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This Master's Project

Assessing Hawaiian Climate Resilience Plans on Flood Management

by

Maggie Chen

is submitted in partial fulfillment of the requirements

for the degree of:

Master of Science

in

Environmental Management

at the

University of San Francisco

Submitted:

Received:

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Abstract

Island coastal communities are increasingly vulnerable to climate change impacts, including storms, flooding, and sea-level rise. In 2017, the state of Hawai‘i saw an unprecedented number of minor flood events due to a combination of higher mean sea levels and seasonal tidal patterns. This research assessed the climate resilience and adaptation initiatives in Hawai‘i’s Resilience plans as they address coastal hazards. This research examined the robustness of resilience strategies to flooding due to climate change. This report focused on a community’s resilience to the physical impacts of climate change specifically on flood events and other environmental hazards that contribute to flooding such as hurricanes, tsunamis, and sea-level rise. The main research questions of this study is: How robust are climate resilience strategies being developed by coastal communities in Hawai‘i? The research focuses on the three Hawaiian Islands most vulnerable to coastal climate impacts: Kaua‘i, Maui, and O‘ahu. Utilizing the Arup City Resilience framework, the Equity by Design framework, and a Flood Management framework, this research conducted a comparative Case Study Analysis and Gap Analysis of the islands’ Resilience Plans. Currently the three plans meet 100% of the flood management guidelines. However, gaps were identified in the Arup City Resilience and Equity by Design guidelines. Therefore, the recommendations in this report focus on addressing the resilience and equity gaps in the plans. I created examples of measures or approaches that could increase inclusivity and equity for communities in Hawai‘i that are increasingly threatened by the effects of anthropogenic climate change. One example to address the gap on ‘Minimal Human Vulnerability’ is to increase inclusivity and include equitable policies by coordinating pre-disaster emergency plans. This emergency plan can be formed by referencing the State of Hawai‘i Emergency Operations Plan which established the framework the state will use to organize its emergency management activities and can be adapted for counties to use as well. It is important to note that while the climate resilience plans for these three communities are relatively new, some of the actions related to increasing overall resiliency within the community have been ongoing within County departments, community organizations, and also state and federal agencies. Through the creation of the climate resilience plans, the county is now specifically identifying, partnering, and referencing relevant actions by other agencies and organizations and bringing attention to these efforts.

1. Introduction

The effects of climate change are being felt throughout society. Currently over 50 billion tonnes of CO₂ are emitted globally every year this is a 40 percent increase compared to the 35 billion tonnes emitted in 1990 (Ritchie & Roser, 2021). The rise in global temperatures due to increasing emissions had subsequent effects on the environment such as increasingly severe and frequent weather events (US EPA, 2016). Exacerbated weather events threaten human health and safety, hinder the local economy, and affect the future livelihood of a community (Center for Disease Control and Prevention, 2017). I define a community in the context of this report as a group of people living in an area, connected through social networks and institutions, and sharing the area's resources and infrastructure. One of the types of communities especially sensitive and vulnerable to climate change effects are coastal communities (Zanon et al., 2020). Coastal communities are increasingly vulnerable to magnified climate hazards. As sea-level rise caused by anthropogenic climate change is accelerating, it is estimated that the area of US flood plains will expand 45% by the end of the century (Denchak, 2019). The populations living in coastal areas are also increasing over time; currently around 50 percent of the world's population live by the coast and this is projected to increase to around 68 percent by the mid-century (Kasmalkar et al., 2020). Low-lying coastal communities are increasingly vulnerable to the effects of climate change especially as the effects of natural hazards are magnifying and exacerbated over time. The resilience and management plans that are currently available have not been effectively implemented due to inconsistent stakeholder actions and complacent attitudes (Iturriza et al., 2020). As climate change continues the anthropogenic phenomenon effects will continue to be felt throughout all levels of society, increasing the severity of hazards to coastal areas, and continuously threaten coastal communities (US EPA, 2016).

While the signs of anthropogenic climate change are felt in many levels of society, the effects are quickly noticeable in vulnerable low-lying coastal locations. For coastal communities, the effects of sea level rise and coastal hazards such as flood events can be devastating. Flooding in the US has a fatality rate of over 100 annually along with widespread property damage (Denchak, 2019). It was estimated that it took \$48.6 billion USD to repair the US public infrastructure damaged from 1998 to 2014 due to flood events (Moore, 2015).

Another exacerbated coastal hazard with high impacts and high future implications is tsunamis. Tsunamis can be a serious and destructive force, wreaking havoc on coastal infrastructure, inflicting damage on reef ecosystems, and even lead to human fatalities or injuries (Strzelecki et al., 2020). Even sea-level rise by one foot could mean an exponential increase in frequency for tsunami events. It has been reported that a 1.5-foot rise in sea levels could mean an increased frequency of tsunami caused flooding by 1.2 to 2.4 times (Li et al., 2018).

Along with tsunamis, another hazard to coastal systems come from hurricanes. A hurricane is an example of an extreme storm where heavy precipitation can lead to flooding. Hurricanes are more damaging to coastal areas as flooding can cover a wide expanse of land (Rey et al., 2020). While it is projected that there would be a decrease in the overall number of hurricanes, the intensity of strong hurricanes is expected to increase by a factor of two by the end of the century (Bender et al., 2010).

Urban areas are complex interconnected systems with multiple interdependent factors that have both direct and indirect effects on each other (Iturriza et al., 2020). There are various definitions of resilience, each with a specific focus and context. One way resilience can be defined is ‘the ability of a system to maintain its overall identity... in the face of internal change and external perturbations’ (Gollner et al., 2017). In this report, the external perturbation or challenge is climate change and its effects on coastal communities. Adaptation measures can be adopted and incorporated to help coastal communities increase their resilience to magnifying hazards. Adaptation measures are specific to the area applied; can join and implement with existing infrastructure and systems; and require active effort and collaboration between stakeholders such as businesses, inhabitants, and relevant groups (De Urbanisten, 2021). It is estimated that around 68 percent of the world’s population will live in coastal areas around mid-century (Kasmalkar et al., 2020), incorporating adaptive measures and resilience to upcoming external changes is important in keeping the functionality and identity of coastal areas. By incorporating adaptive measures, a community has more opportunities to stimulate the economy, encourage active collaboration between community members, increase biodiversity, and improve the overall quality of life at the same time (De Urbanisten, 2021).

One adaptation option to reduce flooding impacts is implementing dikes (Climate ADAPT, 2020). To protect coastal communities in 2100 with dikes is estimated to cost \$12 – 71 billion USD (Hinkel et al., 2014). While there is a high cost of implementing dikes, it is not as costly as repairing flooding damages with no adaptive measures implemented. In 2017 the US had the costliest flood recovery year to date yet at \$60 billion in losses (NOAA, 2017).

The projected exacerbated effects of coastal hazards such as flood events (US EPA, 2016), tsunamis (Li et al., 2018), and hurricanes (Bender et al., 2010) emphasize the need for adaptive measures. The high recovery and maintenance costs after devastating coastal events are likely unacceptable to the public therefore adaptation measures are necessary, timely, and pertinent. Incorporating adaptation measures lowers the cost of repairing infrastructure damages post-disaster (Hinkel et al., 2014) compared to situations with no adaptation measures with higher damage costs (NOAA, 2017; Nofal & Lindt, 2020).

Urban areas are complex and interconnected systems sensitive to drastic changes such as effects from anthropogenic climate change. Coastal flood events can lead to injuries, spread pathogens and disease, and may pose fatal human safety threats (Center for Disease Control and Prevention, 2017). It is projected that around 68 percent of the world's population will live in coastal areas around mid-century (Kasmalkar et al., 2020), resilience to upcoming external changes is important in keeping the functionality and identity of coastal areas. Weather events are increasing in frequency and intensity. In 2017, the state of Hawai'i has seen an unprecedented amount of minor flood events due to a combination of higher mean sea levels and seasonal tidal patterns (Thompson et al., 2019). Magnified coastal hazards threaten coastal communities especially the vulnerable populations as resilience to disasters varies based on a variety of factors. A person's ability to prepare and respond to a flood event depends on factors such as whether they are insured, or employed, or even on their ethnicity as people of color are commonly disproportionately affected by hazardous events (Center for Disease Control and Prevention, 2017). Climate projections such as flood models show that implementation of adaptive and resilience measures must happen before the appearance of minor flood events (Thompson et al., 2019). It is urgent and timely to start planning effective mitigation strategies for coastal communities in Hawai'i, as increasing flood events (Thompson et al., 2019) support

climate projections findings and indicate that coastal communities and their inhabitants will be continuously threatened going into the future.

1.1 Coastal Resilience and Adaptation

While resilience is a broad concept, it is widely accepted that resilience is necessary for coastal management measures (Karavokiros et al., 2016; Viavattene et al., 2018; Rumson et al., 2019). A general definition of community resilience within the US was defined by the Presidential Policy Directive as ‘the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents’ (PPD-21, 2013). More specifically, coastal resilience can be defined as ‘the capacity of the socioeconomic and natural systems in the coastal environment to cope with disturbances, induced by factors such as sea level rise, extreme events, and human impacts, by adapting whilst maintaining their essential functions’ (Masselink and Lazarus 2019). This definition of coastal resilience will be the main resilience definition used in this report.

Resilience is associated with a community’s social, economic, and environmental well-being, along with their ability to keep short term hazards from festering into long-term wide-scale challenges (NOAA, 2020). A community and system’s adaptive capacity relate to its ability to adjust to ‘climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences’ (SF BCDC, 2011). There are different types of adaptation: 1) Autonomous adaption, an unconscious response triggered by climate stimuli; 2) Anticipatory adaptation, which are measures taken before perceiving environmental changes; and 3) Planned adaption, conscious and intentional adaptive policy decisions to retain a current or attain a desired state (SF BCDC, 2011). As the projected effects of climate change show that weather events will exacerbate (US EPA, 2016), it is necessary to equip policy makers and essential stakeholders with the tools capable of shaping effective coastal management strategies (Karavokiros et al., 2016).

1.2 Research Questions

The overall objective of this research is to assess the climate resilience and adaptation initiatives in Hawai‘i’s Resilience plans as they address coastal hazards. This research examines the

robustness of resilience strategies to sea level rise and flooding caused by anthropogenic climate change. The focus of this report will be on a community's resilience to the physical impacts of climate change specifically on flood events and other environmental hazards that contribute to flooding such as hurricanes, tsunamis, and sea level rise.

To achieve these objectives, the main research question of this study is:

How robust are climate resilience strategies being developed by coastal communities in Hawai'i?

Unfortunately, disadvantaged communities are often disproportionately affected by coastal hazards and disasters, such as storm surge and flooding. As the effects of climate change intensify, equity and vulnerable communities must be given extra consideration in resilience measures. As coastal hazards are increasing in severity and variety there are direct and indirect consequences on the local economy, community, and supporting infrastructure. The variety of coastal hazards must be identified for consistent assessment of their complimentary resilience measures. My subsequent sub-questions are:

What are the types and severity of climate change-induced coastal hazards affecting Kaua'i, O'ahu, and Maui?

How can their resilience strategies be designed and implemented to ensure that vulnerable communities are not disproportionately affected by coastal hazards, especially flood events?

Considering climate projections and how the rate of flood events, sea level rise, and hazard intensity are estimated to increase dramatically into the future (US EPA, 2016), it is imperative that measures are taken in Hawai'i to protect their infrastructure, community, and inhabitants. It is also critical to pay attention to the feasibility or even the presence of measures proposed or taken to protect vulnerable Hawaiian communities from coastal hazards.

1.3 Report Overview

This report begins with an overview of key topics highlighting specific climate coastal hazards such as flooding, sea level rise, hurricanes, and tsunamis. It then transitions to defining

important terms such as resilience and coastal resilience and explaining their significance in coastal areas and in this report. The overview of key topics ends with explaining climate change projections, impacts, and implications for the future. Following the overview of key topics, the methodology for my research is outlined and explained. The research will be analyzing case studies and conducting a comparative gap analysis. In the analysis section, the research looks at three islands in Hawai'i and highlights their demographic information and community characteristics, their resilience plan, equity approaches, and analyzes their resilience plan. The analysis section ends with a gap analysis on the resilience plan, where the resilience plans are assessed in comparison to resilience frameworks. To conclude this report the results and discussion section covers the final findings, followed by subsequent recommendations from the author and from the guidance documents, and finishes with our conclusion and comments on future research.

2. Literature Review

This section is an overview of key topics pertinent to this report. Background on coastal hazards is covered and how it is being exacerbated by anthropogenic climate change. Next, specific coastal hazards such as flooding, sea level rise, hurricanes, and tsunamis are described. The significance of resilience and coastal resilience is highlighted as well as their detailed definitions. This section ends with background on climate change projections and noting their varied impacts into the future.

2.1 Coastal Hazards

Weather events and hazards are increasingly intensified and magnified by climate change (US EPA, 2016). Developing an awareness of climate change is integral in assessing the efficacy of the current measures taken and in further developing effective measures moving forward. An awareness of anthropogenic climate change is also key in fostering partnerships and collaborations to address prevalent and underlying systematic issues (Iturriza et al., 2020). While the signs of climate change are felt to some degree in many areas, the effects are quickly noticeable in vulnerable areas such as low-lying coastal locations sensitive to environmental changes.

In terms of climate change, sea level rise and coastal hazards can be devastating to coastal communities. Coastal communities are characterized as areas of rapid growth and urban development. Rapidly growing coastal communities are increasingly threatened by coastal hazards. Climate change will prompt changes in many other extreme weather events such as storm surges, wind waves, and cyclonic events. They are also sources of economic growth for both national and global economies which lead to increasing population growth and urbanization (Yawen et al., 2019). The focus of this report is on anthropogenic climate-change exacerbated flood events. Other coastal hazards may work in conjunction to increase the damage from flood events, such as sea level rise, tsunamis, and hurricanes. Recent studies indicate that extreme sea levels are magnified by tropical cyclones and in turn exacerbate extreme weather such as wind waves and storm surges (City and County of Honolulu, Hawaii, 2019).

Climate change models have estimated that throughout and by the end of the twenty first century there will be a substantial shift in the average, the variation, and the maximum temperatures and precipitation (Schilling et al., 2020). The effects of climate change will not only impact the physical infrastructure of a community but also the socio-economic relationships tied to damaged physical infrastructure (Nofal & Lindt, 2020). This variety of shocks and stresses can overlap and create multidimensional and interconnected challenges going into the future. For the purposes of this report, we will be assessing climate change exacerbated hazards specifically for flood events. Additional sections were covered on tsunamis and hurricanes as these hazards are the main contributors to flood events.

2.1.1 Flooding and Sea Level Rise

An increase in frequency and number of coastal hazards can be deadly and devastating in these highly populated and economically important coastal regions. The global mean sea level rise is projected to rise to 0.2 m to 2.0 m by 2100. At the same time, it is reported that the global population will increase by 29 percent (to 7.6 billion) between 2017 and 2050 (Youjung et al., 2020). The two main reasons for global sea level rise are thermal expansion of water as the overall atmospheric temperature increases over time and the increased rate of melting ice such as ice sheets due to warming waters. It is projected that sea levels will rise at increasingly higher

rates for many centuries moving into the future (National Ocean Service 2021). As weather events and hazards are exacerbated by anthropogenic climate change, coastal communities face increasingly challenging interconnected issues.

Modeling and monitoring systems have shown that flooding can be attributed to wind-related storm surges and precipitation patterns (Rey et al., 2020). It is projected that in 2100 globally 0.2 to 4.6 percent of the population would be flooded annually without adaptation to these estimated coastal flood events. These flood events would be 25 to 123 cm of the mean sea level rise and is expected to cause annual damages that cost around 0.3 to 9.3 percent of the global gross domestic product for the U.S (Hinkel et al., 2014). The estimated damages and threats to coastal populations without adaptation are likely to be unacceptable to the public, and there is a high likelihood that adaptation measures would be taken to address these issues.

