Curtin University

WATERWORLD INCOMING: PREPAREDNESS OF PERTH'S URBAN FORM TO ADAPT TO CLIMATE CHANGE INDUCED FLOODING AND SEA LEVEL RISE

by

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INTRODUCTION

The link between human activity and the exponential severity of weather events as a result of climate change is undeniable. The Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report determined that approximately 3.3 to 3.6 billion people and a high proportion of species inhabit areas that are extremely vulnerable to the impacts of climate change (IPCC, 2022). The Report highlighted that people and ecosystems are experiencing increased exposure to climate-related hazards because of current unsustainable development patterns. The Report's summary on Australasia concluded that climate-related risks are projected to increase across sectors, communities and ecosystems which will be exacerbated by existing social inequalities and geographic exposure.

Unfortunately, despite the obvious need to take action, there is a serious lack of evidence demonstrating the steps Australian governments and agencies are taking to protect communities from the most severe impacts of climate change – most notably those associated with increasing precipitation. Australia is one of the most vulnerable developed nations to the impacts of climate change and the ability for local governments to meet the needs of their communities is already beginning to suffer (Scott and Moloney, 2022). For every degree that the Earth's average temperature increases, the atmosphere can hold up to seven per cent more vapor (Brookes, 2022). The current climate trajectory means that Perth is likely to experience severe precipitation-associated events which could result in flooding similar to what has recently occurred in New South Wales and Queensland which have left more than 5000 homes uninhabitable and more than 1000 people in emergency accommodation (Ludlow, 2022). Perth's urban areas must be prepared for both natural disaster events and the progressive change of the environment and local climactic conditions.

As Perth is likely to see major precipitation events in the future, urban planners must consider how this will impact the urban form. In Australia, 90 per cent of the population lives in urban areas which means that the existing and future urban form will have an enormous role in climate change adaptation. Urban planning has historically fallen short when addressing social equity and justice due to its overemphasis on regulatory and engineering/systemic interventions which has deprived disadvantaged people and vulnerable ecosystems of adequate infrastructure services to cater to their needs and protect them from harm (Chu and Cannon, 2021). Spatial planning in this manner can reinforce the limitations in adaptive capacity and exacerbate the impacts of climate change on already vulnerable groups. "Vulnerability is the degree to which a system is susceptible to climate change and its inability to cope with the adverse effects of climate change" (Dhar and Khifan, 2017). Spatial planning and participatory planning processes can support progressive climate change adaptation

measures which can help to reduce inequalities in urban planning and deliver responsive infrastructure that will improve the resilience of the most vulnerable people and ecosystems.

This dissertation aims to answer the following questions based on the Perth Metropolitan Region:

a) *Where are people and ecosystems most likely to be threatened by the climate impacts of heavy rainfall and flooding events or progressive sea level rise?*
b) *How can planning practices improve the resilience of vulnerable people and ecosystems by proactively implementation adaptation measures for climate-related changes?*

The objective of this research is to utilize academic literature to define best practice for climate-related adaptation in urban planning and leverage this understanding to assess the maturity of Perth's approach. This will be achieved by identifying gaps in Perth's approach to climate change adaptation in key policies and strategies. Primary research was undertaken to determine what is being done to address these shortcomings in Perth's adaptation to climate change-related flooding events and sea level rise and identify opportunities to improve the urban planning response. Opportunities for improvement are identified in the *Analysis* and recommendations have been provided for priority actions that should be undertaken to improve the adaptive capacity of Perth's urban form to flooding and sea level rise by utilizing successful case studies from around the world.

This dissertation consists of a *Literature Review*, *Methodology* for semi-structured interviews, *Results* of the interviews. The outcomes of the research, final remarks and opportunities for further research are presented in the *Analysis* and *Conclusion*. The findings of this research intend to offer planning solutions which could support adaptation strategies for the metropolitan region.

LITERATURE REVIEW

They key focus of this literature review was to understand which areas of the Perth Metropolitan Region would be impacted by climate change the most and what adaptation practices were being implemented in urban planning. This research focusses on precipitation events (namely flooding, inundation due to rainfall and sea level rise) as a core impact of climate change in Perth.

RESEARCH METHODOLOGY

This literature review is structured in the following manner: firstly, a review of literature identifying the theoretical concepts that contribute to sustainable and resilient cities organized by theme; secondly, a collection of spatial planning, strategy and governance publications from the Western Australian government departments to provide a contextual basis for discussion; and lastly, the identification of high-risk geographies and hotspots which are vulnerable to extreme precipitation events and ongoing changes as a result of climate change.

A structured literature review was utilized to understand theoretical concepts related to climate change responses in urban planning and how they have historically contributed to vulnerability of people and ecosystems. Based on research collected in previous studies, a serious of key words was established to develop the search strings. The key words included a series of environmental topics ("climate change", "flood", "sea level rise"), technical topics ("urban planning", "adaptation", "vulnerability', "sustainable cities"), social topics ("social justice", "equity", "activism"), and governance topics ("implementation", "adaptation", "policy design"). The results of the searches were refined by those which were available in English, peer reviewed and predominantly limited to publications released after 2010. Sampling was undertaken from the results of the search strings based on those with titles and abstracts most relevant to the research questions and objectives. The catalogues used to perform these searches included the Curtin University Library Catalogue, ProQuest, and Web of Science. Google Scholar was used for a general search of grey literature due to the emerging nature of the topics presented.

The literature collected consisted primarily of qualitative research from secondary sources which have been produced by other researchers and organisations. The *Theoretical Framework* presented provides an overview of the interrelated concepts that were thematically repeated in the sampled articles. In addition to the scholarly and peer reviewed articles collected, this research required the collection of contextual data from Perth. This included the most current urban planning strategies, spatial and land-use plans for the Perth Metropolitan Region, and climate change analysis from a variety of local, state and regulatory government bodies. The documents published by Western

Australian government agencies provide a basis of information for analysis against the literature to identify gaps and areas for improvement.

RESEARCH INTERVIEWS

This research required inputs from professionals and specialists working in urban planning to determine the current barriers for implementing adaptation measures and gauge the sophistication of local government approaches against global best practices. Local governments that are located in hotspots identified in the literature review were contacted for comment, of which five were available to participate in this study. Prior to the interviews, a review of their spatial planning strategy and local planning schemes and identification of any climate change adaptation plans was conducted. This review informed the interview process and allowed the interview to focus on information that was not publicly available. The interview questions were kept broad to allow for more specific questions about the interviewee's local government area to be asked during the interview processes. An open-ended interview style was utilized to explore the awareness of climate change adaptation principles in local government bodies and identify the current state of action to address flooding and sea level rise related impacts. Interviews were undertaken online via videoconference and recorded to allow for transcripts to be developed.

Seven interviews were conducted with professionals with the following credentials from the local governments:

- Director of Planning;
- Senior Statutory/Strategic Planners, and a
- Coastal Management and Planning Engineer.

Participants were limited to those in senior roles or with at least 5 years of experience in their field to ensure they can provide informed feedback based on their experience level.

Curtin University Human Research Ethics Committee (HREC) approved this study (HREC number HRE2022-76875). [1]

HISTORY OF URBAN PLANNING AND CLIMATE CHANGE

Spatial planning refers to the processes that influence and develop the spatial distribution of social, environmental, and economic functions in urban areas. Adequate spatial planning is essential for

[1] Should you wish to discuss the study with someone not directly involved, in particular, any matters concerning the conduct of the study or your rights as a participant, or you wish to make a confidential complaint, you may contact the Ethics Officer on (08) 9266 9223 or the Manager, Research Integrity on (08) 9266 7093 or email hrec@curtin.edu.au.

facilitating equitable and effective responses to climate change impacts (Macintosh, Foerster, and McDonald, 2015). When used effectively, spatial planning offers solutions to reduce vulnerability on people and ecosystems and improve the overall resilience of the region or community by better managing climate hazards (Macintosh, Foerster, and McDonald, 2015). Spatial planning and climate change have been featured in urban planning related literature for over two decades. The growing number of extreme climactic events and global forums has raised awareness of the need to transition the planet to a more sustainable future. The majority of urban planning literature focused on mitigation efforts to reduce greenhouse gas emissions rather than the adaptation of urban spaces to respond to the impacts of climate change (Dhar and Khirfan, 2017). Of the literature that did discuss adaptation, the focus was on policy design and metrics for measuring climate change vulnerability of certain areas (Dhar and Khirfan, 2017). There is little literature on evidence-based approaches to responding to vulnerabilities in the urban form through adaptation initiatives and even less so that focusses of physical spatial plans and the design of the built environment. A core gap in the literature is the evaluation of climate change adaptation studies at a local or regional scale – a sentiment which is reiterated in the IPCC Sixth Assessment Report. The IPCC suggests that progress in the adaptation of urban environments has been limited due to deficits in adaptive capacity which has led to poor performance in planning, implementation, monitoring, and evaluation (IPCC, 2021). The limitations in adaptive capacity seem to occur as a result of a lack of vision and consistency in policy design, competing priorities and values, misinformation and propaganda, and limited engagement and resources (IPCC, 2021).

THEORETICAL FRAMEWORK

SUSTAINABLE CITIES

The term sustainability has been given different definitions depending on the era and context. The Brundtland Commission, formerly the World Commission on Environment and Development operating as a sub-organisation of the United Nations (UN), defined ‘sustainability’ as a safeguard for future generations to meet their own needs by preventing them from inheriting an unlivable legacy (O’Riordan et al., 2020). A sustainable future in which all of humankind is able to thrive is not guaranteed, and if conditions for thriving are extended to all life on Earth than we have already failed (O’Riordan et al., 2020). Despite this, society must continue to strive for sustainability despite the overwhelming responsibility and complexity of the endeavor. To break the cycle of unsustainable practices, society must evaluate each factor that contributes to global development and growth which to date have resulted in destructive behaviour, increased inequality, and inherited inability for vulnerable groups to adapt and survive (O’Riordan et al., 2020). A re-evaluation of the factors that

contribute to sustainable outcomes will help to support current systems to examine their resilience, adaptive capacity, and equitable distribution of services. Historically, studies tended to focus on mitigation of climate change impacts rather than adaptation. Of the known studies on adaptation, most dealt with governance practices and vulnerability assessments and little emphasis was given to physical urban planning and design interventions (Dhar and Khirfan, 2017). Whilst mitigation is essential to preventing further damage to the Earth, adaptation offers solutions for the inevitable impacts that society will have to face as a result of climate change (Griggs and Reguero, 2021). Local and regional urban planning has significant influence over the characteristics of private and public development, public open spaces, and service provisions. This means that planning and design practices have the potential to incorporate effective climate adaptation initiatives and reshape the urban form to become more resilient (Silva and Costa, 2018). Urban planning must also emphasize participatory planning and community collaboration to respond to the multidimensional impacts of climate change (Dhar and Khirfan, 2017).

Urban planning can be exceptionally adaptable over periods of relatively progressive change. Unfortunately, in the face of potentially extreme climate conditions, urban planning is likely to be ill-equipped to change to rapid impacts (Silva and Costa, 2018). To achieve 'sustainability' cities must balance development across social, economic, and environmental factors and address their existing shortcomings in the short and long-term (Hassan and Lee, 2015). Cities endeavoring to improve their overall sustainability can adopt sustainable city practices which can be adapted to address the specific needs of the population and the structure of the existing urban form. Hassan and Lee describe three types of sustainable city theories which have proven effective across the globe. These include the *compact city*, *ubiquitous eco-city*, and the *zero-carbon city* (2015). Each of these sustainable city theories provide different environmental, social, and economic benefits. For example, compact cities favour social benefits by offering accessible public transport facilities, zero-carbon cities use passive and active features to reduce greenhouse gas emissions, and ubiquitous eco-cities use technology and data collection to optimize efficiencies and identify hotspots for improvement. There are often contradictions and trade-offs between different these theories and how the complexity of sustainability makes it nearly impossible to develop a standardised model for sustainable urban forms (Hassan and Lee, 2015). It is noted that any improvements to the urban fabric must address existing vulnerabilities by using sustainable concepts rather than overlaying a "one size fits all" sustainability model. There are also likely to be winners and losers in the sustainability model due to trade-offs and what is practical during implementation.

VULNERABILITY

Human and ecosystem vulnerability are symbiotic and therefore should be considered in parallel. Whilst all people will experience the impacts of climate change, the degree to which people and ecosystems are considered vulnerable changes substantially between geographies and some groups will experience more substantial loss and impacts than others (Thomas et al., 2018). The factors which determine the vulnerability of people varies between each research community but climate change authors tends to agree that vulnerability is linked to the capacity of a social or environmental system to predict, respond and recover from an impact (Otto Et al., 2017). Vulnerability of populations and ecosystems is the degree to which they are exposed to climate-related impacts and their baseline sensitivity to those impacts (Dhar and Khirfan, 2017). A population or ecosystem's vulnerability to a hazard has three elements: exposure, sensitivity, and adaptive capacity (Alonso and Renard, 2020). Exposure refers to the degree that groups will experience pressure due to climactic conditions and hazards due to their location (Dhar and Khirfan, 2017). Sensitivity refers to the total physiological risk factors of a person or species that determine whether they will experience negative health impacts (Alonso and Renard, 2020). In humans, they key physiological factors that contribute to a person being vulnerable are age (mostly children and the elderly), any underlying health conditions or disabilities, mental health, and being female. The physiological factors that make a person vulnerable can be compounded by their social circumstances which include demographic characteristics, social and economic characteristics, community development features, and public resource provision and public security (Abarca-Alvarez et al., 2019). For example, those who are wealthy often live in spatially advantageous areas and have more opportunities to prepare themselves and recover from hazards (Alonso and Renard, 2020). Social circumstances of vulnerable people are often a result of unsustainable spatial planning practices, marginalization, and inherited systemic inequality because of colonialism (IPCC, 2022). This links to a person's threshold of adaptive capacity meaning that those who are considered more vulnerable have less ability to prepare, respond, and recover to hazards and the initial and long-term impacts are considered more severe.

