



13. HURRICANE

13.1 HAZARD PROFILE

13.1.1 HAZARD DESCRIPTION

This section provides a description of the hazard, including causes, hazard or incident characteristics, and potential impacts.

Overview

Tropical cyclones are organized systems of clouds and thunderstorms that develop in tropical or subtropical waters and have a closed low-level circulation. These weather phenomena are characterized by heavy rainfall, strong and damaging winds, storm surges, high waves, shoreline erosion, and flooding. Tropical cyclones form over warm ocean water when a pre-existing disturbance, such as a tropical wave, interacts with warm, moist air and low wind shear, leading to the formation of a rotating, organized storm system.

Tropical depressions, tropical storms, and hurricanes are all types of tropical cyclones that are distinguished by their sustained wind speeds. A description of each category of tropical cyclones is provided below (NOAA n.d.):

- **Tropical Depression**—Maximum sustained winds of 38 mph (33 knots) or less. Tropical depressions are the weakest type of tropical cyclone and can develop into tropical storms or hurricanes if wind speeds increase. They are typically identified by a number, such as Tropical Depression One (TD 1). A tropical depression can intensify into a tropical storm and then a hurricane. Similarly, a hurricane may be downgraded to a tropical storm and then to a depression.
- **Tropical Storm**—Maximum sustained winds of 39 to 73 mph (34 to 63 knots). A tropical storm is given a name when it reaches tropical storm status. Tropical storms are named by the World Meteorological Organization (WMO) using pre-determined, rotating lists of names, which are maintained by the National Hurricane Center (NHC). If the disturbance or develops into a named storm between 140°W and the dateline, then it receives a Hawaiian name.
- **Hurricane**—Maximum sustained winds of 74 mph (64 knots) or higher. A hurricane is given a name when it reaches tropical storm status, and that name is retained as it strengthens to hurricane status.

This chapter focuses specifically on hurricanes, focusing on hurricane-force winds and storm surge events associated with these storms. Other hazards related to hurricanes are discussed in other hazard profiles pertaining to floods (Chapter 10) and windstorms (Chapter 20).



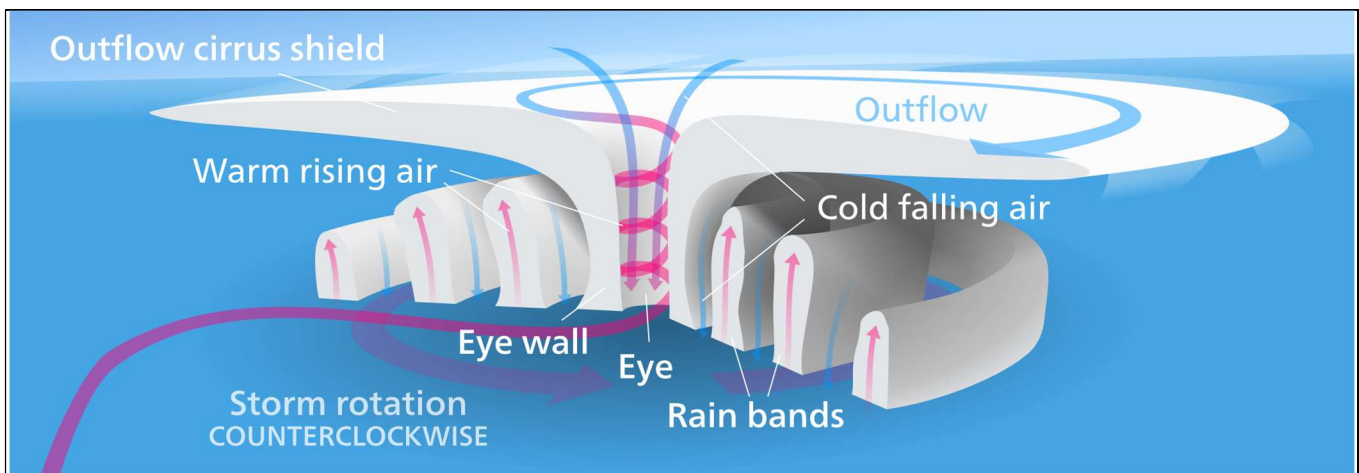
Hurricanes are infrequent in the State of Hawai'i; however, when they do occur, they can have severe, damaging, and potentially life-threatening consequences. The State of Hawai'i is situated in the Central Pacific basin, where the hurricane season spans from June 1 to November 30, with peaks in August and September.

Hurricane Causes

Tropical cyclones form over warm ocean water when a pre-existing disturbance, such as a tropical wave, interacts with warm, moist air and low wind shear, leading to the formation of a rotating, organized storm system

The primary components of a hurricane and a tropical storm include the rainbands, the eye, and the eyewall (see Figure 13-1). In the northern hemisphere, air circulates inward toward the center in a counterclockwise direction, while in the southern hemisphere, it moves in a clockwise manner. Air moves outward at the top in the opposite direction. At the center of the storm lies the "eye," characterized by relatively calm conditions with light winds and clear skies, encircled by the intense eyewall. The eyewall is comprised of a ring of towering thunderstorms that generate heavy rainfall and typically the strongest winds. The rotation, combined with the rising and sinking air, maintains the hurricane's structure and intensity as it moves across the ocean. (NOAA 2023)

Figure 13-1. Tropical Cyclone Structure in the Northern Hemisphere



Source: (Wikimedia 2012)

Typical hurricane strength tropical cyclones are about 300 miles wide although they can vary considerably. Size is not necessarily an indication of a hurricane's intensity. The weather patterns and conditions associated with hurricanes generally persist for about 12 to 18 hours, with slower-moving storms potentially lasting around 24 hours.



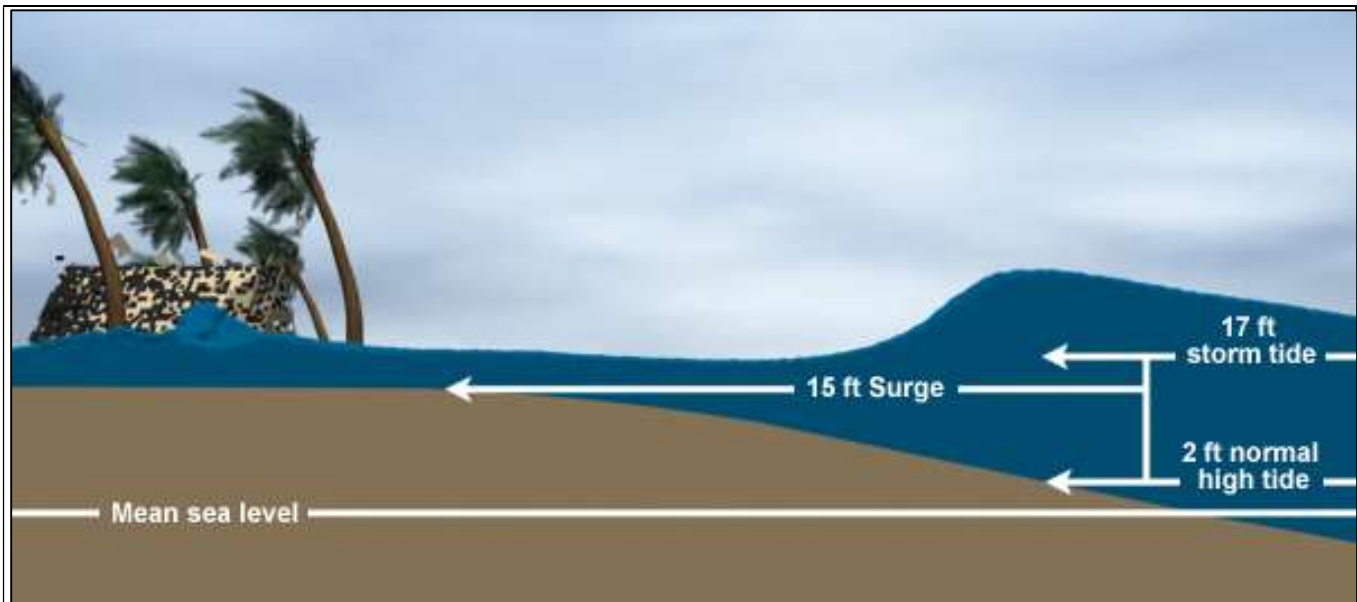
Potential Impacts

The threats caused by an approaching hurricane can be divided into three main categories: storm surge, wind damage, and rain. As a hurricane approaches, its strong winds cause waves to build up. These waves can extend far from the storm's center, impacting coastal areas even before landfall. Hurricane landfall means the storm's center moves from over the ocean onto land, leading to a range of impacts, including strong winds, heavy rainfall, potential tornadoes, and storm surge.

STORM SURGE

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides (see Figure 13-2). Storm surge occurs when water is pushed toward the shoreline by the force of winds from the storm. Friction between the water and the moving air creates drag that, depending upon the distance of water (fetch) and velocity of the wind, can pile water up to depths greater than 20 feet from the shoreline inland. The rise in water level can cause extreme flooding in coastal areas, especially when storm surge coincides with normal high tide (National Hurricane Center 2022).

Figure 13-2. Storm Surge



Source: (National Hurricane Center 2022)

According to the National Hurricane Center, there are many factors that contribute to the amount of surge a given storm produces at a given location:

- **Central Pressure**—Lower pressure of the storm will produce a higher surge; however, the central pressure of the storm is a minimal contribution compared to the other factors.
- **Storm Intensity**—Stronger winds will produce higher surge.



- **Storm Forward Speed**—On the open coast, a faster storm will produce a higher surge. However, a higher surge is produced in bays, sounds, and other enclosed bodies of water with a slower storm.
- **Angle of Approach to Coast**—The angle at which a storm approaches a coastline can affect how much surge is generated. A storm that moves onshore perpendicular to the coast is more likely to produce a higher storm surge than a storm that moves parallel to the coast or moves inland at an oblique angle.
- **Shape of the Coastline**—Storm surge will be higher when a hurricane makes landfall on a coastline that is curved inward, as opposed to a coastline that is curved outward.
- **Size**—A larger storm will produce a higher surge. The winds of a larger storm push on a larger area of the ocean. The strong winds of a larger storm tend to affect a larger area than a smaller storm.
- **Width and Slope of the Ocean Bottom**—Higher storm surge occurs with wide, gently sloping continental shelves, while lower storm surge occurs with narrow, steeply sloping shelves.
- **Local Features**—Storm surge highly depends on local features and barriers that will affect the flow of water. In the state, this includes inlets, bays, and rivers (National Hurricane Center 2022).

STRONG WINDS

The strongest winds are typically located on the right side of the hurricane's center and gradually weaken as towards the outer bands of the hurricane. The size of a hurricane's wind field is typically a few hundred miles across, although the size of a hurricane-force wind field (with sustained wind speeds greater than 73 mph) is typically smaller, averaging about 100 miles across (National Hurricane Center n.d.).

A hurricane does not need to make direct contact with the island for communities to experience wind impacts. Hurricane-force winds can extend outward up to approximately 25 miles from a small hurricane and over 150 miles from a large one. Additionally, tropical storm-force winds can reach distances of up to 300 miles from the center of a large hurricane. Several factors influence wind impacts, including wind strength, the storm's radius of maximum winds, forward speed, and proximity to land. (NOAA 2023)

Hurricanes in the Atlantic and Central Pacific are categorized into five levels based on the Saffir-Simpson Hurricane Wind Scale, which assesses the potential for property damage in relation to the sustained wind speed of the hurricane. For further information about the Saffir-Simpson Scale, please refer to the Extent subsection of this profile.

