How to facilitate access to Motukauatirahi (Cass Bay) Reserve taking into consideration conservation and restoration

2021

A GEOG309 project by Jessica Rodwell, Rachael Nilsson, Jamie Wisker, Ella Harford and Arlia O'Sullivan

Table of Contents

1. Executive Summary

- ***Project aim***

  This project aimed to propose a holistic plan for transforming the Motukauatirahi catchment into an ecological and historical reserve, with public access via walking tracks. This project worked alongside Karen Banwell and the Cass Bay Reserve Management Committee.

- ***Research question***

  The primary research question was “How to facilitate public access to the Cass Bay Reserve taking into account conservation and restoration?”. To do this, the research was split into sub-themes to focus on. These sub-themes included history, ecology, hazards, GIS methods, and public access management.

- ***Methods***

  Literature reviews were a necessary step to provide a base of information about the area and relevant methodologies for our project. Consultation with community locals was essential for all aspects of our project, particularly surrounding the history and walking tracks. Rockfall was assessed by walking the site and creating a set of hazard maps. In terms of constructing proposed walking tracks, incorporation of the least-cost algorithm in Geographic Information System (GIS) software and GPS tracking techniques in conjunction with one another was decided upon as the most appropriate methodology.

- ***Results***

  The key findings presented were the hazard assessment and GIS outputs. Hazard assessments of the rockfall ensured that the walking tracks were positioned in safe spaces. Furthermore, GIS outputs resulted in various conceptual walking track plans within the area, taking into account the slope via least-cost path analysis. To incorporate the various aspects of our topic, Google Earth was the primary software used to amalgamate varying sub-themes. This is accessible and modifiable to the public.

- ***Limitations***

  The overarching limitation to this project was the Covid-19 lockdown. While the consultation process is underway with local iwi, the lockdown resulted in a reduced

period in which key kaumātua could not provide a response. Other limitations included the specific development of a linking track up to Whakaraupo Reserve. This not only requires higher levels of expertise to construct such a track but also extensive consultation with Christchurch City Council (CCC). Hence, facilitating access within the reserve via loop tracks and linking this with historical and educational aspects was the primary focus in this project.

- ***Future Recommendations***

  For future research, it is proposed that a Cultural Impact Assessment is undertaken with Ngāti Wheke. Further consultation with the Christchurch City Council about connecting these tracks up to the Summit Road will also be required. Finally, future research into the long-term continual assessment of how plants and biodiversity are positively or negatively influencing the area will be important for future health of this reserve (e.g., incorporating the Mauri Model within the stream).

2. Introduction

Banks Peninsula is situated near Christchurch on the east coast of the South Island. Cass Bay is within Banks Peninsula, with a reserve above the residential area. Cass Bay Reserve (Motukauatirahi) is currently inaccessible to the public yet holds great potential for future projects, connecting the community to the area. Therefore, there was an opportunity to develop a project at Cass Bay Reserve. Our community partner, Karen Banwell, is the Whaka-Ora Programme Manager and proposed the research question of: 'How to facilitate access to Cass Bay Reserve, taking into account conservation and restoration?'. This research question comprises a wide range of potential, with various sub-themes to focus on. With respect to time limits, the main goal agreed upon was to develop and draft plans of potential walking tracks to include in the reserve, ensuring that historical and ecological aspects are incorporated. To ensure the walkways were positioned in the safest areas, the hazards and Geographical Information System (GIS) methods were considered. Opening this area to the public will enhance community connection whilst acknowledging the educational potential within the reserve. This project will hopefully create a stepping stone in the right direction for future development ideas and public access to Cass Bay Reserve.

This area is rich in history with several extant but mainly derelict bunkers, once used as a place for ammunition in World War II (Beaumont, 2014). This large unoccupied area also has an intermittent stream (Steadfast Stream) meandering through the reserve, draining the hills above. This stream previously flowed through a highly vegetated area, hosting a wide range of native species (Environment Canterbury, 2020). These natural and manmade features must be acknowledged and respected as they hold significance to the reserve. Therefore, the objective is to incorporate and express the historical and ecological elements through developed conceptual walking pathways.

In this report, literature reviews are firstly discussed. These focus on the main sub-themes: history, facilitating public access, ecology/stream restoration, hazards, and GIS. These were essential to give an overall background scope of the project, understanding what is already there and needs to be acknowledged. Secondly, the methodological approaches are discussed in how data was gathered. The methodological approach this project presented was mixed, incorporating both quantitative and qualitative data, with

the latter being more dominant. Throughout this project, GIS was predominately used. GIS is a valuable tool for compiling and portraying multiple forms of data, enhancing collaboration between a variety of stakeholders (Olafsson & Skov-Petersen, 2014). Further, the use of such technology is considered valuable for community planning. This is due to the enhanced analysis and visualisation which could not be achieved via traditional, non-computer-based tools (Al-Kodmany, 2001). Mapping and analytics software (ESRI's ArcGIS and Google Earth) have therefore been used to compile the multiple aspects within the scope of this project. Overall, incorporating both qualitative and quantitative methodological approaches is advantageous and helps to reduce the risk of generating erroneous results (Philip, 1998). Finally, the results/discussion section analyses various figures, displaying the hazards, GIS components and overall management plan regarding potential walkways.

3. Concepts and Literature Review

3.1 History of Motukauatirahi

Motukauatirahi is rich in history. Researching history has been an important aspect in compiling information for the historical signpost (Hampton, 2010). Māori settlement took place approximately 700 years ago. Kaikomako trees were growing in the area and were great for fire-making. Therefore, the name of Motukauatirahi was given to the area with the definition of 'great fire-making tree grove'.

In 1943, ten bunkers were constructed to store ammunition in World War II. This location was chosen due to the easy accessibility from the sea, but the location was not visible from the Lyttelton Harbour Heads due to steep slopes surrounding the area. A timeline of Cass Bay usage was constructed through resources from Robertson (2019) including prehistoric, World War II, subdivision development and current uses.

3.2 Facilitating public access

Through reviewed literature, it was found that while opening public access to reserve land, different management elements are needed to maintain the integrity of the land and potential pathways. Local reserve management plans in Banks Peninsula served as useful guidelines for which public access management applications may be useful in the future for Cass Bay reserve. From the Misty Peaks and Te Oka reserve management plans, mitigation strategies like the inclusion of public restrooms and rubbish bins were essential in reducing visitor waste (Christchurch City Council, 2019a; Christchurch City Council, 2019b).

Other reserve management plans suggested an integrated approach of incorporating local indigenous management knowledge and ongoing scientific indicators of environmental health (Carr, 2003; Cessford, 1999). For future public access in Cass Bay, an approach like this would be most ideal with a combination of suggested waste management elements. This approach would be most effective in preserving the land while still providing an immersive visiting experience for the public.

Including signage on our walking tracks was an important part of facilitating public access in Motukauatirahi. Davis & Thompson (2011) suggested appropriate ways and general rules on the best places for signage on walking tracks. This literature helped dictate where signage was placed on our proposed walking tracks. This included choosing to place signage in natural resting areas. The literature also helped us understand how to make the signage appealing, e.g., including large fonts and interesting information. Ferreira (1998) helped us to understand that it is important and beneficial to educate people about Motukauatirahi during recreational activity. This includes giving people a sense of connection and understanding about the area, and is taken into great consideration throughout the project.

3.3 Freshwater management and ecology

Due to the presence of a freshwater stream (Steadfast Stream) in Cass Bay Reserve, literature was compiled around the importance of freshwater management and the

inclusion and use of Mātauranga Māori. Such literature can then inform future applications within this area, as management of Steadfast Stream needs to be continued to aid both the ecological and cultural worlds. In New Zealand, freshwater management incorporates Māori indigenous knowledge into current legislation, designed to respect and embrace treaty principles. Such treaty responsibilities oblige the Crown and local government to have regard to indigenous rights (Harmsworth et al., 2016). Māori knowledge known as Mātauranga Māori encapsulates life experiences that form the basis of Māori culture, identity, and value systems. Māori have a strong connection to both the land and sea, with water being a central component of the spiritual and physical world (Environmental Protection Authority, 2021). Given their integral role within our society, ensuring their voices are being heard is crucial for meaningful engagement and collaboration (Harmsworth et al., 2016; Hikuroa et al., 2018; Knight, 2019; Morgan, 2006; Stewart-Harawira, 2020; Te Aho, 2019). Relating such literature to Cass Bay Reserve and Steadfast stream, upholding the cultural vitality of freshwater systems, and allowing for a qualitative approach when managing freshwater is essential. This collaboration optimises community engagement, for example including the Mauri or Cultural Health Index (CHI) models which can be seen in Appendix A. Applying such models to Steadfast Stream would be beneficial to the area; however, given the time constraints, this was beyond this project's scope and objective.

Through further research, it was found that the Whaka-Ora healthy harbour group has planting projects underway within the Cass Bay Reserve. The revegetation project aims to restore and improve the Steadfast Stream and the habitat for native species (Environment Canterbury, 2020). Planting projects of such importance are beneficial to the area, however, moving forward a key emphasis could be getting the wider community involved. Engagement with local communities can be enhanced through the application of a Māori cultural lens (Waikato Regional Council, 2017). An approach that includes indigenous knowledge systems will not only enhance waterway management but has the potential to govern a wider sense of community involvement in the Cass Bay reserve.