Coastal hazards pose significant risks to neighboring coastal communities, infrastructure, and ecosystems. The frequency and severity of coastal flooding depend on wave power and height, wave climate, weather patterns and storm occurrence (Winter et al., 2020). Anthropogenic climate change causing ocean warming also significantly affect ocean waves and magnify the effects of flooding (Reguero et al., 2019). An effect of anthropogenic climate change is upper ocean warming, which is seen to be increasing the intensity of global wave patterns. The increase in wave patterns is a strong indicator of the accelerating threat anthropogenic climate change poses (Reguero et al., 2019). The National Oceanic and Atmospheric Administration's (NOAA's) reported that between 2000 and 2016 there were 1,079 people in the U.S. who lost their lives due to coastal flooding and storm surges (NOAA, 2021a). The increasing intensity of the wave climate is affecting ecologically sensitive and vulnerable coastal communities.

Coastal flood events can lead to injuries, spread pathogens and disease, and may pose fatal threats to human safety. The leading cause of mortalities during a flood is drowning from flood waters. Other human health risks during a flood may be injuries from moving or falling debris, motor vehicle accidents when people attempt to drive through flood waters, contaminated drinking water, and hypothermia (Center for Disease Control and Prevention, 2017). After a flood the chance of drinking water contamination increases, as water can be contaminated from washed up agricultural contaminants, sewage, or other pollutants. Mold growth in building

inundated from flood water can affect air quality, damp indoor environments can cause asthmatic episodes, and other mental and stress disorders can arise as well (Center for Disease Control and Prevention, 2017). These are a few of the ways flood events can threaten human health and the exposure to these threats varies based on context.

Certain factors may affect the level of exposure a person can have. As an example, a person's exposure by living and residing in a flood zone increases their chance of encountering a flood event. Those with disabilities or medical illnesses are more at risk especially if they are reliant on regulated drug prescriptions. In addition, a person's ability to pre-emptively prepare and their ability to adequately respond to a flood event changes based on whether they are insured, employed, or even on their ethnicity as people of color are disproportionately affected by hazardous events (Center for Disease Control and Prevention, 2017). Flood events threaten coastal communities in various ways and the inhabitants' exposure and risk to flood events vary based on a variety of factors.

Increasing damages to natural and man-made infrastructure are likely as anthropogenic climate change magnify coastal events over time. An example of a common coastal impact is saltwater intrusion and damages to freshwater lenses which can contaminate potable water and water for agricultural uses (Winter et al., 2020). Processes such as desalination of salt from salt water is a costly and energy intensive process with high saline byproducts difficult to dispose of. There are recent break throughs in artificial intelligence innovations with desalination, but challenges continue to arise and are currently being addressed (Al Aani et al., 2019). Coasts affected by saltwater intrusion may suffer as a result, leaving communities without adaptation a lack of usable water and in turn threaten the community's food security.

Where coastal adaptation is not possible, water security is threatened, and food security suffers, then coastal communities are forced to resort to managed retreat. Coastal communities will have to move inland or relocate elsewhere which can have dire social, cultural, and historical implications (Winter et al., 2020). There are also limited options for managed retreat for island communities facing these natural disasters. Island communities are increasingly vulnerable to coastal hazards and face limited options moving forwards as anthropogenic climate change progresses.

Management solutions and incorporating adaptation measures are costly but not as costly as repairing infrastructure damages post-disaster with no adaptation measures. On average flood events is the costliest annual effect of climate change in the US, including the recovery projects post disaster and the overall losses (Nofal & Lindt, 2020). In 2017, the US had the costliest flood recovery year to date yet at \$60 billion in losses due to four hurricanes (Harvey, Irma, Jose, and Maria) (NOAA, 2017). It is projected that the cost of protecting coastal communities in 2100 with dikes would be a significant \$12 – 71 billion USD including investment and maintenance costs. While this is a significant amount invested for an adaptation measure, it is a smaller cost compared to the global estimate of damages without the dikes as an adaptation measure, not including indirect effects to the US production chain (Hinkel et al., 2014). Financial resources invested into adaptation and mitigation actions were calculated and are projected to be significantly lower than fixing damages to coastal communities after flood events and hazards arise. The need for adaptation measures is emphasized in these projections that show coastal hazards such as flood events exacerbating over time. The recovery and maintenance costs after devastating coastal events are likely unacceptable to the public therefore adaptation measures are necessary and timely.

2.1.2 Tsunamis

Tsunami and hurricane events can pose a threat and have negative effects on the environment and on human safety. After gaining momentum tsunamis can be a serious and destructive force, wreaking havoc on coastal infrastructure, inflicting damage on reef ecosystems, and even lead to human fatalities or injuries (Strzelecki et al., 2020). Even sea level rise by one foot could mean an exponential increase in frequency for tsunami events. Currently small magnitude tsunamis occur frequently and considering sea level rise projections the effects of future small magnitude tsunamis can match the devastating effects seen from present day large magnitude tsunami events (Li et al., 2018). A sea level rise even by a comparatively small degree can significantly affect tsunamis. Tsunamis can be generated in various ways, but 80 percent are generated by earthquakes (NOAA, 2021b). Tsunamis can be incited in other ways such as by landslides, submarine landslides (Aránguiz et al., 2020), volcanic activity, certain types of weather (NOAA, 2021b), and much more. When a tsunami approaches it can travel long distances inland along low inundation depths and result in low retreating speeds if traveling across a planar topography.

Or if a tsunami is confined and meets a steep topographical area it can reach great inundation depths and greater retreating speeds (Williams et al., 2020). The damage a tsunami inflicts can vary based on aspects such as topographical variations.

Researchers from the Earth Observatory of Singapore created a computer simulation that tracks the effects of varying magnitudes of tsunamis on Macau in relation to sea level rise. It has been reported that a 1.5-foot rise in sea levels could mean an increased frequency of tsunami caused flooding by 1.2 to 2.4 times. A 3-foot rise in sea levels could mean an increase frequency of tsunami caused flooding by 1.5 to 4.7 times (Li et al., 2018). As it is projected that sea levels at Macau will increase by 1.5 feet by 2060 and 3 feet by 2100 (Li et al., 2018), the implications of increased flooding frequency due to tsunamis may be catastrophic and pose serious threats.

2.1.3 Hurricanes

Many coastal hazards influence and threaten coastal systems, another hazard come in the form of hurricanes. A hurricane is an example of an extreme storm where heavy precipitation can lead to flooding. Hurricanes are more damaging to coastal areas as flooding can cover a wide expanse of land (Rey et al., 2020). As climate change is expected to exacerbate weather patterns, it can be inferred that small-scale hazards will develop into large scale disasters. A coastal system is increasingly vulnerable to hurricane events as climate change effects lead to a decrease in marine biodiversity thereby hindering a system's ability to recover from a disaster. A coastal system is more vulnerable to hurricanes through the loss or decrease in redundancy, which may have consequences such as stunting the recovery process post-hurricane and decreasing the system's overall resilience.

There are flora and fauna that have adapted to hurricane environments over time, increasing their resilience and lowering their vulnerability to this extreme storm's effects. An example can be seen in Puerto Rico where the local ecosystems have been seen to exhibit natural signs of resistance and resilience to hurricanes. A plethora of tree species in Puerto Rico has shown resistance to hurricane events through immediate mortality during hurricane events (Zimmerman et al., 2020). While coastal birds are thought of as susceptible to hazards especially to hurricanes

and oil spills, it was seen that post-hurricane events it takes less than 20 years for coastal bird species to recover to pre-hurricane population counts as they have high resilience to disturbances and strong resistance to short term challenges (Field et al., 2019). And post-hurricane events it is seen that stream and water bodies in Puerto Rico return to pre-hurricane conditions in as little as five years as a form of resilience (Zimmerman et al., 2020). The adaptive abilities of the ecosystem and of organisms to natural disasters help increase a system's resilience and lower vulnerability.

A system's resilience and vulnerabilities change as the environment the system inhabit changes. It was found that individual resilience increases as income increases, on the caveat that ownership of property increases as well. Research conducted on social vulnerability and resilience has found that low- and middle- income homeowners are less financially resilient than poorer renters (Madajewicz et al., 2020). While short term recovery may be achieved through the coastal system's natural adaptive capacity, long term stresses such as sea level rise, upper ocean warming, and increasing hurricane events have implications on the socio-economic resilience of local coastal economies and communities. Residents with disabilities or illnesses are more vulnerable to hazards. In the event of a hurricane, non-white households are more likely to have longer durations of little to no access to food supplies (Madajewicz et al., 2020). Access to health care and resources like food and clear communication are effective indicators of resilience and subsequently vulnerability as well.

2.2. Resilience

This section synthesizes the concepts and definitions of climate resilience found in the literature. The definition of resilience varies from different sources and situations. The purpose of this section is to characterize different definitions of Resilience in the literature and show how the coastal resilience definition used in this report was chosen. Anthropogenic climate change is creating changes in the environment and subsequently in society on a physical, social, and economic level. Effects of climate change unfairly affect disadvantaged vulnerable peoples. As the environment and the systems within it are changed in unprecedented ways, the various functions and interconnected relationships within society must be assessed on how they affect

the overall system. Management plans moving forward must incorporate resilience as a priority as anthropogenic climate change continues. The subsequent changes due to this phenomenon have dire implications for people everywhere, the systems we live in, and the world as we know it.

Urban areas are complex interconnected and interdependent systems that is sensitive to drastic and dramatic changes such as the effects of climate change. As it is projected that around 68 percent of the world's population will live in coastal areas around mid-century (Kasmalkar et al., 2020), resilience to upcoming external changes is important in keeping the functionality and identity of coastal areas. Urban areas are complex interconnected systems with multiple interdependent factors that have both direct and indirect effects on each other (Iturriza et al., 2020). When referring to resilience it is often to note the dynamics within a population (Dore et al., 2020) but the definition of resilience varies depending on a variety of factors (Gollner et al., 2017).

There are multiple definitions of resilience, each with a particular focus and context. One definition of resilience focuses on the development of prevention, preparedness, and recovery measures when faced with unexpected factors (Iturriza et al., 2020). Another way that resilience can be defined is 'the ability of a system to maintain its overall identity... in the face of internal change and external perturbations' (Gollner et al., 2017). In this report, the external perturbation or challenge is climate change and its effects on coastal communities. While the terms "adaptation" has a connotation of accepting a perturbation, "resilience" has a more active outlook.

Environmental changes have broader implications and effects on society. Factors that can make one group of people more vulnerable than another is their level of exposure to hazards and challenges which may be unequal due to a variety of variables. Resilience to external challenges differs depending on variables such as age, class, gender, education, geographic location, ethnicity, availability of resources and more (Ford et al., 2020). Vulnerable groups may be classified as those who require more humanitarian aid or those who do not have access to and need financial or social resources (Kuran et al., 2020). Climate change creates a living

environment with health impacts, such as increased air pollution, extreme heat, and food insecurity. A few groups that are not as climate-resilient and are especially vulnerable are indigenous peoples, mentally or physically disabled peoples, children, older adults, communities of color, low-income communities, and immigrant groups (Ford et al., 2020; Kuran et al., 2020; APHA, 2020).

3. Methods and Materials

Comparison and comparative analysis have been used over time to gain a deeper and better understanding of the materials present, of the society we live in, and of the world that surrounds us. In scientific analysis, a comparative study must follow a procedural process where two or more cases are studied, compared to find differences and similarities, and assessed to draw conclusions and make findings (Azarian, 2011). The variety of comparative methods has grown to fit different fields and case studies. One comparative method seen as an effective technique is qualitative content analysis, where qualitative data is systematically processed to find underlying patterns (Cho and Lee, 2014). This research utilizes qualitative content analysis to examine the case studies in this report to achieve the objectives and answer the research questions posed. In the qualitative content analysis, the demographic information and community characteristics of each study area are included, such as average income levels, poverty percentage, and the main industries. Additional information examined in the resilience plans is their equity approaches, flood management measures, and the status of the resilience plan.

To answer my research questions, I chose to conduct a case study analysis of three urban coastal communities in Hawai‘i. I used qualitative methods to assess adaptation and mitigation efforts to flooding and coastal hazards to understand the areas of improvement in local frameworks and community measures.

A 2018 study conducted by the University of Hawai‘i analyzed the islands of Hawai‘i and categorized their vulnerability risk from low to high. While the average exposure to hazards throughout the Hawaiian islands is at a low to medium vulnerability, there is an alarming 34 percent of the state that is at medium to high vulnerability (Onat et al., 2018). The range of

factors assessed in order to determine the island's vulnerability was topography, seafloor terrain, tidal energy, surge, and vulnerability to sea level rise in conjunction with natural habitat, physical infrastructure, and human interactions. It was found that the most at risk and vulnerable islands are Kaua'i, Maui, and O'ahu (Onat et al., 2018). The case study analysis analyzed the demographic information, community characteristics, hazard identification, equity approaches, flood management measures, and the status of the resilience plans for the three urban coastal islands in Hawai'i: Kaua'i, O'ahu, and Maui.

In the gap analysis the main elements of each city's local Resilience plan in terms of flood management and community equity were identified. The three urban coastal communities in Hawai'i face similar coastal climate risks, including the effects of sea level rise and flood events. The local Resilience plans of these three urban coastal communities will be compared to the Arup City Resilience Framework, Equity by Design principles, and '4 Steps to Effective Flood Management'.

The Arup City Resilience Framework offers guiding principles to measure and monitor influential resilience factors within a city (Arup, 2014). The analysis portion will identify the main elements of each city's local Resilience plan in terms of flood management and community equity, then compare them to the Arup City Resilience Index: City Resilience Framework and the guiding principles in the document to identify areas in the local Resilience plans that would be improved upon and provide recommendations given by the document. The analysis portion will also compare the three island's Resilience plans to the Five Principles for Enacting Equity by Design to identify areas within the local Resilience plans that meet equity standards, identify whether there are areas that can be improved upon, and make subsequent recommendations from the guidance document.

The Arup City Resilience Framework was developed by Arup International Development, a not-for-profit consulting agency, for the 100 Resilient Cities(100RC) Program of the Rockefeller Foundation. Arup has created a comprehensive framework that reflects reality which can help cities understand and assess their own resilience. The 100RC Program is dedicated to helping cities adapt and become more resilient to social, physical, and environmental stresses and shocks (City of Boston, 2016). 100RC supports the adoption of resilient views that includes both shocks

(e.g. Earthquakes, fires, flooding, etc.) and stresses (e.g. high unemployment, inefficient public transit system, endemic violence, etc.) that are daily challenges for developing cities (City of Boston, 2016). By aiding in addressing and solving these challenges then cities are better equipped and better able to respond to hazardous events. And through acting in implementing change, cities are better able to care and provide basic functions for a wider range of circumstances for its citizens.

The Resilient Cities framework has 12 indicators that fall into four categories. The four categories are: 1) People: the health and well-being of individuals; 2) Place: infrastructure and environment; 3) Organization: economy and society; and 4) Knowledge: leadership and strategy.

The three indicators within the People category are: 1) Minimal human vulnerability; 2) Livelihoods and employment; and 3) Safeguards to human life and health. Minimal human vulnerability refers to inclusive plans focusing on providing an adequate and dependable supply of essential services to a city's population. This focuses on providing and maintaining safe, reliable, and affordable citywide water, sanitation, and energy networks. The Livelihoods and employment indicator refers to enabling individuals to explore a variety of options to obtain the assets that meet their essential need, e.g. through providing access to finance, skills training, and business support. The safeguards to human life and health indicator refers to providing accessible and affordable day to day health care services. This can take the form of population-based interventions at the city or community level.

