

Flood Management in the Avon-Otakaro Corridor: Short-term & Long-term Options



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Table of Contents:

1. Executive Summary.....	
2. Introduction.....	
3. Literature Review.....	
4. Methodology.....	
4.1	<i>Interviews</i>
4.2	<i>Surveys</i>
4.3	<i>GPS & GIS</i>
5. Results & Discussion.....	
5.1	<i>LiDAR Data</i>
5.2	<i>Existing Methods</i>
5.3	<i>Surveys</i>
5.4	<i>Interviews</i>
5.5	<i>Proposed Mitigation Measures</i>
5.6	<i>Spillways</i>
5.7	<i>Stopbanks</i>
5.8	<i>Management Retreat</i>
5.9	<i>Wetlands</i>
5.10	<i>Other Methods</i>
6. Limitations.....	
7. Conclusions.....	
8. Acknowledgements.....	
9. References.....	
10. Appendix.....	
10.1	<i>Survey Questions</i>

1. Executive Summary

1.1 Research Question

- What is the most suitable and viable mitigation option in the lower Avon Otakaro Corridor?

1.2 Aims and Objectives

- What are the current mitigation methods in place?
- What are residents' opinions on current and future flood protection options?
- What mitigation methods are the Christchurch City Council looking into?
- What areas are most at risk of flooding?
- Why is the area so susceptible to flooding following the earthquake?
- What is the most suitable method or combination of methods to best protect the area against flooding in both the short and long-term?

1.3 Context for the Research

- Following the September 4th and February 22nd earthquakes the land has subsided and left the area vulnerable to flooding.
- Current mitigation methods only include stopbanks (either temporary or permanent) and sandbags which are rundown.

1.4 Summary of Method

- Literature reviews aided in the decision on what specific mitigation options should be explored and what methodology should be considered.
- Discussion with our community partner Hugo Kristinsson and using information gathered from our literature reviews, enabled us to decide upon three types of data collection; surveys, interviews and physical data collection.
- Surveys were completed through interviewing residents directly affected by flooding and were done in person and through email; this ruled out any bias information and allowed for spontaneous conversation.
- Interviews of key Christchurch decision makers Tony Oliver, Graham Harrington and Greg Whyte gave slight insight into what current research is being done.

- Physical data was collected in the form of GPS and LiDAR data. These were used to show the current mitigation measures, red zoned areas, flood risk areas, as well as to create maps showing pre and post-earthquake land subsidence.

1.5 Key Findings

- Sand bags are rundown and in desperate need of replacement (Figure 6 & 7), majority of stopbanks are temporary (Figure 8 & 9), there are some well-built stopbanks which have implemented walk ways and vegetation (Figure 10 & 11).
- Residents most preferred options include stopbanks, spillways, vegetation and wetlands.
- Christchurch City Council is mainly looking into stopbanks, but this information is not readily available to the public, as it is “sensitive information”. Other options discussed were management retreat and flooding the estuary during high flow periods.
- The most suitable option found in terms of cost, feasibility, and public preference was to include a combination of stopbanks, spillways and wetlands. These options would be immediate short term mitigation methods. And to explore the option of management retreat as a long term mitigation method to combat future rises in sea-level.

1.6 Limitations

- Major issues came from the lack of information readily available to the public from Christchurch City Council.
- Time was an obvious limitation, due to the size of the study area and how complex the issue is.
- Due to the Christchurch city’s current rebuild costs the mitigation methods are limited to low cost and low importance.

1.7 Suggestions for Further Research

- Due to predicted sea level rise, there is a definite need to further explore the option of management retreat. Looking into what subsidies will be in place for movers, and to try to gage a feel of residents’ resilience to move.

2. Introduction

On September 2010 a 7.1 magnitude earthquake struck the New Zealand city of Christchurch and initiated a series of major earthquakes until June 2011. This increase in seismic activity has had severe impacts on the built and natural environment throughout Christchurch, particularly in the eastern suburbs. A natural impact is the subsidence of land, caused by the sinking of silts and sands; which makes up the majority of Christchurch's underlying sediment. The subsidence has had a direct contribution to the increased flood hazard in the Avon River corridor. This includes areas such as Bexley that have now been deemed as red zones. Our research was set out to discover what conditions currently existed in our selected area, what residents opinions were on current and future options, as well as aiming to gage what direction the Christchurch City Council (CCC) are looking to take towards solving this problem. Following from this our group used a wide array of data collection techniques in order to find the most appropriate mitigation option, the details and results of which are outlined in this report.

3. Literature Review

3.1 Current Flood Management

Literature has shown that there are many mitigation measures that can be implemented to lessen flooding impacts. However, it is about determining the most viable and suitable option for the Avon corridor that would have the most significant effect in reducing the flood risk. Depending on the financial situation of the inflicted area will determine what type of management scheme will be used. The majority of urban flood defences comprise of soft measures or hard engineering structures (van Ree et al., 2011). Where there is no money available, this is when no active intervention is used as engineering options are too expensive (Ledoux et al., 2004). Management retreat is considered a soft measure and is only feasible when all other methods have been exhausted and considered when public or private assets are unsustainable (Ledoux et al., 2004). Therefore flood management techniques used is dependent on the society involved and the economics (Ledoux et al., 2004).

3.2 Resilience in Flood Management

Reducing flooding risk and increasing resilience is a key theme that arises from literature. Since urban areas are more developed they are confined to less space, therefore flood defences and barriers tend to work better in open spaces (Zevenbergen et al., 2011). Urban areas also have a large amount of impervious surface which increases run-off and the flood extent as less infiltration can occur (Jing, 2010). Zevenbergen et al. (2007) discussed a holistic approach is needed for flood management as there are many factors to consider such as flood levels, land elevation and water velocity. Cost is also a key factor as particular areas with different inundation levels experience different types of flooding effects (Zevenbergen et al., 2007).

3.3 Community Participation

Community involvement and awareness is a major factor towards flood management, as people have to live with the mitigation methods chosen. Correia et al. (1998) and Ledoux et al. (2004) discuss the importance of communication and involving the public in the planning and implementation of management techniques. This was one particular issue that our community partner highlighted as information and awareness on the issue is severely lacked in the case study area. Our community partner was concerned that residents were not being informed enough from the CCC. Therefore it was decided by the group to find current plans and research being done by the CCC for flood management.

Geographic Information Systems (GIS) is one technique that can be used to illustrate and model flood management options and their interaction with humans (Correia et al., 1998). Producing GIS maps could be a possible method that was used for the project to inform the public on the flood risk (Correia et al., 1998).

Involvement from other stakeholders such as local, regional and central government as well as wildlife and recreational groups (e.g. walking groups) is also important as all opinions must be taken into consideration (Correia et al., 1998).

