# Building Code Amendments to Reduce Existing and Future Building Stock Vulnerability To Coastal Hazards and Climate Impacts In the City and County of Honolulu

## Final Report

**October 31, 2018**

**For the State Office of Planning**

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*Disclaimer: The following further proposed amendments, changes and/or revisions to the existing federal, state and/or county codes, laws, statutes, ordinances, regulations and/or standards discussed in this report were not suggested for immediate adoption and implementation. The proposed amendments, changes and/or revisions must still be evaluated for county priorities, financial costs and benefits, additional data needs, and operational capabilities, which are beyond the scope of this report.*

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## Executive Summary

The primary goal of this project is to develop disaster resilient measures for use with the relevant codes applicable to the City and County of Honolulu, in order to reduce building construction vulnerability to coastal natural hazards with consideration of climate change effects. Disaster resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. Building codes and regulatory standards currently in effect for the City and County of Honolulu are evaluated with respect to any applications that may need to be updated due to future changes in these hazards. The following effects are pertinent to the vulnerability of buildings and their foundations located in the coastal zone:

i. Sea level rise and increasing rates of beach erosion and groundwater rise
ii. Sea Surface Temperatures increasing and increased tropical cyclone activity
iii. Inundation / flooding from storms and tropical cyclones

Relative sea level rise is the combination of long-term land subsidence and sea level change. In the Intergovernmental Panel on Climate Change - Fifth Assessment Report of 2013, the ensemble mean estimates of the increasing rates of relative sea level rise are given. The current rate of Hawai`i relative sea level rise is actually lower than the global rate. Using this information and applying this to Hawai`i together with the rate of land subsidence, for the more severe RCP8.5 carbon pathway scenario, and assuming no lag between Hawai`i and the global rate, a range of 0.5m to 0.67m (1.6 ft. to 2.2 ft.) is indicated at the end of the century. Accordingly, 2 ft. is suggested as the upper bound of relative sea level rise for Hawai`i based on IPCC AR5 and discounting the present lag. Ambient groundwater in the coastal zone will respond to sea level and tidal fluctuations.

Changes in Sea Surface Temperatures (SST) and climatic circulation patterns may affect the distribution of storm tracks; thus, the hazard for hurricane wind speeds and storm surge/wave setup inundation may not be stationary over time. Sea level rise (combined with land subsidence of the older islands) can result in shoreline changes and higher apparent sea level (relative to a point on land), and this can exacerbate inundation, especially for low-lying areas subject to hurricanes and high surf.

Inundation hazard maps that include climate change effects can be developed for Hawai`i regulatory implementation. It is now possible to obtain stochastic simulations of future tropical cyclone tracks based on downscaled CMIP5 global climate models that have improved modeling of ENSO and Pacific Decadal Oscillation cycles to account for future hurricane events influenced by climate change under various greenhouse gas scenarios. A pilot study of coastal storm inundation for the Kakaʻako-Waikiki coastline including climate change (i.e., sea level rise and change in the distribution of storm track effects) has been performed as a proof-of-methodology. This work should continue so that impacts on the other coasts can be determined.

Sea-level rise and storm intensification pose a combined engineering, social, and economic problem to coastal communities. The regulatory needs addressing climate change have been discussed with stakeholder groups and enforcement agencies under the state or county sponsorship, and the relevant future revisions to improve climate change resiliency were further developed with their input. The language of coordinated revisions to the appropriate codes and standards are now assembled in this report for consideration by the City and for evaluation of their potential applicability by other counties in the state. Such regulatory updates are appropriate to consider implementing over time because the physical and functional lifespans of many types of structures, particularly critical facilities and public infrastructure built by government, will extend into the end of the century.

Initial stakeholder organizations included per the DBEDT Office of Planning:

- City and County of Honolulu Department of Planning and Permitting (DPP)
- State Building Code Council
- HI-EMA Weather Impacts Advisory Committee
- Marine and Coastal Zone Advocacy Council (MACZAC)
- Hawai`i Ocean Partnership Coordinated Working Group

Additional stakeholders to include in next discussions:

- Honolulu Office of Climate Change, Sustainability, and Resiliency – the office created in 2017 to oversee the city's efforts to reduce the effects of climate change on city facilities and the community, especially in the coastal zones
- State of Hawai`i Interagency Climate Adaptation Committee (ICAC), attached administratively to the Hawai'i Department of Land and Natural Resources (DLNR) and co-chaired by the chairperson of the Board of Land and Natural Resources (BLNR) and the director of the Hawai'i Office of Planning (OP). The first task of the ICAC is to develop a statewide Sea Level Rise Vulnerability Assessment and Adaptation Report (SLR Report) by December 31, 2017. Act 32 Session Laws of Hawai`i (SLH) 2017 amended HRS Chapter 225P by renaming the ICAC the "Hawai'i Climate Change Mitigation and Adaptation Commission".
- University of Hawai`i Sea Grant College - Hawai`i Sea Grant has five focus areas which explore pressing issues related to the coasts and coastal economies, and specifically has a Center for Coastal and Climate Science and Resilience:
    - Sustainable Coastal Development
    - Hazard Resilience in Coastal Communities
    - Sustainable Coastal Tourism
    - Indigenous Cultural Heritage
    - Water Resource Sustainability

## Major Findings/Recommendations

- Along the south shore of the Honolulu urban core, the present day NFIP FIRMs, ostensibly representing a 100-year coastal flood, was found to be expanded well past the expected 100-year flood using a refined model, even when sea level rise and the future storm climatology are explicitly included. Therefore, especially for residential construction, it does not appear justified to consider any expansion of the NFIP FIRM due to climate change effects up through the end of the century. The NFIP FIRM maps appear to be similar to 200-300 year flood hazard maps, and implicitly if unintentionally, accounts for some sea level rise.
- The adequacy of the flood insurance rate maps is not known for the north and east shores with respect to future climate change influences, and these areas should be studied further using the techniques of this pilot study and applying this methodology towards a new generation of coastal inundation hazard maps for the remainder of the island of Oahu.
- Probabilistic flood hazard assessments can facilitate planning and regulation of coastal development. In this work a pilot study was performed to establish a practical methodology for mapping of coastal flood hazards associated with sea-level rise and storm intensification toward the end of the 21st century. As demonstrated in the pilot study, the data products from this methodology define the risk basis for future updates of building codes and other regulations to account for climate change. Therefore, use of this methodology should be continued so that end of the century probabilistic inundation maps for the other coastal areas of Oahu and the other Hawaiian islands can be used in the implementation of the climate adaptation process.
- Additional technical watershed and hydrographic studies should be started based on future rainfall intensification during tropical cyclones. The inherent target reliabilities of civil flood control infrastructure should be re-examined. It is recommended that the storm water flood control practices that address requirements for storm runoff quantities for flood control be re-evaluated for possible changes to various flood control design practice standards.
- The severity and probability of extreme flood events depend more significantly on the likelihood of more intense hurricanes in the future than the uncertainties in the sea level. Government infrastructure and flood control projects would be the most effective investment in mitigating these effects, based on the pilot study of the south coast of urban Honolulu. For government and infrastructure projects with much longer functional lifespan requirements, the investment for sea level rise would be applicable for projects in the current planning timeframe.
- However, investment costs for climate change effects could also be justified to be deferred for properties with an economic payoff period of investment of less than 50 years, i.e., low-rise single family residential properties. This deferrable period would be economically arguable because the increased risk to these properties occurs only after sea levels rise approximately 2 ft.
- Therefore, the general approach recommended for adaptation to climate change effects is to focus on public investment in the design of critical facilities (Risk Category III per

the building code), essential facilities (Risk Category IV per the building code), and civil and transportation, combined with appropriate shoreline setbacks and mandatory disclosures of natural hazards that would include future expected sea level rise and erosion of the shorelines.
- The City should consider an adaptive engineering approach. Adaptive engineering is the approach to include the flexibility in the design of facilities to accommodate future modifications without incurring excessive costs prior to the time when features for climate change are necessary (i.e., it is a low regret adaptive strategy in which expenditures have a higher probability of public benefit despite the uncertainty in future scenarios). In accordance with Adapting Infrastructure and Civil Engineering Projects to a Changing Climate (ASCE, 2015), the report utilized best-available science available as of the report's drafting date to arrive at its analyses, findings, conclusions, opinions, and/or recommendations.

## Next Steps

Recommendations for immediate implementation:

- *HRS Chapter 107 Part II* – Hawai`i State Building Code: Include a mandatory state adoption of the IBC if the administrative rule process fails to meet the existing statutory deadline.
- *ROH Chapter 16* – Building-Code applicable revisions for Risk Category III and IV structures: Revise rainfall intensity maps; Adjust windspeed maps; require minimum elevation of the lowest horizontal structural member based on 500-year flood elevation with relative sea level change; consider shoreline erosion in foundation design
- Public Utilities Commission: The PUC should adopt the windspeed maps of the 2010 Hawai`i State Building Code, to replace the National Electric Code (NEC) 2012 Figure 250-2.

Other Recommendations:

The following further proposed amendments, changes and/or revisions to the existing federal, state and/or county codes, laws, statutes, ordinances, regulations and/or standards discussed in this report were not suggested for immediate adoption and implementation. The proposed amendments, changes and/or revisions must still be evaluated for county priorities, financial costs and benefits, additional data needs, and operational capabilities, which are beyond the scope of this report.

- Implementation of coastal flooding mitigation by 2025 (some prerequisite technical maps to be further developed):
    - *ROH Chapter 21A* – Flood Ordinance: Locally develop and adopt a 500-year flood zone applicable to Risk Category III and IV Structures that incorporates sea level rise.

- *ROH Chapter 17* – Electrical Code: Require placement of critical equipment for Risk Category III and IV Structures above 500-year flood or incorporate dry floodproofing protection.
- *ROH Chapter 23* – Shoreline Setbacks: Adopt 50-year setbacks based on historic shoreline erosion rates for Oahu - only for new construction and with exemptions for size / shallowness of lot.
- *ROH Chapter 25* – SMA: Create a Coastal Construction Control Zone to account for sea level rise, shoreline erosion, and coastal flood and hurricanes under future climatic conditions. For Major Permits within the Special Management Area, require evaluation of ~2 feet of relative sea level rise.
- *HRS 205A* – Certified Shoreline: For planning purposes, also include an Expected Shoreline map taking into account shoreline erosion and relative sea level rise over the next 50 years.
- *HRS Chapter 484* - Uniform Land Sales Practices Act: To explicitly include certain natural hazards as well as the expected 50-year erosion of a shoreline, i.e., as defined by the Expected Shoreline map.

- Additional implementation of supporting codes for consistency and comprehensiveness of climate change effects on weather:

  - *ROH Chapter 19* – Honolulu Plumbing Code: For Risk Category III and IV Structures, develop and adopt 500-year rainfall intensity maps.
  - *ROH Chapter 20* – Fire Code: Develop regulatory maps of historic burn areas for use in these regulations based on NFPA-1 and for mandatory seller disclosures.
  - *ROH Chapter 32* – Building Energy Conservation Code: Adopt American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data
  - *HRS Chapter 508D* – Mandatory Seller Disclosures in Real Estate Transactions: Make the mandatory seller disclosure apply to transactions involving vacant lots.

# 1. Project Goals and Objectives

The primary goal of this project is to develop disaster resilient measures for adapting the relevant codes applicable to the City and County of Honolulu for the purpose of reducing building construction vulnerability to natural hazards with consideration of climate change effects. Disaster resilience is the ability to prepare and plan for, absorb, recover from, and more successfully adapt to actual or potential adverse events. This project has developed building code and regulatory amendments to reduce existing and future building stock vulnerabilities to coastal hazards and climate impacts. Note that this project relates to natural hazard and climate change adaptation, or accommodating the potential climate change effects, not climate change mitigation efforts to reduce the amount of climate change (such as trying to reduce the rate of introduction of carbon into the atmosphere); nor does the project necessarily relate to any other energy efficiency/sustainability goals of the State of Hawai`i.

Objective 1: Examine the building codes currently in effect for the City and County of Honolulu and inventory existing regulatory standards intended to protect life and property from coastal hazards and climate impacts.

Objective 2: Propose code amendments to strengthen and/or replace existing regulatory standards in order to reduce existing and future building stock vulnerability to coastal hazards and climate impacts. Include a pilot study of developing 500-year inundation maps including climate change effects.

Objective 3: Preliminarily assess possible implications and feasibility of implementing proposed code amendments, including, but not limited to, the estimated economic cost of implementation.

Objective 4: Develop model ordinances that are transferable for use and potential adoption by the four main counties in Hawai`i, including the City and County of Honolulu, County of Hawai`i, County of Kauai, and County of Maui.

Objective 5: Recommend additional technical information/studies needed to substantiate or implement the proposed code amendments.

# 2. Anticipated Future Coastal Hazard and Climate Impacts to the City and County of Honolulu

Climate change can be summarized as including the following potentially adverse effects to the Hawai`i coastal zone:

i. Sea level rise and increasing rates of beach erosion
ii. Groundwater rise
iii. Sea Surface Temperatures increasing with more frequent Central Pacific El Niño Southern Oscillation (ENSO) events and increased tropical cyclone activity
iv. Inundation / flooding from storms and tropical cyclones
v. Increase in the number of unusually warm days
vi. More severe and longer drought periods due to reduced annual rainfall following a documented drier climate trend for Hawai`i (such as affected by changes in the trade winds per Garza and Chu, et al. 2012); rainfall variation by season altered per duration of ENSO events

Effects i. through iv. are pertinent to the vulnerability of buildings and their foundations located in the coastal zone. These climate change impacts are also of potential relevance to state and county design standards to include stormwater and wastewater infrastructure, flood control infrastructure, coastal zone utility vulnerability, coastal transportation infrastructure, and port and harbor operations.

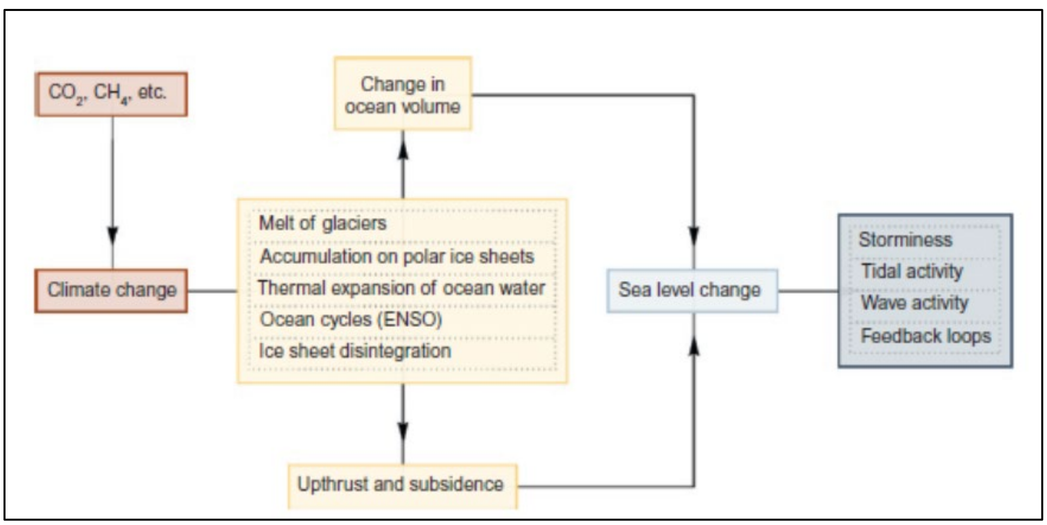


**Figure 2-1. Relative Sea Level Change**

Effect v., an increase in the number of unusually warm days, would influence energy demand and the management of wildland fires. An illustration of climate changes in temperature distributions affecting the frequency of extreme weather conditions is shown in Figure 2-2 for the example of temperature, (Based on IPCC (2012): Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation). Change can take the form of a shift of the entire distribution, and change in the variability of the distribution, or a change in the frequency distribution of the weather metric itself.

Effect vi., the increasing severity and length of drought periods, may be pertinent to water availability, water demand, and reductions in agricultural and ranching productivity, but it does not create an increased vulnerability of the building stock or infrastructure itself. It may require the implementation of water conservation requirements.

Models indicate that the primary environmental responses to radiative forcing are:

- Increasing ocean temperatures, which results in sea level rise due to thermal expansion
- Melting of glaciers (on land).
- Greenland and Antarctic land-ice sheets and Arctic floating ice sheets are not high contributors to sea level rise, according to the IPCC

Therefore, this effect is not uniform and regional relative sea level rise must be considered. However, predictive climate models are admittedly subject to much uncertainty and much variation between numerous models. Therefore, usually an ensemble mean of model results is used as an estimate (such as presented by the IPCC assessments), or a range of the likely values (more than 66% likelihood of realization) is considered.

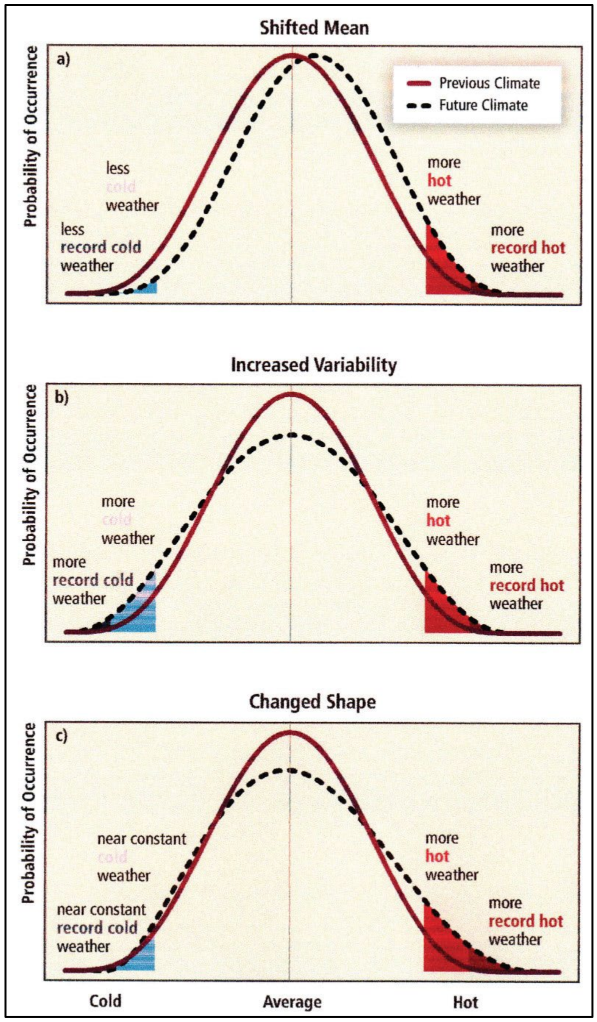


**Figure 2-2. Illustration of Various Modes of Climate Change Resulting in a Greater Frequency of Extreme Conditions**

Historical Relative Sea Level Rise:

The rate of relative sea level rise over 50-year or 100-year periods published in the NOAA literature for Hawai`i (NOAA, 2009); sea level trend data is also available with data up to 2014 from the NOAA Tides and Currents website – Sea Level Trends page is based on historical observation by tide stations in Hawai`i beginning in the 20th century (e.g., for Honolulu, see Figure 3). *The historical data does not show an acceleration in the rate of sea level rise*. *Future sea level rise estimates for the Hawai`i region of the Central Pacific are based on model simulations*.

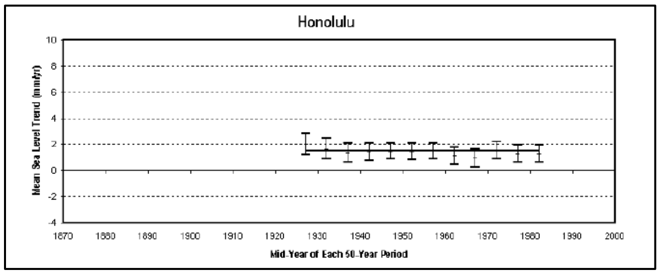


**Figure 2-3. Example Historical Rate of Sea Level Rise for Honolulu (NOAA, 2009)**

Anticipated Sea Level Rise for Hawai`i:

In the IPCC - Fifth Assessment Report of 2013, the Physical Science Basis, Chapter 13 Sea Level Change (Church, et. al., 2013), the ensemble mean estimates of the increasing rates of relative sea level rise are given. Using this information and applying this to Hawai`i together with the rate of land subsidence, a range of ensemble estimates can be calculated for the two more severe Representative Carbon Pathways (RCP), scenarios 6.0 and 8.5.

Future sea levels can thus be estimated starting from the published rate of Hawai`i relative sea level rise, which is lower than the global rate, or for an *upper bound* of this parameter, assuming that the local rate in the Hawai`i region would not lag behind the global rate (however, this assumption is actually contrary to the historical data trend up to 2014). Figures 2-4 and 2-5 show the results of variations of the present sea level rise rate and the RCP6.0 and RCP8.5 carbon pathway scenarios. For the more severe RCP8.5, a range of 0.5m to 0.67m (1.6 ft. to 2.2 ft.) is indicated. Accordingly, 2 ft. is utilized in this report as the relative sea level rise for Hawai`i based on IPCC AR5.

Note that because there is a lag in the actual sea level rise in Hawai`i compared to the modeled estimated global rate, the combined effect of sea level rise and land subsidence would be expected to result in approximately only 0.05m (2 inches) of relative sea level rise in the 2025-2030 timeframe. It is therefore recommended that the implementation initiation of climate change adaptive codes and regulations would be in the 2025-2035 timeframe. From that point in time, projects with service lifespans of 50-75 years hence would fall into the period of the last decades of the 21st century when the climate change effects considered in this report would take place.

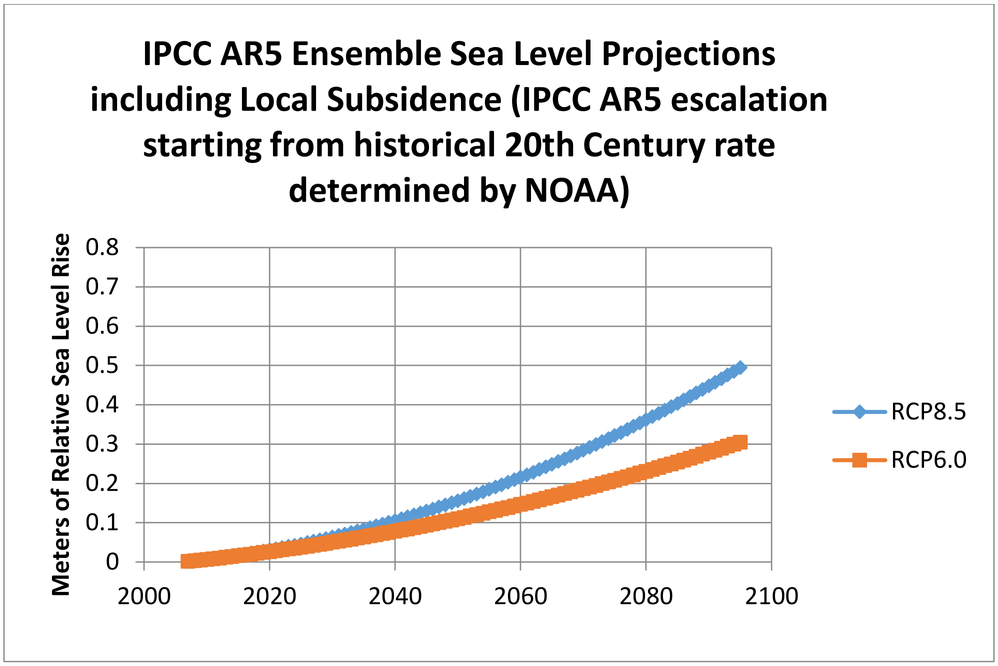


**Figure 2-4. Estimate of Relative Sea Level Rise for Hawai`i with RCP 6.0 and RCP 8.5, assuming the present local relative sea level rise rate is the value given in the NOAA literature based on empirical 20th century data (which lags the estimated global rate of sea level rise)**

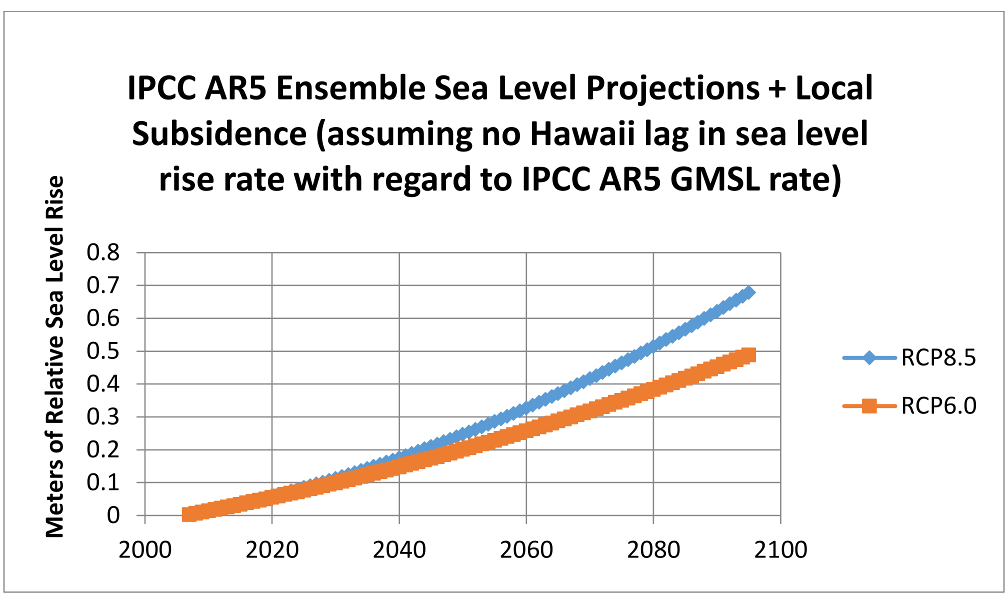


**Figure 2-5. Estimate of Relative Sea Level Rise for Hawai`i with RCP 6.0 and RCP 8.5, discounting the present local relative sea level rise rate lag with respect to the IPCC global estimated rate**

Estimating Changes in Tropical Cyclone Activity:

Particularly relevant to building and infrastructure planning and design are the effects of sea level rise and the effects on tropical cyclone activity. These effects can result in increases in coastal inundation and wind hazard levels from storms and tropical cyclones, and flooding from the associated intense rainfall, which could reduce the disaster resilience of coastal infrastructure and development unless adaptive measures are implemented in future design standards.

Changes in Sea Surface Temperatures (SST) and climatic circulation patterns may affect the distribution of storm tracks; thus, the hazard for hurricane windspeeds and storm surge/wave setup inundation may not be stationary over time. Sea level rise (combined with land subsidence of the older islands) can result in shoreline changes and higher apparent sea level (relative to a point on land), and this can exacerbate inundation, especially for low-lying areas subject to hurricanes or tsunamis.

For example, a suite of future warming experiments (representative of the period 2075–2099) was performed by Murakami (2013), using one of the earlier Coupled Model Inter-comparison Project 3 (CMIP3) global climate models, the Japan Meteorological Agency / Meteorological Research Institute Coupled Ocean-Atmospheric General Circulation Model MRI-CGCM. The model analysis indicated a substantial increase in the likelihood of tropical cyclone frequency around the Hawaiian Islands, primarily associated with a northwestward shifting of the tropical cyclone track in the open ocean southeast of the islands (Figure 2-6).

