HOW FLOOD PROJECTS INFLUENCE URBAN FLOOD RESILIENCE

A CASE STUDY FROM CHRISTCHURCH, NEW ZEALAND

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Abstract
More than 50 percent of the world's population lives in cities, and over two-thirds of the world's cities will be exposed to flooding within the next 30 years. The projected impacts of climate change, such as sea-level rise and an increased likelihood of heavy storms, further increases the need to enhance urban flood resilience. This paper adopts a holistic approach to assess to what extent and why a flood project contributes to urban flood resilience. It combines engineering and social aspects of resilience, with specific attention for the role of the process design, and governance context in which the flood project took place. The approach includes six steps: (1) characterizing the urban system, (2) characterizing the flood project and context, (3) assessing the impact of the project on functional resilience, (4) explaining the functional resilience impact, (5) assessing the impact of the project on adaptive capacity, (6) explaining the adaptive capacity impact. For the functional resilience assessment, a set of 'resilience principles' was used: homeostasis, omnivory, high flux, flatness, buffering, and redundancy. For the adaptive capacity assessment, two hundred sixty adult residents were interviewed using a structured questionnaire. Participants were asked about their involvement in the project, their knowledge, risk perception, perceived adaptive capacity, and motivation. The approach was applied to the Dudley Creek flood project in Christchurch, New Zealand. The study revealed that the flood project as a whole increased the urban flood resilience of the system, both improving functional resilience and adaptive capacity. The project impact was limited in particular with regard to local competences, as the project underutilized the principles of flatness and redundancy, and was not found to significantly impact the motivation and perceived adaptive capacity of citizens. To enlarge the resilience impact of future flood projects, the current study recommends that resilience and local competency targets are incorporated into the project goals. Citizens should be encouraged and facilitated to engage in the response, and to self-respond, to disturbances on a regular basis. A personal/direct engagement approach, two-way dialogue, clear roles for participation, and transparency in decision-making are key.

Keywords: Flood resilience, Urban system, Adaptive capacity, Citizen engagement, Governance, Process design

1. Background

The consequences of climate change are inevitable. Weather is becoming less predictable, rain events more uncertain and heavy storms more likely. Global warming increases flood magnitude as well as flood frequency in many regions (APFM, 2008). Sea-level rise increases the risk of coastal floods even further. The effects of climate change put ecosystems and protected areas under pressure, as many millions of people and infrastructure are projected to be flooded every year (Ministry for the Environment, 2018). Failure in climate change mitigation and adaptation is therefore, as stated by the World Economic Forum (2016), considered the most impactful risk in the years to come.

Urban areas are especially at risk, due to the concentration of people, assets and critical infrastructure, as well as their numerous interdependent sectors and activities (e.g. Fratini et al., 2012; Weyrich, 2016; Kim and Lim, 2016). More than 50 percent of the world's population lives in cities, and over two-thirds of the world's cities will be exposed to flooding within the next 30 years (Ward, Pauw, & Van Buuren, 2013). Particularly at risk are the densely populated low-lying areas in coastal and river flood plains, whose economies are closely linked to climate-sensitive resources, and where adaptive capacity is relatively low (e.g. APFM, 2008; EEA, 2017; Tanner et al., 2009).

The projected impacts of climate change increase the need for making cities 'future-proof'. In this context, the concept of resilience has emerged. It originates from ecology in the 1960's and early 1970's, and has since been adopted by various disciplines (Wardekker, et al., 2010). In particular, resilience has emerged as an attractive perspective with respect to cities, which are often characterized as highly complex and adaptive systems (Godschalk, 2003). The urban resilience approach in the flood risk management field presents resilience as a means by which urban systems can achieve sustainability over time, leading to projects and strategies that better integrate risks into city planning and disaster preparedness (Serre, et al., 2016). It addresses the way cities can sustain progress and development in the face of climate change. It's international recognition is illustrated by the Paris Agreement of 2015, which states that to strengthen the global response to the threat of climate change, a climate resilience approach is needed (UNFCCC, 2015).

A recurring distinction in literature is that between social resilience, engineering resilience and ecological resilience, or a combination of these in the form of socio-ecological resilience (e.g. Kim & Lim, 2016; Liao, 2012; Leichenko, 2011; Adger, 2000; Schlör, Venghaus & Hake, 2016; Wardekker, et al., 2010). Resilience in engineering is usually related to the capacity of a system to resist changes in state and continue functioning, while ecological resilience addresses the adaptive capacity of the system (Rezende, et al., 2019). Considering that urban areas are socio-ecological systems, consisting of both engineering components (e.g. flood measures) and social components (e.g. the individuals acting to manage the system), both definitions (e.g. engineering and ecological resilience) can be joined. Based on Walker, et al. (2004), urban resilience in the current study is defined as the combination of a system's ability to absorb disturbances and retain its functions (from here on referred to as *functional resilience*), and the ability of the individuals' within the system to adapt to disturbances/reorganize while undergoing change (from here on referred to as *adaptive capacity*) (see Figure 1).

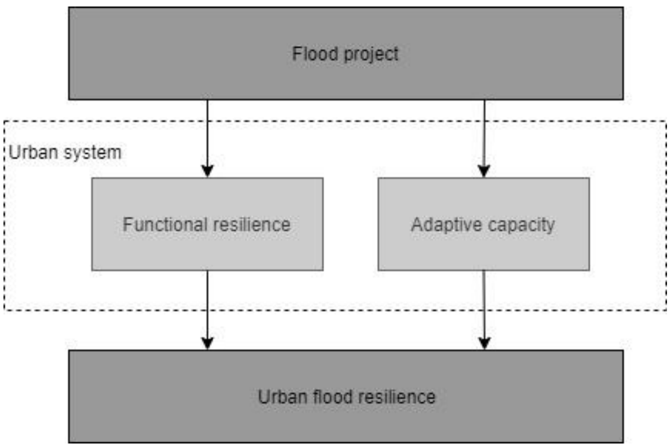

Figure 1: Relation between a flood project, urban system, and urban flood resilience

Though evidence suggests that processes for enhancing urban resilience depend highly on the process design and the governance context in which they are conducted, studies that analyze how they affect the process are still not common practice (e.g. de Vente, et al., 2016; Newig, et al., 2013; Füssel, 2007; Bierbaum & Stults, 2013; Agrawal, 2010; Wolf, 2011). A governance perspective on adaptation and flood risk management has the potential to provide crucial insights into how to improve resilience, and to enhance our understanding of how urban systems can successfully cope with current and future flood risks (Driessen, et al. 2016). Furthermore, literature indicates that research should not only focus on the physical flood measures that are the outcome of the processes, but also on understanding and managing adaptive capacity of the individuals involved (e.g. Carpenter, et al. 2001; Fazey, et al. 2018; Kotzee & Reyers, 2016). As most research focuses on evaluating the process itself, rather than the impact of the process, research is needed that uses specific criteria for evaluating this impact (e.g. Carpini, Cook, & Jacobs, 2004; Rowe & Frewer, 2004; Reed, 2008). In short, literature indicates a need for a holistic approach to understanding and enhancing urban resilience and the processes that lead up to it, as well as a need to build an evidence base of what does (and does not) contribute to resilience (e.g. Silva, Kernaghan, & Luque, 2012; Morrison, Westbrook & Noble, 2017).

The current research applies such a holistic approach, and asks the central question: To what extent and why does a flood project influence the functional resilience and adaptive capacity of an urban system? It contributes to resilience literature by providing directions for enlarging the impact of future flood projects on urban flood resilience. Literature on urban resilience, adaptation, adaptive capacity, governance, and citizen engagement is combined to devise a set of assessment criteria and explanatory variables. Based on this, the research uses a case study approach to assess to what extent and why the Dudley Creek flood project in Christchurch, New Zealand, influences the flood resilience of the urban system. The extent to which the flood project contributes to urban resilience is determined by assessing its impact on the urban systems' ability to absorb disturbances and retain its functions, as well as its impact on the adaptive capacity of the citizens. The impact of the flood project is explained by examining the process design, engagement process, and the governance context in which the project took place.

The outline of the paper is as follows. The next section describes and defines the key concepts of flood projects, urban systems, resilience, and adaptive capacity. Section 3 introduces the case study, and describes the methodology and approach of the research. After this, the paper is divided into two parts. Part I provides a characterization of the urban system and flood project, results of the functional resilience assessment, and analysis of the functional resilience impact. Part II provides the results of the adaptive capacity assessment, and analysis of the adaptive capacity impact. Section 6 brings the two parts back together, discusses the relationships between the results and the theory, and reflects on the presented approach. Section 7 presents the main conclusions and recommendations.

2. Key Concepts

The following section describes and defines the key concepts of flood projects, urban systems, resilience, and adaptive capacity. Based on the relation between these concepts the assessment approach for answering the research question is provided.

Flood project

A flood project in the current study refers to a project in a specific context, targeting a specific area, that uses flood measures to prevent or minimize the occurrence of floods, as well as to prevent or reduce the detrimental effects of floods to that area. At the core of a flood project lies a decision-making (i.e. adaptation) process, which can lead to structural as well as non-structural measures. Structural measures refer to any physical construction activities to reduce or avoid the possible impact of a flood event, or the application of engineering techniques or technology to achieve flood resistance and resilience in structures or systems. Non-structural measures refer to non-physical measures, which use knowledge, practice or agreement to reduce flood risk and its impact (UNDRR, 2009).

Urban system

Since flood management issues are not just social, engineering, or ecological issues, but have multiple integrated elements, the current study focuses on the resilience of an urban (socio-technical-environmental) system. A system is defined as 'an interconnected set of elements, that is coherently organized in a way that achieves something (e.g. has a function or purpose)' (Meadows, 2009, p.11). Elements of an urban system include both engineering components (e.g. flood measures) and social components (e.g. the individuals acting to manage the system).

Resilience

In the literature, resilience is defined in various ways. Resilience may refer to a system, community, institution, region or society as a whole. Jha, Miner, and Stanton-Geddes (2013) describe it as the general ability of something exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard promptly and efficiently. Resilience is closely related to risk and uncertainty, and is often described in relation to the phases of disaster risk management, namely mitigation, preparedness, disaster response, recovery and reconstruction (Jha, Miner & Stanton-Geddes, 2013). However, new definitions have emerged, such as the one by Jovanovic, et al. (2016), who link resilience to the ability to adapt to changing conditions, and include a general understanding of the risk and analysis of the absorption capacity. The importance of 'adaptation' is also stressed by Birkholz, et al. (2014) and Stevenson, et al. (2017), who point towards the need for continuous and flexible adaptation to changing circumstances, in a way that allows for learning, utilizing opportunities and mitigating the adverse impacts in the future. Birkholz, et al. (2014) advise that, in the context of managing flood risks, a resilience based strategy should not aim to return to a status quo after a flood event, but rather be open to continuous and flexible adaptation to changing circumstances.

Adaptation can be interpreted as a reorganization of the system, resulting from a decision-making process and set of actions undertaken to maintain the capacity to deal with future change or perturbations to the system (Nelson, Adger, & Brown, 2007, p.397). Adaptation includes building adaptive capacity, with the goal of increasing the ability of individuals to adjust to changes and implement adaptation decisions. Adaptive capacity refers to the ability of an individual to reduce direct and indirect risk, through marginal or incremental changes to the system (Mochizuki, et al., 2018). Adaptive capacity is an important element of the social context of the urban system, which entails characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from an impact (Wolf, 2011). It is these characteristics of individual capacities that determine behavior, and therefore describe the preconditions necessary for a system to be able to adapt to disturbances (Nelson, Adger, & Brown, 2007).

A study that brings together the aforementioned elements of absorption capacity and adaptation in the context of an urban system is that of Walker, et al. (2004). Based on Walker, et al. (2004), urban resilience in the current study is defined as the combination of a system's ability to absorb disturbances and retain its functions (*functional resilience*), and the ability of the individuals' within the system to adapt to disturbances/reorganize while undergoing change (*adaptive capacity*).

Assessment approach

Based on the provided definitions and relation between a flood project, urban system, and urban flood resilience, the extent to which a flood project contributes to urban resilience in the current study is determined by both its impact on the urban systems functional resilience, and its impact on the adaptive capacity of the individuals within the system. The resilience impact is considered the result of structural- and non-structural flood measures of the project, the process design, citizen engagement, and context in which the flood project took place (see Figure 2). Part I focuses on the impact of the flood project on the functional resilience, and Part II focuses on the impact of the flood project on the adaptive capacity.

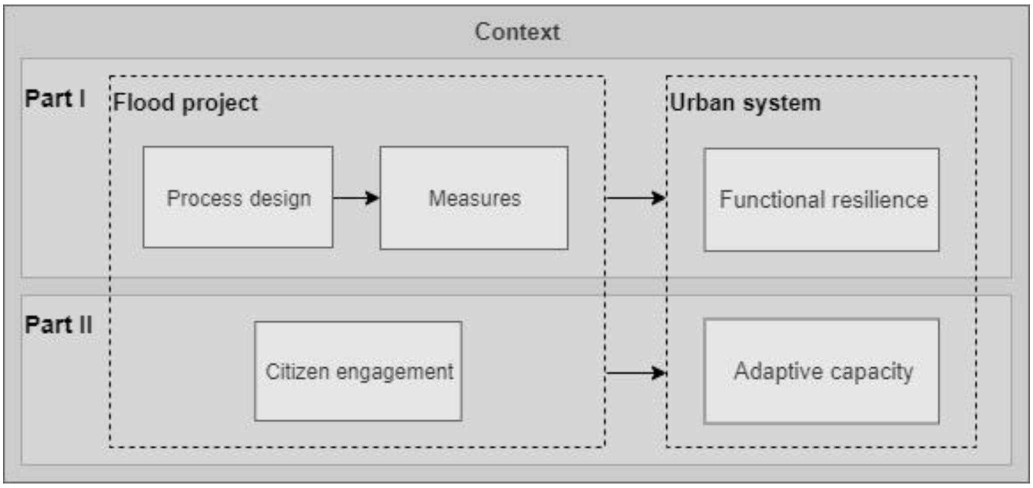

Figure 2: Assessment approach

3. Methodology and approach

To answer the research question of the current study, "To what extent and why does a flood project influence the functional resilience and adaptive capacity of an urban system", a case study approach was chosen. The case study approach is used because of the desire to explore the relation between the implementation process of a flood project and the real-life context in which it takes place. The case study approach allows for a more in depth analysis than other approaches, and allows to deduct relations from the real-life phenomenon.

3.1. Case study

The case study project chosen as subject for the resilience assessment is the Dudley Creek Flood Remediation project in Christchurch, New Zealand. The project was initiated to reduce flood risk in the

Dudley Creek/Flockton area. The project is selected as case study as it was fully completed in August 2018, its process and outcomes are well documented, and it was highly commended for its thorough consultation process and engagement strategy (LGNZ, 2016). The documentation and distinctive action with regard to citizen engagement allows for an assessment of both the impact on the functional resilience of the urban system, and the adaptive capacity of the citizens. The recent completion also means that engaged citizens can recall past events more easily.

Christchurch

Christchurch is naturally flood prone, as the city lies in the vicinity of rivers and the coast, and is built on low-lying land on the flood plain of the Waimakariri River (Regenerate Christchurch, 2018b). Climate change is expected to affect the city in the form of rising sea levels, more frequent storm surges, rising groundwater levels, and higher intensity storms. Recent earthquake events have caused land movement and changes to waterways that have made some areas even more prone to flooding (e.g. Christchurch City Council, 2018c; McFarlane, 2015). Currently already around 30% of Christchurch residents live in areas at risk of flooding (e.g. Christchurch City Council, 2018a and 2018b).

The risk from flooding is not the same in all parts of the city, and ranges from areas where no risk is identified, to areas in potentially significant hazardous conditions. Figure 3 shows the flood prone priority areas of the city. Of the homes with repeated flooding in Christchurch, roughly seventy percent (approx. 600 homes) are situated in the Flockton area, which lies North of the city center (Christchurch City Council, 2014).

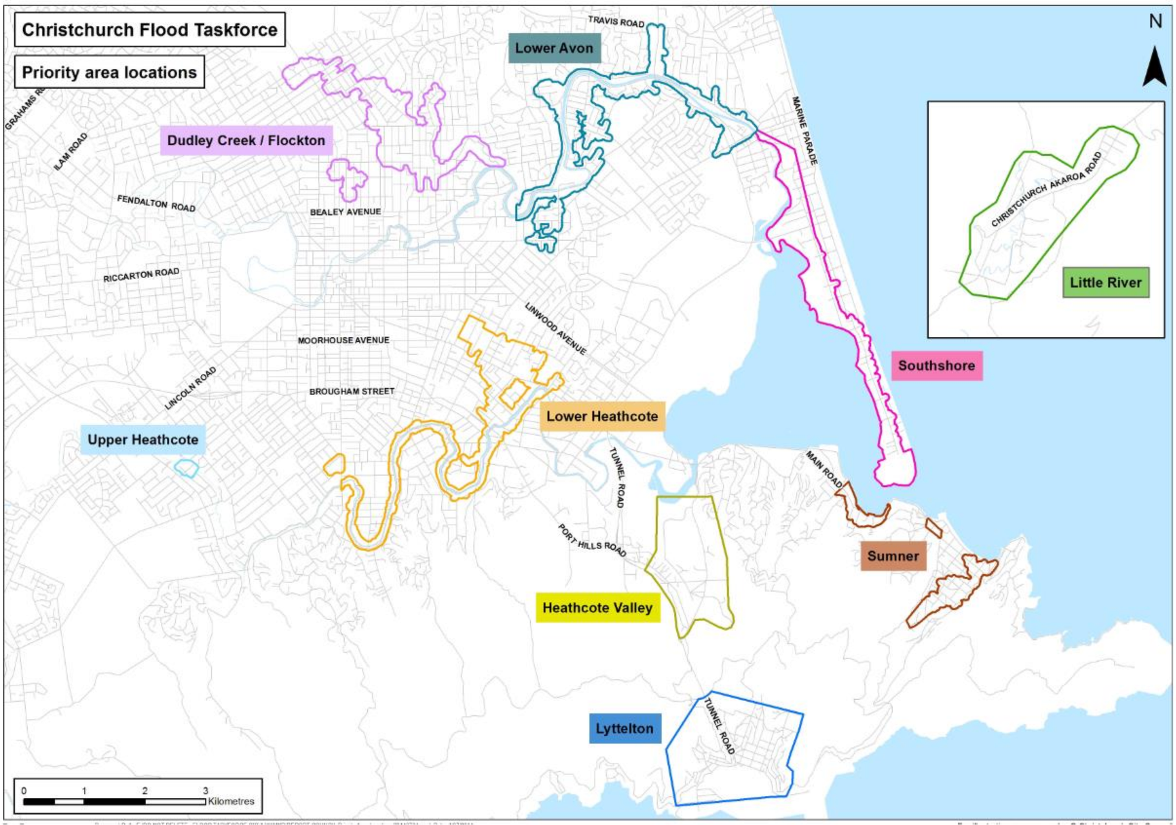

Figure 3: Flood prone priority areas of Christchurch (Mayoral Flood Taskforce, 2014a, p.12)

Dudley Creek/Flockton area

The Dudley Creek/Flockton area is part of the Dudley Creek catchment, which begins in Bishopdale and runs through Papanui, Mairehau and St Albans to Shirley. Dudley Creek ends at River Road, where it flows into the Avon River. Within the catchment lies the Flockton Basin, which is bound by Flockton and Aylesford Streets. It has the topography of a basin, leading to significant ponding during flood events (Mayoral Flood Taskforce, 2014b). The Dudley Creek/Flockton area is mainly residential, with over two thousand properties over an area of about three square kilometers (Smith M. , 2017).

The Dudley Creek catchment has a history of flooding, with documented flood events across the area, dating back to the early 1900's. The area continued to flood up until the 1970's, till the Dudley Creek

Diversion was constructed. The combination of the diversion and a period of fewer severe rainfall events led to a significant decrease in flood risk, and no reported flooding of the area up until the 2010/2011 Canterbury Earthquake Sequence. Since the earthquakes however, there have been several floods in the area, including August 2012, June 2013, and three times within March and April 2014 (Mayoral Flood Taskforce, 2014c).

Figure 4 shows the Dudley Creek case study area, based on the prioritization as made by the Mayoral Flood Taskforce (2014b). Highlighted are the Dudley Creek, Shirley Stream, St. Albans Creek, and Avon River. The red lines indicate the location of Aylesford street and Flockton street, between which the Flockton basin is situated. The two turquoise lines, from top to bottom, represent respectively the Mairehau and the Bing's Drain.

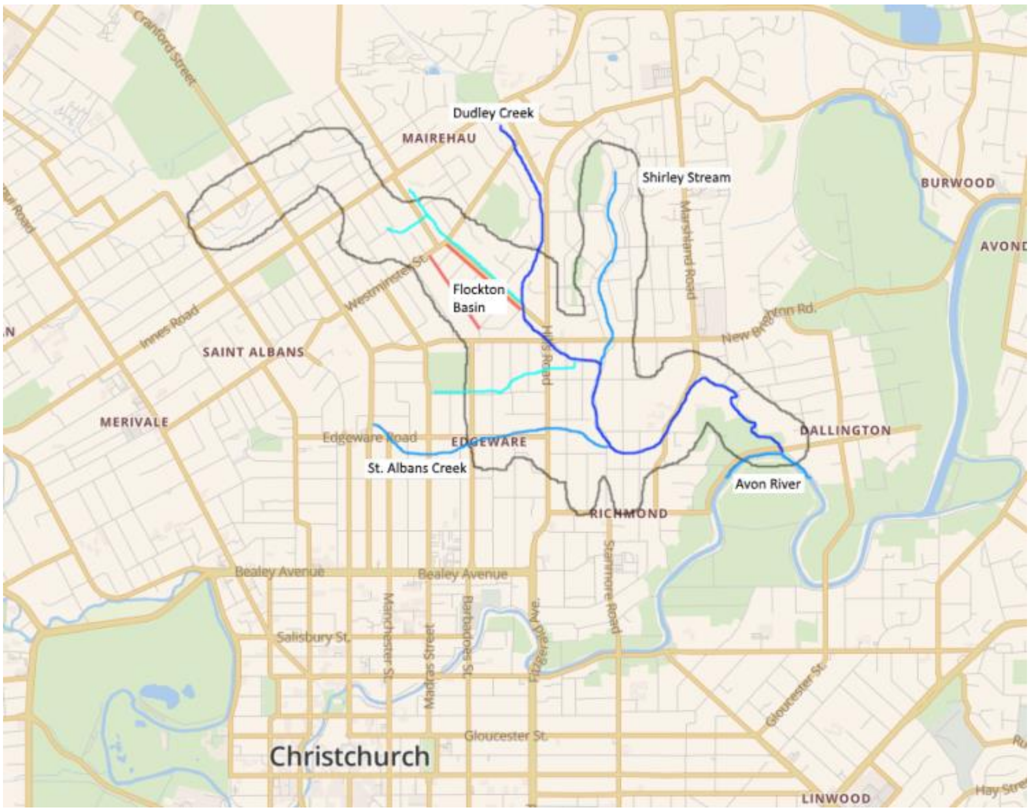

Figure 4: Dudley Creek case study area

3.2. Six-step approach

Data collection and analysis was based on the separation between the two elements of urban resilience (i.e. functional resilience and adaptive capacity), combined in a six-step approach (Figure 5).

For part I – Functional resilience, four distinctive steps were taken:

1. Characterization of the urban system, in terms of the key functions, key disturbances, and impact of the disturbances on the system functions.
2. Characterization of the flood project and context, in terms of the structural- and non-structural flood measures, the process design, governance context, and engagement process.
3. Assessment of the impact of the project on the functional resilience, using resilience principles.
4. Explanation of the impact of the project, analyzing the relation between the functional resilience impact, the process design and governance context.

For part II – Adaptive capacity, two distinctive steps were taken:

5. Assessment of the impact of the project on adaptive capacity, using adaptive capacity indicators.
6. Explanation of the impact of the project, analyzing the relation between the adaptive capacity of citizens, the engagement process, governance context, and interview data.

The steps are discussed in detail in Part I – Functional resilience, and Part II – Adaptive capacity.

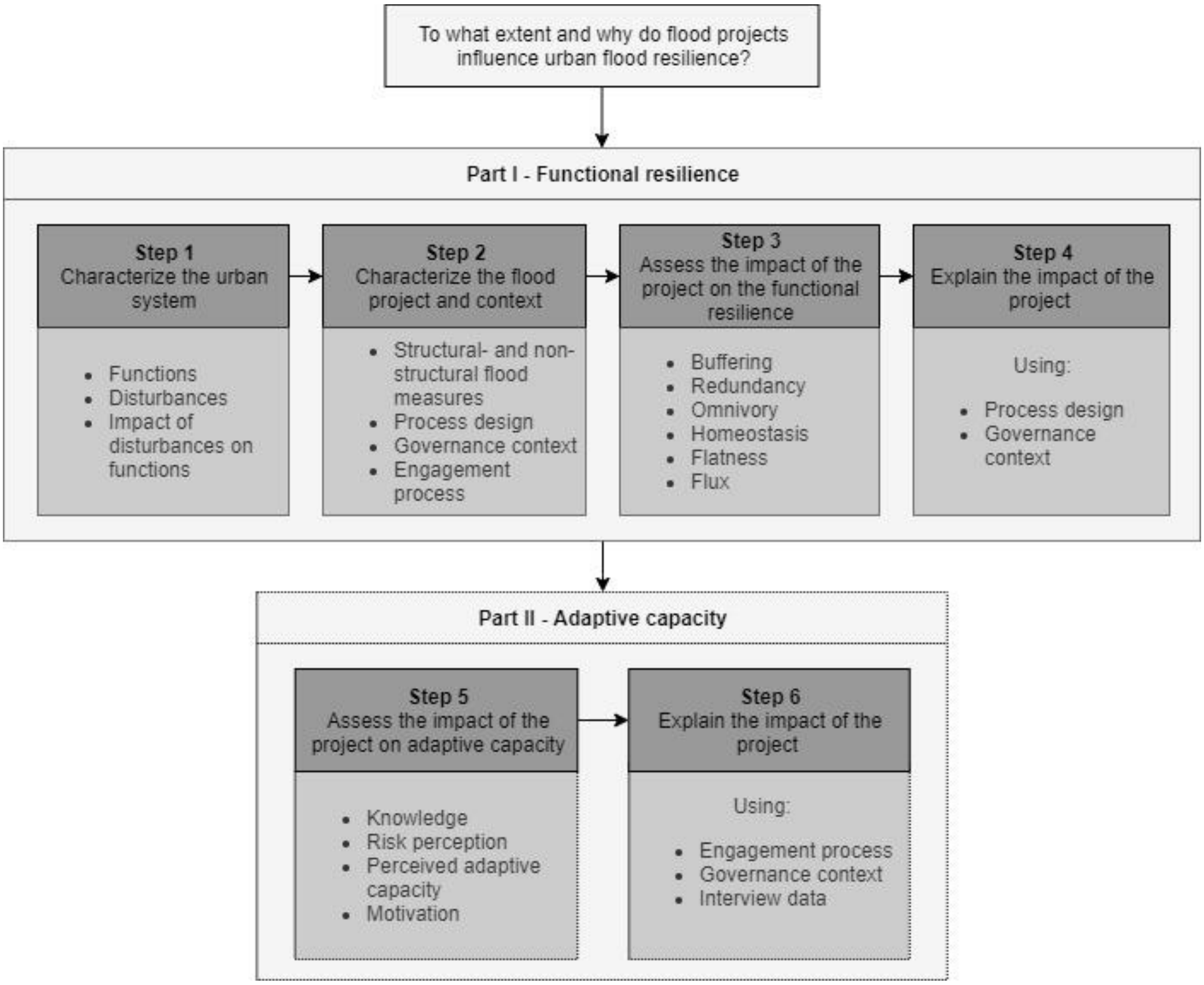

Figure 5: Six-step approach for assessing to what extent and why a flood project contributes to urban resilience

Part I – Functional resilience

1. Theory

1.1. Functional resilience principles

The current study is interested in the operational application of resilience principles to conduct an assessment of the impact of a flood project on the functional resilience of an urban system. A study that brings together the different components/principles of resilient urban systems, in a framework that allows for such an assessment, is that of Wardekker, et al. (2016). The principles they utilize originate from systems dynamics literature, and have been applied successfully to generate and categorize resilience-oriented adaptation options (Watt & Craig, 1986). The functional resilience principles consist of buffering, redundancy, omnivory, homeostasis, flatness, and high flux (Wardekker, 2016). The first three focus on absorbing disturbances, while the others focus on quick responses, recovery, self-organization, and learning. Table 1 provides a brief description of the aforementioned resilience principles. If the measures of a flood project lead to a high level of redundancy, high level of omnivory, high level of buffering, high level of homeostasis, high flux and flatness, this will mean that the project has increased the functional resilience of the urban system.

Table 1: Functional resilience principles (Wardekker, 2016, p. 11)

Resilience principle	Primary mechanism	Description
Buffering	Absorbing disturbances	Essential capacities are over-dimensioned, such that critical thresholds are less likely to be crossed.
Redundancy	Absorbing disturbances	The system contains overlapping functions; if one fails, others can take over. Multiple copies of one approach, function, or service.
Omnivory	Absorbing disturbances, recovery, reorganization	Diversification of resources and means that a specific function depends on or can mobilize in the event of a disturbance. Multiple different approaches that can be used alongside each other, rather than copies of one approach.
Homeostasis	Quick response, self-organization, learning	Multiple feedback loops counteract disturbances and stabilize the system.
Flatness	Quick response, self-organization	The hierarchical levels relative to the base should not be top-heavy. Overly hierarchical systems without local formal competence to decide and act, are too slow to respond to surprise and implement non-standard local responses.
High flux	Quick response, recovery, reorganization	A fast rate of movement of resources through the system ensures quick mobilization of these resources to respond to shocks and changes.

Though urban resilience is widely accepted as a concept that can help cities prepare for the future, its assessment has proven challenging. Various reports have been published discussing the operationalization of resilience, but so far no single universal framework exists. Some researchers describe general resilience characteristics and principles, while others use specific resilience factors and indicators. Literature on the way that resilient systems are described, and the different resilience assessment methods utilized, shows that, even though the description of methods and their application differs, there are common denominators. At first glance, literature seems to disagree on the ways to describe resilient systems, but at closer investigation the greatest difference lies in the wording, as the explanation of the assessment variables is similar.