Hurricane winds can affect all parts of an island, with mountain ranges potentially intensifying wind effects through orographic or topographic amplification. This phenomenon means that even a minimal hurricane can produce significant wind impacts on land, as hurricane winds blowing from various directions interact with the terrain. Hurricanes can also create microbursts—sudden and intense downdrafts—and mini swirls, which are localized wind bursts that can exceed speeds of 200 mph. These phenomena are more likely to occur along the island's cliffs and mountain ranges, where winds are known to accelerate as they move downhill.



HEAVY RAIN

Hurricanes and other tropical cyclones often produce widespread, torrential rains in excess of 6 inches, which may result in deadly and destructive flooding. Rainfall amounts are not directly correlated with the storm's intensity, but rather with its speed and size; larger, slower-moving storms typically produce more precipitation. Furthermore, mountainous regions can exacerbate rainfall amounts associated with a hurricane. The impacts of rainfall may extend for hundreds of miles and persist for several days, affecting areas long before the storm makes landfall and after the hurricane has passed. (National Hurricane Center n.d.)

13.1.2 LOCATION

The entire City is susceptible to impacts related to hurricanes. While it has historically been uncommon for hurricanes to make direct landfall on O‘ahu or other islands in the state, large swells and strong winds from nearby storms are frequently experienced. Significant damage can occur from hurricanes and tropical storms even without direct landfall.

Coastal regions of O‘ahu are particularly vulnerable to damage resulting from a combination of high winds, flooding, and tidal surges. Given that hurricanes and tropical storms rotate counterclockwise in the Northern Hemisphere, east-facing coastlines typically experience the most intense onshore winds as storms approach, while the south and west coastlines are impacted by onshore winds as storms progress to the west.

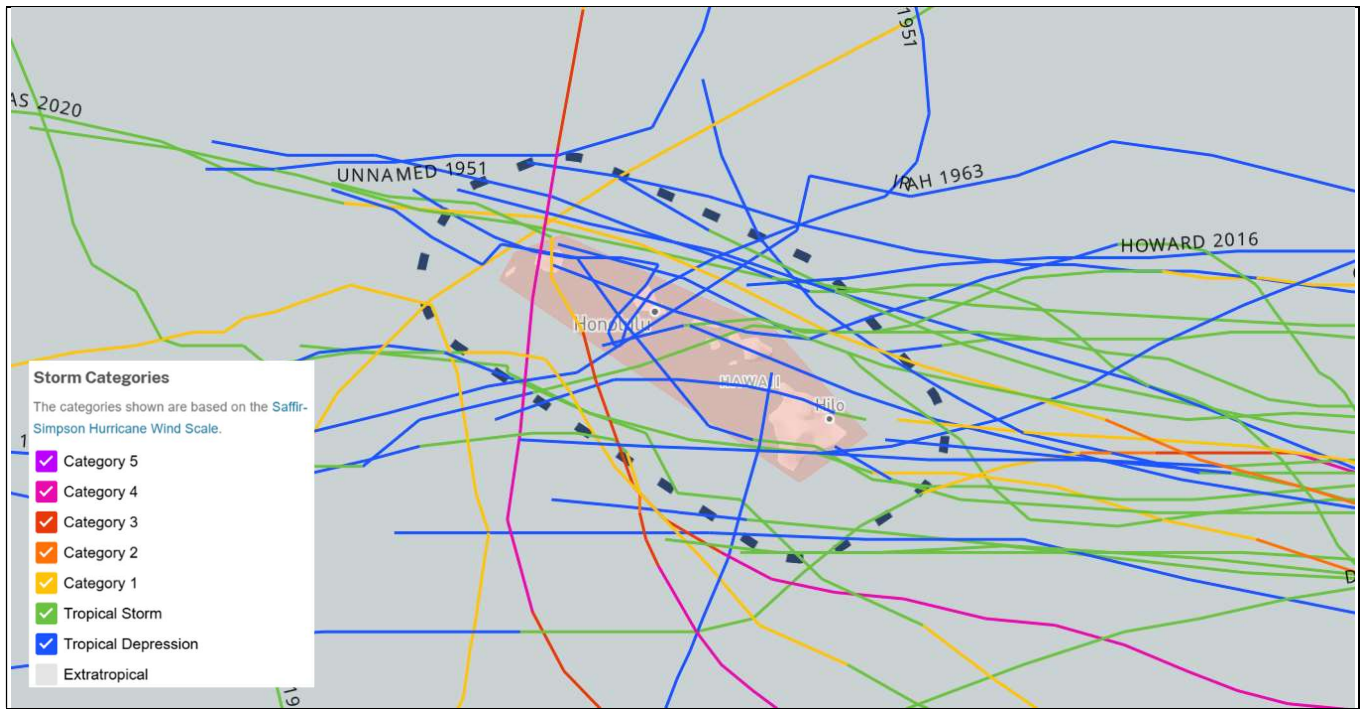
Inland areas, especially those identified as being in the 1% and 0.2% annual chance flood zones on FEMA's Digital Flood Insurance Rate Maps (DFIRMs) (and the Hawai‘i Flood Hazard Assessment Tool Map), are also at risk for flooding due to heavy rainfall associated with hurricanes and tropical storms. For further information regarding inland flooding, please refer to Chapter 10.

All regions of the island face the potential for structural damage from high winds, especially in buildings constructed under earlier codes that did not account for high wind uplift provisions. Structures located in wind speed-up areas, where wind speeds increase over hills, ridges, and escarpments (steep slopes or long cliffs, are more susceptible to wind damage compared to those situated on flat, open terrain.

The NOAA Historical Hurricane Tracks tool is a publicly accessible interactive mapping application that presents data on tropical cyclones from the Atlantic and East-Central Pacific Basins. This tool catalogues tropical cyclones occurring from 1842 to 2025 (the latest available data). Figure 13-3 illustrates the tracks of tropical cyclones within 80 miles of O‘ahu from 1950 to 2023.



Figure 13-3. Historical Tropical Cyclone Tracks within 80 miles of O’ahu (1950 to 2023)



Source: (NOAA 2023)

A probabilistic analysis using Hazus was conducted to evaluate the wind hazard losses for the City, as illustrated in Figure 13-4 through Figure 13-7. This analysis identified the worst-case hurricane wind spend zones for varying hurricane severities using recurrence intervals of 50-, 100-, 500-, and 1000-years. These varying wind events assess the probability of a hurricane of a specific magnitude occurring within a defined timeframe. For instance, a 100-year event indicates a 1% chance (1/100) of occurrence in any given year and 500-year event indicates a 0.2% chance (1/500) of occurring in any given year. Typically, a longer recurrence interval corresponds to an increased severity of the event; therefore, a 500-year event is expected to be more severe than a 100-year event.

The following maps illustrate the potential peak wind gusts and wind speed zones associated with various recurrence intervals. For instance, Figure 13-5 presents the potential peak wind gust for a storm with a 100-year recurrence interval or a 1% chance of occurring in any given year. Areas depicted in green indicate regions where Category 1 wind speeds (74 – 95 mph) are anticipated, while areas shown in blue signify regions where tropical storm wind speeds (39 – 73 mph) are expected.