3.4 Hazards

3.4.1 Natural Hazards

In the review surrounding the hazards of the Cass Bay Reserve, it was first found that rockfall was the major hazard for the reserve (Clifford, 2012). The geology of the Banks Peninsula area is late Miocene alkalic and transitional volcanic rocks formed in the primary eruptions of the Lyttelton and Akaroa (Sewell, 1988). This geology paired with the steep slopes up to the ridge of the crater above the Cass Bay Reserve creates the rockfall hazard for the area (Massey et al., 2012). In terms of local policy, it was found that a risk-based approach is used to mitigate natural hazards by the Canterbury District Council (Christchurch City Council, 2021). To determine the best approach for the Cass Bay Reserve, a variety of methods were assessed. These methodologies included ideas such as the use of RocFall software to create a kinematic analysis and zoning maps (Güi et al., 2016), using LiDAR and eyewitness statements to create a good historical record of rockfall (Borella et al., 2016) and the assessment of lichen and colluvium build-up to assess and record ages of rockfall (Borella et al., 2019). From this assessment of the literature, a background of knowledge and a methodology to best assess the rockfall hazards in the Cass Bay Reserve was developed.

3.4.2 Physical Hazards

The main physical hazard in the Cass Bay Reserve site is the bunkers. These bunkers are currently in varying conditions, ranging from fully intact to “no-go zones”. These “no-go zones” were caused by rockfall triggered by the Christchurch earthquake penetrating the roofs, as can be seen in Figure 1 (Christchurch City Council, 2021). There is limited information as to what was originally stored in the bunkers, however, it is known that these buildings have asbestos roofs. Interaction with asbestos will be hazardous to the community and hence will need to be taken into consideration when opening the area to the public (Lyttelton Review, 2020).

Figure 1. These images show the damage caused by rockfall to the bunkers in the Cass Bay Reserve.

3.5 Trail construction via GIS

Upon investigation of GIS trail creation, the least-cost path algorithm was found to be the favourable methodology in ESRI's ArcGIS (a GIS software). This is achieved by weightings being applied to various factors creating a 'cost-surface'. Given a start and endpoint, the software then computes a line of least resistance (i.e., through the lowest cell values), resulting in optimal route creation. Such methodology is used in a variety of projects, with trail creation varying from walking tracks to large scale ATV trails (Xiang, 1996; Ferrarini et al., 2008; Tomcyzk & Ewertowski, 2013; Hemanth et al., 2021).

Regarding the methodology previously used in the region, email consultation with the Summit Road Society Secretary outlined the role of local knowledge being intrinsic to trail creation in the area. This can be achieved by physically walking the area several times using a handheld GPS device. The .gpx file produced from this can subsequently be imported to GIS software (Triantafyllou et al., 2017). The importance of incorporating such field knowledge in the mapping process is supported by literature (Whitehouse, 2021).

Therefore, given the scale of the area being small enough to physically walk, along with the necessity to incorporate local preferences and knowledge, an appropriate methodology was concluded for the scope of this project. This would incorporate the use of the least-cost algorithm and GPS tracking techniques in conjunction with one another. Resulting from this, an optimal route in the least computationally intensive manner would be produced.

4. Methods

4.1 Community interaction

Compiling information regarding the history of the area was an important aspect of creating information signposts. This included conducting interviews with several people including Noeline Allan, Jenny Healey and locals attending the community planting day, along with reviewing the literature mentioned above. These interviewees all had close connections with the reserve. During these discussions specific questions were asked about the history of the area and if they had any personal stories about the area. These questions helped determine what was important about the area in the past from a local perspective; particularly from times before and during World War II when the area was widely used.

4.2 Determining Walking Track Locations

4.2.1 Reserve Surveying Methods

To distinguish proposed walking track locations, the reserve was firstly walked and explored by the group to evaluate the property. This evaluation helped distinguish general areas of the reserve that were perceived as suitable for tracks. After initially surveying the property, the group discussed track locations with members of the Cass Bay committee, Karen Banwell (the community partner) and other locals. These consultations

enabled insight into what the community wanted from the tracks. From these discussions, it was determined that tracks that walked the east side of the reserve and connected to other tracks in the area would be ideal. Previously proposed walking tracks from the company AECOM (2016) were also taken into consideration (Figure B.1, Appendix B). After community consultation along with physically attending the site, it was evident this trail is not utilising the area to its full potential.

After local consultation, the area was walked again several more times using a handheld GPS through the phone app 'MyTracks'. This refined a distinguished area for the walking track route. While recording the walking of the reserve, suitable areas for lookouts and picnic tables were identified and pinned using the handheld GPS. These were areas that had sufficient views of the Lyttleton harbour for lookouts and/or had flat stable land for tables. Subsequently, these recorded tracks were exported and imported into Google Earth and ArcMap (GIS software) for analysis to confirm that these locations were eligible to be implemented.

4.2.2 GIS Methods

GIS methods were used to verify and more accurately define the recorded tracks. This was done through least-cost path analysis in ArcMap. Elevation data was used from the Land Information New Zealand (LINZ) Christchurch and Selwyn LiDAR 1m DEM (Land Information New Zealand Data Service [LINZ], 2017). Using this DEM data, a slope map was created using the slope tool (Figure C.1, Appendix C). From this slope model, the cost distance and cost backlink spatial analysis tools created two map outputs that would be used for the final cost path analysis (Figure C.2 & Figure C.3, Appendix C). The cost distance output was generated using minimum accumulative cost distance from slope values. The cost backlink output was then generated using the least accumulative neighbour cell. Using these outputs, a cost path was generated using the cost path spatial analysis tool, producing an output raster of pathways that travelled through the lowest slope values in the reserve. These path outputs were then compared against the paths that were previously recorded by the group to modify and alter the output into the most ideal locations. This created multiple track location options.

4.3 Hazard Methods

In terms of the data collection for the hazards present on the site, the resources that were already available were first assessed. This included a mass movement investigation in the Port Hills that was undertaken by the Christchurch City Council (n.d.) and a hazard assessment created by AECOM (2016) for the Cass Bay Reserve. From these investigations, gaps in knowledge and what could be improved on were recognised. Looking at previous hazard maps as it was found that both investigations lacked proper mapping of the rockfall hazard at a local level (Figure B.1, Appendix B & Figure D.1, Appendix D). Taking this into account, a simplified method of Borella et al. (2016) that was used in the qualitative assessment of the lichen growth and colluvium build up around the rockfall to assess the ages of each deposit. Using this method, the Reserve site was walked, marking out the geographic coordinates on a handheld GPS (MyTracks) of each rockfall deposit. From this data, the rockfall was split up into groups of historical and post-Christchurch earthquake rockfalls. This data was then assessed and used to determine the hazard rating of the areas within the reserve. These hazard ratings were then used to create a map of the overall hazards within the Cass Bay Reserve site.

Figure 2. This figure shows the comparison between the historical Post Christchurch earthquake rockfall. The historical rockfall in image A has a large amount of colluvium build up and lichen growth on the deposit because it has been sitting undisturbed for a long period of time. This was then compared to Image B having one face containing lichen growth, correlating with the face exposed to weathering before it fell, as well as the limited colluvium build up around the deposit.

5. Results + Discussion

5.1 Hazard maps

After compiling the collected hazard data, two separate hazard maps were created. This map shows the rockfall in the Cass Bay Reserve separated by age into groups of historical and post-Christchurch earthquake rockfalls (Figure 3). This map enabled the creation of a realistic plan of where to put the walking tracks as it showed where the highest proportion of recent rockfalls were. This allowed the creation of the safest route for people to walk

and will help reduce the hazard on the site. A second map was created to display the overall hazard assessment of the reserve (Figure 4). This map is split up into four sections depending on its determined hazard rating. The right side of the map has a high or very high hazard rating due to the elevated proportions of both historical and post-Christchurch earthquake rockfall. This high rockfall hazard is due to the steep slopes and cliff faces above the right side of the reserve. On the map, the red areas are largely correlated with the ridges and orange areas with the valley. This was very important to consider. In this map, there is not a large proportion of rockfall in the orange areas, but they are still a high hazard rating. This is because the orange areas are likely paths for the rockfall but due to slope gradient and gravity, the rockfall is then funneled down into the red zones. The left side of the map has a far lower hazard rating largely because it does not have steep slopes or cliff faces behind it, which makes the area less susceptible to rockfall in general. This reduced susceptibility to rockfall is the reason that all proposed walking tracks are put on the left side of the map.

In terms of the physical hazards present the proposed walking track goes past several of the bunkers, for which all of these are in relatively good condition. Nonetheless, it is still necessary to reduce the risk to the community. This could be achieved by sealing the doors shut to prevent access and using adequate signage about the hazard. This means that people can interact with the buildings, yet are not interacting with the most hazardous sites.