Adaptive capacity could also be influenced by the Earth's or social system's critical thresholds which could result in cascading impacts which spark an emergency response rather than gradual change (Otto et al., 2017). These critical thresholds are often referred to as 'tipping points' (Otto et al., 2017) but the concept has become popularized through the development of planetary boundaries concept. The concept was developed in 2009 with the intention of identifying the systems that regulate the resilience of the Earth. The lead scientist and author, Johan Rockström, warned that "transgressing one or more planetary boundaries may be deleterious or even catastrophic due to the risk of crossing thresholds that will trigger non-linear, abrupt environmental change within continental to planetary-

scale systems" (2009). The boundaries presented in the study propose the quantitative capacity of each environmental system which will allow humankind to continue to exist safely (see Figure 1). The study demonstrated that humankind had already surpassed the thresholds for climate change and biodiversity loss which is undeniable in the research and evidence of the Earth's current state. The core recommendation provided by Rockström et al. was that the planetary boundary framework should be considered to inform adaptive governance practices at global, national, and local levels (2009).

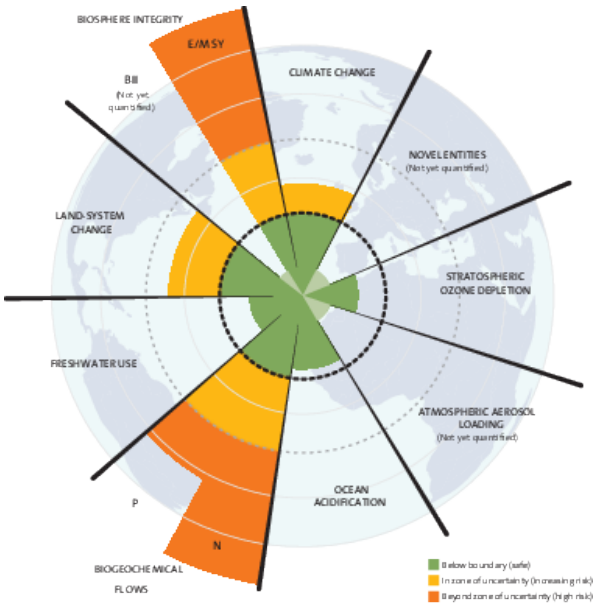

FIGURE 1: PLANETARY BOUNDARIES CONCEPT (J. LOKRANTZ/AZOTE BASED ON STEFFEN ET AL. 2015.)

Cities consume natural resources and disrupt ecosystems which has led to the modification, degradation, and fragmentation of local and regional environments (Depietri, Renaud, and Kallis, 2012). Urban development disrupts the 'occupation' of ecosystem services which reduces their resilience and adaptive capacity to hazards. For example, the extensive use of sealed surfaces (bitumen and concrete for roads and buildings) in urban areas impairs the function of soils designed to be permeable to allow water to naturally drain from the surface into water bodies or underground aquifers. Not only does this increase the risk of flooding in urban areas, but also reduces the soil's capacity to filter out contamination from rainwater before it enters water bodies and potable water supplies. Ecosystems in urban areas provide a significant variety of 'services' including temperature regulation, water regulation and storage, air purification and ventilation, and opportunities for carbon sequestration (Depietri, Renaud, and Kallis, 2012). In addition to these physical services, ecosystems also provide urban populations with wellbeing, cultural, and religious benefits. This symbiotic nature of human and ecosystem vulnerability means that when the ecosystem services become degraded and fragmented it increases the vulnerability of any organism (including humans) that rely on those

services. Urbanisation removes a significant proportion of an ecosystems ability to protect itself from hazards, but it also lessens its ability to act as a buffer for the urban environment to maintain its resilience to climate-related impacts (Depietri, Renaud, and Kallis, 2012). Urban planners must have sufficient knowledge about ecological systems and services to ensure that the ecology itself is able to maintain its existing health plus reserving the ability to respond to climate-related hazards. Biodiversity deterioration is often a result of interacting factors within the urban environment which may include habitat loss, exotic plants or feral animal species, temperature increases (Urban Heat Island effect), and the reduction in the overall quality of environmental areas (Ayers and Rehan, 2021). The composition of the urban landscape can help or hinder the interrelationships required to allow ecosystems to cope in urban environments.

There are many factors that can contribute to human and ecosystem vulnerability. Unfortunately, due to practicality, social and financial circumstances, not every single vulnerability factor can be addressed to protect populations from climate-related impacts. The implementation of management and mitigation measures is determined by what decision-makers and communities consider to be worth preserving and achieving based on their own values and philosophies (O'Brien and Wolf, 2010). Vulnerability is not just concerned with the negative outcomes on the human or ecosystem factors of cities, but how each of these factors is valued differently and how much they contribute to the overall wellbeing of people and environments. For example, in the aftermath of a natural disaster such as Hurricane Katrina, the Black Summer bushfires and more recently the floods that have inundated the eastern states of Australia, questions are asked about the values and ethics that were upheld in decision-making which resulted in some lives and properties being saved and others being left to perish. The aftermath of these events continues to demonstrate how climate change response and adaptation philosophies are overshadowing political debates about cost-benefit analysis which tend to favour the former over the latter (O'Brien and Wolf, 2010). Increasingly, what is considered to be successful and acceptable adaptation depends on what society values as worth saving and whether values-based approaches to climate-related impacts can be justified based on what the population considers desirable (O'Brien and Wolf, 2010).

RESILIENT CITIES

Cities must find ways to address the immediate physical risks associated with climate change as well as building their capacity to cope with the transitional risks of a low emission future. These capacity building exercises will dictate the city's ability to create fundamental change in urban planning and infrastructure management to address the climactic conditions of the future and the increasing complexity of the urban areas (Kim and Lim, 2016). The Intergovernmental Panel on Climate Change (IPCC) defines resilience as "the capacity of social, economic, and environmental systems to cope with

a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation". Resilience interventions for cities that intend to address climate change should consider resilience through ecological, engineering/systemic, and evolutionary lenses. Ecological resilience refers to the environment's ability to absorb a change or disturbance and restructure itself to recover to its original state. Environments that experience too much disturbance, either by changes in climactic conditions or human interference, are pushed beyond their threshold of resilience which can result in irreversible damage and loss of species. Engineering and systemic resilience can be impacted changes in climate or natural disasters (such as floods) and social turbulence (such as economic crises, activism, and war). The speed that the system or urban fabric can return to a state of equilibrium is a core performance indicator for engineering resilience (Kim and Lim, 2016). Ecological and engineering resilience have been explored in urban planning in the form of disaster risk management and emergency response. However, a gap remains in the response to gradual changes such as rising sea levels and increases in precipitation events which puts populations at risk. Evolutionary resilience focusses on socioecological factors and is mainly concerned with the social fabric's ability to continuously improve itself in response to stress and change. Evolutionary resilience relies on creative destruction to drive innovation and growth (see Figure 2). "The impact of slow and steady climate change reshapes the urban system while demanding a shift toward better quality" (Kim and Lim, 2016). Evolutionary resilience principles provide a lens for the type of preparation and response required to adapt to climate change in the long term.

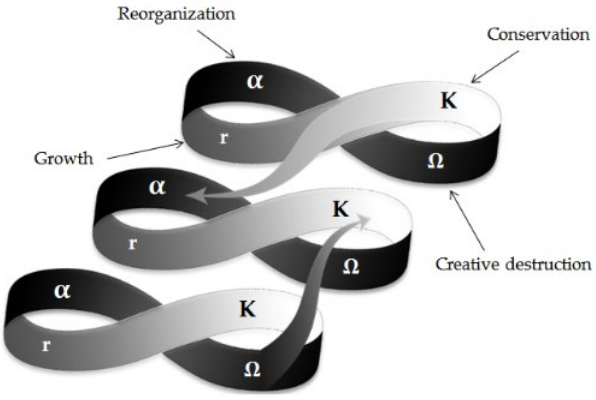

FIGURE 2: THE PANARCHY MODEL OF THE ADAPTIVE CYCLE (KIM AND LIM, 2016)

The actual resilience of cities depends on the alignment of market, regulatory, and civil society forces, making the implementation of resilience theory more complex. Factors such as fear severely undermine how resilient a city can be (Newman et al., 2017). "Invading armies have destroyed cities by sowing fear before an arrow or shot was fired" (Newman et al., 2017). The current war between Russia and the Ukraine is a prime example of how fear can be weaponised in attempt to dismantle a

city. Historically, cities verged on collapse during mass health crisis such as the plague, and more recently the coronavirus pandemic, which emptied the cities and left only the poor and disadvantaged behind. Factors such as terrorism, recessions and financial crisis, resource depletion, unemployment, famine, and disease instil fear in populations which limit their resilience to external factors such as climate change. Fear can also be used to attempt to prevent evolutionary resilience as fossil fuel companies and purists have attempted to do to prevent the transition to a low emission future which has undermined the development of their cities and made them less resilient to future conditions (Newman et al., 2017). "Cities of fear make decisions based on short-term, even panicked, responses, while cities of hope plan for the long term, with each decision building toward that vision in hope that some of the steps will be tipping points that lead to fundamental change" (Newman et al., 2017). This is apparent in cities which has proactively responded to climate change such as Copenhagen which has incorporated *compact city*, *ubiquitous eco-city*, and the *zero-carbon city* principles to adapt the urban environment and inspire collective action in its population (Freethink, 2019).

The current trends of urbanisation and regeneration of dilapidated parts of cities creates an opportunity for cities to begin implementing climate resilient development. Integrated and inclusive urban planning practices guided by sustainability principles can significantly improve the adaptive capacity and resilience of cities (IPCC, 2022). Climate resilient cities will also support adaptive resilience in suburbs and rural areas by maintaining supply chains and economic stability (IPCC, 2022). Newman et al. explains that resilience can be strengthened through adequate measures taken in the strategic planning stages which are: preparedness, response, recovery, and mitigation. Preparedness refers to the activities that can be undertaken prior to a disaster occurring which aim to minimize destruction and death such as evacuation of people from low lying areas during a flood or cyclone. Response refers to the level of capacity and the speed to which actions can be taken to address the disaster. Recovery is a key factor in whether cities improve their resilience by enhancing their long-term sustainability. This can be achieved through improving construction standards, relocation of vulnerable groups, or changing strategic development plans to address similar events in the future. Effective recovery practices can minimize the magnitude of future damage but also facilitates additional co-benefits (Newman et al., 2017) which can improve equality and social justice by providing better outcomes for the health and wellbeing of ecosystems and vulnerable groups (IPCC, 2022).

The final stage in strategic planning is arguably the most important and where Perth's largest gaps are. Mitigation is the core driver in making cities more resilient, particularly to climate change and its associated impacts, as it allows cities to be proactive in reducing their long-term exposure and vulnerability (Newman et al., 2017). Mitigation can be achieved through urban planning by identifying

hotspots which are vulnerable to climate-related events and long-term changes and implementing changes to spatial planning strategies (decreasing density and growth in certain areas), strengthening design guidelines and construction requirements, retreating urbanization from areas subject to sea level rise, and preserving or enhancing ecological areas to act as buffers or natural infiltration sumps. The implementation of these stages of strategic planning should be considered as a feedback loop which contributes to the city's evolutionary resilience over the long-term (Newman et al., 2017).

GOVERNANCE

The circumstances in which majority of the human population live is dictated by urban planning systems which are dictated at a local and regional level. This requires governments to give license to urban planners to make changes to urban planning policy design and practices, and to take responsibility for land that has become vulnerable as a result of climate-related impacts (Grace, 2022). Local and regional governments will bear the brunt of costs associated with rebuilding post-disaster or retreating from areas vulnerable to climate-related impacts. Either way, governments will need to amend their spatial planning and policy design processes to support continuous improvement in engineered and evolutionary resilience of urban areas. Governments should also consider adaptation and mitigation efforts in parallel as they are interrelated and can support improved outcomes through the alignment of policy and implementation (Hurlimann, Moosavi and Browne, 2021). Urban planning has a significant role to play in facilitating the policy and systems required to achieve adaptation and mitigation in response to climate change.

Most historical adaptation policy has focused on specific spatial planning initiatives rather than policy design itself. There are gaps in the literature regarding the combinations of spatial planning practices and policy interventions that can be used to address the barriers to adaptation (Macintosh, Foerster and McDonald, 2015). This is particularly concerning for adaptation requirements, such as natural disasters, which happen rapidly and rely on the 'layering' of disaster and hazard management processes over the pre-existing spatial planning systems to cope with hazards (Macintosh, Foerster and McDonald, 2015). This process of layering is particularly common in Australia where disasters such as bushfires have been managed in this manner, however the increasing magnitude and severity of climate-related events could result in the diminished effectiveness of this approach. Understanding the role of spatial adaptation planning and how it has been framed in policy design is instrumental to overcoming the barriers to progressive adaptation (Macintosh, Foerster and McDonald, 2015). Without a comprehensive understanding of policy design that supports adaptation, decision-makers and planners are unable to implement and maintain systemic change. Policy design refers to the ideal combinations of policies which are developed or refined to produce a desired outcome (Macintosh, Foerster and McDonald, 2015). Macintosh et al. promote the contemporary normative school

approach to policy design which follows a systemic and rational process for assessing the effectiveness and validity of options during the development and review of policies. This approach becomes vital during the integration phase of adaptation to prevent counter-productive policy design and maximise the efficiency of the adaptation efforts (Hurlimann, Moosavi and Browne, 2021). Successful policy reform can be undertaken using the following strategies: strong leadership; unanimous support for the core objectives; participatory planning and community engagement; conflict resolution and/or compensation for opposing stakeholders; providing incentives and adequate information to promote reforms; and ensuring decision-making dynamics do not favour opposing ideologies (Macintosh, Foerster and McDonald, 2015). Barriers for policy reform can occur with the absence of any one of these strategies or the presence of the following: miscommunication or misalignment of values regarding the issue or solution; collaboration between government departments; and limited capacity and power for local governments to implement change (Macintosh, Foerster and McDonald, 2015).

