Assessing the Impact of Interactive Sea Level Rise Maps in New Zealand

Assessing the Impact of Interactive Sea Level Rise Maps in New Zealand

Emily DeBeradinis | Neeraj Dodda | Maia Gifford | Vibhuti Pathare

March 17, 2021

Submitted to

Zoe Heine, Dr. Richard Levy, and Dr. Rebecca Priestley
Antarctic Research Centre, Victoria University of Wellington

Professors Fred Looft and Ingrid Shockey

Worcester Polytechnic Institute
Worcester, MA

Abstract

Sea level rise (SLR) due to climate change is a global threat. Interactive maps illustrate the effects of SLR for the public but their impact is unclear. We conducted interviews with map developers, climate change scientists, and science communication experts, and distributed a public survey, to understand how best to engage the public. We determined that interactive maps are not the most effective method of SLR communication, and we recommend that NZ SeaRise develop a centralized platform for all information regarding SLR.

Executive Summary

Introduction

The extensive coastal communities in New Zealand are threatened by sea level rise (SLR), and it is vital to clearly communicate this risk. Confusing or conflicting communication of data can undermine climate change action and stand in the way of a unified response in environmental decision-making. Providing SLR scientists with better communication strategies can improve community education and response to the actions needed to build long term adaptation.

Figure I. Storm surge on the New Zealand coast (RNZ, 2018)

The Antarctic Research Center (ARC) of Victoria University, in collaboration with other organizations in the NZ SeaRise Programme (NZ SeaRise), works to advance SLR predictions in New Zealand and is interested in improving public awareness of SLR.

The goal of this project was to assess the impact of these interactive maps that convey SLR to the New Zealand public. To meet this goal, we addressed the three objectives listed below.

1. Determine whether the core messages that NZ SeaRise wished to convey to the public about SLR were aligned with those of the map developers
2. Document best practices in science communication to evaluate existing tools used to illustrate the effects of SLR
3. Measure the effectiveness of interactive maps at depicting SLR to the public

Better communication with the public about SLR can help policy makers to streamline research and public policy. Until recently, interactive maps have been a common format for

public engagement. For example, local government councils including the WRC and the GWRC each host interactive maps depicting the impacts of SLR to specific regions of the New Zealand public (shown in Figure II). However, it is not clear if or how the public uses this format to enhance their understanding of SLR.

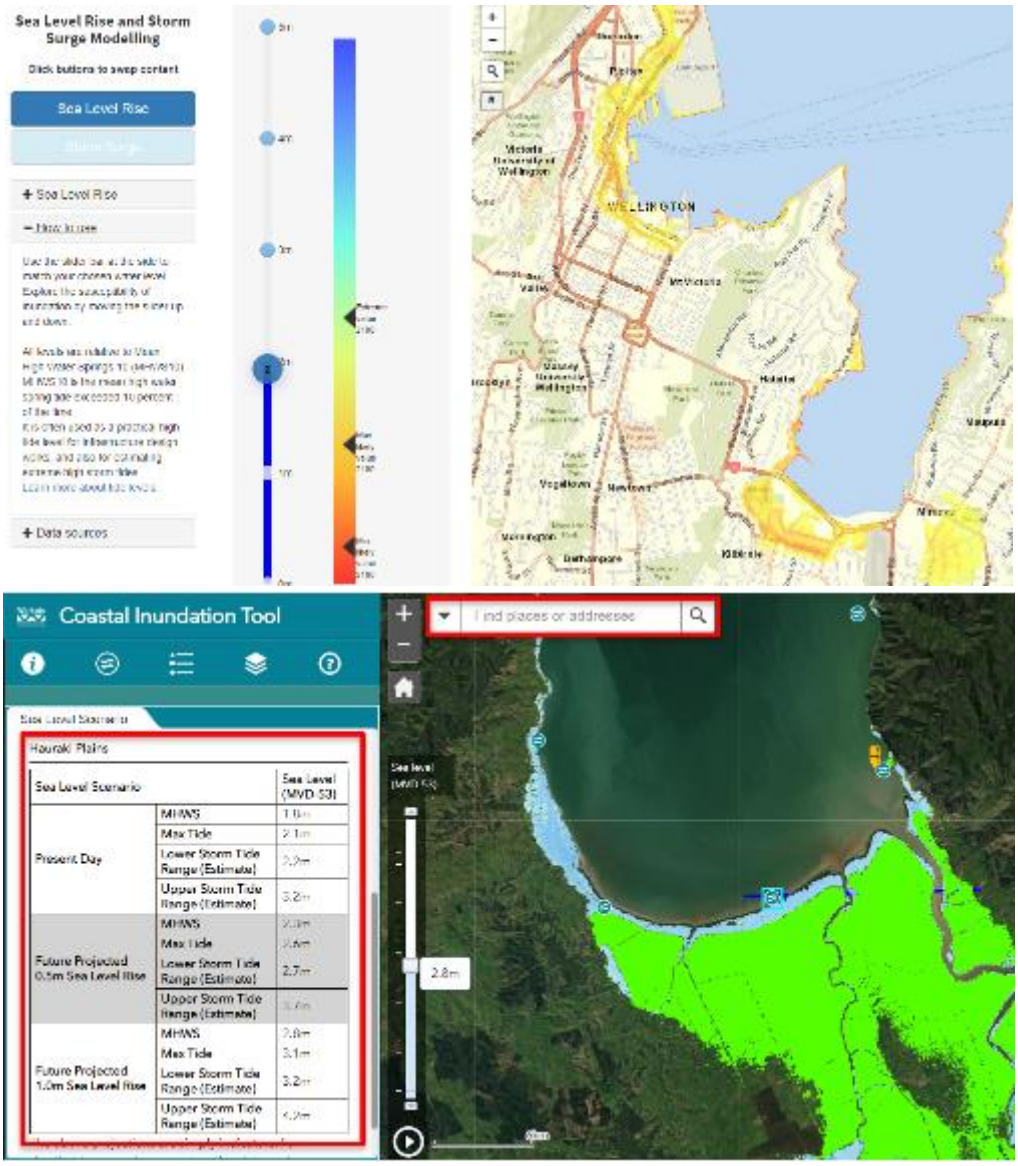


Figure II. Interactive maps provided by the GWRC (top) and WRC (bottom) (GWRC, n.d.; WRC, n.d.)

The greatest challenge of science communication is how to effectively explain data to the public. Successful risk communication strategies include more tailored approaches with personal messaging that can reach groups most affected (Boholm, 2019). We also learned that common pitfalls in risk communication include insufficient organization and planning for communication within an agency, a lack of certainty about the risk, and media misinterpretation of the message. By applying science and risk communication best practices to the SLR communication issue, we

can promote public understanding of the impacts of SLR and we can encourage choices and behaviors that promote better decision making in the community.

Methodology

To determine whether the core messages that NZ SeaRise wanted to convey to the public were aligned with those of the map developers, we conducted open ended interviews with members of NZ SeaRise. We then interviewed developers of the interactive SLR maps from the GWRC and the WRC. In these interviews we asked about the messages they were hoping to convey to the public with their maps and what their overall goals were in creating their maps.

We interviewed science communication practitioners who relay information to the general public. In these interviews we gauged a variety of communication practices and identified strategies for conveying information on SLR. To broaden our research, we evaluated case studies to familiarize ourselves with global science communication. Finally, we used participant observation to experience the tools depicting SLR data firsthand.

To understand perceptions of SLR and user experiences of the maps, we distributed a survey via social media. We assessed map efficacy by asking participants to interact with the maps and then gauging their perception and understanding of SLR.

Results and Discussion

When assessing the core messages, the most notable similarity between NZ SeaRise and the map developers is that they agree on the information that is critical to convey to the general public and that this information needs to be more accessible. However, the key difference between the groups is how they think the information is best conveyed. The map developers understandably believe that maps are the most effective communication method, but scientists at NZ SeaRise are more receptive to trying new communication strategies, more in alignment with findings from our case study research and interviews with science communication experts. From these data, we learned critical points of successful science communication. These points are listed below.

- The communicator must have a clear goal and know what information is most important for their audiences.
- Communication works best when it is customized to specific audiences. Therefore, there is no singular ‘best tool’ to be used when communicating SLR information.
- The messages of the involved agencies must be aligned.
- Governmental support can provide a more streamlined platform for communication.
- Risk communication is most effective when people see how the problem will impact them personally.

We conducted participant observation on multiple interactive maps, a story map, and an online game. The maps that we found to be impactful from our own observations had features such as a scroll bar to demonstrate incremental changes in SLR, displayed location specific information, and indicated the years by which effects might occur. We also found that using

varying colors to highlight types of risk in areas that could be affected by SLR was advantageous. The maps could be improved by highlighting the impacts of SLR management approaches on the amount of SLR in an area. In addition, the lack of a legend made some of the maps confusing, making it hard for the user to understand what data is being presented.

We expanded our participant observation to include story maps, such as the Wellington City Council (WCC) map. We appreciated the additional features provided in the story map format because it showed a 3D satellite view of how SLR is impacting specific areas, as illustrated in Figure III. The story map also included captivating images to give the reader visualization of local scenarios.

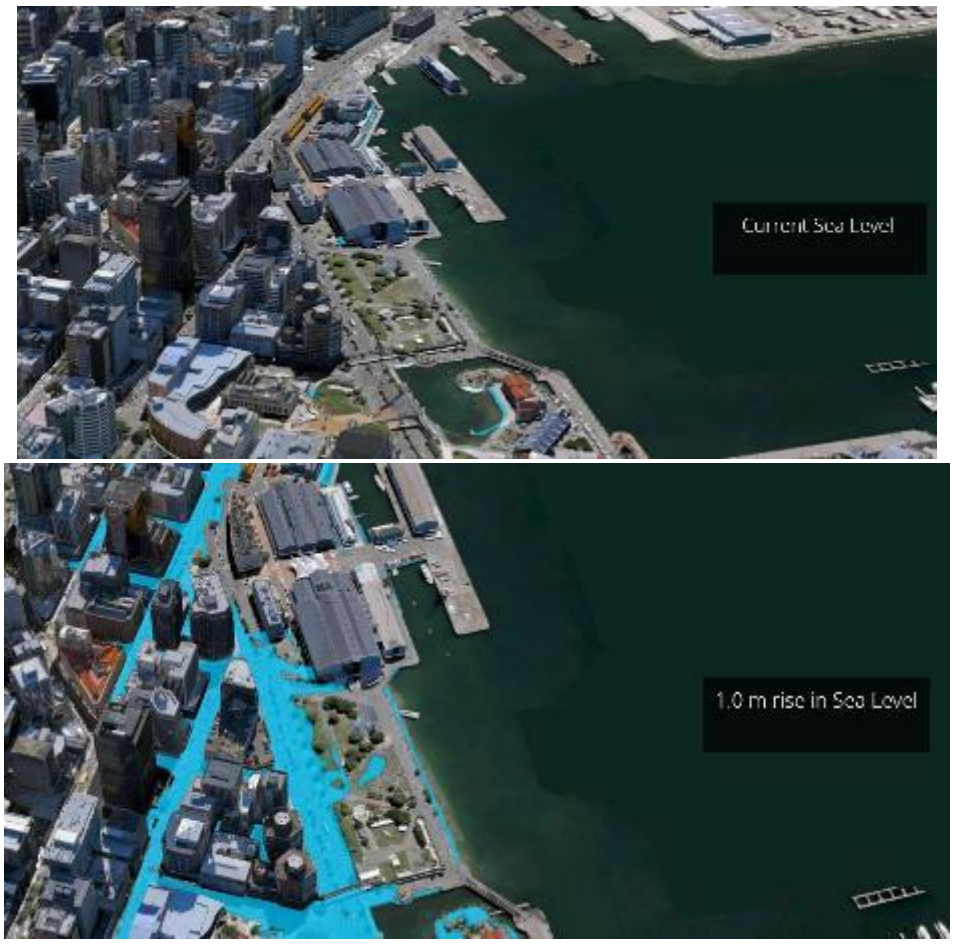


Figure III. Effects of SLR in a 3D satellite map view. Top figure shows current sea level and bottom figure shows a 1 meter rise in sea level (WCC, n.d.)

The story map is a good alternative to simpler maps, but it can also be improved by adding a few key features such as a scroll bar instead of the existing checkbox system. This would allow the map to show increments of risk and uncertainty.

To experience and assess newer educational platforms, we played an online "serious game," called Adaptive Futures, to see how well this format communicated SLR. We found the

game to be more engaging than the maps, since it forced the team to make decisions based on balancing different opinions and limited resources.

It was clear from our NZ SeaRise and map developer interviews that it has been assumed that the interactive SLR maps are the most effective tool for communicating SLR information to the general public by default. However, through interviews with experts in climate science and science communication, we learned that personalization strategies must be used for SLR communication to generate measurable impact on the audience, shown through an increase in public engagement. Interactive maps have some tools that can convey essential SLR data, but they may not be dynamic or personal enough to inspire action.

We found that climate data displayed in a visually appealing manner on the maps can serve their purpose of giving a general overview for SLR projections. Maps should, however, be used with other communication methods such as interactive games, illustrative images, or informative videos and articles if the ultimate goal is to inspire action and effectively convey this urgency to a diverse audience.

Recommendations

Based on our findings outlined above we proposed the following recommendations to NZ SeaRise to help them to better convey information about SLR to the general public.

Create a 'central hub' website for SLR data

The goal of developing a 'central hub' website is to provide a single location for the public to access all of the information concerning SLR. The information source will give general SLR data and its threats on the home page with easy access to additional information in organized tabs. The specific information in the tabs should include, at a minimum, the following information:

- Interactive SLR maps from around the country
- Serious and interactive games
- Reports and Media coverage of stories and updates regarding SLR, global narratives
- Social media page featuring important organizations and events
- Effective methods to mitigate SLR

With this format, the viewer will not have to do extensive research to understand the range of scenarios to prepare for SLR, which often further discourages individuals to take action.

Strengthen NZ SeaRise's social media presence

Hosting a strong social media platform or campaign can boost interactions and gain additional visibility and credibility between the public and NZ SeaRise and help reach a wider demographic. NZ SeaRise can use social media platforms, such as Twitter, Facebook, and Instagram, to communicate research findings and insights. They should also make important updates, illustrative videos and images, personable statements and relevant news about SLR to the public. A sample Instagram post is shown in Figure IV.

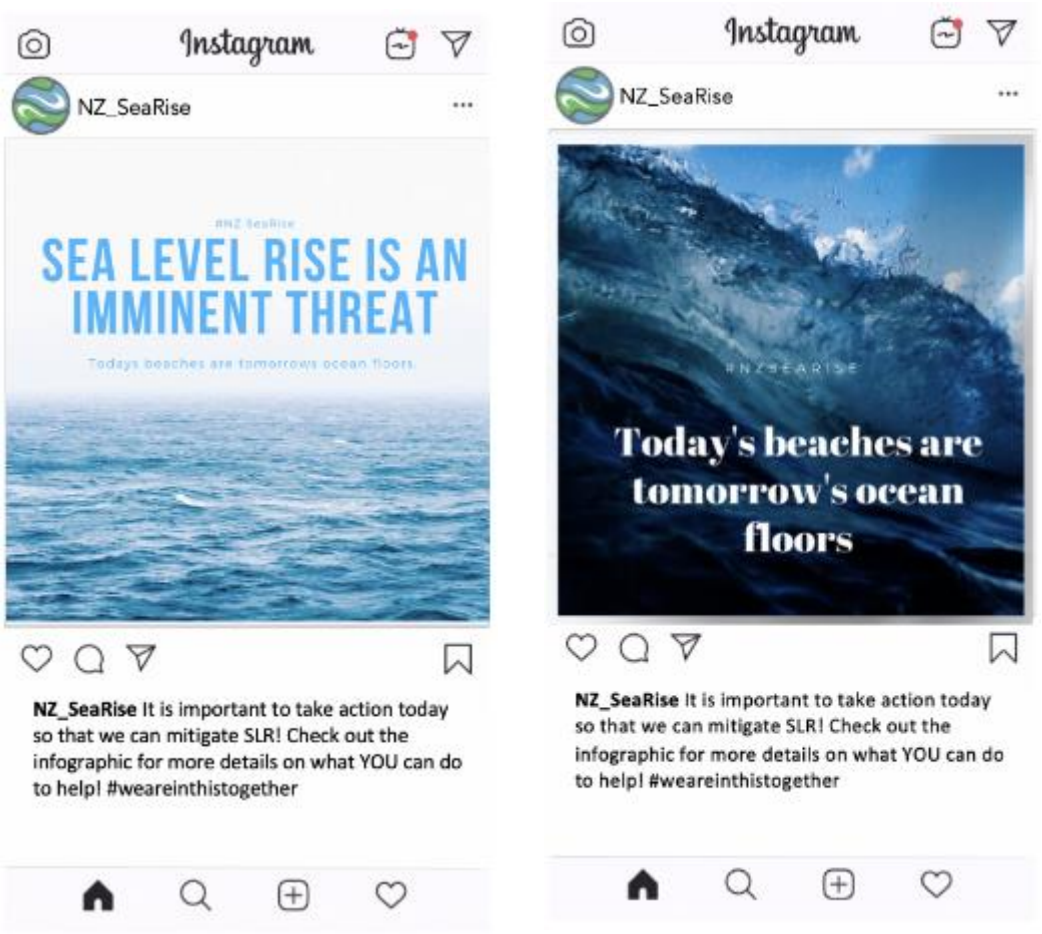


Figure IV. Sample Instagram post for NZ SeaRise.

Create an effective SLR infographic

We recommend designing a series of infographics that includes a brief overview of SLR, ways to mitigate the risks, and QR codes linked to the central SLR hub website to allow viewers an opportunity to gain more information. These infographics can be displayed in public places and posted on social media platforms. A sample infographic is shown in Figure V.

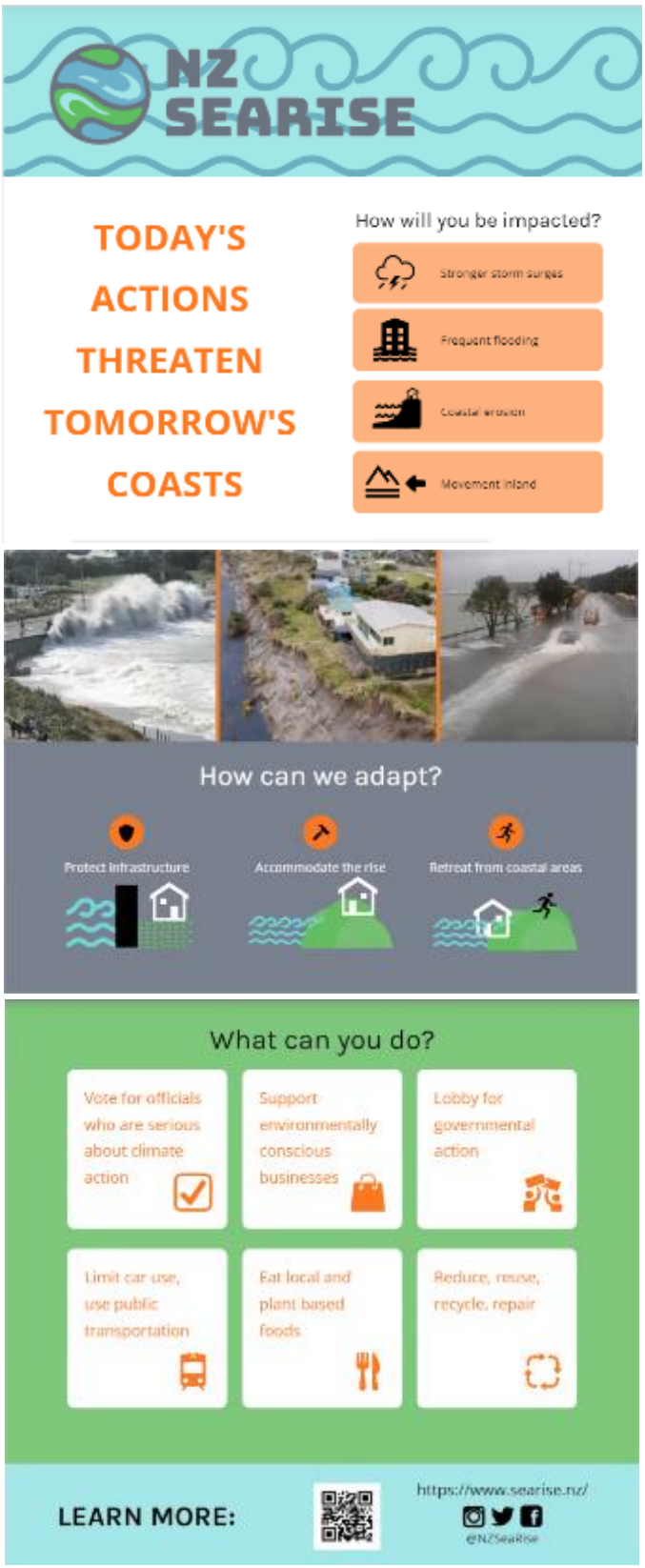


Figure V. Sample infographic for NZ SeaRise

Partner with other organizations and gain governmental support

Finally, we recommend NZ SeaRise to collaborate with other relevant organizations and government agencies at both local and national levels to engage with the public on this topic. The specific steps needed to complete this recommendation are (1) engage the public via the platforms mentioned above; (2) collaborate with local initiatives and other public forums to encourage engagement and information sharing; (3) use the public's help to lobby for climate change advocacy; (4) help receive more funding from the government towards these policies and initiatives; and (5) have both the government and relevant agencies develop additional material useful for SLR communication.

Conclusion

As temperatures increase and sea levels continue to rise, educating the public about the impacts of SLR has never been more important. Public engagement and education is the first step towards motivating action to minimize impacts in the long term. Climate action is a critical component of the UN Sustainable Development Goals. Through this project, we understood the overall impacts of the communication goals for NZ SeaRise, best practices of risk and science communication, and the effectiveness of interactive maps at conveying SLR to the NZ public.

Figure VI. UN Sustainable Development Goal 13 (United Nations, 2020)

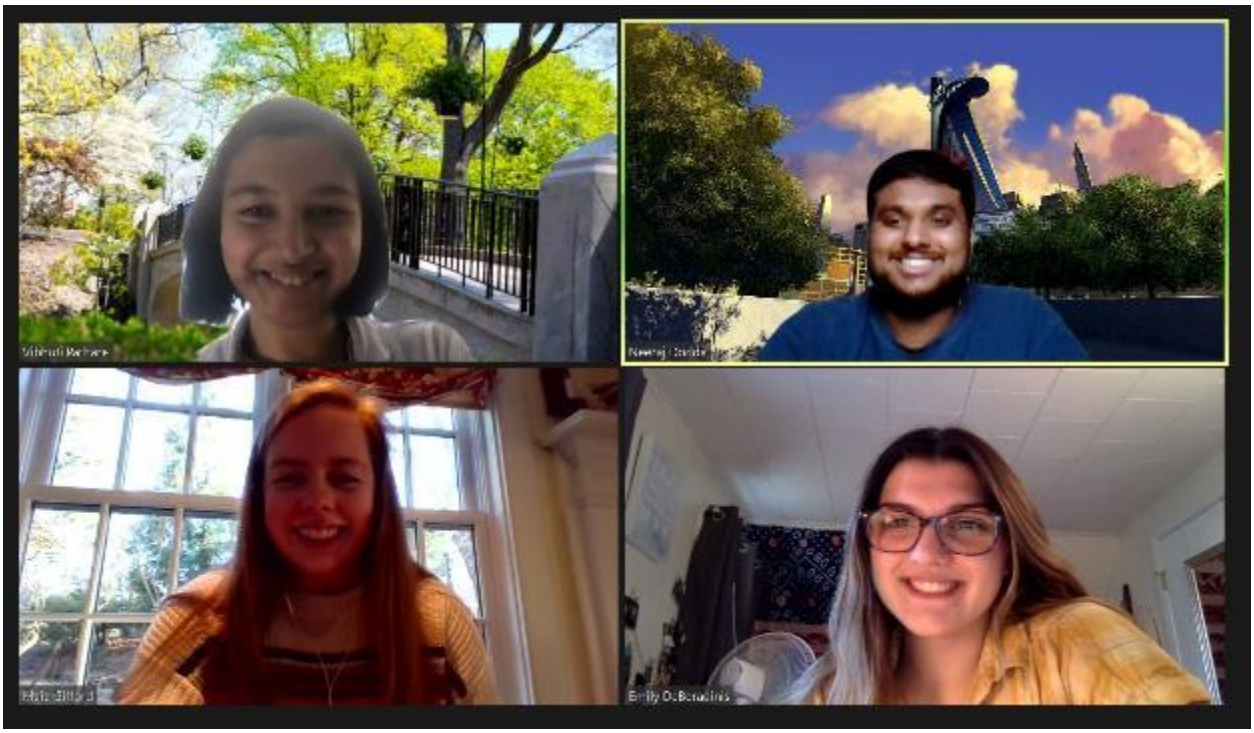
Acknowledgements

We would like to thank the following people for their contributions to our project to guarantee its success.