The principles of Wardekker, et al. (2016) are used, as they encompass the resilience variables/indicators that were mentioned by most works (see Table 2). The functional resilience principles of Wardekker, et al. (2016) (as shown in Table 1) describe specific mechanisms by which a system can absorb disturbances and retain its functions (i.e. can be resilient). They can be used to evaluate proposed options/plans, and be applied in a wider process of resilience assessment, reflecting on the situation, urban systems and its components. This makes the resilience principles of Wardekker (2016) highly suitable for the current study.

Table 2: Relation between resilience indicators and principles of Wardekker, et al. (2016)

Resilience principle of Wardekker, et al. (2016)	Relating indicator of a resilient system	Description of the relation between indicator and resilience principle of Wardekker, et al. (2016)
Buffering	▪ Safe failure (e.g. Tyler & Moench, 2012; Silva, et al., 2012)	Wardekker, et al. (2016) describe buffering as over-dimensioning essential capacities/providing spare capacities, which is also mentioned as part of the safe failure argument. Over-dimensioning essential capacities increases the ability to absorb sudden shocks, including those that exceed design thresholds, or the cumulative effects of stress on the system.
Redundancy	▪ Redundancy (e.g. Cutter, et al., 2010; Ahern, 2011; Tyler & Moench, 2012; Silva, et al., 2012; Biggs, et al., 2012; Kim & Lim, 2016) ▪ Modularity (e.g. Resilience Alliance, 2010; Ahern, 2011; Kim & Lim, 2016; Suárez, et al., 2016) ▪ Safe failure (e.g. Tyler & Moench, 2012; Silva, et al., 2012) ▪ Multi scale networks and connectivity (e.g. Ahern, 2011; Biggs, et al., 2012)	Wardekker, et al. (2016) describe redundancy as having overlapping functions within a system, which act as a back-up. The aim of this principle is to absorb disturbances, by means of having multiple instance of something available, where failure of the one doesn't affect the other. This is closely related to the modularity argument, as it addresses more than one way of meeting specific needs, with physically distributed assets and functions. Modularity ensures that failure of one element doesn't transfer through entire system, which is also an important element of the safe failure argument. At the same time, redundancy relates to networks and connectivity, as it builds resilience through redundant connections.
Omnivory	▪ Diversity (e.g. Cutter, et al., 2010; Resilience Alliance, 2010; Ahern, 2011; Tyler & Moench, 2012; Biggs, et al., 2012; Suárez, et al., 2016)	Wardekker, et al. (2016) describe omnivory as having multiple ways of fulfilling one's needs in the event of a disturbance, which relates to functional diversity, as it means that a specific function is not dependent on a sole resource or means.
Homeostasis	▪ Tightness of feedbacks (e.g. Resilience Alliance, 2010; Suárez, et al. 2016) ▪ Responsiveness (Silva, et al., 2012) ▪ Planning foresight (Kim & Lim, 2016) ▪ Adaptive planning and design (Ahern, 2011)	Wardekker, et al. (2016) describe homeostasis as the property of a system to actively keep a variable constant through feedback mechanisms. In other words, it entails incorporation of multiple feedback loops, that counteract disturbances and stabilize the system. It aims to provide the means for a quick response and self-organization, by targeting the relations between elements of an urban system. It relates to adaptive planning and planning foresight, as it uses the feedback mechanisms to gain information, which forms the input for decision-making and dealing with future uncertainties.

Flatness	▪ Responsiveness (Silva, et al., 2012) ▪ Flexibility (e.g. Tyler & Moench, 2012; Silva, et al., 2012; Kim & Lim, 2016) ▪ Tightness of feedbacks (e.g. Resilience Alliance, 2010; Suárez, et al. 2016) ▪ Innovation (Suárez, et al. 2016)	Wardekker, et al. (2016) use flatness to describe a resilient system as one that has few hierarchical levels/is not top-heavy. By ensuring that there is formal local authority on the lower levels, response decisions can be made more quickly, as early-warning signals directly translate to action. This relates to the flexibility, responsiveness and tightness of feedbacks arguments, as the feedback lines are shortened, decreasing the response time and increasing the flexibility to cope with surprises. This flexibility also relates to the innovation element, as collective learning and experimentation supports creation of new ways to respond to changes.
High flux	▪ Mobility (Kim & Lim, 2016) ▪ Adaptive planning and design (Ahern, 2011) ▪ Planning foresight (Kim & Lim, 2016)	Wardekker, et al. (2016) use the principle of high flux to describe the rate at which resources move through the system. A fast rate enables quick mobilization of these resources in response to a disturbance. It relates to adaptive planning and design, in the sense that the urban land-use plan should include flexible, easy to modify land uses, in order to achieve a high flux. Furthermore, the planning horizon for buildings could be shortened, and their design could include modular elements, allowing quick accommodation to changing conditions. This relates to the planning foresight argument, as it concerns preparing for the future and indicates that constantly changing conditions should be included.

1.2. Process design

Evidence suggests that processes for enhancing urban resilience depend on the design of the process (e.g. de Vente, et al., 2016; Newig, et al., 2013). The current study aims to find out how the process design of a flood project affects (e.g. restricts) the implementation process, and ultimately the projects functional resilience impact. According to literature on project life cycles, decision-making processes, and project success factors, process design elements that play an important role with regard to the outcome (e.g. flood measures) of a flood project are the initiator, goal, rationale, objectives and success criteria, and resources.

The **initiator** is the organization or group who (formally) initiated the decision-making process of the flood project. The initiator can be a governmental actor (e.g. national or local government), non-state actor (e.g. private or civic sector), or citizen(s) (Newig, et al., 2013). Different initiators can have different levels of authority, capacities and resources, depending on their administrative level. Generally, the involvement of higher-level authority is assumed to increase the chances of a project reaching its (resilience) goals (Spalek, 2005). It is closely related to the governance context of the project, as, for example, a local government will design the process based on achieving outcomes for a local situation, while the decision-making process of a national government works on a more global scale (e.g. Spalek, 2005; Newig, et al., 2013).

The main **goal** and purpose of a project is an expression of the motivation of the initiator to start the process. Depending on who the initiator is, different goals may be pursued, leading to different outcomes and outputs (e.g. Spalek, 2005; Beleiu, Crisan, & Nistor, 2015; Taherdoost & Keshavarzsaleh, 2016). This implies that, if the goal does not address resilience, the impact of the project may be limited.

The **rationale** behind the decision-making process can provide insight into why a specific course of action was taken, based on the underlying beliefs of the initiator and project team. The rationale can focus, for example, on empowerment, legitimacy, effectiveness, environmental benefit, long-term efficiency, urban resilience, or climate change adaptation (e.g. Newig, et al., 2013; Driessen, et al., 2016; Bressers, Bressers, & Larrue, 2016). Similar to the formulation of the goal, if the rationale does not focus on urban resilience, the resilience impact of the project may be limited.

The **objectives and success criteria** describe the way in which the initiator aims to achieve its goal. While the goal describes a broad outcome, the objectives concern measurable steps as part of a strategy to reach the specific goal. The success criteria describe when, and to what degree, the specific objectives have been reached. They also reflect the priorities of the project team with regard to the potential outcomes and outputs (e.g. Newig, et al., 2013; Taherdoost & Keshavarzsaleh, 2016). In other words, to maximize the resilience impact of the project, the objectives and criteria need to incorporate resilience.

The **resources** available to support the decision-making process may influence the strategy that is taken, and, in turn, the outcomes and output of the project. If, for example, limited time and money is available, decisions may be made over a shorter time span, allowing less deliberation about potential (alternative) outcomes, and the development of knowledge through scientific assessments (e.g. Newig, et al., 2013; Beleiu, Crisan, & Nistor, 2015; Taherdoost & Keshavarzsaleh, 2016). Consequently, if resources are limited, non-optimal solutions (from a resilience perspective) may be chosen.

1.3. Governance context

In addition to the process design, evidence suggests that processes for enhancing urban resilience depend highly on the governance context in which they are conducted (e.g. de Vente, et al., 2016; Newig, et al., 2013; Füssel, 2007; Bierbaum & Stults, 2013; Agrawal, 2010; Wolf, 2011). The current study aims to find out how the governance context in which flood projects are conducted affects (e.g. restricts) the process design, and ultimately the projects resilience impact.

To describe the underlying governance conditions that influence the process design of a flood project, a set of indicators are needed. A study that provides such a set is that of Bressers, Bressers & Larrue (2016). Their Governance Assessment Tool (GAT) views governance as context for actor interactions and implementation. Bressers, Bressers & Larrue (2016) define governance as "the combination of the relevant multiplicity of responsibilities and resources, instrumental strategies, goals, actor networks and scales that forms a context that to some degree restricts, and to some degree enables actions and interactions" (Bressers, Bressers & Larrue, 2016, p.6). In other words, the governance context is considered a combination of five dimensions: levels and scales, actors and networks, problem perception and goal ambitions, strategies and instruments, responsibilities and resources for implementation. To indicate what condition of the five dimensions of governance contributes to a supportive rather than restrictive governance context, Bressers, Bressers & Larrue (2016) specify four qualitative criteria. These are extent, coherence, flexibility and intensity.

Extent refers to the question whether all elements in the five dimensions that are relevant for the project are taken into account. As different actors and stakeholders may have different opinions/preferences regarding what is important and which approaches to take, choosing who will take part can influence the direction the process takes and the outcome of decision-making (e.g. Spalek, 2005; Newig & Fritsch, 2009; Newig, et al., 2013; Beleiu, Crisan, & Nistor, 2015; Taherdoost & Keshavarzsaleh, 2016). It is assumed that a low extent may restrict an urban flood resilience approach.

Coherence refers to the question whether the elements in the dimensions of governance reinforce, rather than contradict each other. More coherent governance arrangements will lead to less discord, less power imbalances, more win-win situations, and less uncertainty (due to more exchange of information and less distrust) (e.g. Bressers, Bressers, & Larrue, 2016; de Vente, et al., 2016). It is found that non-coherent governance arrangements will lead to more discord between the actors, as they may strive towards different goals, more uncertainty, and more stalemates, due to power imbalances. For this reason, low coherence is associated with restricted implementation (Bressers, Bressers, & Larrue, 2016).

Flexibility refers to the question whether multiple roads to the goals, depending on opportunities and threats as they arise, are permitted and supported. It is assumed that if flexibility is low, adaptive behavior will be avoided, as the governance context does not support and facilitate adaptive actions and strategies (Bressers, Bressers, & Larrue, 2016).

Intensity refers to the question of how strongly the elements in the dimensions of governance urge changes in the status quo or in current development. It assumed that the urge to use adaptive strategies, to deal with and change the setting of the process, increases as the intensity increases (Bressers, Bressers, &

Larrue, 2016). In other words, the lower the intensity, the lower the likeliness of adaptive strategies to be used.

In literature, scholars specify different ways to describe the governance context. An example of this is the research of Newig, et al., (2013), who describe the governance context based on the distinction between the policy space of the decision-making process, and the multi-level spatial aspects (e.g. geographical location, policy levels involved, jurisdictional levels). Larrue, Hegger & Trémorin (2013), on the other hand, focus less on the structure, as they use the categorization of actors, rules, resources and discourses to describe the governance context. An attempt to establish a universal assessment tool is provided by Fleischhauer, et al. (2012). The Risk Governance Assessment tool they propose relies on key questions for comparing objectives to outcomes.

The GAT is used in the current study, as it claims to be a tool for assessing a full governance setting, as opposed to many of the other methods mentioned, which tend to focus on specific aspects. By distinguishing between descriptive and normative elements, the approach separates conditions and activities. The normative criteria are derived from a specific goal, namely the feasibility and likelihood of realization of a certain category of measures or projects (e.g. the promotion of urban flood resilience). While many approaches focus on the performance, and use 'governance' for both the process and the contextual conditions for the process, the GAT uses 'governance' just for the context. It views the context and process as related, but separated, making it possible to study the impact of the governance conditions on the process design.

2. Method

Part I of this study focuses on the first four steps of the research approach, which are summarized in Figure 6.

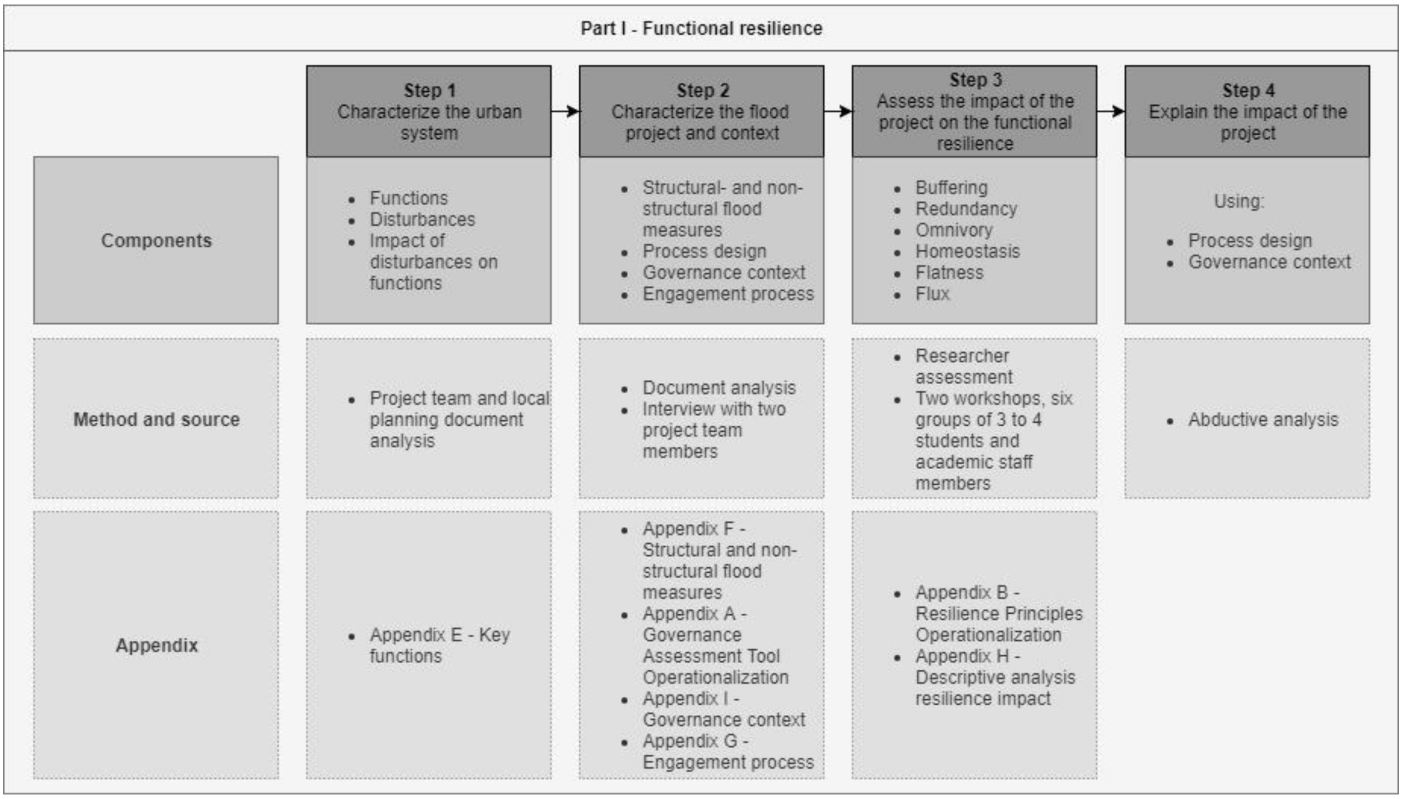

Figure 6: Functional resilience approach, including components, methods and sources, and appendices

Step 1: Characterization of the urban system

Before assessing the resilience implications of a flood project on urban flood resilience, it is necessary to establish what resilience means in the context of the study area. A systems thinking approach can be used, specifying resilience 'of' what, 'to' what (Carpenter et al., 2001). The systems approach is holistic, as it does not focus on a detailed understanding of parts, but on how key components contribute to the dynamics of the whole system (Resilience Alliance, 2010). To describe the resilience of an urban system, the current study draws on the works of the Resilience Alliance (2010) and Wardekker, et al. (2016), who stress the importance of characterizing the system under study and its (current) state. Characterization of the urban system is based on its key functions, key disturbances, and the impact of the disturbances on the functions. The key functions are the desirable aspects of the system which should be made resilient. They depend on what is valued as the most important aspects of the system, and form the base for the assessment of the urban resilience implications of the flood project. The key disturbances describe the main issues/challenges that the system faces. As indicated by Wardekker, et al. (2016), determining what is a key function is inherently subjective. It depends on what local stakeholders and decision makers value as the most important aspects of the region/system. Therefore, identification of the key functions should be participatory, or at least based on existing, stated priorities by local actors, using, for example, existing policy plans, interviews, workshops, and/or other input by stakeholders (Wardekker, et al., 2016).

The key functions of the Dudley Creek urban system are determined by means of local planning documents (e.g. Christchurch District Plan), combined with project team documents (e.g. Mayoral Flood Taskforce, 2014c; Christchurch City Council, 2019). The district plans represent the Council's view on the key functions of the urban system. The disturbances and their impact on the key functions are based on a document analysis.

Step 2: Characterization of the flood project and context

A flood project can be characterized based on its achieved output (e.g. the structural- and non-structural measures that are the result of the decision-making process), the design of the process, the engagement process, and the governance context in which it was conducted. Depending on the intended level of detail, inventarisation of the *achieved output* and *process design* (i.e. initiator, goal, rationale, objectives and success criteria, and resources) can be based upon field observations, project documents, and/or interviews with the project team members. The *engagement process* of a project can be described based on the goal of the engagement, and the participation methods used (e.g. referenda, public hearings, public surveys, focus groups, etc.) (Rowe & Frewer, 2000). The *governance context* can be described using the Governance Assessment Tool of Bressers, Bressers & Larrue (2016). The tool consists of a set of questions, which need to be operationalized to suit the topic of the research (e.g. examine the way in which the governance context influenced the process design of a flood project). The operationalized tool can then be used to describe the governance context in terms of the levels and scales, actors and networks, problem perspectives and goal ambitions, strategies and instruments, and responsibilities and resources. The quality criteria (i.e. extent, coherence, flexibility, intensity) can be used to identify supportive and restrictive elements of the governance context for each of the five dimensions mentioned above. The GAT can be used by stakeholders and (individual) project team members themselves, or as a guidance for interactive workshops/interviews with stakeholders and project team members (Bressers, Bressers & Larrue, 2016).

Characterization of the Dudley Creek flood remediation project is based on project documents (Mayoral Flood Taskforce, 2014a;b;c; Christchurch City Council, 2014; Christchurch City Council 2015), a project managers perspective (Smith, 2017), and information provided by project team members (Personal communication, 2019). A structured interview with two Dudley Creek project team members was conducted, using the operationalized Governance Assessment Tool (Appendix A). The researcher asked the project team members to answer the questions of the GAT together, and discuss the answers to explore the relation between the governance context and the process design. The verbal information provided by the project team members, where possible, was confirmed by written (project) documents.

Step 3: Assessment of the impact of the flood project on the functional resilience

To assess the impact of the flood project on the functional resilience of the urban system, the resilience principles of Wardekker, et al. (2016) (e.g. omnivory, buffering, redundancy, homeostasis, flatness, high flux) are used. The characterization of the flood project (e.g. structural- and non-structural measures) is assessed in relation to the characterization of the urban system (e.g. impact of the key disturbances on the key functions). Before conducting the assessment, the resilience principles need to be operationalized, reflecting on what they could mean for the case study area and the different functions of the urban system.

The impact assessment is then based upon comparing the measure mechanisms to the mechanisms described by the operationalized resilience principles. The individual structural- and non-structural measures are scored on each resilience principle, using a five-point ordinal scale, ranging from ‘very negative’ to ‘very positive’. The collection of scores provides insight into the resilience impact of the flood project, illustrating which measure scores well, and which measure does not. An aggregated resilience score can then be generated for each principle, by taking the median of the scores of all measures. The final resilience scores show on which resilience mechanisms the flood project has had a positive impact, and whether any of the mechanisms are underrepresented.

Before conducting the functional resilience assessment, the researcher operationalized the resilience principles, translating the resilience principles to practical interpretations for the key functions. The operationalization can be found in Appendix B. Using the operationalized resilience principles, the researcher performed an initial descriptive assessment of the impact of the structural and non-structural flood measures. Following this assessment, the researcher organized two workshop sessions with six groups of three to four postgraduate students and academic staff members at the University of Canterbury. The goal of these sessions was to compare findings, and confirm the validity of the researchers initial assessment. The workshop participants were active in the field of Civil Engineering, making them more knowledgeable on the subject then, for example, the average citizen. The participants were introduced to the resilience principles, the Dudley Creek urban system, and the Dudley Creek project. During the workshop session, participants were divided into three groups of three to four people, with each group focusing on a different pair of resilience principles. Since two workshop sessions were held, this means that a pair of resilience principles, for example buffering and homeostasis, was discussed by a total of six to eight participants. Participants were asked to provide their own assessment of the resilience implications, using the same approach as that of the researcher, considering the impact of the flood measures on the key functions of the urban system. In addition to performing their own assessment, the participants were asked to critically compare their findings with those of the researcher. The researcher used the assessment and argumentation of the participants to re-evaluate his own findings. The resulting qualitative (descriptive) analysis of the researcher, combined with the workshop findings, was then translated by the researcher to a semi-quantitative (ordinal scale) assessment. After careful consideration, the researcher attributed scores on a scale from 1 (very negative) to 5 (very positive) to the flood measures.

Step 4: Explanation of the functional resilience impact of the project

To explain why the flood project had a specific impact on the functional resilience, abductive reasoning is used, in which the interplay between empirical data and theoretical concepts is central (Van Maanen, et al., 2007). Abductive reasoning allows the researcher to work back from an unmet expectation (e.g. limited functional resilience impact) to find a plausible explanation (Peirce, 1995).

Based on the functional resilience assessment, the first step of the abductive analysis is to determine which resilience principles are underutilized/provide the greatest room for improvement. The next step is to determine what elements of the process design explain the underutilization of these resilience principles. In other words, to find out how the process design of the flood project restricted the projects functional resilience impact. The elements of process design (i.e. initiator, goal, rationale, objectives and success criteria, and resources) are used as input for the abductive analysis. The final step is to determine what elements of the governance context explain these restrictive process design elements. Or in other words, to identify the specific elements of the governance context that restricted specific process design decisions (and consequently the projects functional resilience impact). The quality criteria (i.e. extent, coherence, flexibility, intensity) are used as input for the abductive analysis.

3. Results

3.1. Characterization of the urban system

This section presents the characterization of Dudley Creek urban system. A detailed description of the urban functions can be found in Appendix E.

For the urban system, as outlined in Figure 4, the following **key functions** can be distinguished:

- Residential function
  The system provides a healthy, attractive, and safe space for people to live, and establish and maintain a community.
- Recreational function
  The purpose of the system in this regard is to provide a space for formal and informal recreational activities, while complementing and enhancing neighborhood amenity values.
- Ecological function
  The urban system provides a space for, and aims to protect 'significant' native and exotic flora and fauna.
- Economic function
  The system provides a space for (local) commerce and industry.

The **disturbances** that the urban system may face in the future consist of both acute shocks (e.g. earthquakes, floods, tsunami's), as well as long-term stresses (e.g. climate change) (e.g. Jacobs SKM, 2014; Greater Christchurch Partnership, 2015; Ministry for the Environment, 2018c; Environment Canterbury, 2019; Christchurch City Council, 2019). As the current study focuses on a flood project, in the context of urban flood resilience, the key disturbance that forms the core of the resilience assessment is flooding. Flooding is the most common hazard to affect the Dudley Creek area (e.g. Christchurch City Council, 2005; Greater Christchurch Partnership, 2015). Flooding occurs regularly, as intense or prolonged rainfall events overwhelm channel design capacities, leading to river breakouts and local surface runoff. The flooding problem is exacerbated by the impacts of earthquakes, tsunami's, and climate change.

The (potential) **impact** of flooding on the key functions of the urban system are the following:

- Residential function
  Flooding can damage or destroy houses and property, including sites or features of historical/cultural significance (e.g. Christchurch City Council, 2005; Ministry for the Environment, 2018c). Of the nearly 600 properties affected by flooding in the Dudley Creek catchment, 28 experienced flooding above the ground floor level, 260 homes experienced flooding below the floor, and 281 homes experienced flooding that prevented access to their homes, in two or more flooding events post-earthquake (Smith M. , 2017). The number of households that flooded above ground floor level increased from 28 to over 80 in the March 2014 rainfall event. The events decreased accessibility of the area, as people were unable to use roads the flooded roads. Stress on the wastewater network from flooding resulted in uncontrolled overflows, contaminating people's homes and properties (Mayoral Flood Taskforce, 2014b). The increased flood risk associated with climate change may also make it more difficult for households to access adequate insurance cover in the future, forcing people to move out of their homes, and decreasing attractiveness of the area (e.g. Mayoral Flood Taskforce, 2014b; Ministry for the Environment, 2018c).
- Recreational function
  Flooding hinders active and passive recreation, as well as the facilities, structures and areas that support these activities. As the water's edge is one of the places of greatest interest and diversity to human activity, flooding has a considerable impact (Christchurch City Council, 2005). If the Dudley Creek is considered a liability to the community, the amenity values of the water features will decrease, making the area less attractive (Christchurch City Council, 2005).
- Ecological function
  Flooding causes contaminated stormwater and sewage disposal to mix with the Dudley Creek, decreasing the water quality, and potentially harming the flora and fauna (Christchurch City Council, 2005). Some fish species are able to adapt to a gradual change in water quality to a point, but are less likely to cope with extreme and sudden changes (NIWA, 2016a). Changes in water flow throughout the stream, or at localized points, affects the movement of fish through the water. The flood event also damages and/or destroys any vegetation along the banks, due to the force of the moving water.
- Economic function

Flooding leads to reduced economic activity in the area, inefficiencies in the transport network, damage to business, goods, and infrastructure, loss of revenue to businesses, and increased insurance costs (Christchurch City Council, 2018e).

3.2. Characterization of the flood project and context

This section presents the characterization of Dudley Creek flood project and context, consisting of the structural- and non-structural flood measures, the process design, the governance context, and the engagement process.

3.2.1. Structural- and non-structural flood measures

A detailed description of the flood measures can be found in Appendix F.

The **structural measures** of the flood project consist of:

1. Deepening of the waterway
2. Widening of the waterway
3. Channel reshaping and in-stream ecological works
4. Replacement of access bridges and (road) culverts
5. Engineered banks
6. Naturalized banks
7. An underground piped bypass
8. A drain backflow prevention device
9. Landscaping
10. Maintenance

The **non-structural measures** of the flood project consist of:

1. Water level monitoring
2. Hydraulic model update
3. Citizen engagement

3.2.2. Process design

The project **initiator** is the Christchurch City Council (e.g. Smith, 2017; Personal communication, 2019). The Christchurch City Council operates as territorial authority at local government level.

The **rationale** behind the Dudley Creek project was the increased flood risk in large parts of Christchurch, following the Canterbury earthquakes. The Dudley Creek catchment was particularly badly affected, as it already had a high risk of flooding prior to the earthquakes. Three separate flood events in the autumn of 2014 led the Council to set up a Mayoral Flood Task Force, and fast track plans to return the Dudley Creek catchment to pre-earthquake levels of flood risk (e.g. Smith, 2017; Personal communication, 2019).

The primary **goal** of the Dudley Creek Flood Remediation project was to return the Flockton Street area to pre-earthquake levels of flood risk, measured by the number of consented residential floor levels that are modelled to flood in the 1 in 10 year, and 1 in 50 year storm (Beca and Opus, 2015).

With regard to the **project resources** of time and money, construction was scheduled to commence by August 2015, and achievement of the primary goal and substantial completion of construction was scheduled for August 2017 (Beca and Opus, 2015). This was just over three years after the Mayoral Flood Task Force was set up (Smith M. , 2017). The Council set a fixed budget for the whole project (upstream and downstream works) at \$48M NZD (≈ €28.2M) (e.g. Beca and Opus, 2015; Smith, 2017; Macky & Thorne, 2017).

The Council identified seven **objectives**, based on the primary goal of the project (Beca and Opus, 2015). These were to:

1. Achieve the primary goal of returning flood risk to pre-earthquake levels in the Flockton Street area.
2. Meet the timelines imposed on the project.
3. Work within the budget.
4. Obtain Resource Management Act (RMA) and building consents to undertake the works.
5. Secure property and access required for the project.
6. The solution must maintain compliance with RMA and building consents.
7. The solution must meet the requirements of the CCC Waterways, Wetlands and Drainage Guide (six values approach).
8. Develop solutions which consider the operation of the entire drainage network over the whole of its life.

In addition, the project team had three **secondary project targets** (Beca and Opus, 2015). These were to:

1. Improve amenity value along waterways.
2. Consider and report on additional flood risk benefits over and above the primary objective.
3. Provide enhanced ecological habitats along waterways.

The six values of the CCC Waterways, Wetlands and Drainage guide are used as **success criteria** for measuring the project's success (e.g. Christchurch City Council, 2003; Macky & Thorne, 2017; Smith, 2017). In order to be considered successful, the project must have a positive impact on:

- Drainage (e.g. reducing flood risk)
- Ecology (e.g. water, plants, birds, fish, invertebrates)
- Landscape (e.g. protect and enhance landscape features, settings and natural processes)
- Recreation (e.g. support both formal and informal recreation)
- Heritage (e.g. heritage values, built and natural sites and settings)
- Culture (e.g. protecting and recognizing Māori values)

3.2.3. Governance context

A full description of the five dimensions (i.e. levels and scales, actors and networks, strategies and instruments, responsibilities and resources) can be found in Appendix I.

Extent

Levels & Scales. For the Dudley Creek project, mainly the local level was involved in the adaptation, as the national, regional, and territorial levels act independently.

Actors & Networks. All relevant stakeholders were involved, though the fast track process meant that stakeholders were informed instead of engaged/consulted. The project team went straight to the Council for decision making, and informed everybody else (e.g. committees, working groups, community groups).

Problem perspectives & Goal ambitions. The various problem perspectives of climate change and future flood risk were taken into account only at a basic level, as the focus of the project was to restore flood risk to pre-earthquake levels. Though the Ministry for the Environment guidance points towards co-generation/co-governance with the public, these governance structures still need more work in the climate change adaptation space. The guidelines and policy statements are not well embedded yet, or necessarily well understood by the community. The local application of the global science is still being built.

Strategies & Instruments. The strategies don't exclude any flood measures. All are considered, though traditional approaches were preferred over novel approaches. Territorial local authorities don't have a power to alter existing user rights, while regional government does. This means that the Council cannot necessarily change the current build, or, in other words, de-develop.

