Earth Sciences New Zealand

Societal vulnerability to flooding: Waikanae catchment case study

Summary of qualitative insights and description of a causal diagram

Prepared for MBIE programme: Increasing flood resilience across Aotearoa

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Executive summary

Flooding is Aotearoa New Zealand's most frequent and consistently damaging hazard. It results in injuries and death, stress, loss of property, reductions in quality of life and delays in life progress (e.g., education), as well as significant financial cost for individuals and society. An increasing frequency and intensity of extreme rainfall and floods due to climate change will increase both the tangible and intangible effects of flooding over time.

The MBIE-funded research programme *Mā te haumaru ō ngā puna wai ō Rākaihautū ka ora mō ake tonu: Increasing flood resilience across Aotearoa* aims to improve understanding of flood risk and increase flood resilience in Aotearoa New Zealand. Among other things, the programme seeks to improve understanding of how flood impacts cascade through Aotearoa New Zealand's social and economic systems. This helps us understand whether and how communities can tolerate future flood risks, and what efforts might be targeted to reduce future community vulnerability to floods.

To investigate flood impacts and resilience, three case study communities subject to repeat flooding were identified: Auckland, Waikanae and Little River/Wairewa. Semi-structured interviews were undertaken with a range of participants in each area. Findings from all case studies were initially collated into a thematic analysis, identifying important issues and topics that were raised, and commonalities across the case study areas. Then for each individual case study, the cause-and-effect relationships between key interview themes were identified and supplemented with key findings on local cascading (flow-on) flood impacts emerging via media reports. Additional analysis followed to explore causal relationships. These were developed into a causal diagram to capture the dynamics of cascading flooding impacts in each case study.

This report summarises the findings for the *Waikanae* case study.

How elements of the interview themes are represented in the causal diagram.

In the Waikanae case study, six key groupings of causal relationships were identified that represent the way in which the community may become more or less vulnerable, due to flooding. These groupings (shown on the right-hand side of the Figure above), along with feedback loops and influencing variables (left hand side of the Figure) that help explain their dynamics, comprise the causal diagram (outlined in the report). The causal diagram demonstrates how each of the groups, loops and variables interact and influence one another over time. The six key groups for Waikanae were:

- *Ability to function in everyday life* – the ways in which flooding can erode people's ability to enjoy their property or community, their agency to do what they need to do and access the goods and services they need, and their desire to stay in place.
- *Trauma* – the ways in which flooding, even small-scale but repeated 'chronic' flooding, can cause significant stress and accumulation of trauma over time.
- *Community connections and functioning* – how community connections and cohesion are influenced by flooding, and vice versa. This includes how the changing nature of communities in Waikanae (through people leaving and new people moving in) may reduce the collective knowledge of flooding events and weaken social connections based on such awareness. Community cohesion is related to support when flooding happens and the ability of the community and individuals to address flood risk through collective action.
- *Investment and regulatory environment* – how a growing population and increasing demand for greenfield housing development is balanced with the ability of the land to absorb rainfall and for council to manage flood risk. Changes in flood risk can be reduced through investment in new and existing infrastructure through capital and operational spending. As councils face funding difficulties to meet community expectations there is more demand on external funding support to reduce flood risk and maintain levels of service.
- *Adaptive capacity of communities* – how community capacity to adapt to flooding risk emerges and changes over time. It includes how resistance to change is related to adaptive capacity, which is also influenced by local knowledge of flood risk and having the necessary resources to stay in place.
- *Insurance* – the insurability of properties is affected by the probability of flooding damage, with consequences for the financial resources people have to stay in place and adapt to future floods.

Across the three case studies, we identified four overarching interactions that contribute an understanding of how flood impacts cascade through Aotearoa New Zealand's social and economic systems in ways that can increase community vulnerability to harm. These are *time*, *tolerance*, *adaptation willingness*, and *agency/hope*:

1. It takes *time* for the full consequences of floods to become apparent, and the time between events matters – if flooding occurs again before people are fully recovered, new trauma accumulates on top of existing trauma. Time also fades memories – without knowledge of what has happened in the past, there is little motivation for change to reduce future flood risks and impacts.

2. *Tolerance* to flooding varies, particularly to the cumulative impacts from flooding. Threats to life, property investments, quality of life, and personal investments in future lifestyles all challenged people's willingness to tolerate future flooding.

3. The *willingness to take adaptation measures* to reduce future flood risk is affected by both personal and collective experience or knowledge of past impacts.

4. Where there is personal, community, and council *agency* to adapt to future flooding risk, people have *hope* to remain in their community. The perceived ability to manage flood risk supports, and is motivated by, connection to place and community.

Addressing these causes of vulnerability should happen across the 4 Rs of emergency management – Reduction of risk, Readiness and Response to events, and Recovery from events. This includes:

- Supporting people's ability to function in everyday life over the extended recovery period.
- Acknowledging and mitigating the trauma caused by all scales of flooding.
- Promoting community connections and functioning before, during and after events.
- Creating and maintaining collective knowledge about flood events to increase the appetite for flood harm reduction measures.
- Fostering collaborative working relationships between communities and councils.
- Supporting investment and regulations that manage and mitigate flood risks.

For communities in the Waikanae Catchment specifically, this raises the questions about how the collective awareness and memory of previous flooding can be kept alive despite changes in the make-up of the community, how best to increase understanding of the individual and collective actions that can be taken to reduce flood risk and how to sustain the community connections that are essential for residents' ability to tolerate and recover from flooding.

1 Introduction

1.1 Programme information

Flooding is Aotearoa New Zealand's most frequent and consistently damaging hazard. Floods can result in injuries and death (e.g., NZ Herald 2019; NZ Herald 2023; Weekes and Ryan 2015), as well as other significant impacts such as stress, loss of personal artifacts and family heirlooms, reduced quality of life and delays in formal education (Fernandez et al. 2015; NZIER 2004). At a financial level, floods in Aotearoa New Zealand regularly damage houses and infrastructure networks, causing months of disruption to communities and businesses. The Insurance Council of New Zealand (2024) observes that the annual cost to Aotearoa New Zealand of extreme weather to be generally in the order of NZD$350 million, with individual flood events being especially costly. For example, the New Zealand Treasury estimated total damages from the 2023 Auckland Anniversary floods and Cyclone Gabrielle to be NZD$9–14.5 billion (RNZ 2023). Recovery planning for the Auckland Anniversary weekend floods of 2023 is presently in the order of NZD$4 billion (Scott 2023).

Flooding around Aotearoa New Zealand reflects a variety of factors including low-lying coastlines (rendering the area susceptible to coastal inundation during storms), steep hills (contributing to flash flooding) and often urbanised environments (where absorption of overland flows is limited by the scale of the drainage systems and or available land for over wash).

As climate change is projected to increase the frequency and intensity of extreme rainfall, the effect is that floods could occur more often (Ministry for the Environment 2010), increasing the scale and frequency of tangible and intangible flood impacts over time.

The MBIE-funded research programme *Mā te haumaru ō ngā puna wai ō Rākaihautū ka ora mō ake tonu: Increasing flood resilience across Aotearoa* aims to improve understanding of flood risk and increase flood resilience by providing better evidence for public policy (NIWA 2024). Among other things, the programme seeks to improve understanding of how flood impacts cascade and flow on through Aotearoa New Zealand's social and economic systems. This understanding provides the foundation for considering whether and how communities can tolerate future flood risks, and what efforts could be targeted to reduce community vulnerability to floods in the future.

This report outlines generalisable insights on the cascading nature of flood impacts across Aotearoa New Zealand. It is not intended to identify specific, prescriptive recommendations for action – this would require dedicated policy research and assessment.

To understand the cascading impacts of flooding, the following steps were taken:

- Three case study communities subject to repeat flooding were identified: Auckland, Waikanae, and Little River/Wairewa. The case study communities were consulted to identify the cascading impacts that they experience. The case studies were selected to capture a variety of flooding histories as well as data availability, community appetite for engagement, the research team's community connections, utility for meaningful change at local, regional, and national scales, and provision to increase understanding.

- Within each case study, community members (residents, spokespersons for community groups), government and non-government agencies affected by flooding or involved in flood planning or response were identified for interview. Potential interviewees were identified using personal contacts, recommendations from relevant agencies, and via snowball sampling (where participants are selected based on characteristics relevant to the study, and on recommendations from other participants).
- Approval was obtained via NIWA's Human Ethics process to interview potential participants.
- Semi-structured individual or paired interviews were conducted with participants between mid-2022 to mid-2023 to discuss the cascading impacts of flooding. Most interviews were conducted online. Participants were asked about their experiences of flooding – the effects they experienced, how they coped and what they would hope to see in the future. Community members who had directly experienced flooding were also asked about their tolerance for future flooding, and how this may or may not affect their willingness to remain in place.
- Thematic analysis of the interviews was conducted to identify key themes from the interview transcripts (Braun and Clarke 2013). Comparisons between case studies allowed for the identification of commonalities and differences to how flooding impacts communities.
- To develop the causal diagram, the team reflected on the different themes. Through a process of iterative refinement, we identified variables from these themes that could best be represented in a causal diagram (i.e., ones that can be phrased in such a way that they have a natural sense of direction – they could increase or decrease). Drawing on the interview data we then identified cause and effect relationships between these variables and collated them into a causal diagram, with a specific focus on seeking to identify feedback loops where possible.
- Each case study's draft causal diagram was supplemented with key findings on local cascading flood impacts derived from an analysis of media reports.

Causal diagrams are a tool developed under the discipline of Systems Dynamics, a conceptual framework aimed at helping us to understand the behaviour in complex systems over time. Causal diagrams are used to identify and display the various factors concerned with an issue and how they interrelate (Senge 2006, Sterman 2000). This helps us understand which parts of a system have the greatest influence and to identify areas where action might be expected to influence matters (Senge 2006).

In this context, the complex system under consideration is flooding – specifically the variety of cascading social and economic impacts of floods that communities experience and the interconnections between those impacts in communities.

1.1.1 Caveats

Where we use the term 'community' throughout this report, we generally refer to place-based communities; that is, 'community' as defined by people sharing a common location and

geographical proximity. It can include residents, businesses and formal and informal organisations and groups. However, we acknowledge that the term 'community' can mean many things to different people, and that not everyone who lives in Waikanae Catchment area may identify as belonging to that place-based community. (For example, some may identify foremost with their local suburb.) Further, some residents may identify with other, non-place-based communities more strongly than they do the Waikanae Catchment area. Some people may also live or operate around Waikanae but not hold the same views or participate in the collective activities that participants described to us.

In their own use of the term, some participants may have adopted alternative or broader 'catch-all' meanings or identities. We have not amended or attempted to define their specific use of the term, simply reflected the wording they used. At times, some participants referred to events of neighbouring locations on the Kāpiti Coast, such as Otaki and Paekākāriki, to give examples of flooding issues. The references have been retained in the analysis because of the interrelationships between the Kāpiti catchments and communities.

We also acknowledge that, because of the small sample size of residents who participated in an interview, the insights gained within this research will not necessarily cover the experiences, values, opinions or worldviews of all members within the Waikanae Catchment area.

This report sets the scene with an overview of the Waikanae Catchment in Section 2. Section 3 presents the analysis of the initial themes from interviews. Section 4 describes the causal diagram approach used and how to read them and Section 5 presents the causal diagram For Waikanae and its key feedback loops. Finally, Sections 6 and 7 discuss the implications of the findings generated by this study for the future efforts to increase flood resilience.

2 Waikanae catchment

The Waikanae catchment lies within the Kāpiti region some 50 km or 40 minutes north of Wellington. Bounded on the east by the mountainous and forested Tararua Range, the Kāpiti Coast includes beaches, marine reserves, coastal lowland swamp forests, Kāpiti Island and several coastal towns. Spanning the 40 km of coastline, the Kāpiti Coast has a population of 55,914 living in areas such as Ōtaki, Te Horo, Waikanae, Paraparaumu, Raumati Beach, Raumati South and Paekākāriki. The region has seen a 13.9 per cent growth in population in the last 10 years (Statistics New Zealand 2025 a). The Kāpiti Coast is primarily reached by two routes from Wellington, State Highway One (SH1) via Transmission Gully or the coastal route (SH59) along Pukerua Bay, and connected by SH1 to Otāki in the north of the region. The North Island main trunk railway for freight and regional and inter-regional passenger trains goes through a rail corridor on the Kapiti Coast. Passenger stations are located at Ōtaki, Waikanae, Paraparaumu, and Paekākāriki. There are also local bus services and the Kāpiti Coast Airport.

Approximately halfway along the coast is the Waikanae catchment and settlement. Waikanae, a Māori name which means 'waters of the grey mullet', is a coastal town positioned between Paraparaumu and Ōtaki. Ātiawa ki Whakarongotai are mana whenua of the Waikanae area. As of the 2023 census, Waikanae has a population of 12,966 (Statistics New Zealand 2025 c; Figure 2-1). As per regional population growth, Waikanae's population is also projected to increase. Compared to the New Zealand population, Waikanae has an older population who are more likely to have post-school qualifications and own their home. The area has a much larger proportion of residents of retirement age than the general population but relatively fewer people living in areas ranked as highly socioeconomically deprived (Statistics New Zealand 2025 b).

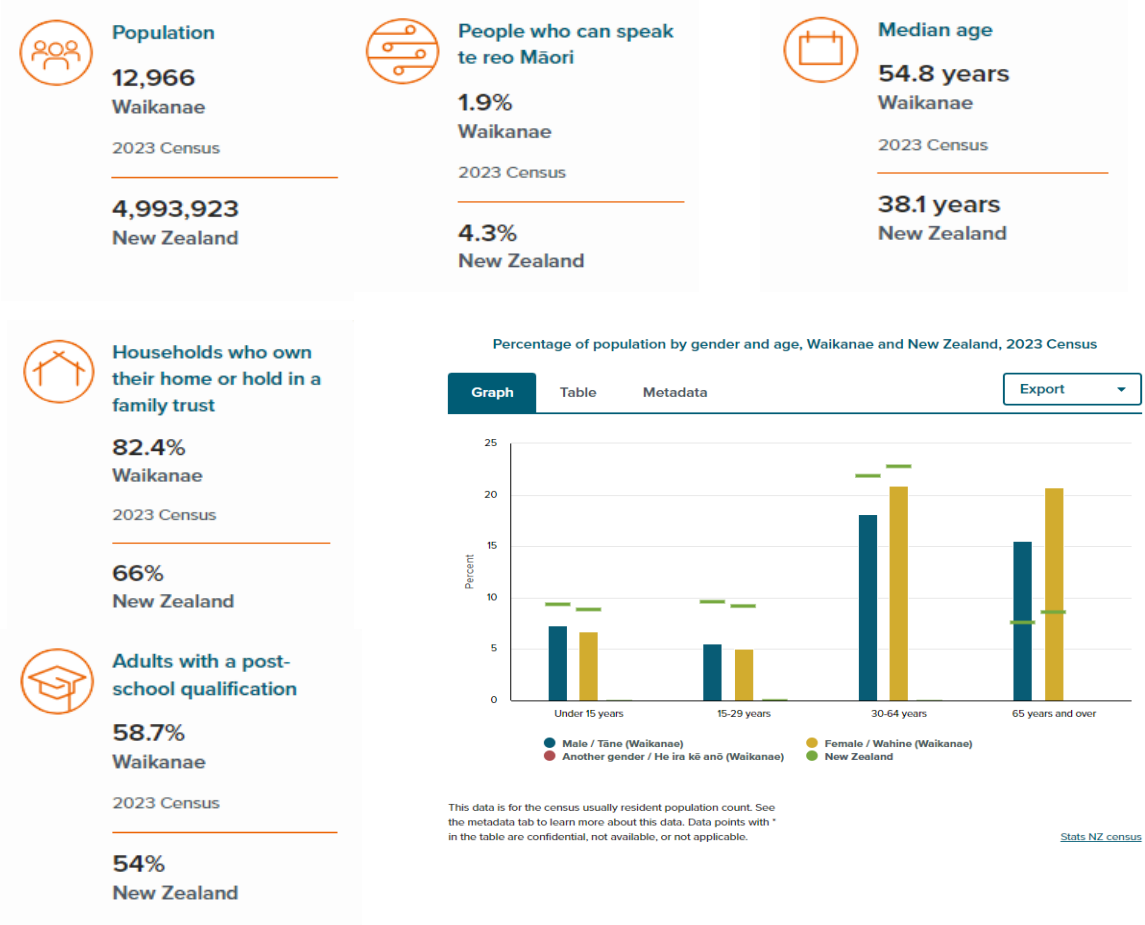

Figure 2-1: Population statistics for Waikanae-Waikanae Beach. Source: Statistics New Zealand (2025 b).

Waikanae township is located within a short, steep catchment area from the inland mountains to the coast (Figure 2-2). The catchment covers 125 km^2 of land, starting from the western side of the Tararua Ranges through the Waikanae River and estuary to the south of Waikanae, out to a 2.4 km sandy beach. The river mouth demarcates the residential settlements of Paraparaumu to the south and Waikanae to the north. Tributaries include the Maungakōtukutuku Stream, Ngatiawa River, and Reikorangi Stream. The Waikanae River catchment contains 40% pastoral land and 60% indigenous forest and native bush (Wellington Regional Council 1997). The river provides drinking water for the Waikanae community with the Waikanae water treatment plant built in 1977.

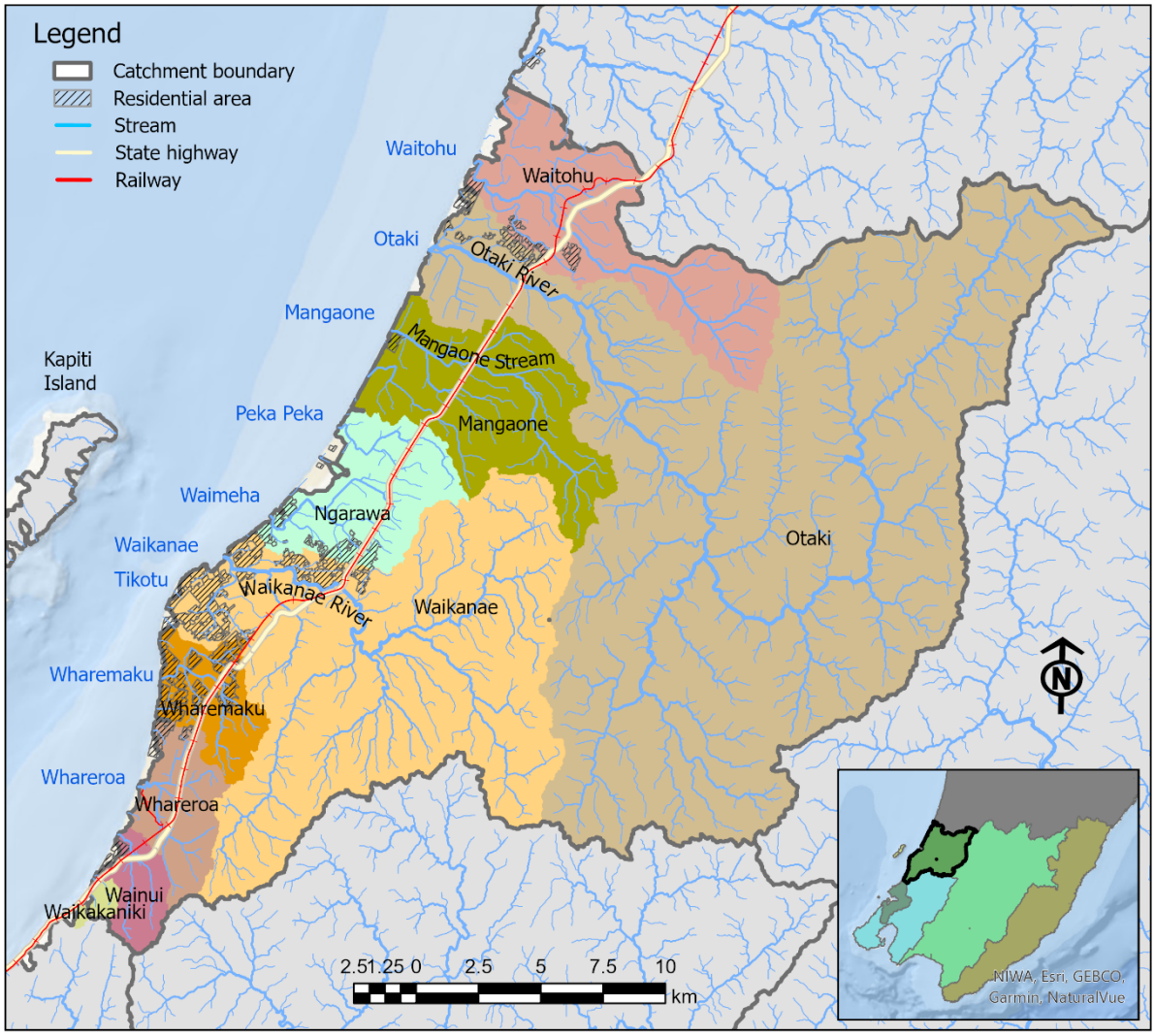

Figure 2-2: Kāpiti Coast catchments and communities.