- Professors Fred Looft and Ingrid Shockey for their advice and mentorship throughout this project.
- NZ SeaRise for sponsoring this project and for their prompt communication, despite being remote.
- Zoe Heine, Dr. Richard Levy, and Dr. Rebecca Priestly for their continued support and encouragement throughout this project.
- Our interview and survey participants for providing us with valuable information.

Authorship

Specific authorship for each section has not been defined due to the numerous edits and revisions made to the report by all team members. Through various collaborative efforts the team worked on the project as a whole and made equal contributions throughout the course of this project. Each team member worked on individual sections which were later edited by the team as a whole through open discussion during virtual meetings.



Meet the Team

Emily DeBeradinis

Hello! My name is Emily DeBeradinis and I'm a Biology/Biotechnology student with a minor in Public Health from Milford, NH. I am also on the pre-Physician Assistant track to work in surgery one day. I loved working with our sponsors for the past 14 weeks, despite meeting them virtually. Researching sea level rise has been inspiring and educating to take action against climate change. I look forward to going to New Zealand and see our research implemented one day!

Neeraj Dodda

Hello! My name is Neeraj (pronunciation: Knee+Ridge = Neeraj) Dodda and I am Biomedical Engineering and Pre-Medical student from Highlands Ranch, CO. Although we didn't travel to New Zealand, I greatly appreciate the opportunity to collaborate with professionals in New Zealand and work on a project regarding climate change and sea level rise and its impacts on people in New Zealand. All the interactions and conversations I have had with people in New Zealand really were beneficial in helping learn more about sea level rise. Hopefully I can travel to New Zealand one day and experience its beautiful atmosphere.

Maia Gifford

Hello! My name is Maia Gifford and I'm an Environmental Engineering student from West Newbury, MA. Despite not being able to travel to New Zealand for this project, I really appreciated the opportunity to work with our sponsor from New Zealand and learn more about climate change and sea level rise. This is a topic that greatly interests me, so I enjoyed learning about it from experts in the field through this unique project experience. I look forward to travelling to New Zealand one day and hopefully meeting some of the people we worked with on this project!

Vibhuti Pathare

Hello, my name is Vibhuti Pathare, and I am a Electrical and Computer Engineering student from Lexington, MA. I enjoyed collaborating with our gracious sponsor in New Zealand and working on a project regarding climate change and its impact on people, something which is outside of my comfort zone and I would have never had the opportunity to do without this valuable project experience. Although we had to be remote this term, I was able to acquire skills in speaking and writing, skills that I will carry with me for a lifetime! I aspire to travel to New Zealand one day and immerse in its amazing culture!

Table of Contents

Citation for title page image: Collins, Ray. (2015). Sunburst [Photograph]. https://raycollinsphoto.com/collections/seascapes-landscape/products/sunburst.

List of Figures

Glossary

Abbreviation	Definition
3D	Three Dimensional
ARC	Antarctic Research Centre
COVID-19	Coronavirus 2019 (SARS CoV-2)
GNS	Geological and Nuclear Sciences
GWRC	Greater Wellington Regional Council
MHWS	Mean High Water Springs
NIWA	National Institute of Water and Atmospheric Research (New Zealand)
NOAA	National Oceanic and Atmospheric Administration (USA)
NZ	New Zealand
NZ SeaRise	New Zealand SeaRise Programme
SLR	Sea Level Rise
WCC	Wellington City Council
WRC	Waikato Regional Council
WWF	World Wildlife Fund

1.0 Introduction

The mean sea level in New Zealand has risen 220mm in the past 100 years. Another 300-400 mm of sea level rise (SLR) is expected in the next 30 to 40 years, with a projected 980mm total by the start of the next century. Rising sea levels also mean higher storm surge, more serious flooding, and significant erosion (*Rising Sea Levels*, 2020).

The SLR threat is serious in New Zealand with its extensive coastal communities. According to the 2018 census, the greater Wellington areas contain a wide range of commercial and residential properties in coastal communities that are built at varying heights above sea level. As a result, many of these communities are threatened by SLR, which is often accompanied by onshore winds, high tides and other natural events that exacerbate the impact. The threat of damaged or lost coastal properties results in a variety of opinions about how to most effectively respond to the impacts of SLR. The vulnerable areas are also home to businesses and residents representing a range of age groups and backgrounds. Each of these stakeholders may not have access to the same SLR updates and critical information. Confusing or conflicting communication of data can undermine climate change action and stand in the way of a unified response in environmental decision-making. Providing SLR scientists with better communication strategies can improve community education and response to the actions needed to build long term adaptation.

The Antarctic Research Center (ARC) of Victoria University, in collaboration with other organizations in the NZ SeaRise Programme (NZ SeaRise), is interested in improving public awareness and understanding of the impacts of SLR. While the ARC works primarily in Antarctica to collect ice core data to make predictions about SLR and climate change, they are working in NZ SeaRise to improve predictions of SLR in New Zealand. With the ability to project critical SLR impacts, the ARC knows that communication and outreach is vital to protect community members at risk of losing their land, homes, or occupations. NZ SeaRise and the ARC would like to adopt a proven strategy for communicating their research to the public. This poses a challenge of creating tools that can be easily interpreted and understood by a diverse audience. Consequently, it is important to understand the best way to engage the public and, in particular, how the public interacts with the interactive SLR maps available from other organizations.

Interactive SLR maps are available to the public through organizations such as the Greater Wellington Regional Council (GWRC), the Waikato Regional Council (WRC), and Climate Central's Surging Seas Program. These maps can be found on each of these organizations' websites. The content provided on the interactive maps illustrates the extent of flooding, both direct and indirect, and which areas are at higher risk. The maps can be more refined using the layers of year, water level, elevation data, and management strategies to help visualize specific coastal areas and better understand the effects of flooding and SLR. However, the impact of existing maps was unknown in a New Zealand context.

The goal of this project was to assess the impact of these interactive maps that convey SLR to the New Zealand public. To achieve this goal, we explored how the public used interactive SLR maps, and whether or not the information presented was helpful when learning about climate change threats. This research examined whether these maps aided the public in understanding SLR and in turn whether they made the public feel more engaged or apathetic towards the problem. In order to accomplish this goal, we addressed the three objectives listed below.

1. Determine whether the core messages that NZ SeaRise wished to convey to the public about SLR were aligned with those of the map developers
2. Document best practices in science communication to evaluate existing tools used to illustrate the effects of SLR
3. Measure the effectiveness of interactive maps at depicting SLR to the public

After achieving these objectives, we made recommendations to NZ SeaRise about how they could optimize their platforms to communicate SLR most effectively to the public.

2.0 Literature Review

The increasing threat of rising sea levels affects coastal communities worldwide. Thus, governments need to employ effective methods to communicate the risks of SLR to coastal communities and how those communities can best adapt to the threat. To that end, this chapter reviewed approaches to SLR communication in New Zealand, current methods used to mitigate the threat of SLR, the primary stakeholders, and the general concept of science communication in greater depth.

2.1 Partnering Across Agencies and Communities

Governmental policies require support from the public, as some adaptation strategies may mean considerable changes to coastal communities. Better communication with the public about SLR can help policy makers to streamline research and public policy recommendations. This can speed policy action on SLR threats and lead to better coordination with the public on adaptation strategies. Furthermore, an informed public will hold their elected officials accountable to enact change.

Academic, agency, and community partners are critical to the process of science communication. Victoria University of Wellington, more specifically the ARC, hosts the research initiative known as NZ SeaRise, the primary goal of which is to improve the accuracy of SLR predictions in New Zealand. Within NZ SeaRise, the ARC works with GNS Science and the National Institute of Water and Atmospheric Research (NIWA) to coordinate data to better understand the effect SLR will have on New Zealand (NZ SeaRise Programme, n.d.). GNS Science is New Zealand's most prominent private research consulting group specializing in Earth, geoscience, and isotope research (GNS Science Staff, n.d.). NIWA is a Crown-owned research institute focusing on environmental science research with the goal of providing information for sustainable management of natural resources (NIWA Staff, 2016). These organizations work together to research and publish critical data from ongoing monitoring projects.

Information gathered as part of NZ SeaRise will likely be outlined in the 2021 Ministry for the Environment report on coastal hazards and climate change, and this kind of data typically includes maps displaying possible scenarios for SLR in New Zealand. These data will be made

available to the public with hopes of improving public understanding and engagement with SLR (Zoë Heine, personal communication, October 22, 2020). Based on the most recent findings, core messages to convey to the public include the following discussion points:

- Sea level in New Zealand is rising and will continue to rise
- SLR impact and extent is dependent on location
- Work is being done to improve SLR projections, both regionally and by location
- 40cm of SLR is expected by 2050, with 1.5m expected by 2100
- In order to avoid further SLR, action must be taken to reduce carbon emissions (Zoë Heine, personal communication, October 22, 2020)

Communicating these messages to the public clearly and effectively are a priority.

Interactive maps have been a common format for communication to get the public interested and engaged on the topic of SLR. For example, the WRC and the GWRC each host interactive maps depicting the impacts of SLR to specific regions of the New Zealand public. Outside of New Zealand-based agencies, public organizations such as Climate Central, an international non-profit organization, also provide a library of interactive maps to engage visitors to their site with information about the effects of SLR. However, it is not clear if or how the public uses this format to learn more about SLR, or if these maps enhance their understanding.

2.2 Understanding and Conveying SLR Data

Communicating SLR to the public means interpreting a range of data including the amount of SLR expected, the locations that will be most affected, and the strategies used to mitigate and adapt to the risks. The greatest challenge of science communication is how to clearly and effectively explain these data to the public. The most common SLR data points are explained below.

2.2.1 Numerical SLR Data

Making numerical data interesting and meaningful can be difficult. The most notable information displayed on current interactive SLR maps is water level and elevation data. These data project how increases in water level will affect areas of varying elevation due to inundation, both connected and disconnected. Connected inundation occurs in places where flooding could occur directly from nearby seas or waterways. Disconnected occurs in places where flooding could

occur due to a rising water table (WRC Staff, 2019). Other numerical data used in SLR research include increases in greenhouse gas emissions which illustrate changes to global temperature rise. These changes in turn result in an increase in ocean temperature and melting rate of glaciers and major polar ice sheets (Ministry of Environment, 2017). Numbers are important, as it is vital for the public to learn that while these changes can occur naturally, they have been accelerated due to anthropogenic factors. The urgency of acceleration is usually conveyed through graphs and charts, as shown in Figure 1.

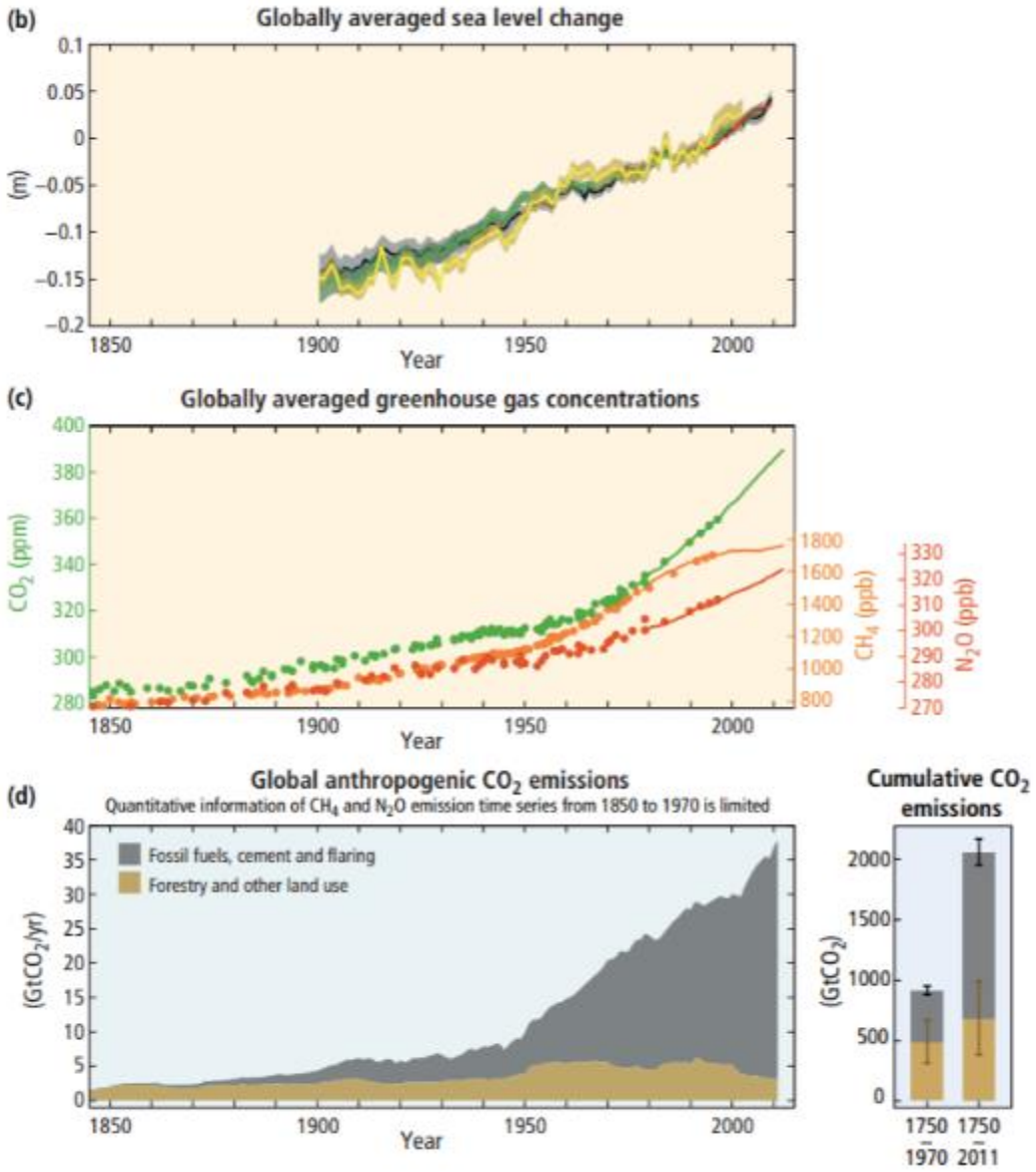


Figure 1. Comparisons of global sea level change to greenhouse gas emissions and global anthropogenic CO_2 emissions from 1850 to 2010 (IPCC, 2014)**.**

Figure 1 shows a series of graphs illustrating the global increase in sea levels since 1900 as compared to greenhouse gas emissions and anthropogenic CO_2 emissions. Viewers of these data can see the direct correlation between rising seas and greenhouse gas emissions.

2.2.2 Presenting Mitigation Efforts to the Public

In addition to learning the causes of SLR, the public must also understand the ways in which to mitigate its risks and the actions that can be taken. For example, scientists try to convey that the best way to limit future SLR is by lowering the global carbon footprint to reduce or halt global warming and, in turn, mitigate SLR (NIWA Staff, n.d.). Reducing the global carbon footprint includes policy changes and increased regulations for large corporations as well as individual choices such as minimizing car use, switching to renewable energy sources for the home, reducing waste, recycling, and eating more local and plant-based foods (WWF, n.d.). Informing the public of these facts can encourage a communal effort.

According to the Ministry of Environment's 2020 report on atmosphere and climate, New Zealand has taken action to reduce the country's carbon footprint. In 2019 the Zero Carbon Act was passed which "put emission reduction targets into law and started the transition to a low-carbon economy" (Ministry for the Environment & Stats NZ, 2020). Since New Zealand has an abundance of clean resources, they have already made great strides towards reducing their emissions from non-renewable resources. In most developed countries, burning coal and gas for electricity accounts for the majority of greenhouse gas emissions. However, in New Zealand, since 84% of electricity is from renewable sources, agriculture is the largest contributor to gross emissions (Ministry for the Environment & Stats NZ, 2020). The next largest contributor to emissions is transportation via cars and other passenger vehicles, making up 27% of gross carbon emissions in 2018 (Ministry for the Environment & Stats NZ, 2020). This information is shown in Figure 2, but it is presented in a complex way that may be difficult for the general public to understand.

Figure 2. New Zealand's gross greenhouse gas emissions in 2018 (Ministry for the Environment & Stats NZ, 2020).

Educating the public on the importance of policy reforms to reduce greenhouse gas emissions as well as individual lifestyle changes, can help New Zealand minimize the effects of climate change through the reduction of carbon emissions, and in turn limit global SLR. However, this information must be communicated in a way that involves the public and makes it easy for them to understand.

2.2.3 Conveying Community Adaptation Approaches

Finally, climate data has to inform community climate adaptation choices. New Zealand is at higher risk from the threat and damage associated with SLR than many other countries. In fact, by 2100 it has been shown that the country is expected to lose 10% more land than the average projection of risk in other countries (Ministry of Environment, 2017). Furthermore, rising seas in New Zealand will drastically affect the 133,000 coastal residents (Ministry of Environment, 2017). A key part of SLR communication involves making sure the public understands the ways that the associated risks can be managed.

There are three approaches communities use to manage the impacts of floods and coastal erosion: protection, adaptation, and retreat (Hanna, White, & Glavovic, 2017). The language and depictions of the three methods are compared in Figure 3 and described in greater detail below.

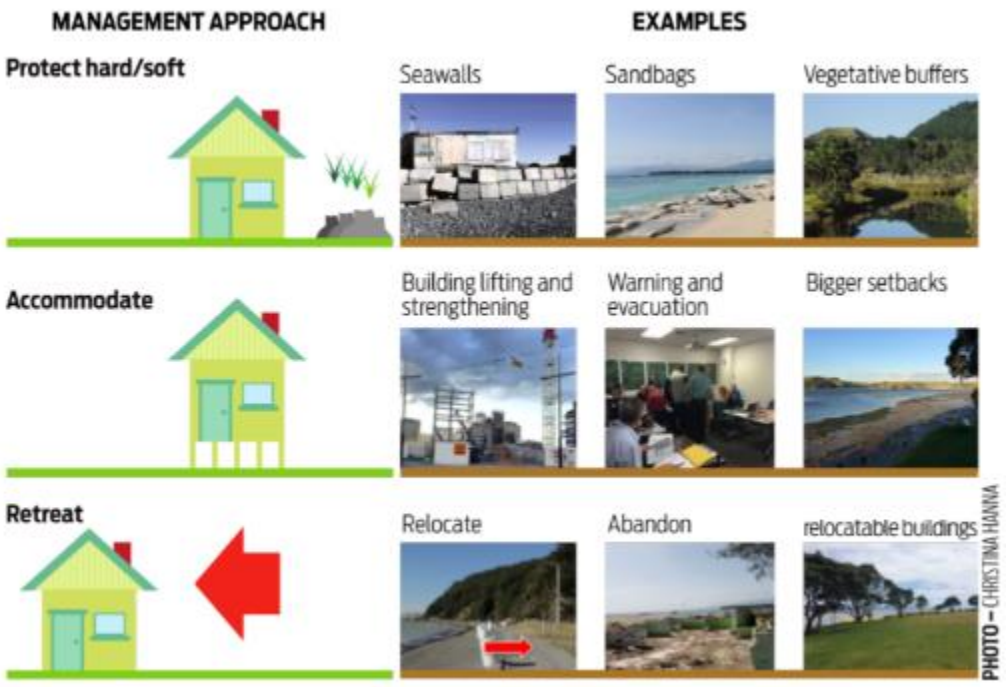


Figure 3. Comparison of SLR Management Approaches (Hanna, White, & Glavovic, 2017).

Protection

As illustrated in Figure 3, one example of protection is seawalls. Policy makers have worked with communities to build seawalls in locations throughout New Zealand to manage the effects of SLR. An example of a seawall in Wellington is shown in Figure 4.

Figure 4. A seawall in Wellington, New Zealand (Devlin, 2018)

Seawalls are typically made of concrete or rock and are designed to stop coastal erosion. Depending on the geography of specific coastal locations, other protection measures can be implemented. For example, in Venice Italy, floodgates were designed and successfully tested in October of 2020 to block incoming water from flooding the streets (see Figure 5) (Povoledo 2020).

Figure 5. A floodgate in Venice, Italy. (Chico, 2019).

Although seawalls and floodgates are useful infrastructure to minimize flooding and erosion, it is important for the public to know that these are only temporary solutions and it is only a matter of time before they become ineffective.

Accommodation

Accommodation involves changing current infrastructure on land to better withstand floods and other weather conditions. An example of accommodation is creating elevated houses and buildings. In New Orleans, Louisiana, this strategy was implemented after Hurricane Katrina destroyed multiple homes. This strategy has been successful, but it is only effective until the rising sea levels reach a higher point. Various forms of accommodation have been designed, including houses, bridges, and roads that float on the water so that as the sea rises the houses will be above the sea level. However, this method is only useful in areas without waves or choppy seas, which can often be intensified by rising sea levels (Spur, 2016). Sharing strategies and effective choices will better inform the public of how to face the effects of SLR.

Managed Retreat

Managed retreat focuses on moving communities inland. While managed retreat has been shown to be effective in some areas, it is still not a widely accepted strategy for SLR adaptation. Many coastal property owners are unwilling to abandon or relocate their properties and often will choose hard protection strategies such as seawalls (Turbott & Stewart, 2006). If the public was more informed on the advantages and disadvantages of these strategies, they may be more receptive to this change.

By understanding these different approaches, individuals that are in affected areas will be better prepared for the impending risk they are to face. Regardless of an individual's geolocation, they will be affected by SLR. However, it is important to note that the impacts of SLR can be abated through proper education and implementation of these strategies. Most importantly, these methods will work most effectively if there is a shared understanding and effort to make these changes. A lack of effective communication could leave people wary, or worse, opposed to committing to these lifestyle changes.

2.3 The Art of Science Communication

Being able to explain the results of scientific research to others has proven to be a challenge for researchers and governmental agencies who need to effectively communicate information to the public in a meaningful and understandable way. There is often a misunderstanding due to differences between scientists and the general public, and concerns have been raised by the scientific community that there is a disregard to important issues by society (Evaluating science communication, 2019). It is critical to be able to effectively communicate scientific research to the public in order to improve public engagement, build support for policy, and communicate risk in hazard management fields.

There are several factors to consider when communicating science to the public. One element of this kind of work is internal collaboration between scientists and communication professionals. An emphasis on strengthening bonds between the two groups enforces better connections and prevents miscommunication that could be potentially dangerous. Not all communication professionals are also scientists, so they may not completely grasp the information that is being conveyed to the public. Therefore, evaluating these relationships regularly can confirm clear

connections and prevent misinterpretations in the spread of vital information. Science communication experts are the crux of the operation and facilitate the collaboration that is required to get the point across to the public. Furthermore, the goal of science communication is to aid people in making "autonomous choices, rather than promoting specific behaviors" (Evaluating science communication, 2019). Eventually, the public should feel confident in making their own decisions regarding SLR, rather than feeling forced to make significant changes. Finally, it is important to communicate information in a way that generates positive action without the general public feeling helpless, imposed upon or forced into action.

2.3.1 Science Communication in Action

One of the main concerns facing scientists is the risk of oversimplification in sharing information with the public. There are many topics that can be explained by scientists who are experts in their field of study and might be explained to the public as if the public are experts in the field as well. Unfortunately, this approach can result in both misunderstanding the explanations or perhaps more likely, the audience simply not listening. Communication strategies that recognize this might go further in the other direction, simplifying the scientific message to the point where it is possibly incorrect or even conveys the wrong message; this also has consequences. If a complex concept is made too general, it can undermine the urgency of the issue or evoke different outcomes in the public than the intended purpose (Kulkarni, 2013). Scientists themselves must be clear and believe in what they are saying in order to educate the general public.