4. Methodology

The yellow box on Figure 1 outlines the case study area in the Avon-Otakaro corridor where we collected our information. This area was chosen as it has the largest flood risk from sea level rise, rainfall and tidal flooding. Although some of this area has been red zoned due to the earthquakes, there are still areas that are inhabitable and are exposed to the flood risk (as shown on Figure 2 and 3).

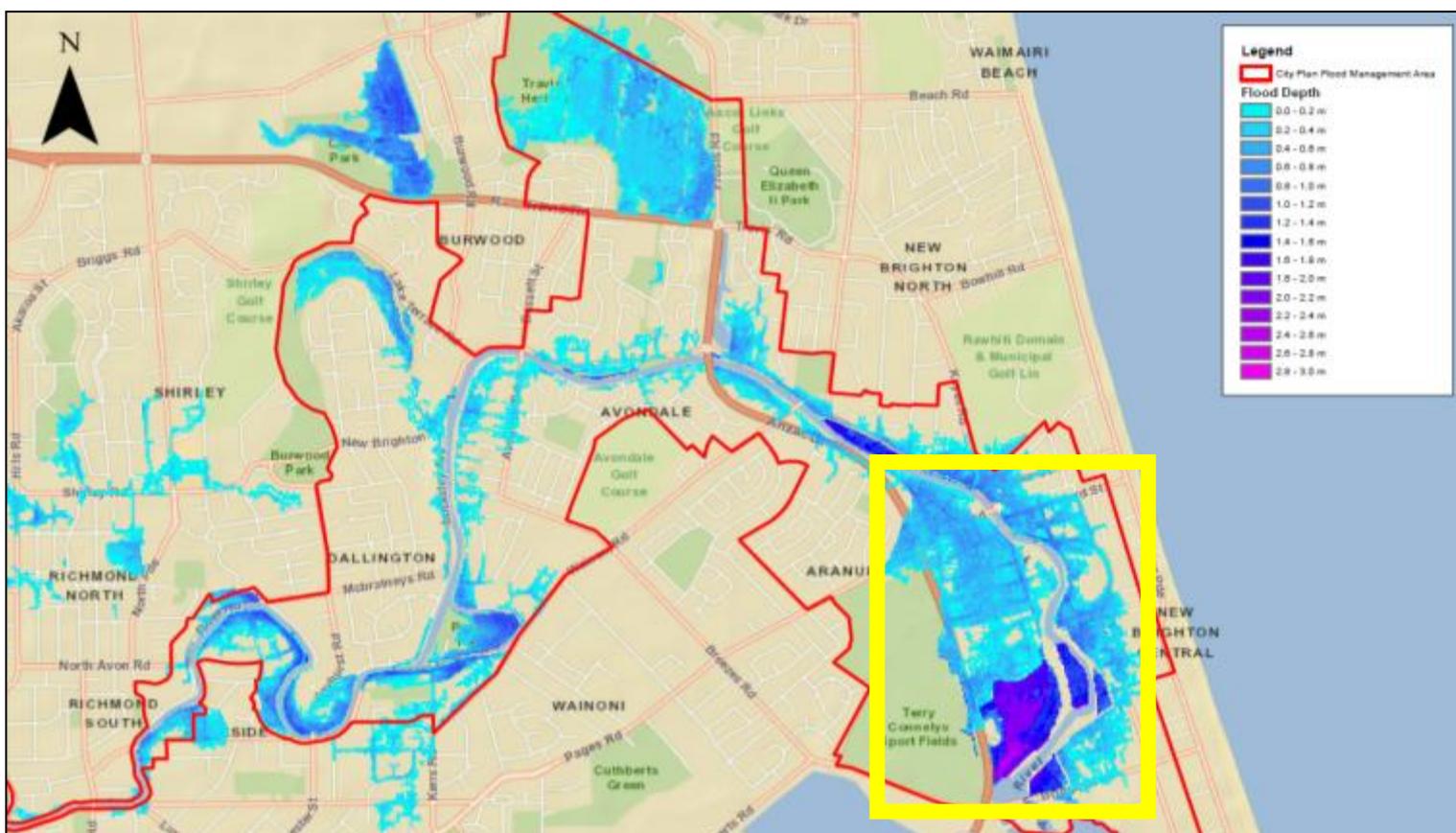


Figure 1: Case study area of the lower Avon River (Christchurch City Council, 2013).

After developing our research question it became clear that we would require both qualitative and quantitative data. We decided on three methods of data collection which included surveying, interviewing and physical data collection.

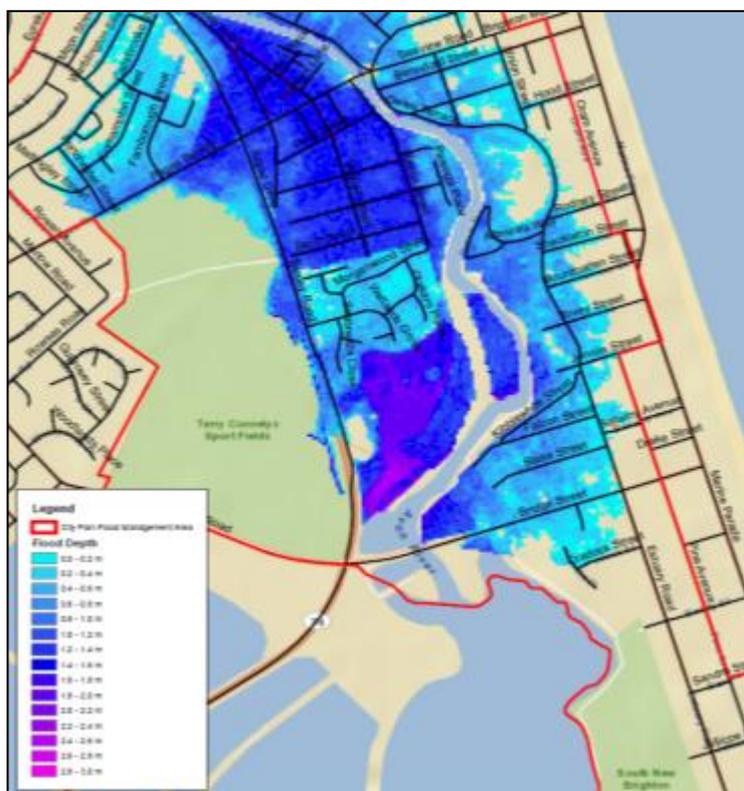


Figure 2: Flood risk of a 0.5 metre rise in sea level (Christchurch City Council, 2013).



Figure 3: Red zone land of the lower Avon (Christchurch Earthquake Recovery Authority, 2012).

4.1 Qualitative

The first step was to develop a survey to address our issue of community involvement. When surveying, we chose random sampling so that we got a good assortment of people with different perceptions and backgrounds and targeted people situated within the flood zone. This was to make sure there was no bias result and that the people being directly affected were surveyed. Surveys were done either face-to-face or through email which our community partner distributed to his contacts in the area.