The river is taonga (treasure) for mana whenua Ātiawa ki Whakarongotai. In a collaborative effort to improve the health of Waikanae River, local iwi and authorities formed Waikanae ki Uta ki Tai, which means "mountains to sea" (Waikanae ki uta ki tai 2025). This partnership brings together Ātiawa ki Whakarongotai, district and regional councils, and the Department of Conservation. The Waitangi Tribunal report – Te Ātiawa-Ngāti Awa ki Kāpiti - Inland waterways: ownership and control (Webb 2019) – identified relevant claims and waterways of cultural value and significance which includes fishing rights in the Waikanae River and tributaries.

Prior to colonial settlement, the Kāpiti Coast was predominantly wetlands (Webb 2019). The Waikanae River mouth has historically moved, feeding the wetlands and changing course. Te Ātiawa/Ngāti Awa Ki Kāpiti in the mid nineteenth century blocked some of the streams, flooding the land between sand dunes. Early settlement in the Kāpiti Coast used the waterways as transport via canoe up until the late 1920s, and for gathering food, fish and eels and the cultivation of crops. Development in Waikanae from the 1930s resulted in the draining of lakes and wetlands for the establishment of roads and other land-uses (i.e., agriculture, horticulture and housing). Flax milling, deforestation, gravel extraction, clearing of forests, population changes and pollution have impacted the waterways with a loss of the wetlands originally found

in the area (Webb 2019). Pākehā settlers released trout in the waterways for recreational fishing and culled native eels. Housing developed along the riverbank, and the implementation of storm water management in the catchment impacted waterway flows. Extensive gravel extraction occurred between 1954–1975 as an approach to flood management, resulting in lowering the riverbed by two metres and causing upstream riverbank erosion (Webb 2019). The Waimeha River – which channelled through salt marsh and swamp forest into the Waikanae River – was drained in the 1970s as part of the sewerage system, leaving a series of lagoons.

Early on, flood protection and managing the course of the river was considered the responsibility of private landowners, with several reports noting the likelihood of flooding and damage. The 1941 Soil Conservation and Rivers Control Act resulted in the Manawatu Catchment Board obtaining powers to undertake flood protection on the Waikanae River catchment area.

According to Greater Wellington Regional Council (2009) there have been at least 13 events in recent recorded history where the Ōtaki and Waikanae rivers have significantly flooded. The most significant floods were in 1955, 1956 and 1998. A flood recorded in 1924 showed damage with a creamery washed away. A large flood was recorded in 1955 that caused extensive damage. The 1956 flood resulted in severe erosion, with further erosion occurring with subsequent floods. Bank erosion, damage to buildings, slips and inundation have been recorded. After the large 1955 flood, protection was put in place between 1956 and 1964.

Stopbanks and erosion protection works as well as extensive gravel extraction have taken place. A large flood in 2005 saw approximately 700 people evacuated to higher ground, and houses were inundated and damaged. The stopbanks were nearly overtopped. In 2017 the stopbanks received a $1.5 million upgrade with the involvement of Ātiawa ki Whakarongotai, including increasing their height to meet climate change projections for river flood levels (Kirkman et al. 2016). The stopbanks currently protect approximately 450 houses at Waikanae Beach. Further improvements have included the planting of native trees on riparian areas.

Human influences on the floodplain (e.g., forest clearance, river management and urban settlement including the bridge being widened in 2016 for the Kāpiti Expressway) have resulted in significant changes to the landscape of the floodplain (Wellington Regional Council 1997). The expressway also crosses a historical river overflow path, which runs through the Waikanae township. According to Kirkman et al. (2016), it was identified in the District Plan that in the event of a large flood, the expressway embankment could potentially block overflows. Consequentially the expressway includes a designed floodway.

3 Thematic analysis results

Across the three case studies, 53 people were interviewed either individually or in small groups, as per their preference. The breakdown by case study is as follows:

- Waikanae – 14 interviews, with 17 people.
- Auckland – 18 interviews with 23 people.
- Little River – 12 interviews with 13 people.

While we were not able to recruit participants from the business sector or mana whenua for this project, we acknowledge the importance of their perspectives and experiences and that they may differ from those described below. The results should be interpreted with this in mind.

The remainder of the findings described in this document refer to the Waikanae case study.

3.1 Thematic analysis summary

Once the interviews were completed across the three case studies, the issues and topics raised were reviewed by the research team. Multiple common themes were identified as well as those that were specific to one or two of the case studies. The findings below focus on themes pertinent to the Waikanae catchment.

Community stress/ trauma was raised in all case studies as an impact from flooding. The ongoing uncertainty, stress and sleeplessness are reported to persist well into the recovery phase. The emotional toll of the floods often lingers, especially with repeat events:

> *... [E]very time it rains, they're wondering whether this is going to be the 100-year flood or not. So rather than only having to worry about maybe 50/50 chance of a lifetime, they're actually worrying about it every day because every day it rains, well, this might be it. This might be the big flood coming ...*

During the interviews, participants mentioned a range of feelings and emotions they have experienced during and after an event such as fear, stress, anger, powerlessness, and feeling demoralised. Smaller scale, more frequent 'chronic' flooding also has an emotional toll:

> *... It's not a huge detrimental thing, but the flooding is getting worse, and I'm concerned that I might... The area at the back might end up being totally useless. I just don't know how much worse it's going to get.*

Tolerance to flooding and whether to stay or go (and when and how) arose in all case studies. The desire to stay in place is positively influenced by multiple factors, including the sense of community and the assistance that residents get from other community members. It also reflects the natural attributes of their homes. This influence was strong in shaping community and place attachment. In Waikanae, residents feel strongly connected with Waikanae River and Beach for their recreational, amenity, and aesthetic value:

> *... I have a strong affinity to the environment and water being, arguably, the barometer of the health of the environment. And so I was very determined in that [river restoration] process to come up with a solution that the community could live with that was sustainable. And we did. So that connected*

me to the river. My property adjoins the Ngatiawa branch of the river.... You can see down the valley there, you can see Kāpiti Island in the distance ...

The likelihood of people moving away arose as a result of the trauma and environmental harm from repeated previous floods while, for others, talk about moving away arose in the context of ongoing threats to life. A number of participants observe potential tipping points for re-considering their desire to stay in a flood prone area. In Waikanae, the breaking point was associated with the sheer number of flood events where the chronic nature of flooding was noted for its ability to erode people's tolerance of staying in the area:

... People often think they can live with the flood risk and they'll take the chance. But it wears them down like an illness in the end ...

Changes in personal land use in Waikanae was a gradual but seemingly permanent shift in the way people were able to use and enjoy their land as a result of chronic flooding, for example, replacing sheep with waterfowl, not being able to grow the things they used to grow on their property, or having to get rid of dead trees that used to decorate their backyards. These shifts in land use were associated with a decline in the ability of residents to do the things they enjoy in the area, and a decline in their ability to realise the outcomes/lifestyles they sought. Over time, these changes were associated with a weakening or loss of community connections and an increased likelihood of some people wanting to move away from the Waikanae area:

... and they're having problems now. And the [commercial] garden centre is a very big area there. It's been there for years. I was only talking to him last Friday, and he was saying they're losing plants because there's so much flooding that they're having to move plants out and put them on [inaudible] because of all the flooding. So it's had a dramatic effect on him and he would certainly be and he's been there, I don't know how many years, but it's been there a long time ...

... I mean, there have been a number of kind of small events where other areas either in Kāpiti or our neighbouring district Porirua have got... have felt it worst. But this last year, so probably from December 2021 to now, the amount of consecutive rain events has been really, really impactful. And it's raised the water table level, which means that when we have the sort of back-to-back events, nothing's draining as quickly, which means we have a lot of standing water around the district in ways that we haven't had before ...

The *impacts on lifestyle* of chronic flooding were particularly noted by Waikanae residents. These impacts surfaced in relation to disrupted access to services, infrastructure, and recreational facilities, as well as limitations to move around or use land in the region as people had planned:

... So, it's sort of comes down to, you know, the basic things of how we get around the district. So, you jump on your bike to go to work. I only live just down the road. I either have to drive now or well, it's sort of when it's really, really muddy in which because you arrive at the office, and you're head to toe covered in mud. So things like access around ... The transport around the district has definitely changed. The ability to enjoy some of our public spaces like you know playgrounds and sports fields, you know, not being able to do that. They've been closed at the weekends and things like that.

To a degree, people tolerate the effects although their lifestyle is definitely impacted:

... You just sort of navigate your surroundings in a different way, and you're not getting that full Kāpiti experience because so many of the things are either temporarily closed or there's road cones there

because of water damage or, you know, you're not you know, you go to the beach for a walk and there's a whole bunch of stuff strewn across the beach because of the high tides and the amount of water.

Some participants observed how chronic flooding restricted their ability to make full use of their own properties:

... I'm really an animal person. So, I wanted to be able to have rescue animals. Well, I can't have hooved ones now, but at least I can have poultry and that sort of thing ...

... So, we've got a lifestyle block, we've got five and a half acres and so the stream overtopped itself and completely flooded our property to the point we had to remove all our animals off that because there was no space for them to um, well virtually even stand ...

Community support during and following flood events is generally common in New Zealand. However, interviews and diagramming revealed that this does not occur in all flood instances:

... often residents call council first and if you ask 'have you asked your neighbours', they say I don't know my neighbours. So there... that social cohesion is a difficult thing in 2022, and it makes you feel sad that she can't ask for neighbour or neighbour guys to just help lift a few bags. Yeah ... In reality, it can take time to build the sense of community for community assistance to emerge.

... They need to know each other first. Often, if people are not familiar with the people that live around them, the threshold to ask for help is really high. Whereas if people have had [sic] met, had a chat over the fence, it's way easier.

Once a sense of community does exist, participants commonly observed how connected communities rally together during and after an event, and how social networks and a sense of community belonging generated essential support during stressful times.

Social networks and community provide essential assistance during difficult times:

... We talked to a neighbour who was actually on higher ground. And so, they were happy to take us too because we could go to them basically to, to stay there if necessary, because they're bound by substantially higher ground than our property is as well. So that's where we would have gone in the meantime ...

Relationships between community and councils are reinforcing, with negative engagements being linked to poor satisfaction and, in turn, ever declining interactions, and positive engagements increasing overall satisfaction and, in turn, further positive interactions.

Negative relationships tend to emerge from community and/or inter-organisational frustration with flood management and response:

... So, we suffer really from the effect of the three different authorities being quite at odds. Greater Wellington Council's job is to, you know, diminish the risk of a flood and they think they're doing quite well, but they're not really ...

Legislative ability of councils to take action to reduce flood risk determines what councils are responsible for and how they are allowed to make decisions. The legislative constraints within which local government operate were raised extensively in Waikanae. Many participants recognise that councils can be limited in their ability to support good urban design that reduces

flood risk, as well as to prevent development in high-risk areas or areas that will become high-risk in the future. In particular, demand for housing adds pressure on both local and central government to allow development.

Changes in land use to reduce risk were raised as concerns in Waikanae where changes in land use to allow more housing that might exacerbate flood risks:

> *... This is the government's new policy, the RMA policy on urban development... the increased urban development, we can build three houses of three stories on a property so that those policies are being promoted. And the council has looked at basically putting in changing the district plan. So to allow that to happen, which we say, look, this is just silly, basically, why are you going to allow this to happen in the areas where there is risk of flooding? Why would you do that? And they don't listen. They still plough ahead because the government's put on policies that supposedly force them to do this. And so, we've put in submissions saying, look, silly doesn't follow their own legislation requirements and under the coastal policy statement ...*

> *... I would personally like to see the river having more room to move and things. And that means less housing along that corridor. And ultimately, if I could wave my magic wand and have anything I want, it would be moving all those houses out of that river sort of space to be able to give it room to move inside and do what it wants, which is great for the environment, but also reduces the risk to people. But we have managed retreat and retreat of property is a... Difficult challenge ...*

Community advocacy action typically arises from frustration with authorities in managing flood risk. In Waikanae, one group of residents mobilised after a tributary to the Waikanae River overflowed due to lack of maintenance:

> *... there was a community meeting in January 2022 where we all got together, about 30 of us... about how we were going to manage it. And so and so that group of 30 has now ended up expanding to about 70... The problem was caused by the drain not being maintained... So basically, that drain, if it had been maintained, would have never caused this problem...*

> *And I suppose dealing with the council was also a very, very stressful process because they weren't interested particularly ...*

A *flood information awareness gap* on flood risks was noted by participants in Waikanae. When the community is unaware that such information is available, or do not fully understand its implications, the results can include:

- Reductions in the number of property-level actions taken by households to lower their flood risk (e.g., installing private pumps or digging private drainage ditches) because they do not understand the risk to begin with.
- Reductions in trust with council – this arises when the community is unaware that flooding information is available from council, so they are taken by surprise when flooding occurs.
- Purchases of land by people in at-risk areas.

Flood risk information can also be difficult for people to understand, undermining their awareness of risk despite best efforts to understand. In Waikanae, participants observed a lack of understanding of the extent of flood risks and the best ways of management:

> *... I guess the only other thing really is like I sort of see it as just the awareness of floods being a bit more permanent and community members that are probably a little bit more likely to actively engage with some of these conversations. Other than the people who live right close to the river, I don't think the Waikanae community takes a lot of notice. Because it seems a very safe river to most people ...*

Collective memory about flooding is affected by the frequency and/or scale of flood impacts. Awareness of flood risk is strongly influenced by local memories – the greater frequency of flooding, the greater the historical awareness of flooding. In turn, greater historical awareness reinforces collective memories of floods. This collective memory of flooding was noted across case studies and is important for promoting adaptive action. Unfortunately, a turnover of residents can mean that collective memory of flooding and its risks is lost and that can impact awareness and preparedness. In time, this might mean that more people move unaware into a high-risk area.

In Waikanae, participants have observed that memories/ awareness of flood risk may not be shared with newcomers:

> *... because the new residents come to the catchment and they bring different ideas or probably they weren't aware of what happened in the past with the catchment and the river and that can be a little bit difficult to deal with when people don't have the updated information of what is happening.*

The impact of increasing frequency of flood events is likely to provide an opportunity to increase community ability to respond in future events as community members have learnt experience of what to do during a flood, how to prepare, and what to expect in terms of flood response and recovery process.

Staff wellbeing in council and government agencies can be affected when the community does not understand or is not aware of flood risk information provided by council, this can result in distrust and anger directed towards council staff, particularly following a flood event. Council and government agency staff reflected on the stresses associated with the emergency response and recovery phases, including dealing with direct anger and abuse as community stress rises.

While council staff recognise the needs of their communities, they can feel constrained in what they are permitted to do as they are legally obligated to only provide specific support, and/or are constrained by existing legislation or rules concerning developments (e.g., the Building Act). They described the stress of trying to do one's best but still feeling unable to live up to the public's expectations.

Public expectations of councils and government agencies can lead to tensions between the community and councils when community expectations of flood threat mitigation do not match council's actual legislated responsibilities. Where this gap between expectations and legislative requirements exists, this can lead to public pressure on council to increase flood risk reduction measures and strain community trust and satisfaction with council.

Inequities were widely discussed by participants as an outcome of flooding. In Waikanae, participants reflected on how poorer residents ended up living in worse houses, and how older people and those with disabilities experienced additional difficulties in dealing with chronic flood events:

> *...in Otaki the social impact of flooding is way higher than Waikanae because in Waikanae we have our, you know, reasonably medium to high value housing. It's a wealthy community, let's put it that*

way. And the people particularly that live around the river and our coast are people that can afford to insure their houses … make choices to move etc; whereas in Otaki, social impacts of flooding is very much is much higher than in Waikanae …

The *interplay between the collective and the individual ability to act* arose as an issue with participants talking about the difference between acts to reduce flood risks faced by the individual and coordinated acts that reduce collective risk. Some actions (or lack of action) may benefit a single family or business but harm others or may confound overall risk reduction.

Insurance coverage for businesses, houses, and personal possessions is an issue in all case studies. Some participants worry that their claims for repairs will affect the willingness of insurers to continue to provide any coverage at all, or will result in price hikes, reducing affordability:

… We haven't had any problems. But the insurance has gone up just like everybody else's because the value has gone up. So, I think you need to separate out those two things where the insurance companies are basically saying it's because there's greater risk or whether it's because of the… Just the increase in the value of the property which has happened there as well …

As well as the wide range of impacts identified, the thematic analysis highlights the extent to which the social impacts of flooding interconnect and flow-on for communities and organisations over time. The next sections describe these causal relationships.

4 How to read the causal diagram outlined in this report

Simply put, causal diagrams are collections of variables (e.g., characteristics of places, people, environments) connected by arrows of influence. This allows us to trace influence along pathways, through multiple variables. They have a particular interest in circular pathways of influence, as these create feedback loops which influence how variables behave over time.

Causal diagrams contain two types of feedback loops that drive system behaviour. *Reinforcing feedback loops* lead to exponential growth or decline, exemplified by phenomena like compounding interest or algae blooms, while *balancing feedback loops* stabilise systems by seeking equilibrium, akin to a thermostat. Recognising these loops helps understand how variables behave and interact within a system, providing a basis for strategic interventions.

To read a causal diagram, you need to understand the below:

1. As you follow influence through a diagram, it is effectively describing to you how "more or less of this (current variable), leads to more or less of that (the next variable)".

2. *Variables* are written in such a way that they have an *inherent sense of direction*. That is, they can either go up or down. For example, 'morale' instead of 'increased morale'.

3. There are two types of arrows which denote two types of relationships between variables:

    3.1 *Solid arrows* denote a *same relationship* (variables move in the *same direction* – if one goes up, so does the other, and vice versa).

    3.2 *Dashed arrows* denote an *opposite relationship* (variables move in the *opposite direction* – if one goes up, the other goes down, and vice versa).

4. Two small lines across an arrow represents a *relative delay*. This influence will take longer to present than others represented in the diagram.

5. Sometimes a variable of particular interest is shown as a *metaphorical bathtub*. This is an analogy used to help us better understand accumulation. Some variables may influence whether the bathtub variable *increases* (things *flow into* the bathtub); while others may influence whether the bathtub variable *decreases* (things *drain* the bathtub).

6. It is important to note that *bathtubs* are used as a *metaphor*. There is no actual limit to their capacity (i.e., they will not ever overflow if they 'fill too much'). They are used as a way of highlighting with more nuance, where things accumulate or reduce.

7. *Bathtubs* can be part of *causality chains and feedback loops*.

8. Causal diagrams are agnostic in the things they describe. They simply help us describe the influences that make things go up or down. Whether changes in these variables is 'good' or 'bad' depends on the perspective of the reader.

