USING SCENARIO PLANNING TO ENHANCE COASTAL RESILIENCE TO CLIMATE CHANGE: COMMUNITY FUTURES IN THE ESTUARINE LANDSCAPES OF BRISBANE WATER, CENTRAL COAST, AUSTRALIA

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ABSTRACT:

Local governments face daunting urban planning challenges in the face of rapid population growth, increasing demand for affordable housing and climate change and divergent community perceptions. There is currently insufficient action to meet these formidable and dynamic challenges. Greater know-how and capacity development need to be invested in local planning and political authorities to promote knowledge-based action. More than two thirds of Australians reside along the coastal cities with over 15 million addresses across 544 local government areas at risk from coastal hazards from 2020 onwards (XDI, 2019). This makes it an urgent priority for local government to fast track adaptation planning for its residents in the low-lying hazard prone areas as well as Council services and infrastructure. In 2019, UNSW students from the Master of Urban Development and Design and Master of Landscape Architecture programs addressed these challenges within a design studio environment. In the studio they developed strategies for urban resilience for a network of five communities surrounding the Brisbane Waters on the Central Coast. The studio adopted an urban scenario planning approach using open source data and on-the-ground evidence to develop diverse community resilience strategies. For each community three scenarios were developed to test alternative urban design strategies and provide insight on possible contrasting futures. This paper demonstrates the benefit of evidence-based scenario planning for local authorities. Such approaches contextualise complex abstract problems and provide new insights for local climate adaptation in accessible and transparent ways. This proactive approach emphasises the need to build the urban design and planning capabilities of local authorities to enhance coastal adaption and resilience to climate change.

1. INTRODUCTION

Within Australia, local government are at the forefront of climate change planning and adaptation while the State and Federal government remain largely silent on growing coastal hazard risks related to climate change such as seal level rise, coastal inundation and erosion. The IPCC (2019), September *Special Report on the Ocean and Cryosphere is a Changing Climate* estimated a likely increase of sea level by 0.43m to 0.84m by 2100 (medium confidence) and continue to rise beyond 2100. Sheehan et al. (2018) warned that coastal risks in coastal policy and planning documents is being underscored and draw attention of the conflicts arising in the near future from uninhabitable coastal properties and properties laws and rights.

According to XDI (2019), in 2020 there are 383,300 existing properties classified as at high risk of climate change related impacts. This number is expected to increase to 735,654 by 2100. While riverine flooding is the major cause of damage and increasing insurance premiums, coastal hazard risks and impacts is projected to increase by 111% between 2020 and 2100. Ranked at number 5, Central Coast LGA is amongst the top 10 LGA's at most risk of climate related coastal hazard risks in both 2020 and 2100 from increasing insurance premiums and number of properties at risks.

There is sufficient evidence to demonstrate that sea levels have risen around the world (CSIRO, 2020; CoastAdapt, 2020; Hanslow et al., 2019; NSW EPA, 2020). That more than two thirds of the global population reside along waterways highlights the urgency to understand the impacts of the rising water level now and into the future and develop adaptations plans accordingly. Adaptation and resilience planning is most effective at the local level (Mirti-Chand, 2018) as it is context specific, which is why local government in collaboration with local communities, is best placed to facilitate informed adaptation to sea level rise. This does not preclude the direction and leadership urgently needed from both Federal and State government to facilitate the development of relevant legal and property rights mechanism for adaptation.

This paper investigates the use of scenario planning in a local context to enhance the coastal resilience of five low-lying communities surrounding the Brisbane Water on the Central Coast. Scenario planning uses evidence-based development within specific situations to test the consequences of different courses of action and the strengths and weaknesses of different adaptation strategies. The methodology applied can be adopted by local government to undertake informed adaptation planning for their regions integrating scientifically informed contexts with design approaches. It emphasises interdisciplinary thinking and integrated evidence-based planning which are key to overcoming silo's in bureaucratic systems (Pettit et al., 2019).

