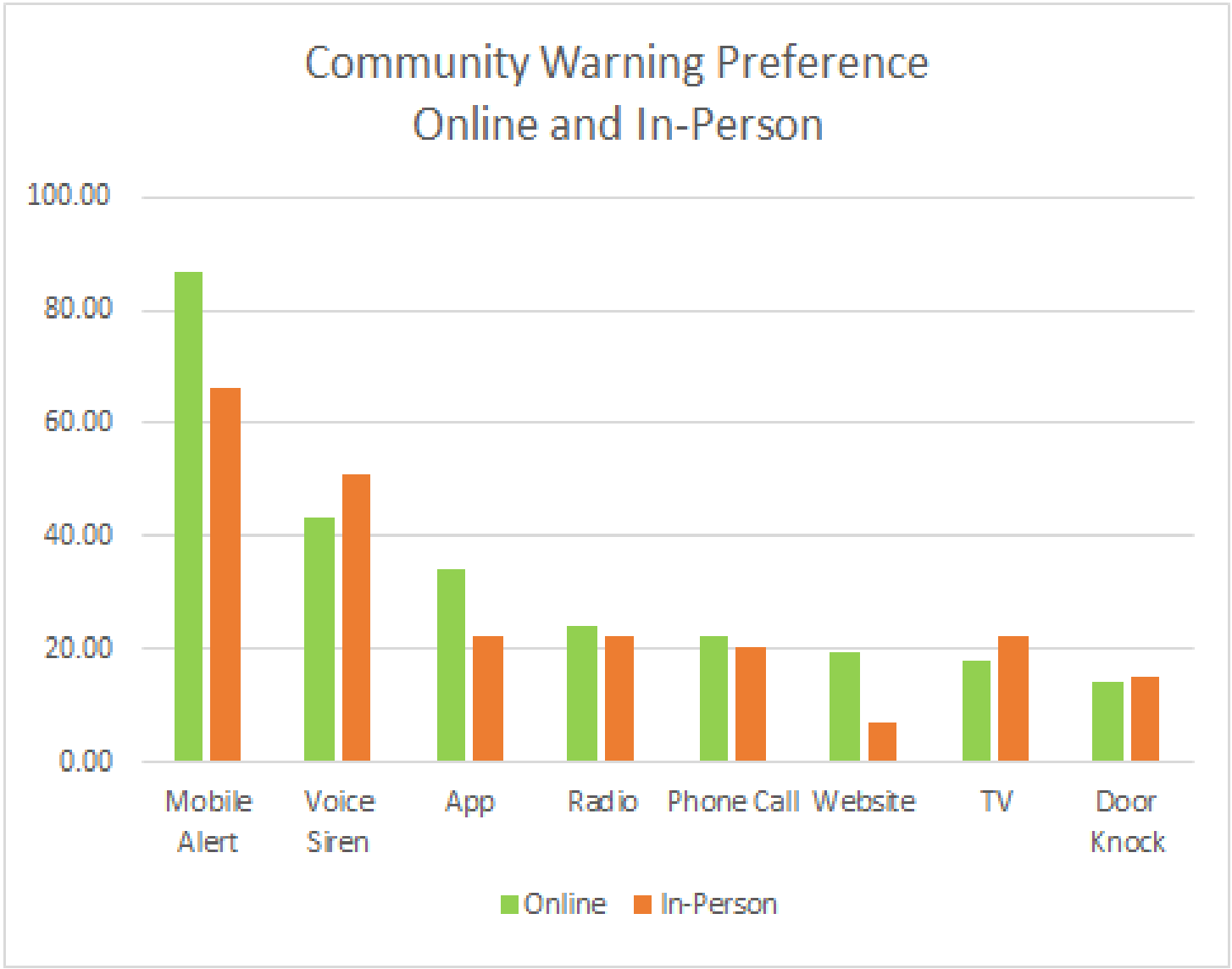


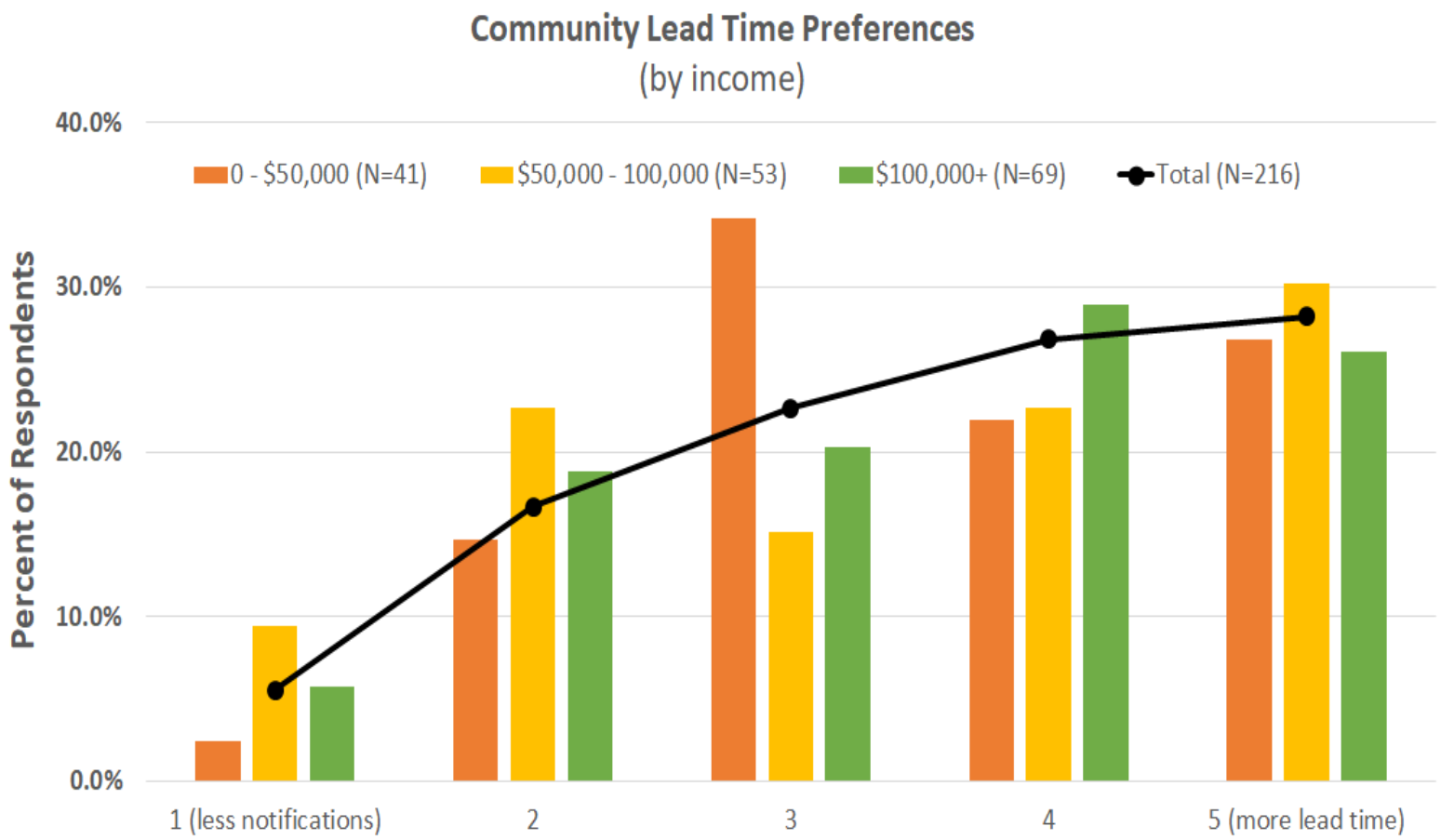

Community Support of Receiving a Warning
10 hours prior to Flooding Event (N=213)
Percent of Respondents Desiring Warning
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
10%
15%
20%
25%
30%
35%
40%
45%
50%
Percent Likelihood of Flood

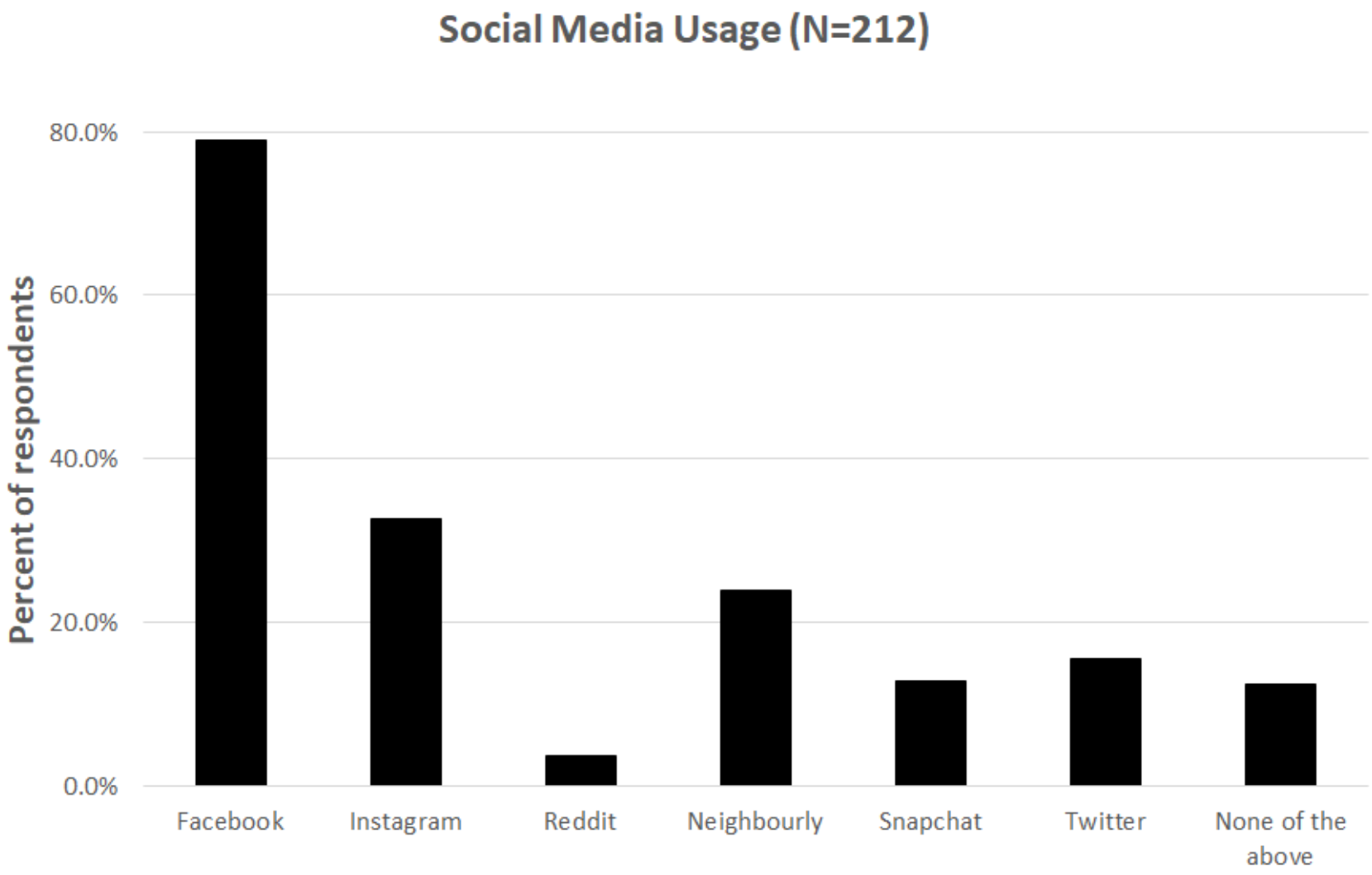
Have You Received a Warning Before? (N=219)