Figure 13-4. 50-Year Peak Wind Gusts

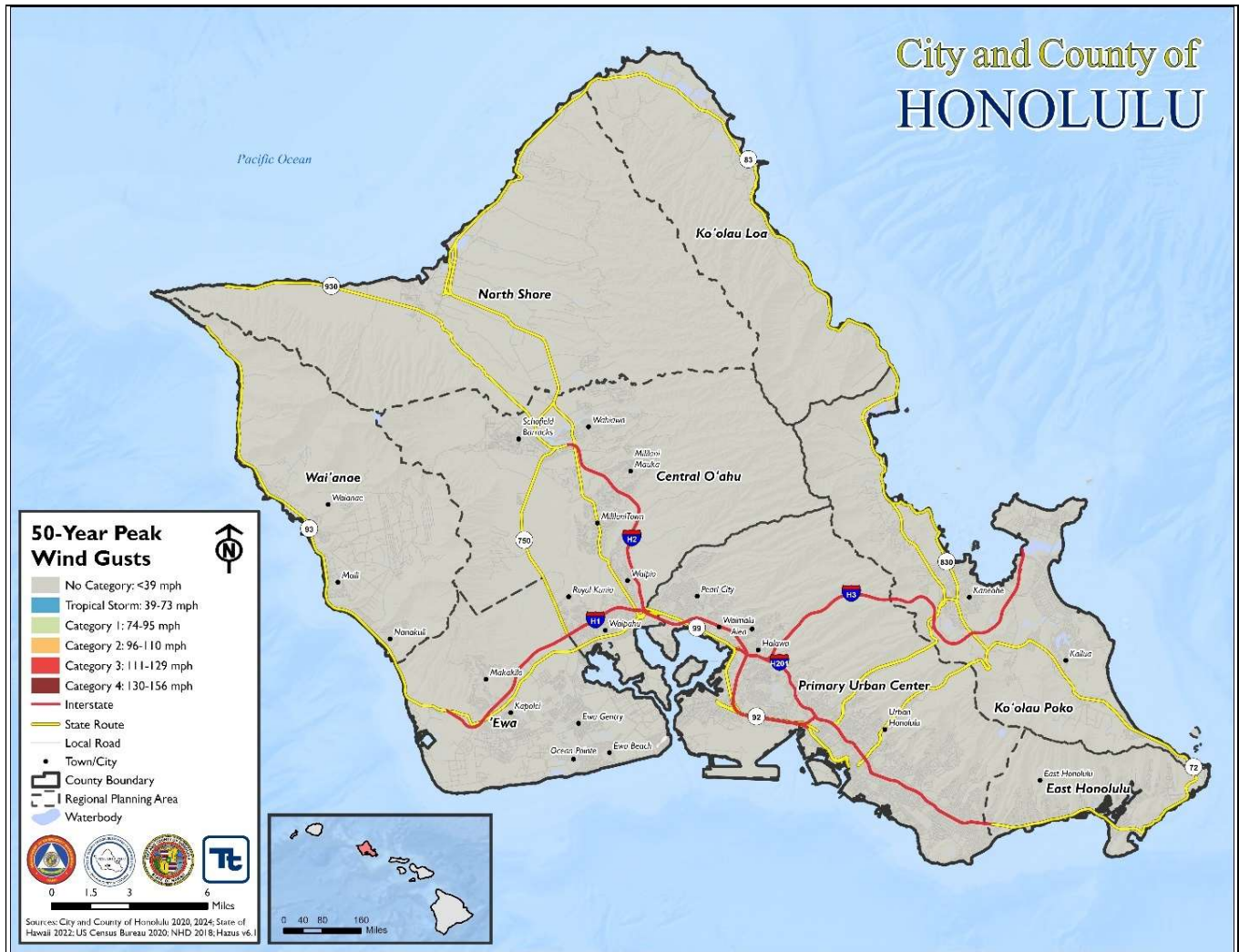




Figure 13-5. 100-Year Peak Wind Gusts

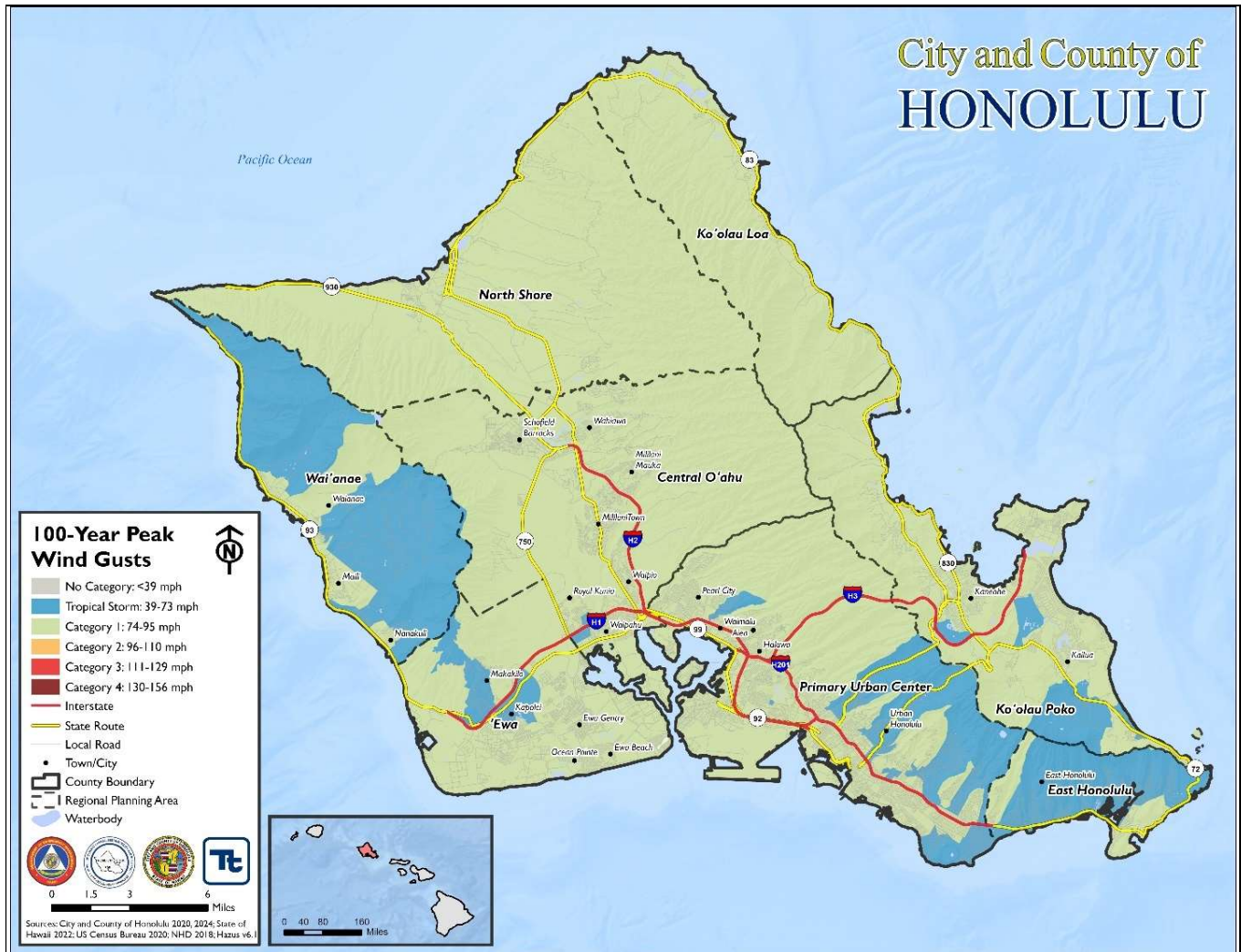




Figure 13-6. 500-Year Peak Wind Gusts

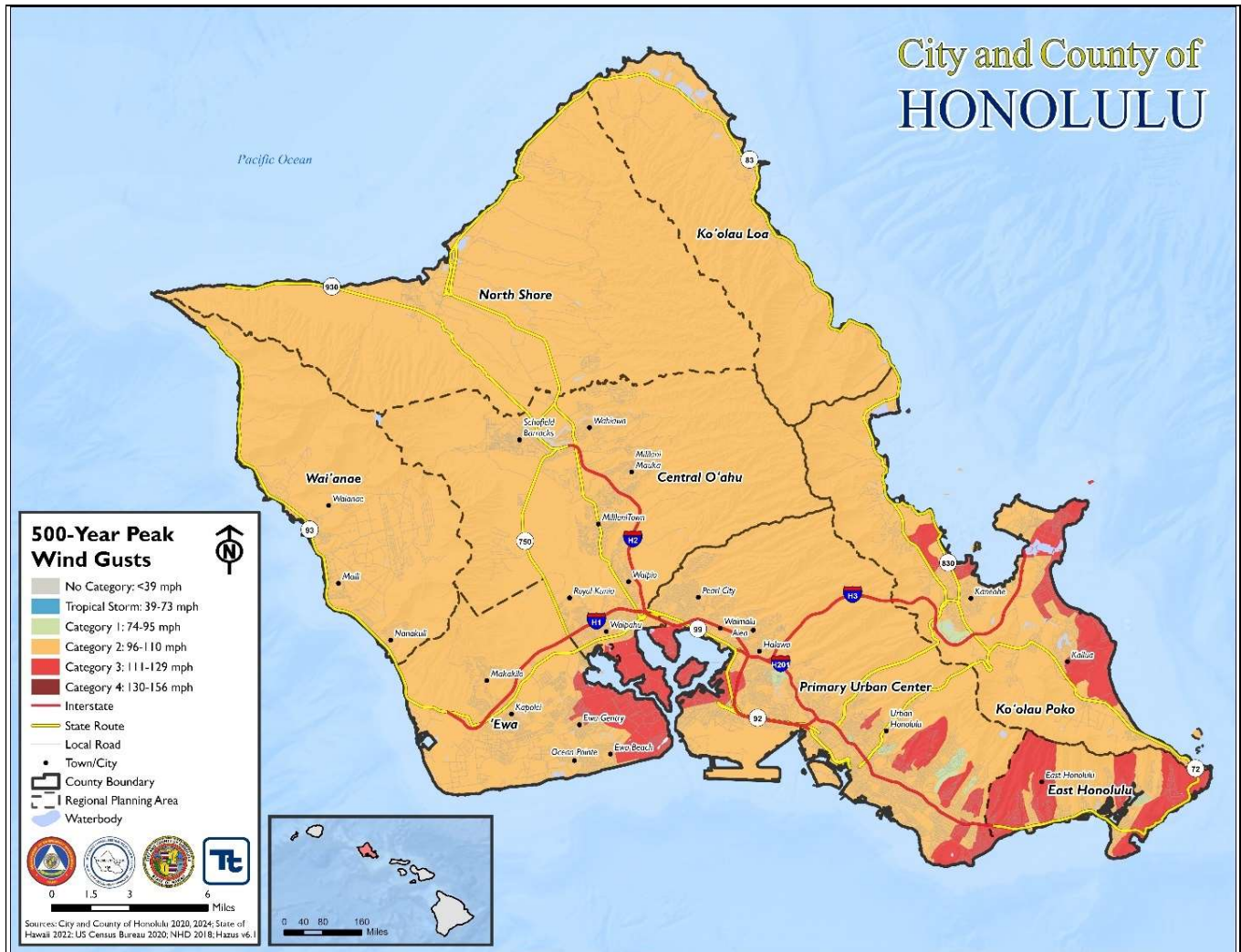
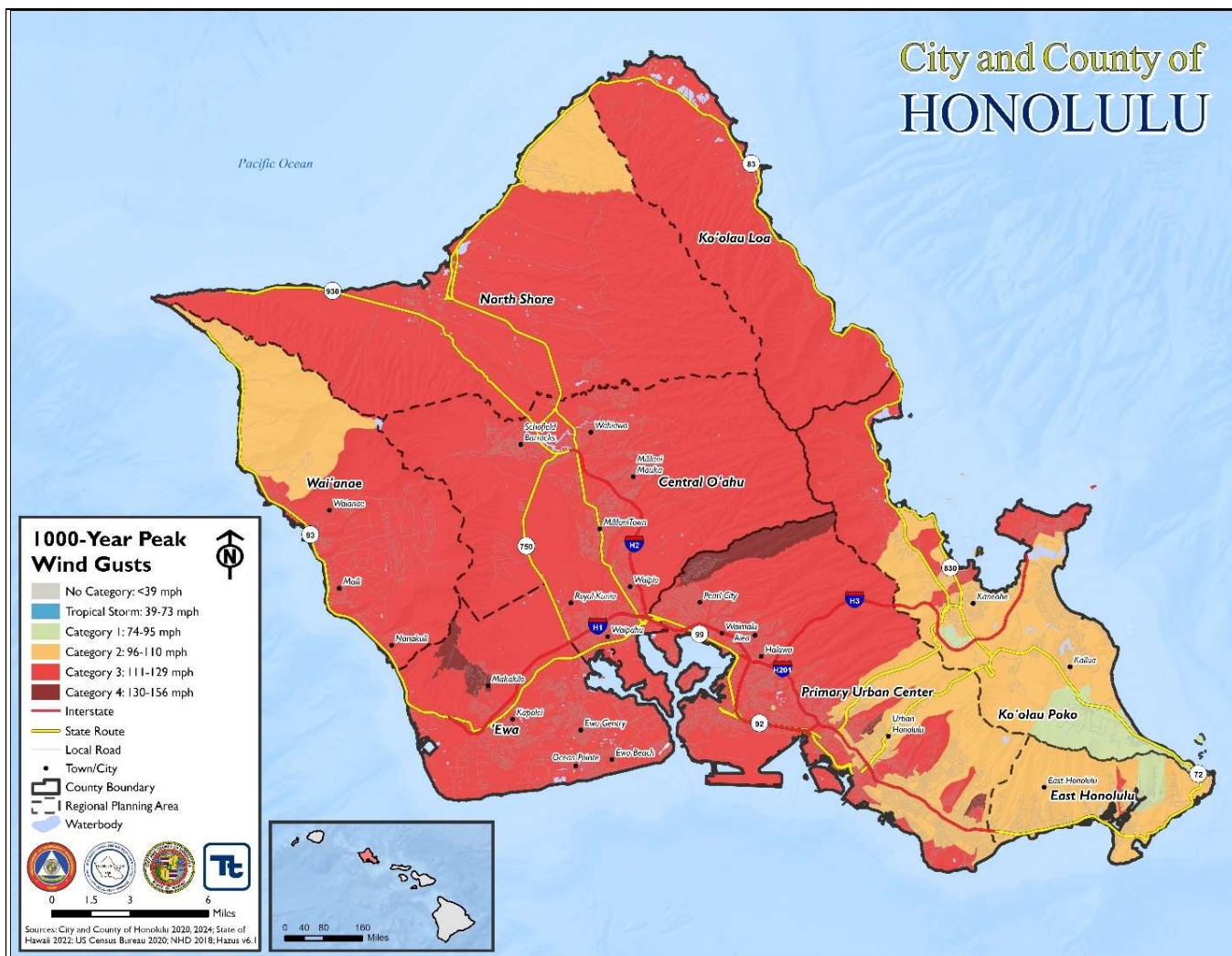


Figure 13-7. 1000-Year Peak Wind Gusts



13.1.3 EXTENT

Hazard extent refers to the potential severity or magnitude of hazard events in a given area. This section describes measurements used to indicate the extent of this hazard and the systems in place for monitoring severity and providing warnings as necessary.