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2. SCENARIO PLANNING

2.1 Central Coast Context

The Central Coast Local Government Area is situated 90km north of the centre of Sydney and 104Km south of Newcastle, covering an area of 1681Km, with either mountainous terrains or low-lying valleys and coastal fronts. Brisbane Waters is situated in the south of the region in an estuarine environment with a wave dominated barrier estuary and tidal tributary of the Lower Hawkesbury River system. The tidal tributary primarily faces coastal flooding risks (Cardno, 2015). The five major communities investigated surrounding Brisbane Waters are Saratoga, Erina Bay (made up of Point Frederick, East Gosford, Green Point & Erina), Gosford, Woy Woy and Booker Bay (Figure 1). Some communities such as Woy Woy were founded one hundred years ago on precarious sand dune landscapes prone to areal flooding. Others such as Saratoga/Davistown, have evolved over the last decades in low lying land in development processes largely blind to the looming dangers of climate change.
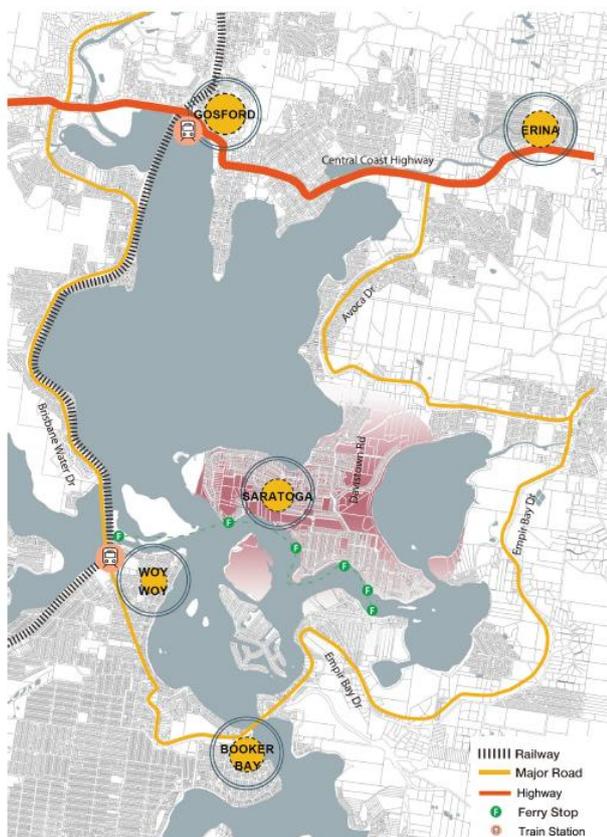

Figure 1: Brisbane Water five major communities and potential additional infrastructure envisaged in one of the scenarios for Saratoga (Map by Studio Student)

Whilst the risks of existing flooding across Brisbane Water floodplain (which is highly developed) was considered relatively low, the potential increased risk due to sea level rise is significant (Cardno, 2015). This places direct threats to both residential properties and Council assets such as roads, drainage, water and sewer infrastructure. Council flood studies for Brisbane Water provide recommendations to adapt to the impacts of projected sea level rise and tidal inundation. As a result of flood studies, in 2015 the former Gosford City council (now Central Coast Council) resolved to incorporate a conservative sea level rise (0.2m/2050, 0.74m/2100) into the flood planning levels. However, these floor planning levels may need to be reviewed in light of the recent events.

Severe storm events in 2007 and 2015 highlighted the increasing tidal inundation risks for these communities. Such compounding climate related events have emphasised the dynamic nature of risk in the region. The potential scale of impact across this densely populated and developed area requires more detailed evidence based strategic land use planning. This can be achieved using urban design mechanisms and detailed three-dimensional spatial thinking at the scale of the local neighbourhood to evaluate the current and potential future risks of flooding and related possible strategies to adapt to these risks.