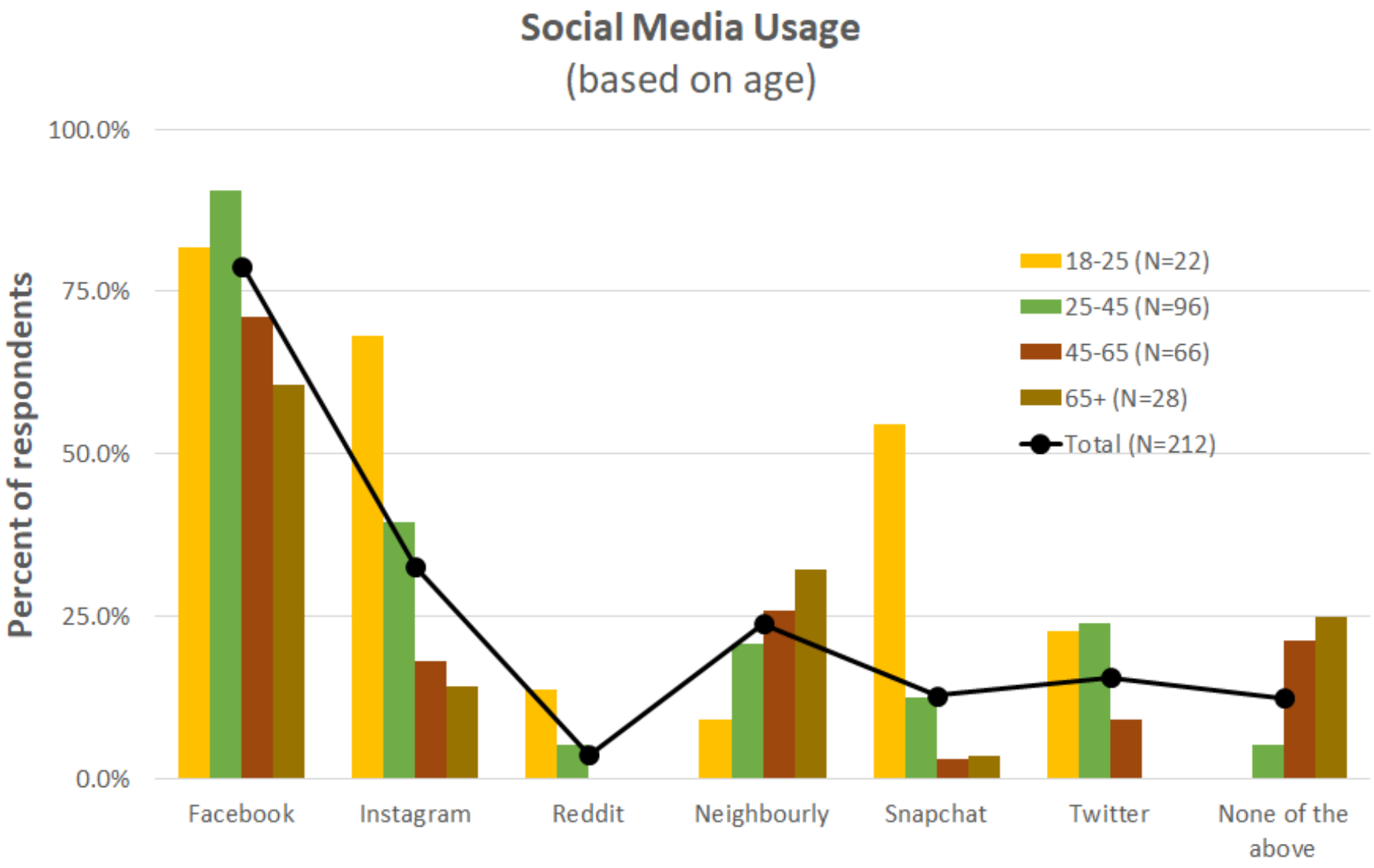


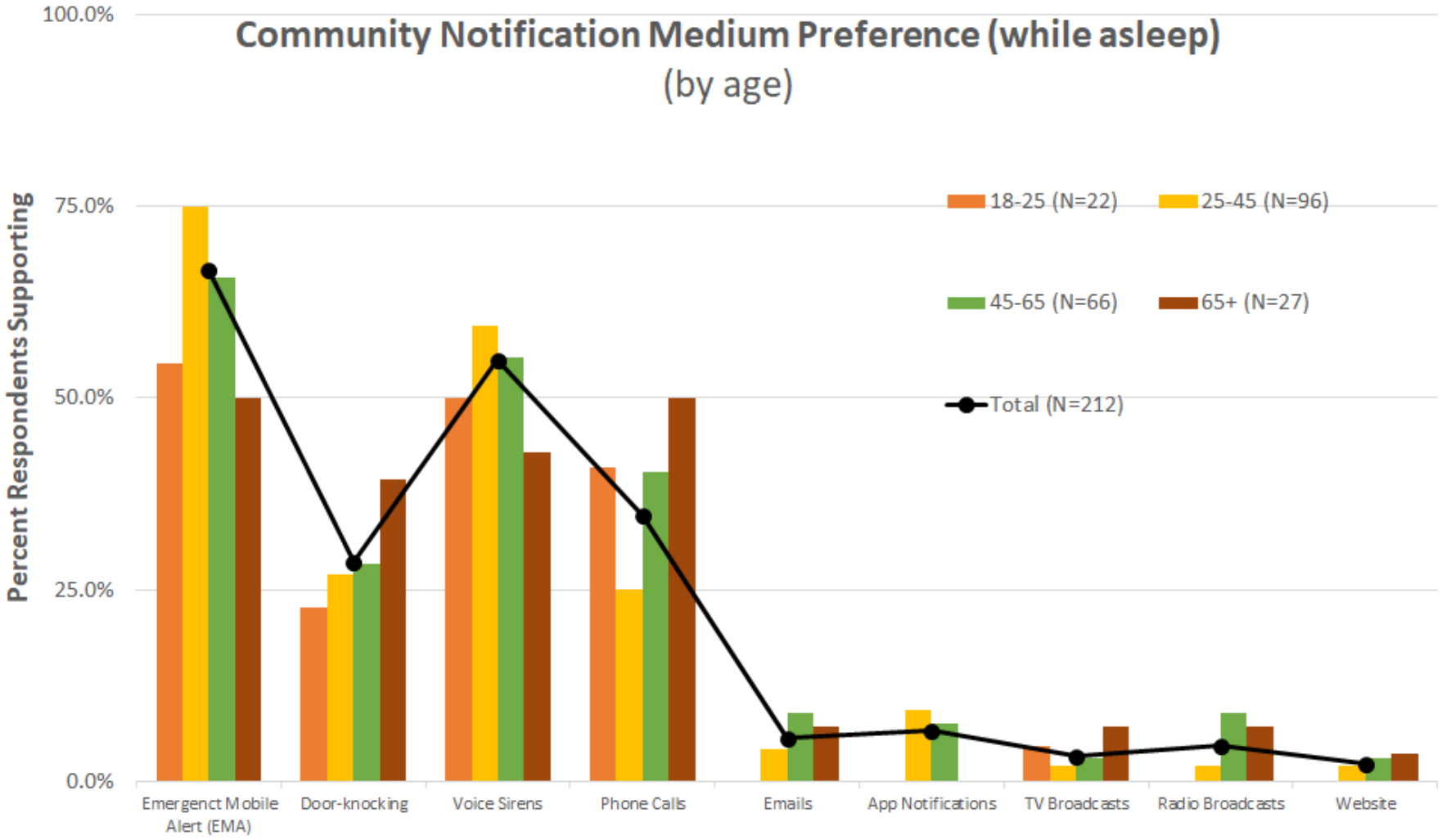

Community Notification Medium Preferences (N=212)
Percent Respondents Supporting
100.0%
80.0%
60.0%
40.0%
20.0%
0.0%
Total (during the day)
Total (while asleep)
Emergenct Mobile Alert (EMA)
Door-knocking
Voice Sirens
Phone Calls
Emails
App Notifications
TV Broadcasts
Radio Broadcasts
Website