Once policy strategies are implemented it is essential that they are monitored and evaluated for their effectiveness to ensure that they are meeting the desired objectives. In Australia, there seems to be a gap in the understanding of which adaptation efforts are effective due to the lack of disclosure from local governments about their monitoring and evaluation process and the results against performance indicators (Scott and Moloney, 2022). Disclosure on these metrics is rare for Australian local governments which is likely to have contributed to this gap in understanding. Monitoring and evaluation of adaptation projects helps to develop a knowledge base which supports the identification of opportunities, design of implementation strategies, a framework for measuring “success”, and creates accountability to justify why the initiative has merit (Scott and Moloney, 2022). Scott and Moloney argue that the evaluation of effective urban planning remains underutilised in Australia and even more so for climate change adaptation in urban planning (2022). This is concerning as evaluation and monitoring are essential for understanding whether adaptation strategies for climate change are increasing the urban area’s adaptive capacity and reducing vulnerability. Embedding processes to evaluate the effectiveness of localised climate change interventions is just as important as the intervention itself. Due to the ongoing circumstantial changes as a result of climate change, unforeseen impacts may not be seen for years or even decades after an initiative has been implemented (Serrao-Neumann et al., 2014). Evaluating and refining adaptation policies and practices over long timeframes is essential for identifying these unforeseen impacts and modifying adaptation interventions to meet the new contexts (Serrao-Neumann et al., 2014). Therefore, climate change adaptation initiatives should follow project management principles which require them to have clear measurable objectives and performance indicators. This is often difficult to achieve at a spatial planning level as most climate change adaptation initiatives are implemented on macro localised

scales. Responding to these gaps requires improved interagency communication, and local government and cross-sectoral collaboration.

The successful implementation of adaptation strategies requires involvement from a wide variety of stakeholders across sectors. This helps to balance trade-offs and reduce policy conflicts which aid in delivering effective adaptation initiatives (Serrao-Neumann et al., 2014).

Historically, Australian government agencies and departments have acted in silos due to the traditional structure of the governance framework. Each department and local government acts with their own rulebooks to meet the specific interests of their function. Over time a culture of distrust has developed between agencies, over issues such as cost shifting or responsibility allocations, which has created a barrier for shared vision and collaboration (Howes et al., 2015). Additional barriers are created through changes to State and Federal leading parties who enact or threaten policy reversals as it creates uncertainty and undermines public confidence – two factors which have significantly reduced the effectiveness of climate change action in Australia (Howes et al., 2015). The lack of shared vision and consistency in policy has resulted in limited integrated management approaches and adaptation planning at a local level (Howes et al., 2015). However, it is possible for these barriers to be addressed by improving interagency communication and collaboration through the use of: shared policy vision; regional spatial and land-use planning; integrating legislation and policy design; and creating a cooperative fund (Howes et al., 2015). This framework has been utilised in Western Australia as part of the Regional Climate Alliance which was established in 2021. The Regional Climate Alliance is the creation of two partnerships between thirteen local governments with the intention of collaborating to address climate change and reduce greenhouse gas emissions (Government of Western Australia, 2021). The Alliance has been granted a cooperative fund of $500,000 to assist with the implementation of adaptation initiatives. It is yet to be determined how this will translate into adaptation outcomes which reflects the outstanding need for performance indicators and a monitoring and evaluation framework. Whilst this is a step forward for climate change adaptation, the literature suggests that “the success or failure of [these reforms] will come down to an effective community engagement strategy, the political will to act and the ability to create an enduring bipartisan consensus over time" (Howes et al., 2015).

SOCIAL JUSTICE

Global morale is low due to a combination of the coronavirus pandemic, economic recession and global debt, and the increasing prevalence of climate change impacts, all of which have exacerbated social injustices and inequality. Despite this, the world has been aligned in their values to act on behalf of the common good and respond to global challenges which has energized a reevaluation of

sustainability and is driving discussions on resilience (O'Roirdan et al., 2020). This reevaluation of what it means to be a sustainable society has exposed various governance practices that have systemically embedded injustice and discrimination through a lack of ethics and ambition (O'Roirdan et al., 2020). Without the guidance of adequate moral compasses, governance practices have allowed themselves to become systemically, ethically, and politicly unprepared to respond to global challenges (O'Roirdan et al., 2020). There is a resounding disappointment in global administrations who continue to act with disregard for sustainability. These attitudes reveal a deep degradation of the intention and spirit of democracy which can only function effectively when people are empowered and engaged (Ayers, 2011). Egalitarians who continue to advocate for democracy and the establishment of robust public services are labelled radicals by neoliberalists and elite classes who rely on maintaining the ideology that fulfillment is found in wealth and status (Ayers, 2011). However, achieving global sustainability is rooted in the ideology that all people have immense value and can provide input into to a self-governing society which takes responsibility for its actions. "The extraordinary ordinary people are those who are capable of fundamentally changing the world" (Ayers, 2011). The era of climate change activism is in full swing with everyday people, particularly young people, standing up to corporations and governments and demanding action on climate change. Public figures, such as Greta Thunberg, have sparked activism of individuals and communities who are lobbying for climate action through strikes and demonstrations across the world. Activism and protests are a platform for democratic discussions which test alternative social arrangements and ethical viewpoints (Ternes, Ordner and Cooper, 2020). Unfortunately, neoliberalism has also driven the militarization of police forces and criminalization of protest movements which makes these democratic discussions a risky pursuit.

Despite the blockades of neoliberalism, grassroots community activism continues to demonstrate not just willpower and capacity to mobilize democratic debate for the greater good, but also the ability to win the argument (Ternes, Ordner and Cooper, 2020). In the case of the Keystone XL Pipeline in Nebraska, individual property owners were unified by their values to protect their private property rights which sparked mass community opposition to the development of the pipeline. Cultural engagement and education techniques were used to mobilize the local community to fight back against the project by harnessing collective civil and legal action which led to the demise of the pipeline project. Unfortunately, not all communities can be unified and mobilized, and advocating for climate change adaptation is more complex than a single project. The issue with climate change is that it is a 'wicked problem' that permeates every aspect of economics, society and the environment making it much more complicated to unify values, mobilize communities, and successfully undertake collective action which results in the change of policy and development practices. This can be seen in attempts to drive coastal adaptation to climate change through collective action – a problem that is

significant for Perth in particular. Coastal adaptation practices would benefit a large portion of coastal communities, however individuals do not believe that there is enough incentive for them to act alone (Griggs and Reguero, 2021). Social barriers tend to arise when individuals hold conflicting interests and values. Whilst governance practices may help to overcome these barriers, the most effective methods stem from informal community engagement and involvement (Griggs and Reguero, 2021) as seen in the instance of the Keystone XL Pipeline project. That's not to say that governance practices, including spatial planning, can't be effective for empowering groups, supporting social justice and responding to the most extreme impacts of climate change.

Cities have always faced natural disasters whether that be the Hurricane Katrina which devastated the United States or more recently the floods that have devastated the eastern states of Australia. Not only is the increasing severity and frequency of climate-related natural disasters driven by human impacts, but poor spatial planning and environmental management are compounding these impacts (Barbosa and Pradilla, 2021). In addition, the socio-spatial makeup of the urban area can lead to hotspots which are most at likely to become vulnerable to climate-related impacts. There are emerging critiques of managerial and technocratic interventions that aim to mitigate and manage climate change impacts. Academia has begun to highlight the overemphasis on regulatory, economic, and engineering/systemic interventions which tend to marginalize socioeconomic and cultural deficiencies that reinforce limitations in adaptive capacity (Chu and Cannon, 2021). Urban planning has played a limited role in advocating for social justice despite the clear connection that planning is critical for delivering climate change adaptation projects (Chu and Cannon, 2021). Urban planning must recognize that strategic development has the ability hinder or empower minority and disadvantaged groups' ability to address their structural vulnerability to climate change due to their inherited socioeconomic and cultural standpoint. To improve social justice in cities, planners must incorporate equity and inclusion principles into distribution of opportunities and resources, and facilitate participatory planning practices during design, decision-making, and implementation processes. Success of urban climate change adaptation strategies will be determined by their ability to address existing inequalities in socioeconomic structures and how the inequalities contribute to inherent drivers of vulnerability to climate change (Chu and Cannon, 2021).

PERTH'S CONTEXT

In order to answer the first research *question "where are people and ecosystems most likely to be threatened by the climate impacts of heavy rainfall and flooding events or progressive sea level rise?",* an examination was conducted to understand Perth's climactic conditions and urban planning context.

This examination intends to highlight the locations which are subject to the greatest risk of heavy rainfall, floodings events, and progressive sea level rise.

OVERVIEW

Prior to the settlement of British colonies along the Swan River, the indigenous Noongar people inhabited the southwest region of Western Australia. The location in which the city of Perth currently exists was known as Boorloo which was abundant in natural resources and provided significant spiritual sustenance for the Noongar people. Perth is situated within two Aboriginal Native Title Settlements – Whadjuk which encompasses the Central Business District and norther areas, and Gnaala Karla Booja which connects to the southern areas (South West Aboriginal Land and Sea Council, 2021). The current Perth Metropolitan Region covers 6,422 square kilometers of landmass in the west of Western Australia which borders the Indian Ocean. Perth's predominant land uses are residential and rural residential, with a minor amount of commercial, industrial, and maritime functions (City of Perth, 2021). The land is predominantly flat (ranging between 5 – 80 meters above sea level) until it meets the Darling Scarp (or Darling Range) in the east (ranging between 100 – 550 meters above sea level). The urban area of Perth contains more than 800,000 dwellings of which the majority are located along the coastline and adjacent to the Swan and Canning Rivers (ABS, 2021). Majority of the rural land is located along the Darling Scarp which is a minor escarpment that runs parallel to the coastline. These areas are utilized for agriculture and viticulture, quarrying and forestry. Perth's population density is expected to continue rising which increases the risk associated with climate change as those living in larger cities are considered more susceptible to climate-related impacts (DWER, 2021).

Perth's has a Mediterranean climate meaning that it is subject to hot, dry summers and cool, wet winters. Perth's weather is impacted by the shifting anticyclone wind system which creates east-west winds across Western Australia. This system moves north in the winter which brings cold fronts which result in cold, wet weather and westerly gales along the south coast (Britannica, 2019). The occurrence of tropical weather, including tropical cyclones, in the north of Western Australia have occasionally travelled south as far as Perth. Perth's inland areas often experience frost during July and August which are the coldest months of the year. Perth also experiences winter thunderstorms, and some summer thunderstorms, which have been known to cause flash flooding, hail, and extreme winds which have historically damaged infrastructure and homes, cut of electricity connections, and caused the closure of schools and businesses.

CLIMATE CHANGE PROJECTIONS AND EXTREME WEATHER EVENTS

In 2021, the West Australian Government commissioned the Climate Projects Report by the Department of Water and Environmental Regulation (DWER) which outlined the climate change projections for Western Australia under the Representative Concentration Pathways (RCPs)

developed by the IPCC. The RCPs are greenhouse gas concentration pathways which represent different future global warming scenarios. The scenarios range between ambitious global action to keep global warming below 2°C (RCP 2.6) and business as usual resulting in emissions continuing to rise moving towards warming of 4°C (RCP 8.5). The Report utilizes RCP 2.6, RCP 4.5, and RCP 8.5 which outlines the scenario of global emissions reduce emissions towards the end of the century. The Report highlights that Western Australia temperatures have already warmed by approximately 1.3°C since 1910 and total annual rainfall has increased over most of the State, except for in the far west and south-west which has experienced more rainfall decline than anywhere else in Australia. Perth's climate will become harsher regardless of which emissions scenario is undertaken (DWER, 2021). The expected impacts of climate change on Perth include:

- Increasing average temperatures in all seasons (very high confidence),
- Increased number of hot days and heatwaves (very high confidence),
- Less likely presence of frost (high confidence),
- Ongoing decrease in the amount of winter and spring rainfall (high confidence),
- Extended periods of drought (high confidence), and
- Mean sea levels will continue rising both in gradual change and during extreme events (very high confidence).

For the purpose of this research the factors discussed will be limited to those pertaining to precipitation and water-related changes including rainfall and sea level rise resulting in flooding events.

RAINFALL

Perth has experienced an exponentially dryer climate since the 1970s particularly in autumn and early winter. Today, Perth's winter and spring storm systems are shifting southward which is expected to continue decreasing the amount of rainfall in these seasons (CSIRO, 2022). By 2030, under all emission pathways, rainfall in the winter period is expected to decrease by 15 per cent which could increase to 25 per cent under RCP 4.5 or 45 per cent under RCP 8.5 (CSIRO, 2022). Despite annual rainfall decreasing over time, the projections indicate with high confidence that rainfall events will be more intense and extreme (CSIRO, 2022). The magnitude of these weather events cannot be confidently modelled at this point.

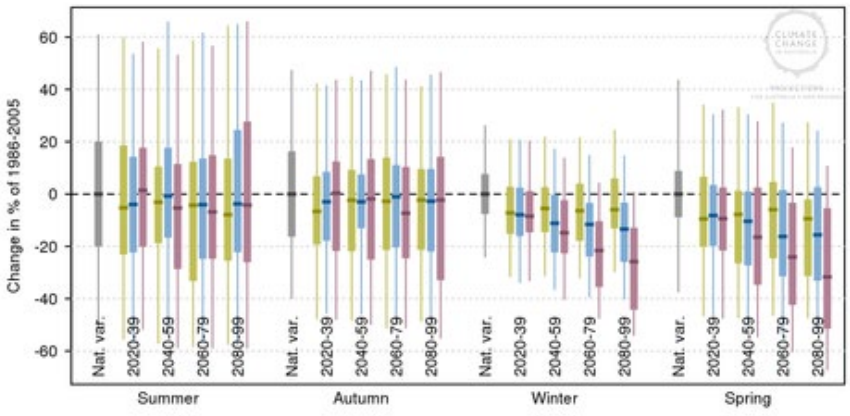

FIGURE 3: PROJECTED CHANGE IN SEASONAL PRECIPITATION FOR 2090 (2080-99). GRAPHS SHOW CHANGE IN (FROM LEFT) SUMMER, AUTUMN, WINTER AND SPRING. ANOMALIES ARE GIVEN IN % RELATIVE TO 1995(1986-2005) UNDER RCP2.6 (GREEN), RCP4.5 (BLUE) AND RCP8.5 (PURPLE). NATURAL CLIMATE VARIABILITY IS REPRESENTED BY THE GREY BAR (CSIRO, 2022).

SEA LEVEL RISE

Between 1986 – 2005, the average rate of sea level rise observed across Australia equated to 1.4 millimeters per annum. Perth's coastline is expected to rise by 0.07 to 0.18 meters above this benchmark by 2030 regardless of the emissions pathway (CSIRO, 2022). The impacts are projected to become exacerbated towards the end of the century with sea level rise expected to reach 0.28 to 0.65 meters under RPC 4.5 and 0.39 to 0.85 meters under RCP 8.5 (CSIRO, 2022). Under exceptional circumstances it is possible that the sea level may rise higher than projected under RCP 8.5 (CSIRO, 2022). The Coastal Risk Australia 2100 map identifies the areas of Perth which are likely to flood due to sea level rise. Appendix 1: lists the areas which are likely to flood under RCP 4.5 and RCP 8.5.