2.3.2 Risk Communication

When communicating information regarding hazards and risks there are strategies that have been proven to be more successful than others. In a Swedish study examining science communication, government officials from six different agencies (food, chemicals, environmental protection, housing and building, traffic, and contingency planning and management) were interviewed on successful and failed risk communication cases (Boholm, 2019). Overall, the study found that the effectiveness of a communication strategy depended on the content of the message, the way in which the information was shared, and the communication's aims and objectives. In cases that were successful, key factors that were identified were overall organization and collaboration within the agency, transparency between the agency and the audience, and a strong connection with risk management efforts (Boholm, 2019). Additionally, successful cases used a tailored

approach that targeted groups that would be most affected by the risk. Failed cases shared struggles of insufficient organization and planning within the agency, a lack of knowledge of the risk being communicated, and the media making their own interpretations of the information. This last factor is problematic because it can result in "[the information] that reaches the audience, although initially deriving from an agency (through factual information disseminated in various ways), [to be] substantially modified and altered in ways that the agency cannot control" (Boholm, 2019). Themes of risk communication strategies were identified as organizational planning and strategic decision making, collaboration and responsibility within the agency, knowledge and understanding of the message, connection to risk management, and public trust. Successful communication strategies excelled in these areas, whereas the failed cases fell short in at least one of the categories. Extra funding and time were also constraints mentioned in the interviews, but most failed efforts were due to struggles with organizational planning and strategic decision making.

2.3.3 Climate Change Communication

In a study about strategies for communicating climate change impacts on public lands, science communication experts found that the leading challenge in communicating climate change to the public is that there aren't enough local examples to show that climate change is happening and affecting our life and landscape. Polls sent out during the study regarding concern for climate change, found that people feel "there's nothing they can do about it -- that someone should do something about it, but that someone isn't them" (Schweizer, 2009). This illustrates that the typical "doom and gloom" messages about climate change can be effective for raising awareness but can discourage people from taking action. In the study experts identified four specific insights for effective communication about climate change and its impacts to the public. The four insights are outlined below.

- "Desired behaviors to mitigate climate change must be linked to a person's values, beliefs, and attitudes regarding the behavior
- Messages about climate change should appeal to both cognitive and affective dimensions
- Using a place-based approach to discuss climate change impacts on specific regions, communities, and locations has promise in making messages more effective
- There is no one-size-fits-all message, as the so-called general public does not exist, and so effective outreach to diverse audiences will require multiple communication strategies and messages" (Schweizer, 2009).

By connecting human choices and behaviors to climate change, the key messages about climate change can be effectively communicated.

2.3.4 Cultural Complications of Science Communication

Cultural lenses add a complex component to science communication because groups of people with dissimilar beliefs will approach scientific principles differently. This can be explained by "lay epistemologies," which is the study of "different ways in which people view, conceptualize, and engage with the world" (Media, 2014). An American study asked individuals of various ages and demographics five things they wanted their children to know about nature, as part of interviews on the discourse of science. Caucasian American parents and grandparents viewed nature as a figure that exists outside of themselves. They expressed that "[they] want [their] kids to respect nature [...] and take care of it, whereas Native Americans were more likely to say 'I want my children to realize that they are a part of nature'" (Media, 2014). These fundamental worldview variations show clear cultural shifts in even the definition of nature, similar to the differences between Tauiwi and Maori perspectives. These variations could impact the way in which different cultural groups view SLR. Therefore, science communication has to take into consideration language and assumptions about the issue at hand. Having multiple modes of communication can help to reach the maximum number of people in ways that make sense and can be reconciled with their personal frameworks.

2.4 Improving Outreach to a Diverse Audience

According to the 2018 Census, the residential population of the greater Wellington area consists of approximately 500,000 people, of which 51% are females and 49% are males. In this region, about 14% are of Māori descent. The largest age group across New Zealand is 25-29 years old for both males and females, representing 7.5% of the population. The second-largest age group is ages 45-49 years old at 7.2% (Stats NZ, 2018).

When looking at current opinions of climate change and SLR, age can be influential. A study from New Zealand, conducted by Horizon Research, examined the influence of age on climate change opinions. The findings showed that concern for the expected impacts of climate change on society declines as age increases. The group representing the most concern was 25-34 year olds and concern reduced at around 55 years old. Within all of these age groups, there were high

proportions of participants who neither agree nor disagree with survey statements that focused on assessing the risks and impacts of climate change. This indicated high degrees of public uncertainty about the risks of climate change (Allan, 2017). In addition, a survey conducted by the Ministry for the Environment New Zealand among 18-24 year olds, showed that only 19% of respondents strongly agreed and 37% somewhat agreed when asked whether climate change was going to have a big impact in New Zealand (Figure 6, Hinton, 2020).

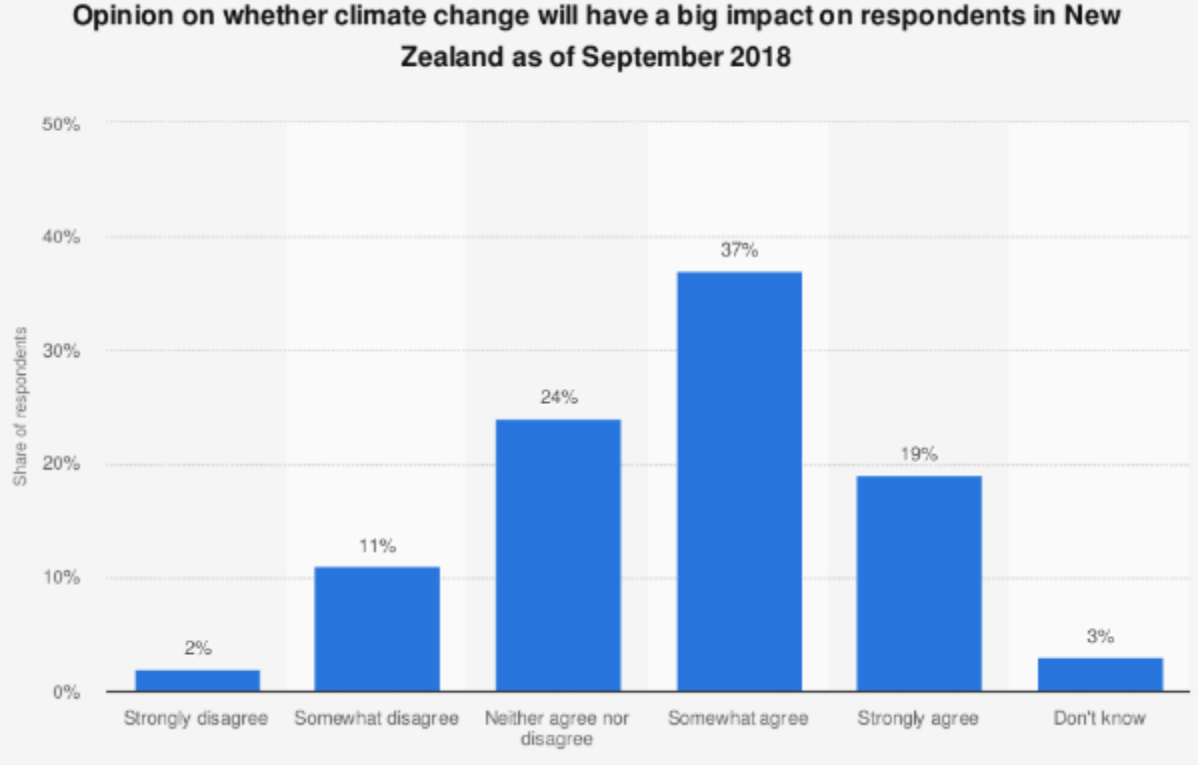


Figure 6. Results of a survey on whether climate change will have an impact on people in New Zealand (Hinton, 2020)

The studies conducted by Horizon Research and Ministry for Environment show that age is a factor in how one views the causes and impacts of climate change. This is illustrated in Figure 7, which shows New Zealand students striking for climate action. According to a survey conducted among the striking students, 69% of respondents have become more concerned about climate change over the past few years, but only 32% believe New Zealand will be able to reduce the impacts of climate change in a meaningful and global way. When asking the youth regarding their own actions, 67% said they were ready to take initiative to reduce impacts of climate change, but 54% said they needed more information on what steps they can take (Fastier, 2019).

Figure 7. New Zealand students take to the streets in Wellington to strike for climate change action (Fastier, 2019).

Increased research on the way the public interprets methods of SLR communication can be a positive change. With more information on how the public best understands SLR, research organizations such as NZ SeaRise will be able to create more effective communication tools than the ones currently used. These tools will then allow the public to make more informed decisions and take the necessary actions when knowing the risks of SLR.

2.5 Summary

Through our preliminary background research, we identified key points of interest for our project. First, we recognized the agencies involved in SLR communication and their roles. We then outlined the information that is most critical to convey to the public regarding SLR. Finally, we noted that age, ethnicity, and New Zealand's political climate will have an impact on the ways in which individuals interpret and understand information. These factors were important to understand when collecting our data and determining how the public interpreted SLR communication methods. Therefore, conveying scientific findings and emphasizing strategies for clear and effective science communication was a key part of designing our project.

3.0 Methodology

The goal of our project was to assess the impact of current interactive maps in conveying SLR to the New Zealand public. To accomplish this goal, we completed the following three objectives.

1. Determined whether the core messages that NZ SeaRise wished to convey to the public about SLR are aligned with those of the map developers
2. Documented best practices in science communication to evaluate existing tools used to illustrate the effects of SLR
3. Measured the effectiveness of interactive maps at depicting SLR to the public

The strategies for data collection are outlined in detail below.

3.1 Determine if the Core Messages Align

To determine whether the core messages that NZ SeaRise wanted the public to know about SLR were aligned with those of the map developers, we first conducted open ended interviews with Zoë Heine, Dr. Rebecca Priestley, Dr. Richard Levy, and Dr. Judy Lawrence who are all members of NZ SeaRise. In these interviews we asked their thoughts on what was most important for the public to know about SLR and the best way to communicate this information. This helped us determine whether those messages were depicted on the interactive maps that were available at the time of the project and if there may be other options to communicate this information. These interviews followed an open-ended format, which allowed us to learn more about the goals for public experience with SLR information. We chose this approach to encourage the interviewees to discuss, express their concerns, and develop their own interpretations of the questions. This allowed our team to collaborate with members of NZ SeaRise to explore a shared set of concerns regarding SLR communication. A guide for the interviews with members of NZ SeaRise can be found in Appendix A.

To gain information regarding the intended usage of the currently available maps, we interviewed members who helped develop the interactive SLR maps from the GWRC and the WRC. In these interviews we asked about the messages they were hoping to convey to the public with their maps and what their overall goals were in creating their maps. We designed this strategy to see if the messages that NZ SeaRise wanted to communicate to the public were aligned with those being expressed in the maps.

We chose a semi-structured model for the interviews with map developers to encourage open conversation while still targeting specific questions. Semi-structured interviews are effective in obtaining qualitative research about participants' opinions and insight. The format of these interviews gave our team control and the ability to direct the line of questions allowing our team to maintain the focus of the interview (Ward, 2020). An interview guide for the map developers can be found in Appendix B.

3.2 Document Best Practices in Science Communication

Our second objective documented best practices in science communication, which included identifying strategies that leverage cultural differences, level of education, spiritual beliefs, and other personal differences. This approach was designed to support strategic recommendations to NZ SeaRise and to better reach the individuals who will use the interactive SLR maps. We interviewed science communication scholars as well as practitioners who relay information to the general public. In these interviews we gauged a variety of science communication practices and identified recommended strategies conveying information on SLR. A guide for our interviews with science communication experts can be found in Appendix C.

To broaden our research, we evaluated case studies and reports to familiarize ourselves with successful science communication campaigns around the globe. For example, New Zealand deployed a very successful awareness campaign for public health during the COVID-19 pandemic in 2020. We researched news accounts and other sources to note the approach used to effectively communicate the dangers of COVID-19 and how they limited the spread. We considered how these same communication strategies could be used in SLR communication. Similarly, we investigated how coastal areas with immediate concerns and experiences regarding rising sea levels have shared information to public audiences around the world. For example, a small-scale study conducted in two coastal regions of the United States (Hampton Roads, Virginia and Space Coast, Florida) suggested that incorporating narratives into interactive maps may be a more effective way to engage the public with the urgency of this issue (Stephens & Richards, 2020).

Finally, we used participant observation to experience the tools depicting SLR data firsthand. Our team engaged with interactive maps to determine the ease of use, our interest in exploration,

and knowledge gained from the maps. We ranked a variety of these maps from the GWRC, the WRC and Climate Central's Surging Seas program for similar information, so we ourselves could identify ideal formats to convey this information. Furthermore, each team member researched an additional map depicting SLR from somewhere outside of New Zealand. This helped broaden our scope and gain more insight on SLR communication worldwide. The list of criteria used can be seen in Appendix D.

3.3 Measure the Effectiveness of Interactive Maps

Our third objective measured the effectiveness of interactive maps at depicting SLR to the public. To understand perceptions of SLR and user experiences of the maps, we distributed a survey via social media platforms that were provided by our sponsors. This was followed by interviewing some of these participants in greater depth. The surveys were hosted in the online survey platform Qualtrics as web-based surveys are a low-cost, easy to distribute method for collecting responses to straightforward questions. (Ward, 2020). In the surveys, we asked general questions about SLR, which were then followed by a series of more targeted questions about the interactive maps to gain a better understanding of the participants' knowledge base regarding SLR. We used the results from our participant observation, described in objective 2, to adapt our survey questions to be map specific.

To experiment with a variety of mapping techniques, we included a link to a selection of available SLR maps in the participants' region. We assessed their efficacy by asking participants to interact with the maps and surveyed them on previous map-related questions to gauge if their perception and understanding of SLR changed. This survey can be found in Appendix E. At the end of the survey, we invited participants to provide their contact information if they were willing to participate in a more in-depth follow up interview.

The list of questions used in the interviews with select survey participants were developed after speaking with members of NZ SeaRise and the map developers, which helped us learn more about the specific elements of the maps that they thought were most important. These questions can be found in Appendix F. These interviews were designed to learn more about how individuals feel towards SLR and their opinions of the tools available to them. The interviews gave our team the opportunity to ask clarifying questions and obtain in depth responses. They

also allowed participants to justify themselves, express their own understanding, their social position, and their personal feelings, which gave us more information than we would have been able to gather from surveys alone (Ward, 2020).

4.0 Results and Discussion

Through our understanding of the core messages of SLR, best practices of science communication, and public perception of the effectiveness of current interactive maps, we identified key trends and patterns to improve SLR communication in the public. This chapter focuses on the findings we obtained through our data collection and analysis.

4.1 Determine if the Core Messages Align

We interviewed individuals from NZ SeaRise and the agencies which develop interactive SLR maps to identify where they align and where they differ in terms of the core messages these agencies wish to convey to the public regarding SLR. Overall, we found that there were some similarities as well as differences amongst these groups regarding what is most important for the public to know. The most notable similarity between NZ SeaRise and the map developers is that they agree on the information that is critical to convey to the general public. However, the key difference between the groups is how they think the information is best conveyed. The similarities and differences between the map developers and NZ SeaRise scientists are highlighted in Figure 8 and explained in greater detail below.

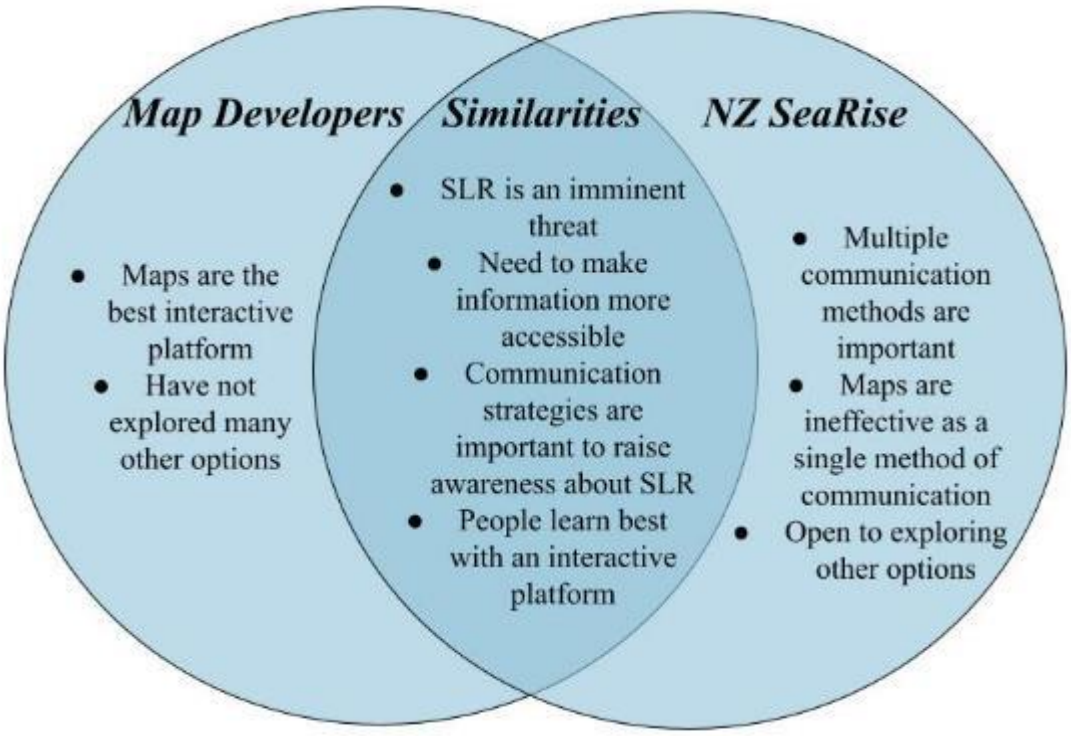


Figure 8. Venn diagram highlighting the similarities and core differences between the map developers and NZ SeaRise.

Both the map developers and the NZ SeaRise scientists agreed that there is a need to make information about SLR more accessible and interactive to the public in a way that engages them to take action. The reason for this is that the general public does not spend time doing extensive research, especially regarding scientific material that does not relate to their daily life. As a result, both groups agree that presenting information in an accessible and interactive manner is likely to be more meaningful to the general public and perhaps mobilize people to take action. For example, a map developer from the WRC spoke to us about how local Iwi members have begun using the WRC interactive map, known as the Coastal Inundation Tool, to their advantage. Through observing the SLR depicted in the interactive tool and understanding how SLR will affect their homes, Iwi members are beginning to understand that they need to take action to adapt to the threat of SLR and understanding that the best way to manage the SLR threat is through retreat (WRC map developer, February 23, 2021). The local Iwi members also have ancestors' graves, called Urupa, situated near the coast, and are becoming concerned about SLR restricting access to their sacred sites. The Iwi members have used the Coastal Inundation Tool

to show policy makers the real danger of SLR that they face, and are now planning a way to move their ancestors to higher ground (WRC map developer, February 23, 2021).

Both the map developers and the NZ SeaRise scientists agree that SLR is an imminent danger and that it will take national and global efforts to reduce the impacts. They also agree on the importance of conveying the urgency of understanding the impacts of SLR coupled with storm surge, which is a direct effect of SLR and in many ways is more impactful on people's lives, as it can reach farther inland and impact property values and the desire to live near the coast. To indicate the importance of the risks associated with storm surge, some map developers have integrated storm surge effects in their maps. For example, as shown in Figure 9, this threat was incorporated into the GWRC interactive SLR map since the map developer had noted that the *"emphasis* [in SLR communication] *has moved away from a static setting* [of SLR] *to a surge event which can lead to serious flooding"* (GWRC map developer 1, February 10, 2021). Users of the GWRC interactive SLR map are able to select a level of SLR from the options on the bottom left of the screen and then view the corresponding storm surge flooding impacts on the map to the right. The shades of blue dictate the varying depth of water during a storm surge event, with darker areas indicating a greater depth and lighter areas showing shallower water.

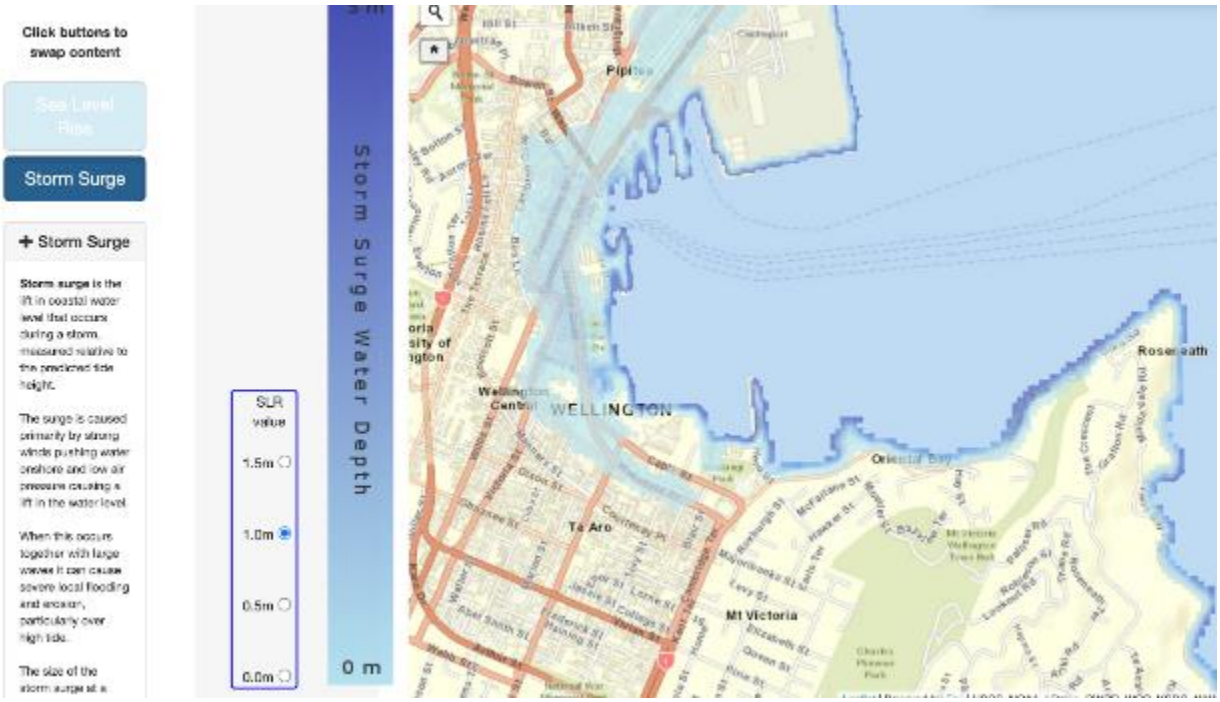


Figure 9. Storm surge water depth button on the GWRC map. (GWRC, n.d.)

While the map developers and NZ SeaRise scientists agree that an interactive model best conveys the threats of SLR, they do not necessarily agree on what format this should be. The map developers we interviewed believe that interactive maps are the most effective method to communicate SLR; although they have conducted limited research on what other potential methods of science communication are available. Some map developers are aware of the maps' inability to incite long lasting action, with one map developer discussing that the maps focus on the short-term wellbeing of New Zealanders, and that there are difficulties in incorporating long term strategies and approaches to SLR into the interactive maps, so a different method may be necessary (WRC map developer, February 23, 2021). In contrast to the map developers, many of the scientists working with NZ SeaRise have experience in the field of public outreach and science communication, and are more receptive to trying new mapping and outreach methods to best inform the public of the threat and impacts of SLR and storm surge. For example, a research scientist of NIWA has researched this topic and created an online game to convey the complicated decision-making process associated with planning for SLR mitigation strategies. Through their experience in science communication, scientists working with NZ SeaRise have hypothesized that there may be ways to communicate SLR as well as its impacts and potential mitigation strategies that are more effective than interactive maps.

Finally, NZ SeaRise is concerned about the implied certainty of SLR data lines drawn in the maps. They believe that it is important for the public to know that SLR is uncertain, and that the values displayed in the maps are projections. Therefore, lawmakers and the public should not solely rely on the maps to make decisions about community adaptation methods and the locations that are at risk.

4.2 Best Practices in Risk Communication

From our case study research and interviews with science communication experts we learned critical points of successful science communication, more specifically risk communication. Risk communication is a subset of science communication that deals with communicating hazards. The key points we learned are most important for communicating risks are listed below and explained in greater detail in this section.

- The communicator must have a clear goal and know what information is most important for their audiences.
- Communication works best when it is customized to specific audiences.
- Risk communication is most effective when people see how the problem will impact them personally.
- The messages of the involved agencies must be aligned.
- Governmental support can provide a more streamlined platform for communication.

When communicating risks to the public, the information conveyed should focus on the big picture. Therefore, it is critical for the communicator to prioritize what is most important for their audience to know in order to communicate efficiently. In a case study about communicating coastal hazards to citizens in Charleston, South Carolina, NOAA[1] wanted to know the most efficient way to communicate this information to the public. To do so they met with a focus group of coastal residents and received input that "having a clear, science-supported description of the issue available as a reference helps interested citizens initiate conversations and communicate more effectively with local officials" (NOAA, 2020). The information sheet that was produced as a result of input from this focus group is shown in Figure 10.