The three indicators within the Place category are: 1) Reliable mobility and communications; 2) Continuity of critical services; and 3) Reduced physical exposure. The indicator reliable mobility and communications refers to affordable, reliable, and diverse transportation systems and information and communication technologies (ICT) networks, and contingency planning. This means ensuring that there are appropriate, inclusive, and affordable multi-modal transportation infrastructure systems (redundant and various options ensure flexibility in the event of emergencies or an increase in demand). Along with a diverse, reliable, and inclusive range of communication options in the event of emergencies to disseminate information within the community, such as radio, internet, mobile phone services, and even specific modes such as social media outlets. The indicator continuity of critical services refers to proactive management of critical ecosystem services and essential infrastructure. This can be accomplished through

educating communities on the importance of ecosystem services so there aren't any careless or damaging actions from lack of awareness. The reduced physical exposure indicator refers to appropriate design and construction of protective functions of city infrastructure. This can be accomplished through improving building codes that promote long-term robustness and flexibility to adapt, and safe failure mechanisms in the event of unexpected emergencies.

The indicators within the Organization category are: 1) Finance resources and contingency funds; 2) Social stability and security; and 3) Collective identity and mutual support. The indicator finance resources and contingency funds refers to actions such as creating contingency funds available to both public and private sectors for emergencies, aligning fiscal procedures in government, and structuring of city budgets to consider the availability of funds for infrastructure and emergency events. The social stability and security indicator refers to measures such as instituting a social system where there is a combination of deterrents and effective policing. An additional action to implement this indicator is through promoting prevention measures such as preventative education. The indicator collective identity and mutual support refers to cohesive and supportive cities that can be created by reinforcing local identity through supporting social networks and community organizations, artistic endeavors and preserving cultural heritage.

The indicators in the fourth and last category are: 1) Effective leadership and management; 2) Empowered stakeholders; and 3) Integrated development planning. The table showing the 12 indicators in the Resilient Cities framework is shown below. The indicator effective leadership and management refers to government, business, and society and is seen in trusted leaders, multi-stakeholder consultations, and decision-making using evidence and reliable data. This indicator can be achieved through supporting relevant and effective decision making through multi-stakeholder and participant agreement and consultations within the community, including the private sector. The baseline for the empowered stakeholder indicator is education. This is reliant on updated and relevant information to ensure communities take appropriate action in the event of an emergency. An example could be to integrate early warning systems for appropriate hazards and access to education and information within the community. The integrated development planning indicator refers to goals, integrated development strategy, and plans regularly reviewed and updated by cross-departmental groups indicate integrated development planning. This can be achieved through developing a shared and aligned city vision with

different stakeholders involved in designing and implementing city projects. In this planning a vision should be based on appropriate evidence, accepts underlying uncertainty, and accomplished through policy and regulations.

Table 3-1. The Twelve Arup City Resilience Framework Indicators	
Category	Indicator
Category 1 <i>People: Health and Well-Being</i>	Minimal Human Vulnerability
	Diverse Livelihoods and Employment
	Adequate Safeguards to Human Life and Health
Category 2 <i>Place: Infrastructure and Environment</i>	Reduced Physical Exposure and Vulnerability
	Continuity of Critical Services
	Reliable Communications and Mobility
Category 3 <i>Organization: Economy and Society</i>	Collective Identity and Mutual Support
	Social Stability and Security
	Availability of Financial Resources and Contingency Funds
Category 4 <i>Knowledge: Leadership and Strategy</i>	Effective Leadership and Management
	Empowered Stakeholders
	Integrated Development Planning

According to the guidance document, the relevance of each indicator would depend on the system's characteristics and the challenges of each individual case. Through Arup's research to identify resilience indicators, these factors were found to be what mattered the most when a city faces their stresses and shocks. Additional examples of the twelve objectives from the Arup City Resilience Framework are listed under Appendix 1.

In conjunction with the Arup City Resilience Framework, the analysis will also be utilizing the Five Principles for Enacting Equity by Design. This framework was developed by the Center of Urban Education, a national leader in higher education equity with experience in creating actionable tools and implementable measures. Researchers from CUE published in January 2015 America's Unmet Promise: The Imperative for Equity in Higher Education, within this were five principles outlined emphasizing actionable ways to enhance equity within a system.

Subsequently, in early 2015, CUE published Five Principles for Enacting Equity by Design. Within this guidance document, the five principles were outlined, and examples were given for each from CUE's experience working in equity design in higher education. The Five Principles for Enacting Equity by Design is an adaptable guidance document that can be applied to other sectors outside of education.

The five principles outlined in the guidance document are utilized to evaluate how equity is addressed within the three islands' climate plans. The five principles are: 1) Clarity in language, goals, and measures; 2) Equity-mindedness; 3) Equitable Practice and Policies; 4) Enacting Equity; and 5) Equity as a system-wide principle (Bensimon et al., 2015). Through using these indicators to clearly identify and make visible the inequities within a system, practitioners can then make the necessary changes to the areas that can improve and within their own organizations. Organizations have a long way to go from rhetoric about equity to action and structural change; these five principles lay out a good place to start. The principles in Five Principles for Enacting Equity by Design, the principles descriptions, and recommendations from the guidance document are listed under Appendix 2.

Complementing the two other frameworks, this analysis will be comparing the three Resilience Plans to the '4 Steps to an Effective Flood Management Plan'. This guideline was developed by Short Elliott Hendrickson Inc (SEH), where different 'government, commercial, and industrial clients are connected to the solutions that help improve their mobility, design overall better places, and engineer clean water and renew infrastructure' (SEH, 2021). SEH Water Resources Engineer Rachel Pichelmann states that as major flood events continue, it is seen that even individuals who do not live in Federal Emergency Management Agency (FEMA)- mapped flood zones can still encounter flooding (SEH, 2021). A subsequent solution is to implement emergency flood plans. The four phases of an emergency flood management plan are listed in Appendix 3.

4. Analysis

Section four covers this reports Case Study analysis and Comparative Gap analysis. This section begins with the Case Study analysis, by looking at the three chosen islands in Hawai'i determined to be most at risk and vulnerable to hazard exposure (Onat et al., 2018): Kaua'i,

O‘ahu, and Maui. Next is the Comparative Gap analysis, where the main elements of the local analytical frameworks are identified and compared to the Arup City Resilience Index: City Resilience Framework, Equity by Design, and ‘4 Steps to an Effective Flood Management Plan’.

4.1 Case Study: Kaua‘i

The county and island of Kaua‘i is susceptible to an interrelated mix of climate, geological, and technical hazards that increasingly threaten local property, livelihood, and inhabitant safety (County of Kaua‘i, 2021a). The County of Kaua‘i Multi-Hazard Mitigation and Resilience Plan is the guiding resilience document developed for reference for local Kaua‘i hazard mitigation actions taken and was updated in 2020. The current resilience plan follows local hazard mitigation plan criteria, authorized by §322 of the Robert T. Stafford Act, and amended by the §104 of the Disaster Mitigation Act of 2000 (DMA 2000), 44 CFR Part 201, Hazard Mitigation Planning (County of Kaua‘i, 2021a).

4.1.1 Demographic Information and Community Characteristics

The ethnicities present in the County of Kaua‘i are aligned with the diversity seen in the rest of the state, where 33.0 percent are White alone; 31.0 percent are Asian alone; 9.1 percent are Native Hawaiian and other Pacific Islander alone; 11.4 percent Hispanic or Latino; 0.7 percent Black or African American alone; 0.5 percent American Indian and Alaska Native alone; and 25.7 percent are two or more ethnicities (U.S. Census Bureau, 2019b). According to the U.S. Census Bureau’s Small Area Income and Poverty Estimates, the 2019 median household income in Kaua‘i is \$83,554, the per capita income in 2019 was \$33,143, and there were 9.3 percent of people in poverty (U.S. Census Bureau, 2019b).

The major industries in Kaua‘i are Agriculture (the island offers a diverse range of crops that can be cultivated all year long); Sustainable Technologies and Practices (in terms of sustainable established organizations partnering with agriculture efforts around the island); Science, Technology, and Defense (many tech related jobs tied to the Pacific Missile Range Facility Barking Sands (PMRF) and renewable Photovoltaic energy projects); Visitor Industry (supported by the non-profit organization Kaua‘i Visitors Bureau and enhanced by the plethora of festivals

and events that happen throughout the year); Health and Wellness; Sports and Recreation; and Arts and Culture (Kaua'i Chamber of Commerce, 2021; OPSH, 2016). Results from an economic analysis on Kaua'i's Strengths, Weaknesses, Opportunities and Threats (SWOT) show that Kaua'i is a talented community with a need for more job opportunities, development of the work force within the county, physical infrastructure, and access to capitol (OPSH, 2016).

Based on land area, the County of Kaua'i is the fourth largest county in Hawai'i at 619.96 square miles and includes four islands: Kaua'i, Ni'ihau, Lehua, and Ka'ula (DBEDT, 2011). The island of Kaua'i has a land area of 552.35 square miles (DBEDT, 2011) and is shown in Figure 4-1 below.

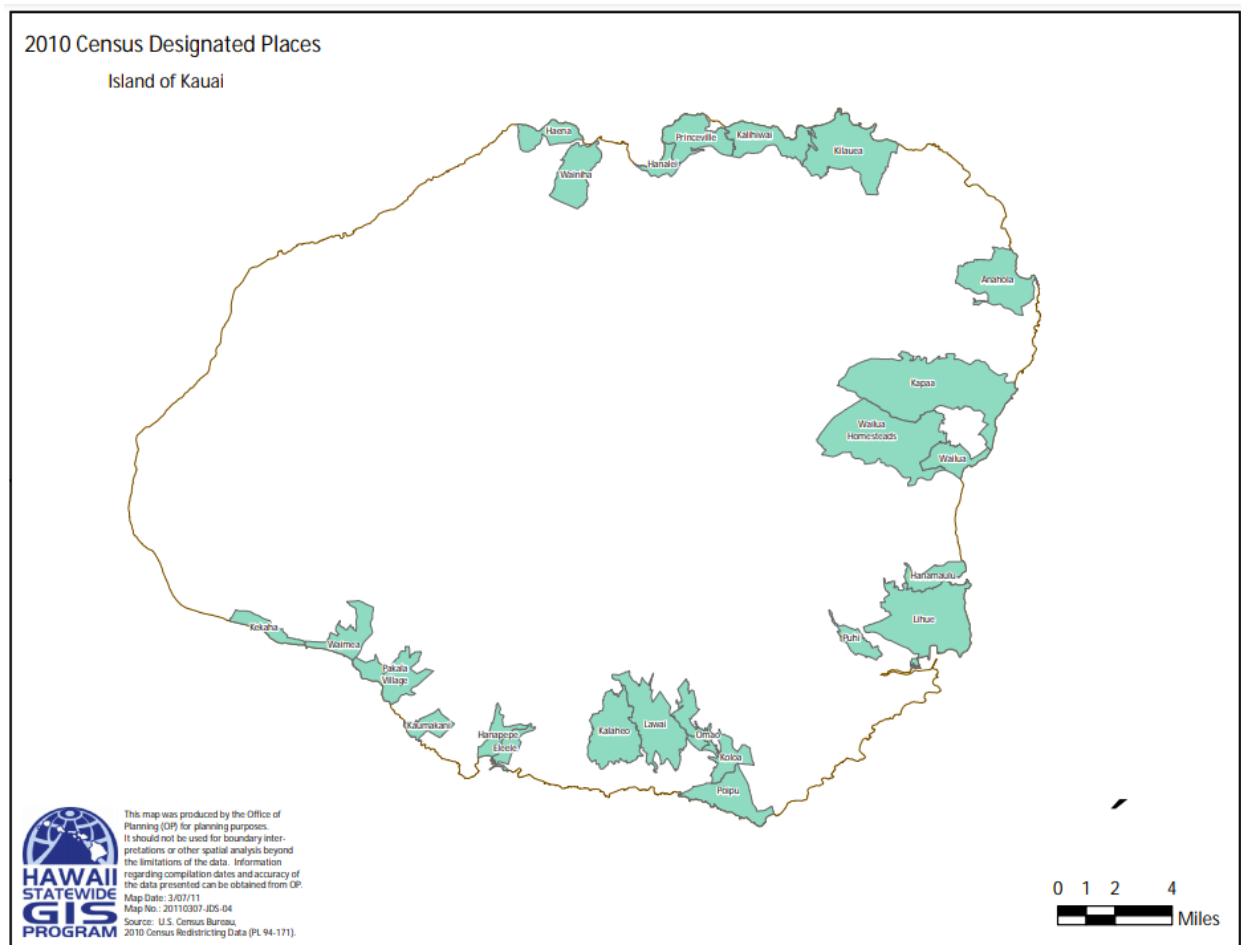


Figure 4-1: Map of Island of Kaua'i, 2010 Census Designated Places, created by the Hawai'i State Office of Planning using data obtained from the U.S. Census Bureau (HSOP, 2011a).

4.1.2 Hazard Identification

For Kaua‘i’s Draft 2020 MHMR plan, the Steering Committee took into consideration the full range of natural hazards that could impact Kaua‘i and ranked them from least to greatest concern. This process considered state and local hazard planning documents and natural hazard characteristics that can or could impact Kaua‘i’s planning area. Kaua‘i’s Draft 2020 MHMR plan identified and categorized the ten hazards of concern using risk ranking which assessed the probability of hazard occurrence along with its impact on the human, society, and infrastructure of the planning area (County of Kaua‘i, 2021b). The ten hazards of concern from highest to lowest are:

- 1) Tropical Cyclone and Other High Winds
- 2) Wildfire
- 3) Climate Change
- 4) Inland Flood
- 5) High Surf, Coastal Flood and Erosion
- 6) Tsunami
- 7) Landslide
- 8) Dam Failure
- 9) Earthquake
- 10) Heat and Drought

The County of Kaua‘i is currently revising their Draft 2020 MHMR plan by holding the secondary round of Steering Committee Meetings with the public and relevant participants, where the draft plan is available for public review and comment. As the County of Kaua‘i’s climate plan is currently under revisions, there are no progress reports on the implementation of the proposed measures within the plan. At the end of this report, recommendations will be given for the County of Kaua‘i as revisions to the draft plan are currently underway.

4.1.3 County of Kaua‘i Multi-Hazard Mitigation and Resilience Plan

The County of Kaua‘i Multi-Hazard Mitigation and Resilience Plan was prepared for the Kaua‘i Emergency Management Agency to plan and coordinate the development of resilience measures throughout the county. The plan was first created in 2005 in compliance with the federal Disaster Mitigation Act (DMA) and updated in 2015. The DMA highlights the importance of incorporating pre-emptive hazard planning and encourages sustainable mitigation practices. The DMA promotes sustainability in mitigation measures, where along with sound management of natural resources, hazards and mitigation is addressed in the largest possible social and economic overview. This encompasses more than financial costs from hazard damages but also considering the scope of costs and benefits, which can include social equity, environmental impacts, and increasing overall system resilience. In 2020, the County of Kaua‘i was drafting an updated plan for 2020 and are holding Steering Committee Meetings to work with and incorporate the concerns of the public, the community, and other relevant participants. The updated resilience plan follows local hazard mitigation plan criteria, authorized by §322 of the Robert T. Stafford Act, and amended by the §104 of the Disaster Mitigation Act of 2000 (DMA 2000), 44 CFR Part 201, Hazard Mitigation Planning. For the purposes of this report, I refer to the Draft 2020 County of Kaua‘i Multi-Hazard Mitigation and Resilience Plan as MHMR.