Responsibilities & Resources. The project/recovery program had clear governance guidelines. Decisions were taken by the Council, to secure the resources necessary to deliver the project. The current legislation granted the Council with wide ranging powers at a local level, though the Council doesn't have the authority to work within the RedZone or to alter user rights, as mentioned before, as that authority resides at the regional and national level. Though everybody wanted to help, not all stakeholders may have been aware of what was expected of them/what their responsibilities were, particularly with regard to the citizen groups.

Coherence

Levels & Scales. For the Dudley Creek project, the degree of mutual dependence and trust within the local level was recognized. This was mainly because of the urgency of the crisis, and the fact that people were in the post-earthquake environment, so understood the need to do things. If the project took place without a trigger (e.g. earthquake or flood) it would have been much harder. The dependency between the national, regional, and territorial level however was not recognized.

Actors & Networks. The actors in the network supported each other, as everyone realized the urgency to do so. The internal actors had experience in working together, as did the Council and Ngai Tahu. The relation between the Council and central government had developed since the earthquakes. The interactions with the Flockton residents group were only formed effectively as a result of the flooding, so that was a new stakeholder group and new interaction. The interactions are relatively well institutionalized through existing processes and procedures. Though there was respect for one another, the different groups had different drivers and different motivations, and those views and aspirations weren't always aligned. Towards the end of the project, some of the residents (groups) were feeling mistrust that things were taking longer than they believe they had been told, and they didn't feel that their voice was heard.

Problem perspectives & Goal ambitions. At the public interface, building understanding in the community around the issues and the potential range of futures is a challenge. The reality of climate change for the people at/on their property is not tangible yet. The severe nature/urgency of the Dudley Creek flooding problem helped in removing barriers and established a sense of common goal.

Strategies & Instruments. Stakeholders were not incentivized at a financial level, but rather by the expected reduction in flood risk. Trade-offs in cost-benefit were taken into account as part of the multi-criteria analysis. Multiple options were considered before coming to a preferred option.

Responsibilities & Resources. Because of the urgency of the matter, there was a strong alignment between the project team and actors/stakeholders. The struggles that did take place were between the residents groups and the Council. Some would be impacted by the works, and opposed them because of that. Others accepted the impacts of the work, but became frustrated by them with time.

Flexibility

Levels & Scales. Currently there is no possibility to move between territorial, regional, or national levels, as the recovery program is only funded at the local level. To facilitate this in the future, a change is needed towards cost-share funding from the national level. Upscaling within the local level was possible, as the Dudley Creek project activities got bigger, but the project was still managed within the same levels. A local responsibility funded locally, even though it's broader in scale.

Actors & Networks. Various actors were drawn into the process, up until the point that the project team had fixed decisions on the preferred option from the Council, and a clear direction on where they were heading. As the process was driven from Council by Council, it didn't allow for flexibility with regard to the leading role. The actors supported each other's tasks and were well aligned in most cases. The exception were the cases where works on individual properties had to take place. An example of the support is the collaboration with SCIRT, who fitted the flood project into their work and delivered one of the culverts.

Problem perspectives & Goal ambitions. The goal of the Dudley Creek project was to return the area to pre-earthquake flood risk, which was well set. To do more would have cost more, and since there was a fixed budget there was no opportunity to reassess the goals. The project did take multifunctionality into account, as multiple goals were achieved through the works (e.g. ecological and recreational benefits).

Strategies & Instruments. The project team didn't consider it necessary to combine or make use of different types of instruments/measures, as the legal framework was strong, and the planning framework didn't inhibit the project. As the Council was not legally obliged to have to do anything, they had the choice to either do nothing, or to spend the money and fix the problem for the community. There is a possibility to adapt the flood measures in the future, as that was part of the initial strategy.

Responsibilities & Resources. Shifting responsibilities and resources, and/or pooling them together happens at a Council level through the Long Term Plan. The Council tries to align the projects and prioritize them accordingly, so that resource requirements are minimized.

Intensity

Levels & Scales. On the community level there was a very strong driver for change. The project was influenced by the feedback of the community, as the Flockton community required change, and weren't going to accept anything less. That was understood through the media, the political levels, and all governance levels.

Actors & Networks. There was pressure from lots of actors towards change. Because feelings were running very high amongst the affected residents, an undertaking was given to Councilors by the Land Drainage Recovery Program team, that works to reduce the flood risk to at least pre-earthquake levels in the Dudley Creek catchment had to be completed by winter 2017 (Smith, 2017).

Problem perspectives & Goal ambitions. The project was fast tracked, driven internally, but also externally by the community. The status quo was different for the Banks Ave residents, who wanted to maintain the pre-project situation, but all other actors wanted change. As the project was fast tracked, the project process was different from the business as usual approach.

Strategies & Instruments. Other than fast tracking the process, the project used well set practices and processes. The consultation process was different than business as usual, as it was more on an inform than consult basis. The project team went straight to the Council for decision making, which was driven by the urgency of the flood risk.

Responsibilities & Resources. The project team considered the amount of resources sufficient for the measures needed in the intend for change, but mentioned that the higher order policy of the government can pose a funding problem. The time and budget available limited the ability to achieve beyond the initial goal. One citizen mentioned that, during the drop-in session, the project team indicated that climate change was not this projects focus, and that that would be a different bucket of money to come at a different time.

3.2.4. Engagement process

In October 2014, the Council identified a preferred option, which was publicly consulted upon. Prior to this formal public consultation, citizens were provided with newsletters and/or web-based info, contacted directly (e.g. phone/email, one-on-one meetings), and invited to drop-in-sessions and public meetings. A detailed description of the **participation methods** used during the Dudley Creek project can be found in Appendix G.

The **goal** of engagement process was to ensure residents understood the decision-making process, and how they could be involved and make their voices heard. In addition, the project team wanted to gain the residents' trust by sharing information, and explain technical aspects of the project and the implications of various options (Personal communication, 2019).

3.3. Functional resilience impact assessment

An initial qualitative (descriptive) analysis of the impact of the structural- and non-structural measures of the Dudley Creek flood project was performed for the four key functions (i.e. residential, recreational, ecological, economic). The researcher used the practical interpretation of the resilience principles to do so. The results of the initial qualitative analysis can be found in the 3rd column of Table 11 and Table 12 in Appendix H.

An example of the procedure is provided for buffering. In relation to the key functions, buffering entails that the system has enough capacity (e.g. hydraulic, ecological, etc.) to ensure that residential homes, commercial buildings, recreational facilities, and flora and fauna do not get damaged beyond repair, but can withstand a certain degree of disturbance. If one wants to apply this to a flood measure, it is necessary to determine how that measure (potentially) impacted one or more of the key functions. Using the example of deepening the creek, this measure includes the removal of stream sediment contaminants and silt, as well as existing ecological habitats. From a buffering perspective, deepening the creek increased the waterways capacity, lowering the risk of the creek overflowing, positively impacting all functions. In addition, as contaminants and silt are removed from the waterway, the waterways capacity to deal with future deposits increased, and the measure therefore supports the ecological function. This led the researcher to conclude that deepening the waterway has a positive impact on the buffering principle. At the same time however, as the redundancy principle entails having sufficiently large nature areas that maintain the ecological function in case of a disturbance, the removal of the existing ecological habitats is considered to have a negative impact. The researchers conclusion, based on this, is that the flood measure of deepening the creek has a positive impact on buffering, but negative impact on redundancy. The same approach was used for the remaining structural- and non-structural measures, in relation to the six resilience principles (e.g. buffering, redundancy, omnivory, homeostasis, flatness, flux).

Following the initial qualitative analysis, performed by the researcher, academic staff and postgraduate students from the University of Canterbury were invited to perform a secondary analysis over two workshop sessions. An overview of the workshop findings is found in 4th column of Table 11 and Table 12 in Appendix H.

Using the flood measure of deepening the creek as an example once more, participants noted an increase in flux, as a greater volume of water (e.g. resources) can flow through the waterway. Since deepening only took place in two locations however, this impact was not considered to reach its full potential. Some participants were also critical with regard to the negative impact on redundancy (e.g. removal of habitats) mentioned by the researcher, as they considered this to be short-term. While it is true that the habitats were only affected during construction, given that they have been completely removed means that they will most likely not return. Lastly, deepening the creek was thought to provide a deeper habitat, which could attract larger fish and bottom dwellers, positively impacting the resilience principle of omnivory.

The qualitative (descriptive) analysis of the researcher, combined with the workshop findings, were used as input for the semi-quantitative (ordinal scale) assessment. The resulting project measure scores on the resilience principles can be found in Table 3. Figure 7 and Figure 8 show respectively the mean resilience scores of the structural vs. non-structural measures, and total mean resilience scores.

Looking at the individual measures of the project, the table shows that the majority has a positive (score > 3) mean impact on resilience. Three of the measures had a neutral (score = 3) mean impact, namely ‘Widening the creek’, ‘(Re)placement of access bridges and (road) culverts’, and ‘Drain backflow prevention’. ‘Widening the creek’ (as well as ‘Deepening the creek’) scored low on redundancy, as elements of the ecological and residential function were removed (e.g. vegetation, habitats, access bridges). These impacts have (partly) been compensated in the project by means of the in-stream ecological works and landscaping. ‘(Re)placement of access bridges and (road) culverts’ has a neutral mean impact, as its impact on buffering and flux is limited. Buffering could have been higher if the project had not only targeted undersized and damaged culverts to bring them up to current standard, but also increased the size of remaining culverts beyond that. The ‘Drain backflow prevention’ scored low on flux, as it limits the ability of resources (e.g. fish) to freely move through the system. If an alternative flexible valve would have been installed, this negative impact may have been reduced.

Noteworthy are the negative (score < 3) scores of ‘Reshaping of the channel and in-stream ecological works’ and ‘Naturalized banks’ on respectively buffering and flux. As reshaping of the channel was done in combination with the other measures, the loss of waterway capacity that is attributed to the creation of the narrow, low-flow channel, is compensated by the creek widening and construction of naturalized banks. With regard to the naturalized banks, while slowing down the flow of water may not be ideal from a flood management perspective, it facilitated elements relevant from an ecological point of view. This is represented by the fact that, even though flux scores negatively, the overall score of naturalized banks is positive.

Table 3: Scores of flood measures on resilience principles

Resilience principle / Measure	Omnivory	Redundancy	Buffering	Flatness	Homeostasis	Flux	Mean
Structural							
1. Deepening Creek	4	2	5	3	3	4	**3.5**
2. Widening Creek	3	2	4	3	4	4	**3.3**
3. Reshaping of the channel and in-stream ecological works	5	4	2	3	5	4	**3.8**
4. (Re)placement of access bridges and (road) culverts	3	3	4	3	3	4	**3.3**
5. Engineered banks	3	3	5	3	3	5	**3.7**
6. Naturalized banks	5	4	4	3	5	2	**3.8**
7. Underground piped bypass	3	5	5	3	4	4	**4.0**
8. Drain backflow prevention	4	3	3	3	4	2	**3.2**
9. Landscaping	4	4	4	3	3	4	**3.7**
10. Maintenance	4	3	3	3	5	5	**3.8**
Mean structural measures	**3.8**	**3.3**	**3.9**	**3.0**	**3.9**	**3.8**	
Non-structural							
1. Water level monitoring	3	4	3	3	5	4	**3.7**
2. Hydraulic model update	3	3	3	3	5	4	**3.5**
3. Citizen engagement	4	3	3	4	5	5	**4.0**
Mean non-structural measures	**3.3**	**3.3**	**3.0**	**3.3**	**5.0**	**4.3**	
Mean all measures	**3.7**	**3.3**	**3.7**	**3.1**	**4.2**	**3.9**	

When comparing the impact of the structural- and non-structural measures (Figure 7), the first thing that can be noted is the fact that the impact of the non-structural measures is mainly focused on homeostasis and flux, while the scores of structural measures are more equally distributed. Furthermore, the combination of non-structural measures has a neutral impact on buffering, while the structural measures score relatively high on this principle. Lastly, the combination of structural measures has a neutral impact on flatness, while the non-structural measures have a minor impact.

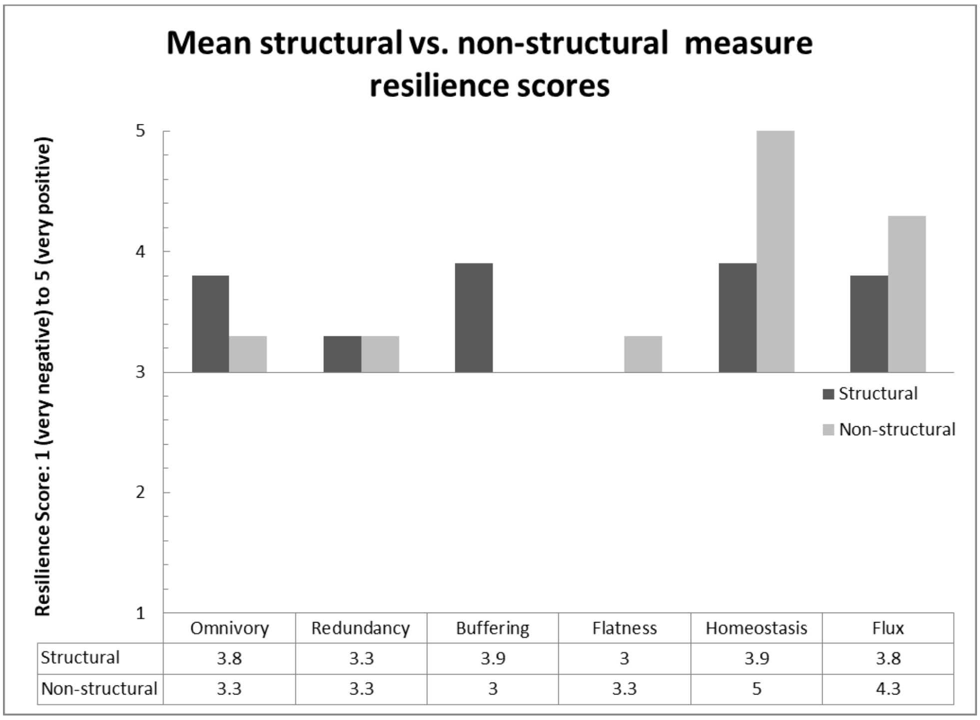

Figure 7: Structural- and non-structural measure resilience scores

Looking at the project in total, Table 3 and Figure 8 show that the combination of measures has a positive (score > 3) mean for all resilience principles. The highest score is achieved on homeostasis (4.2), followed by flux (3.9). The project had an equal impact on omnivory and buffering (3.7). The principles of redundancy (3.3) and flatness (3.1) both have a score that is very close to neutral (score = 3).

As mentioned before, redundancy was particularly negatively affected by the removal of (protected) vegetation, habitats, and access bridges. The positive impacts on redundancy were mostly limited to the ecological and recreational function, the exception being the unground bypass, which has a positive impact on all functions. Only one measure of the project (e.g. 'Citizen engagement) was considered to have a positive impact on flatness. None of the other measures included elements that targeted local competence, and/or specifically addressed the relation between authorities (e.g. decision-makers) and the stakeholders/communities.

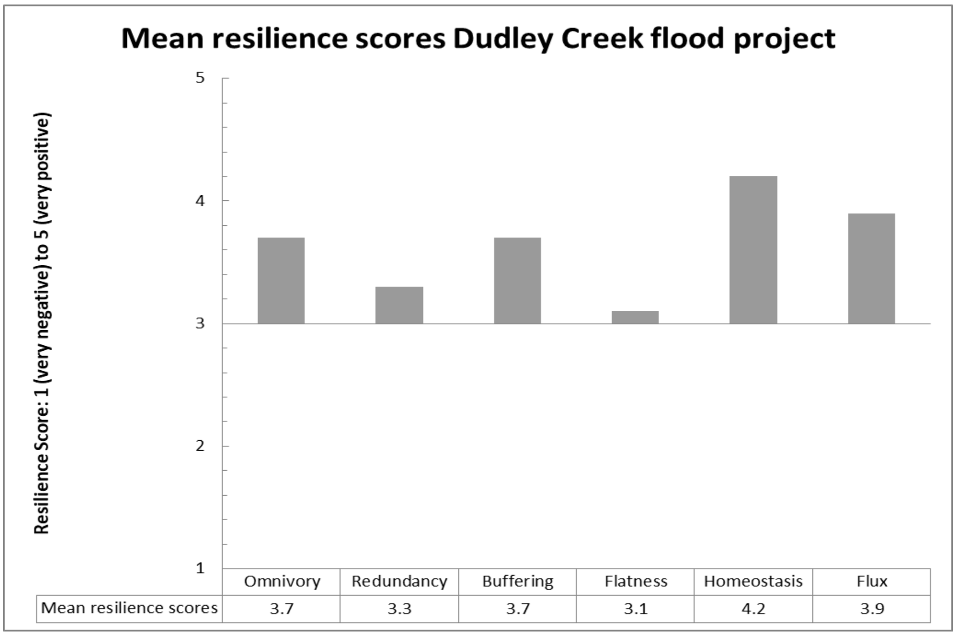

Figure 8: Mean resilience scores Dudley Creek flood project

3.4. Analysis functional resilience impact

Abductive reasoning is used to examine the relation between the project outcome (e.g. functional resilience impact), and the process design and governance context, to explain the resilience impact of the Dudley Creek project. Specific attention is given to the principles of flatness and redundancy, as they received the lowest resilience scores, which suggests that the project had a limited impact on the system's ability to absorb disturbances by means of overlapping functions, and ability to respond quickly to a disturbance by making use of local competence.

3.4.1. Role of process design

Based on the process design, a number of elements are found that explain the resilience impact of the project. Overall, the process design shows that the Dudley Creek scheme has not been designed to account for resilience and the effects of climate change (Beca and Opus, 2015). The project rationale did not focus on urban resilience or climate change adaptation, but on returning flood risk to pre-earthquake levels. This, in combination with the fact that 'consider and report on additional flood risk benefits over and beyond the primary objective' is described as a secondary target, illustrates that a reactive/immediate approach (e.g. returning the area to pre-earthquake flood risk) instead of proactive approach (e.g. resilience building) was taken. The goal of returning the Flockton Street area to pre-earthquake levels of flood risk meant that adaptation to future scenario's was not given specific attention, and resilience implications were considered 'only' as secondary targets. Climate change adaptation and resilience were not considered as initial design criteria, but rather as elements of the Multi Criteria Analysis. The goal itself did not encompass the different individual functions of the area, rather than focusing on the immediate disturbance. From a resilience perspective, this may have led to a non-optimal solution.

Limited flatness

The limited flatness score can be explained by the limited *resources* (e.g. time), as well as the formulation of the *objectives and success criteria*. The fast track process meant that decisions had to be made over a shorter time span, and (citizen/stakeholder) participation took place mainly on an inform basis, as less time was available for consultation and citizen engagement. In addition, no objectives or success criteria were formulated that addressed the citizens/local competence. The limited time and lack of specific objectives/criteria effectively reduced the opportunity and incentive to increase flatness.

Limited redundancy

The limited redundancy score can be explained by the fact that the Christchurch City Council was the *initiator* of the process, the 'minimum-requirement' formulation of the *goal*, the limited *resources* available, and the *focus* on the ecological and recreational function. As Christchurch City Council is a territorial authority, they did not have the authority to work within the RedZone, requiring them to go through a difficult process of acquiring approval from the national and regional level. This consequently led to the choice not to go through that area. As nothing is currently build there, some of the negative (resilience) impacts of the works may have been avoided. Furthermore, in contrast to the regional government, the Christchurch City Council does not have the power to alter existing use rights. The use rights enable the reconstruction of a building without the need for a resource consent under the current planning rules. This means that Christchurch City Council cannot change the current build, or, in other words, de-develop. Similar to the lack of authority to work within the RedZone, this limited the scope of measures/options that the project considered. Another explanation of the limited redundancy score is found in the 'minimum-requirement' goal. The phrasing of the goal meant that a remaining flood risk after project completion was considered acceptable, and a relatively short-term solution would suffice. As implementation of 'backup' options becomes increasingly relevant when dealing with long-term disturbances and future uncertainty, increasing redundancy was less of a priority. The resources (e.g. limited time and fixed budget) influenced the strategy taken, as the project focused on flood management, and did not concern itself with urban development in general. Options such as construction of residential and/or economic areas, as well as construction/re-direction of roads were considered outside the scope of the project. The combination of goal and resources limited the ability to achieve beyond the original goal, and provide additional flood risk reduction. The fact that the positive impacts on redundancy were mostly limited to the ecological and recreational function can be explained by looking at the targets and success criteria. The secondary targets include amenity values and enhanced ecological habitats, and the success criteria require a positive impact on ecology and recreation. The fact that the residential and economic function were underrepresented decreased the projects potential for redundancy.

3.4.2. Role of governance context

Based on the governance context, a number of elements are found that explain the process design (and consequently the functional resilience impact) of the project. The analysis focuses on explaining the process design elements identified before, namely the minimum-requirement' goal, the Christchurch City Council's authority and powers, the availability of resources, the attention to ecology and recreation, and the lack of objectives/criteria targeting citizens/local competence.

As previously mentioned, it is assumed that a low extent, low coherence, low flexibility, and low intensity may restrict an urban flood resilience approach and implementation, lead to avoidance of adaptive behavior, and lower the likeliness of adaptive strategies to be used.

'Minimum-requirement' goal.

Because the guidelines on climate change adaptation and resilience are still under development, an integrated approach is lacking, and there were no additional stimuli for the Council to pursue these ambitions (*low intensity*). In addition, the Council was not legally obliged to do anything, and had the choice to either do nothing, or to spend money and fix the problem for the community. The definitions of resilience and adaptation were still under development throughout the project, which led to some confusion about those terms and what they meant. There is not yet a broader understanding of what potential futures might be, what responses may be appropriate, and what costs are associated with them (*low extent*). For these reasons, the decision making was largely based around the very simplistic view of the Land Drainage Recovery Program.

The expectations with regard to climate change are managed through separate criteria, instead of being embedded in every new design. This means that the Dudley Creek project was not designed with an increased capacity to deal with future disturbances (accounting for resilience and climate change), but rather designed in such a way that plans accommodated (more significant) future works. This approach follows the Councils Long Term Plan and Infrastructure strategy, which stipulates the identification of adaptive pathways, to allow changes to be made in the future as circumstances change (*high flexibility*).

The project was limited by the available resources. There was no opportunity to reassess the goals during the process, as doing more would have cost more, and the project was working with a fixed budget (*low flexibility*). Global warming was not considered the project teams problem, as that would be a different bucket of money to come at a different time. The time constraint also forced the team to stay on the (relatively) safe side, and choose from traditional approaches. Any out of the ordinary approach would have extended the program, which was not considered possible (*low flexibility)*.

Christchurch City Council authority and powers.

The New Zealand government identifies the Christchurch City Council as a territorial authority. In legal terms, being a territorial authority provides the Council with wide ranging powers under the Christchurch District Drainage Act and the Land Drainage Act, including the power of compulsory purchase. However, the way in which powers and authority are allocated between the national, regional, and territorial levels can restrict the use of certain options/measures by the Council, particularly because these levels work independently of one another (*limited coherence*). As the shift from a regulatory approach towards a collaborative approach is relatively new to New Zealand, the national and regional actors were limited in their contributions in the Dudley Creek project, and were more interested in the outcome than being involved in the process. Collaboration between the levels could have made the process of acquiring approval for works within the RedZone and/or de-development easier.

Resources (e.g. limited time and fixed budget).

The project was fast tracked, driven internally, but also externally by the community. Feelings were running very high amongst affected residents, and there was pressure from lots of actors towards change, particularly at the public level (*high intensity*). Because of this, an undertaking was given internally to Councilors by the Land Drainage Recovery Program team to fast-track completion of the flood remediation works.

Since the national, territorial, and local levels work independently of one another, the higher order policy of the government can pose a funding problem (*low coherence*). Though there were national interests, funding was carried out at a local level, and acquiring additional funding from the national level without a cost-share funding mechanism in place proved difficult (*low flexibility*). As resource consents were needed, the regional government took the role of consenting authority.

Attention to ecology and recreation.

The surface water and flood protection strategy of the Christchurch City Council outlines the rationale behind flood management, and guides flood projects towards the Council’s Six Values framework. Because of this framework, in combination with Ngai Tahu and the residents, there was a strong focus on recreation and ecology compared to the other elements (*low extent)*. The Resource Management Act requires the Council to take Māori interests into account, and the spiritual and cultural bonds of Ngai Tahu with water and the environment meant that their interest in the creek was associated with improving the ecology. The consultation with the residents showed that they valued the mature trees and natural habitats highly, in particular along Banks Avenue. As the community boards have some delegated authority for project level decisions, such as those concerning tree removal, there was a balance that had to be met between meeting the project objective to reduce the flood risk, and meeting the ecological needs as mentioned before (*high coherence*).

Lack of objectives targeting citizens/local competence.

The Local Government Act requires the project team to put forward clear options and recommendations to the Council, based on a consensus building/engagement process with all actors, including the public. It requires the project team to consider the views and preferences of the local community. The specifics of the consultation and citizen engagement, however, are not prescribed by this Act. In other words, there is no standardized approach, leaving it open to the interpretation of local decision making (*low extent*).

The importance of co-generation/co-governance with the public is stressed by the RMA, as well as the Ministry for the Environment guidance, but the current guidelines and policy statements aren't well embedded yet (*low extent*). As mentioned before, such a collaborative approach is relatively new to New Zealand, and the local application of co-governance structures (e.g. citizen engagement) is still being build. Therefore, targeting citizens/local competence in a flood project is still not common practice.

Since the project was fast tracked, the project team was less inclined to use any approaches that could have extended the programme. As mentioned before, the goal of the project, in combination with the limited resources, limited the ability to achieve beyond the original goal (*high intensity*). This also included any additional effort directed at the citizens/local competence.

3.4.3. Summary

Table 4 summarizes the analysis of the functional resilience impact, and shows the elements of the process design and governance context that explain the underutilization of the flatness and redundancy principles.

Table 4: Role of process design and governance context

Resilience impact	***Process design***	***Governance context***
Underutilized flatness and redundancy principles	Initiator • Christchurch City Council limited authority and power Goal • 'Minimum-requirement' goal Resources • Limited resources (e.g. fast track and fixed budget) Objectives and success criteria • Lack of objectives targeting citizens/local competence • Focus on ecology and recreation	Extent • Co-governance and citizen engagement approach not well embedded yet • Ambiguity of terms (e.g. resilience, adaptation) and uncertainty of approaches • No specific consultation and engagement requirements stipulated by the Local Government Act • Christchurch City Council Six Values Framework Coherence • Lack of collaboration between national, regional, and territorial authority • Resource Management Act and Local Government Act requirement to consider Māori and citizen interests Flexibility • Adaptive pathways instead of embedding of resilience criteria • Dependency on local funding Intensity • Time pressure of internal and external actors • No stimuli for the Council to pursue adaptation and resilience ambitions

Part II – Adaptive capacity

1. Theory

1.1. Adaptive capacity indicators

Since adaptive capacity is a theoretical construct, direct measurement is not possible. The factors representing adaptive capacity will be determined to a certain extent by the nature of the hazard(s) faced, and by the specific characteristics of the system or population (e.g. Brooks & Adger, 2004; Lockwood, et al., 2015. This means that an assessment of adaptive capacity requires indicators, and the selection of relevant indicators needs to be tailored to each case.

For the current study, we selected four indicators of adaptive capacity at an individual level. These consist of risk perception, knowledge, perceived adaptive capacity, and motivation. Literature on adaptive capacity, as well as social contexts and adaptation processes, agrees upon the importance of **risk perception** as an indicator of adaptive capacity (e.g. Wardekker, et al., 2010; Wolf, 2011; Martinez, et al., 2014; Leiserowitz, 2006). Risk perception can fundamentally compel or constrain actions to address particular risks. By assessing the risk perception of an individual, information can be gained on their interpretation of the risk, perceived urgency for action, as well as their perception of responsibilities. Individual's with a low risk perception, who refuse to accept risks or to accept responsibilities, are considered to have a lower adaptive capacity (e.g. Wolf, 2011; Brooks & Adger, 2004; Adger, et al., 2009; Grothmann & Patt, 2005). The capacity to adapt is also partly determined by an individual's **knowledge** on the nature and evolution of (potential) hazards faced by a society (Brooks & Adger, 2004). An individual's knowledge acts as a filter through which information or a problematic situation is interpreted, and provides an indication of the individual's level of awareness (e.g. Hommes, et al., 2018; Lockwood, et al., 2015). A higher level of knowledge is associated with a better understanding of, and ability to evaluate risks, leading to personal preparedness (e.g. Wachinger, et al., 2013; Lockwood, et al., 2015). In addition to an individual's risk perception and knowledge, Grothmann & Patt (2005) and Wolf (2011) point out that an individual's adaptive response is influenced by the individual's perception of their own adaptive capacity, as well as their motivation. **Perceived adaptive capacity** describes an individual's perception of his/her own ability to perform or carry out adaptive responses to cope with and avert being harmed by a threat (e.g. Grothmann & Patt, 2005; Wolf, 2011). **Motivation** addresses the difference between what an individual thinks he/she can do, and what he/she actually wants to do (Grothmann & Patt, 2005). Including perceived adaptive capacity and motivation as indicators for adaptive capacity provides an indication of the likeliness of an individual to take action and adapt. Unwillingness to believe that one's own actions can protect oneself and a low motivation to act will result in a lower adaptive capacity (e.g. Grothmann & Patt, 2005; Brooks & Adger, 2004; Wolf, 2011).

Desirable is a state in which an individual has a high risk perception, high perceived adaptive capacity, high motivation, and high level of knowledge. High adaptive capacity in this context refers to the situation where an individual has knowledge on/is aware of developments, perceives an urgency and motivation to act/adapt, and feels that he or she can indeed do something. The relation between the adaptive capacity indicators, citizen engagement, and citizen characteristics is illustrated by Figure 9.