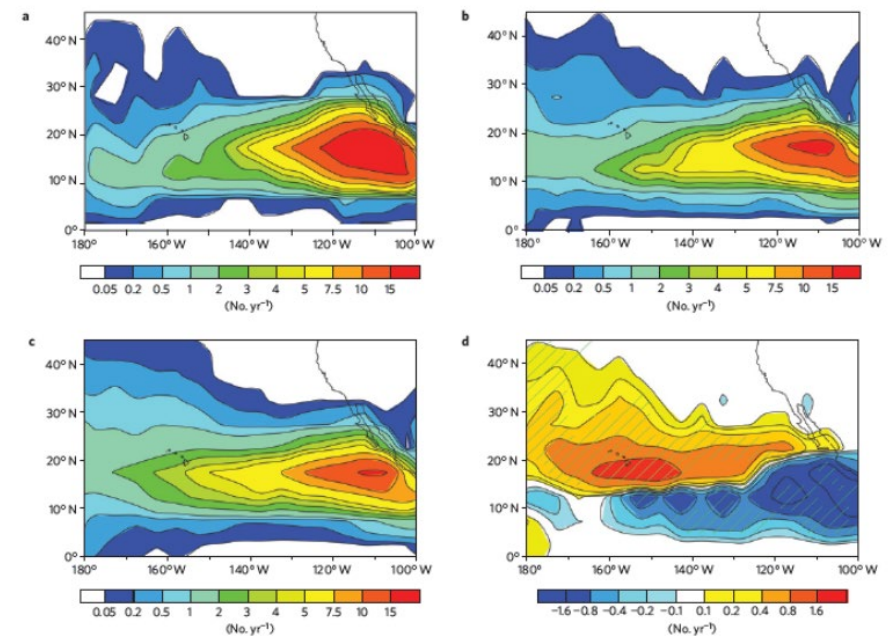


**Figure 1 | Annual mean of TCF (number per year, colour scale) counted at every 5° x 5° grid cell.** **a**, Observations (1979–2003). **b**, Ensemble mean of present-day experiments (1979–2003). **c**, Ensemble mean of future experiments (2075–2099). **d**, The projected future change. The green hatching indicate statistical significance at the 99% confidence level or above (by the bootstrap method) and give an indication of the robustness, with 8 of the 11 future experiments predicting mean changes of the same sign.

**Figure 2-6. Increase in Tropical Cyclone Frequency (TCF) in the East and Central Pacific as derived from a CMIP3 Global Climate Model MRI-CGCM**

More recently, downscaling of the improved Coupled Model Intercomparison Project 5 (CMIP5) global climate models indicated increased tropical cyclone activity in the Pacific, but with less severe change in the Central Pacific than postulated by Murakami. Emanuel (2013) modeled the potential hurricanes as initiated through random space-time seeding across the world's tropical oceans based on the Genesis Potential Index. A global climate model provides the ambient weather to determine the storm evolution from each seed. From Emanuel's recent work, it is now possible to obtain stochastic simulations of tropical cyclone tracks based on downscaled CMIP5 global climate models that have improved modeling of ENSO and Pacific Decadal Oscillation cycles (Bellenger, et. al., 2013). The sea surface temperature increase due to climate change can degrade the natural storm inhibitor of colder waters around Hawai`i and impacts the storm pattern in the subtropics. The results show a shift of the future storms toward the Hawaiian Islands with more northerly headings. In a subsequent section, we discuss how these new models can provide insight into storm surge hazard mapping for regulatory use including the effect of climate change. The change in cyclone track density is shown in Figure 2-7 (from Emanuel, 2013).

**Figure 2-7. Change in Tropical Cyclone Track Density per a Suite of CIMP5 models (Emanuel, 2013)**

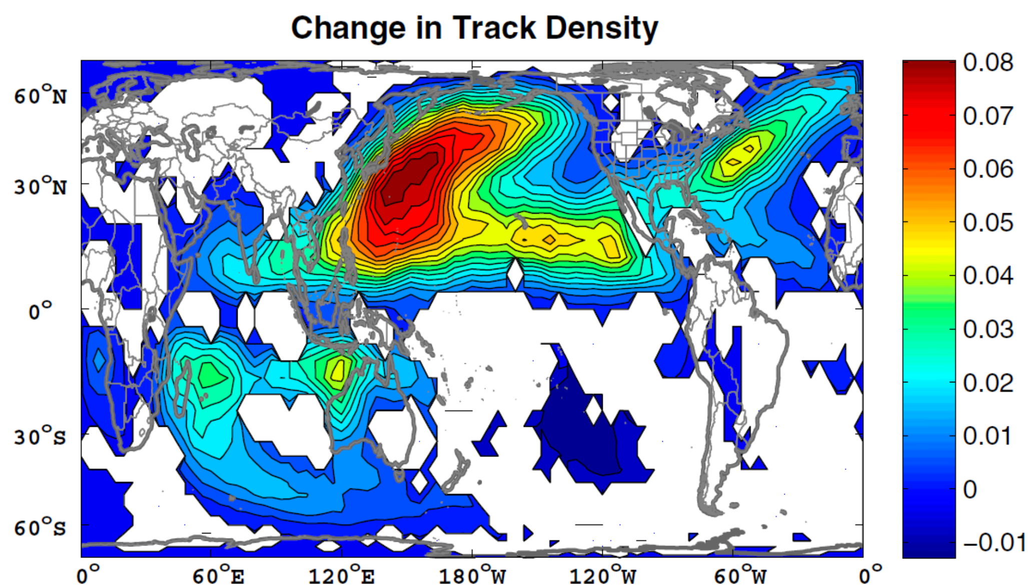


**Fig. 2.** Change in track density, measured in number of events per 4° × 4° grid box per year, averaged over the six models. The change is the average over the period 2006–2100 minus the average over 1950–2005. The white regions are where fewer than five of the six models agree on the sign of the change.

# 3. Adapting Building Construction and Civil Infrastructure to Climate Change

Climate change adaptation measures take the projected climate change effects into account in future regulations. They can be characterized by the following concepts:

- Accommodation of Sea Level Change (SLC) (some of these have been implemented, depending on the jurisdiction)
    - Increased setbacks within existing parcels
    - Codes and design standards for siting, elevation, and building structures and systems
    - Alteration / Retrofitting to mitigate flooding and erosion
    - Post-disaster redevelopment
    - Stream levees and government flood control projects
    - Pumps and tidal gates for short-term mitigation of high tide events

- Protection of existing development (all of these have been done in various situations)
    - Coastal seawall armoring to defend existing property at the expense of public beaches
    - Beach and dune restoration – sand replenishment from offshore
    - Dune vegetation (sometimes done as a defacto change to shoreline extent)
    - Groins and breakwaters to lessen wave erosion

- Retreat (largely hypothetical considerations of possible adaptive risk reduction mechanisms)
    - Acquisition of repetitive loss properties
    - Acquisition of easements
    - Increased zoning restrictions in the coastal zone to prohibit larger developments
    - Transferable development rights/land swapping

- Risk Transfer
    - Flood insurance
    - Litigation for economic compensation for harmful effects/damages/loss of property value

Application of climate change adaptation could be considered in the following sectors:

- Buildings and other structures (buildings of all types and structural aspects of other infrastructure)
- Transportation networks (highways, bridges, culverts, airports, ports, fuel supply)
- Water resources (flood control and risk management, dams, levees, reservoir management, irrigation systems, drought management)
- Urban water systems (storm water systems, water supply, and wastewater systems)

- Coastal management (erosion, seawalls, groins, dredging)
- Energy supply (power distribution, solar and wind power, thermal plant cooling)

Civil engineers and other design professionals are responsible for planning and design of buildings and infrastructure facilities and network systems that commonly include critical facilities. Critical facilities are buildings and structures that provide services that are designated by federal, state, local, or tribal governments to be essential for the implementation of the response and recovery management plan or for the continued functioning of a community, such as facilities for power, fuel, water, communications, public health, major transportation infrastructure, supply chain, and emergency services and essential government operations. Critical facilities comprise all public and private facilities deemed by a community to be essential for the delivery of vital services, protection of special populations, and the provision of other services of importance for that community. Infrastructure and critical facilities most impacted by climate change are often government-owned and built or government-regulated industry owned and built, rather than in the private sector.

There is also construction that would not necessarily be considered critical, but still constitute major investments singly or by general development in a coastal region, such as housing, and generators of economic activity such as commercial, industrial, and hotel buildings. Recreational and agricultural properties may have less intensive development. Buildings codes and standards typically differentiate between these different types of construction by classifications of zoning (dealing with types of economic activities), occupancy (dealing with specific uses), and risk category (dealing with importance and expectations for the reliability of function and safety). Accordingly, zoning ordinances, building codes, and design standards may apply different requirements based on these classifications.

Although for practical purposes of return on ownership investment or benefit-cost analysis, the economic lifespan of the return on investment for a construction project may be relatively short, the actual physical service life of buildings and infrastructure may extend from 50 to 100 years or more. Engineering standards are meant to provide acceptably low risk of failures of functionality or safety over the service life of these structures, during which various natural hazards may occur with significant levels of severity. In the past, the evaluation of natural hazards has largely been based on a stationary climate assumption. However, climate change can potentially affect the severity of natural hazards within the structure's service life, thereby reducing its reliability or safety in the future, unless accommodated in planning and design. Critical infrastructure that is most threatened by changing climate in a given region should be identified, and engineering-economic evaluation of the costs and benefits of implementing mitigation to critical infrastructure at state and local levels should be undertaken.

More severe environmental conditions of use may also diminish the service life of infrastructure such as roadway pavements and utility poles. Bridges and culverts are often designed for floods of a given return period, or in other words, a given frequency of exceedance. If flood frequency and intensities increase, the design flood will be exceeded more often than assumed and cause interruptions and collateral flooding, scour, or erosion damage due to inadequate capacity of drainage and floodways. Storm sewers and wastewater treatment plants may need increased capacity to avoid releases during high rainfall events. Flood control levees at streams may become inadequate. Rising sea levels and potentially more intense storms, compounded by island subsidence, would increase the inundation of highways and roads in coastal areas, and affect piers and wharf structures in harbors. Sea level rise could result in shortened lifespans of coastal infrastructure due to corrosion.

The American Society of Civil Engineers (ASCE) adopted *Policy Statement 360* on the Impact of Climate Change:

> Civil engineers are responsible for design and maintenance of infrastructure projects that facilitate economic development and protect human health, welfare and the environment. Climate change may result in significant impacts to this infrastructure. Civil engineers and government policy makers must work together to anticipate and plan for these impacts. ASCE, its members, leaders, and resources are ready to develop and implement prudent policies as part of their mission to serve the public good. (ASCE, 2012)

The report, *Adapting Infrastructure and Civil Engineering Projects to a Changing Climate* (ASCE, 2015) recommends to:

- Adopt integrated approaches: adaptation should be incorporated into core policies, planning, practices and programs whenever possible.
- Prioritize the most vulnerable: adaptation plans should prioritize helping people, places and infrastructure that are most vulnerable to climate impacts and be designed and implemented with meaningful involvement from all parts of society.
- Use best-available science: adaptation should be grounded in the best-available scientific understanding of climate change risks, impacts and vulnerabilities.
- Maximize mutual benefits: adaptation should, where possible, use strategies that complement or directly support other related climate or environmental initiatives, such as efforts to improve disaster preparedness, promote sustainable resource management and reduce greenhouse gas emissions, including the development of cost-effective technologies.

Climate change modeling at the global, and downscaled regional and local scales have much model uncertainty, with the uncertainty increasing with the planning horizon of interest. Nevertheless, engineering practice could accommodate future projections of increased hazard. Risk analysis and management is the primary approach engineers currently utilize to deal with future uncertainty. Civil engineers use standards as the basis for designs of infrastructure and structural systems, such as designing for a hurricane of a certain return period. The effects of natural hazards are already embedded in design practice with design parameters based on accepted probabilities of occurrence related to the severity of impacts. Engineering design is primarily concerned with the extremes, and existing design standards are based on probabilistic models of hazard occurrence with statistical allowances for variability of the contributing factors. As knowledge is gained over time, the probabilistic estimates of hazards are often adjusted over the course of successive codes and standards.

Adaptive Engineering:

Adaptive Engineering is the approach to include future flexibility in the design of facilities without incurring excessive costs prior to the time when features for climate change are necessary (i.e., it is a low regret adaptive strategy in which expenditures have a higher probability of public benefit despite the uncertainty in future scenarios).

Adaptive engineering approaches may:

1. Design to the most probable (not the worst case) climate conditions expected within the lifespan of the facility
2. Incorporate the design capability to make further alterations to adapt to greater climate change effects as observations indicate to be necessary.
3. Recognize the high uncertainty of modeling and enable the cost of adaptation to be incrementally paid over time.

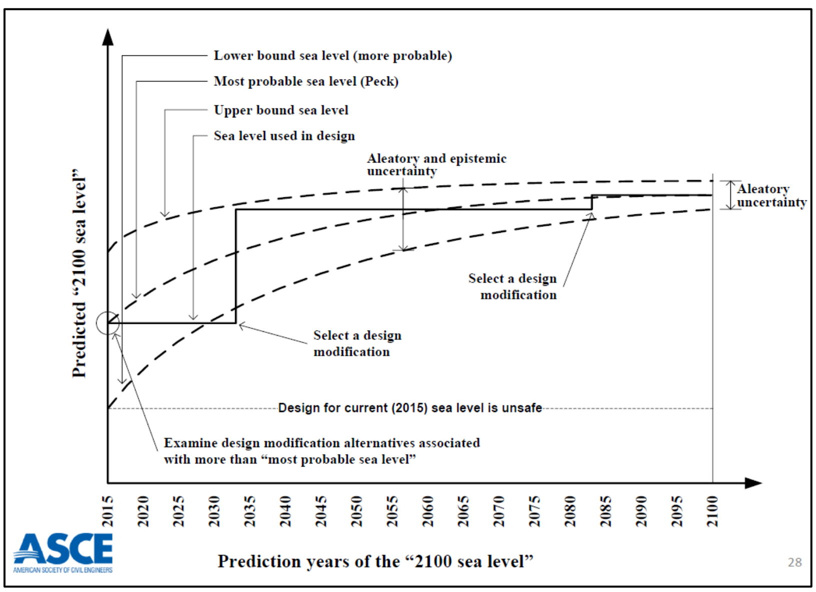


**Figure 3-1. Illustration of an Adaptive Engineering Process (ASCE, 2015)**

Besides natural hazards, there are various sources of change and uncertainty of knowledge that are already recognized to impact the functionality of infrastructure, such as changes in demand, changes in technology and services, land use development, population changes, and development in the coastal zone. Over the course of time after initial construction, a facility may be renovated, expanded, or realigned to adapt to these changes. Recognizing the effect of climate change on a facility has an analogous impact on future suitability for use. Engineering standards would then need to be revised to account for the uncertainty of a changing climate. Greater variability results in a higher frequency of extreme conditions that engineering standards are meant to mitigate. For example, the standard 100-year (1% annual chance of exceedance) flood may actually have much more frequency in the future. Also, rainfall intensity maps used to design roof and site drainage may need to be revised.

If climate change impacts can also be evaluated for a consistent probability of occurrence, it then becomes a parameter of hazard intensity that can be included in engineering design standards. When climate change effects enter into design requirements, then an economic incentive is created for responding to climate change in planning, siting, and construction. Then, there will be an economic investment in the cost of increased resilience to offset the economic consequences of failures to adequately perform their function, loss due to damage, loss of marketability, or even failures of life safety. That is, rational economic analysis would become a tool of climate change adaptation, rather than solely by measures of regulatory prohibition. Adaptive designs that are more resilient would be seen as acceptable as opposed to zoning restrictions that affect entitlements of use.

The State Hazard Mitigation Plan has provided vetted directions for the development of building code amendments to reduce existing and future building stock vulnerability to coastal hazards and climate impacts (i.e., tropical cyclones, tsunamis, flooding, coastal erosion, and sea level rise). The project will advance the following State Hazard Mitigation Plan (2013) strategic measures for coastal hazards and climate change effects. Code and standards developed in consistency with the priorities of the State Hazard Mitigation Plan would have the advantage of being considered by the federal government as being vetted at the state level.

**Table 3-1. State Hazard Mitigation Plan Strategic Measures for Coastal Hazards and Climate Change Effects**

| Strategy Element | Functional Area |
|---|---|
| Develop risk reduction policies for siting and design criteria for critical facilities in the more susceptible coastal hazard zones based on Climate Change Priority Guidelines in HRS § 226-109 (Hawai`i State Planning Act). Include the consideration of the function of the facility and the long-term resilience of the community | Land Use and Building Requirements |
| Establish 500-year coastal inundation zone maps that can be used in land use regulatory decisions for all building construction, and for Critical Infrastructure | Land Use and Building Requirements |
| Adopt more preventative community impact-based mitigation policies using more advanced hazard maps developed for use earlier in the land use and development process. Incorporate longer-term environmental trends, particularly in the coastal zone. | Land Use and Building Requirements |

Risk Categories of Structures:

The building code utilizes delineation of Risk Categories as the means to define the importance or criticality of certain types of buildings and other structures. With increasing functional importance or conversely, consequences of failure, comes additional design strength and other requirements for attaining increased reliability of performance of the building or structure. The ASCE 7 Standard describes each Risk Category in general intent. The International Building Code itemizes specific types of occupancies that are considered to be included in each of these Risk Categories.

Risk Categories III and IV typically include those buildings that are needed for emergency response, critical health care, those with large public assembly use, those facilities providing critical services to the community, and those storing hazardous material. These types of buildings and structures are primarily governmental and utilities, which are designed for an expected long period of service and are not investment properties subject to transfer of ownership. However, they are critical to the sustainment of the community. Therefore, the disaster resilience of Risk Categories III and IV is of greater importance over a longer period of time during which climate change may impact.

**Table 3-2. Risk Categories for Buildings and Structures (ASCE 7)**

| | | |
|---|---|---|
| **Risk Category I** | Buildings and other structures that represent a low risk to humans | Up to 2 persons affected<br>(e.g., agricultural and minor storage facilities, etc.) |
| **Risk Category II** | All buildings and other structures except those listed in Risk Categories I, III, IV | Approximately 3 to 300 persons affected<br>(e.g., Office buildings, condominiums, hotels, etc.) |
| **Risk Category III** | Buildings and other structures, the failure of which could pose a substantial risk to human life.<br>Buildings and other structures with potential to cause a substantial economic impact and/or mass disruption of day-to-day civilian life in the event of failure. | Approximately 300 to 5,000+ affected<br><br>(e.g., Public assembly halls, arenas, high occupancy educational facilities, public utility facilities, etc.) |
| **Risk Category IV** | Buildings and other structures designated as essential facilities<br>Buildings and other structures, the failure of which could pose a substantial hazard to the community. | Over 5,000 persons affected<br>(e.g., hospitals and emergency shelters, emergency operations centers, first responder facilities, air traffic control, toxic material storage, etc.) |

**Table 3-3. Risk Category of Buildings and Other Structures**
(International Building Code TABLE 1604.5)

| Risk Category | Nature of Occupancy |
|---|---|
| I | Buildings and other structures that represent a low hazard to human life in the event of failure, including but not limited to:<br>• Agricultural facilities.<br>• Certain temporary facilities. |
| II | Buildings and other structures except those listed in Risk Categories I, III and IV. |
| III | Buildings and other structures that represent a substantial hazard to human life in the event of failure, including but not limited to:<br>• Buildings and other structures whose primary occupancy is public assembly with an occupant load greater than 300.<br>• Buildings and other structures containing Group E occupancies with an occupant load greater than 250.<br>• Buildings and other structures containing educational occupancies for students above the 12th grade with an occupant load greater than 500.<br>• Group I-2 occupancies with an occupant load of 50 or more resident care recipients but not having surgery or emergency treatment facilities.<br>• Group I-3 occupancies.<br>• Any other occupancy with an occupant load greater than 5,000.[a]<br>• Power-generating stations, water treatment facilities for potable water, wastewater treatment facilities and other public utility facilities not included in Risk Category IV.<br>• Buildings and other structures not included in Risk Category IV containing quantities of toxic or explosive materials that:<br>Exceed maximum allowable quantities per control area as given in Table 307.1(1) or 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and<br>Are sufficient to pose a threat to the public if released.[b] |

| | |
|---|---|
| IV | Buildings and other structures designated as essential facilities, including but not limited to:<br>• Group I-2 occupancies having surgery or emergency treatment facilities.<br>• Fire, rescue, ambulance and police stations and emergency vehicle garages.<br>• Designated earthquake, hurricane or other emergency shelters.<br>• Designated emergency preparedness, communications and operations centers and other facilities required for emergency response.<br>• Power-generating stations and other public utility facilities required as emergency backup facilities for Risk Category IV structures.<br>• Buildings and other structures containing quantities of highly toxic materials that:<br>Exceed maximum allowable quantities per control area as given in Table 307.1(2) or per outdoor control area in accordance with the *International Fire Code*; and<br>Are sufficient to pose a threat to the public if released.[b]<br>• Aviation control towers, air traffic control centers and emergency aircraft hangars.<br>• Buildings and other structures having critical national defense functions.<br>• Water storage facilities and pump structures required to maintain water pressure for fire suppression. |

a. For purposes of occupant load calculation, occupancies required by Table 1004.1.2 to use gross floor area calculations shall be permitted to use net floor areas to determine the total occupant load.
b. Where approved by the building official, the classification of buildings and other structures as Risk Category III or IV based on their quantities of toxic, highly toxic or explosive materials is permitted to be reduced to Risk Category II, provided it can be demonstrated by a hazard assessment in accordance with Section 1.5.3 of ASCE 7 that a release of the toxic, highly toxic or explosive materials is not sufficient to pose a threat to the public.

# 4. Probabilistic Mapping of Storm-Induced Coastal Inundation for Climate Change Adaptation: A Pilot Study of Developing 500-Year Probabilistic Inundation Hazard Maps Including Climate Change Effects

Climate change impacts on coastal hazards can be separated into at least two effects that are not presently considered in design codes and standards. First, changes in Sea Surface Temperatures (SST) and climatic circulation patterns may affect the distribution of storm tracks. Second, relative sea level rise can result in shoreline changes and higher apparent sea level (relative to a point on land). Relative sea level rise can also exacerbate inundation, especially for low-lying areas subject to hurricanes or tsunamis (Cheung, 2013). In this consideration, *relative* sea level change is the significant factor. It is the local change in the level of the ocean relative to the land, which might be due to ocean rise and/or subsidence of the land.

This section reports on a pilot study to quantify flood hazards from hurricanes for Honolulu on the south shore of Oahu, Hawai`i. Probabilistic inundation maps, which take into account increasing hurricane activity and sea level change, will be a useful tool for planning and regulation of coastal development. A pilot study of coastal storm inundation including climate change (sea level rise and change in the distribution of storm track effects) was performed as a proof-of-methodology implementation for the Kakaʻako-Waikiki coastline. While the rates of projected sea-level rise are well publicized, downscaling of global climate models provides an effective means to account for future hurricane events influenced by climate change under various greenhouse gas scenarios. Multiple simulations of a period of interest provide a sufficient number of hurricane events for probabilistic analysis. Screening of the simulated events by track and wind speed can narrow down a scenario set for detailed inundation modeling at a coastal region.

The pilot study utilized 2,492 simulated hurricanes around the Hawaiian Islands from 50 simulations of the 2080-2100 period. Comparison with a control dataset for the 1980-1999 show exacerbation of hurricane impact to Honolulu. The tropical island environment, which includes steep volcanic slopes, shallow fringing reefs, and a mix of coastal flats and terraces, requires modeling of both phase-averaged and phase-resolving processes to account for the flood hazards. The phase-averaged, low-momentum flow can inundate a large expanse of the coastal plain due to its long time scale, while the individual waves can dramatically increase the surface elevation and produce large run-up on steep slopes and overtopping on coastal terraces. The 12 selected events over a 1,000-year period allow delineation of the flood hazard zones along the Honolulu coast with 100 to 500-year return periods.

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) shows a general consensus of 21 global climate models forced by historical and projected greenhouse gas concentrations for the period from 1850 to 2100 (IPCC, 2013). These Coupled Model Inter-comparison Project Phase 5 (CMIP5) models include interactions of the ocean and atmosphere at spatial resolution around 1° to 2.5°. The model results, such as temperature, moisture, precipitation, and wind speed, describe synoptic weather patterns in sufficient detail to provide a glimpse of the future climate conditions. The CMIP5 indicates a 0.6-m ensemble mean of sea-level rise for the Central Pacific from the 1986-2005 to 2081-2100 epochs under the Representative Concentration Pathway (RCP) 8.5. In this study, we select the ensemble mean sea-level rise of 0.6 m along with the mean higher high water (MHHW) level of 0.33 m above the mean sea level (MSL) at Honolulu Harbor. This provides a conservative and yet practical estimate of the future sea level for mapping of storm-induced coastal flood hazards toward the end of the 21st century.

The pilot study utilized hurricane events downscaled from the NCAR-CCSM4 model using the stochastic-deterministic method of Emanuel (2013) and projected sea-level rise under the RCP8.5 scenario to develop an inundation map for the urban Honolulu coast. The techniques used to create statistically valid simulated tropical cyclone datasets are based on the CMIP5 global climate model of NCAR-CCSM4. This model has the finest resolution of 1.25º × 0.94º among the six considered by Emanuel (2013) and better representation of the ENSO and fidelity of atmospheric feedbacks as shown by Bellenger *et al*. (2014). The downscaling is performed for the 2081-2100 period to reflect the storm patterns toward the end of the 21st century. Emanuel (2013) modeled the potential hurricanes as initiated through random space-time seeding across the world's tropical oceans based on the Genesis Potential Index. The downscaling is performed for a 20-year period from 2081 to 2100 to capture the ENSO, which strongly influences the hurricane activity in the Pacific. A total of 50 simulations of the 20-year provide a quasi-stationary dataset of 1,000 years for probabilistic analysis of the flood hazards toward the end of the century. A simulated catalog of 2,492 tropical cyclones near Hawai`i were generated.

These storms also have associated rainfall intensities, and by statistical analysis a rainfall hazard curve can be developed to show the expected change in intensities for various return periods. This analysis shows an increase in total rainfall of about 10% associated with tropical storms in the Central Pacific, relative to the present environment. Since rainfall is also associated with more common climatic weather conditions exclusive of the relatively rare tropical cyclones, it is not necessarily statistically concluded that peak or even hourly rainfall intensities should be increased for design purposes in accounting for climate change.

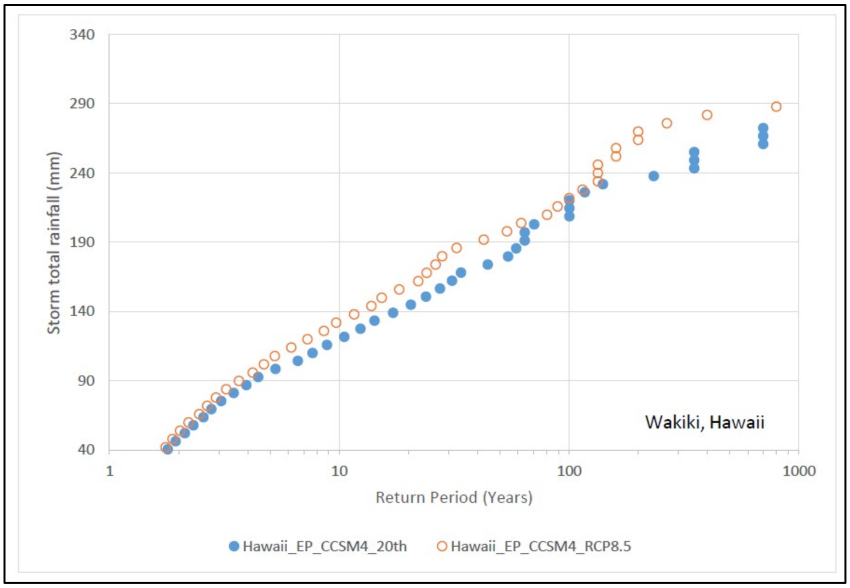


**Figure 4-1. Total rainfall amounts in Waikiki associated with tropical storms and hurricanes, for the present epoch and the epoch at the end of the century assuming the RCP 8.5 scenario**

Statistical analysis of the peak gust wind hazard (based on the pilot study) indicates a tendency for higher winds at longer return periods. However, the statistical sample represented by the stochastic dataset is not long enough to establish the trend past a 500 year return period. *Additional simulations would be necessary to determine whether that trend would continue for return periods of up to 3,000 years, in order to initiate changes to the building code.*

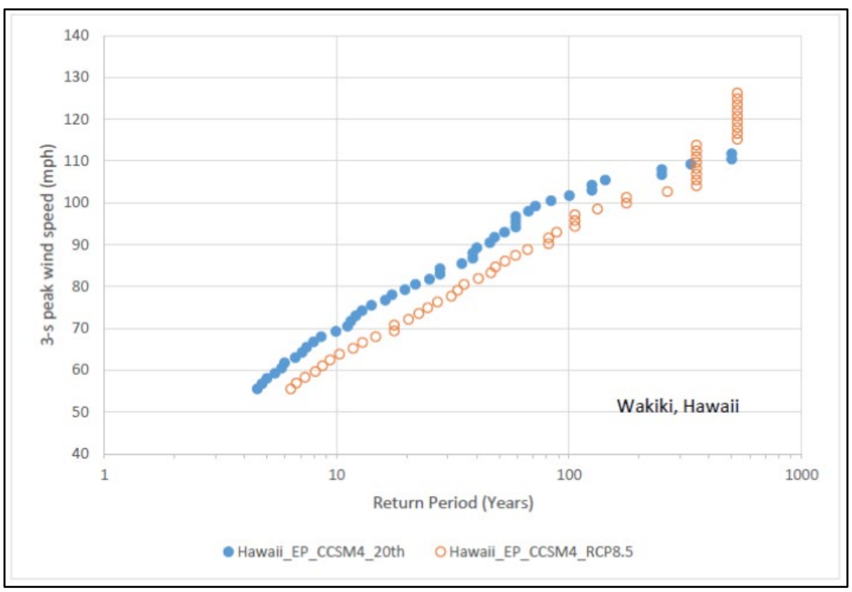


**Figure 4-2. Peak Gust Windspeed Hazard Curve for Waikiki associated with tropical storms and hurricanes, for the present epoch and the epoch at the end of the century assuming the RCP 8.5 scenario**

Each storm path was evaluated to determine if it passes through a region surrounding Oahu (see Figure 4-3 as an example.) 627 out of the 2,492 storms were locally relevant to Oahu. The 40 most severe of these storms were selected for statistical analysis with the larger 1,000-year simulation.