2.2 Methodology

This research used best available open source data and a range of scientific evidence to inform contrasting and plausible scenarios for different courses of action. Such an approach emphasises the uncertainty of the future and helps build preparedness for different outcomes and identify consequence of those outcomes. Scenario based planning is based on the concept that although the future is unpredictable, we can manage it through effective planning (CSIRO Futures, 2016; Harries, 2003). The concept is believed to have developed from military and corporate applications in the 1960s (Bradfield et al., 2005). Since that time, it has been applied to a range of different uses such as technology adaptation and urban development (Bradfield et al., 2005; Walton et al., 2019). It also has a history of application in environmental planning and urban design to test different courses of urban action (Hong 2013, Oteros-Rozas et al., 2015). Methods from geodesign were combined within this approach such as the integration of GIS with environmental planning. Such approaches have been successfully demonstrated by scholars such as Albert et al., (2015) and Pettit et al. (2019). As leading proponent Steinitz (2012) has explained, Geodesign is the coming together of geography and design, assisted by data driven technology.

The studio involved four distinct steps (Figure 2). Firstly in order to develop the necessary understanding of local landscapes, communities and environments, the first step involved four weeks of detailed mapping and visualisation of social, economic and environmental data from sources such as the Australian Bureau of Statistics Census, the NSW Dept of Planning and Environment and a range of sources and maps such as the interactive Coastal Flooding Dashboard, LIDAR terrain data and Open Street Map. All these sources of information are available on request or directly from open source websites. In this way a detailed picture was built up of five selected local communities. Secondly to define what resilience might mean for each of the five selected local communities a series of visualisations were created to understand their possible values. Rather than resilience being considered as an abstract theoretical concept, the term was defined through mapping local exposure, sensitivity and adaptive capacity. Mapping of local patterns of terrain, ecology, community capacity and urban form was carried out. How these conditions might interact with each other and climate related hazards were considered in the mapping. Students were encouraged to pay special attention to the intersection of social and environmental vulnerabilities considering how poverty and social disadvantage might exacerbate climate change impacts. Thirdly following the development of the evidence base and

resilience definitions, three contrasting development strategies were developed for each of the five communities. These strategies could be selected from a range of best practice approaches or business as usual approaches. Students were therefore guided to select strategies that may result in positive adaptations or negative maladaptation. The development of the different evidence base resilience strategies was based on the local resilience concepts. Some were wholly focused on climate change and socio-economic issues were given less prominence. For others such as Erina, urban form and contemporary patterns of consumption and everyday lifestyles overshadowed climate adaptation strategies. Finally, once these strategies were in place each team visualised and communicated their concepts through an extensive series of maps, sections, graphs and perspectives. This allowed each team to spatially test their framework and strategy to gain insight into the possible lived experience for each three scenarios. Consequently, each team made a recommendation on the preferred strategy for enhancing coastal resilience.

Figure 2: The four steps involved in the scenario development and testing. 1.) Development of evidence base, 2.) Development of Resilience framework and strategies, 3.) Development of Scenarios and 4.) testing and evaluation of scenarios and recommendation of more effective strategies (Image by authors)

3. FINDINGS AND DISCUSSION

In this section we present the findings from the scenario-based investigations for all five communities. Firstly, the five communities surrounding the Brisbane Water Estuary evaluated are set out in Table 1 with a brief summary of the multiple and compounding flooding challenges they face due to changing climate. The number of properties affected by 1/100-year flooding is also listed for each community. These raw numbers illustrate the severity of climate related flooding for each community.

Site	Current flooding issues	# of properties affected by 100yr floods
Saratoga/ Davistown	High tides cause foreshore inundation. Inland penetration of flood waters along waterways is also a problem. Both cause longer term asset deterioration.	253/1099
Erina Bay	Existing high tides cause foreshore inundation and some areas affected by catchment flows.	~500
Gosford	Commercial properties are affected by coastal flooding in 100 or 200 yr. events. Existing high tides cause foreshore inundation.	47
Woy Woy	Commercial / residential	704
	properties are subject to over-ground flooding in 5 and 20yr events Existing high tides cause foreshore inundation. Areal Flooding is prevalent due to the high-water table.	
Booker Bay	A high number of residential properties are subject to over-ground flooding in 5 and 20yr events. Existing high tides cause foreshore inundation.	207

Table 1: Brisbane Water Communities background (Cardno, 2015)

Each community has a range of urban environmental possibilities and limitations in adapting to climate related flooding and building community resilience. These are examined in the following five sections.