In addition to sea level rise, it is projected that the ocean temperature is projected to increase between 1.5 °C and 3.9°C by the end of the century (CSIRO, 2022). The ocean's acidity will parallel the amount of greenhouse gas emissions in the atmosphere (CSIRO, 2022). This will heavily impact the marine ecology which is likely to result in changes to quantity of organisms, ecosystem diversity, and increased coral bleaching (CSIRO, 2022).

FLOODS

Flood predictions in Australia utilize the Australian Rainfall and Runoff (ARR) national guideline which determines the core terminology for flood prediction. The ARR guideline meets the requirements outlined by Engineers Australia's National Committee on Water Engineering which ensures consistency in definitions, technical accuracy, and practicality (Ball, 2019). The ARR guideline utilizes the Annual Exceedance Probability (AEP) methodology for identifying the "probability that a given rainfall total accumulated over a given duration will be exceeded in any one year" (Bureau of Meteorology, 2022). AEPs are expressed as probability percentage for events (rain and floods) which

are considered less frequent than a 10 per cent AEP (Ball, 2019). Plainly, it is the chance that a flood of a determined magnitude or larger will occur in any year (see Table 1). The extent of the hydraulic hazard can be determined by the magnitude of the flood depth and velocity, and the extent of negative impacts to people, infrastructure, and vehicles (see Table 2).

Likelihood	
5% AEP	Relatively frequent flood event
1% AEP	Standard design flood event for urban planning purposes
0.05% AEP	Extreme flood event
Probable Maximum Flood (PMF)	Maximum extent of the floodplain with a very rare occurrence

TABLE 1: ANNUAL EXCEEDANCE PROBABILITY (AEP) DEFINITIONS (EMRC, 2018)

Hazard Category	
H1	Generally safe for vehicles, people and infrastructure
H2	Unsafe for small vehicles
H3	Unsafe for vehicles and vulnerable people (children, elderly and disabled)
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people, and all building types are vulnerable to structural damage
H6	Unsafe for vehicles and people, and all building types are considered vulnerable to failure

TABLE 2: HYDRAULIC HAZARD CATEGORY DEFINITIONS (EMRC, 2018)

		Hazard Category					
		H1	**H2**	**H3**	**H4**	**H5**	**H6**
Likelihood	**PMF**						
	0.05% AEP						
	1% AEP						
	5% AEP						

TABLE 3: AEP AND HYDRAULIC HAZARD RISK MATRIX (EMRC, 2018)

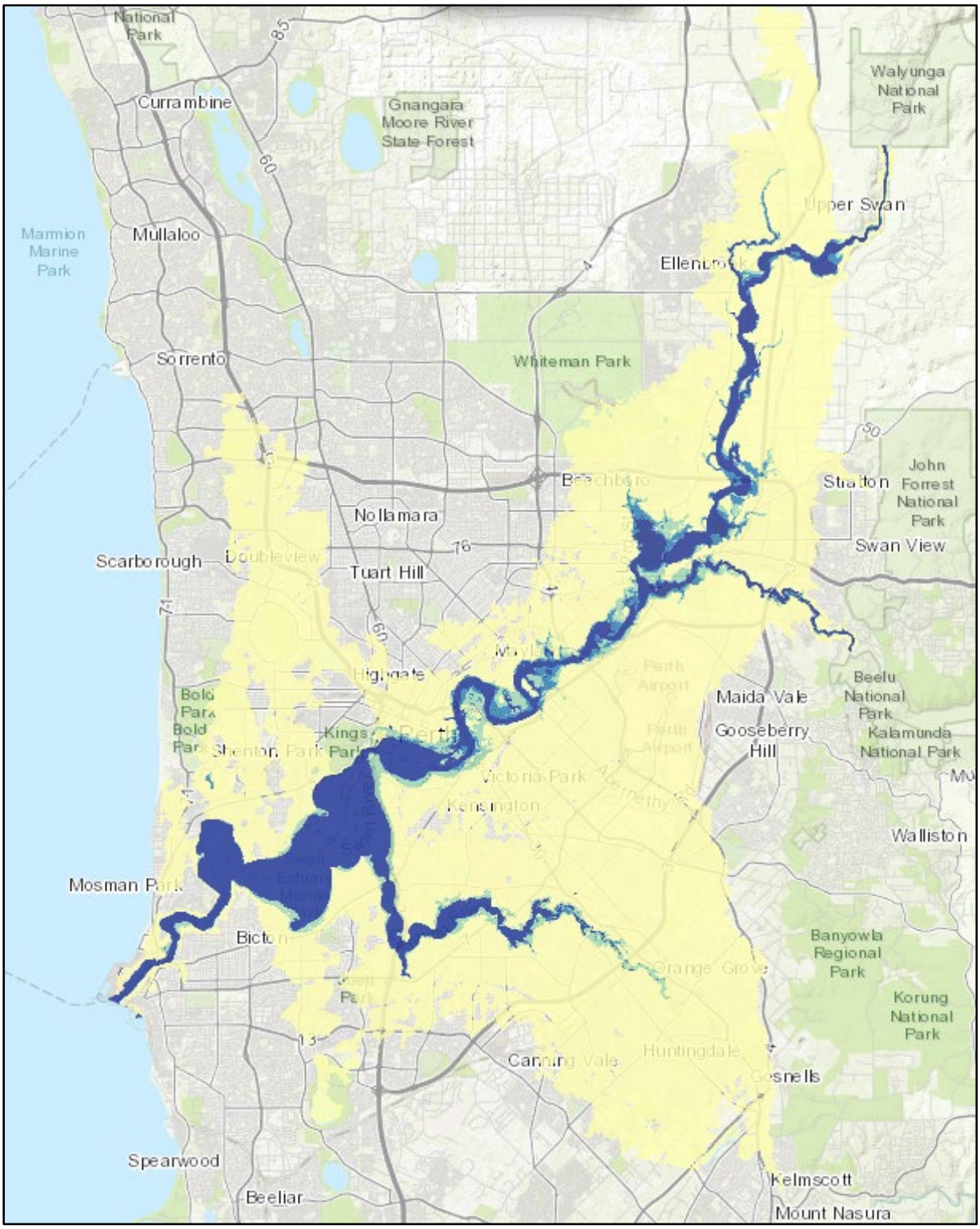

FIGURE 4: AEP AND HYDRAULIC HAZARD RISK MAP (EMRC, 2018)

CLIMATE RISK MAP OF AUSTRALIA

During the development of this research, the Climate Council of Australia released the *Climate Risk Map of Australia* (2022). The map utilizes the three emissions scenarios based on the RCPs developed by the IPCC to explore the impacts of extreme weather events on properties. The map models the percentage of properties that are likely to be at high risk and medium risk of annual damage costs from climate change and extreme weather (Climate Council, 2022). The mapping program and the associated research produced by the Climate Council intends to articulate which electorates and suburbs are likely to be deemed uninhabitable and uninsurable due to the extreme weather. The research deemed that one in 25 homes across Australia are classified as 'high risk' of being exposed to annual damages from extreme weather and climate change impacts resulting in approximately 521,000 properties becoming uninsurable by 2030 (Climate Council, 2022). Over 35,000 of the homes that will be deemed uninsurable are in Western Australia. Figure 5, 6 and 7 show the extent of the risk of riverine flooding, surface water flooding, and coastal inundation to properties in the Perth Metropolitan Region.

As seen in Figure 5, 6, and 7, riverine flooding poses the most significant threat to properties in the Perth Metropolitan Region. This is consistent with the findings in the *Uninsurable Nation Report* which emphasizes that riverine floods pose the largest risks to properties and contributes to 80% of properties being classified as 'high risk' nationally (Climate Council, 2022). The report states that there is "an urgent need to upscale investment in national adaptation and disaster risk reduction to help Australians better prepare for worsening extreme weather events" (Climate Council, 2022). The research recommends that in addition to reducing national emissions, Australia must prioritise the following:

- Invest in risk reduction and resilience,
- Incorporate considerations for climate risks in land use planning,
- Elevate construction standards and compliance, and
- Deliver 'build back better' programs for impacted communities.

The findings of the Climate Council's research have been included to reinforce the urgency and legitimacy of the analysis and recommendations presented this research project.

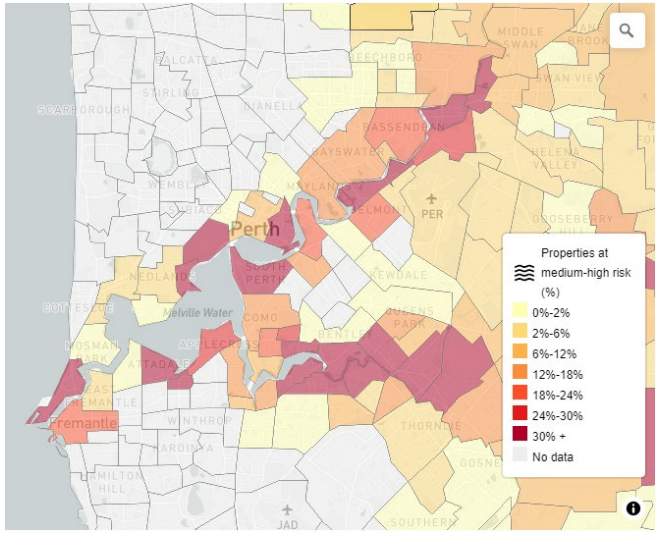

FIGURE 5: RIVERINE FLOODING MAP FOR EMISSION SCENARIO 'HIGH' FOR THE YEAR 2100 (CLIMATE COUNCIL, 2022).

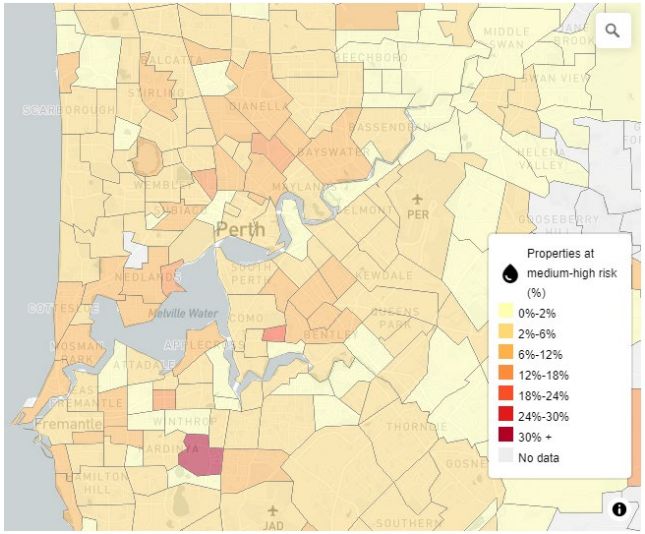

FIGURE 6: SURFACE WATER FLOODING MAP FOR EMISSION SCENARIO 'HIGH' FOR THE YEAR 2100 (CLIMATE COUNCIL, 2022).

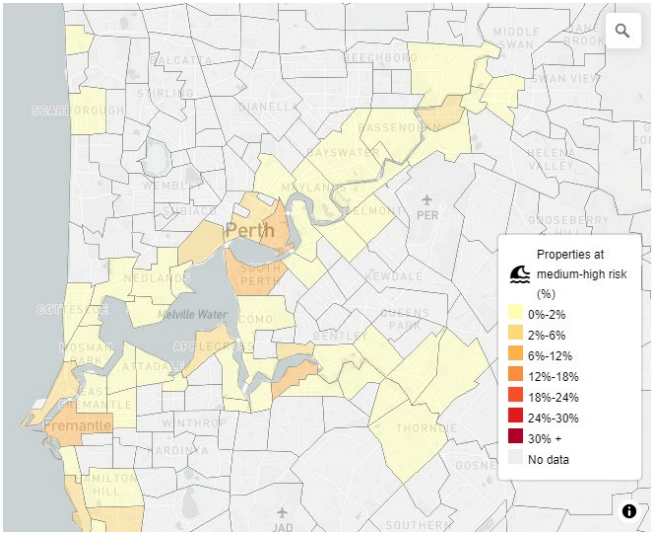

FIGURE 7: COASTAL INUNDATION MAP FOR EMISSION SCENARIO 'HIGH' FOR THE YEAR 2100 (CLIMATE COUNCIL, 2022).

GOVERNANCE FRAMEWORKS

PLANNING POLICIES

The State Planning Policies discussed below outline the current legislative framework that dictates the outcomes for climate change adaptation, flooding, and sea level rise in the Perth Metropolitan Region. A summary is provided in Table 4.

SPP 2.9 PLANNING FOR WATER 2021 (DRAFT)

State Planning Policy 2.9 *Planning for Water 2021 (Draft)* outlines basic considerations which are to be made for urban development in Perth's floodplains. The policy requires development proposals within Perth's floodplains to meet criteria which limit densification and rezoning and must meet a minimum habitable floor level of 0.5 metres above the 1 per cent AEP (see Table 1) equating to approximately 1.5 metres above mean sea level. Whilst this requirement is within the parameters of RCP 8.5 for sea level rise, a flood event of more than 1.5 metres is possible in extreme weather events or with compounding factors. This requirement only applies to new infrastructure and does not address existing infrastructure within the floodplain.

SPP 3.4 NATURAL HAZARDS AND DISASTERS 2006

State Planning Policy 3.4 *Natural Hazards and Disasters 2006* provides a guide for the Western Australian Planning Commission (WAPC) to coordinate the State government agencies approach to land use and development in areas likely to be impacted by natural hazards. Responsibility is placed on the Department of Water and Environmental Regulation to lead floodplain mapping and flood management strategies. The policy also outlines the process for natural hazard mitigation including flooding, inundation from storm surges, and coastal inundation considerations in decision making processes. Development is not prevented in areas that are at risk of natural hazards if proposals can demonstrate that they will not produce adverse impacts on surrounding development and the proposed design has adequate flood or inundation protections. New developments are recommended to undertake studies against the AEP and storm inundation markers to demonstrate that the property won't be inundated. Coastal hazard risk management is more descriptive in its requirements. The minimum requirements for development in at-risk coastal areas are a vulnerability assessment, risk identification and analysis, adaptation, and monitoring program. The monitoring program should consider new information about the likelihood of risks which would trigger a review of the mitigation and management approaches. At-risk coastal areas are also required to be disclosed on the certificate of title to ensure owners are aware of the likelihood of inundation and erosion.