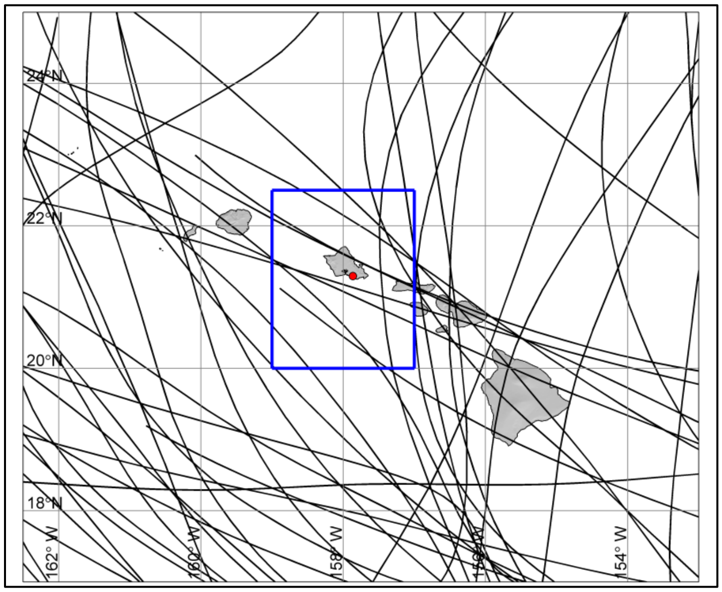


**Figure 4-3. Hurricane tracks around the Hawaiian Islands from one downscaling simulation of the 2081-2100 period. The blue box indicates a zone of higher potential storm surge impact on Oahu and the red dot is the location of wind speed comparison in selection of events for inundation modeling.**

The tropical island environment, which includes steep volcanic slopes, shallow fringing reefs, and a mix of coastal flats and terraces, requires modeling of both phase-averaged and phase-resolving processes to account for the flood hazards. A suite of spectral wave, circulation, and Boussinesq models in a nested grid system describes generation and propagation of surge and waves across the ocean as well as wave setup and runup at the coast. Figure 4-4 illustrates its modular structure with interoperable models. The interoperable package includes phase-averaged and phase-resolving processes to describe coastal flood hazards over a range of spatial and temporal scales during a hurricane event. WAVEWATCH III, NEOWAVE, and SWAN are implemented with three levels of nested grids in spherical coordinates to model the phase-averaged surge and wave processes. Figures 4-5a to 4-5c show the layout of the nested grid system. The Hawai`i grid covers the major island chain at ~5.5 km resolution. The Oahu grid describes the insular slope and shelf at ~550 m resolution, while the south shore grid resolves the nearshore reefs at ~55 m. The third-generation spectral wave model WAVEWATCH III of Tolman (2008) with the source term package of Ardhuin *et al*. (2010) and the coastal wave model SWAN of Booij *et al*. (1999), adapted by Filipot and Cheung (2012) for fringing reef environments, describe the propagation of hurricane waves from the open ocean to the shore. WAVEWATCH III computes the generation and propagation of hurricane waves in the two-way nested Hawai`i and Oahu grids and provides boundary conditions to SWAN for modeling of coastal wave transformation in the south shore grid. The circulation model NEOWAVE of Yamazaki *et al*. (2009, 2011) describes the phase-averaged ocean response to the low pressure and strong winds under a hurricane. NEOWAVE calculates the storm surge within the three levels of two-way nested grids. The package has the option to couple NEOWAVE and SWAN in the south shore grid, where the surface elevation and wave radiation stress are shared between the two models for computation of wave setup and its effects on wave transformation. The shock-capturing Boussinesq-type model BOSZ of Roeber and Cheung (2012) describes wave-by-wave propagation and runup processes in the surf and swash zone.

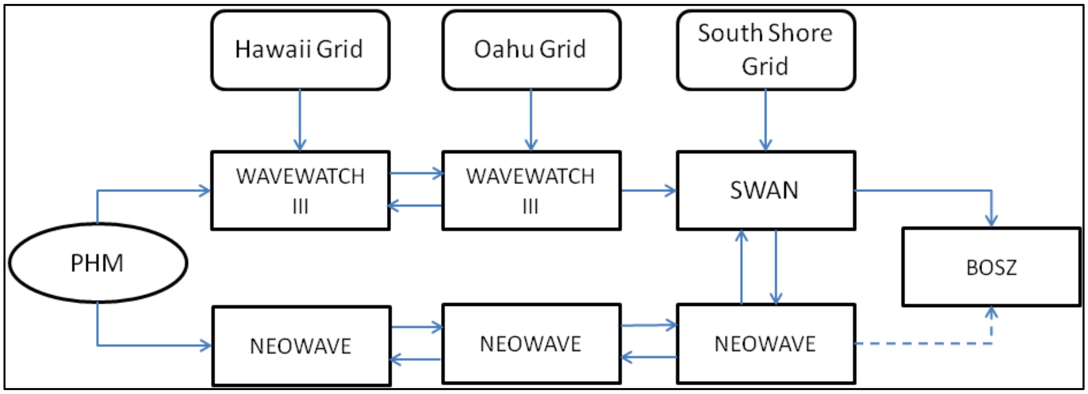


**Figure 4-4. Schematic of the Storm Surge and Wave Runup Modeling System. Arrows indicate information flow and the dashed arrows denotes input to BOSZ from the standalone NEOWAVE**

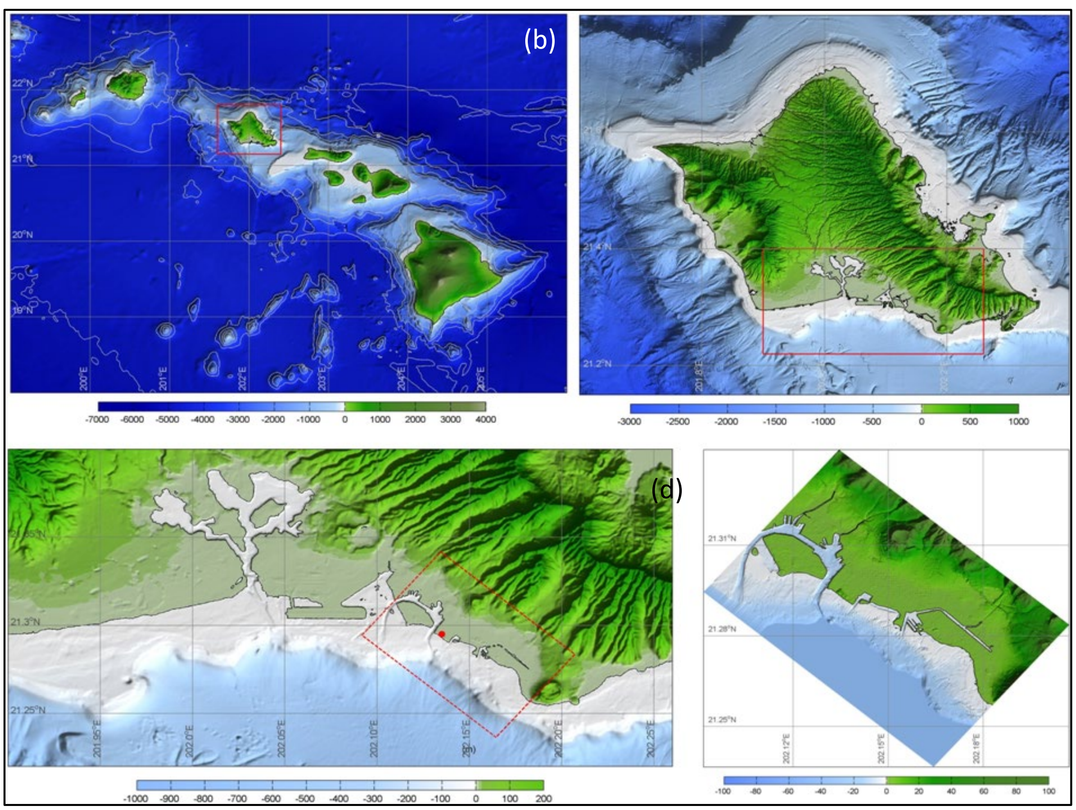


**Figure 4-5. System of nested model geogrids. (a) Hawai`i grid; (b) Oahu grid; (c) South shore grid; (d) Honolulu urban core grid**

The phase-averaged calculation covers the entire event as a hurricane traverses the Hawai`i domain. This allows development of the surge, waves, and setup over time and progression of floodwater on the flat coastal plain to the full extent. The individual waves, which are most severe at landfall, can overtop coastal dunes and reach higher elevations than the combined surge and setup as observed on Kauai after the 1992 Hurricane Iniki (Chiu *et al*., 1995). The large combined flow depth from surge and individual waves can also damage buildings and infrastructure. With the nearshore wave spectrum already defined, the standalone NEOWAVE can provide the surge elevation from inverted barometric pressure and wind forcing to define the initial still-water surface for modeling of phase-resolving processes as well as wave setup using BOSZ. The phase-averaged results describe the flow hazards with time scales of over 10 minutes.

The phase-averaged, low-momentum flow can inundate a large expanse of the coastal plain due to its long time scale, while the individual waves can dramatically increase the surface elevation and produce large runup on steep slopes and overtopping on coastal terraces. It is necessary to utilize the Boussinesq model to capture inundation processes with the time scale of individual waves measured in seconds. In addition to runup over steep near-shore areas, the individual waves propagate on top of the surge and long-period infragravity motion to augment the inundation. The combined surge and waves give rise to considerable flow depth and speed that might be damaging to infrastructure near the shore. The short-period waves, however, do not supply sufficient floodwater to produce substantial inland flows.

Combination of the phase-averaged and phase-resolving results provides a more comprehensive description of the multi-scale processes under a hurricane for flood hazard mapping in tropical coastal environments. Figure 4-6 shows, for example, the inundation maps of the second-highest flood event. Since the simulated dataset corresponds to 1,000 years of hurricanes, the second most severe flood event would have a return period of 500 years or an annual exceedance probability of 0.2% toward the end of the 21st century. A more accurate approach is to aggregate the inundation zones from the 12 hurricane landfalls in the 1,000-year period and tally the inundation probability at each grid cell; for example, the areas inundated at least two and ten times would correspond to the 500 and 100-year flood zones.

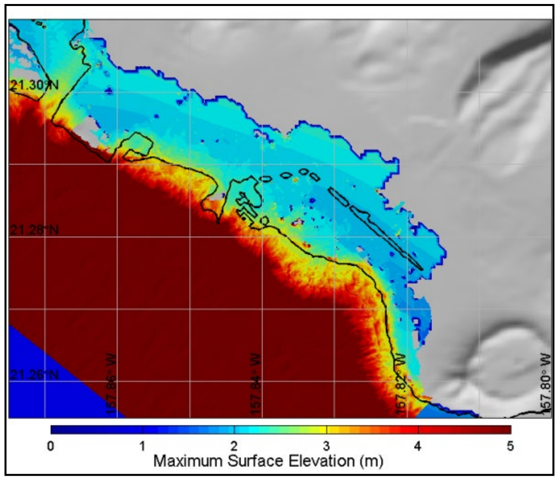


**Figure 4-6. Combined phase-averaged and phase-resolving inundation map for the second highest flood event in the 1,000-year stochastic simulation dataset**

The primary goal of this project is to develop disaster resilient measures for using relevant codes, standards, and local jurisdiction flood regulations as a basis for reducing building and infrastructure vulnerability to natural hazards. The techniques for creating probabilistic inundation maps developed in this study have significant implications for engineering practice and land-use planning. In the past, the evaluation of natural hazards has largely been based on a stationary climate assumption. However, climate change can potentially affect the severity of natural hazards within a structure's service life, thereby reducing its reliability or safety in the future. Projects being designed now will have economic and physical lifespans reaching the end of the century. It is feasible to delineate probabilistic flood hazard zones associated with sea-level rise and hurricane intensification well into the 21st century. As demonstrated in this project, inundation hazard maps that include climate change effects can be developed, indicating how to create 500-year coastal inundation zone maps that can be used in land use regulation decisions and design criteria for all construction and critical infrastructure.

The 500-year flood zone for the case study area of the south shore, which extends 1.7 km inland, covers the most heavily developed and populated area of Oahu. The 100-year flood map shows minor flooding of the coastlines and the banks of Ala Wai Canal as well as low-lying coastal areas in the vicinity. Even with a projected high tide level and long-term sea-level rise, the computed inundation is substantially less than the 100-year flood zone of the present Flood Insurance Rate Map, which is currently the authoritative source of information for flood regulations. The Flood Insurance Study utilized a combined 100-year storm-tide level from 1,000 years of simulated hurricanes based on historical events, but the maximum significant wave height under the most intense stage of the 1992 Hurricane Iniki as input in separate one-dimensional empirical models to compute wave setup and runup (FEMA, 2014). As an unintended result, the resulting product is actually close to the 500-year inundation map at the end of the 21st century. However, the recent FEMA studies were limited to the south and west shores of the islands. The adequacy of the flood insurance rate maps is not known for the north and east shores with respect to future climate change influences, and these areas should be studied further using the techniques of this pilot study and applying this methodology towards a new generation of coastal inundation hazard maps for the remainder of the island of Oahu. A relevant risk analysis is to assess the inventory of buildings and structures in Honolulu that would be exposed to increased flood risks due to climate change. This was done for the Kaka'ako-Waikiki coastal area of the pilot study. City property tax records and the National Structure Inventory database were used to compile information on building occupancy, size, height, and valuations, and geocoded to location (Tax Map Key (TMK) properties). The aforementioned flood inundation modeling results with water elevations were produced in GIS layers, and the water depths determined by normalizing the data by the topographic digital elevation model layer. Then, documentation on flood depth-damage curves (previously compiled in the FEMA HAZUS software) were extracted and converted to loss functions in GIS. With these steps, the structural and nonstructural damages were calculated for each property based on the inundation depth for the storm scenarios of interest. The number of affected properties were also determined for each occupancy.

The following scenarios were used to compute flood losses:

1. The expected 500-year flood depths for climate conditions at the end of the century, with consideration of sea level rise, for all properties affected
2. The expected 500-year flood depths for climate conditions at the end of the century, without consideration of sea level rise, for all properties affected
3. The expected 500-year flood depths for climate conditions at the end of the century, but with consideration of sea level rise, for properties within the present FEMA flood zones
4. The expected 500-year flood depths for climate conditions at the end of the century, but without consideration of sea level rise, for properties within the present FEMA flood zones
5. The present FEMA flood zone extents, which was ostensibly calculated for 100-year return period

Each of these scenarios are mapped in Figures 4-7 through 4-11, respectively. In Figure 4-12, there is a comparison of the 100-year, 200-year, and 500-year flood inundation zones and the present NFIP FIRM map. It is apparent that the present day FIRM map is expanded past the 100-year flood even when sea level rise and the future storm climatology are explicitly included.

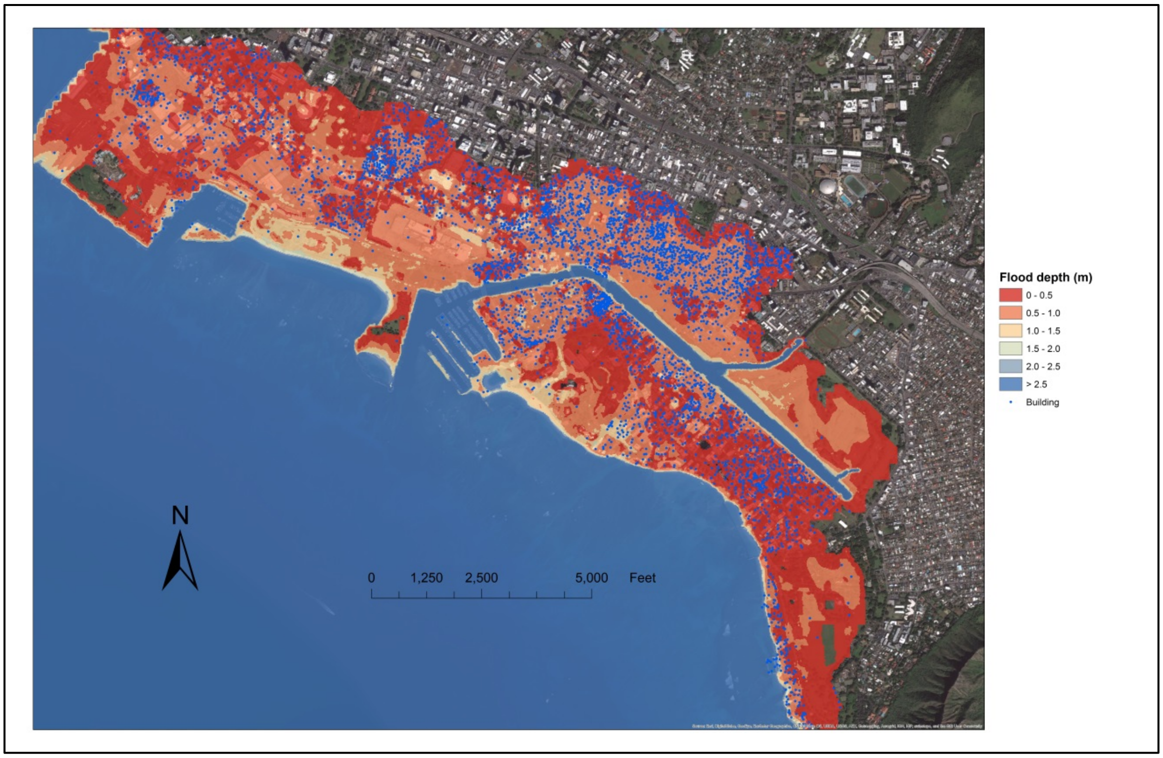


**Figure 4-7. 500-year flood depths and the 5,264 properties affected by climate change and sea level rise**

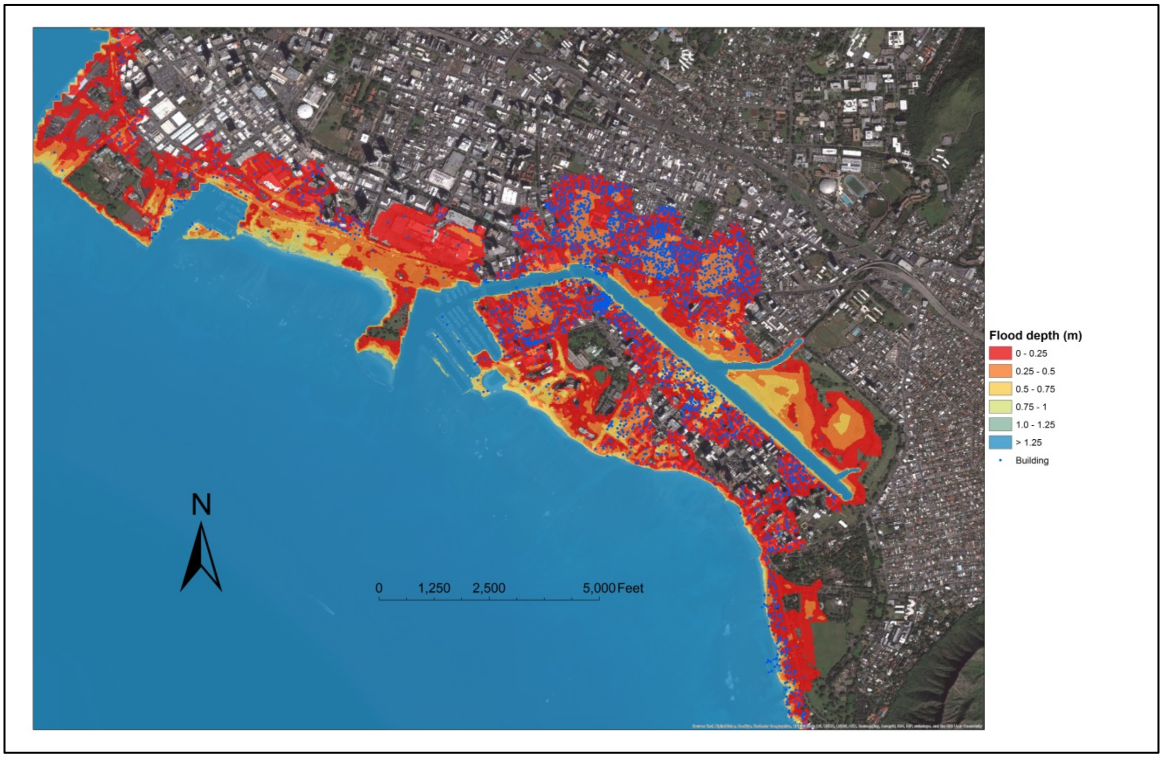


**Figure 4-8. 500-year flood depths and the 3,053 properties affected by climate change but if sea level unchanged**

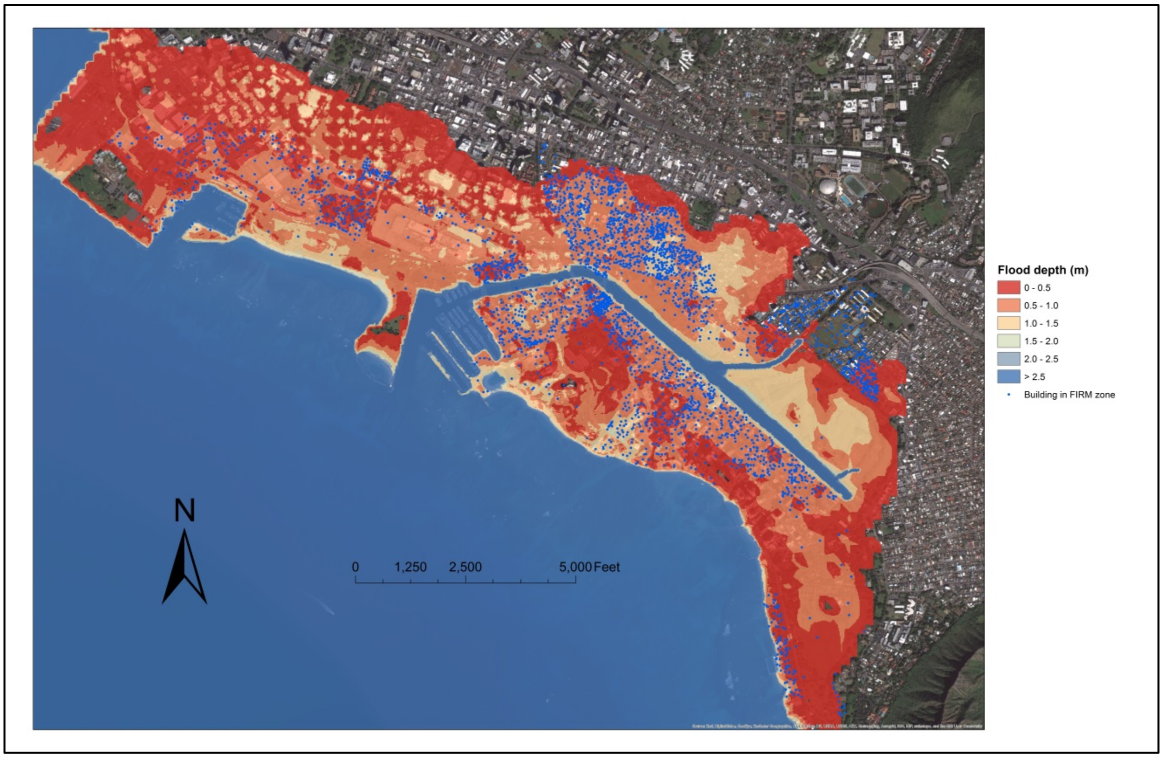


**Figure 4-9. 500-year flood depths and the 3,505 properties within the present FEMA flood zones, for climate change and sea level rise**

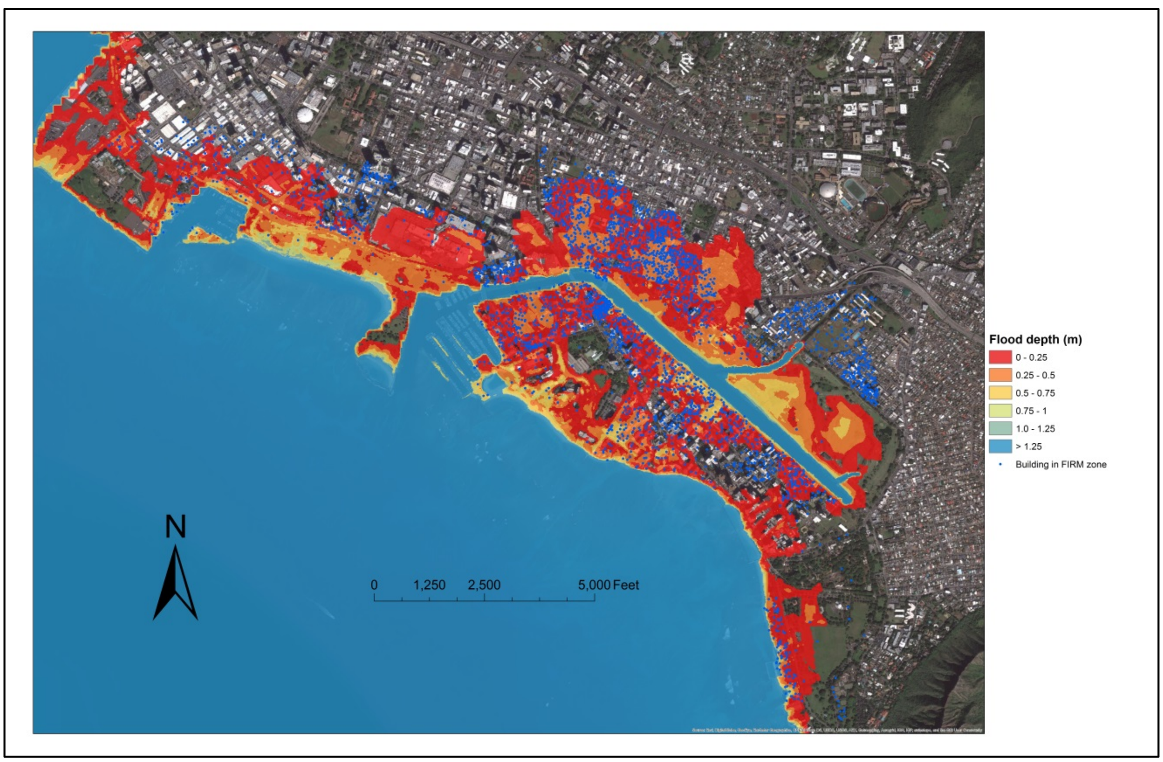


**Figure 4-10. 500-year flood depths and the 3,505 properties within the present FEMA flood zones, for climate change but sea level unchanged**