[1] US National Oceanic and Atmospheric Administration

TODAY'S FLOOD IS TOMORROW'S HIGH TIDE

Sea level rise will turn occasional coastal flooding into a regular event.

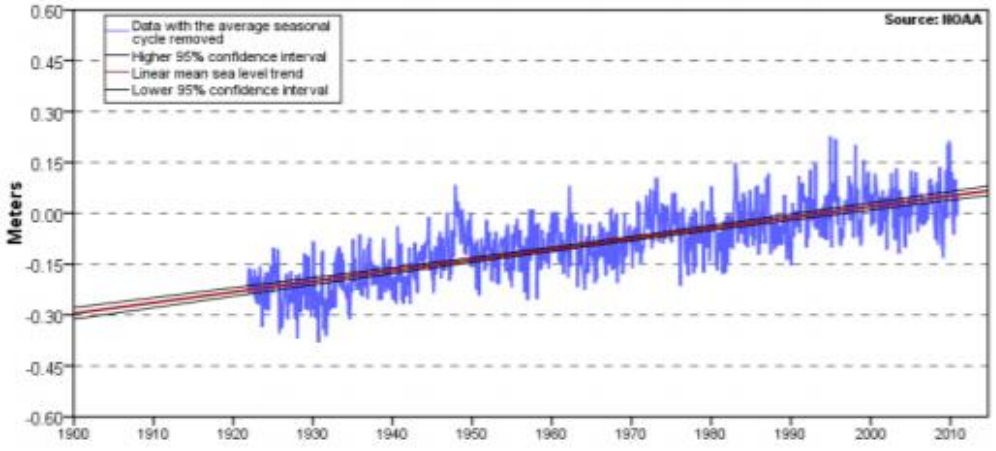
During a tidal flooding event on October 8, 2010, high tide reached 7.66 feet. Wind was from the northeast at less than 10 mph. There was no rain. Had rain accompanied the high tide, flood conditions would have been more extreme.

Tidal Flooding

Charleston, South Carolina. Lowcountry residents are all too familiar with the periodic flooding that occurs during extreme high tides. During these events, salt water backs up through storm drains and can cause hazardous road conditions. Traffic patterns are disrupted, and motorists are forced to take alternate routes. Rain and onshore winds can push the tides even further inland. When this happens, roads and businesses are sometimes forced to close. Damage to buildings from repeated saltwater intrusion is a near certainty.

Water level data measured since the early 1920s in Charleston Harbor indicate a slow increase in sea level. Five flood-producing tides (defined as seven feet or more) were predicted for 2010. These types of predictions don't take into account the increased extent of the flooding made likely when rainfall and winds are added. Data records indicate that water levels reached seven feet or higher 19 times in 2010. As sea level continues to rise, tides will be higher. Eventually today's occasional coastal floods will become regular events.

Water Level Data for Charleston, South Carolina



While some may debate why sea levels are rising, the facts are irrefutable. In Charleston, sea level has risen the equivalent of 1 foot in 100 years.

NOAA Coastal Services Center | South Carolina Sea Grant Consortium | City of Charleston

Figure 10. An information sheet about coastal flooding developed from input from a focus group in South Carolina (NOAA, 2020)

In this image, several key best practices of risk communication can be noted including the use of local images, an overview of the problem and its causes, and a clear statement at the top that engages the viewer. Our research of best risk communication methods indicated that definitive statements, like the one shown in the information sheet, are most effective at inspiring change since "[these] messages have the potential to effectively capture attention and inspire action among a variety of audiences" (Schweizer et. al, 2009). It is also important that these statements be as simple and straightforward as possible to be understood by a diverse public audience that likely does not have extensive background knowledge on the issue (Bearzi, 2017).

While capturing the attention of large audiences is critical for many types of science communication, our research showed that public communication of risks is often most effective when methods are customized to specific audiences. In particular, through our interviews with science communication experts, we learned that there is no singular "best tool" to be used when communicating risk information. Instead, *"there is a mosaic of possibilities for different uses and different places"* which must be balanced to avoid a divide amongst groups of people in communication efforts (climate research scientist 2, February 22, 2021). We also learned that when determining the best way to communicate information to a particular audience, it is important to understand the audience's values, motivations, and lifestyle (climate research scientist 1, February 11, 2021).

When customizing communication methods to fit specific audiences it is also important to note that individuals react to risk communication only when they understand the direct problem and how they can be part of the solution. This was shown in the case of beach erosion in Hawaii (NOAA, 2017). In this case, coastal residents saw how large waves were increasingly causing damage to their beaches and waterfront properties and were drawn to action to adapt and protect these natural landscapes as well as their homes. An image of the damage caused by beach erosion is shown in Figure 11.

Figure 11. Property damage caused by SLR and beach erosion (NOAA, 2017)

Their personal experiences made residents aware of the increasing risk of beach erosion and its connection to SLR. This made it easier for new legislation promoting climate action to be passed and more people were drawn to action due to their own experience with the issue (NOAA, 2017).

In places where SLR has not yet begun to impact people's lives in such an obvious manner, it can be harder to engage the public to take action. As a result, the risks of SLR must be presented in a way that relates to their experiences with similar risks, since when relevant examples are given, people are more likely to take action to mitigate the risk (Stephens & Richards, 2020; Schweizer et. al, 2009). Additionally, communication that promotes compelling narratives inspire people to take action because it attaches emotions to the message (Retchless, 2017). This was shown through our interviews with survey participants, including one who quoted Maya Angelou saying that people will "*forget what you said, they'll forget how you said it, but they won't forget how you made them feel*" which emphasizes the importance of including stories and making communication methods personal (survey participant 1, March 8, 2021).

Communication Between Governmental Agencies

When communicating information about hazards to the public, governmental and environmental agencies act as a bridge between scientists and the general public. These agencies are committed to creating a centralized force to address crises, however, "many of [them] were not designed or organizationally structured to address interdisciplinary issues that transcend agency boundaries" (Schweizer et. al, 2009). Therefore, the governmental agencies are not prepared to communicate information that is not related to their agency's mission. Many agencies simply do not have the resources to effectively communicate risks to the public, which is detrimental since the public relies on them to do so. Additionally, when different agencies do not collaborate to communicate the same message or urgency problems can occur. In New Zealand, when the central government does not develop policies that align with the goals of local governments these local governments have a harder time gaining support for the implementation of adaptation strategies (climate research scientist 3, March 2, 2021). It is vital for these two groups to have common communication goals about SLR so they can best respond and gain support for solutions to this problem.

Amplifying urgency through governmental support can be beneficial in giving authenticity and exposure to risks since the government has a more extensive communication network than most private institutions or local government councils. This was shown in the case of COVID-19 communication in New Zealand. Although different agencies had specific roles in identifying, studying, and managing the viral infection, the central government played a critical role in communicating information about the pandemic to the public. They focused on the rhetoric of health and safety and highlighted the importance of taking a balanced, precautionary approach. Because of this approach, "health professionals were empowered to tackle the virus" since they had the support of the government and the community (Mcguire et. al, 2020). Additionally, the government created a centralized website that consolidated all necessary COVID-19 information, screenshots of which are shown in Figure 12. Since the government took such a strong stance in communicating this information they were able to create a unified response and send a clear message to the public.

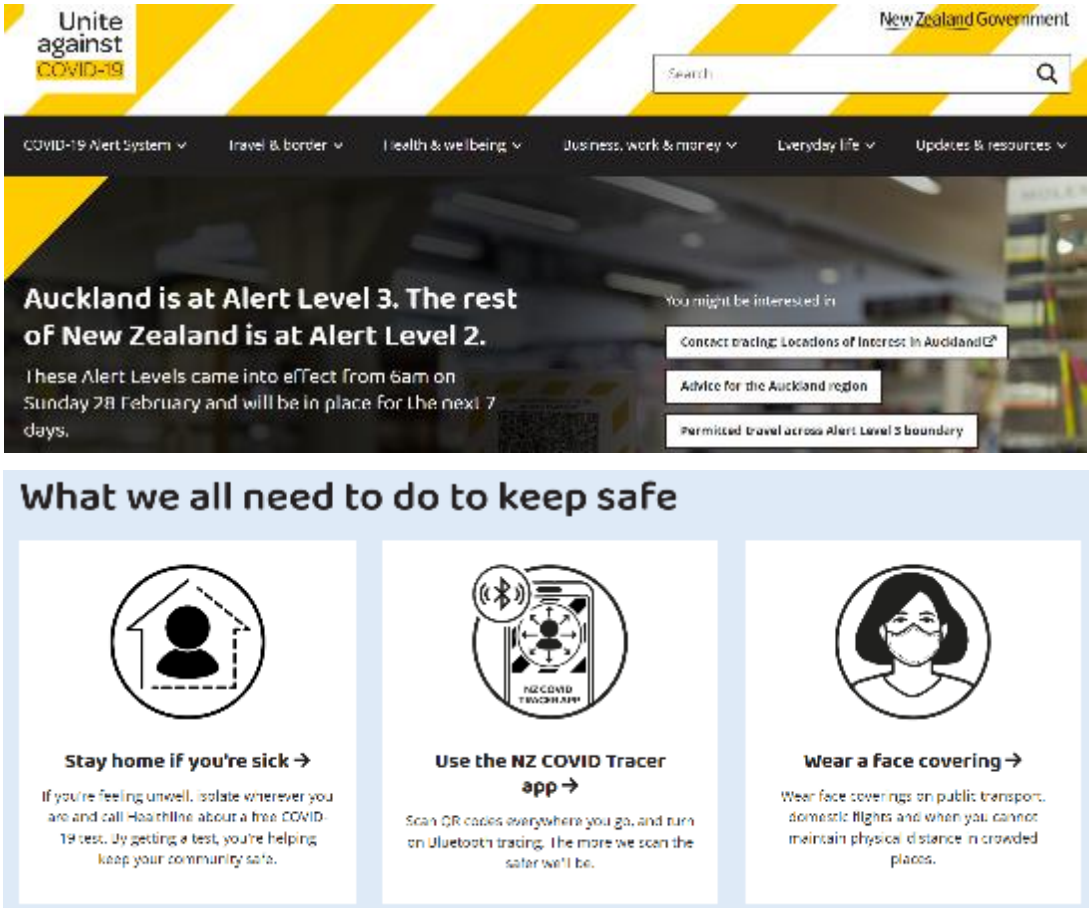


Figure 12. New Zealand's COVID-19 website (NZ government, n.d.)

A key factor in the success of the COVID-19 communication was that New Zealand's leadership "perform[ed] the role of comforter and counsellor, helping individuals to make sense of the crisis and reassuring them about the future" (Mcguire et. al, 2020). During this time, Prime Minister Jacinda Ardern held regular press briefings and recorded podcasts to keep the public informed on the issue and allow people to give feedback and advice regarding the pandemic. The cover photo for this podcast is shown in Figure 13. These approaches illustrated that it is important for organizations to remain honest and transparent when communicating information and that it is often better to be optimistic rather than using doom or gloom statements. The press conferences and podcasts, along with Ardern's active social media presence left people feeling reassured and called to action since they were receiving guidance that was both informative and practical from a capable government.

Figure 13. Jacinda Ardern's COVID-19 podcast (Buzzsprout, 2021)

The methods used to communicate the risks of COVID-19 to the New Zealand public can also be used for the communication of other risks, including SLR. The difference between these issues is that there was a strong sense of urgency in the COVID-19 case as the threat was immediate. SLR is more of a long-term threat, however it is critical that action be taken now to minimize further impacts. This urgency must be conveyed when communicating information on SLR to the public.

4.3 Visual Science Communication Strategies

Our team took the opportunity to engage with some of the interactive SLR communication tools to determine which features were most effective at doing so. This was done to better understand the point of view of the general public. We conducted participant observation on currently available multiple interactive maps as well as a story map, and an informal participant observation on an online game. The complete table which displays the team's participant observation data can be found in Appendix G. Overall, we found that the maps were effective at

displaying some information on SLR, but were incomplete in conveying the message, and did not adequately convey the risks associated with SLR.

For example, the maps that we found to be impactful had features such as a scroll bar to demonstrate incremental changes in SLR, illustrating the SLR risk for different recognizable landmarks. The maps also displayed specific information, such as low and high tide SLR predictions and Mean High Water Spring (MHWS) data (the maximum level of spring tides over a 19-year cycle), for different areas and scenarios, and indicated the years by which effects might occur. We also found that using varying colors to highlight types of risk in areas that could be affected by SLR, whether by storm surges or direct and indirect inundation, was advantageous. In addition, some of the maps allowed for the incorporation of filters showing locations of SLR management approaches, such as flood gates and pump stations, as shown in the WRC map in Figure 14. This feature was beneficial in showing the viewer where SLR mitigation is currently occurring.

Figure 14. Use of flood gates (blue/white circles) & pump stations (yellow squares) in WRC map (WRC, n.d.)

Although the interactive maps have many advantageous features, based on our participant observations there are still opportunities for improvement. For example, in the WRC map shown

in Figure 14, the maps do not show how the flood gates and pump stations help to mitigate SLR impacts. The map could be improved by highlighting the impacts of these SLR management approaches on the amount of SLR in an area by showing different impacts of SLR with and without these mitigation structures. Furthermore, we found that the majority of the maps could have used more definitions to clarify the information so that the public could understand what the data represents. For example, definitions of MHWS, the different mitigation structures such as floodgates and pump stations, and tidal information, such as high, low and max tide, can provide more clarity to the reader. In addition, the lack of a legend made some of the maps confusing, making it hard for the user to understand what data is being presented. For example, the colors in the GWRC map were not well-defined when displaying different levels of risk of SLR, which is shown in Figure 15. The blue color on the scroll bar indicates an extreme case of SLR. This may confuse viewers and give the impression that the blue, inland areas on the map are at higher risk. Only after talking to the developer of this map did we learn that the inland areas, which are blue, represent a more extreme case of SLR which may, or may not occur.

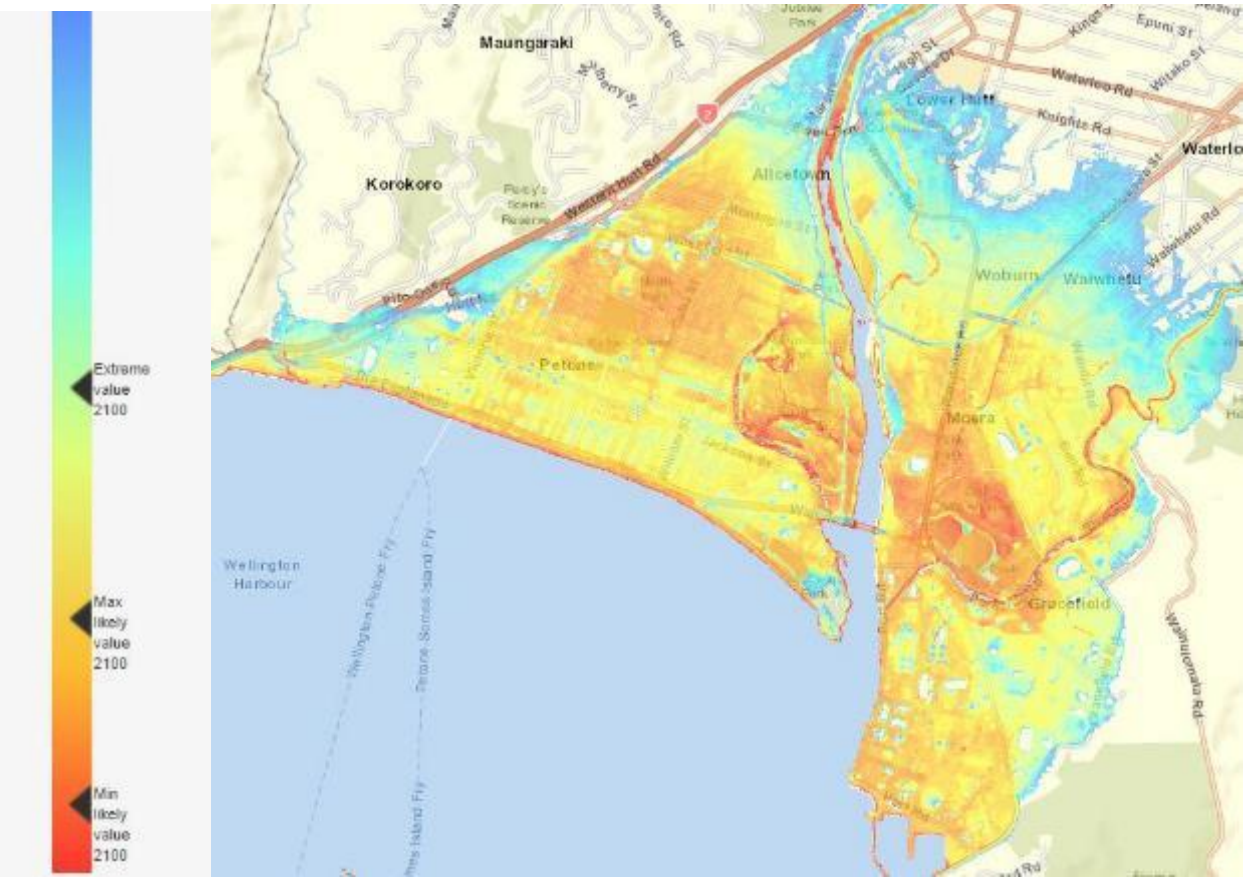


Figure 15. The colors display different levels of SLR on GWRC map (GWRC, n.d.)

In addition, basic elevation data, which shows how impactful SLR can be, was not always provided on the SLR maps. In some of the maps, there are areas where SLR seems to have no effect, but with no elevation data, it is difficult to understand why those specific areas are not impacted by SLR. When interviewing a map developer from the WRC, he said the reason why those areas are not affected is because they are at high elevations, but this elevation data isn't provided in the WRC map. By presenting elevation data, more clarity can be provided to the user.

Based on recommendations from interviews we expanded our participant observation to include story maps, such as the Wellington City Council (WCC) map. A story map is a platform which gives a visual narrative to accompany an interactive map. This helps to add local context to the issue. We appreciated the additional features provided in the story map format because it showed a 3D satellite view of how SLR is impacting specific areas, as illustrated in Figure 16. The story map also included captivating images to give the reader visualization of local scenarios.

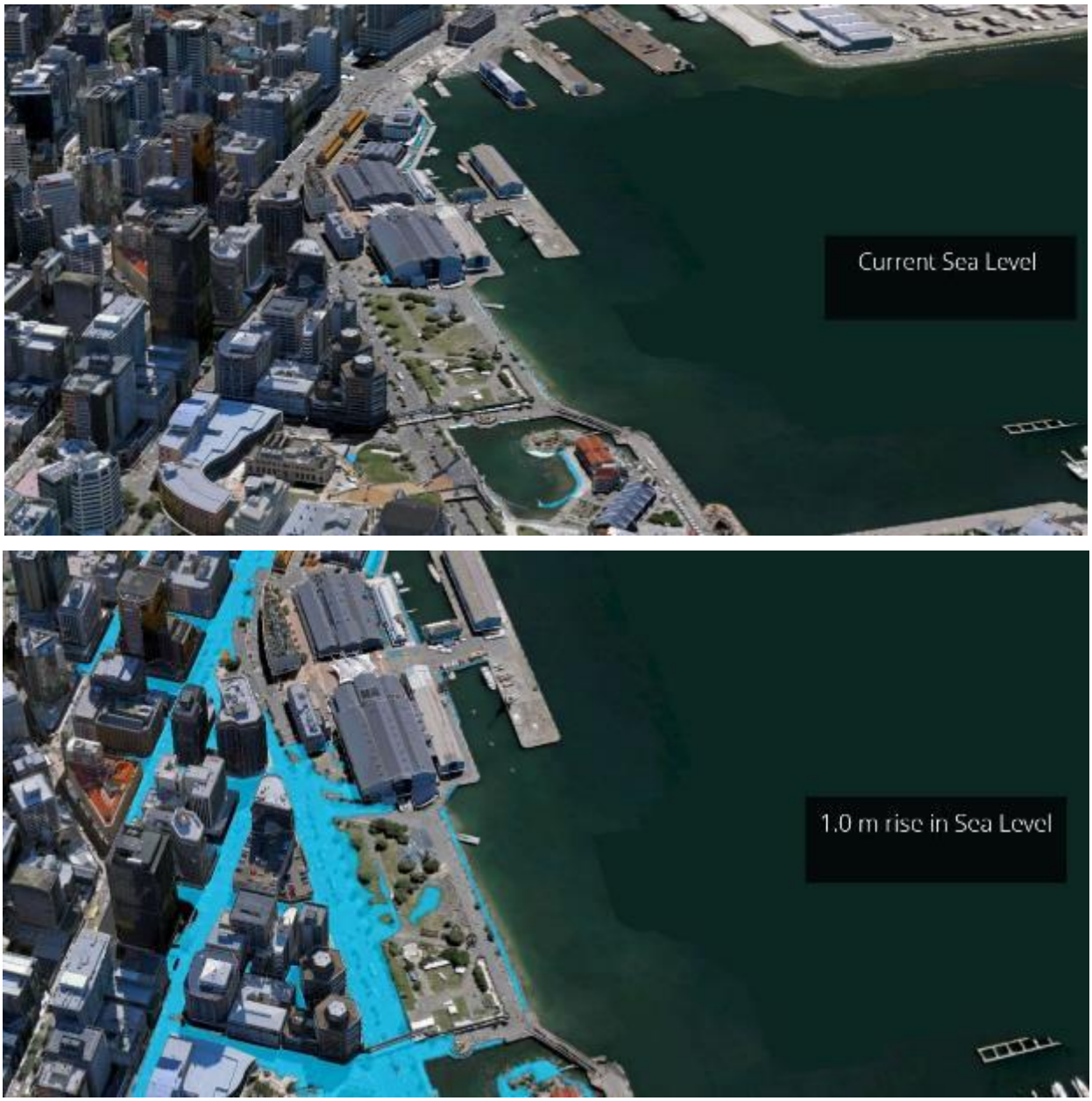


Figure 16. Effects of SLR in a 3D satellite map view. The top image shows current sea level and the bottom shows a 1 meter rise in sea level (WCC, n.d.)

The story map is a good alternative to the other maps but it can be improved by adding a few key features. For example, it would be advantageous to use a scroll bar instead of the current checkbox system, which is shown in Figure 17. This would allow the map to show increments of risk and uncertainty. With the checkbox system, the user cannot see the gradual increase of areas impacted by SLR because the user needs to uncheck and recheck different boxes. The WCC map could also be improved by explaining how the areas will be affected by SLR on the map itself,

which is something that other maps have implemented, and by providing elevation data to show why some areas aren't affected by SLR. The story format provides a narrative on how the areas are affected, but when standing alone, the map can be confusing to the user. Another feature that would be beneficial would be highlighting key locations such as museums, markets, and tourist landmarks to help the viewer better visualize the impacts of SLR.