Figure 4-1 demonstrates how the above concepts work.

While straight forward, these concepts can take some getting used to. To help with this, they are explained in more detail in Appendix A.

We are particularly interested in how various feedback loops interact and the impact this will have on the way variables of interest trend over time. Causal diagrams do not seek to quantify how these things may trend over time. They provide a valuable tool to aid understanding of the broad directions that variables may trend, in response to changes in other variables captured in the diagram.

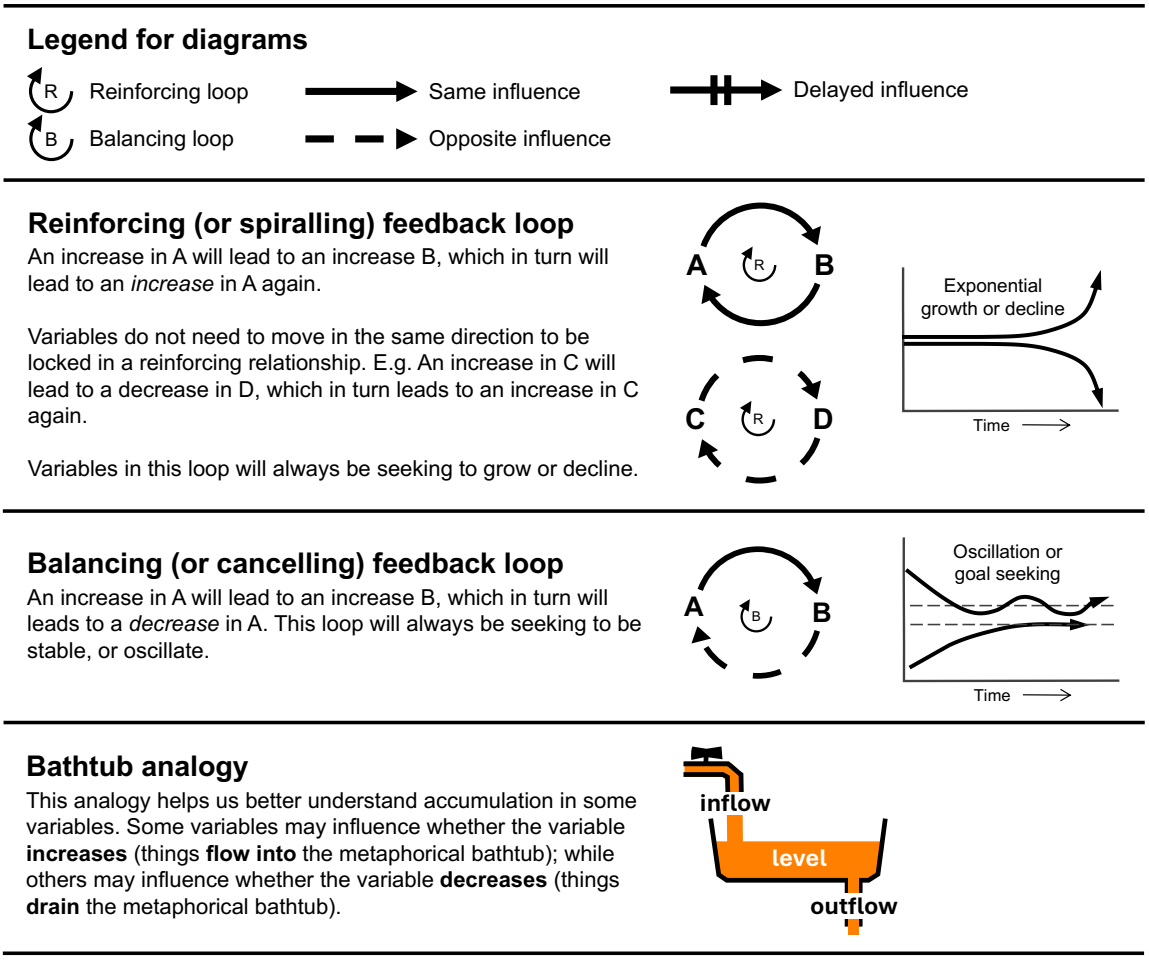

Figure 4-1: How to read a causal diagram.

5 The Waikanae catchment causal diagram: Key feedback groupings and loops

The overall causal diagram for Waikanae is presented in Figure 5-1. It draws on the thematic analysis of the interviews, focussing on the cause-and-effect relationships discussed. Each of the feedback loops that make up the causal diagram are described in detail in the following section. The descriptions below concentrate on variables and pathways related to the feedback loops and bathtub analogy. The contributions of other variables can be understood by following their influence across the wider causal diagram. The feedback groups and loops provide useful insights into how things (e.g., characteristics of places, people, environments) change over time. Therefore, they can reveal where key 'influence' points may lie to reduce harmful impacts and increase resilience.

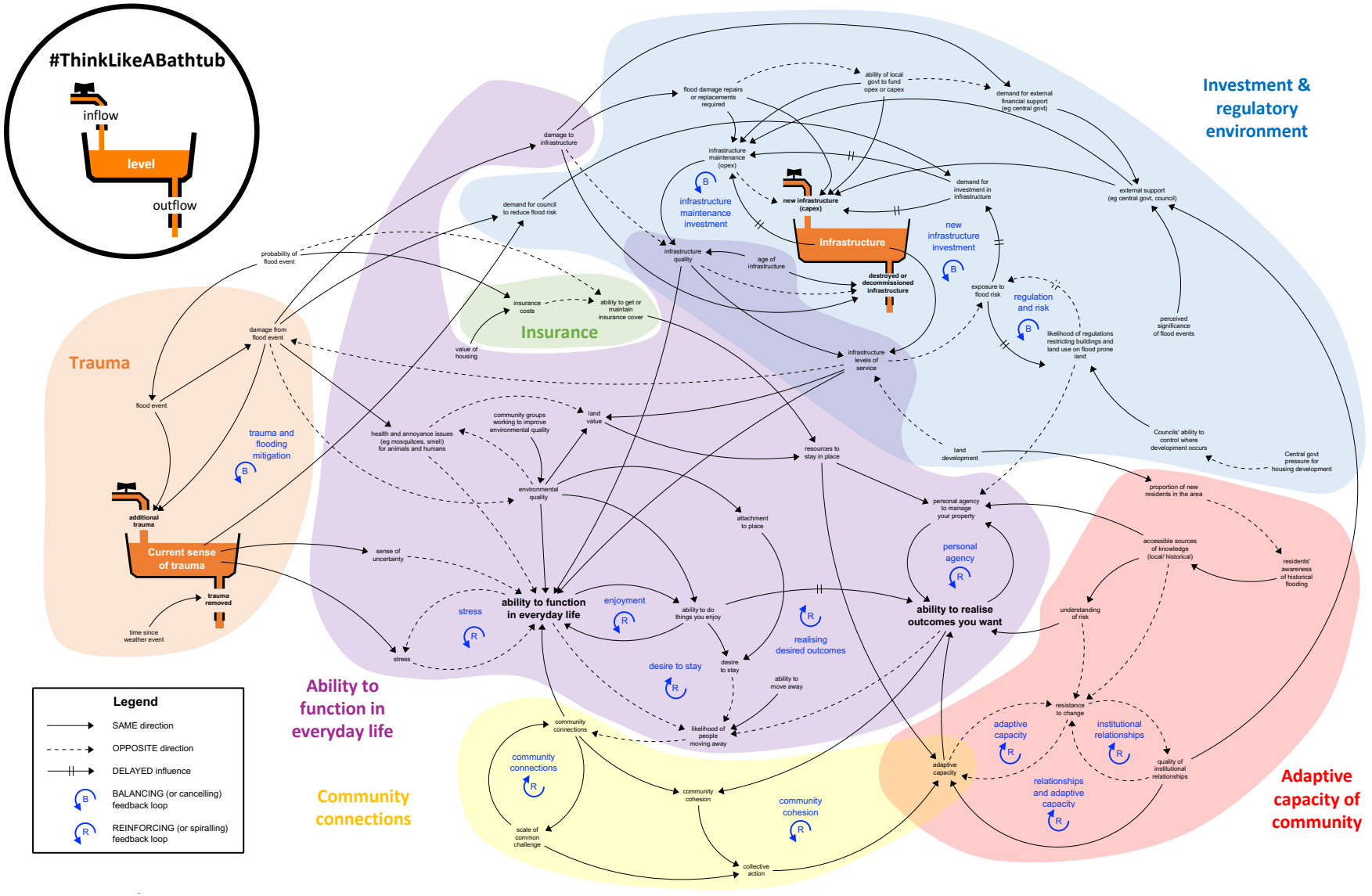

Figure 5-1: Waikanae flooding causal diagram.

Not all themes are fully represented in the causal diagram. Of those that are, six critical groupings of the feedback loops and variables have been identified to represent the way in which people may become more or less vulnerable. These are represented in the diagram by shaded colour. How these shaded groups are informed by the thematic analysis is shown in Figure 5-2):

Figure 5-2: How elements of the interview themes are represented in the causal diagram.

The six groupings captured fourteen key feedback loops in the causal diagram. Ten are reinforcing, with the effect that a change in one variable results in amplifying or 'spiralling' growth or decline (Table 5-1). Four feedback loops are balancing, with the effect that the direction of change in one variable ultimately encourages a balancing or cancelling effect in that same factor. One group, Insurance, does not have a feedback loop but nevertheless plays an important role in other loops (Figure 5-1; Figure 5-2).

Table 5-1: Groupings and associated feedback loops.

Group	*Feedback loop*	Reinforcing or balancing
Ability to function in everyday life	Stress	Reinforcing
	Desire to stay	Reinforcing
	Enjoyment	Reinforcing
	Realising desired outcomes	Reinforcing
	Personal agency	Reinforcing
Trauma	Trauma and flood mitigation	Balancing
Community connections & functioning	Community connections	Reinforcing
	Community cohesion	Reinforcing
Investment & regulatory environment	New infrastructure Investment (capex)	Balancing
	Infrastructure maintenance investment (opex)	Balancing
	Regulation and risk	Balancing

Adaptive capacity of communities	Adaptive capacity Institutional relationships Relationship & adaptive capacity	Reinforcing Reinforcing Reinforcing
Insurance	-	-

The feedback loops are described in the following subsections. The sequence in which the loops are presented does not imply priority or scale of influence.

5.1 Trauma

One bathtub and one feedback loop capture how flooding is related to the level of trauma experienced by people.

5.1.1 Current sense of trauma

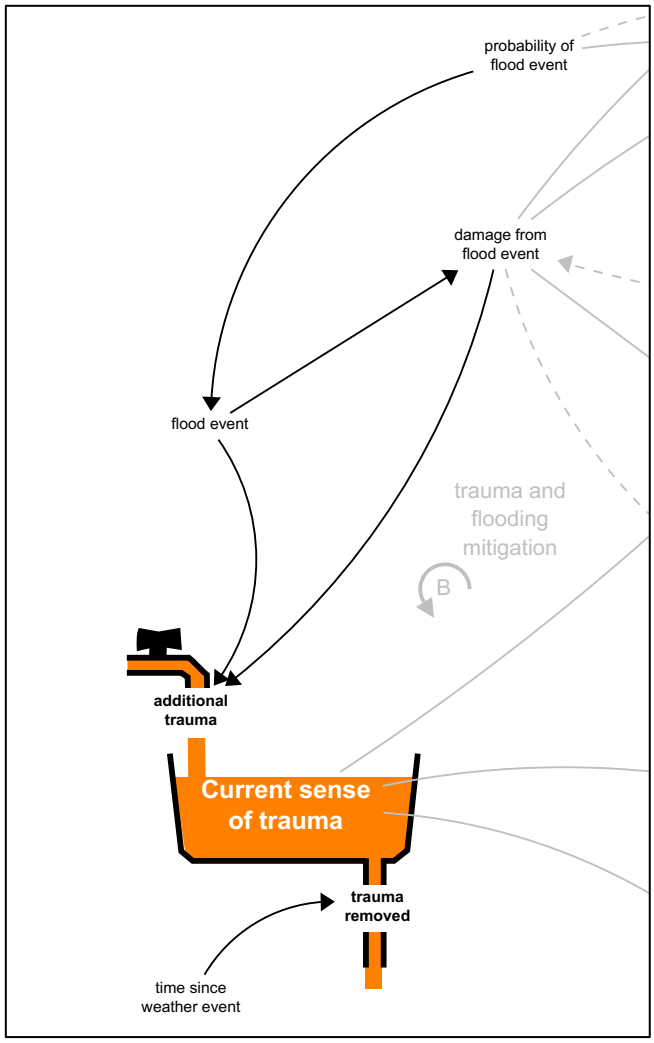

Figure 5-3: The metaphorical bathtub.

Each flood event adds *additional trauma* (inflow) to the *current sense of trauma* (level in the bathtub) that people experience. The higher the *probability of flood event*, the more likely there will be a *flood event* and *damage from flood event*; while *time since weather event* reduces the level of the current sense of trauma experienced (Figure 5-3).

The *current sense of trauma* relates to the *ability to function in everyday life* through the mediating factors of *sense of uncertainty* and *stress*. *Stress* and the *ability to function in everyday life* also form a reinforcing loop labelled *stress* (Figure 5-4). This loop is explained in more detail in Section 5.2.1.

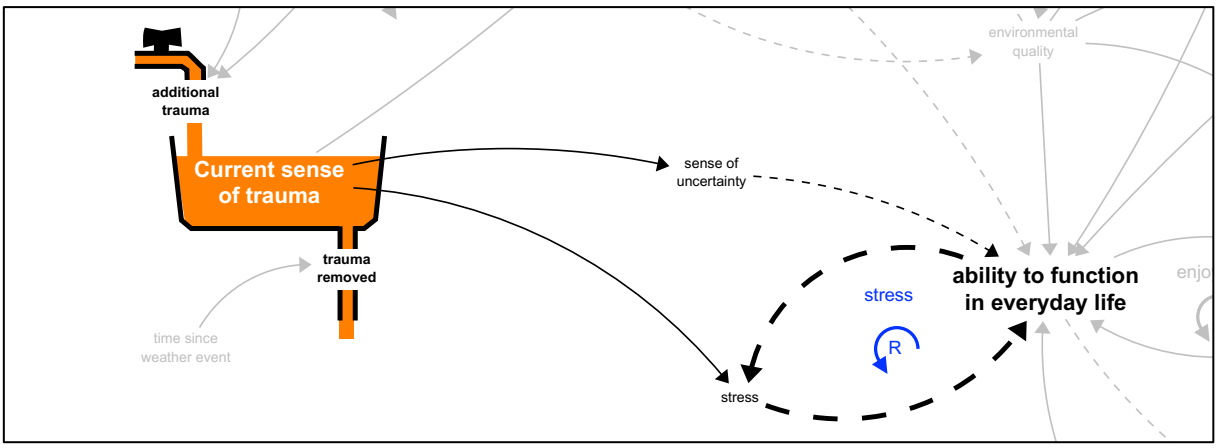

Figure 5-4: Trauma, stress, and the ability to function in everyday life.

5.1.2 Trauma and flooding mitigation

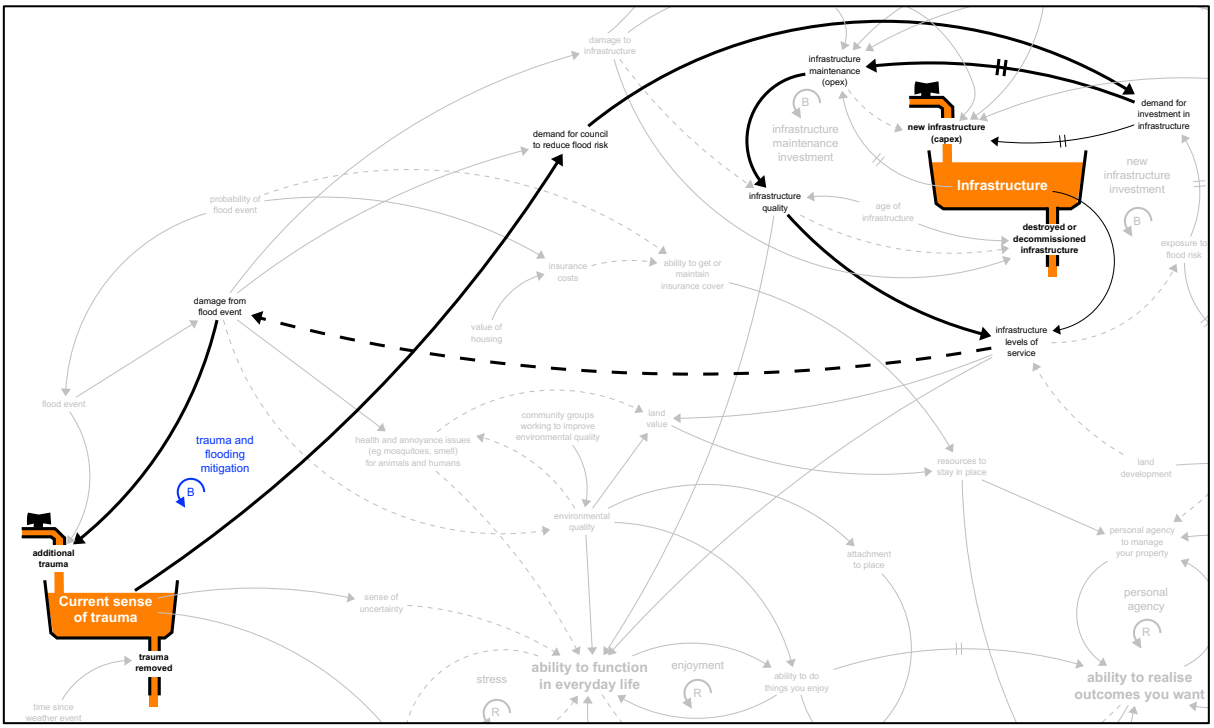

Figure 5-5: Trauma and flooding mitigation balancing loop.

The *trauma and flooding mitigation* balancing loop captures how experience of a *flood event* increases levels of trauma, which in turn leads to increased *demand for council to reduce flood risk* and *demand for investment in infrastructure* (Figure 5-5). That is, when levels of trauma from flood events are sustained, there will be pressure (via two pathways) to reduce risk by increasing the quality (*infrastructure maintenance – operational expenditure*) and capacity (*new infrastructure – capital expenditure*) of flood-related infrastructure. The amount of flood-related

infrastructure is also shown here as a bathtub. This is explained in more detail in section 5.5. If delivered, improved *infrastructure levels of service* will reduce potential for damage from future flood events and therefore reduce additional (future) trauma.

5.2 Ability to function in everyday life

Four feedback loops describe ways in which flooding over time affects the ability of communities and individuals to continue functioning in the way they wish to in their everyday lives.