SPP 2.6 STATE COASTAL PLANNING POLICY 2006

State Planning Policy 2.*6 Coastal Planning Policy 2006* requires coastal development to consider the environmental variables caused by climate change including sea level rise and rainfall/run-off. The policy reiterates the development requirements outlined in State Planning Policy 3.4 *Natural Hazards and Disasters 2006* and notes that the allowance for sea level rise is 0.9 metres vertically over a 100-year planning timeframe.

SPP 2.10 SWAN-CANNING RIVER SYSTEM 2006

State Planning Policy 2.10 *Swan-Canning River System 2006* states that development should not be permitted in locations that would restrict water flow during flood events and setbacks from the river should be greater than the impacts of a 1 in 100-year flood event. The policy does not take climate change considerations into account.

SPP 3 URBAN GROWTH AND SETTLEMENT 2006

State Planning Policy 3 *Urban Growth and Settlement 2006* does not address the flooding, inundation, or sea level rise implication of climate change.

DCP 1.1 SUBDIVISION OF LAND 2020

Development Control Policy 1.1 *Subdivision of Land 2020* does not address the flooding, inundation, or sea level rise implication of climate change.

DCP 4.2 PLANNING FOR HAZARDS AND SAFETY 1991

Development Control Policy 4.2 *Planning for Hazards and Safety 1991* states that the Department of Water and Environmental Regulation is responsible for defining floodplains near river systems. This land should generally be avoided for residential or commercial development as it may impact the flow of watercourses and flooding. The policy does not address inundation from rainfall, sea level rise, or the impacts of climate change on these hazards.

TABLE 4: MATRIX OF URBAN PLANNING GOVERNANCE DOCUMENTATION THEIR CONSIDERATIONS OF CLIMATE CHANGE ADAPTATION, FLOODING, AND SEA LEVEL RISE.

Mechanism	Considers climate change adaptation?	Considers flooding?	Considers sea level rise?
SPP 2.9 Planning for Water 2021 (Draft)	✓	✓	✓
SPP 3.4 Natural Hazards and Disasters	✗	✓	✗
SPP 2.6 State Coastal Planning Policy	✓	✓	✓
SPP 2.10 Swan Canning River System	✗	✓	✗
SPP Urban Growth and Settlement	✗	✗	✗
DCP 1.1 Subdivision of Land	✗	✗	✗
DCP 4.2 Planning for Hazards and Disasters	✗	✓	✗

PLANNING STRATEGY AND GUIDANCE

The strategy and guidance documentation discussed below outlines the current vision and approach that dictates the outcomes for climate change adaptation, flooding, and sea level rise in the Perth Metropolitan Region. A summary is provided in Table 5.

STATE PLANNING STRATEGY 2050

State Planning Strategy 2050 was released in 2021 which outlines how Western Australia will utilise spatial planning to respond to the opportunities and challenges of the future. The State Planning Strategy 2050 outlines the expected impacts of climate change on the State and identifies that coastal and marine infrastructure are vulnerable to these changes. Before responses can be developed, the Strategy outlines that it must gather trend data to better understand the impacts of climate change on the environment, coastal and floodplain systems, and urban areas. The current approach to address climate change impacts is to invest in education and research that will support the State to respond to climate-related hazard events and trending changes (Government of Western Australia, 2021). The Strategy states that "a key challenge is the environmental management of the Swan Canning River System, based on scientific research and direction as to how best to balance and manage competing land uses within the context of the Swan Coastal Plain" (Government of Western Australia, 2021). By 2050, it is expected that the State will be "responsive and resilient to climate change" through the following initiatives:

- Continued implementation of special controls for vulnerable species and areas impacted by climate change,
- Development of climate change adaptation and mitigation strategies for the State's key assets,
- Ongoing management of vulnerable areas to improve ecosystem resilience, and
- Development and implantation of risk management strategies for natural hazard events and ongoing changes.

(Government of Western Australia, 2021).

These aspirations are echoed by State Planning Policy 2.9 *Planning for Water 2021 (Draft)*.

WA: ADAPTING TO OUR CHANGING CLIMATE (2012)

The *WA: Adapting to our changing climate* report is the core climate change strategy for WA. The report highlights the need to be able to adapt critical infrastructure and services (energy, water, and communications) to the volatile climate conditions of the future. It is known that climate change will pose new risks to infrastructure, connectivity, supply of resources, and public and private assets. The report recommends that these risks are addressed through risk assessments and adaptation planning

for new developments and incorporating climate change considerations into land-use planning, development design and assessments, and ongoing maintenance of assets. The WAPC is tasked with the responsibility of determining how Perth will adapt its infrastructure to reduce its sensitivity to the impacts of climate change. Perth and Peel at 3.5 million report was earmarked to contain the spatial framework and strategic plan for how this transition will occur. The report states that "policy decisions, in particular around adaptation, will need to consider science as well as the risks and impacts of events related to a changing climate and the vulnerability to these impacts" (DEC, 2012). Without a sound understanding of Western Australia's future climate the State cannot implement effective adaption policies. Therefore, the report recommends that the State government identifies climate science research priorities, develops an overarching strategy for research on climate science, and a communication plan for delivering the results to communities, government agencies, and the private sector. In May 2022, the Western Australian Government joined the Australian Capital Territory, South Australia, and New South Wales in a partnership to provide $3.1 million to the Climate Science Initiative from Murdoch University which aims to deliver regional and localised climate modelling and build local climate expertise (Government of Western Australia, 2022). Climate change projections for Perth are expected to be delivered in 2024.

WATERWISE PERTH ACTION PLAN 2019-2021

Whilst the *Waterwise Perth Action Plan 2019-2021* report predominantly considers climate change impacts from a water resource availability point of view, it does touch on how climate change will impact waterwise urban design. The report provides guidance on how to navigate the relevant land-use planning, policies, strategies, and guidance documentation to implement waterwise design which supports climate change adaptation. Some of the recommendations provided regarding flooding and stormwater management include the utilisation of artificial wetlands and natural drainage for runoff and flood management, integrating flood storage areas (such as swales) into urban areas, and increasing permeable spaces through urban biodiversity and vegetated public open spaces.

DIRECTIONS 2031 AND BEYOND

The *Directions 2031 and Beyond* strategy lists 'sustainability' as one of the core themes for Perth's future development. The objective of this theme is to grow Perth within the constraints of the environment to create vibrant and adaptable communities. A key strategy to achieve this is to implement mitigation and adaptation responses to climate change, however there is no further guidance on how this will be achieved.

LIVEABLE NEIGHBOURHOODS (2015)

The *Liveable Neighbourhoods* guidance provides requirements for developments to maintain the pre-development flood heights, flow rates and runoff volumes within a water management strategy. The

strategy must include an analysis of the risks to life and infrastructure and articulate how the development will respond to the AEP. The guidance recommends that the design of the development should consider the volume and speed of water during a flood event. In addition, streetscapes are recommended to be designed to accommodate minor flooding events to the extent that vehicular access is still available without posing a safety risk. *Liveable Neighbourhoods* does not specifically address sea level rise; however it does point to the use of SPP 3.4 Natural Hazards and Disasters for guidance on sea level rise assessment and management.

PERTH AND PEEL @ 3.5 MILLION (2018)

The *Perth and Peel @ 3.5 Million* strategy recognises that climate change will continue to exacerbate sea level rise and coastal erosion, and increase the severity of storm surges which will affect communities, infrastructure, and ecosystems. The objective of the strategy is to support Perth's transition into a resilient city that "will continue to thrive in spite of the impacts of climate change and adapts with measures that offer multiple benefits and create vibrant, liveable and successful communities" (WAPC, 2018). The strategy refers to the *WA: Adapting to our changing climate* report as the basis for the vision and strategic approach to Western Australia's climate change response. The strategy recognises that areas that remain available for development are highly constrained due to the threat of flooding and sea level rise.

> "Future urban development needs to increasingly incorporate water sensitive urban design techniques to manage drainage in constrained environments to avoid flooding problems, increase amenity and liveability and reduce adverse impacts" (WAPC, 2018).

Implementation of water sensitive design is the responsibility of multiple organisations and their collaboration is essential for successful flood and drainage management. The delivery of improved development outcomes via greater alignment of strategic land use and infrastructure plans is being coordinated by the recently formed Infrastructure Coordinating Committee (ICC) administered through the WAPC. The ICC intends to encourage collaboration, align governance frameworks, and deliver economies of scale. The State Government also intends to deliver an improved 20-year infrastructure strategy that will provide a better framework for State government decision-making.

RIVER PROTECTION STRATEGY FOR THE SWAN CANNING RIVERPARK (2012)

Perth's Swan, Canning and Helena Rivers and the adjacent foreshores, parklands, and attractions the city's centerpieces. These areas provide social, cultural, and ecological services to Perth's inhabitants and visitors. The projections for sea level rise under RCP 4.5 and 8.5 and probability of flooding put several areas of social, cultural, and ecological value at risk of inundation by the end of the century. The land which is expected to experience the impacts of climate change is encompassed by the Swan Canning Riverpark and Development Control Area (see Appendix 2). This land is managed by the Department of Parks and Wildlife whose policies recognise that the Swan Canning river system will be

subject to exponential pressures from development activities within the Development Control Area (DCA) which needs to be balanced with social, cultural, and environmental demands. Communities have expressed their desire to protect and improve the rivers' ecosystem services, protect the natural amenities, and improve public open spaces for recreational purposes (DPAW, 2016). To meet these community expectations, the policy intends to address the challenges of urban development on a flood plain which impacts natural surface and groundwater flows and contributes to flooding risks. To date, the response to flood management has consisted in many cases of raising ground levels to protect development, however this elevates the risk of disturbance, contamination, and impacts landscape protection (DPAW, 2016).

The DCA is encompassed by the *Swan Canning River Protection Strategy 2015* which outlines the collaborative management approach of the Swan River Trust, DPAW, and nineteen other government agencies who have statutory responsibility over areas of the Swan Canning Riverpark area. The strategy intends to improve the alignment of policy and collaboration between the agencies to build more robust and efficient management practices and project implementation (DPAW, 2015). The strategy identifies how spatial planning and urban development practices have resulted in substantial changes to the surface and groundwater systems, and the functionality of wetland areas, and the river itself was widened and deepened transforming it from a fresh river system into an estuarine system (DPAW, 2015). The permanent altering of water systems through urban development has resulted in higher volumes of surface water being forced through artificial drainage. The strategy also recognises that the DCA has inadequate setbacks from water bodies because infrastructure has been placed too close to the shoreline which has historically been addressed through engineered river walls (DPAW, 2015). Whilst this intervention offers some protection to the foreshore areas, maintaining and upgrading these river walls require significant financial investment. Despite the issues identified, there is still great demand for further residential and commercial development along the foreshore of Perth's Central Business District and throughout the DCA (DPAW, 2015). The Swan Canning River Strategy does not explore management or adaptation practices to cope with potential flooding events or include any mention of climate change.

TABLE 5: MATRIX OF SUPPORTING GUIDANCE DOCUMENTATION THEIR CONSIDERATIONS OF CLIMATE CHANGE ADAPTATION, FLOODING, AND SEA LEVEL RISE.

Mechanism	Considers climate change adaptation?	Considers flooding?	Considers sea level rise?	Considers current climate projections?
State Planning Strategy 2050	✓	✓	✓	No
WA: Adapting to our changing climate (2012)	✓	✓	✓	No
Waterwise Perth Action Plan 2019-2021	✓	✓	✗	No
Directions 2031 and Beyond	✓	✗	✗	No
Liveable Neighbourhoods (2015)	✗	✓	✓	No
Perth and Peel @ 3.5 Million (2018)	✓	✓	✓	No *Refers to WA: Adapting to our changing climate (2012)*
Swan Canning River Protection Strategy 2015	✗	✗	✗	No

HOTSPOTS

Hotspots are areas which are most vulnerable to the impacts of flood-related events and transitional changes to the sea level. Broadly, Perth's hotspots can be categorized as reserves and parklands, reclaimed land and foreshore areas, beaches and jetties, residential areas below 1.5 meter mean sea level rise, and riverside public services and attractions. Examples of these hotspots are presented below as case studies. The case studies were selected due to the multidimensional nature of their vulnerability, meaning that they have a combination of ecological, social/cultural, or infrastructure vulnerabilities. The case studies also contribute value to Perth's identity or supply a valuable service to Perth's inhabitants and visitors.

Each of these case studies present a different combination of challenges for mitigation and adaptation to climate change impacts. The hotspots outlined below are examples of the human, ecological, and infrastructure assets that are likely to be negatively impacted by flooding, inundation, and sea level rise.

Ecological Reserves and Parklands: Heirisson Island, Perth

Heirisson Island located in the Swan River is likely to be enveloped under both RCP 4.5 and 5 per cent AEP scenarios. Heirisson Island is culturally significant to the Noongar People as it was used as a historical crossing point across the Swan River and houses a statue of Whadjuk Noongar warrior Yagan who displayed significant leadership and resistance to conflict during the settlement of the Swan River Colony (DPAW, 2017). Heirisson Island still acts as a core transport route between the north and south of the river via the Causeway. Lastly, the island has a rich ecology of native flora and fauna, particularly wetland species, which have been rehabilitated by the City of Perth during the implementation of the Heirisson Island Sculpture Park Master Plan (Urbis and City of Perth, 2008).