We also set up interviews with key Christchurch decision makers who were involved with the flood issue. Firstly we spoke with Tony Oliver, a principal hazard analyst from Environment Canterbury. We also interviewed Greg Whyte, a principal engineer from DHI Group that runs computer configurations for the CCC using GIS software. Lastly, we interviewed Graham Harrington, a senior surface water planner for the CCC. These

interviews were used to learn more about flood mitigation options and any new plans that were being considered for the Avon corridor.

4.2 Quantitative

We collected GPS data which we analyzed and produced maps using ArcGIS. LiDAR data was obtained from the University of Canterbury's Geography Department and programmed into ArcMap where maps were produced. From the LiDAR data particular grids had to be selected that represented our case study area. Using ArcMap we were able to Mosaic those grids together and make a clean image that would show the elevation pre and post-earthquake. These elevation maps were then used to determine subsidence and suitable locations for proposed mitigation measures.

5. Results & Discussion

5.1 LiDAR Data

The past few years of seismic activity has caused significant land subsidence in the area and some areas have been red zoned because of this. Pre-earthquake LiDAR data (Figure 4) was used as a reliable source to reflect the difference in land elevation compared to post-earthquake LiDAR data (Figure 5). Both pre and post-earthquake LiDAR data show how land has subsided in areas such as Bexley and areas adjacent to the Avon River. These areas have subsided up to 1.0 metres, meaning that the land is now a similar height to the river. This is fine on a day to day basis but when a sea level rise of up to 0.5 metres and a one in a hundred year flood is considered, the seriousness of the situation becomes apparent.

Pre-earthquake DEM of Flood Prone Areas on Lower Reaches of the Avon River

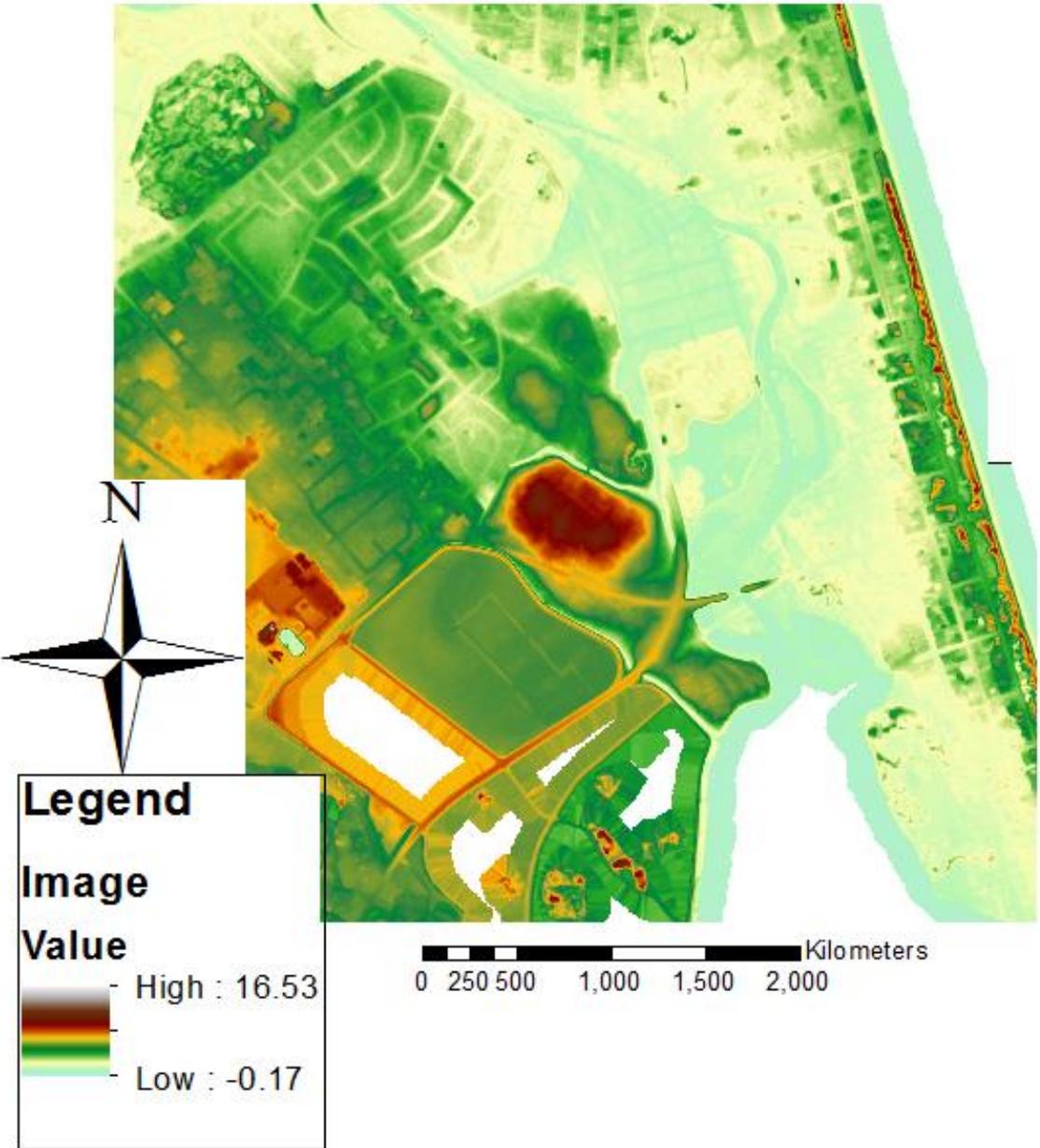


Figure 4: LiDAR data showing land elevation pre-earthquake in the lower Avon corridor.