5.2.1 Stress

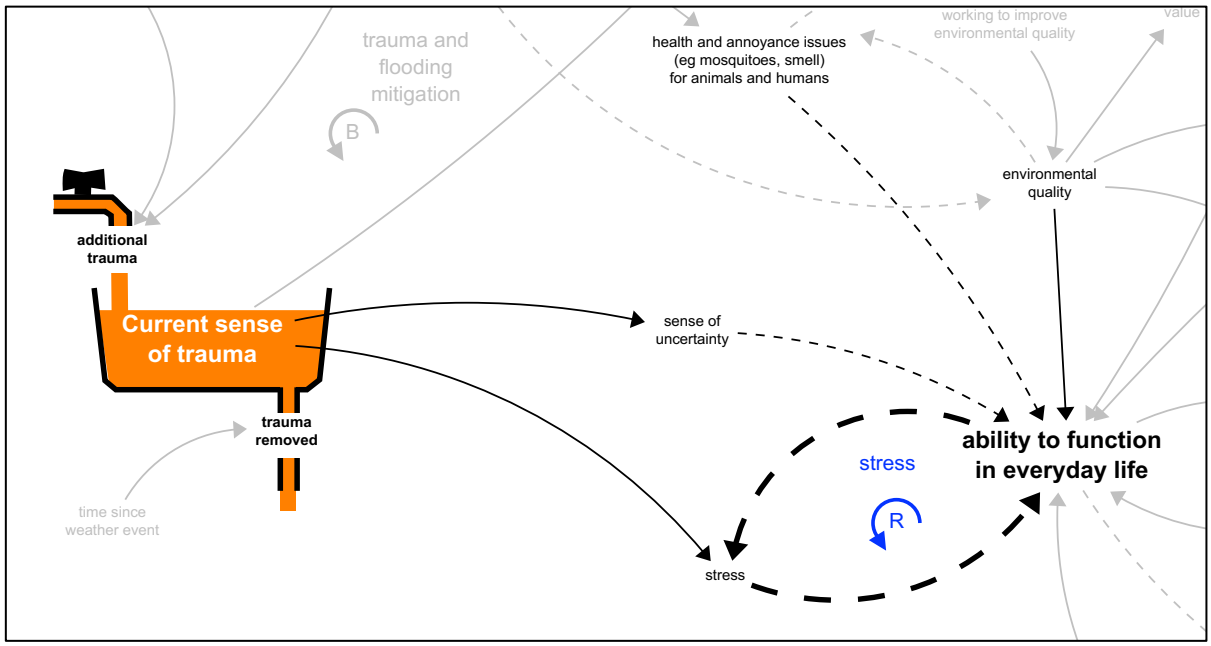

Figure 5-6: Stress reinforcing loop.

The *stress* loop in the causal diagram shows a reinforcing relationship between *ability to function in everyday life* and *stress* (Figure 5-6). In this respect, the lower the ability of Waikanae residents to function in everyday life, the higher their levels of stress. The higher the stress, the lower the ability to function in everyday life.

In Waikanae, flooding events can take an emotional toll, influences already expressed as being influenced by flood events and the *current sense of trauma* as noted in Section 5.1.1. People's *ability to function in everyday life* is also influenced by the condition of the environment. In the diagram this is represented by both the variables *environmental quality* and *health and annoyance issues (e.g., mosquitoes, smell) for animals and humans* having an impact on people's *ability to function in everyday life*. A same influence for the former, and an opposite influence for the latter. These influences then contribute to *stress* and the *stress* loop.

During the interviews, participants mentioned a range of feelings and emotions they experienced during and after an event, such as fear, stress, anger, powerlessness and demoralisation. One participant, who has volunteered for several years to preserve the flora and fauna in the Waikanae River, commented on the restoration work undertaken by the community being affected by the river flooding in December 2021:

... Thousands and thousands and thousands of plants died because they were inundated in water. It was just so stressing. And I suppose dealing with the council was also a very, very stressful process because they weren't interested particularly.

As flooding events become more frequent, uncertainty about the next big event creates a long-running concern among residents, particularly in those areas of Waikanae that tend to flood more often:

... So the mental health impacts at the community level need to be looked at, probably thought about because it certainly affected my wife a lot more probably than me. And she was quite stressed about a lot of the things and what might happen. So, you need to think about that ...

... [E]very time it rains, they're wondering whether this is going to be the 100-year flood or not. So rather than only having to worry about maybe 50/50 chance of a lifetime, they're actually worrying about it every day because every day it rains, well, this might be it. This might be the big flood coming ....

... The people at Otaihanga, when we had the walk over a couple of months ago, a lot of the people who lived out at Otaihanga are really, really concerned about the flood risk down there. And one of the discussions that took place there was how do they get a better warning of when a flood is coming ...

Experiencing the challenges of having a disability adds to the stress and reduces the ability to function in everyday life as noted by a participant with a physical disability:

... Well, I suppose the issue is that I'm actually in a wheelchair as well. So, there's a whole lot of issues about the threat of flooding and what might happen and the stress that that causes directly, because you don't know when you get continuous weather forecast saying there's going to be extreme events.

As noted by another participant from the Peka Peka area, stress not only originates with recent flooding events but also in regard to what may happen in the future:

... It's not a huge detrimental thing, but the flooding is getting worse, and I'm concerned that I might ... The area at the back might end up being totally useless. I just don't know how much worse it's going to get.

Unsolved issues relating to the management of the river also impact residents emotionally:

... The gravel within the estuary. There's this big gravel bar in the middle of the channel and everyone's concerned. The comments have been, well, is this causing the flooding in the main area and things like that. Because it's kind of built up and they've seen it build up and change over... like a lot of the people around that area have been there for a long time. So they've seen changes and it's just...

5.2.2 Desire to stay

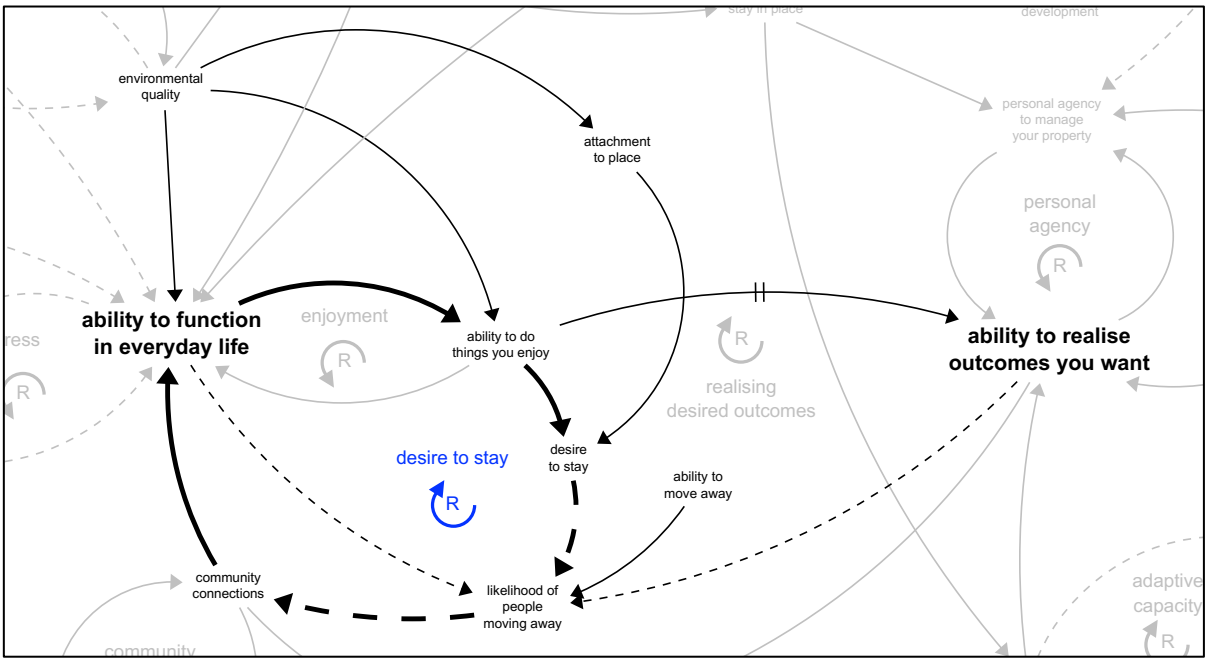

Figure 5-7: Desire to stay reinforcing loop.

Desire to stay is a reinforcing loop which captures the relationship between one's ability to function in everyday life and the desire to remain in place (Figure 5-7). In this respect, the higher one's *ability to function in everyday life* is, the higher is the *ability to do things you enjoy*. The greater one's ability to do the things that are enjoyed, the higher their *desire to stay*, which in turn leads to lower *likelihood of people moving away* from the community.

The lower likelihood of people moving away contributes to stronger *community connections*, which in turn supports residents' *ability to function in everyday life*. Having the capacity to engage in different activities that are a source of enjoyment and connection to others in the community was identified as being important by participants in Waikanae:

> *... It's [the river] a natural feature of the landscape here, and that's very appealing to us as to why we like this property backing onto the river. It's also been a big recreational asset for us with children growing up. And even today we enjoy seeing people. Well, we've now got grandchildren and other cousins and things who come out here and swim and play in the river and walk along the river. And we also see the community using it a lot ... On a sunny day, we'll see a hundred people an hour walking past our back fence on the walking trail. And that's kind of exciting to see that happening.*

Other variables, such as *environmental quality* and *attachment to place*, help reinforce the *desire to stay* loop. In this sense, the higher the environmental quality, the higher not only the ability to function in everyday life but also the ability to do things you enjoy. Similarly, the higher the attachment to place is, the higher the desire to stay.

People's *ability to move away* also has an influence on the *likelihood of people moving away*. The greater their ability (such as being able afford a move elsewhere), the greater the chance they will move away. Yet not everyone will have such ability, and this variable may have an important influence on this feedback loop if it is spiralling in an undesirable direction, contributing to people's feeling a sense of being stuck.

5.2.3 Enjoyment

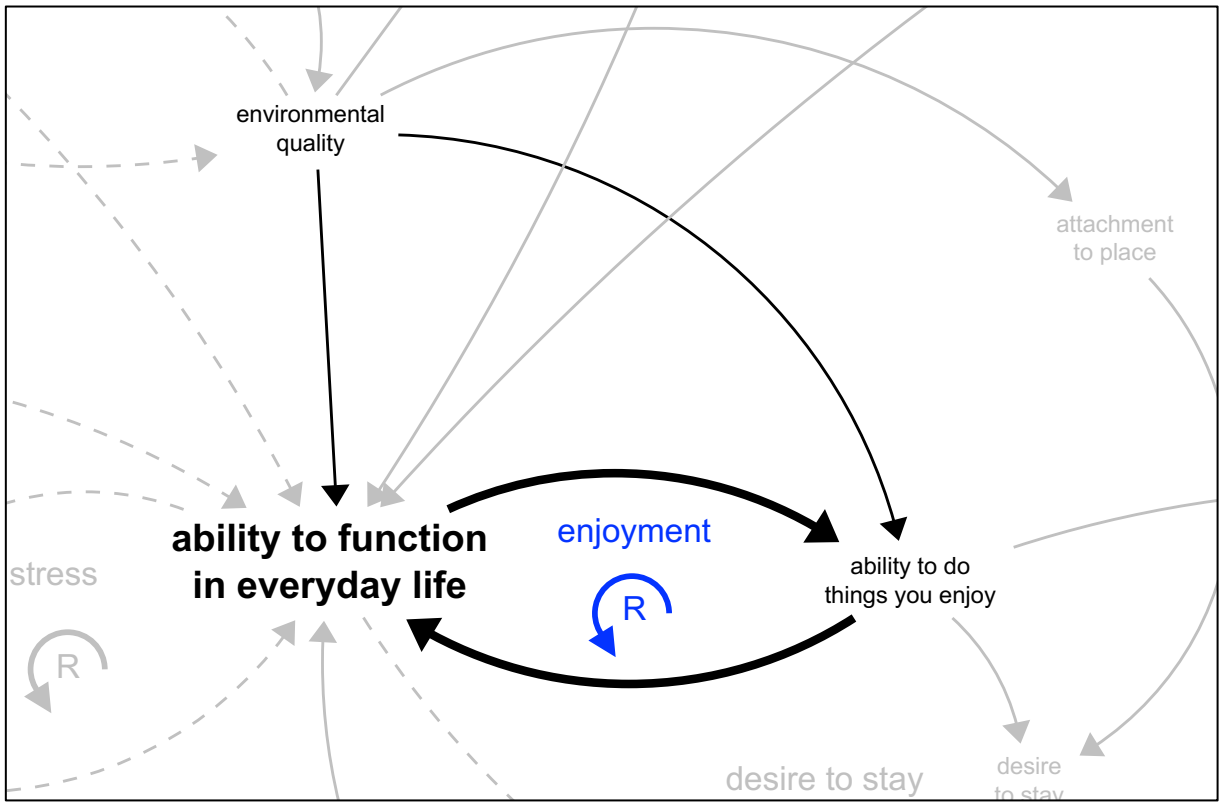

Figure 5-8: Enjoyment reinforcing loop.

The *enjoyment* loop captures the sentiment expressed by participants that greater *ability to do things you enjoy* leads to a greater ability to *function in everyday life*, which, in turn, reinforces one's ability to do things they enjoy (Figure 5-8). Participants considered Waikanae to be a place which positively supports this reinforcing loop, leading to enjoyment of place and life:

> *... My mum's family are all farmers and I've spent a lot of time on farms growing up and it's very much my happy place. I've always lived urban, but my heart was rural and when my children grew up and left home and I was in a position to say, okay, I don't have to live here anymore, I moved up here. I wanted to live rural, but I didn't want to live isolated. ...It was finding a place that that's where I wasn't isolated. And we still had the convenience of shops and that sort of stuff but where I felt like I had something in the country.*

> *The first thought of home is always Kāpiti. It's quiet and safe and a slow rhythm of life. I know that if I go for a walk when I take the dog for a walk, I'll meet three or four people that I know and I have chats with people when I can go to the local shops and they know me, know me by name. And that sort of community feel for Kāpiti is so special. Having lived in cities, I've never experienced that before to the degree that I do here and having a little bit of land and my own garden and now sharing that with my child is really special. And our backyard is the best backyard in the world because we've got, you can go to the beach, go to the river, you can go to the playground, the parks, the open spaces. It's just a lovely, peaceful, calming place that I really identify as home.*

Local *environmental quality* independently influences the two variables that comprise the *enjoyment* loop. That is, the majority of participants discussed how the greater the

environmental quality of Waikanae is (i.e., the river, the fauna and flora), the greater is one's ability to do things they enjoy and to function in everyday life:

> *... Both of us always have been interested in birds, there's very rich bird life here. And our garden is a natural flow on because it was designed, it was already planted from about 12 years ago with native plants and it was originally part of the sand dunes that used to be here and basically flows [from] the scientific reserve down to the river and then across the flats and the spit to Kāpiti Island. So yeah, we feel very engaged with the land and that's why really I got very involved with the Waikanae estuary care group because we wanted to help conserve it, etc. So yes, it has a very strong emotional attachment to us ...*

5.2.4 Realising desired outcomes

The *ability to realise the outcomes you want* to achieve in life is linked in a reinforcing loop with the *ability to function in everyday life*. The *ability to function in everyday life* supports the *ability to do things you enjoy*, which over time allows people the *ability to realise outcomes you want* (Figure 5-9). The more people can realise their outcomes, the less the *likelihood of people moving away*, the greater the *community connections*, contributing to a greater *ability to function in everyday life*.

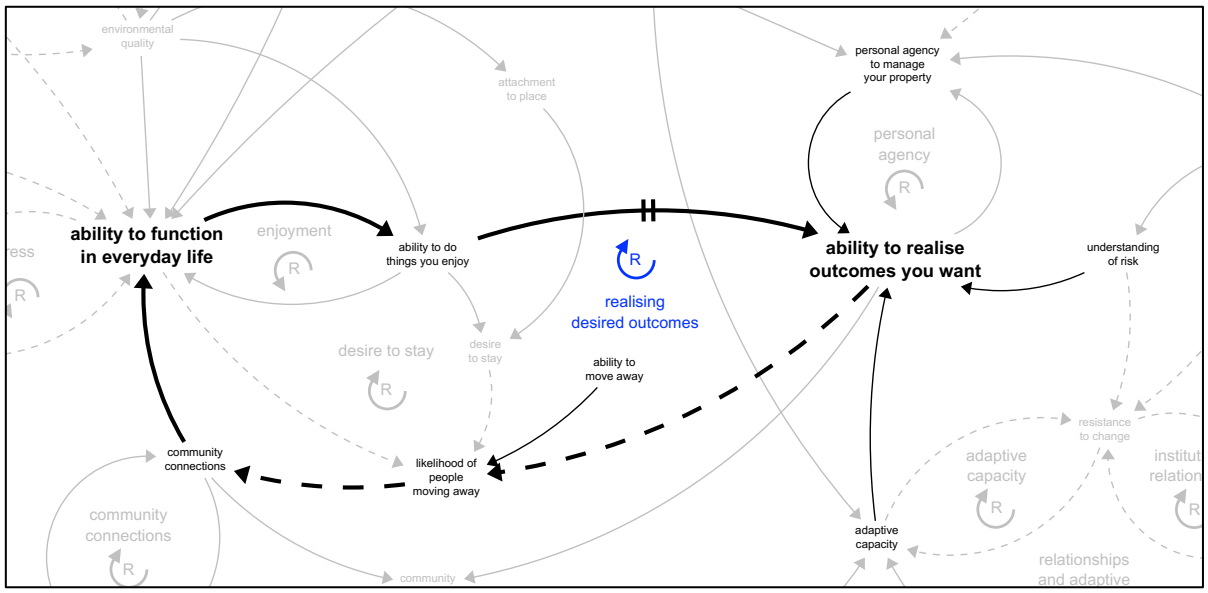

Figure 5-9: Realising desired outcomes.

5.2.5 Personal agency

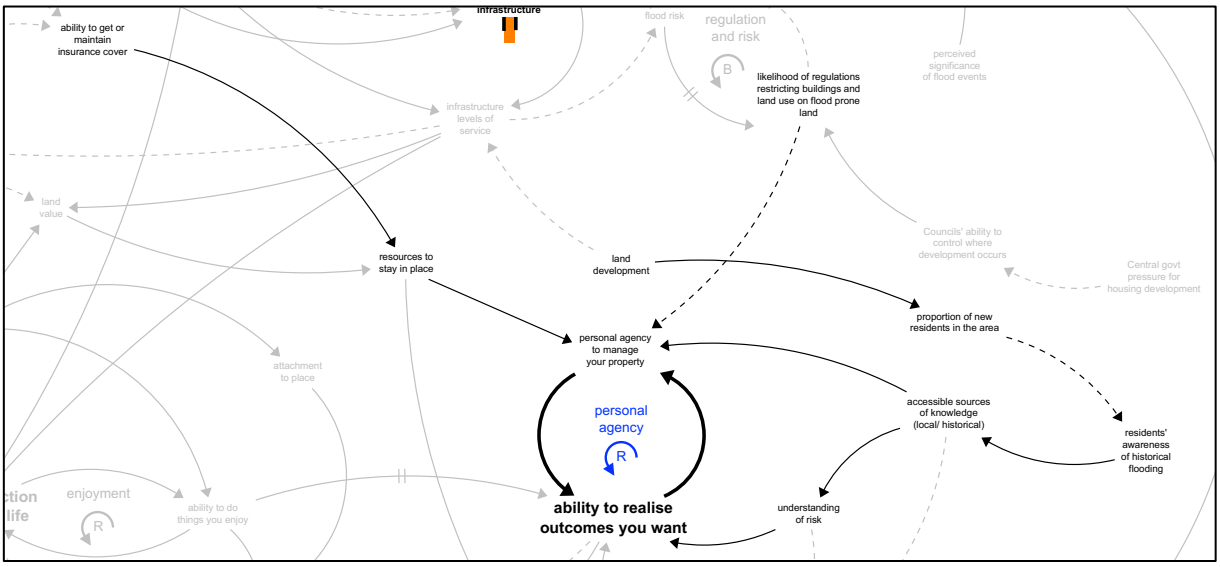

Figure 5-10: Personal agency reinforcing loop.

The *personal agency* feedback loop captures the reinforcing relationship between *personal agency to manage your property* and *ability to realise outcomes you want* (Figure 5-10). The greater a person's personal agency to manage property, the greater their ability to realise outcomes they want, and, in turn, the greater the personal agency to manage property. A couple of participants, whose properties were affected by a flood from a stream in early 2021, described how affected residents' capacity to make choices and take actions were limited by the flooding event:

> *We've had this property 21 years. And this has never happened before. But over time, we were fully aware that the water was rising. But it, you know, the uncertainty about what we can do with our land, our animals. So, all the grass has been destroyed. You know, do we resow it? All the trees along our road have died.*

> *I was only talking to him last Friday, and he was saying they're losing plants because there's so much flooding that they're having to move plants out and put them on [inaudible] because of all the flooding. So it's had a dramatic effect on him... and he's been there, I don't know how many years, but it's been there a long time.*

A number of variables were found to influence the relationship between *personal agency to manage your property* and *ability to realise outcomes you want*. These relate to having knowledge about historical flooding in the area, which can inform decisions about how to reduce flood risk (*accessible sources of knowledge (local/historical), understanding of risk*), which in turn are influenced by the amount of *land development* that occurs and the *proportion of new residents in the area*.