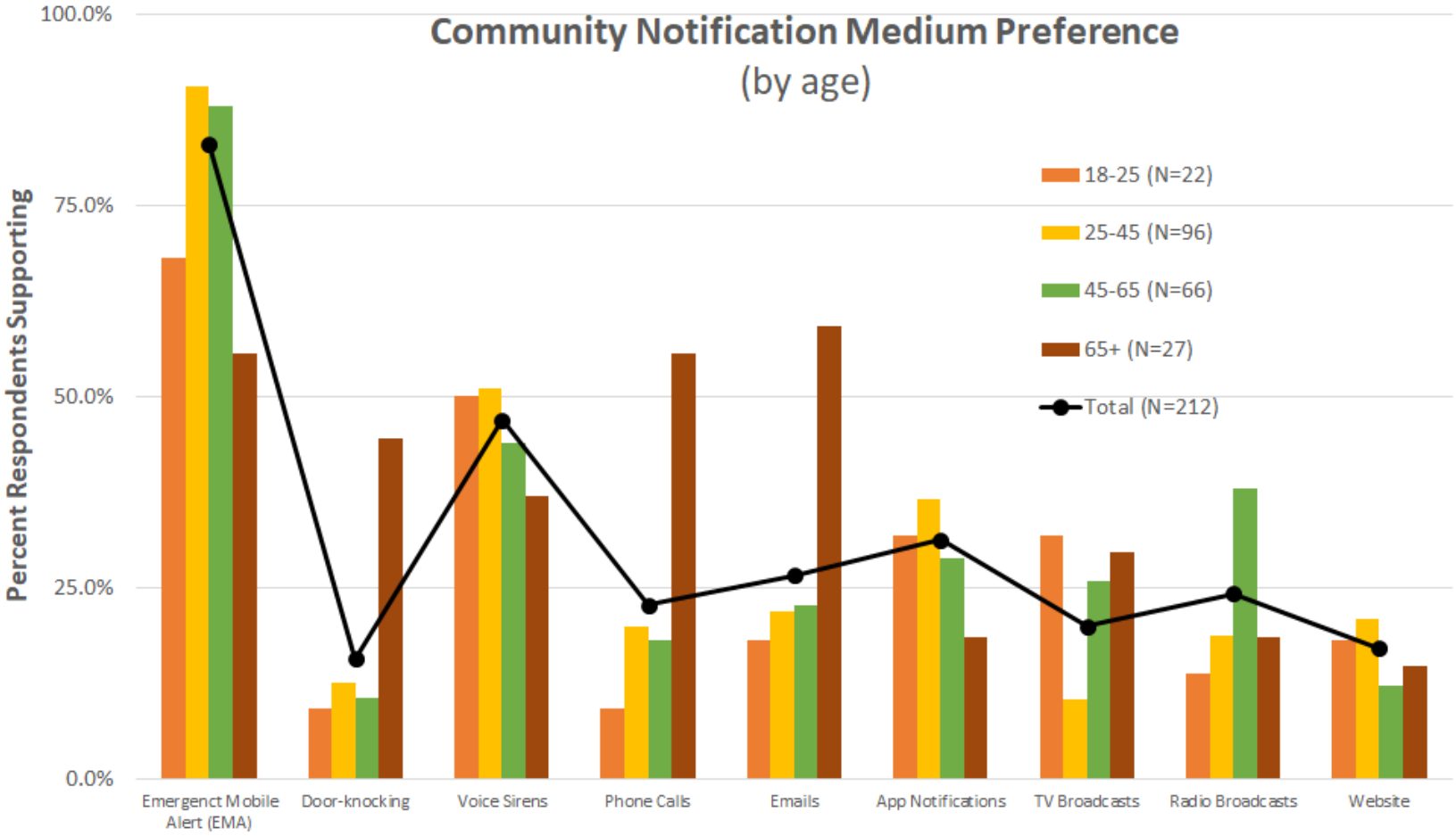

Community Warning Preference
Online and In-Person
100.00
80.00
60.00
40.00
20.00
0.00
Mobile Alert
Voice Siren
App
Radio
Phone Call
Website
TV
Door Knock
Online
In-Person


Community Lead Time Preferences
(by income)
40.0%
30.0%
20.0%
10.0%
0.0%
Percent of Respondents
0 - $50,000 (N=41)
$50,000 - 100,000 (N=53)
$100,000+ (N=69)
Total (N=216)
1 (less notifications)
2
3
4
5 (more lead time)

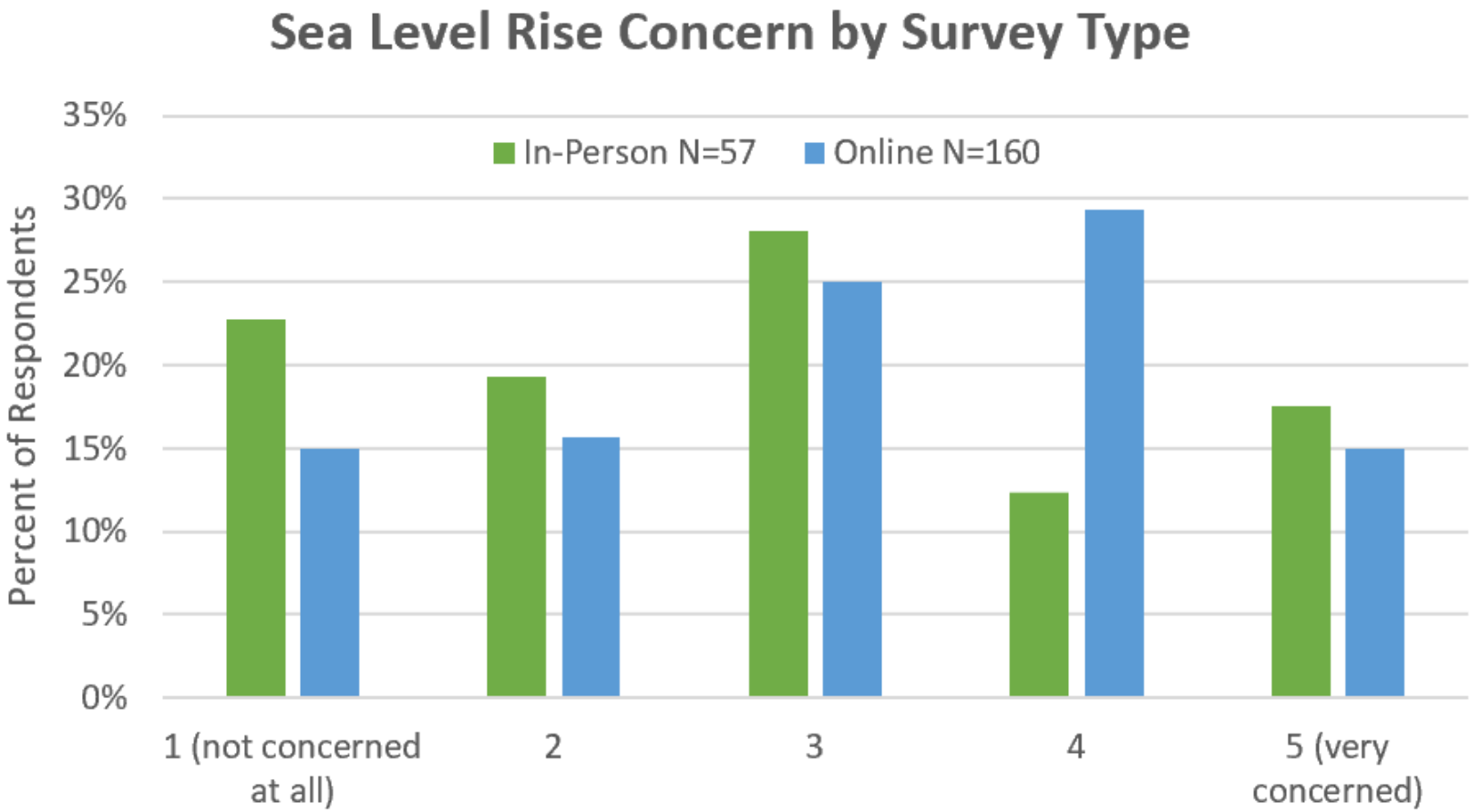

Social Media Usage (N=212)
Percent of respondents
80.0%
60.0%
40.0%
20.0%
0.0%
Facebook
Instagram
Reddit
Neighbourly
Snapchat
Twitter
None of the above

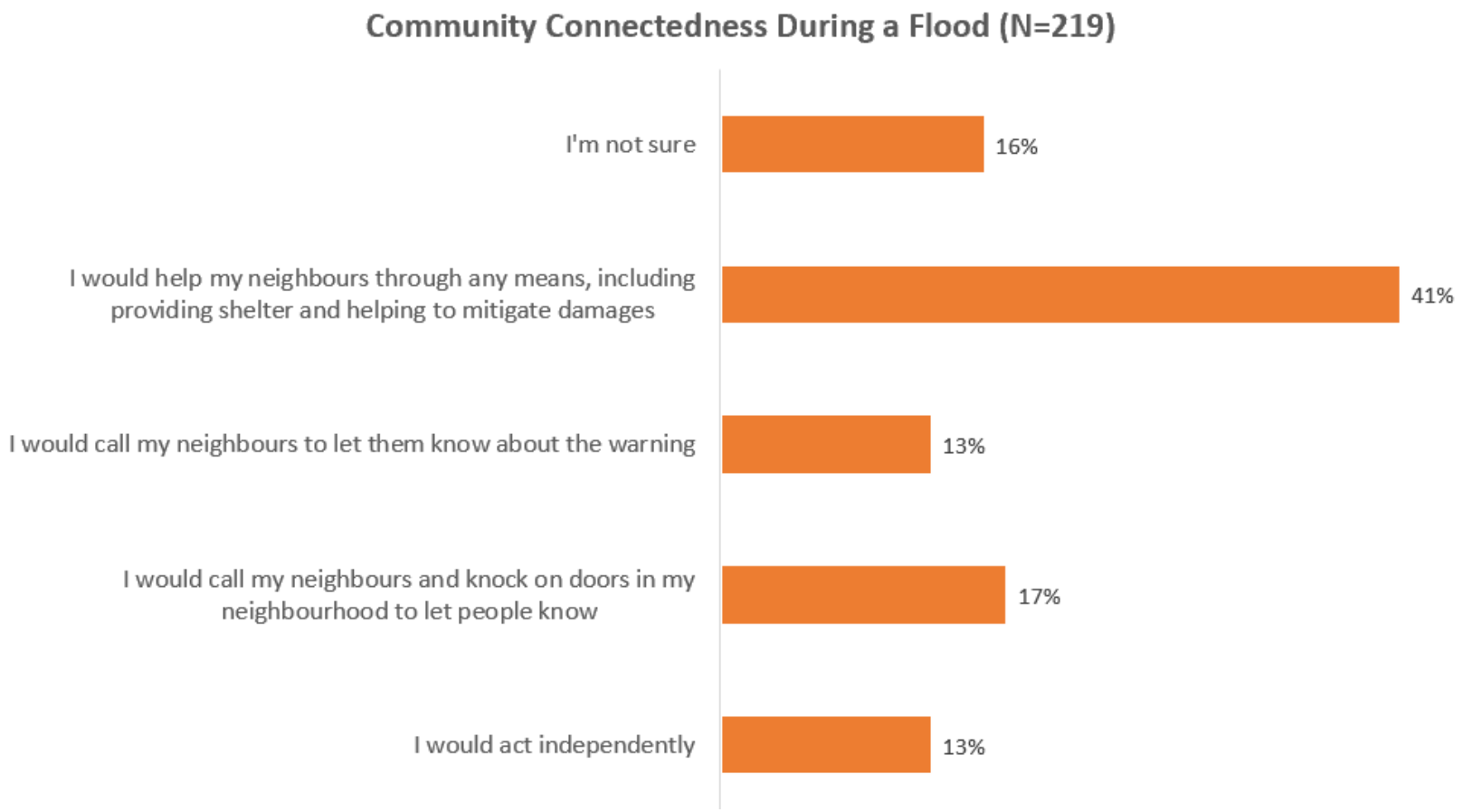

Social Media Usage
(based on age)
Percent of respondents
100.0%
75.0%
50.0%
25.0%
0.0%
18-25 (N=22)
25-45 (N=96)
45-65 (N=66)
65+ (N=28)
Total (N=212)
Facebook
Instagram
Reddit
Neighbourly
Snapchat
Twitter
None of the above