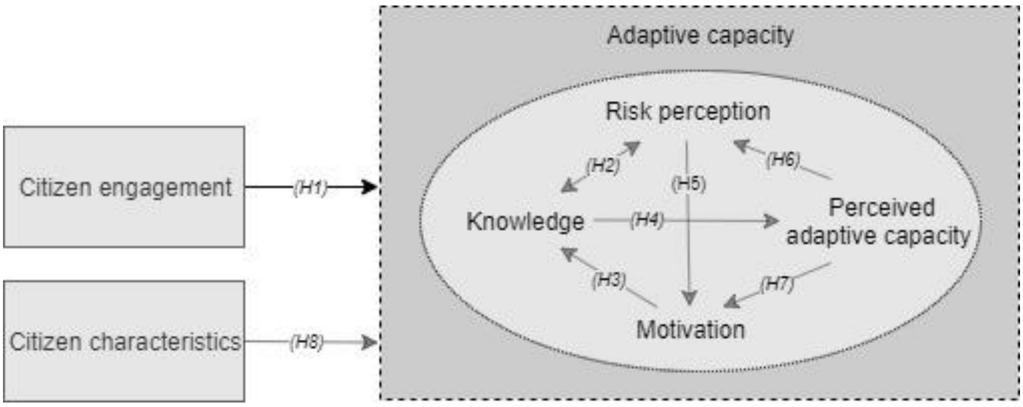

Figure 9: Theoretical model adaptive capacity

1.2. Influence of citizen engagement

The current research will assess the adaptive capacity of the citizens in relation to the engagement process of the flood project. Citizen engagement can be defined as a "Two-way interaction between citizens and governments or the private sector that give citizens a stake in decision-making, with the objective of improving the intermediate and final development outcomes of an intervention" (World Bank, 2014). The spectrum of citizen engagement includes consultation, involvement, collaboration, and empowerment (IAP2 Federation, 2014).

The common understanding in literature is that engagement will increase the knowledge and awareness of the public, with respect to risks and protective measures (e.g. Gaventa & Barret, 2010; O'Sullivan, et al., 2012; Wachinger, et al., 2013). Through the flow of information and learning processes that take place during the engagement, perceptions develop and change (Hommes, et al., 2009). A result of the engagement process may be that, as citizens become more aware of potential disturbances, they are encouraged to take more personal responsibility for protection and disaster preparedness (Wachinger, et al., 2013). Besides the impact of citizen engagement on the level of knowledge and risk perception of individuals, it is found that citizen engagement can increase the personal agency of the public, with respect to risks and protective measures, and lead to a greater sense of empowerment (e.g. Gaventa & Barret, 2010; Wachinger, et al., 2013). In addition, the engagement process can lead to an increased motivation/intention to act (e.g. Gaventa & Barret, 2010; O'Sullivan, et al., 2015). As summarized by Terpstra, Lindell, & Gutteling (2009), the more individuals engage, the more (relevant) information they acquire, the more they reflect on the information, and the stronger is the potential for them to change their attitudes.

The main hypotheses of the current study, concerning the adaptive capacity impact of a flood project, is the following:

H1: Engaged citizens have a higher level of knowledge, risk perception, perceived adaptive capacity, and motivation, than non-engaged citizens.

1.3. Interrelation indicators

In addition to the engagement process, the adaptive capacity of citizens is influenced by interrelations between indicators (i.e. risk perception, knowledge, motivation, and perceived adaptive capacity).

An individual's increased knowledge and insight about the nature, causes and effect of a disturbance, as well as possible solutions and their consequences, influences their risk perception, as the enhanced awareness stimulates new ways of thinking about issues (e.g. Hommes, et al., 2009; O'Sullivan, et al., 2015). The raised awareness can increase an individual's sense of urgency to adapt, as it helps them recognize the need for action (Brooks & Adger, 2004). Information and knowledge can potentially reduce uncertainty, as it is used to turn complex problems/undetermined threats into an at least partly known risk (APFM, 2016). It should be noted, however, that new information can also increase uncertainty, as it may reveal the presence of threats that were unknown or understated until then (Hommes, et al., 2009).

H2: There is a relationship between an individual's knowledge and an individual's risk perception.

Increased motivation causes individual's to pay greater attention to relevant information, and stimulates the collection of more information/knowledge assimilation (Terpstra, Lindell, & Gutteling, 2009).

H3: An individual's motivation has a positive effect on an individual's level of knowledge.

By gaining knowledge, an individual can develop/empower their sense of self-efficacy, and increase the belief in their own ability to participate and act (Gaventa & Barret, 2010).

H4: An individual's level of knowledge has a positive effect on an individual's perceived adaptive capacity.

Risk perception is found to be the main determinant of perceived adaptive capacity and motivation to act/adapt to a changing situation (e.g. Grothmann & Patt 2005; Wachinger, et al., 2013; Lockwood, et al., 2015). Only once a minimum level of threat of concern exists, people will start contemplating the benefits of possible actions, as well as reflect on their own competence to actually perform them. In general, a high threat/risk perception therefore is assumed to lead to high motivation/intention to act (e.g. Grothmann & Patt 2005; Terpstra, Lindell, & Gutteling, 2009).

H5: An individual's risk perception has a positive effect on an individual's motivation.

As described by Grothmann & Patt (2005), after an initial risk perception comes the 'coping appraisal', where a person evaluates his or her ability to cope with, and avert being harmed by the threat. Based on the outcomes of the threat- and coping-appraisal processes, a person then reevaluates the threat. If individuals have a high perceived adaptive capacity, it may give them a false sense of security, and, as a result, cause them to overlook the risk as a threat (Terpstra, Lindell, & Gutteling, 2009).

H6: An individual's perceived adaptive capacity has a negative effect on an individual's risk perception.

If an individual has a high perceived adaptive capacity, this is expected to lead to adaptive behavior (Grothmann & Patt, 2005). This is also found by Wolf (2011), who states that perceived individual agency plays a role in whether or not people act on an issue. If someone perceives the risk, but does not feel that they have the capacity to act, this may lead to maladaptation (e.g. denial of the threat and wishful thinking). In other words, even when an individual has access to all resources, and possesses enough knowledge, if they don't feel like they have the ability to make a change, they will most likely not take part in the adaptation process.

H7: An individual's perceived adaptive capacity has a positive effect on an individual's motivation.

1.4. Influence of citizen characteristics

In addition to the engagement process and interrelation between indicators, the adaptive capacity of citizens is influenced by citizen characteristics (e.g. living situation, education, age, experience).

Owners of a home within the potentially impacted area tend to pay closer attention to risks, and have a higher risk perception compared to tenants, as they have more to lose (e.g. Grothmann & Patt 2005; APFM, 2016). This motivates property owners to inform themselves to a greater degree on the potential disturbances and impacts relevant to their home (APFM, 2016). In the face of a disturbance, owners are assumed to have a greater opportunity to take independent action as compared to a tenant (Grothmann & Patt, 2005).

H8a: Property owners have a higher level of knowledge, risk perception, perceived adaptive capacity and motivation than tenants.

With regard to the level of education, it is assumed that the higher the level, the greater the knowledge. Well-educated people tend to pay more attention to (flood) risks, which is particularly true for those who have pursued a technical education in secondary school, or even more so, at the university level (APFM, 2016).

H8b: Higher-educated individuals have a higher level of knowledge than lower-educated individuals.

A higher age is generally associated with a higher level of knowledge, as knowledge is often grounded in experiences of people, and a higher age means that a person has had more time to gain experience with disturbances (e.g. Hommes, et al., 2009; APFM, 2016).

H8c: Individuals of a higher-age have a higher level of knowledge than individuals of a lower-age.

Direct (e.g. personal) as well as indirect hazard experience is said to increase an individual's motivation to act, because it allows a more rapid/vivid recall of relevant information, and increases the sense of personal involvement (e.g. Grothmann & Patt 2005; Terpstra, Lindell, & Gutteling, 2009).

H8d: The motivation of individuals who have experience with a hazard event is higher than the motivation of individuals who have no experience.

Indirect experience is less likely than direct experience to increase motivation, as it is not as vivid, easily recalled, or personally involving (Terpstra, Lindell, & Gutteling, 2009).

H8e: The motivation of individuals with direct experience is higher than the motivation of individuals with indirect experience.

Direct experience with a natural hazard (e.g. flooding) has also been shown a key factor in the way individuals interpret information, and the degree to which they accept something is a personal risk, essentially shaping their risk perception (e.g. Wolf, 2011; Wachinger, et al., 2013; APFM, 2016). Not only direct experience, but also indirect experience (e.g. through media or personal interaction with other people) is found to affect an individual's perception of potential disturbances and impacts (Wachinger, et al., 2013). In general, negative feelings associated with previous experiences are considered to increase risk perception, while positive feelings decrease risk perception (e.g. Wachinger, et al., 2013; Miceli, Sotgiu, & Settanni, 2007).

H8f: The risk perception of individuals with experience is different from individuals with no experience.

2. Method

Part II of this study addresses step 5 and 6 of the research approach, which are summarized in Figure 10.

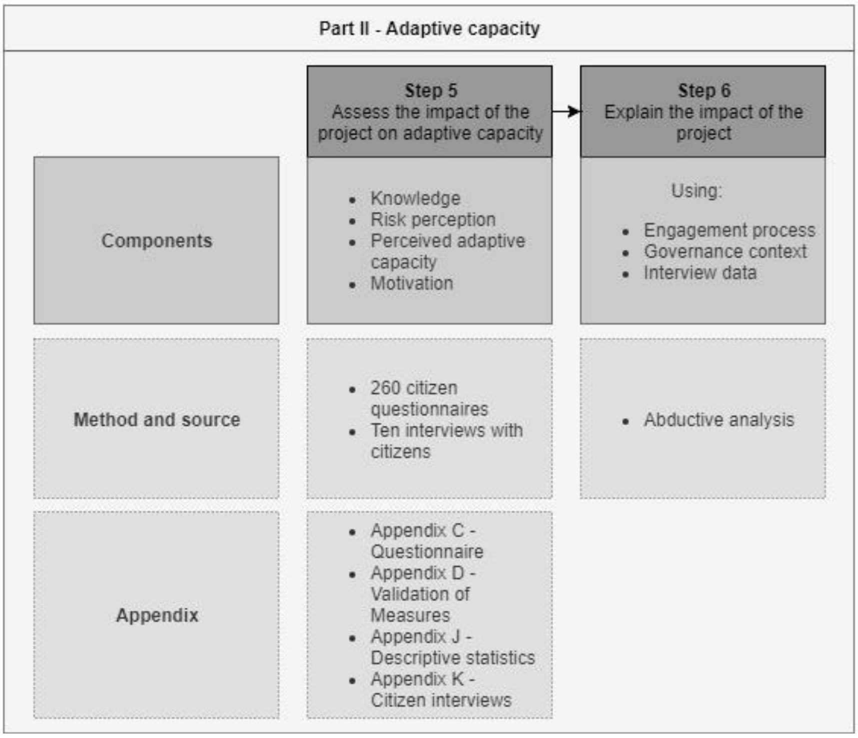

Figure 10: Adaptive capacity assessment, including components, methods and sources, and appendices

Step 5: Assessment of the impact of the flood project on adaptive capacity

To assess the impact of the Dudley Creek project on adaptive capacity, a quantitative field study was conducted by means of a questionnaire. Following the quantitative approach, interviews were conducted for an in depth qualitative analysis of the quantitative findings.

The questionnaire targeted the citizens that live in the Dudley Creek project area. It was conducted in the form of a door-to-door questionnaire, targeting the representative of a household, with a minimum age of 18. As a representative sample was desired, all streets within the predefined project area were included. Before participation, citizens were informed of the intentions of the research, the expected outcome, and the participants role in the process. Citizens were given the opportunity to fill out the questionnaire either on the spot, or at a later point in time. The questionnaire contained questions regarding citizens characteristics (e.g. age, gender, living situation, education, experience, involvement in the Dudley Creek project, etc.), and their knowledge, risk perception, perceived adaptive capacity, and motivation. The measurement and analysis of knowledge and risk perception took place on a sub-construct level. To measure knowledge, questions targeted the sub-constructs of an individual's climate change knowledge, flood related knowledge, and preparedness. To measure risk perception, questions targeted the sub-constructs of an individual's climate change concern, flood related concern, sense of responsibility, and expected flood risk. A detailed description of the questionnaire questions and adaptive capacity measures can be found in Appendix C. The questionnaire also asked the citizens whether they were interested in participating in a follow-up interview. To determine the adaptive capacity impact of the flood project, the answers of the citizens that indicated to have been involved in the project were compared to those of citizens that have not been involved.

To evaluate and confirm the validity of the constructs (i.e. knowledge, risk perception, perceived adaptive capacity, motivation), a factor analysis and reliability check was performed, which can be found in Appendix D. The factor analysis shows that the items of knowledge load onto the sub-constructs of climate change knowledge, flood related knowledge, and preparedness. The items of risk perception load onto the sub-constructs of climate change concern, flooding concern, responsibility, and expected flood risk. To measure the reliability (i.e. internal consistency), in terms of whether the items measure what they should measure, a Cronbach Alpha test was used (see Table 5).

Table 5: Cronbach Alpha values (sub-)constructs

Construct	**Sub-construct**	**Cronbach Alpha (α)**
Knowledge	Climate change knowledge	0.78
	Flood related knowledge	0.89
	Preparedness	0.89
Risk perception	Climate change concern	0.82
	Flooding concern	0.86
	Responsibility	0.89
	Expected flood risk	0.68
Perceived adaptive capacity		0.72
Motivation		0.77

A descriptive analysis was performed, after which the Pearson correlation coefficients (Point-Biserial Correlation) of the continuous and dichotomous variables were determined, to measure the strength and direction of the linear relationship. All citizen characteristic variables included in the model were codified as dichotomous variables. They were coded as follows: gender (female = 0, male = 1), age (below the age of 50/lower age = 0, age of 50 and above/higher age = 1), education (citizens without a university degree or undergraduate diploma/lower education = 0, citizens with a university degree or undergraduate diploma/higher education = 1), living situation (tenant = 0, owner = 1), involvement (no = 0, yes = 1), experience (no = 0, yes = 1). An independent sample T-test was used to test whether the means of the groups differ significantly. A regression analysis was performed to analyze how the continuous variables are related to one another.

Based on the questionnaire response, potential interview candidates were contacted, of whom ten were selected. The interviews took place at the interviewees homes. Before the interview was conducted, the goal of the interview was explained, and key concepts defined and explained (e.g. adaptive capacity, knowledge, risk perception, perceived adaptive capacity, and motivation). This was done to ensure everyone understood the core concepts, reducing ambiguity in their understanding of the questions. The interview questions were based on the earlier conducted questionnaire, with a focus on a qualitative analysis of the adaptive capacity of individuals, uncovering the underlying reasoning of citizens. During the interview, participants were asked about individuals characteristics, consisting of their living situation (e.g. home owner, renting, other), personal experience with floods, and involvement in the Dudley Creek project. Questions were then asked to explore the relation between these characteristics and the individuals knowledge, risk perception, perceived adaptive capacity and motivation. For example, participants were asked 'Do you think personal experience with floods has/would influence(d) your knowledge?', followed by 'Why/why not, and how?'. The interviewees were also asked to describe the interrelation between indicators from their personal point of view. For example, they were asked 'Do you think your level of knowledge influences your perceived adaptive capacity?', followed by 'Why/why not, and how?'. The interviews were recorded, and transcribed after the sessions by the researcher. A full analysis of the interviews can be found in Appendix K.

Step 6: Explanation of the adaptive capacity impact of the project
Similarly to the explanation of the functional resilience impact, abductive reasoning is used to explain the adaptive capacity findings. It allows the researcher to work back from an unmet expectation (e.g. findings that do not align with the hypotheses) to find a plausible explanation (Peirce, 1995).

Based on the adaptive capacity assessment, the first step of the abductive analysis is to determine which quantitative (adaptive capacity) findings do not align with the hypotheses. The next step is to determine how the engagement process, governance context, and interviews with citizens explain these findings. The engagement process and governance context have been described in Step 2 of this research.

3. Results

3.1. Adaptive capacity assessment

3.1.1. Sample

The overall response rate for the questionnaire was 76%. The final sample consisted of 260 adult respondents. Fifty-two percent of the respondents were women (n=135), 47% were men (n=123), and 1% was gender diverse (n=2). Their age ranged from 18 to 70+ years. Three percent was aged 18 to 19, 18% aged 20 to 29, 17% aged 30 to 39, 23% aged 40 to 49, 18% aged 50 to 59, 13% aged 60 to 69, and 8% aged 70+. Regarding the level of education, 10% of respondents had attended high school without qualifications, 21% attended high school with qualifications, 25% had trade of technical qualifications, 6% had an undergraduate diploma, 21% had a bachelor diploma, and 17% had a postgraduate diploma. Of the respondents 59% was a home owner, 37% was renting, and 4% belonged to the 'other' category. About half of the respondents reported to have had no experience with flooding (54%), with 14% reporting only a direct experience, 17% reporting only an indirect experience, and 16% reporting both a direct and indirect experience. Of the respondents, 61% (n=159) indicated not to have been involved in the Dudley Creek flood remediation project, with 39% (n=101) indicating they had been involved.

Ten citizens were interviewed. Of the interviewees, all had some form of experience with flood events, ranging from flooded streets to flooding of their private property. Seven out of ten were home owners, one was renting, one lived in a bus, and one lived with her parents. Half of the respondents were male, the other half female. A full analysis of the interviews can be found in Appendix K.

3.1.2. Descriptive analysis

Table 6 depicts the minimum, maximum, mean, and standard deviation value of the components of adaptive capacity. Except for the concern of flooding, all components have a mean higher than 3 (neutral). The concern of flooding has the lowest mean score (2.67), and the level of motivation has the highest mean score (4.06). The minimum of most components equals one, with the exception of climate change knowledge and expected flood risk. They have a minimum score of respectively 1.3 and 1.7. A full overview of the descriptive statistics per sub-group can be found in Appendix J.

Table 6: Descriptive statistics components adaptive capacity

	N	Min	Max	Mean	Std. Deviation
Climate change knowledge	260	1.3	5.0	3.30	.69
Flood related knowledge	260	1.0	5.0	3.38	.92
Preparedness	260	1.0	5.0	3.19	.97
Concern climate change	260	1.0	5.0	3.57	.85
Concern flooding	260	1.0	5.0	2.67	1.18
Responsibility	260	1.0	5.0	3.70	.71
Expected flood risk	260	1.7	5.0	3.45	.69
Perceived adaptive capacity	260	1.0	5.0	3.80	.75
Motivation	260	1.0	5.0	4.06	.65

3.1.3. Correlation

Table 7 displays the correlations between the sub-components of knowledge, sub-components of risk perception, perceived adaptive capacity, motivation, and the citizen characteristics.

Interrelation components

Regarding the interrelation between the (sub-)components of adaptive capacity, the findings suggest that:

- Individuals who know more about climate change are more concerned about climate change (r = .40), feel a greater responsibility to contribute (r = .19), and perceive their adaptive capacity to be higher (r = .29). In turn, individuals who perceive their adaptive capacity to be high are more motivated to act (r = .31).
- Individuals who are more concerned about climate change perceive their adaptive capacity to be higher (r = .50), and are more motivated to act (r = .33). The same can be said about individuals that feel more responsible, as they are also more motivated (r = .29) and perceive a higher capacity (r = .42).

Table 7: Correlation between study variables (n)

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Knowledge															
1. Climate change knowledge	-	**.408**** (260)	**.338**** (260)	**.404**** (260)	-.008 (260)	**.185**** (260)	.071 (260)	**.289**** (260)	-.014 (260)	.092 (258)	.092 (260)	**.215**** (260)	**.132*** (249)	**.252**** (260)	.119 (260)
2. Flood related knowledge		-	**.497**** (260)	.063 (260)	-.035 (260)	.015 (260)	.019 (260)	.037 (260)	-.105 (260)	**.151*** (258)	**.255**** (260)	.049 (260)	**.417**** (249)	**.427**** (260)	**.276**** (260)
3. Preparedness			-	.076 (260)	-.002 (260)	.040 (260)	.112 (260)	-.002 (260)	-.086 (260)	.079 (258)	**.148*** (260)	-.120 (260)	**.166**** (249)	**.311**** (260)	**.251**** (260)
Risk perception															
4. Concern climate change				-	**.291**** (260)	**.505**** (260)	**.223**** (260)	**.498**** (260)	**.330**** (260)	**-.164**** (258)	-.036 (260)	**.155*** (260)	.084 (249)	.118 (260)	.081 (260)
5. Concern flooding					-	**.146*** (260)	**.203**** (260)	.089 (260)	.003 (260)	**-.161**** (258)	-.007 (260)	**-.182**** (260)	**-.136*** (249)	-.030 (260)	.083 (260)
6. Responsibility						-	**.159*** (260)	**.415**** (260)	**.290**** (260)	**-.204**** (258)	-.092 (260)	**.189**** (260)	.043 (249)	-.025 (260)	-.077 (260)
7. Expected flood risk							-	.113 (260)	.044 (260)	.042 (258)	-.017 (260)	.022 (260)	-.030 (249)	.025 (260)	.097 (260)
PAC and motivation															
8. Perceived adaptive capacity								-	**.306**** (260)	-.096 (258)	-.027 (260)	**.195**** (260)	.060 (249)	.044 (260)	-.038 (260)
9. Motivation									-	**-.197**** (258)	-.110 (260)	.116 (260)	.068 (249)	-.104 (260)	-.032 (260)
Citizen characteristics															
10. Gender										-	.093 (258)	-.099 (258)	.097 (248)	**.157*** (258)	.012 (258)
11. Age											-	**-.148*** (260)	**.273**** (249)	**.304**** (260)	**.212**** (260)
12. Education												-	.046 (249)	.011 (260)	.022 (260)
13. Living situation													-	**.289**** (249)	**.256**** (249)
14. Involvement														-	**.291**** (260)
15. Experience															-

Note: Variables 10, 11, 12, 13, 14, and 15 are dichotomous variables
** $p < .05$*
*** $p < .01$*

Indicators in relation to characteristics

Regarding the relation between the (sub-)components of adaptive capacity and citizen characteristics, the findings suggest that:

- Individuals with a higher level of education have a higher level of climate change knowledge (r = .22), are more concerned about climate change (r = .16), feel more responsible (r = .19), and perceive their adaptive capacity to be higher (r = . 20). However, they are less concerned about flooding (r = -.18).
- Home owners are more prepared (r = .17) and knowledgeable on the topics of climate change (r = .13) and flooding (r = .42) than tenants. However, they are less concerned about flooding (r = -.14)
- Males have a higher level of flood related knowledge (r = .15) than females, but are less concerned about flooding (r = -.16) and climate change (r = -.16), feel a lower responsibility to contribute (r = .-20), and are less motivated to act (r = -.20)
- Older individuals know more about flooding (r = .26) and are more prepared (r = .15) than younger individuals. The same can be said about individuals who have experienced a flood event as compared to individuals who have no such experience.
- Citizens that have been engaged in the Dudley Creek project have a higher level of climate- (r = .25) and flood-related knowledge (r = .43), and are more prepared (r = .31) than citizens that have not been engaged.

3.1.4. Independent sample T-Test

Independent sample T-Tests were used. The Levene's test was used to confirm whether the populations have equal variances.

H1: Engaged citizens have a higher level of knowledge, risk perception, perceived adaptive capacity, and motivation than non-engaged citizens.

- Climate change knowledge scores were significantly higher for involved (M = 3.52, SD = .70) than un-involved citizens (M = 3.16, SD = .65), t(258) = 4.19, one-tailed p < .001.
- Flood related knowledge scores were significantly higher for involved (M = 3.87, SD = .73) than un-involved citizens (M = 3.06, SD = .89), t(242) = 7.93, one-tailed p < .001. Levene's test indicated unequal variances (F = 7.71, p = .006), so degrees of freedom were adjusted from 258 to 242.
- Preparedness scores were significantly higher for involved (M = 3.57, SD = 0.85) than un-involved citizens (M = 2.95, SD = 0.96), t(258) = 5.26, one-tailed p < .001.
- Concern climate change scores were significantly higher for involved (M = 3.69, SD = .73) than un-involved citizens (M = 3.49, SD = .92), t(245) = 2.01, one-tailed p = .023. Levene's test indicated unequal variances (F = 4.42, p = .036), so degrees of freedom were adjusted from 258 to 245.

H8a: Property owners have a higher level of knowledge, risk perception, perceived adaptive capacity, and motivation than tenants.

- Climate change knowledge scores were significantly higher for property owners (M = 3.38, SD = .68) than tenants (M = 3.19, SD = .67), t(247) = 2.09, one-tailed p = .019.
- Flood related knowledge scores were significantly higher for property owners (M = 3.70 , SD = .78) than tenants (M = 2.92, SD = .92), t(247) = 7.22, one-tailed p < .001.
- Preparedness scores were significantly higher for property owners (M = 3.33, SD = .89) than tenants (M = 3.00, SD = 1.07), t(247) = 2.65, one-tailed p = .005.
- Concern flooding scores were significantly lower for property owners (M = 2.53, SD = 1.14) than tenants (M = 2.85, SD = 1.22), t(247) = 2.15, one-tailed p = .016.

H8b: Higher-educated individuals have a higher level of knowledge than lower-educated individuals.

- Climate change knowledge scores were significantly higher for higher-educated (M = 3.47, SD = .72) than lower-educated citizens (M = 3.17, SD = .64), t(258) = 3.54, one-tailed p < .001.
- Preparedness scores were significantly lower for higher-educated (M = 3.06, SD = 1.02) than lower-educated citizens (M = 3.30, SD = .91), t(258) = 1.94, one-tailed p = .027.

H8c: Individuals of a higher-age have a higher level of knowledge than individuals of a lower-age.

- Flood related knowledge scores were significantly higher for higher-age (M = 3.67, SD = .74) than lower-age citizens (M = 3.19, SD = .97), t(250) = 4.50, one-tailed $p < .001$. Levene's test indicated unequal variances (F = 8.55, p = .004), so degrees of freedom were adjusted from 258 to 250.
- Preparedness scores were significantly higher for higher-age (M = 3.37, SD = .88) than lower-age citizens (M = 3.08, SD = 1.00), t(258) = 2.40, one-tailed p = .009.

H8d: The motivation of individuals who have experience with a hazard event is higher than the motivation of individuals who have no experience.

- Motivation (p = .61) scores were not significantly different for citizens with experience and citizens without experience.

H8e: The motivation of individuals with direct experience is higher than the motivation score of individuals with indirect experience.

- Motivation (p = .06) scores were not significantly different for citizens with direct experience and citizens with indirect experience.

H8f: The risk perception of individuals with experience is different from individuals with no experience.

- Climate change concern ($p < .19$), flooding concern ($p < .18$), expected flood risk ($p < .22$), and responsibility ($p < .13$) scores were not significantly different for citizens with experience and citizens without experience.

3.1.5. Regression

To investigate the relationships between adaptive capacity indicators, regression analysis have been performed.

H2: There is a relationship between an individual's knowledge and an individual's risk perception

- The climate change knowledge scores significantly predicted the climate change concern scores, β = .50, t(258) = 7.10 , $p < .001$. Climate change knowledge also explained a significant proportion of variance in climate change concern scores, $R^2 = .16$, F(1, 258) = 50.46, $p < .001$.
- The climate change knowledge scores significantly predicted the responsibility scores, β = .19, t(258) = 3.03 , p = .003. Climate change knowledge also explained a significant proportion of variance in responsibility scores, $R^2 = .03$, F(1, 258) = 9.16, p = .003.

H3: There is a positive relationship between an individual's motivation and an individual's level of knowledge.

- No significant relationship was found between an individual's motivation score, and the individuals climate change knowledge (p = .82), flood related knowledge (p = .09), and preparedness score (p = .17).

H4: There is a positive relationship between an individual's level of knowledge and an individual's perceived adaptive capacity

- The climate change knowledge scores significantly predicted the perceived adaptive capacity scores, β = .31, t(258) = 4.86 , $p < .001$. Perceived adaptive capacity also explained a significant proportion of variance in climate change knowledge scores, $R^2 = .08$, F(1, 258) = 23.59, $p < .001$.

H5: There is a positive relationship between an individual's risk perception and an individual's motivation.

- The concern climate change scores significantly predicted the motivation scores, β = .25, t(258) = 5.6 , $p < .001$. Concern climate change also explained a significant proportion of variance in motivation scores, $R^2 = .11$, F(1, 258) = 31.50, $p < .001$.
- The responsibility scores significantly predicted the motivation scores, β = .27, t(258) = 4.86, $p < .001$. Responsibility also explained a significant proportion of variance in motivation scores, $R^2 = .84$, F(1, 258) = 23.61, $p < .001$.

H6: There is a negative relationship between an individual's perceived adaptive capacity and an individual's risk perception.

- The perceived adaptive capacity scores significantly predicted the climate change concern scores, $\beta = .57$, $t(258) = 9.22$, $p < .001$. Perceived adaptive capacity also explained a significant proportion of variance in climate change concern scores, $R^2 = .25$, $F(1, 258) = 84.96$, $p < .001$.
- The perceived adaptive capacity scores significantly predicted the responsibility scores, $\beta = .39$, $t(258) = 7.33$, $p < .001$. Perceived adaptive capacity also explained a significant proportion of variance in responsibility scores, $R^2 = .17$, $F(1, 258) = 53.75$, $p < .001$.

H7: There is a positive relation between an individual's perceived adaptive capacity and an individual's motivation

- The perceived adaptive capacity scores significantly predicted the motivation scores, $\beta = .27$, $t(258) = 5.17$, $p < .001$. Perceived adaptive capacity also explained a significant proportion of variance in motivation scores, $R^2 = .09$, $F(1, 258) = 26.68$ $p < .001$.

3.1.6. Additional findings

In addition to the hypotheses, some interesting differences were found regarding the level of education, gender, and experience of citizens.

Education and adaptive capacity

- Concern flooding scores were significantly lower for higher-educated (M = 2.43, SD = 1.10) than lower-educated citizens (M = 2.86, SD = 1.21), $t(258) = 2.98$, one-tailed $p = .002$.
- Concern climate change scores were significantly higher for higher-educated (M = 3.72, SD = .84) than lower-educated citizens (M = 3.45, SD = .85), $t(258) = 2.53$, one-tailed $p = .006$.
- Responsibility scores were significantly higher for higher-educated (M = 3.85, SD = .68) than lower-educated citizens (M = 3.58, SD = .70), $t(258) = 3.10$, one-tailed $p < .001$.
- Perceived adaptive capacity scores were significantly higher for higher-educated (M = 3.96, SD = .72) than lower-educated citizens (M = 3.67, SD = .75), $t(258) = 3.20$, one-tailed $p < .001$.

Gender and adaptive capacity

- Flood related knowledge scores were significantly higher for male (M = 3.53, SD = .91) than female citizens (M = 3.25, SD = .92), $t(256) = 2.45$, one-tailed $p = .008$.
- Concern climate change scores were significantly lower for male (M = 3.43, SD = .85) than female citizens (M = 3.7, SD = .83), $t(256) = 2.65$, one-tailed $p = .004$.
- Concern flooding scores were significantly lower for male (M = 2.49, SD = 1.12) than female citizens (M = 2.86, SD = 1.21), $t(256) = 2.60$, one-tailed $p = .005$.
- Responsibility scores were significantly lower for male (M = 3.55, SD = .73) than female citizens (M = 3.84, SD = .65), $t(256) = 3.34$, one-tailed $p < .001$.
- Motivation scores were significantly lower for male (M = 3.93, SD = .67) than female citizens (M = 4.18, SD = .60), $t(256) = 3.22$, one-tailed $p < .001$.