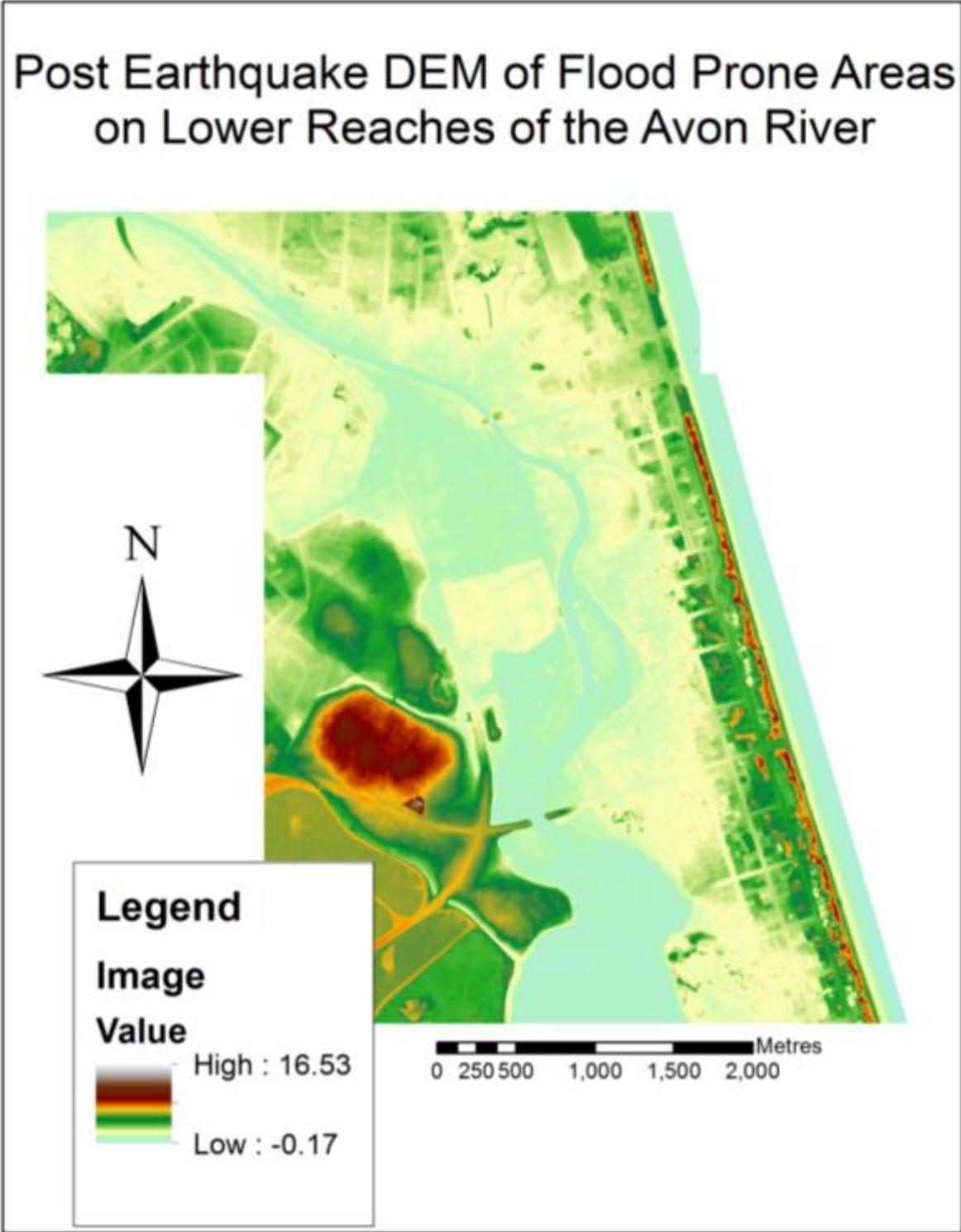


Figure 5: LiDAR data showing land elevation post-earthquake in the lower Avon corridor.

5.2 Existing Methods

There are various types of stopbanks currently in place, these range in size and suitability from worn out stop banks to earthquake proof gravel banks.

The most derelict are seen along Owles Terrace (Figure 6), which have run their course and are in need of immediate replacement.



Figure 6: Photograph of sandbags on Owles Terrace.

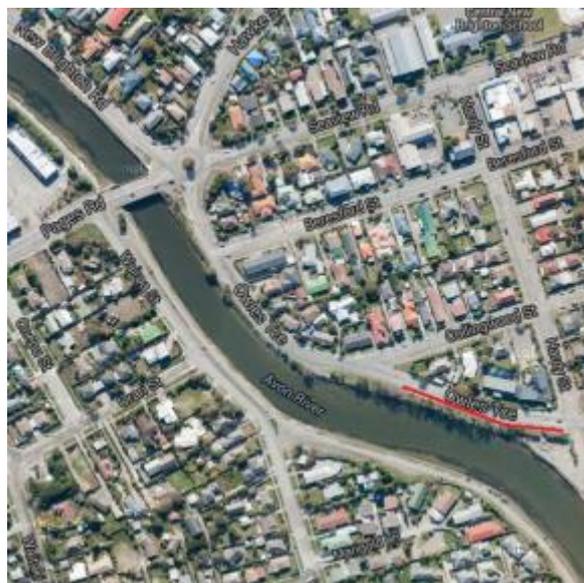


Figure 7: Sandbag location in relation to Avon River (Google Maps 2013).

The majority of the current stopbanks are made up from concrete barriers in filled with gravel (Figure 8); they run for the majority of New Brighton road. These stopbanks are effective but only a temporary mitigation source due to their unattractive appearance.



Figure 8: Photograph of temporary stopbank.

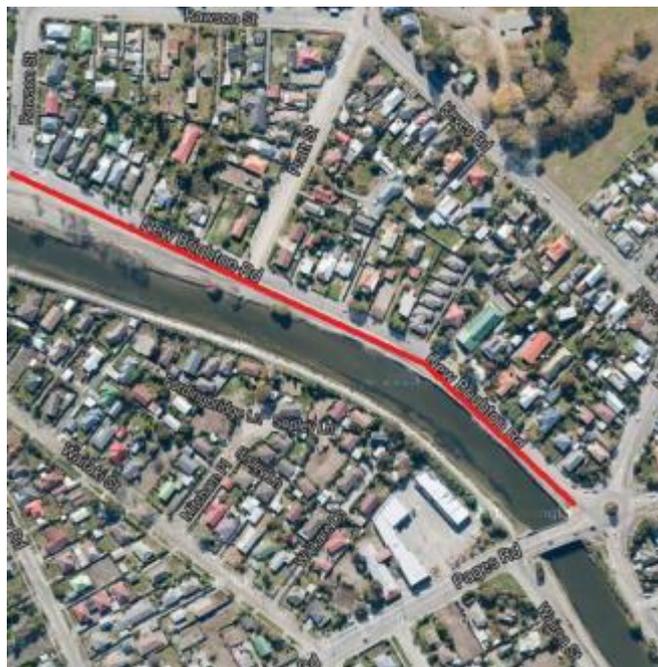


Figure 9: Stopbank location in relation to Avon River Source (Google Maps 2013).

Along Kibblewhite Street there are earthquake proof effective stopbanks, these consist of compacted gravel and are planted to increase stability (Figure 10). They also have walk and

bike paths running on top of them, making them more appealing and functional to the public.



Figure 10: Photograph of permanent stopbank.