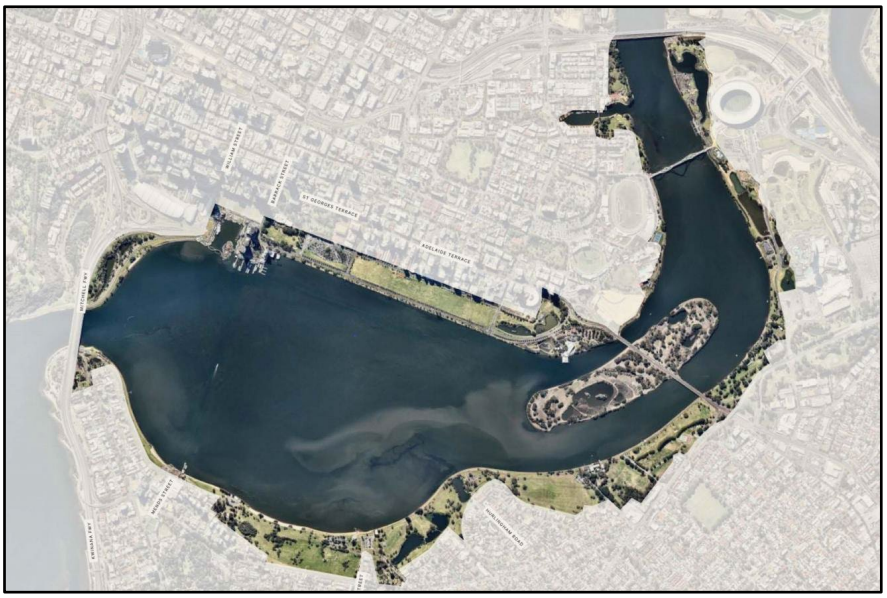

FIGURE 8: PERTH WATER BUNEENBORO LOCALITY PLAN POLICY AREA CONTAINING HEIRISSON ISLAND AND ELIZABETH QUAY (SWAN RIVER TRUST, 2021)

RECLAIMED LAND, FORESHORE AND KEY ATTRACTIONS: ELIZABETH QUAY, PERTH

Elizabeth Quay is one of Perth's most notable attractions and has undergone significant investment and development in recent years. Originally the Esplanade Reserve, Elizabeth Quay has been developed through extensive land reclamation and by dredging mud from the bottom of the Swan River (The Towers Perth, 2019). Design features for Elizabeth Quay were inspired by elements of Noongar culture and art which highlight the significant connection the Whadjuk Noongar people have with the Derbal Yerrigan, also known as the Swan River (The Towers Perth, 2019). Under both RCP 4.5 and 5 per cent AEP scenarios the eastern part of Elizabeth Quay would be inundated. This includes Barrack St Jetty, the Bell Tower and the restaurants and hotels between the Supreme Court Gardens and the river. These features provide significant historical value through linkages with the Swan River Colony and currently act as one of Perth's most significant tourist attractions. In addition to the flood impacts within Elizabeth Quay, access from the east will also be severed as Riverside Drive and Langley Park would flood simultaneously.

RESIDENTIAL AREAS: TOWN OF BASSENDEAN

The Town of Bassendean is home to approximately 45,000 people. The households in the Town of Bassendean have higher rates of disability across all age groups, speak less English, are predominantly low-middle income earners, and have completed less tertiary education than the Greater Perth average (ABS, 2016). These factors elevate the locality's level of vulnerability and reduces its ability to respond and adapt to climate change events and transitional changes. The areas most at risk of flooding under RCP 4.5 and 5 per cent AEP scenarios are generally within a few hundred meters of the Swan River channel. These areas consist of parklands and reserves including Ashfield Flats/Sandy

Beach Reserve and Garvey Park which have ecological significance, and urban areas which are at a high flood risk (EMRC, 2018). The scale of a 0.05 per cent AEP or PMF level flood event would be catastrophic for the southern Bassendean area which would impact approximately half of the suburb. Residents would also be segregated from Bayswater and Guildford due to simultaneous flood impacts which would force evacuees north towards Beechboro.

RESULTS

Primary research was conducted with the intention of answering the second question of this research paper which is "*how can planning practices improve the resilience of vulnerable people and ecosystems by proactively implementation adaptation measures for climate-related changes?*". Six interviews were conducted with professionals with the following credentials from the local governments:

- Director of Planning;
- Senior Statutory and Strategic Planners, and a
- Coastal Management and Planning Engineer.

The information provided by the interviewees was based on their professional insights and opinions on their representative local government and Western Australia's planning system. The results provided are a consolidated summary of the thematic analysis that was conducted from the interview transcripts.

PREPAREDNESS

Of the local governments interviewed, most felt that they had a grasp on the current state of their risk to flooding and sea level rise based on current climactic conditions. Local governments utilise the AEP projection meaning that there is a 1 per cent chance that the flood event could occur on any given year. All the local governments surveyed were updating charts and models to better understand the current state of their local hydrology and coastal circumstances. Many models had not been revised since the last development strategies were created, some of which were developed over a decade ago. However, the motivation of these studies was not necessarily focussed on understanding climate change impacts from an asset risk and vulnerability point of view, but rather an environmental quality and degradation point of view. For example, one local government was undertaking sea level rise studies on their parklands adjacent to the Swan River to determine how to repair the degradation of the ecology. Of those that did have strategies that considered the impacts of climate change, most felt that the articulation of the impacts was not incorporated well with other governance pieces, they were not concise or easy to understand, or the findings were out of date and no longer relevant. There was a unanimous understanding amongst those interviewed that their respective local governments

were as prepared as they could be in the current phase of their implementation of climate change adaptation measures. Whilst some had progressed further with their adaptation and mitigation measures than others, the level of leadership, governance, education, and resources available varied greatly between the local governments interviewed. One interviewee noted that "we are already aware of which areas we're going to lose, and so that's part of what we're planning and engaging with the community on as well to make people aware of what's going to happen in 50 to 100 years' time".

The local governments interviewed agreed that it should be a strategic priority to identify how to ensure that infrastructure, buildings, and people within those buildings reduce their exposure to flooding events and sea level rise. During the exploration of this approach, one interviewee remarked that "if we had that time again would we have wanted people to be building their homes [in flood prone areas] or is it a case of allowing it to occur with certain controls to make it more acceptable because [people] have already purchased the property and have a right to develop". Similar viewpoints were echoed by another interviewee who commented that "responses to adapt to the impacts of climate change [are] almost retrospective". Whilst some responses to flooding and sea level rise may occur retrospectively, the importance of implementing measures proactively was highlighted by all the interviewees. It was understood that implementing adaptive measures may save money in the long run and that actions taken today will inform future strategies that will have to deal with flooding events and sea level rise, their cumulative impacts, and all other associated impacts of climate change. Whilst there was a unanimous consensus that proactive measures are important and necessary to adequately respond to the current and projected impacts of flooding and sea level rise, the interviewees all articulated a plethora of barriers preventing their local government from implementing proactive adaptation measures. These barriers were consistently *leadership, governance, education, resources,* and the *built environment*.

LEADERSHIP

Local governments are looking for strong leadership at both a State and local level to lead the adaptation response to climate change induced flooding and sea level rise. All interviewees articulated that strong and clear leadership trajectories set at a State level for the whole metropolitan region was a key missing component that is required to implement informed and effective local adaptation measures. Some recommendations included:

- Further strategic vision to supplement the objectives outlined in the State Planning Strategy 2050 and the Western Australian Climate Change Policy,
- Amendments to the Metropolitan Region Scheme including zoning changes for vulnerable areas, and

- Amendments to State Planning Policy 7.3 Residential Design Codes to enforce the inclusion of climate adaptive design.

Majority of the interviewees remarked that the lack of strategic vision and governance systems has forced local governments to attempt to fill the gaps and respond to changing local flooding and sea level rise conditions. There were multiple suggestions on how these gaps could be addressed within existing the existing governance frameworks and implemented in a cohesive manner across local governments. One respondent suggested that "there would be value in some sort of climate change advisor function from [the WA Local Government Authority] that would be able to dispense the information to the member Council's as required and then the implementation of plans or frameworks [could be implemented collaboratively by the Council's]". Whilst adaptation to climate change-induced flooding and sea level rise impacts a cross section of government departments, the interviewees suggested that an advisory body should be given responsibility for the overarching leadership vision, strategy, and resource allocation to support local governments to effectively implement local adaptation measures and collaborate with adjoining councils.

At a local government level, all the interviewees emphasized the importance of leadership from council and executives. One local government who's positioning on climate change matters was less progressive explained this positioning was a result of Council's limited prioritization of climate-related interventions. The interviewee from this local government explained that this outcome may be a result of the limited occurrence of climate change-induced flooding and sea level rise in the jurisdiction. They also noted that it would take a "significant event" to occur for the Council to prioritize climate change adaptation over other local development matters. This standpoint of Council impacts urban planner's ability to proactively prepare the built environment and community for such events. One interviewee noted that "there is a lack of courageous leadership in the local government sector which is to a certain extent structurally set up in the planning space [resulting in a] lack of legislative framework to facilitate that courageous leadership". However, in local governments where the Council and executives have elevated the importance of climate change adaptation the gaps in the legislative framework is starting to be addressed with local strategies and interventions for the localized impacts of flooding and sea level rise. One local government attributed the proactive implementation of erosion prevention and sand replenishment interventions to the Council and executive's ability to recognize the increasing severity of climate change impacts on coastal areas and respond with strategies in lieu of strategic or legislative direction from the State government. The consensus from the interviewees was that Council's belief systems about climate change play a role in the prioritization of climate change interventions. This was eloquently summarized by one interviewee who states that "the ideological and philosophical stance on climate change gets driven by each local government based on the will of

its community and Council". The degree to which a Council is aligned in their ideologies and philosophies determines the level of agreement on climate change matters. Therefore, the more aligned council and executives are, the more likely they are to be willing to push the boundaries of what is possible within the current legislative framework and implement progressive responses to climate change.

GOVERNANCE

Some of the most significant findings from the research interviews was the identification of idiosyncrasies, inconsistencies and limitations of Western Australia's urban planning governance and legislative systems. The State government holds majority of the planning powers through its legislative and strategic controls which are exercised under the State Planning Strategy and Policies and facilitated by the Metropolitan Redevelopment Authority, WA Land Authority, and implemented through public agencies such as DevelopmentWA and private development contractors. The developments implemented through this process are high value and intended to be transformative for the state. Some interviewees commented that the implementation of these development projects often means that assets (eg. land, reserves or existing infrastructure) are withdrawn from the local government's responsibilities and their powers to influence the outcomes of the development are muted. This disempowerment of local governments limits their ability to influence outcomes that impact local issues such as the localized impacts of flooding and sea level rise. One interviewee expressed their concern at this manifestation stating that "as years go by and the impact of climate change [becomes clearer] and more acutely felt, people are going to be looking to the State government to say 'how did you allow land to be developed here?'". Other interviewees also raised the question of who would ultimately become liable for assets that have been developed in areas that are vulnerable to flooding and sea level rise – should it be the State government for zoning the areas for development under the Metropolitan Region Scheme or will the burden fall to the local governments who have inherited the schemes and are now responsible for the assets.

Inconsistencies between management approaches of adjacent local governments were also highlighted as a key issue. Due to the absence of a strategy to guide climate change adaptation across the Perth Metropolitan Region, local governments have attempted to implement measures within the boundaries of the current strategy and legislative framework. As a result of this and the interference from other development agencies, there is often a duplication of work between local governments due to the lack of a consolidated strategy for a region and areas are carved up and given to other departments to manage making it difficult for local governments to be empowered and responsible for their own strategic planning. Feedback from the interviewees on this matter included "each local government is doing the same-same but slightly different, which is really confusing for everyone

involved" and "these sorts of things are best dealt with as a higher level with its greater coordination rather than each local government doing its own thing". One interviewee noted that these inconsistencies may be a symptom of WA's local governments not having economies of scale which may have been a result of amalgamations being dismissed in the state.

There were also governance and systematic issues identified within the local governments themselves. The optimum time to consider adaptation responses to climate change in the built environment is during the development of a town planning strategy. The design of a town planning strategy requires consultation across the functions and experts from the local government whose inputs are then collated to generate the strategic development vision and resource allocation. The interviewees from local governments with town planning strategies that considered the impacts of climate change attributed the progressive nature of their strategies to highly collaborative planning and engineering teams, long-term staff retention to drive a consistent vision, and the implementation of localized frameworks and policies that prioritized action on climate change. Local governments who did not have such strategies in place noted the difficulties of attempting to recognize the implications of flooding and sea level at the development approval stage. The difficulties were twofold – by the time a project is ready for development approval it is often too late to adapt the design or request additional adaptation inclusions; and it is impractical to consider climate change impacts on a micro scale as the impacts will affect larger geographies and should be actioned at a macro or regional scale. A consistent recommendation from the interviewees was to amend the Residential Design Codes to include measures for climate responsive design (eg. increased gutter sizes and passive drainage on verges) to help address onsite storm water across jurisdictions. These amendments would give local governments powers to enforce micro level interventions by exercising their statutory approval powers whilst they are in the process of redeveloping their town planning schemes.

EDUCATION AND INFORMATION SHARING

Urban planners are not climate change experts, nor should they be expected to be. However, it will become increasingly important for urban planners to understand how climate change will impact the urban form and be able to identify where the impacts need to be considered within the existing governance frameworks and processes. Local governments are aware that floodplains and coastal areas withing their jurisdiction may be vulnerable to changing climactic conditions. Flood mapping against the AEP projections was undertaken to inform town planning schemes, however some of the interviewees notes that their local government town planning schemes and strategies were due for revision as they were designed up to a decade ago. Where the schemes and strategies are being reviewed, there is an opportunity for climate change considerations, including modelling flooding and sea level rise impacts against the different RCPs, to be better integrated into local government

governance frameworks. However, it was highlighted in the interview process that some of the local governments perceived the current level of climate change impacts to be minimal when considering the remaining life of their current strategies. One interviewee commented that "our current approach seems to be to wait and see… until we get more research there's not much point doing too much at this stage". Other interviewees shared this perception of "waiting for more information" either from a research body, the State governance framework, or by experiencing the physical impacts of inundation, flooding, or sea level rise to understand the extent of their impact. The interviewees predominantly felt that they were not equipped with the frameworks or resources required to make informed decisions about climate change adaptation. This sentiment was seen to be a result of the sporadic approach to climate change adaptation between the State Planning Strategy, State Planning Policies and Development Control Policies. Some of the interviewees felt that there was little support on how to navigate the existing and new State government approach to climate change adaptation and that further guidance was needed to develop a "source of truth" to support implementation at a local government level. Once developed, the interviewees also suggested a range of recommendations for capacity building local government planners and engineers to respond to climate change adaptation requirements including integrated professional development workshops to align planning and engineering approaches and quarterly training programs delivered by the WALGA.