In the updated Draft 2020 MHMR plan the new goals and objectives align more closely to existing County plans and state priorities. The main objectives of the updated plan are to:

- Meet or exceed DMA requirements
- Meet state and federal requirements as well as meet the County’s needs
- Aid the County of Kaua‘i to continue access to FEMA grant funding for disaster mitigation measures
- Consider local hazards of concern and create a risk assessment
- Coordinate existing plans and measure so high priority projects are funded and implemented.

As climate change progresses coastal flood events in conjunction with sea level rise and sea level rise chronic flood events will increase in frequency (County of Kaua‘i, 2021a). Chronic Sea Level Rise Exposure Area (SLR-XA) is the area predicted to be inundated and affected by flood

events under the business-as-usual conditions (County of Kaua‘i, 2021a). As these flood events increase in frequency, the amount of people and infrastructure on Kaua‘i exposed to these hazards will increase. The Core Planning Team from the County of Kaua‘i conducted a hazard risk assessment and determined that as of 2021 around 28.57 percent of Kaua‘i’s population could be exposed to coastal flood events in conjunction with sea level rise and SLR-XA events. There are 9,703 buildings exposed to coastal flood events in conjunction with sea level rise and SLR-XA events which holds a property value of around \$5.798 billion.

In the Draft 2020 MHMR plan, under the Section 6 Climate Change the subsections the refer to flood events, related hazards, and the recommended measures within the section are listed in Table 4-1 below. Detailed steps on the selected actions and plan recommendations, the objectives met through the action, the lead agency for the action, the support agency, cost rating, sources of funding, and timeline are listed from 14-3 to 14-9 in the Draft 2020 MHMR Plan.

Table 4-1. County of Kaua‘i Flood Management Sections and Recommendations		
Flood Management Sections Referred	Climate Change Exacerbated Effects	Plan Recommendations
6.2.3. Inland Flood	<ul style="list-style-type: none"> • High frequency flood events (e.g., 10-year and 100-year floods) will likely increase and strike more often <ul style="list-style-type: none"> ○ Historical hydrological patterns can no longer be solely relied upon to predict weather patterns • Changing precipitation and runoff patterns <ul style="list-style-type: none"> ○ Increasing water availability and quality uncertainty 	<ul style="list-style-type: none"> • Planners will need to incorporate advanced safety measures in the design, operation, and regulation of flood protection infrastructures such as dams, bypass channels and levees, as well as local sewers and storm drains.
6.2.4. High Surf, Coastal Flood and Erosion	<ul style="list-style-type: none"> • Warmer temperatures may lead to an increase in frequency of storms and more weather events that cause coastal erosion • More frequent high surf events 	<ul style="list-style-type: none"> • Develop pamphlets and other messaging about the danger of high surf and distribute within the community

	<ul style="list-style-type: none"> • Inundated and displaced wetlands and lowlands • Eroded shorelines • Salinity increase of estuaries (impairing water quality) • Alteration of tidal rages in rivers and bays • Alteration of sediment depositional patterns 	<ul style="list-style-type: none"> • Develop future impact studies to monitor patterns • Coastal AE Zone Building Standards should be investigated regarding how the infrastructure within AE zones (landward of coastal high hazard zones) will be affected
6.2.5. Tsunami	<ul style="list-style-type: none"> • Sea level rise increases the risk of coastal exposure to tsunamis <ul style="list-style-type: none"> ○ Tsunamis may reach further inland and result in increased infrastructure damage and threaten human safety 	<ul style="list-style-type: none"> • Tsunami Hazard Identification and mapping based off probabilistic scenarios • Create building codes that adequately address the impact tsunamis have on structures • Enhance tsunami warning technologies • Pay special attention to vulnerable populations in tsunami zones • Increase public hazard mitigation education and outreach

Compiled by Chen M, based on *Multi-Hazard Mitigation and Resilience Plan: Volume 1 of 2* by the County of Kaua‘i, 2021.

4.2.4 Equity Approaches

In terms of incorporating equity to ensure that vulnerable communities are not disproportionately affected by climate change, the Draft 2020 MHMR plan had the following objectives:

- Reduce the impacts of hazard events so that they do not become disasters
- Provide a better quality of life for all members of the community
- Build trust and reliable networks for future development events

- Encourage and further advance overall sustainability and resilience

The Draft 2020 MHMR plan strived to consider equity by considering the diversity of communities within the County and each of their access to resources (such as information, news, and technology), social networks, religion and customs, age, gender identity, ethnicity, health, and physical ability. The vulnerable populations to flood events and related hazard listed in the in the Draft 2020 MHMR plan are:

Table 4-2. County of Kaua‘i Flood Event Vulnerable Populations	
Flood Management Sections Referred	Vulnerable Populations
7.2.3. Inland Flood	<ul style="list-style-type: none"> • These populations residing in floodplain are especially vulnerable to flood hazard: <ul style="list-style-type: none"> ○ Economically disadvantages populations (defined as those with an income of \$20,000 or less) ○ Individuals over 65 Years Old ○ Population under 16 Years Old
8.2.3. High Surf, Coastal Flood and Erosion	<ul style="list-style-type: none"> • Beachgoers, swimmers, fisherman, and hikers along the shoreline • The homeless population that gathers among the shoreline are also especially vulnerable • A particularly vulnerable population are surfers, as many amateur and professional surfers seek larger waves the high surf advisories may cause an opposite effect on the population and attract surfers ignoring those warnings
9.2.3. Tsunami	<ul style="list-style-type: none"> • The Elderly, the disabled, the very young, and the homeless who reside near coastlines • Tourists and visitors unfamiliar with tsunami warning systems, appropriate responses, and/ or how to reach higher ground • In the event of a local tsunami generated with little warning time, an even higher population of people may be vulnerable

4.2 Case Study: Maui

The Maui Island Plan was adopted in 2012 to offer direction for future growth and development and guidance for environmental, social, and economic policy decisions over a 2030 timeline. The Draft West Maui Community Plan, updated in 2020, is the guiding resilience document for the future development in west Maui charted over a 20 year timeline. As West Maui is the first area of the island that updated since the adoption of the Maui Island Plan in 2012. For the purposes of this report, the Draft West Maui Community Plan will be analyzed for their resilience and management measures as these sections are included in the 2020 update.

4.2.1 Demographic Information and Community Characteristics

As seen with the other counties, the County of Maui also has a diverse range of ethnicities where 34.9 percent is White alone; 29.0 percent is Asian alone; 11.6 Hispanic or Latino alone; 10.6 percent is Native Hawaiian and Other Pacific Islander alone; 0.8 percent Black or African America; 0.6 percent is American Indian and Alaska Native alone; and 24.2 percent is two or more ethnicities (U.S. Census Bureau, 2019c). According to the U.S Census Bureau's Small Area Income and Poverty Estimates, the 2019 median household income in Maui is \$80,948, the per capita income in 2019 was \$35,241, and there was 10.7 percent of people in poverty (U.S. Census Bureau, 2019c).

Maui's economic drivers are the following industries: Agriculture; Construction; Creative Industries; Energy; Health and Wellness; Science, Technology, and Innovation; Sports and Recreation; and the Visitor industry (MEDB, 2016; OPSH, 2016). While there is a variety of industries in Maui it was found that the main economic driver in Maui is the visitor industry which provides both direct and indirect sources of financial income and makes up around two-thirds of Maui's economic profile (MEDB, 2016).

A few of the major challenges Maui faces is the need to increase the range, scope, and number of jobs available; increase the amount of affordable housing (necessary to attract and keep skilled

workers in the county); and improving Maui's business culture (including addressing complex regulations and improving public opinion) (County of Maui, 2010; MEDB, 2016; OPSH, 2016). The increasing population working, living, and visiting Maui is putting a strain on local infrastructure, roads, and other supporting systems (County of Maui, 2020). Maui's residents generally agree that Maui's economic development must align with and be measured by the increase in resilience and sustainability measures (MEDB, 2016).

Based off of land area the County of Maui is the second largest county in Hawai'i at 1,171 square miles and includes four islands shown below in Figure 4-2: Maui, Moloka'i, Lāna'i, and Kaho'olawe. The island of Maui is the largest island in the county with a land area of 734.5 square miles, is the economic center in county, and is home to the majority of the residents in the county (MEDB, 2016).

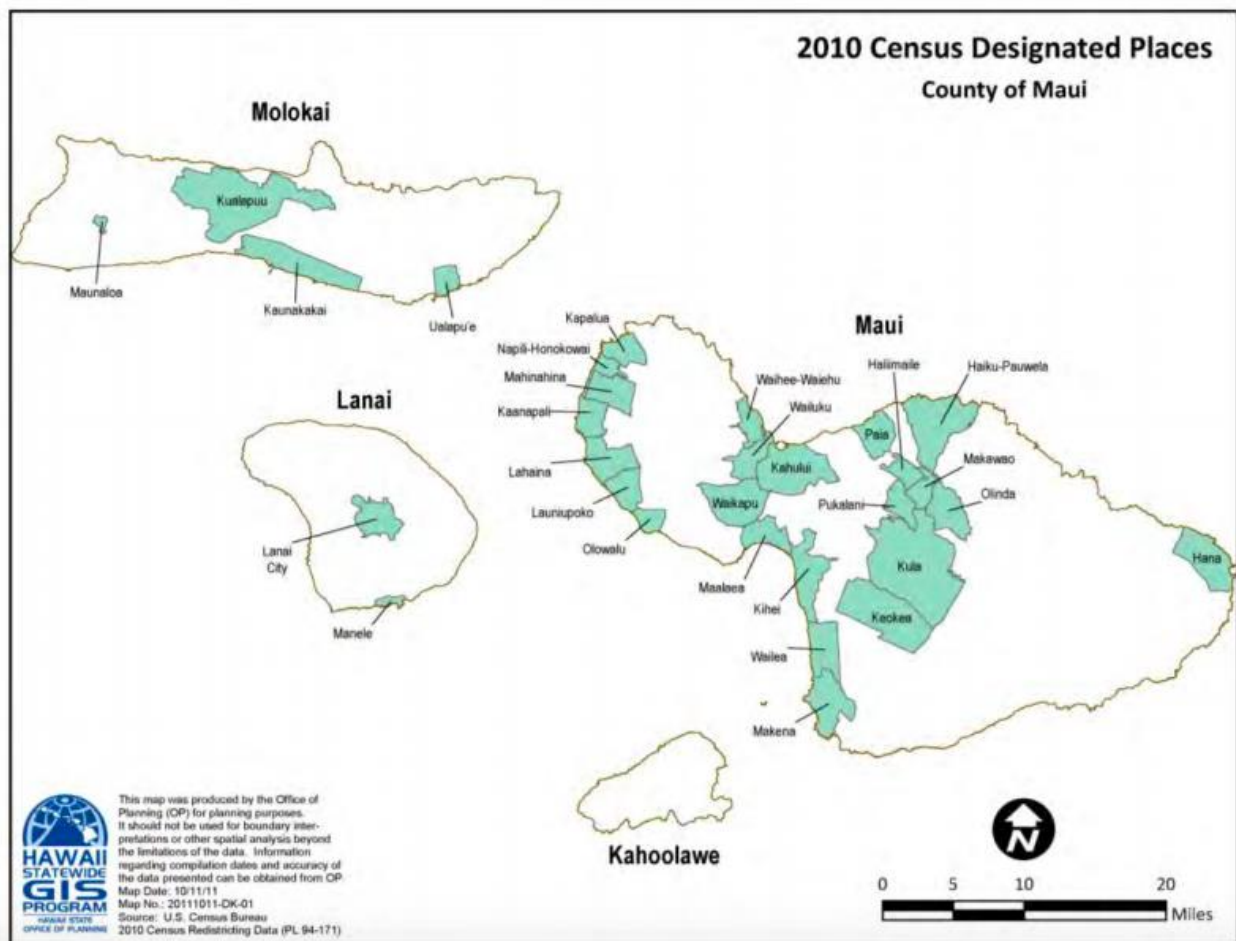


Figure 4-2: Map of Maui County, 2010 Census Designated Places, created by the Hawai‘i State Office of Planning using data obtained from the U.S. Census Bureau (MEDB, 2016).

4.2.2 Hazard Identification

For West Maui’s DWMC plan, the Department of Planning held a series of interviews and small group sessions with the West Maui community including individuals, local organizations, and community groups to consider the collective’s vision for West Maui and categorize the issues important within the community. These issues of concern include in part natural hazards but also include socio-economic and cultural topics as well. In no order, the major topics identified within the Maui community are:

- Community Profile
- Wastewater
- Water
- Housing
- Drainage and Stormwater
- Climate Change and Sea Level Rise
- Historic Preservation
- Economic Prosperity
- Recreation Network
- Transportation and Mobility
- Land Use

As West Maui’s climate plan is currently under final review and adoption consideration, there are no progress reports on the implementation of the proposed measures within the plan. Though within the DWMC plan there is a detailed section on DWMC implementation and tracking measures. In the DWMC plan, Section 4 Implementation and Monitoring describes the Implementation Program, Monitoring and Evaluation Program, and the Implementation Schedule. Recommendations for West Maui’s climate plan will be given at the end of this report.

4.2.3 Draft West Maui Community Plan

The Draft West Maui Community (DWMC) plan was updated in June 2020 and is the product from a 10- month review by the West Maui Community Plan Advisory Committee and a subsequent 5-month review by the Maui Planning Commission. The DWMC plan was a collaborative effort with the West Maui community and County and State departments, building upon best planning practices to promote healthy and resilient communities. The DWMC plan was created as a guidance document for future development, planning, and policy formation on West Maui over a 20- year time period. As confirmed in the Maui County Code under Chapter 2.80B, the DWMC indicates and maps out the community's vision for the future and the steps necessary to accomplish this vision. The DWMC plan has main five sections: 1) Plan Framework; 2) Policy Framework; 3) Growth Framework; 4) Implementation and Monitoring; and 5) Appendices. The DWMC is currently under final review and consideration of adoption.

In 1996 West Maui had the West Maui Community Plan, the June 2020 DWMC update has a revised format and consider the interconnect relationship between West Maui's challenges and the potential strategies. The updated holistic view of systems guidance is reflected in the DWMC plan's goals and actions which are:

- 1) Ready and resilient systems
- 2) A complete, balanced, and connected transportation network
- 3) Responsible stewardship of resources, culture, and character
- 4) Economic opportunity through innovation and collaboration
- 5) Safe, healthy, livable communities for all

Infrastructure systems maintain and provide essential daily services for West Maui's local community and visitors. Growing populations puts a strain on local infrastructure systems, therefore maintenance and improvements to these systems are important as West Maui expects increasing demand and increasing hazard threats (County of Maui, 2020).

In the DWMC plan, within Section 2 Policy Framework there are subsections that refer to climate change and sea level rise and the recommended policy actions (shown in Table 4-3 below).

Table 4-3. West Maui Climate Change and Sea Level Rise Policy Recommendations	
Sections Referred	Policy Recommendations
2.1.1	<ul style="list-style-type: none"> Only approve proposed Community Plan Amendments to the golf course land in Kā'anapali makai of Honoapi'ilani Highway for existing shoreline development that is retreating inland due to impacts from sea level rise or other related coastal hazards.
2.1.2	<ul style="list-style-type: none"> To address projected coastal erosion impacts, the location of new permanent structures should be landward of the Erosion Hazard Line (Maui's recognized coastal erosion threshold) for the projected sea level rise of 3.2 feet. Exceptions shall be provided and allowed for reasonable development.
2.1.3	<ul style="list-style-type: none"> Developers planning redevelopment and development projects within the State-recognized Sea Level Rise Exposure Area shall proactively: <ul style="list-style-type: none"> Collaborate with the Maui County Planning Department and nearby relevant parties affected by the proposed developments to coordinate possible relocations of at-risk structures Integrate collaborative findings to development plans by relocating the planned structure out of harm's way
2.1.4	<ul style="list-style-type: none"> Place priority and emphasis on projects that have multiple benefits from resilience actions
2.1.5	<ul style="list-style-type: none"> When feasible and possible, preserve waterfront land that resides in the State- recognized Sea Level Rise Exposure Area to protect Maui's shoreline and beaches

Compiled by Chen M, based on *Maui Island Plan: Maui County General Plan 2030* by the County of Maui, 2020.