Experience and knowledge

- Flood related knowledge scores were significantly higher for citizens with experience (M = 3.65, SD = .86) than citizens without experience (M = 3.14, SD = .91), $t(258) = 4.62$, one-tailed $p < .001$.
- Preparedness scores were significantly higher for citizens with experience (M = 3.45, SD = .91) than citizens without experience (M = 2.97, SD = .96), $t(258) = 4.17$, one-tailed $p < .001$.

3.1.7. Summary

Table 8 summarizes the findings of the adaptive capacity assessment and hypotheses testing.

Table 8: Summary adaptive capacity assessment

Hypotheses	Hypotheses conclusion	Main findings
H1: Engaged citizens have a higher level of knowledge, risk perception, perceived adaptive capacity, and motivation, than non-engaged citizens.	Partially accepted	Engaged citizens, as compared to non-engaged: ▪ More prepared ▪ Higher level of climate and flood related knowledge ▪ More concerned about climate change ▪ No significant difference between motivation and perceived adaptive capacity
H2: There is a relationship between an individual's knowledge and an individual's risk perception.	Accepted	An individual's climate change knowledge has a positive effect on their climate change concern and sense of responsibility.
H3: An individual's motivation has a positive effect on an individual's level of knowledge.	Failure to accept	No significant relationship between motivation and knowledge.
H4: An individual's level of knowledge has a positive effect on an individual's perceived adaptive capacity.	Accepted	An individual's climate change knowledge has a positive effect on their perceived adaptive capacity.
H5: An individual's risk perception has a positive effect on an individual's motivation.	Accepted	An individual's climate change concern and sense of responsibility have a positive effect on an individual's motivation to adapt.
H6: An individual's perceived adaptive capacity has a negative effect on an individual's risk perception.	Rejected	An individual's perceived adaptive capacity has a positive effect on their climate change concern and sense of responsibility.
H7: An individual's perceived adaptive capacity has a positive effect on an individual's motivation.	Accepted	An individuals perceived adaptive capacity has a positive effect on their motivation.
H8a: Property owners have a higher level of knowledge, risk perception, perceived adaptive capacity and motivation than tenants.	Partially accepted, partially rejected	Property owners, compared to tenants: ▪ More prepared ▪ Higher level of climate and flood related knowledge ▪ Less concerned about flooding ▪ No significant difference between climate change concern, responsibility, expected flood risk, motivation, and perceived adaptive capacity
H8b: Higher-educated individuals have a higher level of knowledge than lower-educated individuals.	Partially accepted, partially rejected	Higher-educated citizens, compared to lower-educated: ▪ Higher level of climate change knowledge ▪ Less prepared
H8c: Individuals of a higher-age have a higher level of knowledge than individuals of a lower-age.	Accepted	Citizens of a higher age, compared to lower age: ▪ More prepared ▪ Higher level of flood related knowledge

H8d: The motivation of individuals who have experience with a hazard event is higher than the motivation of individuals who have no experience.	Failure to accept	No significant difference between the motivation of citizens with experience and citizens without experience.
H8e: The motivation of individuals with direct experience is higher than the motivation of individuals with indirect experience.	Failure to accept	No significant difference between the motivation of citizens with direct experience and citizens with indirect experience.
H8f: The risk perception of individuals with experience is different from individuals with no experience.	Failure to accept	No significant difference between the risk perception of citizens with experience and citizens without experience.
Additional findings		Higher-educated citizens, compared to lower-educated: ▪ More concerned about climate change ▪ Higher sense of responsibility ▪ Higher perceived adaptive capacity ▪ Less concerned about flooding Citizens with experience, compared to no-experience ▪ Higher level of flood related knowledge ▪ More prepared Male citizens, as compared to females: ▪ Higher level of flood related knowledge ▪ Less concerned about flooding and climate change ▪ Lower sense of responsibility ▪ Less motivated to adapt

3.2. Analysis adaptive capacity impact

Abductive reasoning is used to examine the adaptive capacity of citizens, using the engagement process and governance description, as well as the interview data. Specific attention is given to the findings that do not align with the expectations.

3.2.1. The role of engagement

Statistical evidence was found to support hypotheses 1, namely that engaged citizens are more prepared, have a higher level of climate and flood related knowledge, and are more concerned about climate change than non-engaged citizens. However, no evidence was found that engaged citizens score higher on responsibility, concern flooding, expected flood risk, motivation, or perceived adaptive capacity.

Analysis of the engagement process showed that the engagement process mainly focused on increasing the knowledge of the citizens (e.g. understanding of the decision-making process, explaining technical aspects and implications of the project), but did not specifically target other elements of adaptive capacity (e.g. motivation, perceived adaptive capacity, etc.). The analysis of the governance context showed that this focus was strengthened by the fact that citizen participation took place more on an inform than consult basis. The 'engagement', for half of the citizens that indicated on the questionnaire to have been engaged, was based solely on receiving information through newsletters and/or websites. Citizens stated that this information consisted of general information on what the project team was doing, and briefly described what, why, where, and when works would take place. The other half of engaged citizens also participated in more extensive engagement activities (e.g. public meetings, drop-in sessions, etc.), which hold the potential to increase more than just knowledge. However, during the interviews, citizens pointed out that these meetings were mainly used to express concern, instead of providing additional background information. Though the project team tried to inform people of how to get involved, the impact of the project on perceived adaptive capacity and motivation may have been limited by the feeling of citizens that they could have no significant impact on the project, as it would continue regardless of their input. While some citizens felt that involvement increased their preparedness and feeling of knowing what to do, the motivation of others decreased, due to the perceived lack of a two-way dialogue. The absence of a significant difference for most components of risk perception (e.g. flood concern, responsibility expected flood risk) can be explained by the fact that the project both increased and decreased risk perception. During the interviews, citizens explained that they experienced an increased awareness of risks they didn't realize existed before, but at the same time were reassured, knowing that something was being done about it.

3.2.2. Effect of citizen characteristics on adaptive capacity

The quantitative analysis has found statistical evidence to support hypotheses 8c, namely that individuals of a higher-age have a higher level of knowledge than individuals of a lower-age. The analysis shows that citizens of a higher age are more prepared, and have a higher level of flood related knowledge, than citizens of a lower age.

As the evidence of the quantitative analysis partly/does not support(s) hypotheses 8a, b, d, e, and f, concerning an individual's living situation, education, experience, these are further analyzed using the interviews with citizens.

Living situation

Statistical evidence was found that property owners are more prepared and have a higher level of climate and flood related knowledge than tenants. However, no evidence was found that property owners score higher on climate change concern, responsibility, expected flood risk, motivation, and perceived adaptive capacity. This is explained by the fact that a number of citizens considered there to be no difference in risk perception, as, regardless of your living situation, you and your items would be affected by the flood. They also pointed out that, while having to protect one's own investment may increase risk perception, the increased awareness about the conditions of the house and potential risks may decrease the risk perception. Regarding motivation, the fact that a property owner has their house at stake may increase their motivation to take action, and prepare for a future flood event. Since the findings show that their flood concern is relatively low, however, this explains the similarity in motivation, regardless of living situation. Also, as compared to tenants, citizens considered that higher costs associated with taking action/adapting for property owners could potentially decrease their motivation. Regarding perceived adaptive capacity, it was pointed out by the citizens that, while owning a home may increase your capacity to take action (e.g. modify the house), you can also perceive a lower capacity, as you don't have the ability to simply move away. The opposite was considered true for tenants. Furthermore, statistical evidence was found that property owners are less concerned about flooding than tenants. During the interviews, citizens stated that being a home owner meant that they were more aware of the risks, knew more about the conditions of the house, had the ability to have everything checked out, as well as to make modifications to the house if needed. In other words, there was a shared understanding that owners know more about their specific situation. Additionally, as flooding poses a more certain and tangible issue than climate change, preparing for the former is considered less of a concern.

Education

Statistical evidence was found that higher-educated citizens have a higher level of climate change knowledge than lower educated citizens. However, statistical evidence was found that higher-educated citizens are less prepared than lower-educated citizens. Additionally, statistical evidence was found that higher-educated citizens are less concerned about flooding than lower-educated citizens, but are more concerned about climate change, feel more responsible and perceive their adaptive capacity to be higher. This is explained by the significantly higher level of knowledge of higher-educated citizens, as, based on the previous findings, individuals with a higher level of knowledge perceive their adaptive capacity to be higher, and individuals with a higher perceived adaptive capacity are more concerned about climate change and feel a greater responsibility to contribute.

Experience

No statistical evidence was found that citizens with experience are more motivated, or have different risk perceptions, than citizens without experience. During the interviews, citizens shared the expectation that negative feelings associated with previous experiences increased their risk perception, while positive feelings decrease risk perception. Furthermore, they pointed out that the relation between their risk perception and flood experience depends on the specifics (e.g. severity) of the experience. The absence of a significant difference in risk perception and motivation is explained by the fact that, though the experiences made the issue tangible, and increased the sense that something needed to be done, the experience mainly demonstrated that a flood event was not life destroying, and that the citizens were relatively safe. If the citizens had experienced more serious/continual consequences, they agreed that their feeling of a threat and sense of urgency would have been stronger. It was also mentioned that, while experiencing a flood event initially led to an increased motivation to search for information, as soon as they filled the knowledge gap, their risk perception and motivation returned to normal levels.

No statistical evidence was found that direct experience is more likely to increase motivation than indirect experience. This is not completely unexpected, as also no significant differences in motivation were found between citizens with- and without experience. The fact that the citizens experiences with flooding were relatively recent, meaning that both direct and indirect experiences were easily recalled, most likely played a role.

Additionally, statistical evidence was found that citizens with experience have a higher level of flood related knowledge and preparedness than citizens without experience. The citizens attributed this to the fact that their experience (initially) increased their motivation to search for information, leading to an increased knowledge. The experience led them to become more aware of what was going on, what to expect in the future, and showed them what was needed to deal with/prepare for different situations.

3.2.3. Interrelation adaptive capacity indicators

The quantitative analysis has found statistical evidence to support hypotheses 2, 4, 5, and 7, as the analysis shows that (1), an individual's climate change knowledge has a positive effect on their climate change concern and sense of responsibility, (2) an individual's climate change knowledge has a positive effect on their perceived adaptive capacity, (3) an individual's climate change concern and sense of responsibility have a positive effect on an individual's motivation to adapt, and (4), an individuals perceived adaptive capacity has a positive effect on their motivation.

As the evidence of the quantitative analysis partly/does not support(s) hypotheses 3 and 6, concerning the relation between motivation and knowledge, and perceived adaptive capacity and risk perception, these are further analyzed using the interviews with citizens.

Motivation and knowledge

No evidence of significant relationship between motivation and knowledge was found in the current study. Citizens explained this by pointing out that both a high and low level of knowledge could motivate them, influenced by their general attitude/personality. Citizens also mentioned a balance between their motivation and knowledge. While the initial sensation of not knowing enough motivated them to go out and increase their knowledge, a high level of knowledge meant that their threat level decreased, consequently lowering their motivation again.

Perceived adaptive capacity and risk perception

Statistical evidence was found that an individual's perceived adaptive capacity has a positive effect on their climate change concern and sense of responsibility. In other words, the higher perceived adaptive capacity, the higher the risk perception. This is explained by the idea that, as one perceives their own capacity to be higher, they feel a greater responsibility (e.g. to themselves and the community) to use that capacity. Since climate change knowledge is related to climate change concern, and individuals with a higher perceived capacity have a higher level of climate change knowledge, this explains their increased levels of concern, even though their perceived capacity is high. In other words, their increased awareness leads them to be more worried. A number of citizens mentioned that they did not perceive a relation between risk perception and their own capacities at all. They considered their risk perception to be relatively steady (e.g. low), based more on their personalities than their capacities.

3.2.4. Summary

Table 9 summarizes the analysis of the adaptive capacity assessment, and shows what role the engagement process, interrelation indicators, and citizen characteristics played with regard to the adaptive capacity findings that did not align with the expectations.

Table 9: Explanation adaptive capacity findings

Findings that do not align with expectations	Explanation
H1: No significant difference between the motivation and perceived adaptive capacity of engaged vs. non-engaged citizens.	▪ The engagement process focused on informing citizens, instead of increasing the local competence. ▪ Meetings were used mainly to express concern, instead of providing background information. ▪ Citizens perceived a lack of a two-way dialogue/feeling of not being heard.
H3: No significant relationship between motivation and knowledge.	▪ The effect of motivation is mediated by an individual's general attitude/personality towards knowledge. ▪ The initial sensation of not knowing enough can motivate an individual, but filling the knowledge gap will lower it again.
H6: An individual's perceived adaptive capacity has a positive effect on their climate change concern and sense of responsibility.	▪ As one perceives their own capacity to be higher, they may feel a greater responsibility (e.g. to themselves and the community) to use that capacity. ▪ The increased awareness associated with a higher perceived adaptive capacity led citizens to be more worried. ▪ An individual's personality (e.g. generally not worried) may play bigger role on risk perception than their capacity.
H8a: Property owners are less concerned about flooding than tenants. There is no significant difference between their climate change concern, responsibility, expected flood risk, motivation, and perceived adaptive capacity.	▪ Increased awareness on conditions of the house and potential risks decreases risk perception. ▪ Having to protect an investment may increase risk perception and motivation ▪ Property owners associated adaptation with higher costs. ▪ Citizens feel that owning a home increases your capacity to take action (e.g. modify the house, have everything checked out), but also means it's harder to move away.
H8b: Higher-educated citizens, are more concerned about climate change, feel more responsible, perceive their adaptive capacity to be higher, and are less concerned about flooding than lower-educated citizens.	▪ Knowledge is positively related to perceived adaptive capacity, and perceived adaptive capacity is positively related to climate concern and responsibility.
H8d: No significant difference between the motivation of citizens with experience and citizens without experience.	▪ Depending on the severity of the flooding experience, it may demonstrate that a citizens is relatively safe in case of a flood event. ▪ An experience initially increases motivation to gather information, but as soon as the knowledge gap is filled, this returns to normal.
H8e: No significant difference between the motivation of citizens with direct experience and citizens with indirect experience.	▪ The citizens experiences with flooding were relatively recent, meaning that both direct and indirect experiences were easily recalled.

H8f: No significant difference between the risk perception of citizens with experience and citizens without experience.	▪ Negative feelings associated with previous experiences increase risk perception, while positive feelings decrease risk perception. ▪ The more severe/longer the experience, the greater the impact on risk perception.

4. Discussion

A six-step approach for determining to what extent and why a flood project contributes to urban flood resilience was developed and tested. The steps are: (1) characterizing the urban system, (2) characterizing the flood project and context, (3) assessing the impact of the project on functional resilience, (4) explaining the functional resilience impact, (5) assessing the impact of the project on adaptive capacity, (6) explaining the adaptive capacity impact. For the functional resilience assessment, a set of 'resilience principles' was used: homeostasis, omnivory, high flux, flatness, buffering, and redundancy. For the adaptive capacity assessment, 260 adult residents were interviewed using a structured questionnaire, and asked about their knowledge, risk perception, perceived adaptive capacity, and motivation. The approach can be used as a guide towards the assessment of the resilience impact of a project, as well towards an explanation of the observed impact. This allows users to either draw conclusions on what needs to change for future projects, or address potentially limiting factors before commencing a project.

The approach was applied to the Dudley Creek flood project in Christchurch, New Zealand. The analysis revealed that the flood project as a whole increased the urban flood resilience of the system, by improving both the functional resilience and adaptive capacity. Though the impact is positive, the project impact was limited in particular with regard to local competences, as the project underutilized the principles of flatness and redundancy, and was not found to significantly impact the motivation and perceived adaptive capacity of citizens.

4.1. Reflection on results

Regarding the **functional resilience** impact, a similar case as that of the current study was assessed by Wardekker, et al. (2016) in the Dutch wetlands. Though the key functions they identified (i.e. agriculture, nature, clean water, recreation) were different than those of the Dudley Creek system (i.e. residential, recreational, ecological, economic), their analysis revealed that the principle of flatness in particular was underutilized by the management options, which is also found in the current study. Additionally, Wardekker, et al. (2016) found that redundancy was underutilized (for the agriculture function), similarly to the low redundancy score of the Dudley Creek project. The fact that both the current study and that of Wardekker, et al. (2016), using different case study projects, find a limited impact on flatness and redundancy, may indicate a common issue regarding the way in which flood projects aim to increase urban resilience.

Regarding the **adaptive capacity**, literature expects citizen engagement to lead to an increased knowledge, risk perception, motivation, and perceived adaptive capacity. In line with the studies of Gaventa & Barret (2010), O'Sullivan, et al. (2012), and Wachinger, et al. (2013), the current study finds that engaged citizens have a higher level of knowledge, and higher risk perception than non-engaged citizens. However, no evidence was found that engaged citizens score higher on motivation (e.g. Gaventa & Barret, 2010; O'Sullivan, et al., 2015), or perceived adaptive capacity (e.g. Gaventa & Barret, 2010; Wachinger, et al., 2013). This can be explained by the fact that the goal of the engagement process of the case study project focused on informing citizens, instead of increasing the local competence. In addition, though different participation methods were used, citizens that were interviewed perceived a lack of two-way dialogue, and felt that meetings were used mainly to express concern, instead of providing background information.

The current study provides a real-world example of the influence that the **process design** has on the urban resilience impact of a flood project. Spalek (2005) and Newig, et al. (2013) indicate that the level of authority of an initiator can influence the outcome of a project, which was also found in the current study. The lower level of authority/power of the initiator in the case study project limited the scope of measures/options that the project considered, and reduced the opportunities to reduce some of the negative (resilience) impacts. As mentioned by Newig, et al. (2013), Driessen, et al. (2016), Bressers, Bressers, & Larrue (2016), Taherdoost & Keshavarzsaleh (2016), Beleiu, Crisan, & Nistor (2015) the rationale, goal, and objectives of a project also play an important role when it comes to the outcome of the project. The current study confirms this, as it was found that the rationale, goal, and set of objectives of the project limited the resilience impact, as they did not focus on increasing urban resilience, but on returning flood risk to pre-earthquake levels. Adaptation to future scenario's was not given specific attention, and resilience implications were considered as secondary targets. The importance of resources, as suggested by Newig, et al. (2013), Beleiu, Crisan, & Nistor (2015), and Taherdoost & Keshavarzsaleh (2016), was highlighted by the current study, as the resources available limited the incentive for a long-term solution, such as to provide additional flood risk reduction, and to increase local competencies.

The current study also provides a real-world example of the influence of the **governance context** on the process design of a flood project. Spalek (2005), Newig & Frisch (2009), Newig, et al. (2013), Beleiu, Crisan, & Nistor (2015), and Taherdoost & Keshavarzsaleh (2016) consider that the extent of a governance arrangement influences the direction of the process, and the outcome of decision making. The findings of the current study confirm this, as the low extent restricted an urban flood resilience approach. The restriction was the result of the fact that co-governance and citizen engagement approaches were not yet well embedded, there was uncertainty with regard to resilience and adaptation approaches, and no specific requirements for engagement were stipulated by higher order policies. When it comes to restricted implementation, in addition to the extent, Bressers, Bressers, & Larrue (2016) and de Vente, et al. (2016) highlight the importance of coherence. The lack of collaboration between national, regional, and territorial authorities that was found in the current study supports the claim that non-coherent governance arrangements influence the process of a project by restricting implementation. Regarding the flexibility and intensity of a governance arrangement, Bressers, Bressers, & Larrue (2016) assume that if flexibility and intensity are low, the likeliness of adaptive strategies to be used is also low, and adaptive behavior will be avoided. What the current study finds is that adaptive behavior may not only be avoided when intensity is low, but also when intensity is high. The (time) pressure from actors towards change that drove the case study project meant that decision-makers went for traditional/safe approaches, instead of an adaptive approach, as they associated the latter with an increased risk of delays. Regarding flexibility, the current study found that the dependency on local funding restricted the use of adaptive strategies, as suggested by Bressers, Bressers, & Larrue (2016). Interestingly enough, because the decision-makers chose for adaptive pathways, allowing measures to be adapted in the future (e.g. high flexibility), they chose not to embed additional resilience criteria into the current design. Put differently, the potential for adaptation led to a more reactive than proactive design.

When looking at the **citizen characteristic** of age, in line with the study of APFM (2016), evidence was found that citizens of a higher age are more prepared, and have a higher level of flood related knowledge, than citizens of a lower age. Regarding an individual's living situation, in line with the study of APFM (2016), statistical evidence was found that property owners are more prepared and have a higher level of climate and flood related knowledge than tenants. However, no evidence was found that property owners score higher on climate change concern, responsibility, expected flood risk, motivation, and perceived adaptive capacity. Also, while the studies of Grothmann & Patt (2005) and APFM (2016) found property owners to have a higher concern than tenants, the current study found statistical evidence that property owners are less concerned about flooding than tenants. The lower concern can be explained by the fact that owners in the case study area knew more about their specific situation, such as the conditions of their house, were more aware of the risks, and felt prepared for a flood event. Regarding a citizens level of education, in line with the study of APFM (2016), evidence was found that higher-educated citizens have a higher level of climate change knowledge than lower educated citizens. Regarding preparedness, however, the current study finds that higher-educated citizens are less prepared than lower-educated citizens. Regarding the previous flood experiences of citizens, both Grothmann & Patt (2005) and Terpstra, Lindell, & Gutteling (2009) expect an increased motivation for citizens that have had a flood experience. However, the current study finds no evidence that citizens with experience are more motivated, or have different risk perceptions, than citizens without experience. Wachinger, et al. (2013) and Miceli, Sotgiu, & Settanni (2007) provide an explanation as to why this may be the case, in that the feelings (e.g. positive or negative) associated with previous experiences can influence the direction of change of risk perception (e.g. increase or decrease). This suggests that citizens with the same experience may interpret the situation differently, and may therefore experience an opposite impact on their risk perception. While Terpstra, Lindell, & Gutteling (2009) expect direct experience to be more likely to increase motivation, the current study found no evidence to support this claim. One explanation for the absence of a significant difference may be the relatively low number of questionnaire respondents per sub-group (e.g. forty-three citizens with only indirect experience, and thirty-six with only direct experience), as well as the fact that the citizens experiences with flooding were relatively recent. Lastly, regarding gender, the current study found evidence that, though male citizens have a higher level of flood related knowledge, they are less concerned about flooding and climate change, have a lower sense of responsibility, and are less motivated to adapt than female citizens. Previous studies have not found a consistent role of gender. For example, the study of Wachinger, et al. (2013) found that the factors of gender do not play an important role when it comes to risk perception, while the studies of Leiserowitz (2006), Miceli, Sotgiu, & Settanni (2007), and APFM (2016) found that males tend to have a lower risk perception than females, in line with the findings of the current research.

When looking at the **interrelation of adaptive capacity indicators**, in line with the studies of Hommes, et al. (2009), O'Sullivan, et al. (2015), Brooks & Adger (2004), and APFM (2016), evidence was found that an individual's knowledge is (positively) related to their risk perception. Also, evidence was found to support the assumption of Grothmann & Patt (2005) and Terpstra, Lindell, & Gutteling (2009) that a high risk perception leads to a high motivation. Furthermore, in line with the studies of Grothmann & Patt (2005) and Wolf (2011), evidence was found that an individuals perceived adaptive capacity and motivation are positively related. In other words, as Grothmann & Patt (2005) put it, if an individual has a high perceived adaptive capacity, this is expected to lead to adaptive behavior. While the studies of Terpstra, Lindell, & Gutteling (2009) and O'Sullivan, et al. (2015) found that that an enhanced awareness contributes to an individual's motivation, and a higher motivation causes individuals to collect more information, no evidence of significant relationship between motivation and knowledge was found in the current study. The current study explains this by means of the mediating effect of a citizens general attitude/personality, and balance between a citizens motivation and knowledge. While an initial sensation of not knowing enough may motivate individuals to collect more information, as soon as the knowledge gap is filled, motivation is lowered again. Regarding the relation between perceived adaptive capacity and risk perception, the study of Terpstra, Lindell, & Gutteling (2009) assumes that a higher perceived adaptive capacity will lead to a lower risk perception. The current study, however, found the opposite, namely the higher the perceived adaptive capacity, the higher the risk perception. The higher risk perception is explained by the fact that an increased awareness led some citizens to become more worried, while at the same time the perception of a high own capacity increased their overall sense of responsibility. Lastly, in line with Gaventa & Barret (2010), who state that by gaining knowledge an individual can develop their sense of self-efficacy, statistical evidence was found that an individual's climate change knowledge and perceived adaptive capacity are positively related.

4.2. Comparison with other approaches

To answer the research question of the current study, 'to what extent and why did the Dudley Creek flood project influence urban flood resilience', a mixed method case study approach was used, consisting of six-steps, using both qualitative and quantitative data. Compared to other studies that deal with the assessment of resilience, key distinguishable features are the combination of the functional resilience and adaptive capacity, the focus on both assessing as well as explaining the observed impact, and the inclusion of objective and subjective capacities.

The conceptualization of resilience used in the current study bears similarities to the work of Rezende, et al. (2019), who also combine definitions of engineering and ecological resilience, and include adaptive capacity. The Urban Flood Resilience Index used by Rezende, et al. (2019), however, is not capable of directly measuring human risk perception, while the approach presented in the current study does allow for such a measurement. Compared to Cutter, et al. (2010), who focus on the resilience of communities, and provide a baseline set of conditions for communities to foster resilience, the approach of the current study is more suitable for a local application. Though the tool of Cutter, et al. (2010) may be useful for assessing resilience, as mentioned by the authors, it is less compatible with local data. Instead of using the approach of the current study for a local situation/water management plan, it could also be used for the assessment of national water management plans. While the resilience assessment presented in the current paper builds on the work of Wardekker, et al. (2016), the current study extends the approach to allow the user to also include the adaptive capacity of individuals, and explain the observed impacts by analyzing the engagement process, process design, and governance context. Specifically looking at the assessment of adaptive capacity, though both the works of Brooks & Adger (2004) and Lockwood, et al. (2015) provide means of assessing the objective capacity of individuals, contrary to the current study they do not fully incorporate the subjective element associated with human actors (e.g. perceived adaptive capacity and motivation).

4.3. Reflection on approach

Functional resilience assessment

The system-oriented approach of describing a system in terms of key characteristics, functions, and disturbances, provided a straightforward way in which the current- and desirable-system state could be identified. It supported the resilience assessment, as it made it easier for the researcher to communicate what should be made resilient to the workshop participants. Since the identification of key functions is inherently subjective, preferably, decision-makers, as well as different stakeholders from the area would have been consulted. As this was not feasible, identification of key functions in the current study is based on local (district) planning documents, under the assumption that these plans represent the Council's view on the key desirable aspects of the urban system. As these documents apply to a wider scale, this may mean that more specific functions are overlooked. Also, the researcher assumed that all functions are valued equally/receive an equal weighting. This means, for example, that the recreational function was considered as important for the urban system as the residential function. While an unequal weighting by the decision-makers may have led to a different result of the assessment, based on the resources available, the researcher found no reason to assume that any of the functions were valued differently than the others. For a future application, conducting a supplementary sensitivity analysis may provide valuable insights on the impact of key function-choice on the overall assessment.

Regarding the functional resilience assessment, the principles developed by Wardekker, et al. (2016) allowed for a quick impact assessment of a variety of flood measures, and made resilience more understandable for workshop participants. This said, there are some important aspects to consider. First of all, the resilience impact assessment of the flood project is based on a selected set of principles (e.g. omnivory, redundancy, buffering, homeostasis, flux, flatness). Though carefully selected, as resilience comprises the whole picture, other principles mentioned by literature (e.g. adaptive planning and design) may be equally important. In other words, one should realize that the conclusions regarding the resilience impact are inherently limited to the principles used.

There are also uncertainties associated with the actual use of the selected principles and the interpretation of findings. For example, one has to consider trade-offs between principles. While a flood measure may have a positive resilience impact for one principle, it may be negative for another, increasing the potential for misinterpretation of averaged resilience impacts. This also applies to the focus on just one flood project, which is part of a greater flood management scheme. Instead of using the resilience principles to assess individual flood measures, or even one flood project, the most comprehensive assessment is achieved when applied to overarching management plans. Another consideration is the subjectivity of scoring, as individuals may have different time-scales in mind. If you perform the assessment with a very long term perspective, the climate change impacts will be significantly higher, making it hard for measures to achieve a 'maximum' resilience score. For a future application, it may therefore be useful to set the timeframe beforehand (e.g. 10, 20, or 30 years in the future). Also, there may be different explanations of a 'neutral' score of '3' for a specific principle. It can either mean that the measure has no impact at all, or that it has both a positive and negative impact, averaging out as neutral. Arguably, since the goal of a (flood) project is to improve on a previous situation, a 'neutral'-impact might also be considered a negative result.

By organizing resilience assessment workshops, these limitations (e.g. subjectivity of findings) were greatly reduced. The workshops allowed the researcher to validate his own findings, by initiating a discussion between participants, focusing on the participants line of reasoning. The underlying arguments and thought process of the participants provided a better indication of their understanding and assessment of resilience impact than their appointed scores. The researcher took particular care while recording the input of participants, as, due to limited resources, verification of the translation of the researcher of workshop findings into the semi-quantitative (ordinal scale) assessment was not feasible. Having the groups focus on two principles instead of all six allowed them to more carefully consider the impact of the measures regarding their specific principles. The workshop participants consisted of postgraduate students, as well as academic staff, active in the field of civil engineering. Ideally, the workshop would also include practitioners (e.g. project team members), local scientists, and resilience experts. As this was not feasible for the current study, the workshop assessment may lack some practical resilience perspectives, relating to the case study project. Though the resilience principles made the concept of resilience understandable for participants, and provided them with the tools to perform a resilience assessment, it was pointed out that some principles were more difficult to distinguish than others (e.g. redundancy and omnivory). By using the researchers own assessment as an example, and discussing/sharing his understanding with the group, this issue could be resolved.

The governance assessment tool was easily operationalized for a resilience- and adaptation-focus, and guided towards a comprehensive overview of the governance context. Instead of assessing both the supportive and restrictive elements of the governance context, the current research used a more direct application, specifically looking at the elements that influenced (e.g. restricted) the functional resilience impact. Similar to the workshop, to assess a full governance context, it is important to include the perspectives of all relevant actors/stakeholders. The time frame of the current research, however, meant that it was limited to the perspective of project team members. To account for this, project team members were asked to consider the perspectives of others when answering the interview questions.