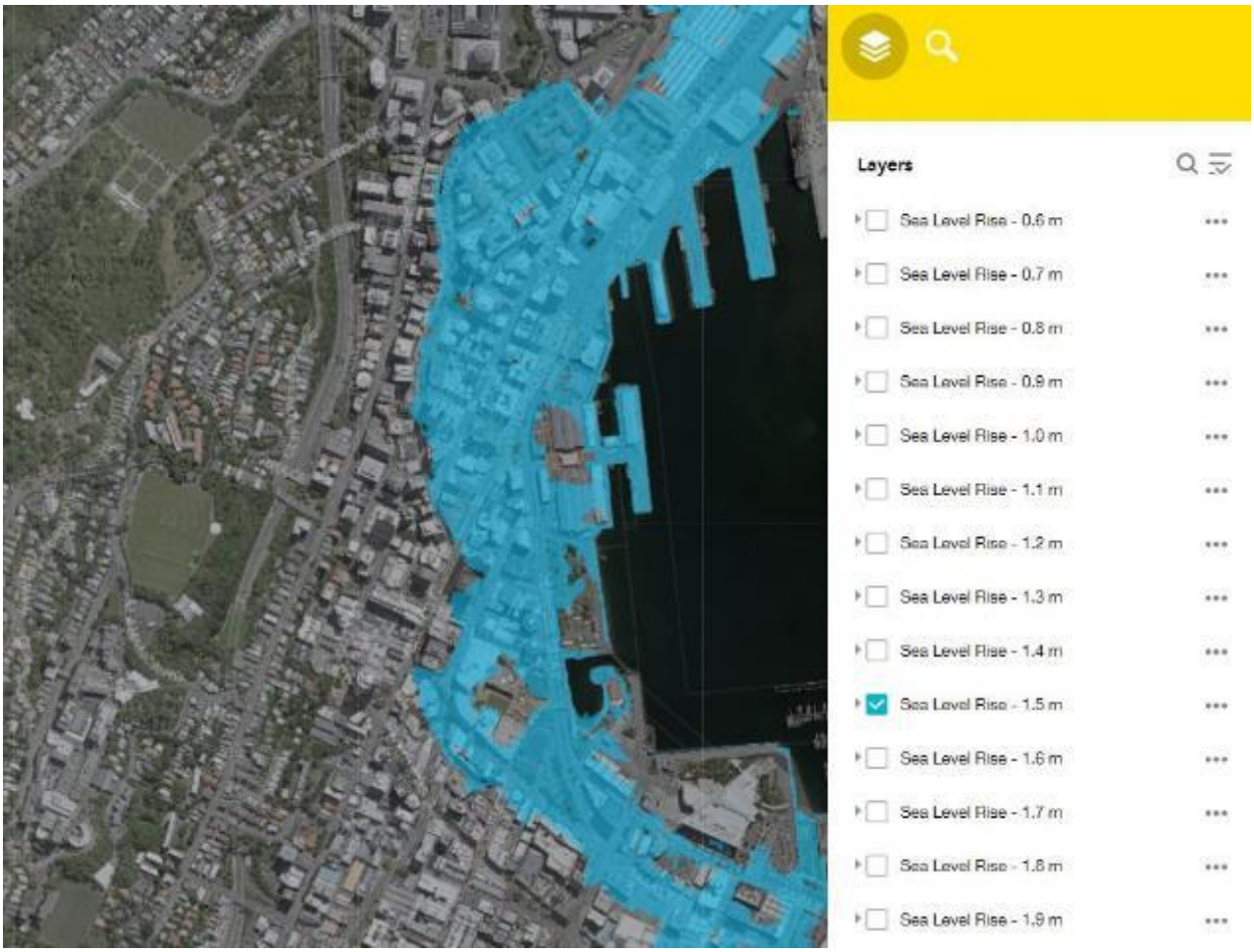


Figure 17. Use of checkboxes to display different levels of SLR in the WCC map. This image shows 1.5 m in SLR (WCC, n.d.).

Additionally, we played an online, serious game, called Adaptive Futures, to see how well this format communicated SLR information. A serious game is a game designed for a primary purpose other than pure entertainment, which in this case is educating the public about SLR and the decision making behind mitigating its impacts. We found the game to be more engaging than the maps we observed, since it forced the team to make critical decisions based on balancing different opinions and limited resources, similar to those that policy makers have to make. The

game also allowed us to draw our own conclusions, which was the main inspiration behind having interactive games to help illustrate the impacts of SLR. The home screen of this game is shown below in Figure 18.

Figure 18. Home screen of the serious game "Adaptive Futures" (Adaptive Futures, n.d.)

When interviewing the developer of this game, they stated that "the games allow users to engage in decision making and gives them a sense of what it's like to make tough decisions" (climate research scientist 2, February 22, 2021). Playing the game gave us a different perspective on SLR by forcing us to consider what it is like to be a government official and consider all the options to make an informed decision that the community members will support. The game also provided a direct insight into how SLR will impact communities. When people play this game, they will get an "a-ha moment" which makes them more likely to understand the situation at hand and potentially take responsibility to help reduce the effects of SLR. When an individual forms their own conclusions about how SLR will impact themselves and their community, they are more likely to develop a personal connection and take ownership in reducing the impacts of SLR.

4.4 The Impact of Interactive SLR Maps on the Public

Current Viewpoints of SLR

The first pattern we identified from our public survey, with 49 responses, was that the participants are reasonably aware of the impacts of SLR. Around 93% of participants believe that climate change is a real and imminent threat to New Zealand and that it is a result of human action. Around 71% of participants said they have experienced impacts of climate change but all participants were able to list specific impacts of climate change. For example, 29% of participants who said they have not been affected by climate change listed the following as climate change impacts: rising sea levels, stronger hurricanes, extreme weather, and coastal erosion. Additionally, 89% of participants agree that they are aware of how SLR will directly affect them, as shown in Figure 19.

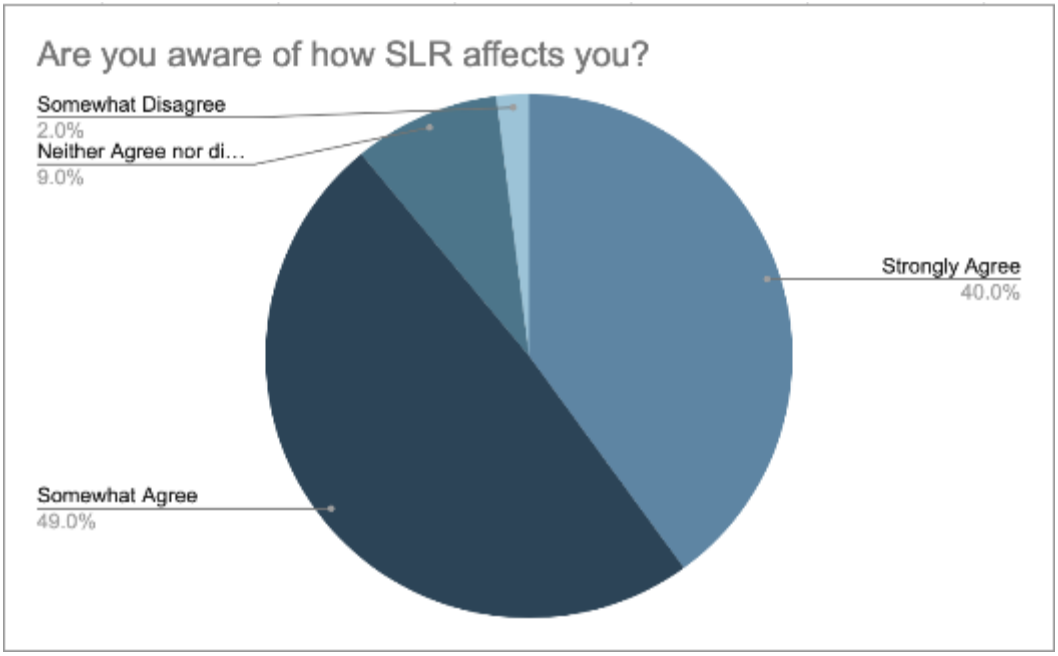


Figure 19. Participants' opinions on whether they are aware of how SLR affects them (n=44)

Furthermore, around 88% of participants know how to find information about SLR but only about half of the 88% said they actively seek out this information. Those who do seek out information view journal articles, research literature, internet videos, television programs, and local council websites and announcements.

Figure 20. Actions that participants have taken to reduce impacts of SLR (n=44)

Another noticeable trend was that participants were actively involved in efforts to mitigate SLR. 88% of participants agreed that they have taken action to reduce the impacts of SLR. A few of the actions taken are illustrated in Figure 20 above. A few words are larger than others which represents that some actions are more common than others.

Thoughts on Interactive Maps

The public survey data showed that the interactive SLR maps did not provide enough useful information on SLR. We found that the maps were not widely used amongst survey participants, with only about 50% of them having viewed interactive SLR maps for their community prior to participating in this survey. The majority (96%) of respondents were, however, able to locate key landmarks on the maps and 81% stated that they know how these areas will be affected. Interestingly, viewing the maps had no effect on the actions that participants plan to take to reduce the threat of SLR. Most people listed the same actions that they planned to take prior to viewing the maps, including limiting car use, buying second hand, reducing waste, and eating a plant-based diet. A few respondents said they do not plan to do anything to mitigate the risk and one said that "whatever [they] do as an individual is meaningless" (NZ SLR Questionnaire, February 23, 2021). This indicates that there may be some fatigue surrounding this issue in the public, leaving individuals feeling helpless and possibly neglected by their government and

community. Additionally, when asked about their feelings towards SLR before and after viewing the maps, a large number of participants responded that their feelings did not change. Figure 21 shows the breakdown of responses to this question before viewing the maps and Figure 22 shows the feeling and opinions of the participants' after viewing the maps. The word bubbles to the right of each figure show the most common responses to the "other" option.

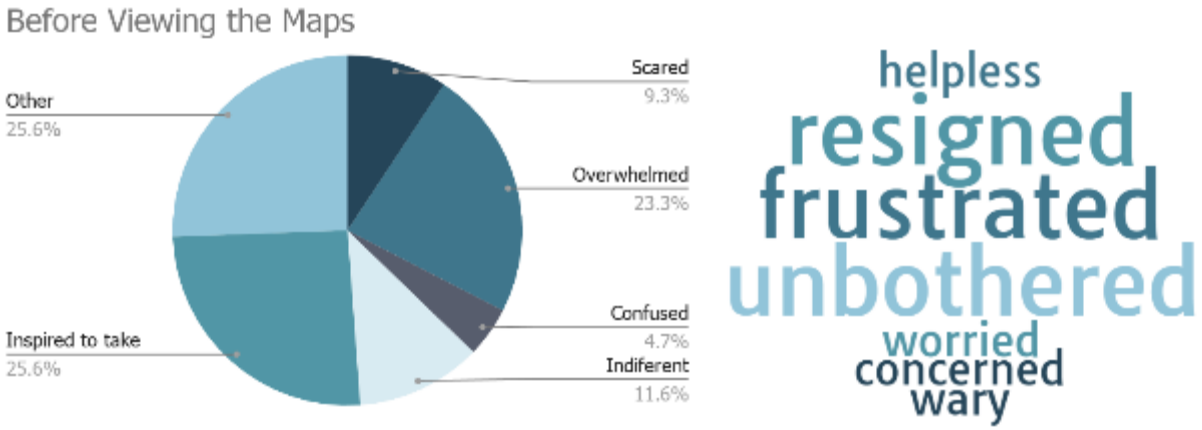


Figure 21. Responses to "How do you feel about SLR?" before viewing the interactive SLR maps (n=44)

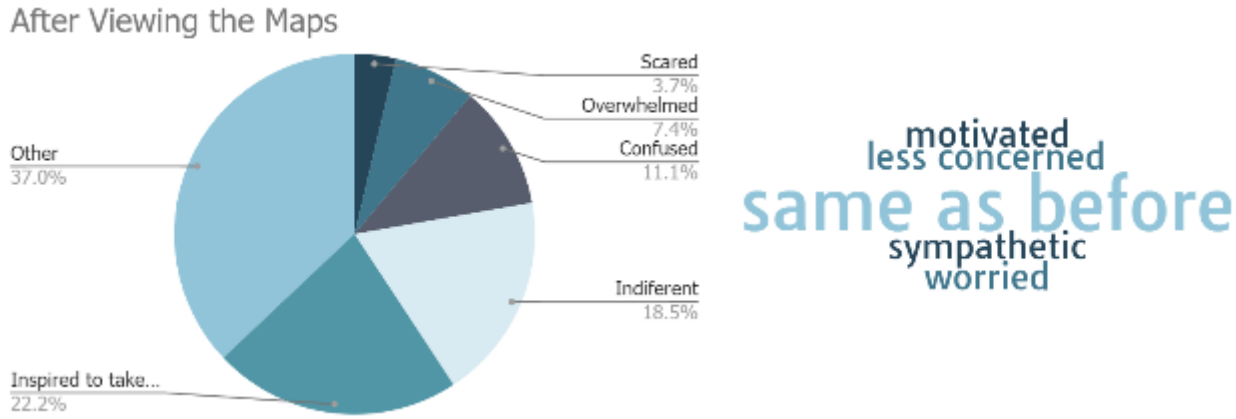


Figure 22. Responses to "How do you feel about SLR?" after viewing the interactive SLR maps (n=27)

The survey data also showed that the interactive SLR maps were not effective at inspiring individuals to take action to mitigate SLR. Only 40% of respondents said that they were more likely to take action after viewing the map while 35% said that they were less likely to do so.

One participant even mentioned that the maps made SLR seem like less of a threat than they had initially thought, emphasizing the maps' inability to spark action. Despite this, 65% of respondents thought that the maps were effective at communicating information about SLR, though they had many suggestions on how the maps could be improved. Most (89%) respondents said that they are not tired of hearing about SLR and 60% expressed that they would like to learn more about SLR. This indicates that the public would likely be receptive to additional information on SLR in a new or improved format.

The participants offered many suggestions for changes to the maps to improve their ability to successfully communicate SLR. They recommended adding information on mitigation and adaptation strategies for SLR, so that they are aware of what actions local councils and the central government are taking to deal with the threat. This would also give individuals an opportunity to take action into their own hands if they know what can be done. Additionally, many respondents expressed a need for personal narratives to be incorporated into the map. One participant suggested that the map give examples of what the "lived experiences of sea level could actually be like at certain levels" (NZ SLR Questionnaire, February 23, 2021). They want to physically see the effects of SLR on their communities, not just numbers on the map, as one participant pointed out that "these tiny increase rates will make most people think that's not a problem [and instead] communication needs to steer...towards the increase in risk (%) of extreme storm surges events reaching [individuals'] house[s]" (NZ SLR Questionnaire, February 23, 2021). Essentially, the technical data is lacking in emotion, and appears quite sterile for the average consumer. Another participant explicitly mentioned that "the average person might need beyond a cool map to really hit home the gravity of the situation," which demonstrates this general consensus amongst the participants (NZ SLR Questionnaire, February 23, 2021). In our interviews with participants, they mentioned how they mostly cared about their homes, neighbors, and communities, and so making the information personable and relatable is key in inspiring people to take action. Another issue that many participants had was that the predictions are projected too far into the future. For many individuals, 2100 is too far away for them to care. Additional predictions for sooner times would therefore be beneficial. Some participants also suggested providing historical data on SLR so that the viewer can have a greater understanding of the issue. Finally, a few respondents thought that the maps displayed a model of SLR that is

too simplistic and that more information is needed to convey the uncertainty of SLR and all that contributes to it.

Alternatives to Interactive Maps

After looking at the interactive maps and asking them to recognize their concerns, we also asked the participants to rank various alternative methods for SLR communication from strongly agree to strongly disagree. Specifically, we asked them to rank story maps, news articles, and interactive serious games based on whether they thought these tools would be more effective at communicating SLR than the interactive maps. Most participants were enthusiastic about the story map, with over 53% of participants say they strongly agree with the idea of a story map. A pie chart showing the complete data is in Figure 23.

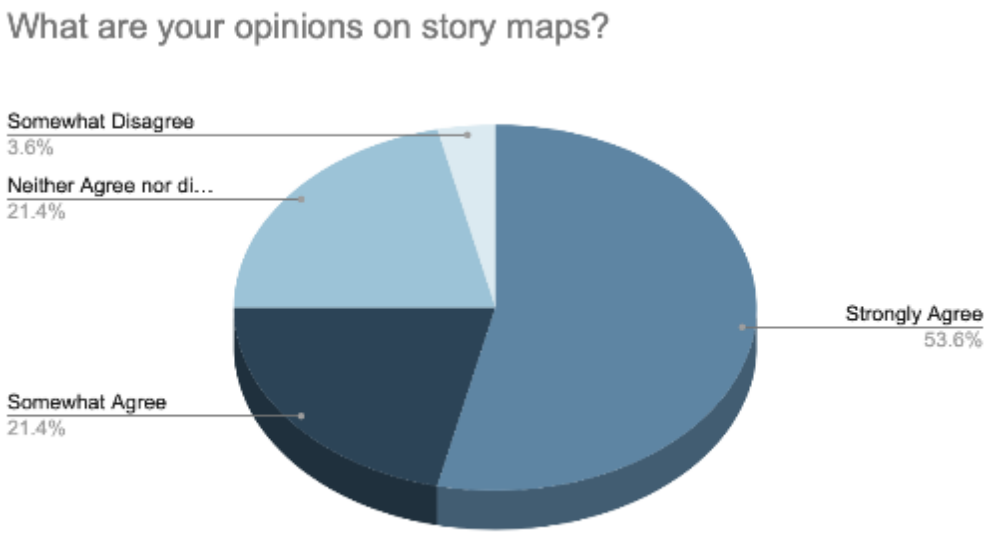


Figure 23. Participants' opinions on whether story maps, such as the WCC map, are more effective than interactive maps at conveying SLR information (n=28)

The story map addresses many of the concerns that the interactive maps needed improvement on, such as necessity of images, narratives, and a simpler yet touching format that is relatable and personable to the audience. Therefore, it is not surprising to see many in favor of this format.

Surprisingly, the participants were lukewarm to the idea of news articles. We as the team believed that the articles would help bring personal stories to the forefront of the public's attention. The data, displayed in Figure 24, disagrees with this thought process.

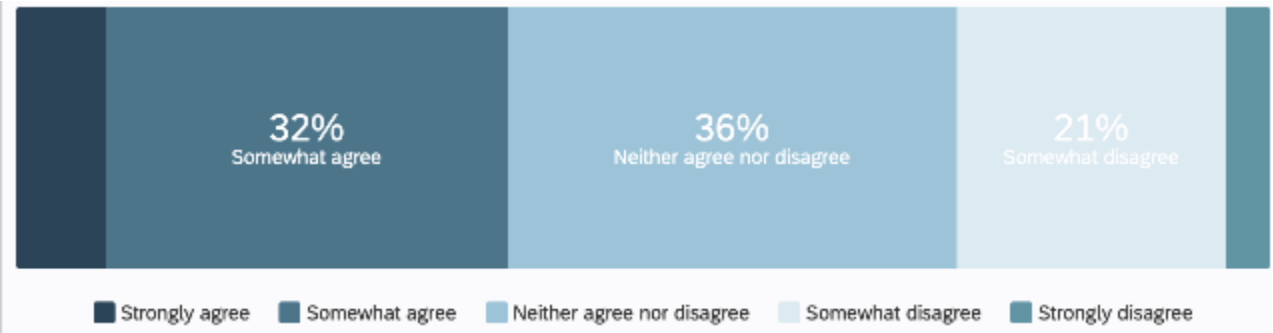


Figure 24. Participants' opinions on whether news articles are more effective than interactive maps at conveying SLR information (n=28)

It seems that many were disinterested in the notion of reading articles, possibly due to the rise in social media, which accounts for shorter attention spans and the dislike for longer articles that have multiple paragraphs of text. Therefore, it is clear that having something more interactive rather than just a passive article is vital to effectively communicate SLR.

We also asked participants to rank their opinion on an interactive game, much like the serious game that we played in our informal participant observation. These opinions are shown in Figure 25.

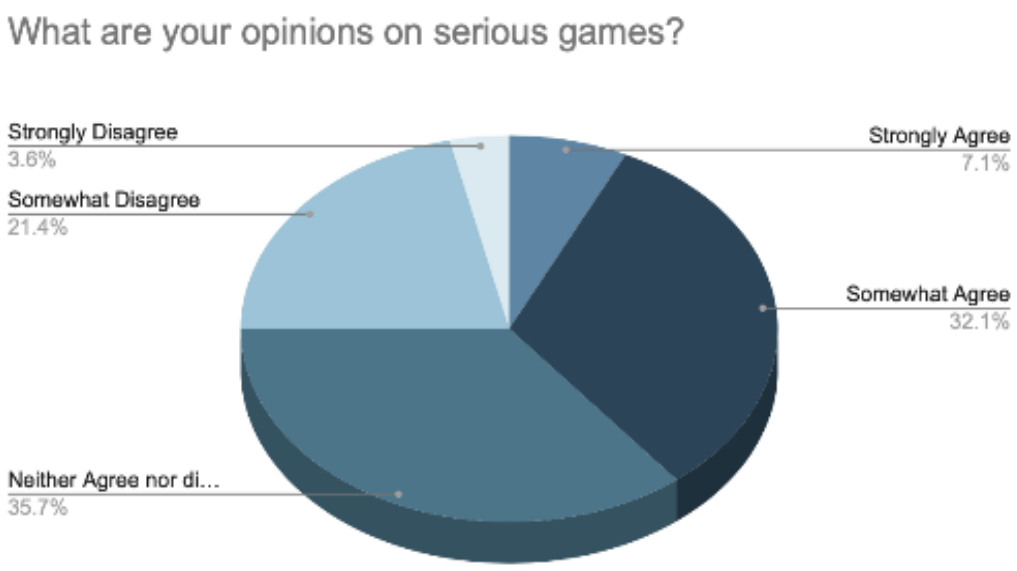


Figure 25. Participants' opinions on whether serious games are more effective than interactive maps at conveying SLR information (n=28)

We found that although 36% of respondents were supportive of the idea of a serious game, more than 64% were disinterested in this idea, which was surprising. A reasoning for this could be that games come with many technicalities, including sharp thinking skills, fast reaction times, and other factors that might influence an individual's opinion on games. Therefore, some people may be disinterested in the idea if they do not align with these factors. Furthermore, creating a serious game is a relatively new concept that hasn't been fully explored, meaning that it is likely that most of the respondents have never seen a SLR serious game before. This can lead to people conceptualizing an interactive SLR game that will vary drastically amongst participants, which could be another cause for the wide disparity in the results.

Lastly, we asked if people were interested in social media posts as an alternative to maps, and to our surprise, many people were not open to the idea of social media posts, with 71% of participants either disinterested or against the idea. The breakdown of the responses is shown in Figure 26.

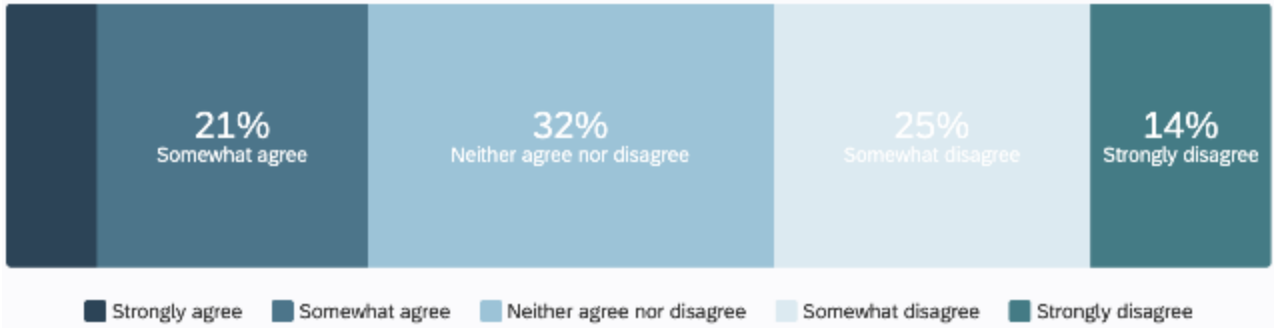


Figure 26. Participants' opinions on whether social media posts are more effective than interactive maps at conveying SLR information (n=28)

This may be because most of the participants of the survey were older, but that may not be the only reason. Currently, there are not a lot of climate change agencies that have a strong and impactful social media presence. With few examples to reference, individuals might feel less inclined to support this concept.

We also noticed that some responses were dependent on age. For future improvement of the maps, we asked the public if they would provide any feedback on the maps, ways that they could be improved, and any specific questions they still had after using the maps. We divided the responses to these questions into age categories of 23-33 (Figure 27), 34-44 (Figure 28), 45-55 (Figure 29), and 56-77 (Figure 30) and highlighted the words used most by each age group in figures 27, 28, 29, and 30. These keywords represent how each group felt about the maps.

Figure 27. Most popular responses for age category 23-33

Figure 28. Most popular responses for age category 34-44

Figure 29. Most popular responses for age category 45-55

Figure 30. Most popular responses for age category 56-77

When analyzing these responses, we discovered that in general, all age groups felt that the interactive SLR maps need improvement. All of the age groups noted that the change in SLR over time was miniscule and they were unable to understand the severity of SLR from looking at the maps. In the 23-33 age category, the public suggested that a 3D Google Earth view of the properties would be more effective at conveying SLR. In general, this age group also felt as though the maps were too vague and that only experts would understand the technical aspects of the maps. Those that specifically looked at the GWRC map found that the orange and red lines were confusing and unclear. In the 34-44 age category, some improvements that were mentioned included improving the resolution of topography, including all of New Zealand on the maps, and developing a mobile-friendly version. Surprisingly, the 45-55 age group seemed to enjoy the maps more than the other age groups since they provided more positive feedback. The last age category, 56-77, represented the older community with some of them noting that they don't use social media often and thus would not be likely to view information this way. Some of their suggestions also included translating the maps into different languages for the Māori community

in Te Reo, or other universal languages, such as Mandarin, to make the maps more accessible for all potential users.