4.2.4 Equity Approaches

Once approved the DWMC plan will act as the guidance document for policy makers. It is acknowledged in Section 1 Plan Framework that West Maui is vulnerable to current and

predicted hazards as it is a region of coastal-focused development with substantial areas of unused agricultural land (County of Maui, 2020). While the DWMC plan considers and refers to the well-being of the West Maui community at large, the plan does not address specific vulnerable populations to flood events and equity concerns in a defined section within the document. Recommendations for West Maui's climate plan will be given at the end of this report.

4.3 Case Study: O'ahu

On the Hawaiian Island of Honolulu, the guiding resilience framework used is the Ola O'ahu Resilience Strategy, which addresses the shocks and stresses of climate change on the island (City and County of Honolulu, 2019). The basic resilience challenges faced are framed by the shocks and stresses identified. The guiding resilience framework was created through a collaboration from the O'ahu community at large, including thousands of O'ahu residents, non-profits, local businesses, and neighborhood organizations to guide O'ahu to a flourishing and equitable future.

4.3.1 Demographic Information and Community Characteristics

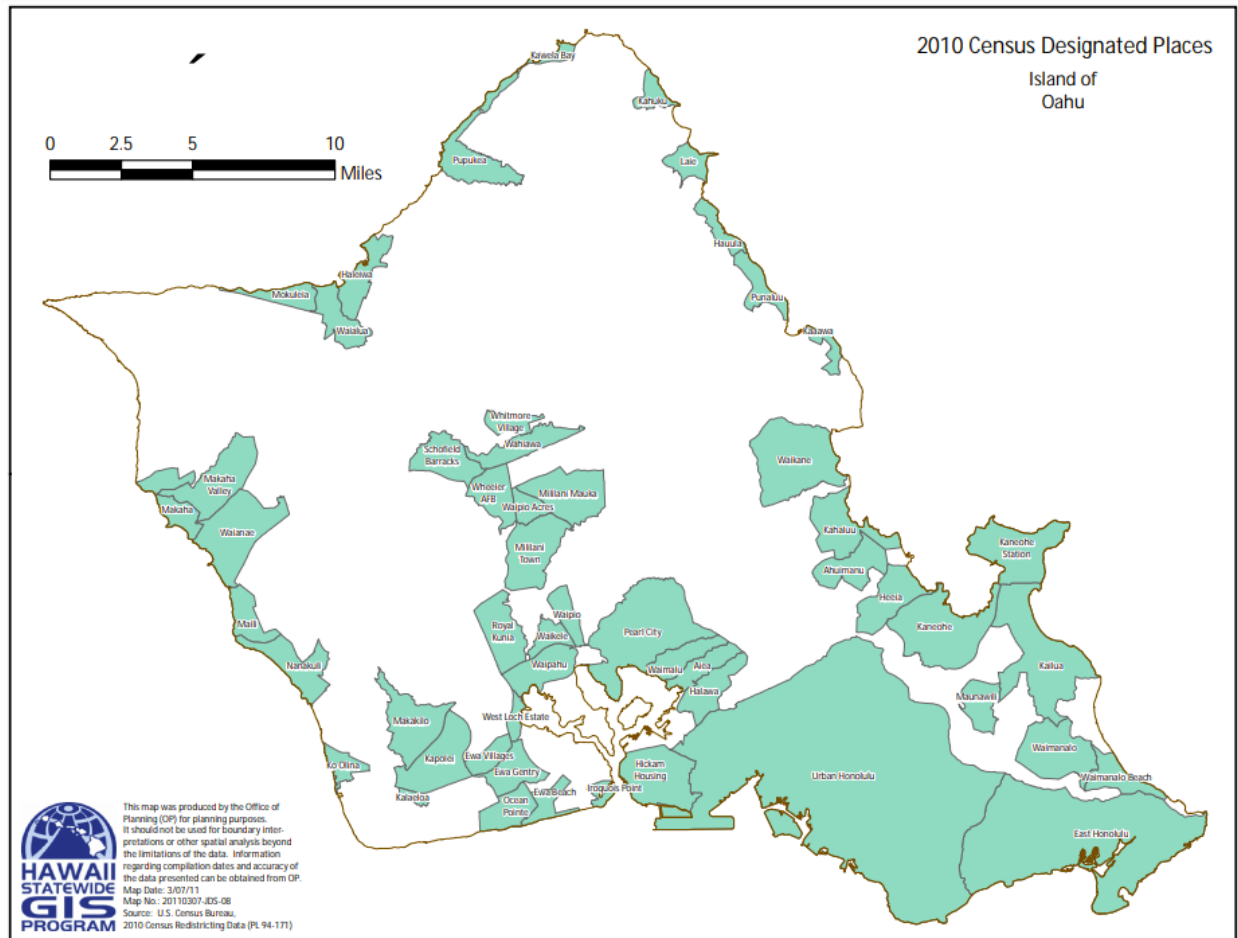
This report refers to Honolulu as the island of O'ahu, because Honolulu County includes the city of Honolulu and the entire island of O'ahu. Though O'ahu is the third largest island among the Hawaiian Islands, it has the highest population density in the State of Hawai'i as seen with its population of 974,563 in 2019 (U.S. Census Bureau, 2019a; OPSH, 2016). Some of the influencing factors that contribute to the City and County of Honolulu's high population density is from business and commerce; the seat of State government; Honolulu International Airport; high tourism attractions and lodging; the high density and presence of k-12 and higher education opportunities; and the highest presence of retail infrastructure (OPSH, 2016).

Hawai'i is one of the states with the smallest population out of all the states in the US, ranking 40th out of the 50 states, yet is one of the most diverse states where around one in four residents identify as multiracial (Krogstad, 2015). The state's range of diversity is echoed in the ethnicities recorded in O'ahu, where 42.9 percent identify as Asian alone; 21.6 percent identify as White alone; 10.0 percent as Hispanic or Latino; 9.6 percent identify as Native Hawaiian and

other Pacific Islander alone; 2.8 percent identify as Black or African American alone; 0.3 percent as American Indian and Alaska Native alone; and 22.8 percent as two or more ethnicities (U.S. Census Bureau, 2019a). According to the U.S Census Bureau's Small Area Income and Poverty Estimates, the 2019 median household income in O'ahu is \$85,857, the per capita income in 2019 was \$36,816, and there was 7.9 percent of people in poverty (U.S. Census Bureau, 2019a). The major industries in O'ahu are the Hospitality and Tourism industry; Health Care; Research, Innovation, Technology and Creative Industries; National Security; Agriculture; Construction/Infrastructure; and Energy (OPSH, 2016).

The island of O'ahu consists of both rural and developed communities and an interdependent mix of challenges associated with both have to be addressed. The main climate risks posed for O'ahu were identified and can be categorized as either shocks or stresses (City and County of Honolulu, Hawaii, 2019). The five main shocks that impact O'ahu are: 1) Hurricanes; 2) Tsunamis; 3) Infrastructure Failure; 4) Rainfall Flooding; and 5) External Economic Crisis (City and County of Honolulu, Hawaii, 2019). And the five identified stresses are: 1) Cost of Living; 2) Aging Infrastructure; 3) Climate Change Impacts; 4) Lack of Affordable Housing; and 5) Over-Reliance on Imports (City and County of Honolulu, Hawaii, 2019). Through the Rockefeller Foundation's 100 Resilient Cities network, the resilience challenges to the City and County of Honolulu were identified to be aging infrastructure and infrastructure failure; economic impacts; natural disasters and hazards (also the impacts from sea level rise and coastal erosion); and complex homelessness issues (OPSH, 2016).

Based off land area alone the County of Honolulu is the smallest county in Hawai'i at 600.74 square miles which includes the island of O'ahu along with several remote islands (DBEDT, 2011). The island of O'ahu has a land area of 597.64 square miles (DBEDT, 2011) and is shown in Figure 4-3 below.



The vulnerability of communities in O‘ahu have been identified using the SOVI, Socioeconomic Vulnerability Index and categorized as Very High, High, Medium, Low, Very Low Vulnerability or No Data. The SOVI for O‘ahu identifies the level of vulnerability of each community based on each of their characteristics to tsunamis, hurricanes, flooding, and sea level rise. O‘ahu’s Vulnerability Map is shown in Figure 4-4 below. As shown in Figure 4-4, one of the areas with a combination of all Vulnerability categories is O‘ahu’s Primary Urban Center (Resilience Office, 2019). Climate projections show coastal hazards such as tsunamis, hurricanes, flooding, and sea level exacerbating over time (US EPA, 2016). Population growth in coastal urban areas is also increasing overtime (Kasmalkar et al., 2020). Coastal hazards are exacerbated over time,

populations in coastal areas are also increasing over time, therefore densely populated coastal areas increase in vulnerability.

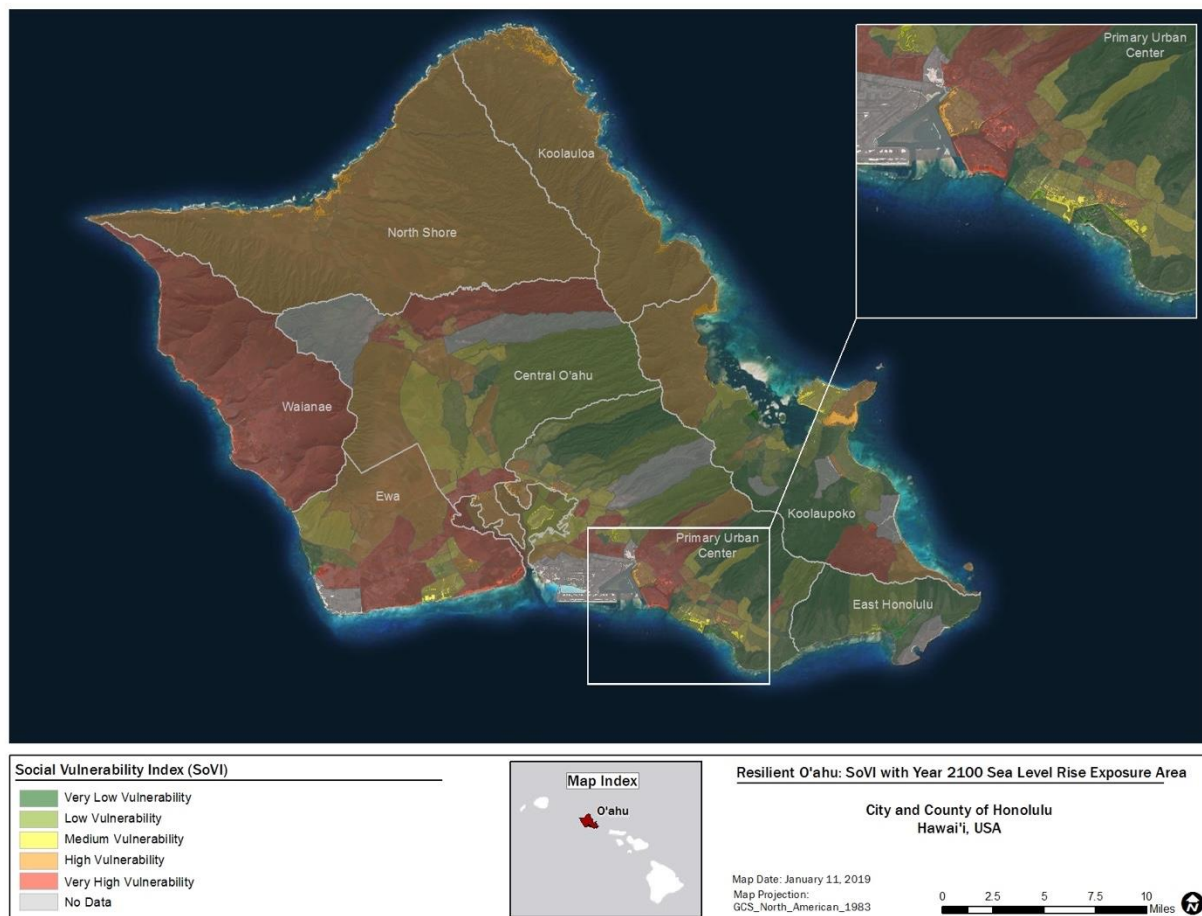


Figure 4-4: Vulnerability Map of O‘ahu using the SOVI, Socioeconomic Vulnerability Index, to characterize community’s vulnerability to tsunamis, hurricanes, flooding, and sea level rise (Resilience Office, 2019).

4.3.2 Hazard Identification

For the Ola O‘ahu Resilience Strategy, the climate risks can be categorized as either shocks or stresses. Shocks are short term events which can unexpectedly and rapidly occur. The main shocks to O‘ahu identified from engaged stakeholders are listed below the percentages indicate the percent of respondents who selected the shock.

- 1) Hurricane (77%)
- 2) Tsunami (51%)
- 3) Infrastructure Failure (37%)

- 4) Rainfall Flooding (29%)
- 5) External Economic Crisis (29%)

While shocks are immediate events to be addressed, stresses also threaten coastal communities as they are on-going strains that gradually deplete a community's strength (City and County of Honolulu, Hawaii, 2019). The main stresses on O'ahu identified from engaged stakeholders are listed below, the percentages indicate the percent of respondents who selected the stress.

- 1) Cost of Living (50%)
- 2) Aging Infrastructure (50%)
- 3) Climate Change Impacts (47%)
- 4) Lack of Affordable Housing (40%)
- 5) Over-reliance on imports (24%)

The 100 Resilient Cities(100RC) Program launched in 2013 and was financially supported by the Rockefeller Foundation. The 100 RC was dedicated to helping cities adapt and become more resilient to social, physical, and environmental stresses and shocks (City of Boston, 2016) and had chosen the City and County of O'ahu for the 100RC Program. In April 2019, the Rockefeller Foundation announced that they will no longer be funding 100RC. While the 100 RC program was overall successful with the intended goal of supporting cities in creating resilient strategies, this change may have been due to budget issues and leadership changes within the foundation in 2017 (Climate Initiative Platform, 2020). The foundation later agreed to fund some of the 100RC initiatives such as the Chief Resilience Officer (CRO) roles created in the cities. In 2019, the Office of Climate Change, Sustainability and Resiliency published the Ola O'ahu Resilience Strategy with 44 proposed actions. While the progress was not tracked through 100RC, the status of the proposed actions was identified in the 2021 Annual Sustainability Report published by the City and County of Honolulu. The status of each goal was reported as an action with 'Substantial Completion', 'Significant Progress', 'Action Initiated', and 'Not Started'. Out of the 44 actions proposed 2 were identified as with 'Substantial Completion' (4.54%); 16 with 'Significant Progress'(36.36%); 8 with 'Action Initiated'(18.18%); and 18 as 'Not Started'(40.90%)(City and County of Honolulu, 2021).

Considering that 29 out of the 44 actions proposed are underway, major progress was achieved in critical areas in 2020.