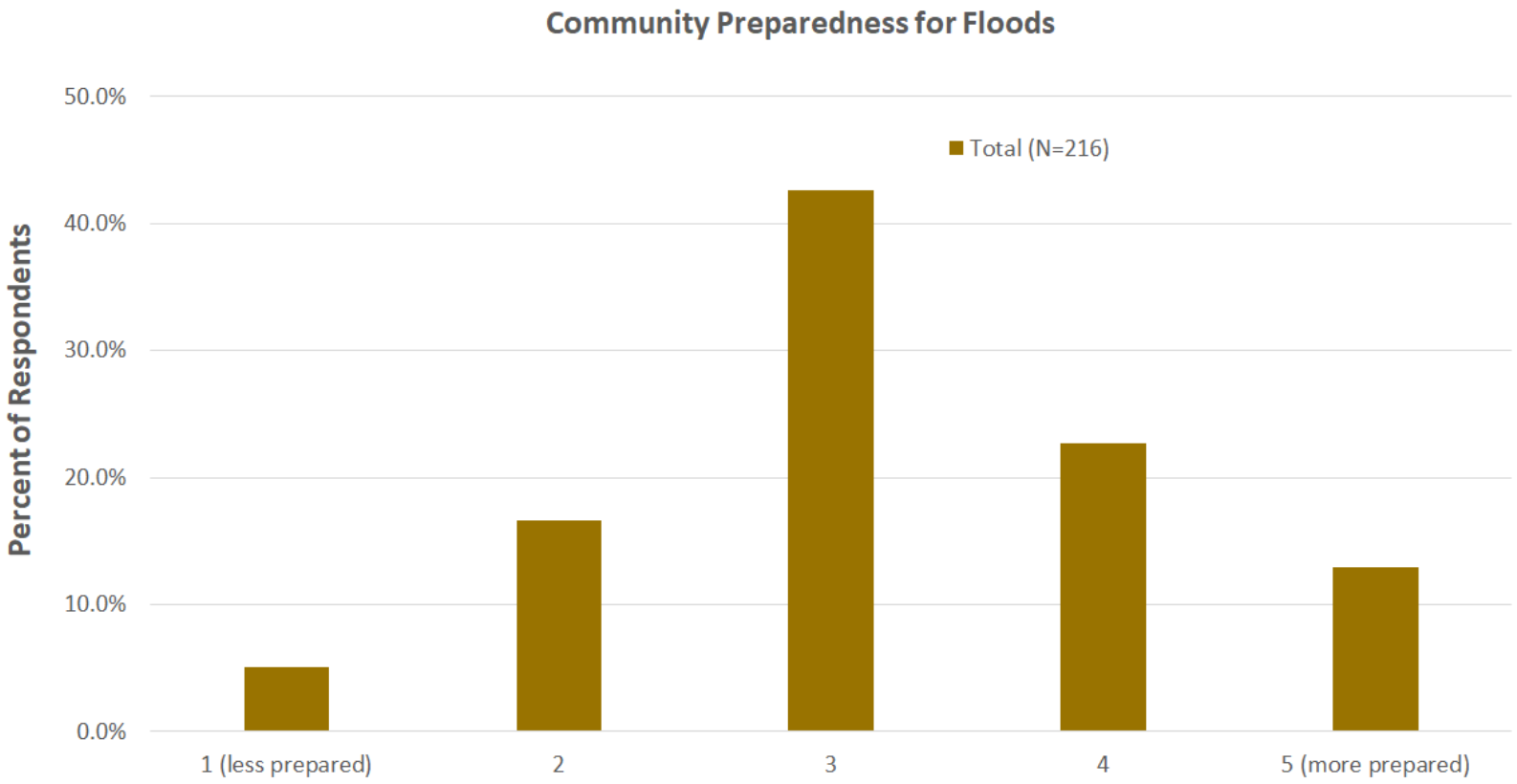

Community Notification Medium Preference (while asleep)
(by age)
Percent Respondents Supporting
100.0%
75.0%
50.0%
25.0%
0.0%
18-25 (N=22)
25-45 (N=96)
45-65 (N=66)
65+ (N=27)
Total (N=212)
Emergenct Mobile Alert (EMA)
Door-knocking
Voice Sirens
Phone Calls
Emails
App Notifications
TV Broadcasts
Radio Broadcasts
Website

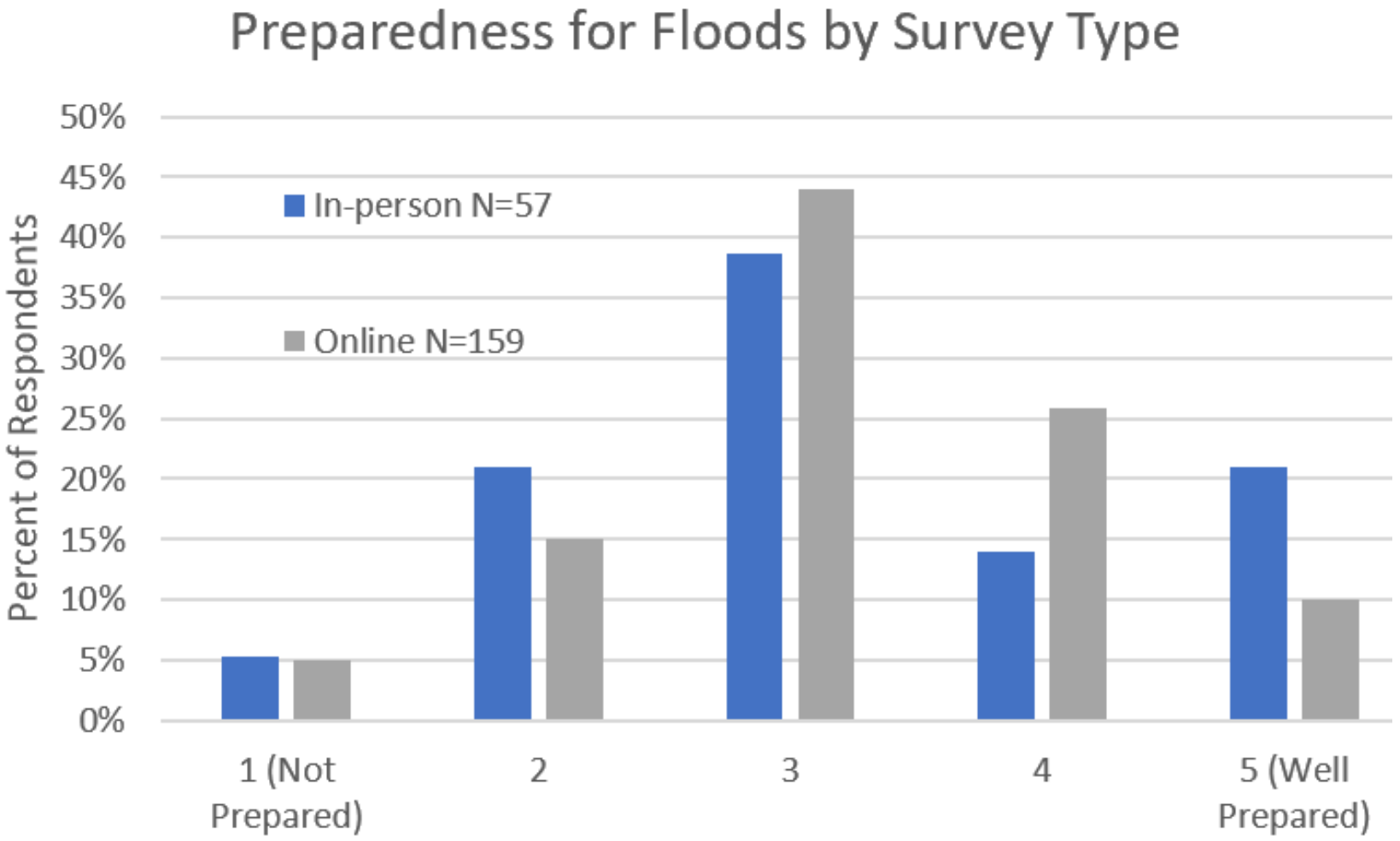

Community Notification Medium Preference
(by age)
Percent Respondents Supporting
100.0%
75.0%
50.0%
25.0%
0.0%
18-25 (N=22)
25-45 (N=96)
45-65 (N=66)
65+ (N=27)
Total (N=212)
Emergenct Mobile Alert (EMA)
Door-knocking
Voice Sirens
Phone Calls
Emails
App Notifications
TV Broadcasts
Radio Broadcasts
Website