Severity Ratings

Once a tropical cyclone is classified as a hurricane, its intensity is assessed using the Saffir-Simpson Hurricane Scale. This scale rates hurricanes on a scale from 1 to 5 based on their sustained wind speeds, and it provides an estimate of potential property damage as outlined in Table 13-1. Hurricanes that reach Category 3 and above are categorized as major hurricanes due to their capability to cause significant loss of life and extensive damage. It is important to note that Category 1 and 2 hurricanes also pose serious risks to lives and property.



Table 13-1. The Saffir-Simpson Hurricane Scale

Category	Wind Speed	Expected Damage
1	74-95 mph	Very dangerous winds will produce some damage: Well-constructed frame homes could have damage to roofs, shingles, vinyl siding, and gutters. Large branches of trees will snap, and shallowly rooted trees may be toppled. Extensive damage to power lines and poles likely will result in power outages that could last a few to several days.
2	96-110 mph	Extremely dangerous winds will cause extensive damage: Well-constructed frame homes could sustain major roof and siding damage. Many shallowly rooted trees will be snapped or uprooted and block numerous roads. Near-total power loss is expected with outages that could last from several days to weeks.
3 (Major)	111-129 mph	Devastating damage will occur: Well-built framed homes may incur major damage or removal of roof decking and gable ends. Many trees will be snapped or uprooted, blocking numerous roads. Electricity and water will be unavailable for several days to weeks after the storm passes.
4 (Major)	130-156 mph	Catastrophic damage will occur: Well-built framed homes can sustain severe damage with the loss of most of the roof structure and/or some exterior walls. Most trees will be snapped or uprooted, and power poles downed. Fallen trees and power poles will isolate residential areas. Power outages will last weeks to possibly months. Most of the area will be uninhabitable for weeks or months.
5 (Major)	>157 mph	Catastrophic damage will occur: A high percentage of framed homes will be destroyed, with total roof failure and wall collapse. Fallen trees and power poles will isolate residential areas. Power outages will last for weeks to possibly months. Most of the area will be uninhabitable for weeks or months.

Source: NWS 2013

As previously mentioned, storm surge inundation resulting from hurricanes can have catastrophic effects on coastal areas. Table 13-2 provides a summary of the coastline that may be at risk of inundation from storm surges associated with hurricane Categories 1 through 4. Notably, within the state, the City has the highest number of square miles susceptible to storm surge inundation.

Table 13-2. Storm Surge Inundation Area

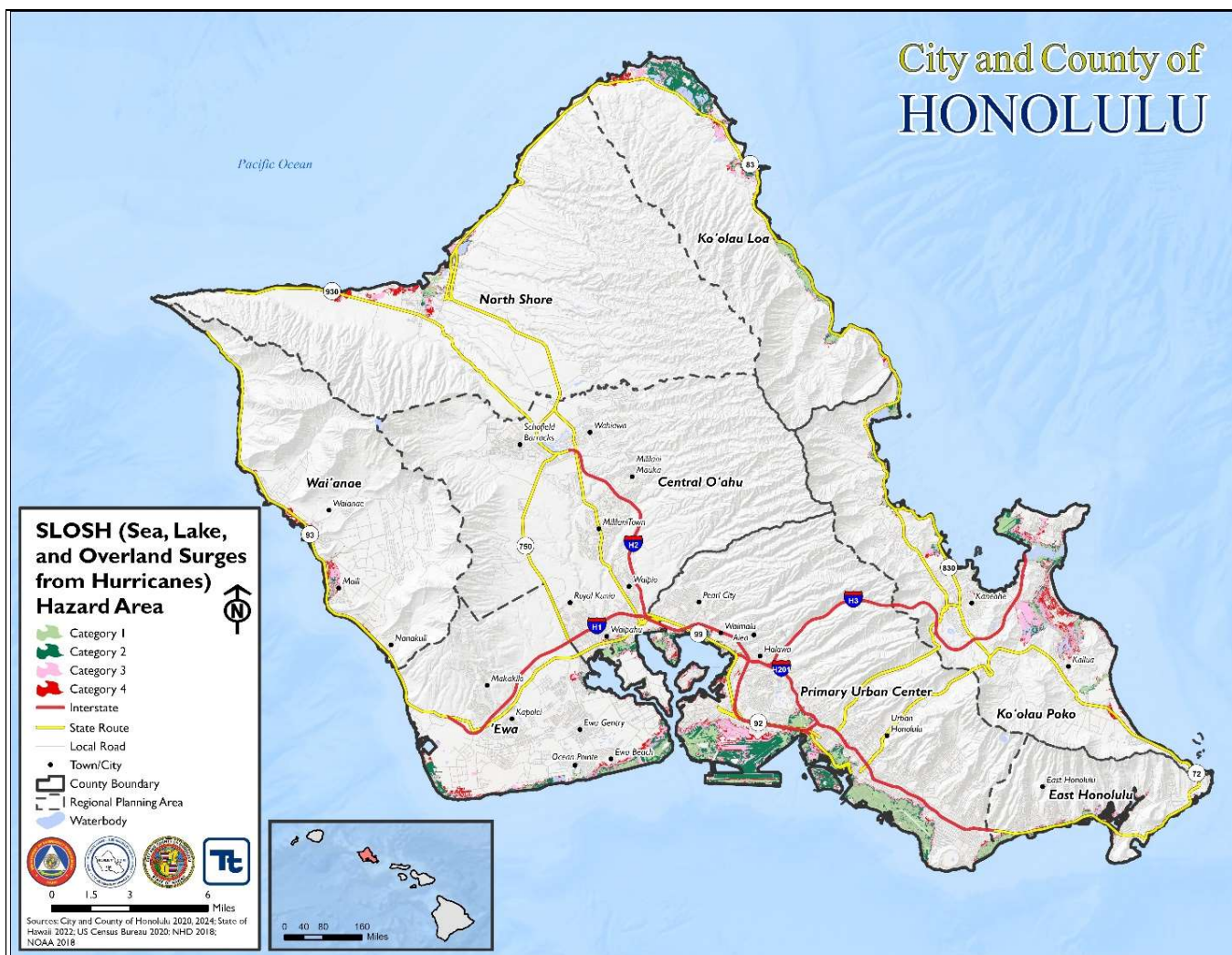
Area (in square miles)								
Total City Area	Category 1 Hurricane	Cat 1 as % of Total Area	Category 2 Hurricane	Cat 2 as % of Total Area	Category 3 Hurricane	Cat 3 as % of Total Area	Category 4 Hurricane	Cat 4 as % of Total Area
598.5707	10.9	1.82%	22.3	3.73%	31.8	5.31%	38.2	6.38%

Source: Federal Emergency Management Agency; National Weather Service; National Oceanic and Atmospheric Administration



To further assess the extent of hurricanes and associated hazards, a Sea, Lake, and Overland Surges from Hurricanes (SLOSH) analysis was conducted to evaluate potential storm surge losses for the City. The SLOSH model incorporates factors such as inundation, wind stress, and pressure, which take into account the effects of hurricane-force winds. Figure 13-8 illustrates the coastal areas that may be vulnerable to storm surge for hurricanes ranging in strength from Category 1 to 4.

Figure 13-8. Storm Surge for Category 1 to 4 Hurricanes



Monitoring and Warning

Tropical cyclones are a unique weather phenomenon that allow for close monitoring and tracking. This capability enables the issuance of accurate warnings up to several days in advance, with track models offering possible storm movements up to a week in advance. The accuracy of track forecasts has improved, in part due to the increased number of satellites equipped with advanced weather-monitoring technology. Additionally, advancements in supercomputing and ongoing enhancements in forecasting computer models have contributed



to this progress. However, predicting the severity of a storm remains a challenge, as minor changes in atmospheric conditions can significantly influence forecasts (NOAA 2024).

The Central Pacific Hurricane Center generates tropical cyclone advisory packages whenever a tropical cyclone is active in the Central Pacific region. In contrast, the National Hurricane Center is responsible for issuing these packages when a tropical cyclone occurs in the Eastern Pacific region. Within the Tropical Cyclone Public Advisory (TCP) and Tropical Cyclone Forecast/Advisory (TCM) advisory packages, watches and warnings are provided to inform the public about potential or imminent hazardous conditions. These watches and warning are detailed in Table 13-3

Table 13-3. National Weather Service Hurricane and Tropical Storm Watch and Warning Products

Advisory	Definition
Tropical Cyclone Warning	Tropical storm conditions are expected in the area within 36 hours and consist of sustained winds between 39 to 73 mph.
Hurricane Warning	Hurricane conditions are expected in the area with sustained winds of 74 mph or greater. Generally, a hurricane warning is issued within 36 hours before a tropical storm-force wind is expected to give time for preparations.
Tropical Storm Watch	Tropical storm conditions are possible within the area, consisting of sustained winds of 39 to 73 mph.
Hurricane Watch	Hurricane conditions of sustained winds 74 mph or greater are possible in the area. Generally, a hurricane watch is issued 48 hours before a tropical storm-force wind is expected.

Source: NWS n.d.

The following outlines the definitions for the tropical cyclone advisory packages as established by the Central Pacific Hurricane Center.

TROPICAL CYCLONE PUBLIC ADVISORY

The TCP serves as the primary tropical cyclone informational product intended for a general audience. The key components of the TCP include the following:

- A summary table with the cyclones position (location), distance from a reference point, maximum sustained winds (intensity or severity), direction and speed of motion, and minimum central pressure. Additionally, a general forecast of the predicted track and intensity over the next 72 hours is included. When conditions are warranted, a discussion of the cyclone’s forecast track and intensity over the following five days will be included.
- A summary of all current coastal watches and warnings associated with the cyclone. Recent changes to the watches and warnings are highlighted at the top of the report.
- Information regarding potential hazards to the land, including information on storm surge, wind, rainfall, and tornadoes (if applicable), and rip currents associated with the cyclone. In instances where multiple



locations are impacted by storm surge or rainfall, weblinks will direct users to relevant graphical hazard information.

Public advisories are generally issued every six hours at 5:00 a.m., 11:00 a.m., 5:00 p.m., and 11:00 p.m. Hawai'i Standard Time. However, the frequency increases under certain conditions.

- Every three hours when coastal watches or warning are in effect
- Every 2 hours when coastal watches or warnings are in effect and land-based radars have identified a reliable storm center

Special public advisories may be issued at any time due to significant changes in warning or in the cyclone.

TROPICAL CYCLONE FORECAST/ADVISORY

The TCM provides specific detailed meteorological data and forecasts. The information is provided in a standardized format designed to be analyzed by a computer. The key components of the TCM include the following:

- The latitude and longitude of the cyclone's center, direction, and speed of motion.
- Information on the cyclone's maximum sustained winds (intensity and severity) and central pressure. The extent of the winds of different intensities (e.g., 34 knots, 50 knots, and 64 knots) is provided in four quadrants around the cyclone.
- Predicted positions (track), intensities, and size (radial extent) of the cyclone at 12, 24, 36, 48, 72, 96, and 120 hours from the forecast's nominal initial time.