Overall, we discovered that people of different age groups all felt that improvements were necessary to the maps, and that respondents were more open to story maps that have captivating narratives, as well as serious games, both options which are more engaging, interactive, and therefore, meaningful to the audience.

4.5 Discussion

It was clear from our NZ SeaRise and map developer interviews that it has been generally assumed that the interactive SLR maps are the most effective tool for communicating SLR information to the general public. However, through interviews with experts in climate science and science communication, we learned that personalization strategies need to be used for SLR communication to generate measurable impact on the audience, shown through an increase in public engagement. Interactive maps have some tools that can convey essential SLR data, and therefore are a useful resource, but they may not be dynamic or personal enough to inspire action. This common theme was also noticed in data collected during our participant observation and public surveys.

Both the map developers and NZ SeaRise scientists agreed that the goal of the maps is to be a conversation starter; they are designed to display complex scientific data in an accessible and simplified format. Numerous case studies indicated that communicators should “lead with [their] strongest argument” and make it as clear as possible to allow the public to easily comprehend the information being presented (Schweizer, 2009). This idea of simplifying information was supported by the comments and responses of several interviewees. For example, a map developer from the GWRC expressed that with the map, they wanted “to give the public simple information about SLR so [the viewers] understand it better but also [remain] engaged” (GWRC map developer 2, February 18, 2021). He further elaborated that although the information is easily accessible, it is hard to understand the impacts if the information is too scientific or technical, which can make the public feel overwhelmed and disinterested in learning more. This notion of simplicity was also supported by a climate research scientist from NZ SeaRise, who stated that there are two types of public involved, technical and general, which is why when presenting

information to the general public, it should be given in a non-technical format. By portraying information in a simple format, it can leave an emotional impact on the reader. Therefore, when conveying information, making it personal will encourage people to act upon the situation or problem.

Many of our survey participants expressed that the maps did not personalize the information enough and that they could be improved by adding personal narratives and showing direct impacts. As one participant mentioned, “SLR is 3mm per year [and their] house, like most houses on the coast, is not 3mm or 3cm or even 30cm above the high tide mark, the latter of which would take 100 years of SLR to reach” (NZ SLR Questionnaire, February 23, 2021). In order to successfully communicate the threat of SLR and help individuals better understand the risks, local examples and personal narratives must be included. This idea is similar to the story map and serious game which combine these concepts, providing both the scientific information and a compelling narrative, which is much more impactful than a standard interactive map. We found that as long as the data is displayed in a visually appealing manner, the maps can serve their purpose of giving a general overview of places that will be impacted by SLR. However, the interactive map alone could be improved by delivering a personal connection with the effects of SLR. Maps should be coupled with other communication methods such as interactive games, illustrative images, or informative videos in order to most effectively convey this information to a diverse audience. The ultimate goal is for people to discuss the topic of SLR and when a consensus starts to form, individuals start to match their own opinions with those around them.

5.0 Recommendations and Conclusion

Based on our findings outlined above we have proposed the following recommendations to NZ SeaRise to help them to better convey information about SLR to the general public. We have organized these recommendations into categories of high priority, medium priority, and future opportunities if time permits.

High Priority

Recommendation 1: Create a 'central hub' website for SLR data

In our interviews with science communication experts and case study research we found that the general public does not know how to react to the increasing threat of SLR. For this reason, we recommend developing a 'central hub' website that accounts for the diversity of the public. This information hub should provide information about SLR and its threats on the home page with easy access to additional information in organized tabs, much like Figure 31, which shows an example of New Zealand's COVID-19 central website.

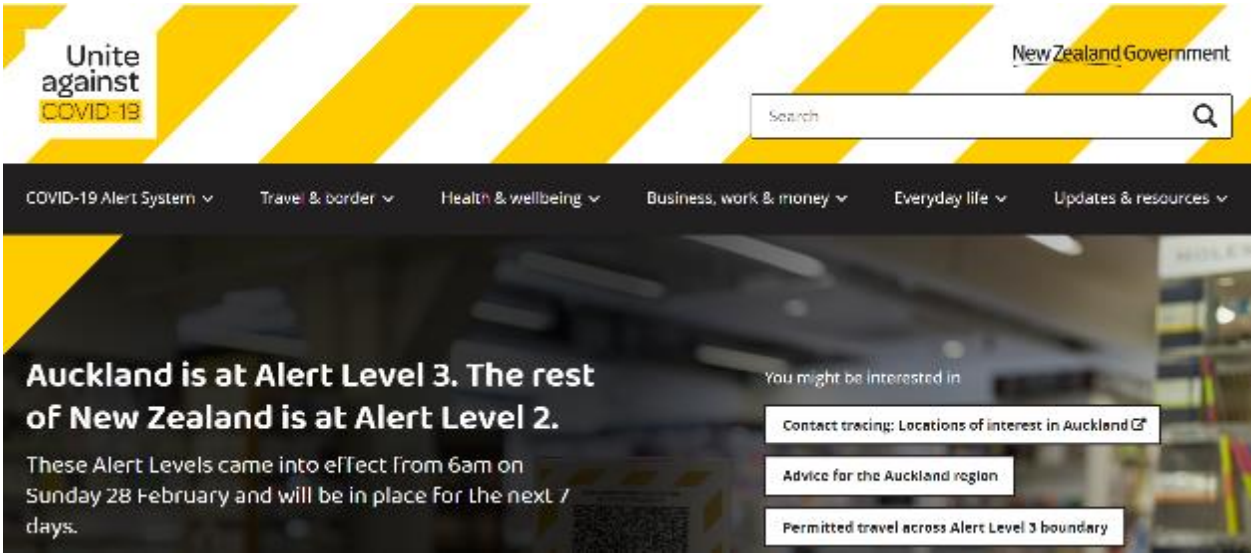


Figure 31. New Zealand's COVID-19 Information Portal (NZ Government, n.d.)

The specific information to be found in this website would include, at a minimum:

- Interactive SLR maps from around the country
- Serious and interactive games, such as Blackett's Adaptive Futures
- Reports and media links that depict stories and updates regarding SLR.
- Global narratives, as in touching stories of those that are directly impacted by SLR

- Social media links to important organizations, such as NZ SeaRise, NIWA, and New Zealand Central Government
- Effective methods to mitigate SLR (for example, a “What can you do?” tab)
- Citizen science opportunities
- Advertisements for local climate change events
- Option to sign up for a monthly newsletter to get updates and more information

This website should include all of the relative information regarding SLR, presented in a simple format that includes technical data to accommodate all audiences. The WRC has worked on such a concept, creating a ‘hazards portal’, which has numerous facts on coastal inundation, as well as the interactive map. A screenshot of the WRC Hazards Portal is shown in Figure 32.

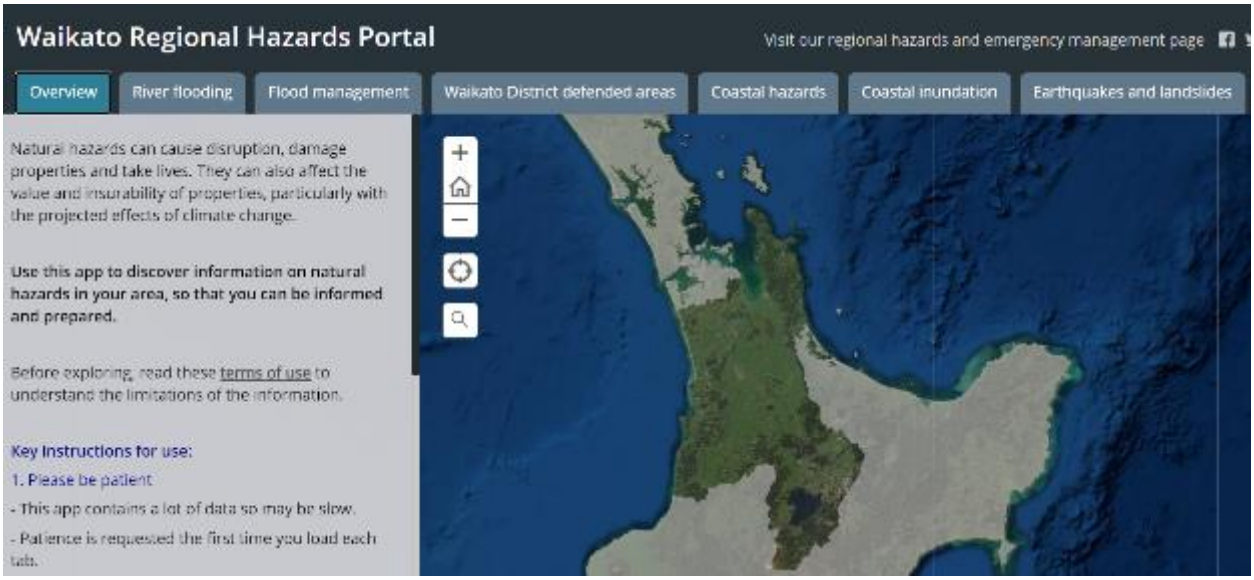


Figure 32. WRC Hazards Portal (WRC, n.d.)

As shown in both of these figures (31, 32), the tabs at the top can provide more detailed information for specific audiences depending on the viewer’s interests. With this format, the general public will not have to do extensive research to understand SLR, which often further discourages people to take action to mitigate it, a trend that is detrimental to both coastal communities and countries alike.

Implementing this plan is estimated to take less than a year, which accounts for factors such as climate science staff working together to create, as well as gather, materials from critical sources and contracting with IT staff or interns to build and maintain the website. When the website is complete, it will be the center of SLR communication, where individuals, agencies, educators,

and others can interact with a range of tools to keep themselves and others more informed. NZ SeaRise can use website trackers like Google Analytics to measure traffic on the website, which can be a direct indicator of engagement.

Recommendation 2: Strengthen NZ SeaRise's social media presence

This recommendation is inspired from the COVID-19 communication strategies in New Zealand. Hosting a strong social media platform or campaign can boost interactions between the public and NZ SeaRise while also reaching a wider demographic. Although NZ SeaRise has a Twitter account, a reconstruction and revisioning of their social media presence is needed. The reconstruct would involve updating their Twitter presence and incorporating other social media platforms such as Facebook and Instagram. The suggested platforms should be utilized in these ways:

- *Facebook:* to communicate research findings and insights, important updates, and relevant news about SLR to the public by consistently posting, having Facebook Lives, and connecting to people directly in the comments. This is most effective when communicating to ages 25 and older (Tankovska, 2021).
- *Instagram:* to post illustrative images of the effects of SLR and also introduce the research scientists and experts to the public making them more relatable and credible. Additional engagement could include the "stories" feature for fact/knowledge test polling. This is most effective when communicating to ages 18-34 (Tankovska, 2021). Sample posts that could be used on Instagram are shown in Figure 33.
- *Twitter:* to post primary findings, personable statements, and videos to show SLR research and its impacts. This is most effective when communicating to ages 18-49 (Tankovska, 2021).

These social media platforms can be accessible via the 'central hub' website, providing easy access to new followers.

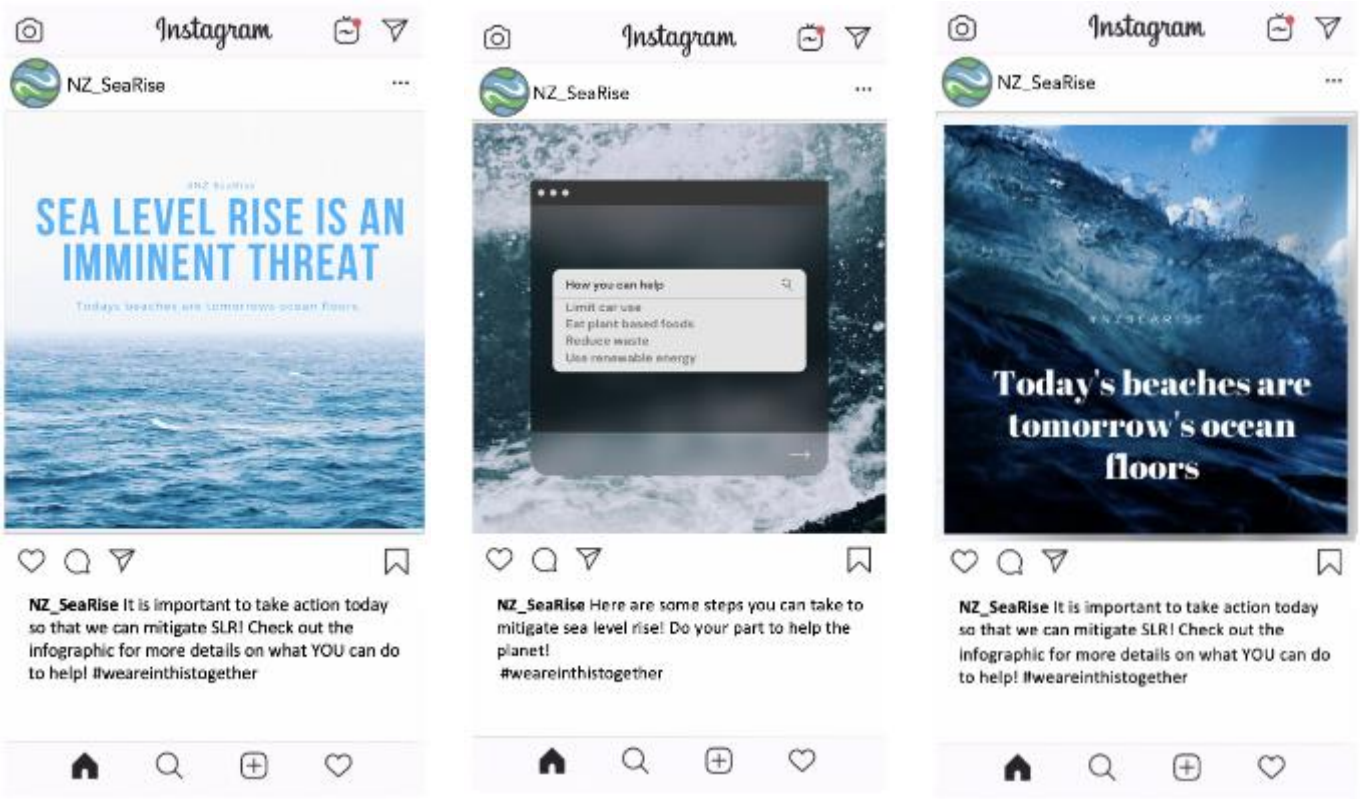


Figure 33. Sample Instagram posts for NZ SeaRise

Unfortunately, engaging the public through social media requires time and a consistent effort to attract a range of followers and it can be difficult to maintain. If this recommendation were to be implemented, the timeline would be around six months to one year which is typical to build a strong social media presence. The timeline is as follows:

- First 1-2 months: Identify the goals and objectives of what information to share and set up the groundwork for each platform.
- Next 4-5 months: Share informative content, post at a comfortable rate, and most importantly, engage in discussions with the public.
- Final 6 months: Share these platforms with other organizations and optimize the media using keywords.

NZ SeaRise can gain inspiration from successful social media accounts such as World Economic Forum, Green Matters, and National Geographic. In order to gain more exposure in a shorter period of time, NZ SeaRise can contact the owners of popular social media accounts that already have a large following in New Zealand. These accounts can potentially post about NZ SeaRise to spread the word to a larger audience and increase NZ SeaRise's follower base. To manage the

social media, NZ SeaRise can interact with in-house PR teams, or with interns or area university/high school students who can populate the platforms and build its presence. The team would be in charge of carrying out the tasks listed above for each respective platform. To determine if the strategy is successful, it is necessary to monitor the follower base and determine whether conversations are being started. Overall, building a strong social media platform can help NZ SeaRise gain additional visibility, make them a credible messenger, and keep the public informed and educated about SLR.

Medium Priority

Recommendation 3: Create an effective SLR infographic

In our participant observation we found that SLR information can be difficult to find if the viewer does not know exactly what they are looking for. By displaying an overview of SLR in a public area or online platform, people will be more aware of the issue and the information that is available. The critical information that is to be displayed on this infographic is listed below:

- The core messages that *SLR is an urgent, imminent threat* and *a certain amount of SLR is inevitable, but action can be taken to prevent more*
- Information on adaptation and mitigation actions
- QR codes linked to additional SLR information
- NZ SeaRise logo and website

We have provided a sample infographic in Figure 34.


NZ SEARISE
TODAY'S ACTIONS THREATEN TOMORROW'S COASTS
How will you be impacted?
Stronger storm surges
Frequent flooding
Coastal erosion
Movement inland
How can we adapt?
Protect infrastructure
Accommodate the rise
Retreat from coastal areas

Figure 34. An outline of a potential infographic design

Infographics and representative icons are more of a passive learning tool, but can be visually appealing, recognizable, and provide essential information in a simple manner. Our interviews with map developers confirmed that SLR communication is not easily understood by the public. By simplifying this information into a brief visual format or providing a QR code to the central SLR hub website, the data can be viewed quickly. Infographics can easily be displayed in public places, such as at public events, grocery store notice boards, schools, public walkways, and train stations. They can be posted online either on governmental web pages relating to climate change or social media platforms. This infographic format should be posted in both online and offline platforms in order to reach audiences that may not have access to a computer or the internet.

The implementation of this recommendation would be relatively simple as it would just require designing the infographic, compiling QR codes to either the central SLR hub or other sources of SLR information, such as interactive maps or games, and gaining permission to post the infographic on public forums. There are numerous software platforms available to aid in the

development of infographics. For example, Venngage was used to develop the example shown in Figure 30 and offers discounts to universities and nonprofits to access premium features such as the ability to brand and export infographics. We believe that this tool would be a successful, low-cost way to raise awareness. This recommendation bypasses the other web-based options and can be a useful and easy way to distribute part of the SLR awareness toolkit.

Recommendation 4: Partner with organizations to gain governmental support

We recommend that NZ SeaRise work with other organizations and the government to host conversations with the public about SLR as a public threat to their wellbeing. NZ SeaRise could collaborate with other well-known environmental organizations, shown in Figure 35, to gain governmental support and start critical conversations. As we learn best through conversation and through interactions with one another, a centralized governmental platform can allow for these conversations to reach more people, including those who may not actively seek out SLR information.

Figure 35. NZ SeaRise's potential partnerships to gain government support

The cost to accomplish this will be high in every aspect, from finding people to cooperate, to budgeting and management strategies, but it is a necessary step towards demonstrating to the

general public that they are not alone in mitigating and adapting to SLR and that their government is actively working to help reduce the impacts. We have already seen this concept successfully implemented when dealing with the COVID-19 pandemic in New Zealand, so we know that when people are motivated with urgency and by a capable government, they are more likely to take action. However, it is more difficult to get people to rally for changes to mitigate SLR, because there is a perception that SLR is not an urgent issue. Unfortunately, this is far from the truth; we have to plan for a common climate future that considers social and environmental justice. The specific steps needed to complete this recommendation complement each other and are cyclic, since these are consistent efforts that must be taken. These steps are shown in Figure 36.

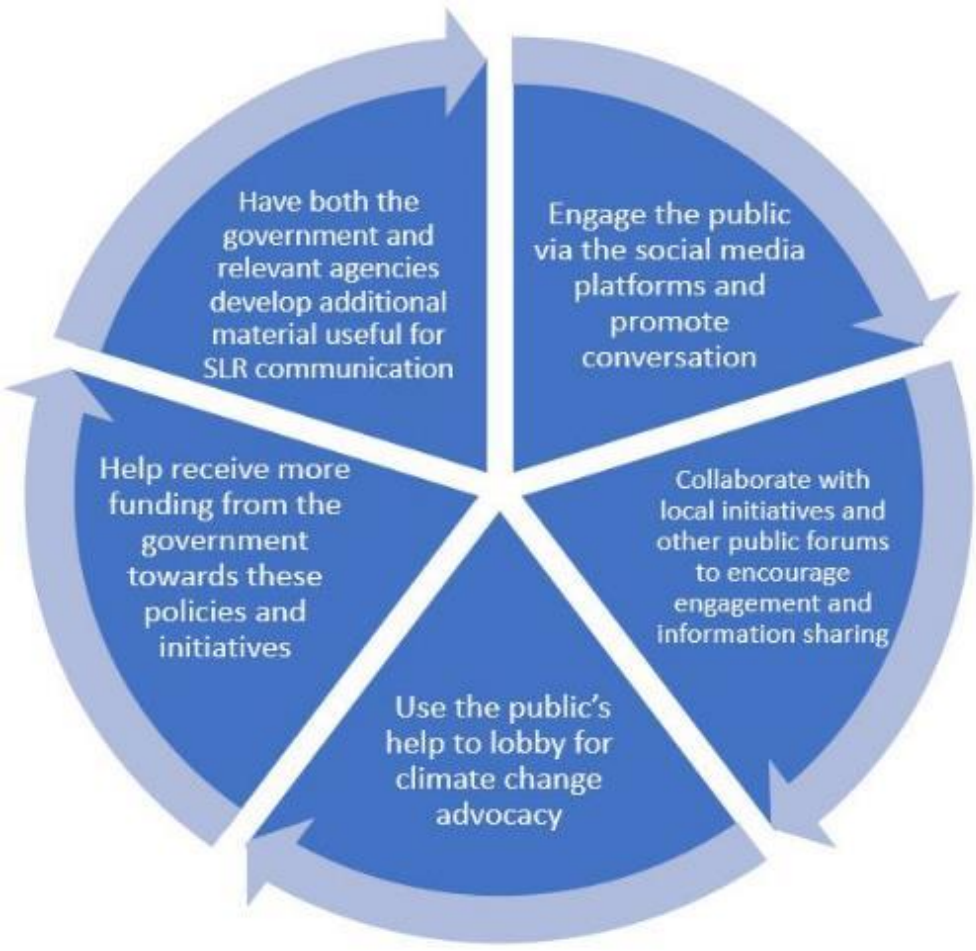


Figure 36. Specific steps needed to promote conversations and gain governmental involvement.

This initiative is inclusive and forward thinking and can bring real change in the way policies are implemented across diverse communities.

Future Opportunities

Recommendation 5: Create a public art display

We learned in our case study research that communication methods are more effective when they are personalized, visual, and engaging. Seeing the effects of SLR in a physical format can make the issue seem more tangible and change people's perspective. In the state of Texas and other areas that are subject to high flooding, flood gauges are used to measure the level of the water during a flood. An image of this is shown in Figure 37.

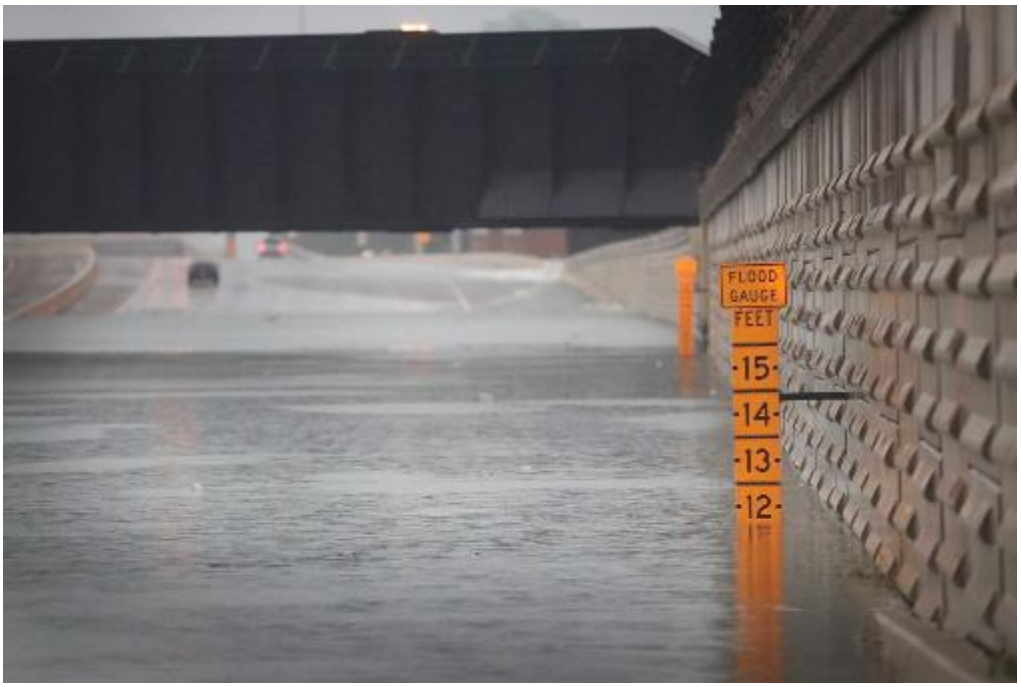


Figure 37. A flood gauge in Houston, TX (Olson, 2017)

This concept could be applied to a visual display of SLR with physical markers in coastal regions that depict the levels of SLR that are expected. We recommend installing painted markers on public buildings which display where the flood line would be with the inevitable amount of SLR as well as an extreme case if no action is taken. Showing both cases would indicate the severity of SLR and the necessity to take action. Having physical indications would clear ambiguity and would be a constant reminder of this impending issue. The implementation of these visual

displays may be more time consuming than other communication methods, but have the added benefit of citizen participation. The specific steps that must be taken are listed below.