Whether regulations exist or not, *restricting buildings and land use on flood-prone land* has the potential to limit one's ability to make decisions about their property. Additionally, *personal agency to manage your property* is in part determined by the resources one has that allows them to stay in place (shown as *resources to stay in place*). That is, the greater the *ability to get or maintain insurance cover*, the greater the *resources to stay in place*, and the greater the *personal agency to manage property*:

In Ōtaki the social impact of flooding is way higher than Waikanae because in Waikanae we have our, you know, reasonably medium to high value housing. It's a wealthy community, let's put it that way. And the people particularly that live around the river and our coast are people that can afford to insure their houses, can afford to... Make choices to move etc., whereas in Ōtaki social impacts of flooding is very much higher than in Waikanae.

Conversely, there was concern that those people in communities with fewer socioeconomic resources had less agency to manage the property they lived in and were less likely be insured:

The other thing we get I suppose on the Kāpiti Coast and everywhere is that the more vulnerable communities don't complain. We've just tried to validate the new stormwater flood hazard maps and we've got lots of data and service requests from maybe Paraparaumu, Waikanae... But you get to Ōtaki and although I know there's properties that flood every time it rains, they never... You never get a service request coming from them...They probably don't have insurance because they can't afford the premiums. You know. So, it kind of does... And that's what I'm hoping your study will kind of... not address, but, you know, there will be some... output in terms of this is defining the problem as the vocal because we get a lot of complaints of people that it's not even their dwelling that's being flooded, like my lawn.

5.3 Community connections and functioning

Two feedback loops illustrate how community connections are reinforced, the way they function and how they can be impacted by flooding (and vice versa).

5.3.1 Community cohesion

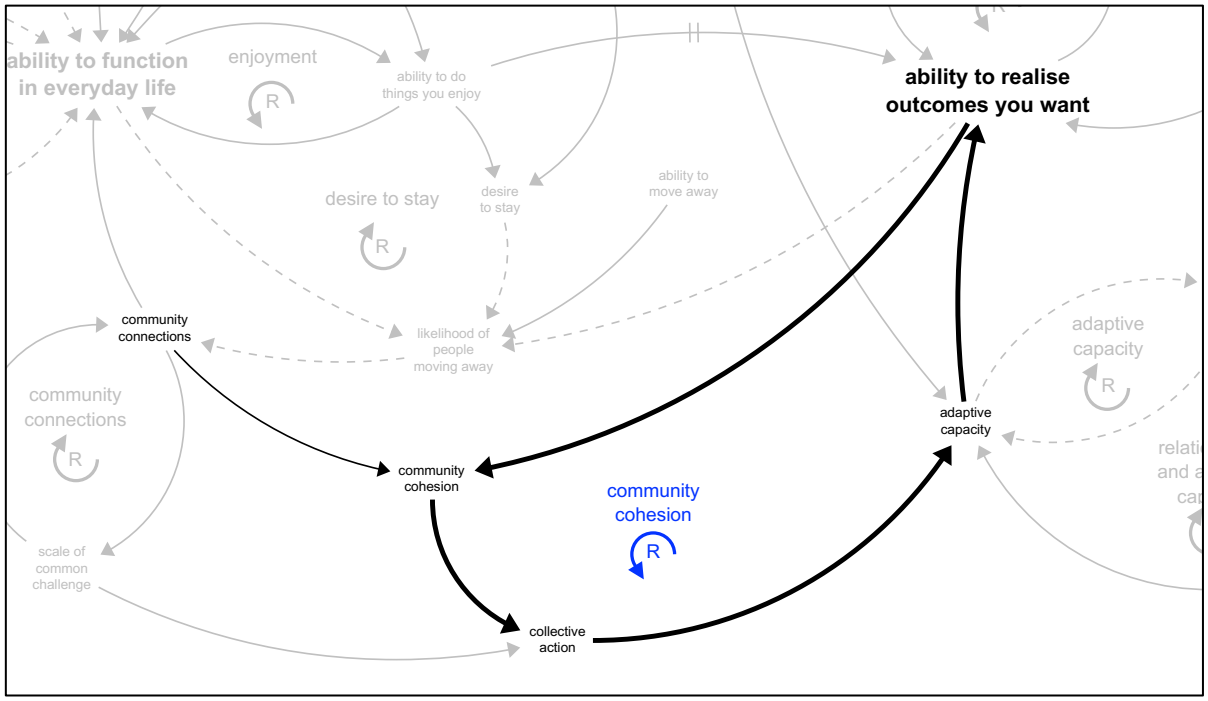

Figure 5-11: Community cohesion reinforcing loop.

The *community cohesion* loop captures the reinforcing relationships between c*ommunity cohesion*, *collective action*, *adaptive capacity*, and *ability to realise outcomes you want* (Figure

5-11). Community cohesion is understood as the sense of unity, belonging, and positive relationships among Waikanae residents.

In this respect, the higher the *community cohesion*, the higher the *collective action* is by the community to work together (both in terms of immediate flood response and reducing flood risk). Then, higher *collective action* supports higher *adaptive capacity* which in turn leads to *greater ability to realise outcomes you want*. The more that residents are able to realise the outcomes they want while living in their community, the higher the degree of com*munity cohesion* there is.

In Waikanae, participants emphasised how forming and maintaining connections within the community enhanced collective action. One participant commented on how taking action to clear a flooded drain improved the adaptive capacity of the community and in consequence its ability to realise desired outcomes:

> *... So, a couple of weeks ago we were out on the street, you know, working together with the neighbour down the road just to clear the drain, much to the children's disappointment because they were happy playing in the water... So, I mean in that way it's kind of a bonding experience.*

> *We've noticed that actually some areas, like in Waikanae, they are a very engaged community. If you actually look right now at every day for that upcoming local election there, they post how many votes have come in from each part of the district. Waikanae is over 40%, which is insanely high. They are an active, engaged community and they will never... They don't mind calling us. They want us to do something for them all the time, you know.*

For vulnerable residents, community cohesion also means the ability to access support when flooding happens. A resident experiencing a physical impairment commented on a past flooding experience affecting their property and how existing social connections (represented as community connections) helped to support them during the flood event:

> *... We talked to a neighbour who was actually on higher ground. And so, they were happy to take us too because we could go to them basically to stay there if necessary, because they're bound by substantially higher ground than our property is as well. So that's where we would have gone in the meantime.*

As indicated, community cohesion leads to the ability to realise outcomes Waikanae residents want. These outcomes are not only related to dealing collectively with flood-related events but also other activities impacting on the community and the Waikanae catchment. An example of this was the experience of a long-term Waikanae resident who is also part of a volunteer group working to improve the environment of the Waikanae River corridor:

> *... One of the things about the [volunteer group] and the people is you are doing active things and trees and tidying up on the river. But there's also the social interaction of actually meeting every week and working together for a couple of hours and having a cup of tea and then having the odd sort of end of year function at somebody's house, and also the interactions of people who got to know each other through the river group and they help each other [at] times of their lives and there's that social interaction, is part of it as well.*

Local council officers have also observed how community cohesion and sense of belonging can be boosted among Waikanae residents through different community activities:

... As council, we've always done quite a lot on the neighbourhood level, so we drive projects that are called like greener streets, for example. Even though people set up a community garden together, it means they know each other and as soon as people know each other, people will help each other because most people are good people and in times of need, to actually help each other out, they do that.

5.3.2 Community connections

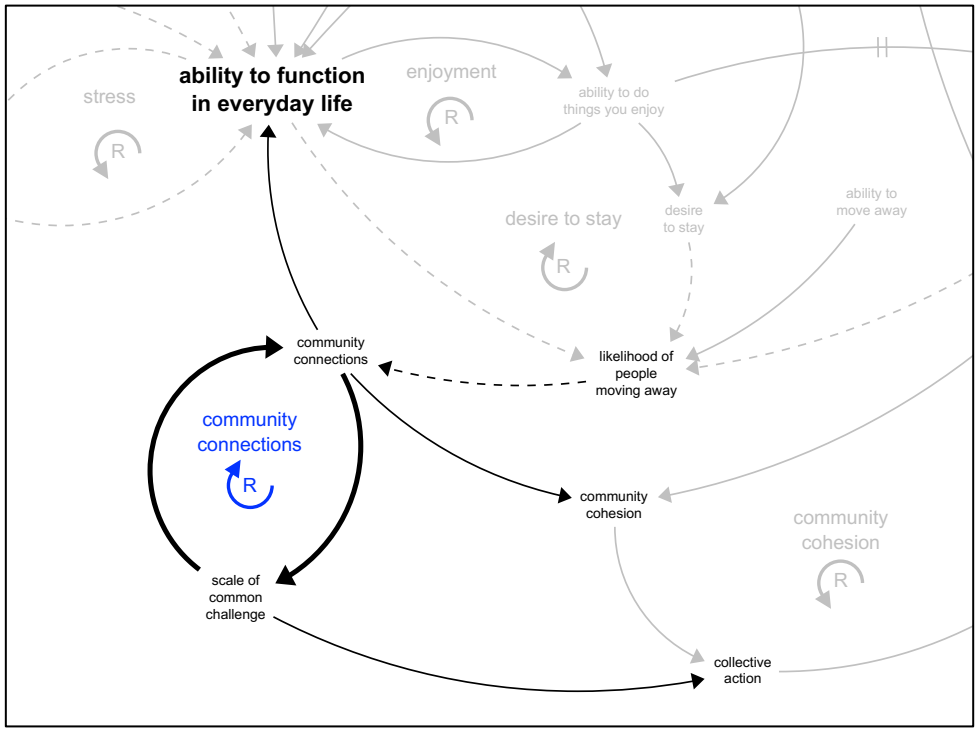

Figure 5-12: Community connections reinforcing loop.

Closely connected to *community cohesion*, the *community connections* reinforcing loop shows how a greater *scale of common challenge* (which refers to the challenge of responding, preparing and/or mitigating a flood event) leads to greater *community connections* and, in turn, relates to a greater scale of *common challenge* (Figure 5-12). The *scale of common challenge* also influences the level of *collective action* described in the previous section.

In late 2021, residents of Peka Peka faced a common challenge: flooding caused by one stream of the Waikanae River. After intense rainfall, the stream overtopped affecting some properties, including residents' livestock, for several weeks. Residents from Peka Peka met to discuss solutions to the common challenge they were facing. While different options were analysed, they prioritised their community connections (the networks of relationships and interactions) to have the issue of further flooding in the future resolved. This is how one resident recalled that experience:

... So initially it was about going to the media. Initially it was about going to talk to lawyers or it was actually dealing with the KCDC, the local council. And I think at the end of the day, it was decided to try and work with the council because the other two solutions would take a really long time.

It was pointed out that building community connection requires a multilevel approach in which not only residents but also schools, council, and other community organisations play a role to address common challenges such as a flooding event:

> *... They need to know each other first often, if people are not familiar with the people that live around them, the threshold to ask for help is really high. Whereas if people have met, had a chat over the fence, it's way easier. They know which neighbour they can ask for help and council have a role to play yes, but council is not the organisation that has enough manpower to... I mean we can be enablers to a certain point, I guess, to create better social cohesion and to make sure that people do engage. But it happens at schools, it happens at sports clubs. I mean, it's your whole social fabric that helps build that.*

Community connections are also inversely influenced by the likelihood of people moving away – the more people move away; the less connections remain. Also, community connections links to and supports both the level of collective action and people's ability to function in everyday life, as described in previous sections.

5.4 Adaptive capacity of communities

Two feedback loops describe how community capacity to adapt to flooding risk emerges and changes over time. Adaptive capacity spirals up or down, depending on the level of community knowledge, understanding, relationships, and so on.

5.4.1 Adaptive capacity

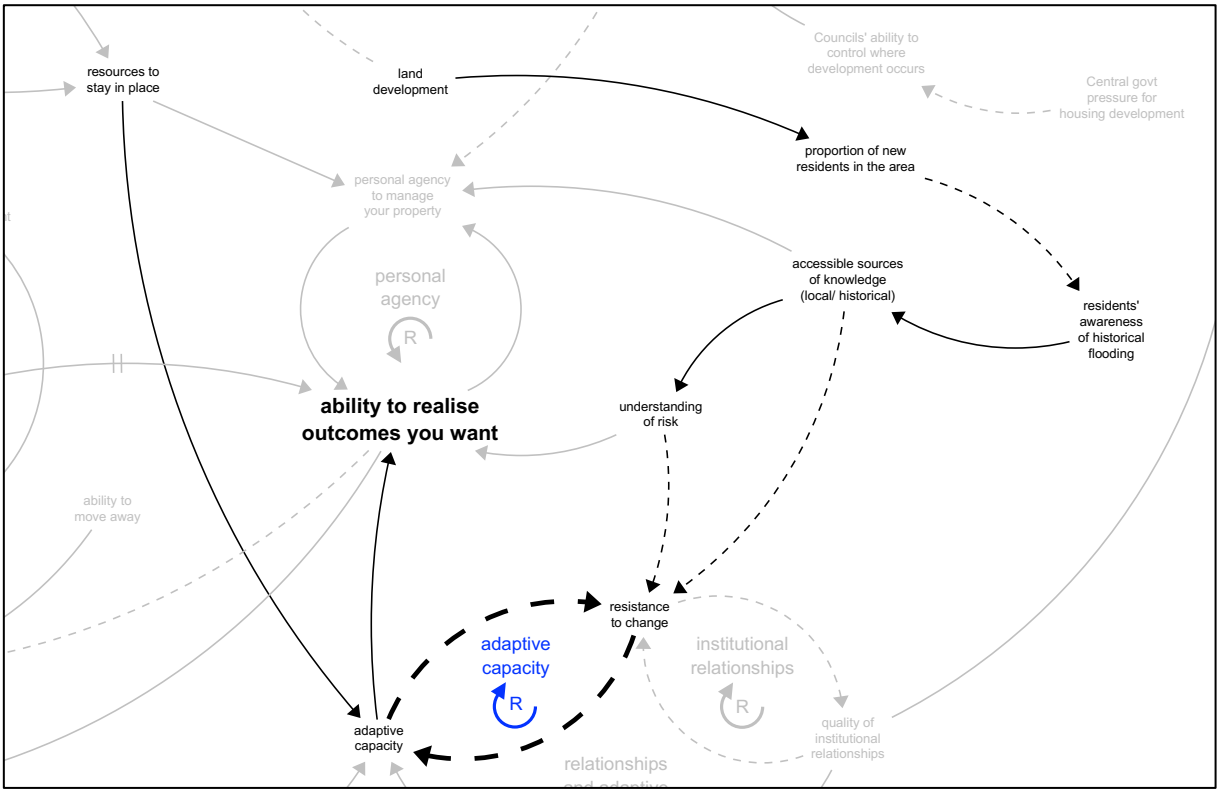

Figure 5-13: Adaptive capacity reinforcing loop.

The *adaptive capacity* feedback loop comprises the reinforcing relationship between the factors resistance to change and *adaptive capacity* (Figure 5-13). The higher the *resistance to change* is among Waikanae residents, the lower the *adaptive capacity* which, in turn, reinforces their resistance to change.

The reverse may also apply. The lower the *resistance to change*, the higher the *adaptive capacity* and, thus, the lower the resistance to change.

Residents' knowledge of local flood risk also influences the *adaptive capacity* loop. In this respect, the more that Waikanae residents are aware of, and able to access, local knowledge about flood risk, the greater their understanding of risk, and the lower their resistance to change that aims to reduce future risk. This was the case of one participant:

> *... The groundwater level since the December flood has come up. So, we've had probably four or five ponding events since then. When I built this house, I got commissioned a once in 500-year study because I'm a risk analyst. And I wanted to understand a bit more what ... We add extra height to our house to kind of build outside of that. But I didn't expect that the groundwater level, the whole of the groundwater levels across the whole of Waikanae have gone up considerably since last year. I think the council are quite concerned about that.*

However, the ability of Waikanae residents to adapt or cope with past and potential new flood events can be impacted when other types of *resources to stay in place* are lacking (e.g., financial). Also, lower understanding of risk was perceived by participants to be linked to *resistance to change*. This point of reluctance to adapt to a new situation was highlighted by regional and local council officers:

> *... We did a very short survey ... inviting people to tell us what they thought of our new approach to the stormwater framework. And it was clear that ... They don't understand this concept of Te Mana o te Wai and they repeatedly said 'your only job is to prevent my house from flooding. That's what we expect from council ....*
>
> *People often think they can live with the flood risk, and they'll take the chance. But it wears them down like an illness in the end. And generally, you know, they sort of think, oh no, it's only going to flood a big flood once every hundred years, so I'll be okay.*

Challenges regarding residents' understanding of local risk may also arise due to the makeup of the Waikanae community. According to some residents and regional and local officers, Waikanae is a changing community. New urban developments (represented as *land development*) are attracting new residents, especially young families, while the existing population is aging (*proportion of new residents in the area*). This means that history and local knowledge can be lost (a reduction in *residents' awareness of historical flooding*), and that effective engagement of new residents can be more difficult:

> *... That's the challenge, keeping the community up to date with what's going on. And the challenge is trying ... you know, not reinventing the wheel because you get new people come along and they don't know everything that's been done in the past and trying to make sure that our information is ... you know, because things don't change that fast.*

5.4.2 Institutional relationships and their impact on adaptive capacity

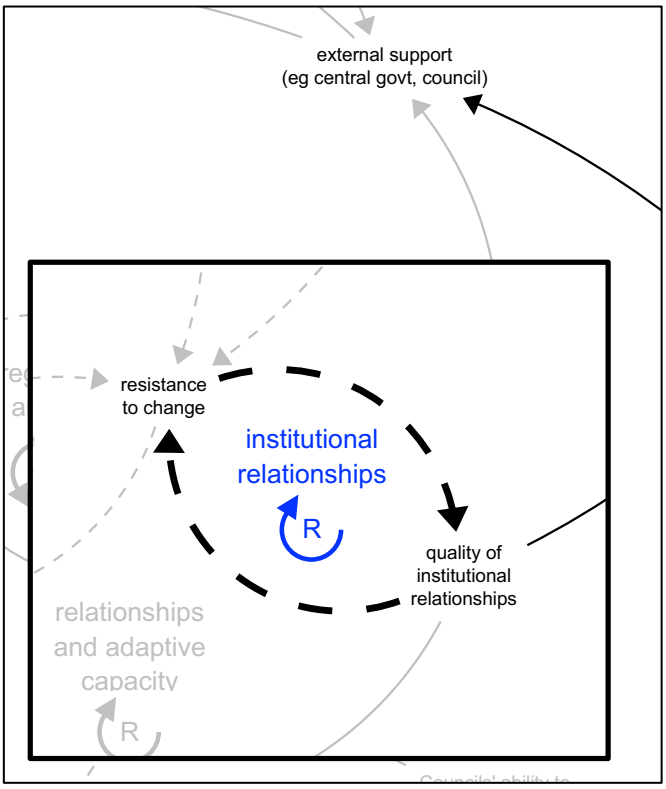

Figure 5-14: Institutional relationships reinforcing loop.