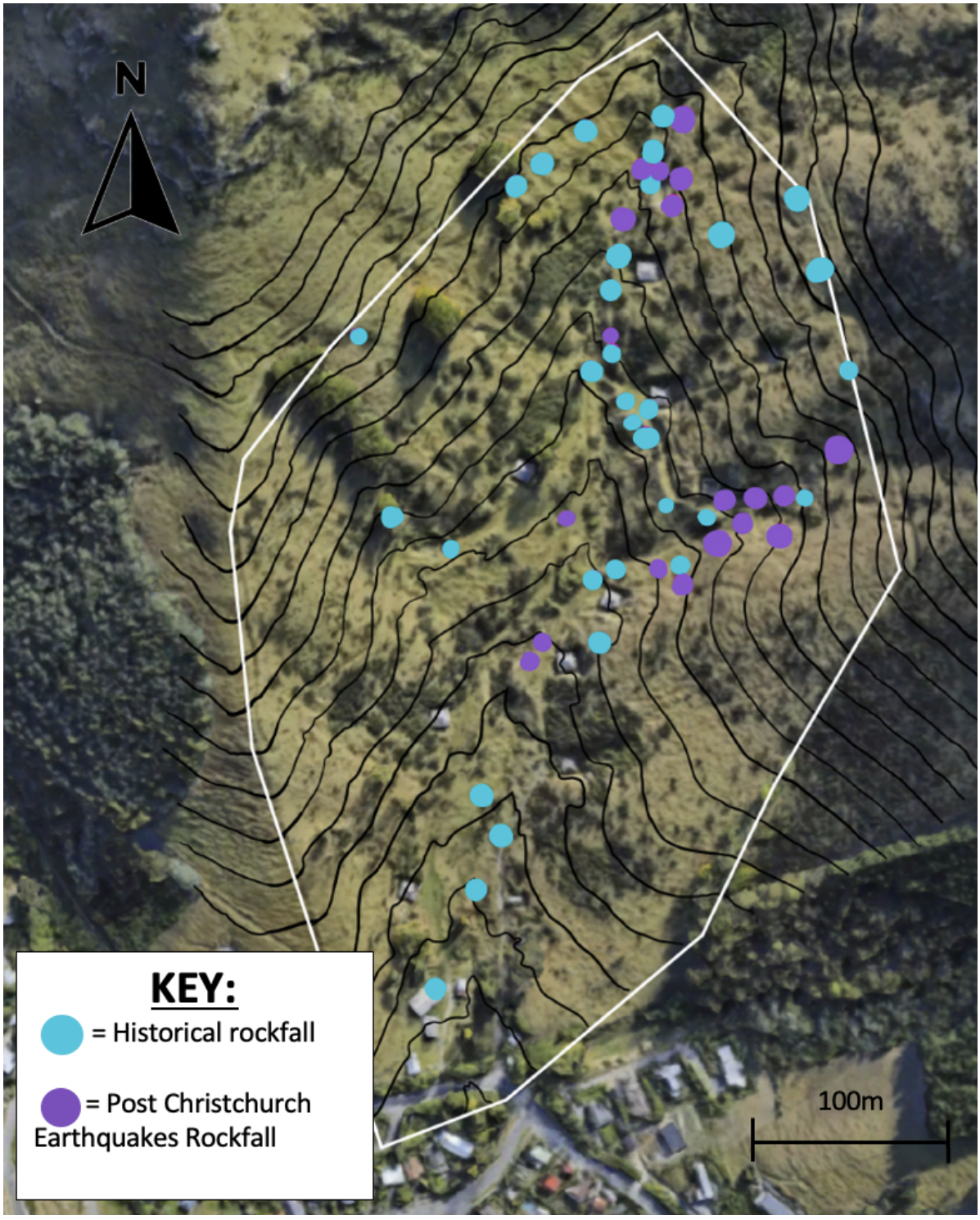

Figure 3. This map shows rockfall separated into Historical and Post Christchurch Earthquake rockfall events based on the colluvium and lichen growth assessment.

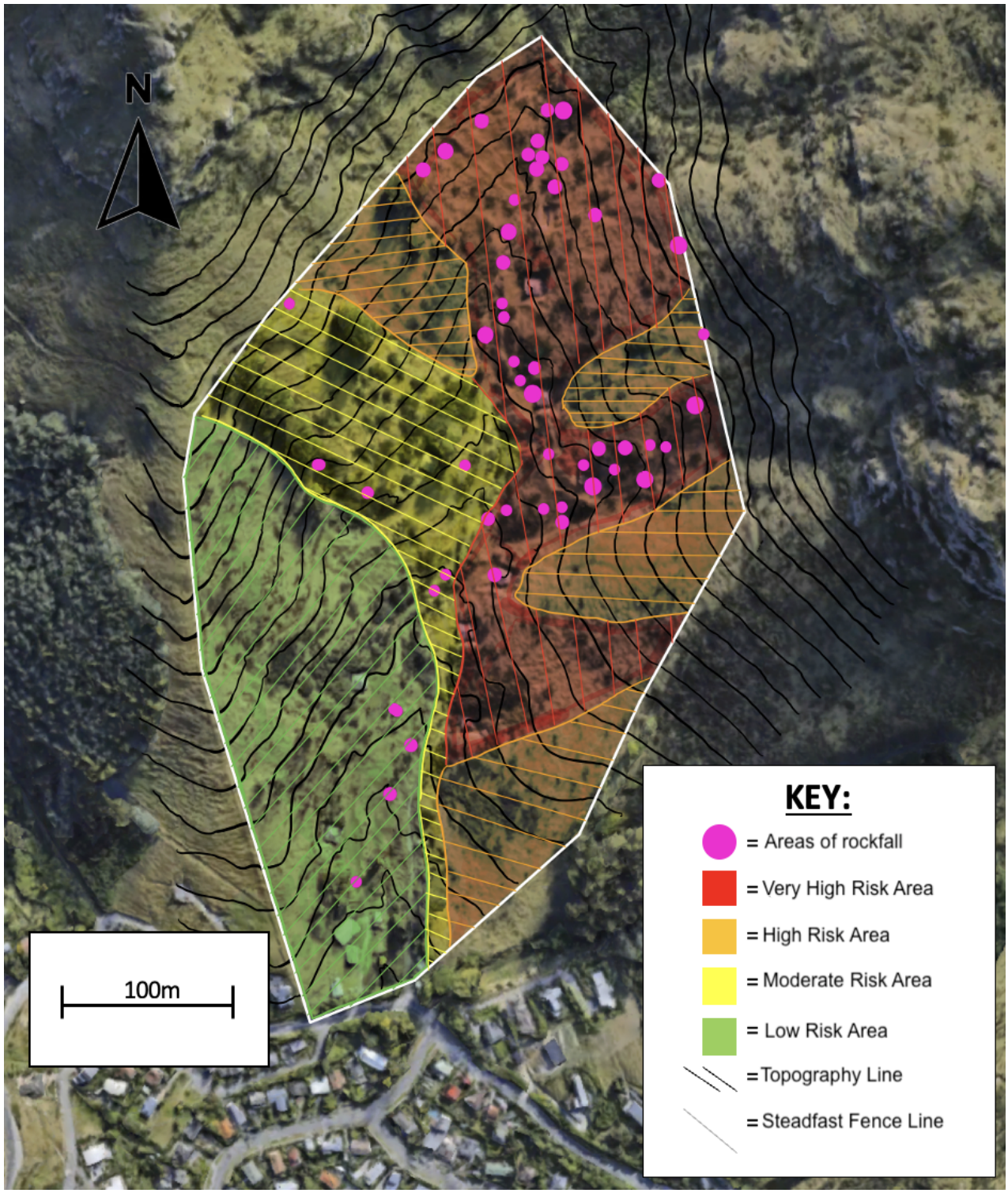

Figure 4. This map shows the overall hazard ratings within the Cass Bay Reserve area.

5.2 Final walking tracks

5.2.1 Unmodified Walking Track Recommendation

Using reserve surveying and GIS methods, several different recommendations were created for the locations of walking tracks in the reserve. The first recommendation is shown in Figure 5, which is the unmodified output from the least-cost path analysis. There are four tracks shown in this map which have been categorised by difficulty (from easy to expert level). This first map output connects to the Summit Road which would be beneficial for linking the reserve to other walking tracks in the local area. The output has some constraints as the red track to the Summit Road is in an area of the reserve where it is very steep and has been categorised as having very high hazard risk (refer to Figure B.1, Appendix B). Due to this steepness, a straight path at the top of the reserve would not be practical for the use of visitors.