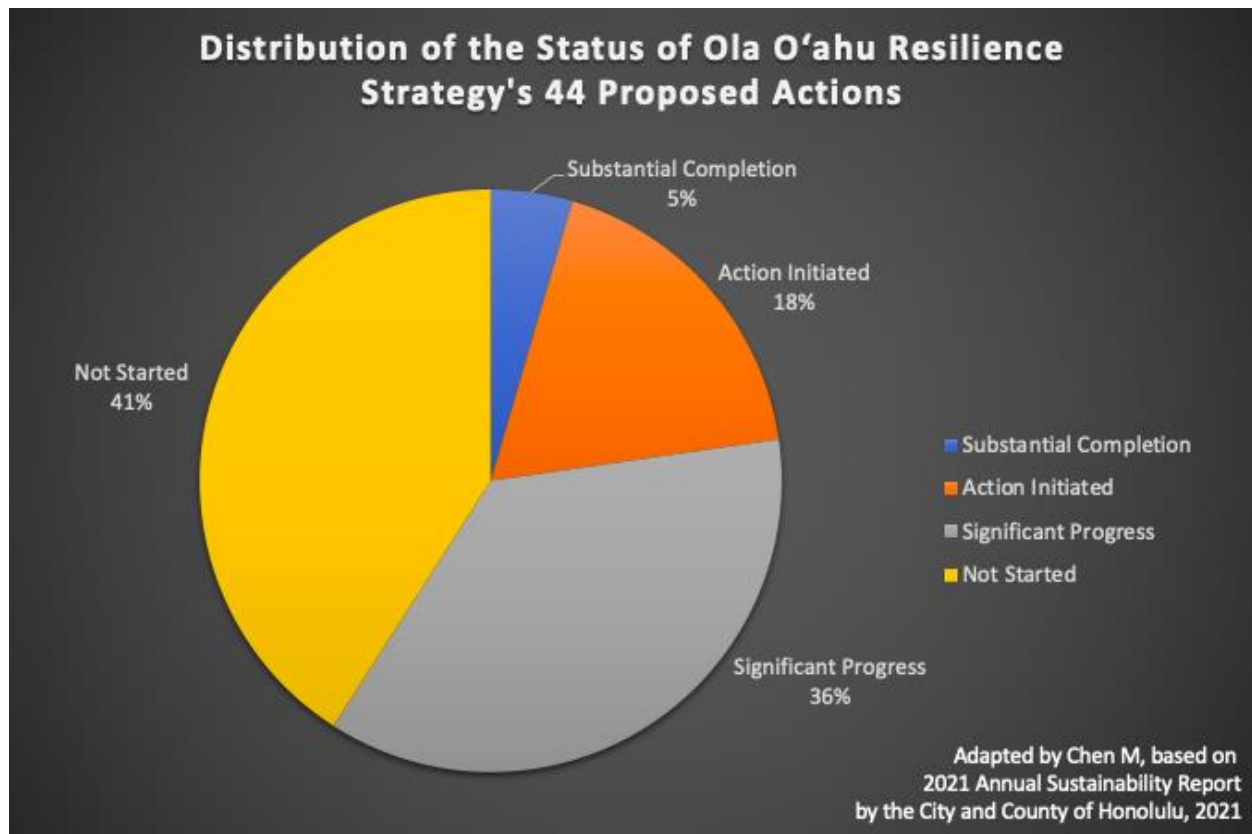


Figure 4-5: Distribution of the Status of Ola O'ahu Resilience Strategy 44 Proposed Actions
Adapted by Chen M, based on 2021 Annual Sustainability Report by the City and County of Honolulu, 2021

4.3.3 Ola O'ahu Resilience Strategy

In 2019, the Ola O'ahu Resilience Strategy was created through the inputs and collaboration of working groups, community members, business leaders, and non-profit organizations within Hawai'i. A few of the concerns that affect Honolulu's overall resilience is the widening gap between the rich and poor, the effects from increasing tourism activity, and climate risks and disasters that are increasingly putting stress onto local communities (City and County of Honolulu, Hawaii, 2019). The Ola O'ahu Resilience Strategy was developed and shaped over an 18-month period by grassroots O'ahu residents and community leaders. The Ola O'ahu

Resilience Strategy comprises of 44 actions to address the direct and indirect effects of climate hazards affecting the island inhabitants. Through the collaborative efforts from the local stakeholders, four Pillars or areas of focus were identified. The four Pillars are: 1) Remaining Rooted; 2) Bouncing Forward; 3) Climate Security; and 4) Community Cohesion (City and County of Honolulu, Hawaii, 2019). The first Pillar Remaining Rooted considers the high cost of living on the island and considers long term solutions for local communities. The second Pillar Bouncing Forward addresses the climate disasters and the measures that could increase the community's overall resilience. The third pillar Climate Security specifically applies to anthropogenic climate change challenges like the increase in greenhouse gas emissions and changing policies to incorporating protective measures against exacerbating climate change effects. And the fourth Pillar Community Cohesion is fostering connectivity and community, which was identified as the greatest strength in implementing these necessary and urgent changes. Within each pillar are three subsequent goals to achieve the pillar's outcome:

Pillar 1: Remaining Rooted

- 1) Supporting Affordable Housing Development
- 2) Reducing Additional Cost Burdens
- 3) Improving Economic Opportunity

Pillar 2: Bouncing Forward

- 1) Pre-Disaster Preparation
- 2) Effective Disaster Response
- 3) Successful Disaster Recovery

Pillar 3: Climate Security

- 1) Clean Energy Economy
- 2) Clean Ground Transportation
- 3) Climate Resilient Future

Pillar 4: Community Cohesion

- 1) Empower Grassroots Resilience Champions

- 2) Communicate and Affirm Island Values
- 3) Island-Wide Alignment

Within the Ola O‘ahu Resilience Strategy, the goals and plan recommendations that refer to flood events are listed under Pillar 2: Bouncing Forward and Pillar 3: Climate Security and shown in Table 4-4 below. Details on the selected actions and plan recommendations, the lead agency for the action, the timeframe, aligned Aloha+ Challenge Goal, primary aligned UN Sustainable Development Goal, and secondary aligned UN Sustainable Development Goal are listed under the Actions Summary Section from page 130 to 134 in the Ola O‘ahu Resilience Strategy.

Table 4-4. O‘ahu Flood Management Sections and Recommendations	
Pillar 2: Bouncing Forward	
Fostering Resilience in the Face of Natural Disasters	
Goals Referred	Action and Plan Recommendations
Goal 1: Pre-Disaster Preparation	<ul style="list-style-type: none"> • Action 11: Protect Lives and Property by Updating Building Codes • Action 12: Launch Residential Hurricane Retrofit Program to Strengthen Properties Vulnerable to Hurricanes • Action 13: Increase Flood Insurance Affordability for O‘ahu Residents • Action 14: Establish Future Conditions Climate Resilience Design Guidelines
Pillar 3: Climate Security	
Tackling Climate Change by Reducing Emissions and Adapting to Impacts	
Goals Referred	Action and Plan Recommendations
Goal 3: Climate Resilient Future	<ul style="list-style-type: none"> • Action 29: Protect Beaches and Public Safety with Revised Shoreline Management Rules • Action30: Protect Coastal Property and Beaches Through Innovation and Partnerships • Action 31: Establish a Storm Water Enterprise Fund to Better Finance Storm Water Management

Compiled by Chen M, based on *Ola O‘ahu Resilience Strategy* by the City and County of Honolulu, Hawaii, 2019.

4.3.4 Equity Approaches

Hawai‘i has the highest cost of living and housing prices within the United States and while development continues within O‘ahu, homelessness rates are steadily increasing, and O‘ahu continues to have the highest homelessness per capita rate within the nation (City and County of Honolulu, 2019). The Ola O‘ahu Resilience Strategy emphasizes the importance of returning to traditional values of equity and responsible stewardship to survive and thrive as an island community. Special recognition was placed on how as a society aloha, inclusion, equity, and respect for differences is a fundamental part to our collective identity. Within the Ola O‘ahu Resilience Strategy, specific equity actions and recommendations are shown in Table 4-5 below.

Table 4-5. O‘ahu Equity Actions and Plan Recommendations	
Pillar 1: Remaining Rooted Ensuring an Affordable Future for Our Island	
Goals Referred	Action and Plan Recommendations
Goal 1: Pre-Disaster Preparation	<ul style="list-style-type: none">• Action 1: Reduce Empty Homes and Increase Affordable Housing Funding• Action 4: Expand Affordable Housing Funding by Implementing Progressive Property Taxes• Action 5: Implement a Guaranteed Security Program to Support Local Home Ownership
Pillar 3: Climate Security Tackling Climate Change by Reducing Emissions and Adapting to Impacts	
Goals Referred	Action and Plan Recommendations
Goal 3: Climate Resilient Future	<ul style="list-style-type: none">• Action 25: Accelerate Carbon-Free New Mobility Options• Action 26: Ensure Equitable Access to Sustainable Transportation and Cost Savings

Compiled by Chen M, and based on *Ola O‘ahu Resilience Strategy* by the City and County of Honolulu, Hawaii, 2019

As with the flood management actions within the plan, details on the equity actions and plan recommendations are also listed under the Actions Summary Section from page 130 to 134 in the

Ola O‘ahu Resilience Strategy. Under the Actions Summary Section, the additional details given the equity measure are the lead agency for the action, the timeframe, aligned Aloha+ Challenge Goal, primary aligned UN Sustainable Development Goal, and the secondary aligned UN Sustainable Development Goal.

4.4 Comparative Gap Analysis of Resilience Plans

The robustness or completeness of the resilience strategies are included in this section covering the Comparative Gap Analysis of Resilience Plans. The Gap Analysis is conducted to determine the areas of strength, areas of improvement in the resilience plans, and to provide recommendations. The three guidance frameworks chosen for the Gap Analysis is the Arup City Resilience Framework, Equity by Design: Five Principles, and ‘4 Steps to an Effective Flood Management Plan’.

The Arup City Resilience Framework is the guidance document with guiding principles is used to analyze the influential resilience factors within the resilience plans and its capacity to function. The Arup City Resilience Framework has twelve guideline objectives which are: 1) Minimal Human Vulnerability; 2) Diverse Livelihoods and Employment; 3) Adequate Safeguards to Human Life and Health; 4) Collective Identity and Mutual Support; 5) Social Stability and Security; 6) Availability of Financial Resources and Contingency Funds; 7) Reduced Physical Exposure and Vulnerability; 8) Continuity of Critical Services; 9) Reliable Communications and Mobility; 10) Effective Leadership and Management; 11) Empowered Stakeholders; and 12) Integrated Development Planning. The Gap Analysis comparing O‘ahu, Maui, and Kaua‘i’s Resilience Plans using the Arup City Resilience Framework, assessing the robustness of the plans, is shown in Table 4-6.

Table 4-6. Gap Analysis Using the Arup City Resilience Framework for O‘ahu, Maui, and Kaua‘i Resilience Plans					
Guidance Document	Category	Guideline Objectives	O‘ahu	Maui	Kaua‘i
Arup City Resilience Framework	People: Health and Well-being	Minimal Human Vulnerability	x		x
		Diverse Livelihoods and Employment	x	x	

		Adequate Safeguards to Human Life and Health	x		x
	Place: Infrastructure and Environment	Reduced Physical Exposure and Vulnerability	x	x	x
		Continuity of Critical Services	x	x	x
		Reliable Communications and Mobility	x	x	
	Organization: Economy and Society	Continuity of Critical Services	x	x	x
		Reliable Communications and Mobility	x	x	
		Availability of Financial Resources and Contingency Funds	x	x	x
	Knowledge: Leadership and Strategy	Effective Leadership and Management	x	x	x
		Empowered Stakeholders	x	x	x
		Integrated Development Planning	x	x	x

Compiled by Chen M, based on the *Ola O‘ahu Resilience Strategy* by the City and County of Honolulu, Hawaii, 2019; *Maui Island Plan: Maui County General Plan 2030* by the County of Maui, 2021; and *Multi-Hazard Mitigation and Resilience Plan: Volume 1 of 2* by the County of Kaua‘i, 2021. Using the *City Resilience Framework* by Arup, 2014.

Table 4-6 shows if the Resilience Plans for O‘ahu, Maui, and Kaua‘i fall within the guidelines of the Arup City Resilience Framework. Overall, the Resilience Plan for O‘ahu met 100% of the Arup guideline objectives and provided a thorough and detailed plan of responsible agencies and timelines to mitigate and adapt to flood events and other flood related hazards. The Resilience Plan for Maui met 75% of the Arup guideline objectives, and is lacking in areas of addressing human vulnerability, safeguarding human health, and detailed actions specifically to protect social stability and security. The Resilience Plan for Kaua‘i also met 75% of the Arup guideline objectives, and is lacking in areas of ensuring job opportunities, protecting social stability and security, and reliable communications and mobility in the event of emergencies.

The Equity by Design: Five Principles is the framework used to identify areas within the plans that meet equity standards. This framework has five guideline objectives, they are: 1) Clarity; 2) Equity-Mindedness; 3) Equitable Practice and Policies; 4) Analyzing Effectiveness; and 5)

System Wide Principle. The Gap Analysis comparing O‘ahu, Maui, and Kaua‘i’s Resilience Plans in terms of equity using the Equity by Design: Five Principles framework is shown in the following table. Categories filled with an [x] indicate that the Resilience Plan met this guideline objective; categories filled with an [N/A] indicate that currently this category cannot be assessed due to insufficient information; and categories left blank indicate that the Resilience Plan did not meet this guideline objective. The presence and scale in which equity is addressed varies in different plans and on also on different levels of government. Overall, the degree to which equity was included and addressed in the three Resilience Plans varied.

The Resilience Plan for O‘ahu met 100% of the Equity by Design guideline objectives. In the Ola O‘ahu Resilience Strategy, importance was placed on returning to traditional values of equity and responsible stewardship to survive and thrive as an island community. Within the Ola O‘ahu Resilience Strategy, the five specific equity actions were listed in the plan and under the Actions Summary Section additional details can be found such as the lead agency responsible for the action, the timeframe, and the goal addressed through the action. In terms of equity measures in the plan, there are two goals with five actions that specifically address equity issue. The Ola O‘ahu Resilience Strategy was published in 2019 as a part of the 100 RC and while the Rockefeller Foundation stopped funding most of the 100RC program in April 2019, the status of the measures implemented was identified and tracked in the 2021 Annual Sustainability Report published by the City and County of Honolulu. Of the five actions aimed to improve equity, *Action 1: Reduce Empty Homes and Increase Affordable Housing Funding* has had action initiated and the remaining four actions have not been started.

The Resilience Plan for Maui met 20% of the Equity by Design guideline objectives. West Maui’s DWMC plan is lacking in clarity on equitable approaches, presence of equitable policies, analyzing effectiveness, and system wide principle. In the West Maui’s DWMC plan it is acknowledged in Section 1 Plan Framework that West Maui is vulnerable to current and predicted hazards as it is a region of coastal-focused development with substantial areas of unused agricultural land. While the DWMC plan considers and refers to the well-being of the West Maui community at large, the plan does not address specific vulnerable populations to flood events and equity concerns in a defined section within the document. In addition, as of

2021 the West Maui's DWMC plan is undergoing review for adoption, therefore there is no progress tracked or implementation reported on this plan.

The Resilience Plan for Kaua'i met 60% of the Equity by Design guideline objectives. Kaua'i's Draft 2020 MHMR plan is lacking in including equitable system wide principles. The plan is also lacking in tracking the effectiveness of the approaches, due to Kaua'i's Draft 2020 MHMR plan undergoing review for adoption as of 2021. Therefore, no progress has been tracked at the time this report was written. Kaua'i's Draft 2020 MHMR plan strove to consider equity by considering the diversity of communities within the County and each of their access to resources. In the Draft 2020 MHMR the vulnerable populations to flood events and other related hazard are listed in the hazard sections within the plan.

Table 4-7. Gap Analysis Using the Equity by Design: Five Principles for O'ahu, Maui, and Kaua'i Resilience Plans				
Guidance Document	Guideline Objectives	O'ahu	Maui	Kaua'i
Equity by Design: Five Principles	Clarity	x		x
	Equity-Mindedness	x	x	x
	Equitable Practice and Policies	x		x
	Analyzing Effectiveness	x	N/A	N/A
	System Wide Principle	x		

Source: Bensimon et al., 2015; City and County of Honolulu, Hawaii, 2019; County of Maui, 2020; County of Kaua'i, 2021a.