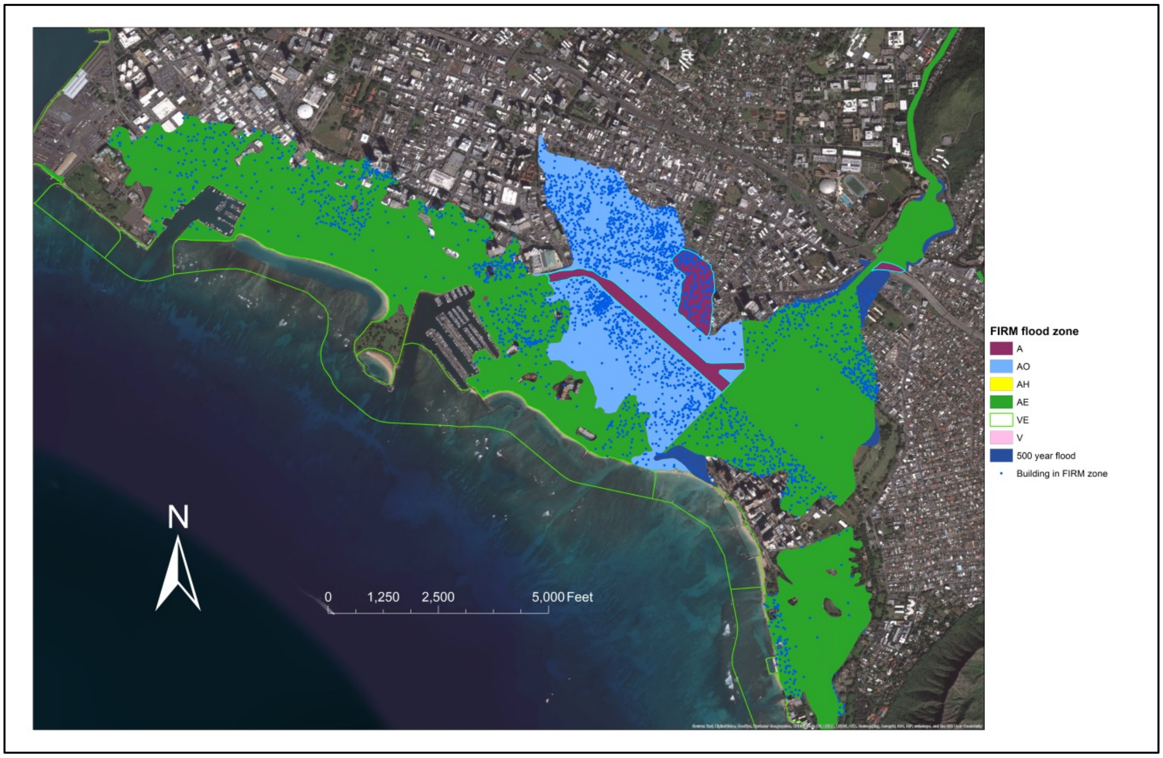


**Figure 4-11. Current day FEMA Flood Zones and the 3505 properties contained within it**

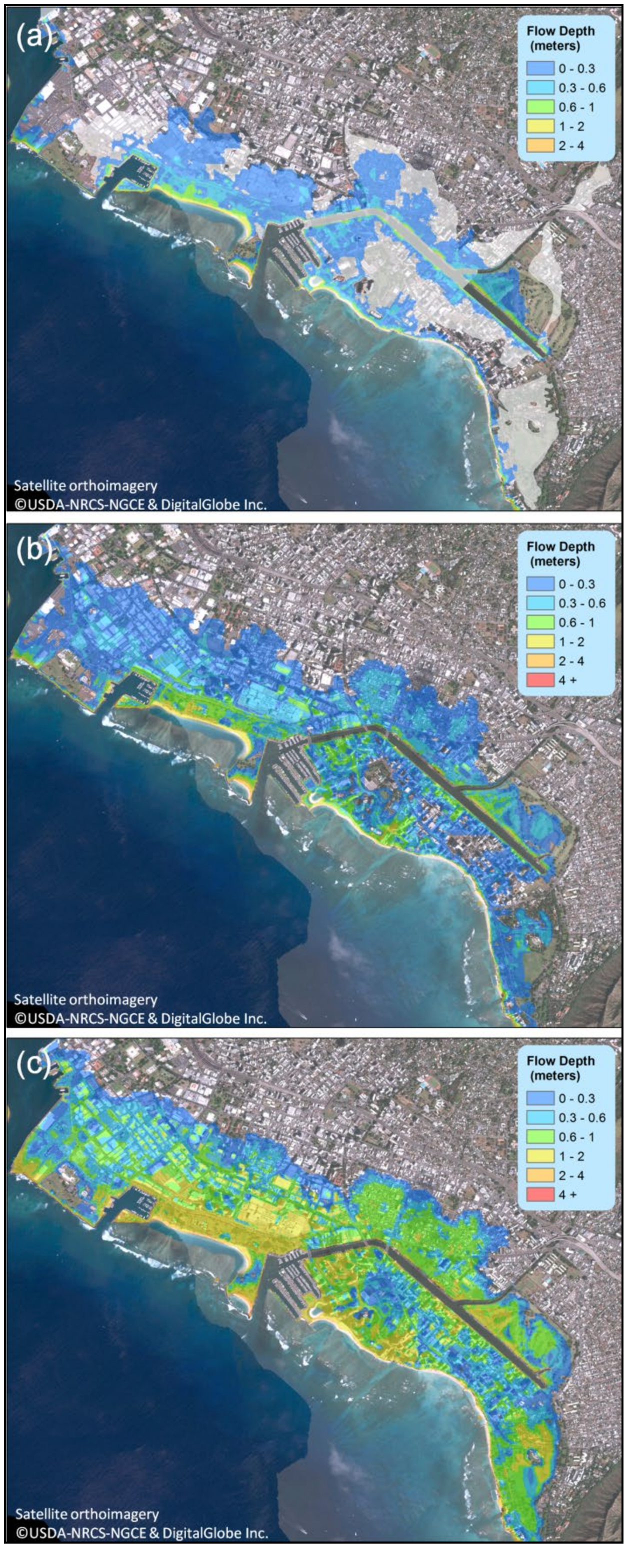


**Figure 4-12. Inundation maps at the end of the 21st century (a) 100-year. (b) 200-year. (c) 500-year return period. The transparent white layer denotes the FIRM with 1% exceedance probability. It is apparent that the present day FIRM map is expanded in figure (a) past the 100-year flood even when sea level rise and the future storm climatology are explicitly included.**

# 5. Discussion of Economic Risk

Additional losses from hurricane inundation due to climatic and sea level conditions towards the end of the century can be separated into the contributions from a) increased inundation depth over properties presently in the regulatory flood zones, and b) inundation over properties presently outside of the regulatory flood zones. The first contribution to losses would be as a result of regulatory flood elevations being insufficient for future climate conditions, especially sea level rise. The second contribution would result from the extent of flood zone being insufficient to incorporate new areas exposed to flood risk in the future due to climate change. The aforementioned inundation analyses allows us to examine these two components of losses for their significance. We also examine the significance of sea level rise.

Relevant Findings from the pilot study analysis:

- Expected rainfall volume from severe hurricanes increases only about 10% from present expectations. Therefore, any increased losses are primarily due to coastal flooding; this indicates recent U.S. Army Corps of Engineers flood mitigation studies of the Ala Wai Canal due to stream runoff flows due to intense storm rainfall is possibly neglecting the principal long term cause of high losses due to coastal flooding.
- 500-year flood losses under future climate conditions *within the FEMA flood zones* are not greater than what would result if the regulatory flood elevations are reached. This indicates that present FEMA flood zone map elevations are vastly overextended from the actual 100-year inundation depths and that present insured are already paying now for climate conditions not expected to develop for many decades. See Figure 4-12.
- FEMA incorporated hurricane inundation from model scenarios into a flood insurance study for all islands including Hawai`i. The Hurricane Flood Insurance Study (FIS) for the Hawaiian Islands was conducted under FEMA contract number EMW-2003-CO-0046, RMTC/URS Task Order 013, to evaluate and map the magnitude and extent of coastal hazards due to hurricanes for six Hawaiian Islands, divided into four counties: Kaua`i (Kaua`i County), O`ahu (City and County of Honolulu), Molokai, Maui, Lanai (Maui County), and Hawai`i (Hawai`i County).
  The FIS utilized a combined 100-year storm-tide level from 1,000 years of simulated hurricanes based on the historical climate, but the maximum significant wave height under the most intense stage of the 1992 Hurricane Iniki was input in separate one-dimensional empirical models to compute wave setup and run-up (FEMA, 2014).
- As an unintended result of assuming the 100-year storms would all have Hurricane Iniki wave heights, the resulting map products used for flood insurance and flood ordinances for the south and west shores are actually close to the 500-year flood elevations with sea level rise map at the end of the 21st century produced with more sophisticated and accurate modeling. To that extent, there does not appear to be justification for extending the Oahu flood elevations for the south and west shores, regardless of climate change impacts.

Due to the overreaching of the FEMA NFIP south shore flood zone due to an excessive wave runup assumption in the FIS, the baseline flood zone and inundation depths are not representative of the 100-year flood. Essentially, the existing flood zone along the south shore is a hybrid combination of probabilistic 100-year storm surge stillwater and deterministic superposition of about a 1,000-year wave runup. (This follows from that study's decision to apply Hurricane Iniki wave runup; Iniki was a Category 4 hurricane near landfall and the wind hazard curve for Hawai`i in the ASCE 7 standard would classify that as a 2,000-year to 5,000-year wind event at landfall. See Figure 5-2. Since Iniki made direct landfall from the south, it is strongly correlated to a similar return period for coastal inundation.)

However, it is worth noting that the recent FEMA FIS studies were limited to the south and west shores of the islands (see the Figure 5-1 below). Therefore, preceding flood maps for the other areas not covered by this study may not necessarily offer similar mitigation of climate change effects (however, unintentional).

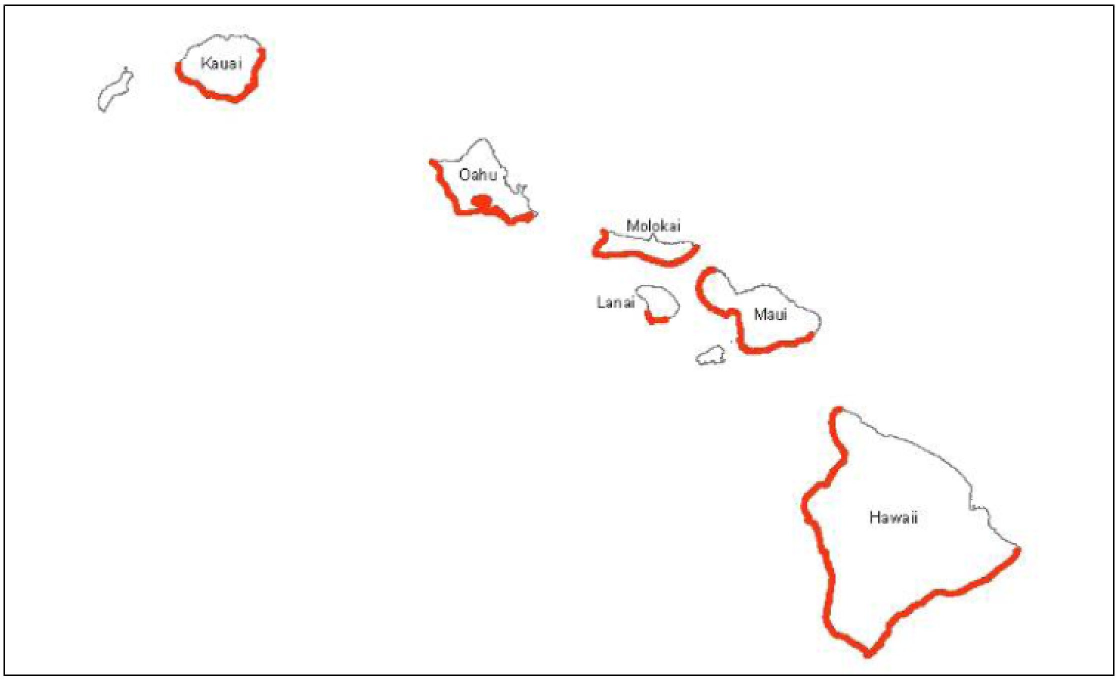


**Figure 5-1. Extents of the Tropical Cyclone FIS for the Four Counties**

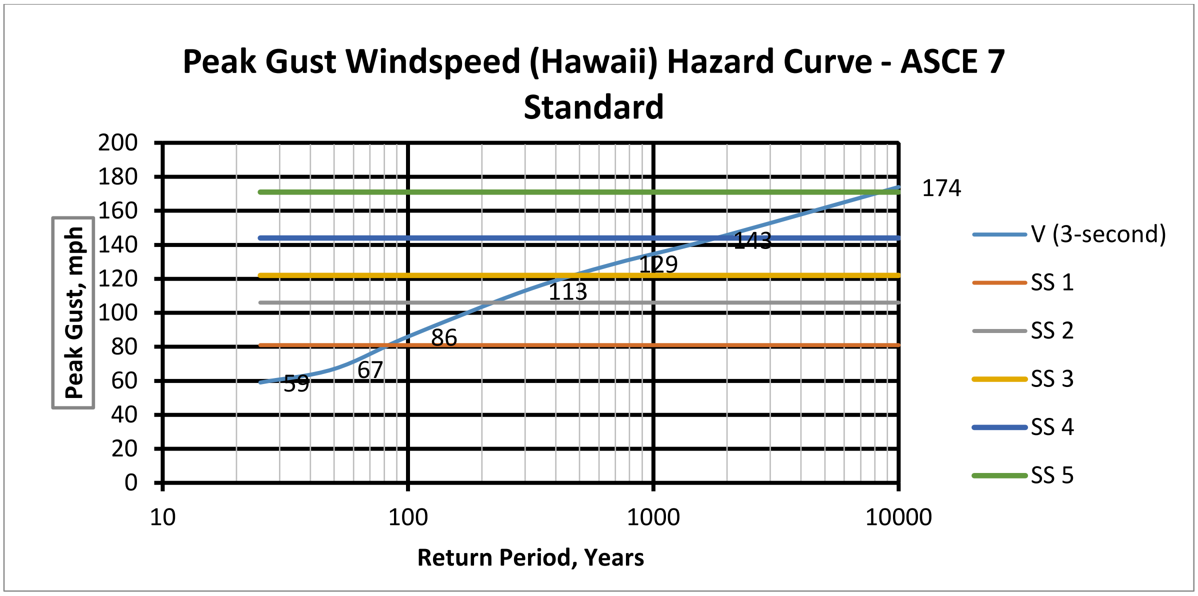


**Figure 5-2. Peak Gust Windspeed Hazard Curve for Hawai`i - with Saffir Simpson (S/S) limits shown**

Figures 5-3 through 5-5 show the effect of the present NFIP flood insurance in mitigating flood loss risk, and the extent of risk created under future climate change with sea level rise effects. The effect of climate change and sea level rise increases the future expected hurricane flooding damage in Waikiki to Kaka'ako from $0.76 Billion to $3,623 Billion, or about a 475% increase.

- The sea level rise contribution to the future expected hurricane flooding damage in Waikiki to Kaka'ako is responsible for about 75% of the future total losses. That is, the total losses from hurricane flooding due to climatic shift in hurricane hazard and sea level rise are four times that of a similar hurricane hazard today without sea level rise.
- Due to sea level rise alone, about 1,750 additional properties become affected by hurricane flooding; almost all of these are not presently in the FEMA flood zones (and therefore presently not required to be insured). Future Losses are $1.228B in this new area of flooding, with an aggregate Average Annualized Loss of $2.46M. This is the primary contributor to increased losses that are not presently mitigated by the flood ordinance.
- The increased flooding does not result directly from coastal wave set-up and runup, but in this area, increased flooding occurs primarily due to overtopping of the Ala Wai Canal embankments and its tributary. The combined surge and waves give rise to considerable flow depth and speed that might be damaging to infrastructure near the shore. These short-period waves, however, do not supply sufficient floodwater to produce substantial inland flows. Therefore, mitigation of the increased flooding extent would need to include the Ala Wai Canal.
- To preclude the increased flooding of the urban core of Honolulu in the future period that is about 75 years from the present, a master–planned flood control project involving the Ala Wai Canal and the adjacent tributary stream from Manoa and Palolo would become necessary. The annualized cost of the increased flooding damage will become approximately $2.46M (in present dollars) per year. Applying a 30-year

municipal bond financing model with a coupon rate of 5% to fund an infrastructure project with a benefit cost ratio of 1.5, a $22.5 million present day additional investment would be justified for sea level rise considerations. The flood control project may have basic justification of initial costs to mitigate present day flooding due to heavy rainfall and tropical storms, to which the $22.5 million would be added to ensure future reliability of flood control beyond 2050.

- In comparison, the U.S Army Corps of Engineers has been developing a proposed $173M project to mitigate flooding due to Ala Wai Canal overtopping. The proposal includes increasing the height of concrete canal walls by 4 ft. and pump stations and floodwater repositories along streams in Mānoa, Palolo and Makiki, to prevent $318M in expected damage to 3,000 properties in the case of a “100-year” flooding event ($3.2 average annualized loss). Using the same bond financing model, approximately $30M would be justified.
- Increased losses from a major hurricane with climate change compounded by sea level rise are approximately the following per building in the flooded area:
    - Residential, $380,000, dominated by multi-unit buildings, not single family residences
    - Commercial, $410, dominated by the retail sector
    - Industrial, $210,000, dominated by food processing
    - Government, $715,000, dominated by government offices and emergency services
    - Religious, $300,000
    - Education, $1,430,000, dominated by Grade Schools and community colleges
    - Agricultural, $95,000
- The Average Annualized Loss per larger residential, retail, professional service office buildings, hospitals and medical clinics, government buildings and emergency services, and schools and colleges exceeds $1,500 per building. Flood damage to contents is about more than 30% of the total losses for these types of buildings. Average total losses (structural and contents) per building for future climatic conditions are generally at least double the losses that would occur without the sea level rise effect on flooding.
- All the above losses suggest that some mitigation of sea level rise could result in more stringent requirements for the above occupancy types. Applying a 30-year financing model with an interest rate of 4% to fund the additional project costs, given that the annualized loss is about $2,200 per property, a $475,000/property present day investment on average for these larger buildings would be justified on a break even basis to mitigate damage. For government and infrastructure projects with much longer functional lifespan requirements, the investment for sea level rise would be applicable for projects in current planning.
- However, investment costs for climate change effects (primarily sea level rise) could also be justified to be deferred for properties with an economic lifespan (or payoff period of investment) of less than 50 years, i.e., low-rise single family residential properties. This deferrable period would be economically arguable because the increased risk occurs only after sea levels rise approximately 2 ft., and would not exist to nearly the same extent under present day sea levels.

- A risk transfer approach to the increased flooding of single family residential properties would justify additional insurance basis annual costs of only about $100, plus the insurance company's costs and return on investment. If the results of this study are considered by the insurance industry, this nominal increase for single family residential buildings should not presently warrant cost concerns about disclosure considerations for low-rise residential properties in the area of flood zones that include climate change effects.

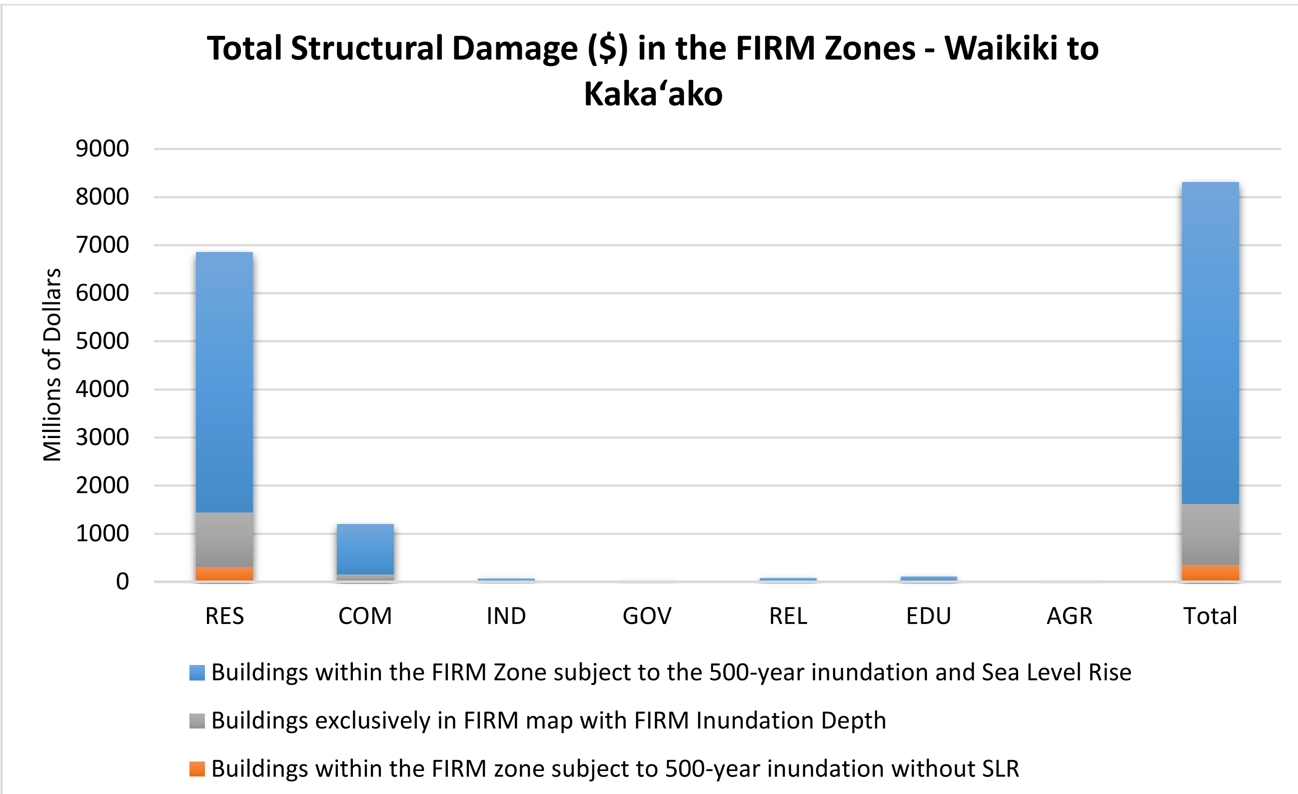


**Figure 5-3. Structural Damage from Storm Inundation to Buildings Located in the FIRM Zones - from Waikiki to Kaka'ako**

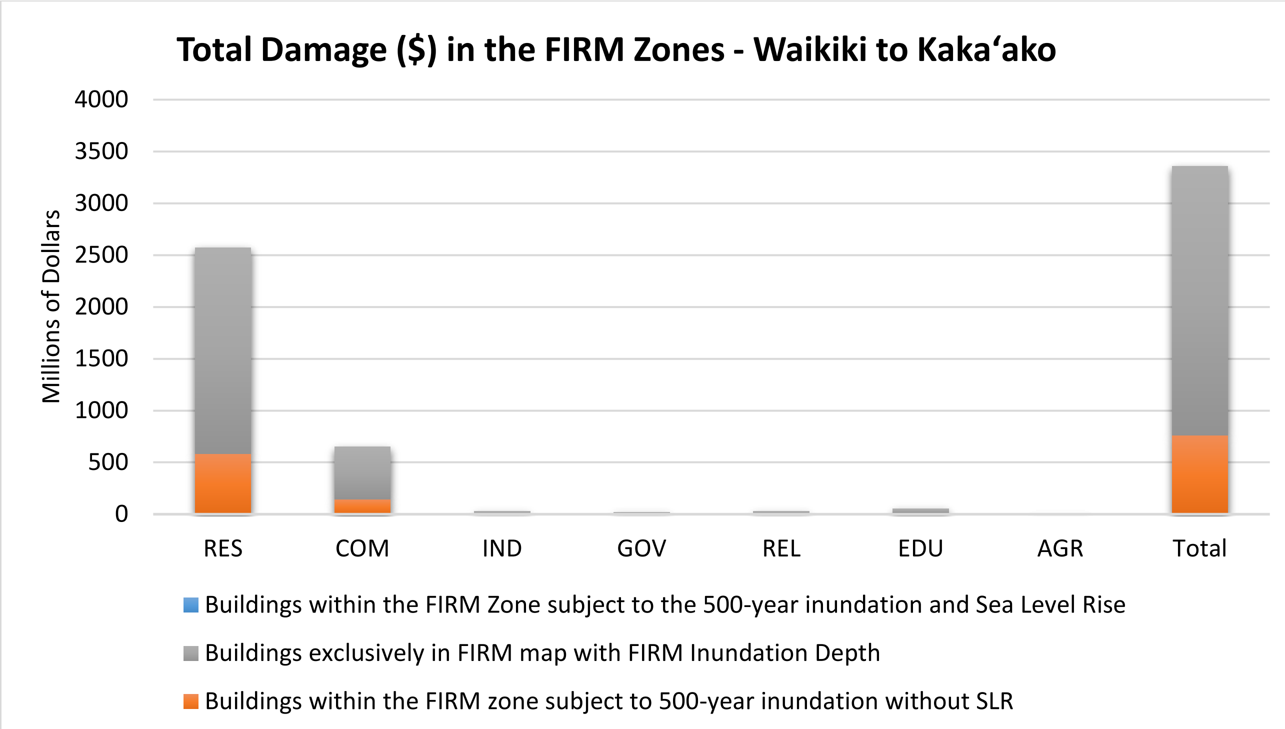


**Figure 5-4. Total Damage from Storm Inundations of Buildings Located in the FIRM Zones from Waikiki to Kaka'ako**

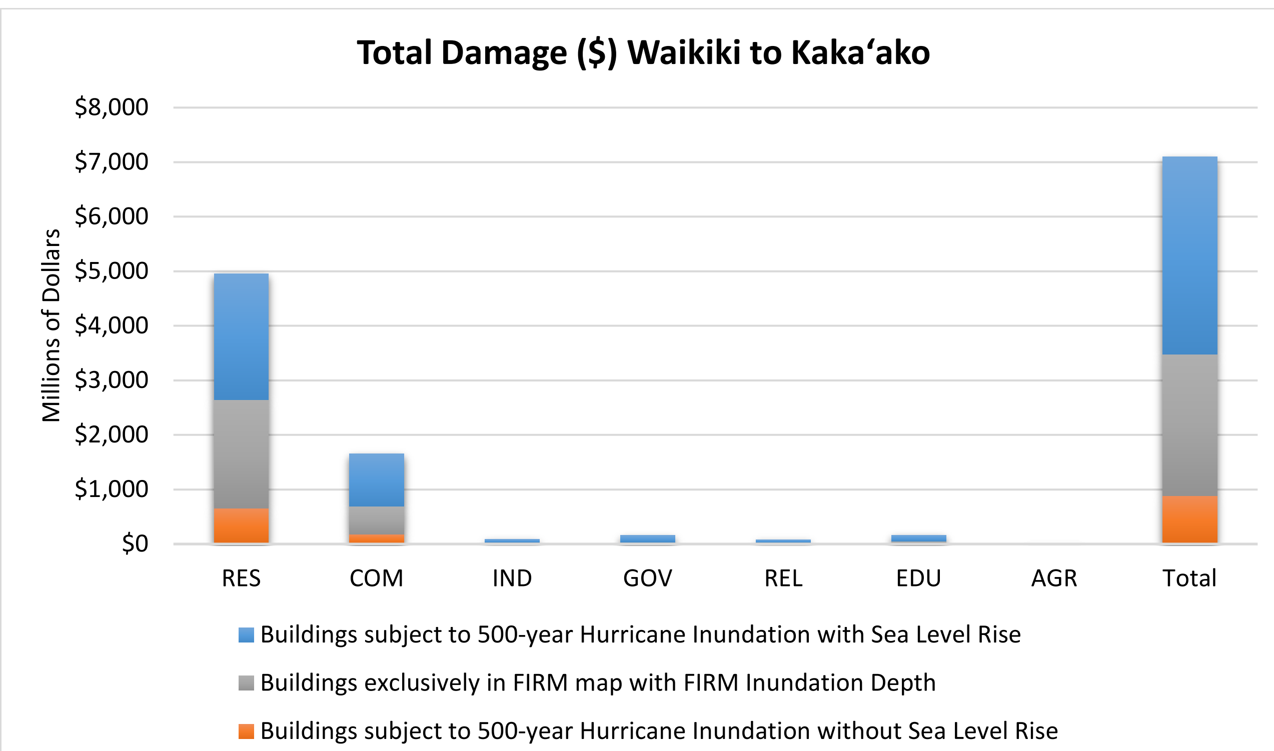


**Figure 5-5. Total Damage from Storm Inundation to Buildings from Waikiki to Kaka'ako**

# 6. Building Codes and Regulatory Standards Currently in Effect for the City and County Of Honolulu That Are Intended To Protect Life and Property from Coastal Hazards – Assessment of Potential Future Changes to Address Gaps in Consideration of Future Climate Conditions

## 6.1 *City Standards*

### a. Honolulu Building Code, ROH Chapter 16 (October 18, 2012)

The Honolulu Building Code is presently based on the 2006 IBC, which has the following local amendment provisions relating to hurricane and flood protective design measures:

- The basic wind speed and design equations are intended to result in achieving structural integrity of typical new construction for windspeeds up to 130 mph, which is a mid-Category III hurricane.
- Recognizes Hawai`i as a Special Wind Region with maps that account for topographic wind effects.
- Windborne debris protection is mandated for critical facilities.
- State- and City-Owned High Occupancy Buildings have Enhanced Hurricane Protection Area wind, windborne debris, and flood design requirements.
- For other categories of buildings, internal pressurization requirements are included to address glazing breakage during hurricanes.
- Certain atypical single-family residences without windborne debris protection, where located outside of the flood zone, have safe room provisions for refuge with safety equivalent to that of a shelter.
- There are Complete Load Path wind uplift resistance requirements for light frame residential construction.
- Design rain load maps for a 100-year 1-hour rainfall rates apply to roof design and roof drainage, the same as in the Plumbing Code.
- Flood hazard requirements are to document compliance with the 24 Standard based on a 100-year flood, which is the same minimal flood level as the NFIP.