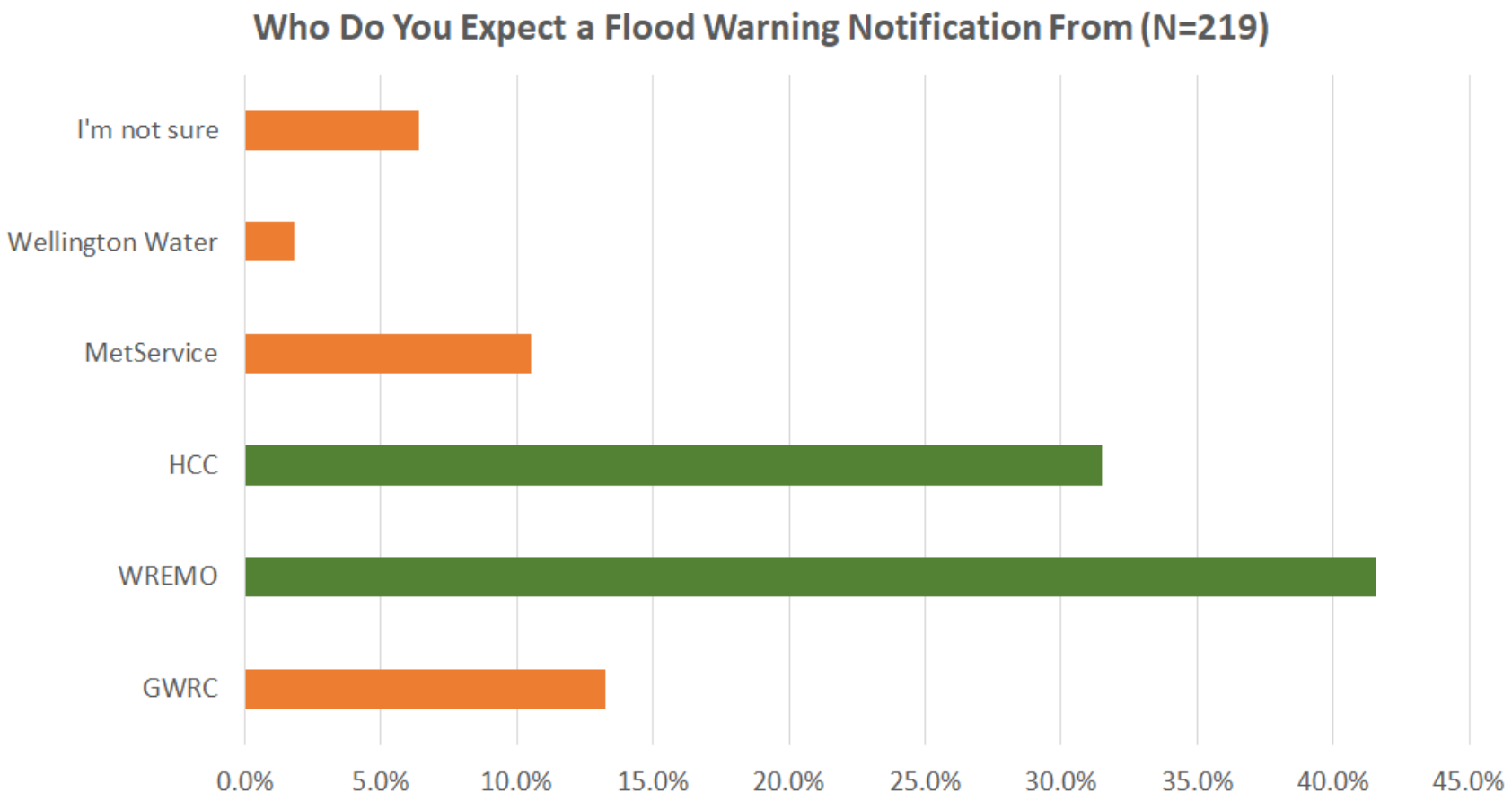
Appendix D - Preparedness and Awareness Data

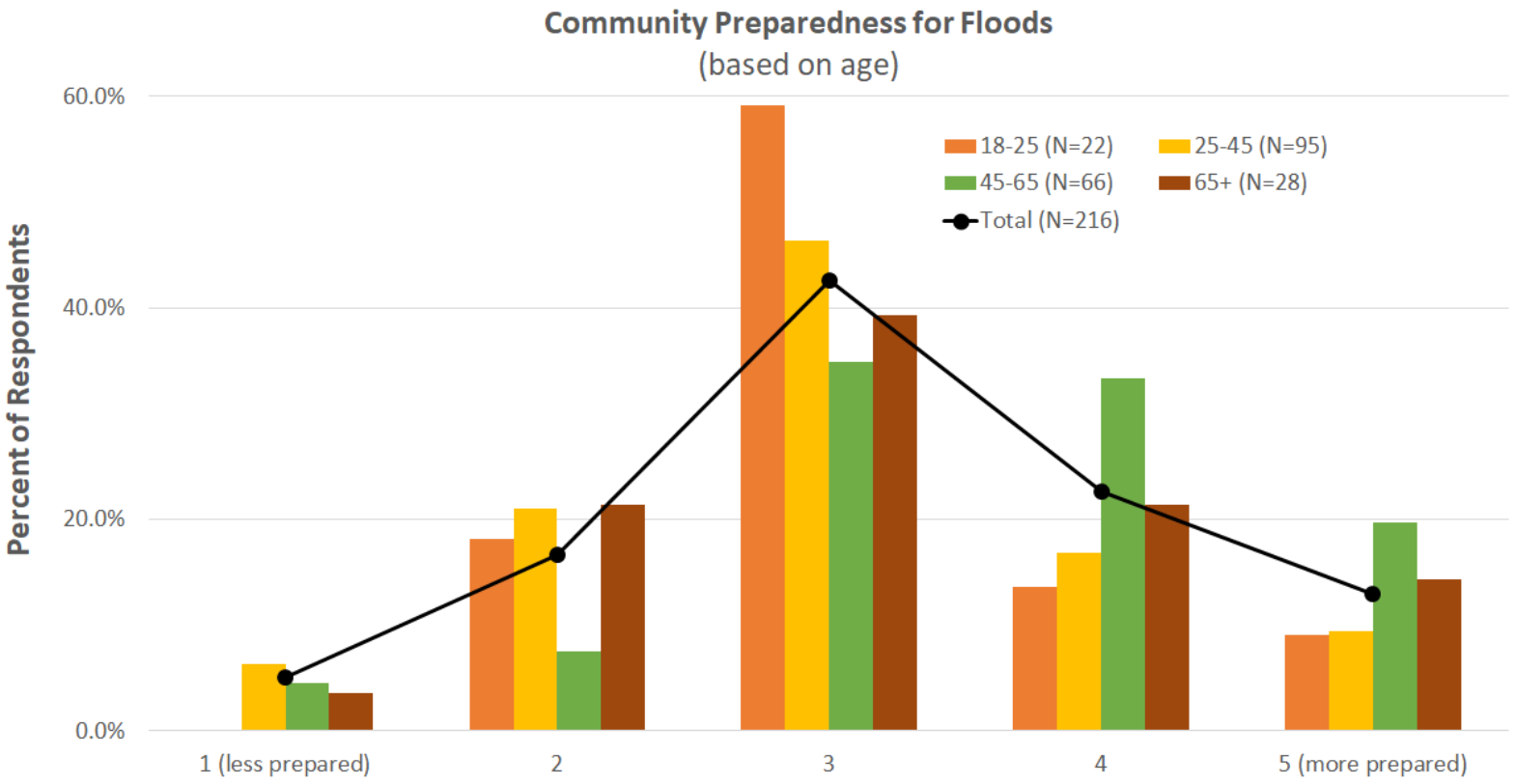

Sea Level Rise Concern by Survey Type
In-Person N=57
Online N=160
Percent of Respondents
35%
30%
25%
20%
15%
10%
5%
0%
1 (not concerned at all)
2
3
4
5 (very concerned)

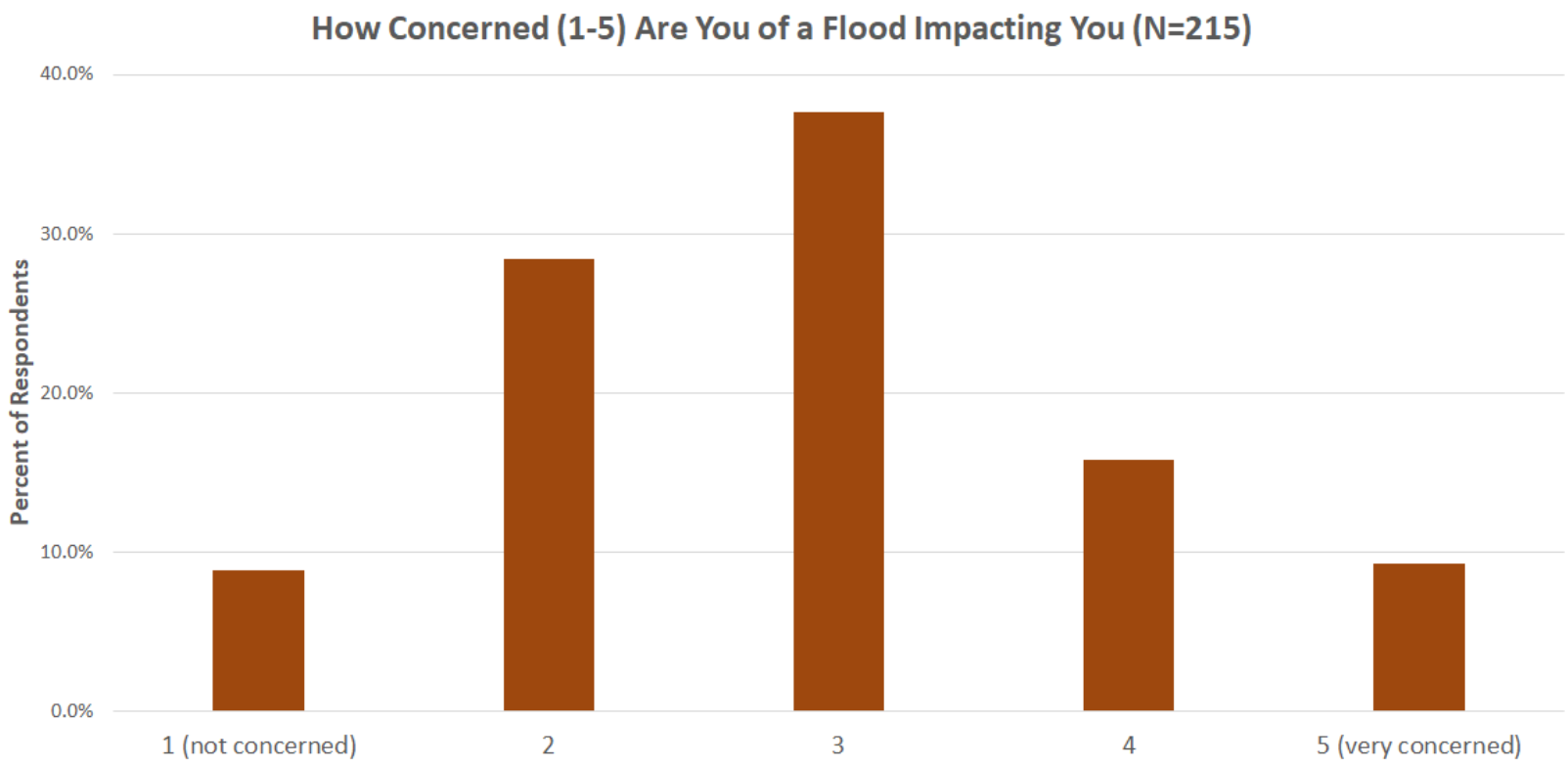

Community Connectedness During a Flood (N=219)
I'm not sure
16%
I would help my neighbours through any means, including providing shelter and helping to mitigate damages
41%
I would call my neighbours to let them know about the warning
13%
I would call my neighbours and knock on doors in my neighbourhood to let people know
17%
I would act independently
13%