3.1 Saratoga/ Davistown

Saratoga/Davistown is a densely populated low-lying area that floods at least twice a year during king tides and major storm events (which is equivalent to 0.2m sea level rise). These events result in salt water inundation of the roads and drainage system. This causes damage to vehicles, infrastructure and coastal ecosystems. The number of dwellings affected by tidal inundation is expected to increase over time. Further the number of properties affected by flooding increased for 1 in 100year event overtime from 725 properties today to 920 by 2100. The area also has a single access road and high car dependency which highlight the challenges to efficiently evacuate people from the area in a disaster event.

The three urban adaptation scenarios developed and tested (Table 2) explored different strategies and trade-offs across key themes including transport infrastructure, landuse change, planned retreat, and development of recreation and green infrastructure.

Scenarios	Description
1 'Adaptable land'	- avoid any further development in high risk flooding areas of Davistown. - retreat all existing development from high risk areas flooding areas over the next 20 years. - transform high risk areas into recreational parks. - increase density in neighbouring low risk areas of Saratoga to accommodate the 373 properties to be retreated. - There is a very high cost associated with this scenario.
2 'Energetic loop'	- separated high risk Davistown area into three sites using landform modifications. - Construct defensive dykes surounding each of the sites to protect and regulate water flows. - Integrate dykes into an 'energetic loop' for cycling and jogging to enhance community connectivity. - 73 remaining properties outside the three sites to be retreated. - Properties inside the loop to be raised - There is an intermediate cost associated with this scenario.
3 'Green	- Create a barrier or buffer using green

Barrier'	infrastructure (bio swales, rain garden and urban wetland) and sluice gates around Davistown - The buffer will operate to reduce flooding by accomodating and draining excess water. - No properties retreated and green space is increased however risk of flood still remains. - There is a low cost associated with this scenario.

Table 2: Adaptation Scenarios for Saratoga/Davistown

The three scenarios involve different levels of social and economic cost. Strategy two with an intermediate social and economic cost was selected by the students as it minimised social disruption and had an intermediate cost (Figure 3). It also resulted in a more interesting urban experience and higher civic and ecological outcomes with better public connectivity.

Figure 3: Scenario two coastal adaptation strategy for Saratoga / Davistown

3.2 Erina

The community of Erina is one of the key employment areas and a major retail hub for the Central Coast. The data mapped for the area indicated flooding risk from overland flow and tidal inundation related to Erina creek on the west and the Brisbane Water Estuary in the south. The area has been subject to rapid urbanisation and faces increasing demand for housing. Whilst the number of properties at risk from flooding is lower in Erina compared to other areas of Brisbane Water, the high percentage of ageing population, lack of public transport and large scale infrastructure, increase the vulnerability of this community through isolation and fragmentation. The three scenarios used a variety of strategies to examine their affect on addressing fragmentation.

Urban design strategies were developed for key themes such as improving connectivity, supporting industry, supporting medium density mixed use types development, natural ecosystem enhancement and mitigation of flooding impacts. Each scenario resulted in different levels of connectivity and liveability (Table 3).

Strategy	Description
1 Urban Retreat	- Planned retreat of flood affected properties along waterfront areas. - Minimal zoning to accommodate local climate refugees.
2 Erina	- Conversion of Erina Fair into an intense high

Junction	density Transit Oriented Development (TOD) town centre. - Infill commercial and residential development around Erina Fair. - Education focused development in the area. - A rapid bus transit route and commuter cycleway. - Development of a major wetland park system along the waterfront to stablise the landscape.
3 Nature Expansion	- Comprehensive redevelopment and rezoning of Erina Fair as a mixed-use development. - Light rail, community bus, footpaths and cycleways to improve connectivity - Development of a new park system with green flood-defence infrastructures such as water sensitive boulevards, wetlands and sea walls.