These advisories are issued every six hours, and more frequently if significant changes occur.

TROPICAL CYCLONE DISCUSSION

The tropical cyclone discussion (TCS) provides in-depth analysis and rationale behind the forecast for a tropical cyclone. This provided is intended for meteorologists and other professionals to equip them with a deeper understanding of the cyclone's behavior and forecast. The key components of the TCS include the following:

- A summary of the cyclone's location, intensity, and movement.
- Comprehensive observations supporting the forecast, including an analysis of how environmental factors such as atmospheric conditions, sea surface temperatures, and interactions with other weather systems may impact on the cyclone's future trajectory and intensity
- Discussion of numerical guidance models, including discrepancies and uncertainties.
- An assessment of the forecaster's degree of confidence in the official forecast, highlighting alternate scenarios, unusual hazards, and a summary of key messages.

The TCS is issued every six hours.



TROPICAL CYCLONE SURFACE WIND SPEED PROBABILITIES

The wind speed probabilities report presents the likelihood, expressed as percentages, of sustained wind speeds reaching or exceeding thresholds of 34 knots, 50 knots, and 64 knots. These probabilities are derived from forecasts and uncertainties related to track, intensity, and wind structure provided by the Central Pacific Hurricane Center. The wind speed probabilities are calculated for both coastal and inland cities, in addition to offshore locations such as buoys. This report is typically issued in conjunction with the advisory package every six hours.

13.1.4 PREVIOUS OCCURRENCES

This section provides an overview of hazard occurrences since the publication of the previous LHMP, covering the period between January 2020 and February 2025. It identifies events that resulted in federal disaster declarations and/or state or local emergency proclamations. For events prior to 2020, refer to the 2020 LHMP.

Recent Events

Once known tropical cyclone impacted the City between January 2020 and August 2024 as shown in Table 13-4.

Table 13-4. Local, State, and Federal Declarations

Event Date	Disaster Declaration/ Proclamation			Description
	Federal	State	Mayoral	
July 20, 2020 – July 30, 2020	EM-3529	July 23, 2020	Proclamation of Emergency or Disaster (Hurricane Douglas)	Hurricane Douglas was a tropical cyclone and the closest passing hurricane to the island of O’ahu on record

Source: (FEMA 2024)

Federal Disaster Declarations

Under the Stafford Act, the President of the United States may issue an Emergency Declaration (EM) or Major Disaster Declaration (DR) for health related events and activate certain federal assistance programs based on factors related to the magnitude of the hazard threat or impacts. Table 13-4 indicates recent events that received EM or DR declarations under the Stafford Act.

State and Local Emergency Proclamations

State law authorizes the Governor to issue emergency proclamations if an emergency or disaster has occurred, or there is imminent danger or threat of an emergency or disaster in any portion of the state. County Mayors have the authority to issue local emergency proclamations when such conditions exist within any part of their respective jurisdictions. Table 13-4 indicates recent events that received a local or state proclamation.



13.1.5 PROBABILITY OF FUTURE OCCURRENCES

Historical data regarding hurricane occurrences in the City was used to assess the likelihood of future events. Until 1950, tropical storms affecting the Hawaiian Islands were not classified as hurricanes. It was not until the advent of weather satellites that the occurrence of hurricanes in this part of the world was understood (HI EMA 2023). Although O’ahu has not experienced a direct impact from hurricanes, there have been several instances of nearby hurricanes affecting the island:

- Hurricane Nina in 1957 resulted in record winds
- Hurricane Dot in 1959 led to damage to homes along the shoreline
- Hurricane Estelle in 1986 caused flooding
- Hurricane Lane in 2018 brought significant rainfall and flash flooding
- Hurricane Olivia in 2019 resulted in heavy rainfall, flooding, downed trees, and power outages
- Hurricane Douglas in 2020 produced strong winds, heavy rain, and high surf.

These previous incidents were analyzed to assess the likelihood of the City being affected by a hurricane, either directly or indirectly. Table 13-5 lists the number of events from various sources over the 73-year period from 1950 to 2024 which is the most complete period of record for all sources reviewed. Based on these records and input from the Core Planning Team, the probability of the occurrence of a hurricane in the City is considered “rare.”

Table 13-5. Probability of Future Hurricane Events Affecting the City

Hazard Type	Number of Occurrences Between 1950 and 2024	Percent Chance of Occurring in Any Given Year
Hurricane	6	8.00%

Source: (FEMA 2024)

Note: The time period presented in this table is the most complete period of record for the various data sources reviewed.

13.2 VULNERABILITY AND IMPACT ASSESSMENT

To understand risk, a community must evaluate what assets are exposed and vulnerable in the identified hazard area. The following text evaluates and estimates the potential impact of the hurricane hazard on the City. Two analyses were conducted:

- One analysis utilized FEMA’s Hazus software to perform a hurricane wind hazard assessment aimed at estimating potential losses. Recurrence intervals of 50-, 100-, 500-, and 1000-years were considered to provide a comprehensive range of potential loss estimates (see Figure 13-4 through Figure 13-7). These scenarios reflect the worst-case hurricane wind speed zones across various hurricane severities and are



intended for planning purposes, acknowledging that each hurricane presents unique characteristics and that wind speeds will differ based on the storm's trajectory and prevailing conditions.

- A storm surge analysis was conducted using the SLOSH model to assess potential losses attributed to storm surge. This analysis approaches loss estimation based on hurricane categories rather than recurrence intervals. For this LHMP, Categories 1 through 4 were evaluated using the SLOSH model. The categories were mapped against the centroids of updated assets, including population, building stock, critical facilities, historic sites, and new developments. Centroids that fell within the buffered areas were identified to calculate the replacement cost value (RCV) of buildings and to estimate the population at risk from storm surge.

These two analyses are independent and should be utilized separately to assess vulnerability.

13.2.1 LIFE, HEALTH, AND SAFETY

It is assumed that the entire island's population, property, critical facilities, and environment are exposed to the wind, rainfall/flooding, or storm surge impacts of hurricanes to some degree.

Overall Population

The City is home to more than 1 million people, and they are all at risk from wind impacts during a hurricane, especially homes and facilities on unexposed ridgelines

The SLOSH analysis revealed that 2.8% of the City's total population is within a Category 1 storm surge area, while that number jumps to 9.1 % within the Category 4 storm surge area. Outside the densely populated Primary Urban Center, other regional planning areas like East Honolulu, Ko'olau Poko and Ko'olau Loa have over 10 percent of the region's total area within the Category 4 storm surge area affecting roughly 43,000 residents. See Table 13-6 for the complete results of the City's population within the storm surge hazard area by hurricane category.

Table 13-7 presents the estimated number of households and individuals who may require shelter during hurricanes with wind return periods of 50-, 100-, 500-, and 1,000-years. Hazus generates these estimates by evaluating physical damage, which encompasses structural damage, roof damage, and the potential for total destruction. The figures provided for the number of households and individuals needing shelter are intended for planning purposes and are based on the projected losses to structures.



Table 13-6. City Population in Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Total Population (2022 ACS)	Population in the Category 1 SLOSH Hazard Area		Population in the Category 2 SLOSH Hazard Area		Population in the Category 3 SLOSH Hazard Area		Population in the Category 4 SLOSH Hazard Area	
		Number of Persons	% of Regional Planning Area Total	Number of Persons	% of Regional Planning Area Total	Number of Persons	% of Regional Planning Area Total	Number of Persons	% of Regional Planning Area Total
Central O’ahu	175,966	1,126	0.6%	1,607	0.9%	2,247	1.3%	2,775	1.6%
East Honolulu	49,947	1,438	2.9%	2,569	5.1%	4,956	9.9%	6,835	13.7%
’Ewa	128,498	4,239	3.3%	8,034	6.3%	10,897	8.5%	12,239	9.5%
Ko’olau Loa	14,512	1,205	8.3%	3,594	24.8%	5,315	36.6%	6,158	42.4%
Ko’olau Poko	120,704	2,136	1.8%	4,546	3.8%	14,921	12.4%	25,021	20.7%
North Shore	18,176	456	2.5%	380	2.1%	570	3.1%	1,770	9.7%
Primary Urban Center	451,030	17,733	3.9%	22,861	5.1%	27,531	6.1%	32,300	7.2%
Wai’anae	51,266	26	0.1%	474	0.9%	2,629	5.1%	4,874	9.5%
City and County of Honolulu (Total)	1,010,100	28,359	2.8%	44,065	4.4%	69,066	6.8%	91,972	9.1%

Source: U.S. Census Bureau ACS 2022; NOAA 2018



Table 13-7. Estimated Displaced Population from Hurricane based on Hazus Wind Analysis

Regional Planning Area	Total Population (2022 ACS)	50-Year Mean Return Period Hurricane		100-Year Mean Return Period Hurricane		500-Year Mean Return Period Hurricane		1,000-Year Mean Return Period Hurricane	
		Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering	Displaced Households	Persons Seeking Short-Term Sheltering
Central O’ahu	175,966	0	0	5	13	423	869	4,296	8,681
East Honolulu	49,947	313	381	26	32	1,450	1,738	429	483
’Ewa	128,498	0	0	0	0	641	1,584	4,081	10,135
Ko’olau Loa	14,512	0	0	4	11	133	439	438	1,690
Ko’olau Poko	120,704	0	0	53	114	1,144	2,430	901	2,046
North Shore	18,176	0	0	15	22	352	544	516	950
Primary Urban Center	451,030	0	0	472	724	2,433	3,034	6,928	10,553
Wai’anae	51,266	0	0	32	150	180	817	1,182	5,654
City and County of Honolulu (Total)	1,010,100	313	381	607	1,066	6,756	11,455	18,771	40,192

Source: U.S. Census Bureau ACS 2022; Hazus v6.1



Socially Vulnerable Population

Socially vulnerable populations are most susceptible to hurricane impacts, based on several factors including their physical and financial ability to react or respond during a hazard and the location and construction quality of their housing. The population over the age of 65 is also more vulnerable because they may require extra time or outside assistance during evacuations and are more likely to seek or need medical attention that may not be available due to isolation during a storm event. Those with low English proficiency may not understand critical evacuation messages.

The SLOSH analysis was used to understand the socially vulnerable populations living within the Category 1 to 4 storm surge hazard areas. The results are displayed in Table 13-8 to Table 13-11. In a Category 4 hurricane, 42 percent of the Ko‘olau Loa region is vulnerable to storm surge.