The local community has an important role to play in the integration of adaptation measures into the urban environment. The consensus of the interviewees was that educating the community on climate change adaptation measures for new homes and retrofits could help to reduce the vulnerability of people and homes that are likely to be exposed to inundation, flooding, and sea level rise. Majority of the interviewees felt that they didn't have enough background knowledge about climate change to provide concise and useful information to the community about reducing their vulnerability and exposure to flooding and sea level rise risks. Improving the education of the community would require the development of educational resources, such as maps and graphics, which would support planners to demonstrate potential impacts and articulate the level of risk to the local community. One interviewee explained this in detail stating that:

> "I think if we had better resources, we would be much more persuasive at having those conversations. If we had graphics and mapping, better utensils, to be able to show people and be able to explain it more clearly. At this stage we don't really have anything other than our ability to negotiate with people, we don't have anything to show them what the impact will be".

Difficult conversations about climate change-related topics are seen as being multifaceted. There is a perceived lack of general knowledge about climate change, how it will impact the geographies people

inhabit, and a downplay of the likelihood of exposure to risks caused by climate change induced inundation, flooding, and sea level rise. One interviewee noted that "there's a fair bit of 'it'll never happen' thinking in the community". These perceptions cause difficulty for planners trying to encourage improved climate adaptation measures because individuals must choose to implement the changes at their own free will as there are no requirements under the Residential Design Codes to do so. One interviewee suggested that climate change exposure risk ratings should be assigned to properties within floodplains or close to coastal areas to inform landowners of their potential exposure to these risks and allow them to decide if they are willing to assume the liability of residing on those properties. As the facilitators of these conversations, the interviewees felt that planners would need endorsement and clear evidence from the State government to be able to substantiate their recommendations, particularly in jurisdictions where the impacts of climate change are currently limited.

RESOURCES

There were two key resourcing issues that were raised by the interviewees. The first issue is that local governments are limited to funding from ratepayers and income from community facilities. This means that the wealth of the local government is generally dependent on demographics and number of households within the local government area. These funds are often already allocated to maintaining essential local infrastructure and services, therefore prioritizing funds to new projects to support adaptation to climate change would mean that another service would have to be defunded. One interviewee noted that "local governments don't have sufficient funds to maintain all of their current assets". This means that funding to address local climate change adaptation will need to come from alternative income streams such as State or Federal government grants. Unfortunately, State and Federal government grants are often too specific to allow for general improvements to local government areas to support improvements to their adaptive capacity and resilience to climate change impacts. A contrast can be seen in wealthier local governments with high value assets such as coastal reserves and marinas which produce additional income. These areas have been heavily invested in to improve their resilience to coastal hazards and degradation from erosion and sea level rise. This is because these assets are valued highly by the community and Council. One interviewee from a coastal local government explained that the adaptation measures that were implemented on their coastline had been successful because of the community and Council were willing to prioritise the funds to do an exceptional job at preserving its assets. A stark contrast is seen in the other surveyed local governments where the link between asset preservation and climate change impacts is not high on the community or Council agenda. Some interviewees from these local governments suggested that this outcome was a result of a lack of a "burning platform from council to prioritise

resource allocation to drive policy changes or infrastructure changes at this point when there's so many other pressing needs at this time" and that there is a tradeoff for reallocating public funds towards climate change adaptation. The interviewees felt that "it will take something significant to put [climate change] on everybody's radar" which is likely to be the occurrence of a weather event that causes disruption and damages.

The second issue is dealing with the non-financial resource constraints, assets, and liabilities. From a human resourcing perspective, the local governments that were interviewed did not have staff dedicated to addressing climate change nor were urban planning staff being upskilled to integrate climate change considerations into their disciplines. The interviews highlighted a reliance on engineering disciplines to integrate flooding and sea level rise models into structural solutions. However, whether these models include the implications of long-term climate change is unknown. The interviewees were asked if there was value in having a sole inhouse resource dedicated to climate change management. The responses varied between incorporating the responsibility into existing roles (such as environment and sustainability specialists), utilising consultants when required, and lobbying other agencies (such as WALGA) to provide guidance. Based on this feedback, there is likely to be a place for each solution depending on the circumstances and resource availability of each local government. Similarly, the response to managing assets and liabilities will be driven by the circumstances and priorities of the local government. One of the interviewees noted that their local government was reducing its assets and liabilities to reduce their emissions and therefore its impacts on climate change by reducing their light vehicle fleet sizes and transitioning to electric vehicles. Justification for this type of intervention was that "there is a preference to start with low hanging fruit and then work up to the bigger projects unless there is a significant risk in those bigger projects and there is significant demand for them". Whilst this type of solution does not directly address the adaptive capacity of the urban form to flooding and sea level rise, interventions such as these could provide value by freeing up funds by reducing assets that need maintenance and initiating climate change discussions which could lead to more strategic interventions.

BUILT FORM

The majority of climate change adaptation interventions will require the existing urban form to be retrofitted and altered to meet new climactic conditions. The Perth Metropolitan Region is predominantly established with new developments consisting of infill and subdivision of existing urban areas resulting in increased population density and pressure on infrastructure resources, and reduced permeability of the soil and displacement of natural watercourses. The interviewees all agreed that there is a plethora of issues with adapting the physical urban form resulting in a consensus that the improving adaptive capacity is limited and costly. One interviewee commented that existing

infrastructure is “past the point of no return” and another stated that “we are not well placed to be able to respond and react”. Others discussed how engineering solutions were exceptionally costly and could still fail to respond to the severity of long-term climate impacts. An example was used of the Thames River walls which are unlikely to prevent London from flooding in its current form post 2030 as it was only designed to prevent impacts from a 1 in 100 year flood. Parallels were drawn between the Canning River seawalls and the cost of increasing the height and robustness of the limestone walls which have begun to deteriorate. One of the interviewees commented that the “issues around infrastructure maintenance are only going to get worse”.

Other solutions such as active retreat from the coastline and flood prone areas were also considered costly due to the need to buy properties and relocate residents and businesses. The interviewees were also unclear on who would be responsible for purchasing the properties for an active retreat approach and explained their preference for the State government to provide the funds to do so. Even if the State government was to provide the funds, one interviewee noted that “the cost of acquiring all that land is just completely obscene”. Some of the urban planners who were interviewed offered suggestions of low cost interventions that may help to support the management of excess water in urban areas where the built form was difficult to structurally alter. These suggestions included incorporating water tanks on residential properties and improving passive drainage on verges. These measures could be encouraged by amending local government design guidelines. However, for existing households it was noted by the interviewees that it would be difficult to enforce these changes as they can’t force residents to redevelop. “We have to either convince people that they want to do this to their properties of their own free will, or we have to hope these properties are getting redeveloped and we can pick them up as part of a future planning process”. The other barrier for implementing these requirements is the demographics and wealth of those living in the local government area. One interviewee explained that it would be very difficult for their local government to expect residents to implement improved design measures because their key demographic was first home buyers. “The bulk of our residential development really caters for the first home buyer market, so that actually does influence the nature of our policies… We tend to be more flexible and pro developer”. The result of this stance is that the local government is careful not to raise property prices by implementing measures that would push first home buyers out of the market, and that their ultimate responsibility is to serve local ratepayers. Local governments with wealthier demographics noted that they had begun to implement design requirements that were focussed on reducing household impacts on climate change such as requirements for Green Star Certifications, participating in tree planting programs, and electrifying car fleets and public assets. Whilst these practices don’t

directly address the adaptive capacity of the urban form, these practices may open the door for more proactive and progressive flood and sea level rise adaptation measures.

ANALYSIS

The findings of this research indicate that the Perth Metropolitan Region is subject to a concerning lack of climate change strategy and policy based on current climate projections which exposes people and ecosystems to severe impacts of flooding, inundation, and sea level rise. The research findings echo the IPCC's commentary regarding the limitation of progress towards climate change adaptation in urban environments due to insufficiencies in adaptive capacity which has led to poor performance in planning, implementation, monitoring, and evaluation (IPCC, 2021). The research interviews confirmed the IPCC's theory that these limitations in adaptive capacity are occurring as a result of a lack of vision and consistency in policy design, competing priorities and values, misinformation and propaganda, and limited engagement and resources. The findings also confirmed the hypothesis that the Perth Metropolitan Region's urban form and governance system is grossly underprepared to respond to the impacts of climate change induced flooding, inundation, and sea level rise. The interviews explored many of the justifications for this current predicament, and the strength of alignment of the feedback provided was resounding. It was expected that there would be greater variation in the responses due to the contrasting circumstances of each of the local governments interviewed. The strength of the consensus could be tested further by interviewing a larger sample size, however it is unlikely to add additional weight to this particular research project but may provide value for future research.

The results of this research are a wake-up call for the Western Australian State Government. The State government has neglected its duty of care for Western Australians and has implicated local governments by limiting their ability to adapt urban environments to the impacts of climate change. Under this current regime, the Perth Metropolitan Region is likely to experience the same disastrous consequences of this shortsighted approach as the eastern states of Australia. The findings of this research intends to light a fire of urgency under the State and local governments to work towards reforming Western Australia's approach to climate change adaptation. The recommendations outlined below intend to provide a practical roadmap for addressing the implications of these findings. Regardless of whether the State and local governments adopt this roadmap, it is critical that these agencies respond to this warning and implement a strategy to protect West Australians from the looming threat of flooding, inundation, and sea level rise.

RECOMMENDATIONS

Transitioning the Perth Metropolitan Region into an adaptable and resilient city will require a long-term strategy to improve the maturity of Western Australia's urban planning response to climate change. In order to close the current gaps in the urban planning system and improve adaptive capacity there will need to be a staged response which supports the State and local governments, urban planners, and engineers to effectively respond to the infrastructure challenges of future climate impacts.

A proposal for the approach is outlined in Figure 6 and discussed below.

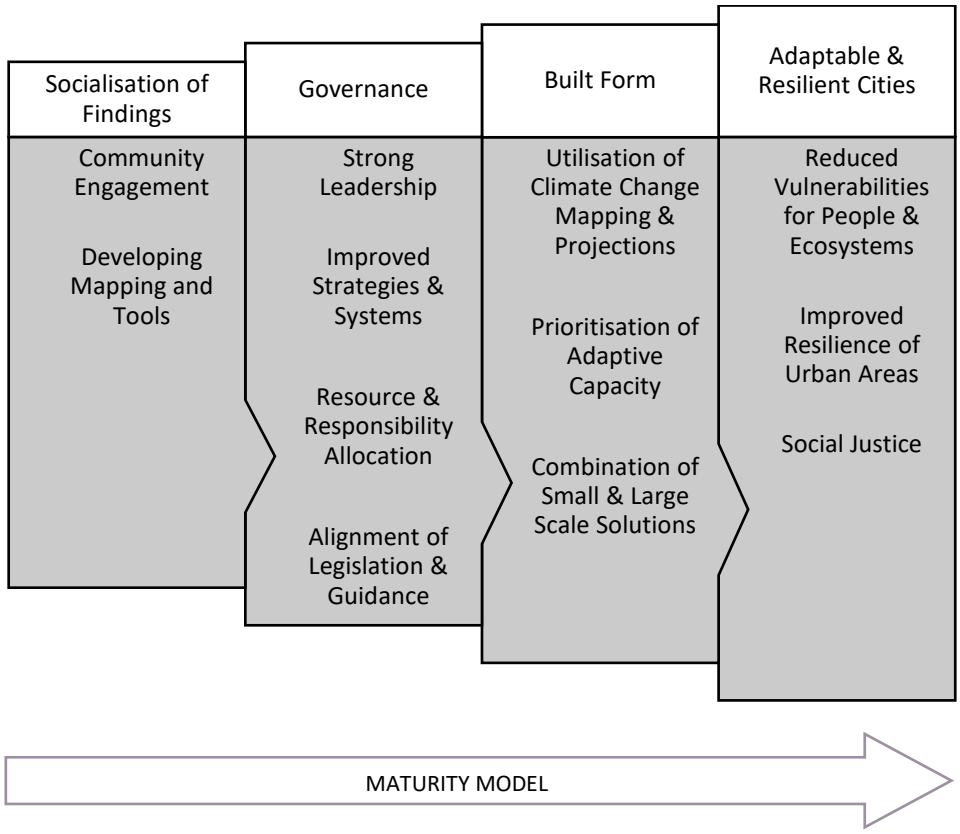

FIGURE 6: MATURITY MODEL FOR IMPROVING THE ADAPTIVE CAPACITY OF PERTH'S URBAN FORM

SOCIALISATION OF FINDINGS

There is not necessarily a lack of education surrounding adaptation to flooding and sea level rise impacts in urban planning – the information and modelling exists in many forms. However, there is a severe lack of socialization of this information and it lacks integration with systemic and legislative urban planning processes. This poses an extraordinary risk of exposure to the impacts of flooding and sea level rise which can and should be addressed in a proactive and urgent manner. To address this, it is recommended that community and government engagement programs are conducted to provide an executive summary of the findings of this research and connect them to existing resources, mapping, and toolkits which will highlight their level of exposure and inform localised adaptation

measures in the short term. Utilising the modelling and risk profiles will help local governments to identify risks where flood or sea level rise planning hasn't been addressed in structure plans or has been misrepresented by out-of-date modelling techniques. This will help identify the most vulnerable people, ecosystems, and infrastructure. It will be important for local governments to coordinate engagement programs with the community to identify which public assets and services hold the most social value to determine which assets are a priority for protecting. This consultation process will also give local governments an opportunity to discuss individual household adaptation measures, and socialise potential changes to local design guidelines or amendments to town planning schemes or policies. That way, those who are currently redeveloping, or are planning to develop in the area have an opportunity to address their exposure to flood or sea level rise risk whilst they are in design phases, reducing future exposure risks. Local governments can also leverage on their existing networks and relationships with residents in high-risk areas to begin strategizing about how to best protect their assets in the short and long-term.