Adaptive capacity assessment

Regarding the adaptive capacity assessment, a key element was the selection of indicators (e.g. knowledge, risk perception, perceived adaptive capacity, and motivation). Similar to the resilience principles, there is no common understanding in literature as to what factors are most important. Though the indicators were carefully selected, their understanding and measurement is inherently subjective. For example, measurement of risk perception, in the current study, was based on an individual's climate change concern, flood concern, sense of responsibility, and expected flood risk. The current study assumes that, if individual's have high scores on the aforementioned indicators, their risk perception is high. As other aspects may play an equally important role when it comes to adaptive behavior, one has to be careful drawing overall conclusions. An example of this is one's personality and attitude. If a person is not worried in general, this may mean that the impact of a flood experience will be limited. Also, risk perception is relative, meaning that if someone is struggling to pay rent, for example, they will not be as worried about flooding. By presenting both the individual- and summarized-components of the four adaptive capacity indicators, the current research attempts to refrain itself from unjustified generalizations.

To gather data, the current research used door-to-door questionnaires. The researcher found that the personal approach increased the citizens willingness to participate, and ensured that a representative sample of the area could be achieved. The use of an online survey would have resulted in the exclusion of some of the elderly citizens. As the researcher randomly selected addresses, based on achieving an equal spread of the area, and the response rate was high (76%), the potential bias in the selection of addresses is limited. However, the current approach does have some limitations. For measuring the impact of the engagement process, ideally, a pre- and posttest set-up would be used. This was not feasible in the current study, and the assumption was made that the impact of the engagement process can be determined by comparing the post-engagement adaptive capacity of citizens. Since there is no pre- and posttest set-up, it is not possible to take into account other/additional factors that may have influenced adaptive capacity. An example of this is knowledge that has been gained by watching the news or reading articles online, not related to the engagement process. Another example, specifically to the current study, was the mosque shooting that happened in Christchurch prior to the door-to-door questionnaire. As explained above, this may have put flood- and climate change issues in a different perspective, and consequently influenced citizens risk perception. Another (potential) limitation of the current study is the fact that no children were included in the research. Since they are the adults of the future, one may want to take their knowledge and risk perceptions into account when designing future engagement processes. The underlying assumption of the current study in this regard is that, within one household, people share ideas/perceptions and information, leading to similar adaptive capacities of individual members. Determining the exact degree to which this exchange takes place requires further research.

The qualitative data, gathered by the interviews with citizens, reduced the aforementioned ambiguity of adaptive capacity, and supported the interpretation of findings. It is important to note a potential bias in the interview findings, as the current study was limited by a relatively low number of participants. The willingness of the citizens to participate in the interviews may have different explanations. For example, it may be that the citizens had a higher risk perception and motivation to start with, which encouraged them to participate. Also, it may be that citizens who had a negative engagement experience were more inclined to take part, as it provided an opportunity for them to share their comments and feedback on the process. A higher number of interview participants in future research would reduce this bias.

Further research

The six-step approach as proposed in the current study can be used as a diagnostic tool (e.g. by practitioners) for completed, as well as future (flood) projects (e.g. as part of a multi criteria analysis). As it includes both functional resilience and adaptive capacity, it provides a more comprehensive assessment of the urban resilience than most other tools, which address these elements separately, or in less detail (e.g. Carpenter, et al. 2001; Fazey, et al. 2018; Kotzee & Reyers, 2016). Though other resilience principles may be equally relevant, the principles of omnivory, buffering, redundancy, flux, flatness, and homeostasis, provide a quick and useful means for a resilience impact assessment. Similarly, while adaptive capacity can be considered broader than the combination of knowledge, risk perception, perceived adaptive capacity, and motivation, the suggested combination provides a broad insight into the capacity of individuals. The approach not only guides towards the assessment of the resilience impact, but also towards an explanation of the observed resilience impact, as opposed to many similar works (e.g. de Vente, et al., 2016; Newig, et al., 2013; Füssel, 2007; Bierbaum & Stults, 2013; Agrawal, 2010; Wolf, 2011).

This said, the current study has some important limitations. One limitation is the focus of the current research on urban flood resilience. Though, for the case study area, flooding is considered to be the biggest threat, it is not the only relevant disturbance when considering urban resilience. For a more comprehensive resilience assessment, all disturbances (e.g. earthquakes, temperature increase, etc.) should be taken into account, as they will impact urban areas in different ways. Furthermore, the combination of limited time, and a low number of suitable flood projects in the city of Christchurch, led to the use of a single case. Though focusing on a single case allowed for an in depth analysis/assessment, the results of this study are referred to a population and context which are very specific. The presented approach should be applied to multiple flood projects, in order to compare findings, and allow generalization to other contexts. Regarding the explanation of the resilience impact, the choice was made to focus on the governance context, and to not assess the influences of other contexts (i.e. political, cultural, etc.), as these are assumed to have an influence through the governance context. Ideally one would want to include all contexts, as they interact, and may reveal additional relations.

Future research should not only focus on the application of the resilience principles and adaptive capacity indicators to evaluate programs, but also on how they can be adopted by decision-making processes, so that they can reduce ambiguity and guide decision-makers right from the start.

5. Conclusion & Recommendations

Regarding the impact of the project on *functional resilience*, out of a maximum of 5 points, the project scored highest on homeostasis (4.2) and flux (3.9), followed by an equal impact on omnivory (3.7) and buffering (3.7). The positive impact of the project was limited (e.g. close to neutral) for the principles of redundancy (3.3) and flatness (3.1). In other words, the project had a only a minor impact on the system's ability to absorb disturbances by means of overlapping functions, and ability to respond quickly to a disturbance by making use of local competence. The current study found that the process design of the flood project limited the functional resilience impact, due to a lower level of authority/power of the initiator, a limited amount of resources available, and a rationale, goal, and set of objectives that did not incorporate resilience. The process design was influenced by the fact that co-governance and citizen engagement approaches were not yet well embedded, there was uncertainty with regard to resilience and adaptation approaches, no specific requirements for engagement were stipulated by higher order policies, and there was a lack of collaboration between national, regional, and territorial authorities.

Regarding the impact of the project on *adaptive capacity*, engagement increased the knowledge and risk perception of citizens. However, no significant impact on their motivation or perceived adaptive capacity was found. The fact that no impact was observed on motivation and perceived adaptive capacity is explained by the focus of the engagement process on informing citizens, instead of on increasing local competences. In addition, regarding the participation methods, meetings were mainly used to express concern, instead of providing background information, and citizens perceived a lack of a two-way dialogue.

The study found evidence of a positive relationship between the perceived adaptive capacity of citizens, and their knowledge, their risk perception, and their motivation. Additionally, knowledge was found to be positively related to risk perception, and risk perception was positively related to an individual's motivation.

Regarding citizen characteristics and adaptive capacity, the study found that property owners, compared to tenants, are more prepared, and have a higher level of climate change- and flood related knowledge, but are less concerned about flooding. Higher-educated citizens were found to have higher levels of climate- and flood related knowledge, a higher perceived adaptive capacity, and a greater sense of responsibility, but were less prepared, and less concerned about flooding than lower-educated citizens. Higher-aged citizens and citizens with flood experience were found to have higher levels of flood related knowledge, and higher levels of preparedness than, respectively, lower-aged citizens and citizens with no flood experience. Male citizens, compared to female citizens, had higher levels of flood related knowledge, but were less concerned about climate change and flooding, had a lower sense of responsibility, and were less motivated.

Recommendations

To enlarge the impact of future flood projects on urban resilience, the current study provides recommendations on a flood measure, process design, and engagement level for future project teams, as well as recommendations regarding governance arrangements for local, regional, and national governments.

At a flood measure level, project teams are advised to:

1. Provide regular (e.g. daily) updates to the public as part of the water level monitoring. They should also be given access to live data feeds, informing them, and raising their general awareness of how the hydrological system works. This increases the local competence, as it allows citizens, as well as other parties, to monitor rainfalls, flows, and river levels, helping them plan and make better decisions around their properties and communities.
2. Encourage citizens to help maintain the ecology of the creek, by, for example, including them in the process of/allowing them to plant new trees and plants. They can perform their own testing of the water quality, which enables them to understand the water quality close to their properties. They can report any issues they come across, and the daily data collection that the citizens provide will enable more accurate modelling.
3. Establish/define facilities and locations for the community to coordinate their efforts to help each other, during, and after a disaster. These pre-defined areas allow the community to self-respond to a disturbance (e.g. flooding).

At a process design level, project teams are advised to:

1. Supplement limiting authority and power of the initiator (regarding the process and potential outcomes) by involving actors who can provide the additional authority and power in the process from the outset.
2. Incorporate resilience and adaptation into the project goals, stimulating a long-term focus/future outlook.
3. Base objectives on a system analysis (e.g. 'what' exactly you want to make resilient), and include local/community competence targets. An early system analysis can prevent too much focus on one specific function.

At a citizen engagement level, project teams are advised to:

1. Not limit citizen engagement/consultation to one project, but consider it a transcending and ongoing process. Continuous involvement over different projects increases the local competence, as well as the speed at which information is shared between decision-makers and citizens, as the actors involved become familiar with procedures.
2. Use a personal engagement approach, such as knocking on doors, and/or visiting community areas. Use known and trusted community boards to get in contact with/engage citizens. Key is to ensure a two-way dialogue, as only informing instead of a full consultation increases the risk of adverse outcomes (e.g. decreased trust and motivation).
3. Provide background information and drivers of decisions/options, instead of just presenting the result of these decisions (e.g. plan of action). Do not only communicate the positive aspects of the project, but also the difficulties surrounding the problem/issue (e.g. be transparent). If not, the communication effort may be interpreted as advertisement, instead of actual information.
4. Provide simple information at the project site (e.g. storyboards), explaining problem and plans, or through email and mailboxes, allowing citizens to find answers in their own time. This information should not contain too many technical terms, but instead be focused on directing the theoretical understanding towards a practical one. In other words, make the issue tangible for the citizens.
5. Build an understanding in the community around the range of potential futures, and issues associated with those futures. Threats need to be made tangible, translating long-term issues to short term impacts. Communicating an issue at a personal threat level can be used to draw individuals into the process, after which they should (partially) be reassured by their involvement in the project, and the collective effort to mitigate the risks.
6. Provide clear roles for participation. Citizens need to understand how to get involved, what they can do, and what is expected of them (e.g. their responsibilities). As an example, local residents can inform the Council/project team if they spot any problems in their area. It is important that this feedback loop is kept short, meaning that citizens should not be asked to give their input by means of lengthy forms.

At a governance level, local, regional, and national governments are advised to:

1. Promote collaboration/integration between all levels of government. To facilitate upscaling in the future and incorporate changes beyond minimum goals, there needs to be an increased support from the national level. Incentives should be provided to local governments to pursue climate change adaptation and resilience ambitions (e.g. a climate change adaptation/resilience fund). This includes setting up a cost-share mechanism, as well as sharing of responsibilities, authority, and powers.
2. Reduce ambiguity of concepts (e.g. resilience, adaptation) and uncertainty of approaches, and put effort into increasing awareness, knowing more about what’s going to happen in the future, what response may be appropriate, and what costs are associated with them. One way to achieve this is by organizing resilience workshops, were practitioners, decision-makers, and lay-people are invited to share their thoughts on future developments and resilience, familiarize themselves with different approaches (such as the use of resilience principles), and come to a shared understanding of the concepts. These events can take place at a local as well as national level.
3. Establish clear guidelines and baseline for consultation/engagement approaches, stipulating specific engagement requirements (e.g. evaluation methods) and objectives for future projects (e.g. the impact on local competences).
4. Use a combination of a ‘reactive’ approach of establishing adaptive pathways (e.g. measures that have the opportunity to be adapted in the future), and ‘proactive’ approach, embedding resilience criteria into every new design (objectives and measures).

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Appendix A - Governance Assessment Tool Operationalization, adapted from Bressers, Bressers & Larrue (2016)

Governance dimension	Descriptive questions
Levels and scales	▪ Which administrative levels are involved in the flood risk project and how? ▪ Which hydrological scales are considered and in what way? ▪ Do local, regional, territorial and national actors communicate and cooperate with each other? ▪ To what extent do they depend on each other or are able to act productively on their own? ▪ Have any of these changed over time or are likely to change in the foreseeable future?
Actors and networks	▪ Which actors are involved in the process of the flood risk project? ▪ Do flood managers coordinate their actions with other domains? ▪ To what extent do they have network relationships also outside of the flood risk project? ▪ What are their roles? ▪ Which actors are only involved as affected by or beneficiaries of the flood risk measures taken? ▪ What are the conflicts between these stakeholders? ▪ What forms of dialogue take place between them? ▪ Are interested parties given the possibility to participate in policy making or, at least, informed? ▪ Have any of these changed over time or are likely to change in the foreseeable future?
Problem perspectives and goal ambitions	▪ Which problem perspectives and ambitions are taken into account with regard to future flood risk, climate change and urban resilience? ▪ What levels of climate change and increase in flood risk are current policies designed to cope with? ▪ What levels of flood risk are deemed acceptable by different stakeholders as a result of the process? ▪ What climate change adaptation, resilience and flood risk management goals are stipulated in relevant higher-order policies? ▪ Are objectives based on comprehensive risk assessments, maps and plans? ▪ Have any of these changed over time or are likely to change in the foreseeable future?
Strategies and instruments	▪ Do plans pay attention to resilience, climate change adaptation and adaptive capacity? ▪ What types of flood risk measures are considered? ▪ Are plans based on a variety of instruments? ▪ Have any of these changed over time or are likely to change in the foreseeable future?
Responsibilities and resources	▪ Which actor has a responsibility for which task under the relevant policies and customs? ▪ Do responsible actors coordinate their actions? ▪ What resources and legal authority does the flood project team have? ▪ Is there sufficient knowledge on the water system and influence of climate change? ▪ Is there sufficient knowledge on resilience and adaptation approaches? ▪ Have any of these changed over time or are likely to change in the foreseeable future?

Governance dimension	Evaluative questions			
	Extent	**Coherence**	**Flexibility**	**Intensity**
Levels and scales	▪ How many levels are involved and dealing with resilience, flood risk and climate change adaptation? ▪ Are all relevant levels included?	▪ Do these levels work together and do they trust each other between levels? ▪ To what degree is the mutual dependence among levels recognized?	▪ Is it possible to move between local, regional, territorial or national levels (upscaling and downscaling)?	▪ Is there a strong impact from a certain level towards change?
Actors and networks	▪ Are all relevant stakeholders involved, or are some not involved or excluded?	▪ Are there interactions between actors in the network, and do they support/restrict one another? ▪ To what degree are the interactions institutionalized? ▪ Do the stakeholders have experience in working together? ▪ Do they trust and respect each other?	▪ Does the process allow new actors to be included during the project? ▪ Does the process allow flexibility with regard to the leading role? ▪ Do the actors support each other's tasks?	▪ Is there a strong pressure from an actor towards change?
Problem perspectives and goal ambitions	▪ To what extent are the various problem perspectives of climate change and future flood risk taken into account?	▪ To what extent do the perspectives and goals regarding resilience, climate change adaptation and flood risk support/restrict each other?	▪ Are there opportunities to reassess goals? ▪ Is there an option for multifunctionality/dealing achieving multiple goals at the same time?	▪ How different are the goal ambitions from the status quo or business as usual?
Strategies and instruments	▪ What types of instruments and flood measures are included in the strategy? ▪ Are any excluded? ▪ Are monitoring and enforcement instruments included?	▪ To what extent are stakeholders incentivized to contribute? ▪ Are trade-offs in cost benefit considered?	▪ Are there opportunities to combine or make use of different types of instruments/measures? ▪ Is there a choice? ▪ Is there a possibility to adapt a measure/instrument in the future?	▪ What is the implied behavioral deviation from current practice and how strongly do the instruments require and enforce this?
Responsibilities and resources	▪ Are all responsibilities clearly assigned and facilitated with resources?	▪ To what extent do the assigned responsibilities create struggles or cooperative behavior?	▪ To what extent is it possible to shift responsibilities/resources or pool them together?	▪ Is the amount of allocated resources sufficient to implement the measures needed for the intended change?

Appendix B – Resilience Principles Operationalization, adapted from Wardekker, et al. (2018)

Resilience principle	Mechanism	Primary mechanism	Practical interpretation for key functions
Buffering	Essential capacities are over-dimensioned, such that critical thresholds are less likely to be crossed	Absorbing disturbances	▪ Residential The system has enough capacity (e.g. hydraulic capacity, residential land, etc.) to ensure that residential homes do not get damaged beyond repair, and residents do not have to leave their homes. The homes are designed in such a way that they are able to withstand disturbances to a greater degree. Residents have enough resources to handle disturbances for a longer period of time. ▪ Recreational Recreational facilities are designed in such a way that they can withstand a certain degree of disturbance and still remain operational. ▪ Ecological The system has enough ecological capacity (e.g. area of land, number of tree species, etc.) and ecological memory to be able to cope with short-term shocks and long-term stresses, so that flora and fauna can recover after disturbances and/or do not get damaged/eroded beyond repair. ▪ Economic The system has enough capacity (e.g. hydraulic capacity, potential customers, excess storage space and goods, etc.) to ensure that commercial buildings do not get damaged beyond repair, and that service delivery does not come to a halt. The buildings are designed in such a way that they are able to withstand disturbances to a greater degree.
Redundancy	Overlapping functions; if one fails, others can take over. Multiple copies of one approach, function, or service	Absorbing disturbances	▪ Residential The system has backup options to maintain the residential function during a disturbance. For example, if the lower floor of a home is affected by the disturbance, their functions are transferred to the unaffected higher floors. ▪ Recreational There are multiple recreational areas/facilities, so that if one is affected by a disturbance, the others are still functional, and can see to the recreational needs. ▪ Ecological Nature areas are compartmentalized, and vegetation- and animal populations are sufficiently large to be able to handle situations where specific locations or individuals are impacted by a disturbance. ▪ Economic The system has backup options to maintain the economic function during a disturbance. For example, the businesses can have a second location/storage facility located outside of the flooded area, so that business and service delivery can continue.

Omnivory	Diversification of resources and means. Multiple different approaches that can be used alongside each other, rather than copies of one approach. Multifunctionality of functions.	Absorbing disturbances	▪ Residential There are multiple (different) ways of maintaining the residential function in the area, and residents have multiple ways of dealing with the disturbance. An example of this is temporary housing in an unaffected area. ▪ Recreational The recreational facilities are designed in such a way that they can change the form of recreation, based on the situation/disturbance. ▪ Ecological There is sufficient biodiversity available in the area to maintain the desirable nature types and animal species in the area. Multiple types of species fulfil the same ecological function, or there are diverse ways to cope with any shocks of changes. ▪ Economic There are multiple ways of maintaining the economic function in the area, and the local commerce and industry has multiple ways of dealing with the disturbance. For example, the businesses can offer a different service than usual, which is not affected by the disruptive event.
Homeostasis	Multiple feedback loops counteract disturbances and stabilize the system	Quick response	▪ Residential There are clear lines of interaction between residents and the authorities. Procedures (e.g. response procedures) and mechanisms (e.g. monitoring, maintenance) are in place to monitor the functioning and health of residential areas, spot (potential) problems, and quickly act upon these. ▪ Recreational Mechanisms are in place to monitor the functioning and health of recreational facilities/areas, spot (potential) problems, and quickly and creatively act upon these. This includes long term matters such as embeddedness in the area's other functions. ▪ Ecological There are clear lines of interaction among nature managers with other relevant parties (e.g. recreation, local business, residents, water sector). Procedures and mechanisms are in place to monitor the area's health, spot problems, and act upon these. Natural dynamics through which local nature copes with shocks and stresses are stimulated and maintained. ▪ Economic Mechanisms are in place to monitor the functioning and health of local commerce/industry, spot (potential) problems, and quickly and creatively act upon these. This includes long term matters such as embeddedness in the area's other functions.
Flatness	The hierarchical levels relative to the base should not be top-heavy. Systems without local competence and mandate to act are too	Quick response	▪ Residential There is close interaction between the residents and the authorities (e.g. public participation in decision-making), limiting the management layers between the people observing potential problems and the people making decisions, so that information (e.g. early warning signs, suggestions for improvement, expression of residential needs) is picked up and shared rapidly. ▪ Recreational

	inflexible and slow to cope with surprises		The interaction between citizens and authorities concerned with recreational facilities/activities should be as direct as possible, so that information (e.g. suggestions for improvement, expression of recreational needs) is picked up and shared rapidly. ▪ Ecological The interaction between nature managers and other people involved in the practical maintenance and functioning of the area should be as direct as possible (e.g. no complex lines of responsibility, long decision chains), so early warning signs and suggestions for improvement are picked up rapidly. ▪ Economic There is close interaction between the local commerce/industry and the authorities/decision makers relevant to the area, and/or the former has the means and authority to act in response to disturbances themselves.
High flux	Fast rate of movement of resources through the system to ensure quick mobilization to respond to threats and changes	Quick response	▪ Residential Resources (e.g. money, land, buildings, knowledge, ideas) can be quickly mobilized to cope with shocks and stressed and adapt to changes. Transportation through the area is rapid and unhindered. Adaptive capacity of the citizens is high. ▪ Recreational Resources (e.g. money, land, facilities, structures) can be quickly mobilized to cope with shocks and stressed and adapt to changes. ▪ Ecological Resources (e.g. nutrients, biological components, water, knowledge, ideas) can be quickly mobilized to cope with shocks and stressed and adapt to changes. Natural dynamics and processes are rapid and unhindered. Adaptive capacity is high. ▪ Economic Resources (e.g. money, land, buildings, knowledge, ideas, services, goods) can be quickly mobilized to cope with shocks and stressed and adapt to changes. Transportation through the area is rapid and unhindered. Adaptive capacity of the businesses is high.

Appendix C – Questionnaire

The questionnaire was devised to measure adaptive capacity of individuals, based on their level of knowledge, their risk perception, and their perceived adaptive capacity and motivation.

Citizen characteristics

The first section of the questionnaire asked participants to respond to three socio-demographic questions (e.g. gender, age, level of education). It also asked the participant to indicate their current living situation (e.g. home owner, tenant, other), and indicate whether or not they have had a direct and/or indirect experience with flooding. This section also included a question regarding the participants involvement in the Dudley Creek flood project (e.g. involved yes/no). If the participants answered 'yes' to the previous question, this was followed by a multiple choice option to describe their involvement (e.g. received information in the form of a newsletter and/or web-based info, phone or e-mail contact, public meeting, drop-in session, one-on-one meeting, formal public consultation).

Knowledge

In order to measure respondents knowledge in this particular context, a set of items was developed on the basis of existing literature (e.g. Brooks & Adger, 2004; Hansen, 2009; Hommes, et al., 2009; Gaventa & Barret, 2010). Different domains of knowledge were considered, consisting of climate change knowledge, flood related knowledge, and knowledge regarding an individual's preparedness. Respondents were asked to rate their knowledge, with the possible response categories ranging from 1 (very poor) to 5 (very good).

Climate change knowledge

Question 1	How would you rate your knowledge on climate change in general?
Question 2	How would you rate your knowledge on the implications of climate change for Christchurch?
Question 3	How would you rate your knowledge on the process of adapting to climate change?

Flood related knowledge

Question 4	How would you rate your knowledge on the degree of flood risk in the area you currently live?
Question 5	How would you rate your knowledge on the impacts of flooding in your area?
Question 6	How would you rate your knowledge on current flood risk management in your neighborhood?

Preparedness

Question 7	How would you rate your knowledge on what you need to do to prepare for flood events?
Question 8	How would you rate your knowledge on procedures to follow in case of an actual flood event?

Risk perception

In order to measure respondents risk perception in this particular context, a set of items was developed on the basis of existing literature (e.g. Grothman & Patt, 2005; Brooks & Adger, 2004; Leiserowitz, 2006; Miceli, Sotgiu, & Settani, 2007; O'Sullivan, et al., 2012). Different domains of risk perception were considered, consisting of climate change related concern, flood related concern, an individual's sense of responsibility, and their expected flood risk. Respondents were asked to rate their concern on a scale from 1 (not at all concerned) to 5 (extremely concerned), and urgency on a scale from 1 (not at all urgent) to 5 (extremely urgent). The possible response categories for responsibility ranged from 1 (strongly disagree) to 5 (strongly agree). Respondents were asked to rate the likelihood of a flood impact on a scale from 1 (very unlikely) to 5 (very likely), and extent of increasing/decreasing on a scale from 1 (strongly decreasing) to 5 (strongly increasing).

Concern climate change

Question 9	How concerned are you about potential implications of climate change in general?
Question 10	How concerned are you about the impact of climate change in your area?
Question 20	How urgent do you consider global action to deal with the implications of climate change?

Concern flooding

Question 11	How concerned are you of your own home being seriously damaged or destroyed due to a flood event?
Question 12	How concerned are you about physical injury to yourself or your loved ones because of a flood event?

Responsibility

Question 15	To what extent do you agree/disagree with the following statement: I feel a responsibility to contribute to making my community resilient to the impacts of climate change
Question 16	To what extent do you agree/disagree with the following statement: I feel a responsibility to contribute to making the city of Christchurch resilient to the impacts of climate change

Expected flood risk

Question 18	How likely do you think it is that a flood event will impact the area where you live during the next 5 years?
Question 19	How likely do you think it is that a flood event will impact the area where you live during the next 30 years?
Question 21	To what extent do you consider the flood risk in your area to be increasing/decreasing?

In addition to the constructs above, a number of exploratory questions have been asked, in order to gain a broader insight into the risk perception of the citizens. The possible response categories for question 13 and question 14 ranged from 1 (strongly disagree) to 5 (strongly agree). With regard to the climate change challenges, respondents were asked to select a top-three from a list of potential implications. To answer the question of whom citizens considered responsible for managing the impacts of climate change, respondents were asked to select one or more options of a predetermined list of parties (e.g. national government, regional authority, Christchurch City Council, Department of Conservation, Environment Canterbury, the community, landowners, others).

Exploratory questions

Question 13	To what extent do you agree/disagree with the following statement: Humans are the main cause of climate change
Question 14	To what extent do you agree/disagree with the following statement: We should focus on short-term solutions instead of long-term solutions
Question 17	What do you consider the main challenges of climate change for the city of Christchurch?
Question 23	Who do you consider responsible for managing the impacts of climate change?

Perceived adaptive capacity and motivation

In order to measure respondents perceived adaptive capacity and motivation in this particular context, a set of items was developed on the basis of existing literature (e.g. Grothmann & Patt, 2005; Leiserowitz, 2006). The possible response categories for perceived adaptive capacity and motivation ranged from 1 (strongly disagree) to 5 (strongly agree).

Perceived adaptive capacity

Question 24	To what extent do you agree/disagree with the following statement: It's no use worrying about climate change, I can't do anything about it anyway
Question 25	To what extent do you agree/disagree with the following statement: It's no use worrying about flood risk, I can't do anything about it anyway.
Question 26	To what extent do you agree/disagree with the following statement: The future is too uncertain for a person to make long term plans.

Motivation

Question 27	To what extent do you agree/disagree with the following statement: I am open to new ideas and alternatives about flood risk management
Question 28	To what extent do you agree/disagree with the following statement: I am willing to try new things and adjust my way of living, in order to adapt to future climate change

Appendix D – Validation of Indicators

Factor analysis
To control whether the proposed items (i.e. questions) are related to each other, their component loading was checked. The rotated component matrix, as presented in Table 10, shows that the items load onto 9 different components. The exception to this are the items of 'Concern climate change', which seems to have a relation to the 'Climate change knowledge' items. It is important to note here that the process of determining the components (i.e. indicators) was an iterative process, meaning that the factor analysis informed the (initial) formation of components. After examining the factor analysis, the commonality between the individual items was used to name the aforementioned indicators. Based on this examination, the first column of the rotated component matrix was divided into items that target an individual's concern, and items that target an individual's knowledge.

Table 10: Rotated component matrix

Rotated Component Matrix[a]

	Component							
	1	2	3	4	5	6	7	8
Climate change knowledge - Question 1	,786							
Climate change knowledge - Question 2	,725							
Climate change knowledge - Question 3	,715							
Concern climate change - Question 9	,553							
Concern climate change - Question 20	,404							
Flood related knowledge - Question 4		,903						
Flood related knowledge - Question 5		,888						
Flood related knowledge - Question 6		,804						
Responsibility - Question 16			,911					
Responsibility - Question 15			,880					
Concern flooding - Question 12				,913				
Concern flooding - Question 11				,909				
Concern climate change - Question 10	,470			,542				
Motivation - Question 27					,868			
Motivation - Question 28					,849			
Expected flood risk - Question 19						,883		
Expected flood risk - Question 18						,844		
Expected flood risk - Question 21						,535		
Preparedness - Question 8							,876	
Preparedness - Question 7							,864	
Perceived adaptive capacity - Question 26								,841
Perceived adaptive capacity - Question 25								,691
Perceived adaptive capacity - Question 24			,402					,603

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Cronbach alpha
To measure the reliability (i.e. internal consistency), in terms of whether the items measure what they should measure, a Cronbach Alpha test was used.

Knowledge
Based on the factor analysis, knowledge is comprised of three separate components. These are climate change knowledge ($\alpha = 0.78$), flood related knowledge ($\alpha = 0.89$), and preparedness ($\alpha = 0.89$).

Risk perception
Based on the factor analysis, risk perception is comprised of four separate components. These are climate change concern ($\alpha = 0.82$), flooding concern ($\alpha = 0.86$), responsibility ($\alpha = 0.89$), expected flood risk ($\alpha = 0.68$). As 'expected flood risk' has an $\alpha < 7$, the Cronbach Alpha value was also calculated for the situation where item/question 21 was left out. This resulted in a Cronbach Alpha value of 0,81. However, the choice was made to retain the initial three items, instead of reducing it to two, to prevent a decrease in validity.
Perceived adaptive capacity and motivation

Based on the factor analysis, the components of perceived adaptive capacity ($\alpha = 0.72$) and motivation ($\alpha = 0.77$) are retained.

Appendix E – Key functions

Residential function

The residential function refers to the main purpose of the area, namely to provide a healthy, attractive, and safe space for people to live, and establish and maintain a community. Living in a warm, dry, healthy home is considered a priority for physical health and personal wellbeing (Ministry for the Environment, 2018c). As part of the residential function, the urban system also provides the people with access to services (e.g. access to clean water), facilities (e.g. schools), employment, retailing, entertainment, parks and the transportation network (e.g. public transport, cycle ways). Environmental changes and the impact of natural disasters are expected to influence the ability of the system to fulfill its residential function in a negative way.