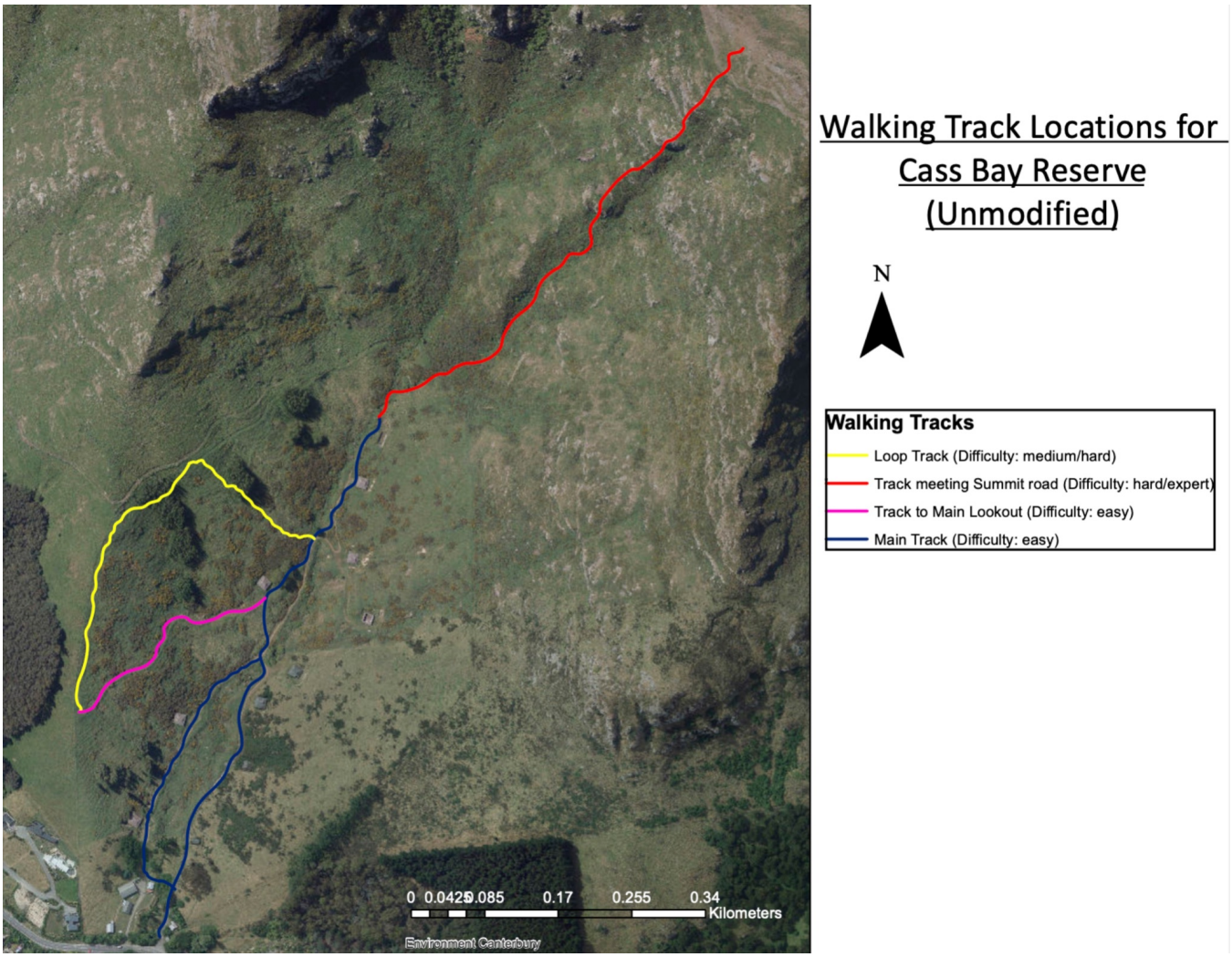

Figure 5. Proposed walking tracks with the unmodified output from the least-cost path analysis in ArcGIS.

5.2.2 Modified Walking Track Recommendation

The second recommendation shown in Figure 6 is a modified version of the first least-cost path analysis output. As mentioned previously, the first output would cause difficulty for visitors because of how steep the top of the reserve is. Because of this, a second modified version of the tracks has been recommended. As seen in Figure 6, the red track meeting the Summit Road has been modified into a zig-zag pattern at the top. This has been changed to help mitigate the slope by decreasing the incline of the tracks. This track will remain classified as an expert level.

These first two walking track recommendations sufficiently link the Cass Bay reserve to other tracks in the local area while also extensively utilizing the space. However, these two recommendations use routes that lie within high hazard risk areas. As mentioned in the previous section and shown in Figure 4, the track meeting the summit road as well as other parts of the main track is in the direct zone of very high risk. Because of this, these two recommendations will have some health and safety concerns. If either of these track locations were to be implemented, they would require no stopping zones in areas of high risk while people walk the tracks to help mitigate this.

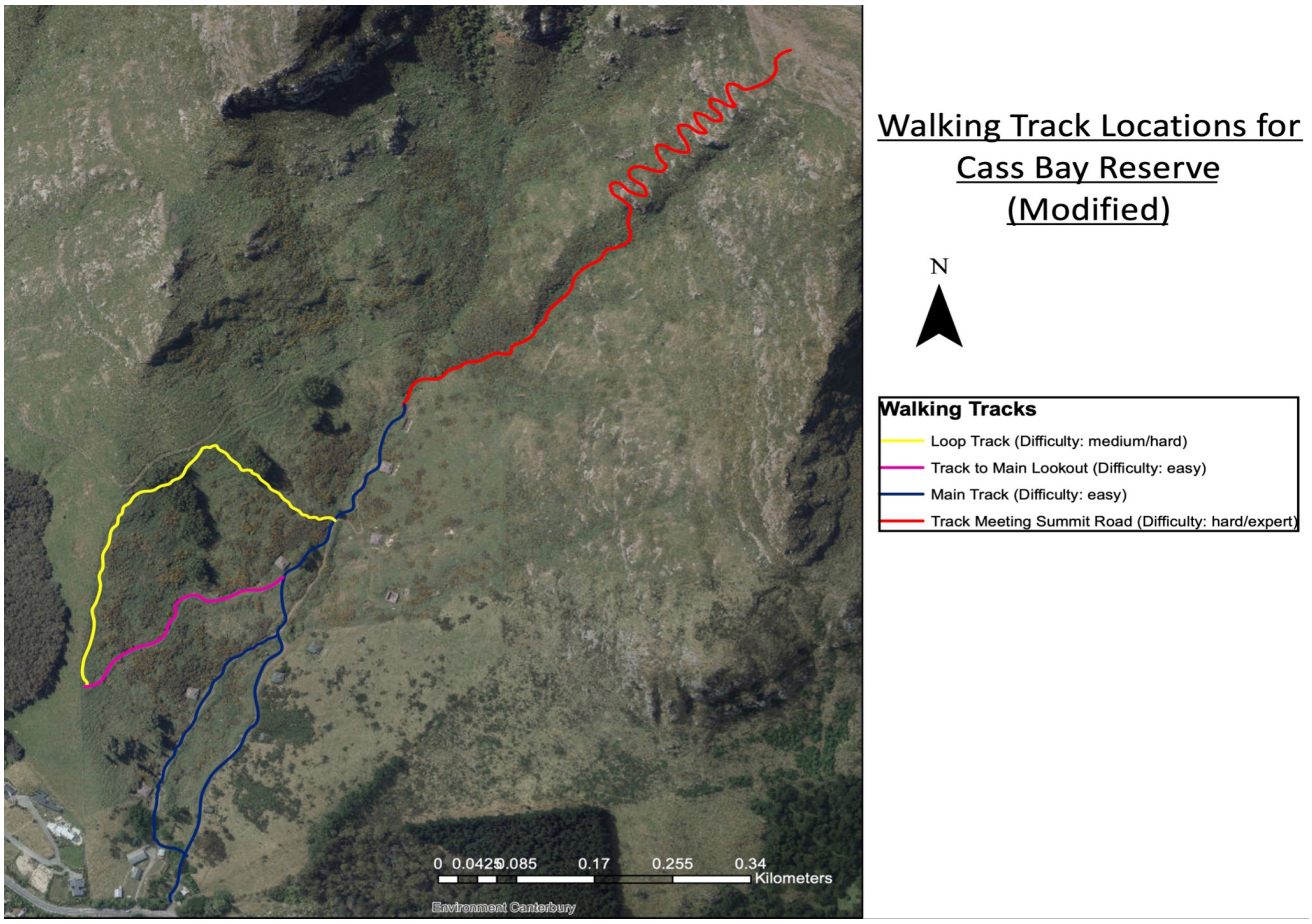

Figure 6. Proposed walking tracks of the modified version of the least-cost path analysis.

5.2.3 Minimal Risk Walking Track Recommendation

The third and final walking track location recommendation has been modified to avoid high hazard risk areas while also continuing to utilize the area of the reserve. The walking tracks in this third recommendation all lie within low and moderate risk areas of the reserve and ultimately would be the safest location. As seen in Figure 7, the minimal risk recommendation avoids areas of high rockfall risk and passes fewer man-made structures (bunkers and reservoirs). Therefore, less maintenance would be required for these structures. This track recommendation does not link to other tracks in the local area which is a constraint.

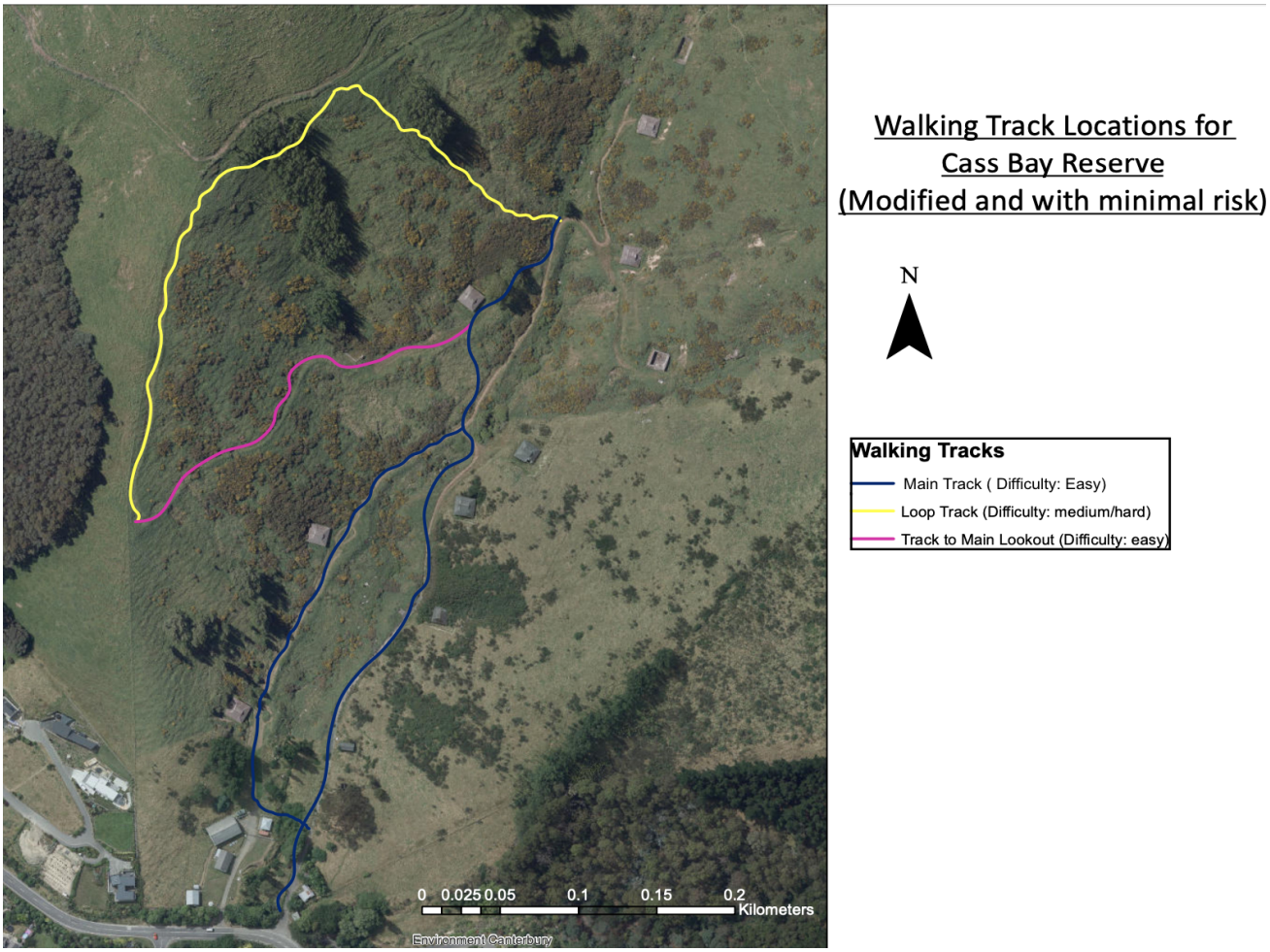

Figure 7. Proposed walking tracks with the minimal risk output of the least-cost path analysis.