The *institutional relationships* loop describes a reinforcing influence. As Figure 5-14 shows, the lower the *quality of institutional relationships*, the higher the *resistance to change*, which further lowers the *quality of institutional relationships*. The *quality of institutional relationships* also has a same influence on the level of external support that the community may experience from external parties, such as central government and council (shown as *external support, e.g., central government or council*). Residents talked about the frustrations and difficulties making changes because of poor institutional relationships when council and agencies struggle to agree in the protection of the Waikanae River in the context of Waikanae ki Uta ki Tai:

> *... We were kind of hoping that when we formed Waikanae ki Uta ki Tai the fact that all the government parties, DoC, Greater Wellington, KCDC, iwi, community ... We were all together on this, that it was going to start to have, you know, a more dynamic effect and things would happen a lot quicker. That hasn't happened ... So, we suffer really from the effect of the three different authorities being quite at odds.*

In the Waikanae catchment, interaction, coordination and agreement between agencies is also important. Agencies recognised the limits of any one agency which means there needs to be trust and working relationships between institutions to overcome resistance to change:

> *... It's a pretty big catchment. But from a flood management perspective, we only actually manage a very small portion of it. So it's the lower part through the urban area, like I said, from the old state Highway 1 right down to that, just sort of around the river. Yeah, out to the river mouth.... But yes, it does miss a massive part of that catchment... There's a bunch of trees and debris will build up on them. So we work alongside KCDC because they own different parts, and we own different parts of*

the tracks. So jointly, we clear that debris up. There's also issues of erosion for the river. Taking some of those tracks away.

At the same time, the *quality of institutional relationships* has a same relationship with *adaptive capacity* which has an opposite relationship with *resistance to change*. This creates another reinforcing loop called *relationships and adaptive capacity* (Figure 5-15). This describes the impact that institutional relationships have on adaptive capacity, in addition to the other influences. When institutional relationships are positive, this spirals with increased adaptive capacity and reduced resistance to change. If the quality of institutional relationships reduces, these can spiral in the opposite, undesirable, direction.

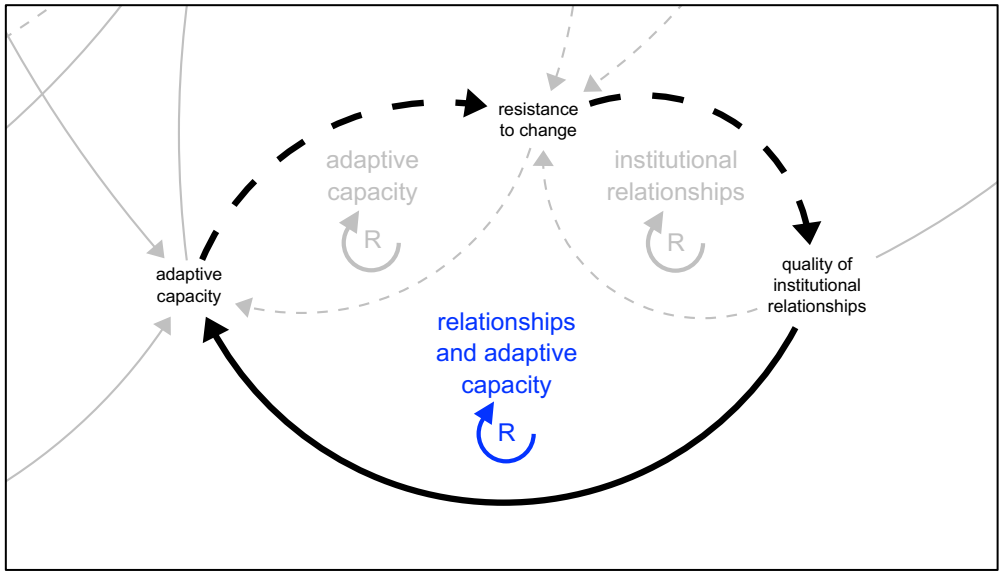

Figure 5-15: Relationships and adaptive capacity reinforcing loop.

5.5 Investment and regulatory environment

Three feedback loops show how flood risks and impacts are balanced out over the longer term (note the delays, indicated by the short double lines across the arrows) in infrastructure investment processes and regulatory environments.

5.5.1 Long-term capital and operational expenditure as investment in infrastructure

Two loops are described in this *Investment in infrastructure* section. Both describe the long run process of capital expenditure (capex) or operational maintenance (opex) investment in infrastructure. *Capex* adds to the total *amount* of infrastructure (represented as a bathtub) while *opex* is the process of maintaining the *quality* (and hence performance) of that existing stock of infrastructure – this is represented by the variable *infrastructure maintenance (opex)*.

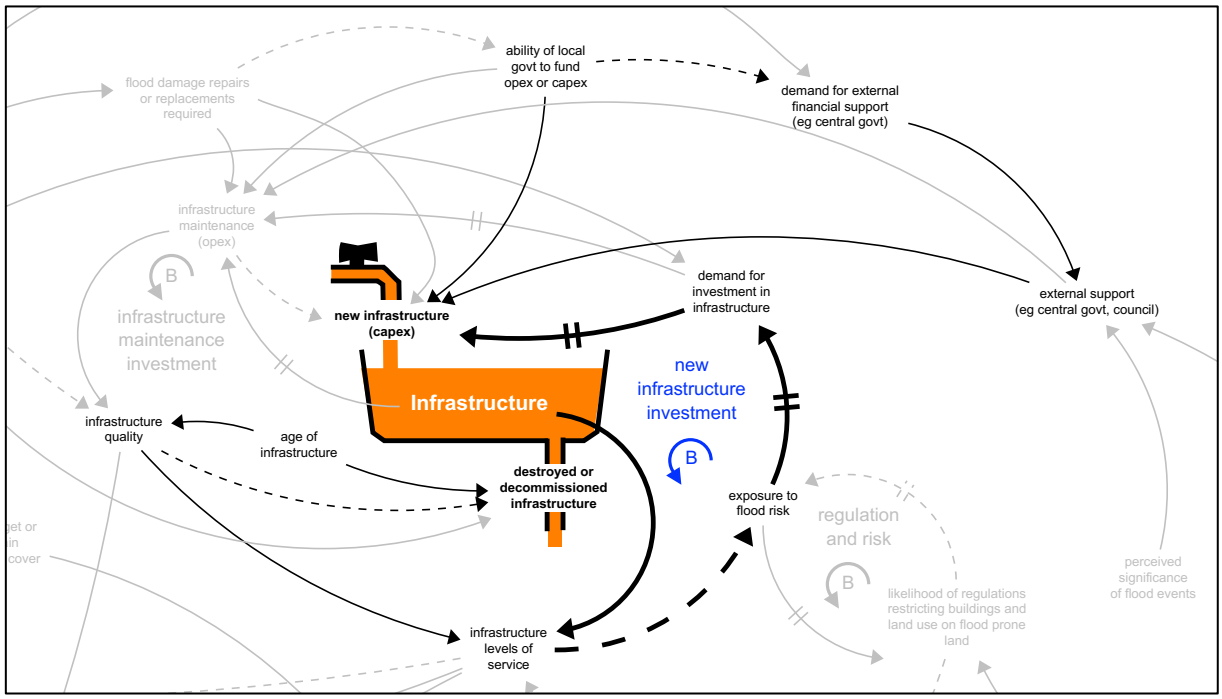

Figure 5-16: New infrastructure investment (capex) balancing loop.

The volume of *infrastructure* in place in the community is represented here as a bathtub. The tap into the bathtub *(capex)* represents any additional infrastructure that is built that adds to the total volume of *infrastructure* in place – be that stop banks, drains, overland flow paths, etc. (Figure 5-16). The drain out of the bathtub represents any *destroyed or decommissioned infrastructure*. This could be destroyed by flooding or might be a planned decommission and the end of an asset lifecycle. The focus of this loop is the decommissioning of assets at their end of life.

This is influenced by both the *age of the infrastructure* and the *infrastructure quality*. The greater the age and the lower the quality, the greater the likelihood of an asset's decommission. In other words, the age of an asset does not strictly determine whether it is retired, if it is performing well it remains in the stock of assets.

This *infrastructure* bathtub is central to the *new infrastructure investment* loop. This captures the balancing relationship between the demand for investment in new local infrastructure and the impact that such investments have on improving the levels of service provided by that infrastructure. The volume of *infrastructure* (the bathtub) and how well it performs (*infrastructure quality*) both have a same influence on the *infrastructure levels of service*. The greater these variables, the higher the *infrastructure levels of service*. The better the levels of service being provided then the lower the *exposure to flood risk*, which (over time) balances out any further *demand for investment in infrastructure*. Through this process the flooding risk is in part adequately mitigated by building new assets. The building of new assets depends on the *ability of local government to fund opex or capex*, and the availability of external funding from central government (*external support, e.g., central government or council*). The lower the *ability of local government to fund repairs*, the higher the *demand for external financial support (e.g., central government*).

The *infrastructure maintenance investment (opex)* loop captures a similar balancing relationship, this time between demand for investment in *maintaining already existing* local infrastructure and the impact that such maintenance has on maintaining the levels of service provided by that infrastructure (see Figure 5-17).

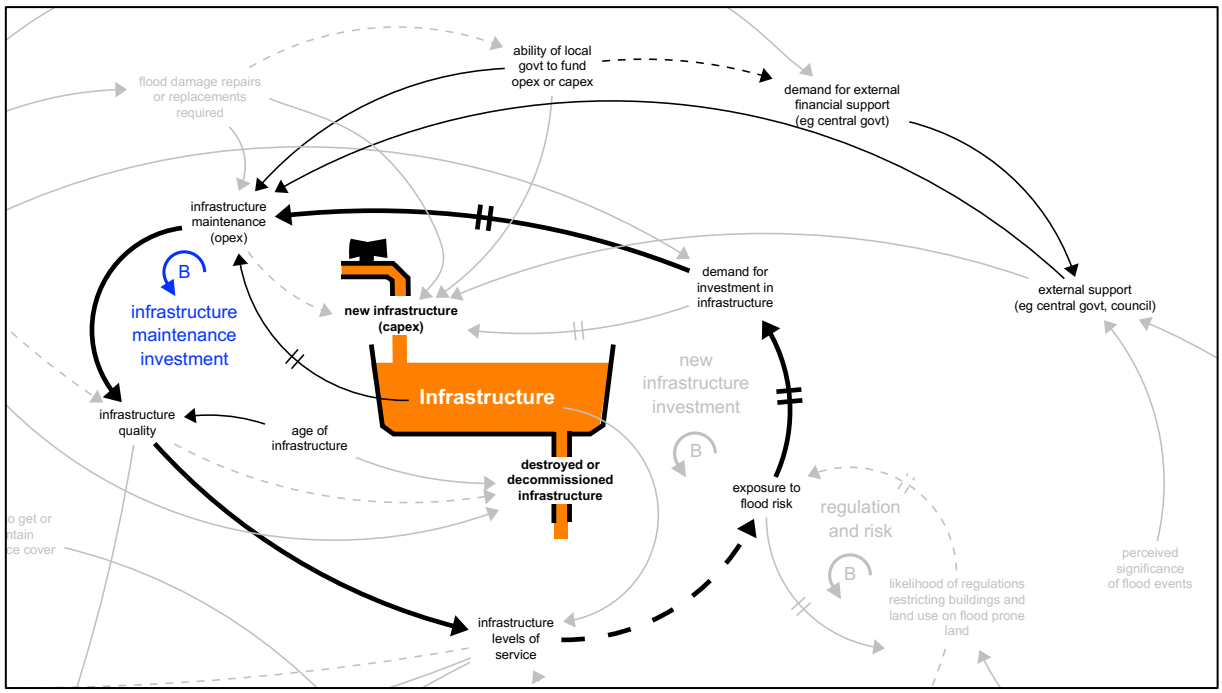

Figure 5-17: Infrastructure maintenance investment (opex) balancing loop.

When the quality and levels of service provided by infrastructure decline due to a combination of age and quality, the *exposure to flood risk* increases. Over time, this increases demand for investment in *opex*, which restores the performance of the asset (*infrastructure quality*), increases the *infrastructure levels of service* and reduces *exposure to flood risk*. Again, whether repairs are made to infrastructure depends on the *ability of local government to fund opex or capex* efforts, or the availability of external funding from central government (represented by *external support, e.g., central government and or council)*. As before, the lower the *ability of local government to fund repairs*, the higher the *demand for external financial support (e.g., central government)*.

Finally, and importantly, these long running investment in infrastructure loops influence residents' *ability to function in everyday life*, as good-quality infrastructure and high levels of infrastructure service support the community to function at a high-level.

An example of the loop playing out in Waikanae relates to a past flood event which raised concerns about the quality of existing flood infrastructure to protect the community. After some years of discussion, work done to upgrade the stopbank increased its level of service, reducing community exposure to flood risk and the demand for more infrastructure investment. As one participant commented:

> *... There's a playground called Jim Cooke... And that's where they rebuilt the stop bank in the last four or five years, because there's a lot of houses behind that stop bank. And the stop bank was never built very well. And the 2005 flood, that was the one that almost got overtopped... That park was*

completely covered in debris and wood and broken trees and everything because the water was about waist deep over the whole of that park. Rebuilding of the stop bank has changed some... had an effect on the houses there.

However, when infrastructure levels of service are insufficient, it increases exposure to flood risk and, therefore, a higher demand for investment in infrastructure. In the data generated for this report, apart from upgrading the stop bank, the *infrastructure maintenance investment* loop includes pending issues such as cleaning work on drains and streams periodically. For some participants, these unsolved issues create a risk for potential future flooding:

... One is that there needs to be a much better way to be able to maintain it. Basically, I think there needs to be an acknowledgement that cleaning out drains, enlarging pipes is actually a really good way of actually providing resilience in our community.

So probably from December 2021 to now, the amount of consecutive rain events has been really, really impactful. And it's raised the water table level, which means that when we have the sort of back-to-back events, nothing's draining as quickly, which means we have a lot of standing water around the district in ways that we haven't had before. That's quite concerning and it's sort of meant rethinking things like soak pits around our property. It's had big impacts on the landscape of the beach... and the use of fields and parks and things like that that are just unusable or have been unusable for the last six months.

And at the end of the day, this is a major stormwater system. It has... had 26 square kilometres of catchment. And part of that catchment is... includes a lot of subdivisions in Waikanae so every year, more and more people are living within that catchment and sending water down basically, you know, through the infrastructure into that drain. And so basically, when I got there, it couldn't get out because it's not been cleaned out for about ten years.

Earlier this year, the Waikanae River flooded quite heavily and it eroded portions of the side of the river, of the banks. And there are paths that go next to the river. Those paths were quite badly damaged in several places. And the council had to make a new path, really, because the old path was destroyed. And that also happened last year as well in a different place. So next to the Waikanae River is definitely an area that is strongly impacted.

5.5.2 The cascading impact of short-term repairs to infrastructure from flood damage

Short-term repairs to infrastructure required from flood damage impact the dynamics of capex and opex investment described above. Firstly, when infrastructure requires replacement or repairs due to flood damage, this is normally required in the short-term. If there is an increase in *damage from a flood event* and *damage to infrastructure*, this reduces the *infrastructure quality* or destroys more infrastructure (increasing the rate of *destroyed or decommissioned infrastructure*). This also increases the *flood damage repairs or replacements required*. This leads to an increase in either: capex (*new infrastructure – capex)* to replace a destroyed asset (e.g., a washed out stop bank); or opex (*infrastructure maintenance – opex)* to maintain or repair a damaged asset (e.g., clearing sediment from a stormwater pipe or overland flow path).

Yet there is a cascading impact from this type of construction or repairs (Figure 5-18). Capex or opex that occurs due to flooding damage is reactive, where the long-term capex and opex is planned. It tends to be reactionary and undertaken at short notice. Financing for this is often

sourced from council funds intended for other things or from government support money in response to the flood event.

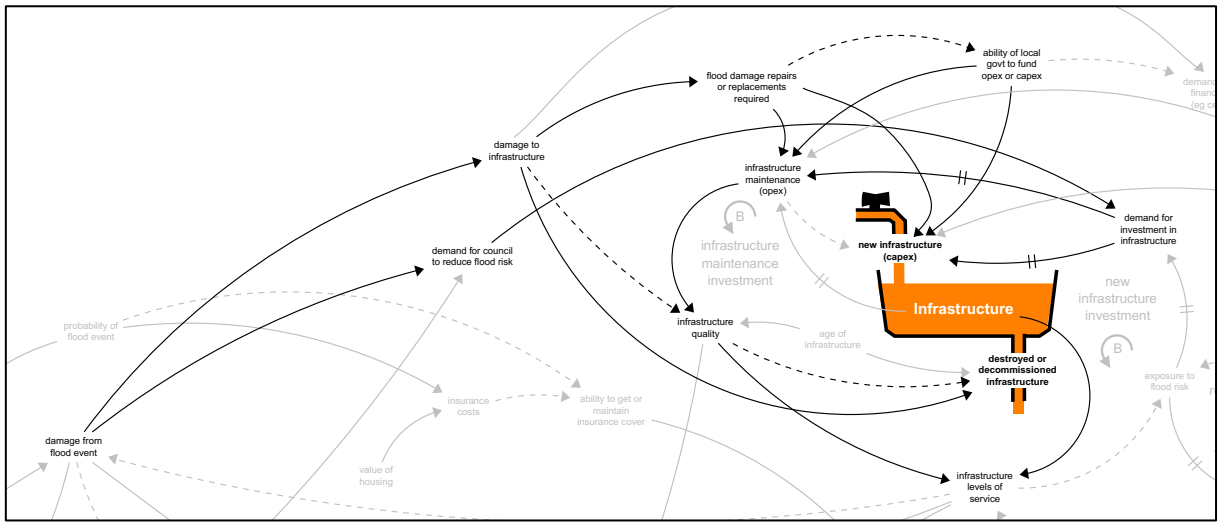

Figure 5-18: The cascading impact of flood repairs.

A key dynamic here is that while this means that damaged or destroyed assets are usually repaired or replaced in the short term. The event *increases* the *demand for council to reduce flood risk* (increasing the *demand for investment in infrastructure*), yet the expenditure *reduces* the *ability of local government to fund opex or capex* in the longer-term. Effectively, recovering from flood events impacts the long-term financial ability of councils to proactively plan for and deliver asset-based flood risk reduction.

While capex investment was recognised as necessary to reduce future flood risk and subsequent damage, council officers talked about the struggle to gain funding for 'big ticket items' in between major events:

> *... I think it's kind of the lack of traction if you don't have any events. But if you have a long time where there isn't any rainfall or event, then the councillors can get a bit like they robbed Peter to pay Paul.*

Nevertheless, taking a more strategic approach to planning for and implementing a network wide maintenance and renewals programme was seen as a way of reducing risk and damage:

> *...So, we've made clearing that sort of stuff [sand, roots etc] [so that] the same rainfall event potentially wouldn't have caused the same damage because we've done quite a bit of work in maintaining the network since then and replacing pipes that aren't operating...*

5.5.3 Regulation and risk

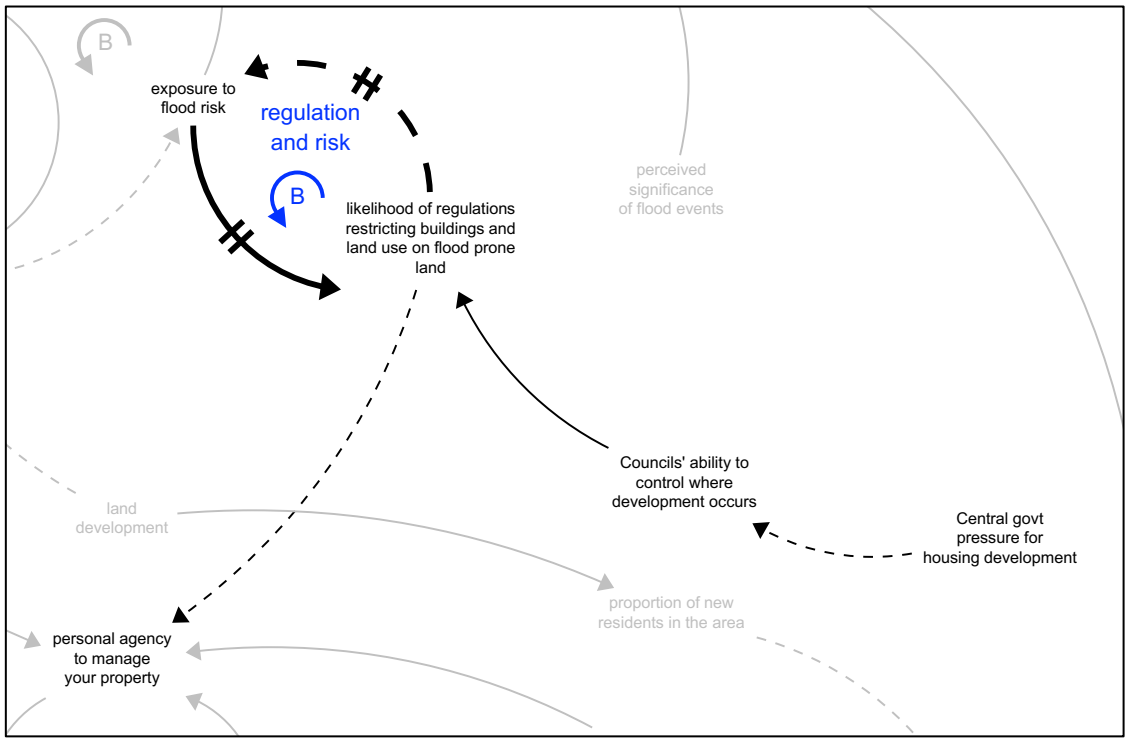

Figure 5-19: Regulation and risk reinforcing loop.