Table 3: Adaptation scenarios and strategies for Erina

Despite the high cost associated with scenario three's comprehensive redevelopment it maximised long term productivity and liveability and accommodated current and future housing needs for local climate refugees (Figure 4).
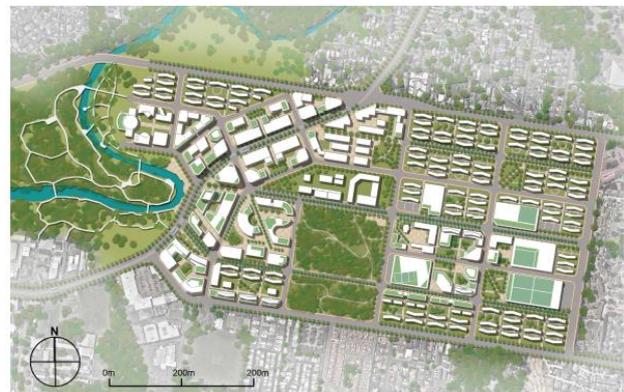

Figure 4: Scenario three vision for Erina

3.3 Gosford

Gosford is a town centre set in a scenic valley at the head of the estuary. The valley setting of the area is subject to several water flow pathways that originally were creeks or running water course that were progressively piped as the area developed. Development on the waterfront is constrained by the high-water table and critical road infrastructure. The area faces flooding risks from rising sea levels, flash flooding of Narara Creek as well as bushfire risks. Gosford has a sensitive ecology with threatened vegetation species that need to be protected. Socially it has a high commuter population with a high car dependency.

These local risks informed the development of three scenarios which examined different ways of addressing climate related risk. These are summarised in Table 4.

Strategies	Description
1 Retreat via Eco-hydrology	- Acquiring flood prone land and converting to constructed wetlands. - Relocate flood affected residential and commercial development.
2 Adaptive Urban Interventions	- Flood mitigation using water sensitive urban design solutions such as floodable parks, wetlands, ponds, bioswales - New transport connections for security and

		evacuatation.
3 Defend and Evolve		- Landform modelling to guide seawater incursion and overland flows. - Construction of elevated platforms to support and protect future clusters of dense development from flooding.

Table 4: Adaptation scenarios and strategies for Gosford.

The comprehensive analysis of each scenario informed the development of a hypothetical hybrid model to assist with the climate adaptation of Gosford (Figure 5). This hybrid model included increased flood adaptation using green infrastructure. It proposed revitalisation of the city centre using mixed use development that include university, commercial and residential density through the transfer of development rights from the vulnerable sites. The redefinition of the waterfront edge by moving the stadium and diverting the bridge to create public domain that generates economic activity, promote walkability and connect the city to the waterfront. The protection of high environmental values and existing landscapes along the Narara Creek and public domain landscape developments improving the creek's accessibility to the public. Finally, the hybrid model integrated the town centre through the development of transport network infrastructure which included new light rail, pathways and pedestrian friendly streets.

Figure 5: The hybrid scenario developed for Gosford town centre.

3.4 Woy Woy

Woy Woy is a highly vulnerable site as it is built on low lying sand dunes and has a high-water table. Areal and nuisance flooding are common, and the landscape is vulnerable to inundation from sea level rise. The flood vulnerability assessment indicated the number of lots that will be affected in different flooding events. These ranged from 1602 lots in a 1-year ARI[1] flood to 4965 lots in a 100-year ARI +0.4 SLR[2] floods. Additionally, Woy Woy has the highest ageing population, high Urban Heat Island effect due to rapid expansion of residential properties causing loss of canopy trees.