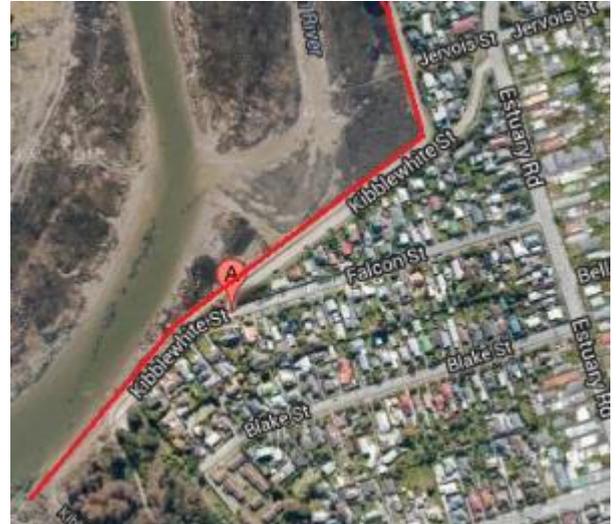


Figure 11: Location of stopbanks in relation to Avon River (Google Maps, 2013).

5.3 Surveys

Survey Locations



Figure 12: Map of locations where surveys were taken in the lower Avon Otakaro corridor.

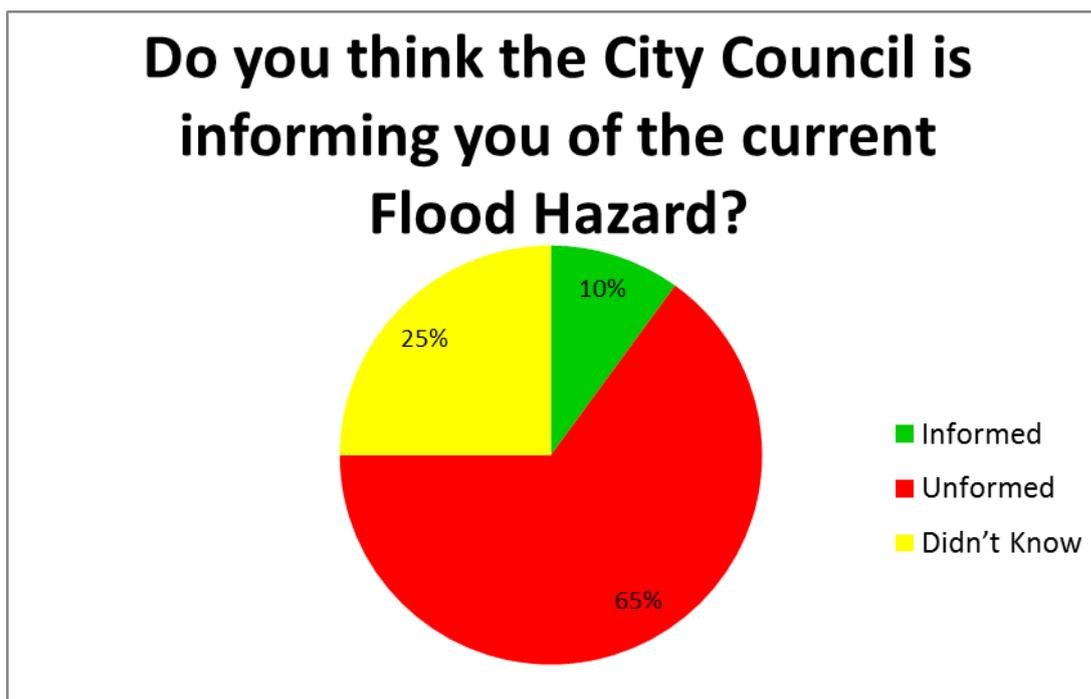


Figure 13: Percentage of people who are informed of the flood risk by the city council as answered by surveys.

We collected surveys from 20 different households with their locations shown on Figure 12. The questions that were answered by residents in the case study area are in Appendix 10.1. Our survey results showed that there was only one street (Kibblewhite Street) who had received a pamphlet that obtained information from the CCC about the current flood hazard. This is why 10% of households thought the council was informing them on the current flood hazard, as shown on Figure 13. Whilst 65% of households had not heard anything and 25% of households did not even know there was a flood hazard. This was interesting because areas where people were experiencing flooding were receiving no information from the council. However, people that were not experiencing flooding were receiving pamphlets from the council about the flood risk. This suggests that the council needs to better plan the areas that require flood information based on the areas flooding experiences.

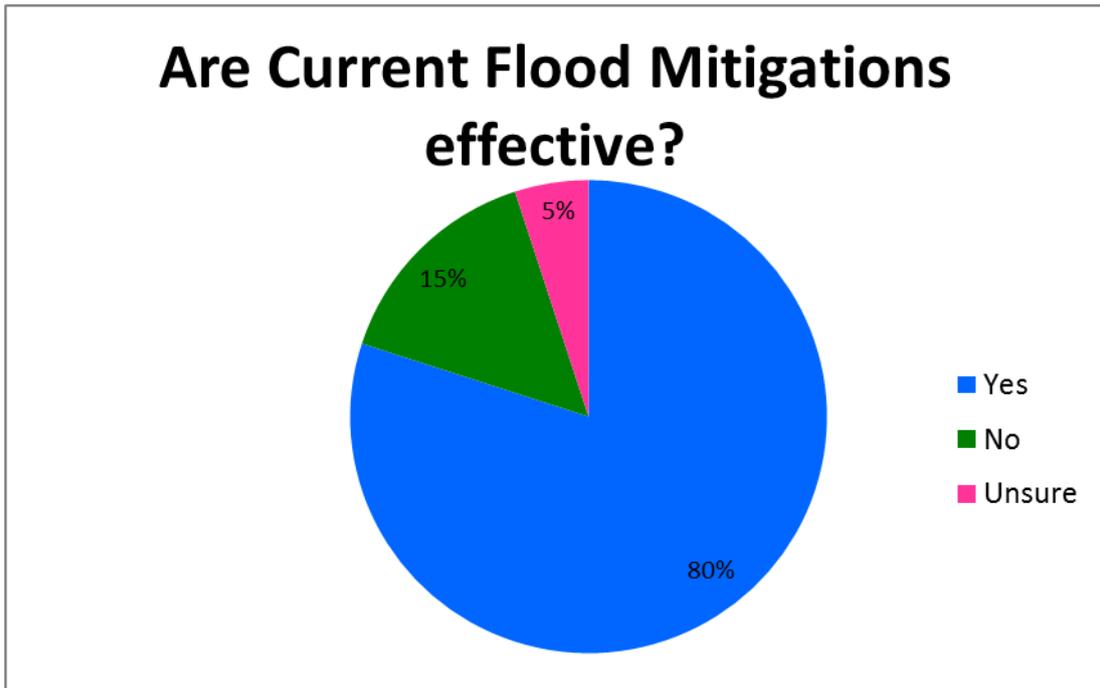


Figure 14: Percentage of people who think current flood mitigation is effective as answered by surveys.

There were 80% of households that thought current flood mitigation was effective but only in the short term, as shown on Figure 14. This is due to some parts of the stopbanks failing and currently being held up by sand bags or concrete barriers, suggesting that the CCC need to implement more permanent flood mitigation.