A balancing relationship forms the basis of the *regulation and risk* loop (Figure 5-19). In this regard, the lower the *likelihood of regulations restricting building and land use on flood prone land* is, the higher the *exposure to flood risk*. Over time, as *exposure to flood risk* increases, so too will the likelihood that regulations restricting development on flood prone land will be enacted (all else remaining the same). In this respect one participant commented that:

> *... Acknowledging that the Kāpiti coast is already developed to an extent which in some areas, it compromises the [opportunity for greater] resilience to flooding. I think preserving and enhancing to the best extent possible the existing open space areas to be able to accommodate flooding would be a great start.*

This point was complemented by another participant:

> *... Unfortunately, that's the way it is. Our land use laws pretty much don't allow us to change land use in a way that can match it with the appropriate estimate of flood risk. So we're just getting worse and worse scenarios where sections in floodable areas will be subdivided. So instead of one house, now there'll be two houses down there.*

As the Waikanae causal diagram shows, two other variables (*central government pressure for housing development* and *Council's ability to control where development occurs*) influence the *regulation and risk* loop. The greater the central government pressure for housing development, the lower the ability of councils to control where development occurs. In turn, the lower councils' ability to control where development occurs, the lower the likelihood of regulations restricting development on flood prone land. In this regard, several participants, both residents and local officials, warned of the risks of incentivising urban development in Waikanae, for example:

... The increased urban development, we can build three houses of three stories on a property so that those policies are being promoted. And the council has looked at basically putting in... changing the district plan. So to allow that to happen, which we say, look, this is just silly, basically, why are you going to allow this to happen in the areas where there is risks of flooding? Why would you do that? And they don't listen. They still plough ahead because the government's put in policies that supposedly force them to do this. And so we've put in submissions saying, look, ... doesn't follow their own legislation requirements and under the coastal policy statement.

In addition, the *regulation and risk* loop influence the *personal agency* loop. This is because the higher the likelihood of regulations restricting land use in areas prone to flooding, the lower one's personal agency to manage property.

5.5.4 Insurance

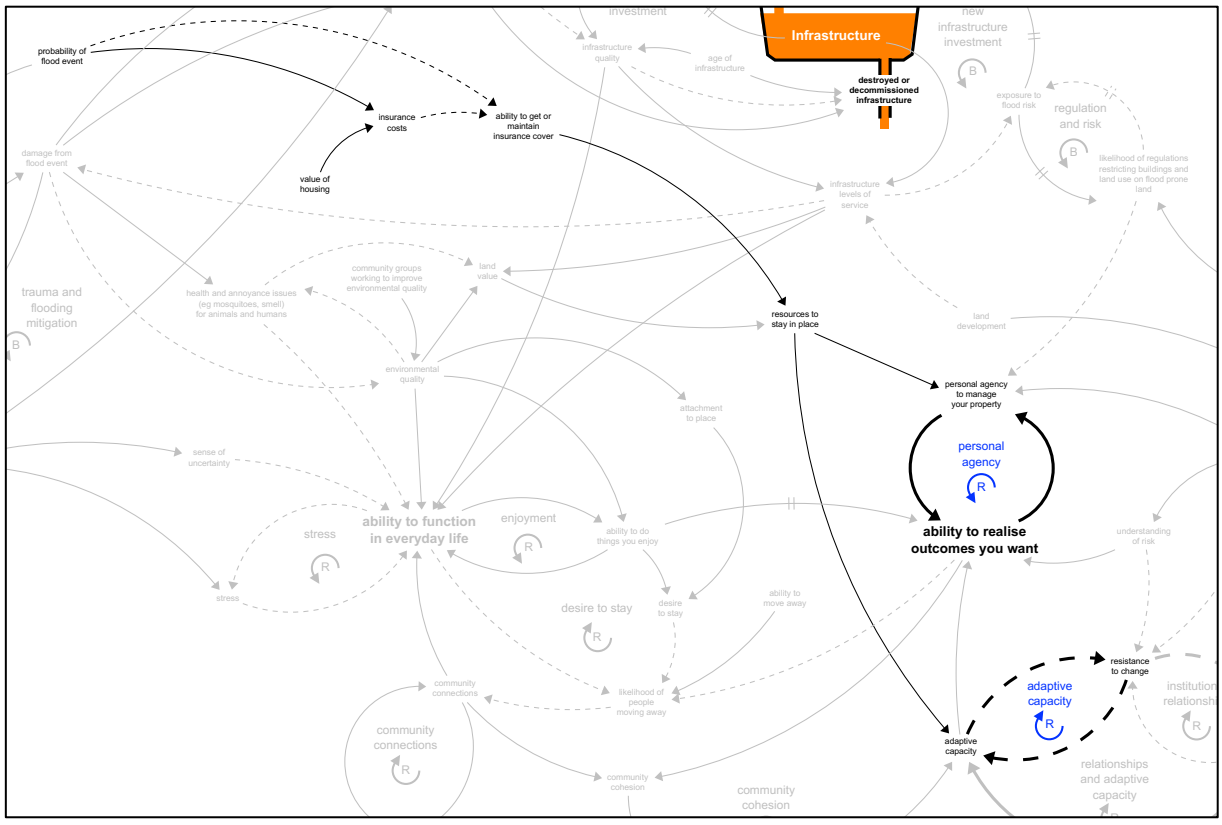

Figure 5-20: Insurance.

While the insurance group does not include a feedback loop, it includes influential pathways to other groups and loops (Figure 5-20). The ability to have insurance is affected by the *probability of a flood event* and the *value of housing,* as well as resident's financial means. The *higher* the *probability of a flood event*, the lower *ability to get or maintain insurance cover* as well as affording higher *insurance costs*. Participants recognised the impact of greater flood frequency on insurance cover and affordability, for example:

... There's a couple of properties that are beginning to not to be able to be insured because it's happened so often.

> *... But you get to Otaki and although I know there's properties update that flood every time it rains, they never... You never get a service request coming from them. So they don't actually complain. They probably don't have insurance because they can't afford the premiums.*

The greater the insurability (the *ability to get or maintain insurance*) the greater the level of *resources to stay in place* (in the event of a damaging flood), which then contributes to both the personal agency and adaptive capacity reinforcing loops. Conversely, when the *probability of flood event* decreases, the insurability increases, increasing the level of *resources to stay in place*, levels of personal agency to manage flooding, and capacity to adapt to flood risks.

6 Future-focused impacts

As well as the loops developed from the data analysis, several future-focused themes were identified. These were developed from commentary on what the future might hold for the Waikanae catchment and the wider Kāpiti Coast, given changes to the climate, sea-level rise, and the changing nature of the community and built environment. It is intended that they will be explored in subsequent publications.

6.1 Chronic flooding

Waikanae participants talked about significant flood events that resulted in widespread and substantial damage and about smaller scale but increasingly frequent flooding. While so-called chronic flooding is usually not seen as a crisis, it was recognised as having an impact on individuals and communities, particularly with regard to the future. The figures below show how flooding can result in vulnerability and harm by becoming chronic.

Figure 6-1 shows the accumulated *trauma from flooding* bathtub where the level of the bathtub represents the accumulated level of trauma experienced at any point in time. *Additional or new trauma* is a function of both the *physical impact of the flood event* and a lowered *ability to function in everyday life*, *quality of life*, and the *ability to realise outcomes you want in life*.

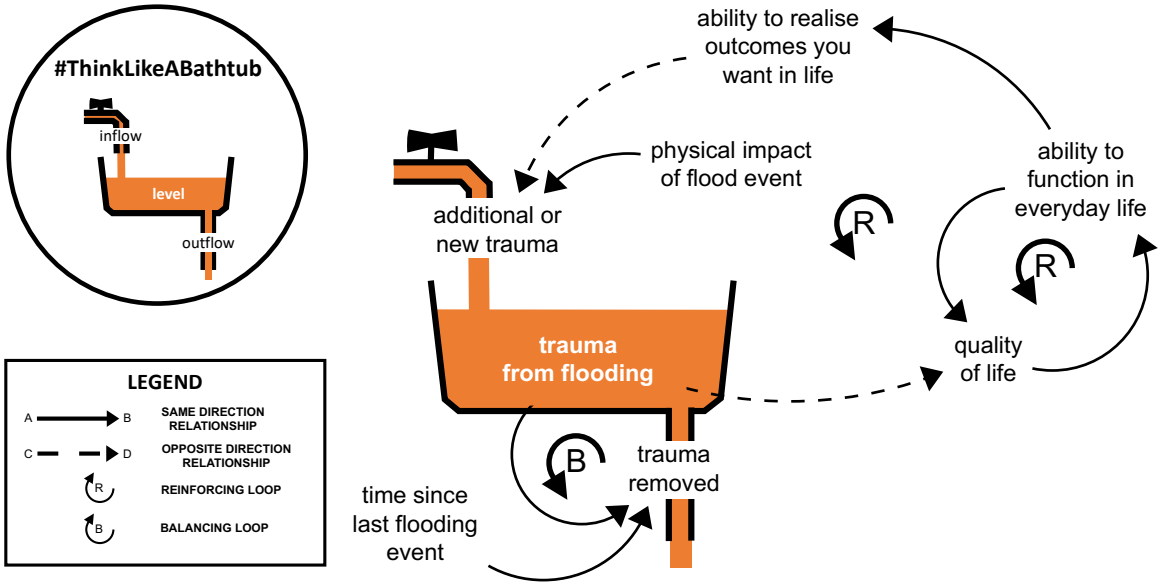

Figure 6-1: Accumulated trauma bathtub

The balancing loop shows how trauma levels drain from the bathtub as time passes, gradually balancing out the level of trauma currently being experienced. Reinforcing loops are also present: the more *trauma from flooding* one is already experiencing when a new flooding event happens, the greater any *additional trauma* accumulated from that new event. Additionally, each flood event reduces the *ability to function in everyday life*, further reducing *quality of life*.

With chronic flooding, the additional trauma from any new event may be small, but it is compounded by previous unresolved trauma where insufficient time has passed to fully 'drain the bathtub' (Figure 6-2). This can result in a chronic condition of spiralling, decreasing *ability to*

function in everyday life and increased levels of accumulated *trauma from flooding* from the small but repeated events:

> *... It's not a huge detrimental thing, but the flooding is getting worse, and I'm concerned that I might... The area at the back might end up being totally useless. I just don't know how much worse it's going to get.*

Over time, balancing and reinforcing loops related to small, frequent flood events may lead to increased vulnerability and harm, due to the accumulation of *trauma from flooding*. Their 'chronic' nature may wear down the coping capacity of communities and individuals and reduce their tolerance for impacts. Without support, residents exposed to chronic flooding may leave communities or face accumulating stress from remaining in increasingly vulnerable places.

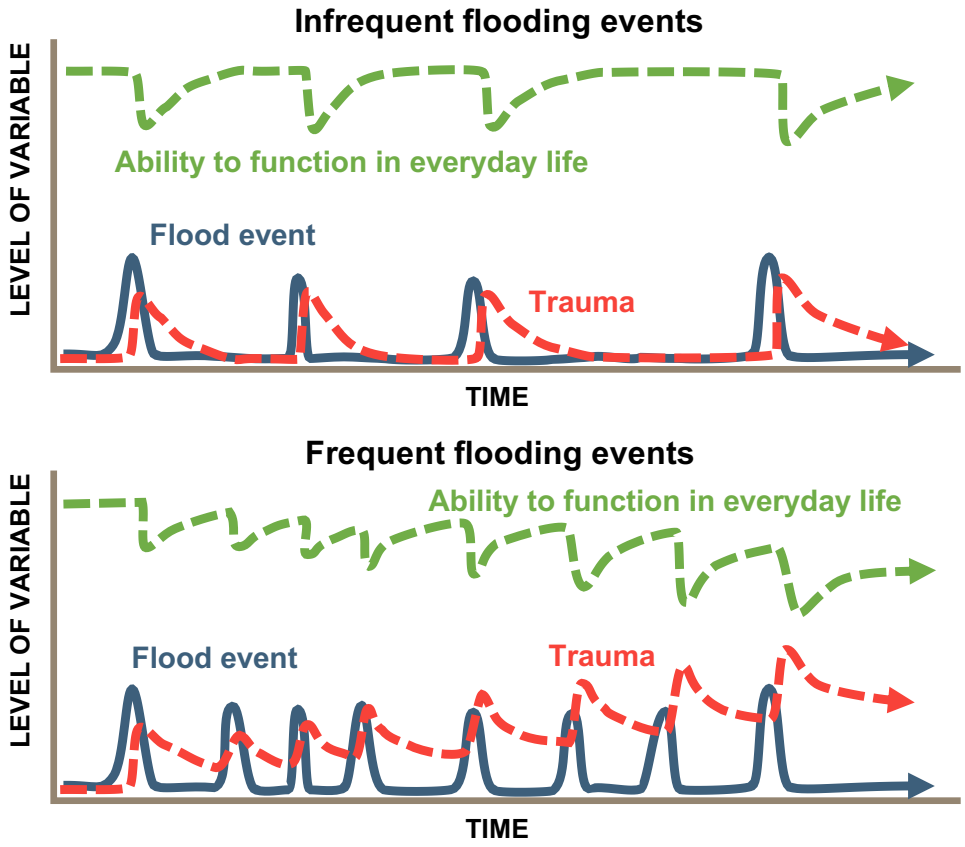

Figure 6-2: Compounding impacts from frequent flood events

6.2 Changing communities

The Kāpiti Coast has a growing population. New residents are less likely to have experiences and knowledge of flooding events themselves and weak social connections to longer-term residents who do. The thematic and loop analyses discussed above suggests that, in the event of flooding, there may be less capacity within the community to support each other. It may also be harder to get communities on board with flood resilience measures if there is less collective memory and flood awareness. Limited understanding of the issues within the community may mean that public expectations of the council's role in flood resilience may not match what is possible or practical. Newer residents are less likely to have strong place attachment which

may mean they are less tolerant of repeated flooding events and more likely to leave the area (if they have the means to move) or become increasingly distressed (if they are unable to leave).

6.3 Changing built environments

Along with a growing population, the Kāpiti Coast is experiencing pressure for more housing developments. Land use is changing from farm and lifestyle blocks to resident housing and the associated roading. When combined with sea level rise, more greenfield development places pressure within the catchment on the groundwater capacity and on the ability of the land to absorb rainfall, increasing the flood risk for all. Local authorities are trying to balance the provision of stormwater infrastructure to existing urban areas at the same time as coping with new developments. While the regulation and risk loop indicate authorities will be able to reduce the flood risk by regulating where building takes place, there is a lag which suggests things must get worse before they can get better.

7 Where do we go from here?

We have learnt about the nature of flooding impacts in three communities over time, and how they come about. The impacts of floods go well beyond the inundation and damage experienced during and immediately after an event, affecting trauma levels that remain within the community, the ability to function in everyday life, how communities connect and function, the capacity of communities to adapt to flood risk, and the ability of the investment and regulatory environment to manage flood risk. We identified four mechanisms for understanding how flood impacts cascade through Aotearoa New Zealand's social and economic systems in ways that, if not addressed, can increase community vulnerability to harm (Figure 7-1).

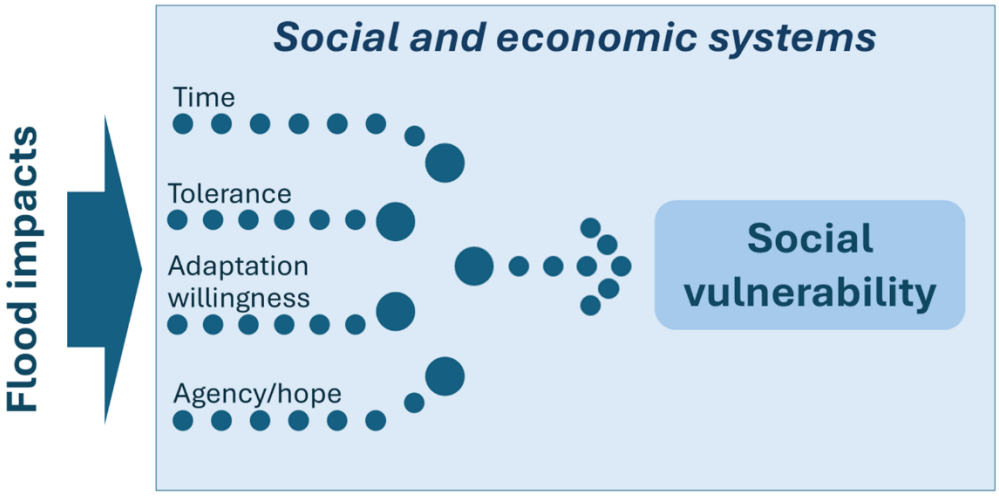

Figure 7-1: How flood impacts cascade through social & economic systems to increase social vulnerability.

Time plays an important role in understanding how impacts from flood events develop. Firstly, the full consequences of floods take time to become apparent and often only when things are well into post-event recovery phase. Secondly, time between events matters – without sufficient time to fully recover and experience life as normal, the trauma from flooding accumulates. And thirdly, time fades memories – without knowledge of what has happened in the past, there is little motivation for change in terms of actions to reduce the risk of future flood impacts.

Tolerance to flooding varies, particularly to the cumulative impacts from repeated historical events, or the threat of repeated future flooding. Threats to life, property investments, quality of life, and personal investments in future lifestyles all challenged people's willingness to tolerate future flooding.

We found that the *willingness to take adaptation measures* to reduce future risk and trauma was affected by knowledge of past impacts. This included both personal experiences and collective memories held within the community. Greater knowledge of previous events motivates adaptive change at the personal property level and supports willingness within the community to address risks. Conversely, where there is less willingness to adapt (perhaps because of few memories), people are inadvertently less able to reduce their future flood risks and will be more vulnerable to harm.

Where there is personal, community, and council *agency* to manage and adapt to future flooding risk, people have *hope* for their future in their community. This belief in the ability to manage flood risk supports, and is motivated by, connection to place and community. Where flood risk mitigations are no longer possible or sufficient, desire to remain in place can weaken and negative implications for wellbeing can emerge.

Addressing these causes of vulnerability include should happen across the 4 Rs of emergency management – reduction of risk, readiness and response to events, and recovery from events:

- Supporting people's ability to function in everyday life over the extended recovery period.
- Acknowledging and mitigating the trauma caused by flooding, no matter the scale of events.
- Promoting community connections and functioning before, during and after events.
- Creating and maintaining collective knowledge about flood events to increase the appetite for flood harm reduction measures, so those who do not have direct experience are also better protected in the future.
- Building and maintaining collaborative working relationships between communities and their respective councils.
- Supporting investment and regulations that manage and mitigate flood risks.
- Supporting the adaptive capacity of communities.