- Agreement from businesses and the local government to paint on public property
- SLR scientists determine appropriate levels at which to paint SLR lines
- An artist can be hired or an event can be organized to paint the buildings
- Installation includes QR codes and/or NZ SeaRise logo

If the recommendations above are completed, this would be a rather easy step, requiring some communication through channels that are already open. These small indicators would provide a real-world context to the information while serving as a reminder of the threat.

Recommendation 6: Create a 3D SLR simulation

An alternative for conveying SLR is the interactive game platform that we discovered through our participant observation. It was the most engaging due to its educational style. Specifically, we recommend the use of a platform with:

- A simulation format using a 3D interactive map that can respond to user decisions to mitigate SLR
- Options to add structures to help reduce the risks of SLR such as seawalls, floodgates, and other infrastructure strategies to see how they influence SLR.
- Options to adjust levels of carbon emission and pollution cuts
- A 3D view of the specific locations that will be impacted by SLR

This recommendation combines the advantages of the interactive maps and the serious game into one simulation platform that is interactive, engaging, fun, and meaningful for the audience. This game can be distributed in schools and other institutions to teach the younger generations about the effects of climate change in a way that engrosses them. Young people are the future scientists who have to deal with the consequences of high levels and storm surges. This game prepares them from a young age.

This recommendation takes more time and creative energy than others to complete a final product. The timeline for implementation would cycle between:

- Programming the game
- Having users beta test the game
- Editing the code until the bugs of the program have been fixed
- Publishing on gaming platforms for other people to use and provide feedback

Creating the game and hiring employees, which take time and money, would be factors that would make this project more challenging to execute. However, the benefits of implementing this recommendation would be raising more awareness for SLR on a platform that engages and educates the audience in a new futuristic format. The measure of success will be a test of knowledge on SLR, assessing popularity of the game, and social media opinions. Overall, we feel as though the benefits of this recommendation still outweigh the costs.

Conclusion

Climate communication needs a revolution in thinking. It needs to be personalized and in our homes, our cars, and our social media. We are now at the point when reaching as many people as possible is the only way to ensure we are ready for conversations about SLR and climate action. Many of the map developers and NZ SeaRise members expressed this goal and had a common sentiment among them that *SLR is real, it will have local impacts on the people of New Zealand, and hopefully the public can take this information into their own thinking and take action to mitigate SLR.* The difficulty that these groups face is how to effectively communicate this information to a diverse audience. Since map developers and NZ SeaRise cannot directly speak to all New Zealand citizens, they must find a way to spark these conversations among the public in a way that encourages them to take action without leaving the public feeling fatigued or overwhelmed.

Our research has given us insight, knowledge and empathy for the imminent threat of SLR. As temperatures increase and sea levels continue to rise, educating the public about the impacts of SLR has never been more important. Public engagement and education is critical towards motivating action to minimize impacts in the long term. Climate action is a fundamental component of the UN Sustainable Development Goal #13.

Figure 38. UN Sustainable Development Goal 13 (United Nations, 2020)

The goal includes divesting in fossil fuels but also adapting to the impacts of climate change, and to SLR more specifically. This goal emphasizes the importance of developing disaster risk reduction strategies. Currently only about 85 countries have implemented such policies (United Nations, 2020). An increase in public engagement and awareness will likely pressure governments to develop risk reduction strategies which support the UN goal of improving climate action, but the rising seas will themselves provide the greatest incentive over time.

As one map developer observed, "*when they have the personal impact, that's when people start to listen*" (WRC map developer, February 23, 2021). By connecting the message to life experiences that are meaningful for the audience, and communicating across all channels, the public will be inspired and prepared to have a role in planning for the future.

6.0 References

Allan, R. (2017). *Understanding New Zealand public opinion on climate change*. https://mro.massey.ac.nz/bitstream/handle/10179/12278/02_whole.pdf?sequence=2&isAllowed=y.

Antarctic Research Centre. (2020). Victoria University of Wellington. https://www.wgtn.ac.nz/antarctic.

Antarctic Research Centre Staff. (n.d.). *Antarctic Research Centre Te Puna Pātiotio*. Victoria University of Wellington Te Herenga Waka. https://www.wgtn.ac.nz/antarctic/about.

Bearzi, M. (2017, November 16). *5 Simple Tips for Communicating Science*. National Geographic Society Newsroom. https://blog.nationalgeographic.org/2013/10/11/5-simple-tips-for-communicating-science/.

Bradt, G. (2012, March 16). How Leaders Can Inspire Action Through Compelling Storytelling. Forbes. https://www.forbes.com/sites/georgebradt/2012/03/14/how-leaders-can-inspire-action-through-compelling-storytelling/?sh=55d895844683.

Chico, S. P. (2019, November 19). How Venice's plan to protect itself from flooding became a disaster in itself. Retrieved December 10, 2020, from https://www.washingtonpost.com/world/europe/how-venices-plan-to-protect-itself-from-flooding-became-a-disaster-in-itself/2019/11/19/7e1fe494-09a8-11ea-8054-289aef6e38a3_story.html

Climate Central Staff. (n.d.a). *Climate Central: Home*. Climate Central. https://www.climatecentral.org/.

Climate Central Staff. (n.d.b). *Maps & Tools*. Surging Seas: Sea level rise analysis by Climate Central. https://sealevel.climatecentral.org/maps/.

Conversations through COVID-19 with Jacinda Ardern. Buzzsprout. (2021). https://www.buzzsprout.com/979993.

Desmarais, F. (2019, June 28). *Sea level mapping tool reveals effects of climate change on Wellington region*. Stuff. https://www.stuff.co.nz/environment/climate-news/113783214/sea-level-mapping-tool-reveals-effects-of-climate-change-on-wellington-region.

Devlin, D. G. (2018, October 12). Wellington retaining and sea walls in 'very poor condition', council documents show. Retrieved December 10, 2020, from https://www.stuff.co.nz/national/107803648/wellington-retaining-and-sea-walls-in-very-poor-condition-council-documents-show

Fastier, B. (2019, July 24). *Poll: New Zealanders' climate change fears are growing*. Stuff. https://www.stuff.co.nz/environment/climate-news/114485675/poll-new-zealanders-climate-change-fears-are-growing.

Gibson, J. (2019, June 6). *Sea level rise data viewers released*. GW Mapping News - Sea Level Rise Mapping. https://mapping.gw.govt.nz/News11_Sea_Level_Rise.htm.

GNS Science Staff. (n.d.). *About Us*. GNS Science. https://www.gns.cri.nz/Home/About-Us.

Greater Wellington Regional Council (n.d.). *Sea level rise and storm surge modeling* [Interactive map]. Retrieved December 3, 2020, from https://mapping1.gw.govt.nz/GW/SLR/. Screenshot by author.

Hanna, C., White, I., Glavovic, B. (2017). Managed retreat in New Zealand: revealing the terminology, approaches and direction of local planning instruments. Report for the National Science Challenge: Resilience to Natures Challenges, University of Waikato, New Zealand.

Hinton, T. (2020, March 27). *New Zealand - perceived climate change personal impact 2018*. Statista.https://www.statista.com/statistics/934923/new-zealand-perceived-climate-change-personal-impact/ .

Kulkarni, P. (2013). Rethinking "Science" Communication. *Issues in Science and Technology, 30*(1), 25-29. http://www.jstor.org/stable/43315816

Level Organization Staff. (2020, May 11). *Rising Sea Levels.* From http://www.level.org.nz/site-analysis/hazards/rising-sea-levels/#:~:text=Sea%20levels%20around%20New%20Zealand,the%20end%20of%20the%20century

Medin, D., & Bang, M. (2014). The cultural side of science communication. *Proceedings of the National Academy of Sciences of the United States of America, 111*, 13621-13626. http://www.jstor.org/stable/43043100

Ministry for the Environment. (2017, December). *Preparing for coastal change*. New Zealand Government.https://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/coastal-hazards-summary.pdf

Ministry for the Environment & Stats NZ (2020). *New Zealand's Environmental Reporting Series: Our atmosphere and climate 2020*. https://www.mfe.govt.nz/publications/environmental-reporting/our-atmosphere-and-climate-2020

Ministry of Business, Innovation and Employment. (n.d.). *Science and Innovation*. Ministry of Business, Innovation and Employment. https://www.mbie.govt.nz/about/.

New Zealand Parliament. (2020, January 24). *Budget policy statement 2020.* New Zealand Parliament.https://www.parliament.nz/en/pb/sc/make-a-submission/document/52SCFE_SCF_FINS_93457/budget-policy-statement-2020

NIWA Staff. (2016, May 18). *Our mission*. NIWA. https://niwa.co.nz/about/our-mission.

NIWA Staff. *Climate tips for climate solvers*. NIWA. https://niwa.co.nz/education-and-training/schools/students/climate-change/tips-for-climate-solvers

NOAA. (2020, December 9). *Designing a Communications Handout About Sea Level Rise* . U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/case-studies/designing-communications-handout-about-sea-level-rise.

NOAA. (2017, May 16). *Confronting Shoreline Erosion on O'ahu* . U.S. Climate Resilience Toolkit. https://toolkit.climate.gov/case-studies/confronting-shoreline-erosion-o%E2%80%98ahu.

NZ SeaRise Programme. (n.d.). https://www.searise.nz/.

Olson, S. (2017). [Houston flood gate during Hurricane Harvey] [Photograph]. Getty Images. https://www.vox.com/science-and-health/2017/8/28/16211686/houston-flood-harvey-flooding-photos

Pezza, A., Uys, R., & Dawe, I. (2020). *Home Page – Sea Level Rise*. Wellington Region Sea Level Rise. https://slr-gwrc.org/home-page-sea-level-rise/.

Povoledo, E. (2020, October 03). *Floodgates in Venice work in first major test*. The New York Times Company. Retrieved November 30, 2020, from https://www.nytimes.com/2020/10/03/world/europe/venice-floodgates-flooding.html

RNZ. (2018, October 12). *Sea level rise worse in Pacific than other regions*. RNZ. https://www.rnz.co.nz/international/pacific-news/368514/sea-level-rise-worse-in-pacific-than-other-regions.

Stats NZ. (October 2020). *New Zealand's greenhouse gas emission*. Stats NZ. https://www.stats.govt.nz/indicators/new-zealands-greenhouse-gas-emissions

Stats NZ. (2018). *Population and Dwellings, 2018 Census.* Stats NZ. https://www.stats.govt.nz/tools/2018-census-place-summaries/wellington-region

Stephens, S. H., & Richards, D. P. (2020, February 25). *Story mapping and sea level rise: listening to global risks at street level*. http://sigdoc.acm.org/story-mapping-and-sea-level-rise-listening-to-global-risks-at-street-level/.

“Strategies for Managing Sea Level Rise.” *SPUR*, 9 Mar. 2016, www.spur.org/publications/urbanist-article/2009-11-01/strategies-managing-sea-level-rise

Tankovska, H. (2021, February 1). U.S.: Average age of Instagram users. Statista. https://www.statista.com/statistics/398166/us-instagram-user-age-distribution/.

Tankovska, H. (2021, February 2). Facebook: age and gender demographics in U.S. Statista. https://www.statista.com/statistics/187041/us-user-age-distribution-on-facebook/.

Tankovska, H. (2021, February 9). Global Twitter user age distribution 2021. Statista. https://www.statista.com/statistics/283119/age-distribution-of-global-twitter-users/.

Turbott, C., & Stewart, A., Ltd. (2006, April). *Managed Retreat from Coastal Hazards : Options for Implementation* (Tech. No. 1130816v2). https://www.waikatoregion.govt.nz/assets/WRC/WRC-2019/tr06-48.pdf.

United Nations. (2020). *Goal 13 infographic.* https://sdgs.un.org/goals/goal13

Waikato Regional Council. (n.d.). *Coastal inundation tool* [Interactive map]. Retrieved December 3, 2020 from https://coastalinundation.waikatoregion.govt.nz/. Screenshot by author.

Waikato Regional Council Staff. (2019). *Coastal inundation tool*. Waikato Regional Council. https://waikatoregion.govt.nz/services/regional-services/regional-hazards-and-emergency-management/coastal-hazards/coastal-flooding/coastal-inundation-tool.

Ward, K. (2020). *Researching the city: a guide for students*. SAGE.

WWF. (n.d.). *You can reduce your impact*. WWF. https://www.wwf.org.nz/what_we_do/climateaction/reduce_your_impact/

7.0 Appendices

Appendix A: Interview Questions for NZ SeaRise

This appendix includes questions that were used to interview members of the NZ SeaRise Programme regarding their goals for public engagement with SLR communication. Some of the questions have been modified to better suit the interviewee.

Section 1: Project Overview

As we mentioned in our email communication, we are a team of undergraduate university students from Worcester Polytechnic Institute in Worcester, Massachusetts collaborating with Zoë Heine from Victoria University of Wellington and the New Zealand SeaRise Programme on a project regarding public perception of sea level rise in Wellington, New Zealand. Based on your background and expertise in this field of study, we felt you would be able to provide us with valuable information regarding your thoughts on SLR communication in general and the goals that NZ SeaRise has in communicating SLR to the public. The information you provide will help us understand what NZ SeaRise wants the public to know about SLR which will in turn help us determine if interactive maps are the best way to communicate this information. We expect this interview to take between 45 minutes to an hour in which we will ask some open ended questions about your experience. Before we begin, would it be okay for us to record this interview and use the information we gathered in our final report? If so, would you be willing to sign the consent form?

Section 2: General Questions

1) We want to learn a little more about you. Could you talk a little bit about your background and your role in the NZ SeaRise?

2) It's our understanding that NZ SeaRise wishes to determine what the public engagement is with SLR information and if interactive maps are the best method to communicate this kind of information. Could you tell us a bit more about what you think the goals of NZ SeaRise are regarding the public's experience with the maps?

a) Do you hope to generate interest in SLR among the public? Encourage return visits to the maps? Inspire community members to take action to minimize the effects of SLR?

b) To confirm, is the public the intended audience?

3) Through our preliminary research we noticed that the main goal of NZ SeaRise is to improve predictions of SLR until 2100 in New Zealand. When we received our initial information about this project we were given this set of core messages of NZ SeaRise, do these still align with your goals for what the public should know about SLR?

a) The sea level in the New Zealand area is rising and will continue to rise

b) SLR impact and extent is dependent on location

c) Work is being done to improve projections of SLR, both regionally and location-specific

d) 40cm of SLR is expected by 2050 and 1.5 meters by 2100

e) In order to avoid further SLR action must be taken to reduce carbon emissions

Appendix B: Interview Questions for Map Developers

This appendix includes questions that were used to interview members of the GWRC, the WRC, and Climate Central on their development of interactive maps to communicate SLR. Some of the questions have been modified to better suit the interviewee.

Section 1: Project Overview

Good morning! As we mentioned in our email communication, we are a team of undergraduate university students from Worcester Polytechnic Institute in Worcester, Massachusetts collaborating with Zoë Heine from Victoria University of Wellington and the New Zealand SeaRise Programme on a project regarding public perception of sea level rise in Wellington, New Zealand. A part of our research involves understanding the current sea level rise maps and how accurately they depict information to the people of Wellington. Based on your background and expertise in this field of study, we felt you would be able to provide us with valuable information regarding the development and usage of interactive maps for the communication of SLR. The information you provide will help us understand the intended impact of these maps which will in turn help us to determine if they have been successful. We expect this interview to take between 45 minutes to an hour in which we will ask some open ended questions about your experience. Before we begin, would it be okay for us to record this interview and use the information we gathered in our final report? If so, would you be willing to sign the consent form?

Section 2: General Questions for Map Developers

1) Could you talk a little bit about your background and your role in [organization]?

2) What are the benefits and unique features that your map provides? Why should someone use your map instead of others that are available?

3) What were your goals in creating your interactive SLR map?

    a) Were you more focused on conveying SLR facts, raising awareness of SLR, increasing the public's engagement with SLR, or promoting the public to take action to mitigate the effects of SLR?

4) Who was the intended audience of your map?

a) What impact do you hope your maps will have on the intended audience?

5) Have you done any research on the best ways to communicate science/risk to your intended audience?

    a) Why did you decide a map was the best option to communicate SLR to your audience?

    b) What frustrations/drawbacks of using maps in communicating SLR data to your audience?

    c) Have you used any other methods to communicate SLR to the public?

    d) Where have you seen the best possible use of maps to communicate SLR?

6) Is your map accessible/displayed/advertised anywhere besides your website?

7) Have you received any feedback about your map and the impact that it has had?

    a) If so, what have you done with this feedback?

    b) Are you planning to make any future changes to the maps?

Section 2: Specific Questions for GWRC

1) What was the objective of the storm surge feature on your map?

2) Have you considered modeling different years? What was the significance of 2100?

3) What do the different colors on the map represent?

    a) Why do the more extreme effects appear to be more inland?

4) How will the areas shown on your map be affected by SLR?

    a) Did you consider differentiating between connected and disconnected inundation? (we noticed that some other SLR maps had this feature)

Section 3: Specific Questions for WRC

1) Your map shows information on 0.5m and 1m SLR projections. Why were these values chosen? Did you consider displaying the year in which these values are projected for?

2) What is the significance of showing the locations of features such as flood gates and pump stations? Do these affect the projected SLR for the areas in which they are shown?

3) Do you provide data on current ground elevation?

Appendix C: Interview Questions for Science Communication Experts

This appendix includes open ended questions that were used to interview science communication experts. Some of the questions have been modified to better suit the interviewee.

Section 1: Project Overview

Good morning! As we mentioned in our email communication, we are a team of undergraduate university students from Worcester Polytechnic Institute in Worcester, Massachusetts collaborating with Zoë Heine from Victoria University of Wellington and the New Zealand SeaRise Programme on a project regarding public perception of sea level rise in Wellington, New Zealand. A part of our research involves understanding the impact that current sea level rise maps have on their audiences. Based on your background and expertise in science communication, we felt you would be able to provide us with valuable information regarding methods used to communicate science, specifically hazards, to public audiences. The information you provide will help us gauge if interactive maps are the most effective in communicating information on SLR. We expect this interview to take between 45 minutes to an hour in which we will ask some open-ended questions about your experience. Before we begin, would it be okay for us to record this interview and use the information we gathered in our final report? If so, would you be willing to sign the consent form?

Section 2: General Questions

1. Have you done any work related to communicating climate change, more specifically SLR, to the public?

2. What methods have you found work best when communicating scientific information to the public?

    a. Are there methods that work better for risk communication specifically?

    b. Are there methods that you have found to be ineffective? Why did they not work?

3. Have you had any experience using maps to communicate scientific information to the public?

    a. Have you found this to be an effective communication method?

4. What would you say are major challenges when it comes to science communication?
    a. How do these challenges apply to communication in New Zealand?

Appendix D: Participant Observation Chart

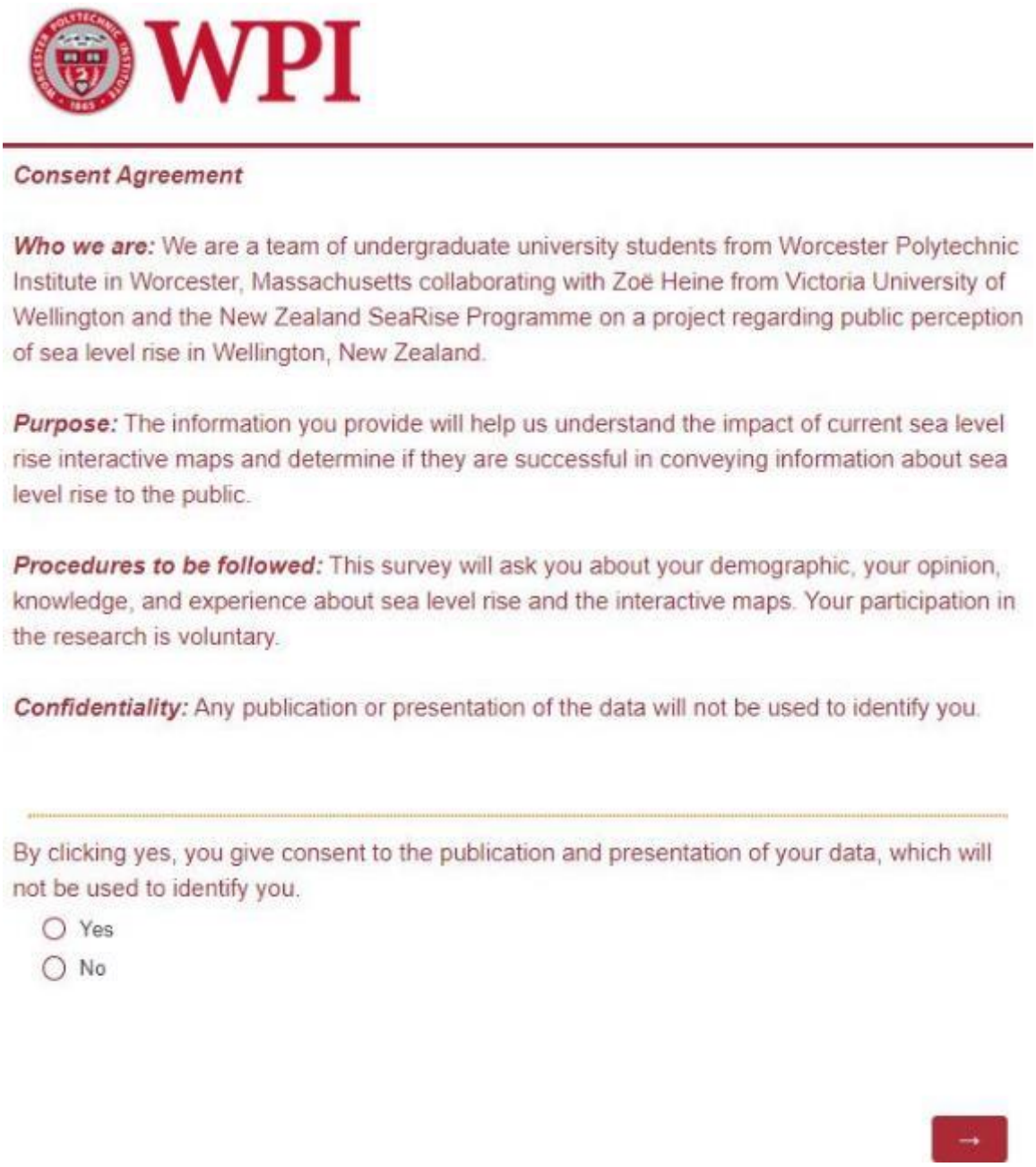
The following chart was used by our team to rank interactive SLR maps. The maps were rated in each category on a scale of 1 to 7, with 7 being “strongly agree” and 1 being “strongly disagree.”

	GWRC	WRC	Climate Central	WCC	1 additional map from outside of NZ
The map was easy to find with a simple google search					
The map was easy to use.					
Using the map I could see the effect of SLR in specific locations					
The map showed which areas will be most affected by SLR.					
The map showed the way in which areas will be affected by SLR					
I understand the meaning of the values on the scroll bar & can adjust it to a realistic level of SLR.					
I know more about the effects of SLR in the given region after viewing the map					
Questions about SLR after viewing the map					
Recommendations for improvements					
Other comments					

Appendix E: Public Survey Questions

The following questions were asked in an online public survey on Qualtrics, which was distributed through social media platforms, to gauge their knowledge of SLR and the effectiveness of interactive maps in communicating information regarding SLR.

Note: Selected questions are answered because they have additional follow up questions



WPI

Consent Agreement

Who we are: We are a team of undergraduate university students from Worcester Polytechnic Institute in Worcester, Massachusetts collaborating with Zoë Heine from Victoria University of Wellington and the New Zealand SeaRise Programme on a project regarding public perception of sea level rise in Wellington, New Zealand.

Purpose: The information you provide will help us understand the impact of current sea level rise interactive maps and determine if they are successful in conveying information about sea level rise to the public.

Procedures to be followed: This survey will ask you about your demographic, your opinion, knowledge, and experience about sea level rise and the interactive maps. Your participation in the research is voluntary.