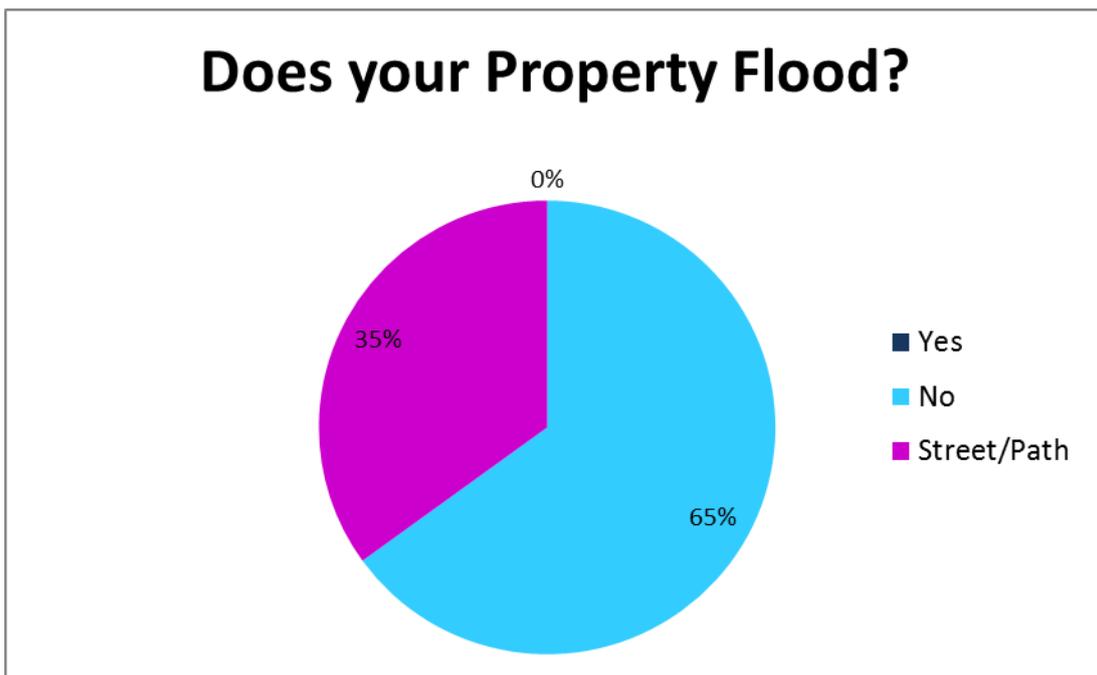
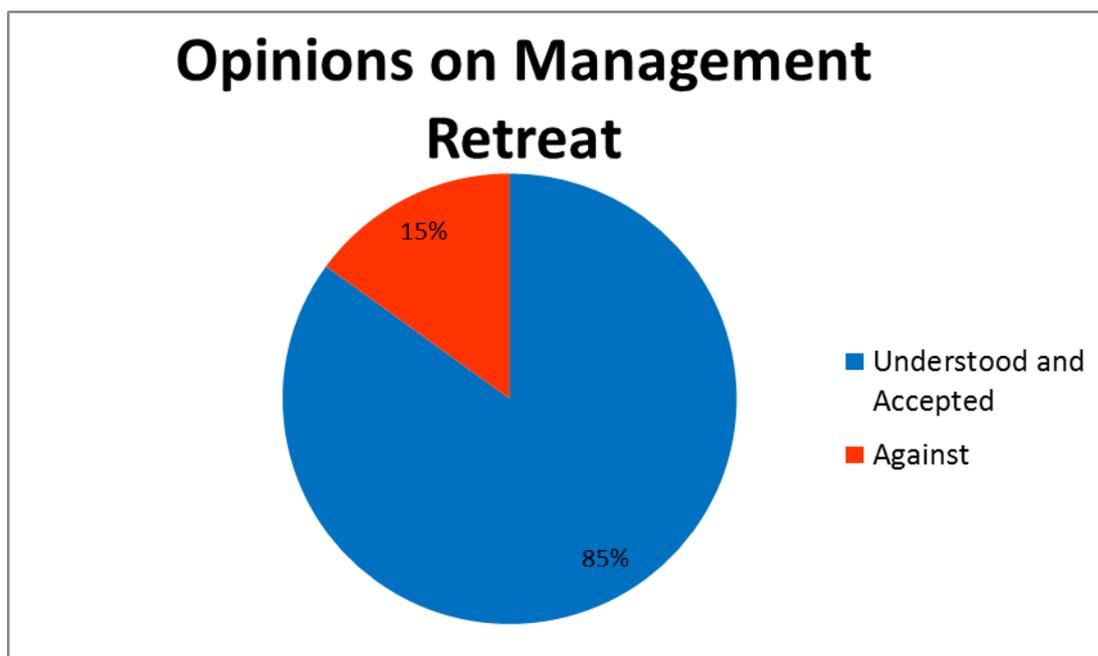


Figure 15: Percentage of people whose property floods as answered by surveys.

Surprisingly, no one had flooding on their property, but 65 % of households had experienced street/path flooding, as shown on Figure 15. This caused difficulty for children that had to walk to school, which made parents quite concerned for their children’s safety. Therefore this increases the need for more effective mitigation measures to be installed.



Although many people did not know a significant amount about management retreat it was surprising to find that 85% of households accepted the concept of it, as shown on Figure 16. Our surveys found that once we had explained the concept of management retreat, people were willing to move if it came down to it. From this result it can be suggested that management retreat has a significant community backing which makes it significantly easier to proceed with. This is explained further in *5.8 Management Retreat*.

5.4 Interviews

From our first interview with Tony Oliver we were provided with a report he wrote called ‘Issues and Options for managing the Avon River floodplain’. This report contained various flood mitigation options that could be implemented in the Avon river corridor. Although this report was written before the earthquakes occurred it still provided relevant options for the area. This information was then used to further develop our ideas about the most viable

flood mitigation techniques. Stopbanks was the main option highlighted in the report, which are discussed further in *5.7 Stopbanks*.

While interviewing Greg Whyte we were able to obtain a better visualization of the flood risk in the Avon corridor through the use of GIS. The main point we took from this interview was that not one mitigation measure will be able to mitigate all flood types. This allowed us to understand that a combination of mitigation techniques are needed to constrain the flood extent. Greg also suggested the idea of spillways and noted the issue of the land being high in elevation compared to the river so would therefore require significant excavation. This issue is discussed further in *5.6 Spillways*.

Obtaining information from the CCC was also crucial as they are key decision makers in Christchurch. Although Graham Harrington could not provide great detail on the work the council is doing due to it not being disclosed information, he assured us the council is looking into stopbanks and potentially management retreat. Questions were asked about whether stopbank height was considered in comparison to sea level rise. This allowed for insight into whether the council was looking into long-term mitigation strategies. We also asked if the council had considered management retreat in the New Brighton area. It had briefly been considered and they have said there is more information in which they need to learn before taking further steps.