The heritage and cultural function refers to the role of the urban system in providing protection against the loss of heritage values, as well as protect local culture and community values. Though this function is less obvious than the others, it has a significant importance when looking at the City as a whole. The conservation of the City's heritage buildings plays an important role in maintaining the City's appeal as a cultural and tourist center. Within the current case study area there are three buildings that are considered heritage sites. As people currently reside within these buildings, for the analysis the heritage and cultural function will be grouped together with the residential function.

Recreational function

Related to the provision of a healthy and attractive space is the recreational function of the urban system. The purpose of the system in this regard is to provide a space for formal and informal recreational activities, while complementing and enhancing neighborhood amenity values. Formal activities refer to organized or structured activities, while informal are more spontaneous in nature (e.g. walking, cycling). The community parks and water's edge enable such formal and informal activities, as the public spaces promote interaction within the local community. In the smaller parks, landscaping and seating is combined with playground equipment and informal playing fields. The larger parks within the urban system accommodate public and private sports- and recreation facilities, and have the potential capacity of multifunctional use. Examples of these facilities are the squash club and the designated rugby field. These areas can host city, regional, national, and international events, providing entertainment to residents and visitors. This means that, in addition to contributing to the well-being of the citizens living within the area, these facilities also attract citizens from other parts of the city.

Ecological function

In addition to the residential and recreational function, the urban system also has an ecological function, as it provides a space for, and aims to protect 'significant' native and exotic flora and fauna. The protection of the natural qualities (e.g. the water quality) and habitats of water bodies and margins is especially relevant, given the presence of a diverse fish community, including three threatened species of fish and a number of culturally significant eels (McMurtrie & James, 2015). There are a number of significant park, street, and individual trees within the case study area. There is a high diversity of native and exotic plants and trees along the stream, which attract native birds as well as monarch butterflies (McMurtrie & James, 2015). These, in combination with other (protected) vegetation, are considered to provide amenity value and contribute to the character and environmental quality of the area. This results in a healthier environment for the residents. The urban parks, in addition to providing for entertainment, also have an important botanical value.

Economic function

Besides the aforementioned people and environmental based functions, the area also has an economic function, in the sense that it provides a space for (local) commerce and industry. The local commerce is comprised of small, standalone groups of primarily convenience shops, restaurants, and community facilities, which serve the immediate area. With regard to industry, the area provides industrial and other compatible activities that, due to the nature and limited effects of these activities (e.g. noise, odor, traffic) can operate in close proximity to more sensitive zones, such as the residential areas. The transportation network plays a crucial role with regard to this function, as it determines the general accessibility and allows for a quick distribution of goods and services.

Appendix F – Structural- and non-structural flood measures

Structural measures of the flood project

1. *Deepening waterway*
   Deepening of waterways took place at two locations, namely at Dudley Creek (from Aylesford Street to Petrie Street), and Shirley Stream (from Shirley Road to Dudley Creek). As part of the deepening, stream sediment contaminants and silt were removed. The deepening also affected existing habitats.

2. *Widening waterway*
   Widening of waterways took place at three locations, namely at Dudley Creek (from Aylesford Street to Petrie Street), at St. Albans Creek (from Slater Street to Dudley Creek), and at Shirley Stream (from Shirley Road to Dudley Creek). As part of this process, some existing vegetation and trees had to be removed, and the bank along the water's edge was lowered and re-graded to allow easy access. Due to the space requirement for channel widening, some access bridges had to be removed, and some land-owners had to give up part of their land.

3. *Reshaping of channel and in-stream ecological works*
   Aquatic ecologists undertook a comprehensive assessment of Dudley Creek to understand its existing ecological conditions, such as the number and type of fish species in the waterways. Shirley Stream (upstream of Shirley Road) was reshaped to create a narrow, meandering, low-flow channel, lined with gravel, rocks and woody material. In addition, pipes have been set into the bank to provide a habitat for eels to rest and mate.

4. *Replacement of access bridges and (road) culverts*
   The existing access bridges on Shirley road were replaced. The bridges were in a poor condition, (potentially) obstructing flow, leading to increased flood risk. With regard to the existing culverts, a number of measures can be observed. Firstly, undersized and damaged culverts were removed from Dudley Creek, and/or replaced by larger and stronger ones. The Chancellor Street culvert that previously allowed cars to cross was replaced with a foot bridge. The undersized culverts have been observed on site during flood conditions to obstruct flow.

5. *Engineered banks*
   Engineered banks were constructed along St. Albans- and Dudley Creek. The engineered banks consist of concrete and timber constructions.

6. *Naturalized banks*
   Naturalized banks were constructed along St. Albans- and Dudley Creek. The naturalized banks are grassed to continue the character of the current river bank, or planted with a mix of exotic and native shrub species. Rocks were placed along the river banks. Similar to the widening of the banks, the re-grading required additional land.

7. *Underground piped bypass*
   An 800 meter long, four by two meter underground piped bypass was installed, running from the Petrie Street Inlet to the Avon River. The inlet and outlets from the pipe are engineered structures with grills/grates.

8. *Drain Backflow Prevention*
   The Flockton Basin area drains to the Flockton Invert to the south, but the pipe loses functionality when the Dudley Creek is in flood, as it begins to backflow. Subsequently, a drain backflow device (flap valve) was installed on the Flockton Invert.

9. *Landscaping*
   Changes to the landscape have been made, addressing the composition and diversity of trees, as well as the construction of walkways and access points to the waterway. Planting and their placement on the river banks is done in accordance with Crime Prevention Through Environmental Design principles, which supports clear visibility of walkways. Planting is chosen overhand the low bank to provide cover and egg-laying sites for fish and invertebrates, as well as to increase bird life. Poor tree stock, ecologically risky tree species and those that produce allergen were removed. Removal included some (culturally) significant and/or protected mature trees. The (approximately) 120 removed trees have been replaced with (approximately) 300 semi-mature native and exotic trees. The open areas and parks within the area were retained.

10. *Maintenance*
   On-going maintenance of the channel takes place to manage the vegetation, as well as maintain channel capacity and geometry (e.g. given the continues deposition of silt). Maintenance also takes place in the form of pipe and gutter cleaning before rainfall events.

Non-structural measures of the flood project

1. *Water level monitoring*
   The water level and predicted weather of the Dudley creek is monitored, so that (preventive) action can be undertaken in case of a disruptive event. If there is a risk of a significant weather event (such as more than 50 mm expected within 48 hours), a higher level of weather monitoring and rainfall prediction is put into place until the risk is over.

2. *Hydraulic model update*
   The hydraulic model was updated and used to simulate/predict the hydraulic performance once measures are implemented, enabling a review of the catchment area.

3. *Citizen engagement*
   As part of the Dudley Creek flood project, citizens were engaged and consulted upon, which influenced the outcome of the project. The project team worked closely with local schools and community groups to maintain a cultural link with the creek. Where large flax have been removed the plants were given to a local community group to use for weaving baskets and mats. Schools have been involved in tree planting, and helped move fish from areas where work has taken place.

Appendix G – Engagement process

The participation methods used during the Dudley Creek project and their execution are the following:

1. Newsletter and/or web-based info

A periodic LDRP Dudley Creek hard-copy newsletter has been circulated to members of the public. The members were also given the opportunity to subscribe to an e-newsletter. The goal of the Dudley Creek e-newsletter was to keep residents updated and informed pre- and post-decision (e.g. Beca and Opus, 2015; Personal communication, 2019). The letters contained general information on what the project team was doing, and briefly described what, why, where, and when works would take place (Smith M. , 2017). Fourteen editions have been circulated, and more than 200 people subscribed to the e-newsletter. In addition to the newsletters a Council website was set up, allowing members of the public to find answers to their questions, score the importance to them of various key aspects (e.g. ecological and environmental improvements), look at the cost of each option, and also voice any other concerns they had (e.g. Beca and Opus, 2015; Smith, 2017).

2. Phone or e-mail contact

In case members of the public had any questions and/or concerns that couldn't be resolved by means of the newsletter or website, the engagement team made available two staff members, who were contactable directly via phone or email. These staff members also attended the majority of the one-on-one meetings, and provided the opportunity to discuss the project in more detail (Personal communication, 2019).

3. Public meetings

Several public (community) meetings were held at various locations throughout the area (e.g. Mayoral Flood Taskforce, 2014a; Personal communication, 2019). The goal of these meetings was to facilitate question and answer sessions between residents, Council officers and key members of the design team (Smith M. , 2017). Project experts and engagement advisers met with residents to explain technical aspects of the project, and discuss the proposed options, in terms of what they would mean for the citizens, their properties, and their neighborhood (Personal communication, 2019). During the public meetings, displays were put up to help the public identify the proposed options, and they provided the project team with an opportunity to gauge public opinion (Smith M. , 2017).

4. Drop-in session

Four public drop in sessions were offered by the Council in the first consultation, and three in the second consultation (Personal communication, 2019). The goal was to discuss the temporary options that were being explored, and allow the residents to ask questions and seek specific information on their properties (Beca and Opus, 2015). The engagement staff supported/guided the residents during the decision meetings, so that they were able to speak freely about the project. The sessions were fronted by technical staff, design consultants, and members of the engagement team, with the aim of being available to answer any questions the community had (Personal communication, 2019). The citizens were also asked questions by the project team, such as whether they would accept the noise resulting from pumping during flood events (Mayoral Flood Taskforce, 2014b). If providence of an immediate answer was found difficult, the members of the community were contacted at a later date with a response (Personal communication, 2019).

5. One-on-one meeting

Council staff and project team members had direct contact and face-to-face meetings with individual property owners affected by the flooding, property owners who would be affected by the proposed physical works, and those that were likely to remain at risk after enacting the proposed works (e.g. Smith, 2017; Personal communication, 2019). The goal was to explain the (specific) components of the project team's proposals and the need to carry out the work, provide an outline of the works, have a discussion to identify and validate flooding, as well as discuss their concerns (e.g. Mayoral Flood Taskforce, 2014b; Smith, 2017). This direct form of engagement (e.g. one-on-one meetings) was also used in situations where access to land or its acquisition for channel improvement was required (Mayoral Flood Taskforce, 2014b).

6. Formal public consultation

The community was asked for feedback and consulted two times, concerning the options being proposed. The first round of consultation concerned two options for flood alleviation, with a third option of retreating. Submitters were asked to state whether they agreed or disagreed with the preferred option, and whether they preferred retained (engineered) or naturalized banks (Beca and Opus, 2015). Residents were asked for feedback via an online or hard-copy form, and questions included the preferred option, a rating of importance against key criteria, and additional comments (Beca and Opus, 2015). Residents expressed a strong desire to protect the mature trees and natural habitat along Banks Avenue, and did not support the downstream scheme. The feedback provided by the citizens supported investigating an alternative bypass option from Warden Street, to divert floodwater through an alternative route. The community also supported naturalized banks rather than engineered banks.

Following the community feedback from the first consultation, the options for the initial design were changed significantly. The second round of consultation involved three options for the downstream section, as the community strongly expressed its desire to protect the area's mature trees and natural habitat. The consultation asked for the citizens feedback on proposed options, as well as their rating of criteria considered important (Personal communication, 2019).

Appendix H – Descriptive analysis resilience impact

The descriptive analysis as performed by the researcher, as well as the workshop findings, can be found respectively in the 3rd and 4th column of Table 11 and Table 12.

Table 11: Resilience implications of structural measures on key functions

Structural measure	Researchers assessment of resilience impact	Workshop findings
1. Deepening Creek	Multiple functions ▪ The main implication of deepening of the creek is an increase in waterway capacity (buffering), lowering the risk of the creek overflowing. Ecological function ▪ Stream sediment contaminants and silt are removed from the waterway, improving the overall water quality. This increases the waterways capacity to deal with future deposits (buffering). ▪ During the construction phase, deepening of the creek had a negative impact on the ecological function, as it required a complete removal of existing in-stream and riparian habitat along the entire extent of the watercourse upgrade works (redundancy).	Multiple functions ▪ Participants noted an increase in flux, as a greater volume of water could flow through the waterway. Since deepening only took place in two locations however, this impact is limited. Ecological function ▪ Participants considered the negative impact on redundancy (removal of the habitats) to be short term. While it is true that the habitats were only affected during construction, given that they have been completely removed means that they will most likely not return. ▪ Deepening the creek was thought to provide a deeper habitat, which could attract larger fish and bottom dwellers (omnivory).
2. Widening Creek	Multiple functions ▪ Similar to deepening, widening of the creek increases the waterway capacity (buffering), lowering the risk of the creek overflowing. Ecological function ▪ To allow widening of the creek, existing mature trees and vegetation had to be removed (redundancy). Residential function ▪ In the situations where widening required additional land, land-owners had to give up part of their property (buffering). ▪ Some access bridges had to be removed (redundancy), as the channel widening left little room for additional structures. This means that the residents may be restricted in leaving their property in case of a flood event (flux).	Multiple functions ▪ While the participants agreed that widening the creek in this situation has a positive impact on the waterway capacity (buffering), they critically pointed out that this is only achieved due to the combination with reshaping. If this were not the case, the buffer could be lost against neighboring houses, and may actually have had a negative impact on buffering. ▪ Participants pointed out that the water level in a wider creek rises more slowly than in a narrow creek. This may give residents more time to respond, as well as reduces the impact of the rising water on existing vegetation (homeostasis). ▪ Similar to deepening the creek, participants mentioned an increase in flux, as a greater volume of water could flow through the waterway. In the situations were widening of the creek included removal of blockages that could obstruct flow, flux was expected to be improved further.
3. Reshaping of the channel and in-stream ecological works	Ecological function ▪ Creation of a narrow, meandering, low-flow channel, lined with gravel, rocks and woody material helps sustain life in the creek	Ecological function ▪ The workshop participants pointed out that the in-stream works not only supported the natural dynamics of the creek and increased habitat

	▪ ...through natural dynamics (homeostasis), and reduces areas of stagnant water (flux), contributing to an ecologically healthier and stable habitat for plants, animals and insects. ▪ The in-stream works and pipes that were set into the banks increase the diversity (omnivory) of habitats.	diversity, but also increased the number of habitats (redundancy). Multiple functions ▪ The way reshaping is done (e.g. narrow, low flow channel) was considered to increase the chances of flooding, as it decreases the capacity of the creek to deal with the water flow (buffering).
4. (Re)placement of access bridges and (road) culverts	Multiple functions ▪ The access bridges and culverts increased in size, allowing creek widening and channel reshaping. The larger size improved the channel flow (flux), and increased culvert capacity (buffering). ▪ The Chancellor Street drive-over bridge was replaced by a pedestrian only bridge, as part of the water's edge walkway. Though this has a positive impact on the recreational function, it negatively impacts the residential and economic function, as the traffic flow is hindered (flux). Residential function ▪ The access bridges and culverts that were in poor condition were replaced with stronger ones (buffering), so that the potential for a breakdown and resulting obstruction of the flow decreased.	Multiple functions ▪ Though the participants agreed that the culvert capacity increased (buffering), this was considered to provide only little additional/spare capacity, as the project mainly targeted culverts that were already undersize and damaged.
5. Engineered banks	Multiple functions ▪ The engineered banks, more than naturalized banks, increase the capacity of the waterway to deal with disturbances (buffering). They are, however, visually not very appealing, limiting the recreational amenity benefits. ▪ The concrete and timber constructions prevent soil and vegetation erosion, and lead to uniformed flows in the waterway, increasing the speed at which the water passes through (flux).	Ecological function ▪ Some workshop participants pointed out that engineered banks form barriers that may disconnect existing ecological habitats (flux). In order to know the degree of the impact however, one would have to know what specific ecological processes took place before the banks were constructed. As the engineered banks are based on comprehensive assessments of the surrounding environment, their impact on the ecological habitats is considered minor.
6. Naturalized banks	Multiple functions ▪ The vegetation/planting on the naturalized banks, as well as the rock edges, increases habitat diversity for various plants and animal species (omnivory). The banks are sloped, so that they provide a suitable environment for vegetation. This also benefits the area's aesthetic value and recreational function, as the area is easily accessible. ▪ The vegetation on the natural bank increases the capacity to retain water (buffering). ▪ The naturalized banks slow down the flow of water (flux), increasing the risk of keeping contaminants in the system for a longer period of time, while at the same time creating a suitable habitat for insects.	Ecological function ▪ The participants were unsure as to how big the impact of filtration by vegetation would be on the water quality, but agreed that it would have (at least) a positive impact (homeostasis). Recreational function ▪ Participants considered naturalized banks to provide additional opportunities for recreation (redundancy) .

	Though the biodiversity increases, which is positive from the ecological perspective, the residential, recreational, and economic function along the water's edge is negatively affected (i.e. mosquito's). Ecological function ▪ The naturalized banks also provide erosion/sediment control through natural processes (homeostasis). Rain, river, and flood water can be absorbed and released into the waterway properly and without large amounts of sediments. The rocks that are placed along the river banks in turn prevent soil erosion. ▪ The vegetation on the natural banks filters and cleans the water (homeostasis). Residential function ▪ The construction of naturalized banks and re-grading required additional land, and some land-owners had to give up part of their property (buffering).	
7. Underground piped bypass	Multiple functions ▪ The underground bypass allows water to be moved out of the area faster (flux), increasing waterway capacity, and has the potential to act as a buffer, as it allows (temporary) storage of excess water (buffering). It is an alternative approach to the above ground/in stream works for dealing with flooding (omnivory). The bypass is placed underground, so that the impact on the key functions of the area is minimized. As the bypass drains into the tidal intersection with the Avon river, however, given future sea level rise it's contribution may be limited.	Multiple functions ▪ The participants noted that, since the bypass diverts excess water directly to the Avon river instead of forcing it through Dudley Creek, it counteracts the disturbance, leading to stabilized effects downstream (homeostasis). The bypass was considered a means to quickly respond to the disturbance, as it comes into effect when a certain threshold is met, and returns to it's normal (empty) state once the disturbance is over. ▪ Instead of viewing the bypass as an alternative approach for dealing with flooding (omnivory), the participants considered it to be an additional (back-up) pathway for the river (redundancy). If Dudley Creek were completely blocked off, the bypass could potentially take over its function and divert the water.
8. Drain backflow prevention	Multiple functions ▪ The installation of a backflow device (flap valve) on the Flockton Invert provides a different approach to preventing the water from flowing into/flooding this area whenever the Dudley Creek exceeds its capacity (omnivory).	Multiple functions ▪ Similar to the bypass, the participants considered the backflow device a means to quickly respond to the disturbance, as it aims to keep the water level constant, comes into effect when a certain threshold is met, and returns to it's normal (open) state once the disturbance is over (homeostasis). As the water will be increasing on both sides of the backflow device, the impact, though positive, is considered temporary. Ecological function ▪ Since the backflow device is closed during a flood event, it forms a

		barrier that fish cannot pass, potentially preventing them from returning to their habitat (flux).
9. Landscaping	Multiple functions ▪ The open areas/parks function as a buffer against flood events, as they can be used as retention areas (buffering). They can also change function if the situation demands this, for example by providing temporary shelter for citizens who's houses are flooded (omnivory). ▪ The removal of the poor tree stock, ecologically risky tree species, and those that produce allergen, has a positive effect on the ecological as well as residential function. The removal of (culturally) significant or protected mature trees, on the other hand, has a negative impact (redundancy). ▪ To counteract the negative impacts of tree removal (e.g. loss of ecological diversity), trees have been replaced with semi-mature native and exotic trees, which ensures the current character is the area is maintained (redundancy). The replacement trees have an ecological as well as aesthetic function, as they help to provide a habitat and food for native birds and insects (e.g. Monarch Butterfly). Recreational function ▪ In areas of bank widening, the bank along the water's edge is lowered to improve the recreational (amenity) value of the waterway. Re-grading of the existing waterway bank edges, in combination with new walkways and resting areas along the creek and road, provide multiple access points to the water's edge, and safe places for people to walk and cycle (redundancy). Ecological function ▪ Planting is chosen overhand the low bank to provide cover and egg-laying sites for fish and invertebrates, as well as to increase bird life, increasing habitat diversity (omnivory).	Multiple functions ▪ The participants pointed out that, though the open areas/parks have the potential to function as a retention area (buffering), this is not 'actively' pursued. This would be the case if, for example, a pump system was installed to transfer water in and out of the retention areas. A critical side-note is that the open areas/parks cannot simultaneously have a positive impact on buffering and omnivory (e.g. providing temporary shelter), as the area would be flooded. ▪ The new walkways and access points to the waterway allow residents to move more freely through the area (flux). Ecological function ▪ As more plants and trees were planted than removed, the participants regarded this a positive development (redundancy). This does not apply to the significant and protected mature trees, as they cannot be replaced.
10. Maintenance	Multiple functions ▪ Gutter and pipe cleaning before rainfall events prevents blockages from forming, which potentially decrease the hydraulic capacity of the waterway/stormwater drains, and allow the water to flow freely (flux). Ecological function ▪ The ongoing maintenance of the channel involves procedures to monitor the health of the creek and the vegetation, spot problems and act upon these (homeostasis).	Multiple functions ▪ The participants considered gutter/drain cleaning to be an different/alternative approach to reduce flood risk in the area (omnivory).

Table 12: Resilience implications or non-structural measures on key functions

Non-structural measures	Initial description of resilience implications on key functions	Workshop findings
1. Water level monitoring	Multiple functions ▪ Monitoring of the water level increases the capacity of the system to respond quickly and alert the residents/businesses to take precautions in time, potentially preventing damage to themselves and/or their property (homeostasis). ▪ In case of a significant weather event, the amount/level of monitoring and prediction is increased (redundancy).	Multiple functions ▪ The water level monitoring system allows decision makers to respond quickly, as they receive a continuous flow of information (flux).
2. Hydraulic model update	Multiple functions ▪ The hydraulic model allows for monitoring of the system and the effectiveness of its components, so that (future) disturbances can quickly be identified and dealt with (homeostasis).	Multiple functions ▪ The workshop participants pointed out that the hydraulic model update allows for knowledge on the catchment area and its components to be spread more rapidly, supporting (future) adaptation to changes (flux). Residential function ▪ The improved hydraulic model provides feedback to inform policy and design, as well as supports maintenance (homeostasis).
3. Citizen engagement	Residential function ▪ As part of the project, citizens were involved in the decision making process, resulting in close interaction with decision makers (flatness). ▪ The engagement may have made the citizens more aware of water/flood monitoring applications and temporary response procedures (homeostasis), as well as (potentially) increased their adaptive capacity, allowing them to more adequately respond to disturbances (flux).	Multiple functions ▪ The participants considered the fact that citizens clear the drains of leafs in case of a heavy rainfall, which helps prevent flooding on the street (omnivory). ▪ Involvement of the citizens means that they can provide field-observations and inform the Council, shortening the feedback loop, and increasing the residential response (homeostasis). ▪ With regard to the potential positive impact on flatness, the workshop participants critically pointed out that, though positive, its impact may be limited, due to the lack of ongoing engagement after project completion, and lack of changes to the existing management/communication structure. Also, in the situations where land owners had to give up part of their land, this may have led to a decreased motivation for further (future) participation.

Appendix I – Governance context

The governance context is described based on the five governance dimensions (i.e. levels and scales, actors and networks, problem perspectives and goal ambitions, strategies and instruments, responsibilities and resources). As the Dudley Creek project is at the core a water drainage project, the governance context focuses on water governance. In New Zealand, water governance is enacted through agencies (e.g. central government agencies and local authorities), laws (primarily the Resource Management Act 1991), rules (in regulations and in regional plans) and practices (e.g. administrative procedures) (Fenemor, et al., 2011). A conceptual overview of water governance in New Zealand is shown in Figure 11.

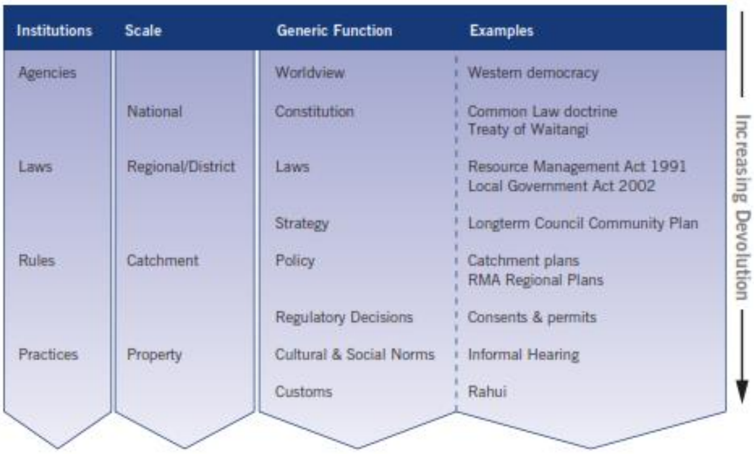

Figure 11: Conceptual view of water governance in New Zealand (Fenemor, et al., 2011, p.12)

Levels and scales

New Zealand has two levels of government, namely national and local. These levels are politically, financially and administratively independent of one another. Local government in New Zealand consists of two tiers. The first tier consists of the 9 regional councils, who are responsible for environmental management policy, and regulations with regard to water, air and the coastline. The second tier is comprised of territorial authorities, of which there are 67 (13 city councils and 54 district councils), who deliver a wide range of local services. This includes potable water, sewerage, libraries, parks, recreation, cultural and community facilities, town planning and economic development (CLGF, 2018).

The Dudley Creek project was a Christchurch City Council (territorial authority) response. The project mainly focused on the local Dudley Creek catchment flooding, but also considered the influences of the broader network and catchment systems, including the Avon River catchment. The national and regional actors were limited in their contributions in the Dudley Creek project. Though there were national interests, the project, decision making, and funding was carried out on a local level. There was engagement with the central government (e.g. Canterbury Earthquake Recovery Authority and the Department of the Prime Minister and Cabinet) on the issue, but they were interested in the outcome, rather than interested in being involved in the process. Effectively, the territorial, regional, and national actors acted/worked independently from one another. The central government provided guidance and guidelines, but did not directly influence the project. The project team worked on an inform basis with the government and ministry, as they initially weren't in a position to contribute. The Canterbury Earthquake Recovery Authority (CERA) became a funding source, and groups like the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) were set up in order to repair damaged infrastructure and the post-quake environment, which, in turn, attracted government funding. As resource consents were needed, the regional government (Environment Canterbury, or ECAN) took the role of consenting authority.

At one stage during the project, when there was a chance that governmental land would be impacted, cooperative work did take place. Access through the Residential Red Zone proved to be problematic, as a decision on the use of the Residential Red Zone meant that CERA would have to get Cabinet approval from the Government to use the land for an infrastructure project with a long asset life (Smith M. , 2017). Due to the way the legislation on the Red Zone was written, the decision was made to stay out of that area altogether.

Actors and networks

There are two main actors involved in the process of the Dudley Creek project. The first actor consists of the Councilors and the Council, and the second actors is formed by the community boards. The community boards are the local representatives of the citizens, working with the communities to meet local needs, goals and aspirations. Both the Council and the community boards were involved/engaged in the decision making process of the Dudley Creek project, though primarily the former. The community boards have some delegated authority for project level decisions, for example concerning tree removal.

There are also community based actors (e.g. individual landowners, residents groups), internal actors for different service providers, and different asset owners (e.g. roading network, storm water drainage network, etc.) inside the Council. The managers of different domains, such as transportation and water, work closely together. This is particularly the case for the relation between the waterways team and flood managers with the roading and transport teams, as corridors and assets overlap. The teams regularly work together on different projects, leading to well established relationships. Many of the relationships were formed pre-earthquake or during earthquake events, which means that most of the staff involved were familiar with one another. An example of this is the coordination with SCIRT, who were active in road- and other infrastructure repairs in the Dudley Creek area. Some of the works of SCIRT were delayed, so that the underground works could take place before the surface work. SCIRT also delivered one of the culverts along St. Albans road, as that fitted in with their work.

The residents groups don't have any delegated authority, but through the public consultation process they can influence the project outcome in terms of what happens on the ground. When looking at the residents groups that were involved in the project, three parties can be distinguished. They consist of the Flockton Cluster Residents group, the Richmond Resident Association, and the Banks Avenue Residents Association. The Flockton group represented the residents living in the flooded area, while the Richmond association and the Banks Avenue residents represented the residents that would experience the construction works. These three groups had very different drivers, as the works impacted them in different ways. The Richmond and Banks Avenue residents, being downstream of the Flockton area, would only experience the impacts of the works without any benefits. Initially, the Richmond residents were very sympathetic towards the Flockton residents, and supported the works coming through their area. However, as works went on for longer periods of time, conflicts arose between the Richmond residents and the Council. These conflicts concerned the flood measures, as well as road repair works that were outside of the current project. The Banks Avenue residents also had empathy for the Flockton residents, but were least inclined to hear from the works. They recognized the need to do the works, but didn't want it to affect them.

Other actors include Ngai Tahu (e.g. local Māori community) local schools (e.g. Marian College, Shirley Boys High School), Housing New Zealand (who owned properties along the route of the by-pass), CERA (as some of the options proposed impacted on residential red zone land, and they could potentially provide cost-share funding), and SCIRT (to coordinate work and ensure appropriate scheduling of the project) (e.g. Mayoral Flood Taskforce, 2014a; Smith, 2017; Personal communication, 2019).

Since the project sat inside the earthquake envelope, it wasn't considered just a flood risk project. This meant that, in addition to the aforementioned actors, the project team potentially had to deal with the layers of governance wrapped around the Land Drainage Recovery Program. However, because of the crisis consideration of the project, the project team was able to cut through many layers of governance (e.g. normal working groups, committees, community boards, etc.). This resulted in the dialogue between actors and the project team taking place on an inform basis only. Information was taken to them, rather than going through a staged approach of seeking agreement all the way.

The dialogue that took place amongst the actors was limited, and only took place after the preceding process (including an initial option appraisal) had been completed. Public meetings took place where all resident groups were in the room, but no deliberate action was taken to try and engage them in a conversation. The dialogue was mainly from the residents towards the project team, and vice versa. In other words, at a resident level with the authority.

Problem perspectives and goal ambitions

The central government of New Zealand aims to increase the resilience of their national infrastructure, people, environment and economy to the impacts of climate change. It does so by providing the legislative and policy framework, as well as providing information and guidance to support local government in making effective adaptation decisions (Ministry for the Environment, 2018d). An example of this is the New Zealand National Civil Defense Emergency Management (CDEM) framework, which provided guidelines in the form of a National Resilience Strategy. This strategy, amongst others, focuses on the principles of integrated governance of risk and resilience (e.g. Ministry of Civil Defence & Emergency Management, 2012; Stevenson, et al., 2017). The CDEM Act 2002 requires a comprehensive risk management based approach to hazard management, comprising risk reduction, readiness, response and recovery (McFarlane, 2015).