Table 13-8. Socially Vulnerable Population in Category 1 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Estimated Number of Vulnerable Persons Located in the Category 1 SLOSH Hazard Area									
	Persons Over 65	% of Total	Persons Under 5	% of Total	Non-English Speaking Persons	% of Total	Persons with a Disability	% of Total	Persons in Poverty	% of Total
Central O’ahu	189	0.6%	73	0.6%	42	0.6%	125	0.6%	82	0.6%
East Honolulu	396	2.9%	62	2.9%	44	2.8%	139	2.9%	60	2.9%
’Ewa	481	3.3%	322	3.3%	88	3.3%	423	3.3%	298	3.3%
Ko’olau Loa	129	8.2%	80	8.2%	20	8.2%	106	8.3%	103	8.3%
Ko’olau Poko	418	1.8%	132	1.8%	24	1.7%	214	1.8%	120	1.8%
North Shore	86	2.5%	34	2.5%	10	2.3%	55	2.5%	46	2.5%
Primary Urban Center	3,702	3.9%	889	3.9%	1,906	3.9%	2,041	3.9%	1,702	3.9%
Wai’anae	3	<0.1%	2	<0.1%	0	<0.1%	3	<0.1%	4	<0.1%
City and County of Honolulu (Total)	5,404	2.9%	1,594	2.6%	2,134	3.4%	3,106	2.8%	2,415	2.8%

Source: U.S. Census Bureau ACS 2022; NOAA 2018



Table 13-9. Socially Vulnerable Population in Category 2 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Estimated Number of Vulnerable Persons Located in the Category 2 SLOSH Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Central O’ahu	269	0.9%	104	0.9%	61	0.9%	178	0.9%	117	0.9%
East Honolulu	707	5.1%	111	5.1%	79	5.1%	249	5.1%	107	5.1%
’Ewa	913	6.3%	611	6.2%	167	6.2%	803	6.3%	565	6.2%
Ko’olau Loa	387	24.7%	241	24.7%	60	24.7%	316	24.7%	308	24.7%
Ko’olau Poko	890	3.8%	281	3.8%	52	3.7%	455	3.8%	257	3.8%
North Shore	72	2.1%	29	2.1%	9	2.1%	45	2.0%	38	2.1%
Primary Urban Center	4,772	5.1%	1,146	5.1%	2,458	5.1%	2,632	5.1%	2,194	5.1%
Wai’anae	61	0.9%	40	0.9%	7	0.8%	64	0.9%	86	0.9%
City and County of Honolulu (Total)	8,071	4.3%	2,563	4.3%	2,893	4.6%	4,742	4.2%	3,672	4.2%

Source: U.S. Census Bureau ACS 2022; NOAA 2018



Table 13-10. Socially Vulnerable Population in Category 3 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Estimated Number of Vulnerable Persons Located in the Category 3 SLOSH Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Central O’ahu	377	1.3%	145	1.3%	85	1.3%	249	1.3%	164	1.3%
East Honolulu	1,364	9.9%	214	9.9%	153	9.9%	480	9.9%	207	9.9%
’Ewa	1,238	8.5%	829	8.5%	227	8.5%	1,089	8.5%	767	8.5%
Ko’olau Loa	573	36.6%	357	36.6%	89	36.6%	467	36.6%	456	36.6%
Ko’olau Poko	2,921	12.4%	922	12.4%	173	12.3%	1,495	12.4%	845	12.4%
North Shore	108	3.1%	43	3.1%	13	3.0%	68	3.1%	58	3.1%
Primary Urban Center	5,747	6.1%	1,380	6.1%	2,960	6.1%	3,169	6.1%	2,642	6.1%
Wai’anae	341	5.1%	227	5.1%	43	5.0%	355	5.1%	480	5.1%
City and County of Honolulu (Total)	12,669	6.8%	4,117	6.8%	3,743	6.0%	7,372	6.6%	5,619	6.5%

Source: U.S. Census Bureau ACS 2022; NOAA 2018



Table 13-11. Socially Vulnerable Population in Category 4 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Estimated Number of Vulnerable Persons Located in the Category 4 SLOSH Hazard Area									
	Persons Over 65	Percent of Total	Persons Under 5	Percent of Total	Non-English Speaking Persons	Percent of Total	Persons with a Disability	Percent of Total	Persons in Poverty	Percent of Total
Central O’ahu	466	1.6%	180	1.6%	105	1.6%	308	1.6%	203	1.6%
East Honolulu	1,882	13.7%	296	13.7%	211	13.6%	663	13.7%	285	13.7%
’Ewa	1,390	9.5%	931	9.5%	255	9.5%	1,223	9.5%	861	9.5%
Ko’olau Loa	664	42.4%	413	42.4%	103	42.4%	541	42.4%	528	42.4%
Ko’olau Poko	4,899	20.7%	1,547	20.7%	290	20.7%	2,508	20.7%	1,417	20.7%
North Shore	337	9.7%	135	9.7%	42	9.6%	213	9.7%	180	9.7%
Primary Urban Center	6,743	7.2%	1,619	7.2%	3,473	7.2%	3,718	7.2%	3,100	7.2%
Wai’anae	633	9.5%	421	9.5%	81	9.5%	658	9.5%	889	9.5%
City and County of Honolulu (Total)	17,014	9.1%	5,542	9.2%	4,560	7.3%	9,832	8.8%	7,463	8.6%

Source: U.S. Census Bureau ACS 2022; NOAA 2018



13.2.2 ECONOMY AND GENERAL BUILDING STOCK

The economy of the State, and by extension that of the City, is largely dependent on tourism, making it susceptible to the impacts of natural disasters. Historical hurricanes have caused considerable damage to infrastructure within the State, resulting in extensive effects on both the State's and local economies. For instance, Hurricane Iniki, the most recent major hurricane to significantly affect Hawai'i, primarily impacted the island of Kaua'i in 1992. This storm inflicted approximately \$7.4 billion in direct damage, leading to a dramatic rise in the unemployment rate on Kaua'i, which escalated from 6.8% to 19.1% immediately following the event. It is estimated that Kaua'i experienced a loss of around 3,000 private sector jobs due to the devastation caused by Iniki (Coffman 2012). O'ahu, with its economy similarly reliant on tourism, could encounter comparable long-term recovery challenges if faced with a hurricane of similar severity to that of Iniki.

To enhance the understanding of the potential economic impacts, insights can be drawn from the estimated replacement cost value (RCV) of structures. The Hazus analysis was conducted to understand the potential impact of hurricanes on the island's building stock. Table 13-12 to Table 13-15 display the residential, commercial, and industrial building stock losses that could occur during a 50-, 100-, 500-, and 1,000-year hurricane. A 1,000-year hurricane could cause more than \$16 billion in residential, commercial, and industrial building stock losses.

Table 13-12. Building Loss Estimates for 50-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Building Loss for 50-Year Mean Return Period Hurricane				
	All Occupancies	Residential	Commercial	Industrial	Other ^a
Central O'ahu	\$38,282	\$37,115	\$782	\$244	\$141
East Honolulu	\$371,550,851	\$331,906,836	\$21,990,818	\$1,152,547	\$16,500,649
'Ewa	\$239,437	\$227,237	\$4,014	\$7,436	\$750
Ko'olau Loa	\$0	\$0	\$0	\$0	\$0
Ko'olau Poko	\$0	\$0	\$0	\$0	\$0
North Shore	\$0	\$0	\$0	\$0	\$0
Primary Urban Center	\$4,078,273	\$3,567,687	\$141,894	\$14,332	\$354,361
Wai'anae	\$2,048,655	\$1,121,527	\$110,645	\$24,245	\$792,237
City and County of Honolulu (Total)	\$377,955,498	\$336,860,402	\$22,248,153	\$1,198,805	\$17,648,138

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

a. Other = Government, Religion, Agricultural, and Education



Table 13-13. Building Loss Estimates for 100-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Building Loss for 100-Year Mean Return Period Hurricane				
	All Occupancies	Residential	Commercial	Industrial	Other ^a
Central O’ahu	\$71,847,422	\$49,376,346	\$9,991,668	\$1,481,324	\$10,998,084
East Honolulu	\$97,974,662	\$89,213,933	\$4,221,908	\$392,481	\$4,146,339
’Ewa	\$25,743,749	\$17,312,467	\$3,238,070	\$1,494,912	\$3,698,300
Ko’olau Loa	\$19,694,616	\$14,468,082	\$1,496,639	\$712,613	\$3,017,282
Ko’olau Poko	\$138,118,267	\$115,410,068	\$13,002,221	\$1,759,284	\$7,946,693
North Shore	\$43,408,859	\$36,071,785	\$4,620,025	\$906,137	\$1,810,912
Primary Urban Center	\$839,900,221	\$626,015,727	\$132,248,147	\$17,258,704	\$64,377,643
Wai’anae	\$70,604,120	\$52,203,499	\$7,229,710	\$473,061	\$10,697,849
City and County of Honolulu (Total)	\$1,307,291,916	\$1,000,071,907	\$176,048,389	\$24,478,517	\$106,693,102

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

a. Other = Government, Religion, Agricultural, and Education

Table 13-14. Building Loss Estimates for 500-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Building Loss - 500-Year Mean Return Period Hurricane				
	All Occupancies	Residential	Commercial	Industrial	Other ^a
Central O’ahu	\$664,684,896	\$493,593,254	\$80,463,678	\$13,812,428	\$76,815,535
East Honolulu	\$1,482,275,735	\$1,353,231,106	\$64,110,799	\$7,125,842	\$57,807,988
’Ewa	\$770,040,971	\$597,618,944	\$75,807,021	\$31,254,935	\$65,360,071
Ko’olau Loa	\$145,104,273	\$116,343,363	\$9,920,449	\$5,210,617	\$13,629,844
Ko’olau Poko	\$1,313,810,866	\$1,111,945,947	\$124,251,537	\$15,324,364	\$62,289,018
North Shore	\$355,635,690	\$291,642,463	\$42,931,772	\$8,954,299	\$12,107,156
Primary Urban Center	\$3,756,940,244	\$2,648,266,487	\$726,016,796	\$101,982,717	\$280,674,243
Wai’anae	\$235,754,578	\$176,476,433	\$28,778,722	\$2,545,933	\$27,953,490
City and County of Honolulu (Total)	\$8,724,247,253	\$6,789,117,998	\$1,152,280,775	\$186,211,134	\$596,637,346

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

a. Other = Government, Religion, Agricultural, and Education



Table 13-15. Building Loss Estimates for 1,000-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Building Loss - 1,000-Year Mean Return Period Hurricane				
	All Occupancies	Residential	Commercial	Industrial	Other ^a
Central O’ahu	\$3,249,350,319	\$2,570,364,393	\$365,859,049	\$69,056,803	\$244,070,075
East Honolulu	\$606,321,479	\$552,278,687	\$25,190,323	\$2,457,744	\$26,394,725
’Ewa	\$2,829,203,945	\$2,160,832,885	\$332,747,652	\$151,019,522	\$184,603,886
Ko’olau Loa	\$395,119,845	\$308,485,408	\$32,375,274	\$16,974,110	\$37,285,052
Ko’olau Poko	\$1,056,281,979	\$880,787,376	\$104,966,343	\$12,989,156	\$57,539,105
North Shore	\$424,819,719	\$351,689,429	\$46,288,467	\$7,972,412	\$18,869,411
Primary Urban Center	\$7,270,981,895	\$4,962,393,684	\$1,513,191,912	\$262,620,285	\$532,776,013
Wai’anae	\$917,395,398	\$708,767,254	\$111,750,602	\$12,477,413	\$84,400,130
City and County of Honolulu (Total)	\$16,749,474,580	\$12,495,599,117	\$2,532,369,621	\$535,567,446	\$1,185,938,395

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

The SLOSH analysis was conducted to understand the building stock located within the Category 1 to 4 storm surge hazard areas. The results are displayed in Table 13-16 to Table 13-19. A category 1 hurricane could damage 3.9 percent of the island’s buildings and cost \$25 billion in damages; a category 4 hurricane could damage 12.3 percent of the island’s buildings and cost \$58 billion in damages.