Gaps to be addressed in the upcoming Honolulu Building Code update based on the 2012 IBC:

- Upgraded fastening of roofing underlayment and roofing systems for high wind.
- Wind design of photovoltaic panels and their attachments.
- Use of the more severe Exposure D wind profile for the coastal zone based on the effect of more intense hurricane windspeeds acting on open ocean wave breaking.

Remaining Gaps:

- The roof design requirement for rain loading has no allowance for long-term trends of climate causing more intense storms. Also, at the very least, for building design purposes, the 15 minute rainfall rate is now considered by national standard ASCE 7-16 as the more appropriate measure of intensity for roof drainage design. This design data is available at the NOAA Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

- If the frequency and intensity of tropical cyclones changes within the economic lifespan of the building, then it would be justified to make a proportionately commensurate increase in the basic wind speed and associated maps. However, present modeling indicates a shift in tropical cyclone activity that affects the proportionate occurrences of various categories of storms without necessarily significantly changing the probabilistic wind hazard curve. Thus, the climate change effect appears to be exhibited more in coastal inundation rather than high wind hazard, and the wind hazard level does not appear to be a known gap.
- If coastal storm inundation depths increase because any effects of coastal erosion, shoreline recession, subsidence, and sea level rise, then greater “freeboard” requirements for clearance above the base flood elevation can be mandated in the Honolulu Building Code, without seeking changes to the Federal Emergency Management Agency (FEMA) FIRM.
- Foundation design requirements do not account for shoreline erosion.

Proposed Honolulu Building Code Changes for Risk Category III and IV structures:

- Revise rainfall intensity map figure 1611.1 to add 15 minute duration 500-year intensity to comply with the latest ASCE 7 Standard. This data is already available at the NOAA Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).
- Use windspeed maps for Risk Category III and IV structures based on 1,700-year and 3,000-year windspeeds, respectively, to comply with the latest ASCE 7 Standard.
- Amend section for minimum elevation of the lowest horizontal structural member, based on 500-year flood elevation taking into account relative sea level change.
- Require consideration of shoreline erosion on foundation design.

**b. Honolulu International Residential Code (IRC), ROH Chapter 16 (October 18, 2012)**

- This is an alternative set of non-engineered semi-prescriptive code provisions that are permitted as an *exception* to the Honolulu adoption of the International Building Code to apply to the construction, alteration, movement, enlargement, replacement, repair, equipment, use and occupancy, location, removal and demolition of detached one- and two-family dwellings and multiple single family dwellings (townhouses) not more than two stories high with separate means of egress and their accessory structures.

Gaps:

- Wind Limitations: the IRC model code was originally developed for areas on the mainland where design professionals and design standards for residential construction were historically lacking. It is a code that does not include the engineering of the structure. Instead, prototypical assumptions of building types were used to develop a series of prescriptive requirements for low to moderate seismic and low wind conditions (windspeeds less than 100 mph) outside of the hurricane-prone regions.

- However, the wind uplift prescriptive requirements of the IRC pertain only to the roof to wall connections; a complete load path of prescriptive connections is not provided and must be otherwise designed.
- Nevertheless, building code officials in three of the four counties and the American Institute of Architects Hawai`i Chapter (AIA Hawai`i) desired to have a separate building permit review process for single-family homes based on the IRC. Maps were developed to show where the IRC assumptions were violated and the prescriptive structural requirements would not be adequate.
- Construction in regions where the effective wind speed, $V_{eff}$, shown on the Oahu wind maps, equal or exceed 100 miles per hour shall be structurally designed in accordance with engineered design standards.
- However, it does not appear that the building permit review process includes checking for applicability. As a result, many homes and accessory structures are permitted under the alternative IRC where the structural integrity provisions are invalid. Thus, as presently administered, the Honolulu IRC is a loophole for single family residence permitting without adequately designing for hurricanes.
- The public interest in having protection from hurricane winds is not met in the current IRC, since the adoption of this alternative code leads to a lower tier of substandard construction compared to the requirements of the building code.
- The ICC-600, Standard for Residential Construction in High-Wind Regions, was developed by the International Code Council in 2008 to provide a set of residential specifications that is consistent with the 2006 International Building Code and 2005 ASCE 7 wind loads. This is a contemporary set of prescriptive requirements that can supplement the International Residential Code provisions. However, as of the present, these high-wind requirements have not been adopted as amendments to the International Residential Code by the State or any of the counties. The supplemental standard would need to reference the effective wind speed maps as the source of the design windspeed.

Proposed Honolulu Building Code Change to the IRC:

- Require structural and foundation design in accordance with IBC.

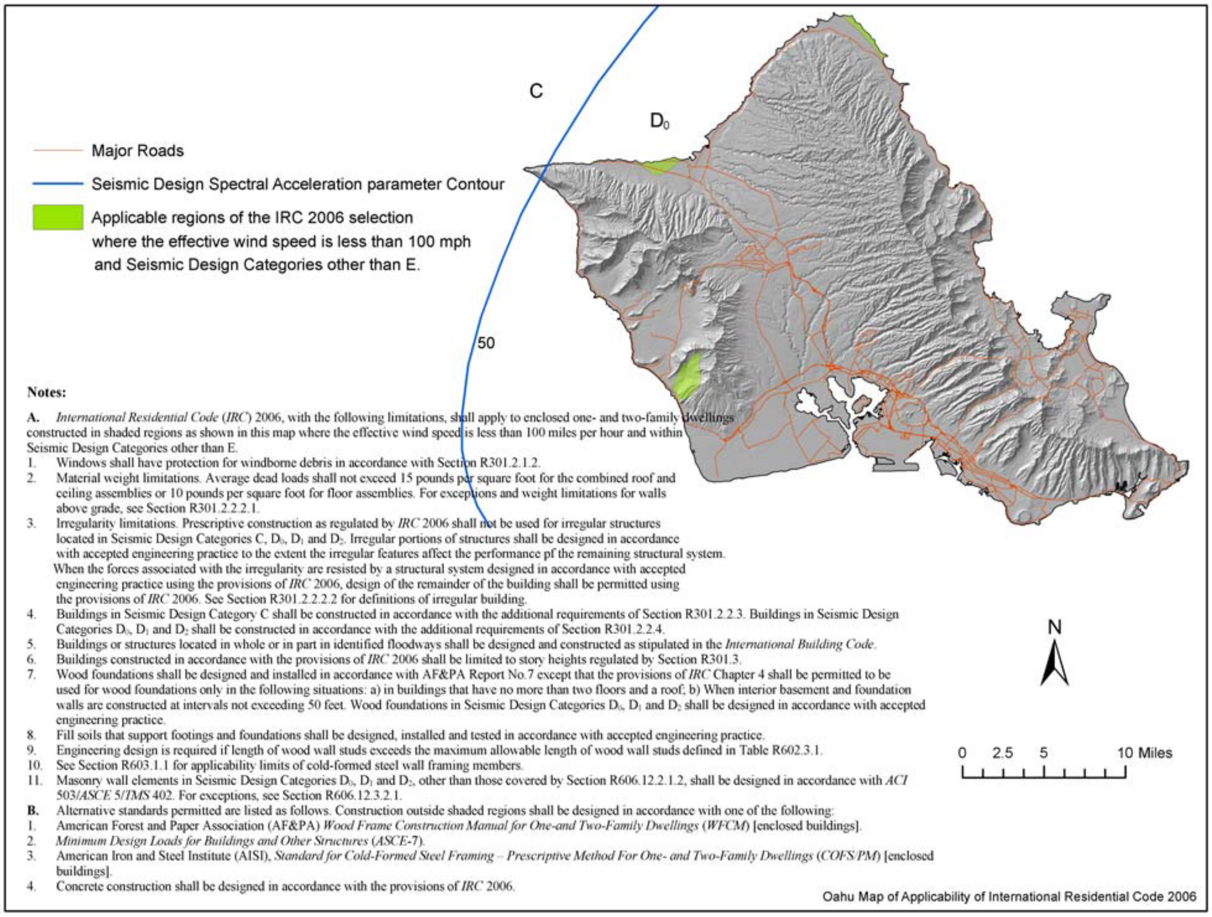


**Figure 6-1. City and County of Honolulu map showing the very few areas in green where the IRC is applicable without an engineered structural design using the IBC or other referenced wind and seismic standards (IRC (Honolulu) Figure R301.2 (8c))**

### c. Honolulu Electrical Code, ROH Chapter 17

- Special requirements for electrical work in the flood hazard zone, typically the installation of ground fault protectors and ground fault circuit interrupters.
- Elevation of electrical equipment above the base flood elevation or ground fault protection is required.
- Applicability is essentially linked to the Based Flood Elevation (BFE) of the flood insurance rate maps.

Gap:

There are no restrictions on locating electrical transformers and switchgear in basements within the flood hazard zone.

Proposed Change for Risk Category III and IV Structures:

Require placement above 500-year flood or dry floodproofing for 500-year flood developed considering climate change.

**d. Honolulu Plumbing Code, ROH Chapter 19 (per State Plumbing Code 2010 based on 2006 Uniform Plumbing Code (UPC))**

- Plumbing drains and gutters to be designed consistent with the statistical 100-year 1-hour rainfall rate for Hawai`i as mapped by the National Weather Service.
- The Honolulu Plumbing Code has some provisions that allow the use of recycled water under certain circumstances:
    - Gray-water systems are allowed for landscape irrigation purposes in single-family dwellings, provided design is substantiated by soil conditions for absorption and the lot area. It is not allowed within 3 feet of the highest known ground water, nor where contamination of groundwater or ocean may occur. The discharge of graywater is by drip irrigation or leach field; no surface or spray distribution of graywater is permitted.
- There is an allowance for septic tank requirements based on soil percolation rates for leaching.

Gap:

This requirement has no allowance for long-term trends of climate change causing more intense storms.

Proposed Change for Risk Category III and IV Structures:

- Adopt 100-year and 500-year 15 minute rainfall intensity, these rainfall intensities are already available at the NOAA Precipitation Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html).

**e. Land Use Ordinance (LUO), Revised Ordinances of Honolulu (ROH) Chapter 21 (amended 2014)**

- This is probably one of the key points of regulatory review and enforcement or exemptions, with a high degree of political visibility. Permitting is for “conditional use” that essentially involves conditions of additional specific requirements to meet “intent.”
- Development and design standards for the location, height, size of structures, density and open spaces, traffic and amount and type of parking, property line setbacks, outdoor lighting and zoned uses. Includes Specific Use Development Standards by type of occupancy and economic activity.
- Zoning Classification System implemented in maps; also includes preservation zoning for lands having an elevation below the maximum inland line of the zone of wave action, land susceptible to floods and soil erosion, land undergoing major

erosion damage or susceptible to inundation (See ROH Chapter 24 § 24-1.3 for land use categories).

- Flood hazard areas: "Dwellings in country, residential and agricultural districts, as well as detached dwellings and duplex units in apartment and apartment mixed use districts, may exceed the maximum height in the district by no more than five feet if required to have its lowest floor elevated to or above the base flood elevation, provided such additional height shall not be greater than 25 feet above the base flood elevation."
- Special Districts such as Diamond Head, Waikiki, and Haleiwa, each having design controls.
- Pre-permitting process requires public input at neighborhood boards.
- Includes the process for zone changes that are essentially negotiated.

Postulated Gap:

The LUO's Design Advisory Committee (DAC), a panel appointed by the City, does not have any representative expertise for natural hazards and climate change adaptation; no design controls exist in the LUO related to these concerns, so presently, natural hazard concerns may not have explicit standing in the application of the LUO.

Initially Proposed Revision:

ROH Chapter 21 - LUO Article 2 Administration and Enforcement: For Major Permits within the Shoreline Management Area, require evaluation of 50-years (beyond 2025) of relative sea level rise on the functionality of the development and land use and mitigation of the deleterious effects of the proposed use, and require the Director to consider that as a criteria for permitting new development, variances, or zone changes.

Analysis:

The advisory authority of the DAC is only for the review within Special Design Districts, which have cultural geography and architectural history considerations in their extent, rather than physical geography or hazard. Therefore, Chapter 25 Shoreline Management is probably the better means of implementing climate change adaptation. The proposed revisions to the LUO may expand its scope beyond the original intent, so therefore it would not be updated for the purposes of climate change.

**f. Flood Hazard Area, ROH Chapter 21A (May 2014)**

- Enacted to maintain compliance with the NFIP. Regulations administered by the Department of Planning and Permitting.
- Stated to be for the purposes of flood and tsunami protection; however, no tsunami provisions exist.

- One of the amended provisions was the use of "market value" instead of "replacement value" for purposes of establishing when proposed renovations, additions or expansions of non-conforming structures in a flood zone should be made compliant with the flood ordinance requirements.
- A project that equals or exceeds 50 percent of the market value of the existing structure within a cumulative period of five years is subject to full compliance with flood ordinance requirements.
- "Substantial improvement" means any reconstruction, rehabilitation, addition, or series of reconstruction, rehabilitation, or additions, or other proposed new development of a structure or repetitive loss structure, in any five-year period, the cumulative cost of which equals or exceeds fifty percent of the market value of the structure (excluding land) before the "start of construction" of the first improvement during that five-year period.
- Functionally dependent use includes only docking facilities, port facilities for cargo and passengers, and ship building and repair facilities.
- Based on FEMA 100-year flood zones in the FIRM that also establish the 1% annual exceedance base flood. Digital Flood Insurance Rate Maps (DFIRM) was effective September 30, 2004; coastal revision to account for hurricane storm surge was effective January 19, 2011.
    - V-zones: Minimum elevation of the lowest structural member above the BFE; break-away wall construction below the BFE; use of fill for structural support is prohibited in the V-zone.
    - A zones: Minimum elevation of lowest floor or basement above the BFE.
- Areas beneath the BFE has restricted use as parking or storage only and must meet minimum opening requirements.
- Certification standards for the flood boundary, flood elevation, lowest floor elevation certification, and post –construction certification.

Gap:

100-year flood hazard has a 40% chance of being exceeded with a 50-year economic horizon; these are reliability targets that are far below any other engineering standard, even before the consideration of climate change effects that may increase inundation in the future. This is a case of risk transfer for insurance purposes that does not provide high reliability of structures and sufficient protection of lives and property.

Proposed Changes for Risk Category III and IV Structures:

- Locally develop and adopt a 500-year flood zone that incorporates sea level rise applicable to major construction and infrastructure, and RCP 8.5 equivalent storm inundation. This would not involve housing construction.
- Focus on local mapping processes referenced to a local county ordinance and not associated with mandatory NFIP requirements.

Other Possible Considerations:

It is recommended that the storm water flood control practices that address requirements for storm runoff quantities for flood control be re-evaluated for possible changes to various flood control design practice standards**.**

*City and County of Honolulu Rules Relating to Storm Drainage Standards (June 2013)*
Re-evaluate the Hydrologic Criteria of the Standards for Flood Control and the design basis Rainfall Intensity maps, in keeping with the risk level including climate change and the longevity of City infrastructure

*City and County of Honolulu Design Standards of the Department of Wastewater Management, General Requirements for Wastewater Facilities*
Re-evaluate the wet weather design period for Quantity of Wastewater for Chapter 20, Sewers and for Chapter 30, Pump Stations
Re-evaluate the 20-year and 50-year Design Periods and Flow Projections for design peak flow capacity, Chapter 40, Wastewater Treatment Facilities

*State of Hawai`i Department of Transportation Highways Division's Storm Water Permanent Best Management Practices Manual (March 2007)*
Re-evaluate the Chapter 4 Permanent BMP Consideration in Project Planning and Design Phase to include climate change effects on rainfall intensity (and storm water), and Chapter 5, Storm Water Quantity Control, recurrence interval design criteria

**g. Shoreline Setbacks, ROH Chapter 23 (amended 2010)**

- "It is a primary policy of the City and County of Honolulu to protect and preserve the natural shoreline, especially sandy beaches; to protect and preserve public pedestrian access laterally along the shoreline and to the sea; and to protect and preserve open space along the shoreline. It is also a secondary policy of the City and County of Honolulu to reduce hazards to property from coastal floods." (ROH Sec. 23-1.2(a))
- Prohibits any construction or activity that may adversely affect beach processes, shoreline access, and shoreline open space.
- Standard 40-foot setback from the certified shoreline, with exception that a minimum 30 foot buildable area is to be maintained.
- "Shoreline" means the upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth, or the upper limit of debris left by the wash of the waves.
- If a nonconforming structure is destroyed by any means to an extent of more than 50 percent of its replacement cost at the time of destruction, it shall not be

reconstructed except in conformity with the provisions of Chapter 23. Existing nonconforming structures require a variance to reconstruct.

- New subdivisions must accommodate a 60-foot setback, with exceptions for areas that are not within the coastal high hazard district and where the shoreline is a fixed rocky shoreline.
- Illegal shoreline protection structures are those that are not nonconforming structures and have not been authorized by permits.

Gap:

These regulations are not based on historic shoreline erosion rates, although such information exists and is readily available for Honolulu. Therefore, the level of setback protection for structures is not consistent, such that properties with high erosion rates have less protection over a shorter time than others.

Proposed Changes:

For Oahu, provide the variable setbacks based on historic shoreline erosion rates only for new construction, with a waiver for existing structures and improvements and repairs to them and for certain lot dimensions.

**h. Special Management Area, ROH Chapter 25 (amended November 2011)**

- Special Management Area (SMA) means the land extending inland from the shoreline, as established by Chapter 25 and delineated on the maps established by the City Council.
- Special controls on development within an area along the shoreline are necessary to avoid permanent loss of valuable resources and foreclosure of management options, and to insure that adequate public access is provided to public owned or used beaches, recreation areas, and natural reserves, by dedication or other means. It is also the policy of the City and County of Honolulu to avoid or minimize damage to natural or historic special management area wetlands wherever prudent or feasible.
- "Development" does not include construction or reconstruction of a single-family residence that is less than 7,500 square feet of floor area and is not part of a larger development; nor repair or maintenance of roads and highways or streams, channels, drainage ways, and underground utilities, provided that no cumulative impact or significant environmental or ecological effect will be generated.
- "Shoreline" means the upper reaches of the wash of the waves, other than storm and tidal waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edges of vegetation growth or the upper limit of debris left by the wash of the waves.
- SMA use assessments include the following, among others:
    - Adequate access to publicly-owned beaches
    - Protection of water resources and water quality and natural habitats

- Consistent with the general plan and Chapter 24 development plans and Chapter 21 zoning
- Minimizes dredging and filling

Gap:

SMA maps may need adjustment in the future in high erosion rate areas. There is no statutory minimum lifespan of development defined for SMA considerations; the actual lifespan of major building and infrastructure development (excluding single family homes) will typically be over 100 years. This brings standing to considerations of climate change.

Proposed Changes: starting in 2025:

- Create another level of SMA zone maps to account for sea level rise, shoreline erosion, and coastal flood modeling under CMIP AR5 RCP 8.5 climatic conditions. Have this applicable only to major (definition to be determined) long-term *developments.*
- For Major Permits within the proposed Coastal Construction Control zone, require evaluation of 50-years of relative sea level rise, flood, wind, and erosion on the functionality of the development and land use and mitigation of the deleterious effects of the proposed use, and require the Director to consider that as criteria for permitting new development, variances. Consider other uniform standards within this new zone, such as making this zone inapplicable for the IRC.

### 6.2 *State Standards*

#### a. Hawai`i State Building Code, HRS Chapter 107, Part II

This statute of 2007 gives the State Building Code Council (SBCC) the authority to adopt, amend, and update codes and standards including but not limited to those applicable to buildings, residential structures, and hurricane resistant standards related to loss mitigation standards in accordance with HRS § 431P-12, flood and tsunami, and existing buildings. This statute makes the SBCC the primary means of implementing new codes and design standards for the State. All counties in Hawai`i are required by this statute to update their county building code within two years of the adoption of any state building code. If a county does not meet the two-year adoption schedule, the Hawai`i State Building Code version of that code automatically becomes effective in the interim, until the county makes a formal adoption by ordinance. Therefore, the building, electrical, plumbing, and flooding hazard codes of the ROH are largely dependent on the maintenance and updating of the Hawai`i State Building Code.

**Table 6-1. Status of Principal Building-Related Codes in the State and Honolulu (Sept 2017)**

| State Building Code Council | | Pending Hearing Authorization by Governor | Current Codes by Jurisdiction |
|---|---|---|---|
| **Currently Considering** | **Recently or soon to be Approved** | **Administrative Rules** | **C&C Honolulu** |
| Building<br>2018 IBC | 2012 IBC | 2012 IBC | 2006 IBC<br>Adopted 10/3/2012 |
| Plumbing<br>2018 UPC | 2012 UPC<br>(July 8, 2014) | 2012 UPC | *2006 UPC* † ‡ |
| Electrical<br>2017 NEC | 2014 NEC | 2014 NEC<br>03/27/2017 | 2008 NEC<br>Adopted 2009 |
| Residential<br>2018 IRC* | 2012 IRC* | 2006 IRC* | 2006 IRC*<br>Adopted 10/3/2012 |

† State Version applies.
‡ County version being checked by Corporation Counsel.
* IRC not applicable to high seismic areas and has limited applicability due to hurricane wind speeds.

Gaps:

Since the SBCC inception in 2007, State agencies have not been very active participants. With the exception of the State Fire Council, the Department of Business, Economic Development and Tourism - Office of Planning and State Energy Office, State agencies have been slower to support modernizing building codes to present standards, much less accounting for climate change effects. Therefore, the implementation of any climate change adaptation measures may be severely impeded if funding of the State Building Code Council is not provided on a sustainable basis.

Proposed Changes to HRS Chapter 107, Part II:

- Mandatory adoption of International Building Code as the interim state code when DAGS does not adopt HAR within 3 years of publication. (see ACT 141, HB637 HD2 SD2 CD1, 7/10/2017)
- Create funding mechanism that provides a long-term source of support.

**b. State of Hawai`i Land Use Commission, HRS Chapter 205**

In 1961 the State Land Use Law was enacted and established the State Land Use Commission (LUC). The law provides that the LUC has the power to classify all lands in the State into four districts: Agriculture, Conservation, Rural, and Urban. Act 187 vested DLNR with jurisdiction over the Conservation District, enabling DLNR to formulate subzones within the Conservation District, and to regulate land uses and activities therein. Since 1964, the Board of Land and Natural Resources (BLNR) has adopted and administered land use rules for the Conservation District (HAR Chapter 13-15), and has made major changes to the rules in 1978 and 1994.

The Conservation District has five subzones: Protective, Limited, Resource, General, and Special. Omitting the Special subzone, the four subzones are arranged in a hierarchy of environmental sensitivity, ranging from the most environmentally sensitive (Protective) to the least sensitive (General); the Special subzone is applied in special cases specifically to allow a unique land use on a specific site.

The Conservation District includes numerous segments of coastal areas landward from the shoreline. Besides these lands, the Conservation District also includes all submerged lands seaward of the certified shoreline, to the limit of state territorial waters.

The BLNR, staffed by DLNR, is responsible for establishing the procedures for certifying where the shoreline is located, and for promulgating and administering the Conservation District use regulations. All activities proposed within the Conservation District must submit to an application and review permit in order to obtain a Conservation District Use Permit from BLNR.

**c. State of Hawai`i Coastal Management Program, HRS Chapter 205A**

The National Coastal Zone Management Act (CZMA) was enacted in 1972 to assist coastal states in developing management policies for the coastal resources located within the state coastal zone. Coastal erosion is specifically mentioned in the CZMA as an area of concern to be addressed by state policy. The CZMA requires that state programs include a planning process for assessing the effects of shoreline erosion, study ways to lessen the impact, and restore areas adversely affected by erosion.

The State of Hawai`i Coastal Zone Management Program (CZMP) was enacted in 1977 under Chapter 205A of the HRS. Hawai`i's coastal zone includes all lands, and all waters from the shoreline to the seaward limit of the state's jurisdiction. The State Office of Planning (OP), administratively attached within DBEDT, is the lead agency for administering the CZMP in Hawai`i. The OP administers the CZMP through a network of state agencies and the county planning departments. The erosion planning and management activities fall primarily under the jurisdiction of the counties through the administration of the Special Management Area (SMA) and shoreline setback provisions of HRS Chapter 205A, and the DLNR, Conservation District Regulations of land use (HAR Title 13 Chapter 5). The boundary of the SMA includes the land extending inland from the shoreline delineated on maps filed with the appropriate county authority.

**Table 6-2. Required SMA Permitting and Hazard Assessments At Different Stages of Development**

| Stage of Development | Special Management Area Permit HRS Chapter 205A | Potential Gaps in Hazard Assessment |
|---|---|---|
| State District | No<br>HRS §205A-29 | County reclassification of State districts (land <15 acres).<br>Standards for hazard mitigation analysis |
| General, Community, Development Plans | No<br>HRS §205A-29 | Actions proposed by county that go through review process.<br>Standards for hazard mitigation analysis |
| County Zoning | No<br>HRS §205A-29 | Small zoning changes (less than 10 acres),<br>Standards for hazard mitigation analysis |
| Subdivision | Yes | Standards for hazard mitigation analysis |
| Infrastructure Improvement | Yes | Standards for hazard mitigation analysis |
| Lot Transfer | No | |
| Home Construction | Yes – county discretion | Standards for hazard mitigation analysis |
| Hazard Noticed-Remedial Action Analyzed | Yes | Standards for hazard mitigation analysis |

### d. State of Hawai`i Certified Shoreline, HRS Chapter 205A

The State Board of Land and Natural Resources was authorized by HRS Chapter 205A, to adopt rules for determining the shoreline and appeals of shoreline determinations, and to enforce the established rules. In the State of Hawai`i, the coastal setback for development (per ROH Chapter 23 – Shoreline Setbacks, for example) is measured from the shoreline, defined in HRS Chapter 205A as:

> *The upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, usually evidenced by the edge of vegetation growth or the upper limit of debris left by the wash of the waves. (HRS §205A-1)*

Gap:

This definition creates temporal ambiguity; there are many dynamic variables associated with the shoreline. Unfortunately the "edge of vegetation growth", often appears to be migrating seaward as commercial interests and homeowners frequently landscape their beachfront in order to gain valuable coastal building space, constituting a slow encroachment of the property line. On the other hand, encouraging vegetative growth can help mitigate the erosion of sand dunes. Also, measuring by the variable characteristics of wave run-up does not allow for a more accurate means of measurement, such as a fixed natural monument or datum.

Proposed Revision:

*HRS Chapter 205A Certified Shoreline: For planning purposes, also include an Expected Shoreline map taking into account shoreline erosion and relative sea level rise over the next 50 years.*

**e. State of Hawai`i CLP of DLNR Land Division (HAR Title 13, Subtitle 10, Chapters 219-223)**

On November 20, 1997, the State of Hawai`i Board of Land and Natural Resources established the Coastal Lands Program (CLP) within the Land Division. The purpose of the CLP is to establish a strategic and comprehensive framework to protect and conserve the state's beaches. This framework is set out in the Coastal Erosion Management Plan (COEMAP), a joint effort of the State of Hawai`i DLNR and the University of Hawai`i, Department of Geology and Geophysics. The major goals of the CLP are as follows:

- Develop consensus on the causes and consequences of beach loss for the beaches of the State of Hawai`i.
- Develop agency agreements with respect to coordinating regulatory functions (i.e., permit streamlining and enforcement) and planning goals with other state, county and federal agencies.
- Build support for legislative actions needed to implement COEMAP.
- Strike a balance between coastal development and beach conservation by promoting alternatives to shoreline hardening, such as beach and dune restoration, coastal lands acquisition and strategic redevelopment.
- Form linkages with federal agencies and community groups and provide funds for research and planning to support county land management efforts along the coast.