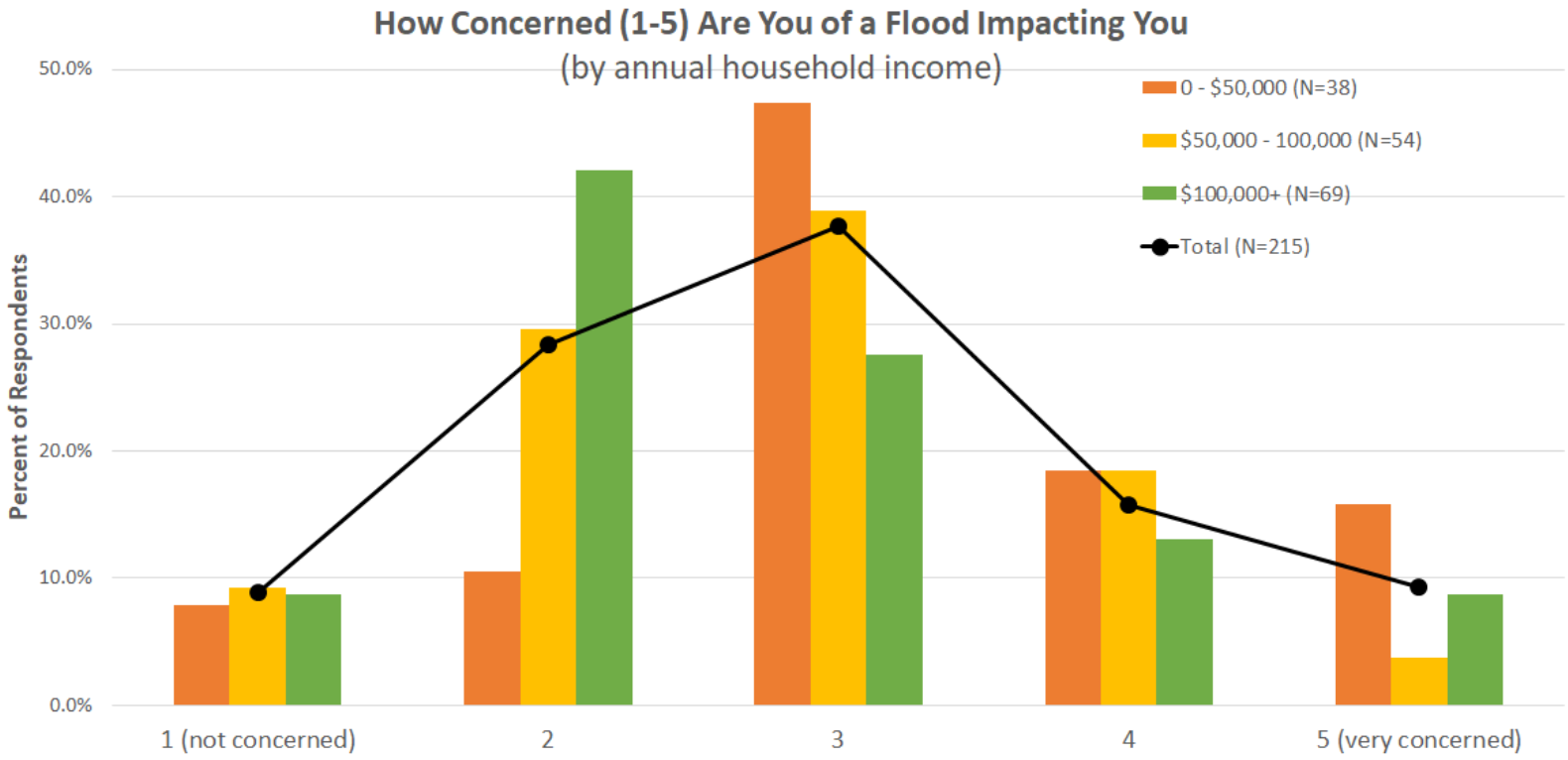

Community Preparedness for Floods
Percent of Respondents
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
Total (N=216)
1 (less prepared)
2
3
4
5 (more prepared)

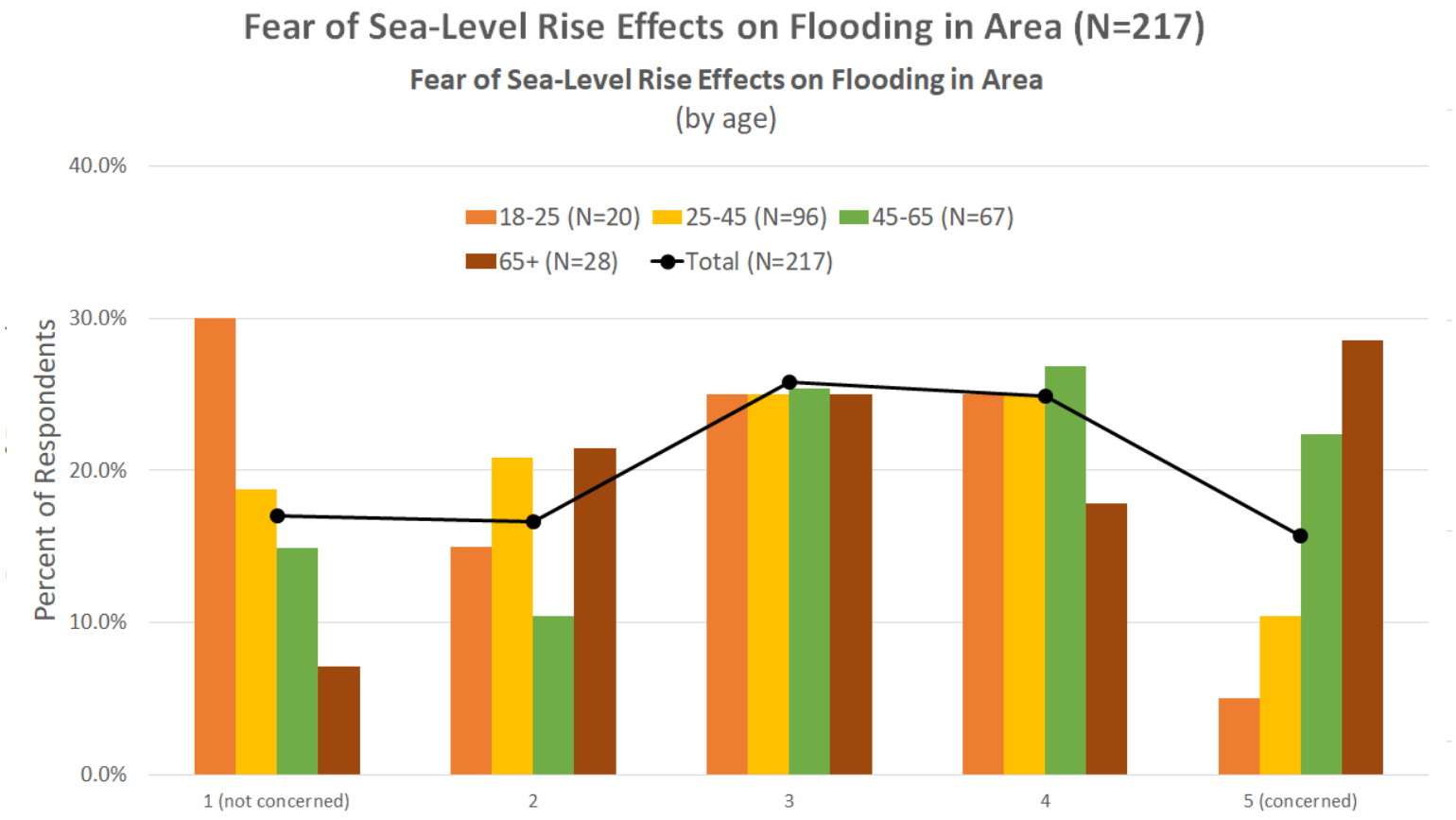

Preparedness for Floods by Survey Type
Percent of Respondents
50%
45%
40%
35%
30%
25%
20%
15%
10%
5%
0%
In-person N=57
Online N=159
1 (Not Prepared)
2
3
4
5 (Well Prepared)


Who Do You Expect a Flood Warning Notification From (N=219)
I'm not sure
Wellington Water
MetService
HCC
WREMO
GWRC
0.0%
5.0%
10.0%
15.0%
20.0%
25.0%
30.0%
35.0%
40.0%
45.0%