5.3 - Signage

Figure 8 shows what is proposed to be portrayed on the historical signpost to be placed along a point of the walking track. This includes an image on the top left of Cass Bay in 1962. This is then followed on the top right with a timeline of historical events in Cass Bay. This ranges from volcanic formation 7-11 million years ago, through to early human settlement and then locking of the gates in 2003. The picture on the bottom right is a current image of war bunker number three. Information obtained from interviews and literature have been collated.

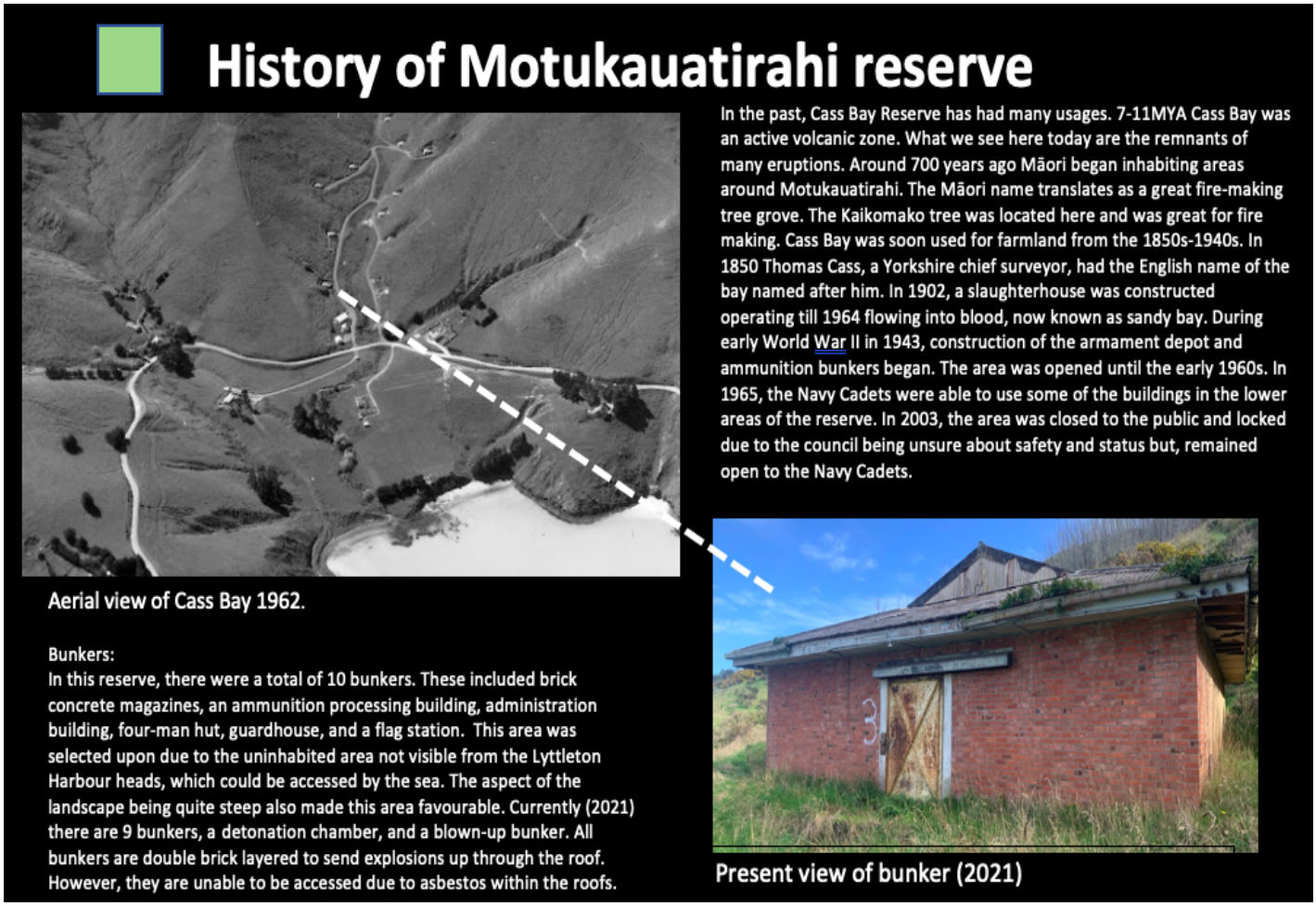

Figure 8. Proposed historical signpost signboard to include along the walking tracks. This signboard incorporates a general timeline of the area and outlines World War II history.

Figure 9 demonstrates what it proposed to be displayed on an ecological signpost. It is intended to educate the community on ecology and ultimately enhance their connection to the land.

Figure 9. Proposed stream restoration and planting signboard to include along the walking tracks. This sign board incorporates what is currently there and projects underway within the area. Information on the signboard was collated from Environment Canterbury (2020) and Harmsworth et al. (2016).

5.4 Combining all aspects of research to facilitate public access

Figure 10 outlines the steps necessary to facilitate access to Motukauatirahi, combining sub-themes of our topic with practical steps. Incorporation of these steps will ensure not only public access can occur, but in a way that will reduce risks to people and the environment.

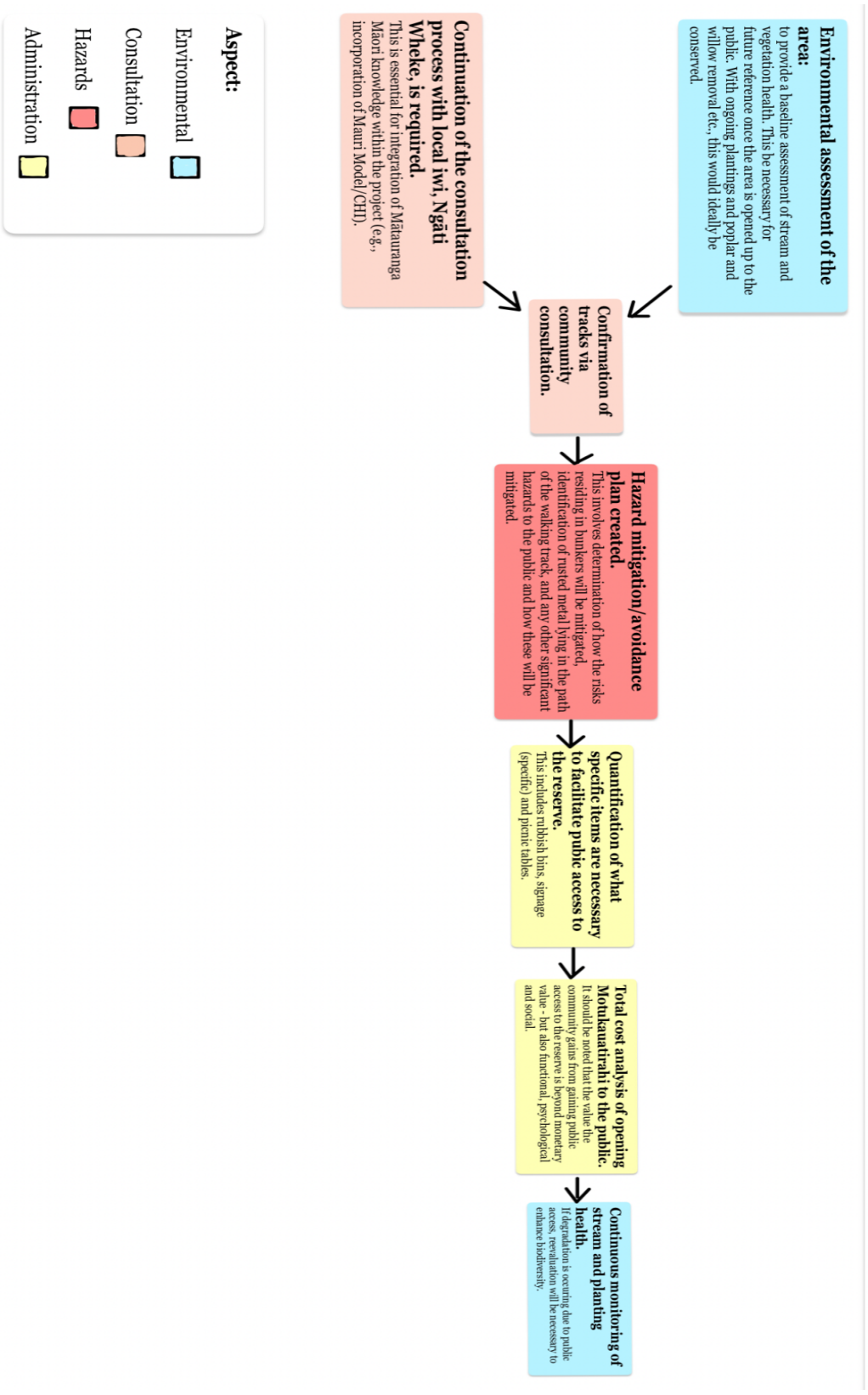

Figure 10. Recommended steps for facilitation of public access to Motukauatirahi.