The CLP is overseen by the State of Hawai`i DLNR through the Office of Conservation and Coastal Lands (OCCL). Some of the initiatives taken by the CLP include developing pilot programs for beach nourishment, streamlining the beach nourishment regulatory process, and funding sediment and coastal engineering studies to better understand complex coastal areas such as Waikiki Beach. The CLP has also been developing public education programs and distributing information and guidelines on the best management, erosion control and construction practices for Hawai`i's coastal areas. Through these programs, the OCCL seeks to promote improved collaborative management of coastal resources utilizing the best and most current scientific information.

**f. Uniform Land Sales Practices Act, HRS Chapter 484**

The Uniform Land Sales Practices Act was enacted in 1967 and deals specifically with the sale of subdivided lands. Under this law, a public offering statement is to be delivered to all purchasers and prospective purchasers of a lot in a subdivision. HAR § 16-104-26(a). The public offering statement is to fully and accurately disclose the physical characteristics of the subdivided lands offered and all unusual or material circumstances or features affecting the subdivided lands. HAR § 16-104-2.

Required information in the public offering statement that is relevant to hazard mitigation includes:

1. Existing zoning regulations, including land use classifications and general plan;
2. Encumbrances, easements, liens, restrictions;
3. Elevation of the land;
4. Soil conditions- drainage; and
5. Exposure to natural hazards; e.g., earthquakes, floods, tidal waves, volcano, forest fires, slides, etc. HAR § 16-104-25.

From the landowner/developer prospective, disclosure of hazard risks creates an incentive to design projects, subdivisions or lots that avoid hazard problems. This is because the combination of a poorly designed (substandard) lot and a knowledgeable buyer will reduce market value. The developer benefits from proper hazard mitigation design by offering a more valuable product and establishing a quality reputation. Aside from protecting the buyer and providing incentive for the landowner to implement hazard mitigation measures, seller disclosure laws promote economic efficiency. Hawai`i's disclosure law was implemented, in part, after statistics showed that a leading cause of real estate litigation was due to the failure to disclose material facts regarding a property.

Gap:

The statutes do not reference any particular hazard maps or criteria of the severity of the hazard that warrants disclosure. Another problem with the public offering statement is the timing of receipt – at "time of sale" which is after a decision has been made to purchase. This, coupled with vagueness of information required, renders disclosure ineffective. A buyer has little recourse after the sale if the seller did not follow the disclosure requirements. Tropical cyclones are not considered. Climate change effects are not considered.

Proposed Change:

g. **Mandatory Seller Disclosures in Real Estate Transactions, HRS Chapter 508D**

Expand list of disclosable hazards in public offering to include, more explicitly: "Exposure to natural hazards: e.g., 2,500-year earthquake ground motion in excess of SDC B levels and earthquake –induced ground failure, rockfalls / landslides, 100-year and 500-year flooding, tsunami evacuation zone and extreme tsunami zone, lava inundation hazard zone 1, 2, or 3 per USGS 1992 map, forest and wildfire historic burn areas per DOFAW, effective windspeed hazards above 145 mph per Hawai`i State Building Code", dam failure inundation map per DLNR, high surf inundation, and 100-year coastal shoreline erosion."

The Mandatory Seller Disclosures in Real Estate Transactions Act ("Mandatory Disclosures Act") was passed in 1994. [HRS Chapter 508D]. This law requires the seller or the seller's agent to prepare a disclosure statement in good faith and with due care regarding material facts that would be expected to measurably affect the value to a reasonable person of the residential real estate being offered for sale.

Related to hazard mitigation, disclosure is expressly required for residential property in the special flood hazard area, (see HRS § 508D-15(a)(1)). These are areas on the Flood Insurance Rate Maps subject to the 100-year flood and are equivalent to FEMA's V, VE, A and AE zones. Disclosure is also required for anticipated inundation areas designated on the Department of Defense's civil defense tsunami inundation maps, (see HRS § 508D-15(a)(4)).
The Hawai`i Supreme Court has indirectly indicated that erosion is a material factor to disclose. The Court ruled that a shoreline property boundary that was in dispute was a material fact that required disclosure. Shaffer v. Earl Thacker Co., 6 Haw. App. 188, 716 P.2d 163 (1986). Erosion changes the location of shoreline property boundaries, resulting in diminution of coastal lot size over time. County of Hawai`i v. Sotomura, 54 Haw. 176 (1973).

Gap:

The Mandatory Disclosures Act covers only residential real property with one to four dwelling units or a condominium or cooperative apartment, the primary use of which is occupancy as a residence, (see HRS § 508D-1.) Empty lots with no structures on them are not covered, even though the lot may have a history of flooding and erosion.

Proposed Change:

Make mandatory seller disclosure apply to vacant lots as well.

**h. Public Utilities Commission (PUC) 2007 adoption of the 2002 National Electric Safety Code (Department of Budget and Finance HAR 6-73 Installation, Operation, and Maintenance of Overhead and Underground Electrical Supply and Communication Lines)**

- Prior to Hurricane Iwa, Hawai`i's PUC adopted General Order No.6 – Rules for Overhead Electric Line Construction (GO-6), in 1966. GO-6 specified a "Light Loading" condition applied to facilities where the elevation above sea level is 6,250 feet or less. "A horizontal wind pressure of 8 psf (56 mph) on projected area on cylindrical surfaces, and 13 psf (71 mph) on flat surfaces shall be assumed." In 1972, in recognition of the latest industry standards/practices, portions of the National Electric Safety Code (NESC) were adopted by the Hawaiian Electric Company (HECO) Engineering Department for use in the development of HECO's design criteria for transmission lines. According to NESC's General Loading Requirements and Maps, Hawai`i was classified as a "Light" Loading District. The specified horizontal wind pressure was 9 psf (60 mph).
- After Hurricane Iwa, a design wind speed of 80 mph was adopted for all major 138 kV overhead lines except in the Pacific Palisades to Fort Shafter area. In this area, a 100 mph wind speed was used pending the outcome of the data from a wind tunnel model. Upon completion of the wind tunnel model tests, in some cases, the design wind speed was increased to 125 mph.
- In 2007, the PUC rescinded General Order 6 and adopted the 2002 NESC that uses a 105 mph basic wind speed.
- The 2002 NESC uses a design load methodology that references the ASCE 7-05 wind load provisions for windspeed. It does not include the topographic windspeed maps that were adopted beginning with the 2007 Honolulu Building Code and the 2010 Hawai`i State Building Code.

Gaps:

There is a code exemption for existing installations when they are repaired or maintained. Therefore, deteriorated poles are replaced in-kind without upgrade.

Proposed Change:

The PUC should adopt the windspeed maps of the 2010 Hawai`i State Building Code, to replace the NESC 2012 Figure 250-2. Otherwise, the wind design standard is deficient with respect to actual wind speeds that would occur during tropical storms and hurricanes.

6.3 *Federal Standards*

### a. National Flood Insurance Program (NFIP) – Background Information

The federal government created the NFIP to insure those who suffer from flood disasters. From 1968 until the adoption of the Flood Disaster Protection Act of 1973, the purchase of flood insurance was voluntary. The Flood Disaster Protection Act of 1973 mandated flood insurance coverage for many properties. For the first time, regulated lending institutions could not make, increase, extend, or renew any loan secured by improved real estate located in a Special Flood Hazard Area (SFHA) in a participating NFIP community unless the secured building and any personal property securing the loan were covered for the life of the loan by flood insurance. Congress established this requirement because, after major flood disasters, it became evident that relatively few individuals in eligible communities who sustained flood damage had purchased flood insurance. Also, federal officers or agencies could not approve any form of loan, grant, guaranty, insurance, payment, rebate, subsidy, disaster assistance loan or grant, for acquisition or construction purposes within a SFHA in a participating community unless the building and any personal property to which such financial assistance relates were covered during the life of the property.

Following the multi-billion dollar flood disaster in the Midwest in 1993, Congress enacted the National Flood Insurance Reform Act of 1994. One of the purposes of the 1994 Act is to improve compliance with the mandatory purchase requirements of the NFIP by lenders, servicers, and secondary-market purchasers. Congress was concerned over the low level of insurance participation among eligible property owners and resulting increases in Federal disaster relief payments. The law requires Federal agency lender regulators to develop regulations to direct their federally regulated lenders not to make, increase, extend, or renew any loan on applicable property unless flood insurance is purchased and maintained. The changes in NFIP regulations since 1994 have required additional homeowners in Hawai`i to buy flood insurance. There are over 30,000 properties in Hawai`i with flood insurance policies in force.

On June 30, 2004, President George W. Bush signed into law the Bunning-Bereuter-Blumenauer Flood Insurance Reform Act of 2004. The reforms covered by the Act include measures to address repetitive losses. The Biggert-Waters Flood Insurance Reform Act of 2012 (BW-12) was passed by Congress and signed by the President on July 6, 2012. The Reform extends the NFIP for five years, while requiring significant program reform. The law requires changes to all major components of the program, including flood insurance, flood hazard mapping, grants, and the management of floodplains. Many of the changes are designed to make the NFIP more financially stable, and ensure that flood insurance rates more accurately reflect the real risk of flooding. The changes (with subsequent amendments to Biggert-Waters) are being phased in over time, beginning in 2013.

Under the NFIP, each county has mapped flood hazard areas and established a permit system to regulate development within these flood hazard areas. The FIRMs include areas prone to rainfall flooding (A zones) and high waves (V zones). Floodplain management regulations for the City and County of Honolulu are stipulated in Chapter 21A, Flood Hazard Areas, of the Revised Ordinances of the City and County of Honolulu (May 2014). The NFIP mandates federal insured banks to require purchasing of flood insurance as a condition for financing the construction or purchase of existing buildings in flood plain areas, thereby shifting the primary burden for flood disaster relief to those who choose to live or conduct business in flood hazard areas.

The recurrence interval of a flood, or flood frequency, is the average time interval within which a flood of a given magnitude will be equaled or exceeded. Flood frequencies can be determined by plotting a graph of the size of all known floods for an area and determining how often floods of a particular size may occur, or gathering hydrologic and hydraulic data from streams and calculating probabilities through models. The FIRM maps identify a flood hazard area as the area that would be inundated by a 100-year flood, or a flood with a 1% chance of occurring annually. The 100-year flood, also referred to as the base flood, is a national standard adopted by the NFIP that represents a compromise between minor floods and the greatest flood likely to occur in a given area. The FIRM maps delineate the 100-year flood zones for rainfall flooding, coastal flooding, shallow flooding, and distinguish areas where detailed studies have been conducted to determine base flood elevations. While the 100 year floodplain identifies the boundary of a flood having an annual probability of occurrence of 1%, there are areas within the floodplain with higher probabilities of occurrence. The probability of recurrence increases with proximity to the stream channel or the coastline. Therefore, sites located at or near streams or shorelines have higher probabilities of occurrence than that of the floodplain.

The NFIP sets minimum requirements for participating communities' building Under the NFIP, each county has mapped flood hazard areas and established a permit system to regulate development within these flood hazard areas. The FIRMs include areas prone to rainfall flooding (A zones) and high waves (V zones). Floodplain management regulations for the City and County of Honolulu are stipulated in Chapter 21A, Flood Hazard Areas, of the Revised Ordinances of the City and County of Honolulu (May 2014). The NFIP mandates federal insured banks to require purchasing of flood insurance as a condition for financing the construction or purchase of existing buildings in flood plain areas, thereby shifting the primary burden for flood disaster relief to those who choose to live or conduct business in flood hazard areas.

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1. All development in the base floodplain must have a permit from the community. Agriculture and forestry activities are not exempt.
2. Encroachments, including fill, new construction, substantial improvements and other developments shall not be allowed in the floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge. The floodway is the channel and central portion of the floodplain that is needed to convey the base flood. It is usually the most hazardous area of a riverine floodplain and the most sensitive to development. At a minimum, no development in the floodway can cause an obstruction to flood flows.
3. New buildings may be built in the floodplain, but they must be protected from damage by the base flood. The lowest floors of residential building must be elevated to or above the BFE. Non-residential buildings must be elevated or protected against floods.
4. When an addition, improvement or repair of damage to an existing building is valued at 50% or more than the value of the original building, then it is a considered a substantial improvement. A substantial improvement is treated as new construction and the building must be protected from damage by the base flood.
5. In coastal high hazard areas (V-zone), new buildings and substantial improvements to existing buildings must be elevated on open columns or piles so that the bottom of the lowest horizontal structural member is elevated at or above the BFE. New buildings shall also be on an anchored foundation engineered for the site. Construction projects are not allowed to alter sand dunes.

There are four significant benefits of participating in the NFIP. One focuses on property protection and three focus on financial security. Specifically:

1. Development that complies with the minimum NFIP performance criteria is less likely to experience major damage. Studies have shown that, on average, buildings that meet the NFIP criteria sustain approximately 75% less damage than those that do not.
2. Federally insured or regulated lenders must require that improvements located in mapped flood hazard areas be insured for flood damage. If a community does not participate in the NFIP, then lenders must notify borrowers that federal disaster assistance for flood damage will not be available, including grants and loans.
3. People who have flood insurance have a significant advantage over those who have no financial support or those who have to get loans to help repair and rebuild. Most homeowners' property insurance explicitly excludes damage from floods, and non-NFIP flood insurance is hard to find. However, it is easy for most home and business owners to get NFIP flood insurance because many private companies write and sell policies on behalf of the NFIP.

4. Federal assistance is available to repair or restore public infrastructure and buildings in flood hazard areas if damaged by a disaster that is declared by the president.

Gaps:

- The 100-year flood, or the flood with a 1% annual chance of being exceeded, results in a 40% chance of being exceeded over a typical economic lifespan of 50-years. That level of reliability is very far below the criteria used for any other natural hazard. For example, the wind design provisions of the code are based on the 700-year windstorm, which has about a 5% chance of being exceeded over 50 years.
- Floods are a special case where the design criteria has not been set by engineers, but by the NFIP legislation, resulting in relatively low requirements for flood mitigation that are exceeded in “real” disasters, such as due to surge and waves setup by hurricanes. Problems develop when flood loads start to overwhelm wind design capacity. In other words, flood loads will be much higher than wind loads, but the flood elevation prescribed is much lower than what the design level hurricane will produce, creating a severe gap of vulnerability.
- Flood zones based on the 100-year mean recurrence interval BFE do not include all structures exposed to flood hazard. For storm events of greater return period, the flood hazard expands both in spatial extent and in depth. For those structures and components of structures that were not subject to the prescriptive flood design requirements, the ratio of flood load to design resistance becomes infinite, resulting in failure. Therefore, the flood loads that are associated with NFIP regulations do not have a uniform or consistent reliability basis to the same extent as the other natural hazards.

**b. Standards for Civil Works Under the Jurisdiction of the U.S. Army Corps of Engineers (USACE), Relating to Vulnerabilities to Climate Extremes**

- Policy (June 2014): “It is the policy of USACE to integrate climate change preparedness and resilience planning and actions in all activities for the purpose of enhancing the resilience of our built and natural water-resource infrastructure and the effectiveness of our military support mission, and to reduce the potential vulnerabilities of that infrastructure and those missions to the effects of climate change and variability.”
- Regulation No. 1100-2-8162 SLC in Civil Works Programs
  - United States Army Corps of Engineers (USACE, 2013) guidance for incorporating the direct and indirect physical effects of projected future sea level change across the project life cycle in managing, planning, engineering, designing, constructing, operating, and maintaining USACE projects and systems of projects.
  - Potential local relative sea level change must be considered in every USACE coastal activity as far inland as the extent of estimated tidal influence.

- Engineer Technical Letter 1100-2-1 Procedures to Evaluate Sea level Change: Impacts, Responses, and Adaptation (USACE, 2014)
  - This Engineer Technical Letter integrates the recommended planning and engineering to understand and adapt to impacts of projected SLC through a hierarchy of decisions and review points that identify the level of analysis required as a function of project type, planning horizon, and potential consequences.

Gap:

The USACE technical specification on how to evaluate and design for SLC does not apply to any construction outside the regulatory domain of the USACE. These documents have procedures for what would typically be followed by coastal engineers involved in the design of coastal infrastructure. However, the methodology is based on outdated climate change projections, and needs to be revised reflect local relative SLC conditions and IPCC AR5.

Proposed Change for Risk Category III and IV Structures:

Any proposed Hawai`i codes and standards incorporating climate change effects should simply specify the amount of relative sea level rise in order to have clear and uniform standards.

**c. The U.S. Navy Climate Change Roadmap (2010)**

- Provides a list of planning actions over a five-year period to assess, predict and adapt to global climate change, having the following focus areas:
  - Navy's strategies, policies, and plans are informed by scientifically-based climate change assessments and predictions
  - Identify potential changes to Navy activities based on the projected effects of climate change
  - Determine what modifications, if any, of weapons, platforms, and sensors, command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR), installations, and facilities are required to adapt to the effects of climate change
  - Openly engage in public discussion
  - Understand the current environmental changes and identify with high confidence projected effects of climate change on the type, scope, and location of future Navy missions and installations

Gap:

This is essentially an internal planning strategy document of the Navy that does not have a regulatory intent onto itself.

**d. *The American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data for Building Design Standards (ASHRAE 2006)***

- This standard provides regional climatic zones for use in the application of ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings, Except Low-Rise Residential Buildings.

Gap:

The 2006 edition is undergoing revision to account for the effects of climate change. However, the counties have not adopted any mechanical codes, but rather defers to the minimalist administrative rules of the Department of Health, and so this does not necessarily become a mandatory document, unless addressed by the State Building Code Council. All four county building officials are required to agree on any code provisions considered by the State Building Code Council. Many design professionals and county administrators would not have used this weather data standard since it is not referenced in the regulations, and therefore not explicitly considered in design.

Proposed Change:

- ROH Chapter 32 Building Energy Conservation Code: Adopt American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data for Building Design Standards for use in the application of ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential Buildings

e. **The National Fire Protection Association NFPA 1144: Standard for Reducing Structure Ignition Hazards from Wildland Fire (NFPA 2013)**

- This is a model code that is adopted by state and local governments as the basis for protection from wind driven conflagrations and wildfire.

Gap:

The urban-wildland fire interface is not presently considered in development standards (such as the creation of buffer zones). However, it is a practice of Department of Forestry and Wildlife (DOFAW) wildfire management to try to remove excess growth to establish fire break zones.

Proposed Change:

- ROH Chapter 20 Fire Code: Create regulatory maps of historic burn areas for use in these regulations and for mandatory seller disclosures. Since the wildfire maps of DOFAW are based on historic experience, some interpretative judgement would need to be applied to derive a regulatory map that would not be changed as often. However, at the least, the wildfire regulatory map would need to be updated whenever county zoning maps were changed that involve revisions in permitted use.

# 7. Proposed Code Amendments to Strengthen and/or Replace Existing Regulatory Standards In Order to Reduce Existing and Future Building Stock Vulnerability To Coastal Hazards and Climate Impacts

The proposed code amendments were further developed with consideration of feedback received at each of the following meetings:

- City and County of Honolulu Department of Planning and Permitting (DPP) (November 25, 2015, then only Office of State Planning staff met separately with DPP on October 15, 2016 and subsequently a November 16, 2016 letter of comments was sent by the acting director of DPP to the Office of State Planning),
- State Building Code Council (October 13, 2015 and March 14, 2017), and
- HI-EMA Weather Impacts Advisory Committee (September 16, 2015; note: this committee later became inactivated in 2016 and did not meet after April 25, 2016)
- Marine and Coastal Zone Advocacy Council (MACZAC) (October 16, 2015 and January 27, 2017)
- Hawai`i Ocean Partnership Coordinated Working Group (November 5, 2015 and January 5, 2017).

Stakeholder input and comments were considered and incorporated into a summary of final recommendations.

**Summary of Final Recommendations taking stakeholder input in consideration:**

*City Standards*

- **ROH Chapter 16 Building-Code** applicable revisions for Risk Category III and IV structures:
  - Honolulu Building Code: For Risk Category III and IV Structures:
    - Revise rainfall intensity map figure 1611.1 to add 15 minute and 1 hour *500-year* intensity *note: the Precipitation Frequency Server presently includes 500-year rainfall rates – these would need to be developed further with the inclusion of the increase in precipitation due to climate change.
    - Adjust windspeed map for 1700-year and 3000-year windspeeds for Risk Category III and IV Structures to comply with ASCE 7-16
    - Amend section for minimum elevation of the lowest horizontal structural member, based on 500-year flood elevation taking into account relative sea level change
    - Require consideration of shoreline erosion on foundation design

- **ROH Chapter 17 Electrical Code:** for Risk Category III and IV Structures: Require placement above 500-year flood or incorporate dry floodproofing protection for 500-year flood, developed considering climate change.
- **ROH Chapter 19 Honolulu Plumbing Code**: For Risk Category III and IV Structures, develop and adopt 500-year rainfall intensity maps.
- **ROH Chapter 20 Fire Code**: Develop regulatory maps of historic burn areas for use in these regulations based pm NFPA-1 and for mandatory seller disclosures.
- **ROH Chapter 21A – Flood Ordinance:** For Risk Category III and IV Structures, locally develop and adopt a 500-year flood zone that incorporates sea level rise, and RCP 8.5 equivalent storm inundation. It would be done locally by ordinance without any incorporation into the FEMA map layers.
- **ROH Chapter 23 – Shoreline Setbacks**: Adopt setbacks based on historic shoreline erosion rates for Oahu - only for new construction and with exemptions for shallow lots.
- **ROH Chapter 25 SMA**: Create another level of SMA zone maps (to be defined as the Coastal Construction Control Zone) to account for sea level rise, shoreline erosion, and coastal flood and wind modeling under CMIP RCP8.5 climatic conditions. Have this applicable to major (definition by 25,000 sf or more) developments. E.g., for Major Permits within the Special Management Area, require evaluation of ~2 feet of relative sea level rise on the functionality of the development and land use and mitigation of the deleterious effects of the proposed use, and require the director to consider that as a criteria for permitting new development, variances, or other changes.
- **ROH Chapter 32 Building Energy Conservation Code**: Adopt American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data for Building Design Standards for use in the application of ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings, Except Low-Rise Residential Buildings.
- **Other possible considerations for further analysis – It is recommended that the storm water flood control practices that address requirements for storm runoff quantities for flood control be re-evaluated:**
    - **City and County of Honolulu Rules Relating to Storm Drainage Standards (June 2013) – Re-evaluate the Hydrologic Criteria of the Standards for Flood Control and the design basis Rainfall Intensity maps, in keeping with the risk level including climate change and the longevity of City infrastructure**
        - It is not established by downscaled climate studies that Hawai`i rainfall rates and peak discharge for watershed and storm drainage infrastructure needs to be revised to account for climate change. However, the recurrence intervals used in the present standards have an inherently high probability of being exceeded even under current conditions.
        - The rainfall rate maps appear to be consistent with the U.S. Geological Survey rainfall intensity maps. It is recommended that U.S. Geological Survey historical data be used to update the Design Curves for Peak Discharge vs. Drainage Area

- **City and County of Honolulu Design Standards of the Department of Wastewater Management, General Requirements for Wastewater Facilities**
  - Re-evaluate the wet weather design period for Quantity of Wastewater for Chapter 20, Sewers and for Chapter 30, Pump Stations
  - Re-evaluate the 20-year and 50-year Design Periods and Flow Projections for design peak flow capacity, Chapter 40, Wastewater Treatment Facilities
  - Although peak wet weather flow into wastewater plants and wet weather inflow into sewers need to be considered, it is not established by downscaled climate studies that Hawai`i rainfall rates and peak discharge for watershed and storm drainage infrastructure needs to be revised to account for climate change.

*State Standards*

- **HRS Chapter 107 Part II - Hawai`i State Building Code:** Include a mandatory adoption of International Building Code as the interim state code when DAGS does not adopt HAR within 3 years of publication of the national model code, subject to the State Building Code Council option to use a 6-year cycle to avoid having code updates with relatively small amounts of technically substantive revisions. [ACT 141, HB637 HD2 SD2 CD1, 7/10/2017]
- **HRS 205A Expected Shoreline:** For planning purposes, also include an Expected Shoreline map taking into account shoreline erosion and relative sea level rise over the next 50 years.
- **HRS Chapter 484 - Uniform Land Sales Practices Act:** Expand list of disclosable hazards in public offering to include, more explicitly: E.g., "Exposure to natural hazards: e.g., 2500-year earthquake ground motion in excess of SDC B levels and earthquake –induced ground failure, rockfalls/landslides, 100-year and 500-year flooding, tsunami evacuation zone and extreme tsunami zone, lava inundation hazard zone 1, 2, or 3 per USGS 1992 map, forest and wildfire historic burn areas per DOFAW, effective windspeed hazards above 145 mph per Hawai`i State Building Code", dam failure inundation per DLNR maps, high surf inundation, and 50-year coastal shoreline erosion."
- **HRS Chapter 508D Mandatory Seller Disclosures in Real Estate Transactions:** Make the mandatory seller disclosure apply to transactions involving vacant lots as well.
- **Public Utilities Commission:** The PUC should adopt the windspeed maps of the 2010 Hawai`i State Building Code, to replace the NEC 2012 Figure 250-2. Otherwise, the wind design standard for power transmission and distribution systems is deficient with respect to actual wind speeds that would occur during tropical storms and hurricanes.

**Further considerations requiring technical investigation**

Revising the State Department of Transportation storm water flood control practices to address requirements for storm runoff quantities for flood control:

- **State of Hawai`i Department of Transportation Highways Division's Storm Water Permanent Best Management Practices Manual (March 2007)**
  - Re-evaluate the Chapter 4 Permanent BMP Consideration in Project Planning and Design Phase to include climate change effects on rainfall intensity (and storm water), and Chapter 5, Storm Water Quantity Control, recurrence interval design criteria
  - Although peak wet weather needs to be considered, it is not established by downscaled climate studies that Hawai`i rainfall rates and peak discharge for watershed and storm drainage infrastructure needs to be revised to account for climate change.

## Discussion of implications and feasibility of implementation

The foundation of any implementation of coordinated code amendments and regulations addressing climate change effects starts with having a working process for the adoption of such measures. Adaptation to climate change effects requires appreciation of the nuances of the expected effects over time and technical knowledge of how existing codes and standards are applied. Presently, the State of Hawai`i does not have a functional process for doing this because the State Building Code Council's work is not being implemented even for updating the codes to current standards, much less being able to address future needs. Therefore, the highest priority for implementing any climate change adaptation is to restore the code adoption process of HRS Chapter 107 Part II. It has been given the pre-eminent authority in the State for the adoption of codes – "Any law to the contrary notwithstanding, the council shall establish the Hawai`i state building codes." If the State Building Code Council process does not have any implementation in administrative rules, then most all other measures identified in this report will not be feasible.

500-year flood losses under future climate conditions *within the FEMA flood zones* are not greater than what would result if the regulatory flood elevations are reached. This indicates that present FEMA flood zone map elevations are vastly overextended from the actual 100-year inundation depths and that present insured are already paying now for climate conditions not expected to develop for many decades. Expansion of the FEMA flood zones does not appear warranted.

Additional flooding in the future is primarily influenced by expected relative sea level rise. Government infrastructure and flood control projects would be the most effective investment in mitigating these effects, based on the pilot study of the south coast of urban Honolulu.
For larger residential, retail, professional service office buildings, hospitals and medical clinics, government buildings and emergency services, and schools and colleges, average total losses (structural and contents) per building for future climatic conditions are generally at least double the losses that would occur without the sea level rise effect on flooding.

All the above losses suggest that some mitigation of sea level rise could result more stringent requirements for the above occupancy types. Applying a 30-year financing model with an interest rate of 4% to fund the additional project costs, given that the annualized loss is about $2,200 per property, a $475,000/property present day investment on average for these larger buildings would be justified on a break even basis to mitigate damage. For government and infrastructure projects with much longer functional lifespan requirements, the investment for sea level rise would be applicable for projects in the current planning timeframe.