During this engagement period, it is recommended that the local governments and supporting agencies, such as WALGA, lobby the State government to allocate funding and resources to developing improved models that align with the IPCC Sixth Assessment Report projections and utilising the Representative Concentration Pathways (or the latest projections at the time of development). This will supersede the science and principles that are being referred to in the *Western Australia: Adapting to our changing climate (2012)* report which forms the basis of Western Australia's response to climate change. These maps and tools will help to improve the accuracy of flood, rainfall inundation and sea level rise which will inform the long-term strategic interventions including large-scale capital investment and amendments to governance and legislative frameworks. Improvements to mapping will identify high risk areas, high value assets that need protecting, and which people and ecosystems will be most vulnerable within the high risk areas. This will help local governments to prioritise interventions based on risk profile and the value of the assets which will feed into strategic adaptation responses. This will also mean that local governments and agencies can coordinate their responses and operate from one source of truth, which will ultimately align their approaches, and support collaboration with other agencies such as DevelopmentWA, Department of Water, Main Roads, and Department of Environment on a shared vision. This collaboration may also help to identify further gaps in responsibility, resource allocation, and misalignment of policies which will inform amendments to the State Planning Policies, Metropolitan Region Scheme, and local town planning schemes and strategies.

GOVERNANCE

Identifying leaders to champion local climate change adaptation and enhancing overall leadership from a State level will be a crucial factor in implementing proactive responses to climate change induced flooding, inundation and sea level rise. Identifying local champions and leaders can help spread awareness and gain support for action by providing a voice for climate change. Leaders will need to stand up in the local government space to advocate for change at a State level and participate in collaborative forums to drive change. It is evident that the State government cannot deliver the leadership required to effectively drive change whilst reducing the risk of exposure of climate disasters to West Australians. Unfortunately, due to the limitations of resources at a local government level, it may be necessary to leverage off alternative leadership resources by working with community groups, other local governments, WALGA or local members of parliament to develop an advocacy presence. This may also be achieved by creating a permanent agenda item or by creating a position for a climate change representative to ensure it is prioritised during community development decisions.

Governance systems will need refinement to address the gaps and misalignment of policies, strategies, and legislation. Solutions will need to be scalable and flexible to allow for local governments to implement changes that suit their local circumstances. An amendment is required for the State Planning Policies to ensure that all relevant policies incorporate climate change adaptation, flooding, and sea level rise considerations. SPP 2.6 *Planning for Water (Draft)* is an example of how these amendments can be structured to address policy gaps. Navigating the various policy changes will require the development of a new climate change guidance document for urban planning and development across Perth. The guidance will supersede *Western Australia: Adapting to our changing climate report* (2012) and build on the objectives of *Perth and Peel @ 3.5 million*. New guidance should include a consolidated vision, a matrix for decision making and alignment with policy, links to resources and models, and a roadmap for ongoing revision of climate change projections to ensure that decisions are being made based on the most current science. Improved modelling, accurate and current climate change projections, and stronger leadership will support improvements to strategies, policies and legislative frameworks. Flooding and sea level rise projections will need to feature more heavily in strategy and policy to address the exposure risks based on current climate change projections. Governance systems will need to respond to issues where precedents have been set in the eastern states (such as insurance). Policy reform requires an alignment of values and collaboration to support local governments to implement change.

BUILT FORM ADAPTATION

Planning and engineering mechanisms have the capacity to reduce exposure and sensitivity to climate impacts, and improve the threshold of community's adaptive capacity. By increasing the threshold of

adaptive capacity, communities will be able to protect themselves, assist the most vulnerable, and preserve assets and services that are most valuable. There is no one-size-fits-all solution. The State and local governments will need to develop strategic, behavioural, and technical solutions to best cope with local circumstances and regional constraints. There is an opportunity to learn from international examples and incorporate and adapt them where appropriate. Technical studies will need to be undertaken for specific projects to ensure that they can meet structural requirements necessary for urban growth and climate change. There will need to be a combination of small-scale solutions (household) and large or capital-intensive solutions such a redevelopment, infrastructure adaptation (sea walls, drainage expansions) and active retreat.

Many challenges are likely to arise during the implementation phase of built form adaptations. One of the key challenges will be the allocation of responsibility for implementation funding and ongoing maintenance of infrastructure. Funding and non-financial resource constraints, assets, and liabilities will need to be addressed to support local governments to adequately implement adaptive capacity measures. The resounding feedback from the interviewees was that there is no unallocated budget which would allow them to implement structural changes and maintain additional assets. This may take the form of State government grants and pooling of resources across local governments and agencies. Whether this is a State government agency that coordinates all efforts or responsibility for different functions is distributed across State and local governments, and other departments to utilise their specialist functions. The solution to this hurdle is currently unknown and will require further consultation with the State government.

Another key issue is the lag time on the physical implementation of climate change adaptation infrastructure. The nature of Western Australia's bureaucracy is arguably conservative and slow to react meaning that it may be some time before infrastructure can be amended. It is likely that West Australians will begin to feel the impacts of flooding, inundation, and sea level rise before the infrastructure solutions can be implemented. This will reduce their ability to act as proactive and preventative measures, therefore reducing their effectiveness to reduce community and ecosystem risk of exposure to severe climate impacts. It is essential that immediate action is taken to prevent future limitations of the effectiveness of technical and infrastructure solutions.

LIMITATIONS

The intention of this research was to identify where people and ecosystems within the Perth Metropolitan Region are most vulnerable to exposure to climate change induced flooding, inundation, and sea level rise, and explore how urban planning practices can reduce this vulnerability. A review of publicly available modelling and datasets supported the identification of geographic areas which are

most vulnerable to flooding, inundation, and sea level rise. However, the level of analysis conducted did not determine which specific groups of people and ecosystems were most vulnerable. It is recommended that this task be undertaken be local governments who are familiar with the demographics and species, and their spatial distributions, in combination with an assessment of social value of assets and services. This will allow the local governments to determine the populations and assets that are most vulnerable in conjunction with the identification of what the local community values preserving. This will support the local governments to develop an adaptation priority matrix for their local circumstances.

This research focussed solely on the perspectives of local governments. The sample size for this research was limited to a small representative group of local governments due to the time constraints of this research project. Therefore, the feedback provided does not represent the entire Perth Metropolitan Region. The feedback should be interpreted as generalised commentary regarding the experiences of the interviewees within their local government organisation and their professional opinions about the topics raised. There is value in assessing whether other government agencies (such as the Department of Water and Environmental Regulation) have strategies in development that could support local governments to improve their climate change adaptation strategies to reduce their exposure to flooding, inundation, and sea level rise. Whilst public documentation for these agencies was reviewed when preparing this research, there may be projects or strategies which have not yet been disclosed. It would also be useful to identify their perceived level of responsibility for providing resources, guidance, and implementation of adaptation projects in local government jurisdictions. Further consultation and engagement are necessary to navigate the nuances between government agencies and develop a progressive vision to protect Perth's urban form, people, and ecosystems.

CONCLUSION

This research identifies a pathway forward for the State government and local governments to address the shortcomings in the existing urban planning system to positively contribute to the overall adaptive capacity of communities and environments. Addressing these shortcomings and implementing proactive adaptation measures would result in a reduction in their vulnerability to the impacts of extreme rainfall, flooding events, and sea level rise as a result of climate change. The review of State and local planning documentation identified the need for improvements to adaptive capacity, particularly Western Australia's State Planning Strategy 2050 (WAPC, 2021). The review of literature and government documentation articulates that there is minimal consideration of current science-based climate change projections in urban planning strategy, policy, and guidance material. Whilst datasets are currently being developed, it is likely that there will be a lag between the datasets and

models being finalised, integrated into governance frameworks, and adaptations are incorporated into the built form. This would confirm the commentary from the local government interviewees that climate change adaptation measures are likely to be retrospective. It is concerning that communities and ecosystems are at high risk of being exposed to negative impacts of climate change induced flooding, inundation, and sea level rise before solutions can be designed and implemented.

The pathway outlined in the *Recommendations* of this research intends to provide measures that can be taken immediately in lieu of the State government developing datasets and additional guidance to support climate change adaptation. Local governments should continue to advocate for local leadership for climate change adaptation and prepare their communities and governance systems for the release of State sanctioned modelling and datasets. Local governments and communities should also lobby the State government to accelerate the delivery of the climate change modelling and regional mapping to reduce the lag time between the release of the datasets and the time of exposure to climate hazards. There is an opportunity for local governments to strengthen their collaborative relationships and participate in collective action whilst continuing to put pressure on the State government to allocate resources to local adaptation initiatives. Community engagement and business collaboration should be prioritised to prepare homeowners, developers, and businesses for localised climate change impacts and changes to future development requirements. These recommendations hope to inspire accelerated climate action from the Western Australian State Government and all local governments within the Perth Metropolitan Region to protect the region against the severe impacts of flooding, rainfall inundation, and sea level rise. These actions will support Perth's transition towards a more adaptable, resilient, and sustainable city.

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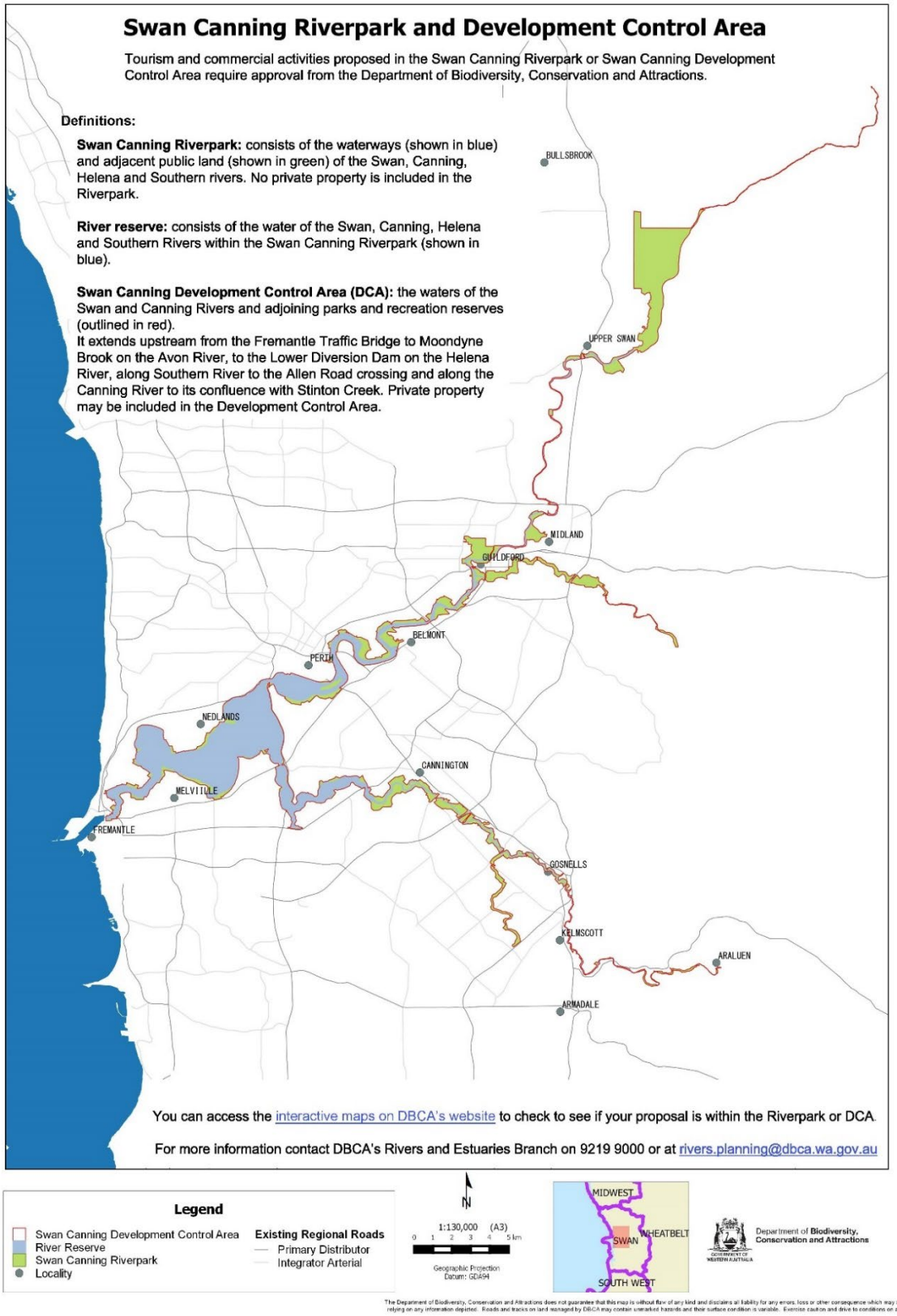
APPENDIX 1: URBAN AREAS PRONE TO FLOODING AS A RESULT OF SEA LEVEL RISE

	RCP 4.5 at 0.6 meter sea level rise	RCP 8.5 at 0.8 meter sea level rise *(in addition to those listed in RCP 4.5)*
Vulnerable Urban Areas and Infrastructure	• Gilbert Reserve, *North Fremantle* • Sardine Jetty, *Fremantle* • Esplanade Park, *Fremantle* • Mindarie Marina, *Mindarie* • Swan Yacht Club and Leeuwin Boat Ramp, *East Fremantle* • Claremont Jetty, *Claremont* • Elizabeth Quay, *Perth* • Trinity College, *Perth* • Maylands Police Complex, *Maylands* • Maylands Peninsula Public Golf Course, *Maylands*	• Ascot Racecourse, *Ascot* • Ascot Waters Marina, *Ascot* • Western Australian Cricket Association (WACA) Grounds, *Perth* • South Perth Foreshore, *South Perth* • Government House Gardens, *Perth* • Mends Street Jetty, *South Perth* • Riverton Drive North Reserve, *Shelley*
Vulnerable Environments and Public Open Spaces	• Mosman Beach, *Mosman Park* • Bathers Beach and South Beach, *South Fremantle* • Woodman Point, *Coogee* • Lake Coogee, *Coogee* • Collins Pool, *Mandurah* • Mullaloo Beach, *Joondalup* • Foreshore Reserve, *Yanchep* • Attadale Conservation Area and Cover Nature Reserve, *Attadale* • Matilda Bay Reserve, *Crawley* • Supreme Court Gardens, *Perth* • Heirisson Island, *Perth* • Ashfield Flats, *Ashfield* • Salter Point Lagoon and Reserve, *Salter Point* • Shelley Foreshore, *Shelley* • Andrew Thompson Conservation Reserve, *Waterford* • Bicentennial Adenia Park and Canning River Regional Park, *Riverton*	• Langley Park, *Perth* • McCallum Park, *Victoria Park*

(COASTAL RISK AUSTRALIA, 2021).

APPENDIX 2: SWAN CANNING RIVERPARK AND DEVELOPMENT CONTROL AREA



(DBCA, 2015)