5.5 Proposed Mitigation Measures

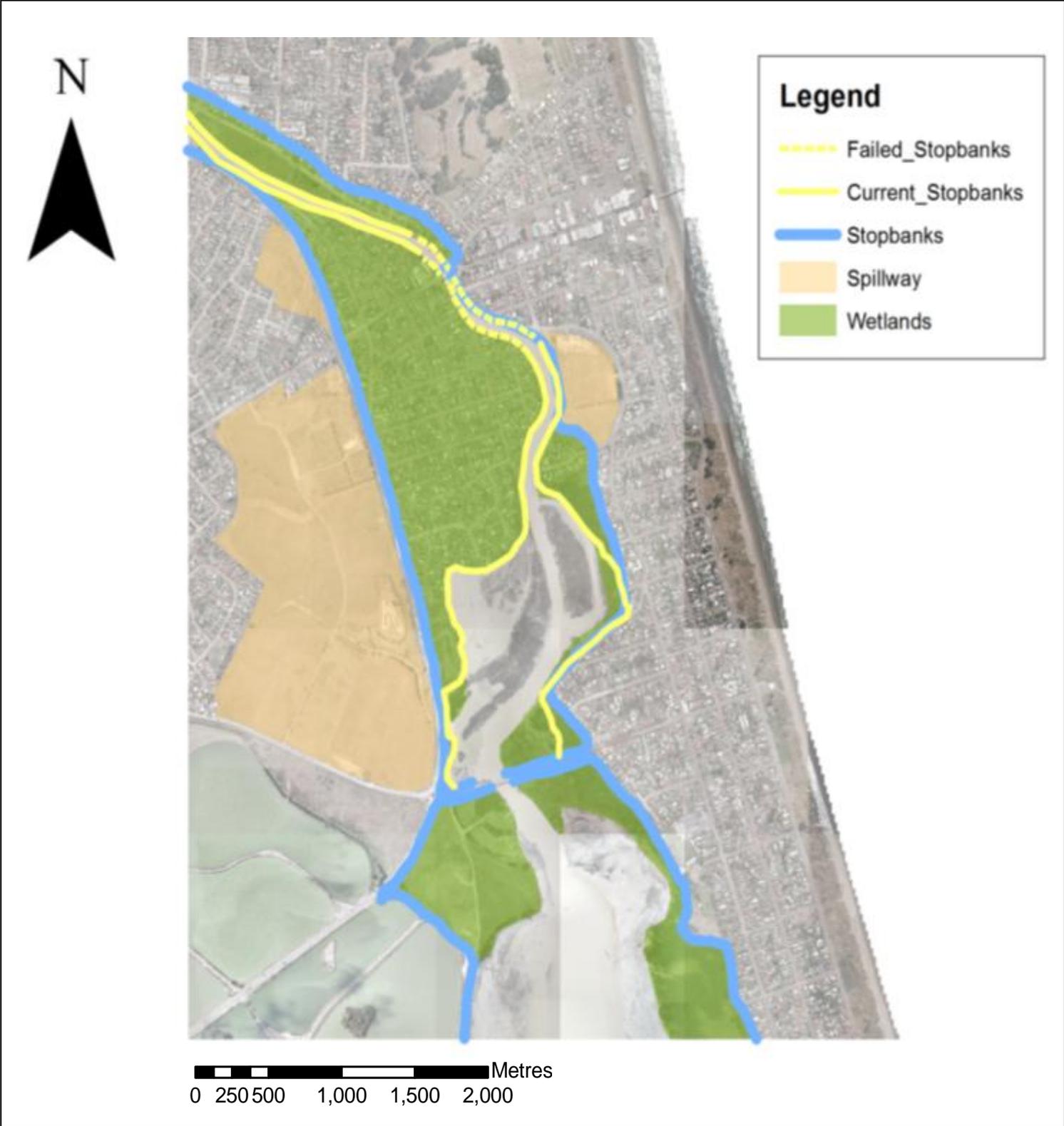


Figure 17: Proposed mitigation measures for the lower Avon Otakaro corridor produced in ArcMap.

Figure 17 shows the proposed mitigation measures that were produced using the digitize tool in ArcMap. This map was completed based on the research we had found and the mitigation measures that were believed to be the most appropriate for the area. The blue

lines indicate where new stopbanks would be implemented and are located around the edge of the red zone. These stopbanks are placed here because when the river is in flood, the water is able to flow over the banks and into the wetlands. The wetlands (green areas) will allow water to infiltrate and reduce run-off, which will reduce flood extents. Since Bexley was severely damaged in the earthquakes and this area has now been deemed uninhabitable and uneconomic to build on, this area would be restored back to wetlands. The orange area represents spillways that will be used to store water during flood events.

5.6 Spillways

Spillways or flood storage ponds are a common stormwater management approach in controlling the level of river flow. It works on the principle of storing a portion of the water coming from the upstream and allowing a limited flow to the downstream of the catchment. In this way, the flow rate is restricted to stay within the capacity of the downstream river banks (Drainage Services Department, 2012). This is achieved through having closable gates both into and out of the storage area. Gates are opened during a high flow event and then releasing water when levels have lowered.

5.7 Stopbanks

Stopbanks are a suitable mitigation measure as they are one of the most effective methods for flood protection (Christchurch City Council, 1997). They provide protection from multiple flood types including sea-level rise, tidal flooding and river flooding (Christchurch City Council, 1997). There is also significant prior knowledge of stopbanks as they are currently used along the Avon River and many other rivers around New Zealand and the World. This includes the Waihou River in Waikato where stopbanks protect hundreds of acres of prime dairy land from flooding every year (Waikato District Council, personal communication, September 24, 2013). There is also a strong community backing for stopbanks as they are prominent features in the environment and can be used for recreational activities such as walking and cycle paths. These recreational activities can be used to draw people back into the area and create an identity that has been lost since the earthquakes.

Like all other options, stopbanks also have limitations. This includes the cost of upkeep and construction (Christchurch City Council, 1997). The cost of a stopbanks would be an estimated \$50 – 75 per metre and this figure can also vary depending on the source of material and how far it has to be moved from (Fulton Hogan, personal communication, September 27, 2013). However, by using recycled material close to the site can lessen the costs of stopbanks. But even though there is this expense, our interview with the CCC has indicated that stopbanks will be implemented as a main mitigation measure on the Avon River.

Some residents were also concerned that stopbanks could reduce their view of the river and estuary, particularly when this is the main reason why they brought the property. They noted that the construction of stopbanks needs to be efficient and must maintain the natural look of the area. This could be done by planting vegetation on them to restore the natural environment of the Avon River.

The council believes that the stopbanks are at the most suitable level at the moment and have no intention on raising the height. Current stopbanks implemented are 11 metres in height and 1 metre off the ground. This suggests that they would not be effective if a sea level rise of 0.5 metres was to occur. Therefore we have proposed stopbanks as a short-term option for the Avon corridor.