However, investment costs for climate change effects (primarily sea level rise) could also be justified to be deferred for properties with an economic lifespan (or payoff period of investment) of less than 50 years, i.e., low-rise single family residential properties. This deferrable period would be economically arguable because the increased risk to these properties occurs only after sea levels rise approximately 2 ft., and would not exist to nearly the same extent under present day sea levels. Moreover, a risk transfer approach to the increased flooding of single family residential properties would justify additional insurance basis annual costs of only about $100, plus the insurance company's costs and return on investment. If the results of this study are considered by the insurance industry, this nominal increase for single family residential buildings should not presently warrant cost concerns about disclosure considerations for low-rise residential properties in the area of flood zones that include climate change effects.

Therefore, the general approach recommended for adaptation to climate change effects is to focus on public investment in the design of critical facilities (Risk Category III per the building code), essential facilities (Risk Category IV per the building code), and civil and transportation infrastructure to include climate change effects, combined with appropriate shoreline setbacks and mandatory disclosures of natural hazards that would include future expected sea level rise and erosion of the shorelines.

## Table 7-1. Summary of Economic Direct Damage by Occupancy Type of Building (from the Pilot Study of the South Shore of Urban Honolulu under Climate Conditions at the End of the 21st Century)

| Occupancy type | Occupancy Type | # of buildings | Aggregate Building value ($) | Average Building Value | Aggregate Structural damage ($) | Structural damage (%) | Average Structural Damage | Aggregate Content value ($) | Aggregate Content damage ($) | Content damage (%) | Average content damage | total average damage/Bldg for 500-year storm | Average Annualized Loss per Building |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RES1 | Single Family Dwelling | 3816 | 844647352 | $221,344 | 103370796 | 12.2% | $27,089 | 422386025 | 73603981 | 17% | $19,288 | $46,377 | $93 |
| RES2 | Manufactured Housing | 6 | 306000 | $51,000 | 223020 | 72.9% | $37,170 | 154000 | 97284 | 63% | $16,214 | $53,384 | $107 |
| RES3 | Multi-unit Dwelling bldgs | 1962 | 7044033912 | $3,590,231 | 1434097589 | **20.4%** | $730,937 | 3522159040 | 988916475 | 28% | $504,035 | $1,234,971 | $2,470 |
| RES4 | Temporary Lodging | 81 | 1086225020 | $13,410,185 | 44538928 | 4.1% | $549,863 | 543130000 | 84626372 | 16% | $1,044,770 | $1,594,633 | $3,189 |
| RES5 | Institutional Dormitory | 71 | 295736341 | $4,165,301 | 19662796 | 6.6% | $276,941 | 147875999 | 48648162 | 33% | $685,185 | $962,126 | $1,924 |
| RES6 | Nursing Home | 0 | 0 | | 0 | | | 0 | 0 | | | | $0 |
| COM1 | Retail Trade | 238 | 450163000 | $1,891,441 | 52039806 | **11.6%** | $218,655 | 450163000 | 163219431 | **36%** | $685,796 | $904,451 | $1,809 |
| COM2 | Wholesale Trade | 168 | 187240000 | $1,114,524 | 10069512 | 5.4% | $59,938 | 187240000 | 33616338 | 18% | $200,097 | $260,035 | $520 |
| COM3 | Personal and Repair | 236 | 203202006 | $861,025 | 18364692 | 9.0% | $77,816 | 203202006 | 73105765 | 36% | $309,770 | $387,587 | $775 |
| COM4 | Professional/Technical | 283 | 1218046030 | $4,304,050 | 99112789 | 8.1% | $350,222 | 1218046030 | 156398223 | 13% | $552,644 | $902,866 | $1,806 |
| COM5 | Banks | 77 | 74557222 | $968,276 | 4022636 | 5.4% | $52,242 | 74557222 | 23171936 | **31%** | $300,934 | $353,176 | $706 |
| COM6 | Hospital | 13 | 173309000 | $13,331,462 | 75851 | 0.0% | $5,835 | 259964960 | 81386 | 0% | $6,260 | $12,095 | $24 |
| COM7 | Medical Office/Clinic | 141 | 164159839 | $1,164,254 | 15321973 | 9.3% | $108,666 | 246264338 | 91603566 | **37%** | $649,671 | $758,337 | $1,517 |
| COM8 | Entertainment | 499 | 576506013 | $1,155,323 | 50055842 | 8.7% | $100,312 | 576506013 | 249225180 | 43% | $499,449 | $599,762 | $1,200 |
| COM9 | Theaters | 11 | 4624000 | $420,364 | 155737 | 3.4% | $14,158 | 4624000 | 251509 | 5% | $22,864 | $37,022 | $74 |
| COM10 | | 0 | 0 | | 0 | | | 0 | 0 | | | | $0 |
| IND1 | Heavy | 28 | 15942000 | $569,357 | 1318468 | 8.3% | $47,088 | 23922000 | 3478910 | 15% | $124,247 | $171,335 | $343 |
| IND2 | Light | 100 | 49869000 | $498,690 | 4738581 | 9.5% | $47,386 | 74829000 | 10518241 | 14% | $105,182 | $152,568 | $305 |
| IND3 | Food/Drugs/Chemical | 33 | 25834000 | $782,848 | 3458795 | **13.4%** | $104,812 | 38759000 | 12398591 | **32%** | $375,715 | $480,527 | $961 |
| IND4 | Metals/Mineral Processing | 3 | 703000 | $234,333 | 87726 | 12.5% | $29,242 | 1055000 | 316376 | 30% | $105,459 | $134,701 | $269 |
| IND5 | High Technology | 0 | 0 | | 0 | | | 0 | 0 | | | | $0 |
| IND6 | Construction Services | 73 | 30196000 | $413,644 | 6358032 | **21.1%** | $87,096 | 30196000 | 11287336 | **37%** | $154,621 | $241,717 | $483 |
| GOV1 | General Services | 111 | 168170377 | $1,515,048 | 5056822 | 3.0% | $45,557 | 168170377 | 103705792 | **62%** | $934,286 | $979,843 | $1,960 |
| GOV2 | Emergency Response | 6 | 9811000 | $1,635,167 | 537736 | 5.5% | $89,623 | 14719000 | 7815194 | **53%** | $1,302,532 | $1,392,155 | $2,784 |
| REL1 | Churches | 128 | 143372500 | $1,120,098 | 11315666 | 7.9% | $88,404 | 143372500 | 47489126 | 33% | $371,009 | $459,412 | $919 |
| EDU1 | Grade Schools | 79 | 261647352 | $3,311,992 | 8509863 | 3.3% | $107,720 | 261647352 | 102021362 | **39%** | $1,291,410 | $1,399,129 | $2,798 |
| EDU2 | Colleges/ Universities | 11 | 16666000 | $1,515,091 | 602343 | 3.6% | $54,758 | 25003000 | 9367382 | **37%** | $851,580 | $906,339 | $1,813 |
| AGR1 | Agriculture | 20 | 4614000 | $230,700 | 257618 | 5.6% | $12,881 | 4614000 | 1751794 | 38% | $87,590 | $100,471 | $201 |
| **Total** | | 8194 | 13049580965 | $1,592,578 | 1893353618 | 14.5% | $231,066 | 8642559862 | 2296715714 | 27% | $280,292 | $511,358 | $1,023 |

## Ranking of General Priorities of the Proposed Revisions

The general ranking given below is based on the importance and timeliness of the measure(s) and any associated related measures that need to made consistent as a grouping, as described below:

7.1 *For immediate implementation*

**HRS Chapter 107 Part II - Hawai`i State Building Code:** Include a mandatory state adoption of International Building Code if the administrative rule process fails to meet the existing statutory deadline. The State Building Code Council is the linchpin board that governs the adoption of updated codes and standards throughout the state. Therefore, dysfunction of the SBCC would prevent nearly all other codes and standards impacted by climate change effects. Also, coordination of related codes would not be accomplished without deliberations of the SBCC. (See ACT 141, HB637 HD2 SD2 CD1, 7/10/2017).

**ROH Chapter 16 Building-Code applicable revisions for Risk Category III and IV structures:** Revise rainfall intensity map figure 1611.1 to add 15 minute and 1 hour *500-year* intensity; Adjust windspeed map for Risk Category III and IV Structures to comply with ASCE 7-16; minimum elevation of the lowest horizontal structural member based on 500-year flood elevation taking into account relative sea level change; require consideration of shoreline erosion on foundation design

**Public Utilities Commission:** The PUC should adopt the windspeed maps of the 2010 Hawai`i State Building Code, to replace the NEC 2012 Figure 250-2. Otherwise, the wind design standard for power transmission and distribution systems is already deficient with respect to actual wind speeds that would occur during tropical storms and hurricanes.

7.2 *Implementation of coastal flooding mitigation by 2025*

The following further proposed amendments, changes and/or revisions to the existing federal, state and/or county codes, laws, statutes, ordinances, regulations and/or standards discussed in this report were not suggested for immediate adoption and implementation. The proposed amendments, changes and/or revisions must still be evaluated for county priorities, financial costs and benefits, additional data needs, and operational capabilities, which are beyond the scope of this report. Some prerequisite technical maps need to be further developed.

**ROH Chapter 21A – Flood Ordinance:** Locally develop and adopt a 500-year flood zone applicable to Risk Category III and IV Structures that incorporates sea level rise, and RCP 8.5 equivalent storm inundation. It would be done locally by ordinance (without any incorporation into the FIRM).

**ROH Chapter 17 Electrical Code:** Require placement of critical equipment **for Risk Category III and IV Structures** above 500-year flood or incorporate dry floodproofing protection

**ROH Chapter 23** – Shoreline Setbacks: Adopt 50-year setbacks based on historic shoreline erosion rates for Oahu - only for new construction and with exemptions for size / shallowness of lot.

**ROH Chapter 25 SMA**: Create another level of SMA zone maps (to be the Coastal Construction Control Zone) to account for sea level rise, shoreline erosion, and coastal flood and wind modeling under CMIP RCP8.5 climatic conditions. For Major Permits within the Special Management Area, require evaluation of ~2 feet of relative sea level rise on the functionality of the development and mitigation of the deleterious effects of the proposed use.

**HRS 205A Expected Shoreline**: For planning purposes, also include an Expected Shoreline map taking into account shoreline erosion and relative sea level rise over the next 50 years.

**HRS Chapter 484 - Uniform Land Sales Practices Act:** to explicitly include certain natural hazards as well as the expected 50-year erosion of a shoreline, i.e., as defined by the Expected Shoreline map.

7.3 *Additional implementation of supporting codes for consistency and comprehensiveness of climate change effects on weather E.g., rainfall, drought, hot weather:*

**ROH Chapter 19 Honolulu Plumbing Code**: For Risk Category III and IV Structures, develop and adopt 500-year rainfall intensity maps.

**ROH Chapter 20 Fire Code**: Develop regulatory maps of historic burn areas for use in these regulations based pm NFPA-1 and for mandatory seller disclosures.

**ROH Chapter 32 Building Energy Conservation Code**: Adopt American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data

**HRS Chapter 508D Mandatory Seller Disclosures in Real Estate Transactions:** Make the mandatory seller disclosure apply to transactions involving vacant lots as well. This is somewhat less critical than the disclosures on developed properties

# 8. Text for Model Ordinances for Consideration of Use and Potential Adoption by the Four Main Counties in Hawai`i, Including the City and County Of Honolulu, County of Hawai`i, County of Kaua`i, and County of Maui

**Potential Changes to Codes and Standards**
**(Subject to further vetting and revision by the Counties)**

- **ROH Chapter 16- Honolulu Building Code: For Risk Category III and IV Structures:**
  - Adjust windspeed map for 1,700-year and 3,000-year windspeeds to comply with national standards
  - Revise rainfall intensity map figure 1,611.1 to add 15 minute and 1 hour *500-year* intensity Amend section for minimum elevation of the lowest horizontal structural member, based on 500-year flood elevation taking into account relative sea level change; align nomenclature with ASCE 7-24 Standard
  - Require consideration of shoreline erosion on foundation design

Section 1609.3 is amended to read as follows:

**1609.3 Ultimate design wind speed and topographic and directionality factors.** The ultimate design wind speed, $V_{ult}$ in mph, for the determination of the wind loads shall be determined by Figure 1609A, 1609B, 1609C, and 1609D. The ultimate design wind speed $V_{ult}$, for use in the design of Risk Category II buildings and structures shall be obtained from Figure 1609A. The ultimate design wind speed, $V_{ult}$, for use in the design of Risk Category III buildings and structures shall be obtained from Figure 1609B. The ultimate design wind speed, $V_{ult}$, for use in the design of Risk Category IV buildings and structures shall be obtained from Figure 1609C. The ultimate design wind speed, $V_{ult}$, for use in the design of Risk Category I buildings and structures shall be obtained from Figure 1609D. The effective ultimate design wind speed, $V_{eff\text{-}ult}$, for the special wind regions indicated near mountainous terrain and near gorges shall be in accordance with Section 1609.3.2.

Special wind regions near mountainous terrain and valleys are accounted within the Topographic Factor defined in Section 1609.3.3. Wind speeds derived from simulation techniques shall only be used in lieu of the wind speeds given in Figure 1609 when, (1) approved simulation or extreme-value statistical-analysis procedures are used (the use of regional wind speed data obtained from anemometers is not permitted to define the hurricane wind speed risk in Hawai`i) and (2) the ultimate design wind speeds resulting from the study shall not be less than the resulting 700-year return period wind speed for Risk Category II, 1700-year return period wind speed for Risk Category III, 3000-year return period wind speed for Risk Category IV , and 300-year return period design wind speed for Risk Category I.

Section 1611.1 is amended to read:

**1611.1 Design Rain Loads.** Each portion of a roof shall be designed to sustain the load of rainwater that will accumulate on it if the primary drainage system for that portion is blocked plus the uniform load caused by water that rises above the inlet of the secondary drainage system at its design flow. The design rainfall rate shall be based on a rainfall intensity equal to or greater than the 15-min duration/500-year return period (frequency) storm. Primary drainage systems shall be designed for a rainfall intensity equal to or greater than the 60-min duration/ 500-year return period (frequency) storm ~~the 100-year 1-hour rainfall rate indicated in Figure 1611.1~~ as published by the National Weather Service [Precipitation Frequency Data Server]* or on other rainfall rates determined from approved local weather data.

**note: the Precipitation Frequency Server presently includes 500-year rainfall rate maps. An example map follows: these would need further development to account for climate change.*

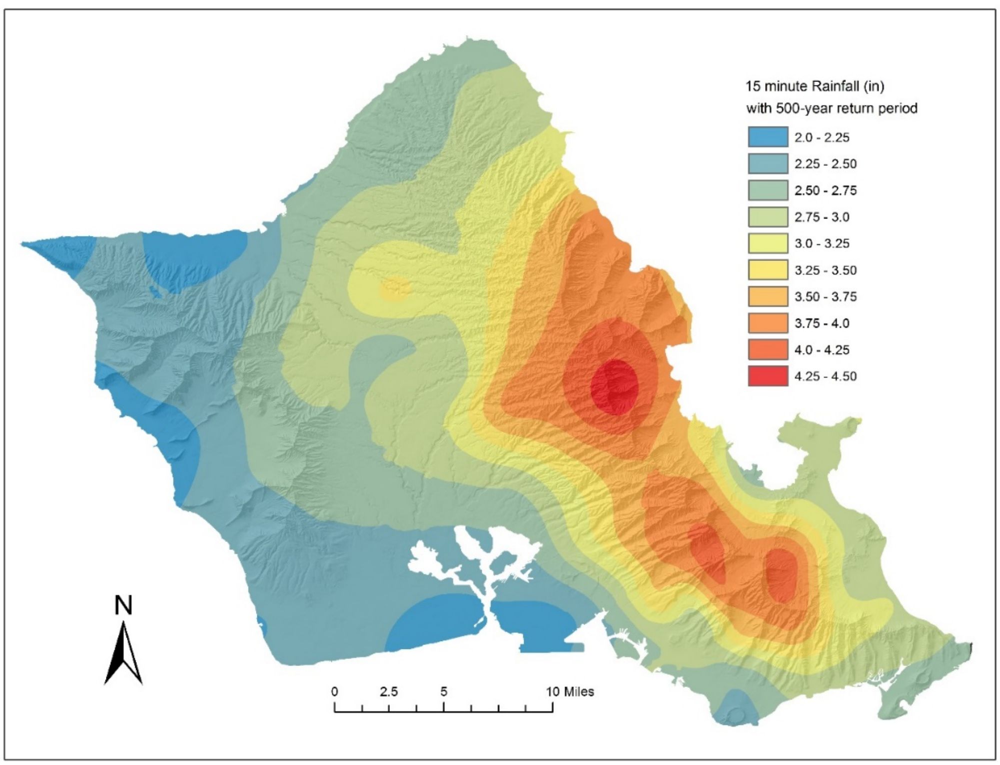



**Figure B-1. 15 Minute Rainfall (in) with 500-year return period**

Article 14 is amended to read:

Article 14 STATE- AND COUNTY-OWNED PUBLIC HIGH OCCUPANCY BUILDINGS - DESIGN CRITERIA FOR ENHANCED HURRICANE PROTECTION AREAS

Sec. 16-14.1 Intent and scope.
The purpose of this article is to establish minimum life safety design criteria for enhanced hurricane protection areas within high occupancy state- or county-owned buildings permitted to be occupied during hurricanes of up to Saffir Simpson Category 3. This article shall apply to Occupancy Category Ill and IV buildings defined by ROH Section 16-1.1 (173), Table 1604.5, of the following specific occupancies:

(1) Covered structures whose primary occupancy is public assembly with an occupant load greater than 300.

(2) Health care facilities with an occupant load of 50 or more resident patients, but not having surgery or emergency treatment facilities.

(3) Any other state- or county-owned building with an occupant load greater than 5,000.

(4) Hospitals and other health care facilities having surgery or emergency treatment facilities.

Exception: Facilities located within flood zone V and flood zone A that are designated by the owner to be evacuated during hurricane warnings declared by the National Weather Service, shall not be subject to these requirements.

Sec. 16-14.2 Site criteria.
(a) Flood and Tsunami Zones. Comply with ASCE 24-~~05~~14, Flood Resistant Design and Construction, based on provisions for ~~Occupancy Category III~~ Flood Design Class 3 or 4 as applicable.

(1) Floor slab on grade shall be 2.0 feet ~~1.5 feet~~ above the 500-year ~~Base~~ Flood Elevation of the county's flood hazard map, or at higher elevation as determined by a modeling methodology that predicts the maximum envelope and depth of inundation, including the combined effects of storm surge and wave actions with respect to a Category 3 hurricane landfall.

(2) Locate outside of V and Coastal A flood zones unless justified by site-specific analysis or designed for vertical evacuation in accordance with a method approved by the building official. When a building within a V or Coastal A zone is approved, the bottom of the lowest structural framing member of any elevated first floor space shall be 2 feet above the 500-year ~~Base~~ - Flood Elevation of the county's flood hazard map, or at a higher elevation as determined by a modeling methodology that predicts the maximum envelope and depth of inundation, including the combined effects of storm surge and wave actions with respect to a Category 3 hurricane landfall.

(3) Locate outside of Tsunami evacuation zones unless justified by site-specific

analysis or designed for vertical evacuation in accordance with a method approved by the building official.

(b) Emergency vehicle access. Provide at least one route for emergency vehicle access. The portion of the emergency route within the site shall be 2 feet above the 100-year flood elevation.
(c) Coastal Erosion. Provide foundation systems to maintain support of the structure considering 50 years of shoreline erosion projected forward from the year 2025 using the historical rate and further including 2 ft. of sea level rise.
(d) Landscaping and utility laydown impact hazards. Landscaping around the building shall be designed to provide standoff separation sufficient to maintain emergency vehicle access in the event of mature tree blowdown. Trees shall not interfere with the functioning of overhead or underground utility lines, nor cause laydown or falling impact hazard to the building envelope or utility lines.
(e) Adjacent buildings. The building shall not be located within 1,000 feet of any hazardous material facilities defined by ROH Section 16-1.1(173), Table 1604.5. Unanchored light-framed portable structures shall not be permitted within 300 feet of the building.

- **ROH Chapter 17 Electrical Code: for Risk Category III and IV Structures: Require placement above 500-year flood or incorporate dry floodproofing protection for 500-year flood, developed considering climate change.**

Chapter 17 Electrical Code

Article 6 Electrical Work within Flood Hazard Districts and Developments Adjacent to Drainage Facilities

Sec. 17-6.2 Definitions.

Coastal Construction Control Zone. The zone defined by Chapter 21A as the 500-year coastal flood inundation limit including the effects of 2 feet of sea level rise.

Sec. 17-6.3 Requirements.

For electrical work on projects subject to the provisions of this article, the provisions of this section shall supplement the requirements of Section 17-5.1.

(a) Main Power Service. The incoming main commercial power service equipment, including all metering equipment, shall be located above the ~~regulatory~~ flood elevation of the Coastal Construction Control Zone or in a waterproof enclosure or barrier with GFP on the main disconnecting means.

(b) Stationary and Portable Equipment. Switchgear, control centers, transformers, distribution and power or lighting panels shall be located above the ~~regulatory~~ flood elevation of the Coastal Construction Control Zone or in a waterproof enclosure or barrier with GFP on the main disconnecting means. Stationary and portable or movable electrical equipment shall be permitted to be located below the regulatory flood elevation provided that the circuit and equipment shall be protected with GFCI, except sump pump and its circuit may be without GFCI. In cases where GFCI cannot be installed because of amperage size or usage, GFP shall be installed.

(c) Normal and Emergency Lighting Circuits. All normal lighting circuits extending into areas below the regulatory flood elevation shall be energized from a common distribution panel located above the regulatory flood elevation or in a waterproof enclosure or barrier with GFP. All emergency lighting circuits into areas below the regulatory flood elevation shall be energized from an independent distribution panel also located above the regulatory flood elevation or in a waterproof enclosure or barrier with GFP.

(d) Emergency Lighting Requirements. All components of emergency lighting systems installed below the regulatory flood elevation shall be so located that no component of the emergency lighting system is within reach of personnel working at floor level in the areas where emergency lighting systems are utilized unless the emergency lighting circuits are provided with GFCI. The emergency lighting may be furnished by a storage battery, prime mover generator system, a separate commercial power supply system, the same commercial power system, or a combination thereof, subject to the following provisions:

(1) Storage Battery (including battery operated lighting units). Battery operated lighting units shall be completely self-contained and shall indicate the state of charge of the battery at all times. Lighting units shall automatically provide light when the normal source of lighting in the areas is de energized.

(2) Separate Commercial Power Supply System. This source of energy shall have a degree of reliability satisfactory to the building official. A system fed from a transformer other than that used for the regular supply and not on the same poles (except service pole) as the regular supply is deemed to have the required degree of reliability if the transformer is elevated above the flood elevation of the Coastal Construction Control Zone. A secondary circuit fed from the same primary circuit as the regular supply shall be regarded as a separate system.

(3) Separate Commercial Power Supply System. The system shall be an underground secondary system and a separate service shall be connected on the line side of that service switch or breaker of the regular service.

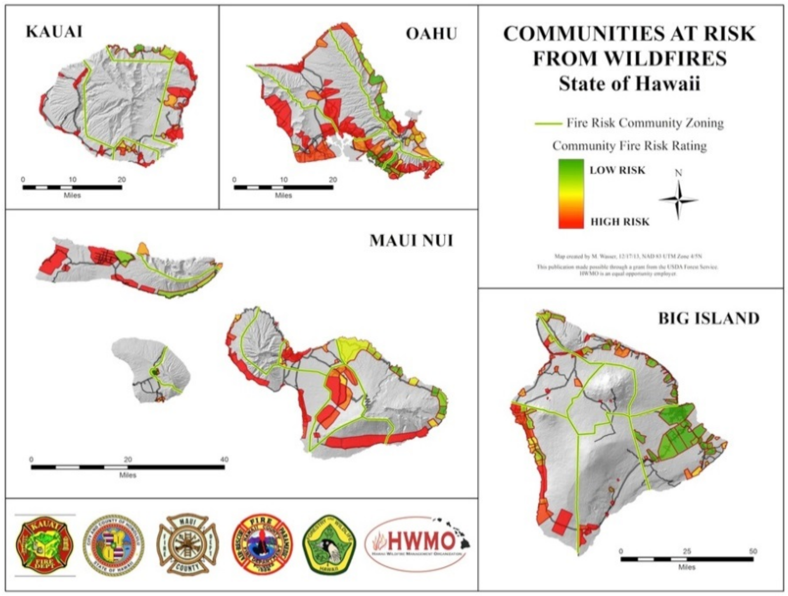
(e) Receptacle Circuits Below Regulatory Flood Elevation. Receptacle circuits shall be permitted to be installed below the regulatory flood elevation, provided that these circuits shall be protected with GFCI.

- **ROH Chapter 19 Honolulu Plumbing Code: For Risk Category III and IV Structures, develop and adopt 500-year rainfall intensity maps.**

Chapter 19: Plumbing Code
Storm Drainage
Section 1101.11.1 Primary Roof Drainage. Roof areas of a building shall be drained by roof drains or gutters. The location and sizing of drains and gutters shall be coordinated with the structural design and pitch of the roof. Unless otherwise required by the authority having jurisdiction, roof drains, gutters, vertical conductors or leaders, and horizontal storm drains for primary drainage shall be sized based on a rainfall intensity equal to or greater than the 15-min duration/500-year return period (frequency) storm. Primary drainage systems shall also be designed for a rainfall intensity equal to or greater than the 60-min duration/ 500-year return period (frequency) storm, as published by the National Weather Service Precipitation Frequency Data Server or on other rainfall rates determined from approved local weather data.

- **ROH Chapter 20 Fire Code: Create regulatory maps of historic burn areas for use in these regulations based on NFPA 1 (and for mandatory seller disclosures).**

***High Fire Risk Map Zones have been developed in 2013 by the Hawai`i Wildfire Management Organization***




Amending Section 3.3.252 to read:
3.3.252 Wildland/Urban Interface. The areas where improved property and wildland fuels meet at the boundary of the High Risk Wildfire Zone, as issued by the Hawai`i Wildfire Management Organization.

- **ROH Chapter 21A – Flood Ordinance: For Risk Category III and IV Structures, locally develop and adopt a 500-year flood zone that incorporates sea level rise, and RCP 8.5 equivalent storm inundation. It would be done locally by ordinance without any incorporation into the FEMA map layers.**

**Sec. 21A-1.4 Definitions.**
"Coastal Construction Control Zone" is the map area within the coastal inundation limit of the 500-year flood developed including the effects of expected climate change by the year 2100 and sea level rise of 2 feet above the year 2000 mean high water.
**Sec. 21A-1.12 Coastal Construction Control Zone**
Risk Category III and IV Buildings and structures within the Coastal Construction Control Zone shall be designed for 2 feet of sea level rise above the year 2000 mean high water.

- **ROH Chapter 23 – Shoreline Setbacks: Adopt setbacks based on historic shoreline erosion rates for Oahu - only for new construction.**

**Sec. 23-1.4 Shoreline setback line.**

(a) General Rule. Except as otherwise provided in this section, the shoreline setback line shall be established 40 feet inland from the certified shoreline.

(b) Adjustment of Shoreline Setback Line on Shallow Lots. Where the depth of the buildable area of a lot, as measured seaward from its inland edge, is reduced to less than 30 feet, the shoreline setback line shall be adjusted to allow a minimum depth of buildable area of 30 feet; provided that the adjusted shoreline setback line shall be no less than 20 feet from the certified shoreline.

(c) Adjustment of Shoreline Setback Line Related to the Construction of a Shore Protection Structure. Once a shoreline has been certified from which a shoreline setback line can be established, no shoreline setback line shall be established farther seaward as the result of a subsequent certified shoreline survey following the construction of a shore protection structure. On a lot where the certified shoreline is permanently fixed by a shore protection structure, the shoreline setback line shall be established by measuring inland from the shoreline, as it was located prior to the construction of the shoreline protection structure.

Where the shore protection structure was constructed without a shoreline survey first being made and certified by the state department of land and natural resources, the director shall determine the prior location of the shoreline solely for the purpose of establishing the shoreline setback line. In so doing, the director shall consider the actual location of the high wash of the waves during the year and the location of the shoreline and the shoreline setback line on adjacent properties.

The resulting shoreline setback line may be further than 40 feet from the shoreline established by the department of land utilization following construction of the shore protection structure.

(d) Adjustment of Shoreline Setback Line Related to the Construction of a New Building or Structure, or to a new Addition to an Existing Building or Structure.

i. The shoreline setback line shall be established 25 feet inland from the certified shoreline plus a distance of 50 times the historical annual erosion hazard rate from the shoreline established by county maps.
ii. Where the lot has average depth of less than 160 feet, the shoreline setback need not exceed 40 feet.
iii. Accretion rates shall not be considered.