Figure 11 enables visualisation of what the holistic plan may look like if it were implemented. Not only is the modified walking track incorporated, but proposed lookout points, signage, and picnic tables. A version of this file is accessible and modifiable online to the public and is located here.

Figure 11. Google Earth visualisation of the area with proposed elements.

6. Future Recommendations

Continuation of the consultation process with local iwi is required. While this was initiated by the group, the timeframe for the project compounded with COVID-19 level 3 and 4 lockdowns resulted in not enough time for key kaumātua to provide a response. Ngāti Wheke has, however, expressed their willingness to further continue this process in future. It is therefore recommended that a Cultural Impact Assessment and hui are fulfilled in the future.

Regarding the track itself, linkage to Whakaraupo Reserve has the potential to be investigated further. This requires significant consultation with CCC along with further research and development on track linkage at the top of the hill. While proposed map concepts provide linkage to Summit Road, alteration of this track will be necessary to connect with the trail route of Whakaraupo Reserve. For the purpose of this project, facilitation of access within the reserve was prioritised via the creation of loop tracks, signage and local hazard assessment.

Given the huge opportunity for potential which resides in the area, it is recommended future projects give a greater weighting to conservation and restoration. Examples of this could include investigation of bird corridors, and ideally incorporation of the Mauri Model. Additionally, for future projects, a long-term continual assessment of how plants are positively or negatively influenced would be beneficial. These aspects, however, are beyond the scope of our project of facilitating access to Motukauatirahi (Cass Bay) Reserve and incorporate a far greater ecological aspect, especially with the significant ecological assessment already underway.

7. Conclusion

The research question of facilitating access while incorporating restoration and conservation proposes great potential for connecting the reserve to the community. Holistic walking track plans were developed for the area incorporating history, ecology, hazards, and GIS components. Opening this area to the public with proposed walking

tracks will create an area not only for recreation but also for education. Through the aforementioned literature reviews, interviews and signpost concepts this can be achieved.

To conclude, Motukauatirahi has great potential for future projects incorporating the community. This would involve various parties and future in-depth research. We hope that this report provides a stepping stone towards opening up access to Cass Bay reserve to unlock its full potential.

8. Acknowledgements

We would firstly like to acknowledge our community partner, Dr Karen Banwell, for her wealth of knowledge and advice for the project. Along with the support of the Cass Bay Reserves Management Committee, we could not have done it without you.

We would also like to express our gratitude to our tutor, Dr Darren Gravley, for his continued support throughout this project. Your dedication to the project was second to none.

To our interviewees Noelene Allen and Jenny Healy, we are very appreciative of your extensive knowledge of the Cass Bay area. Such knowledge shaped the way we developed this project.

Finally, thank you to the GIS manager at the University of Canterbury; John Thyne for his beyond helpful advice in completing the GIS component of the project.

9. References

AECOM. (2015). Steadfast - Umumua Reserves, Hazard Zones and Potential New Routes.

Al-Kodmany, K. (2001). Visualization tools and methods for participatory planning and design. Journal of Urban Technology, 8(2), 1-37. doi:10.1080/106307301316904772

Beaumont, L., Carter, M., & Wilson, J. (2014). *Banks Peninsula contextual historical overview and thematic framework*. https://healthyharbour.org.nz/wp-content/uploads/2019/07/Beaumont-et-al-2014-Banks-Peninsula-Contextual-Historical-Overview-and-thematic-Framework.pdf

Borella, J. W., Quigley, M., & Vick, L. (2016). Anthropocene rockfalls travel farther than prehistoric predecessors. *Science Advances*. 2(9). doi:10.1126/sciadv.1600969

Borella, J., Quigley, M., Krauss, Z., Lincoln, K., Attanayake, J., Stamp, L., Lanman, H., Levine, S., Hampton, S., & Gravley, D. (2019). Geologic and geomorphic controls on rockfall hazard: how well do past rockfalls predict future distributions? *Nat Hazards Earth Syst Sci*. 19(10), 2249-2280. doi:10.5194/nhess-19-2249-2019

Christchurch City Council. (2019a). Misty Peaks Reserve Management Plan 2019. [online] Retrieved from: https://ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/park-management-plans/misty-peaks-reserve/

Christchurch City Council. (2019b). Te Oka Reserve Management Plan 2019. [online] Retrieved from: https://ccc.govt.nz/the-council/plans-strategies-policies-and-bylaws/plans/park-management-plans/te-oka-reserve/

Christchurch City Council. (2021). *HMNZS Steadfast draft landscape plan*. https://www.ccc.govt.nz/the-council/haveyoursay/show/402

Christchurch City Council. (2021). *Plans, strategies, policies and bylaws - Chapter 5 - Natural hazards* (Christchurch District Plan). Christchurch City Council. https://ccc.govt.nz/assets/Documents/The-Council/Plans-Strategies-Policies-Bylaws/Plans/district-plan/Print-Chapters/Chapter-5.pdf

Christchurch City Council. (n.d.). *Boulder Location Maps*. https://ccc.govt.nz/environment/land/slope-stability/boulder-location-maps/

Clifford, J. (2012). *The preparedness and response of the population of Lyttelton, New Zealand, and surrounding areas, for and to hazards*. [Master's thesis, University of Canterbury]. UC Research Repository. doi:10.26021/6912

Davis, S. K., & Thompson, J. L. (2011). Investigating the impact of interpretive signs at neighbourhood natural areas. Journal of Interpretation Research, 16(2), 55.

Environment Canterbury. (2020). *Cass Bay planting gives native biodiversity a helping hand*. Retrieved from https://www.ecan.govt.nz/get-involved/news-and-events/2020/cass-bay-planting-gives-native-biodiversity-a-helping-hand/

Environmental Protection Authority. (2021). *Mātauranga Māori: Applying a Māori lens to environmental management*. Retrieved from https://www.epa.govt.nz/community-involvement/science-corner/matauranga-maori/

Ferrarini, A., Rossi, G., Parolo, G., & Ferloni, M. (2008). Planning low-impact tourist paths within a Site of Community Importance through the optimisation of biological and logistic criteria. *Biological Conservation, 141*(4), 1067-1077. doi:10.1016/j.biocon.2008.01.013

Ferreira, G. (1998). Environmental education through hiking: A qualitative investigation. Environmental Education Research, 4(2), 177-185. https://doi.org/10.1080/1350462980040205

Gül, M., Özbek, A., & Karacan, E. (2016). Rock fall hazard assessment in Asar Hill, ancient Mabolla City, Mugla—SW Turkey. *Environmental Earth Sciences*. 75(19), 1310. doi:10.1007/s12665-016-6113-4

Hampton, S. J. (2010). Growth, structure and evolution the Lyttelton volcanic complex, Banks Peninsula, New Zealand

Hemanth, K. V., Jain, M., Singh, I., & Chundeli, F. A. (2021). An Assessment of Turahalli Mountain Biking Trail Using Sustainable Trailing Design Guidelines of IMBA. *Journal of the Institution of Engineers (India). Series A, Civil, architectural, environmental and agricultural Engineering*. doi:10.1007/s40030-021-00537-w

Hikuroa, D., Clark, J., Olsen, A., & Camp, E. (2018). Severed at the head: towards revitalising the mauri of Te Awa o te Atua. *New Zealand journal of marine and freshwater research*, *52*(4), 643-656. https://doi.org/10.1080/00288330.2018.1532913

LINZ Data Service. (2017). *Canterbury- Christchurch and Selwyn LiDAR 1m DSM* https://data.linz.govt.nz/layer/53588-canterbury-christchurch-and-selwyn-lidar-1m-dsm-2015/?fbclid=IwAR3n8D0s_s1xIPCebEzFjCRKMX0l5tjjrIzFcaLVuNKB3x_U6HI8F9kPrXE

Lyttelton Review. (2020). Lyttelton Review - 255. Retrieved from https://issuu.com/lytteltonharbourreview3/docs/255_may_2020_print

Massey, C. I., McSaveney, M. J., Heron, D., & Lukovic, B. (2012). *Canterbury Earthquake 2010/11 Port Hills Slope Stability: Pilot study for assessing life-saving risk from rockfall (boulder rolls)* (GNS Consultancy Report 2011/311). GNS Science. https://www.ccc.govt.nz/assets/Documents/Environment/Land/CR2011-311-01AUG2013.pdf

Morgan, T. K. K. B. (2006). Waiora and Cultural Identity: Water quality assessment using the Mauri Model. *AlterNative: an international journal of indigenous peoples*, *3*(1), 42-67. https://doi.org/10.1177/117718010600300103

Olafsson, A. S., & Skov-Petersen, H. (2014). The use of GIS-based support of recreational trail planning by local governments. *Applied Spatial Analysis and Policy, 7*(2), 149-168. doi:10.1007/s12061-013-9094-7