5.8 Management Retreat

Management retreat is defined by relocation through setback limits and causes prevention of further development (Alexander et al., 2012; Cooper, 2003). It requires a community to gradually withdraw investment in public assets in affected areas and actively pursue withdrawal of settlement in some areas over time. This is an option that the New Brighton area could implement in the long term as the issue of sea level rise increases with climate change. The Kapiti Coast in the North Island, New Zealand is one example of where this mitigation option is beginning to occur. Although there has been no current action, the Kapiti Coast District Council has included it in their proposed district plan (Kapiti Coast

District Council, 2012). Management retreat is a suitable option as moving people out of the affected area reduces the risk to the community and allows for long-term planning and management.

However there are still limitations to this option. Although whilst carrying out our surveys we were able to further explain the option to some of the community, there was still a definite lack of understanding and awareness. Community awareness needs to be addressed and the public need to be educated for acceptance to be gained on management retreat (Alexander et al., 2012). This could be done through the use of workshops and meetings to ensure understanding is achieved.

Subsidizing people that need to move from the area is also an issue. Since there has already been a significant amount of money issued to the rebuild, the CCC and insurance companies may not be as willing to compensate people's homes. Set back limits also need to be carefully considered as it requires a significant amount of scientific knowledge which can also be expensive (Alexander et al., 2012).

Since people have lived in these areas for many years, there comes the issue of attachment to homes and neighborhoods (Agyeman et al., 2009). It needs to be emphasized that this is people's livelihood that is being interrupted so it is important that their feelings and thoughts are considered especially when relocating them to a different area as their happiness, safety and security is important.

5.9 Wetlands

Wetlands are another flood mitigation measure we have proposed for the lower Avon corridor. Wetlands have recreational value with the use of walkways and cycleways that can attract people back into the area. As discussed on The Press (2012) online forum the public are behind wetland restoration as they are important for native wildlife and plants and contribute to improving water quality.

However there are also downfalls to wetlands as they do not provide habitat security during flood events. Therefore wildlife and plants are disturbed, limiting their populations. Wetlands are also difficult to restore as they have been drained and altered to

accommodate human needs (Zedler, 2000). Adequate timing, frequency, amplitude and duration of high water levels need to be maintained to support biodiversity and functionality of wetlands (Zedler, 2000). Therefore wetlands are a suitable option for the lower Avon but would require a significant scientific knowledge and research on the existing wetland conditions.

5.10 Other Methods

The following includes a brief summary of other methods that we researched but did not think were appropriate for the case study area due to their economic viability.

Raising Houses & Floatable Houses

Raised and floatable houses are both similar concepts as they require foundations to be raised above flood water levels. Raising houses involves lifting the lowest level above the expected flood level by using piles or columns to elevate the foundation (Zevenbergen et al., 2011). Floatable houses are structures which are built on hollow concrete pontoons or polystyrene blocks that become buoyant when floods occur (Zevenbergen et al., 2011). Since these methods require significant costs and are extremely expensive, this option is not economically viable for Christchurch.

Dredging

We also looked into dredging, a method that is carried out underwater to move bottom sediments off of rivers. Dredging makes the river deeper and therefore allows the river to hold more water. This option was very expensive and would have to be repeated often. It also creates disturbances to ecosystems, possible contamination and release of toxic chemicals from bottom lying sediments (Xing et al., 2006).

5. Limitations

Management Retreat

Management retreat is one of our long term options. When talking to Graham Harrington from the CCC he said that management retreat had only briefly been considered and that there is more information in which they need to learn before taking further steps. Meaning

that it is an idea that has come up, but no one is willing to do the research needed, making it harder for us to find information.

Short-term and Long-term Definitions

The terms "short term" and "long term" are both hard to define and are dependent on the issue and situation. Due to there being ongoing seismic activity and disruption to Christchurch it is hard to determine when the flood mitigation measures will be implemented. In our current situation "short term" is defined as occurring during the next 5 to 7 years. Whilst in the long term we can expect the measures to take place in up to 10 years or more as these measures require more planning and management. There is also the question of how fast climate change will occur and when Christchurch will encounter sea level rise. This can only be determined by further research and modeling to define the impact of sea level rise on the area.

Time

An important constraint for our study was time as we only had 12-13 weeks to carry out our research. This has caused us to restrict the case study area to only the lower Avon corridor instead of the entire river. Time restraints also lessened the amount of people surveyed which limited the information and opinions received from the community. A larger time frame would have allowed for a more in depth analysis including cost of spillways, location of setback limits for management retreat and a design layout for wetlands.

Survey Restrictions

We wanted to get the public involved to get their opinions and thoughts of the current flood hazard, and see what they thought needed to be done. To begin with the area we wanted to survey was half red zone, meaning no one was living there or they were not willing to complete the survey. We did manage to get 20 completed surveys in the end though the methods of door knocking and emailing. But it was a lot more time consuming than we first thought.

7. Conclusion

Following the series of earthquakes which have struck Christchurch since September 4th 2010 the Avon Otakaro corridor has undergone a great deal of subsidence and has now become more susceptible to flooding. Through qualitative and quantitative data collection in the form of surveys, interviews and physical data collection we have decided upon the most appropriate mitigation options. This includes two stages, short and long term; initially in the short term there will need to be immediate remediation of current stopbanks along with the introduction of spillways into selected red zoned areas. Following these initial techniques, wetlands and management retreat could be implemented in response to both predicted sea level and ground water level rise. It needs to be understood that these mitigation measures require significant planning and management. Involvement and awareness from all stakeholders is also highly important for flood mitigation measure to be effective.

8. Acknowledgements

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10. Appendix

10.1 Survey Questions

1. What is your current street address?
2. How long have you been living in the address above?
3. Are you a business owner or household owner?
4. Are you aware of the current flood hazard in your area?
5. Does your property flood, if so how often pre earthquake?
6. Extent of flooding? (Where does the water accumulate)
7. Post earthquake?
8. Extent of flooding? (Where does the water accumulate)
9. Personal experiences, of flooding within your household?
10. Are you willing to spend money on flood mitigation measure on your own property or business?
11. If you are tenants, is your landlord willing to spend money on flood mitigation measure?
12. Do you think the council is doing everything they can to inform you of the current flood situation?
13. Is the council, doing enough to manage the current flood hazard?
14. If not, what do you think should be changed and enforced?
15. How effective do you think the existing flood mitigation methods are? (Stopbanks, sand bags etc)
16. What would be your preferred flood hazard management, mitigation measures?
17. Rank these in ascending order of your preferred preferences

Spillways

Stock banks

Vegetation

Manage retreat

Raising houses

Dredging

Other

18. How much do you know about Management retreat?

19. Would you be willing to move house?