- **ROH Chapter 25 SMA: Create another level of SMA zone maps (to be defined as the Coastal Construction Control Zone) to account for sea level rise, shoreline erosion, and**

**coastal flood and wind modeling under CMIP RCP8.5 climatic conditions. Have this applicable to major (definition TBD) developments. E.g., for Major Permits within the Special Management Area, require evaluation of ~50-years of relative sea level rise on the functionality of the development and land use and mitigation of the deleterious effects of the proposed use, and require the director to consider that as a criteria for permitting new development, variances, or other changes.**

**Chapter 25 Special Management Area**

**Sec. 25-1.3 Definitions.**

"Coastal Construction Control Zone" is the map area within the coastal inundation limit of the 500-year flood developed including the effects of expected climate change by the year 2100 and sea level rise of 2 feet above the year 2000 mean high water.

**Sec. 25-3.2 Review guidelines.**

The following guidelines shall be used by the council or its designated agency for the review of developments proposed in the special management area.

25-3.2 (a) All development in the special management area shall be subject to reasonable terms and conditions set by the council to ensure that:

25-3.2 (a) (5) <u>for developments exceeding 25,000 square feet of building gross area, provisions are for made to accommodate or mitigate effects of flooding including sea level rise within the Coastal Construction Control Zone.</u>

25-3.2 (b) No development shall be approved unless the council has first found that:

25-3.2 (b) (4) for developments exceeding 25,000 square feet of building gross area, the adverse effects of climate change and sea level rise as defined by the Coastal Construction Control Zone have been minimized to the extent practicable and clearly outweighed by public health and safety, or compelling public interest. Such adverse effect shall include, but not be limited to, the potential cumulative impact of individual developments, each one of which taken in itself might not have a substantial adverse effect and the elimination of planning options.

- **ROH Chapter 32 Building Energy Conservation Code:**
  **Adopt American Society of Heating, Refrigerating, and Air-Conditioning Engineers Standard 169, Weather Data for Building Design Standards for use in the application of ANSI/ASHRAE/IESNA Standard 90.1-2004, Energy Standard for Buildings, Except Low-Rise Residential Buildings.**

  Section C401.2.1 is amended as follows:
  "the requirements of ASI/ASHRAE/IESNA Standard 90.1, Energy Standard for Buildings, Except Low-Rise Residential Buildings, as supplemented by ASI/ASHRAE/IESNA Standard 169, Weather Data for Building Design Standards"

*State Standards*

- **HRS Chapter 107 Part II - Hawai`i State Building Code: Implement mandatory adoption of International Building Code as the interim state code when DAGS does not adopt HAR within 3 years of publication, subject to 6-year cycle.**

  **PART II. STATE BUILDING CODE AND DESIGN STANDARDS**
  §107-27 Design of state buildings. (a) No later than one year after the adoption of rules under this chapter, the design of all state building construction shall be in compliance with the Hawai`i state building codes, except state building construction shall be allowed to be exempted from:

  (1) County codes that have not adopted the Hawai`i state building codes;
  (2) Any county code amendments that are inconsistent with the minimum performance objectives of the Hawai`i state building codes or the objectives enumerated in this part; or
  (3) Any county code amendments that are contrary to code amendments adopted by another county.
  (b) Exemptions shall include county ordinances allowing the exercise of indigenous Hawaiian architecture adopted in accordance with section 46-1.55.
  (c) The department of accounting and general services shall adopt rules for the codes listed in section 107-25 pursuant to section 107-29 no later than two years after adoption by the council.
  (d) If the state does not adopt rules for the Hawai`i state building codes within the two-year time frame, the model building codes listed in section 107-25 shall become applicable as the interim state building codes applicable per section 107-27, except that any requirements of these interim codes shall not be less stringent than the current adopted rules.

  **Note: See ACT 141, HB637 HD2 SD2 CD1, 7/10/2017 for the similar language based on the above text that became state law in 2017.**

- **HRS 205A Certified Shoreline: For planning purposes, also include an Expected Shoreline map taking into account shoreline erosion and relative sea level rise over the next 50 years.**

  **Part I. Coastal Zone Management**
  **§205A-1 Definitions.**
  " Expected Future Shoreline" means the future expected upper reaches of the wash of the waves, other than storm and seismic waves, at high tide during the season of the year in which the highest wash of the waves occurs, estimated including the effects of 1 feet of sea level rise and shoreline erosion projected forward to the year 2060. The expected future shoreline is shown on [*new maps required*].

**Part II. Special Management Areas**
§205A-26 Special management area guidelines.
In implementing this part, the authority shall adopt the following guidelines for the review
of developments proposed in the special management area:
(1) All development in the special management area shall be subject to reasonable terms and conditions set by the authority in order to ensure:

(E) Provisions are made to accommodate the future retreat of the shoreline as indicated by the maps of the Expected Future Shoreline.

- **HRS Chapter 484 - Uniform Land Sales Practices Act: Expand list of disclosable hazards in public offering to include, more explicitly: E.g., "Exposure to natural hazards: e.g., 2500-year earthquake ground motion in excess of SDC B levels and earthquake – induced ground failure, rockfalls/landslides, 100-year and 500-year flooding, tsunami evacuation or extreme tsunami evacuation zones, lava inundation hazard zone 1, 2, or 3 per USGS 1992 map, forest and wildfire historic burn areas per DOFAW, effective windspeed hazards above 145 mph per Hawai`i State Building Code", dam failure inundation, high surf inundation, and 100-year coastal shoreline erosion."**

**CHAPTER 484**
**UNIFORM LAND SALES PRACTICES ACT**
§484-6 Public offering statement. (a) A public offering statement shall disclose fully and accurately the physical characteristics of the subdivided lands offered and shall make known to prospective purchasers all unusual and material circumstances or features affecting the subdivided lands. The proposed public offering statement submitted to the director shall be in a form prescribed by the director's rules and shall include, but not be limited to, the following:
…
(9) any subdivided property or portion thereof lies:
(a) Within the boundaries of a special flood hazard area as officially designated on Flood Insurance Administration maps promulgated by the United States Department of Housing and Urban Development for the purposes of determining eligibility for emergency flood insurance programs;
(b) Within the boundaries of the noise exposure area shown on maps prepared by the department of transportation in accordance with Federal Aviation Regulation Part 150-Airport Noise Compatibility Planning (14 Code of Federal Regulations Part 150) for any public airport;
(c) Within the boundaries of the Air Installation Compatibility Use Zone of any Air Force, Army, Navy, or Marine Corps airport as officially designated by military authorities; or
(d) Within the anticipated inundation areas designated on the department of defense's emergency management (i) tsunami evacuation zone or (ii) extreme tsunami evacuation zone maps;

(e) where the site includes any extent of the Expected Future Shoreline, as defined in HRS §205A-1;

(f) Within the Coastal Construction Control Zone, defined by Chapter 21A as the 500-year coastal flood inundation limit including the effects of 2 feet of sea level rise

(g) within lava inundation hazard zone 1, 2, or 3 per USGS (1992)

(h) within a high risk wildfire zone designated by the Hawai`i Wildfire Management Organization

- **HRS Chapter 508D Mandatory Seller Disclosures in Real Estate Transactions: Make the mandatory seller disclosure apply to transactions involving vacant lots as well.**

**CHAPTER 508D**
**MANDATORY SELLER DISCLOSURES IN REAL ESTATE TRANSACTIONS**

§508D-1 Definitions. As used in this chapter, unless the context requires otherwise:
"Residential real property" means fee simple or leasehold real property on which currently is situated, or is currently zoned to permit the construction of:

(1) From one to four dwelling units; or

(2) A residential condominium or cooperative apartment, the primary use of which is occupancy as a residence.

§508D-15 Notification required; ambiguity. (a) When residential real property lies:

(1) Within the boundaries of a special flood hazard area as officially designated on Flood Insurance Administration maps promulgated by the United States Department of Housing and Urban Development for the purposes of determining eligibility for emergency flood insurance programs;

(2) Within the boundaries of the noise exposure area shown on maps prepared by the department of transportation in accordance with Federal Aviation Regulation Part 150-Airport Noise Compatibility Planning (14 Code of Federal Regulations Part 150) for any public airport;

(3) Within the boundaries of the Air Installation Compatibility Use Zone of any Air Force, Army, Navy, or Marine Corps airport as officially designated by military authorities; or

(4) Within the anticipated inundation areas designated on the department of defense's emergency management extreme tsunami inundation maps;

(5) where the site includes any extent of the Expected Future Shoreline, as defined in HRS §205A-1;

(6) Within the Coastal Construction Control Zone, defined by Chapter 21A as the 500-year coastal flood inundation limit including the effects of 2 feet of sea level rise.

(7) within lava inundation hazard zone 1, 2, or 3 per USGS (1992)

(8) within a high risk wildfire zone designated by the Hawai`i Wildfire Management Organization

subject to the availability of maps that designate the ~~four~~ eight areas by tax map key (zone, section, parcel), the seller shall include such material fact information in the disclosure statement provided to the buyer subject to this chapter.

- **Public Utilities Commission: The PUC should adopt the windspeed maps of the 2010 Hawai`i State Building Code, to replace the NEC 2012 Figure 250-2. Otherwise, the wind design standard for power transmission and distribution systems is deficient with respect to actual wind speeds that would occur during tropical storms and hurricanes.**

  **Chapter 6-73, Hawai`i Administrative Rules, Department of Budget and Finance, "Installation, Operation, and Maintenance of Overhead and Underground Electrical Supply and Communication Lines,"**

  Section 6-73-21 Modifications to the National Electrical Safety Code
  Rule 250:

  Page 161, the definition of V is replaced with the following:
  V Basic Wind Speed, 3 s gust wind speed in mph at 33 ft. above ground, that shall be taken as the value given in Figure 250-2 for the effective ultimate wind speed, multiplied by the factor √0.625.

  Page 163, the first paragraph is replaced to state,
  "The wind pressure parameters ($k_z$ , V, and $G_{RF}$ ) are based on Exposure C per ASCE 7-16, which is the basis for the NESC extreme wind criteria."

  Page 166 to 169, Fig 250-2 is replaced with the following:

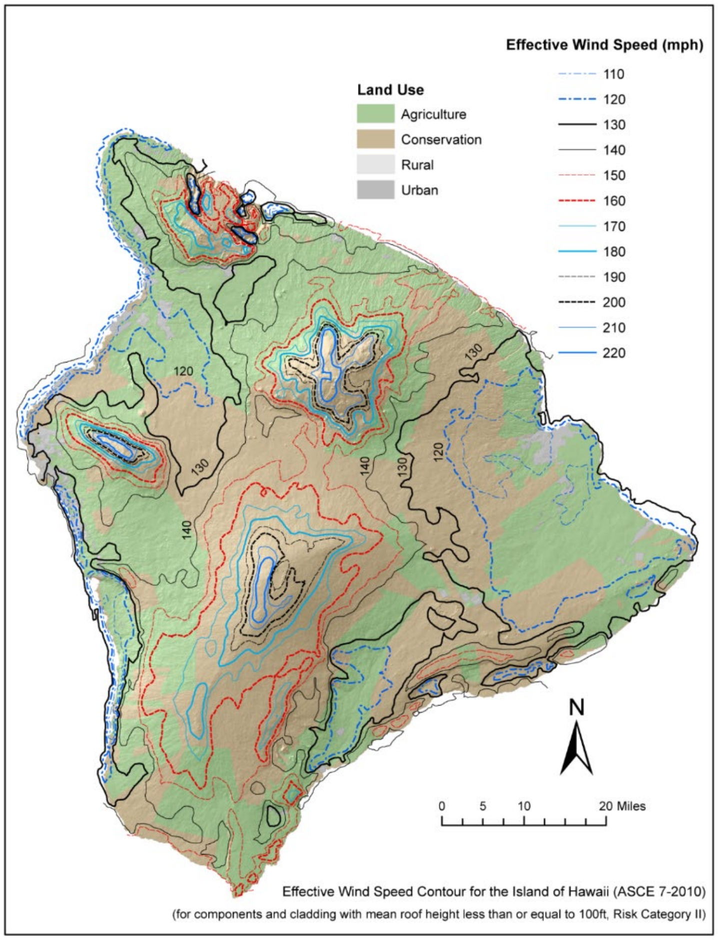



**Figure 250-2(a) County of Hawai`i Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

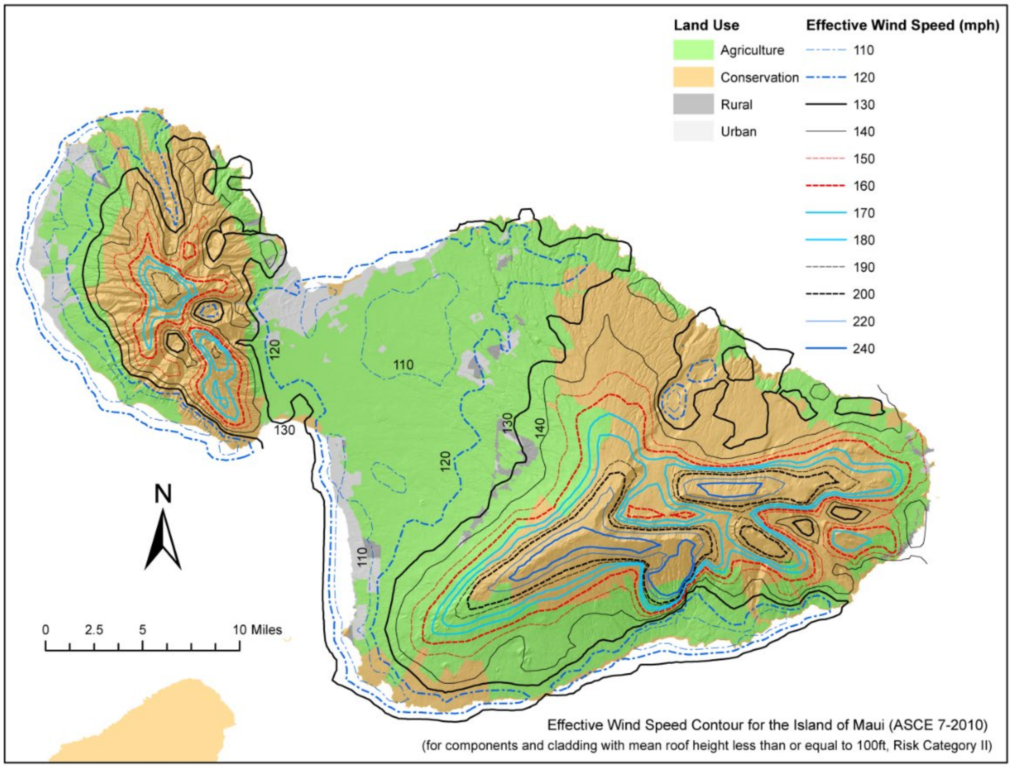



**Figure 250-2(b) County of Maui, Island of Maui Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

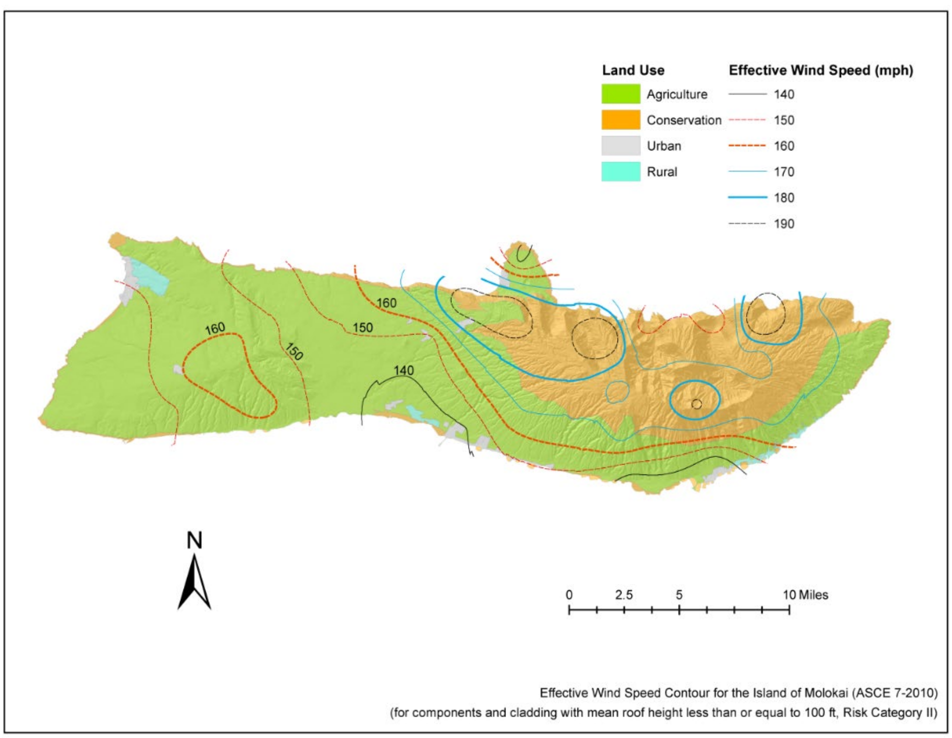



**Figure 250-2(c) County of Maui, Island of Molokai Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

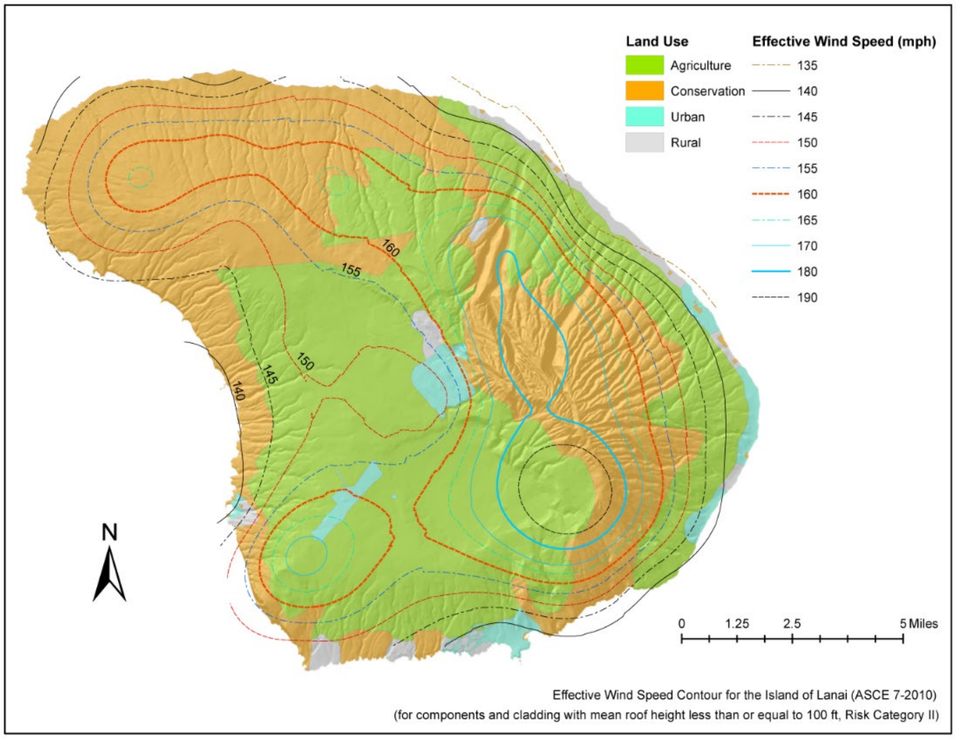



**Figure 250-2(d) County of Maui, Island of Lanai Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

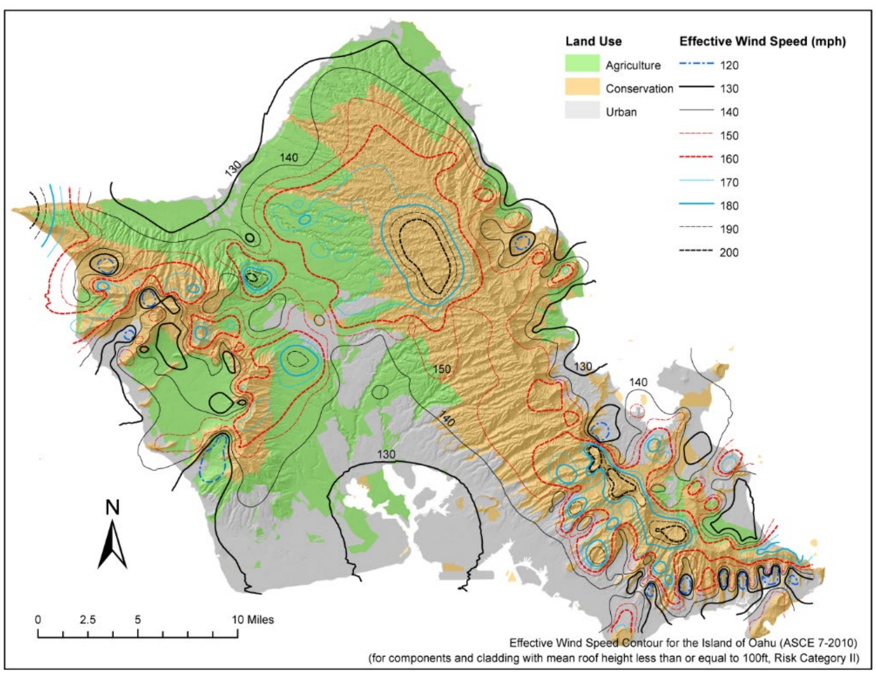



**Figure 250-2(e) City and County of Honolulu Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

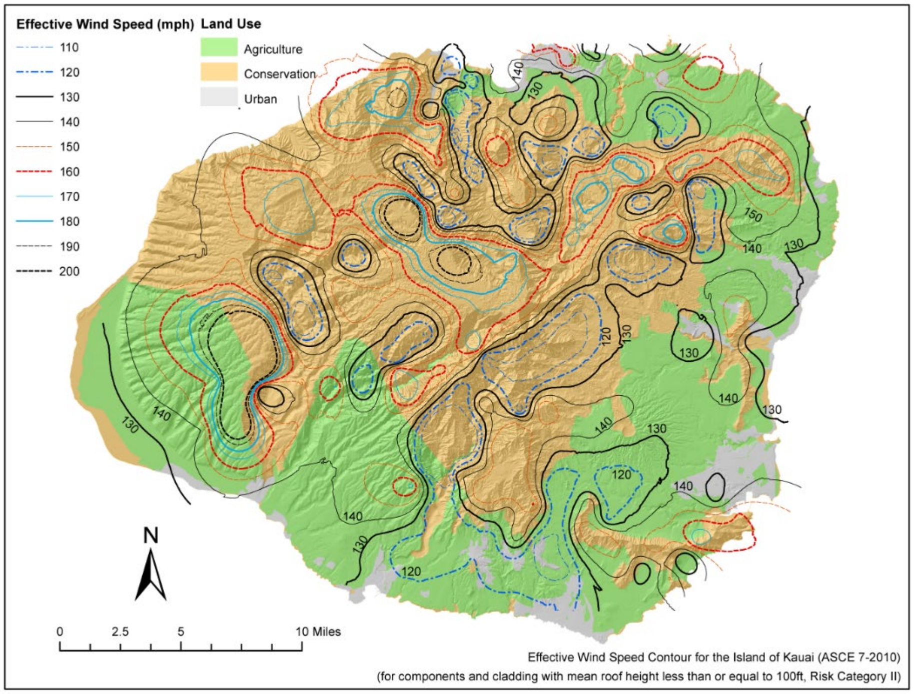



**Figure 250-2(f) County of Kauai Effective Ultimate Wind Speed, $V_{eff\text{-}ult}$ (ASCE, 2010)**

# 9. Recommendations for Technical Information and Studies Needed to Implement the Proposed Code Amendments Relating to Climate Impacts on Building Vulnerability in Hawai`i

- Sea-level rise and storm intensification pose a combined engineering, social, and economic problem to coastal communities. In addition to a projection of sea-level rise, stochastic future storm events influenced by regional climate change are needed to probabilistically determine the expected future high wind and flood hazards. Probabilistic flood hazard assessments, which take into explicit account the effects of sea-level rise and the intensification of the regional storm climatology as stochastically simulated from a downscaled climate model, can facilitate planning and regulation of coastal development. In this work a pilot study was performed to establish a practical methodology for mapping of coastal flood hazards associated with sea-level rise and storm intensification toward the end of the 21st century. As demonstrated in the pilot study, the data products from this methodology define the risk basis for future updates of building codes and other regulations to account for climate change. **Therefore, use of this methodology should be continued so that end of the century probabilistic inundation maps for the other coastal areas of Oahu and the other Hawaiian islands can be used in the implementation of the climate adaptation process.**

- Additional technical watershed and hydrographic studies should be started based on future rainfall intensification during tropical cyclones. The inherent target reliabilities of civil flood control infrastructure should be re-examined. **It is recommended that the storm water flood control practices that address requirements for storm runoff quantities for flood control be re-evaluated for possible changes to various flood control design practice standards**
    - City and County of Honolulu Rules Relating to Storm Drainage Standards (June 2013)
        - Re-evaluate the Hydrologic Criteria of the Standards for Flood Control and the design basis Rainfall Intensity maps, in keeping with the risk level including climate change and the longevity of City infrastructure
    - City and County of Honolulu Design Standards of the Department of Wastewater Management, General Requirements for Wastewater Facilities
        - Re-evaluate the wet weather design period for Quantity of Wastewater for Chapter 20, Sewers and for Chapter 30, Pump Stations
        - Re-evaluate the 20-year and 50-year Design Periods and Flow Projections for design peak flow capacity, Chapter 40, Wastewater Treatment Facilities
    - State of Hawai`i Department of Transportation Highways Division's Storm Water Permanent Best Management Practices Manual (March 2007)

    - Re-evaluate the Chapter 4 Permanent BMP Consideration in Project Planning and Design Phase to include climate change effects on rainfall intensity (and storm water), and Chapter 5, Storm Water Quantity Control, recurrence interval design criteria
  - Revising the State Department of Transportation storm water flood control practices to address requirements for storm runoff quantities for flood control in the State of Hawai`i Department of Transportation Highways Division's Storm Water Permanent Best Management Practices Manual (March 2007)
    - Re-evaluate the Chapter 4 Permanent BMP Consideration in Project Planning and Design Phase to include climate change effects on rainfall intensity (and storm water), and Chapter 5, Storm Water Quantity Control, recurrence interval design criteria
    - Although peak wet weather needs to be considered, it is not established by downscaled climate studies that Hawai`i rainfall rates and peak discharge for watershed and storm drainage infrastructure needs to be revised to account for climate change.

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## List of Acronyms

| | |
|---|---|
| ASCE | American Society of Civil Engineers |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| BFE | Base Flood Elevation |
| BLNR | Board of Land and Natural Resources |
| CLP | Coastal Lands Program |
| CMIP | Coupled Model Inter-comparison Project |
| COEMAP | Coastal Erosion Management Plan |
| CZMA | Coastal Zone Management Act |
| CZMP | Coastal Zone Management Program |
| DBEDT | Department of Business, Economic Development, and Tourism |
| DFIRM | Digital Flood Insurance Rate Maps |
| DLNR | Department of Land and Natural Resources |
| DOFAW | Department of Forestry and Wildlife |
| ENSO | El Nino Southern Oscillation |
| FEMA | Federal Emergency Management Agency |
| FIRM | Flood Insurance Rate Maps |
| HAR | Hawai`i Administrative Rules |
| HECO | Hawaiian Electric Company |
| HRS | Hawai`i Revised Statutes |
| IBC | International Building Code |
| ICC | International Code Council |
| IECC | International Energy Conservation Code |
| IPCC | Intergovernmental Panel on Climate Change |
| IRC | International Residential Code |
| LUC | Land Use Commission |
| LUO | Land Use Ordinance |
| NEC | National Electric Code |
| NESC | National Electric Safety Code |
| NFIP | National Flood Insurance Program |
| NFPA | National Fire Protection Association |
| OCCL | Office of Conservation and Coastal Lands |
| OP | Office of Planning |
| PUC | Public Utilities Commission |
| ROH | Revised Ordinances of Honolulu |
| SBCC | State Building Code Council |
| SFHA | Special Flood Hazard Area |
| SLC | Sea Level Change |
| SMA | Special Management Area |
| UPC | Uniform Plumbing Code |
| USACE | United States Army Corps of Engineers |