Table 13-16. Buildings in Category 1 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Category 1 SLOSH Hazard Area			
	Count	Replacement Cost Value	Number of Buildings		Replacement Cost Value	
			Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central O’ahu	32,090	\$31,358,898,963	228	0.7%	\$195,197,713	0.6%
East Honolulu	14,670	\$12,765,314,977	422	2.9%	\$526,541,274	4.1%
’Ewa	23,477	\$23,523,097,571	749	3.2%	\$397,389,342	1.7%
Ko’olau Loa	3,131	\$3,703,783,129	249	8.0%	\$176,113,237	4.8%
Ko’olau Poko	28,843	\$24,614,804,769	529	1.8%	\$687,310,010	2.8%
North Shore	4,723	\$3,819,600,126	115	2.4%	\$88,550,364	2.3%
Primary Urban Center	71,191	\$137,698,243,063	5,076	7.1%	\$23,629,223,477	17.2%
Wai’anae	10,213	\$7,730,241,840	5	<0.1%	\$2,365,737	<0.1%
City and County of Honolulu (Total)	188,338	\$245,213,984,438	7,373	3.9%	\$25,702,691,154	10.5%

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018; RS Means 2024



Table 13-17. Buildings in Category 2 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Category 2 SLOSH Hazard Area			
	Count	Replacement Cost Value	Number of Buildings		Replacement Cost Value	
			Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central O’ahu	32,090	\$31,358,898,963	385	1.2%	\$482,106,778	1.5%
East Honolulu	14,670	\$12,765,314,977	768	5.2%	\$896,174,298	7.0%
’Ewa	23,477	\$23,523,097,571	1,436	6.1%	\$1,047,882,656	4.5%
Ko’olau Loa	3,131	\$3,703,783,129	752	24.0%	\$575,771,384	15.5%
Ko’olau Poko	28,843	\$24,614,804,769	1,099	3.8%	\$1,208,267,986	4.9%
North Shore	4,723	\$3,819,600,126	105	2.2%	\$94,749,727	2.5%
Primary Urban Center	71,191	\$137,698,243,063	6,798	9.5%	\$33,323,004,052	24.2%
Wai’anae	10,213	\$7,730,241,840	91	0.9%	\$58,196,114	0.8%
City and County of Honolulu (Total)	188,338	\$245,213,984,438	11,434	6.1%	\$37,686,152,996	15.4%

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018; RS Means 2024

Table 13-18. Buildings in Category 3 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Category 3 SLOSH Hazard Area			
	Count	Replacement Cost Value	Number of Buildings		Replacement Cost Value	
			Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central O’ahu	32,090	\$31,358,898,963	555	1.7%	\$741,607,484	2.4%
East Honolulu	14,670	\$12,765,314,977	1,527	10.4%	\$1,911,977,640	15.0%
’Ewa	23,477	\$23,523,097,571	1,946	8.3%	\$1,472,903,271	6.3%
Ko’olau Loa	3,131	\$3,703,783,129	1,150	36.7%	\$1,261,627,580	34.1%
Ko’olau Poko	28,843	\$24,614,804,769	3,641	12.6%	\$3,114,642,660	12.7%
North Shore	4,723	\$3,819,600,126	156	3.3%	\$127,548,897	3.3%
Primary Urban Center	71,191	\$137,698,243,063	8,275	11.6%	\$40,763,692,221	29.6%
Wai’anae	10,213	\$7,730,241,840	536	5.2%	\$420,219,296	5.4%
City and County of Honolulu (Total)	188,338	\$245,213,984,438	17,786	9.4%	\$49,814,219,050	20.3%

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018; RS Means 2024



Table 13-19. Buildings in Category 4 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Regional Planning Area Total Buildings		Buildings in the Category 4 SLOSH Hazard Area			
	Count	Replacement Cost Value	Number of Buildings		Replacement Cost Value	
			Count	% of Regional Planning Area Total	Value	% of Regional Planning Area Total
Central O’ahu	32,090	\$31,358,898,963	661	2.1%	\$905,212,323	2.9%
East Honolulu	14,670	\$12,765,314,977	2,152	14.7%	\$3,144,877,431	24.6%
’Ewa	23,477	\$23,523,097,571	2,210	9.4%	\$1,828,315,999	7.8%
Ko’olau Loa	3,131	\$3,703,783,129	1,356	43.3%	\$1,579,036,266	42.6%
Ko’olau Poko	28,843	\$24,614,804,769	6,066	21.0%	\$5,315,749,444	21.6%
North Shore	4,723	\$3,819,600,126	450	9.5%	\$258,936,519	6.8%
Primary Urban Center	71,191	\$137,698,243,063	9,330	13.1%	\$44,772,567,565	32.5%
Wai’anae	10,213	\$7,730,241,840	996	9.8%	\$1,041,434,878	13.5%
City and County of Honolulu (Total)	188,338	\$245,213,984,438	23,221	12.3%	\$58,846,130,424	24.0%

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018; RS Means 2024

To further understand the damage to building stock from storm surge, the number of residential, commercial, industrial, government, religious, agricultural, and educational buildings were analyzed by regional planning areas in Table 13-20 to Table 13-23. The storm surge from a Category 1 hurricane could damage more than 4,000 residential structures across the island; that number rises to almost 17,000 for a category 4 hurricane.

Table 13-20. Building Class in Category 1 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Buildings in the Category 1 SLOSH Hazard Area by Occupancy Class			
	Residential	Commercial	Industrial	Other ^a
Central O’ahu	192	23	10	3
East Honolulu	402	10	5	5
’Ewa	733	10	1	5
Ko’olau Loa	236	10	1	2
Ko’olau Poko	475	44	6	4
North Shore	108	4	1	2
Primary Urban Center	2,324	2,205	355	192
Wai’anae	5	0	0	0
City and County of Honolulu (Total)	4,475	2,306	379	213

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018

a. Other = Government, Religion, Agricultural, and Education



Table 13-21. Building Class in Category 2 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Buildings in the Category 2 SLOSH Hazard Area by Occupancy Class			
	Residential	Commercial	Industrial	Other ^a
Central O’ahu	274	87	16	8
East Honolulu	718	35	6	9
‘Ewa	1,389	21	18	8
Ko’olau Loa	704	36	5	7
Ko’olau Poko	1,011	69	12	7
North Shore	90	12	1	2
Primary Urban Center	2,996	2,967	545	290
Wai’anae	90	1	0	0
City and County of Honolulu (Total)	7,272	3,228	603	331

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018

a. Other = Government, Religion, Agricultural, and Education

Table 13-22. Building Class in Category 3 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Buildings in the Category 3 SLOSH Hazard Area by Occupancy Class			
	Residential	Commercial	Industrial	Other ^a
Central O’ahu	383	142	20	10
East Honolulu	1,385	108	14	20
‘Ewa	1,884	28	26	8
Ko’olau Loa	1,041	81	14	14
Ko’olau Poko	3,318	240	56	27
North Shore	135	18	1	2
Primary Urban Center	3,608	3,586	716	365
Wai’anae	499	26	4	7
City and County of Honolulu (Total)	12,253	4,229	851	453

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018

a. Other = Government, Religion, Agricultural, and Education



Table 13-23. Building Class in Category 4 Storm Surge Hazard Area based on SLOSH Analysis

Regional Planning Area	Buildings in the Category 4 SLOSH Hazard Area by Occupancy Class			
	Residential	Commercial	Industrial	Other ^a
Central O’ahu	473	151	23	14
East Honolulu	1,910	184	29	29
’Ewa	2,116	45	39	10
Ko’olau Loa	1,206	108	18	24
Ko’olau Poko	5,564	370	83	49
North Shore	419	27	2	2
Primary Urban Center	4,233	3,907	791	399
Wai’anae	925	49	6	16
City and County of Honolulu (Total)	16,846	4,841	991	543

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; NOAA 2018

a. Other = Government, Religion, Agricultural, and Education

It is important to note that the structures damaged are not equivalent to households or tenants that could be displaced; each building was counted by footprint. Therefore a 500-unit condo building or a government building housing many agencies was counted as one structure in our analysis. The number of displaced households, businesses, and organizations from storm surge in hurricanes could be much higher than the number of structures damaged.

Another planning consideration for major hurricanes is the amount of debris that could be created and require clean-up by recovery crews. Table 13-24 to Table 13-27 display the debris in tons that would require disposal after a 50-, 100-, 500-, and 1,000-year hurricane. Hazus estimates debris generation by assessing the extent of damage to structures based on the structure’s vulnerability characteristics (e.g., construction material, location, and occupancy) and the modeled wind speeds.



Table 13-24. Debris Estimates for 50-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Estimated Debris Created During the 50-Year Mean Return Period Hurricane Wind Event		
	Brick and Wood (tons)	Concrete and Steel (tons)	Tree (tons)
Central O’ahu	0	0	0
East Honolulu	27,899	2,395	2,256
‘Ewa	2	0	0
Ko’olau Loa	0	0	0
Ko’olau Poko	0	0	0
North Shore	0	0	0
Primary Urban Center	154	2	357
Wai’anae	115	5	0
City and County of Honolulu (Total)	28,170	2,402	2,613

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

Table 13-25. Debris Estimates for 100-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Estimated Debris Created During the 100-Year Mean Return Period Hurricane Wind Event		
	Brick and Wood (tons)	Concrete and Steel (tons)	Tree (tons)
Central O’ahu	4,900	271	14,933
East Honolulu	6,403	352	1,642
‘Ewa	1,619	12	1,969
Ko’olau Loa	1,172	17	14,897
Ko’olau Poko	8,665	394	9,208
North Shore	2,508	62	29,168
Primary Urban Center	54,301	1,952	16,515
Wai’anae	4,643	338	6,044
City and County of Honolulu (Total)	84,210	3,398	94,376

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1



Table 13-26. Debris Estimates for 500-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Estimated Debris Created During the 500-Year Mean Return Period Hurricane Wind Event		
	Brick and Wood (tons)	Concrete and Steel (tons)	Tree (tons)
Central O’ahu	47,120	3,137	38,843
East Honolulu	106,702	7,213	7,555
‘Ewa	55,601	4,361	6,936
Ko’olau Loa	9,733	428	35,791
Ko’olau Poko	85,018	3,951	27,402
North Shore	24,142	1,083	65,494
Primary Urban Center	243,792	4,972	32,211
Wai’anae	15,500	980	14,766
City and County of Honolulu (Total)	587,607	26,126	228,998

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1

Table 13-27. Debris Estimates for 1,000-Year Hurricane based on Hazus Wind Analysis

Regional Planning Area	Estimated Debris Created During the 1,000-Year Mean Return Period Hurricane Wind Event		
	Brick and Wood (tons)	Concrete and Steel (tons)	Tree (tons)
Central O’ahu	258,302	31,849	59,210
East Honolulu	39,241	1,922	5,674
‘Ewa	210,037	22,194	10,624
Ko’olau Loa	26,501	1,699	49,592
Ko’olau Poko	68,053	3,125	26,569
North Shore	28,057	1,326	74,401
Primary Urban Center	453,976	13,344	49,517
Wai’anae	64,923	5,991	19,979
City and County of Honolulu (Total)	1,149,090	81,451	295,566

Source: U.S. Army Corps of Engineers, National Structure Inventory 2022; RS Means 2024; Hazus v6.1



13.2.3 COMMUNITY LIFELINES AND OTHER CRITICAL FACILITIES

A Hazus analysis was conducted to understand the potential impact of hurricanes on community lifeline facilities. Table 13-28 to Table 13-31 display the loss of days and damage that could occur to community lifelines during a 50-, 100-, 500-, and 1,000-year hurricane.