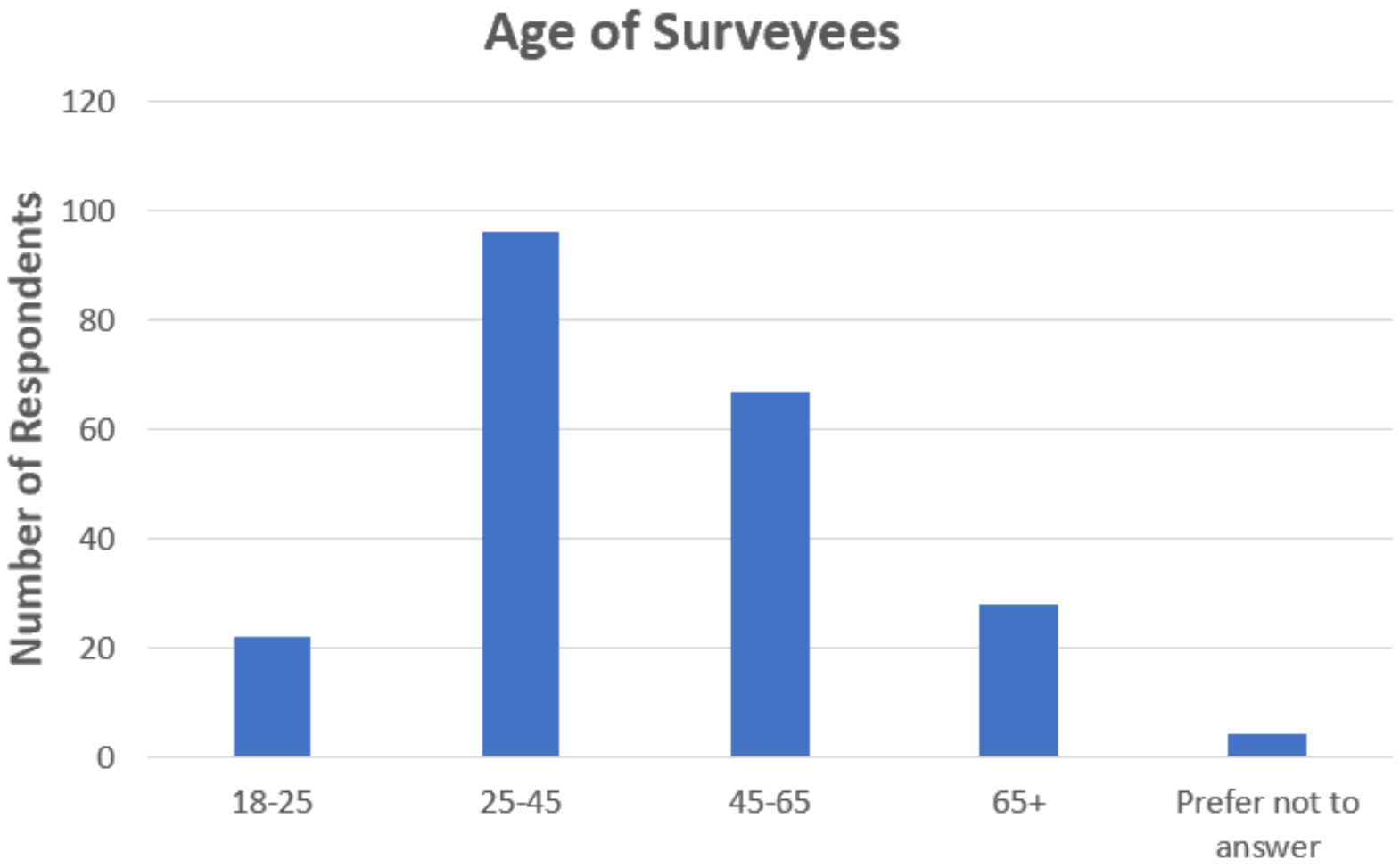

Community Preparedness for Floods
(based on age)
Percent of Respondents
60.0%
40.0%
20.0%
0.0%
18-25 (N=22)
25-45 (N=95)
45-65 (N=66)
65+ (N=28)
Total (N=216)
1 (less prepared)
2
3
4
5 (more prepared)

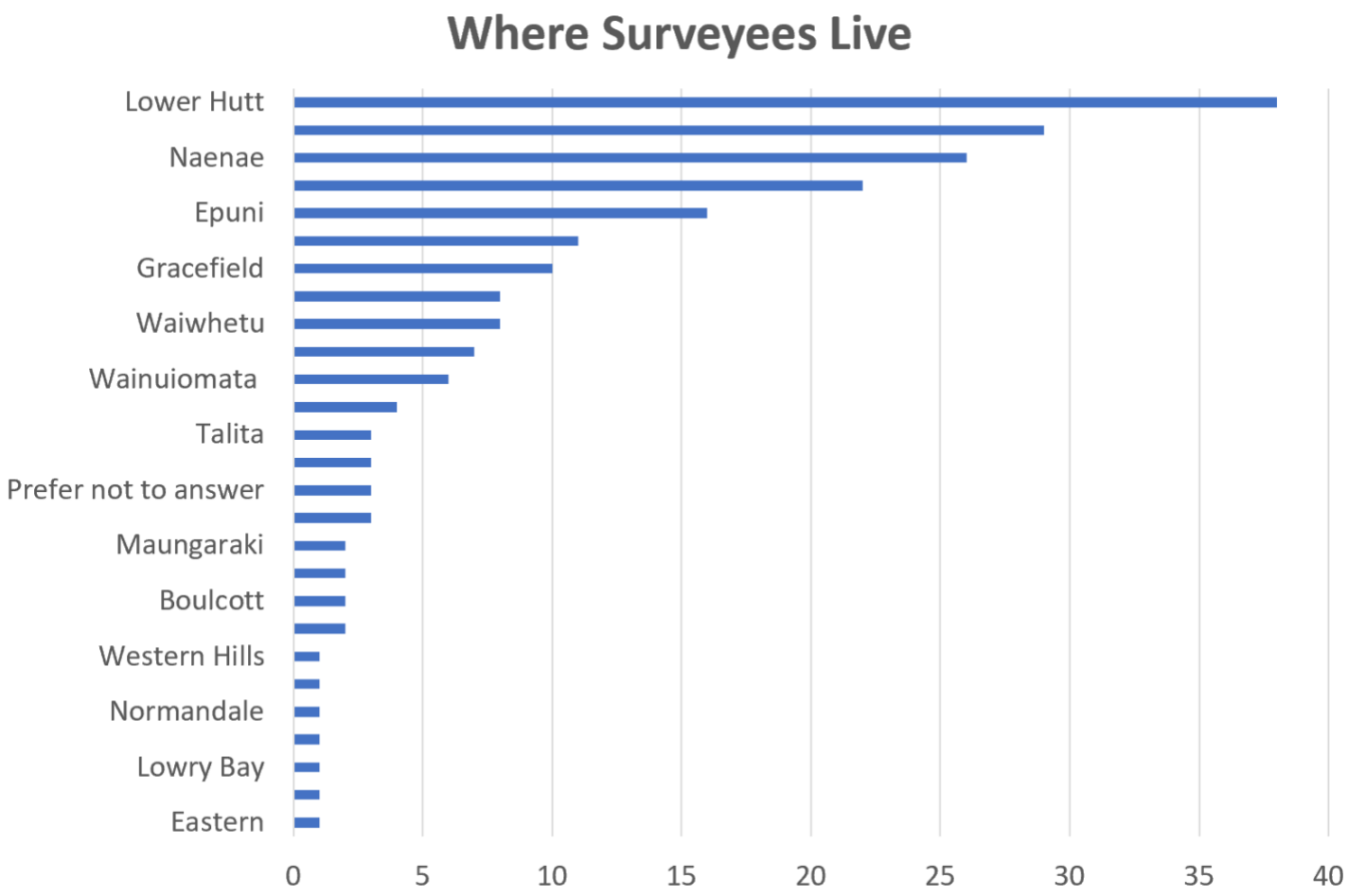

How Concerned (1-5) Are You of a Flood Impacting You (N=215)
Percent of Respondents
40.0%
30.0%
20.0%
10.0%
0.0%
1 (not concerned)
2
3
4
5 (very concerned)

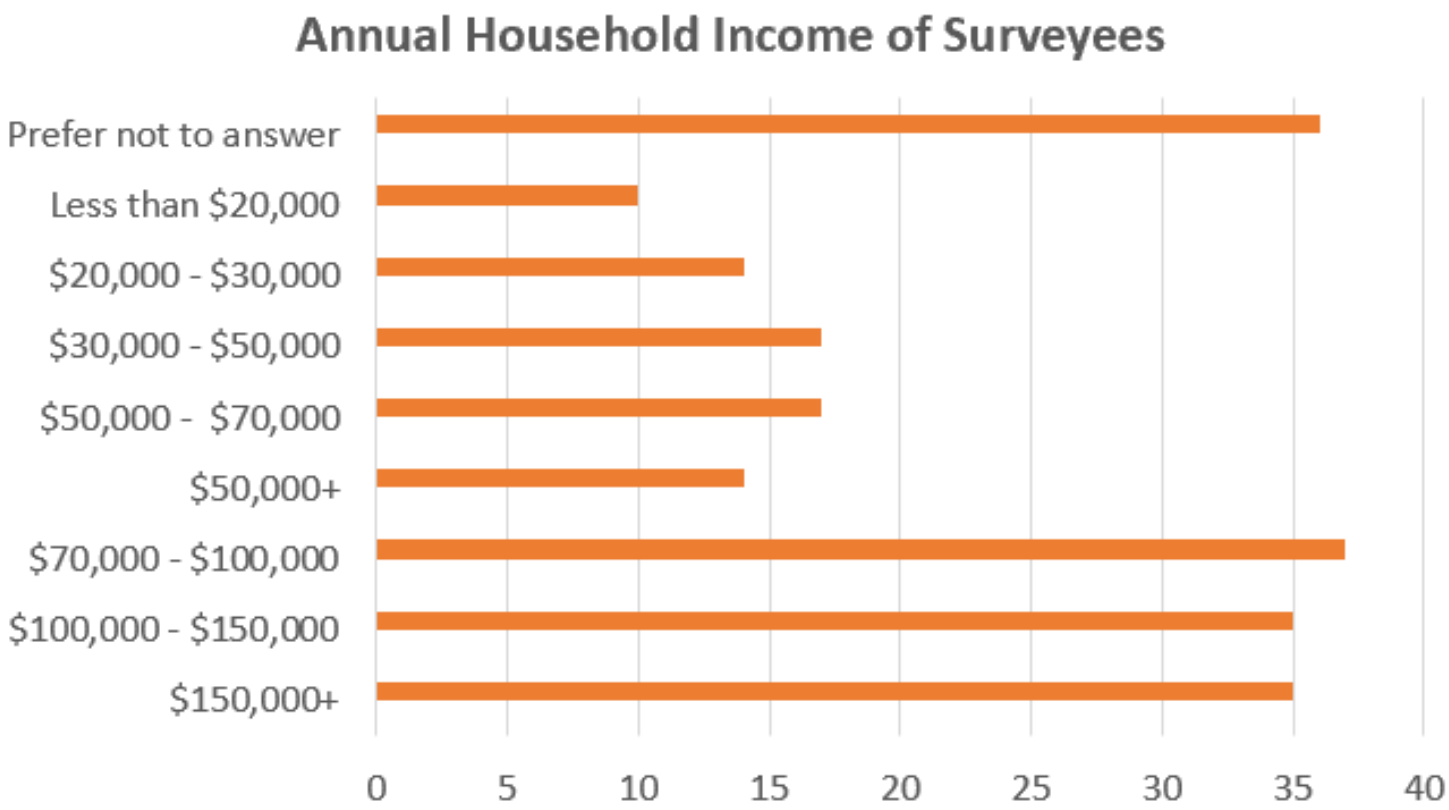

How Concerned (1-5) Are You of a Flood Impacting You
(by annual household income)
Percent of Respondents
50.0%
40.0%
30.0%
20.0%
10.0%
0.0%
0 - $50,000 (N=38)
$50,000 - 100,000 (N=54)
$100,000+ (N=69)
Total (N=215)
1 (not concerned)
2
3
4
5 (very concerned)