Philip, L. J. (1998). Combining quantitative and qualitative approaches to social research in human geography - An impossible mixture? *Environment and planning. A*, *30*(2), 261-276. https://doi.org/10.1068/a300261

Robertson, J. (2019, June 16th). Between land and sea: Jetties of Whakaraupō/Lyttelton Harbour. Retrieved from http://lytteltonharbourjetties.blogspot.com/2019/06/cass-baymotukauatirahi.html

Sewell, R. J. (1988). Late Miocene volcanic stratigraphy of central Banks Peninsula, Canterbury, New Zealand. *New Zealand Journal of Geology and Geophysic*s, 31(1), 41-64. doi:10.1080/00288306.1988.10417809

Stewart-Harawira, M. W. (2020). Troubled waters: Maori values and ethics for freshwater management and New Zealand's freshwater crisis. *Wiley interdisciplinary reviews. Water*, *7*(5), n/a-n/a. https://doi.org/10.1002/wat2.1464

Tomczyk, A. M., & Ewertowski, M. (2013). Planning of recreational trails in protected areas: Application of regression tree analysis and geographic information systems. *Applied geography (Sevenoaks), 40,* 129-139. doi:10.1016/j.apgeog.2013.02.004

Waikato Regional Council. (2017). *Māori engagement framework*. Retrieved from https://www.waikatoregion.govt.nz/assets/WRC/Council/Policy-and-Plans/11340016-Maori-Engagement-Framework-Guide.pdf

Whitehouse, C. (2021). Planning a Trail Using Landowner Preferences: A Multivariable Least-Cost Path Approach. Retrieved from https://krex.k-state.edu/dspace/handle/2097/41466

Xiang, W. N. (1996). A GIS based method for trail alignment planning. *Landscape and urban planning, 35*(1), 11-23. doi:10.1016/0169-2046(96)00303-9

10. Appendices

Appendix A

Definitions for freshwater management methodological approaches

Mauri Model: Decision-making framework evolved around engaging with indigenous values while simultaneously aligned with New Zealand legislations and policy (Hikuroa et al., 2018; Morgan, 2006; Stewart-Harawira, 2020). Local communities assess freshwater systems through four main well-being dimensions, environmental, social, economic and cultural using a weighting approach (Morgan, 2006).

Cultural Health Index (CHI): An indicator method used when assessing freshwater, continuing to strengthen effective Māori values in the restoration of waterways. The CHI measures factors of cultural significance to Māori through three main components; cultural stream health measure, use-status of the site and mahinga kai potential (Morgan, 2006; Stewart-Harawira, 2020). With this tool, monitoring can be taken over time in assessing the changes to the Mauri (life force).

Appendix B

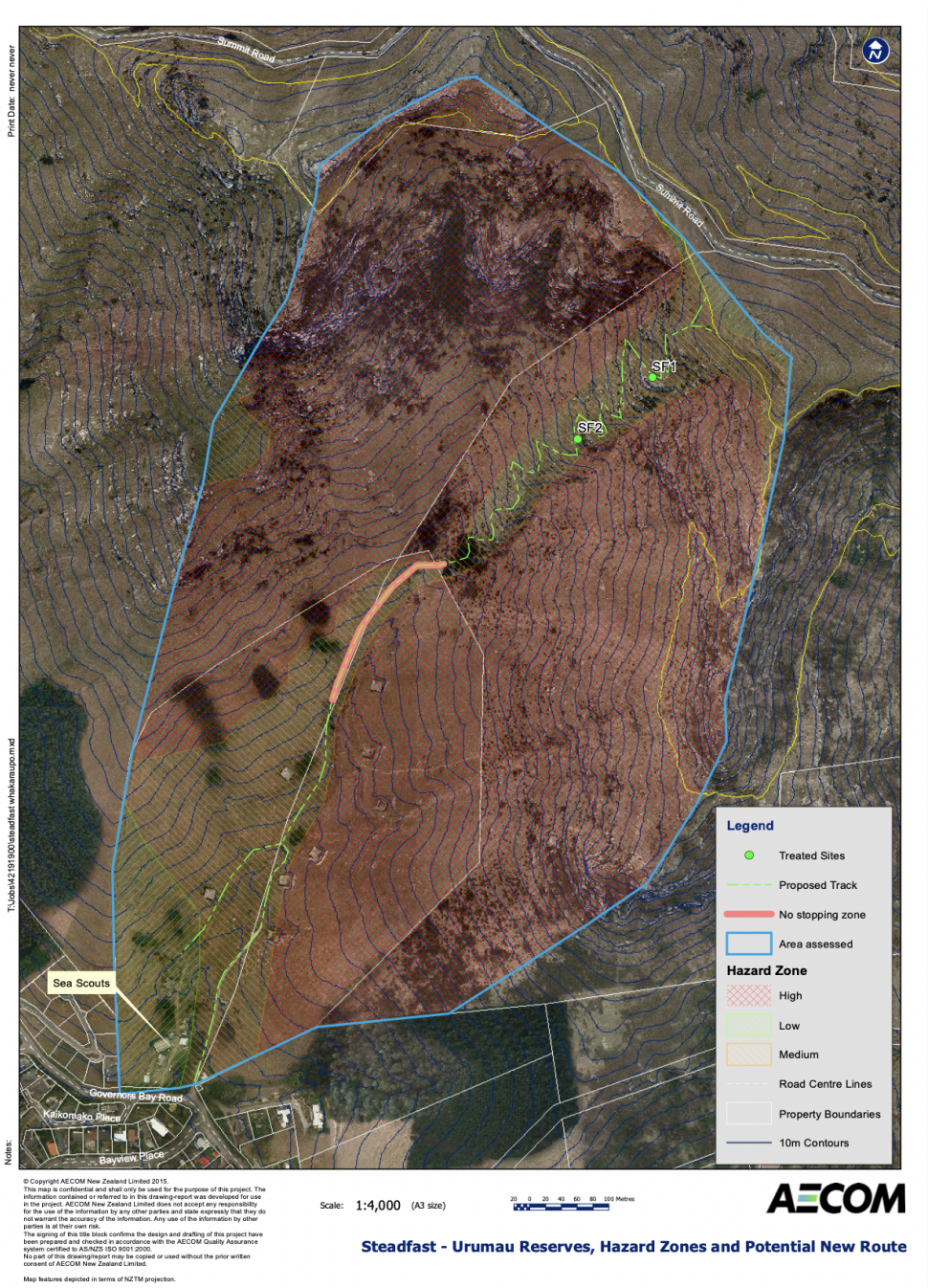

Figure B.1: Hazard map and proposed walking trail by AECOM (2015).

Appendix C

Maps produced during the least-cost path analysis in ArcGIS

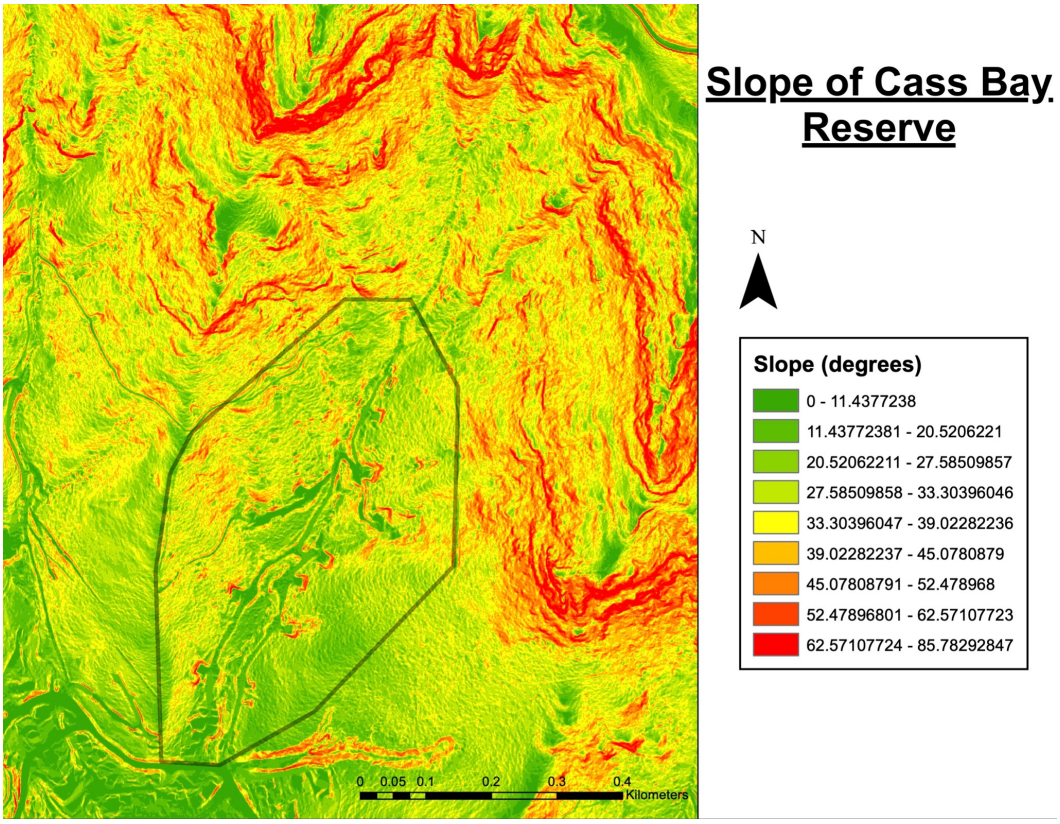

Figure C.1: Slope map produced of Cass Bay Reserve during the least-cost analysis methodology.