Table 13-28. Damage to Community Lifelines from a 50-Year Hurricane Based on Hazus Wind Analysis

Lifeline	Loss of Days	Average Percent Probability of Sustaining Damage 50-Year Mean Return Period Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	0.1%	<0.1%	0.0%	0.0%
Energy	0	0.2%	<0.1%	0.0%	0.0%
Food, Hydration, Shelter	0	0.2%	<0.1%	0.0%	0.0%
Hazardous Materials	0	0.2%	0.0%	0.0%	0.0%
Health and Medical	76	0.1%	0.1%	0.1%	0.1%
Safety and Security	214	0.1%	0.1%	0.1%	0.1%
Transportation	0	0.4%	0.2%	0.1%	<0.1%
Water Systems	0	0.1%	0.0%	0.0%	0.0%

Source: City and County of Honolulu 2023, 2024; State of Hawaii 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1

Table 13-29. Damage to Community Lifelines from a 100-Year Hurricane Based on Hazus Wind Analysis

Lifeline	Loss of Days	Average Percent Probability of Sustaining Damage 100-Year Mean Return Period Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	2.6%	1.3%	0.2%	<0.1%
Energy	0	1.8%	0.4%	<0.1%	0.0%
Food, Hydration, Shelter	0	2.3%	0.8%	<0.1%	0.0%
Hazardous Materials	0	3.1%	1.5%	0.9%	0.2%
Health and Medical	118	1.0%	0.5%	0.2%	0.1%
Safety and Security	558	1.4%	0.9%	0.4%	0.1%
Transportation	0	3.8%	2.7%	0.9%	0.1%
Water Systems	0	4.4%	2.3%	0.2%	<0.1%

Source: City and County of Honolulu 2023, 2024; State of Hawaii 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1



Table 13-30. Damage to Community Lifelines from a 500-Year Hurricane Based on Hazus Wind Analysis

Lifeline	Loss of Days	Average Percent Probability of Sustaining Damage 500-Year Mean Return Period Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	20.1%	10.3%	2.1%	0.1%
Energy	0	17.8%	9.2%	0.5%	0.0%
Food, Hydration, Shelter	0	21.1%	14.6%	2.1%	<0.1%
Hazardous Materials	0	15.7%	14.6%	4.9%	0.7%
Health and Medical	493	10.3%	8.7%	0.8%	0.1%
Safety and Security	2,755	10.0%	13.8%	1.7%	0.1%
Transportation	0	15.8%	19.0%	2.6%	<0.1%
Water Systems	0	17.1%	20.8%	3.4%	0.1%

Source: City and County of Honolulu 2023, 2024; State of Hawaii 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1

Table 13-31. Damage to Community Lifelines from a 1,000-Year Hurricane Based on Hazus Wind Analysis

Lifeline	Loss of Days	Average Percent Probability of Sustaining Damage 1,000-Year Mean Return Period Hurricane			
		Minor	Moderate	Severe	Complete
Communications	0	20.8%	17.7%	4.3%	0.1%
Energy	0	28.9%	24.6%	5.7%	<0.1%
Food, Hydration, Shelter	0	24.1%	17.8%	4.1%	<0.1%
Hazardous Materials	0	16.7%	24.8%	15.1%	2.9%
Health and Medical	1,591	11.9%	19.3%	3.7%	0.3%
Safety and Security	7,605	10.2%	24.5%	5.7%	0.3%
Transportation	0	18.1%	27.7%	6.8%	0.1%
Water Systems	0	18.7%	31.9%	8.5%	0.1%

Source: City and County of Honolulu 2023, 2024; State of Hawaii 2017,2021,2022,2023,2024; US Energy Atlas 2024; Hazus v6.1

All lifeline categories have the potential to sustain damage that results in facility closures and could result in significant disruption across the City. Facilities in the health and medical lifeline category are of particular concern given potential impacts on the ability of O’ahu’s residents to obtain needed medical care. that provide critical health and safety services those lifelines are health and medical and transportation. The safety and security community lifeline includes law enforcement facilities, fire stations, search and rescue, emergency operations centers, government offices, and schools. A disruption to this lifeline could result in delayed response times by emergency responders or disruptions to other essential government services.



Transportation lifelines are not considered particularly vulnerable to wind hazards; they are more vulnerable to storm surge and cascading effects such as flooding, falling debris, etc. Of particular concern are potential impacts to the island's sea ports and airports which would have immediate and consequential impacts on the supply chain and the ability to get response and recovery resources into the state.

Power utilities in the energy lifeline category may suffer extended outages due to wind impacts to power lines. The loss of power would result in cascading impacts across all other lifelines, to include disruption of other water and communications utilities.

13.2.4 NATURAL, HISTORIC, AND CULTURAL RESOURCES

Natural Resources

Hurricanes can have both direct and indirect environmental impacts on the City. The primary direct effects are caused by high winds, which lead to several consequences:

- Storm surge along the coastline, accelerating coastal erosion
- Potential permanent changes to beach topography, especially after multiple cyclones
- Damage to natural vegetation, including downed trees and blocked waterways

The severity of these impacts depends on the location and magnitude of the storm. Additionally, tropical cyclones can exacerbate ocean acidification, which is already threatening coral reefs. The changes in salinity and pH levels following a cyclone can persist, affecting living coral and potentially dissolving existing coral structures (NOAA - Atlantic Oceanography and Meteorological Lab 2013).

The long-term implications for the City include:

- Potential loss of beach areas, affecting both wildlife habitats and tourism
- Damage to inland ecosystems due to flooding and debris
- Increased stress on coral reefs, which are crucial for marine biodiversity and coastal protection

Historic and Cultural Resources

A SLOSH analysis was conducted to understand the impact that hurricane storm surge may have on cultural and historic resources on O'ahu. Table 13-32 displays the number of sites on the National and State Register of Historic Places that would be damaged in categories 1 to 4 hurricanes.



Table 13-32. Historic Sites Impacted by Hurricane based on SLOSH Analysis

Regional Planning Area	Number of Historic Sites in the SLOSH Category 1 Hazard Area		Number of Historic Sites in the SLOSH Category 2 Hazard Area		Number of Historic Sites in the SLOSH Category 3 Hazard Area		Number of Historic Sites in the SLOSH Category 4 Hazard Area	
	Count	% of Regional Planning Area Total	Count	% of Regional Planning Area Total	Count	% of Regional Planning Area Total	Count	% of Regional Planning Area Total
Central O’ahu	1	11.1%	1	11.1%	2	22.2%	3	33.3%
East Honolulu	4	50.0%	4	50.0%	7	87.5%	7	87.5%
’Ewa	0	0.0%	0	0.0%	0	0.0%	0	0.0%
Ko’olau Loa	0	0.0%	1	50.0%	1	50.0%	1	50.0%
Ko’olau Poko	1	3.7%	2	7.4%	5	18.5%	12	44.4%
North Shore	1	12.5%	1	12.5%	1	12.5%	1	12.5%
Primary Urban Center	18	4.0%	28	6.2%	36	8.0%	54	12.0%
Wai’anae	0	0.0%	0	0.0%	0	0.0%	0	0.0%
City and County of Honolulu (Total)	25	4.9%	37	7.3%	52	10.2%	78	15.4%

Source: City and County of Honolulu 2024; NOAA 2018

13.2.5 FUTURE CHANGES THAT MAY AFFECT RISK

Potential or Planned Development

The City's directed growth policy encourages expansion beyond the primary urban center. This policy has significant implications for O’ahu's landscape, potentially leading to increased development in previously undeveloped areas and putting pressure on the island's limited land resources.

In response to growing concerns about coastal hazards and community resilience, the City amended the Revised Ordinances of Honolulu (ROH) Shoreline Setback in 2023. Key changes include (City and County of Honolulu 2023):

- Increasing the shoreline setback from 40 feet to 60 feet, effective July 1, 2024
- Establishing a 3-foot minimum above base flood elevation requirement for new structures within special flood hazard areas
- Including a historic erosion rate consideration in the setback for properties outside the Primary Urban Center



The Building Code ROH establishes minimum life safety design criteria for county-owned high-occupancy buildings in Honolulu. These requirements include safety elements to mitigate impacts from up to a Category 3 hurricane, addressing wind, rain, and impact risks. This focus on hurricane preparedness is crucial for O’ahu, as the island's location and topography make it vulnerable to tropical cyclones. By implementing these standards, Honolulu aims to enhance the resilience of its critical infrastructure and protect its residents during severe weather events. These policy changes and building standards collectively demonstrate Honolulu's efforts to balance urban growth with environmental protection and disaster preparedness, addressing the unique challenges faced by the City as a densely populated island with limited land resources and exposure to natural hazards.

Projected Changes in Population

Honolulu’s population is expected to moderately increase over the coming decades, as shown in Table 13-33. While population increases are unlikely to have an impact on the incidence of hurricanes, significant population increases could strain existing emergency services, sheltering, and supply chains.

Table 13-33. Honolulu County Population Projections

	2020	2030	2040	2050
Population	1,012,305	1,033,600	1,054,670	1,060,110

Source: (DBEDT 2023)

Climate Change

Current studies indicate a complex future for tropical cyclones in the Pacific Ocean. While hurricanes in the Pacific are projected to decrease overall, the intensity of these storms is expected to increase, with stronger winds, heavier rainfall, and more severe storm surges. This trend is particularly concerning for O’ahu, given its vulnerable coastal areas and concentrated urban development.

The Pacific Ocean, including the waters surrounding Hawai’i, is experiencing sea temperature increases at a rate faster than the global average. This warming trend is projected to continue throughout the century.

Sea level rise in the Pacific varies regionally, with the western Pacific seeing the most dramatic increases. For O’ahu, the projections are alarming:

- If global temperatures rise more than 3.6°F (2°C), the island could face sea level rises of 3.5 to 7.5 feet by 2100.
- This level of rise would have catastrophic impacts on O’ahu's coastal communities, infrastructure, and economy, particularly in low-lying areas like Waikīkī and urban Honolulu.

Changes in rainfall patterns are also expected to affect O’ahu:

- Decreased rainfall from November to April



- Increased rainfall from May to October

These shifting patterns, combined with warming oceans, may extend the hurricane season beyond its historical June-November timeframe (USGCRP 2023). For O‘ahu, this could mean:

- Increased risk of flooding and landslides during the extended wet season
- Water scarcity issues during the drier months
- Longer periods of vulnerability to tropical cyclones

The combination of more intense tropical cyclones, rising sea levels, and changing rainfall patterns presents significant challenges for O‘ahu’s infrastructure, water management, and disaster preparedness. These projections underscore the urgent need for comprehensive climate adaptation strategies across the island, particularly in densely populated urban areas and vulnerable coastal zones.