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[1] ARI – average recurrence interval

[2] SLR – sea level rise

Woy Woy Train station is a key transport node for the southern population of the central coast. This results in parking and congestion issues. The three scenarios developed for Woy Woy envisaged different approaches for flood mitigation and revitalisation (Table 5).

Strategies	Description
1 The Fort	- Construction of a 6km long wall along the coastal edge to protect Woy Woy from sea level rise. - Elevation of the train line and critical transport infrastructure. - Construction of a network of open green spaces in areas that are subject to nuisance flooding. - Zoning changes to accommodate medium density around the train station.
2 The Green Jacket	- Construction of a flood buffer with salt marsh and mangroves surrounding the shoreline of Woy Woy. - The creation of bioretention swales to manage nuisance flooding. - The relocation and elevation of the train to avoid flood impacts. - The creation of a medium to high density zone change near the train station to offset development costs of new infrastructure.
3 Amphibious Living	- Construction of a 6km defensive seawall to protect Woy Woy from sea level rise. - Establishment of a research and education precinct in the town centre to help manage and support transition to amphibious ways of living. - The relocation and elevation of the train to avoid flood impacts. - The creation of a medium to high density residential precinct serviced by water taxi. - New green infrastructure to mitigate floods in areas that suffer from nuisance flooding.

Table 5: Adaptation scenarios and strategies for Woy Woy

Each scenario was evaluated against a of criteria that included visual connections with nature, connections to the water edge, flood resilience, ecological resilience and economic feasibility. The scenario evaluation also considered the population change over time, the number of new dwelling and lots affected by flooding within each strategy over a period spanning the years from 2020 to 2100. Scenario three had the highest flood resilience and facilitated the most dynamic growth for Woy Woy despite its high cost of implementation (Figure 6).

Figure 6: Scenario three for Woy Woy emphasised "Amphibious living".

3.5 Booker Bay

The community of Booker Bay lies in the south of the Brisbane Water estuary. The suburban settlement faces immediate flooding risks from coastal erosion, saltwater intrusion through sea level rise and areal nuisance flooding. Like Woy Woy, Booker Bay also has high percentage of low socio-economic and ageing population, living in isolation.

The scenario analysis considered the need to protect the high environmental values and marine habitat and identify housing solutions for the vulnerable properties. The three scenarios developed used the low, medium and high emissions concentration levels scenarios that correspond to sea level rise (SLR) levels (low – 0.4m; medium – 0.6m and high 0.9m) (Table 6).

Scenarios	Description & Scenario analysis
1 Sponge City	- Based on the low emissions scenario (SLR of 0.4m) - Development of retention and detention ponds and an urban forest to accomodate flood waters. - Stablisation of the beach using geotechnical reinforcement. - Installation of bioretension swales along the streets to manage flooding in residential areas.
2 Retreat and transform	- Based on the medium emissions scaenario (SLR of 0.6m) - Rezoning specific areas to higher density to accommodate properties that need to retreat from sea level rise. - The creation of pockets parks in residential areas to mitigate flooding. - Development of detention ponds and park to accomodate flood waters.
3 Semi aquatic housing landscapes	- Based on the high emissions scenario (SLR of 0.9m). - Creation of an experiential climate education centre. - Buildings with lesser flood risk elevated on mounds and platforms.
	- Buildings with high flood risk redeveloped with capacity to float during flood events. - Development of detention ponds and park to accomodate flood waters.

Table 6: Three Scenarios for Booker Bay.

All scenarios provided feasible solutions for flood mitigation, improve sustainability and liveability and environmental values in the area but failed to improve the local economy or boost employement which are already low in this area. Scenario two and three adaptation strategies were also costly. A hybrid adaptation scenario for Booker Bay was recommended (Figure 7) that involved rezoning to accommodate climate refuges from the high-risk areas and establishment of wetland park along the waterfront that acts as a buffer and provides a public domain for recreation and improve local liveability.