The '4 Steps to an Effective Flood Management Plan' is the guiding steps used to identify areas within the three Resilience Plans that meet effective flood management standards. This guiding document has four guideline objectives, they are: 1) Mitigation; 2) Preparedness; 3) Response; and 4) Recovery. The Gap Analysis comparing O'ahu, Maui, and Kaua'i's Resilience Plans in terms of flood management using the guiding document '4 Steps to an Effective Flood Management Plan' is shown in the following table. Categories filled with an [x] indicate that the Resilience Plan met this guideline objective. The presence and scale in which flood management is addressed varies between the three plans and on also on different levels of government.

Table 4-8. Gap Analysis ‘4 Steps to an Effective Flood Management Plan’ for O‘ahu, Maui, and Kaua‘i Resilience Plans				
Guidance Document	Guideline Objectives	O‘ahu	Maui	Kaua‘i
4 Steps to an Effective Flood Management Plan	Mitigation	x	x	x
	Preparedness	x	x	x
	Response	x	x	x
	Recovery	x	x	x

Source: SEH, 2021; City and County of Honolulu, Hawaii, 2019; County of Maui, 2020; County of Kaua‘i, 2021a.

Table 4-8 shows if the Resilience Plans for O‘ahu, Maui, and Kaua‘i fall within the guidelines of the ‘4 Steps to an Effective Flood Management Plan’. Overall, the Resilience Plans for O‘ahu, Maui, and Kaua‘i met 100% of the ‘4 Steps to an Effective Flood Management Plan’ and both addressed pre-, during, and post- flood event measures with thorough and detailed plans of responsible agencies and timelines on flood event measures along with other flood related hazards.

5. Recommendations

The preceding Gap Analysis found that the three Climate Resilience Plans had not addressed some of the criteria in the Arup City Resilience Framework or in the Equity by Design framework. In contrast, this research found that the three Resilience plans have thorough and detailed flood management strategies and met 100% of the flood management plan guidelines from the ‘4 Steps to an Effective Flood Management Plan’. Therefore, the recommendations in this section focus on addressing the resilience and equity gaps in the plans. I created examples of measures or approaches that could increase inclusivity and equity for communities in Hawai‘i that are increasingly threatened by the effects of anthropogenic climate change.

It is important to note that while the climate resilience plans for these three communities are relatively new, some of the actions related to increasing overall resiliency within the community have been ongoing within County departments, community organizations, and within state and federal agencies. Through the creation of the Climate Resilience plans, the county is now

specifically identifying, partnering, and referencing relevant actions by other agencies and organizations and bringing attention to these efforts.

5.1. Recommendation #1: Minimize Human Vulnerability

The first gap identified in the Resilience Plan analysis is on ‘Minimal Human Vulnerability’.

The category of Minimal Human Vulnerability refers to inclusive plans that focus on providing an adequate and dependable supply of essential services to a city’s entire population. I recommend providing and maintaining a secure, dependable, and reasonably priced water, sanitation, and energy system. My recommendation is aimed at West Maui’s DWMC plan. I recommend including equitable policies by coordinating a West Maui pre-disaster emergency plan in the event of urgent emergencies which require quick responses. Inclusive plans are essential in extreme circumstances to ensure that all community members have access to resources that meet their minimum needs, such as food and water (Arup, 2014). An example of a pre-disaster emergency plan is the State of Hawai‘i Emergency Operations Plan which is a useful framework that can be used to coordinate emergency measures and save lives and protect people, health, and property (HI-EMA, 2017). This plan establishes the emergency management responsibilities of state departments and how the Hawai‘i Emergency Management Agency (HI-EMA) will coordinate and respond in the event of a disaster. I recommend that the West Maui DWMC plan increase clarity and inclusivity by utilizing the State of Hawai‘i Emergency Operations Plan as a reference in forming a West Maui pre-disaster emergency plan. I also recommend that the West Maui emergency plan is continuously updated and revised to be accurate and relevant, coordinating with changing conditions and possible threats.

The DWMC plan must address the ‘Minimal Human Vulnerability’ gap by working on being more inclusive, including various city government departments, participants, and populations (especially marginalized groups) through every step of the planning and implementing process. I recommend sharing the cost and benefits of implementing actions throughout the city as an equitable solution to create a fair resilience plan. It is also important for climate plans to have cost effective actionable proposals that can reasonably be executed by the participants involved given the laws in place and the resources available (UN Habitat, 2015). The DWMC plan is a

result of a review from the West Maui Community Plan Advisory Committee (CPAC), a review from the members of the Maui Planning Commission (MPC) and was formed from substantial community input and collaboration with County and State departments. I recommend that these inclusive efforts continue, and regular updates be made on changing circumstances while working with the West Maui community to stay relevant and applicable. The DWMC team should reference the State of Hawai'i Emergency Operations Plan about which departments to coordinate with or refer to for specific concerns and on how to structure their own pre-disaster emergency plan.

5.2. Recommendation #2: Protect Livelihoods and Employment

The second gap identified in the Resilience Plan analysis is on 'Diverse Livelihoods and Employment'. The category of Diverse Livelihoods and Employment refers to plans with inclusive measures to ensure that every citizen in a community can find employment and has a secure livelihood. My recommendation is aimed at Kaua'i's Draft 2020 MHMR plan. I recommend that the MHMR plan improve in this guideline objective, as well as meet the Equity by Design objective of system wide inclusivity, by providing access to finance, skills training, and business support that help citizens explore the variety of livelihood and employment opportunity and help them meet their financial needs. To do this the MHMR plan would make information like financial grants readily available and accessible to the community. An example of a financial grant is the Hawai'i Financial Assistance program which provides support to needy families and parents with job preparation, and employment and support services that would eventually enable them to become self-sufficient (Department of Human Services, 2021). This program references strategies from the Pursuit of New Opportunities (PONO) welfare reform program which offers cash relief and the First-to-Work (FTW) program which extends employment preparation and support services. I recommend that the MHMR plan reference and incorporate measures from these programs to increase system-wide inclusivity and give their citizens access to financial and support services.

Additionally, I recommend that West Maui incorporates incentive programs and a living wage as a system wide principle increasing equity and job opportunities available for county citizens.

During periods of time where there are economic strain business aid programs can be offered to help businesses and individual citizens secure alternative employment (Arup, 2014). To address the ‘Diverse Livelihoods and Employment’ category, I recommend that the MHMR plan incorporates more relevant local priorities and deliver local benefits. Through including a broad range of perspectives from within the city government and the concerns of the overall community, a plan can be guaranteed to meet a wide scope of community goals that will garner extensive support (UN Habitat, 2015). While the MHMR plan does reference grants such as FEMA’s Pre-Disaster Mitigation (PDM) grant and the Hazard Mitigation Grant Program (HMGP), I recommend that the MHMR plan include additional grants such as the Hawai‘i Financial Assistance Program, PONO program, or FTW program to support social equity and secure financial livelihoods.

5.3. Recommendation #3: Safeguard Human Life and Health

The third gap identified in the Resilience Plan analysis is on ‘Adequate Safeguards to Human Life and Health’. The category of ‘Adequate Safeguards to Human Life and Health’ refers to plans with aspects such as accessible and reasonably priced health care services and suitable population-based interventions. My recommendation is aimed at Maui’s DWMC plan. I recommend that the DWMC plan implements adaptation and mitigation measures across sectors of the city and support broader regional objectives when possible and timely. This will address the ‘Clarity’ gap identified in the Equity by Design gap analysis. The ‘Clarity’ category can also be addressed by creating a clear and transparent policy- and decision- making process. I recommend a transparent policy making process in conjunction with milestones where the progress is tracked, recorded, verified by an outside party, and evaluated for overall efficacy.

I recommend that the DWMC plan improve in this guideline objective, as well as meet the Equity by Design objective of ‘Equitable Practice and Policies’, by implementing inclusive services and facilities that protect vulnerable groups and ensuring that there is a diverse network of medical practitioners in the event of an emergency. I recommend that reflective learning and future planning are implemented to fulfill the ‘Effectiveness’ category from the Equity by Design framework. These measures ensure that health practices are appropriate in the social and

physical context of the city e.g. preventative education (Arup, 2014). An example of inclusive services that protect vulnerable groups in Hawai‘i and includes preventative education is seen through the Leadership in Disabilities & Achievement of Hawai‘i (LDAH). LDAH strives to enhance educational, work, and life opportunities for youth at risk of disabilities by providing these children and their families with services such as screening, identification, training and advising, as well as through outreach and advocacy (LDAH, 2021). LDAH as a non-profit is an example of an organization implementing health measures appropriate to the social and physical context of Hawai‘i while also meeting the ‘Equitable Practice’ objective from Equity by Design.

5.4. Recommendation #4: Social Stability and Security

The fourth gap identified in the Resilience Plan analysis is on ‘Social Stability and Security’. The category of ‘Social Stability and Security’ refers to plans where a clear and transparent ethical system is established, including a mix of disincentive and functional policies. My recommendation is aimed at Maui’s DWMC plan and Kaua‘i’s Draft 2020 MHMR plan. I recommend that both plans implement evidence-based policies that reflect verifiable scientific knowledge and local community understanding. Using vulnerability assessments, emission transmission rate, and other relevant empirical data to inform decision making is another approach that could be taken to improve on ‘Social Stability and Security’ (UN Habitat, 2015). Kaua‘i’s Draft 2020 MHMR plan does include a risk assessment that identified local threats, its actors, and the possibility of these threats resulting in increased exposure or damage. However, I recommend that an additional vulnerability assessment be conducted to prioritize the threats and vulnerability within the system. The Sea Level Rise Vulnerability and Adaptation Report by the Hawai‘i Climate Change Mitigation and Adaptation Commission (HCCMAC) is an example of an assessment with relevant empirical data with recommendations that help inform decision making (HCCMAC, 2017). The HCCMAC recommendations combine verifiable data from the Intergovernmental Panel on Climate Change (IPCC) Assessment Report 5 (IPCC, 2014) with scientific reports from NOAA, NASA, and other peer-reviewed articles. This report represents verifiable scientific knowledge combined with local community understanding to inform policy making.

5.5. Recommendation #5: Reliable Communications and Mobility

The fifth gap identified in the Resilience Plan analysis is on ‘Reliable Communications and Mobility’. The category of ‘Reliable Communications and Mobility’ refers to plans with various, dependable, and comprehensive range of communication and transportation options in the event of emergencies to distribute appropriate information within the community, such as radio, internet, mobile phone services, and even specific modes such as social media outlets. Inclusive communication options are especially important when considering a community’s most vulnerable populations. My recommendation is aimed at Kaua‘i’s Draft 2020 MHMR plan. I recommend that the MHMR plan implement measures to ensure the availability of reasonably priced, reliable, and varied transportation systems, information, and communication technologies (ICT) networks, and contingency planning. I recommend applying area specific, comprehensive, and reasonably priced multi-modal transportation infrastructure systems. A variety of redundant transportation options establishes flexibility in the event of an emergency or in an increase in demand. An example of implementing redundant transportation options is seen in the Ola O‘ahu Resilience Strategy, under Goal 2 Action 25 the City committed to developing a Carbon-Free Corridor along the twenty-mile 21 station transit system (City and County of Honolulu, Hawaii, 2019). A New Mobility Working Group would be established to implement along this planned corridor a network of clean and sustainable micro-mobility options e.g., e-scooters, bike share, car share, and including other dockless mobility options. The City is also planning to expand the available bike lanes by 40 percent by 2023 to both increase the range of safe and protected lanes for bikes and for the increase in micro-mobility options.

Robust and redundant communication services also ensure that citizens have reliable access to information, which helps emergency services coordinate in the event of an emergency (Arup, 2014). I recommend that the MHMR plan implement equitable solutions to unequal communication avenues. The costs and benefits of improving communication and mobility methods can be shared across the community (UN Habitat, 2015). An example of increasing coordination and ensuring citizens have reliable access to information is seen through the Department of Community Services (DCS) in Hawai‘i working with local preparedness groups to locate vulnerable peoples within the community that might need extra assistance and resources

(City and County of Honolulu, Hawaii, 2019). This measure expanded to include neighborhood-level volunteer checks on the local vulnerable peoples before and during disasters.

6. Conclusion and Further Research

The overall objective of this research was to assess the climate resilience and adaptation initiatives in Hawai‘i’s Climate Resilience plans as they address coastal hazards. I aimed to examine the robustness of resilience strategies to sea level rise and flooding due to anthropogenic climate change. Within the Climate Resilience Plans of O‘ahu, Maui, and Kaua‘i, I focused on the physical impacts of climate change specifically from flood events and other environmental hazards that contribute to flooding such as hurricanes, tsunamis, and sea level rise. To achieve these objectives, the main research question of this study was: How robust are climate resilience strategies being developed by coastal communities in Hawai‘i? Considering the Arup guideline objectives, from most to least robust, O‘ahu’s Ola O‘ahu Resilience Strategy met 100% of the objectives and both Kaua‘i’s Draft 2020 MHMR plan and West Maui’s DWMC plan Maui met 75% of the objectives.

Disadvantaged communities are often disproportionately affected by coastal hazards and disasters. As the effects of climate change intensify, equity and vulnerable communities must be given extra consideration in resilience measures. The variety of coastal hazards must be identified and categorized for consistent assessment of their complimentary resilience measures. My subsequent sub-questions were: What are the types and severity of climate change-induced coastal hazards affecting Kaua‘i, O‘ahu, and Maui categorized? How can their resilience strategies be designed and implemented to ensure that vulnerable communities are not disproportionately affected by coastal hazards, especially flood events?

For the hazards affecting Kaua‘i, the resilience plan identified 10 hazards of concern in total, including tropical cyclone, wildfires, and climate change. Risk ranking was used to categorize the 10 hazards of concern from highest to lowest. For O‘ahu’s resilience plan, 10 risks were identified as either shocks (unexpected short-term events) or stresses (ongoing strains). Examples of shocks affecting O‘ahu are hurricanes and tsunamis. Examples of stresses affecting O‘ahu are aging infrastructure and lack of affordable housing. For Maui’s resilience plan, 12

topics of concern were identified including natural hazard, socio-economic, and cultural concerns. The topics of concern were listed in no specific order.

In the preceding Recommendations section, I created examples of measures that could increase inclusivity and equity for communities in Hawai‘i that are increasingly threatened by the effects of anthropogenic climate change. The recommendations focused on addressing the resilience and equity gaps in the three resilience plans as the analysis found that the plans had not addressed some of the criteria in the Arup City Resilience Framework or in the Equity by Design framework. In contrast, this research found that the three Resilience plans have thorough and detailed flood management strategies and they met 100% of the flood management plan guidelines from the ‘4 Steps to an Effective Flood Management Plan’.

Considering climate projections and how the rate of flood events, sea level rise, and hazard intensity are estimated to increase dramatically into the future (US EPA, 2016), it is imperative that measures are taken in Hawai‘i to protect their infrastructure, community, and inhabitants. It is also critical to pay attention to the feasibility or even the presence of measures proposed or taken to protect vulnerable Hawaiian communities from coastal hazards.

6.1. Conclusion

My research analyzed the Resilience Plans of O‘ahu, Maui, and Kaua‘i on the robustness of their plans, the categorization of their hazards, and the equity aspects integrated as well. The three chosen islands in this report were determined to be the most at risk and vulnerable to hazard exposure in Hawai‘i. The populations living in coastal areas are also increasing over time, this means that low-lying coastal communities are increasingly vulnerable to the effects of climate change especially as the effects of natural hazards are magnifying and exacerbating. The vulnerability of a coastal community and of specific individuals to disasters varies based on a plethora of interrelated factors, such as if they are employed, insured, or even on ethnicity.