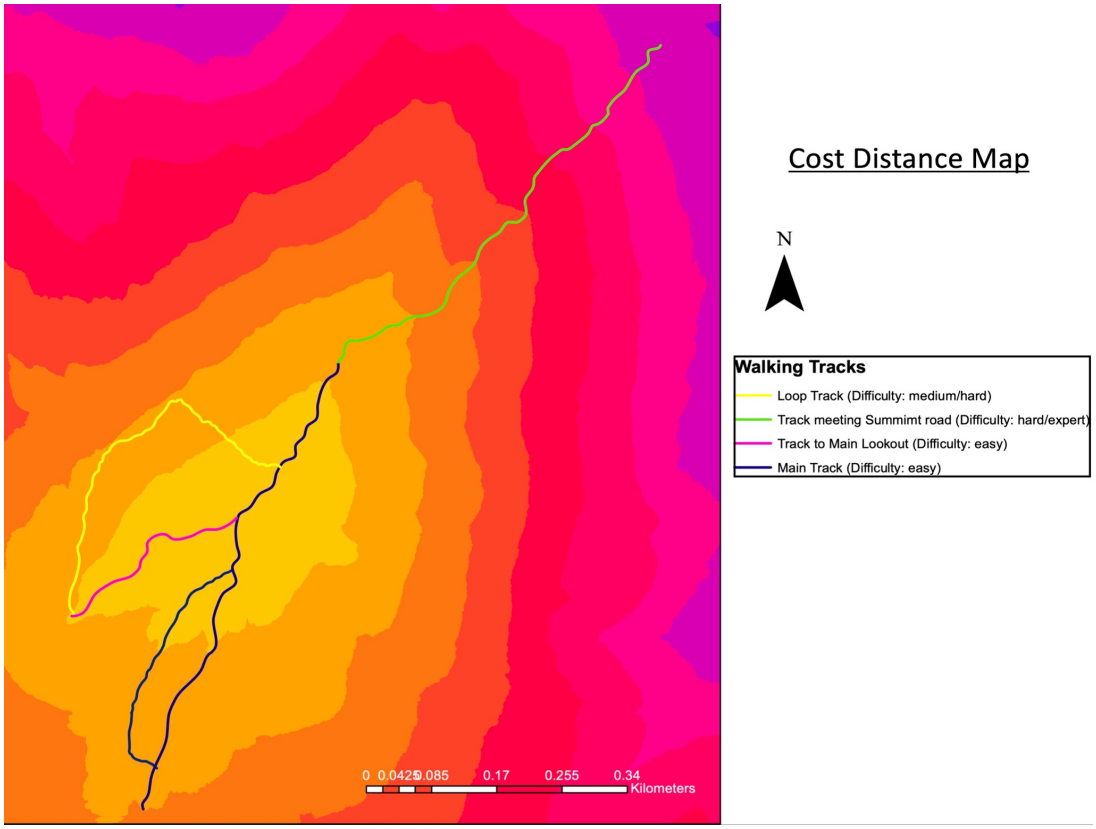

Figure C.2: Cost distance map created of Cass Bay Reserve during the least-cost analysis methodology.

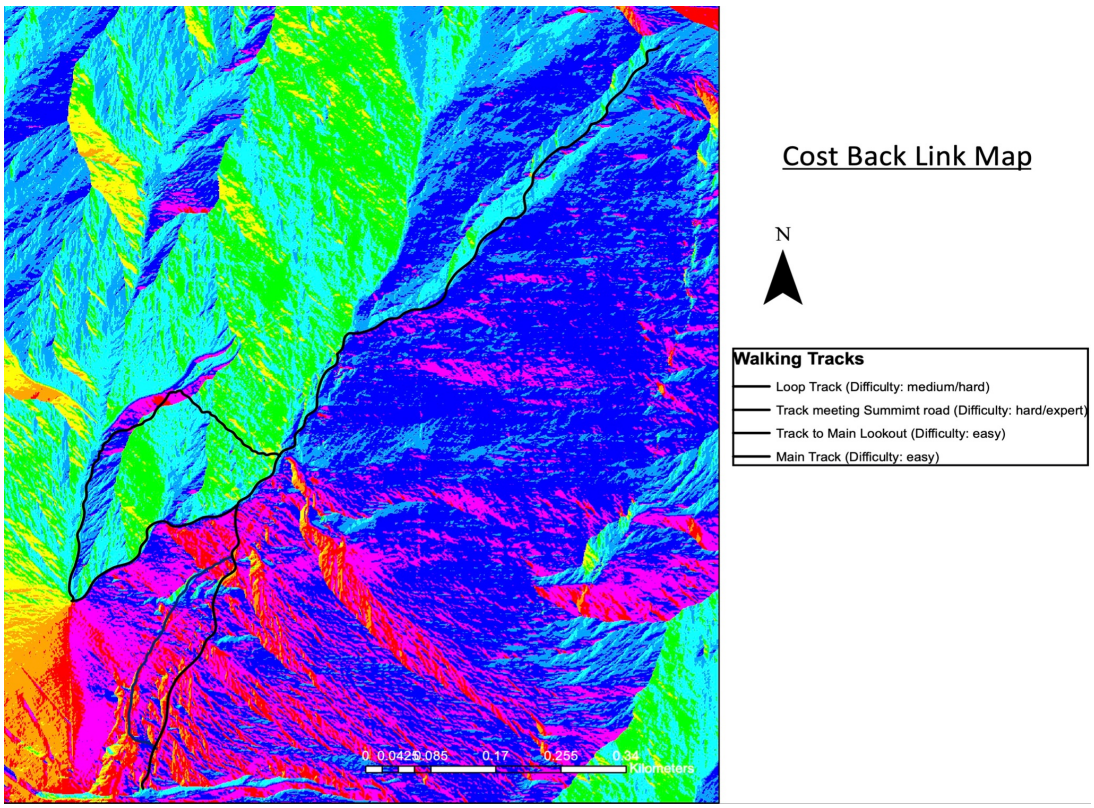

Figure C.3: Cost back link map created of Cass Bay Reserve during the least-cost analysis methodology.

Appendix D

Maps produced during the least-cost path analysis in ArcGIS

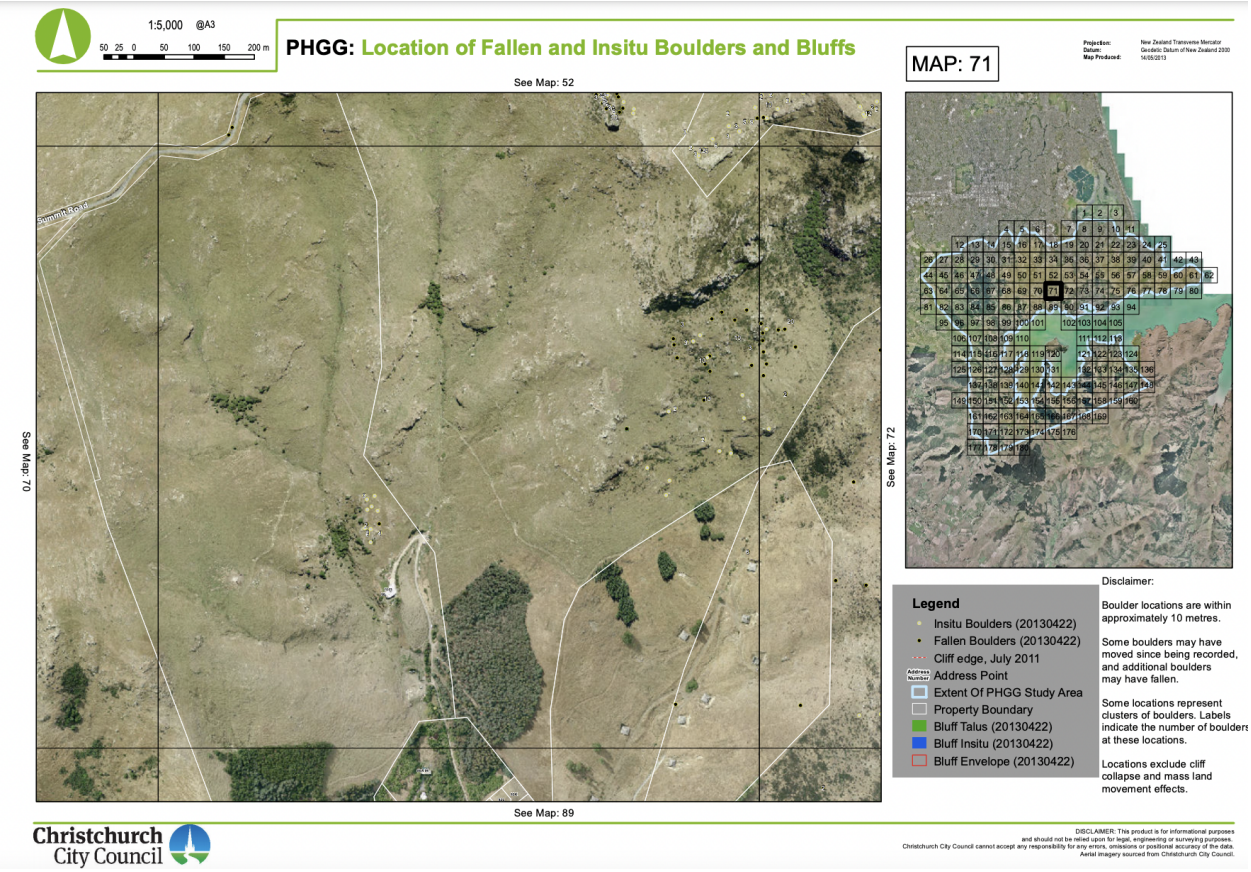

Figure D.1: Boulder location maps from Christchurch City Council (n.d.) Lack of detail at the local level evident.