7.1 What does this mean for communities in the Waikanae catchment?

- It is evident that past events were significant. So how can we ensure we do not forget what happened before? How can we keep collective memory alive? For example, are there community spaces where images and memories can be kept?
- If there are gaps in what Council does and the level of risk management we want, what actions can we achieve as a community – either ourselves (e.g., advice for homeowners in looking after their own land and creeks) or through advocacy (who can we advocate to? What do we need to say and how?).
- Community connections are critical for our tolerance and for local support during and following a flood. How do we ensure that we sustain this?

8 Acknowledgements

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We also wish to thank all participants who shared their stories and knowledge with us as part of this project. We are incredibly grateful for the time you took to provide us with your insights and lived experiences.

9 Glossary of abbreviations and terms

capex	Capital expenditure on infrastructure which adds to the total amount of infrastructure
opex	Expenditure on operational maintenance that maintains the quality (and hence performance) of that existing stock of infrastructure

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Appendix A How to read a causal diagram (detailed)

This appendix provides a more comprehensive explanation for how to read a causal diagram.

Causal diagrams help us visualise the relationships between different related variables and how they influence each other. This visual articulation of inter-connected relationships is called the 'causal structure'. This causal structure helps us understand how the behaviour of variables in the diagram will change over time will change (or not), in response to changes (or not) in factors within the wider causal structure.

This section outlines important fundamental elements of causal structure. These are:

- The bathtub analogy.
- Feedback loops – the basic building blocks of a causal diagram.
- How feedback loops and causal diagrams are annotated.
- Goals and gaps – driving individual loop dominance.
- How influence operates differently upstream and downstream of a change in flow.

Reading this section will help the reader understand and navigate the causal diagram in this report

The bathtub analogy

Causal diagrams often draw on the analogy of a bathtub. A metaphorical bathtub has been used in the diagram described in this report. The analogy of the bathtub (Figure A-1) represents an accumulated level or amount of something (also called a stock) that is of interest to the issue you are seeking to understand. It may even be the central feature of the issue you are seeking to better understand.

The level of the bathtub (stock) can only be increased by adding more through a metaphorical tap (also called an inflow); and it can only be decreased by removing some of what is in the bathtub through a metaphorical drain (also called an outflow).

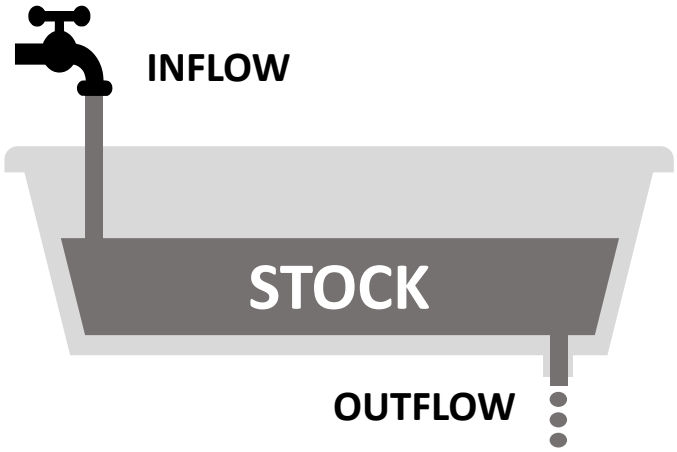

Figure A-1: The bathtub analogy.

This simple analogy can provide powerful insights. For example, an action may stop an issue being added to by reducing or stopping the inflow (the tap). This will stop the level of the bathtub increasing but will not reduce it. To demonstrate this, think of greenhouse gas emissions into the atmosphere. If all greenhouse gas emissions were to stop tomorrow, this would not cause their level in the atmosphere to reduce, it would simply stop them increasing.

Another example is an action that may increase the outflow (the drain) from the bathtub in an attempt to reduce the level of the bathtub. But if there is still a significant inflow through the tap into the bathtub, this will reduce the impact of the increased outflow from the drain. Or if the inflow was to increase more than the outflow, the level of the bathtub will still continue to rise, but at a slower rate due to the increase in the outflow (drain). Greenhouse gases are another good way of demonstrating this point. Even though there are many increased efforts to remove greenhouse gases from the atmosphere (e.g., increasing the flow from the drain (i.e., sequestering carbon) by planting trees or using direct carbon air capture technology), if the emissions (the tap) increase by more than the drain, the level of the bathtub will still increase.

Simply put, if more flows in through the tap than out the drain, the level of the bathtub increases. If more flows out than in, it decreases. It is noted that the bathtub is a metaphor – it will never overflow as it does not technically have a specific capacity. However, it may be fully exhausted (drained).

Feedback loops – the basic building blocks of a causal diagram

Causal diagrams focus on moving away from thinking of causality as linear, to circular. That is, a linear way of thinking about causality might be that A influences B, whereas a circular way of thinking about causality might be that A influences B, and then B also influences A (Figure A-2). This means the causality 'feeds back' on itself, so where this is identified it is known as feedback loops.

Figure A-2: From linear to circular causality.

There are two types of feedback loops, reinforcing and balancing (Senge 2006).

Reinforcing loops seek to spiral in the direction they are already heading (hence reinforcing). They can spiral up or spiral down, and they tend to drive growth or decline (see Figure A-3). They can also change direction and spiral the opposite way, in response to influences from outside the feedback loop (i.e., how they interact with other influences). But the influence from within the loop will always seek to continue spiralling it in the same direction that it is heading.

A simple example of a reinforcing loop is money in a bank account earning interest. Assuming no withdrawals, the more money in the bank then the more interest earned, thus resulting in even more money in the bank. This influences back on itself in the same direction and has the effect of compounding on itself.

Balancing loops seek to cancel or balance themselves out. They tend to create control, restraint or resistance (Figure A-3). Depending on how they interact with other loops they may not always manage to cancel themselves out or come back into balance, but this is what the influences within them will be seeking to do.

A simple example of a balancing loop is thermostat-controlled heating. Let's say that the room temperature drops so the thermostat clicks on and generates heating, this increases the room temperature, so the thermostat clicks off, stopping the heating. This has the effect of cancelling itself out.

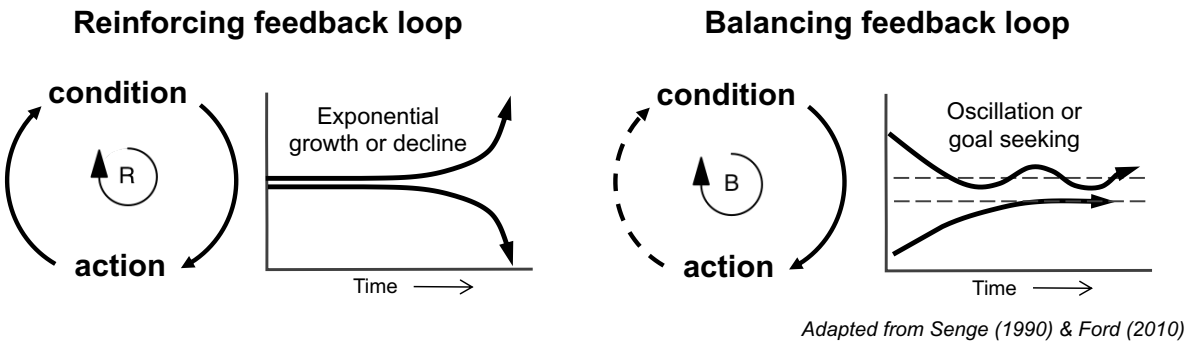

Figure A-3: The two types of feedback loops.

Feedback loops can be made up of more than two variables and can be linked together to form a causal diagram. How these interact in a wider network of loops and influences provides insight into the influences that may be causing a change in the system over time.

How feedback loops and causal diagrams are annotated

This section describes how feedback loops and causal diagrams are annotated.

Labelling variables

As noted in the bathtub analogy section, an important concept within causal diagrams is demonstrating where things build-up (accumulation) or decrease (decumulation). Not all variables need to be represented using the bathtub analogy, but all variables in a causal diagram should be labelled in such a way that they can increase or decrease. This means that they should be described as nouns; have a clear sense of direction, therefore making it obvious that it could increase or decrease; and/or have a normal sense of direction that is positive (or at least when a change in direction is included, it does not become a double negative – e.g., instead of more or less unhappiness we have more or less happiness. Examples to demonstrate this are shown in Figure A-4. In this report, when factors from the diagram are referenced in the text, they are italicised.

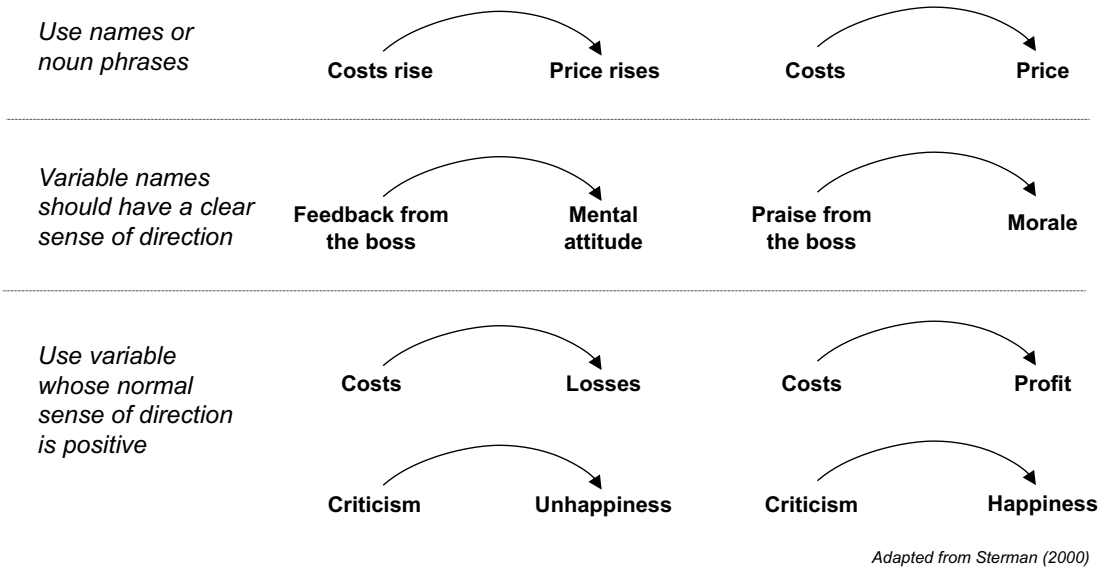

Figure A-4: Labelling variables.

Annotating loops

Variables within causal diagrams are connected (and made into feedback loops) by arrows, indicating that one factor has a causal relationship with the next. These arrows are solid or dashed lines, because they work in either the 'same' or 'opposite' direction. These terms correspond to the direction of change caused by one variable on another (Figure A-5).

For example, if change in one variable leads to change in the next variable in the same direction, it is a same relationship (solid line). Likewise, if the second variable changes in the opposite direction, it is an opposite relationship (dashed line).

Relative delays in the cause-and-effect influence between two variables, when compared to other influences outlined in the causal diagram, are annotated as a double line crossing the arrow. An example of this is shown in Figure A-5.

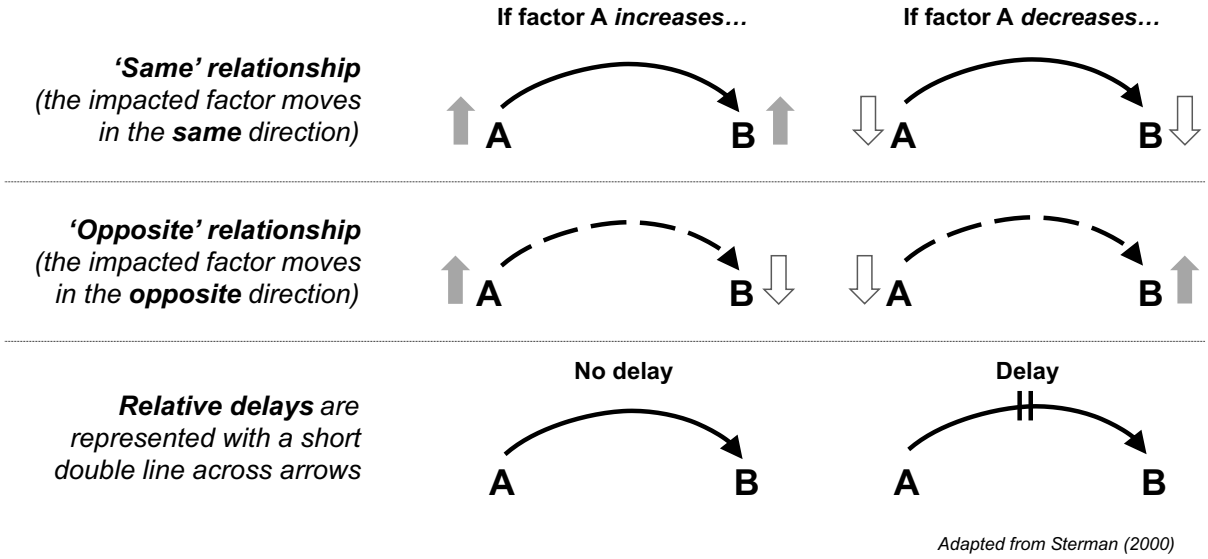

Figure A-5: How arrows and delays are labelled in causal diagrams.

Goals and gaps – driving individual loop dominance

Realising that multiple loops are operating together to generate the behaviour you are trying to understand is the first useful insight of a causal diagram. A further useful insight is understanding that not all loops operate at the same strength all the time. Different loops can dominate at different times. For example, the behaviour generated in a causal diagram might be dominated by a period of growth, but when a physical limit is approached (e.g., the available space in a pond for algae to grow) a balancing loop will start to dominate, therefore slowing the rate of growth.

One useful mechanism for gaining insight into the strength of a balancing loop is '*goal/gap' structure*. This is a feature within the causal diagram that combines both the *desired or aspirational* level for something (a 'goal'), with its *actual* level. The difference between these – aspiration versus actual - is the 'gap'. The higher the desired level and the lower the actual level, the greater the 'gap'. The result is movement towards activities/decisions that narrow the gap between desired and actual. The lower the desired level and the higher the actual level, the lower the 'gap'. This usually leads to decreases in activity because it is nearer its goal.

An example of filling a glass of water is shown in Figure A-6. Initially, while the gap/difference between the desired and actual water level is high, the tap will be opened more. As the desired level of water is approached the gap/difference reduces, so the tap is closed further, until it is fully closed when the water level reaches the desired amount.

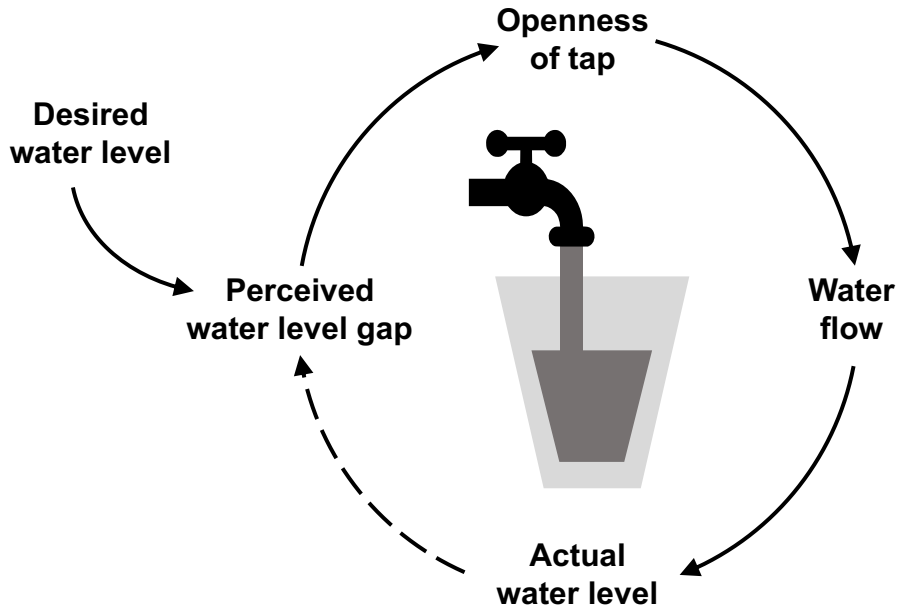

Figure A-6: Example of a 'goal/gap' structure in a system map – filling a glass of water. Adapted from Senge (2006).

How influence operates differently upstream and downstream of a change in flow

When a diagram is made up partly of variables and arrows of influence, as well as a visual bathtub analogy (stock and flows - as this report has), then the flows in or out of a stock

themselves often form pathways of influence within feedback loops. When this occurs, the influence can be either same or opposite, depending on which way along the flow the influence is travelling.

When a flow forms part of a feedback loop and the influence is travelling *with the flow* (i.e., downstream), then that is a same influence. That is, if the flow was to increase (or decrease), then the stock to which it is flowing would also increase (or decrease), all other things being equal.

When a flow forms part of a feedback loop and the influence is travelling *against the flow* (i.e., upstream), then that is an opposite influence. That is, if the flow was to increase (or decrease), then the stock from which it is flowing would decrease (or increase), all other things being equal.

For example, imagine a stock of 'students' at a university and a stock of 'students that have graduated' from that university, joined by a flow of 'students graduating'. An *increase* in the flow of people graduating will *increase* the number of people in the 'graduated' stock – a same influence. At the same time, an *increase* in that flow will *decrease* the number of people in the 'students' stock – an opposite influence.

The flow structure and the variable/arrow influence structure are compared below in Figure A-7.

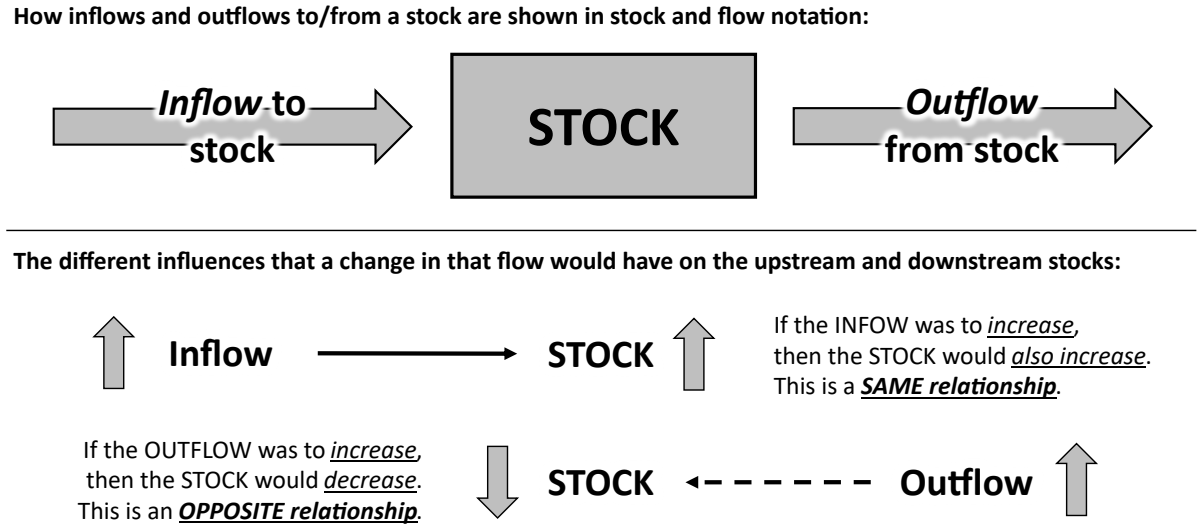

Figure A-7: How influence operates differently upstream and downstream of a change in flow.