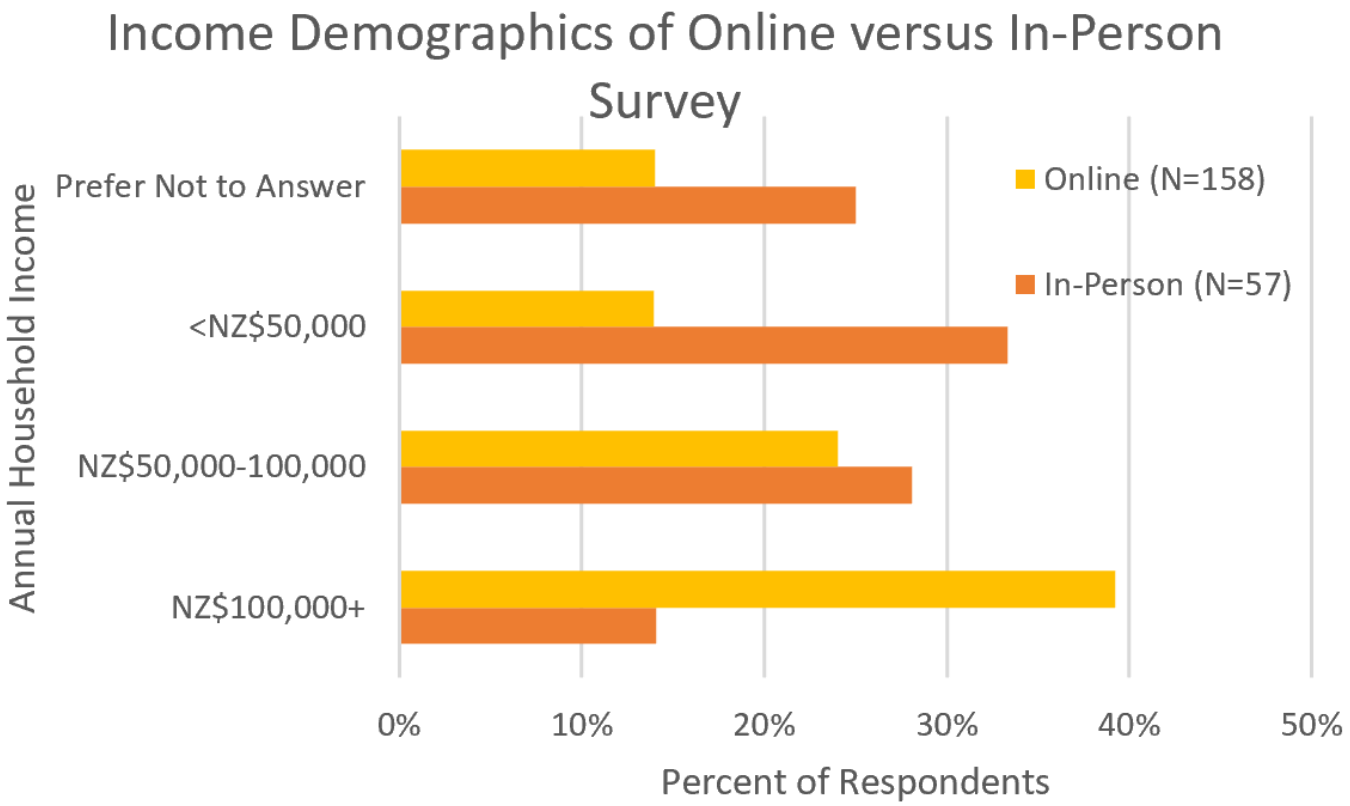

Fear of Sea-Level Rise Effects on Flooding in Area (N=217)
Fear of Sea-Level Rise Effects on Flooding in Area
(by age)
40.0%
30.0%
20.0%
10.0%
0.0%
Percent of Respondents
18-25 (N=20)
25-45 (N=96)
45-65 (N=67)
65+ (N=28)
Total (N=217)
1 (not concerned)
2
3
4
5 (concerned)

Appendix E - Demographics of Surveys

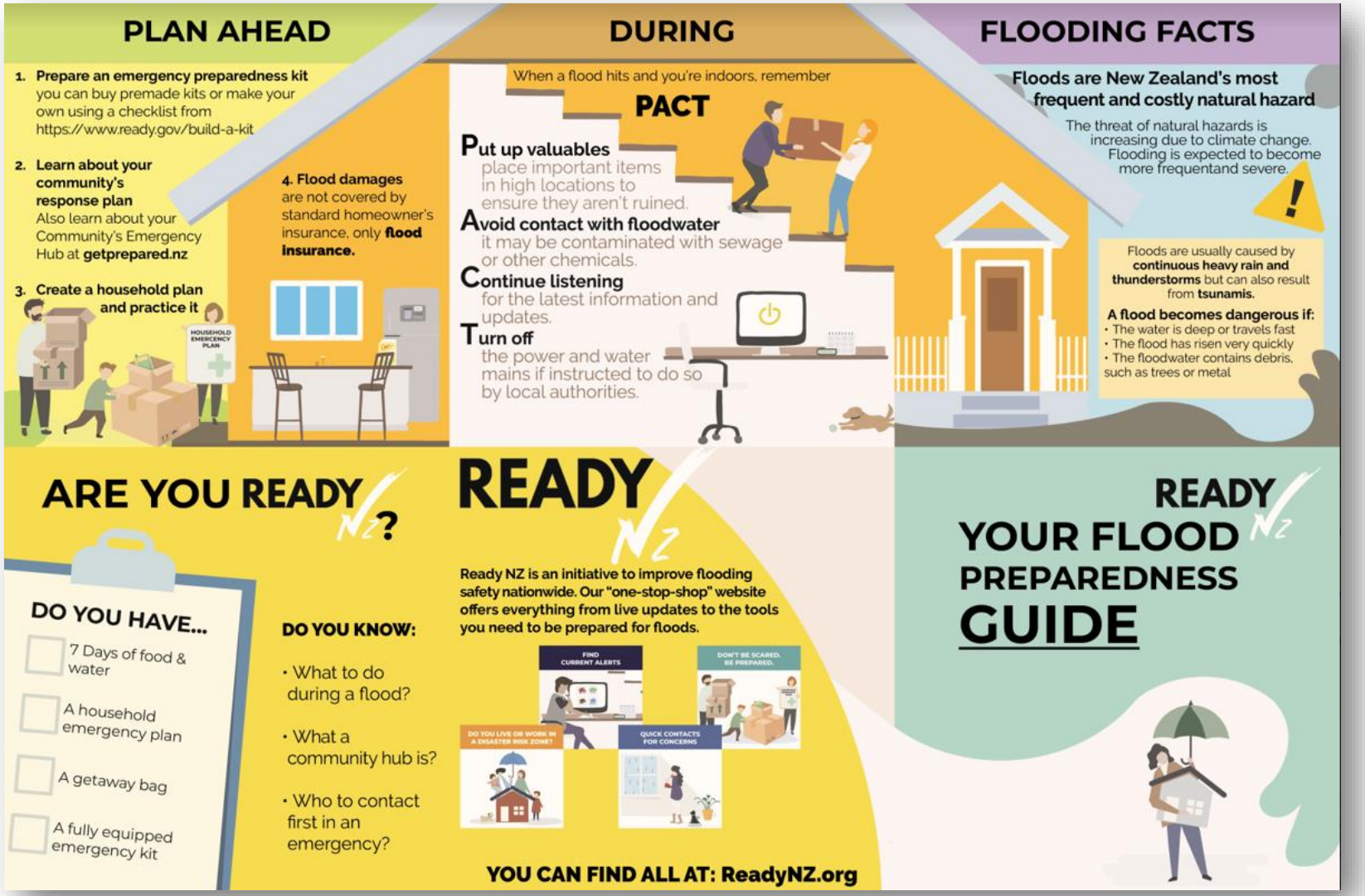



Where Surveyees Live
Lower Hutt
Naenae
Epuni
Gracefield
Waiwhetu
Wainuiomata
Talita
Prefer not to answer
Maungaraki
Boulcott
Western Hills
Normandale
Lowry Bay
Eastern
0
5
10
15
20
25
30
35
40


Annual Household Income of Surveyees
Prefer not to answer
Less than $20,000
$20,000 - $30,000
$30,000 - $50,000
$50,000 - $70,000
$50,000+
$70,000 - $100,000
$100,000 - $150,000
$150,000+
0
5
10
15
20
25
30
35
40


Income Demographics of Online versus In-Person Survey
Annual Household Income
Prefer Not to Answer
<NZ$50,000
NZ$50,000-100,000
NZ$100,000+
Online (N=158)
In-Person (N=57)
0%
10%
20%
30%
40%
50%
Percent of Respondents

Appendix F - Pamphlet




What to know
After a large flood, you might not be able to use your phone, send an email or use social media. Plan now for when you can't communicate.
Keep your children safe
Schools have plans to keep your kids safe.
Agree on a safe meeting place
Sort out home and contents insurance
Know your risk zone
getprepared.nz/FloodZone
Community
Meet your neighbours
Most people are rescued by the people who are there at the time. Your neighbours are your first and best source of support.
getprepared.nz/Neighbours
What to do
During a flood:
· Listen to the civil defense
· Call 111 if youre in real trouble
· Call the local police for non-emergency
· Put up valuables if time allows
· Check with your neighbours to make sure they're okay
Before:
Put together your emergency kit
Put together a grab bag
Store water
getprepared.nz/Water
getprepared.nz/GrabBag
After a flood:
We're READY NZ
If a severe flood is expected:
If we have to evacuate we will:
Household meet-up spot
Our utilities are located:
Our community hub is:
IMPORTANT PHONE NUMBERS
FOR POLICE, FIRE OR AMBULANCE CALL 111
Get involved
Free emergency preparedness courses
Free business continuity workshops
Community response plans
Contact us