Figure 7: Booker Bay coastal resilience strategy

3.6 Summary

The scenario-based planning approach adopted in this educational studio highlights the wicked problems associated with coastal community adaptation to climate change. Urban design and urban planning knowledge is essential to accommodate urban growth, build coastal resilience and facilitate climate adaptation within vulnerable coastal areas. The scenario-based planning approach highlights the potential for combining evidence from urban analysis with creative urban design driven approaches. Such approaches integrate in-depth knowledge of the area, help identify potential design solutions, and test the feasibility of these strategies. Whilst local councils have a lot of the data, the critical and creative application of this data through scenario-planning is not a common practice. Various reasons exist for this including a lack of urban design capacity and minimal integration across professional government knowledge silos. Traditional government based urban planning does not accommodate such innovative and powerful approaches. Local government would greatly benefit from this proactive and long-term approach to planning. Benefits include expanding narrow engineered approaches to climate change, the fostering of greater community confidence in government decision making, the generation of unexpected and innovative solutions, the identification of serious risks and potential impacts from certain courses of action. Finally, scenario planning can help generate better conversations around climate change and therefore build more resilient communities. The outcome of each community scenario planning study is summarised in Table 7.

Site	Strategy 1	Strategy 2	Strategy 3	Preferred Scenario
Saratoga/ Davistown	Avoid developing in high risk areas and retreat those in flooding areas	Adapting by raising properties and increasing density to accommodate those retreating from flood prone areas	Using urban design solutions to adapt, increase liveability and mitigate flood risks without retreating	Hybrid model with land modification to improve liveability, transfer of development rights to increase density
Erina Bay	Medium density to settle climate immigrants from flood prone areas that can be used as parks & agriculture	Transit oriented development, new bus routes high density to cater for those retreating from surrounding areas	Intensive development with high connectivity, high density and adaptable housing in flood areas	Strategy 3 with improved access, environment and density
Gosford	Naturalisation of the water edges, improved ecology & tourism but loss of land and density	Using urban design solutions to mitigate flood, improved local environment but flood risks persists	Elevating protected zones to reduce flood risks and increase density & uses	Hybrid model to mitigate flooding in high risks areas using landform intervention, increase density & uses
Woy Woy	Mitigating flood by elevating the train station, open spaces and sea wall along the coastal edges; medium density	Create a flood buffer, bio retention parks, relocating the train station and medium density	Transfer of development rights to increase to high density, living in aquatic areas, relocate train station	Strategy 3 provided the highest flood resilience, economic growth despite high cost to implement.
Booker Bay	Low emission scenario: using swales and ponds to mitigate flooding but low impact on local economy	Medium emission scenario: increase density to retreat from water front and turn them into parks, improve food resilience and create employment	High emission scenario: create floating community, parks and raise building but does not improve local economy	Hybrid model provided the highest coastal resilience, density to retreat from water front, increased liveability.

Table 7: Summary of scenario analysis

4. CONCLUSION

In this paper we have examined how scenario planning and data driven approaches, integrating geodesign, can expand current thinking about coastal resilience and climate adaptation. The scenario analysis deepens understanding of climate change impacts and can identify design solutions to address those impacts. Each of the scenarios drew on a rich history of urban development and landscape approaches evident in long term analyses of the regional landscape (Hawken, 2008). Such long-term thinking is virtually absent from community planning and neighbourhood level urban design in coastal areas. Limitations of this study include the use of best available data. Future research can be improved through integrating higher resolution datasets and through working directly with local communities and stakeholder to further embed local insights and values and generate local knowledge networks (Melo Zurita et al., 2018; Pettit et al., 2019). The approach adopted in this paper demonstrates the potential of scenario thinking to generate diverse and robust approaches to complex issues. Such systematic and lateral future-based thinking can help in three ways. Firstly, it can identify possible unforeseen courses of action not presently discussed within the everyday political economy. Second it can free up discussions around contentious and divisive issues. Thirdly it can build upon and find new uses for current scientific data through creative forward-thinking strategies. This synergistic approach can significantly add value to local councils' capacity for informed planning that build their communities resilience to coastal and flood risks to changing climate.

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