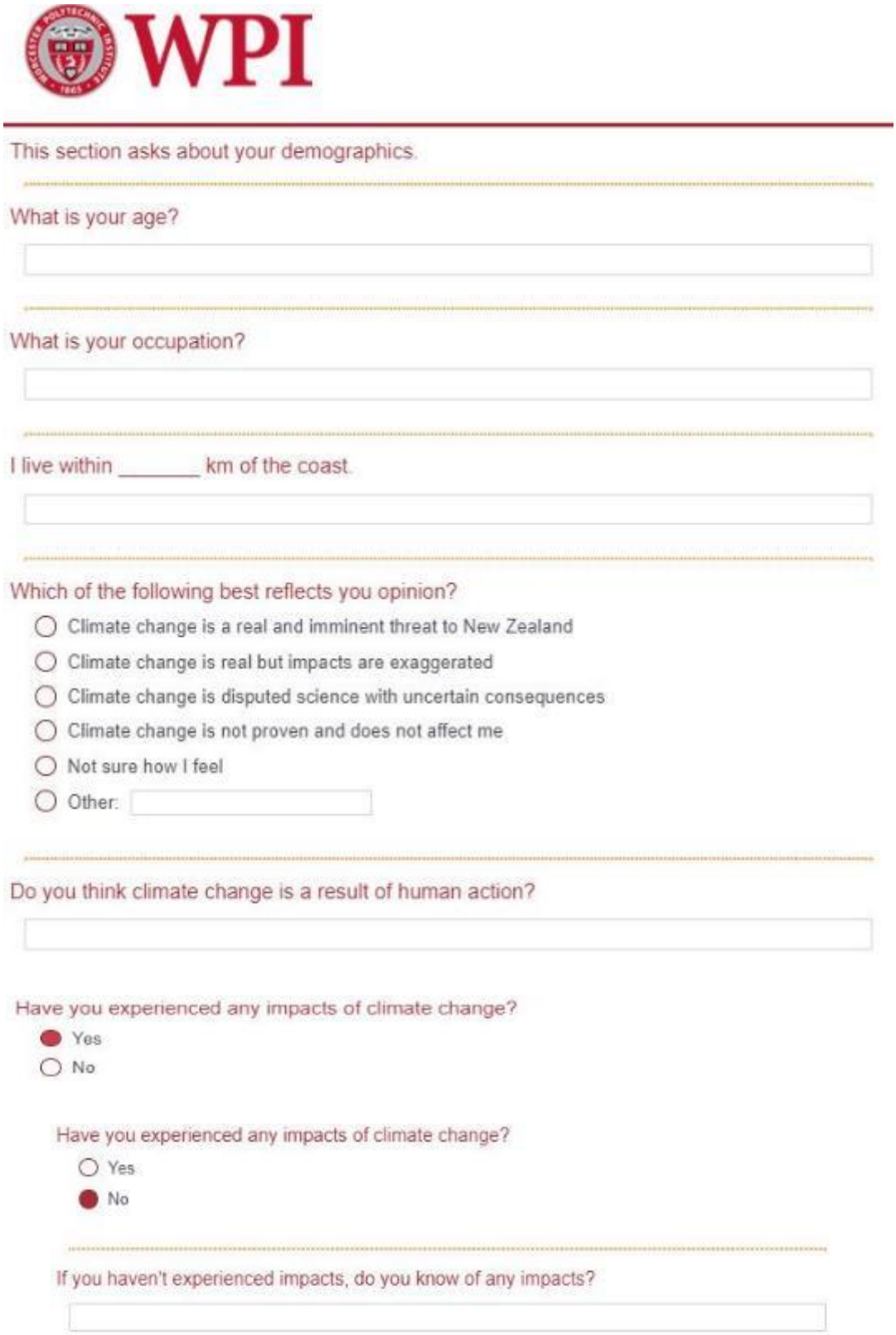
Confidentiality: Any publication or presentation of the data will not be used to identify you.

By clicking yes, you give consent to the publication and presentation of your data, which will not be used to identify you.

- ○ Yes
- ○ No

→

Section 1: Demographic Questions



WPI

This section asks about your demographics.

What is your age?

What is your occupation?

I live within _____ km of the coast.

Which of the following best reflects you opinion?

- ○ Climate change is a real and imminent threat to New Zealand
- ○ Climate change is real but impacts are exaggerated
- ○ Climate change is disputed science with uncertain consequences
- ○ Climate change is not proven and does not affect me
- ○ Not sure how I feel
- ○ Other:

Do you think climate change is a result of human action?

Have you experienced any impacts of climate change?

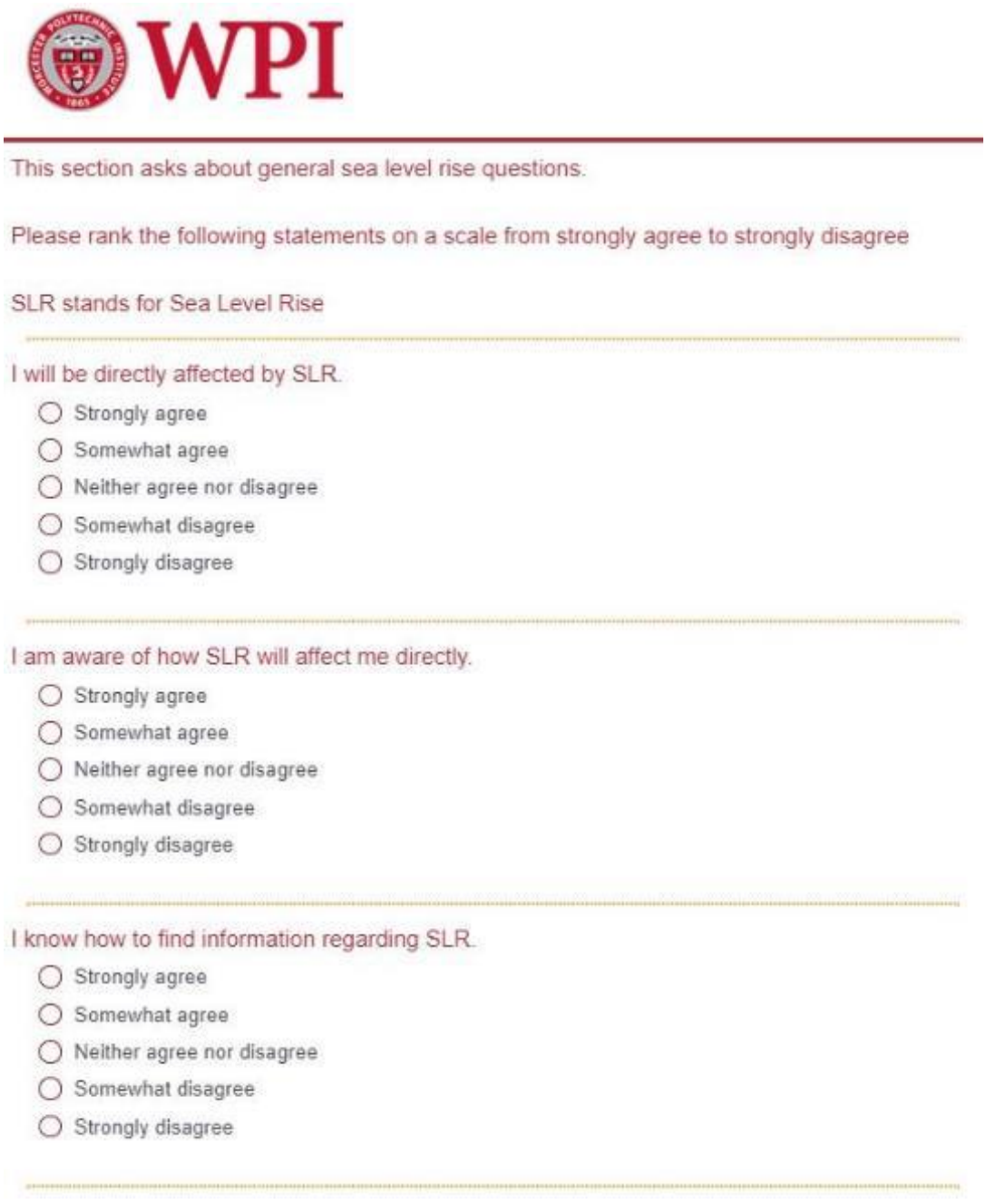
- ● Yes
- ○ No

Have you experienced any impacts of climate change?

- ○ Yes
- ● No

If you haven't experienced impacts, do you know of any impacts?

Section 2: General SLR Questions



WPI

This section asks about general sea level rise questions.

Please rank the following statements on a scale from strongly agree to strongly disagree

SLR stands for Sea Level Rise

I will be directly affected by SLR.

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

I am aware of how SLR will affect me directly.

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

I know how to find information regarding SLR.

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

I typically seek out information regarding SLR.

- (●) Strongly agree
- ( ) Somewhat agree
- ( ) Neither agree nor disagree
- ( ) Somewhat disagree
- ( ) Strongly disagree

From what source did you find this information? What was the format of this information? (Ex. Map, Video, News Article)

I know how to reduce the impacts of SLR.

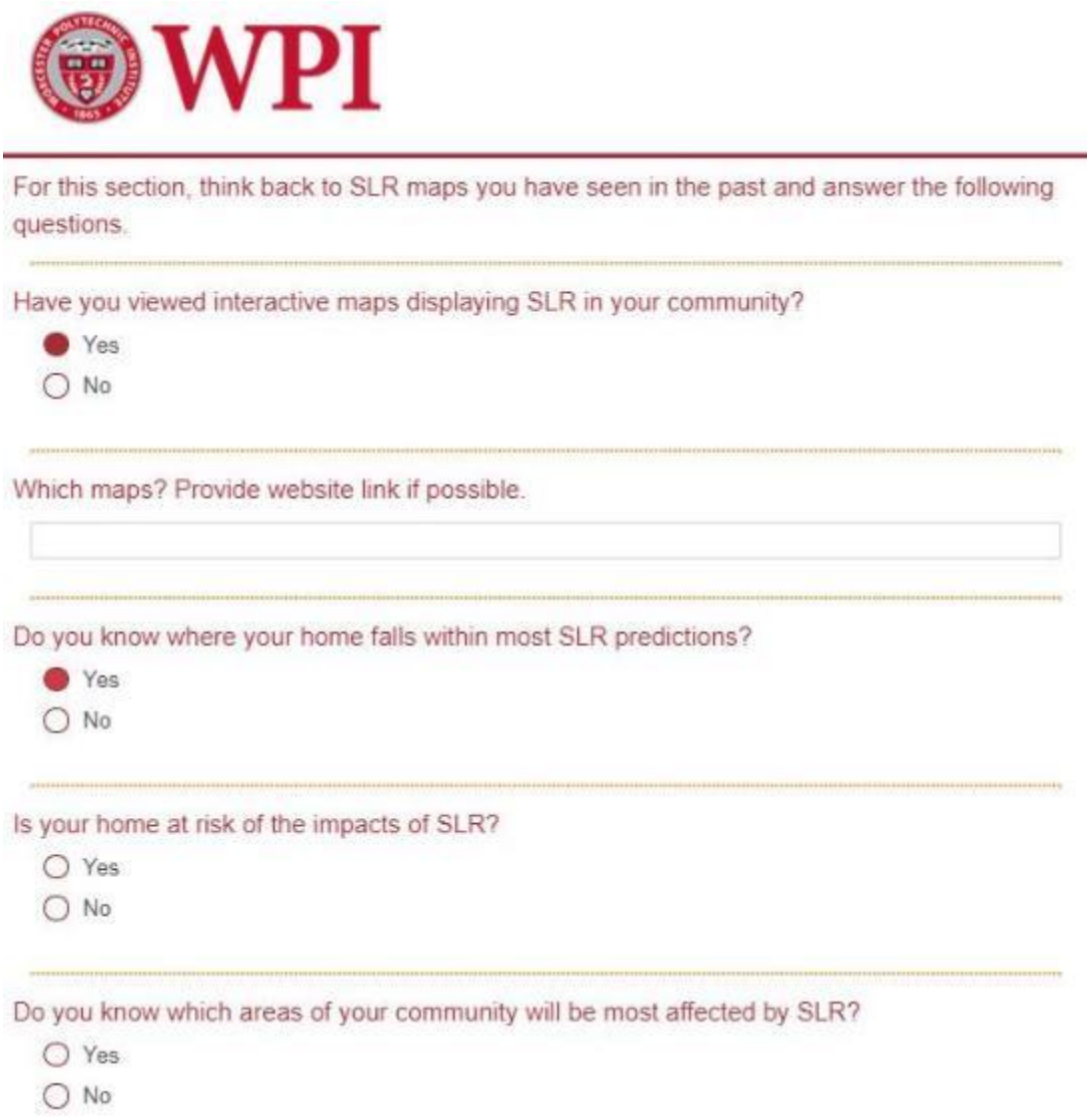
- ( ) Strongly agree
- ( ) Somewhat agree
- ( ) Neither agree nor disagree
- ( ) Somewhat disagree
- ( ) Strongly disagree

I have taken action to reduce the impacts of SLR.

- (●) Strongly agree
- ( ) Somewhat agree
- ( ) Neither agree nor disagree
- ( ) Somewhat disagree
- ( ) Strongly disagree

What actions have you done to reduce the impacts of SLR?

Section 3: Background Map Questions



WPI

For this section, think back to SLR maps you have seen in the past and answer the following questions.

Have you viewed interactive maps displaying SLR in your community?

- (●) Yes
- ( ) No

Which maps? Provide website link if possible.

Do you know where your home falls within most SLR predictions?

- (●) Yes
- ( ) No

Is your home at risk of the impacts of SLR?

- ( ) Yes
- ( ) No

Do you know which areas of your community will be most affected by SLR?

- ( ) Yes
- ( ) No

Do you know how your community will be affected by SLR?

- ◯ Yes
- ◯ No

How do you currently feel about the impacts of SLR?

- ◯ Scared
- ◯ Overwhelmed
- ◯ Confused
- ◯ Indifferent
- ◯ Inspired to take action
- ◯ Other, please specify

Section 4: Map Interaction

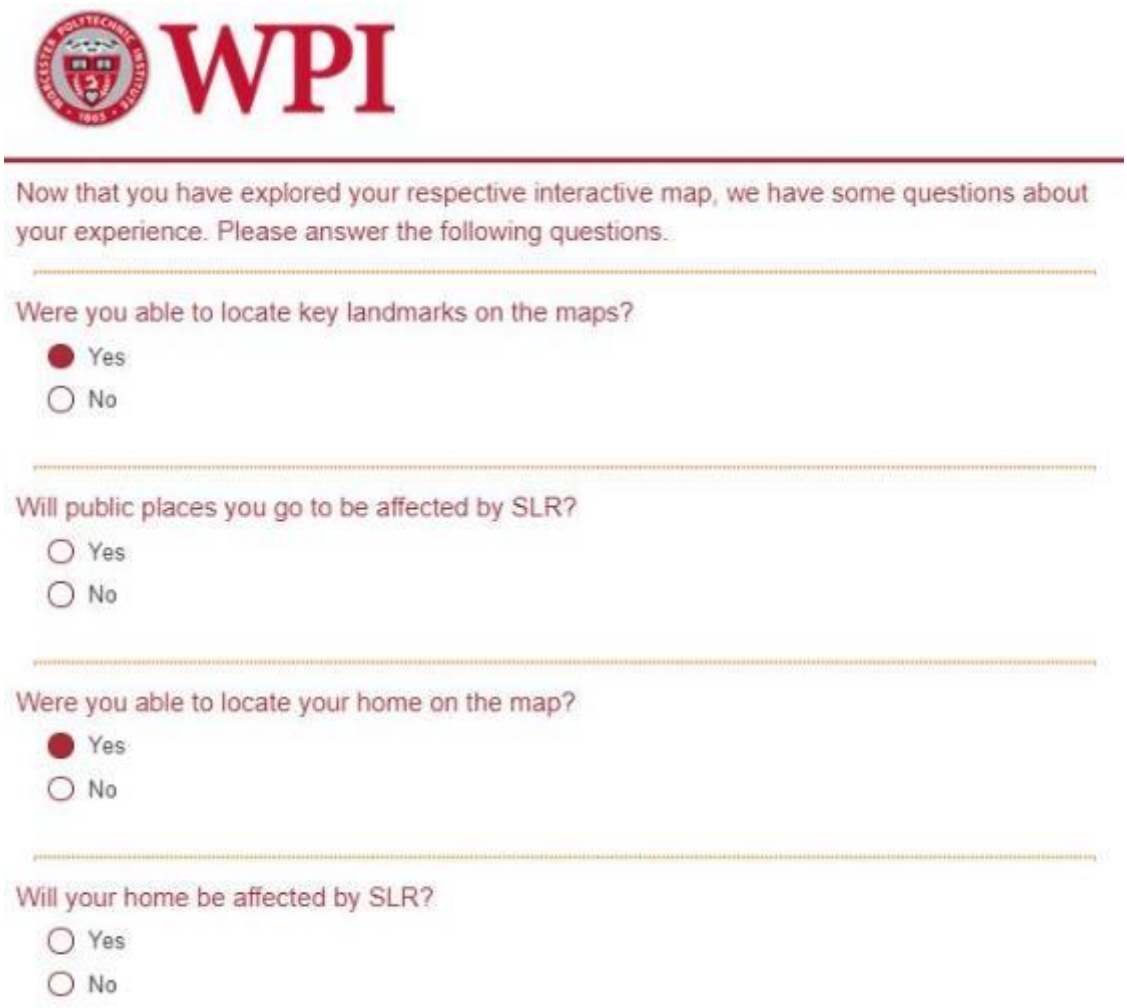
The following maps are provided by the Greater Wellington Regional Council (GWRC) and the Waikato Regional Council (WRC). Please view the map that corresponds to your region. After viewing, continue on to answer questions related to your map.

GWRC: https://mapping1.gw.govt.nz/GW/SLR/
WRC: https://coastalinundation.waikatoregion.govt.nz/

Which map did you view?

- ◯ GWRC map
- ◯ WRC map

Section 5: Map Follow Up Questions



WPI

Now that you have explored your respective interactive map, we have some questions about your experience. Please answer the following questions.

Were you able to locate key landmarks on the maps?

- (●) Yes
- ( ) No

Will public places you go to be affected by SLR?

- ( ) Yes
- ( ) No

Were you able to locate your home on the map?

- (●) Yes
- ( ) No

Will your home be affected by SLR?

- ( ) Yes
- ( ) No

Do you know which areas of your community will be most affected by SLR?

- (●) Yes
- ( ) No

Will your neighbors be affected by SLR?

- ( ) Yes
- ( ) No

Based on the impact SLR will have on you personally, what will you do to reduce these impacts?

How do you feel about SLR after viewing the map?

- ( ) Scared
- ( ) Overwhelmed
- ( ) Confused
- ( ) Indifferent
- ( ) Inspired to take action
- ( ) Other

Please rank the following statements on a scale from strongly agree to strongly disagree

SLR stands for Sea Level Rise

My concern about SLR has increased.

- ( ) Strongly agree
- ( ) Somewhat agree
- ( ) Neither agree nor disagree
- ( ) Somewhat disagree
- ( ) Strongly disagree

I am more likely to take action to reduce the impacts of SLR.

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

I would like to learn more about the impacts of SLR.

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

My fatigue towards climate related issues has increased. (Are you bored of listening about SLR?)

- ◯ Strongly agree
- ◯ Somewhat agree
- ◯ Neither agree nor disagree
- ◯ Somewhat disagree
- ◯ Strongly disagree

What questions did this experience generate about SLR that are not answered?

Are there any ways in which you think the map could be improved?

Section 6: Additional Feedback

Please provide any additional feedback you have regarding the interactive map you viewed and current SLR communication methods.

Would you willing to meet with our team to further discuss your experiences towards SLR and current communication methods?

- (●) Yes
- ( ) No

Please provide your name and the best way to reach you. (Email, phone number, etc)

Appendix F: Interview Questions for Survey Participants

This appendix includes questions which were used to interview willing survey participants to expand on their thoughts on SLR and the way information regarding SLR is communicated. Some of the questions have been modified to better suit the interviewee.

Section 1: Project Overview

Good morning! Thank you for your willingness to participate in this interview. As we mentioned in our email communication, we are a team of undergraduate university students from Worcester Polytechnic Institute in Worcester, Massachusetts collaborating with the New Zealand SeaRise Programme on a project regarding public perception of sea level rise in Wellington, New Zealand. A part of our research involves understanding the impact that current sea level rise maps have on their audiences. The information you provide will help us gauge if interactive maps are effective in communicating information on SLR to the public. We expect this interview to take 45 minutes in which we will ask some open-ended questions about your experience with SLR and interactive maps. We saw that you have signed the consent form so we will begin recording now and get started with our first question.

Section 2: General Questions

1. Could you tell us a little bit more about yourself, your involvement in civil defense emergency management, and the work that you do regarding climate change and sea level rise?

2. What impact did climate change/SLR have on you and your community?

3. Are there maps available in your region that depict SLR? (N)

4. Could you give us an overview of your thoughts on and experiences with SLR interactive maps?

    a. What were your main takeaways from viewing the map?

5. Are concerned about SLR, could you elaborate a bit more on your concern?

6. What did you think of other communication methods?

    a. What are your thoughts on a central hub website that has all the information on SLR, like the COVID-19 dashboard website that was implemented in New Zealand?

7. Why do you think it's important to make communication personal when telling people about SLR?

8. After viewing these maps do you feel more inspired to participate in efforts to adapt to and minimize SLR or do you feel more detached from the problem?

Appendix G: Participant Observation of SLR Maps

The following chart shows the cumulative results of our group participant observation. The maps were rated in each category on a scale of 1 to 7, with 7 being "strongly agree" and 1 being "strongly disagree."

	Advantages	Disadvantages
GWRC Story Map Overall score: 5.72 / 7	- Storm surge feature - Showed values by 2100 - Search bar to easily find specific locations - Easy to find online	- Colors were not well explained - Unclear what levels meant (max, min, extreme values by 2100) - No legend (need more definitions and clarity overall) - No data given for different years - Effects were unclear (how will areas be affected?) - General overview, not very location specific
WRC Story Map Overall score: 6.16 / 7	- Very location specific data (SLR scenarios given for specific locations) - Lots of information given - Colors were well explained - Legend provided	- No information given for projected years in which impacts may occur - Definitions of values are not well integrated onto the sea level scenario chart - Layers (flood gates, pump stations, etc.) don't explicitly

	- Overall easy to understand - Ability to add filters - Play button (shows changing effects) - Mobile friendly	impact inundation - No elevation data - Doesn't allow for comparison between larger areas (need to zoom in to see effects)
Climate Central Surging Seas Overall score: 5.30 / 7	- Can zoom in and see specific landmarks - Can adjust the specific circumstance (how much pollution is cut, how bad climate change actually is) - Shows impact of carbon emissions on SLR (risk finder map) - Option to view effects by year - Many different types of maps available on the same website	- Degree of impact is not shown (everything is one color) - Users can rank luck (this is not a reliable metric) - Water level map does not give a metric for what level is reasonable by a certain time - No option to view year and water level simultaneously (need to switch between 2 maps) - "Details and limitations" tab does not give information in an accessible manner (not visually appealing, more organization instead of a whole paragraph) - Risk finder map was very pixelated (good ideas not good execution) - Different maps have different info, must look at multiple

		maps to get the full picture
WCC Story Map Overall score: 4.25 / 7	- Very nice satellite map (could see landmarks clearly) -- 3D - Use of images in story map gave local context - Story map provides relatable narrative	- Difficult to find online - No increment of risk - No scroll bar (check boxes instead, not as user friendly as other maps) - Doesn't show HOW places will be affected
NOAA Sea level Rise Viewer	- Can see images of specific locations and the effects of SLR - Multiple different scenarios (multifaceted) - Clear descriptions of each mode - Very easy to find online - Shows specific locations and landmarks	- US only - Legend was somewhat difficult to find (labels might be good)
Miami-Dade County Story Map	- Good website design - Info is easy to digest for average consumer - Local pictures that show impacts that are currently	- The maps themselves aren't great - Unclear what the map data is showing

	being seen - Shows ways the county is doing to adapt to SLR - Gives information on how to reduce the risk	
Sea Change Boston SLR Map	- Options for SLR and major storm - Can explore impacts on different topic areas (homes, energy, economy, transportation) which goes beyond scope of just if your home will be affected - Study area is clearly defined	- Not very customizable (only 4 scenarios) - No scroll bar