Considering the Arup guideline objectives, from most to least robust, O‘ahu’s Ola O‘ahu Resilience Strategy met 100% of the objectives and both Kaua‘i’s Draft 2020 MHMR plan and West Maui’s DWMC plan Maui met 75% of the objectives. A robust system is well-designed,

implemented, and oversees physical functions so that endure and survive the effects of hazards without substantial damages or loss of function. Considering the comparative gap analysis, both Kaua‘i’s and Maui’s Resilience Plan can further prepare for possible failures to create a safe outcome with limited damages. This can be through addressing the objective ‘minimal human vulnerability’, covered in Recommendation 1, where a pre-disaster emergency plan is created for the community using the State of Hawai‘i Emergency Operations Plan as a guide.

Recommendation 2 addresses ‘Diverse Livelihoods and Employment’ where the Hawai‘i Financial Assistance program can be referenced to create local programs to provide support to needy families and parents in terms of job preparation and support services that would eventually enable them to become self-sufficient. Recommendation 3 addresses the gap in ‘Adequate Safeguards to Human Life and Health’ by providing an example of a local initiative, Leadership in Disabilities & Achievement of Hawai‘i (LDAH), that provide services to youth at risk of disabilities and their families with services such as screening and identification through outreach and advocacy.

In terms of the Equity by Design guideline objectives, the Ola O‘ahu Resilience Strategy met 100% of the objectives, Kaua‘i’s Draft 2020 MHMR plan met 60%, and West Maui’s DWMC plan met 20%. In the recommendations, the fourth gap ‘Social Stability and Security’ was addressed by referencing the Sea Level Rise Vulnerability and Adaptation Report which is an example of an assessment with relevant empirical data with recommendations that can help inform decision making. The fifth recommendation addresses the gap in ‘Reliable Communications and Mobility’, referring to the Department of Community Services (DCS) in Hawai‘i which is working with local preparedness groups to locate vulnerable peoples within the community that might need extra assistance and resources.

Through the comparative gap analysis, it was seen that the Resilience Plans for O‘ahu, Maui, and Kaua‘i met 100% of the ‘4 Steps to an Effective Flood Management Plan’ and addressed pre-, during, and post- flood event measures with thorough and detailed plans of responsible agencies and timelines on flood event measures along with other flood related hazards. In terms of flood preparation and emergency flood plans, all three Resilience Plans are well equipped to manage flooding as efforts to prepare for such events have been ongoing and continuously updated. The

three Climate Resilience Plans have thorough flood management measures as they met 100% of the flood management guidelines from the ‘4 Steps to an Effective Flood Management Plan’, therefore the recommendations were aimed at the gaps in the robustness and equity aspects.

While the Climate Resilience plans for these three communities are relatively new, some of the actions related to increasing overall resiliency within the community have been ongoing within County departments, community organizations, and within state and federal agencies. As the three most vulnerable and at risk islands to hazards, the plans are well prepared for flood events and adequately robust in terms of resiliency with varying degrees of equity addressed. Through creating the resilience plans, communities can now specifically identify and reference relevant departments to work with, possible solutions to local problems, and bring attention to these resources through publishing the resilience plans. It is timely to start planning robust mitigation strategies for coastal communities in Hawai‘i, as increasing flood events support climate projections findings and indicate that coastal communities and their inhabitants will be continuously threatened going into the future.

6.2. Further Research

Based on findings and limitations of this research, I suggest the following recommendations to further the research on equity approaches and overall robustness in Resilience Plans. The first recommendation for further research is aimed at Maui’s DWMC plan and Kaua‘i’s Draft 2020 MHMR plan. When are both approved for adoption, a more in-depth analysis is needed on the flood management measures within the plan’s climate change action sections, and on the range and scope of equity approaches, especially on addressing actions to protecting and care for the well-being of vulnerable peoples. The second recommendation is for monitoring and evaluation of the implementation of Maui’s DWMC plan and Kaua‘i’s Draft 2020 MHMR plan. After publication of the Plans and initiation of their actions, the implementing agencies should record and assess the success of the plans, especially in terms of the gaps like including diverse forms of livelihoods and adequate safeguards to human life and health. While the overall robustness of the three Climate Resilience Plans was analyzed in this report, future studies can continue to assess and compare the implementation of the Plans after Maui’s and Kaua‘i’s plans are

approved. The third recommendation is to conduct further analysis on the strengths of the Plans that could be utilized by other communities with similar characteristics, as well on the weaknesses of the Plans that need improvement.

Appendix

Table A-1. The Twelve Arup City Resilience Framework Indicators

The Twelve Arup City Resilience Framework Indicators	
Indicator	Explanation and Examples
Category 1 <i>People: Health and Well-Being</i>	
1) Minimal Human Vulnerability	<ul style="list-style-type: none"> • Inclusive plans focusing on providing an adequate and dependable supply of essential services to a city's whole population • Provide and maintain safe, reliable, and affordable citywide water, sanitation, and energy networks • Need coordinated and pre-prepared emergency plans in case of unexpected emergencies that need quick responses • In extreme circumstances, need inclusive plans that ensure all community members receive the minimum basic supplies, such as food and water
2) Diverse Livelihoods and Employment	<ul style="list-style-type: none"> • Access to finance, skills training, and business support enables individuals to explore a variety of options to obtain the assets that meet their essential needs • Training and skills development, microfinance, incentive and innovation programs, and a living wage • During times of economic strain, business incentives and aid programs to help businesses and individuals find diverse employment options • Inclusive approach to livelihoods where all citizens within a city can find employment
3) Adequate Safeguards to Human Life and Health	<ul style="list-style-type: none"> • Accessible and affordable day to day health care services • Appropriate population-based interventions (e.g., at the community or city level) • Effective, inclusive, and well-prepared medical staff and procedures • Responsive emergency services provided during surge capacity during a crisis • Reflective learning and future planning to ensure health practices are appropriate in a social and physical context of the city (e.g., preventative education) • Inclusive services or facilities that target vulnerable groups • In emergencies, a diverse network of medical practitioners and facilities

Category 2 <i>Place: Infrastructure and Environment</i>	
4) Reduced Physical Exposure and Vulnerability	<ul style="list-style-type: none"> • Appropriate design and construction of protective functions of city infrastructure • Integrate urban systems, of ecosystems and infrastructure, to reduce vulnerability and physical exposure • Building codes and standards that promote long-term robustness and flexibility to adapt, and safe failure mechanisms in the event of unexpected emergencies
5) Continuity of Critical Services	<ul style="list-style-type: none"> • Proactive management of critical ecosystem services and essential infrastructure • Educating communities on the importance of ecosystem services so there aren't any careless or damaging actions from lack of awareness • Frequent and active monitoring of essential ecosystem services and plans on improving and updating infrastructure as needed • Long-term robustness and flexibility to changing conditions can be aided through consistent and active monitoring and maintenance programs • Approaches that incorporate reflective aspects may be intelligent technologies that monitor service and infrastructure performance and distribute alerts in the event of performance declines
6) Reliable Communications and Mobility	<ul style="list-style-type: none"> • Possible through affordable, reliable, and diverse transportation systems and information and communication technologies (ICT) networks, and contingency planning • Ensure appropriate, inclusive, and affordable multi-modal transportation infrastructure systems (redundant and various options ensure flexibility in the event of emergencies or an increase in demand) • Have a diverse, reliable, and inclusive range of communication options in the event of emergencies to disseminate information within the community, such as radio, internet, mobile phone services, and even specific modes such as social media outlets (inclusive communication options are especially important when considering a community's most vulnerable populations) • Ensure robust and redundant communication services to enable safe and reliable communication and reliable access to information, which aids in events where emergency services need to be coordinated

Category 3 <i>Organization: Economy and Society</i>	
7) Collective Identity and Mutual Support	<ul style="list-style-type: none"> • Create cohesive and supportive cities through reinforcing local identity through supporting social networks and community organizations, artistic endeavors and preserving cultural heritage • Providing provisions of communal facilities, public spaces, and physical accessibility • Promote community engagement in planning and decision-making processes
8) Social Stability and Security	<ul style="list-style-type: none"> • Instituting a transparent social system based on ethical principles, where there is a combination of deterrents and effective policing • Promote prevention measures, such as preventative education • Reduce corruption by involving other relevant actors in law enforcement, such as community members
9) Availability of Financial Resources and Contingency Funds	<ul style="list-style-type: none"> • Create contingency funds available to both public and private sectors for emergencies • Align fiscal procedures in government • Careful structuring of city budgets to consider the availability of funds for infrastructure and emergency events • For the private sector, develop business continuity plans where businesses can continue functioning during and after emergencies • Diversify the city economy and, when appropriate, encourage public-private partnerships, direct investment, and grant funding
Category 4 <i>Knowledge: Leadership and Strategy</i>	
10) Effective Leadership and Management	<ul style="list-style-type: none"> • Refers to government, business, and society and is seen in trusted leaders, multi-stakeholder consultations, and decision-making using evidence and reliable data • Support relevant and effective decision making through multi-stakeholder and participant agreement and consultations within the community, including the private sector • Coordinated government practices and procedures (e.g., emergency management structures and emergency response plans) • Forging cross-sector relationships (e.g., with universities, grassroots organizations within the community) the effectiveness of coordination within the community increases in the event of an emergency

11) Empowered Stakeholders	<ul style="list-style-type: none"> • The baseline for empowered stakeholders is education, and this is reliant on updated and relevant information to ensure communities take appropriate action in the event of an emergency • Integrate early warning systems for appropriate hazards and access to education and information within the community • Ensure relevant information for decision making is up to date and evidence based to reflect the changing conditions • In terms of disseminating knowledge and identifying best practices, information exchange between cities is beneficial (e.g., city networks or ‘twin city’ schemes)
12) Integrated Development Planning	<ul style="list-style-type: none"> • Goals, integrated development strategy, and plans regularly reviewed and updated by cross-departmental groups indicate integrated development planning • Coordinate urban development and manage future investments by creating development plans and land use regulations • Develop a shared and aligned city vision with different stakeholders involved in designing and implementing city projects; a vision should be based on appropriate evidence, accepts underlying uncertainty, and accomplished through policy and regulations • Land Use Plans should be regularly updated and permanently enforced, with ongoing monitoring of urban patterns • Integrated strategies and processes should be inclusive to account of all members of society, especially the most vulnerable populations

Table A-2. The Five Principles for Enacting Equity by Design

The Five Principles for Enacting Equity by Design	
1) Clarity in language, goals, and measures is vital to effective equitable practices	<ul style="list-style-type: none"> • Clarity in language: inequality is revealed or hidden in structural organizations through language imbued with political and social meaning • Clarity in goals and measures: quantitative data must be available in user-friendly formats to avoid confusion <ul style="list-style-type: none"> ○ The Center for Urban Education designed the Benchmarking Equity and Student Success Tool (BESST) an interactive tool

	that helps make the message behind the data visible, understandable, and usable for practitioners
2) “Equity-mindedness” should be the guiding paradigm for language and action	<ul style="list-style-type: none"> • Color-conscious (as opposed to color-blind) in a critical sense: noticing and questioning outcomes that place minoritized peoples in unexplained outcomes • Aware that beliefs, expectations, and practices assumed to be neutral can have outcomes that are racially disadvantageous: recognizing practices based on stereotypical assumptions that creates racial disadvantages • Willing to assume responsibility for the elimination of inequality: allowing for the possibility of inequalities magnified by taken-for-granted policies, inadequate knowledge, or lack of institutional support – all of which can be changes • Aware that while racism is not always overt, racialized patterns nevertheless permeate policies and practices in structural organizations: policies disproportionately impacting people of color have an effect of maintaining racial hierarchies
3) Equitable practice and policies	<ul style="list-style-type: none"> • Equitable practice and policies are designed to accommodate differences in the contexts of people’s backgrounds– not treat everyone the same
4) Enacting equity requires a continual process of learning, disaggregating data, and questioning assumptions about relevance and effectiveness	<ul style="list-style-type: none"> • The Center of Urban Education has drawn on participatory critical action research, an approach preferred to social and educational change, where practitioners are able to question inequitable routines, advance habits of equity minded practice, and continuously improve
5) Equity must be enacted as a pervasive institution- and system-wide principle:	<ul style="list-style-type: none"> • Reframing inequality as an issue created by color-blind practices and enacting equity as an institution- and system- wide principle would mean practitioners would have to: <ul style="list-style-type: none"> • Let go of traditional schemata • Understand the difference between horizontal and vertical equity:

	<ul style="list-style-type: none"> i. Horizontal equity claims that those with equal needs deserve equal access to resources ii. Vertical equity, more widely endorsed, states that those with greater needs should receive greater resources <ul style="list-style-type: none"> • Learn to make the pursuit of equity a normal practice
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Table A-3. ‘4 Steps to an Effective Flood Management Plan’

‘4 Steps to an Effective Flood Management Plan’	
Phase	Additional Details
<p>1. Mitigation</p> <p>Mitigation measures are meant to considerably decrease or completely nullify flood risks before the events occur. A few of the common flood mitigation measures are:</p>	<p>A few of the common flood mitigation measures are:</p> <ul style="list-style-type: none"> • Reviewing and improving building codes and zoning, communities can also participate in FEMA’s Community Rating System where community members and local property owners can receive flood insurance premium reductions • Perform a vulnerability analysis, locating flood prone areas and assess alternative measures that can be applied to decrease the risk and damage from flood events • Utilize Geographic Information Systems (GIS) to create a database of infrastructure and natural resources that note historic and existing water systems, which is useful for a plethora of situations such as hydrologic modeling • Incorporate and enact mitigation projects, which can address a variety of water management systems and can include a mix of traditional and inventive measures like levees, wetland restoration, and even storm water reuse. • Conduct public outreach and education to increase public awareness of flood risk and knowledge of easily accessible tools available to the public to help stay informed
<p>2. Preparedness</p>	<p>A few ways to achieve this is:</p> <ul style="list-style-type: none"> • Develop and tailor a plan that addresses the individual and unique needs of the community

<p>Preparedness measures implemented to appropriately prepare and get a sense of preparedness for emergency flood events.</p>	<ul style="list-style-type: none"> • Practice emergency drills and run-throughs to locate areas of improvement in the plan and address them accordingly • Incorporate and use emergency warning systems and use publicly available tools to predict flooding patterns • Purchase flood insurance, which can be obtained by anyone whose community is a part of the National Flood Insurance Program (NFIP) • Document existing infrastructure. Obtaining accurate and up to date data is a preventative measure that can help save money. • Provide appropriate maintenance when necessary, for example for clearing drainage structures with proper equipment using appropriate safety measures • Identify and store emergency materials in the event a flood occurs. Examples of materials could be pumps, sandbags for emergency levees as well as food, water, and emergency kits
<p>3. Response</p> <p>This phase includes post-flooding assistance like emergency relief and search and rescue</p>	<p>The specific of this phase depends and varies based on the community's individual characteristics and needs. Though the main purpose of this phase is to meet basic needs until the recovery phase starts</p>
<p>4. Recovery</p> <p>The recovery phase is intended to close the schism between emergency and normalcy. This phase may comprise of constructing emergency housing, rebuilding, disaster counseling, and</p>	<p>Additional measures that are helpful for the community but are often overlooked are:</p> <ul style="list-style-type: none"> • Applying for grants: FEMA's Hazard Mitigation Assistance (HMA) grant programs include both pre- and post- disaster funding opportunities. • Documenting the flood events: after the flood event and when safe to do so, the high-water lines can be marked to note the maximum flood capacity; photographs are also helpful but only taken in safe locations; and interview residents impacted by the event. This information can be used to show need for financial assistance, educate the public on the severity of flood events, and increase flood modeling accuracy.

supplementary education.	
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