In addition to the Ministry for the Environment guidance, there is the Resource Management Act (RMA), which provides a legal framework for water management, and sets out the principles for sustainably managing waterways and wetlands (Christchurch City Council, 2003). With regard to the Resource Management Act, a general shift from the regulatory approach towards a collaborative approach can be noted (Russel, Frame, & Lennox, 2011). This type of approach is relatively new to New Zealand citizens, politicians and other policy actors (Eppel, 2014).

Besides the Ministry guidance and RMA, there are national policy statements concerning fresh water management, and New Zealand coastal policy statements describing how people should adapt in the coastal environment with time. The RMA requires these to be fitted within the regional policy statement. The resulting regional policy statement have to be given effect to by the policies and rules of the City Council planners, taking into account its Local Government Act requirements for healthy communities, long term financial viability, etc.

Local councils use the legislation, policy and guidance produced by central government to consider the risks for their region. They respond by means of preparing adaptation strategies, building adaptation into existing district/city plans, construction of protective works and land use planning (Ministry for the Environment, 2014). The climate change and resilience objectives are based on comprehensive risk assessments, varying to the scale of the particular strategy. There are catchment wide plans, which are informed by catchment wide modeling, but also more specific plans with detailed modeling, as was the case for the Dudley Creek catchment.

With regard to current policies, wider infrastructure design standards and guidelines allow for 16% increase in rainfall, and up to a meter sea level rise. The Council's current climate change strategy and flood intervention policy considers a 1 in 50 year flood level to be acceptable for extreme events, and 1 in 10 years for frequent events. With the 1 in 50 years, there is a 2% annual exceedance probability, which is the level that is stipulated in the Building Act. The floor levels of new properties in the Flockton area are designed for a 200 year rainfall event, with a 20 year tide and one meter sea level rise. Building the new properties at a higher level allows for future changes, but existing properties are allowed to sit at lower levels. This means that you can have properties that sit below the 1 in 50 or 1 in 10 that are still considered acceptable.

Though urban resilience was one of the considerations of the Dudley Creek project, and climate change and flood risk were considered during design, the expectations with regard to climate change were managed through separate designed criteria. This meant that the current project has not been designed with an increased capacity to deal with future disturbances, but rather designed in such a way that, if deemed necessary, additional works/improvement could take place at a later time. While the multi criteria analysis included items such as resilience, the deliberations were all at design level. It was not put in front of the governance group specifically to make decisions on, as those design decisions were dealt with at official level. In terms of the decision making, it was largely based around the very simplistic view of the Land Drainage Recovery Program, which was used as a guide to deliver a project that returned flood risk to pre-earthquake levels.

Strategies and instruments

The Christchurch City Council has a surface water and flood protection strategy, and is working on an integrated (climate) strategy. These strategies outline the rationale behind flood management, and guide towards the Council's six values framework. The Council has indicated in their long term plans and infrastructure strategy that, in order to cope with the changes, learning to adapt to a changing environment and making decisions in the face of uncertainty will be the most important steps (Christchurch City Council, 2018c). This includes identification of adaptive pathways, which allow changes to be made in the future as circumstances change (Christchurch City Council, 2018a). Even though the Council has begun to plan and respond to the likely effects of climate change by, for example, taking future flooding and climate change effects into account in the design of projects, they are yet to develop a strategy about which areas to defend from the effects and which areas to retreat from (Christchurch City Council, 2018a). No specific projects to address climate change are included in their infrastructure strategy at the moment, which is why the Council is attempting to develop a climate resilience approach, with the goal of providing clear direction about governance and management (Christchurch City Council, 2018a). As this approach is scheduled for 2021, they face the risk that newly placed infrastructure will need to be abandoned and alternatives are 'mistakenly' rejected (Christchurch City Council, 2018a).

The Dudley Creek scheme has not been designed to account for resilience and the effects of climate change (Beca and Opus, 2015). However, the design was tested for sensitivity and adaptability to climate change, as project plans were to accommodate (more significant) future works. Resilience against climate change was an important consideration with regard to the selection (multi-criteria analysis) of the preferred option (Smith, 2017). The Council requested hydraulic sensitivity testing of the scheme to understand how each option might be affected by climate change, and how readily each option could be upgraded to provide a higher future level of service (if required), or modified to respond to climate change (Beca and Opus, 2015).

The project team noted a tendency towards more soft than hard engineering, as they considered the former to increase flexibility (e.g. the potential for adjustments). The flood protection strategy (e.g. types of flood risk measures that were considered) had no specific restrictions, and ranged from wider land purchase and flood storage in the (affected) area to pumping stations and construction of an underground bypass.

This said, the plans were not based on a variety of instruments. The reason for this is the fact that the project was considered a fast track project, which meant that the project team had to stay within traditional approaches. Any out of the ordinary approaches would have extended the program, which was not considered possible. Because it was a fast track project, the Council's business as usual approach was also not an option. Promises and commitments were made before the project team even had a scheme concept. As a result, the upstream options reached an agreement while the downstream options were still up for discussion. While the project team was going through those processes, the deadline of project delivery did not change. This time constraint forced the team to choose from relatively safe options in terms of the physical works.

Responsibilities and resources

Water management in New Zealand is undertaken through the Local Government Act 2002 (LGA) and the Resource Management Act 1991 (RMA) (Fenemor et al., 2011). The LGA provides local authorities with the capacity (e.g. rights, powers and privileges) to undertake any activity or business in order to achieve their purpose (CLGF, 2018). The RMA puts much of the responsibility for water management in the hands of regional councils, and requires that all relevant actors take into account matters related to climate change. In the case of local governments, this means considering the effects of a changing climate on communities, as well as incorporating climate change into existing frameworks, plans, projects and the standard decision-making procedures (Ministry for the Environment, 2018e). The central government (e.g. Department of Internal Affairs) set some fixed criteria that the Council has to report against, regarding specific levels or service associated with flooding. When making decisions, Councils are also required to take account of the interests of the indigenous Māori population (CLGF, 2018).

In terms of legal authority, the Council has got wide ranging powers at the local level under the Christchurch District Drainage Act and the Land Drainage Act, including the power of compulsory purchase. In case of the Dudley Creek project, some of the powers under the District Drainage Act were necessary to enact the works on private property.

The project team was responsible for putting clear options and recommendations to the Council, which was based on the consensus building with all the other actors, as well as the public consultation process. This process is described in the Local Government Act as being a part of the Council's responsibility, as it requires them to consider the views and preferences of the local community. Details on the form and process of consultation are not prescribed by this Act, as this is left to local decision making.

As mentioned before, responsible actors coordinated their actions as their assets and corridors overlapped. The project team gathered the resources needed to deliver the project by deliberate selection of consultants and contractors, as well as by including SCIRT, who delivered part of the works. As the project team started researching the post-earthquake hydraulics and hydrology right after the earthquakes, there was a relatively good base understanding on the water system. Since the influence of climate change is dictated through the central government guidance and the local guidelines, no additional effort was put in there. In terms of resilience and adaptation approaches, the project relied on SCIRT, who had done work on how to consider resilience, probabilities of future earthquakes, and other disturbances. The definitions of resilience and adaptation were still under development throughout the project, which caused some confusion about those terms and what they mean. Works to decrease the ambiguity of such concepts are ongoing, which may influence future projects.

Appendix J – Descriptive statistics

Table 13 depicts the mean and standard deviation of the components of adaptive capacity of involved and uninvolved citizens. The means of most components are higher for involved than uninvolved citizens. The exceptions are 'Concern flooding', 'Responsibility' and 'Motivation', where uninvolved citizens have a higher mean. Both for involved and uninvolved citizens the mean is lowest on 'Concern flooding', and highest for 'Motivation'.

Table 13: Descriptive statistics involvement

Component	Involvement			
	Yes (N = 101)		No (N = 159)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.518	.698	3.161	.652
Flood related knowledge	3.868	.732	3.063	.892
Preparedness	3.569	.855	2.953	.961
Concern climate change	3.693	.730	3.486	.917
Concern flooding	2.629	1.079	2.701	1.247
Responsibility	3.678	.695	3.714	.715
Expected flood risk	3.469	.711	3.434	.680
Perceived adaptive capacity	3.838	.745	3.771	.749
Motivation	3.975	.760	4.113	.565

Table 14 depicts the mean and standard deviation of the components of adaptive capacity of home owners and tenants. The means of most components are higher for home owners than tenants. The exceptions are 'Concern flooding' and 'Expected flood risk', where tenants have a higher mean. The difference between means of home owners and tenants on 'Expected flood risk' is very small. Both for home owners and tenants the mean is lowest on 'Concern flooding', and highest for 'Motivation'.

Table 14: Descriptive statistics living situation

Component	Living situation			
	Home owner (N = 153)		Tenant (N = 96)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.375	.679	3.191	.670
Flood related knowledge	3.704	.778	2.920	.916
Preparedness	3.327	.889	2.995	1.072
Concern climate change	3.597	.787	3.451	.924
Concern flooding	2.526	1.137	2.854	1.225
Responsibility	3.729	.691	3.667	.731
Expected flood risk	3.423	.733	3.465	.652
Perceived adaptive capacity	3.830	.783	3.740	.649
Motivation	4.085	.661	3.995	.630

Table 15 depicts the mean and standard deviation of the components of adaptive capacity of citizens with lower education and citizens with higher education. The means of most components are higher for citizens with higher education than citizens with lower education. The exceptions are 'Preparedness' and 'Concern flooding', where citizens with lower education have a higher mean.

Table 15: Descriptive statistics level of education

Component	Education			
	Lower education (N = 146)		Higher education (N = 114)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.169	.640	3.468	.720
Flood related knowledge	3.336	.855	3.427	.999
Preparedness	3.295	.915	3.061	1.020
Concern climate change	3.450	.851	3.716	.837
Concern flooding	2.863	1.210	2.430	1.105
Responsibility	3.582	.707	3.851	.678
Expected flood risk	3.434	.699	3.465	.684
Perceived adaptive capacity	3.669	.745	3.962	.719
Motivation	3.993	.519	4.145	.781

Table 16 depicts the mean and standard deviation of the components of adaptive capacity of citizens with an age below 50, and citizens aged 50 and above. The mean of citizens aged 50 and above is higher than the mean of citizens with an age below 50 for all components of knowledge. The mean of citizens with an age below 50 is higher than citizens of a higher age for all other components.

Table 16: Descriptive statistics age

Component	Age			
	Lower age (N = 159)		Higher age (N = 101)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.249	.694	3.380	.683
Flood related knowledge	3.189	.975	3.670	.742
Preparedness	3.079	1.004	3.371	.882
Concern climate change	3.591	.878	3.528	.817
Concern flooding	2.679	1.220	2.663	1.127
Responsibility	3.752	.709	3.619	.697
Expected flood risk	3.457	.639	3.432	.768
Perceived adaptive capacity	3.813	.689	3.772	.833
Motivation	4.116	.609	3.970	.703

Table 17 depicts the mean and standard deviation of the components of adaptive capacity of males and females. The mean of males is higher than the mean of females for all components of knowledge, as well as 'Expected flood risk'. The mean of 'Concern climate change', 'Concern flooding', 'Responsibility', 'Perceived adaptive capacity' and 'Motivation' is higher for females than for males.

Table 17: Descriptive statistics gender

Component	Gender			
	Male (N = 123)		Female (N = 135)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.371	.717	3.244	.664
Flood related knowledge	3.526	.908	3.247	.917
Preparedness	3.268	.899	3.115	1.027
Concern climate change	3.425	.850	3.704	.833
Concern flooding	2.484	1.122	2.863	1.210
Responsibility	3.553	.729	3.841	.654
Expected flood risk	3.482	.691	3.425	.690
Perceived adaptive capacity	3.721	.822	3.864	.672
Motivation	3.927	.667	4.181	.603

Table 18 depicts the mean and standard deviation of the components of adaptive capacity of citizens that have no experience with flooding, and citizens that have either a direct or indirect experience with flooding. The means of most components are higher for citizens with experience than citizens without experience. The exceptions are ‘Responsibility’, ‘Perceived adaptive capacity’, and ‘Motivation’, where citizens without experience have a higher mean.

Table 18: Descriptive statistics experience

Component	Experience			
	No experience (N = 140)		Experience (N = 120)	
	Mean	Std. Deviation	Mean	Std. Deviation
Climate change knowledge	3.224	.637	3.389	.743
Flood related knowledge	3.140	.910	3.650	.858
Preparedness	2.968	.960	3.454	.912
Concern climate change	3.502	.880	3.642	.819
Concern flooding	2.582	1.158	2.779	1.207
Responsibility	3.750	.723	3.642	.683
Expected flood risk	3.386	.634	3.519	.748
Perceived adaptive capacity	3.824	.741	3.767	.755
Motivation	4.079	.582	4.038	.722

Figure 12 shows that the majority of the respondents (89%) considers humans to be the main cause of climate change, while eighteen percent of the respondents thinks this is not the case.

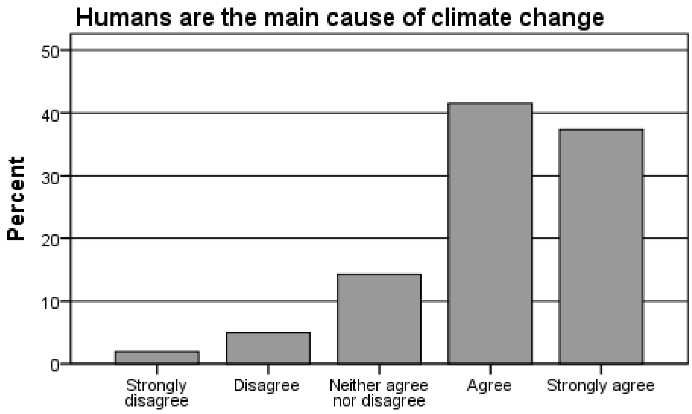

Figure 12: Cause of climate change

Figure 13 shows that the majority of the respondents (55%) disagrees with the statement that we should focus on short-term solutions instead of long-term solutions. A high number of respondents (34%) neither agrees or disagrees with the statement.

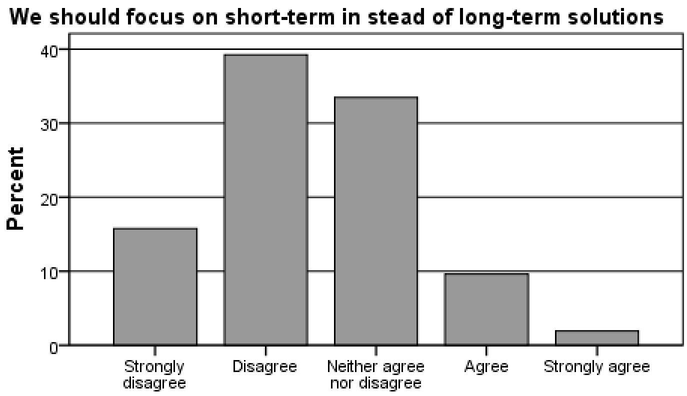

Figure 13: Short- or long-term solutions

Figure 14 shows the respondents perception of the main climate change challenges for Christchurch. The top three consists of sea level rise, increased extreme weather events, and increased natural disasters. Respondents that chose the ‘Other’ option considered the challenges of endangerment of endemic species, pollution, changing of seasonal rainfall and wind patterns, deflection of resources, and political authoritarianism.

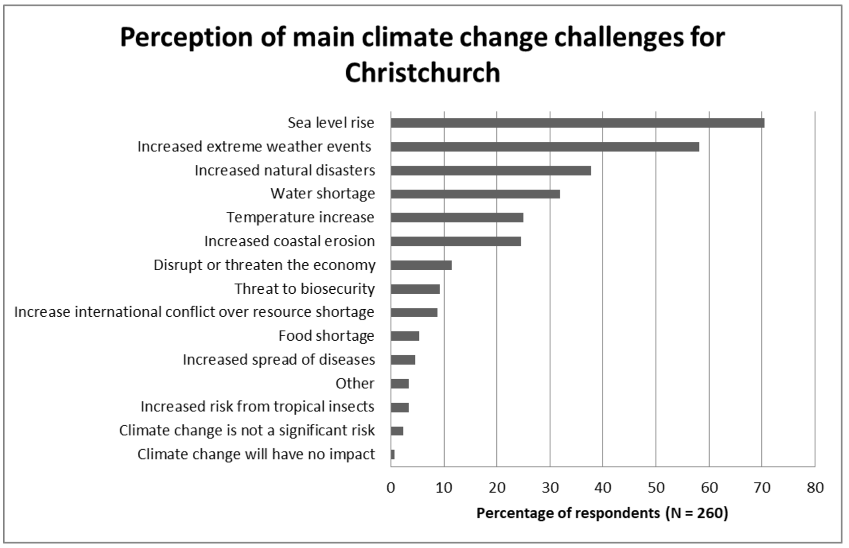

Figure 14: Perception of main climate change challenges for Christchurch

Figure 15 shows the respondents perception of responsibilities for managing the impacts of climate change. The top three consists of the National Government, Christchurch City Council, and Environment Canterbury. Forty-four percent of the respondents considered the community to be (partially) responsible. Respondents that chose the 'Other' option mentioned a responsibility of international organizations, private enterprises, oil companies, the world governments, the United Nations, dairy farmers, and educational institutions.

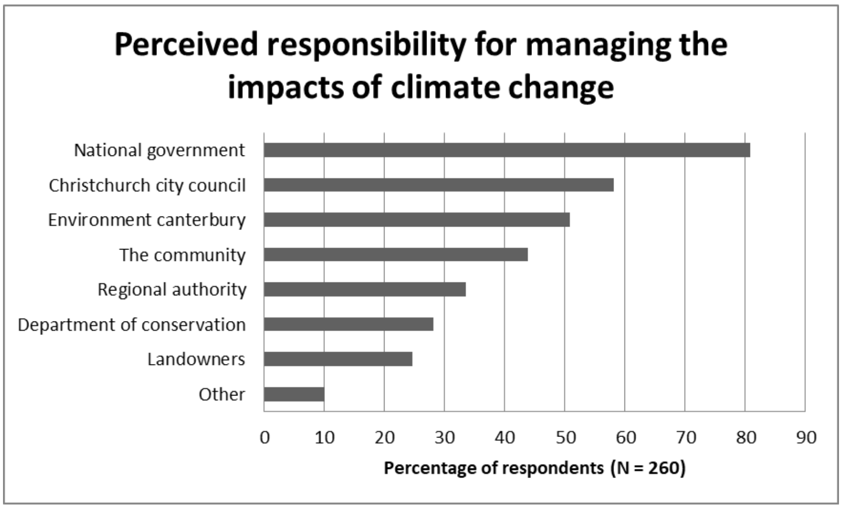

Figure 15: Perceived responsibility for managing the impacts of climate change

Interrelation adaptive capacity indicators

When asked about the relation between knowledge and risk perception, most of the interviewees considered a continuous interaction. An initial high risk perception would lead to information seeking behavior, which increases knowledge, and consequently lowers the risk perception. If risk perception is low, for example if a threat seems far away, a more reactive than proactive role is assumed, as there is no immediate incentive to act. When people have to deal with unknown risks, worry increases, and more efforts are put into lowering the uncertainty surrounding the problem and finding an appropriate response. Feeling more informed and aware of what is happening around you allows for a better assessment of the risk, and can lower your concern. The interviewees mentioned that the way in which the knowledge influences one's risk perception, however, is not always the same. According to them, it depends on the type of information, how well you understand it, as well as what you think you can do with it. If you don't understand, or are suddenly presented with new information, this can increase your worry. If the information helps you understand the problem, and, for example, shows you what is done to mitigate the risks, this decreases worry. A number of interviewees mentioned that, while they became more aware of risks in their area, which increased risk perception, the information they found on the flood measures that have been put into place lessened their risk perception. While the above was true for most interviewees, there was one who indicated that her low knowledge/awareness meant that she simply didn't think about risks and/or potential consequences, which lowered her risk perception, explaining it as 'blissful ignorance'.

When asked about the relation between knowledge, perceived adaptive capacity, and motivation, the prevalent opinion was that a high level of knowledge would lead to a high capacity, as well as a high motivation. A low level of knowledge was thought to have the opposite effect, meaning a low capacity and low motivation. The underlying argument provided is that knowledge increases your ability to assess and mitigate risks, as well as makes you feel more competent when it comes to making decisions. It is seen by some of the interviewees as a tool to change your environment as you need to. Knowledge on the risks increased their feeling of preparedness, as it allowed them to weigh their options, and perform actions as part of a planned approach. If your knowledge (e.g. awareness) on what is happening around you is low, you may feel like you're trapped, preventing you from taking action. In other words, they describe a negative spiral, where, if you don't possess the knowledge, you feel less capable, and in turn are less motivated to take action. This said, some interviewees pointed out that both a high- and low level of knowledge would motivate them. In their case, the initial sensation of not knowing enough, and perceiving an inadequate capacity to deal with the current threat, motivated them to go out and increase their knowledge. That not only a low, but also a high perceived adaptive capacity can lead to a rather reactive approach, is illustrated by interviewees stating that, because of their high capacity, they feel no threat, and are less motivated to undertake action.

With regard to the relation between risk perception, perceived adaptive capacity, and motivation, almost all interviewees described a positive relation. In other words, if you have a high risk perception, this will lead to high motivation and high perceived adaptive capacity. If your risk perception is low, so would be the others. Looking at the relation from the other direction, the shared opinion is that a high perceived adaptive capacity lowers risk perception, and a lower perceived capacity leads to a higher risk perception. The interviewees gave a number of reasons as to why they expected this to be the case. Firstly, having a low risk perception means that you are not worried about flooding, don't think about it too much, and therefore have no incentive to do anything. As you experience a threat and become more worried, for example because your knowledge on future events is low, your sense of urgency increases, and your motivation to act and increase your own capacity to deal with it (e.g. fill the knowledge gap) changes accordingly. Put differently, a high level/immediate threat will lead to more immediate action. Consequently, as the perceived adaptive capacity increases, the risk perception lowers again. Some interviewees mentioned that, initially when the flood took place, worry increased due to a lack of understanding and knowledge. Now, because they feel able to deal with a future flood event (e.g. moving away if needed, finding information, having friends that can help), their worry is less. The perceived adaptive capacity is interpreted by the interviewees as having a way out of the unfavorable situation, which, in turn, is used to assess the threat level. This said, some of the interviewees mentioned that, for them personally, there was no relation between risk perception and perceived adaptive capacity. They considered their risk perception to be relatively steady (e.g. low), regardless of their own capacities.

Role of involvement

When asked about the relation between (hypothetical) involvement in the Dudley Creek project and their adaptive capacity, the interviewees gave varied responses. A distinction is made between the responses of citizens that have not been involved in the Dudley Creek project, and those that have been involved. The response of the first group entails expectations of the impact of hypothetical involvement in a flood project, while the latter entails the description and perception of actual involvement.

With regard to the impact of involvement on their knowledge, almost all interviewees that had not been involved in the Dudley Creek project expected an increase in their knowledge. This expectation was based upon an increased awareness of potential flood risk developments, as well as on flood risk management in the area. Involvement was thought to mentally activate people, leading to more knowledge seeking behavior. Some of the interviewees pointed out that the impact of involvement on knowledge depends on the type of information provided, as well as the initial level of knowledge and the individuals risk perception. If your initial level of knowledge is high, you will look more critical at the provided information. Interestingly, the citizens who had actually been involved in the project stated the opposite, in that they did not think it influenced their knowledge. This was mainly based upon their perception that no background information on the flooding problem was provided by the project team. The citizens felt that the meetings were mainly to express concern, and instead of explaining the situation, the project team conveyed the message of ‘this is what we are going to do’. In addition, some information presented was perceived as hard to understand (e.g. jargon).

With regard to the impact of involvement on the risk perception, interviewees that had not been involved mentioned that involvement can both increase, and/or decrease the perception of risk, depending on the information provided. On the one hand, you become more aware of risks you may not have realized existed before, while on the other hand you know that a problem is being addressed. It can be reassuring to know what’s going on/being done, but may also lead to more worry because you are more aware of the danger. The opinions of the interviewees that had actually been involved in the project confirm these expectations, in that it increased the sense of worry for some, while others were reassured. The biggest contributing factor mentioned for an increased worry was the (initial) lack of/vague information and explanation of the situation by the project team. Also, the fact that the project team stated they weren’t taking global warming into account was unsettling for some. Worry decreased for others, as they were reassured by the fact that a plan was underway, and works were being undertaken.

With regard to the impact on perceived adaptive capacity and motivation, the interviewees that had not been involved thought that involvement can increase, as well as decrease perceived adaptive capacity and motivation. They stated that the impact depends on the form of involvement, the information given, and the role that you are appointed/can fulfill. More clarity increases interest. If vague information is provided instead of clear roles, this lowers the connection to what is going on, and consequently the motivation. Involvement has the potential to improve your problem solving/decision making ability, directing it towards practical risks. Only one of the interviewees that were involved in the project thought that the involvement actually increased her perceived adaptive capacity and motivation. Being involved increased her perceived preparedness, and feeling of knowing what to do. The provided information also spurred interest, and increased motivation to keep an eye out for more information. The majority of the involved citizens, however, stated that the involvement decreased their perceived adaptive capacity and motivation. The explanation for this was the feeling that the citizens were not heard by the project team. Based on the interactions, citizens felt that they could have no significant impact, and that the project team would continue regardless. Some citizens mentioned that the involvement didn’t feel like engagement, as there was no two-way dialogue, but just informing of plans.

Role of living situation

When asked about their living situation and knowledge, almost all interviewees considered that both owning a property and the act of buying a property would lead to a higher level of knowledge. It was frequently mentioned that, if you own a house as compared to renting, you will take a more active approach, putting more effort into finding out what the situation is and gaining information/knowledge. Owning a house means that you have to protect your own investment, while, as a renter, there may be other (more immediate) problems to worry about. Two interviewees pointed out that their personality mediated how they went about seeking information. To them, it didn't matter whether or not they owned the house, as they would go through the effort of investigating what the flood risk is regardless.

With regard to the role of their living situation on their risk perception, opinions were more divided. There were some interviewees that didn't consider a difference between owning a house and being a tenant, as, regardless of the situation, you and your items would be affected by a flood. Most of the interviewees, however, considered owning a house to increase their risk perception, while renting would decrease their risk perception. The main argument for this distinction is the feeling that, when you own a house, your investment is at stake, and your asset(s) may lose value. This may sharpen the risk, and increase the sense of worry. Also mentioned was the responsibility to those in the house, including your children (e.g. passing on the investment). When considering the situation as a tenant, there were two arguments for a lower risk perception. Firstly, it was pointed out that the house and it's risks (e.g. flooding, damaged structures, assets losing value) are not the tenants problem, but that of the landlord. Some home owners reflected on their previous period as renter as them being more 'naïve' then they are now, not worrying about flood risk at all. This, combined with the fact that renting allows you to quickly/simply move away, lowers the interviewees risk perceptions. In contrast to the aforementioned increased risk perception of home owners, some interviewees also considered a decrease in risk perception. The argumentation for this is closely related to knowledge and perceived adaptive capacity, as being a home owner meant that they were more aware of the risks, knew more about the conditions of the house, had the ability to have everything checked out, as well as to make modifications to the house. As this is not the case when renting, they concluded that owning the house would lower their risk perception, while renting would increase it.

When asked about the role of their living situation on their perceived adaptive capacity and motivation, most interviewees considered that owning a house would increase the aforementioned. As an owner, the fact that you have something at stake may motivate you to a higher degree to take action, protect it, and prepare for a future flood event. Your ability to do so is also higher, as you know more about your specific situation, and have the power to modify the house without having to ask for permission. This said, some interviewees also pointed out that owning a house can decrease your perceived adaptive capacity, as you don't have the ability to simply move away. You may be forced to stay where it is bad, and if there is a problem with the house, you have to fix it yourself. Comparing this to the situation of being a tenant, though you may not be able to make changes to the house itself, you do have the option of moving to a new place with a lower risk. The flipside of this is that the temporality of your living situation may lower your motivation to adapt to specific circumstances.

Role of experience

All of the interviewees reported a certain degree of direct and/or indirect experience with flooding, ranging from flooded/damaged properties to flooded gardens and streets. When asked about the relation between the interviewees experience with a flood event and their knowledge, everyone stated that the experience led to an increase in knowledge, both directly or indirectly. The direct impact on knowledge was explained as an increased awareness of what's going on, what to expect from future flood events, and what was needed to effectively deal with them. The indirect impact on knowledge was attributed to the fact that the interviewees went out and actively sought more information/informed themselves to a greater degree. This concerned, for example, the Creek outline, where it was going, why it was backing up, and what was being done about it. From their responses, it can be concluded that the personal experience and specific impact of flooding (e.g. flooded house, or flooded garden, etc.) influenced the degree to which the interviewees changed their behavior. In other words, the people that were most affected were most inclined to increase their knowledge.

With regard to the impact of their experience on risk perception, even though some of the interviewees saw their homes flooded, most mentioned a decreased risk perception. For the worst affected interviewees, the general opinion was that flooding is an annoyance, but not life destroying. For others, the decreased risk perception is explained by the fact that the flood event showed them that their homes were relatively safe, demonstrated that they would be able to cope with future flood events, and showed them firsthand what (heavy) rainfall was needed to cause such flooding. Some of the interviewees pointed out that any experience with flooding makes the problem tangible, as it increases awareness that it doesn't just happen to other people, and increases the sense that something needs to be done. In the current situation, none of the interviewees considered their experience to be devastating. If they had experienced more serious/continual consequences, they agreed that their feeling of a threat and sense of urgency would have been stronger.

When asked about the relationship between experience, perceived adaptive capacity, and motivation, the interviewees in general assumed an increased perceived capacity and increased motivation. Experience with floods was considered a 'learning' experience, in that the affected have a better idea of what needs to be done to deal with future events, have procedures in place, and, as a result, are more prepared. Those that experienced a flood know what to do in future events, because they have done if before. The experience demonstrated their own ability to ensure personal safety. One interviewee critically pointed out that this may have led to him becoming overconfident. In addition to the aforementioned, the interviewees showed an increased motivation to search for information, and to take preventive action. Examples of this are the checking and cleaning of storm water drains, as well as the act of moving items to higher places within the house to protect them from flooding. This said, one of the interviewees noted a decreased perceived adaptive capacity. His experience led him to conclude that, though you can manage the flooding by taking measures to some degree, there is not much more humans can do in case of an actual flood event then to simply get out of its path.